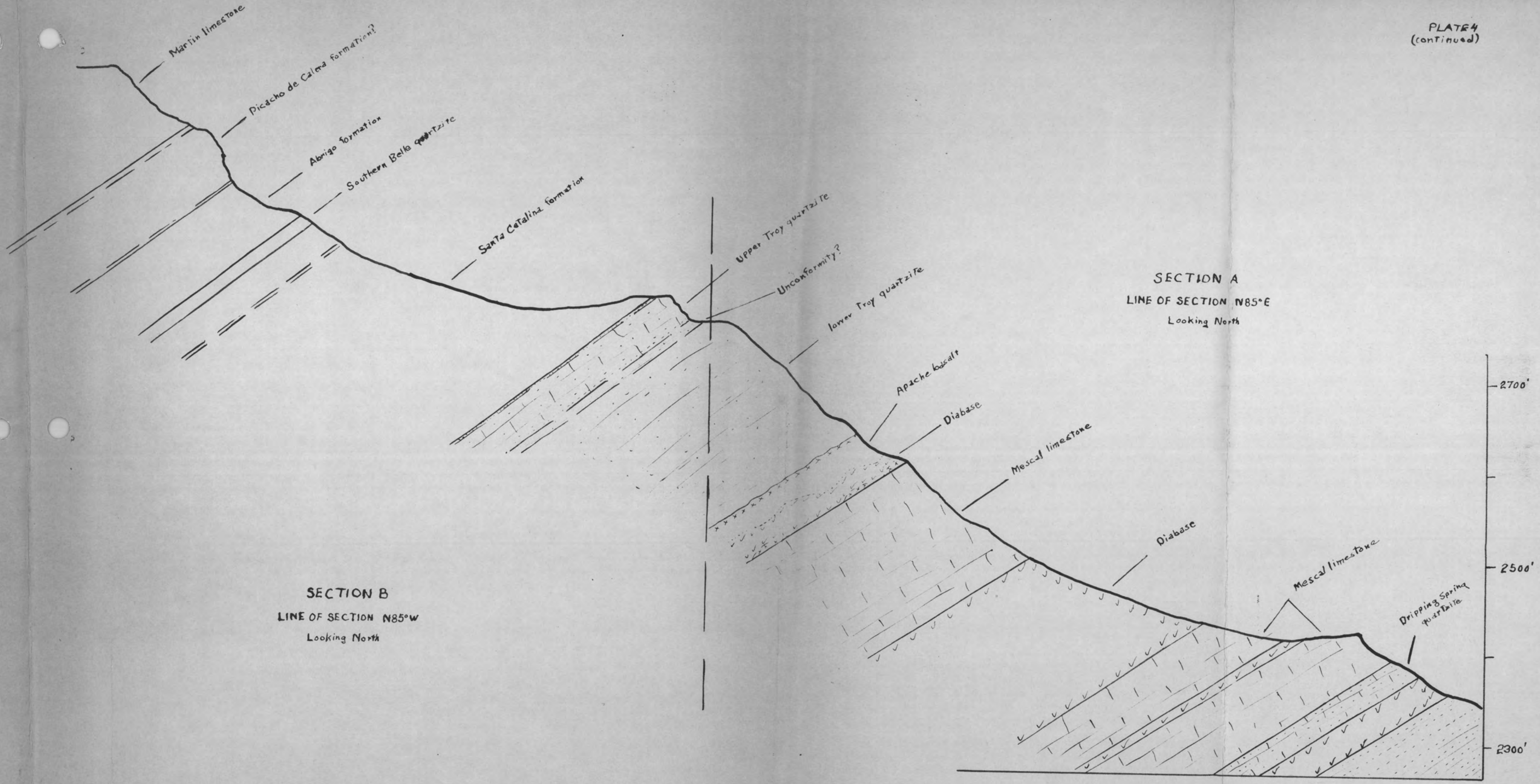
CONTACT INFORMATION
Mining Records Curator
Arizona Geological Survey
3550 N. Central Ave, 2nd floor
Phoenix, AZ, 85012
602-771-1601
http://www.azgs.az.gov
inquiries@azgs.az.gov

THE GEOLOGY AND ORE DEPOSITS
OF THE VEKOL MOUNTAINS

PINAL COUNTY, ARIZONA

By
Robert Halstead Carpenter
July, 1947

PLATE 4
(continued)



THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS
PINAL COUNTY, ARIZONA.

* * *

A DISSERTATION

SUBMITTED TO THE SCHOOL OF MINERAL SCIENCES

AND THE COMMITTEE OF GRADUATE STUDY OF STANFORD UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

* * *

By

Robert Halstead Carpenter

July, 1947

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ILLUSTRATIONS

Promontory Ridge, located on the Vekol Mountains quadrangle map, is the ridge starting from 3326 peak and going in a northeast direction. It is just to the left and up from the "A" in reservation.

Plane Table Traverse A was started near the bottom of the Promontory Ridge and goes in a general east direction. Traverse B was started about half way up the ridge and travels in a eastwardly direction. Traverse C was started near the top of the ridge and it also trends toward the east.

Plane Table Traverse D-D' was taken in an east-west direction. It is due north of 2865 peak and a little below due west of 2907 peak to the southeast of Copperosity Mine.

Diabase Traverse #1 was taken in a general north-south direction. It is southeast of the Hill Top Mines (peak 3231). It was taken in the valley that separates 2191 hill with the unnumbered hill just north of it.

Diabase Traverse #3 was taken in an east-west direction. Starting to the south of P.T.T. C, ie, just below the top of 3326 peak and continuing down the slope.

Print 1.

Diabase Unconformity

This photograph, looking westward, is a view of the partly eroded fault scarp at the head of Promontory Canyon, just south of Promontory Ridge. The gray strata at the top are Escabrosa limestone. The rocks included in the Upper Devonian section are exposed in the bench, the brown cliff, and the banded cliff beneath the Escabrosa cliffs. The Southern Belle quartzine marker bed is represented by Ꞓsb. The steep, greenish cliff in the foreground is the basal conglomerate of the Santa Catalina formation which rests on the sloping diabase erosion surface. A thin wedge of "upper" Troy (Ꞓt) is exposed on the right just above the unconformity. The Naco limestone, which caps the down-faulted block of Promontory Ridge, may be seen in the upper right. The position of the Promontory Ridge fault is shown by the dashed lines.

THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS
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I. INTRODUCTION

Location and Accessibility.

The Vekol Mountains, in southern Arizona, occupy the central part of the Vekol Quadrangle, United States Geological Survey topographic sheet, between the latitudes 32° 33' - 32° 39' north and longitude 112° 04' - 112° 12' west. (Plate 1.)

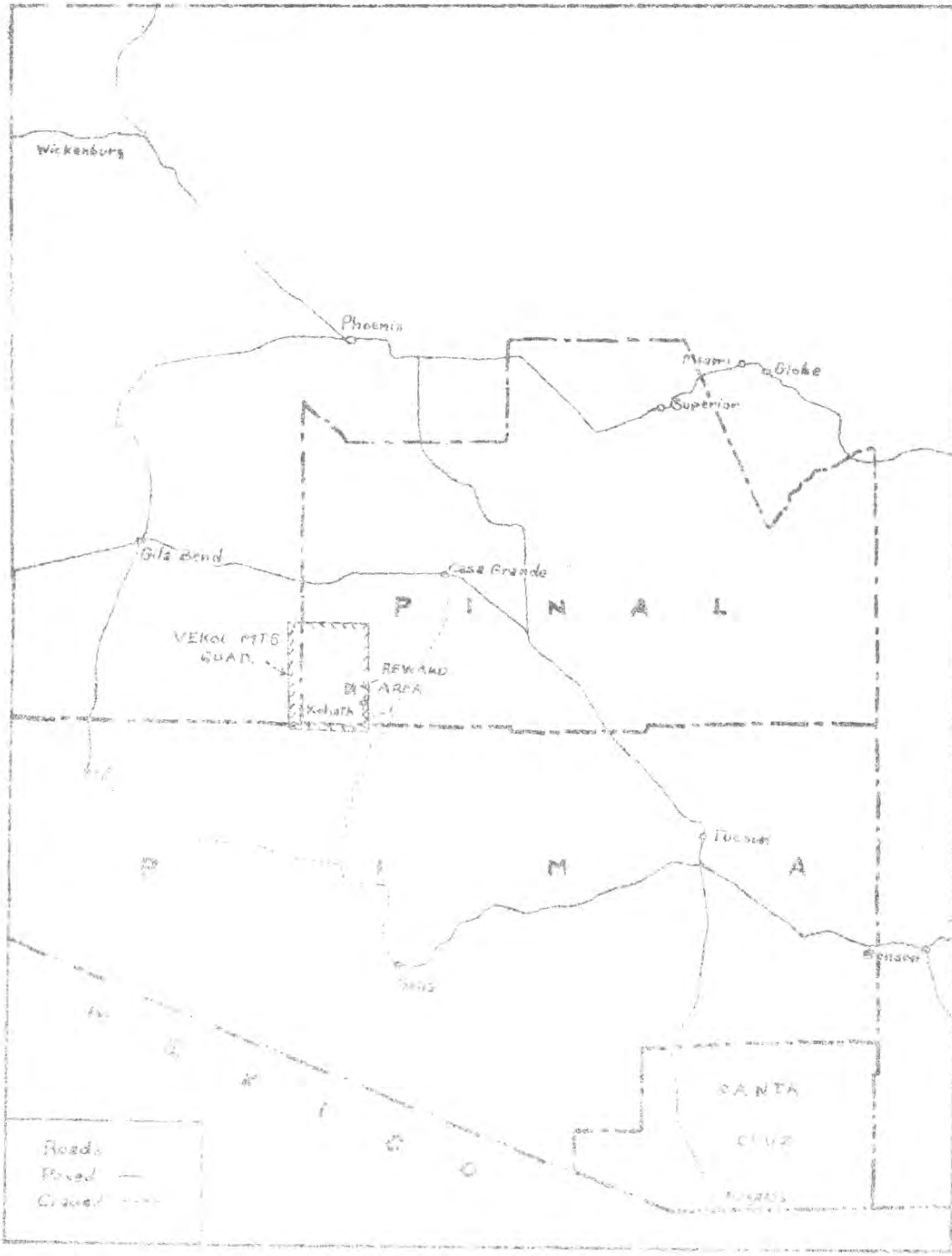
The area is reached by a graded road which follows the natural gas line from Casa Grande to Ajo. The northwestern edge of the Vekol Mountains is approximately forty miles from Casa Grande. The southern edge may be reached by driving southwest on the well-graded Casa Grande-Sells road for twenty-seven miles to the Kohatk Indian Village turnoff, and then driving northwestward to the foot of the range on any one of a number of poor desert roads. (Plate 2.)

Physical Features.

The Vekol Mountains have a roughly circular outline. The main range, situated on the south and west, is connected with the east ridges by a series of hills with an alluvial basin in the center. Both the northern end of the main range and the east ridges trend northwest.

From U.S.G.S.

PLATE 1



MAP OF S[illegible] CENTRAL ARIZONA
SHOWING L[illegible] IN REWARD [illegible]

The mountains are bordered on the south and east by the broad Santa Rosa Valley, on the north by low hills, on the northwest by Vekol Valley, and on the southwest by the Copperosity Hills and Cimmaron Mountains.

The altitudes in the Vekol Mountains range from lass than 1,800 feet to 3,625 feet. The highest point in the main range is an unnamed peak due south of Promontory Ridge. (Plage 3.). The total relief is thus over 1,825 feet. The maximum relief of 1,300 feet per mile, is found on the east side of the 3,625-foot peak. The mountains are rugged with percipitous slopes and cliffs, particularly along the east side of the main range.

Climate

The climate is semi-arid with a wide range in daily temperatures. The average precipitation at Casa Grande is 19.4 inches a year.[1] Most of this rainfall comes during the summer cloudbursts and midwinter showers. The average mean temperature in Casa Grande is 70° with a high of 105° in July and a low of 64° in December. The Vekol Mountains are 1,000 to 3,000 feet higher than Casa Grande. Consequently, the mean temperature is somewhat lower, and the precipitation higher.

Flora and Fauna

In spite of the arid climate, the vegetation in the Vekol

1. Smith, H. V. Climate of Arizona, Bull. 197, Agri. Experiment Sta., Univ. of Ariz., Tucson. July, 1945.

Mountains is profuse and varied and includes those forms typical of the Upper Sonoran Zone. Palo verde, mesquite, catsclaw, and ocotillo are numerous on the pediments and alluvial slopes and are concentrated along the washes. Greasewood is seen occasionally. The large and spectacular Sahuaro cactus is well-distributed over the area except in the higher slopes and cliffs. Barrel cactus, prickly pear, hedgehog, antler cactus, pincusion and cholla are numerous. Several varieties of Yucca grow above an elevation of 3,000 feet. There are a few organ pipe cacti near the Copperosity mine.

Flowering shrubs and wild flowers make a vivid display after each heavy rain. Grass, green plants and ferns are abundant in the shady spots along the eastern cliffs during the rainy periods.

Mountain sheep inhabit the precipitous areas, whereas javelinas or peccaries and black-tail deer range in the foothill region. Coyotes, foxes, ring-tailed cats, desert swifts, jack rabbits, cottontails and ground squirrels thrive throughout the area. Snakes, lizards and desert turtles ane common during hot weather. There are ravens, buzzards and many varieties of birds of prey, as well as the song birds typical of this region.

Previous Work

C. F. Tolman, late Professor of Economic Geology at

Stanford University examined the Vekol mine in 1908, but copies of his report could not be located.

Kirk Bryan, in his study of the erosion and sedimentation in the Papago country, briefly visited the Vekol Mountains in 1922.[4]

N. H. Darton describes the Vekol Mountains briefly in his Resumé of Arizona Geology.[7]

J.B. Tenney, in January, 1933, completed an economic geological reconnaissance of the mines of the Casa Grande Mining District.[8] His work, although brief, covers all of the important areas of mineralization in the Vekol Mountains. Tenney's conclusions regarding the Vekol mine will be referred to in the economic section of this paper.

The general distribution of the rock types is shown on the geological map of Arizona published by the Arizona Bureau of Mines in 1925.

No detailed work was completed in the Vekol Mountains until 1942, when a party of the Stratigic Minerals section of the

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

7. Darton, N.H. Resumé of Arizona Geology, Bull. 119, Arizona Bureau of Mines, 1925, pg. 264.

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of Casa Grande Mining District, Pinâl County, Arizona, Arizona Bureau of Mines, 1934.

U. S. Geological Survey, headed by J. B. Hadley, Mapped a part of the eastern Vakol Hills. (See Plate 3.). A careful study was made of the Reward and related prospects in that area. The results are published in a preliminary report of the U. S. Geological Survey.[6]

Field Work

Field work for this report was begun early in October, 1946, and continued until late in March, 1947. The entire region was mapped on a scale of one inch to one thousand feet; and plane table traverses and topographic maps were made on a scale of one inch to one hundred feet and one inch to two hundred feet, where detail was desired. Several one inch to one hundred feet brunton-tape traverses were completed to show details of the Stratigraphy and in connection with a study of the diabase that occurs in the region. The main levels in the Vekol mine were mapped on a scale of one inch to fifty feet.

Acknowledgments

The writer wishes to express his sincere appreciation to Dr. M. N. Short for his interest and assistance while the field work was in progress. He also wishes to thank the other members of the Geology Department at the University of Arizona for their many helpful suggestions, particularly Dr. A. A. Stoyanow, for

6. Hadley, J. B. Copper and Zinc Deposits of the Reward Area, Pinal County, Arizona, Preliminary Report, Stratigic Minerals Div. U. S. G. S. 1942.

his aid in determining the fossils in the area; and to thank him, Dr. E.D. McKee and Dr. Short, for visiting the area and reviewing some of the more critical stratigraphic problems.

The writer is greatly indebted to Dr. Eldred Wilson, geologist of the Arizona Bureau of Mines, for his suggestions, and for copies of pertinent geological literature.

Sincere appreciation is expressed to Dr. A. C. Waters of Stanford University, for his assistance in checking the field and petrographic evidence, and for criticizing the original manuscript, and to the other members of the School of Mineral Sciences for their constructive criticism.

Permission to use the library and laboratory facilities at the Geology Department at California Institute of Technology was most sincerely appreciated.

The writer wishes to record his gratitude to Mr. Cale Smith, superintendent of the Casa Grande High School, for his cooperation and help while the field work was in progress; and to Mr. Jack Schoellhamer of Pomona College, for his assistance with the plane table work.

II. GENERAL GEOLOGY

Summary

The rocks in the Vekol Mountains range in age from pre-

Print 2

Pre-Cambrian Pinal schist.

This exposure of Pinal schist in Copperosity Basin consists of sericite-quartz schist with lenses of quartz along the trend of the foliation. Occasional thin quartz bands are present also.

Print 3

Algonkian Mescal limestone

This thinly ribbed outcrop of Mescal limestone was photographed at the eastern end of Promontory Ridge. It consists of thinly banded, light gray limestone with numerous siliceous layers. The latter are resistant to weathering, and form a corrugated surface.

Print 4

Upper Paleozoic section on Promontory Ridge

This view, looking north, shows the Naco limestone and the Escabrosa limestone along the crest of Promontory Ridge. The Naco (Cn) is thinly bedded and light gray; the Escabrosa (Ce) is massive tan, banded blue and gray, and massive gray. The Promontory Ridge fault, shown by dashed lines, is well-exposed at the base of the ridge. It separates the down-faulted upper Paleozoic beds from the diabase and Middle Cambrian strata.

Print 5

Lower Paleozoic section, Promontory Ridge.

The Lower Ouray (?) formation is exposed on the bench in the upper left corner of the print. The Martin limestone (Dm) forms the brown cliff, whereas the Picacho de Calera (?) formation forms the blue and tan cliffs below. The Southern Belle quartzite (Csb) separates the Abrigo formation from the Santa Catalina formation. The Troy quartzite is exposed in the dark cliffs. The Mescal limestone forms a faint brown band on the right side of the print.

Cambrian to Quaternary, and comprise one of the most complete columnar 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.[6] Dacite porphyry, sills, dikes and flows of intermediate composition 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.

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

Metamorphic Rocks: -- Pinal schist.

Correlation

The basement schist of the Vekol Mountains is correlated with the Pinal schist of central and southern Arizona, described by Ransome[10, 11, 14] and others. T his correlation is based on the close similarity in lithology and the fact that the schist is separated from the Apache Group by an unconformity, just as it is in the Ray-Miami region and in other parts of central and southern Arizona.

Distribution and General Structure.

The rocks included in the Pinal schist are well-exposed in the southeastern section of the main range and to a limited extent on the northwestern side of the Copperosity basin around the flanks of 2913 peak. (See Plate 3.).

The schistosity usually is well-developed and is steeply inclined, although its inclination varies from horizontal to vertical. The trend of the schistosity is shown on Plate 3. It corresponds, in a general way, to the regional folding, and may have influenced the development of the folding. The schistosity roughly parallels the borders of the granite. It may have been contorted by intrusive forces. Intricate folding is developed in the less resistant horizons; the axis of these folds follows the

10. Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona, U. S. G. S. Prof. Paper 115, 1912.

11. Ransome, F. L. The Geology of the Globe Copper District, Arizona. U. S. G. S. Prof. Paper 12, 1903.

14. Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U. S. G. S. Prof. Paper 21, 1904.

general trend of the schistosity. The schistosity and the bedding are roughly parallel wherever relic bedding is definitely discernable.

Lithology

By far the greater part of the schist exposed in the Vekol Mountains consists of a well-foliated, light gray to greenish-gray quartz-sericite schist with occasional quartz bands or quartz lenses. (See Print 2.). The latter are particularly common in the crests and saddles of tight folds. Sandy and pebbly beds were noted, as well as a few layers of altered siltstone. In texture, the varieties range from a well-foliated, very finely crystalline sericitic schist to an imperfectly cleavable, coarsely crystalline pebbly schist.

Kinds of Schist

In the southeastern area three kinds were found:

a. Sericite schist: This type is generally thinly laminated, light gray to bluish-gray schist with a satiny luster. In thin section, it consists largely of somewhat contorted sericite blades up to 0.5 mm, considerable disseminated magnetite averaging 0.01 mm, and sparse garnet. The latter probably were detrital grains in the sediment prior to metamorphism. Very thin bands of anhedral quartz are often present. Chlorite is a variable constituent ranging up to 30% in some specimens. The well-developed fissility of this type is the result of the roughly parallel orientation of the sericite flakes into alternate layers, with occasional thin bands of quartz.

b. Sandy or Pebbly Schist: Megascopically, the sandy type consists of thin bands of quartz granules averaging about 1mm in diameter in a matrix of finer quartz grains and scattered flakes of sericite and greenish chloritic material. The pebbly type contains ellipsoidal pebbles ranging up to 1 cm in diameter, which are roughly oriented in a poorly foliated matrix of quartz grains averaging 1 mm in diameter, together with sericite and chlorite. Both types break with an irregular fracture roughly parallel to the former bedding trend.

c. Banded Schist: This type consists of alternate 1 mm to 5 mm bands of finely crystalline anhedral quartz and 0.5-1.0 mm bands of sericite. Chlorite is a variable constituent in the latter. Small magnetite grains are sparsely distributed in the micaceous bands.

Along the north flank of 2913 peak, occasional layers of greenish phyllite occur as bands a few feet wide in the sericitic schist described above.

This very fine-grained, gray rock often shows a faint banding of alternate gray and tan horizons. Barely, 1 mm quartz bands are seen. In thin sections, the rock consists of anhedral quartz, orthoclase and a little plagioclase, all of which average 0.05-0.1 mm in diameter. Sparse anhedral hornblends, largely altered to chlorite in present. Secondary chlorite is well-dispersed as a matrix mineral, and quartz and calcite stringers up to 0.3 mm wide cut across the specimen. A definite banding is evident in thin section.

Origin

In the Globe area[11] and in the Pinal Range,[10] Ransome has shown the Pinal schist to have been derived mainly from arkosic sediments, although rhyolites are included also. The lithologic

10. Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona U. S. G. S. Prof. Paper 115, 1912, pg. 25.

11. Ransome, F. L. The Geology of the Globe Copper District, Arizona. U. S. G. S. P. P. 12, 1903, pg. 27.

similarity of the schist in the Vekol Mountains with the schist in the Pinal Range would indicate a similar origin for both. This assumption is supported by the fact that sandy and pebbly beds of undoubted sedimentary origin are "interbedded" with the sericitic schist in the southeastern section of the main Vekol Range. The greenish phyllite bands in the Copperosity area (See Plate 3.) probably were derived from siltstones, but might have been volcanics.

Age

The crystalline Pinal schist, in which metamorphism has destroyed most of the original bedding structures, is separated from the overlying, non-foliated, Algonkian Apache group by a clear cut unconformity. This unconformity probably represents the Ep-Archean erosion surface described by Sharp[12] in the Grand Canyon region. If so, the Pinal schist is of early pre-Cambrian age.

Sedimentary Rocks --- Algonkian Apache Group

The rocks of the Apache group were described and designated as Cambrian by Ransome[10] in his work in the Ray and Miami area of central Arizona. He included the Scanlan conglomerate, the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite and the Troy quartzite within this group. Darton[7] and

7. idem pg. 36.

10. idem pg. 39.

12. Sharp, R. P. Ep-Archean and Ep-Algonkian Erosion Surfaces, Grand Canyon, Arizona. (Abstract) G. S. A. Bull. Vol. 50 #12, pt. 2. pg. 1933, Dec. 1939.

others, however, consider the Apache group as equivalent to the Grand Canyon series. Furthermore, Darton[7] found evidence, pointed out under 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 schish 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

7. idem pg. 36.

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,[10] these are caused by the reduction and removal of ferruginous pigment. This characteristic marking of the Pioneer shale indentifies 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 jasper. 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,

10. idem pg. 40.

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 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 on page 19.

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 1/2 inch thick interbedded with thin-banded limestone. In some exposures, the more resistant chert 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[18] and the writer concur that this arcuate 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

18. Personal communication.

Print 6

Pseudo-Intraformational Conglomerate

The above specimen of thin-bedded, impure limestone collected from the Santa Catalina formation represents a well-developed stage of the phenomenon described on page 17. Fracturing, solution along the fractures, compaction and recrystallization have all been effective to form this intraformational conglomerate-like rock. This phenomenon often can be traced laterally into normal, impure limestone.

unaffected intermediate areas into the arcuate

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 Pronomtory 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 southwesterd edge of Bitter Wells Basin;

Print 7

Profile of Apache basalt and Troy quartzite.

This view, looking northward at the eastern end of Promontory Ridge, shows the Troy quartzite, the bench-forming Apache basalt, and the cliffs of the underlying Mescal limestone. Down-faulted Troy quartzite south of the Pomona Canyon fault ridges are visible in the background.

Print 8

Troy quartzite cliffs

The upper and lower members of the Troy quartzite are shown by the letters "u" and "l" on the above print. Apache basalt and diabase are poorly exposed at the base of the cliff. Mescal limestone lies below the basalt.

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 R idge, shown on Plate 4., is as follows:

Upper Member	a.	Strongly cross-badded, rusty, midium-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?----------	
Lower Member	c.	Well-banded 1-foot quartzite beds interbedded with calcareous quartzite.	30 feet
	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 1/4 inch to 3 inch banding.	48 feet
		Total	252 feet

The upper, brown, highly cross-badded quartzite (a.) consists mainly of calcareous quartzite with occasional patches of calcareous sandstone. The latter often contain small, poorly pre-

Print 9

Troy Quartzite

Looking south toward 3625 Peak. The lower Troy unit and upper troy unit are separated by a prominent bench shown in the upper part of the print. Apache basalt and diabase are poorly exposed beneath the talus at the base of the cliff.

Print 10

Upper Troy quartzite

Cross-bedded, calcareous quartzite in this print forms the topmost cliff in Print 8. The calcareous lenses weather rapidly to form narrow depressions on an exposed surface.

served 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 the upper Troy unit and the overlying Santa Catalina formation, for the quartzite beds become less numerous, and finally, are 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 1/4 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.

<u>Age and Correlation</u>

In his early work in the Globe area, [11]Ransome considered the Troy quartzite a part of the Dripping Spring Quartzite. Later, in the Ray quadrangle,[10] he 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 bo the Troy and the Apache group in the Cambrian.

10. idem pg. 44

11. idem pg. 28

Subsequent work has shown that the Apache group is not gradational into the Devonian. Stoyanow[13] has measured over 700 feet of fossiliferous 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[7] is also opposed to the Cambrian 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 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,[16] in the Santa Catalina Mountains,[13] and in other areas.

Stoyanow[13] separates the Troy from the Apache group "not only because 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

7. Darton, N. H. Resumé of Ariz. Geol., Bull. 119 Ariz. Bureau of Mines, 1925, pag. 36

13. Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A. Vol. 47, pp 459-540, 1937, pg. 474.

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

as 1904 in the Troy in Deer Creek Canyon south of the Mescal Mountains in central Arizona.[13] They were determined by Walcott as Lingulella Pogonipensis (Walcott) and Dicellomus Politus (Hall) and were classified as "probably Middle Cambrian."

Stoyanow[13] also mentions that in the Mescal Mountains near the top of 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.

13. idem pg. 475

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 both at the top and bottom of this member of the Troy. No fossils have been found to date it as Middle or Lower Cambrian; now 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 opinoin of the writer, further regional work should be carried out to see if the unconformity separating the upper

Print 11

Santa Catalina basal conglomerate cliff.

The six foot cliff shown above consists of boulders, cobbles and pebbles of diabase embedded in a calcareous and cherty matrix at the base of the Santa Catalina formation. The weathered diabase erosion surface lies about ten feet below the base of the cliff.

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[7] involve the entire Troy as described 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 Promontory Ridge is typical. (See Plate 4) It is 265 feet thick. The lower sixty feet consists 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, 1/2 to 1 inch, brown, micaceous sandstone, shally 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 numbrous in this part of the section.

7. idem pg. 36.

Print 12

Santa Catalina basal conglomerate

Rounded orthoclase diabase cobbles and pebbles are embedded in a calcareous matrix. This horizon is located about 20 feet above the diabase erosion surface.

The Santa Catalina formation was first described by Stoyanow[13] in the Santa Catalina Mountains north of Tucson. He designates the Santa Catalina as a separate formation of Middle Cambrian age on paleontologic evidence. An unnamed trilobite persists through the entire formation, and 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

13. idem pg. 476

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 of 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[13] in southern Arizona. No fossils were found, however, and the writer tentatively includes these beds in the Abrigo.

The thickness of the Abrigo formation at Promontory Ridge is 82 feet. (See Plate 4) In the southern edge of the area, on the south side of 2854 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 #4, 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[14] at Bisbee, and was named 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[13], in the Santa Catalina Mountains, has divided this section into the following formations:

Upper Cambrian	Peppersauce sandstone Abrigo formation

13. idem pg. 471

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

13. Stoyanow, A. A. Corr. of Ariz. Paleo. Formations, Bull. G. S. A. Vol. 47, pg. 480.

Middle Cambrian	Southern Belle Quartzite Santa Catalina formation Troy Quartzite (Bolsa Equivalent?)

In this report, the writer follows Stoyanow's resistricted 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[2] in the Slate Mountains ten miles southeast of the Vekol Mountains. The rocks of the Abrigo formatimn 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 236 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 paleontolocig 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.

2. Hogue, W. G. The Geology and Ore Deposits of the Northern End of the Slate Mountains, Pinal Co., Arizona. Masters Thesis, Univ. of Ariz. 1940.

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 Calero? 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 Hill twenty-five miles northwest of Tucson.[13] Stoyanow's section is quoted as follows:

13. idem pg. 488.

	(Top)
"a. Brown calcareous sandstone replete with fish teeh, <u>Ptyctodus</u> aff. <u>calceolus</u> (Newberry and Worthen), two species of <u>Cladodus</u>, and one species of <u>Lambodus</u>(?) 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 calerous sandstone with well-rounded sand grains probably of sub-eolian origin.	4 feet
Total	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.

<u>Martin limestone</u>

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:

		(Top)
a.	Muddy, gray limestone in 1-3 foot beds.	13 feet
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 1/2 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 occassionally, together with other poorly preserved froms which have not been identified. Cladopora prolifica Hall and Whitfield occur sporadically in this same horizon.

The Martin limestone was first described by Ransome[14] at Bisbee. There, 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.[13, 14]

13. idem pg. 487

14. idem pg. 35-38

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:

		(Top)
a.	Roughly-banded, light tan to white, cliff-forming, medium-grained quartzite with sandy, calcareous bands.	12 feet
b.	6 inch to 3 foot beds of pinkish-gray limestone	16 feet
c.	1/2 inch to 6 inch, yellowish-to reddish-tan, soft, highly-jointed, poorly bedded limestone, mudstone and calcareous shale. <u>Atrypa reticularis</u> (Linne).	23 feet
	Total	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[13] describes this formation in Peppersauce Canyon in the Santa Catalina Mountains, twenty-five miles north of Tucson. It also is described by Hogue[2] in the Slate Mountains, ten miles east of the Vekol Mountains. Hogue's section is as follows:

2. idem

13. idem pg. 489.

(Top)

" 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.	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[6] reports a maximum of 420 feet in the Reward area 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, tand and bluish-gray beds ranging from 6 inches to 5 feet; the upper 200 feet is a massive, gray limestone with occasional cherty horizona.

The top 20 to 100 feet of Escabrosa is altered to a pinkish-tan colo. 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 an 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 in to 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. <u>Spirifer centronatus</u> Winchell, the guide fossil of the

6. idem.

Escabrosa, and a Syringopora coral were the only two definitely identifiable fossils found by the writer. Hadley[6] reports numerous Pentremites 800 feet from the base of the formation in the Reward area.

According to Stoyanow[13], the Escabrosa limestone is Lower Mississippian 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 colo. 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 the area:

6. idem.

13. idem pg. 505.

(Top)

a.	Alternate 1-2 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.	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:

Dictyoclostus americanus Dunbar and Condra
Spirifer occidentalis Girty
Spirifer Rockymontamus Marcou
Spirifer cameratus Morton
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 gastropods were found in the topmost exposed beds just north of the Vekol ghost town. Crinoid stems 1/2 inch in diameter are numerous in the upper part of the Naco.

The following forms were collected by Bryan[4] from the south slope of the mountains at the Vekol mine and were determined by G. H. Girty:[7]

Cladochonus sp.	Productus semireticulatus
Campophylum Torquium	Marginifera splendens
Rhombophora lepidodendroides	Spirifer cameratus
Schizophoria? sp.	Spirifer Rockymontanus
Chonetes verneuilianus	Composita subtilita

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

According to Stoyanow,[19] the forms collected in the Vekol Mountains by 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 the Vekol mine, the exposed thickness is 415 feet. The top is covered by terrace gravels and alluvium.

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

7. Darton, N. H. Resumé of Arizona Geology, Bull. 119, Ariz. Bureau of Mines, pg. 74, 1926.

19. Stoyanow, A. A. Personal Comm.

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 areas of reddish-brown and gray sandstone, finely crystalline limestone 1/4 of an inch to 1 foot in diameter, and zoned chert nodules which have white centers and reddish halos 1/16 to 1/2 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 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:

a. Pebbly breccia with angular chert fragments in a somewhat silicified, shaly matrix.	1 foot
b. Brick red to chocolate colored, splintery shale with a few zoned chert nodules.	5 feet
c. Tan, medium-grained quartzite.	1 foot
d. Impure red shale with numerous zoned chert nodules, the with an occasional thin shaly sandstone bed 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. Thay 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[14] at Bisbee from the section in the Naco Hills newr 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 dnd are more aphanitic in texture. The thickness at B isbee is estimated at 3,000 feet.

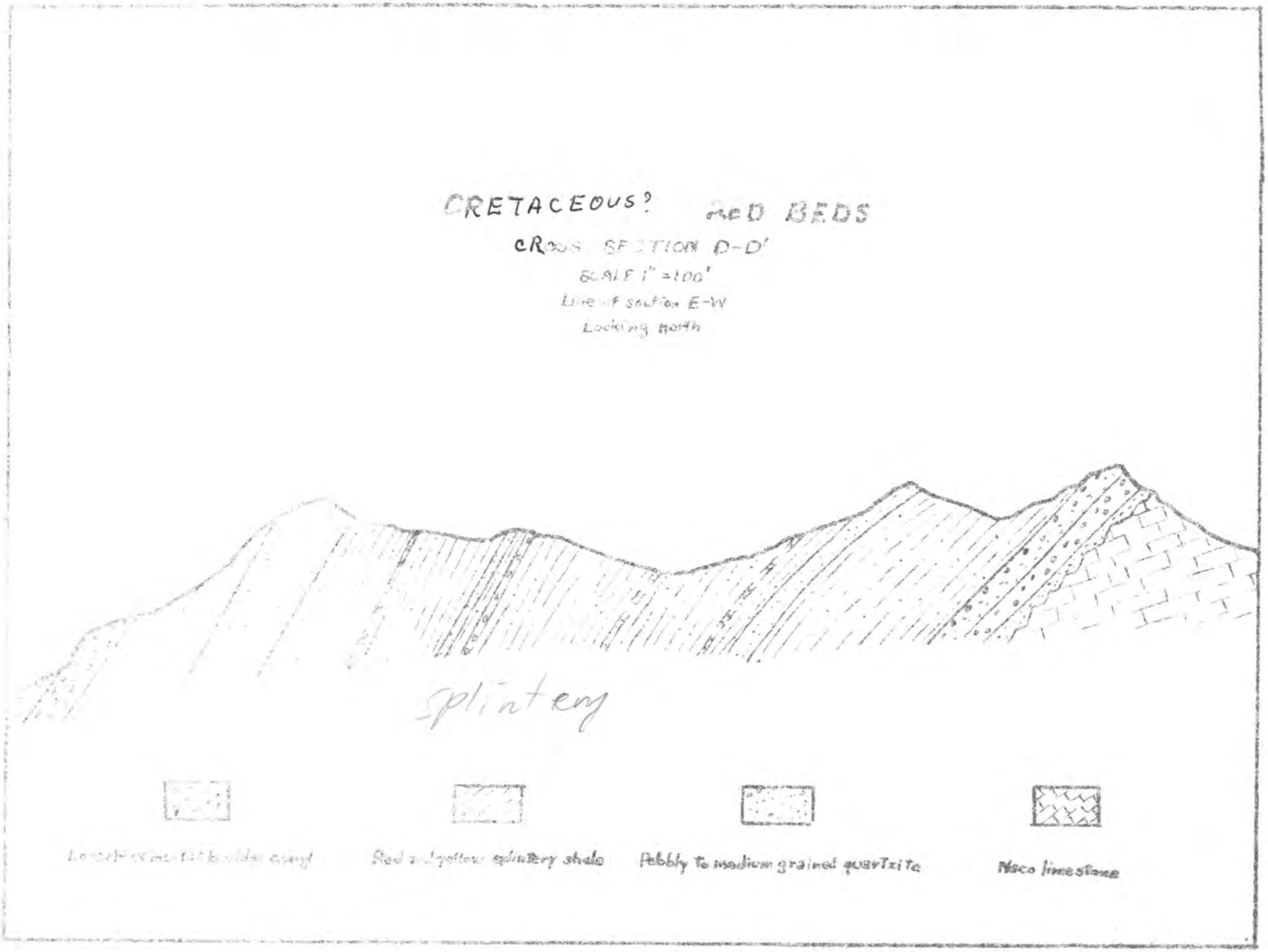
Mesozoic Rocks

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

14. idem pg. 44


CRETACEOUS? RED BEDS
CROSS SECTION D-D'
SCALE 1" = 100'
Line of section E-W
Looking North
Splintery
Red and yellow splintery shale
Pebbly to medium grained quartzite
Naco limestone

Print 14

Cretaceous? red beds
and
Naco Limestone unconformity

This photograph, taken on the west slipe of the main range about one half mile south of the Pomona mine, shows the unconformity between the Naco limestone and the overlying basal conglomerate of the Cretaceous? red bed series.

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 1/4 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 gray, coarse, arkozic 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[6] in the Reward area should be included. Further work will be required 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 ex-

6. idem.

cept 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[20] in the Tucson Mountains are somewhat similar and may be comtemporaneous. 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° SW. This conglomerate appears to rest directly on a Naco limestone erosion surface

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

Print 15.

Gila conglomerate west of Pomona mine.

The cobble conglomerate shown above is well-distributed along the western edge of the main range from Copperosity Basin to the Vekol Valley. It rests unconformably on all older rocks, but is overlain and interbedded with Quarternary volcanics.

Print 16.

Troy Quartzite-diabase contact.

The intrusive contact between the Troy quartzite and the diabase exposed just east of the Hinshaw mine is shown above. A narrow "hybrid" zone is found along this contact.

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 foot pebble and cobble horizon, which may grade laterally northward into the thick tuff beds on the flank of 2917 peak.

Terrace Gravels

The debris which has accumulated in alluvial fans and piedmont slopes along the foot of the main range, is cut by ravines formed by recent changes in base level. The resulting topography consists of a series of terraces separated by ravines 50 or more feet deep. Locally, within the ravines is a second and often a third bench or terrace of minor extent.

The alluvial debris which forms the terraces consists of poorly sorted, angular to sub-angular boulders, cobbles and pebbles and coarse sand derived from the rocks exposed upstream. On the western slope of the main range. Naco limestone is the main constituent, whereas along the eastern slopes, both Paleozoic and pre-Cambrian rocks contribute to the deposits. Granite is an important constituent at the southeast end of the main range, and volcanics make up a large part of the debris on the northwestern fringe of the mountains.

Locally, as in the vicinity of the Vekol mine, caliche has cemented the limestone talus and wash into a hard pan which is covered by a thin veneer of alluvium.

Alluvium

The most recent alluvium cannot be distinguished from the alluvial material of the terrace gravels except for its distribution. It fills the bottom of the ravines and washes, and forms a thin veneer over the terrace deposits and pediments. Some of this material has been recently eroded from the adjacent ridges, and some appears to be reworked terrace material and Gila conglomerate.

Igneous Rocks

Apache Basalt

This group of flows is described by Ransome[10] in the Ray quadrangle about 85 miles northeast of the Vekol Mountains. The basalt which occurs above the Mescal limestone and beneath the Troy quartzite in the Vekol Mountains is correlated with the Apache basalt of central Arizona because of its comparable stratigraphic position.

It reaches its maximum thickness of about 200 feet just south of Promonotory Ridge in the central part of the main range. Farther north, it averages less than 75 feet, and along the southern fringe of the range, it is missing. In its place is a 20 foot bed of dark greenish-red shale containing occasional angular to sub-angular quartz fragment. More than one flow is believed.

10. idem pg. 43.

to be represented in the area, for rusty, more highly vesicular zones were noted in cliff exposures.

The basalt is intruded by diabase. In the vicinity of orthoclase diabase sills it is penetrated by orange-colored granophyric juices and related end products of the intrusive. Chalcopyrite was noted in one veinlet. Splotches, stringers and amygdular fillings of granophyre result in an unusual greenish rock mottled with orange.

The contacts with the diabase are clear-cut, and often are knife-edge. The fragments of basalt found within the diabase are angular with fairly sharp borders. A sugary, recrystallized zone a few feet wide is present, adjacent to the diabase contact in some exposures.

