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EXPLORATION AT LAKESHORE MINE

Pinal County, Arizona

Claude E. Barron

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El Paso Natural Gas Company

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ABSTRACT

As the result of a general reconnaissance of the Slate Mountain area, an interpretation