Megascopically, the basalt is a compact, fine-grained, amygdular, greenish-gray rock. The amygdules and vesicles range up to 5 mm in diameter, with only slight elongation in most exposures. The amygdules usually are filled with epidote, calcite and serpentine minerals. The lower 2 feet of the flow is highly vesicular, with the vesicles somewhat elongated vertically. The mass of the rock is believed to consist largely of sericite, koalin, serpentine minerals and iron oxides. The exposures of Apache basalt in the Vekol Mountains are, everywhere, badly weathered or highly altered. A microscopic analysis of this rock is given by Short and others in Bulletin 151, of the Arizona Bureau of Mines. [16]

The old Mescal limestone erosion surface upon which the basalt flowed is well-exposed on the crest of the sharp ridge just east of 3625 peak. It is somewhat irregular and, for a few inches, the limestone is altered to a dark brown color. Calcite bands, pods and occasional limestone fragments occur at the base of the basalt.

Diabase

This intrusive rock is widely distributed throughout the southeastern third and along the southern fringe of the main range. A few exposures were noted at the northeastern edge of the mountains. It occurs mainly as sills in the rocks of the Apache group and Troy quartzite, and as dikes in the schist.

Diabase occurs extensively throughout central and south-central Arizona from the Upper Salt River region to the Santa Catalina Mountains near Tucson. It has been well-described by Ransome in the Globe, and Ray-Miami Professional Papers of the U. S. Geological Survey,[11, 10] and by Short and others in the Superior area. [16]

16. idem pg. 34.
10. idem pg. 53.
11. idem pg. 80.
16. idem pg. 35.

The diabase in the Vekol Mountains undoubtedly represents the same general period of diabasic intrusive activity as in central Arizona. It is similar both in character and in geologic occurrence to that described in the above reports.

Intrusive relationships

The magma appears to have forced its way into the Apache and lower Troy rocks. The diabase occurs as fairly persistent sills, but it often cuts across the bedding at a low angle, jumping from one horizon to another and apparently forming a network of interconnected sills and dikes. The attitude of the beds, however, is relatively undisturbed. Many of the sills wedge out laterally. The thickness of the individual sills ranges from a few feet up to 300 feet.

Assimilation does not seem to have been important except locally. An exposure on the ridge east of the Hinshaw mine on the south side of the main range in which diabase intrudes Troy quartzite is an example. The following transition zone was noted:

1.	Medium-grained, unaltered vitreous quartzite.	4 feet
2.	Shattered, stained quartzite in a dark, greenish-gray matrix.	6 inches
3.	"Hybrid" diabase with numerous small ghost-like quartzite fragments and individual quartz grains.	1-3 feet
4.	Normal diabase with well-dispersed quartzite fragment or quartz grains.	2-4 feet

Print 17

Photo-micrograph
of the diabase-Troy quartzite intrusive contact
of Print 16. (47x, crossed nicols)

The diabase, shown on the right, and the quartzite on the left, are well-sericitized and chloritized, but the former include the relix quartz of the orthoclase-quartz graphic intergrowth pattern. The latter contains sub-angular quartz grains. Occasional quartz grains are found within the diabase. These show corroded borders.

5. Orthoclase diabase with no apparent quartzitic material. 15 feet exposed

This intrusive contact is believed to be within a few feet of the shale marker that separates the lower and the upper Troy. The sill is well over 200 feet thick.

In thin section, type 3. consists of "ghost" quartzite fragments included in altered diabase. The individual quartz grains within the fragments are well-dispersed in a sericite-chlorite matrix. The siliceous cement has been removed, and many of the quartz grains are corroded around the edges. In the altered diabase, scattered granophyric intergrowth areas are evident, indicating a granophyric composition in the contact phase of the sill. The sericite and chlorite which replaced the matrix of the feldspars and ferromagnesians of the diabase probably replaced the matrix of the quartzite fragments. Magnetite grains are abundant in the quartzite, while skeletal growths of ilmenite are numerous in the diabase. Small, very fine-grained quartz veinlets cut across both the diabase and the quartzite.

Type 5., in thin section, has a typical ophitic texture and consists of:

A. Labradorite laths averaging 0.5 mm in length, and totaling about 30% of the section.

b. Hornblende and uralite 0.3-0.4 mm, about 30%.

c. Quartz-orthoclase intergrowth, 0.3 mm, estimated at 20%.

d. Magnetite and Ilmenite, 0.3-0.4 mm, about 15%

e. Secondary sericite and chlorite, about 5%.

This type is comparable to the topmost orthoclase diabase sill in the Promontory Ridge area, exposed along Diabase Traverse 3, described below.

Petrography

In the Superior area[16] the diabase was divided into three types mineralogically; the quartz-orthoclase diabase, normal or augite diabase, and the olivine-augite diabase. All three types are believed to be present in the Vekol Mountains, but because of alteration the olivine type has not been definitely established.

Petrography of the quartz-orthoclase diabase: Megascopically, this type, when unaltered, has a well-developed ophitic texture. Gray plagioclase laths 1 mm to 2 cm long, are embedded in a greenish ferromagnesian background. Scattered throughout are magnetite grains and irregularly shaped, pink areas from 1 mm to 1 cm, which resemble orthoclase.

In thin section, these pink areas prove to be a graphic intergrowth of quartz and orthoclase. They make up from 5% to 60% of the rock. In a speciment which contains approximately 20% quartz and orthoclase, the labradorite is estimated at 35%, augite at 20%, uralite at 10%, and boitite at 5%. Apatite is present in

16. Short, M. N. and others. Geology and Ore Deposits of the Superior Mining Area, Arizona. Bull. 151, Arizona Bureau of Mines. pg. 35, 1943.

Print 18

Photo-Micrograph
of
Orthoclase-quartz diabase. (47x, crossed nicols)

The above print illustrates the ophitic texture of the diabase and shows knots of orthoclase-quartz graphic intergrowth. The augite is partly altered to uralite, biotite, and chlorite. The plagioclase is corroded, but essentially unaltered.

very minor amounts. The augite is partly altered to uralite, biotite, and magnetite, while the feldspars show slight sericitization.

Petrography of the normal diabase: the Normal diabase is very similar to the orthoclase-quartz diabase, both megascopically and in thin section, except for the abasence of orthoclase and quartz. In the field these two types appear to be gradational.

Petrography of the olivine diabase: Thus far, the writer has not been able to definitely establish the presence of olivine in thin section. Alteration of the original ferromagnesian minerals to uralite, chlorite and serpentine minerals has been extensive in sills suspected to olivine diabase.

Differentiation is suggested both within the individual sills and in the diabasic intrusive activity as a whole.

The sillat the base of the Apache group, and the topmost orthoclase diabase sill illustrate both textural and compositional variation from the borders toward the center.

In the southeastern part of the main range, this basal sill intruded along the major unconformity between the Pioneer shale and the Pinal schist. No Scanlan conglomerate is present in this area. In some exposures, scattered patches and blocks of Pioneer shale lie between this sill and the schist.

Diabase cross section #1, illustrated on Plate 6., shows the textural relationships within this sill. The location of this section is shown on Plate 3. At the base, a 2 foot chilled border is clearly exposed. The texture immediately above is fine-grained diabasic, but gradually becomes coarser upward. From 100 to 150 feet from the base, the texture is medium-grained. The feldspars average between 2 and 3 mm in length. At 150 feet from the base, the sill has a pegmatitic texture with many of the plagioclase phenocrysts over 1 cm in length. Megascopically, the composition appears to be more siliceous, although the writer has not found sufficiently fresh material to warrant a thin section study of this type.

The coarsely crystalline zone is more than 50 feet thick. It appears to grade rather rapidly into a medium-textured, normal diabase, and finally, to a very fine-grained rock near the upper contact. This contact was not exposed, but float indicates the presence of a narrow, chilled border.

Because of the gradation in texture and the apparent gradation in composition, the writer believes this sill to represent a single intrusive rather than separate intrusion of the border, intermediate and central zones.

In the topmost sills, where orthoclase diabase predominates, a similar relationship is exposed. These sills have fine-

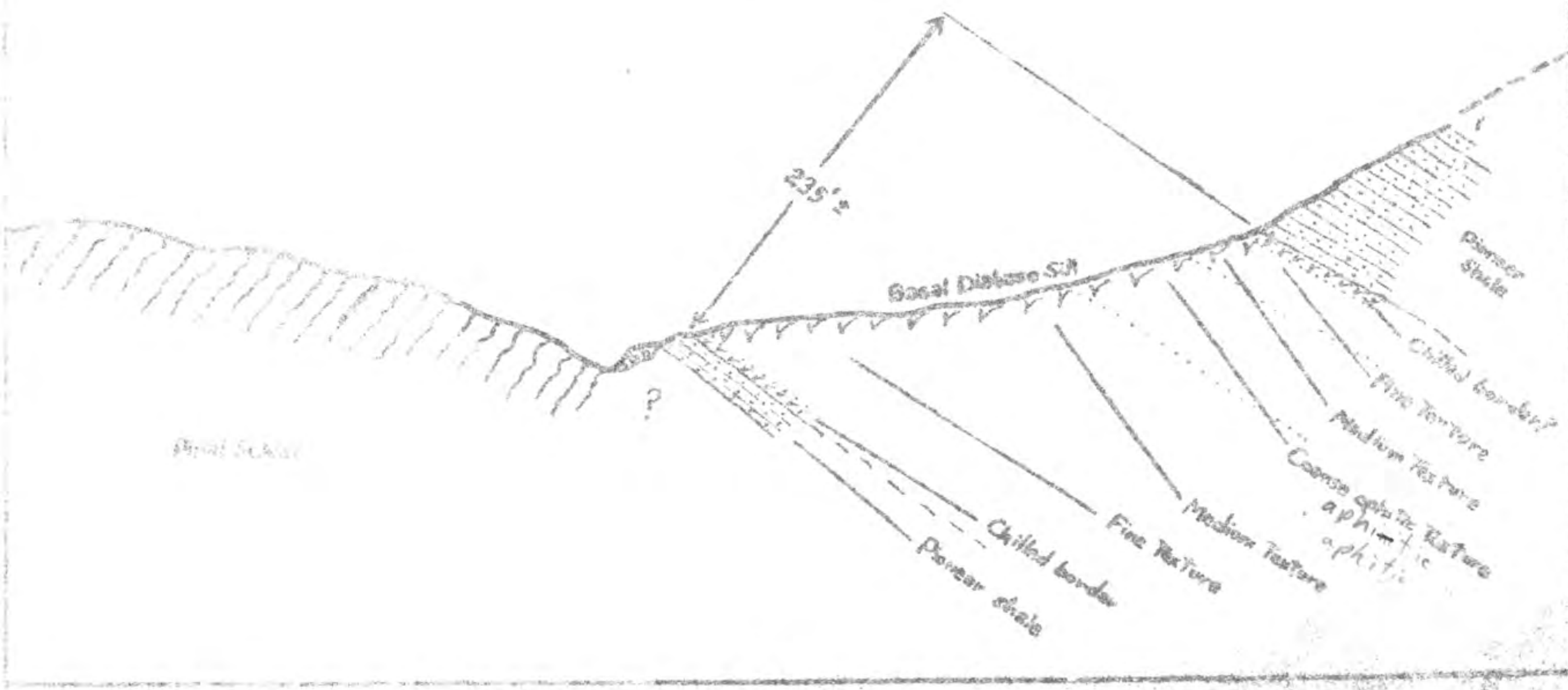
CROSS SECTION

DIABASE TRAVERSE I.

SCALE, 1" = 100'

LINE OF SECTION NORTH-SOUTH

Looking West



grained borders. They grade to medium and coarse-textured diabase toward the middle where the more acidic, granophyric segregate is widespread.

These sills are exposed from Promontory Ridge southward to the Copperosity fault zone and to a limited extent at the northeastern edge of the mountains. Apache basalt and Mescal limestone form the lower contact, whereas the upper surface is generally eroded, and covered with upper Troy or Santa Catalina basal conglomerate.

The cross section along Diabase Traverse #3, illustrated on Plate 7., and located on Plate 3., shows the relationships between these diabase sills and the underlying Mescal limestone, the intruded Apache basalt and the overlying Paleozoic rocks.

The Mescal limestone, shown at the bottom of the section on Plate 7., is slightly bleached along the contact with the small diabase sill. No differentiation was noted in this sill, and the texture is medium to fine diabasic. The lower part of the Apache basalt consists of greenish to bluish-gray, finely crystalline, amygdular basalt. The amygdule filling is largely epidote and calcite. Jointing parallel to the trend of the Mescal limestone is well-developed locally.

The central diabase sill has fine-textured borders which

PLATE 7

grade inward to a medium to coarse texture at the center. In thin section, up to 10% granophyric intergrowth of quartz and orthoclase was noted.

The base of the overlying Apache basalt contains epidote-calcite alteration, but toward the top, it is permeated by small stringers, irregular splotches and anygdular fillings of orange-colored granophyric material. This exposure of basalt, also, is fine-grained, greenish-gray, and well-altered.

The 6 foot basal zone of the adjacent orthoclase diabase sill is fine-textured. The remaining exposure along the line of section is coarsely crystalline, very highly altered, pegmatitic orthoclase diabase. Basal conglomerate of the Santa Catalina formation covers the upper surface. (See Prints 11. and 12.) Fifty feet south of the traverse, medium-to-fine-textured orthoclase diabase at least 30 feet thick is well-exposed above the pegmatitic horizon.

The medium-to fine-textured phase of this sill was described under the heading "Petrography of the orthoclase-quartz diabase" on page 49. There appears to be a considerable variation in the amount of the orthoclase-quartz segregate in this phase. This is ture, also, in the coarser "pegmatitic" phase. It varies from 10-60% in thin section. The orthoclase-quartz granophyric segregate is generally well-dispersed throughout the rock, but there

Print 19

Graphic replacement of plagioclase
by
quartz and orthoclase. (47X)

Print 19 under ordinary light, and Print 20 under crossed nicols, show the zonal replacement of plagioclase by the graphic network of orthoclase and quartz. A part of the core, also, is replaced.

Print 20

Graphic replacement of plagioclase
by
quartz and orthoclase. (47x, crossed nicols)

Print 21

Photomicrograph of partly altered diabase
(47x)

This specimen, collected from the intermediate sill of Diabase Traverse 3, represents the early stages of alteration in the diabase. The plagioclase is relatively unaltered. The augite, however, shows reaction rims of uralite, hornblende, and biotite. Chlorite is present in small amounts.

is definite indication in thin section that it selectively replaces the feldspars in many instances. (See prints 19 and 20.)

Plagioclase, augite and hornblende apparently crystallized early from the magma and formed a large part of the rock. Toward the late stages of crystallization, the orthoclase-quartz segregate probably gathered in knots, filled the remaining open spaces, and replaced some of the plagioclase. Uralitization is widespread throughout most of the diabase sills, (See print 21) and many have occurred soon after the consolidation of the orthoclase-quartz segregate.

Saussuritization has greatly affected the orthoclase diabase, and in particular, the pegmatitic phase. The feldspars appear to have been altered to epidote or clinozoisite, albite, quartz, sericite and calcite, whereas the ferromagnesians have been altered to chlorite, uralitic amphibole, and hematite.

Within the pegmatitic zone of the upper sill, orange-brown to dull gray knots of alteration products are clearly visible. Stringers of similar material, some of which contain knots of epidote up to 1 cm and calcite up to 6 mm with small bunches of chalcopyrite, cut both the fine-grained border phase of the sill and adjacent Apache basalt.

Johannsen[20] describes the saussuritization of intermediate plagioclase as follows:

20. Johannsen, albert. A Descriptive Petrography of Igneous Rocks. Vol. 111, pp 210-211. Unviv. of Chicago Press, (1937)

"$Na_2O.Al_2O_3.6SiO_2$ (Albite) + $8(CaO.Al_2O_3.2SiO_2)$ (Anorthite) + $4H_2O$ (Water) =

$2(4CaO.3Al_2O_3.6SiO_2H_2O)$ (zoisite) + $Na_2O.3Al_2O_3.6SiO_2.H_2O$ (Paragonite) + $4SiO_2$ (quartz) "

Other authorities have written equations differing from that given by Johannsen. Indeed, field and petrographic evidence indicates that in most localities, a more complicated series of reactants and products are involved than those represented in the above equation. Paragonite rarely or never appears. Instead, the common sodium-aluminum silicate in saussuritized rocks is albite. If white mica appears, it is nearly always the potash mica, sericite. Epidote or clinozoisite are much more common than zoisite.

Johannsen[20] explains that when the plagioclase is somewhat more sodic, secondary albite is an alteration product. When potash is present, sericite may form. If CO_2 is present, calcite may develop, but this is less common. Also, if iron is released by the breakdown of the ferromagnesiam minerals in the diabase, epidote may appear in place of zoisite, or may accompany it.

The potash in the sericite of the saussuritized Vekol orthoclase diabase may have been released by the destruction of the orthoclase. The calcite may have formed from Mescal limestone inclusions

20. idem, pg. 210-211.

in the sill or it may be of hydrothermal origin. The presence of chalcopyrite in some of the stringers would support the latter contention. The iron necessary for the development of epidote undoubtedly came from the destruction of the ferromagnesians.

Both Johannsen[20] and Harker[19] believe uralitization of the ferromagnesian minerals accompanies saussuritization. This results in a breakdown of the pyroxenes to uralitic amphibole, hematite, etc., and of olivine to serpentine, talc, chlorite, iron ores, etc. Actinolite, garnet, chlorite and rutile, which often develop in feldspars during saussuritization, derive some of their constituents from the ferro-magnesians. A part of the uralitization of the diabase in the Vekol Mountains probably accompanied the saussuritization, but some is believed to have been earlier, for some specimens show uralitization but no saussuritization. (See print 18).

Johannsen,[20] Tyrrell[21] and others disagree with Harker[19] as to the cause of saussuritization. The former attribute this type of alteration to dynamo-alteration, whereas the latter considers it a late stage process in the cooling of an igneous rock. In the opinion of the writer the saussuritization of the diabase in the

19. Harker, Alfred. Metamorphism, 2nd ed. pp 174-176, Methuen and sons, (1939)

20 idem, pg. 228.

21. Tyrell, G. W. The Principles of Petrology, 2nd ed. pg. 311, E. P. Dutton and Co., Inc. (1929.)

Vekol Mountains is a very late hydrothermal effect. There is no evidence that shearing has played a major role in this process. It is ture that alteration appears to be more intense near the fractures, but this is believed to be due to the fractures acting as channel ways for the altering solutions. In the intermediate, less altered areas, the original ophitic texture is well-preserved. Also, thin section study of specimens in which saussuritization is just beginning shows partly altered phenocrysts of unstrained plagioclase in totally unsheared rock.

Contact Metamorphism The metamorphic effects brought about by the diabase are relatively unimportant. Slight bleaching is evident along the borders of the dikes in the schist, and scattered epidote has developed in the Pioneer shale where calcareous bands intersect the contact. The smaller slivers of Mescal limestone are well-bleached. Tremolite fibers were noted with the hand lens at one locality, and in some cases, the limestone is recrystallized for a few inches from the contact. The Dripping Spring and Troy quartzites contacts also are sharp. The contact between the Troy quartzite and the diabase is described in detail on page 47. The lack of a contact metamorphic zone adjacent to the diabase may be the result of the "dry" nature of the diabasic melt.

Age of the Diabase

The age of the diabase has been one of the leading controversial issues in Arizona geology for many years. Ransome,[10] after his study of the Ray-Miami districts condluded that the diabase is late Paleozoic or early Mesazoic. He found dikes of diabase cutting the Martin and Tornado (Escabrosa dnd Naco) limestones in both the Tortilla Mountains and the Dripping Spring range.

Darton,[17] however, concluded that these dikes are not the same as the extensive sills and dikes of the Apache Group, but feeders of some Tertiary or Quaternary basalt. He found that "the diabase invades mainly the strata older than the Troy, but in some instances the lower part of the quartzite is invaded."

Short and Ettlinger found similar evidence in the Magma mine at Superior,[15] and concluded that the diabase does not intrude the Martin limestone. They believed the diabase to be post-middle Cambrian and pre-Upper Devonian.

The relationships between the Santa Catalina formation, the two members of the Troy quartzite and the diabase in the Vekol Mountains, discussed in the section on General Geology, page 22., is summariz ed as follows:

1. The lower, massive member of the Troy quartzite is intruded by the diabase within a few feet of the shale marker division between the lower and upper Troy.

10. idem pg. 56.

7. idem pgs. 254-255.

15. Short, M. N. and Ettlinger, I. A. Ore deposition and enrichment at the Magma miher, Superior, Arizona. Am. Inst. Min. Eng. Trans. Vol. 74, pg. 181, 1926.

2. The upper Troy appears to rest unconformably on a diabase erosion surface. An exposure in the canyon south of Promontory Ridge shows diabase cobbles, pebbles and fragments in a matrix of cross-bedded quartzite, limy sandstone and chert.

3. The overlying Santa Catalina formation shows a definite overlapping relationship with a sloping diabase erosion surface. A well-developed basal conglomerate of diabase cobbles and pebbles is exposed along the contact. (See Prints 11. and 12.).

4. Similar small Cambrian brachiopods were found in the upper Troy, the Santa Catalina formation, and the Southern Belle quartzite, while no fossils have been found in the lower Troy.

5. The lower Troy shows no sign of diabasic detrital material in the specimens examined thus far.

The writer concludes that the diabase is not younger than Middle Cambrian. The exact age of the diabase cannot be determined until the age of the lower Troy has been worked out, but the writer is of the opinion that the diabase is either Middle or Lower Cambrian.

Cretaceous volcanics?

The volcanics in the Reward area may be related to the Cretaceous (?) rocks, for they appear to be conformable and interbedded with the upper bouldery beds of that series. These rocks, described by Hadley,[6] in the Reward area, are as follows:

"Upper part: Mostly volcanic conglomerate, breccia, tuff-breccia and andesitic lava."

6. idem.

"Lower part: Mostly conglomerate with abundant well-rounded fragments of limestone, quartzite, felsite porphyry and granite commonly 6 inches, locally 18 to 30 inches in diameter. Includes lenses of feldspathic sandstone 1 to 5 feet thick. Bedsoof volcanic breccia, red feldspathic sandstone, quartzites and quartz conglomerate at base. Erosional unconformity."

The writer has not done sufficient work on the volcanics in Bitter Wells Basin to establish the contact between the Cretaceous? volcanics and the volcanics farther north. Most of the secure a clear-cut relationship between the volcanics described by Hadley and those in the northern end of the basin which are overlain by the Quaternary rocks described on page 69.

Some of the basal flows along the west flank of the main range, which directly overlie the bouldery beds believed to be the upper member of the Cretaceous series in that area, may also be Cretaceous in age.

Tertiary intrusives and volcanics

Biotite granite, granite porphyry, rhyolite porphyry, dacite porphyry, andesite, and volcanics of varied composition are believed to be Tertiary in age. Their distribution, lithology and age relationships are described below:

Biotite granite

The northwestern edge of a granite intrusive of undetermined size is well-exposed along the southeastern fringe of the main range. Its intrusive relationship is restricted to the Pinal schist, and yet, it probably is not pre-Cambrian in age, for it is remarkably fresh and non-foliated. Also, no diabase dikes could be found in any of the granite exposures.

Megascopically, it is a reddish-gray, porphyro-phanerocrystalline rock with euhedral phenocrysts of orthoclase ranging up to 2 cm in length, surrounded by an equigranular matrix of subhedral to anhedral orthoclase, quartz, biotite and plagioclase with an average grain size of approximately 3 mm.

In thin section, subhedral crystals of orthoclase up to 8 mm long are intergrown with quartz, averaging about 2 mm, plagioclase, 1 mm, and biotite 1 mm. The plagioclase appears to be gradational from oligoclase to albite. The feldspars are zoned and sericite has selectively replaced the cores or alternate zones. Only a slight halo of chlorite is visible around the edges of the biotite flakes. The larger feldspar phenocrysts include small, anhedral phenocrysts of all the other minerals. Euhedral, basal sections and subhedral apatite prisms up to 1 mm, and anhedral to euhedral magnetite 0.1-0.3 mm are well-distributed as accessories.

The following is an estimate of the composition:

Orthoclase	45%	Biotite	10%
Quartz	15-20%	Magnetite	5%
Plagioclase	15-20%	Apatite	1%

A small amount of micrographic intergrowth of quartz and orthoclase appears to selectively replace the feldspars.

The contact with the schist is intrusive, and dips steeply northward. At the north end of the exposure, small granite dikes penetrate the schist for at least 300 feet. Also, pegmatite-aplite dikes cut across the contact at several places along the contact. A greenish-brown, highly altered, felsite dike intrudes the granite at the north end of the intrusive. A granite porphyry dike, described below, also cuts the granite in that area.

The granite is jointed by two sets of joints. The most apparent is a steep set roughly parallel with the contact, whereas the second is an east-west set which dips gently northward. Exfoliation has developed to a moderate extent.

The granite exposed on the surface of the pediment to the west of the Copperosity Basin consists of well-weathered, medium-grained granite with an average grain size of 4 mm. No large phenocrysts are evident in the areas examined.

Megascopically, this granite is phanerocrystalline with anhedral to subhedral phenocrysts of quartz, 3 to 4 mm, feldspar, 2 to 5 mm and biotite, 1 mm in diameter. The biotite is generally well-altered to chlorite. Thin films of epidote line small veinlets in some areas, and , in others, the feldspar is predominately flesh color. The quartz is estimated at 25%, the feldspar at 50%, the biotite at 20%, and the epidote up to 5%. The feldspars are partly altered to sericite.

The writer has no evidence as to the age of this granite, except that it intrudes the schist, and that flows of probably Tertiary age rest on the eroded granite surface. Furthermore, the andesite plug of Hill 2456, shown on Plate 3., contains fragments of granite. It may be related to the granite on the southeast end of the main range described above. Both are biotite granites, but differ in texture.

A third area of granite is extensively exposed along the northwestern edge of Santa Rosa Valley, north of the pipe line road. (See Plate 2.). It is very similar in appearance to the granite at the southeastern edge of the main range. The writer believes both are a part of the same intrusive activity.

Granite porphyry

Megascopically, the granite porphyry, which intrudes the northern end of the southeastern granite area is a porphyro-phanerocrystalline to porphyro-aphanitic rock. It consists of a few phenocrysts from 2 to 3 mm in diameter, orthoclase 1 to 2 mm, plagioclase about the same length, and scattered biotite flakes altering to chlorite averaging about 1.5 mm. All are embedded in a fine-grained groundmass of orthoclase and quartz which is barely discernible with the hand lens.

This rocks appears to cut the granite in dikes several feet thick, but the exposures are poor. Consequently, no detailed picture of its relationship to the granite could be secured. It may be related to the rhyolite porphyry described below.

Tertiary Volcanics

The flows and related volcanics of intermediate composition along the west front of the main range in the vicinity of 2913 peak and on the pediment to the west and northwest appear to be a part of the volcanics of the Copperosity Hills. They are believed to be Tertiary for they overlap the granite and are covered by the Quaternary volcanics.

The following kinds were collected and studied:

a. Dacite from 2913 peak:

Gray, porphyro-aphanitic rock with feldspar phenocrysts between 1 mm and 1 cm in lenth, slender hornblende needles between 0.5 and 4 mm long, and biotite flakes 1 mm in diameter embedded in a very finely crystalline to aphanitic groundmass. There is a faint tendency toward banding with a rough orientation of the hornblende and biotite. The porphyritic texture is not conspicuous because of the light gray color of both the phenocrysts and the groundmass.

In thin section, this rock is clearly porphyritic with euhedral to subhedral plagioclase phenocrysts up to 6mm long, and a second generation averaging about 1 mm, hornblende phenocrysts averaging 3 mm in length, and biotite 1 to 2 mm in diameter surrounded by a very finely crystalline groundmass. The plagioclase phenocrysts are probably andesine. They are partly altered, with sericite developed along fractures. The hornblende and biotite are highly corroded and altered to iron oxides. Many have halos of magnetite grains around their borders. There is no evidence in thin section of the development of secondary biotite by magmatic resorption of the hornblende. Devitrification of the groundmass has produced a cryptocrystalline mass of small crystals. Sparse, anhedral quartz up to 0.3 mm was noted, and small amounts of calcite are present also. Finely crystalline sanidine may be present.

b. Flows from the pediment west of 2913:

These flows consist of coarse porphyro-aphanitic rocks, fine-grained felsites and tuffaceous types.

1. Andesite? The porphyro-aphanitic type consists of tabular plagioclase phenocrysts averaging 5 to 6 mm in length, brown hornblende relics up to 10 mm long, and numerous euhedral biotite books 1 mm or less in diameter embedded in a dense, brownish-gray matrix. The plagioclase shows both carlsbad and albite twinning and is remarkably unaltered. The hornblende has been almost entirely replaced by iron oxides the the biotite, in hand specimen, appears to be relatively fresh.

2. Felsite. Fine, porphyro-aphanitic type with sparse plagioclase phenocrysts up to 2 mm, highly altered, brown hornblende up to 1 mm long, with numerous relatively unaltered biotite flakes averaging about 1 mm in diameter. All are embedded in a brown, aphanitic groundmass.

3. Tuff. Angular fragments of andesite described above, ranging from 5 mm to 1.5 cm, together with occasional hornblende phenocrysts up to 8 mm long: sparse plagioclase phenocrysts up to 4 mm in length, euhedral biotite books about 1 mm in diameter are embedded a matrix of gray ash. Many of the hornblende phenocrysts are relatively unaltered.

All three types are so similar, mineralogically, that the writer believes them to be a part of the same period of volcanic activity. Similar rocks were collected at the Papago mine at the western edge of the Vekol Quadrangle, and in the northern end of the Copperosity Hills.

c. Andesite from Hill 2456:

This sharp pointed hill is believed to be a volcanic plug. The trend of the flow lines is roughly circular. (See Plate 3.). Granite fragments are included around the edges.

Megascopically, this rock is extremely fine-grained with but a few altered biotite flakes up to 2 mm in diameter. In thin section, it is porphyritic with shreds of altered biotite, augite phenocrysts up to 0.6 mm and ghost outlines of hornblende and biotite replaced by magnetite grains up to 1.3 mm: all are embedded in a groundmass of roughly oriented shreds of plagioclase 0.01 to 0.05 mm long, small augite and magnetite specks which are surrounded by glass in the process of devitrification. A few apatite sections were noted ranging from 0.01 to 0.03 mm. No reaction rims of biotite were noted around the edges of the hornblende.

Dikes filling east-west fault zones

The andesite? dikes such as the one which cuts across the main range at the Vekol mine, the one at the Great Eastern mine, and others in the northern end of the main range and in the eastern hills, vary from a few feet up to 50 feet in width. They fill east-west fault zones, but later faulting has been effective along some of the dikes. The writer considers them as pre-Quaternary, since volcanics of that sequence cover them locally.

> In hand specimen, the texture of the andesite exposed in these dikes is porphyro-aphanitic with numerous altered feldspar phenocrysts, averaging 2 mm, and altered biotite, 1 mm, in a dense brownish groundmass. A rough flow banding is evident in some specimens.
>
> In thin section, this rock consists of numerous highly altered feldspar phenocrysts up to 4 mm long, hornblende phenocrysts reaching 2.5 mm and biotite 0.6 mm maximum, in a felt-like groundmass of sericitized? feldspar lathes averagin 0.03 mm in length. A few small, anhedral ferromagnesians are scattered throughout the matrix as well as small grains of magnetite. If glass was present it has been devitrified.
>
> Most of the feldspars are almost completely replaced by sericite. A few, which show fair extinction are believed to be andesine. All, however, have well-preserved crystal outlines. The hornblende and biotite are partly replaced by calcite, and are altering to magnetite around their borders.
>
> Apatite prisms up to 0.6 mm and scattered magnetite up to 0.03 mm are accessory minerals. Narrow veinlets, consisting of calcite 0.3 mm and quartz, 0.05 mm, cut across the section

Dacite Porphyry

The dacite porphyry of the east ridges and hills occurs in sills and dikes ranging from a few feet to over 200 feet thick where it has intruded the thin-bedded Abrigo and Santa Catalina formations. It appears to be earlier than most of the east-west faulting, and may have accompanied the earlier stages of the northwest faulting.

Megascopically, this rock is light gray to tan, porphyro-aphanitic with stubby phenocrysts of feldspar, 1 to 2 mm long, hornblende needles up to 1 mm and biotite flakes 1 to 2 mm in diameter, embedded in a pinkish-gray, aphanitic matrix. The rock generally consists of about 50% phenocrysts. The white, chalky feldspar phenocrysts make up about 30%, while the hornblende needles and biotite flakes total about 20%. Chlorite has partly replaced these minerals.

In thin section, phenocrysts of feldspar averaging 1 mm long, hornblende up to 2.5 mm, but averaging less than 1 mm, biotite about 1 mm, and scattered magnetite make up about 45% of the section. The feldspars are almost completely altered to sericite. Recognizable anhedral quartz and sanidine up to 0.1 mm are minor constituents. The grain size in the matrix averages about 0.04 mm and consists of brownish, sericitized plagioclase laths with corroded, equidimensional, anhedral sanidine? and quartz? together with sparse, scattered hornblende, biotite and magnetite. The texture of the groundmass is microfelsitic.

Calcite has replaced the cores of hornblende phenocrysts and magnetite grains form an intermediate zone between the calcite and the outer rim of unreplaced hornblende. Apatite is a minor constituent of the rock.

In the Reward area, Hadley designates the rock described above as a hornblende diorite porphyry. The writer prefers the term dacite porphyry since the groundmass is generally aphanitic, and appreciable quartz and sanidine are present. In most of the exposures examined by the writer, biotite and hornblende are present in about equal proportions.

Rhyolite porphyry

At the southeast edge of Bitter Wells Basin, a small east-west trending plug of rhyolite porphyry is located just south of hill 2427. (See Plate 3.,). It averages about 1,000 feet in width, and is exposed for about 3,500 feet along its trend.

Megascopically, this rock has a porphyro-aphanitic texture with short prismatic phenocrysts of clear quartz and highly sericitized feldspar 2 mm in diameter embedded in a highly altered, gray, very finely crystalline to aphanitic groundmass. A few badly altered biotite flakes are evident, and knots of columnar epidote ranging up to 5 mm give the rock a spotted greenish appearance.

In thin section, subhedral to euhedral phenocrysts of beta quartz, 1 to 2 mm in diameter, subhedral orthoclase and plagioclase (probably oligoclase) 1 to 3 mm long, and biotite 1 mm in diameter, together with numerous small phenocrysts are embedded in an extremely fine, sericitized matrix.

The feldspars are partly sericitized, and both the feldspars and quartz are embayed. Chlorite almost completely replaces the biotite. Areas of radial epidote and calcite up to 5 mm are present. They appear to replace the larger feldspar phenocrysts. Apatite is sparsely present in 1 mm subhedral crystals. Magnetite, ranging from 0.05 to 0.1 mm is a very minor constituent.

The mineral composition of the phenocrysts is estimated as follows:

Primary		Secondary	
Orthoclase	10-15%	Sericite	5%
Quartz	15%	Chlorite	3-%
Plagioclase	10%	Epidote	5%
Biotite, largely altered to chlorite		Calcite	3-5%

Primary

Magnetite	1%
Apatite	minor

The fine-grained matrix represents about 50% of the total.

This plug intrudes diabase, Troy Quartzite, Santa Catalina formation and the remainder of the Paleozoic section with the exception of the Naco limestone at hill 2427, and farther east, cuts the rocks of Cretaceous? age. Also, according to Hadley,[6] it offsets dikes of hornblende diorite porphyry or dacite porphyry. It is believed to be Tertiary in age.

A dike approximately 100 feet wide cuts across the southern end of the limestone hill just east of the rhyolite porphyry plug. (See Plate 3.). Itx texture ranges from porpjyro-aphanitic to fine porphyro-phanerocrystalline and is similar to that of the granite porphyry dike which intrudes the northern end of the granite at the southeastern edge of the main range. Both probably are related to the rhyolite porphyry intrusive activity.

Along the contact of the rhyolite porphyry and granite porphyry with the Escabrosa limestone are thin patches of metamorphosed limestone a few inches to several feet in width. The garnet-epidote-calcite rock is developed in the mineralized areas also, and may be the product of hydrothermal alteration related to a

6. idem

period of metallic mineralization, or it may be a result of the direct contact effects of the intrusive. A further study of this problem will be made by the writer.

Quaternary Volcanics

The sequence of volcanic rocks exposed along the northwestern edge of the Vekol Mountains is believed to be of Quaternary age. These volcanics dip gently northwest and occur in isolated, recently uplifted blocks. (See Plate 3.). This sequence includes the following rocks:

	Thickness (Top)
a. Highly vesicular, dark gray, olivine basalt.	50-200 feet
b. Agglomerate or volcanic breccia consisting of scoria, tuff, and irregular areas and blocks of basalt.	100-500 feet
c. Thin basalt flows.	10-100 feet
d. Thin, gray, platy, finely crystalline andesitic? basalt.	50-100 feet
e. Gray tuff interfingering with Gila conglomerate?	10-200 feet
Poorly exposed flows and clastics, possibly Tertiary or Cretaceous age.	Unknown

The underlying rocks consist of thin tuff beds, occasional medium-to corase-grained sandstone beds consisting largely of volcanic material, and thin flows ranging in composition from andesite? to rhyolitic obsidian. This group of rocks is poorly exposed for it occurs in the central and northern part of Bitter

Print 22.

Quarternary Volcanics,
north end of Bitter Wells Basin.

Olivine basalt caps the ridge on the upper left. Underlying the basalt are agglomerate beds and occasional thin basalt flows. Just above the road, Gila conglomerate is interbedded with tuff.

Print 23.

Quarternary Agglomerate

The 5 foot exposure of agglomerate shown in the above print consists of angular fragments of basalt and andesite averaging about 4 inches in length embedded in a matrix of finer fragments and ash. A faint bedded tendency is evident in most exposures.

Wells Basin, which is largely covered with alluvium. The writer has not studied these rocks in sufficient detail to establish their relationship with the rocks described by Hadley[6] in the Reward area.

The gray tuff of unit 3., exposed on the southwest flank of 2917 peak, is made up of angular, 1/2 to 1 inch volcanic fragments, largely pporphyro-aphanitic andesite in a matrix of buff-colored tuff consisting of ash and pumice fragments. Toward the southwest, this unit appears to grade into a well-rounded pebble and boulder conglomerate which is believed to be comparable to the Gila conglomerate described by Ransome.[10]

The thin, gray, platy basalt of unit d. is a persistent flow along the northwest edge of the area. It is found at the base of 2804 peak west of the Vekol mine, at the base of the northern end of the main range, and immediately above the gray tuff bed of 2913 peak. Megascopically, it is a dense, gray rock with occasional vesicles up to 3 mm long, scattered augite phenocrysts 1 mm in diameter, and a few olivine phenocrysts up to 1.5 mm, with a variable, brown halo of iddingsite.

In thin section, augite phenocrysts up to 2mm, but averaging 0.6 mm, make up about 5% of the rock: olivine up to 0.6 mm in diameter, partly altered to iddingsite, account for about 10%.

6. idem

10. idem pg. 71

A few plagioclase laths, which reach a maximum length of 0.5 mm are present, but they could not be identified. The groundmass consists of a mesh of roughly oriented feldspar laths averaging about 0.1 mm long, enclosing anhedral areas of iddingsite and numerous augite grains. A small amount of interstitial glass fills the intermediate areas. The vesicles, 1-3mm in length, are elongate and make up about 10% of the section. The vesicles and plagioclase laths are aligned by flow.

The thin basalt flows of unit c. consist of gray to dark gray, vesicular, olivine basalt in flows 1 to 10 feet thick. These flows are not consistent and are missing locally.

Agglomerate

The agglomerate or volcanic breccia consists largely of scoria boulders with an occasional vesicular basalt boulder 3 feet or more in diameter embedded in a matrix grading from boulders to fine-grained tuff and ash. Locally, areas of gray, vesicular basalt appear to have intruded the breccia, and toward the top, occasional thin basalt flows are interbedded with the agglomerate.

Olivine basalt

Capping the agglomerate is a group of dark gray, vesicular olivine basalt flows interbedded with agglomerate identical to that described above. The flows range from 50 to 30 feet in thickness except for thin, platy flows which are 20 to 3 feet thick.

Print 24

Photo-micrograph of Olivine
Basalt (47x)

The above print of the vesicular, Quarternary olivine basalt, shows an olivine phenocryst in the first stage of alteration to iddingsite. Many of the small phenocrysts are completely altered. A small augite phenocryst can be seen on the right side of the print. The groundmass consists of plagioclase laths, small grains of augite and iddingsite, and scattered magnetite. A small amount of glass is present in the groundmass.

The agglomerates are from 5 to 10 feet thick. The vesicles in the basalt are generally elongated in the direction of the flow. The maximum thickness of this unit is estimated at 200 feet.

In hand specimen, this rock is dark, brownish-gray on fresh surfaces. It is highly vesicular with elongate vesicles ranging up to 4 cm long and 5 mm wide. They are partly filled with calcite. The pore space varies from 25% to 50%. Occasionally, phenocrysts of olivine 1 to 2 mm long, augite 2 mm in length, and plagioclase laths 0.5 to 1 mm long are visible on fresh surfaces. The matrix is aphanitic, but contains many minute vesicles. Calcite fills some of these.

In thin section, the basalt shows the following composition:

Primary		Alteration	
Olivine	0.5 - 1 mm in phenocrysts 0.01 in groundmass 2%	Iddingside	8%
Labradorite	1.2 mm max. length in phenocrysts. 0.5 mm average in groundmass 5%	Amygdular	
Augite	2.2 mm max. in phenocrysts 0.1 mm av. in groundmass 10%	Calcite	1%
Accessory			
Magnetite	0.03 mm av. 5%		

Occasional subhedral phenocrysts of labradorite up to 1.2 mm long, subhedral phenocrysts of augite up to 2.2 mm in length and subhedral to euhedral phenocrysts of olivine 1.5 mm long are embedded in a finely crystalline groundmass of labradorite laths 0.1 mm long, intergrown with small grains of augite and iddingsite.

Many of the larger labradorite phenocrysts are zoned. The augite and labradorite are relatively unaltered. The larger olivine phenocrysts have a narrow rim of iddingsite, whereas many of the smaller are completely altered to reddish-brown iddingsite. Small magnetite grains are well-distributed throughout the groundmass.

The small laths of labradorite in the groundmass are well-orianted. This parallelism, together with the elongation of the vesicles clearly illustrates the flow banding.

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, showsn 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 Apache time and the Paleozoic except for possible disturbances due to the replacement of the diabase. During the Ordovician, Silurian and much of the Devonian, this area, like most of southern Arizona was uplited 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.

d 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 quiescence 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 suncline is located along the southwestern 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 ousthesst 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 tranding Copperosity and Bitter Wells faults divided the mountains into three distinct structural blocks: the southern, the central, and the northeastern. 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 trand northwest. Also, it intrudes many of the east-west fault zones. An east-west trending rhyolite porphyry plug and dike cuts 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 the 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 from 35° to 50° southwesterly. This folding may represent minor flexures on the sunclinal flank or may have been developed by faulting.

The marked drag folding on the north side of 3231 peak north of the Hinshaw 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.).

<u>Names and Location of Major Faults</u>

The writer has named some of the major faults in the area for the purpose of simplifying the description of the structure. They are shown on Plate 3.

The Copperosity fault zone extends from the western side of the main range across the south-central section to the southeastern fringe, where it disappears under the alluvium of Santa Rosa Valley.

The Bitter Wells fault is not exposed at any point along its trend. However, the writer feels justified in assuming that this fault is present because of the obvious stratigraphic displacement between the Escabrosa limestone at the Republic mine at the southeastern edge of Bitter Wells Basin, and the schist immediately to the south. As shown on Plate 3., this fault is believed to trend east-west in the vicinity of the Republic mine and northwest across Bitter Wells Basin.

The Promontory Ridge fault is well-exposed at the western end of Promontory Ridge and in adjacent canyons. It strikes northwest and dips moderatly eastward.

The Transverse fault trends east-west across the main range just south of Promontory Ridge. It dips steeply to the south.

The Pomona fault, of similar trend and dip, crosses the range just north of Promontory Ridge.

The Vekol and Great Eastern dikes and fault zones, located toward the northern end of the main range also trend east-west. They appear to be fault zones which have been filled with andesite, and then broken by subsequent movement.

Evidence of Faulting

T The actual fault surfaces frequently are visible in the Vekol Mountains, particularly in the precipitous areas. The majority of the faults, where not actually seen, can be inferred without much doubt. In some instances, where the faults cross talus slopes, flank the alluvial fringes of the range, or cross Bitter Wells Basin, their trend and attitude are entirely speculative.

Distribution

The most intense faulting is localized along the Copperosity fault zone in the vicinity of the synclinal axis. (See Plate 3.). East-west and northwest faults are found in places at the northern end of the main range and in the eastern ridges and hills.

Type of Movement

The faulting appears to be predominately normal, but strike-slip movement has occurred on the Copperosity and possibly on the Bitter Wells faults. There are local instances of reverse movement. No major thrust faults could be found in the Vekol Mountains.

Fault Systems

The northwest trending, normal faults, and the generally east-west trending Copperosity and Bitter Wells faults constitute the two major fault systems in the Vekol Mountains. Associated with these are steep, east-west trending tensional faults and steep, north-south adjustment faults. (See Plate 3.).

The northwest system of faults has a range in strike from N 10° W to N 45° W. These faults, particularly in the main range, have a moderate dip to the east, averaging between 45° and 50°. They are believed to be mostly normal faults. The stratigraphic throw ranges from a few feet up to an estimated 720 feet on the Promontory Ridge fault. Assuming an average dip of the beds of 33°, the estimated stratigraphic throw across the northern end of Bitter Wells Basin, between the Vekol ridge and the east ridges, is in the neighborhood of 6,800 feet. This large displacement probably is the result of combined movement on the faults of the northwest system and the unexposed Bitter Wells fault. (See Plate 3.). Minor folding, described above, may reduce this figure somewhat.

Associated with the northwest faults are west dipping faults of approximately the same strike. The throw on these faults is but a few feet, and the movement is either normal or reverse. They have been effective as channel ways for the mineralizing solutions at the Vekol mine. They are cut off by the stronger east dipping faults, but, in some instances, they have moved in conjunction with them. Post mineral movement is present on both

Print 25

Drag fold on the north flank of 3231 peak.

The axis of the drag fold, which trends southeast, is showsn by the dashed line. Strands of the Copperosity fault zone are indicated by the dotted lines. Naco limestone caps the ridge, and quartzite of the Cretaceous red beds and diabase occur as slivers within the fault zone.

the strong east dipping and the minor west dipping, northwest faults.

Faulting on the Copperosity-Bitter Wells system has divided the area into three primary blocks. The southern block is separated from the central block by the Copperosity fault. The northeastern block lies north of the proposed Bitter Wells fault.

Individual faults of the Copperosity fault zone dip from 60° to 80° south. The trend of this zone is southeastward at the edge of the Santa Rosa Valley, east-west in the south-central part of the main range, and northwestward along the western edge of the area. The offset of the granite contact at the edge of Santa Rosa Valley is at least 800 feet. In the vicinity of the Hinshaw mine, the offset of the beds approaches 1,700 feet. The greater offset in this area may be the result of combined movement along the spur faults and differential movement on the main zone. The movement on the Copperosity fault zone is believed to be, in part, strike-slip, for a pronounced drag-fold has developed adjacent to the fault on the north end of 3231 peak north of the Hinshaw mine. (See Print 25.). The south block appears to have moved eastward. Also, sliver blocks within the zone include schist, Apache, Paleozoic and Cretaceous rocks. (See Plate 3.).

Within the central block east-west faults cross the range at frequent intervals. They may be tensional faults between the Copperosity and Bitter Wells fault zones. Many are occupied by

Print 26

Block Faulting north of Copperosity fault zone.

A view across the nose of the Vekol syncline northward to the highly faulted section in the central part of the main range.

Print 27

Fault Block
Immediately north of the Copperosity fault zone
in the central part of the main range.

Blocks a, b, and c, shown on Print 26 are clearly showsn in the above photograph. Block a consists of Naco limestone, b of Escabrosa limestone, and c of Santa Catalina formation. The blocks are separated by steep, east-west branches of the Copperosity fault zone.

andesite dikes and also show post-andesite movement. They range from N 75° E. to N 75° W, and dip steeply north or south. They are particularly numerous in the central part of the range north of the Copperosity zone. Their displacement is moderate, ranging up to 400 feet on the Transverse fault. (See Plate 3.).

Faults of north-south trend in the central part of the main range appear to be adjustment breaks between east-west faults and the Copperosity fault zone. The result is a group of fault blocks of randome orientation illustrated by Print 26. The dip of these faults is steep, and the movement in some cases is hinge-like.

Since the Bitter Wells fault is not exposed, its trend, attitude and position are speculative. South of the Republic mine, it is located in the alluvial-covered area between the exposure of Escabrosa limestone on the north and the Pinal schist to the south. Here, the displacement is at least 1,300 feet. Since a fault of this magnitude does not cut across the main range, it is believed to trend northwest across Bitter Wells Basin, where it appears to offset the Quaternary volcanics.

Relative ages of faults

The northwest trending normal faults are believed to be earlier than the major movement on the Copperosity-Bitter Wells system. The Copperosity fault zone truncates all other faults. Also, in most cases, the east-west trending faults offset faults of the northwest system. The Pomona fault clearly displaces the Promontory Ridge fault at Promontory Ridge. (See Plate 3.). In some cases, however, the faults of the northwest system have acted in conjunction with the east-west faults. Such a relationship is well-exposed just east of the Great Eastern mine and east of the Vekol mine, where northwest faults are terminated by the Great Eastern and Vekol faults. (See Plates 3. and 8.).

There is a possibility that the Coppersoty-Bitter Wells system of faults, including the east-west and north-south adjustment faults, may have been superimposed on the earlier northwest system.

The faults of the Copperosity-Bitter Wells system, although probably pre-Quaternary for the most part, do offset the Quaternary volcanics. There may be recent movement along faults of the northwest system as well. This will be discussed in the economic section of this paper.

Faulting and igneous intrusion

The diabase appears to have forced its way into the Apache rocks and Troy quartzite rather than to have followed a pre-existing fault pattern. Many of the sills wedge out laterally. The included blocks within the network of sills and dikes retain practically the same orientation as the adjacent blocks. They seem to be forced apart by the diabase.

There is no indication of a direct relationship between the faulting and the granite intrusives. It is possible that the northwest faulting may have been initiated by stresses developed by the intrusion of the granite. The major movement on the Copperosity fault zone is later than the granite, for it offsets the contact at least 800 feet. The trend of the granite intrusives along their exposed contacts is northward and northeastward, and may be controlled by deep-seated basement structures not apparent in the younger rocks.

The dacite porphyry, particularly in the northeastern part of the area, probably was intruded along both northwest and east-west faults. Sills, sheets and dikes several hundred feet wide, in some cases, have intruded the Cambrian and Devonian rocks in a manner very similar to the diabasic intrusion.

Formation of the Mountains

The writer suggests the following steps in the formation of the Vekol Mountains:

a. Northwest faulting to from the hogback ridges and intermediate troughs, accompanied by east-west faulting and possibly by dacite and andesite intrusions in the later stages.

b. Faulting along the Copperosity and Bitter Wells fault zones and related east-west and north-south faults.

c. Tilting of the region to the northwest to account for the regional dip of the Quaternary flows.

d. Minor faulting on various individual faults.

e. Erosion of the uplifted blocks, controlled by faulting, folding, and the local character of the rocks.

IV. PHYSIOGRAPHY

The Vekol Mountains are included in the Sonoran desert section of the Basin Range province,[3] as, in most of the province, the bedrock structure is controlled to a great extent by faulting, although, to some extent, by folding.

The surface forms in the Vekol Mountains may be divided into three groups: a. The mountains, which are generally precipitous on the east and gently sloping of the west; b. Pediments, or gently sloping rock plains with a thin cover of alluvium. These border a large part of the main range and the eastern hills. c. Bajadas, the alluvial slopes which flank the mountains on the northwest, east and southeast.

Mountains

There are two types of mountains in the area, the sierra type and the mesa type. The sierra type is represented by the main range, the east ridges, and, in a minor sense, the eastern hills. All three are characterized by steep escarpments on the east side,

3. Fenneman, N. M. and others. The Physical Divisions of the United States. U. S. Geological Survey Map, 1930.

the dip slopes on the west except in the southeast end of the main range, where the granite and schist form a northeast-trending ridge. The greater part of the main range is in a stage of late youth to early maturity, topographically. The canyons, particularly on the east side, are V-shaped with steep gradients, and occasionally have narrow, flat-topped divides. The east ridges, and certainly the eastern hills, are in a stage of topographic maturity with sharp ridge lines and wide stream bottoms, pediments and alluvial slopes separating the hills and ridges.

The Mesa type is represented by flat-topped volcanic peaks on the northwestern edge of the mountains. They are steep-sided on the southeast, and dip gently to the northwest. They are flanked by thick talus slopes, and probably represent segments of Quaternary flows recently elevated to their present position by faulting.

Pediments

A large part of the minutely dissected, but relatively smooth slopes which surround the main range in the Vekol Mountains, are carved rock surfaces or pediments. Pediments were recognized by Davis as early as 1902[5] and are described in detail by Bryan.[4] Their slopes average about 100 feet to the mile and their profiles

5. Davis, W. M. Mountain Ranges of the Great Basin: Harvard Coll. Mus. Comp. Zoology. Bull. 42, pp 129-177, 1903: reprinted in Geographical Essays. pp 725-772. Ginn & Co., 1909.

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

are concave upward.

Often the bedrock is exposed in extensive areas, but, in most cases, the rock floor is covered by a moderate thickness of alluvium, and it is exposed along the sides of ravines and in the bottom of streams of in slight hummocks on the terrace surfaces. The pediments are not well-developed in the vicinity of the mesa-like peaks. Apparently, the presence of the thick talus slopes which recede slowly has restricted their development.

The most clear-cut pediment in the area occupies the gently sloping section west and southwest of Copperosity Basin. (See Plate 3.). It extends for more than a mile toward the Kohatk wash, and has been developed on schist, Paleozoic rocks and granite. Another well-developed pediment occupies the northwest corner of Bitter Wells Basin just east of the Vekol mine. The Cambrina, Santa Catalina formation, and volcanics form the rock-carved surface. In this area, the gentle dip of the beds aided in the development of this surface. The southern end of Bitter Wells Basin and the southern fringe of the main range are believed to be pediments also, but they are covered more extensively by alluvial deposits.

Bajadas

The broad Santa Rosa Valley to the south and east of the Vekol Mountains, and the Vekol Valley to the northwest, appear to be alluvial-filled structural depressions. Each is many miles wide with gentle slopes and no sign of buried ridges or pediments. They probably represent alluvial-filled structural depressions.

The bajadas, which fringe the Vekol Mountains and adjacent pediments, slope gently toward the middle of the Santa Rosa and Vekol Valleys. Their average slope is estimated at 50 feet to the mile, and their profile, like the pediments, is concave upward.

Drainage

The drainage in the Vekol Mountains is southward and eastward into the Santa Rosa Valley, a tributary valley to the Santa Cruz-Gila River system. Drainage to a very minor extent flows northward into the Vekol Valley from the northwestern edge of the area. This valley, also, is tributary to the Gila River. The streams in the Vekol Mountains are ephemeral, flowing but occasionally during the rainy seasons.

V. ORE DEPOSITS

General Features

The mineralization in the Vekol Mountains may be divided into three general areas. The first includes the Vekol, Great Eastern, and Pomona, silver, lead and zinc deposits of the northern and central part of the main range. The second includes the copper and zinc deposits along the southern flank of the main range where the Copperosity mine, the Hinshaw claims and other prospects are located. The third encompasses a group of low hills on the eastern edge of the mountains. The Reward, Christmas Gift, Republic and other prospects are found here.

The ore deposits in the first area are unusual in that they have been localized in a structure comparable to an oil trap. They occur along the upper weathered surface of the Escabrosa limestone beneath the tight, contact shale bed close to north-south trending normal faults. (See Plate 8.).

The second area includes mineralization associated with the Copperosity fault zone and related faults, and as limestone replacement ore bodies related to faulting.

The mineralization in the third area consists largely of limestone replacement ore bodies controlled by mineralized faults of minor displacement.

Geology of the Vekol mine area

History and Production at the Vekol mine

Mining activity began in the Vekol Mountains in 1879, when the Vekol silver mine was located. The original discovery is credited to the Papago Indians. High-grade silver ore was shipped from the mine during the early eighties by a Judge Walkder, the owner. In 1885, a ten stamp mill was put into operation. It averaged about 470 tons a month and ran until 1889, when the mill-ing ore was exhausted. Shipment of high-grade ore was continued until 1894 , when the owners died. Litigation closed the property until 1908, when a New Orleans and Texas company sank the 400-foot Vekol shaft and completed several hundred feet of deep level prospecting with negative results. In 1918, a group of Phoenix men reopened the mine and reconditioned the mill. They attempted to mill the dumps, but the grade was too low. The property is now owned by Paul R. Daggs of Upland, California.

Tenney[8] reports a production of about $1,000,000.00 from 1882 to 1916, almost entirely in silver.

Stratigraphy

The section at the northern end of the main range in the vicinity of the Vekol mine includes rocks from Cambrian to Pennsylvanian age. These formations are well-exposed on the eastern escarpment of the Vekol Ridge and on the Western dip slope. (See Plate 8.). Terrace gravels and alluvium flank both sides of the ridge. The lithology is similar to that described under the heading General Geology, pages 24 to 39. Except for the Devonian, the thicknesses are somewhat greater than at Promontory Ridge. They are compared below:

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of Casa Grande Mining District, Pinal County, Arizona. Ariz. Bureau of Mines, 1934.

	Vekol mine area	Promontory Ridge
Naco limestone	415 feet minimum	270 feet (Copper-osity area)
Escabrosa Limestone	400 feet minimum	353 feet
Upper Devonian	250 feet	255 feet
Abrigo formation	95 feet	82 feet
Southern Belle quartzite	26? feet	21 feet
Santa Catalina formation	75 feet exposed	265 feet

T The Lower Mississippian Escabrosa limestone, a thick-bedded, granular, crinoidal, gray limestone, is of particular interest since it is the host rock for the ore deposits at the Vekol, Great Eastern and Pomona mines. As shown above, it is at least 50 feet thicker at the Vekol mine than at Promontory Ridge. A similar thickening occurs southward toward 2854 peak, where the Escabrosa is about 410 feet thick. Hadley[6] reports from 300 to 420 feet in the Reward area along the eastern edge of the Vekol Mountains.

The writer believes the variation in thickness to be a result of pre-Naco erosion of the Escabrosa limestone. At the base, the Escabrosa rests conformably on the persistent, white quartzite marker at the top of the Upper Devonian section. There is no indication of an unconformity within the Escabrosa. Measure-

6. Hadley, J. B. Copper and Zinc Deposits of the Reward Area, Pinal co., Arizona. Preliminary Report, Stratigic Min. Div. U. S. G. S. 1942.

Print 28

The contact shale bed at the base of the Naco limestone near the portal of the Vekol incline level.

Print 29

The relative position of the Vekol mine workings.

The surface excavation and mine entrances shown in the above print illustrate the position of the mineralized horizon along the upper surface of the Escabrosa limestone directly beneath the tight contact shale bed shown in Print 28.

ments from a marker bed near the middle of the formation to the upper contact indicate the variation in thickness to be along the upper contact.

An altered zone, extending from 10 to 100 feet below the Naco limestone contact bed, gives the appearance of weathering along an old erosion surface. It is generally pinkish-tan in color, jointed and fractured locally. Recrystallization along joints may be the result of ground water solution and redeposition.

The contact shale may be an old weathered soil. In the vicinity of the Vekol mine, it consists of numerous pitted, rounded, white chert nodules, occasional lenses of grit which are made up largely of angular to sub-rounded chert fragments, and a few limestone and sandstone pebbles and cobbles. The matrix is a soft, brick-bed shale which is altered to a light greenish-gray color in the mineralized areas. The thickness of this horizon ranges from 5 to 20 feet and averages about 8 feet. A more detailed description is given on page 34.

The finely crystalline, lgiht gray, 3 to 10-foot beds at the base of the Lower Pennsylvanian, Naco limestone appear to rest disconformably on the Escabrosa limestone. Red shale partings, usually from an inch to a foot or more in width, separate the Naco beds. One shale horizon, 140 feet from the base, is over 40 feet thick. The writer believes the Naco limestone represents relatively shallow marine deposition. A detailed section is described on page 35. It is illustrated on the cross section of Plate 8. The Naco reaches its maximum thickness at the Vekol mine where it exceeds 415 feet.

Structural Geology in the Vekol mine area

The northern part of the main range is a north-west-trending, faulted, structural ridge with a relief of approximately 500 feet at the Vekol mine. The strike of the beds average N 20° W and the dip ranges from 15° to 45° SW.

Two sets of faults are represented in the area: the Northwest-trending normal faults, and the steep, east-west-trending structures. (See Plate 8.).

The northwest set includes major east dipping normal faults and minor west-dipping normal and reverse faults. The latter appear to be earlier than the Major normal faults, but, in some cases, may be contemporaneous with them. In the latter case, they probably acted as adjustment faults. Both sets range from north-south to N 20° W. The displacement on the east dipping faults ranges from a few feet to over 100 feet. (See cross section of plate 8.). The displacement on the west dipping faults is generally not more than 10 feet. The dip on both averages between 60° and 70°.

The steep, east-west trending faults include the Vekol dike and fault zone (described on page 77.) which cuts across the ridge at the Vekol mine, and minor east-west faults in adjacent canyons such as the Argosy fault. (See Plates 8. and 10.). Andesite fills the Vekol fault zone, but no andesite was noted along the minor structures. These faults trend from east-west to N 70° E and dip about 80° northward.

Relative ages

The northwest trending faults on the north side of the Vekol dike are terminated by the dike on the east side of the ridge, and they appear to be cut off by the dike on the west side of the ridge at the Vekol mine. Mine dumps cover the critical areas on the surface, however, and the Vekol shaft workings are inaccessible. The intense alteration of the Vekol dike at the Vekol mine is believed to be due to the hydrothermal alteration which accompanied the ore-bearing solutions. There has been some post-mineral movement on the major faults in the Vekol mine. The writer is of the opinion that the east-west faulting is later than most of the northwest faulting, but late adjustment on the northwest faults may have been simultaneous with post-andesite movement on the east-west faults.

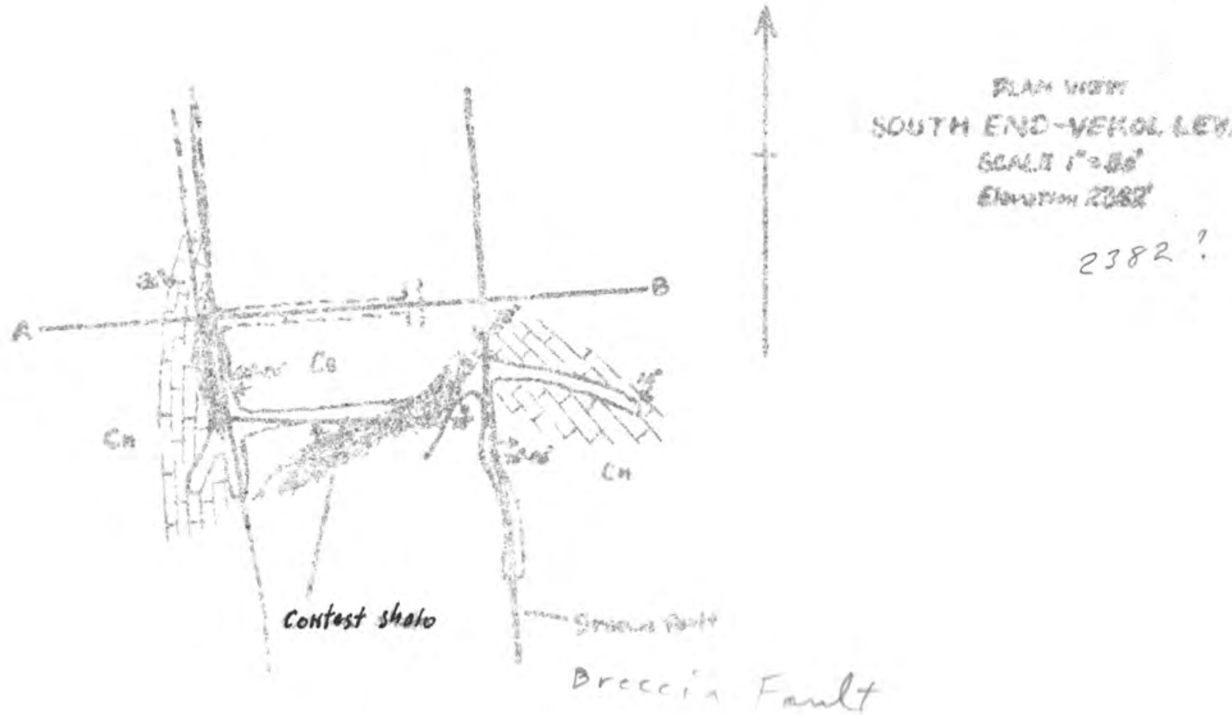
Controls of Mineralization

The Vekol mine is located on the west side of the ridge near the head of the Vekol arroyo. A network of interconnected workings extends from the Vekol dike southward at a gentle inclination along the east-dipping Breccia fault and related faults to the east-west Argosy fault at the Argosy shaft, a distance of over 1000 feet. These workings are largely restricted to the Altered, weathered Escabrosa surface directly beneath the contact shale horizon.

The individual ore bodies range from small pods to shattered mineralized areas 20 to 30 feet in dimension. All are irregular in shape and are connected by faults and fissures to form a honeycomb horizon along the old erosion surface. The overlying contact bed appears to have been an effective barrier for the ore-bearing solutions. Mineralizing solutions penetrated the lower part of this 5 to 10-foot shale and chert horizon, but here is no evidence that the solutions were able to work through the shale in sufficient strength to form ore bodies in the overlying Naco limestone beds. The Naco, both on the surface and in exposures underground, shows only local areas of hydrothermal alteration, and no mineralization was noted.

The individual ore bodies are controlled by a combination of faults, fissures, joints and bedding slips to form locally shattered, favorable areas. The mineralized area near the end of the main Vekol level (See Plate 9.) is typical of the horizon immediately below the contact bed. The contact shale dips about 30° to the west, and is terminated on the west by a steep, west-dipping

PLATE 9



N83°E
Looking North
Scale 1" = 50'

normal fault with a stratigraphic throw of about 10 feet, and on the east by the Breccia fault which dips east at 70°. (See Pring 30.). The stratigraphic throw on the latter exceeds 100 feet. (See Plate8.). The strike of the beds and of the two faults is roughly parallel. Consequently, the stopes continue erratically for 400 feet or more at about the same horizon. The slope distance of the mineralized zone between the two faults is approximately 65 feet. Post-mineral movement has occurred on both faults.

The west-dipping fault is thought to be a channel way for the mineralizing solution, for scattered mineralization was found along this fault both in this area and on the levels below. Apparently, the solutions worked up this zone and possibly along the Breccia fault as well, to the base of the contact bed and then permeated the upper few feet of the Escabrosa beneath the tight cover of contact shale. Weathering, ground water action, pre-ore-hydrothermal alteration, recrystallization and shattering may have contributed to the permeability of this zone. It is difficult to ascertain a clear-cut picture because of post-ore movement on the faults and oxidation of the ore bodies. The individual ppokets and small ore bodies appear to have been localized by the intersection of small fissures along the base of the contact bed with bedding slips a few feet below the contact. The stopes usually extend from 50 to 20 feet below the contact bed.

Print 30.

Underground view of the Breccia fault
in the Vekol mine. (See Plate 8.).

This print shows the breccia developed along a major northwest trending normal fault in the Vekol mine. There has been post-mineral movement on this fault. Its dip is approximately 68° northeast.

Oxidation has destroyed all signs of the primary sulphide mineralization in this area, but carbonates and sulfates of lead and zinc, together with sparse silver chloride? and copper carbonate stain are present. The wall rock is an altered, medium crystalline limestone, in part, recrystallized to dolomite. It is brown to reddish-brown colo. In shattered areas, the openings are lined with tan dolomite crystals rimmed with a dark reddish-brown outer zone of siderite and a very thin film of finely crystalline, translucent calcite. Numerous patches of a white, clay-like mineral, which may be dickite, and scattered throughout the area along the base of the contact bed and in the mineralized zone. Coarsely crystalline calcite veins were noted locally.

The ore from the oxidized zone, according to Tenney,[8] consisted of small nodules of horn silver, argentite, and silver-bearing tetrahedrite, in a gangue of iron-stained, slightly copper-stained, kaolinized limestone with abundant secondary calcite veins.

The stopes on the Argosy level, the bottom level in the mine, are approximately 250 feet below the collar of the Argosy shaft. They extend downward irregularly from the intermediate level above and illustrate the structural control 25 to 50 feet below the contact bed. Here, the intersection between a N 10° E, 70° W. fissure with N 30° W, 55-60° W fissures, together with steep

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of the Casa Grande Mining District, Pinal Co., Ariz. Ariz. Bureau of Mines, 1934.

n 15° E. joints and N 25° W, 25° SW bedding slips, formed a shattered area into which ore-bearing solutions penetrated. (See Plate 10.).

The ore in this level is largely oxidized to lead and zinc carbonates and sulphates and to various oxides, but considerable galena and sphalerite can be found in the broken ore and in the "tight", less shattered limestone area. The wall rock is altered Escabrosa limestone, partly recrystallized to dolomite with irregular areas of white clay which have developed along the bedding and near the fissures.

Mineralization

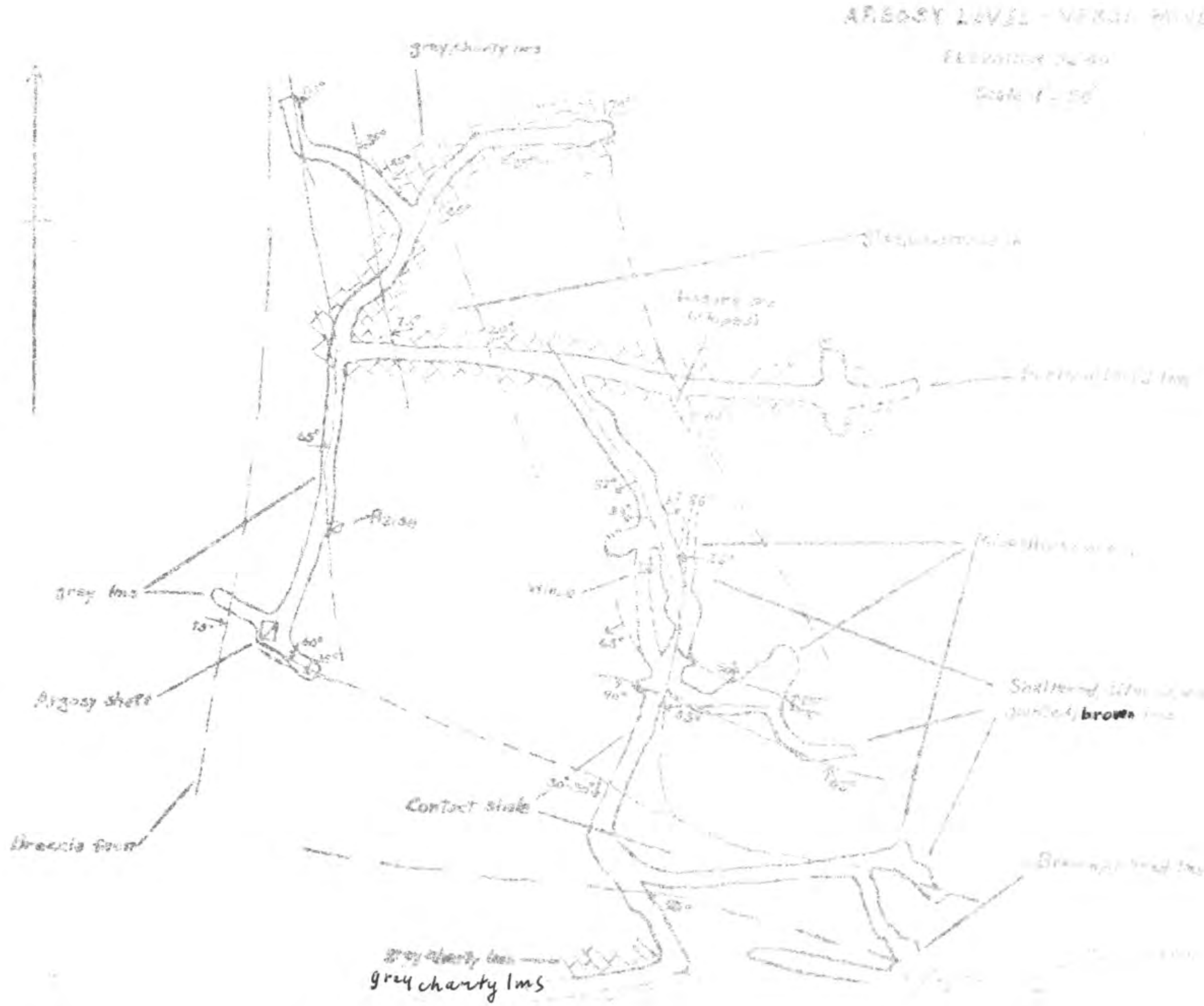
The mineralization in the Vekol mine was of relatively low temperature type with galena, sphalerite and probably tetrahedrite as the silver-bearing sulphide in a carbonate gangue. Quartz in a minor constituent in the gangue. The writer expects to complete a detailed laboratory study of the paragenetic relationships of the ore minerals and of the oxidation of the ore bodies in the near future.

The mineralization is believed to be of late Tertiary age, occurring after the intrusion of the andesite of the Vekol dike, but before the adjustment faulting on the north-south and east-west faults.

J. B. Tenney,[8] in his brief study of the Vekol mineraliza-

8. idem pg. 7

PLATE 10



ARGOSY LEVEL
grey lms
Raise
Winze
Contact slide
grey charty lms
brown

tion, concluded the high-grade silver ore to be the result of leaching of values from a series of closely spaced, nearly vertical veinlets and their redeposition at an old water table surface. He states: "The fact that the ore horizon is now inclined with the dip of the limestone and overlying lavas shows that this old water table was established before the tilting of the beds to their present attitude".

The writer does not agree with this conclusion. In the first place, most of the ore was mined from a horizon within a few feet of the Naco - Escabrosa contact at various elevations within the mine, and is not restricted to one tilted horizon. It would be pure coincidence if the water table did coincide with this particular horizon. Furthermore, the writer believes that much of the faulting which displaced the contact bed in the Vekol mine was pre-minerals. Secondly, a surface and underground study does not reveal mineralization to any extent in the Naco limestone. The mineralizing solutions appear to have been largely dammed off by contact shale bed.

The writer agrees that the minerals may have been deposited in a series of veinlets, but in a narrow zone along the upper surface of the Escabrosa limestone, and that the enrichment was largely caused by oxidation in place and removal of material by ground water, rather than transportation of the values into the mined area.

Future Possibilities

The zone between the Vekol dike and the Argosy shaft has been well-prospected along the ore-bearing horizon in the vicinity of the Breccia fault.

Tenney[8] believes the Argosy fault limits the southward extent of the northwest series of mineralized faults. The writer is not convinced this is true. The underground headings thus far driven, have not located the contact bed south of the Argosy fault. (See Plate 10.). The limestone on the south side of the fault is generally unaltered, but in the eastern heading, it is identical to the wall rock in the mineralized areas north of the fault. Also, the Mt. Vernon prospect, on the east side of the ridge, is located south of the Argosy fault. Although the mineralization is weak in this prospect, it does prove the presence of mineralization south of the Argosy fault on east-west-trending fissures at the top of the Escabrosa limestone. There is a possibility that these east-west fissures may intersect north-south fissures south of the Argosy fault at the contact horizon, not far from the Argosy shaft.

A second northwest-trending fault zone is located approximately 325 feet west of the Breccia fault zone. It may be a favorable zone at the intersection with the contact bed. A few well-placed diamond drill holes could prospect this zone at a moderate cost. (See Plate 8.).

Additional mineralized, northwest-trending fault zones may be present under the alluvium west of the Vekol mine between the Vekol dike and the Argosy arroyo.

The contact horizon at the intersection with northwest faults north of the Vekol dike is also a possibility. A fifty scale topographic map of this area is suggested to work out the relationship between the minor east-west and northwest faults in this block.

Although there is no evidence of mineralization in the middle or lower horizons of the Escabrosa limestone or in the Upper Devonian beds, it is possible that ore bodies have formed at these horizons beneath the Vekol workings, along the same mineralized faults and fissures which have supplied the Vekol mineralization. A favorable horizon, in the opinion of the writer, would be the soft limestone beds of the Lower Ouray? formation directly beneath the white contact quartzite bed at the base of the Escabrosa limestone. (See Plate 8.). This horizon is about 400 feet stratigraphically below the contact horizon at the Vekol Mine.

Geology at the Great Eastern Mine

The relationships at the Great Eastern mine are comparable to those at the Vekol except that the mineralization is more directly related to the east-west faults and dikes than to the northwest faults.

A small amount of silver-lead ore was produced from the Great Eastern from 1885-1894, some of which was treated at the Vekol mill.

Geology at the Pomona mine

The relationships at this property, shown on Plate 3., are similar to those at the Vekol. The ore bodies are small, and are restricted to the intersection between an east-west fault and the upper surface of the Escabrosa limestone. Mineralization occurs in identical conditions in a small sliver block of Naco and Escabrosa limestone within the Pomona fault zone on the east side of the main range.

Production at the Pomona mine has been negligible.

Geology at the Copperosity mine area

The Copperosity mine and other copper and zinc prospects along the southern part of the main range are included in the second area of mineralization in the Vekol Mountains. (See Plate 3.).

Copperosity Mine

History and Production

The ore at the Copperosity mine, located at the south-western edge of Copperosity Basin, was discovered in the early eighties and was developed sporadically from 1890 to 1907, when a small tonnage of copper ore was shipped. Its main production was during the war years from 1915 to 1917. A two compartment shaft 300 feet deep was sunk, and considerable ore was developed and shipped. The mine is credited with a production of 360,000 pounds of copper with a gross value of $80,000.00. The present owner is the Houston-Arizona Copper Company.

The surface exposure at the Copperosity shaft consists of red shale of the Cretaceous? red beds. A short distance south of the shaft the red beds appear to overlap limestones of the Abrigo formation.

Since the underground workings at the Copperosity mine are inaccessible, the writer quotes the following description from Tenney:[8]

> "The ore occurs as a single body of oxidized ore replacing Devonian limestone on either side of a series of closely-spaced parallel faults striking N 60° W and dipping 45° SW. Mineralization extends about 50 feet on either side of the faults and extends down the dip of the individual beds for a distance of 25 feet and over. The ore outcropped and was followed down to a depth of over 20 feet on the incline following the dip of the fault zone. The thickness of the ore varies from a few inches to 5 feet with an average width of about 3 feet.
>
> The ore consists of replacement deposits in limestone of carbonates, silicates and oxides of copper in a gangue of limonite, gypsum and calcite."

The U. S. Bureau of Mines reopened the Copperosity shaft in 1936, and found scattered copper carbonates and oxides in the

8. idem pg. 14

red shale down to the limestone contact at the 120-foot level. They could find no important showings below in the limestone. As a consequence, the workings were abandoned.

Other deposits in the Copperosity area

Along the Copperosity fault zone, and particularly in the Escabrosa limestone, are scattered showings of copper and zinc. None, however, has produced any sizable tonnage. They appear to be weak limestone replacement areas along mineralized faults. The ore minerals are carbonates, silicates and oxides of copper and carbonates of zinc.

The Hinshaw willemite prospect is located at the southern edge of the main range in the cliffs near the top of 3231 peak. A small tonnage of willemite ore reportedly was shipped from small pits and adits in recent years and sold as mineral specimens. Mineralized fractures near the top of the Escabrosa limestone contain small irregular areas of carbonate ore. The fractures are probably related to the pronounced drag-fold developed along the Copperosity fault zone just north of the Hinshaw prospect.

The Reward area

This area encompasses a group of low hills along the eastern edge of the Vekol Mountains and includes the Reward, the Republic and the Christmas Gift mines.

History and Production

The Reward mine, located about 1880, was developed in the early eighties during high copper prices. About 1,000 tons of 26% ore were produced. A small tonnage was mined in 1903, in 1905, and again in 1907-1908 during favorable copper prices. A little ore was shipped, and considerable development work was done during the years of World War I. Kimball Pomeroy and Dr. Shorneck are the present owners. The mine is credited with about 450,000 pounds of copper, with a gross value of $75,000.00

The geology in the Reward area is well-described by Hadlay.[6] The following is a brief summary of the ore deposits in that area:

The ore occurs in the Escabrosa and Martin limestone as bedding replacement ore bodies and, to a minor extent, at the intersection of fractures. The mineralization is controlled by faults and associated fractures, joints and bedding. The largest deposits, according to Hadley, are from 3 to 5 feet thick and extend from 50 to 200 feet from the mineralized fractures, the channel ways for the ore-bearing solutions.

The ore consists of pyrrhotite, pyrite, iron-rich sphalerite, and chalcopyrite in rather variable proportions in a gangue of chlorite and serpentine with a variable amount of tremolite, diopside and talc. In the oxidized areas, these minerals

6. idem

are mixed with earthy hematite together with malachite, cryso-colla, hydrozincite, smithsonite, aurichalcite and probably hemimorphite.

Siliøification of the limestone is an important feature of these deposits. Garnetization of the Reward ore bed is believed to be related to the ore-bearing solutions. Hadley concludes: "In general, the ore deposits seem to have formed at relatively high temperatures after most of the faulting and at about the same time as the metamorphism."

The Republic mine, located at the southeastern edge of Bitter Wells Basin, produced a small amount of copper ore in 1917. The geology and occurrences of ore are comparable to that in the Reward mine.

The Christmas Gift mine, adjoins the Reward mine to the north. A rick pocket of high-grade gold ore associated with galena and cerussite outcropped on the surface. It produced about $45,000.00 in gold. Although considerable prospecting has been done, no further high-grade ore has been found.

A SUMMARY OF IMPORTANT CONCLUSIONSL

The study of the geology of the Vekol Mountains has resulted in several contributions to Geology. Among them are the following:

1. The age of the Apache diabase has been a controversial issue in Arizona geology for many years. The writer has definitely established the upper limit of the age of this diabase in the Vekol Mountains as pre-Santa Catalina and pre-Upper Troy. Both os these formations are believed to be Middle Cambrian. The lower Troy, which is intruded by the diabase, is either Middle or Lower Cambrian. The exact age of the diabase depends on the age of the lower Troy.

2. Stratigraphy. The Vekol Mountains constitute the western-most area in southern Arizona in which the Apache and Paleozoic rocks are exposed. The thicknesses, lithology and fossil content worked out b y the writer in this area are important in the regional study of Arizona stratigraphy.

3. Structure. The structure of the Vekol Mountains contributes further pertinent data to the study of the structural evolution of Arizona and the Basin Range province.

4. Unconformity control of ore bodies. The ore bodies at the Vekol mine were formed along an old erosion surface at the top of the Escabrosa limestone of Lower Mississippian age beneath the tight, red, cherty shale at the base of the Naco limestone of Lower Pennsylvanian age. They are localized in shattered limestone within a north-south zone of faulting.

T The control of the ore bodies at the Vekol mine is clear-cut. In the opinoin of the writer, similar control by unconformities may have been effective in many other areas, but has not received general recognition.

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THE GEOLOGY AND ORE DEPOSITS
OF THE VEKOL MOUNTAINS

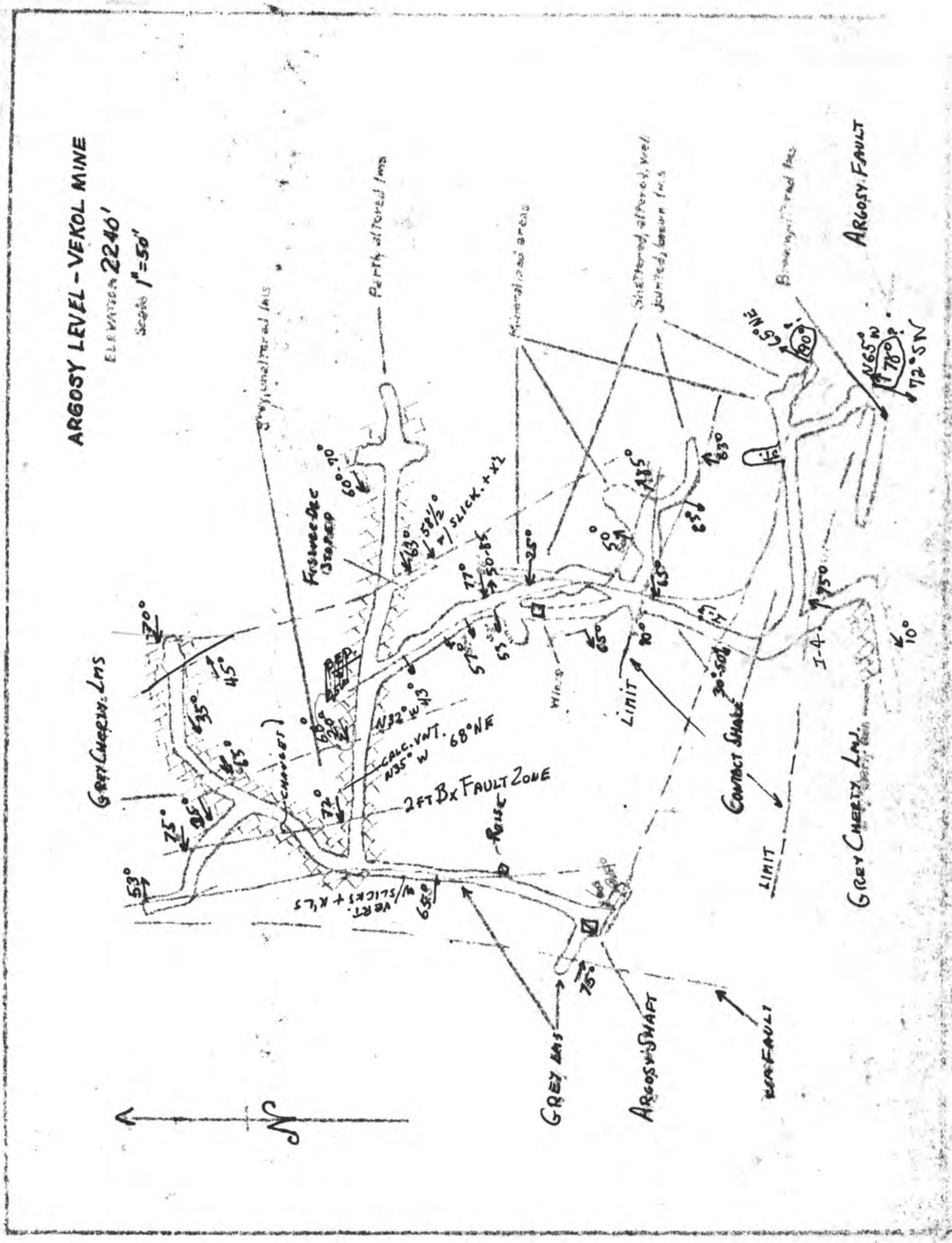
PINAL COUNTY, ARIZONA

By

Robert Halstead Carpenter

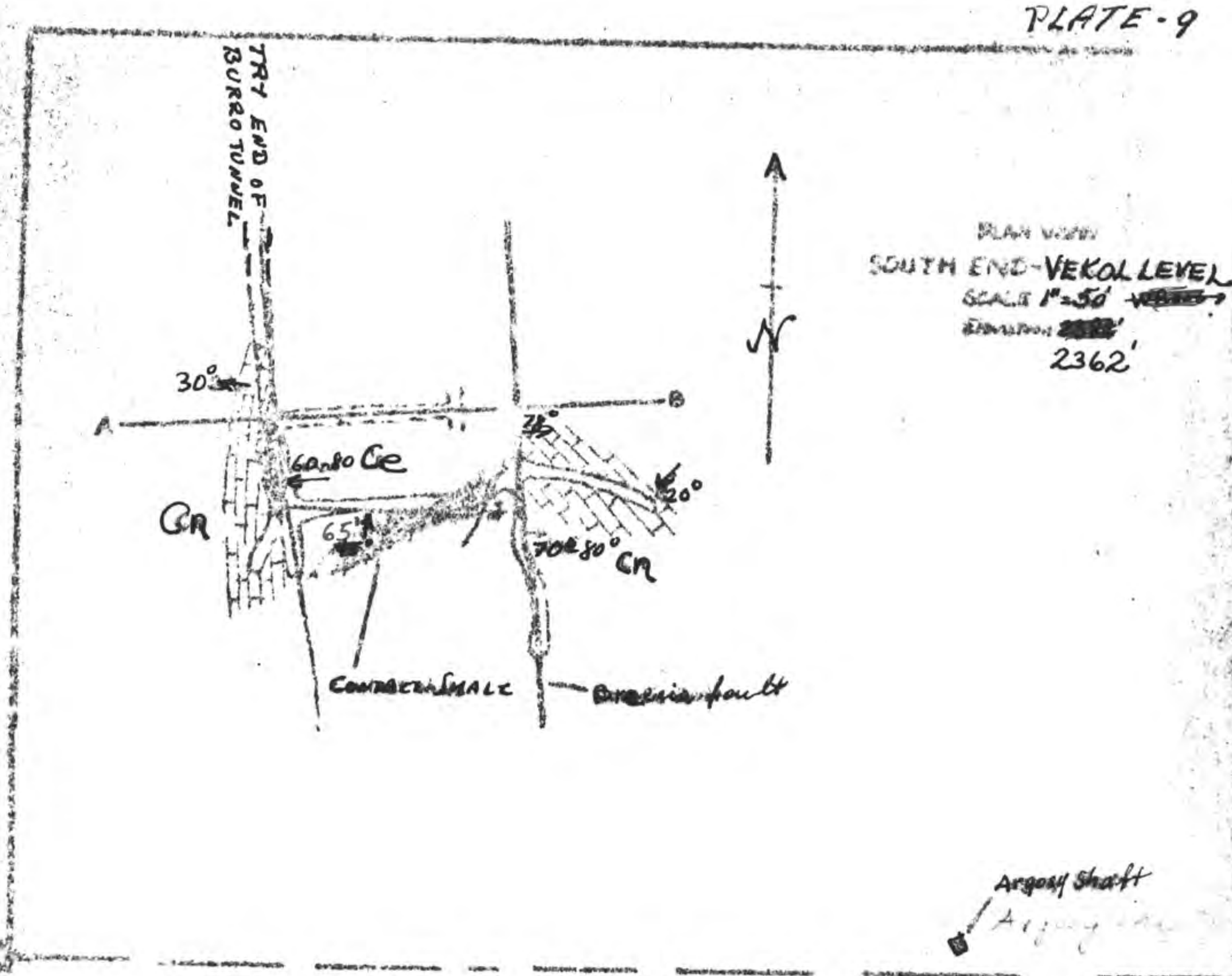
July, 1947

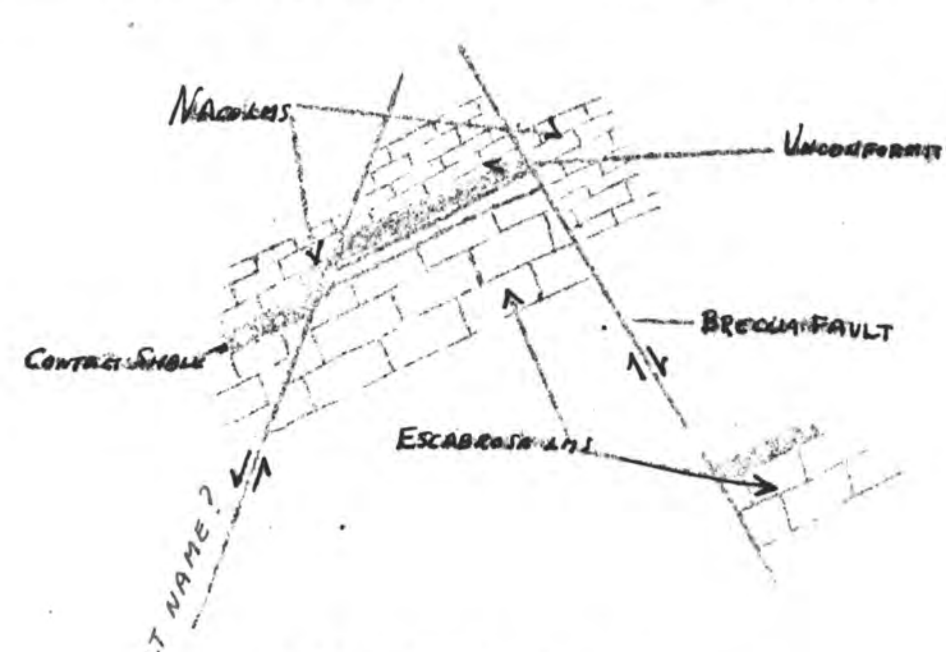
Plate-10



ARGOSY LEVEL - VEKOL MINE
ELEVATION 2240'
Scale 1"=50'
GREY CHERTY LMS
2FT Bx FAULT ZONE
CALC. VNT. N35° W 68°NE
N32° W 43°
VERT. w/SLICKS + K'LS
Raise
LIMIT
CONTACT SHALE
GREY CHERTY LMS.
ARGOSY FAULT
GREY LMS
ARGOSY SHAFT
FAULT
N65° W
72° SW

PLATE - 9





CROSS SECTION A-B
LINE OF SECTION ~~N85°E~~ N 86° E
Looking North
Scale 1" = 50'

THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS
PINAL COUNTY, ARIZONA.

* * *

A DISSERTATION

SUBMITTED TO THE SCHOOL OF MINERAL SCIENCES

AND THE COMMITTEE OF GRADUATE STUDY OF STANFORD UNIVERSITY

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS

FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

* * *

By

Robert Halstead Carpenter

July, 1947

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LIST OF PLATES AND ILLUSTRATIONS

ILLUSTRATIONS

Promontory Ridge, located on the Vekol Mountains quadrangle map, is the ridge starting from 3326 peak and going in a northeast direction. It is just to the left and up from the "R" in reservation.

Plane Table Traverse A was started near the bottom of the Promontory Ridge and goes in a general east direction. Traverse B was started about half way up the ridge and travels in a eastwardly direction. Traverse C was started near the top of the ridge and it also trends toward the east.

Plane Table Traverse D-D' was taken in an east-west direction. It is due north of 2865 peak and a little below due west of 2907 peak to the southeast of Copperosity Mine.

Diabase Traverse #1 was taken in a general north-south direction. It is southeast of the Hill Top Mines (peak 3231). It was taken in the valley that separates 2191 hill with the unnumbered hill just north of it.

Diabase Traverse #3 was taken in an east-west direction. Starting to the south of P.T.T. C, ie, just below the top of 3326 peak and continuing down the slope.

Print 1.

Diabase Unconformity

This photograph, looking westward, is a view of the partly eroded fault scarp at the head of Promontory Canyon, just south of Promontory Ridge. The gray strata at the top are Escabrosa limestone. The rocks included in the Upper Devonian section are exposed in the bench, the brown cliff, and the banded cliff beneath the Escabrosa cliffs. The Southern Belle quartzine marker bed is represented by Ꞓsb. The steep, greenish cliff in the foreground is the basal conglomerate of the Santa Catalina formation which rests on the sloping diabase erosion surface. A thin wedge of "upper" Troy (Ꞓt) is exposed on the right just above the unconformity. The Naco limestone, which caps the down-faulted block of Promontory Ridge, may be seen in the upper right. The position of the Promontory Ridge fault is shown by the dashed lines.

THE GEOLOGY AND ORE DEPOSITS OF THE VEKOL MOUNTAINS
PINAL COUNTY, ARIZONA

I. INTRODUCTION

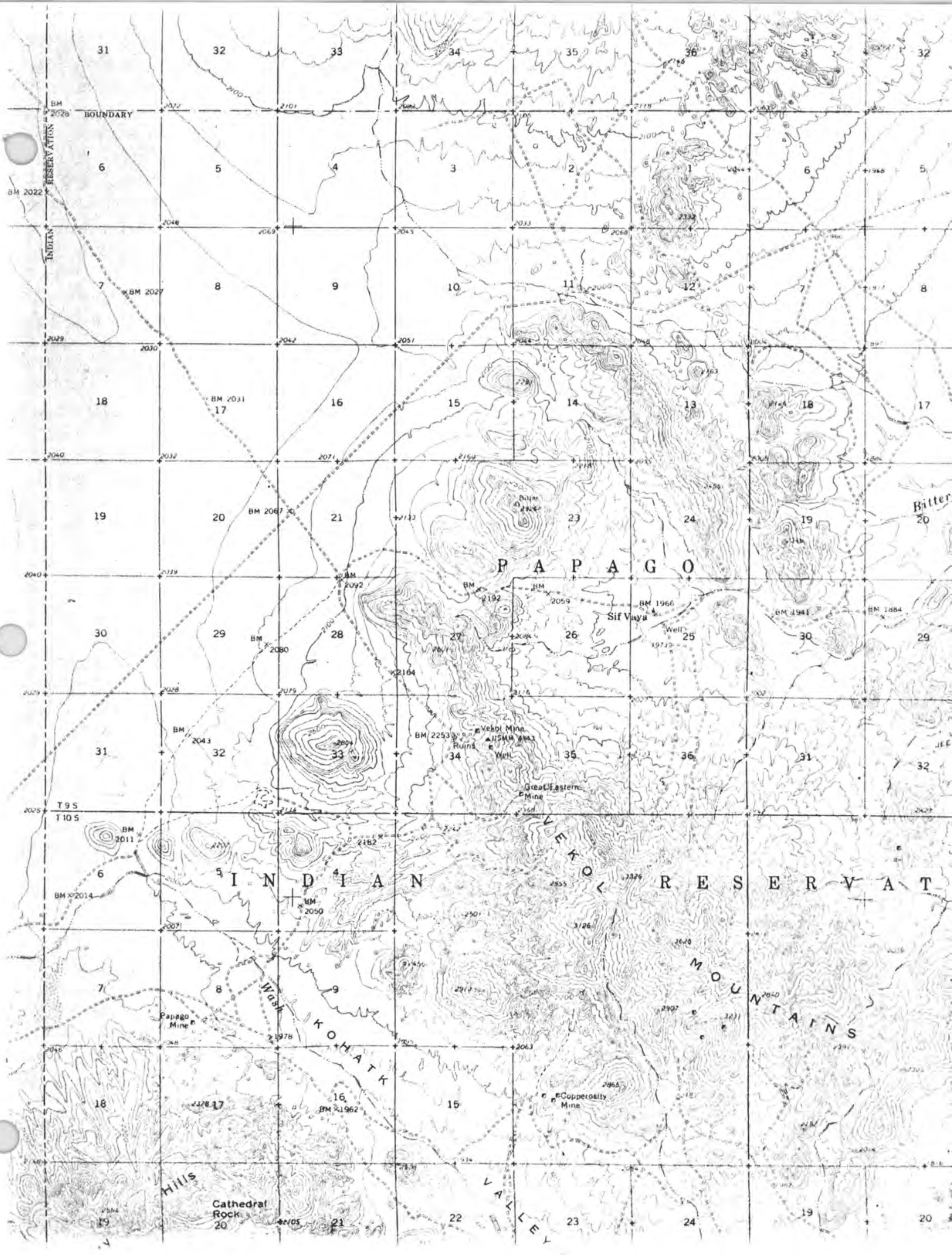
Location and Accessibility.

The Vekol Mountains, in southern Arizona, occupy the central part of the Vekol Quadrangle, United States Geological Survey topographic sheet, between the latitudes 32° 33' - 32° 39' north and longitude 112° 04' - 112° 12' west. (Plate 1.)

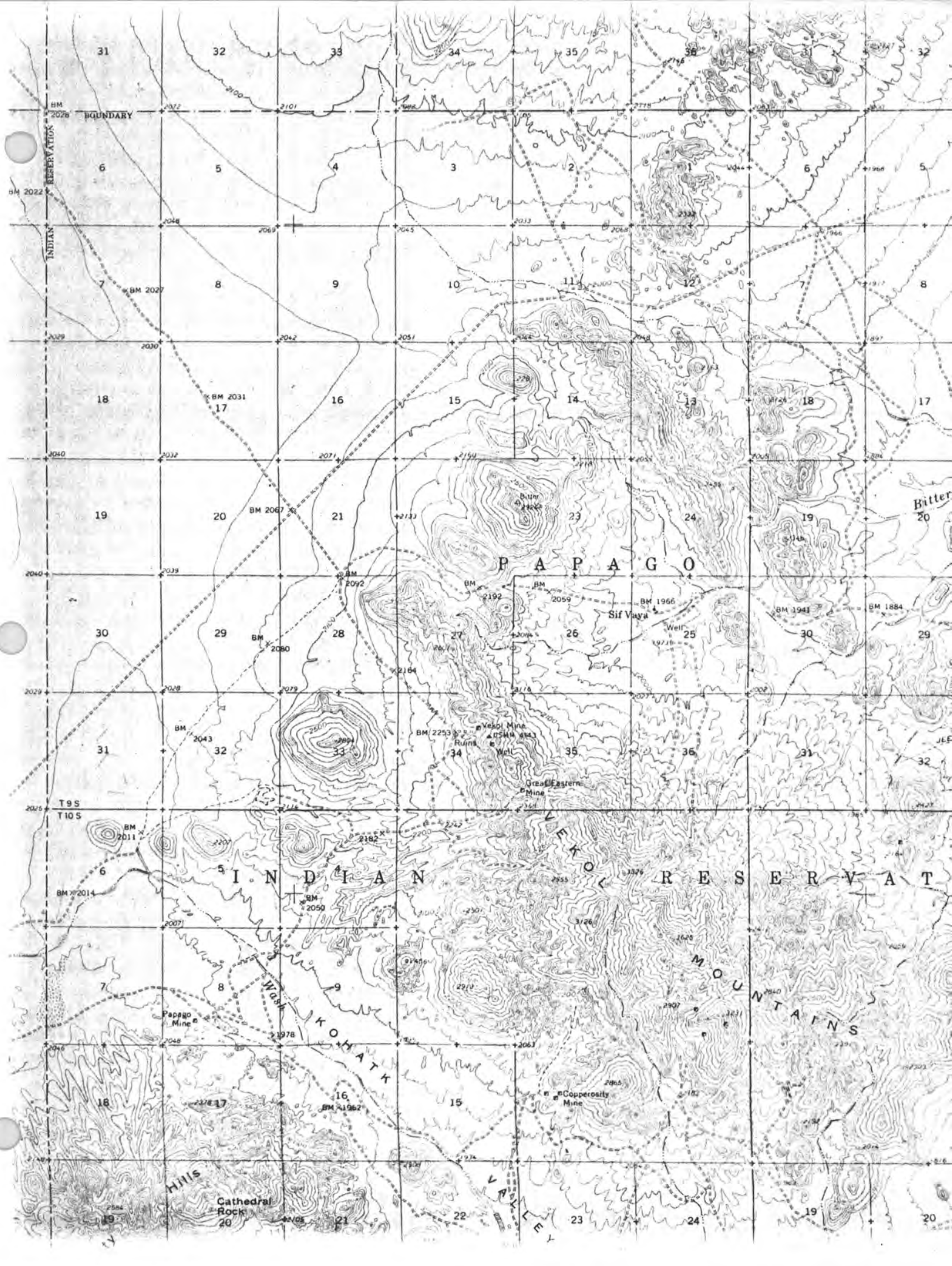
The area is reached by a graded road which follows the natural gas line from Casa Grande to Ajo. The northwestern edge of the Vekol Mountains is approximately forty miles from Casa Grande. The southern edge may be reached by driving southwest on the well-graded Casa Grande-Sells road for twenty-seven miles to the Kohatk Indian Village turnoff, and then driving northwestward to the foot of the range on any one of a number of poor desert roads. (Plate 2.)

Physical Features.

The Vekol Mountains have a roughly circular outline. The main range, situated on the south and west, is connected with the east ridges by a series of hills with an alluvial basin in the center. Both the northern end of the main range and the east ridges trend northwest.



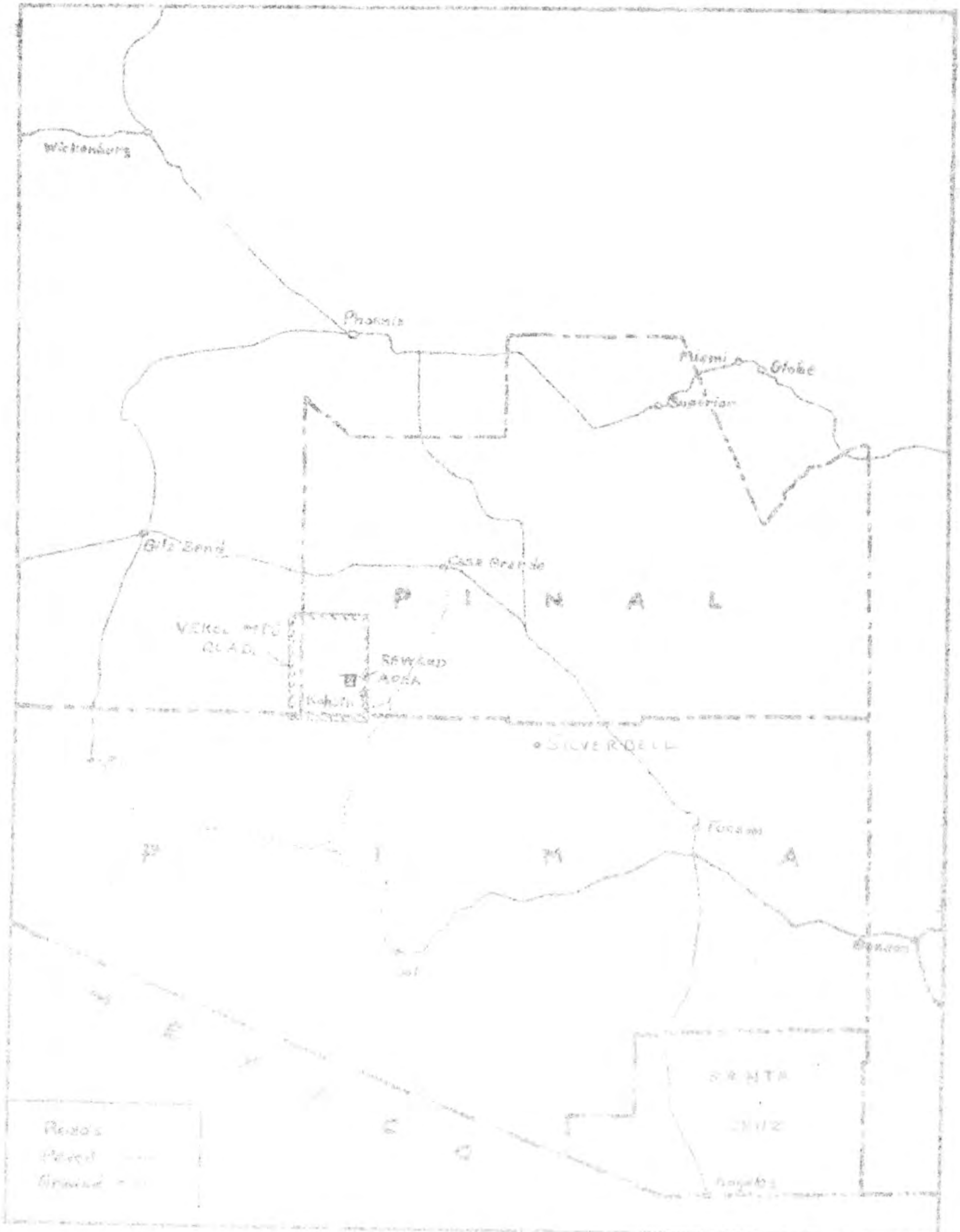
BOUNDARY
INDIAN RESERVATION
P A P A G O
I N D I A N
R E S E R V A T
VEKOL
MOUNTAINS
KOHATK
VALLEY
Sif Vaya
Well
Vekol Mine
Ruins
Great Eastern Mine
Copperosity Mine
Papago Mine
Wash
Hills
Cathedral Rock
Bitter
T 9 S
T 10 S
BM 2022
BM 2027
BM 2031
BM 2067
BM 2092
BM 2080
BM 2192
BM 2059
BM 1966
BM 1941
BM 1884
BM 2043
BM 2253
BM 2011
BM 2014
BM 2050
BM 1962



INDIAN RESERVATION BOUNDARY
P A P A G O
I N D I A N R E S E R V A T
VEKOL MOUNTAINS
KOHATK VALLEY
Wash
Hills
Sif Vaya
Well
Vekol Mine
Ruins
Great Eastern Mine
Copperosity Mine
Papago Mine
Cathedral Rock
Bitter
T9S
T10S
BM 2022
BM 2027
BM 2031
BM 2067
BM 2092
BM 2080
BM 2192
BM 2059
BM 1966
BM 1941
BM 1884
BM 2253
BM 2043
BM 2011
BM 2014
BM 2050
BM 1962

From U.S.G.S.

PLATE I



MAP OF SOUTH-CENTRAL ARIZONA
SHOWING LOCATION OF THE REWARD AREA

The mountains are bordered on the south and east by the broad Santa Rosa Valley, on the north by low hills, on the northwest by Vekol Valley, and on the southwest by the Copperosity Hills and Cimmaron Mountains.

The altitudes in the Vekol Mountains range from less than 1,800 feet to 3,625 feet. The highest point in the main range is an unnamed peak due south of Promontory Ridge. (Plage 3.). The total relief is thus over 1,825 feet. The maximum relief of 1,300 feet per mile, is found on the east side of the 3,625-foot peak. The mountains are rugged with percipitous slopes and cliffs, particularly along the east side of the main range.

Climate

The climate is semi-arid with a wide range in daily temperatures. The average precipitation at Casa Grande is 19.4 inches a year.[1] Most of this rainfall comes during the summer cloudbursts and midwinter showers. The average mean temperature in Casa Grande is 70° with a high of 105° in July and a low of 64° in December. The Vekol Mountains are 1,000 to 3,000 feet higher than Casa Grande. Consequently, the mean temperature is somewhat lower, and the precipitation higher.

Flora and Fauna

In spite of the arid climate, the vegetation in the Vekol

1. Smith, H. V. Climate of Arizona, Bull. 197, Agri. Experiment Sta., Univ. of Ariz., Tucson. July, 1945.

Mountains is profuse and varied and includes those forms typical of the Upper Sonoran Zone. Palo verde, mesquite, catsclaw, and ocotillo are numerous on the pediments and alluvial slopes and are concentrated along the washes. Greasewood is seen occasionally. The large and spectacular Sahuaro cactus is well-distributed over the area except in the higher slopes and cliffs. Barrel cactus, prickly pear, hedgehog, antler cactus, pincusion and cholla are numerous. Several varieties of Yucca grow above an elevation of 3,000 feet. There are a few organ pipe cacti near the Copperosity mine.

Flowering shrubs and wild flowers make a vivid display after each heavy rain. Grass, green plants and ferns are abundant in the shady spots along the eastern cliffs during the rainy periods.

Mountain sheep inhabit the precipitous areas, whereas javelinas or peccaries and black-tail deer range in the foothill region. Coyotes, foxes, ring-tailed cats, desert swifts, jack rabbits, cottontails and ground squirrels thrive throughout the area. Snakes, lizards and desert turtles are common during hot weather. There are ravens, buzzards and many varieties of birds of prey, as well as the song birds typical of this region.

Previous Work

C. F. Tolman, late Professor of Economic Geology at

Stanford University examined the Vekol mine in 1908, but copies of his report could not be located.

Kirk Bryan, in his study of the erosion and sedimentation in the Papago country, briefly visited the Vekol Mountains in 1922.[4]

N. H. Darton describes the Vekol Mountains briefly in his Resumé of Arizona Geology.[7]

J.B. Tenney, in January, 1933, completed an economic geological reconnaissance of the mines of the Casa Grande Mining District.[8] His work, although brief, covers all of the important areas of mineralization in the Vekol Mountains. Tenney's conclusions regarding the Vekol mine will be referred to in the economic section of this paper.

The general distribution of the rock types is shown on the geological map of Arizona published by the Arizona Bureau of Mines in 1925.

No detailed work was completed in the Vekol Mountains until 1942, when a party of the Stratigic Minerals section of the

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

7. Darton, N.H. Resumé of Arizona Geology, Bull. 119, Arizona Bureau of Mines, 1925, pg. 264.

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of Casa Grande Mining District, Pinâl County, Arizona, Arizona Bureau of Mines, 1934.

U. S. Geological Survey, headed by J. B. Hadley, Mapped a part of the eastern Vekol Hills. (See Plate 3.). A careful study was made of the Reward and related prospects in that area. The results are published in a preliminary report of the U. S. Geological Survey.[6]

Field Work

Field work for this report was begun early in October, 1946, and continued until late in March, 1947. The entire region was mapped on a scale of one inch to one thousand feet; and plane table traverses and topographic maps were made on a scale of one inch to one hundred feet and one inch to two hundred feet, where detail was desired. Several one inch to one hundred feet brunton-tape traverses were completed to show details of the Stratigraphy and in connection with a study of the diabase that occurs in the region. The main levels in the Vekol mine were mapped on a scale of one inch to fifty feet.

Acknowledgments

The writer wishes to express his sincere appreciation to Dr. M. N. Short for his interest and assistance while the field work was in progress. He also wishes to thank the other members of the Geology Department at the University of Arizona for their many helpful suggestions, particularly Dr. A. A. Stoyanow, for

6. Hadley, J. B. Copper and Zinc Deposits of the Reward Area, Pinal County, Arizona, Preliminary Report, Stratigic Minerals Div. U. S. G. S. 1942.

his aid in determining the fossils in the area; and to thank him, Dr. E.D. McKee and Dr. Short, for visiting the area and reviewing some of the more critical stratigraphic problems.

The writer is greatly indebted to Dr. Eldred Wilson, geologist of the Arizona Bureau of Mines, for his suggestions, and for copies of pertinent geological literature.

Sincere appreciation is expressed to Dr. A. C. Waters of Stanford University, for his assistance in checking the field and petrographic evidence, and for criticizing the original manuscript, and to the other members of the School of Mineral Sciences for their constructive criticism.

Permission to use the library and laboratory facilities at the Geology Department at California Institute of Technology was most sincerely appreciated.

The writer wishes to record his gratitude to Mr. Cale Smith, superintendent of the Casa Grande High School, for his cooperation and help while the field work was in progress; and to Mr. Jack Schoellhamer of Pomona College, for his assistance with the plane table work.

II. GENERAL GEOLOGY

Summary

The rocks in the Vekol Mountains range in age from pre-

Cambrian to Quaternary, and comprise one of the most complete columnar 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

Print 2

Pre-Cambrian Pinal schist.

This exposure of Pinal schist in Copperosity Basin consists of sericite-quartz schist with lenses of quartz along the trend of the foliation. Occasional thin quartz bands are present also.

Print 3

Algonkian Mescal limestone

This thinly ribbed outcrop of Mescal limestone was photographed at the eastern end of Promontory Ridge. It consists of thinly banded, light gray limestone with numerous siliceous layers. The latter are resistant to weathering, and form a corrugated surface.

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.[6] Dacite porphyry, sills, dikes and flows of intermediate composition 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.

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

Print 4

Upper Paleozoic section on Promontory Ridge

This view, looking north, shows the Naco limestone and the Escabrosa limestone along the crest of Promontory Ridge. The Naco (Cn) is thinly bedded and light gray; the Escabrosa (Ce) is massive tan, banded blue and gray, and massive gray. The Promontory Ridge fault, shown by dashed lines, is well-exposed at the base of the ridge. It separates the down-faulted upper Paleozoic beds from the diabase and Middle Cambrian strata.

Print 5

Lower Paleozoic section, Promontory Ridge.

The Lower Ouray (?) formation is exposed on the bench in the upper left corner of the print. The Martin limestone (Dm) forms the brown cliff, whereas the Picacho de Calera (?) formation forms the blue and tan cliffs below. The Southern Belle quartzite (Csb) separates the Abrigo formation from the Santa Catalina formation. The Troy quartzite is exposed in the dark cliffs. The Mescal limestone forms a faint brown band on the right side of the print.

Metamorphic Rocks: -- Pinal schist.

Correlation

The basement schist of the Vekol Mountains is correlated with the Pinal schist of central and southern Arizona, described by Ransome[10, 11, 14] and others. This correlation is based on the close similarity in lithology and the fact that the schist is separated from the Apache Group by an unconformity, just as it is in the Ray-Miami region and in other parts of central and southern Arizona.

Distribution and General Structure.

The rocks included in the Pinal schist are well-exposed in the southeastern section of the main range and to a limited extent on the northwestern side of the Copperosity basin around the flanks of 2913 peak. (See Plate 3.).

The schistosity usually is well-developed and is steeply inclined, although its inclination varies from horizontal to vertical. The trend of the schistosity is shown on Plate 3. It corresponds, in a general way, to the regional folding, and may have influenced the development of the folding. The schistosity roughly parallels the borders of the granite. It may have been contorted by intrusive forces. Intricate folding is developed in the less resistant horizons; the axis of these folds follows the

10. Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona, U. S. G. S. Prof. Paper 115, 1912.

11. Ransome, F. L. The Geology of the Globe Copper District, Arizona. U. S. G. S. Prof. Paper 12, 1903.

14. Ransome, F. L. The Geology and Ore Deposits of Bisbee, Arizona. U. S. G. S. Prof. Paper 21, 1904.

general trend of the schistosity. The schistosity and the bedding are roughly parallel wherever relic bedding is definitely discernable.

Lithology

By far the greater part of the schist exposed in the Vekol Mountains consists of a well-foliated, light gray to greenish-gray quartz-sericite schist with occasional quartz bands or quartz lenses. (See Print 2.). The latter are particularly common in the crests and saddles of tight folds. Sandy and pebbly beds were noted, as well as a few layers of altered siltstone. In texture, the varieties range from a well-foliated, very finely crystalline sericitic schist to an imperfectly cleavable, coarsely crystalline pebbly schist.

Kinds of Schist

In the southeastern area three kinds were found:

a. Sericite schist: This type is generally thinly laminated, light gray to bluish-gray schist with a satiny luster. In thin section, it consists largely of somewhat contorted sericite blades up to 0.5 mm, considerable disseminated magnetite averaging 0.01 mm, and sparse garnet. The latter probably were detrital grains in the sediment prior to metamorphism. Very thin bands of anhedral quartz are often present. Chlorite is a variable constituent ranging up to 30% in some specimens. The well-developed fissility of this type is the result of the roughly parallel orientation of the sericite flakes into alternate layers, with occasional thin bands of quartz.

b. Sandy or Pebbly Schist: Megascopically, the sandy type consists of thin bands of quartz granules averaging about 1mm in diameter in a matrix of finer quartz grains and scattered flakes of sericite and greenish chloritic material. The pebbly type contains ellipsoidal pebbles ranging up to 1 cm in diameter, which are roughly oriented in a poorly foliated matrix of quartz grains averaging 1 mm in diameter, together with sericite and chlorite. Both types break with an irregular fracture roughly parallel to the former bedding trend.

c. Banded Schist: This type consists of alternate 1 mm to 5 mm bands of finely crystalline anhedral quartz and 0.5-1.0 mm bands of sericite. Chlorite is a variable constituent in the latter. Small magnetite grains are sparsely distributed in the micaceous bands.

Along the north flank of 2913 peak, occasional layers of greenish phyllite occur as bands a few feet wide in the sericitic schist described above.

This very fine-grained, gray rock often shows a faint banding of alternate gray and tan horizons. Rarely, 1 mm quartz bands are seen. In thin sections, the rock consists of anhedral quartz, orthoclase and a little plagioclase, all of which average 0.05-0.1 mm in diameter. Sparse anhedral hornblends, largely altered to chlorite in present. Secondary chlorite is well-dispersed as a matrix mineral, and quartz and calcite stringers up to 0.3 mm wide cut across the specimen. A definite banding is evident in thin section.

Origin

In the Globe area[11] and in the Pinal Range,[10] Ransome has shown the Pinal schist to have been derived mainly from arkosic sediments, although rhyolites are included also. The lithologic

10. Ransome, F. L. The Copper Deposits of Ray and Miami, Arizona U. S. G. S. Prof. Paper 115, 1912, pg. 25.

11. Ransome, F. L. The Geology of the Globe Copper District, Arizona. U. S. G. S. P. P. 12, 1903, pg. 27.

similarity of the schist in the Vekol Mountains with the schist in the Pinal Range would indicate a similar origin for both. This assumption is supported by the fact that sandy and pebbly beds of undoubted sedimentary origin are "interbedded" with the sericitic schist in the southeastern section of the main Vekol Range. The greenish phyllite bands in the Copperosity area (See Plate 3.) probably were derived from siltstones, but might have been volcanics.

Age

The crystalline Pinal schist, in which metamorphism has destroyed most of the original bedding structures, is separated from the overlying, non-foliated, Algonkian Apache group by a clear cut unconformity. This unconformity probably represents the Ep-Archean erosion surface described by Sharp[12] in the Grand Canyon region. If so, the Pinal schist is of early pre-Cambrian age.

Sedimentary Rocks --- Algonkian Apache Group

The rocks of the Apache group were described and designated as Cambrian by Ransome[10] in his work in the Ray and Miami area of central Arizona. He included the Scanlan conglomerate, the Pioneer shale, the Barnes conglomerate, the Dripping Spring quartzite and the Troy quartzite within this group. Darton[7] and

7. idem pg. 36.

10. idem pg. 39.

12. Sharp, R. P. Ep-Archean and Ep-Algonkian Erosion Surfaces, Grand Canyon, Arizona. (Abstract) G. S. A. Bull. Vol. 50 #12, pt. 2. pg. 1933, Dec. 1939.

others, however, consider the Apache group as equivalent to the Grand Canyon series. Furthermore, Darton[7] found evidence, pointed out under 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 schish 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

7. idem pg. 36.

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,[10] these are caused by the reduction and removal of ferruginous pigment. This characteristic marking of the Pioneer shale indentifies 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 jasper. 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,

10. idem pg. 40.

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 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 on page 19.

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 1/2 inch thick interbedded with thin-banded limestone. In some exposures, the more resistant chert 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[18] and the writer concur that this arcuate 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

18. Personal communication.

Print 6

Pseudo-Intraformational Conglomerate

The above specimen of thin-bedded, impure limestone collected from the Santa Catalina formation represents a well-developed stage of the phenomenon described on page 17. Fracturing, solution along the fractures, compaction and recrystallization have all been effective to form this intraformational conglomerate-like rock. This phenomenon often can be traced laterally into normal, impure limestone.

unaffected intermediate areas into the arcuate

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 southwesterd edge of Bitter Wells Basin;

Print 7

Profile of Apache basalt and Troy quartzite.

This view, looking northward at the eastern end of Promontory Ridge, shows the Troy quartzite, the bench-forming Apache basalt, and the cliffs of the underlying Mescal limestone. Down-faulted Troy quartzite south of the Pomona Canyon fault ridges are visible in the background.

Print 8

Troy quartzite cliffs

The upper and lower members of the Troy quartzite are shown by the letters "u" and "l" on the above print. Apache basalt and diabase are poorly exposed at the base of the cliff. Mescal limestone lies below the basalt.

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 R idge, shown on Plate 4., is as follows:

Upper Member	a.	Strongly cross-badded, rusty, midium-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?---------------	
Lower Member	c.	Well-banded 1-foot quartzite beds interbedded with calcareous quartzite.	30 feet
	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 1/4 inch to 3 inch banding.	48 feet
		Total	252 feet

The upper, brown, highly cross-badded quartzite (a.) consists mainly of calcareous quartzite with occasional patches of calcareous sandstone. The latter often contain small, poorly pre-

Print 9

Troy Quartzite

Looking south toward 3625 Peak. The lower Troy unit and upper troy unit are separated by a prominent bench shown in the upper part of the print. Apache basalt and diabase are poorly exposed beneath the talus at the base of the cliff.

Print 10

Upper Troy quartzite

Cross-bedded, calcareous quartzite in this print forms the topmost cliff in Print 8. The calcareous lenses weather rapidly to form narrow depressions on an exposed surface.

served 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 the upper Troy unit and the overlying Santa Catalina formation, for the quartzite beds become less numerous, and finally, are 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 1/4 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, [11]Ransome considered the Troy quartzite a part of the Dripping Spring Quartzite. Later, in the Ray quadrangle,[10] he 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 bo the Troy and the Apache group in the Cambrian.

10. idem pg. 44
11. idem pg. 28

Subsequent work has shown that the Apache group is not gradational into the Devonian. Stoyanow[13] has measured over 700 feet of fossiliferous 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[7] is also opposed to the Cambrian 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 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,[16] in the Santa Catalina Mountains,[13] and in other areas.

Stoyanow[13] separates the Troy from the Apache group "not only because 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

7. Darton, N. H. Resumé of Ariz. Geol., Bull. 119 Ariz. Bureau of Mines, 1925, pag. 36

13. Stoyanow, A. A. Correlation of Arizona Paleozoic Formations. Bull. G.S.A. Vol. 47, pp 459-540, 1937, pg. 474.

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

as 1904 in the Troy in Deer Creek Canyon south of the Mescal Mountains in central Arizona.[13] They were determined by Walcott as Lingulella Pogonipensis (Walcott) and Dicellomus Politus (Hall) and were classified as "probably Middle Cambrian."

Stoyanow[13] also mentions that in the Mescal Mountains near the top of 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.

13. idem pg. 475

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 both 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 opinoin of the writer, further regional work should be carried out to see if the unconformity separating the upper

Print 11

Santa Catalina basal conglomerate cliff.

The six foot cliff shown above consists of boulders, cobbles and pebbles of diabase embedded in a calcareous and cherty matrix at the base of the Santa Catalina formation. The weathered diabase erosion surface lies about ten feet below the base of the cliff.

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[7] involve the entire Troy as described 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 Promontory Ridge is typical. (See Plate 4) It is 265 feet thick. The lower sixty feet consists 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, 1/2 to 1 inch, brown, micaceous sandstone, shally 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 numbrous in this part of the section.

7. idem pg. 36.

Print 12

Santa Catalina basal conglomerate

Rounded orthoclase diabase cobbles and pebbles are embedded in a calcareous matrix. This horizon is located about 20 feet above the diabase erosion surface.

The Santa Catalina formation was first described by Stoyanow[13] in the Santa Catalina Mountains north of Tucson. He designates the Santa Catalina as a separate formation of Middle Cambrian age on paleontologic evidence. An unnamed trilobite persists through the entire formation, and 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.

<u>Southern Belle quartzite</u>

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

13. idem pg. 476

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 intra-formational conglomerate structure. Approximately five feet from the base, the character of the beds changes to thin-bedded lime-stones and brown, sandy shales. The thickness of the beds ranges from a fraction of 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[13] in southern Arizona. No fossils were found, however, and the writer tentatively includes these beds in the Abrigo.

The thickness of the Abrigo formation at Promontory Ridge is 82 feet. (See Plate 4) In the southern edge of the area, on the south side of 2854 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 #4, 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[14] at Bisbee, and was named 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[13], in the Santa Catalina Mountains, has divided this section into the following formations:

Upper Cambrian	Peppersauce sandstone Abrigo formation

13. idem pg. 471

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

13. Stoyanow, A. A. Corr. of Ariz. Paleo. Formations, Bull. G. S. A. Vol. 47, pg. 480.

Middle Cambrian	Southern Belle Quartzite Santa Catalina formation Troy Quartzite (Bolsa Equivalent?)

In this report, the writer follows Stoyanow's resistricted 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[2] 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 236 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 paleontolocig 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.

2. Hogue, W. G. The Geology and Ore Deposits of the Northern End of the Slate Mountains, Pinal Co., Arizona. Masters Thesis, Univ. of Ariz. 1940.

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 Calero? 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 Maeuntains:

		(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 Hill twenty-five miles northwest of Tucson.[13] Stoyanow's section is quoted as follows:

13. idem pg. 488.

		(Top)
"a.	Brown calcareous sandstone replete with fish teeh, 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, 20 to 4 feet thick composed of large spherical stromatoporoids and algae with abundant, but poorly preserved zaphretoid and favositoid corals.	40 feet
e.	Yellow calerous sandstone with well-rounded sand grains probably of sub-eolian origin.	4 feet
	Total	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:

		(Top)
a.	Muddy, gray limestone in 1-3 foot beds.	13 feet
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 1/2 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 occassionally, together with other poorly preserved froms which have not been identified. Cladopora prolifica Hall and Whitfield occur sporadically in this same horizon.

The Martin limestone was first described by Ransome[14] at Bisbee. There, 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.[13, 14]

13. idem pg. 487

14. idem pg. 35-38

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:

		(Top)
a.	Roughly-banded, light tan to white, cliff-forming, medium-grained quartzite with sandy, calcareous bands.	12 feet
b.	6 inch to 3 foot beds of pinkish-gray limestone	16 feet
c.	1/2 inch to 6 inch, yellowish-to reddish-tan, soft, highly-jointed, poorly bedded limestone, mudstone and calcareous shale. *Atrypa reticularis* (Linne).	23 feet
	Total	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[13] describes this formation in Peppersauce Canyon in the Santa Catalina Mountains, twenty-five miles north of Tucson. It also is described by Hogue[2] in the Slate Mountains, ten miles east of the Vekol Mountains. Hogue's section is as follows:

2. idem

13. idem pg. 489.

		(Top)
" 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.	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[6] reports a maximum of 420 feet in the Reward area 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, tand and bluish-gray beds ranging from 6 inches to 5 feet; the upper 200 feet is a massive, gray limestone with occasional cherty horizona.

The top 20 to 100 feet of Escabrosa is altered to a pinkish-tan colo. 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 an 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 in to 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

6. idem.

Escabrosa, and a Syringopora coral were the only two definitely identifiable fossils found by the writer. Hadley[6] reports numerous Pentremites 300 feet from the base of the formation in the Reward area.

According to Stoyanow[13], the Escabrosa limestone is Lower Mississippian 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 the area:

6. idem.

13. idem pg. 505.

(Top)

a.	Alternate 1-2 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.	100 feet
b.	Coral marker bed containing numerous <u>Campophylum</u> <u>Torquium</u> (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:

<u>Dictyoclostus</u> <u>americanus</u> Dunbar and Condra p. 218
<u>Spirifer</u> <u>occidentalis</u> Girty
<u>Spirifer</u> <u>Rockymontamus</u> Marcou p 258
<u>Spirifer</u> <u>cameratus</u> Morton
<u>Squamularia</u> <u>perplexa</u> McChesney
<u>Composita</u> <u>subtilita</u> Hall p. 260
<u>Campophylum</u> <u>torquium</u> Owen
<u>Rhynchopora</u> Sp. p242
<u>Cleiothyridina</u> sp. p. 260

Numerous bryozoans were found locally, as well as plates and spines of sea urchins. Well-preserved <u>Orthoceras</u> sp., p. 348 and unidentified gastropods were found in the topmost exposed beds just north of the Vekol ghost town. Crinoid stems 1/2 inch in diameter are numerous in the upper part of the Naco.

The following forms were collected by Bryan[4] from the south slope of the mountains at the Vekol mine and were determined by G. H. Girty:[7]

Cladochonus sp.	Productus semireticulatus
Campophylum Torquium	Marginifera splendens
Rhombophora lepidodendroides	Spirifer cameratus
Schizophoria? sp.	Spirifer Rockymontanus
Chonetes verneuilianus	Composita subtilita

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

According to Stoyanow,[19] the forms collected in the Vekol Mountains by 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 the Vekol mine, the exposed thickness is 415 feet. The top is covered by terrace gravels and alluvium.

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

7. Darton, N. H. Resumé of Arizona Geology, Bull. 119, Ariz. Bureau of Mines, pg. 74, 1926.

19. Stoyanow, A. A. Personal Comm.

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 areas of reddish-brown and gray sandstone, finely crystalline limestone 1/4 of an inch to 1 foot in diameter, and zoned chert nodules which have white centers and reddish halos 1/16 to 1/2 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 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:

a. Pebbly breccia with angular chert fragments in a somewhat silicified, shaly matrix.	1 foot (TOP)
b. Brick red to chocolate colored, splintery shale with a few zoned chert nodules.	5 feet
c. Tan, medium-grained quartzite.	1 foot
d. Impure red shale with numerous zoned chert nodules, the with an occasional thin shaly sandstone bed 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. Thay 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[14] at Bisbee from the section in the Naco Hills newr 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 B isbee is estimated at 3,000 feet.

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

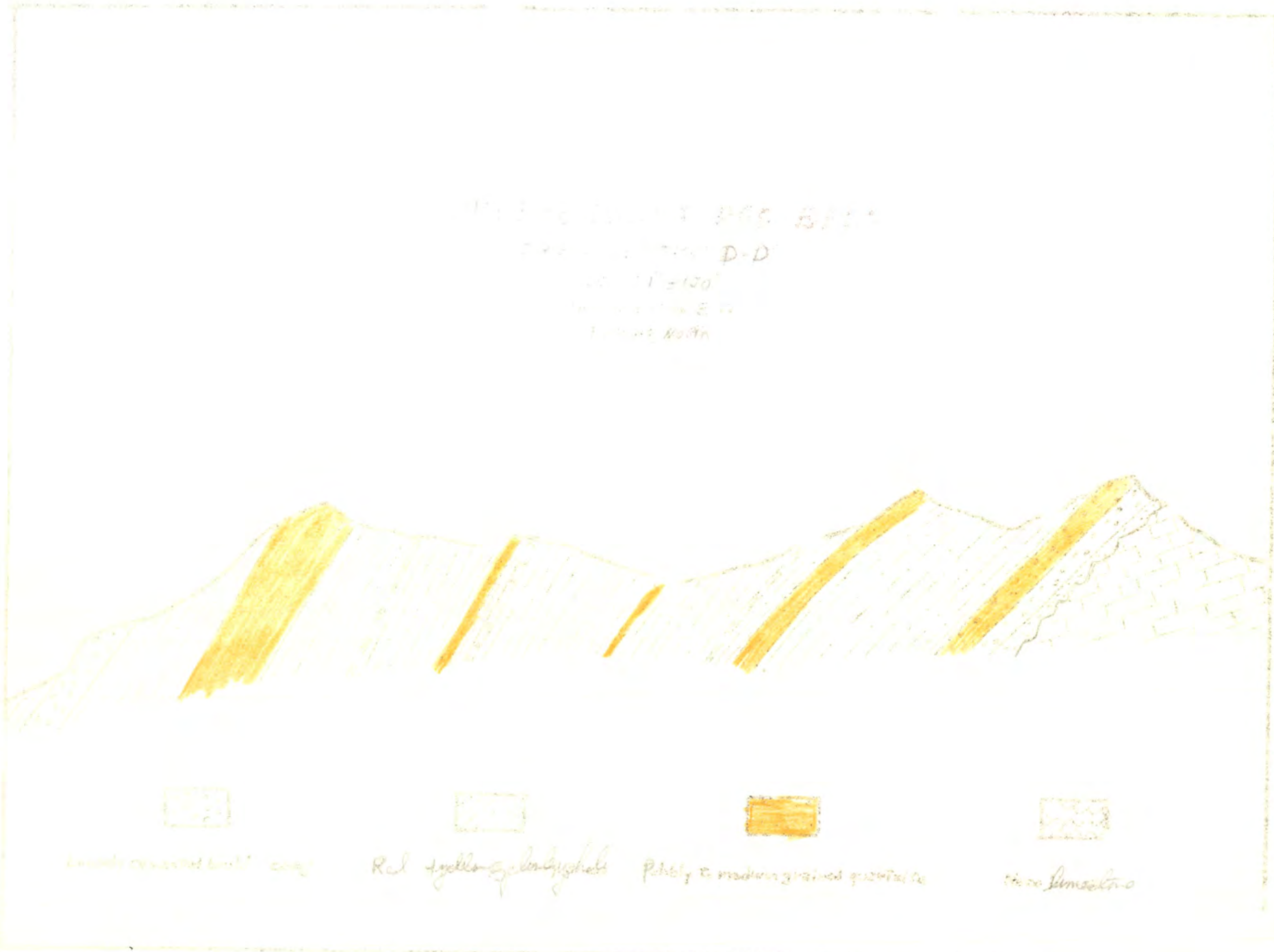
14. idem pg. 44

Print 14

Cretaceous? red beds
and
Naco Limestone unconformity

This photograph, taken on the west slipe of the main range about one half mile south of the Pomona mine, shows the unconformity between the Naco limestone and the overlying basal conglomerate of the Cretaceous? red bed series.

PLATE 5



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 1/4 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 gray, coarse, arkozic 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.

~~The~~ 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[6] in the Reward area should be included. Further work will be required 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.

<u>Age and Correlation</u>

The writer has no evidence of the age of these rocks ex-

6. idem.

cept 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[20] in the Tucson Mountains are somewhat similar and may be comtemporaneous. 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° SW. This conglomerate appears to rest directly on a Naco limestone erosion surface

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

Print 15.

Gila conglomerate west of Pomona mine.

The cobble conglomerate shown above is well-distributed along the western edge of the main range from Copperosity Basin to the Vekol Valley. It rests unconformably on all older rocks, but is overlain and interbedded with Quarternary volcanics.

Print 16.

Troy Quartzite-diabase contact.

The intrusive contact between the Troy quartzite and the diabase exposed just east of the Hinshaw mine is shown above. A narrow "hybrid" zone is found along this contact.

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 foot pebble and cobble horizon, which may grade laterally northward into the thick tuff beds on the flank of 2917 peak.

Terrace Gravels

The debris which has accumulated in alluvial fans and piedmont slopes along the foot of the main range, is cut by ravines formed by recent changes in base level. The resulting topography consists of a series of terraces separated by ravines 50 or more feet deep. Locally, within the ravines is a second and often a third bench or terrace of minor extent.

The alluvial debris which forms the terraces consists of poorly sorted, angular to sub-angular boulders, cobbles and pebbles and coarse sand derived from the rocks exposed upstream. On the western slôpe of the main range. Naco limestone is the main constituent, whereas along the eastern slopes, both Paleozoic and pre-Cambrian rocks contribute to the deposits. Granite is an important constituent at the southeast end of the main range, and volcanics make up a large part of the debris on the northwestern fringe of the mountains.

Locally, as in the vicinity of the Vekol mine, caliche has cemented the limestone talus and wash into a hard pan which is covered by a thin veneer of alluvium.

Alluvium

The most recent alluvium cannot be distinguished from the alluvial material of the terrace gravels except for its distribution. It fills the bottom of the ravines and washes, and forms a thin veneer over the terrace deposits and pediments. Some of this material has been recently eroded from the adjacent ridges, and some appears to be reworked terrace material and Gila conglomerate.

Igneous Rocks

Apache Basalt

This group of flows is described by Ransome[10] in the Ray quadrangle about 85 miles northeast of the Vekol Mountains. The basalt which occurs above the Mescal limestone and beneath the Troy quartzite in the Vekol Mountains is correlated with the Apache basalt of central Arizona because of its comparable stratigraphic position.

It reaches its maximum thickness of about 200 feet just south of Promonotory Ridge in the central part of the main range. Farther north, it averages less than 75 feet, and along the southern fringe of the range, it is missing. In its place is a 20 foot bed of dark greenish-red shale containing occasional angular to sub-angular quartz fragment. More than one flow is believed.

10. idem pg. 43.

to be represented in the area, for rusty, more highly vesicular zones were noted in cliff exposures.

The basalt is intruded by diabase. In the vicinity of orthoclase diabase sills it is penetrated by orange-colored granophyric juices and related end products of the intrusive. Chalcopyrite was noted in one veinlet. Splotches, stringers and amygdular fillings of granophyre result in an unusual greenish rock mottled with orange.

The contacts with the diabase are clear-cut, and often are knife-edge. The fragments of basalt found within the diabase are angular with fairly sharp borders. A sugary, recrystallized zone a few feet wide is present, adjacent to the diabase contact in some exposures.

Megascopically, the basalt is a compact, fine-grained, amygdular, greenish-gray rock. The amygdules and vesicles range up to 5 mm in diameter, with only slight elongation in most exposures. The amygdules usually are filled with epidote, calcite and serpentine minerals. The lower 2 feet of the flow is highly vesicular, with the vesicles somewhat elongated vertically. The mass of the rock is believed to consist largely of sericite, koalin, serpentine minerals and iron oxides. The exposures of Apache basalt in the Vekol Mountains are, everywhere, badly weathered or highly altered. A microscopic analysis of this rock is given by Short and others in Bulletin 151, of the Arizona Bureau of Mines.[16]

The old Mescal limestone erosion surface upon which the basalt flowed is well-exposed on the crest of the sharp ridge just east of 3625 peak. It is somewhat irregular and, for a few inches, the limestone is altered to a dark brown color. Calcite bands, pods and occasional limestone fragments occur at the base of the basalt.

Diabase

This intrusive rock is widely distributed throughout the southeastern third and along the southern fringe of the main range. A few exposures were noted at the northeastern edge of the mountains. It occurs mainly as sills in the rocks of the Apache group and Troy quartzite, and as dikes in the schist.

Diabase occurs extensively throughout central and south-central Arizona from the Upper Salt River region to the Santa Catalina Mountains near Tucson. It has been well-described by Ransome in the Globe, and Ray-Miami Professional Papers of the U. S. Geological Survey,[11, 10] and by Short and others in the Superior area.[16]

16. idem pg. 34.
10. idem pg. 53.
11. idem pg. 80.
16. idem pg. 35.

The diabase in the Vekol Mountains undoubtedly represents the same general period of diabasic intrusive activity as in central Arizona. It is similar both in character and in geologic occurrence to that described in the above reports.

Intrusive relationships

The magma appears to have forced its way into the Apache and lower Troy rocks. The diabase occurs as fairly persistent sills, but it often cuts across the bedding at a low angle, jumping from one horizon to another and apparently forming a network of interconnected sills and dikes. The attitude of the beds, however, is relatively undisturbed. Many of the sills wedge out laterally. The thickness of the individual sills ranges from a few feet up to 300 feet.

Assimilation does not seem to have been important except locally. An exposure on the ridge east of the Hinshaw mine on the south side of the main range in which diabase intrudes Troy quartzite is an example. The following transition zone was noted:

NOT TRUE! SEE CHAFFEE 1974

1.	Medium-grained, unaltered vitreous quartzite.	4 feet
2.	Shattered, stained quartzite in a dark, greenish-gray matrix.	6 inches
3.	"Hybrid" diabase with numerous small ghost-like quartzite fragments and individual quartz grains.	1-3 feet
4.	Normal diabase with well-dispersed quartzite fragment or quartz grains.	2-4 feet

Print 17

Photo-micrograph
of the diabase-Troy quartzite intrusive contact
of Print 16. (47x, crossed nicols)

The diabase, shown on the right, and the quartzite on the left, are well-sericitized and chloritized, but the former include the relix quartz of the orthoclase-quartz graphic intergrowth pattern. The latter contains sub-angular quartz grains. Occasional quartz grains are found within the diabase. These show corroded borders.

5. Orthoclase diabase with no apparent quartzitic material. 15 feet exposed

This intrusive contact is believed to be within a few feet of the shale marker that separates the lower and the upper Troy. The sill is well over 200 feet thick.

In thin section, type 3. consists of "ghost" quartzite fragments included in altered diabase. The individual quartz grains within the fragments are well-dispersed in a sericite-chlorite matrix. The siliceous cement has been removed, and many of the quartz grains are corroded around the edges. In the altered diabase, scattered granophyric intergrowth areas are evident, indicating a granophyric composition in the contact phase of the sill. The sericite and chlorite which replaced the matrix of the feldspars and ferromagnesians of the diabase probably replaced the matrix of the quartzite fragments. Magnetite grains are abundant in the quartzite, while skeletal growths of ilmenite are numerous in the diabase. Small, very fine-grained quartz veinlets cut across both the diabase and the quartzite.

Type 5., in thin section, has a typical ophitic texture and consists of:

A. Labradorite laths averaging 0.5 mm in length, and totaling about 30% of the section.

b. Hornblende and uralite 0.3-0.4 mm, about 30%.

c. Quartz-orthoclase intergrowth, 0.3 mm, estimated at 20%.

Print 18

Photo-Micrograph
of
Orthoclase-quartz diabase. (47x, crossed nicols)

The above print illustrates the ophitic texture of the diabase and shows knots of orthoclase-quartz graphic intergrowth. The augite is partly altered to uralite, biotite, and chlorite. The plagioclase is corroded, but essentially unaltered.

d. Magnetite and Ilmenite, 0.3-0.4 mm, about 15%

e. Secondary sericite and chlorite, about 5%.

This type is comparable to the topmost orthoclase diabase sill in the Promontory Ridge area, exposed along Diabase Traverse 3, described below.

Petrography

In the Superior area[16] the diabase was divided into three types mineralogically; the quartz-orthoclase diabase, normal or augite diabase, and the olivine-augite diabase. All three types are believed to be present in the Vekol Mountains, but because of alteration the olivine type has not been definitely established.

Petrography of the quartz-orthoclase diabase: Megascopically, this type, when unaltered, has a well-developed ophitic texture. Gray plagioclase laths 1 mm to 2 cm long, are embedded in a greenish ferromagnesian background. Scattered throughout are magnetite grains and irregularly shaped, pink areas from 1 mm to 1 cm, which resemble orthoclase.

In thin section, these pink areas prove to be a graphic intergrowth of quartz and orthoclase. They make up from 5% to 60% of the rock. In a speciment which contains approximately 20% quartz and orthoclase, the labradorite is estimated at 35%, augite at 20%, uralite at 10%, and boitite at 5%. Apatite is present in

16. Short, M. N. and others. Geology and Ore Deposits of the Superior Mining Area, Arizona. Bull. 151, Arizona Bureau of Mines. pg. 35, 1943.

very minor amounts. The augite is partly altered to uralite, biotite, and magnetite, while the feldspars show slight sericitization.

Petrography of the normal diabase: the Normal diabase is very similar to the orthoclase-quartz diabase, both megascopically and in thin section, except for the abasence of orthoclase and quartz. In the field these two types appear to be gradational.

Petrography of the olivine diabase: Thus far, the writer has not been able to definitely establish the presence of olivine in thin section. Alteration of the original ferromagnesian minerals to uralite, chlorite and serpentine minerals has been extensive in sills suspected to olivine diabase.

Differentiation is suggested both within the individual sills and in the diabasic intrusive activity as a whole.

The sillat the base of the Apache group, and the topmost orthoclase diabase sill illustrate both textural and compositional variation from the borders toward the center.

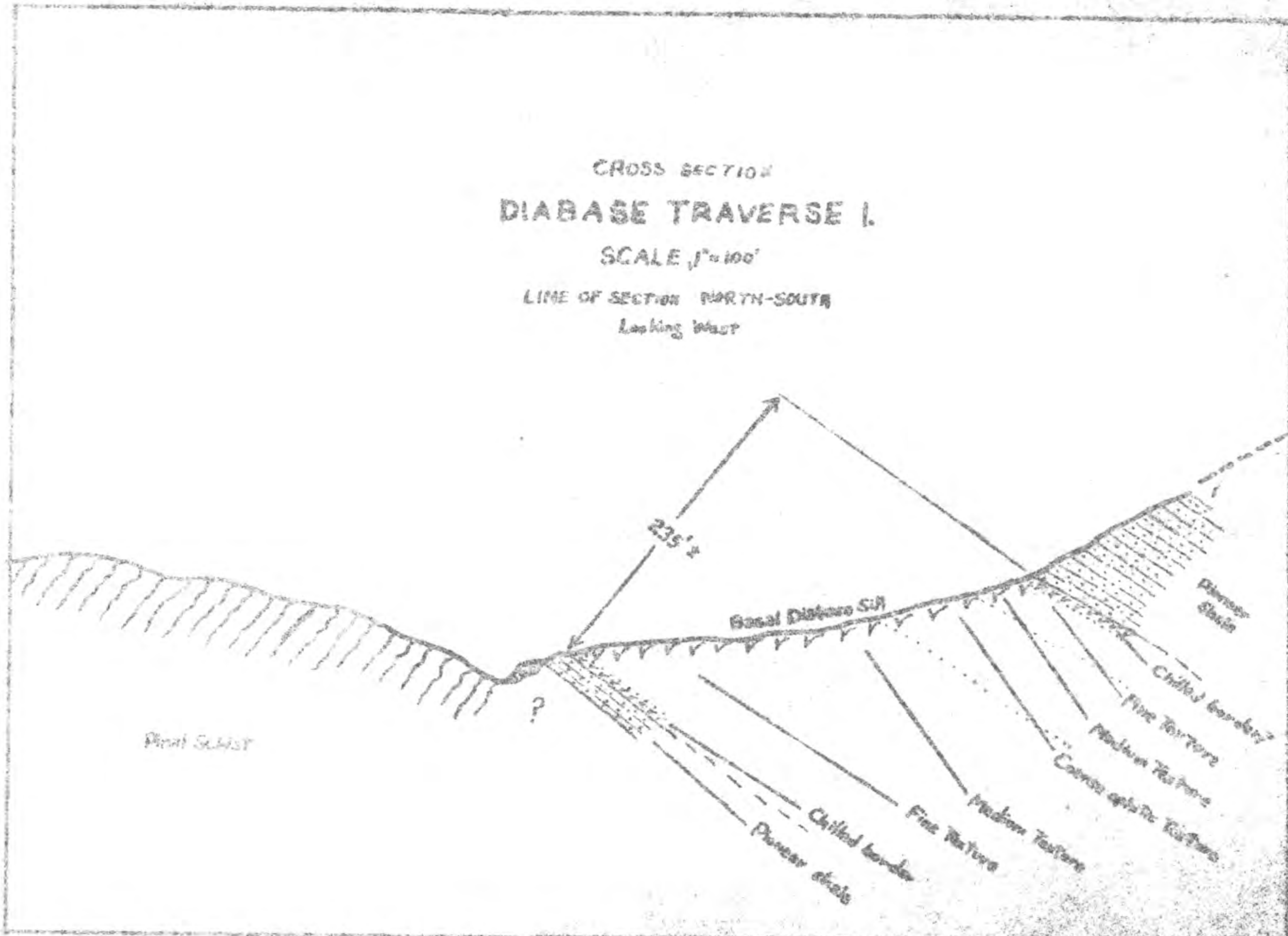
In the southeastern part of the main range, this basal sill intruded along the major unconformity between the Pioneer shale and the Pinal schist. No Scanlan conglomerate is present in this area. In some exposures, scattered patches and blocks of Pioneer shale lie between this sill and the schist.

Diabase cross section #1, illustrated on Plate 6., shows the textural relationships within this sill. The location of this section is shown on Plate 3. At the base, a 2 foot chilled border is clearly exposed. The texture immediately above is fine-grained diabasic, but gradually becomes coarser upward. From 100 to 150 feet from the base, the texture is medium-grained. The feldspars average between 2 and 3 mm in length. At 150 feet from the base, the sill has a pegmatitic texture with many of the plagioclase phenocrysts over 1 cm in length. Megascopically, the composition appears to be more siliceous, although the writer has not found sufficiently fresh material to warrant a thin section study of this type.

The coarsely crystalline zone is more than 50 feet thick. It appears to grade rather rapidly into a medium-textured, normal diabase, and finally, to a very fine-grained rock near the upper contact. This contact was not exposed, but float indicates the presence of a narrow, chilled border.

Because of the gradation in texture and the apparent gradation in composition, the writer believes this sill to represent a single intrusive rather than separate intrusion of the border, intermediate and central zones.

In the topmost sills, where orthoclase diabase predominates, a similar relationship is exposed. These sills have fine-


CROSS SECTION
DIABASE TRAVERSE I.
SCALE 1"=100'
LINE OF SECTION NORTH-SOUTH
Looking West
235'±
Basal Diabase Sill
Pioneer Shale
Chilled border?
Fine Texture
Medium Texture
Coarse ophitic Texture
Medium Texture
Fine Texture
Chilled border
Pioneer shale
?
Pinal Schist

grained borders. They grade to medium and coarse-textured diabase toward the middle where the more acidic, granophyric segregate is widespread.

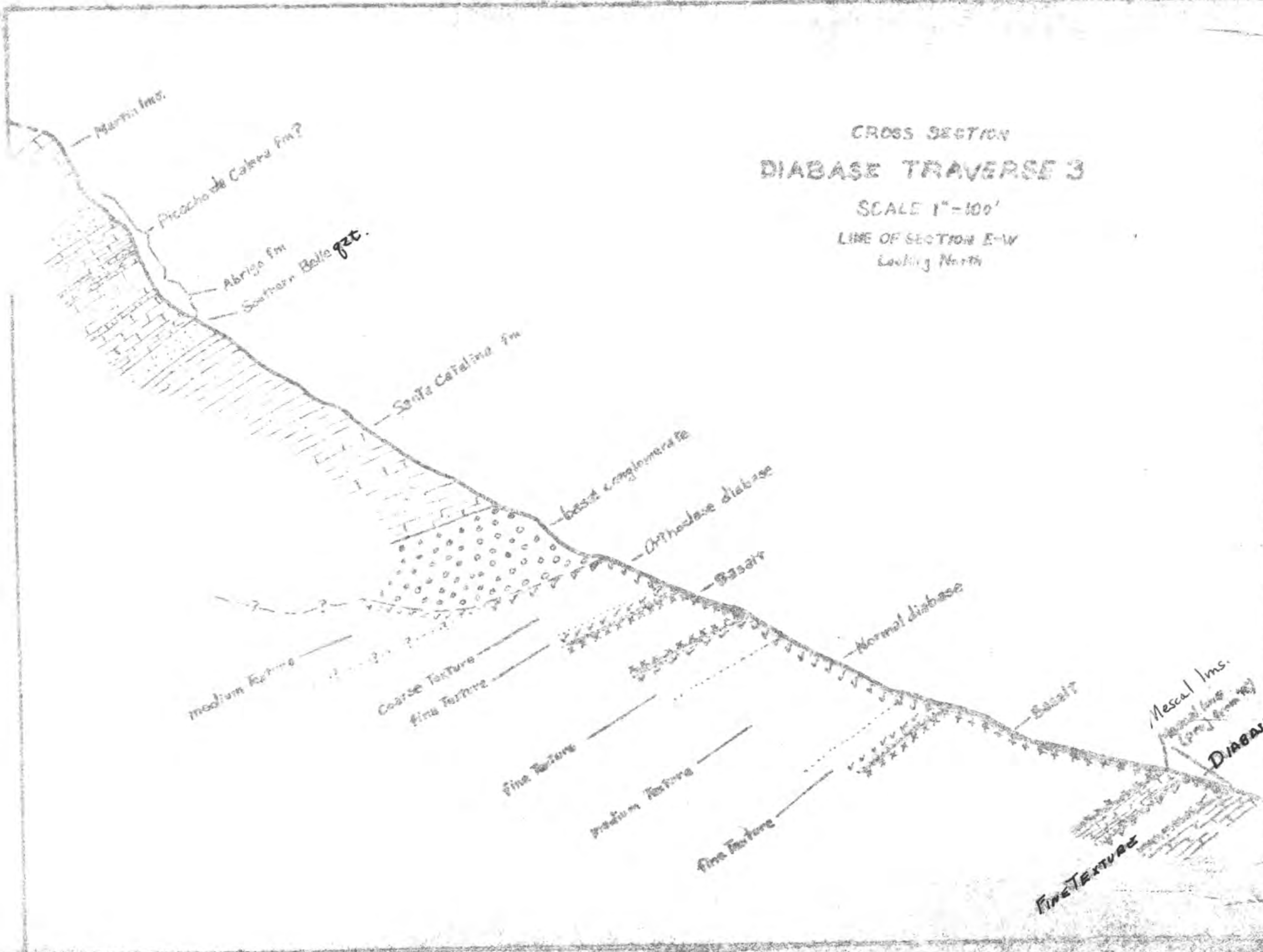
These sills are exposed from Promontory Ridge southward to the Copperosity fault zone and to a limited extent at the northeastern edge of the mountains. Apache basalt and Mescal limestone form the lower contact, whereas the upper surface is generally eroded, and covered with upper Troy or Santa Catalina basal conglomerate.

The cross section along Diabase Traverse #3, illustrated on Plate 7., and located on Plate 3., shows the relationships between these diabase sills and the underlying Mescal limestone, the intruded Apache basalt and the overlying Paleozoic rocks.

The Mescal limestone, shown at the bottom of the section on Plate 7., is slightly bleached along the contact with the small diabase sill. No differentiation was noted in this sill, and the texture is medium to fine diabasic. The lower part of the Apache basalt consists of greenish to bluish-gray, finely crystalline, amygdular basalt. The amygdule filling is largely epidote and calcite. Jointing parallel to the trend of the Mescal limestone is well-developed locally.

The central diabase sill has fine-textured borders which

PLATE 7


CROSS SECTION
DIABASE TRAVERSE 3
SCALE 1" = 100'
LINE OF SECTION E-W
Looking North
Martin lms.
Picacho de Calera fm?
Abrigo fm
Southern Belle qzt.
Santa Catalina fm
basal conglomerate
Orthoclase diabase
Basalt
Normal diabase
Basalt
Mescal lms.
DIABASE
medium Texture
Coarse Texture
Fine Texture
Fine Texture
medium Texture
Fine Texture
FINE TEXTURE

grade inward to a medium to coarse texture at the center. In thin section, up to 10% granophyric intergrowth of quartz and orthoclase was noted.

The base of the overlying Apache basalt contains epidote-calcite alteration, but toward the top, it is permeated by small stringers, irregular splotches and anygdular fillings of orange-colored granophyric material. This exposure of basalt, also, is fine-grained, greenish-gray, and well-altered.

The 6 foot basal zone of the adjacent orthoclase diabase sill is fine-textured. The remaining exposure along the line of section is coarsely crystalline, very highly altered, pegmatitic orthoclase diabase. Basal conglomerate of the Santa Catalina formation covers the upper surface. (See Prints 11. and 12.) Fifty feet south of the traverse, medium-to-fine-textured orthoclase diabase at least 30 feet thick is well-exposed above the pegmatitic horizon.

The medium-to fine-textured phase of this sill was described under the heading "Petrography of the orthoclase-quartz diabase" on page 49. There appears to be a considerable variation in the amount of the orthoclase-quartz segregate in this phase. This is ture, also, in the coarser "pegmatitic" phase. It varies from 10-60% in thin section. The orthoclase-quartz granophyric segregate is generally well-dispersed throughout the rock, but there

Print 19

by myrmekite

Graphic replacement of plagioclase
by
quartz and orthoclase. (47X)

Print 19 under ordinary light, and Print 20 under crossed nicols, show the zonal replacement of plagioclase by the graphic network of orthoclase and quartz. A part of the core, also, is replaced.

Print 20

by myrmekite

Graphic replacement of plagioclase
by
quartz and orthoclase. (47x, crossed nicols)

Print 21

Photomicrograph of partly altered diabase
(47x)

This specimen, collected from the intermediate sill of Diabase Traverse 3, represents the early stages of alteration in the diabase. The plagioclase is relatively unaltered. The augite, however, shows reaction rims of uralite, hornblende, and biotite. Chlorite is present in small amounts.

is definite indication in thin section that it selectively replaces the feldspars in many instances. (See prints 19 and 20.)

Plagioclase, augite and hornblende apparently crystallized early from the magma and formed a large part of the rock. Toward the late stages of crystallization, the orthoclase-quartz segregate probably gathered in knots, filled the remaining open spaces, and replaced some of the plagioclase. Uralitization is widespread throughout most of the diabase sills, (See print 21) and many have occurred soon after the consolidation of the orthoclase-quartz segregate.

Saussuritization has greatly affected the orthoclase diabase, and in particular, the pegmatitic phase. The feldspars appear to have been altered to epidote or clinozoisite, albite, quartz, sericite and calcite, whereas the ferromagnesians have been altered to chlorite, uralitic amphibole, and hematite.

Within the pegmatitic zone of the upper sill, orange-brown to dull gray knots of alteration products are clearly visible. Stringers of similar material, some of which contain knots of epidote up to 1 cm and calcite up to 6 mm with small bunches of chalcopyrite, cut both the fine-grained border phase of the sill and adjacent Apache basalt.

Johannsen[20] describes the saussuritization of intermediate plagioclase as follows:

20. Johannsen, albert, A Descriptive Petrography of Igneous Rocks. Vol. 111, pp 210-211, Unviv. of Chicago Press, (1937)

"$Na_2).Al_2O_3.6SiO_2$ + $8(CaO.Al_2O_3.2SiO_2$ + $4H_2O$ =
Albite Anorthite Water

$2(4CaO.3Al_2O_3.6SiO_2H_2O$ + $Na_2O.3Al_2O_3.6SiO_2.H_2O$ + $4SiO_2$ "
zoisite Paragonite quartz

Other authorities have written equations differing from that given by Johannsen. Indeed, field and petrographic evidence indicates that in most localities, a more complicated series of reactants and products are involved than those represented in the above equation. Paragonite rarely or never appears. Instead, the common sodium-aluminum silicate in saussuritized rocks is albite. If white mica appears, it is nearly always the potash mica, sericite. Epidote or clinozoisite are much more common than zoisite.

Johannsen[20] explains that when the plagioclase is somewhat more sodic, secondary albite is an alteration product. When potash is present, sericite may form. If CO_2 is present, calcite may develop, but this is less common. Also, if iron is released by the breakdown of the ferromagnesiam minerals in the diabase, epidote may appear in place of zoisite, or may accompany it.

The potash in the sericite of the saussuritized Vekol orthoclase diabase may have been released by the destruction of the orthoclase. The calcite may have formed from Mescal limestone inclusions

20. idem, pg. 210-211.

in the sill or it may be of hydrothermal origin. The presence of chalcopyrite in some of the stringers would support the latter contention. The iron necessary for the development of epidote undoubtedly came from the destruction of the ferromagnesians.

Both Johannsen[20] and Harker[19] believe uralitization of the ferromagnesian minerals accompanies saussuritization. This results in a breakdown of the pyroxenes to uralitic amphibole, hematite, etc., and of olivine to serpentine, talc, chlorite, iron ores, etc. Actinolite, garnet, chlorite and rutile, which often develop in feldspars during saussuritization, derive some of their constituents from the ferro-magnesians. A part of the uralitization of the diabase in the Vekol Mountains probably accompanied the saussuritization, but some is believed to have been earlier, for some specimens show uralitization but no saussuritization. (See print 18).

Johannsen,[20] Tyrrell[21] and others disagree with Harker[19] as to the cause of saussuritization. The former attribute this type of alteration to dynamo-alteration, whereas the latter considers it a late stage process in the cooling of an igneous rock. In the opinion of the writer the saussuritization of the diabase in the

19. Harker, Alfred. Metamorphism, 2nd ed. pp 174-176, Methuen and sons, (1939)

20 idem, pg. 228.

21. Tyrell, G. W. The Principles of Petrology, 2nd ed. pg. 311, E. P. Dutton and Co., Inc. (1929.)

Vekol Mountains is a very late hydrothermal effect. There is no evidence that shearing has played a major role in this process. It is ture that alteration appears to be more intense near the fractures, but this is believed to be due to the fractures acting as channel ways for the altering solutions. In the intermediate, less altered areas, the original ophitic texture is well-preserved. Also, thin section study of specimens in which saussuritization is just beginning shows partly altered phenocrysts of unstrained plagioclase in totally unsheared rock.

Contact Metamorphism The metamorphic effects brought about by the diabase are relatively unimportant. Slight bleaching is evident along the borders of the dikes in the schist, and scattered epidote has developed in the Pioneer shale where calcareous bands intersect the contact. The smaller slivers of Mescal limestone are well-bleached. Tremolite fibers were noted with the hand lens at one locality, and in some cases, the limestone is recrystallized for a few inches from the contact. The Dripping Spring and Troy quartzites contacts also are sharp. The contact between the Troy quartzite and the diabase is described in detail on page 47. The lack of a contact metamorphic zone adjacent to the diabase may be the result of the "dry" nature of the diabasic melt.

Age of the Diabase

The age of the diabase has been one of the leading controversial issues in Arizona geology for many years. Ransome,[10] after his study of the Ray-Miami districts condluded that the diabase is late Paleozoic or early Mesazoic. He found dikes of diabase cutting the Martin and Tornado (Escabrosa and Naco) limestones in both the Tortilla Mountains and the Dripping Spring range.

Darton,[17] however, concluded that these dikes are not the same as the extensive sills and dikes of the Apache Group, but feeders of some Tertiary or Quaternary basalt. He found that "the diabase invades mainly the strata older than the Troy, but in some instances the lower part of the quartzite is invaded."

Short and Ettlinger found similar evidence in the Magma mine at Superior,[15] and concluded that the diabase does not intrude the Martin limestone. They believed the diabase to be post-middle Cambrian and pre-Upper Devonian.

The relationships between the Santa Catalina formation, the two members of the Troy quartzite and the diabase in the Vekol Mountains, discussed in the section on General Geology, page 22., is summariz ed as follows:

1. The lower, massive member of the Troy quartzite is intruded by the diabase within a few feet of the shale marker division between the lower and upper Troy.

10. idem pg. 56.

7. idem pgs. 254-255.

15. Short, M. N. and Ettlinger, I. A. Ore deposition and enrichment at the Magma miher, Superior, Arizona. Am. Inst. Min. Eng. Trans. Vol. 74, pg. 181, 1926.

2. The upper Troy appears to rest unconformably on a diabase erosion surface. An exposure in the canyon south of Promontory Ridge shows diabase cobbles, pebbles and fragments in a matrix of cross-bedded quartzite, limy sandstone and chert.

3. The overlying Santa Catalina formation shows a definite overlapping relationship with a sloping diabase erosion surface. A well-developed basal conglomerate of diabase cobbles and pebbles is exposed along the contact. (See Prints 11. and 12.).

4. Similar small Cambrian brachiopods were found in the upper Troy, the Santa Catalina formation, and the Southern Belle quartzite, while no fossils have beem found in the lower Troy.

5. The lower Troy shows no sign of diabasic detrital material in the specimens examined thus far.

The writer concludes that the diabase is not younger than Middle Cambrian. The exact age of the diabase cannot be determined until the age of the lower Troy has been worked out, but the writer is of the opinion that the diabase is either Middle or Lower Cambrian.

Cretaceous volcanics?

The volcanics in the Reward area may be related to the Cretaceous (?) rocks, for they appear to be conformable and interbedded with the upper bouldery beds of that series. These rocks, described by Hadley,[6] in the Reward area, are as follows:

"Upper part: Mostly volcanic conglomerate, breccia, tuff-breccia and andesitic lava."

6. idem.

> "Lower part: Mostly conglomerate with abundant well-rounded fragments of limestone, quartzite, felsite porphyry and granite commonly 6 inches, locally 18 to 30 inches in diameter. Includes lenses of feldspathic sandstone 1 to 5 feet thick. Beds of volcanic breccia, red feldspathic sandstone, quartzites and quartz conglomerate at base. Erosional unconformity."

The writer has not done sufficient work on the volcanics in Bitter Wells Basin to establish the contact between the Cretaceous? volcanics and the volcanics farther north. Most of the basin is filled with alluvium, and it may not be possible to (LINE MISSING) secure a clear-cut relationship between the volcanics described by Hadley and those in the northern end of the basin which are overlain by the Quaternary rocks described on page 69.

Some of the basal flows along the west flank of the main range, which directly overlie the bouldery beds believed to be the upper member of the Cretaceous series in that area, may also be Cretaceous in age.

<u>Tertiary intrusives and volcanics</u>

Biotite granite, granite porphyry, rhyolite porphyry, dacite porphyry, andesite, and volcanics of varied composition are believed to be Tertiary in age. Their distribution, lithology and age relationships are described below:

<u>Biotite granite</u>

The northwestern edge of a granite intrusive of undetermined size is well-exposed along the southeastern fringe of the main range. Its intrusive relationship is restricted to the Pinal schist, and yet, it probably is not pre-Cambrian in age, for it is remarkably fresh and non-foliated. Also, no diabase dikes could be found in any of the granite exposures.

Megascopically, it is a reddish-gray, porphyro-phanero-crystalline rock with euhedral phenocrysts of orthoclase ranging up to 2 cm in length, surrounded by an equigranular matrix of subhedral to anhedral orthoclase, quartz, biotite and plagioclase with an average grain size of approximately 3 mm.

In thin section, subhedral crystals of orthoclase up to 8 mm long are intergrown with quartz, averaging about 2 mm, plagioclase, 1 mm, and biotite 1 mm. The plagioclase appears to be gradational from oligoclase to albite. The feldspars are zoned and sericite has selectively replaced the cores or alternate zones. Only a slight halo of chlorite is visible around the edges of the biotite flakes. The larger feldspar phenocrysts include small, anhedral phenocrysts of all the other minerals. Euhedral, basal sections and subhedral apatite prisms up to 1 mm, and anhedral to euhedral magnetite 0.1-0.3 mm are well-distributed as accessories.

The following is an estimate of the composition:

Orthoclase	45%	Biotite	10%
Quartz	15-20%	Magnetite	5%
Plagioclase	15-20%	Apatite	1%

A small amount of micrographic intergrowth of quartz and orthoclase appears to selectively replace the feldspars.

The contact with the schist is intrusive, and dips steeply northward. At the north end of the exposure, small granite dikes penetrate the schist for at least 300 feet. Also, pegmatite-aplite dikes cut across the contact at several places along the contact. A greenish-brown, highly altered, felsite dike intrudes the granite at the north end of the intrusive. A granite porphyry dike, described below, also cuts the granite in that area.

The granite is jointed by two sets of joints. The most apparent is a steep set roughly parallel with the contact, whereas the second is an east-west set which dips gently northward. Exfoliation has developed to a moderate extent.

The granite exposed on the surface of the pediment to the west of the Copperosity Basin consists of well-weathered, medium-grained granite with an average grain size of 4 mm. No large phenocrysts are evident in the areas examined.

Megascopically, this granite is phanerocrystalline with anhedral to subhedral phenocrysts of quartz, 3 to 4 mm, feldspar, 2 to 5 mm and biotite, 1 mm in diameter. The biotite is generally well-altered to chlorite. Thin films of epidote line small veinlets in some areas, and , in others, the feldspar is predominately flesh color. The quartz is estimated at 25%, the feldspar at 50%, the biotite at 20%, and the epidote up to 5%. The feldspars are partly altered to sericite.

The writer has no evidence as to the age of this granite, except that it intrudes the schist, and that flows of probably Tertiary age rest on the eroded granite surface. Furthermore, the andesite plug of Hill 2456, shown on Plate 3., contains fragments of granite. It may be related to the granite on the southeast end of the main range described above. Both are biotite granites, but differ in texture.

A third area of granite is extensively exposed along the northwestern edge of Santa Rosa Valley, north of the pipe line road. (See Plate 2.). It is very similar in appearance to the granite at the southeastern edge of the main range. The writer believes both are a part of the same intrusive activity.

Granite porphyry

Megascopically, the granite porphyry, which intrudes the northern end of the southeastern granite area is a porphyro-phanerocrystalline to porphyro-aphanitic rock. It consists of a few phenocrysts from 2 to 3 mm in diameter, orthoclase 1 to 2 mm, plagioclase about the same length, and scattered biotite flakes altering to chlorite averaging about 1.5 mm. All are embedded in a fine-grained groundmass of orthoclase and quartz which is barely discernible with the hand lens.

This rocks appears to cut the granite in dikes several feet thick, but the exposures are poor. Consequently, no detailed picture of its relationship to the granite could be secured. It may be related to the rhyolite porphyry described below.

Tertiary Volcanics

The flows and related volcanics of intermediate composition along the west front of the main range in the vicinity of 2913 peak and on the pediment to the west and northwest appear to be a part of the volcanics of the Copperosity Hills. They are believed to be Tertiary for they overlap the granite and are covered by the Quaternary volcanics.

The following kinds were collected and studied:

a. Dacite from 2913 peak:

Gray, porphyro-aphanitic rock with feldspar phenocrysts between 1 mm and 1 cm in lenth, slender hornblende needles between 0.5 and 4 mm long, and biotite flakes 1 mm in diameter embedded in a very finely crystalline to aphanitic groundmass. There is a faint tendency toward banding with a rough orientation of the hornblende and biotite. The porphyritic texture is not conspicuous because of the light gray color of both the phenocrysts and the groundmass.

In thin section, this rock is clearly porphyritic with euhedral to subhedral plagioclase phenocrysts up to 6mm long, and a second generation averaging about 1 mm, hornblende phenocrysts averaging 3 mm in length, and biotite 1 to 2 mm in diameter surrounded by a very finely crystalline groundmass. The plagioclase phenocrysts are probably andesine. They are partly altered, with sericite developed along fractures. The hornblende and biotite are highly corroded and altered to iron oxides. Many have halos of magnetite grains around their borders. There is no evidence in thin section of the development of secondary biotite by magmatic resorption of the hornblende. Devitrification of the groundmass has produced a cryptocrystalline mass of small crystals. Sparse, anhedral quartz up to 0.3 mm was noted, and small amounts of calcite are present also. Finely crystalline sanidine may be present.

b. Flows from the pediment west of 2913:

These flows consist of coarse porphyro-aphanitic rocks, fine-grained felsites and tuffaceous types.

1. Andesite? The porphyro-aphanitic type consists of tabular plagioclase phenocrysts averaging 5 to 6 mm in length, brown hornblende relics up to 10 mm long, and numerous euhedral biotite books 1 mm or less in diameter embedded in a dense, brownish-gray matrix. The plagioclase shows both carlsbad and albite twinning and is remarkably unaltered. The hornblende has been almost entirely replaced by iron oxides the the biotite, in hand specimen, appears to be relatively fresh.

2. Felsite. Fine, porphyro-aphanitic type with sparse plagioclase phenocrysts up to 2 mm, highly altered, brown hornblende up to 1 mm long, with numerous relatively unaltered biotite flakes averaging about 1 mm in diameter. All are embedded in a brown, aphanitic groundmass.

3. Tuff. Angular fragments of andesite described above, ranging from 5 mm to 1.5 cm, together with occasional hornblende phenocrysts up to 8 mm long: sparse plagioclase phenocrysts up to 4 mm in length, euhedral biotite books about 1 mm in diameter are embedded a matrix of gray ash. Many of the hornblende phenocrysts are relatively unaltered.

All three types are so similar, mineralogically, that the writer believes them to be a part of the same period of volcanic activity. Similar rocks were collected at the Papago mine at the western edge of the Vekol Quadrangle, and in the northern end of the Copperosity Hills.

c. Andesite from Hill 2456:

This sharp pointed hill is believed to be a volcanic plug. The trend of the flow lines is roughly circular. (See Plate 3.). Granite fragments are included around the edges.

Megascopically, this rock is extremely fine-grained with but a few altered biotite flakes up to 2 mm in diameter. In thin section, it is porphyritic with shreds of altered biotite, augite phenocrysts up to 0.6 mm and ghost outlines of hornblende and biotite replaced by magnetite grains up to 1.3 mm: all are embedded in a groundmass of roughly oriented shreds of plagioclase 0.01 to 0.05 mm long, small augite and magnetite specks which are surrounded by glass in the process of devitrification. A few apatite sections were noted ranging from 0.01 to 0.03 mm. No reaction rims of biotite were noted around the edges of the hornblende.

Dikes filling east-west fault zones

The andesite? dikes such as the one which cuts across the main range at the Vekol mine, the one at the Great Eastern mine, and others in the northern end of the main range and in the eastern hills, vary from a few feet up to 50 feet in width. They fill east-west fault zones, but later faulting has been effective along some of the dikes. The writer considers them as pre-Quaternary, since volcanics of that sequence cover them locally.

> In hand specimen, the texture of the andesite exposed in these dikes is porphyro-aphanitic with numerous altered feldspar phenocrysts, averaging 2 mm, and altered biotite, 1 mm, in a dense brownish groundmass. A rough flow banding is evident in some specimens.
>
> In thin section, this rock consists of numerous highly altered feldspar phenocrysts up to 4 mm long, hornblende phenocrysts reaching 2.5 mm and biotite 0.6 mm maximum, in a felt-like groundmass of sericitized? feldspar lathes averagin 0.03 mm in length. A few small, anhedral ferromagnesians are scattered throughout the matrix as well as small grains of magnetite. If glass was present it has been devitrified.
>
> Most of the feldspars are almost completely replaced by sericite. A few, which show fair extinction are believed to be andesine. All, however, have well-preserved crystal outlines. The hornblende and biotite are partly replaced by calcite, and are altering to magnetite around their borders.
>
> Apatite prisms up to 0.6 mm and scattered magnetite up to 0.03 mm are accessory minerals. Narrow veinlets, consisting of calcite 0.3 mm and quartz, 0.05 mm, cut across the section

Dacite Porphyry

The dacite porphyry of the east ridges and hills occurs in sills and dikes ranging from a few feet to over 200 feet thick where it has intruded the thin-bedded Abrigo and Santa Catalina formations. It appears to be earlier than most of the east-west faulting, and may have accompanied the earlier stages of the northwest faulting.

Megascopically, this rock is light gray to tan, porphyro-aphanitic with stubby phenocrysts of feldspar, 1 to 2 mm long, hornblende needles up to 1 mm and biotite flakes 1 to 2 mm in diameter, embedded in a pinkish-gray, aphanitic matrix. The rock generally consists of about 50% phenocrysts. The white, chalky feldspar phenocrysts make up about 30%, while the hornblende needles and biotite flakes total about 20%. Chlorite has partly replaced these minerals.

In thin section, phenocrysts of feldspar averaging 1 mm long, hornblende up to 2.5 mm, but averaging less than 1 mm, biotite about 1 mm, and scattered magnetite make up about 45% of the section. The feldspars are almost completely altered to sericite. Recognizable anhedral quartz and sanidine up to 0.1 mm are minor constituents. The grain size in the matrix averages about 0.04 mm and consists of brownish, sericitized plagioclase laths with corroded, equidimensional, anhedral sanidine? and quartz? together with sparse, scattered hornblende, biotite and magnetite. The texture of the groundmass is microfelsitic.

Calcite has replaced the cores of hornblende phenocrysts and magnetite grains form an intermediate zone between the calcite and the outer rim of unreplaced hornblende. Apatite is a minor constituent of the rock.

In the Reward area, Hadley designates the rock described above as a <u>hornblende diorite porphyry</u>. The writer prefers the term dacite porphyry since the groundmass is generally aphanitic, and appreciable quartz and sanidine are present. In most of the exposures examined by the writer, biotite and hornblende are present in about equal proportions.

Rhyolite porphyry

At the southeast edge of Bitter Wells Basin, a small east-west trending plug of rhyolite porphyry is located just south of hill 2427. (See Plate 3.,). It averages about 1,000 feet in width, and is exposed for about 3,500 feet along its trend.

Megascopically, this rock has a porphyro-aphanitic texture with short prismatic phenocrysts of clear quartz and highly sericitized feldspar 2 mm in diameter embedded in a highly altered, gray, very finely crystalline to aphanitic groundmass. A few badly altered biotite flakes are evident, and knots of columnar epidote ranging up to 5 mm give the rock a spotted greenish appearance.

In thin section, subhedral to euhedral phenocrysts of beta quartz, 1 to 2 mm in diameter, subhedral orthoclase and plagioclase (probably oligoclase) 1 to 3 mm long, and biotite 1 mm in diameter, together with numerous small phenocrysts are embedded in an extremely fine, sericitized matrix.

The feldspars are partly sericitized, and both the feldspars and quartz are embayed. Chlorite almost completely replaces the biotite. Areas of radial epidote and calcite up to 5 mm are present. They appear to replace the larger feldspar phenocrysts. Apatite is sparsely present in 1 mm subhedral crystals. Magnetite, ranging from 0.05 to 0.1 mm is a very minor constituent.

The mineral composition of the phenocrysts is estimated as follows:

Primary		Secondary	
Orthoclase	10-15%	Sericite	5%
Quartz	15%	Chlorite	3-%
Plagioclase	10%	Epidote	5%
Biotite, largely altered to chlorite		Calcite	3-5%

Primary

Magnetite	1%
Apatite	minor

The fine-grained matrix represents about 50% of the total.

This plug intrudes diabase, Troy Quartzite, Santa Catalina formation and the remainder of the Paleozoic section with the exception of the Naco limestone at hill 2427, and farther east, cuts the rocks of Cretaceous? age. Also, according to Hadley,[6] it offsets dikes of hornblende diorite porphyry or dacite porphyry. It is believed to be Tertiary in age.

A dike approximately 100 feet wide cuts across the southern end of the limestone hill just east of the rhyolite porphyry plug. (See Plate 3.). Itx texture ranges from porpjyro-aphanitic to fine porphyro-phanerocrystalline and is similar to that of the granite porphyry dike which intrudes the northern end of the granite at the southeastern edge of the main range. Both probably are related to the rhyolite porphyry intrusive activity.

Along the contact of the rhyolite porphyry and granite porphyry with the Escabrosa limestone are thin patches of metamorphosed limestone a few inches to several feet in width. The garnet-apidote-calcite rock is developed in the mineralized areas also, and may be the product of hydrothermal alteration related to a

6. idem

period of metallic mineralization, or it may be a result of the direct contact effects of the intrusive. A further study of this problem will be made by the writer.

Quaternary Volcanics

The sequence of volcanic rocks exposed along the northwestern edge of the Vekol Mountains is believed to be of Quaternary age. These volcanics dip gently northwest and occur in isolated, recently uplifted blocks. (See Plate 3.). This sequence includes the following rocks:

		Thickness (Top)
1	a. Highly vesicular, dark gray, olivine basalt.	50-200 feet
2	b. Agglomerate or volcanic breccia consisting of scoria, tuff, and irregular areas and blocks of basalt.	100-500 feet
3	c. Thin basalt flows.	10-100 feet
4	d. Thin, gray, platy, finely crystalline andesitic? basalt.	50-100 feet
5	e. Gray tuff interfingering with Gila conglomerate?	10-200 feet
	Poorly exposed flows and clastics, possibly Tertiary or Cretaceous age.	Unknown

The underlying rocks consist of thin tuff beds, occasional medium-to corase-grained sandstone beds consisting largely of volcanic material, and thin flows ranging in composition from andesite? to rhyolitic obsidian. This group of rocks is poorly exposed for it occurs in the central and northern part of Bitter

Print 22.

Quarternary Volcanics,
north end of Bitter Wells Basin.

Olivine basalt caps the ridge on the upper left. Underlying the basalt are agglomerate beds and occasional thin basalt flows. Just above the road, Gila conglomerate is interbedded with tuff.

Print 23.

Quarternary Agglomerate

The 5 foot exposure of agglomerate shown in the above print consists of angular fragments of basalt and andesite averaging about 4 inches in length embedded in a matrix of finer fragments and ash. A faint bedded tendency is evident in most exposures.

Wells Basin, which is largely covered with alluvium. The writer has not studied these rocks in sufficient detail to establish their relationship with the rocks described by Hadley[6] in the Reward area.

The gray tuff of unit 5., exposed on the southwest flank of 2917 peak, is made up of angular, 1/2 to 1 inch volcanic fragments, largely pporphyro-aphanitic andesite in a matrix of buff-colored tuff consisting of ash and pumice fragments. Toward the southwest, this unit appears to grade into a well-rounded pebble and boulder conglomerate which is believed to be comparable to the Gila conglomerate described by Ransome.[10]

The thin, gray, platy basalt of unit 4. is a persistent flow along the northwest edge of the area. It is found at the base of 2804 peak west of the Vekol mine, at the base of the northern end of the main range, and immediately above the gray tuff bed of 2913 peak. Megascopically, it is a dense, gray rock with occasional vesicles up to 3 mm long, scattered augite phenocrysts 1 mm in diameter, and a few olivine phenocrysts up to 1.5 mm, with a variable, brown halo of iddingsite.

In thin section, augite phenocrysts up to 2mm, but averaging 0.6 mm, make up about 5% of the rock: olivine up to 0.6 mm in diameter, partly altered to iddingsite, account for about 10%.

6. idem

10. idem pg. 71

A few plagioclase laths, which reach a maximum length of 0.5 mm are present, but they could not be identified. The groundmass consists of a mesh of roughly oriented feldspar laths averaging about 0.1 mm long, enclosing anhedral areas of iddingsite and numerous augite grains. A small amount of interstitial glass fills the intermediate areas. The vesicles, 1-3mm in length, are elongate and make up about 10% of the section. The vesicles and plagioclase laths are aligned by flow.

The thin basalt flows of unit ~~ø~~ 3. consist of gray to dark gray, vesicular, olivine basalt in flows 1 to 10 feet thick. These flows are not consistent and are missing locally.

Agglomerate

The agglomerate or volcanic breccia consists largely of scoria boulders with an occasional vesicular basalt boulder 3 feet or more in diameter embedded in a matrix grading from boulders to fine-grained tuff and ash. Locally, areas of gray, vesicular basalt appear to have intruded the breccia, and toward the top, occasional thin basalt flows are interbedded with the agglomerate.

Olivine basalt

Capping the agglomerate is a group of dark gray, vesicular olivine basalt flows interbedded with agglomerate identical to that described above. The flows range from 50 to 30 feet in thickness except for thin, platy flows which are 20 to 3 feet thick.

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Print 24

Photo-micrograph of Olivine
Basalt (47x)

The above print of the vesicular, Quarternary olivine basalt, shows an olivine phenocryst in the first stage of alteration to iddingsite. Many of the small phenocrysts are completely altered. A small augite phenocryst can be seen on the right side of the print. The groundmass consists of plagioclase laths, small grains of augite and iddingsite, and scattered magnetite. A small amount of glass is present in the groundmass.

The agglomerates are from 5 to 10 feet thick. The vesicles in the basalt are generally elongated in the direction of the flow. The maximum thickness of this unit is estimated at 200 feet.

In hand specimen, this rock is dark, brownish-gray on fresh surfaces. It is highly vesicular with elongate vesicles ranging up to 4 cm long and 5 mm wide. They are partly filled with calcite. The pore space varies from 25% to 50%. Occasionally, phenocrysts of olivine 1 to 2 mm long, augite 2 mm in length, and plagioclase laths 0.5 to 1 mm long are visible on fresh surfaces. The matrix is aphanitic, but contains many minute vesicles. Calcite fills some of these.

In thin section, the basalt shows the following composition:

Primary		Alteration	
Olivine	0.5 - 1 mm in phenocrysts 0.01 in groundmass 2%	Iddingside	8%
Labradorite	1.2 mm max. length in phenocrysts. 0.5 mm average in groundmass 5%	Amygdular	
Augite	2.2 mm max. in phenocrysts 0.1 mm av. in groundmass 10%	Calcite	1%
Accessory			
Magnetite	0.03 mm av. 5%		

Occasional subhedral phenocrysts of labradorite up to 1.2 mm long, subhedral phenocrysts of augite up to 2.2 mm in length and subhedral to euhedral phenocrysts of olivine 1.5 mm long are embedded in a finely crystalline groundmass of labradorite laths 0.1 mm long, intergrown with small grains of augite and iddingsite.

Many of the larger labradorite phenocrysts are zoned. The augite and labradorite are relatively unaltered. The larger olivine phenocrysts have a narrow rim of iddingsite, whereas many of the smaller are completely altered to reddish-brown iddingsite. Small magnetite grains are well-distributed throughout the groundmass.

The small laths of labradorite in the groundmass are well-oriented. This parallelism, together with the elongation of the vesicles clearly illustrates the flow banding.

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, showsn 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 Apache time and the Paleozoic except for possible disturbances due to the replacement of the diabase. During the Ordovician, Silurian and much of the Devonian, this area, like most of southern Arizona was uplited 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.

d 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 quiescence 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 suncline is located along the southwestern 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 oustheast 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 tranding Copperosity and Bitter Wells faults divided the mountains into three distinct structural blocks: the southern, the central, and the northeastern. 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 trand northwest. Also, it intrudes many of the east-west fault zones. An east-west trending rhyolite porphyry plug and dike cuts 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 the 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 from 35° to 50° southwesterly. This folding may represent minor flexures on the sunclinal flank or may have been developed by faulting.

The marked drag folding on the north side of 3231 peak north of the Hinshaw 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.).

<u>Names and Location of Major Faults</u>

The writer has named some of the major faults in the area for the purpose of simplifying the description of the structure. They are shown on Plate 3.

The Copperosity fault zone extends from the western side of the main range across the south-central section to the southeastern fringe, where it disappears under the alluvium of Santa Rosa Valley.

The Bitter Wells fault is not exposed at any point along its trend. However, the writer feels justified in assuming that this fault is present because of the obvious stratigraphic displacement between the Escabrosa limestone at the Republic mine at the southeastern edge of Bitter Wells Basin, and the schist immediately to the south. As shown on Plate 3., this fault is believed to trend east-west in the vicinity of the Republic mine and northwest across Bitter Wells Basin.

The Promontory Ridge fault is well-exposed at the western end of Promontory Ridge and in adjacent canyons. It strikes northwest and dips moderatly eastward.

The Transverse fault trends east-west across the main range just south of Promontory Ridge. It dips steeply to the south.

The Pomona fault, of similar trend and dip, crosses the range just north of Promontory Ridge.

The Vekol and Great Eastern dikes and fault zones, located toward the northern end of the main range also trend east-west. They appear to be fault zones which have been filled with andesite, and then broken by subsequent movement.

Evidence of Faulting

T The actual fault surfaces frequently are visible in the Vekol Mountains, particularly in the precipitous areas. The majority of the faults, where not actually seen, can be inferred without much doubt. In some instances, where the faults cross talus slopes, flank the alluvial fringes of the range, or cross Bitter Wells Basin, their trend and attitude are entirely speculative.

Distribution

The most intense faulting is localized along the Copperosity fault zone in the vicinity of the synclinal axis. (See Plate 3.). East-west and northwest faults are found in places at the northern end of the main range and in the eastern ridges and hills.

Type of Movement

The faulting appears to be predominately normal, but strike-slip movement has occurred on the Copperosity and possibly on the Bitter Wells faults. There are local instances of reverse movement. No major thrust faults could be found in the Vekol Mountains.

Fault Systems

The northwest trending, normal faults, and the generally east-west trending Copperosity and Bitter Wells faults constitute the two major fault systems in the Vekol Mountains, Associated with these are steep, east-west trending tensional faults and steep, north-south adjustment faults. (See Plate 3.).

The northwest system of faults has a range in strike from N 10° W to N 45° W. These faults, particularly in the main range, have a moderate dip to the east, averaging between 45° and 50o. They are believed to be mostly normal faults. The stratigraphic throw ranges from a few feet up to an estimated 720 feet on the Promontory Ridge fault. Assuming an average dip of the beds of 33o, the estimated stratigraphic throw across the northern end of Bitter Wells Basin, between the Vekol ridge and the east ridges, is in the neighborhood of 6,800 feet. This large displacement probably is the result of combined movement on the faults of the northwest system and the unexposed Bitter Wells fault. (See Plate 3.). Minor folding, described above, may reduce this figure somewhat.

Associated with the northwest faults are west dipping faults of approximately the same strike. The throw on these faults is but a few feet, and the movement is either normal or reverse. They have been effective as channel ways for the mineralizing solutions at the Vekol mine. They are cut off by the stronger east dipping faults, but, in some instances, they have moved in conjunction with them. Post mineral movement is present on both

Print 25

Drag fold on the north flank of 3231 peak.

The axis of the drag fold, which trends southeast, is showsn by the dashed line. Strands of the Copperosity fault zone are indicated by the dotted lines. Naco limestone caps the ridge, and quartzite of the Cretaceous red beds and diabase occur as slivers within the fault zone.

the strong east dipping and the minor west dipping, northwest faults.

Faulting on the Copperosity-Bitter Wells system has divided the area into three primary blocks. The southern block is separated from the central block by the Copperosity fault. The northeastern block lies north of the proposed Bitter Wells fault.

Individual faults of the Copperosity fault zone dip from 60° to 80° south. The trend of this zone is southeastward at the edge of the Santa Rosa Valley, east-west in the south-central part of the main range, and northwestward along the western edge of the area. The offset of the granite contact at the edge of Santa Rosa Valley is at least 800 feet. In the vicinity of the Hinshaw mine, the offset of the beds approaches 1,700 feet. The greater offset in this area may be the result of combined movement along the spur faults and differential movement on the main zone. The movement on the Copperosity fault zone is believed to be, in part, strike-slip, for a pronounced drag-fold has developed adjacent to the fault on the north end of 3231 peak north of the Hinshaw mine. (See Print 25.). The south block appears to have moved eastward. Also, sliver blocks within the zone include schist, Apache, Paleozoic and Cretaceous rocks. (See Plate 3.).

Within the central block east-west faults cross the range at frequent intervals. They may be tensional faults between the Copperosity and Bitter Wells fault zones. Many are occupied by

Print 26

Block Faulting north of Copperosity fault zone.

A view across the nose of the Vekol syncline northward to the highly faulted section in the central part of the main range. ~~AT~~ (TOWARD HILL 3625 IN DISTANCE)

Print 27

Fault Block
Immediately north of the Copperosity fault zone
in the central part of the main range.

Blocks a, b, and c, shown on Print 26 are clearly showsn in the above photograph. Block a consists of Naco limestone, b of Escabrosa limestone, and c of Santa Catalina formation. The blocks are separated by steep, east-west branches of the Copperosity fault zone.

andesite dikes and also show post-andesite movement. They range from N 75° E. to N 75° W, and dip steeply north or south. They are particularly numerous in the central part of the range north of the Copperosity zone. Their displacement is moderate, ranging up to 400 feet on the Transverse fault. (See Plate 3.).

Faults of north-south trend in the central part of the main range appear to be adjustment breaks between east-west faults and the Copperosity fault zone. The result is a group of fault blocks of randome orientation illustrated by Print 26. The dip of these faults is steep, and the movement in some cases is hinge-like.

Since the Bitter Wells fault is not exposed, its trend, attitude and position are speculative. South of the Republic mine, it is located in the alluvial-covered area between the exposure of Escabrosa limestone on the north and the Pinal schist to the south. Here, the displacement is at least 1,300 feet. Since a fault of this magnitude does not cut across the main range, it is believed to trend northwest across Bitter Wells Basin, where it appears to offset the Quaternary volcanics.

Relative ages of faults

The northwest trending normal faults are believed to be earlier than the major movement on the Copperosity-Bitter Wells system. The Copperosity fault zone truncates all other faults. Also, in most cases, the east-west trending faults offset faults of the northwest system. The Pomona fault clearly displaces the Promontory Ridge fault at Promontory Ridge. (See Plate 3.). In some cases, however, the faults of the northwest system have acted in conjunction with the east-west faults. Such a relationship is well-exposed just east of the Great Eastern mine and east of the Vekol mine, where northwest faults are terminated by the Great Eastern and Vekol faults. (See Plates 3. and 8.).

There is a possibility that the Coppersoty-Bitter Wells system of faults, including the east-west and north-south adjustment faults, may have been superimposed on the earlier northwest system.

The faults of the Copperosity-Bitter Wells system, although probably pre-Quaternary for the most part, do offset the Quaternary volcanics. There may be recent movement along faults of the northwest system as well. This will be discussed in the economic section of this paper.

Faulting and igneous intrusion

The diabase appears to have forced its way into the Apache rocks and Troy quartzite rather than to have followed a pre-existing fault pattern. Many of the sills wedge out laterally. The included blocks within the network of sills and dikes retain practically the same orientation as the adjacent blocks. They seem to be forced apart by the diabase.

There is no indication of a direct relationship between the faulting and the granite intrusives. It is possible that the northwest faulting may have been initiated by stresses developed by the intrusion of the granite. The major movement on the Copperosity fault zone is later than the granite, for it offsets the contact at least 800 feet. The trend of the granite intrusives along their exposed contacts is northward and northeastward, and may be controlled by deep-seated basement structures not apparent in the younger rocks.

The dacite porphyry, particularly in the northeastern part of the area, probably was intruded along both northwest and east-west faults. Sills, sheets and dikes several hundred feet wide, in some cases, have intruded the Cambrian and Devonian rocks in a manner very similar to the diabasic intrusion.

<u>Formation of the Mountains</u>

The writer suggests the following steps in the formation of the Vekol Mountains:

a. Northwest faulting to from the hogback ridges and intermediate troughs, accompanied by east-west faulting and possibly by dacite and andesite intrusions in the later stages.

b. Faulting along the Copperosity and Bitter Wells fault zones and related east-west and north-south faults.

c. Tilting of the region to the northwest to account for the regional dip of the Quaternary flows.

d. Minor faulting on various individual faults.

e. Erosion of the uplifted blocks, controlled by faulting, folding, and the local character of the rocks.

IV. PHYSIOGRAPHY

The Vekol Mountains are included in the Sonoran desert section of the Basin Range province,[3] as, in most of the province, the bedrock structure is controlled to a great extent by faulting, although, to some extent, by folding.

The surface forms in the Vekol Mountains may be divided into three groups: a. The mountains, which are generally precipitous on the east and gently sloping of the west; b. Pediments, or gently sloping rock plains with a thin cover of alluvium. These border a large part of the main range and the eastern hills. c. Bajadas, the alluvial slopes which flank the mountains on the northwest, east and southeast.

Mountains

There are two types of mountains in the area, the sierra type and the mesa type. The sierra type is represented by the main range, the east ridges, and, in a minor sense, the eastern hills. All three are characterized by steep escarpments on the east side,

3. Fenneman, N. M. and others. The Physical Divisions of the United States. U. S. Geological Survey Map, 1930.

the dip slopes on the west except in the southeast end of the main range, where the granite and schist form a northeast-trending ridge. The greater part of the main range is in a stage of late youth to early maturity, topographically. The canyons, particularly on the east side, are V-shaped with steep gradients, and occasionally have narrow, flat-topped divides. The east ridges, and certainly the eastern hills, are in a stage of topographic maturity with sharp ridge lines and wide stream bottoms, pediments and alluvial slopes separating the hills and ridges.

The Mesa type is represented by flat-topped volcanic peaks on the northwestern edge of the mountains. They are steep-sided on the southeast, and dip gently to the northwest. They are flanked by thick talus slopes, and probably represent segments of Quaternary flows recently elevated to their present position by faulting.

Pediments

A large part of the minutely dissected, but relatively smooth slopes which surround the main range in the Vekol Mountains, are carved rock surfaces or pediments. Pediments were recognized by Davis as early as 1902[5] and are described in detail by Bryan.[4] Their slopes average about 100 feet to the mile and their profiles

5. Davis, W. M. Mountain Ranges of the Great Basin: Harvard Coll. Mus. Comp. Zoology. Bull. 42, pp 129-177, 1903: reprinted in Geographical Essays. pp 725-772. Ginn & Co., 1909.

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

are concave upward.

Often the bedrock is exposed in extensive areas, but, in most cases, the rock floor is covered by a moderate thickness of alluvium, and it is exposed along the sides of ravines and in the bottom of streams of in slight hummocks on the terrace surfaces. The pediments are not well-developed in the vicinity of the mesa-like peaks. Apparently, the presence of the thick talus slopes which recede slowly has restricted their development.

The most clear-cut pediment in the area occupies the gently sloping section west and southwest of Copperosity Basin. (See Plate 3.). It extends for more than a mile toward the Kohatk wash, and has been developed on schist, Paleozoic rocks and granite. Another well-developed pediment occupies the northwest corner of Bitter Wells Basin just east of the Vekol mine. The Cambrina, Santa Catalina formation, and volcanics form the rock-carved surface. In this area, the gentle dip of the beds aided in the development of this surface. The southern end of Bitter Wells Basin and the southern fringe of the main range are believed to be pediments also, but they are covered more extensively by alluvial deposits.

Bajadas

The broad Santa Rosa Valley to the south and east of the Vekol Mountains, and the Vekol Valley to the northwest, appear to be alluvial-filled structural depressions. Each is many miles wide with gentle slopes and no sign of buried ridges or pediments. They probably represent alluvial-filled structural depressions.

The bajadas, which fringe the Vekol Mountains and adjacent pediments, slope gently toward the middle of the Santa Rosa and Vekol Valleys. Their average slope is estimated at 50 feet to the mile, and their profile, like the pediments, is concave upward.

Drainage

The drainage in the Vekol Mountains is southward and eastward into the Santa Rosa Valley, a tributary valley to the Santa Cruz-Gila River system. Drainage to a very minor extent flows northward into the Vekol Valley from the northwestern edge of the area. This valley, also, is tributary to the Gila River. The streams in the Vekol Mountains are ephemeral, flowing but occasionally during the rainy seasons.

V. ORE DEPOSITS

General Features

The mineralization in the Vekol Mountains may be divided into three general areas. The first includes the Vekol, Great Eastern, and Pomona, silver, lead and zinc deposits of the northern and central part of the main range. The second includes the copper and zinc deposits along the southern flank of the main range where the Copperosity mine, the Hinshaw claims and other prospects are located. The third encompasses a group of low hills on the eastern edge of the mountains. The Reward, Christmas Gift, Republic and other prospects are found here.

The ore deposits in the first area are unusual in that they have been localized in a structure comparable to an oil trap. They occur along the upper weathered surface of the Escabrosa limestone beneath the tight, contact shale bed close to north-south trending normal faults. (See Plate 8.).

The second area includes mineralization associated with the Copperosity fault zone and related faults, and as limestone replacement ore bodies related to faulting.

The mineralization in the third area consists largely of limestone replacement ore bodies controlled by mineralized faults of minor displacement.

Geology of the Vekol mine area

History and Production at the Vekol mine

Mining activity began in the Vekol Mountains in 1879, when the Vekol silver mine was located. The original discovery is credited to the Papago Indians. High-grade silver ore was shipped from the mine during the early eighties by a Judge Walkder, the owner. In 1885, a ten stamp mill was put into operation. It averaged about 470 tons a month and ran until 1889, when the mill-ing ore was exhausted. Shipment of high-grade ore was continued until 1894 , when the owners died. Litigation closed the property until 1908, when a New Orleans and Texas company sank the 400-foot Vekol shaft and completed several hundred feet of deep level prospecting with negative results. In 1918, a group of Phoenix men reopened the mine and reconditioned the mill. They attempted to mill the dumps, but the grade was too low. The property is now owned by Paul R. Daggs of Upland, California.

Tenney[8] reports a production of about $1,000,000.00 from 1882 to 1916, almost entirely in silver.

Stratigraphy

The section at the northern end of the main range in the vicinity of the Vekol mine includes rocks from Cambrian to Pennsylvanian age. These formations are well-exposed on the eastern escarpment of the Vekol Ridge and on the Western dip slope. (See Plate 8.). Terrace gravels and alluvium flank both sides of the ridge. The lithology is similar to that described under the heading General Geology, pages 24 to 39. Except for the Devonian, the thicknesses are somewhat greater than at Promontory Ridge. They are compared below:

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of Casa Grande Mining District, Pinal County, Arizona. Ariz. Bureau of Mines, 1934.

	Vekol mine area	Promontory Ridge
Naco limestone	415 feet minimum	270 feet (Copperosity area)
Escabrosa Limestone	400 feet minimum	353 feet
Upper Devonian	250 feet	255 feet
Abrigo formation	95 feet	82 feet
Southern Belle quartzite	26? feet	21 feet
Santa Catalina formation	75 feet exposed	265 feet

T The Lower Mississippian Escabrosa limestone, a thick-bedded, granular, crinoidal, gray limestone, is of particular interest since it is the host rock for the ore deposits at the Vekol, Great Eastern and Pomona mines. As shown above, it is at least 50 feet thicker at the Vekol mine than at Promontory Ridge. A similar thickening occurs southward toward 2854 peak, where the Escabrosa is about 410 feet thick. Hadley[6] reports from 300 to 420 feet in the Reward area along the eastern edge of the Vekol Mountains.

The writer believes the variation in thickness to be a result of pre-Naco erosion of the Escabrosa limestone. At the base, the Escabrosa rests conformably on the persistent, white quartzite marker at the top of the Upper Devonian section. There is no indication of an unconformity within the Escabrosa. Measure-

6. Hadley, J. B. Copper and Zinc Deposits of the Reward Area, Pinal co., Arizona. Preliminary Report, Stratigic Min. Div. U. S. G. S. 1942.

ments from a marker bed near the middle of the formation to the upper contact indicate the variation in thickness to be along the upper contact.

An altered zone, extending from 10 to 100 feet below the Naco limestone contact bed, gives the appearance of weathering along an old erosion surface. It is generally pinkish-tan in color, jointed and fractured locally. Recrystallization along joints may be the result of ground water solution and redeposition.

The contact shale may be an old weathered soil. In the vicinity of the Vekol mine, it consists of numerous pitted, rounded, white chert nodules, occasional lenses of grit which are made up largely of angular to sub-rounded chert fragments, and a few limestone and sandstone pebbles and cobbles. The matrix is a soft, brick-bed shale which is altered to a light greenish-gray color in the mineralized areas. The thickness of this horizon ranges from 5 to 20 feet and averages about 8 feet. A more detailed description is given on page 34.

The finely crystalline, lgiht gray, 3 to 10-foot beds at the base of the Lower Pennsylvanian, Naco limestone appear to rest disconformably on the Escabrosa limestone. Red shale partings, usually from an inch to a foot or more in width, separate the Naco beds. One shale horizon, 140 feet from the base, is over 40

Print 28

The contact shale bed at the base of the Naco limestone near the portal of the Vekol incline level.

Print 29

The relative position of the Vekol mine workings.

The surface excavation and mine entrances shown in the above print illustrate the position of the mineralized horizon along the upper surface of the Escabrosa limestone directly beneath the tight contact shale bed shown in Print 28.

feet thick. The writer believes the Naco limestone represents relatively shallow marine deposition. A detailed section is described on page 35. It is illustrated on the cross section of Plate 8. The Naco reaches its maximum thickness at the Vekol mine where it exceeds 415 feet.

Structural Geology in the Vekol mine area

The northern part of the main range is a north-west-trending, faulted, structural ridge with a relief of approximately 500 feet at the Vekol mine. The strike of the beds average N 20° W and the dip ranges from 15° to 45° SW.

Two sets of faults are represented in the area: the Northwest-trending normal faults, and the steep, east-west-trending structures. (See Plate 8.).

The northwest set includes major east dipping normal faults and minor west-dipping normal and reverse faults. The latter appear to be earlier than the Major normal faults, but, in some cases, may be contemporaneous with them. In the latter case, they probably acted as adjustment faults. Both sets range from north-south to N 20° W. The displacement on the east dipping faults ranges from a few feet to over 100 feet. (See cross section of plate 8.). The displacement on the west dipping faults is generally not more than 10 feet. The dip on both averages between 60° and 70°.

The steep, east-west trending faults include the Vekol dike and fault zone (described on page 77.) which cuts across the ridge at the Vekol mine, and minor east-west faults in adjacent canyons such as the Argosy fault. (See Plates 8. and 10.). Andesite fills the Vekol fault zone, but no andesite was noted along the minor structures. These faults trend from east-west to N 70° E and dip about 80° northward.

Relative ages

The northwest trending faults on the north side of the Vekol dike are terminated by the dike on the east side of the ridge, and they appear to be cut off by the dike on the west side of the ridge at the Vekol mine. Mine dumps cover the critical areas on the surface, however, and the Vekol shaft workings are inaccessible. The intense alteration of the Vekol dike at the Vekol mine is believed to be due to the hydrothermal alteration which accompanied the ore-bearing solutions. There has been some post-mineral movement on the major faults in the Vekol mine. The writer is of the opinion that the east-west faulting is later than most of the northwest faulting, but late adjustment on the northwest faults may have been simultaneous with post-andesite movement on the east-west faults.

Controls of Mineralization

The Vekol mine is located on the west side of the ridge near the head of the Vekol arroyo. A network of interconnected workings extends from the Vekol dike southward at a gentle inclination along the east-dipping Breccia fault and related faults to the east-west Argosy fault at the Argosy shaft, a distance of over 1000 feet. These workings are largely restricted to the Altered, weathered Escabrosa surface directly beneath the contact shale horizon.

The individual ore bodies range from small pods to shattered mineralized areas 20 to 30 feet in dimension. All are irregular in shape and are connected by faults and fissures to form a honeycomb horizon along the old erosion surface. The overlying contact bed appears to have been an effective barrier for the ore-bearing solutions. Mineralizing solutions penetrated the lower part of this 5 to 10-foot shale and chert horizon, but here is no evidence that the solutions were able to work through the shale in sufficient strength to form ore bodies in the overlying Naco limestone beds. The Naco, both on the surface and in exposures underground, shows only local areas of hydrothermal alteration, and no mineralization was noted.

The individual ore bodies are controlled by a combination of faults, fissures, joints and bedding slips to form locally shattered, favorable areas. The mineralized area near the end of the main Vekol level (See Plate 9.) is typical of the horizon immediately below the contact bed. The contact shale dips about 30° to the west, and is terminated on the west by a steep, west-dipping normal fault with a stratigraphic throw of about 10 feet, and on the east by the Breccia fault which dips east at 70°. (See Print 30.). The stratigraphic throw on the latter exceeds 100 feet. (See Plate8.). The strike of the beds and of the two faults is roughly parallel. Consequently, the stopes continue erratically for 400 feet or more at about the same horizon. The slope distance of the mineralized zone between the two faults is approximately 65 feet. Post-mineral movement has occurred on both faults.

The west-dipping fault is thought to be a channel way for the mineralizing solution, for scattered mineralization was found along this fault both in this area and on the levels below. Apparently, the solutions worked up this zone and possibly along the Breccia fault as well, to the base of the contact bed and then permeated the upper few feet of the Escabrosa beneath the tight cover of contact shale. Weathering, ground water action, pre-ore-hydrothermal alteration, recrystallization and shattering may have contributed to the permeability of this zone. It is difficult to ascertain a clear-cut picture because of post-ore movement on the faults and oxidation of the ore bodies. The individual pockets and small ore bodies appear to have been localized by the intersection of small fissures along the base of the contact bed with bedding slips a few feet below the contact. The stopes usually extend from 50 to 20 feet below the contact bed.

Print 30.

Underground view of the Breccia fault
in the Vekol mine. (See Plate 8.).

This print shows the breccia developed along a major northwest trending normal fault in the Vekol mine. There has been post-mineral movement on this fault. Its dip is approximately 68° northeast.

Oxidation has destroyed all signs of the primary sulphide mineralization in this area, but carbonates and sulfates of lead and zinc, together with sparse silver chloride? and copper carbonate stain are present. The wall rock is an altered, medium crystalline limestone, in part, recrystallized to dolomite. It is brown to reddish-brown colo. In shattered areas, the openings are lined with tan dolomite crystals rimmed with a dark reddish-brown outer zone of siderite and a very thin film of finely crystalline, translucent calcite. Numerous patches of a white, clay-like mineral, which may be dickite, and scattered throughout the area along the base of the contact bed and in the mineralized zone. Coarsely crystalline calcite veins were noted locally.

The ore from the oxidized zone, according to Tenney,[8] consisted of small nodules of horn silver, argentite, and silver-bearing tetrahedrite, in a gangue of iron-stained, slightly copper-stained, kaolinized limestone with abundant secondary calcite veins.

The stopes on the Argosy level, the bottom level in the mine, are approximately 250 feet below the collar of the Argosy shaft. They extend downward irregularly from the intermediate level above and illustrate the structural control 25 to 50 feet below the contact bed. Here, the intersection between a N 10° E, 70° W. fissure with N 30° W, 55-60° W fissures, together with steep

8. Tenney, J. B. Economic Geological Reconnaissance of the Mines of the Casa Grande Mining District, Pinal Co., Ariz. Ariz. Bureau of Mines, 1934.

N 15° E. joints and N 25° W, 25° SW bedding slips, formed a shattered area into which ore-bearing solutions penetrated. (See Plate 10.).

The ore in this level is largely oxidized to lead and zinc carbonates and sulphates and to various oxides, but considerable galena and sphalerite can be found in the broken ore and in the "tight", less shattered limestone area. The wall rock is altered Escabrosa limestone, partly recrystallized to dolomite with irregular areas of white clay which have developed along the bedding and near the fissures.

Mineralization

The mineralization in the Vekol mine was of relatively low temperature type with galena, sphalerite and probably tetrahedrite as the silver-bearing sulphide in a carbonate gangue. Quartz in a minor constituent in the gangue. The writer expects to complete a detailed laboratory study of the paragenetic relationships of the ore minerals and of the oxidation of the ore bodies in the near future.

The mineralization is believed to be of late Tertiary age, occurring after the intrusion of the andesite of the Vekol dike, but before the adjustment faulting on the north-south and east-west faults.

J. B. Tenney,[8] in his brief study of the Vekol mineraliza-

8. idem pg. 7

tion, concluded the high-grade silver ore to be the result of leaching of values from a series of closely spaced, nearly vertical veinlets and their redeposition at an old water table surface. He states: "The fact that the ore horizon is now inclined with the dip of the limestone and overlying lavas shows that this old water table was established before the tilting of the beds to their present attitude".

The writer does not agree with this conclusion. In the first place, most of the ore was mined from a horizon within a few feet of the Naco - Escabrosa contact at various elevations within the mine, and is not restricted to one tilted horizon. It would be pure coincidence if the water table did coincide with this particular horizon. Furthermore, the writer believes that much of the faulting which displaced the contact bed in the Vekol mine was pre-minerals. Secondly, a surface and underground study does not reveal mineralization to any extent in the Naco limestone. The mineralizing solutions appear to have been largely dammed off by contact shale bed.

The writer agrees that the minerals may have been deposited in a series of veinlets, but in a narrow zone along the upper surface of the Escabrosa limestone, and that the enrichment was largely caused by oxidation in place and removal of material by ground water, rather than transportation of the values into the mined area.

Future Possibilities

The zone between the Vekol dike and the Argosy shaft has been well-prospected along the ore-bearing horizon in the vicinity of the Breccia fault.

Tenney[8] believes the Argosy fault limits the southward extent of the northwest series of mineralized faults. The writer is not convinced this is true. The underground headings thus far driven, have not located the contact bed south of the Argosy fault. (See Plate 10.). The limestone on the south side of the fault is generally unaltered, but in the eastern heading, it is identical to the wall rock in the mineralized areas north of the fault. Also, the Mt. Vernon prospect, on the east side of the ridge, is located south of the Argosy fault. Although the mineralization is weak in this prospect, it does prove the presence of mineralization south of the Argosy fault on east-west-trending fissures at the top of the Escabrosa limestone. There is a possibility that these east-west fissures may intersect north-south fissures south of the Argosy fault at the contact horizon, not far from the Argosy shaft.

A second northwest-trending fault zone is located approximately 325 feet west of the Breccia fault zone. It may be a favorable zone at the intersection with the contact bed. A few well-placed diamond drill holes could prospect this zone at a moderate cost. (See Plate 8.).

Additional mineralized, northwest-trending fault zones may be present under the alluvium west of the Vekol mine between the Vekol dike and the Argosy arroyo.

The contact horizon at the intersection with northwest faults north of the Vekol dike is also a possibility. A fifty scale topographic map of this area is suggested to work out the relationship between the minor east-west and northwest faults in this block.

Although there is no evidence of mineralization in the middle or lower horizons of the Escabrosa limestone or in the Upper Devonian beds, it is possible that ore bodies have formed at these horizons beneath the Vekol workings, along the same mineralized faults and fissures which have supplied the Vekol mineralization. A favorable horizon, in the opinion of the writer, would be the soft limestone beds of the Lower Ouray? formation directly beneath the white contact quartzite bed at the base of the Escabrosa limestone. (See Plate 8.). This horizon is about 400 feet stratigraphically below the contact horizon at the Vekol Mine.

<u>Geology at the Great Eastern Mine</u>

The relationships at the Great Eastern mine are comparable to those at the Vekol except that the mineralization is more directly related to the east-west faults and dikes than to the northwest faults.

A small amount of silver-lead ore was produced from the Great Eastern from 1885-1894, some of which was treated at the Vekol mill.

Geology at the Pomona mine

The relationships at this property, shown on Plate 3., are similar to those at the Vekol. The ore bodies are small, and are restricted to the intersection between an east-west fault and the upper surface of the Escabrosa limestone. Mineralization occurs in identical conditions in a small sliver block of Naco and Escabrosa limestone within the Pomona fault zone on the east side of the main range.

Production at the Pomona mine has been negligible.

Geology at the Copperosity mine area

The Copperosity mine and other copper and zinc prospects along the southern part of the main range are included in the second area of mineralization in the Vekol Mountains. (See Plate 3.).

Copperosity Mine

History and Production

The ore at the Copperosity mine, located at the southwestern edge of Copperosity Basin, was discovered in the early eighties and was developed sporadically from 1890 to 1907, when a small tonnage of copper ore was shipped. Its main productions was during the war years from 1915 to 1917. A two compartment shaft 300 feet deep was sunk, and considerable ore was developed and shipped. The mine is credited with a production of 360,000 pounds of copper with a gross value of $80,000.00. The present owner is the Houston-Arizona Copper Company.

The surface exposure at the Copperosity shaft consists of red shale of the Cretaceous? red beds. A short distance south of the shaft the red beds appear to overlap limestones of the Abrigo formation.

Since the underground workings at the Copperosity mine are inaccessible, the writer quotes the following description from Tenney:[8]

> "The ore occurs as a single body of oxidized ore replacing Devonian limestone on either side of a series of closely-spaced parallel faults striking N 60° W and dipping 45° SW. Mineralization extends about 50 feet on either side of the faults and extends down the dip of the individual beds for a distance of 25 feet and over. The ore outcropped and was followed down to a depth of over 20 feet on the incline following the dip of the fault zone. The thickness of the ore varies from a few inches to 5 feet with an average width of about 3 feet.
>
> The ore consists of replacement deposits in limestone of carbonates, silicates and oxides of copper in a gangue of limonite, gypsum and calcite."

The U. S. Bureau of Mines reopened the Copperosity shaft in 1936, and found scattered copper carbonates and oxides in the

8. idem pg. 14

red shale down to the limestone contact at the 120-foot level. They could find no important showings below in the limestone. As a consequence, the workings were abandoned.

Other deposits in the Copperosity area

Along the Copperosity fault zone, and particularly in the Escabrosa limestone, are scattered showings of copper and zinc. None, however, has produced any sizable tonnage. They appear to be weak limestone replacement areas along mineralized faults. The ore minerals are carbonates, silicates and oxides of copper and carbonates of zinc.

The Hinshaw willemite prospect is located at the southern edge of the main range in the cliffs near the top of 3231 peak. A small tonnage of willemite ore reportedly was shipped from small pits and adits in recent years and sold as mineral specimens. Mineralized fractures near the top of the Escabrosa limestone contain small irregular areas of carbonate ore. The fractures are probably related to the pronounced drag-fold developed along the Copperosity fault zone just north of the Hinshaw prospect.

The Reward area

This area encompasses a group of low hills along the eastern edge of the Vekol Mountains and includes the Reward, the Republic and the Christmas Gift mines.

History and Production

The Reward mine. located about 1880, was developed in the early eighties during high copper prices. About 1,000 tons of 26% ore were produced. A small tonnage was mined in 1903, in 1905, and again in 1907-1908 during favorable copper prices. A little ore was shipped, and considerable development work was done during the years of World War I. Kimball Pomeroy and Dr. Shorneck are the present owners. The mine is credited with about 450,000 pounds of copper, with a gross value of $75,000.00

The geology in the Reward area is well-described by Hadlay.[6] The following is a brief summary of the ore deposits in that area:

The ore occurs in the Escabrosa and Martin limestone as bedding replacement ore bodies and, to a minor extent, at the intersection of fractures. The mineralization is controlled by faults and associated fractures, joints and bedding. The largest deposits, according to Hadley, are from 3 to 5 feet thick and extend from 50 to 200 feet from the mineralized fractures, the channel ways for the ore-bearing solutions.

The ore consists of pyrrhotite, pyrite, iron-rich sphalerite, and chalcopyrite in rather variable proportions in a gangue of chlorite and serpentine with a variable amount of tremolite, diopside and talc. In the oxidized areas, these minerals

6. idem

are mixed with earthy hematite together with malachite, crysocolla, hydrozincite, smithsonite, aurichalcite and probably hemimorphite.

Silicification of the limestone is an important feature of these deposits. Garnetization of the Reward ore bed is believed to be related to the ore-bearing solutions. Hadley concludes: "In general, the ore deposits seem to have formed at relatively high temperatures after most of the faulting and at about the same time as the metamorphism."

The Republic mine, located at the southeastern edge of Bitter Wells Basin, produced a small amount of copper ore in 1917. The geology and occurrences of ore are comparable to that in the Reward mine.

The Christmas Gift mine, adjoins the Reward mine to the north. A rick pocket of high-grade gold ore associated with galena and cerussite outcropped on the surface. It produced about $45,000.00 in gold. Although considerable prospecting has been done, no further high-grade ore has been found.

A SUMMARY OF IMPORTANT CONCLUSIONSL

The study of the geology of the Vekol Mountains has resulted in several contributions to Geology. Among them are the following:

1. The age of the Apache diabase has been a controversial issue in Arizona geology for many years. The writer has definitely established the upper limit of the age of this diabase in the Vekol Mountains as pre-Santa Catalina and pre-Upper Troy. Both os these formations are believed to be Middle Cambrian. The lower Troy, which is intruded by the diabase, is either Middle or Lower Cambrian. The exact age of the diabase depends on the age of the lower Troy.

2. Stratigraphy. The Vekol Mountains constitute the western-most area in southern Arizona in which the Apache and Paleozoic rocks are exposed. The thicknesses, lithology and fossil content worked out b y the writer in this area are important in the regional study of Arizona stratigraphy.

3. Structure. The structure of the Vekol Mountains contributes further pertinent data to the study of the structural evolution of Arizona and the Basin Range province.

4. Unconformity control of ore bodies. The ore bodies at the Vekol mine were formed along an old erosion surface at the top of the Escabrosa limestone of Lower Mississippian age beneath the tight, red, cherty shale at the base of the Naco limestone of Lower Pennsylvanian age. They are localized in shattered limestone within a north-south zone of faulting.

   T The control of the ore bodies at the Vekol mine is clear-cut. In the opinoin of the writer, similar control by unconformities may have been effective in many other areas, but has not received general recognition.

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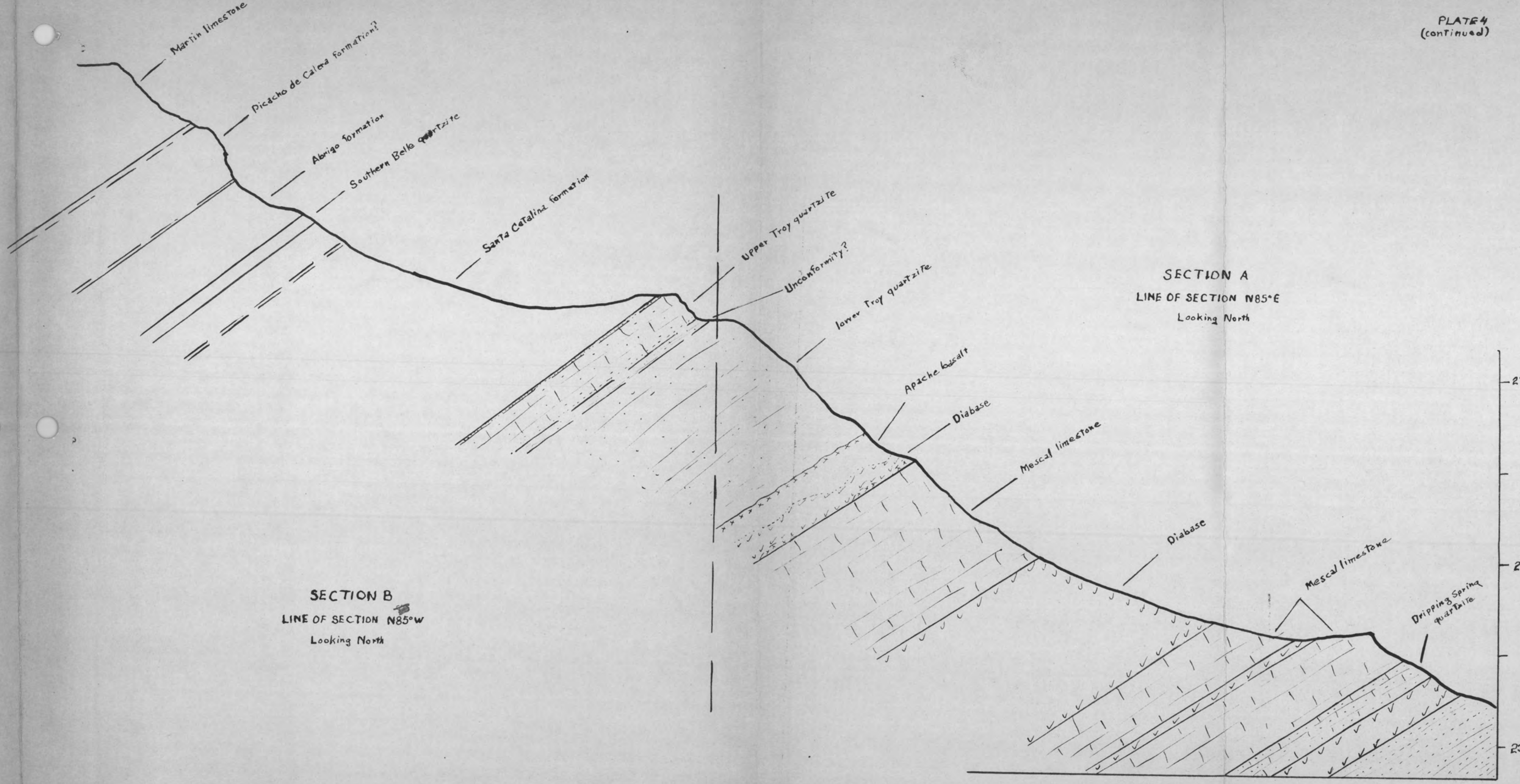
PLATE 4
(continued)



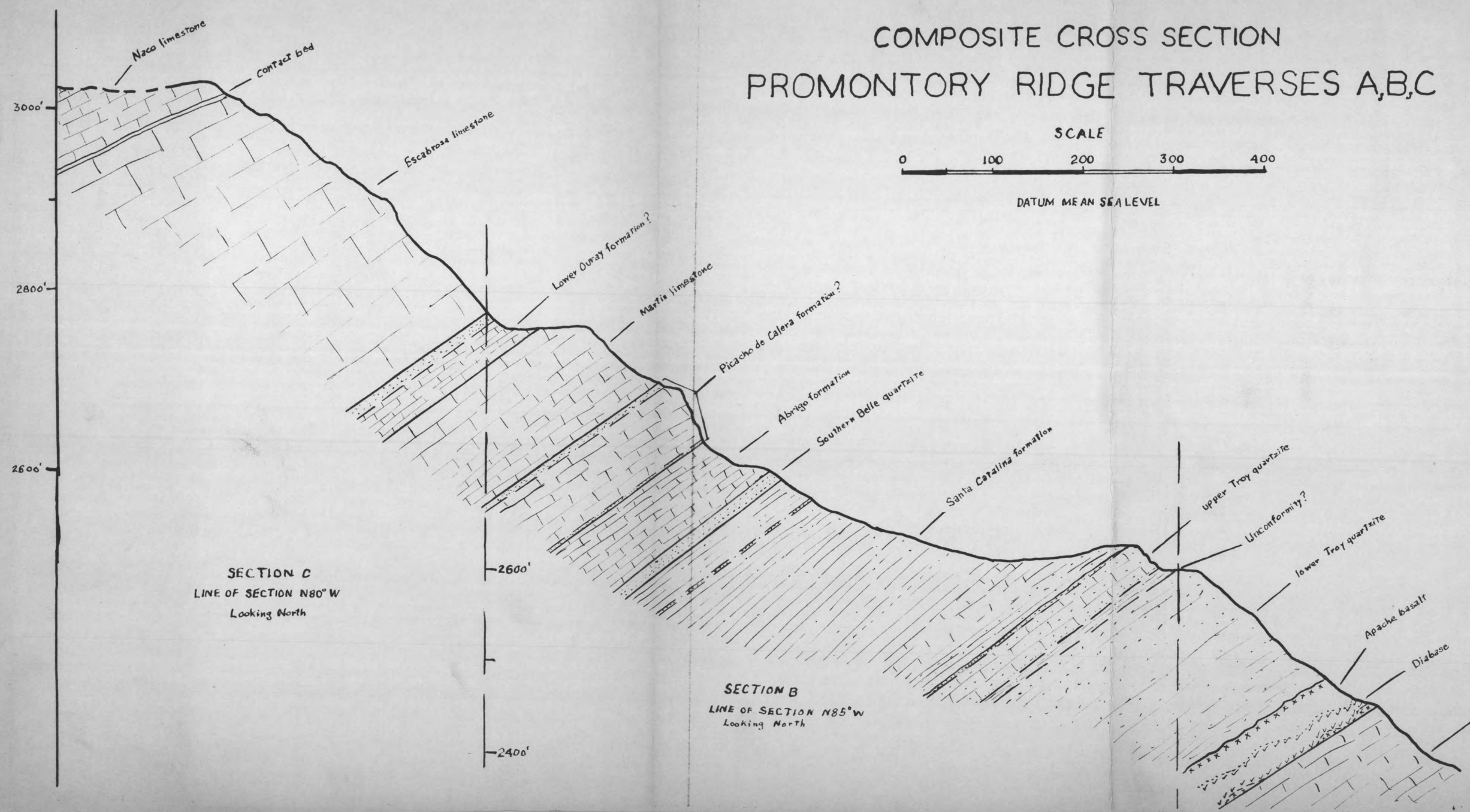
COMPOSITE CROSS SECTION

PROMONTORY RIDGE TRAVERSES A,B,C

SCALE

0 100 200 300 400

DATUM MEAN SEALEVEL



COPPER STATE ANALYTICAL LAB., INC.

DNYANENDRA A. SHAH
ARIZONA REG. NO. 8888

REGISTERED ASSAYER
P. O. BOX 7517
TUCSON, ARIZONA 85725

710 E. EVANS BLVD.
PHONE 602-884-5811
884-5812

Heinrichs GEOEX
Box 5964
Tucson, AZ 85703

JOB# 002589
RECEIVED 10/12/83
REPORTED 10/21/83
INVOICE# C 2866

SAMPLE NUMBER	Ag ppm	Cu ppm	Pb ppm	Zn ppm	Au opt	Ag opt		
GCS-#1	2.0	2	28	62		PDP 2	92	? @ LO-4
2	1.6	4	16	60			80	
3	2.2	8	24	66			98	?
4	2.0	10	26	68	@ claim corner	PDP 3	104	✓
5	1.4	12	18	38			68	
6	0.6	14	24	50			88	
7	0.3	18	11	52			81	
8	<0.1	89	22	60			171	✓
9	2.6	10	28	80			118	✓
10	1.0	12	60	160			232	✓
11	1.2	12	14	16			42	
12	6.0	508	0.18%	580	.004	0.16	2888	✓
13	1.8	16	32	116			164	✓
14	0.1	18	18	14			50	
15	<0.1	4	18	12			34	
16	13.0	4	224	169			397	✗ PORTAL
17, 18, 19	13/32 OF OUNCE							TOTAL 7 DRILL SITES

COPY
Shah 10-21-83

1 ppm = 0.0001%   1 troy oz./ton = 34.286 ppm   1 ppm = 0.0292 troy oz./ton
* Gold and Silver reported in troy oz. per 2,000 lb. ton.

Job #1668
Vekol

4—888

MINERAL SURVEY No. 4143

ARIZONA Land District

FIELD NOTES

OF THE SURVEY OF THE MINING CLAIM OF

PAUL R. DAGGS.

KNOWN AS THE

VEKOL, MOUNT VERNON, ARGOSY, GRAND FATHER, LOOKOUT, and FLAT IRON, lodes

CASA GRANDE Mining District,

PINAL County, ARIZONA.

Section ~~8~~ E½ Uns.Sec.34 & W½ Uns.Sec.35 Township 9 South, Range 2 East GASRBAM.

Surveyed under instructions dated March 10th., 1931.

By Harry E. Jones.
U. S. Mineral Surveyor.

Claim located See location notices., 19

Survey commenced March 19th., 1931,

Survey completed March 24th., 1931,

Address of claimant John H. Page & Co.
P.O.Box 1706 Phoenix, Arizona.

LAWYER

DATES OF AMENDED LOCATIONS

See location notices.

Feet	MINERAL SURVEY NO.4143
	Vekol Lode
	Beginning at Cor. No. 1, identical with loc. mon. a 3ft. 2in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 1-V; set 18ins. in ground and surrounded with a substantial mound of earth and rock.
	The corner common to Sections 26, 27, 34 and 35, T. 9 S. R. 2 E. bears N.28°49'30"E. 1065.59 ft.
	No other suitable bearings available.
	Thence S. 21° 24' W.
730.00	Intersect Cor.4 Lookout lode of this survey.
	Along line 4-3 Lookout lode of this survey.
1328.93	Intersect line 3-4 Argosy lode of this survey, whence Cor. 3, bears N.35°32'W. 154.54 ft.
1500.00	To Cor. No. 2, identical with loc. mon. and Cor.3, Lookout lode, Cor.2 Flat Iron lode, both of this survey, a 3ft. 2in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 2-V; 3-L; 2-FI; set 15ins. in ground and surrounded with a substantial mound of earth and rock.
	Cor.3 Argosy lode of this survey bears N.5°28'50"W. 286.44 ft. No other suitable bearings available.
	Thence N. 68° 36' W.
	Along line 2-1 Flat Iron lode of this survey.
295.85	Intersect line 2-3 Argosy lode of this survey, whence Cor. 2 bears S.54°28'W. 295.13 ft.
300.00	To Southwest End Center, identical with loc. mon. and Northeast End Center Flat Iron lode of this survey, a substantial mound of earth and rock.
600.00	To Cor. No. 3, identical with loc. mon. and Cor.1 Flat Iron lode, on line 2-3 Grand Father lode, both of this survey, a 3ft. 2in. pipe with a 2in. brass cap marked U. S. MINERAL SURVEY NO.4143; 3-V; 1-FI; set 18ins. in ground and surrounded with a substantial mound of earth and rock.
	No suitable bearings available.
	Thence N. 21° 24' E.
	Along line 3-2 Grand Father lode of this survey.

762.32 Intersect Cor.2 Grand Father lode of this survey.

1489.40 To Witness Cor. No.4, a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; W.C.4-V; set 18ins. in ground and surrounded with a substantial mound of earth and rock.

1500.00 To true point for Cor. No. 4, identical with loc. mon. a substantial mound of rock, falls on exposed limestone bedrock in 5 ft. wash, course Ely. marked X; 4-V-4143; No suitable bearings available.

Thence S. 68° 36' E.

300.00 To Northeast End Center, a substantial mound of rock, identical with loc. mon.

600.00 To Cor. No. 1 the place of beginning.

Mount Vernon Lode

Beginning at Cor. No. 1, identical with loc. mon. and NW. Cor. New Rocky lode uns. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 1-MV; set 20ins. in ground and surrounded with a substantial mound of earth and rock. The corner common to Sections 2, 3, 34 and 35. Ts. 9 and 10 S. R. 2 E. bears S.1°18'25"W. 1655.59 ft. No other suitable bearings available.

Thence N. 35° 32' W.

475.50 Intersect Cor.4 Argosy lode of this survey, identical with NE. Cor. New Great Eastern lode uns.

Along line 4-3 Argosy lode of this survey.

1500.00 To Cor. No. 2, identical with loc. mon. and on line 2-3 Lookout lode of this survey, a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 2-MV; set 16ins. in ground and surrounded with a substantial mound of earth and rock. Cor.2 Lookout lode of this survey bears S.72°13'E. 359.88 ft. No other suitable bearings available.

Thence N. 54° 28' E.

300.00 To Northwest End Center, a substantial mound of rock, identical with loc. mon.

600.00 To Cor. No. 3, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 3-MV; set 20ins. in ground and surrounded with a substantial mound of earth and rock. Cor.2 Lookout lode of this survey bears S.17°36'45"W. 481.17 ft. No other suitable bearings available.

Thence S. 35° 32' E.

37.93 Intersect line 1-2 Lookout lode of this survey, whence Cor.2 bears S.21°24'W. 459.43 ft.

1500.00 To Cor. No. 4, identical with loc. mon. and NE. Cor. New Rocky lode, uns. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 4-MV; set 14ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence S. 54° 28' W.

Along NW. end line New Rocky lode uns.

300.00 To Southeast End Center, a substantial mound of rock, identical with loc. mon. and NW. end center New Rocky lode uns.

600.00 To Cor. No. 1 the place of beginning.

Argosy Lode

Beginning at Cor. No. 1, identical with loc. mon. and NW. corner New Great Eastern lode uns. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 1-A; set 16ins. in ground and surrounded with a substantial mound of earth and rock. The corner common to Sections 2, 3, 34 and 35, Ts.9 and 10 S. R. 2 E. bears S.27°13'50"E. 1842.81 ft. No other suitable bearings available.

Thence N. 35° 32' W.

919.82 Intersect line 2-3 Flat Iron lode of this survey, whence Cor. 2 bears N.21°24'E. 544.79 ft.

1275.00 Cross center road bearing Ely. and Wly.

1465.00 To Cor. No. 2, whence the loc. mon. bears N.35°32'W. 35 ft. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL

SURVEY NO.4143; 2-A; set 20ins. in ground and surrounded with a substantial mound of earth and rock.
No suitable bearings available.

Thence N. 54° 28' E.

295.13 Intersect line 1-2 Flat Iron lode identical with line 3-2 Vekol lode, both of this survey, whence Cor.2 respectively of the Flat Iron and Vekol lodes bears S.68°36'E. 295.85 ft.

300.00 To Northwest End Center, a substantial mound of rock, whence the loc. mon. bears N.35°32'W. 35.0 ft.

600.00 To Cor. No. 3, whence the loc. mon. bears N.35°32'W. 35 ft.
A 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 3-A; set 18ins. in ground and surrounded with a substantial mound of earth and rock.
Cor.2 Vekol lode identical with Cor. 2 Flat Iron lode both of this survey bears S.5°28'50"E. 286.44 ft.
No other suitable bearings available.

Thence S. 35° 32' E.

154.54 Intersect line 1-2 Vekol lode identical with line 3-4 Lookout lode, both of this survey, whence Cor.2 Vekol lode identical with Cor.3 Lookout lode bears S.21°24'W. 171.17 ft.

440.50 Intersect line 2-3 Lookout lode, identical with Cor.2 Mount Vernon lode both of this survey, whence Cor.3 Lookout lode bears N.72°13'W. 240.12 ft.
Along line 2-1 Mount Vernon lode of this survey.

1465.00 To Cor. No. 4, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 4-A; set 18ins. in ground and surrounded with a substantial mound of earth and rock, identical with NE. corner New Great Eastern lode uns. No suitable bearings available.

Thence S. 54° 28' W.

Along the NW. end line New Great Eastern lode uns.

300.00 To Southeast End Center, identical with loc. mon. and NW. end center New Great Eastern lode uns.

600.00 To Cor. No. 1 the place of beginning.

Grand Father Lode

Beginning at Cor. No. 1, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 1-GF; set 14ins. in ground and surrounded with a substantial mound of earth and rock, identical with NE.cor Grand Father Ext. lode uns.
The ¼ corner common to Sections 27 and 34, T. 9 S. R. 2 E. bears N.31° 32' 40"W. 1384.51 ft.
No other suitable bearings available.

Thence S. 68° 36' E.

300.00 To Northeast End Center, a substantial mound of rock, identical with the loc. mon.

600.00 To Cor. No. 2, identical with the loc. mon. and on line 3-4 Vekol lode of this survey, a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 2-GF; set 18ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence S. 21° 24' W.

Along line 4-3 Vekol lode of this survey.

762.32 Intersect Cor.3 Vekol lode identical with Cor.1 Flat Iron lode, both of this survey.
Along line 1-4 Flat Iron lode of this survey.

1150.00 Cross center of road bearing NWly. and SEly.

1500.00 To Cor. No. 3, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 3-GF; set 20ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence N. 68° 36' W.

300.00 To Southwest End Center, a substantial mound of rock, identical with the loc. mon.

600.00 To Cor. No. 4, identical with loc. mon. and SE. corner Grand Father Ext. lode uns. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 4-GF; set 20ins. in ground and surrounded with a substanial mound of earth and rock. No suitable bearings available.

Thence N. 21° 24' E.

Along SE. side line Grand Father Ext. lode uns.

620.00	Cross road bearing NEly. and SWly.
825.00	Cross center of 10 ft. wash course SWly.
855.00	Cross road bearing NEly. and SWly.
1500.00	To Cor. No. 1 the place of beginning.

Lookout Lode

Beginning at Cor. No. 1, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 1-L; set 15ins. in ground and surrounded with a substantial mound of earth and rock.
The corner common to Sections 26, 27, 34, and 35, T. 9 S. R. 2 E. bears N. 6° 37' 50" E. 1808.66 ft.
No other suitable bearings available.

Thence S. 21° 24' W.

310.57	Intersect line 3-4 Mount Vernon lode of this survey, whence Cor.3 bears N.35°32'W. 37.93 ft.
770.00	To Cor. No. 2, a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 2-L; set 20ins. in ground and surrounded with a substantial mound of earth and rock. Loc. mon. bears S.21°24'W. 30 ft. Cor.3 Mount Vernon lode of this survey bears N.17°36'45"E. 481.17 ft. No other suitable bearings available.

Thence N. 72° 13' W.

300.00	To Southwest End Center, a substantial mound of rock, whence the loc. mon. bears S.21°24'W. 30 ft.
359.88	Intersect line 3-4 Argosy lode, identical with Cor.2 Mount Vernon lode, both of this survey, whence Cor.3 Argosy lode bears N.35°32'W. 440.50 ft.
600.00	To Cor. No. 3, identical with Cor.2 Vekol lode and Cor.2 Flat Iron lode both of this survey, previously described. The loc. mon. bears S.21°24'W. 30 ft.

Thence N. 21° 24' E.

Along line 2-1 Vekol lode of this survey.

171.17	Intersect line 3-4 Argosy lode of this survey, whence Cor. 3 bears N.35°32'W. 154.54 ft.
770.00	To Cor. No. 4, identical with loc. mon. a 3ft. ½in. pipe

with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 4-L; set 14ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence S. 72° 13' E.

300.00	To Northeast End Center, a substantial mound of rock, identical with loc. mon.
600.00	To Cor. No. 1 the place of beginning.

Flat Iron Lode

Beginning at Cor. No. 1, identical with loc. mon. and Cor.3 Vekol lode, on line 2-3 Grand Father lode of this survey, previously described.
The ¼ corner common to Sections 27 and 34, T. 9 S., R. 2 E. bears N. 25° 28' 45" W. 2335.78 ft.

Thence S. 68° 36' E.

Along line 3-2 Vekol lode of this survey.

300.00	To Northeast End Center, a substantial mound of rock, identical with loc. mon. and Southwest End Center Vekol lode of this survey.
304.15	Intersect line 2-3 Argosy lode of this survey, whence Cor. 2 bears S. 58°28'W. 295.13 ft.
600.00	To Cor. No. 2 identical with loc. mon. and Cor.2 Vekol lode, Cor.3 Lookout lode both of this survey, previously described.

Thence S. 21° 24' W.

142.00	Cross center of road bearing NWly. and SEly.
544.79	Intersect line 1-2 Argosy lode of this survey, whence Cor. 2 bears N. 35° 32'W. 545.18 ft.
1000.00	To Cor. No. 3, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 3-FI; set 14ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence N. 68° 36' W.

300.00	To Southwest End Center, a substantial mound of rock, identical with loc. mon.

600.00 To Cor. No. 4, identical with loc. mon. a 3ft. ½in. pipe with a 2in. brass cap marked U.S.MINERAL SURVEY NO.4143; 4-FI; set 20ins. in ground and surrounded with a substantial mound of earth and rock. No suitable bearings available.

Thence N. 21° 24' E.

262.32 Intersect Cor.3 Grand Father lode of this survey.
Along line 3-2 Grand Father lode of this survey.

612.32 Cross center of road bearing NWly. and SEly.

1000.00 To Cor. No. 1 the place of beginning.

The mean magnetic variation at all corners is 14°40'E.

Lode Lines

As near as can be determined from the present developments the lode lines of the several locations embraced in this claim extend as follows from their respective discovery points:

Vekol lode, N.21°24'E. 750 ft. and S.21°24'W. 750 ft.
Mount Vernon lode, N.35°32'W.820 ft. and S.35°32'E. 680 ft.
Argosy lode, N.35°32'W. 270 ft. and S.35°32'E. 1195 ft.
Grand Father lode, N.21°24'E. 175 ft. and S.21°24'W. 1225 ft.
Lookout lode, N.21°24'E. 85 ft. and S.21°24'W. 685 ft.
Flat Iron lode, N.21°24'E. 725 ft. and S.21°24'W. 275 ft.

Areas

Total area Vekol lode.		20.661 Acres
Total area Mount Vernon lode.		20.661 "
Total area Argosy lode.		20.179 "
Area in conflict with:		
Vekol lode of this survey.	1.122	"
Total area Grand Father lode.		20.661 "
Total area Lookout lode.		10.585 "
Area in conflict with:		
Mount Vernon lode of this survey.	2.155	"
Argosy lode of this survey.	0.471	"

Areas Continued

Total area Flat Iron lode.		13.774 Acres
Area in conflict with:		
Argosy lode of this survey.	3.697	"

Location

This survey is located in the E½ Uns., of Section 34, and the W½ Uns., of Section 35; T. 9 S. R. 2 E. Gila and Salt River Base and Meridian, Casa Grande Mining District, Papago Indian Reservation, Pinal County, Arizona.

Expenditure of Five Hundred Dollars

I certify that the value of the labor and improvements made upon or for the benefit of the locations embraced in said mining claim by the claimant or his grantors is not less than Five Hundred Dollars, and that said improvements consist of:

Vekol Lode

No.1 Disc. cut 4x15x8 ft. facing Nwly. the mouth of which bears N.21°24'E. 750 ft. from Southwest end center.
Value $100.00

No.2 portal of West Mule and Burro tunnel which bears S.41°10'E. 277 ft. from the 514.44 ft. point on line 3-4, being part of an intricate system of underground development, part of which is set forth upon the accompanying photostat maps in triplicate, said underground development to be used as a common improvement and described as follows:

The system of underground development used as a common improvement is made upon a vein which outcrops upon the Vekol, Lookout and Mount Vernon lodes and dips about 35° to the Northwest and West, the apex of the ridge in which this vein occurs, lies in a general Nly. and Sly. direction through the SE. corner of the Argosy lode, centrally through the Lookout lode and through the Nly. end of the Vekol lode with the surface sloping both

to the East and West in general, the common improvement has been extended so that portions of it are now under the surface of parts of each lode of this claim, and the bottom of No.2 improvement Grand Father lode, a shaft 7x9x380 ft. deep, timbered, extends well below all of the surface of the entire claim group which is participating in said common improvement, and by extending the present underground works towards and under each lode of the entire claim group, for the purpose of extracting the ore therefrom, the future expediency with which the ore under each of these lode claims can be mined will be materially facilitated and therefore the common improvement will redound to the benefit of each lode of this claim, and to each lode of the entire claim group not included in this survey.

VEKOL SHAFT

The estimates of the underground development in this common improvement are from 6 miles to 8 miles, and many thousands of feet of such work is shown upon the accompanying maps, however much of the old workings have been backfilled with waste material and are not available to survey, I have put the amount of underground workings at 3 miles having a total value of $237,600.00; The lode claims participating in said common improvement are the Vekol, Mount Vernon, Argosy, Grand Father, Lookout, and Flat Iron lodes of this survey, and New Rocky, New Great Eastern, New May Flower, New Knob, New Western, New Cut Off, Aggsy Annex, Grand Father Ext. East Side No.1, North Side No.1, North Side No.2, North Side No.3, West Side No.1, West Side No.2, West Side No.3 and West Side No.4 lodes all unsurveyed, therefore each lode of this claim group has an undivided 1/22nd. interest in said common improvement, and an undivided 1/22nd. interest in said common improvement is accredited to this lode.

22 CLAIMS

Value $ 10,800.00

No.3 portal of West Zig Zag tunnel being part of the hereinbefore described common improvement bears S.45°15'E. 325 ft. from the 514.44 ft. point on line 3-4.

No.4 portal of East Zig Zag tunnel being part of the hereinbefore described common improvement, bears S.60°30'E. 278 ft. from the 514.44 ft. point on line 3-4.

No.5 incline shaft 4x6x30 ft. deep bears S.6°47'W. 340 ft. from the 514.44 ft. point on line 3-4.

Value $375.00

No.6 cut 5x10x8 ft. facing SWly. and tunnel 4x6x74 ft. long running NEly. the cut mouth of which bears N.62°15'E. 323 ft. from the 514.44 ft. point on line 3-4.

Value $925.00

No.7 tunnel portal 4x6x30 ft. long running Nly. bears N.69°E. 470 ft. from the 514.44 ft. point on line 3-4.

Value $ 375.00

No.8 cut head, 3x20x8 ft. facing NEly. with tunnel 4x6x12 ft. long running Sly. from the cut head, bears N.59°30'E. 470 ft. from the 514.44 ft. point on line 3-4.

Value $ 300.00

Mount Vernon Lode

No.1 Disc. cut 4x25x14 ft. facing NEly. with tunnel 4x5x60 ft. long running SWly. the cut mouth of which bears N.35° 32'W. 680 ft. from SE. end center. Value $ 800.00

No.2 cut 5x8x5 ft. facing NEly. with tunnel 4x6x18 ft. long running SWly. the cut mouth of which bears N.21°44'E. 342 ft. from the 475.50 ft. point on line 1-2.

Value $ 300.00

No.3 cut mouth 6x25x10 ft. facing NEly. with tunnel 4x6x40 ft. long running SWly. with a drift 4x6x15 ft. to Sly. from 10 ft. point, and drift 4x6x6 ft. to Sly. from face, bears N.28°20'E. 346 ft. from the 475.50 ft. point on line 1-2. Value $ 962.50

No.4 shaft 10x15x15 ft. deep, caved, bears N.3°45'E. 497 ft. from the 475.50 ft. point on line 1-2.

Value $ 250.00

No.5 shaft 4x6x100 ft. deep, partially caved, bears N.17° 26'W. 620 ft. from the 475.50 ft. point on line 1-2.

Value $ 1250.00

An undivided 1/22nd. interest in the common improvement No.2 Vekol lode is accredited to this lode.

Value $ 10,800.00

Argosy Lode

No.1 Disc. cut 12x25x10 ft. facing SWly. bears S.35°32'E. 270 ft. from NW. end center. Value $ 200.00

No.2 cut mouth 8x12x6 ft. facing SWly. bears S.73°45'W. 380 ft. from the 440.50 ft. point on line 3-4.

Value $ 100.00

ARGOSY SHAFT No.3 shaft 6x8x215 ft. deep, timbered, being connected with and part of the system of underground development used as a common improvement described in No.2 improvement Vekol lode, bears S.27°24'W. 258.48 ft. from the 440.50 ft. point on line 3-4.

An undivided 1/22nd. interest in said common improvement is accredited to this lode. Value $ 10,800.00

No.4 cut mouth 7x18x10 ft. facing NWly. bears S.24°15'W. 490 ft. from the 440.50 ft. point on line 3-4.

Value $ 325.00

Grand Father Lode

LOOK FOR No.1 Disc. shaft 6x7x10 ft. deep bears S.21°24'W. 175 ft. from NE. End Center. Value $ 125.00

VEKOL SHAFT No.2 shaft 7x9x380 ft. deep timbered which connects by drifts and cross-cuts and a raise from the 120 ft. level with the underground works used as common improvement and described in No.2 improvement Vekol lode, bears S.87°29'W. 115.83 ft. from the 247.88 ft. point on line 2-3.

An undivided 1/22nd. interest in said common improvement is accredited to this lode. Value $ 10,800.00

FIRST WATER WELL No.7 an 8 inch drilled well 700 ft. deep bears S.70°28'W. 167 ft. from the 247.88 ft. point on line 2-3.

Value $ 2100.00

No.4 cut mouth 4x22x8 ft. facing Nwly. bears N.22°45'W. 286 ft. from the 827.75 ft. point on line 2-3.

Value $ 230.00

GF-5. No.5 shaft 4x6x50 ft. deep bears S.32°40'W. 32d ft. from the 247.88 ft. point on line 2-3. Value $ 625.00

35°32'
27°24'
(2°05')

No.6 cut mouth 5x30x8 ft. facing Nwly. with tunnel 4x6x20 ft. long running SEly. bears S.28°20'W. 328 ft. from the 247.88 ft. point on line 2-3. Value $ 562.00

SQUIRE No.

LOOK FOR No.7 cut mouth 8x20x10 ft. facing SEly. with incline shaft from face 4x6x20 ft. deep bears N.75°05'W. 120 ft. from Cor. 2. Value $ 790.00

No. 8 shaft 4x6x8 ft. deep bears S.61°35'W. 154 ft. from Cor. 2. Value $ 100.00

Lookout Lode

No.1 Disc. cut 6x20x6 ft. facing SEly. bears S.21°24'W. 85 ft. from NE. End Center. Value $ 187.50

No.2 shaft 4x6x6 ft. deep bears S.70°10'W. 80 ft. from NE. End Center. Value. $ 75.00

No.3 shaft 4x6x15 ft. deep bears S.75°12'W. 243 ft. from NE. End. Center. Value $ 187.50

No.4 cut mouth 6x40x15 ft. facing NEly. with a double tunnel 4x6x10 ft. each running SWly. and Sly. to points where each is caved in, bears N.80°W. 250 ft. from NE. end center. Value $ 1187.50

An undivided 1/22nd. interest in No.2 improvement Vekol lode is accredited to this lode. Value $ 10,800.00

Flat Iron Lode

No.1 Disc. cut 6x25x12 ft. facing Nly. bears N.21°24'E. 275 ft. from SW. end center. Value $ 465.00

COMBINATION SHAFT No.2 shaft 4x6x200 ft. deep, timbered, bears S.33°42'W. 510 ft. from Cor.2. Value $ 5000.00

No. 3 shaft 10x12x5 ft. deep caved, bears S.40°52'W. 730 ft. from Cor. 2. Value $ 150.00

No.4 cut mouth 5x25x8 ft. facing Nly. bears S.24°10'W. 732 ft. from Cor. 2. Value $ 260.00

An undivided 1/22nd. interest in No.2 improvement Vekol lode is accredited to this lode. Value $ 10,800.00

Other Improvements

The SE. corner of frame hoist house 12x14 ft. bears N.79° 40'W. 53 ft. from the 247.88 ft. point on line 2-3 Grand Father lode.

The NE. corner of a frame blacksmith shop 13x28 ft. bears S.63°35'W. 78 ft. from the 247.88 ft. point on line 2-3 Grand Father lode.

The SE. corner of a mill building (frame) housing power plant and machine shop, having an overall dimension of 128 ft. Nly. and Sly. and 104 ft. Ely. and Wly. bears N.59°22'W. 182 ft. from the 247.88 ft. point on line 2-3 Grand Father lode.

PLOT THESE

The SW. corner of an adobe mess house 30x60 ft. bears N.57°58'W. 552 ft. from the 827.75 ft. point on line 2-3 Grand Father lode.

The SE. corner of an adobe store house 16x20 ft. bears N.63°30'W. 560 ft. from the 827.75 ft. point on line 2-3 Grand Father lode.

The SW. corner of a frame house 24x30 ft. bears N.33°16'W. 392 ft. from the 827.75 ft. point on line 2-3 Grand Father lode.

Adjoining Claims

This claim is bounded on the East by the East Side No.1 lode, on the South by New Rocky, New Great Eastern, New Knob, New Cut Off, and Argosy Annex lodes, on the West by the Grand Father Ext. lode, and on the North by the North Side No.1 lode, all unsurveyed and owned by the claimant herein.

Instrument

This survey was made with a C.L.Berger & Sons light mountain transit.

The courses were deflected from true meridians as determined by direct solar observations and checked by Polaris observations.

The distances were measured with 50 ft. and 660 ft. steel tapes.

Report

The U.S.G.L.O public land corners to which this survey is tied are all bronze capped pipe properly set and marked.

The amended location notices of the Argosy, Grand Father, Lookout and Flat Iron lodes do not correctly give the proper distances to the discovery works, and said distances are correctly given in the foregoing field notes.

Harry E. Jones
U. S. Mineral Surveyor.

GRANDFATHER CLAIM

SINE 21°24' x 1500 = ~~620.05~~ 547.32 + 5000 E = 5547.32 E } 1
~~TAN~~ COS 21°24' x 1500 = 1396.58 + 5000 N = 6396.58 N

GIVEN 4 = 5000 E , 5000 N

90° - 68°36' = 21°24'

COS 21°24' x 600 = 558.63 + 5547.32 E = 6105.95 E } 2
SINE 21°24' x 600 = -218.93 + 6396.58 = 6177.65 N

SINE 21°24' x 1500 = -547.32 + 6105.95 E = 5558.63 E } 3
COS 21°24' x 1500 = -1396.58 + 6177.65 N = 4781.07 N

90° - N68°36'W = 21°24'

COS 21°24 x 600 = -558.63 + 5558.63 E = 4999.996 = 5000 E } 4
SIN 21°24 x 600 = +218.93 + 4781.07 N = 4999.996 = 5000 N

VEKOL CLAIM

SINE 21°24' x (1500 - 762.32) [737.68] = +269.~~03~~16 + 6105.95 E = 637~~4.98~~5.11 E } 4
COS 21°24' x (1500 - 762.32) = +686.82 + 6177.65 N = 6864.47 N

90° - 68°36' = 21°24'

COS 21°24 x 600 = +558.63 + 637~~4.98~~5.11 E = 6933.~~67~~74 E } 1
SIN 21°24' x 600 = -218.93 + 6864.47 N = 6645.54 N
SIN 21°24' x 1500 = -547.32 + 6933.~~64~~74 E = 6386.~~29~~42 E } 2 *
COS 21°24' x 1500 = -1396.58 + 6645.54 N = 5248.96 N
COS 21°24' x 600 = -558.63 + 6386.~~29~~42 E = 5827.~~66~~79 E } 3
SIN 21°24' x 600 = +218.93 + 5248.96 N = 5467.89 N
SIN 21°24' x 762.32 = +278.15 + 5827.~~66~~79 E = 6105.~~81~~94 E } GF. 2
COS 21°24' x 762.32 = +709.76 + 5467.89 N = 6177.65 N

FLAT IRON CLAIM

1 = VEKOL 3 = 5827.79 E, 5467.89 N
2 = VEKOL 2 = 6386.42 E, 5248.96 N

SIN 21°24' x 1000 = -364.88 + 6386.42 E = 6021.54 E } 3
COS 21°24' x 1000 = -931.06 + 5248.96 N = 4317.~~83~~90 N

COS 21°24' x 600 = -558.63 + ~~6386.42 E~~ 6021.54 E = 5462.91 E } 4
SIN 21°24' x 600 = +218.93 + ~~5248.69 N~~ 4317.~~83~~90 N = 4536.~~86~~83 N

SIN 21°24' x 1000 = +364.88 + 5462.91 E = 5827.79 E } 1
COS 21°24' x 1000 = +931.06 + 4536.~~86~~83 N = 5467.89 N

LOOKOUT CLAIM

LOOKOUT 3 = VEKOL 2 = 6386.42 E, 5248.96 N

SINE 21°24' x 770 = +280.96 + 6386.42 E = 6667.38 E } 4
COS 21°24' x 770 = +716.91 + 5248.96 N = 5965.87 N

90° - 72°13' = 17°47°

COS 17°47' x 600 = +571.33 + 6667.38 E = 7238.71 E } 1
SIN 17°47' x 600 = -183.25 + 5965.87 N = 5782.62 N
SIN 21°24' x 770 = -280.96 + 7238.71 E = ~~7519.67~~ 6957.75 E } 2
COS 21°24' x 770 = -716.91 + 5782.62 N = 5065.71 N
COS 17°47' x 600 = -571.33 + ~~7519.67 E~~ 6957.75 E = ~~6948.34~~ 6386.42 E } 3
SIN 17°47' x 600 = +183.25 + ~~6948.34~~ 5065.71 N = 5248.96 N

GRANDFATHER CLAIM

GIVEN 1: 5000 E, 5000 N

SINE 21°24' x 1500 = 547.32 + 5000 E = 5547.32 E } 1
COS 21°24' x 1500 = 1396.58 + 5000 N = 6396.58 N

90° - 68°36' = 21°24'

COS 21°24' x 600 = 558.63 + 5547.32 E = 6105.95 E } 2
SINE 21°24' x 600 = -218.93 + 6396.58 = 6177.65 N

SINE 21°24' x 1500 = -547.32 + 6105.95 E = 5558.63 E } 3
COS 21°24' x 1500 = -1396.58 + 6177.65 N = 4781.07 N

90° - N68°36'W = 21°24'

COS 21°24 x 600 = -558.63 + 5558.63 E = 4999.996 = 5000 E } 4
SIN 21°24 x 600 = +218.93 + 4781.07 N = 4999.996 = 5000 N

VEKOL CLAIM

SINE 21°24' x (1500-762.32) = +269.16 (737.68) + 6105.95E = 6375.11 E } 4
COS 21°24' x (1500-762.32) = +686.82 + 6177.65N = 6864.47N

90° - 68°36' = 21°24'

COS 21°24 x 600 = +558.63 + 6375.11E = 6933.74 E } 1
SIN 21°24' x 600 = -218.93 + 6864.47N = 6645.54 N

SIN 21°24' x 1500 = -547.32 + 6933.74 E = 6386.42 E } 2 *
COS 21°24' x 1500 = -1396.58 + 6645.54 N = 5248.96 N

COS 21°24' x 600 = -558.63 + 6386.42 E = 5827.79 E } 3
SIN 21°24' x 600 = +218.93 + 5248.96 N = 5467.89 N

SIN 21°24' x 762.32 = +278.15 + 5827.79 E = 6105.94 E } GF 2
COS 21°24' x 762.32 = +709.76 + 5467.89 N = 6177.65 N

FLAT IRON CLAIM

1 = VEKOL 3 = 5827.79E, 5467.89N
2 = VEKOL 2 = 6386.42E, 5248.96N

SIN 21°24' x 1000 = -364.88 + 6386.42 E = 6021.54E } 3
COS 21°24' x 1000 = -931.06 + 5248.96N = 4317.90N

COS 21°24' x 600 = -558.63 + 6021.54E = 5462.91E } 4
SIN 21°24' x 600 = +218.93 + 4317.90 N = 4536.83N

SIN 21°24' x 1000 = +364.88 + 5462.91E = 5827.79 E } 1
COS 21°24' x 1000 = +931.06 + 4536.83N = 5467.89 N

LOOKOUT CLAIM

LOOKOUT 3 = VEKOL 2 = 6386.42 E, 5248.96 N

SINE 21°24' x 770 = +280.96 + 6386.42 E = 6667.38 E } 4
COS 21°24' x 770 = +716.91 + 5248.96 N = 5965.87 N

90° - 72°13' = 17°47'

COS 17°47' x 600 = +571.33 + 6667.38 E = 7238.71 E } 1
SIN 17°47' x 600 = -183.25 + 5965.87 N = 5782.62 N

SIN 21°24' x 770 = -280.96 + 7238.71 E = 6957.75 E } 2
COS 21°24' x 770 = -716.91 + 5782.62 N = 5065.71 N

COS 17°47' x 600 = -571.33 + 6957.75 E = 6386.42 E } 3
SIN 17°47' x 600 = +183.25 + 5065.71 N = 5248.96 N

ARGOSY CLAIM

START AT VEKOL 2   6386.42 E, 5248.96 N

SINE 5°28'50" ✓ × 286.44 ✓ = − 27.36 + 6386.42 E = 6359.06 E
COS 5°28'50" × 286.44 = + 285.13 + 5248.96 N = 5534.09 N } 3

SIN 35°32' × 1465 = + 851.42 + 6359.06 E = 7210.48 E
COS 35°32 × 1465 = − 1192.18 + 5534.09 N = ~~6726.27 N~~ 4341.91 N } 4

ALSO

SIN 35°32' × 440.50 = + 256.01 + 6359.06 E = 6615.07 E
COS 35°32' × 440.50 = − 358.47 + 5534.09 N = ~~5892.56 N~~ 5175.62 N } INT

COS 17°47' × 240.12 = − 228.65 + 6615.07 E = ~~6843.72 E~~ 6386.42
SIN 17°47' × 240.12 = + 73.34 + ~~5892.56 N~~ 5175.62 N = ~~5965.90 N~~ 5248.96 N } 3 L.O.

THAT CHECKS WITH PREVIOUS CALCULATION

90° − 54°28' = 35°32'

~~SIN~~ COS 35°32' × 600 = − 488.27 + 7210.48 E = 6722.21 E
~~COS~~ SIN 35°32' × 600 = − 348.71 + 4341.91 N = 3993.20 N } 1

SIN 35°32' × 1465 = − 851.42 + 6722.21 E = 5870.79 E
COS 35°32' × 1465 = + 1192.18 + 3993.20 N = 5185.38 N } 2

COS 35°32' × 600 = + 488.27 + 5870.79 E = 6359.06 E
SIN 35°32' × 600 = + 348.71 + 5185.38 N = 5534.09 N } 3

MOUNT VERNON CLAIM

MOUNT VERNON 2 = ARGOSY INT = 6615.07 E, 5175.62 N

COS 35°32' × 600 = + 488.27 + 6615.07 E = 7103.34 E
SIN 35°32' × 600 = + 348.71 + 5175.62 N = 5524.33 N } 3

SIN 35°32' × 1500 = + 871.76 + 7103.34 E = 7975.10 E
COS 35°32' × 1500 = − 1220.67 + 5524.33 N = 4303.66 N } 4

COS 35°32' × 600 = − 488.27 + 7975.10 E = 7486.83 E
SIN 35°32' × 600 = − 348.71 + 4303.66 N = 3954.95 N } 1

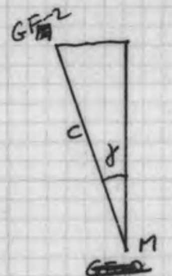
SIN 35°32' × 1500 = − 871.76 + 7486.83 E = 6615.07 E
COS 35°32' × 1500 = + 1220.67 + 3954.95 N = 5175.62 N } 2

IMPORTANT CALCUATIONS

35' OFFSET MON. FROM ARGOSY 3   START AT ARGOSY 3 = 6359.06 E, 5534.09 N

SIN 35°32' × 35 = − 20.34 + 6359.06 E = 6338.72 E
COS 35°32' × 35 = + 28.48 + 5534.09 N = 5562.57 N } POINT M

BASE LINE FROM POINT M TO GRANDFATHER 2
6338.72 E, 5562.57 N   6105.95 E, 6177.65 N



TAN α = E/N = 6338.72 − 6105.95 / 6177.65 − 5562.57 = 232.77/615.08

TAN α = 0.378438577   TAN⁻¹ = 20.72857597° = 20°43'42.87"

α = N 20°43'42.87" W

C = 615.08 / cos α = 657.65 = BASELINE

ARGOSY CLAIM

START AT VEKOL 2   6386.42 E, 5248.96 N

SINE 5°28'50" x 286.44 = - 27.36 + 6386.42 E = 6359.06 E } 3
COS 5°28'50" x 286.44 = + 285.13 + 5248.96 N = 5534.09 N

SIN 35°32' x 1465 = + 851.42 + 6359.06 E = 7210.48 E } 4
COS 35°32 x 1465 = - 1192.18 + 5534.09 N = ~~6726.27 N~~ 4341.91 N

ALSO

SIN 35°32' x 440.50 = + 256.01 + 6359.06 E = 6615.07 E } INT
COS 35°32' x 440.50 = - 358.47 + 5534.09 N = ~~5892.56 N~~ 5175.62 N

COS 17°47' x 240.12 = - 228.65 + 6615.07 E = ~~6843.72 E~~ 6386.42 } 3
SIN 17°47' x 240.12 = + 73.34 + ~~5892.56 N~~ 5175.62 N = ~~5965.90 N~~ 5248.96 N } L.O.

THAT CHECKS WITH PREVIOUS CALCULATION

90° - 54°28' = 35°32'

~~SIN~~ COS 35°32' x 600 = - 488.27 + 7210.48 E = 6722.21 E } 1
~~COS~~ SIN 35°32' x 600 = - 348.71 + 4341.91 N = 3993.20 N

SIN 35°32' x 1465 = - 851.42 + 6722.21 E = 5870.79 E } 2
COS 35°32' x 1465 = + 1192.18 + 3993.20 N = 5185.38 N

COS 35°32' x 600 = + 488.27 + 5870.79 E = 6359.06 E } 3
SIN 35°32' x 600 = + 348.71 + 5185.38 N = 5534.09 N

MOUNT VERNON CLAIM

MOUNT VERNON 2 = ARGOSY INT = 6615.07 E, 5175.62 N

COS 35°32' x 600 = + 488.27 + 6615.07 E = 7103.34 E } 3
SIN 35°32' x 600 = + 348.71 + 5175.62 N = 5524.33 N

SIN 35°32' x 1500 = + 871.76 + 7103.34 E = 7975.10 E } 4
COS 35°32' x 1500 = - 1220.67 + 5524.33 N = 4303.66 N

COS 35°32' x 600 = - 488.27 + 7975.10 E = 7486.83 E } 1
SIN 35°32' x 600 = - 348.71 + 4303.66 N = 3954.95 N

SIN 35°32' x 1500 = - 871.76 + 7486.83 E = 6615.07 E } 2
COS 35°32' x 1500 = + 1220.67 + 3954.95 N = 5175.62 N

IMPORTANT CALCULATIONS

35' OFFSET MON FROM ARGOSY 3   START AT ARGOSY 3 = 6359.06 E, 5534.09 N

SIN 35°32' x 35 = - 20.34 + 6359.06 E = 6338.72 E } POINT M
COS 35°32' x 35 = + 28.48 + 5534.09 N = 5562.57 N

BASE LINE FROM POINT M TO GRANDFATHER

6338.72 E   6105.95 E
5562.57 N   6177.65 N

TAN α = E/N = 6338.72 - 6105.95 / 6177.65 - 5562.57 = 232.77/615.08

TAN α = 0.378438517 TAN^{-1} = 20.72857597 = 20°43'42.87"

α = N20°43'42.87"W

C = 615.08/cos α = 657.65 = BASELINE

IMPROVEMENTS IN VEKOL CLAIM

MAIN PORTAL

START AT VEKOL 3 = 5827.79 E, 5467.89 N

~~COS~~ SIN 21°24' x 514.44 = + 187.71 + 5827.79 E = 6015.50 E } INT
COS 21°24' x 514.44 = + 478.97 + 5467.89 N = 5946.86 N }

SIN 41°10' x 277 = + 182.34 + 6015.50 E = 6197.84 E } No. 2 MAIN PORTAL
COS 41°10' x 277 = − 208.53 + 5946.86 N = ~~6155.39 N~~ 5738.33 N }

No 3 PORTAL OF WEST ZIG ZAG TUNNEL

START AT INT POINT = 6015.50 E, 5946.86 N
90° - 45°15' = 44° 45'
COS 44° 45' X 325 = + 230.81 + 6015.50 E = 6246.31 E } No. 3 WEST ZIGZAG
SIN 44° 45' x 325 = − 228.80 + 5946.86 N = 5718.06 N }

No. 4 PORTAL OF EAST ZIG ZAG TUNNEL

START AT INT POINT = 6015.50 E, 5946.86 N
90° - 60°30' = 29° 30'
COS 29°30' x 278 = + 241.96 + 6015.50 E = 6257.46 E } No. 4 EAST ZIGZAG
SIN 29° 30' x 278 = − 136.89 + 5946.86 N = 5809.97 N }

VK-5 SHAFT 30 FT DEEP

START AT INT. POINT = 6015.50 E, 5946.86 N
SIN 6°47' x 340 = − 40.16 + 6015.50 E = 5975.34 E } VK-5
COS 6° 47' x 340 = − 337.62 + 5946.86 N = 5609.24 N }

VK-6 CUT AND TUNNEL

START AT INT POINT = 6015.50 E, 5946.86 N
90° ~~-69° = 21°0'~~ -62°15' = 27° 45'
COS 27°45' X 333 = + 294.70 + 6015.50 E = 6310.20 E } VK-6
SIN 27°45' X 333 = + 155.05 + 5946.86 N = 6101.91 N }

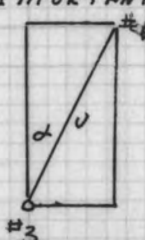
VK-7 TUNNEL PORTAL

START AT INT. POINT = 6015.50 E, 5946.86 N
90° - 69° = 21°0'
COS 21°0' x 470 = + 438.78 + 6015.50 E = 6454.28 E } VK-7
SIN 21°0' x 470 = + 168.43 + 5946.86 N = 6115.29 N }

No. VK-8 CUT AND TUNNEL

START AT INT. POINT = 6015.50 E, 5946.86 N
90° - 59°30' = 30°30'
COS 30°30' x 470 = + 404.97 + 6015.50 E = 6420.47 E } VK-8
SIN 30°30' x 470 = + 238.54 + 5946.86 N = 6185.40 N }

IMPORTANT CALCULATION No. 3 WEST ZIG ZAG TO No. 4 EAST ZIG ZAG



TAN α = E/N = 6246.31 - 6257.46 / 5718.06 - 5809.97 = −11.15 / − 91.91 =
= 0.121314329
TAN⁻¹ = 6° 55' 1.19"   α = N 6°55' 1.19" E
C = 91.91 / COS α = 92.58 FT

Improvements in Vekol Claim

Main Portal

Start at Vekol 3 = 5827.79 E, 5467.89 N

~~cos~~ sin 2°24' x 514.44 = + 187.71 + 5827.79E = 6015.50 E } Int
cos 2°24' x 514.44 = + 478.97 + 5467.89N = 5946.86 N }

sin 41°10' x 277 = + 182.34 + 6015.50E = 6197.84 E } No.2 Main
cos 41°10' x 277 = − 208.53 + 5946.86N = ~~6155.39N~~ 5738.33N } Portal

No 3 Portal of West Zig Zag Tunnel

Start at Int Point = 6015.50 E, 5946.86 N
90° − 45°15' = 44°45'
cos 44°45' x 325 = + 230.81 + 6015.50E = 6246.31 E } No.3 West
sin 44°45' x 325 = − 228.80 + 5946.86N = 5718.06 N } ZigZag

No.4 Portal of East Zig Zag Tunnel

Start at Int Point = 6015.50E, 5946.86N
90° − 60°30' = 29°30'
cos 29°30' x 278 = + 241.96 + 6015.50E = 6257.46E } No.4 East
sin 29°30' x 278 = − 136.89 + 5946.86N = 5809.97 N } ZigZag

VK-5 Shaft 30Ft Deep

Start at Int. Point = 6015.50E, 5946.86N
sin 6°47' x 340 = − 40.16 + 6015.50E = 5975.34E } VK-5
cos 6°47' x 340 = − 337.62 + 5946.86 N = 5609.24N }

VK-6 Cut and Tunnel

Start at Int Point = 6015.50E, 5946.86N
90° ~~69° 21°0'~~ − 62°15' = 27°45'
cos 27°45' x 333 = + 294.70 + 6015.50E = 6310.20E } VK-6
sin 27°45' x 333 = + 155.05 + 5946.86N = 6101.91 N }

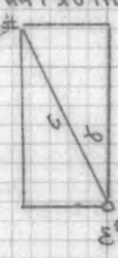
VK-7 Tunnel Portal

Start at Int. Point = 6015.50E, 5946.86N
90° − 69° = 21°0'
cos 21°0' x 470 = + 438.78 + 6015.50E = 6454.28E } VK-7
sin 21°0' x 470 = + 168.43 + 5946.86N = 6115.29 N }

VK- No.8 Cut and Tunnel

Start at Int. Point = 6015.50E, 5946.86N
90° − 59°30' = 30°30'
cos 30°30' x 470 = + 404.97 + 6015.50E = 6420.47E } VK-8
sin 30°30' x 470 = + 238.54 + 5946.86N = 6185.40N }

Important Calculation No.3 West Zig Zag to No.4 East Zig Zag



Tan α = E/N = 6246.31 − 6257.46 / 5718.06 − 5809.97 = −11.15/−91.91 =
= 0.12131429
Tan⁻¹ = 6°55' 1.19" α = N 6°55' 1.19" E
C = 91.91/cos α = 92.58 Ft

IMPROVEMENTS IN ARGOSY CLAIM

No. 3 ARGOSY SHAFT

START AT MOUNT VERNON 2 : ARGOSY INT.: 6615.07 E. 5175.62 N

SIN 27°24 × 258.48 : − 118.95 + 6615.07E = 6496.12E } ARGOSY
COS 27°24 × 258.48 = − 229.48 + 5175.62N : 4946.14N } SHAFT

IMPROVEMENTS IN GRAND FATHER CLAIM

START AT GRANDFATHER 2 = 6105.95 E, 6177.65 N

SIN 21° 24' × 247.88 = − 90.45 + 6105.95 E = 6015.50E } INT POINT
COS 21° 24' × 247.88 = −230.79 + 6177.65 N = 5946.86N } ON LINE 2-3

90° − 87°29' = 2°31'

COS 2°31' × 115.83 : − 115.72 + 6015.50 E = 5899.78 E } VEKOL
SIN 2°31 × 115.83 : − 5.09 + 5946.86N = 5941.77N } SHAFT

90° − 70°28' = 19°32'

COS 19°32' × 167.0 = − 157.39 + 6015.50 E = 5858.11 E } FIRST
SIN 19°32' × 167.0 = − 55.84 + 5946.86N = 5891.02 N } WATER WELL Z

~~90~~ − 32°40' = ~~=~~

SIN 32°40' × 328.0 = − 117.04 + 6015.50 E = 5838.46 E } GF.5
COS 32°40' × 328.0 = − 276.12 + 5946.86N = 5670.74N }

SIN 28°20' × 328.0 : − 155.67 + 6015.50 E = 5859.83E } GF-6
COS 28°20' × 328.0 = − 288.71 + 5946.86 N = 5658.15N }

FROM CORNER 2 GRANDFATHER: 6105.95E, 6177.65N

90 − 75°05' = 14°55'

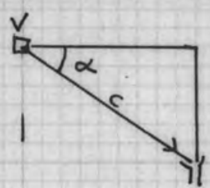
~~SIN~~ COS 14°55' × 120 = − ~~30.89~~ 115.96 + 6105.95E = 5989.99 E } GF-7
~~COS~~ SIN 14°55' × 120 = + 30.89 + 6177.65N = 6208.53 N }

90° − 61°35' = 28°25'

COS 28°25' × 154' : − 135.44 + 6105.95E = 5970.51 E } GF-8
SIN 28°25' × 154' : − 73.29 + 6177.65N = 6104.36N }

IMPORTANT CALCULATIONS:

VEKOL SHAFT TO MAIN PORTAL
5899.78E TO 6197.84E
5941.77N TO 5738.33N



TAN α = N/E = −203.44/298.06

TAN α = .682547

TAN⁻¹ = 34.3153

α = 34°18' 55.36"

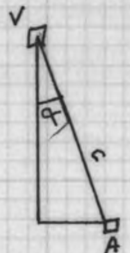
BEARING = S 55°41' 04.64" E LOOKS GOOD

(C) DISTANCE × Cos α = 298.06

C = 298.06 / cos α

C = 360.87 LOOKS GOOD

VEKOL SHAFT TO ARGOSY SHAFT
5899.78E 6496.12E
5941.77N 4946.14N



TAN α = E/N = 59634/995.63

TAN α = .598957

TAN⁻¹ = 30.91981 = 30°55' 11.33"

C = 995.63 / cos α

C = 1160.56 FT OLD MAP GAVE

IMPROVEMENTS IN ARGOSY CLAIM

No. 3 ARGOSY SHAFT

START AT MOUNT VERNON 2 : ARGOSY INT: 6615.07 E. 5175.62 N

sin 27°24 x 258.48: − 118.95 + 6615.07E = 6496.12E } ARGOSY SHAFT
cos 27°24 x 258.48 = − 229.48 + 5175.62N = 4946.14N

IMPROVEMENTS IN GRANDFATHER CLAIM

START AT GRANDFATHER 2 = 6105.95 E, 6177.65 N

sin 21°24' x 247.88 = − 90.45 + 6105.95 E = 6015.50E } Int Point on Line 2-3
cos 21°24' x 247.88 = −230.79 + 6177.65 N = 5946.86N

90°−87°29' = 2°31'

cos 2°31' x 115.83 = − 115.72 + 6015.50E = 5899.78E } VEKOL SHAFT
sin 2°31 x 115.83 = − 5.09 + 5946.86N = 5941.77N

90° − 70°28' = 19°32'

cos 19°32' x 167.0 = − 157.39 + 6015.50E = 5858.11E } FIRST WATER WELL 2
sin 19°32' x 167.0 = − 65.84 + 5946.86N = 5881.02N

~~90°~~ − 32°40' =

sin 32°40' x 328.0 = − 177.04 + 6015.50E = 5838.46E } GF-5
cos 32°40' x 328.0 = − 276.12 + 5946.86N = 5670.74N

sin 28°20' x 328.0 = − 155.67 + 6015.50E = 5859.83E } GF-6
cos 28°20' x 328.0 = − 288.71 + 5946.86N = 5658.15N

FROM CORNER 2 GRANDFATHER: 6105.95E, 6177.65N

90 − 75°05' = 14°55'

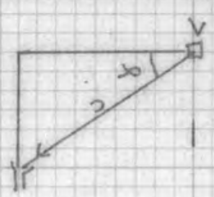
~~sin~~ cos 14°55' x 120 = − ~~30.89~~ 115.96 + 6105.95E = 5989.99E } GF-7
~~cos~~ sin 14°55' x 120 = + 30.89 + 6177.65N = 6208.53N

90°−61°35' = 28°25'

cos 28°25' x 154' = − 135.44 + 6105.95E = 5970.51E } GF-8
sin 28°25' x 154' = − 73.29 + 6177.65N = 6104.36N

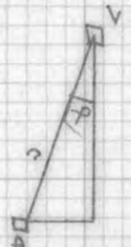
IMPORTANT CALCULATIONS:

VEKOL SHAFT TO MAIN PORTAL
5899.78E to 6197.84E
5941.77N to 5738.33N



TAN α = N/E = −203.44/298.06
TAN α = .682547
TAN⁻¹ = 34.3153
α = 34°18'55.36"
BEARING = S 55°41'46.4' E Looks Good
(C) DISTANCE x COS α = 298.06
C = 298.06/cos α
C = 360.87 LOOKS GOOD

VEKOL SHAFT TO ARGOSY SHAFT
5899.78E 6496.12E
5941.77N 4946.14N



TAN α = E/N = 596.34/995.63
TAN α = .598957
TAN⁻¹ = 30.91981 = 30°55'11.33"
C = 995.63/cos α
C = 1160.56 FT OLD MAP GAVE

IMPROVEMENTS IN FLAT IRON CLAIM

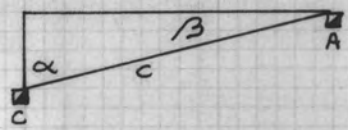
START AT FLAT IRON CORNER No. 2 = VEKOL CORNER No. 2 = LOOKOUT CORNER No. 3
= 6386.42 E, 5248.96 N

SHAFT No. 2 = COMBINATION SHAFT

SIN 33° 42' × 510 = − 282.97 + 6386.42 E = 6103.45 E
COS 33° 42' × 510 = − 424.30 + 5248.96 N = 4824.66 N

IMPORTANT CALCULATION

COMBINATION SHAFT TO ARGOSY SHAFT



TAN β = N/E = ~~6496.12~~ 4946.14 − 4824.66 / 6496.12 − 6103.45

TAN β = 121.48 / 392.67

TAN⁻¹ = β = 17° 11' 25.64"

α = 90° − β = N 72° 48' 34.36" E

C = 392.67 / COS α = 411.03 FT.

Improvements in Flat Iron Claim

Start at Flat Iron Corner No. 2 = Venol Corner No. 2 = Lookout Corner No. 3

= 6386.42E, 5248.96N

Shaft No. 2 = Combination Shaft

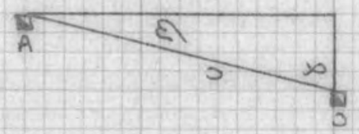
$\sin 33°42' \times 510 = -282.97 + 6386.42E = 6103.45E$

$\cos 33°42' \times 510 = -424.30 + 5248.96N = 4824.66N$

Important Calculation

Combination Shaft to Argosy Shaft

$\tan\beta = N/E =$ ~~6496.12~~ $4946.14 - 4824.66 / 6496.12 - 6103.45$

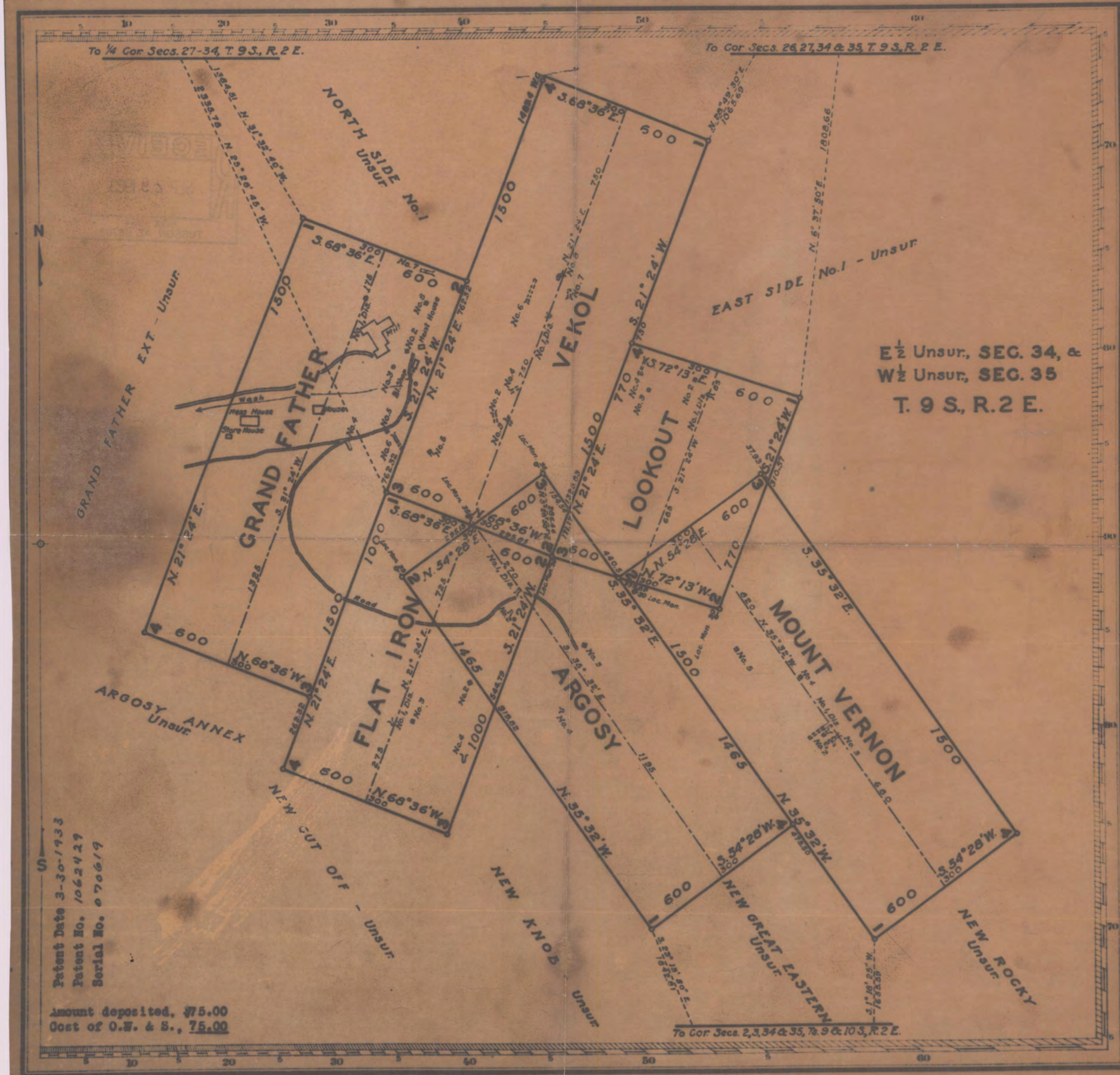


$\tan\beta = 121.48/392.67$

$\tan^{-1} = \beta = 17° 11' 25.64''$

$\alpha = 90° - \beta = N 72° 48' 34.36'' E$

$c = 392.67 / \cos\alpha = 411.03$ FT.



Patented 3-30-1933

Mineral Survey No. **4143**

ARIZONA Land District.

PLAT

OF THE CLAIM OF

Paul R. Daggs

KNOWN AS THE

VEKOL, MOUNT VERNON, ARGOSY, GRAND FATHER, LOOKOUT, and FLAT IRON lodes

IN Casa Grande *MINING DISTRICT,*
Pinal *COUNTY,* Arizona

Containing an Area of *Acres.*
Scale of 300 *Feet to the inch.*
Variation 14° 40' E.

SURVEYED March 18 - 24 19 31 *BY*
Harry E. Jones,
U. S. Mineral Surveyor.

The Original Field Notes of the Survey of the Mining Claim of Paul R. Daggs *known as the*

VEKOL, MOUNT VERNON, ARGOSY, GRAND FATHER, LOOKOUT, and FLAT IRON lodes

from which this plat has been made under my direction, have been examined and approved, and are on file in this Office, and I hereby certify that they furnish such an accurate description of said Mining Claim as will, if incorporated into a patent, serve fully to identify the premises, and that such reference is made therein to natural objects or permanent monuments as will perpetuate and fix the locus thereof.

I further certify that Five Hundred Dollars worth of labor has been expended or improvements made upon, or for each of, *said Mining Claims by claimant* *or* his *grantors and that said improvements consist of* 16 cuts, 12 tunnels, 13 shafts, 1 well and 2 drifts, together with an intricate system of at least 3 miles of underground development, total value $255,907, of which $172,800 is reserved for 16 unsurveyed claims *that the location of said improvements is correctly shown upon this plat, and that no portion of said labor or improvements has been included in the estimate of expenditures upon any other claim.*

And I further certify that this is a correct plat of said Mining Claim made in conformity with said original field notes of the survey thereof, and the same is hereby approved.

PUBLIC SURVEY OFFICE
Phoenix, Arizona.
May 7, 1931.

John D. Adams
Office Cadastral Engineer
at Phoenix, Arizona.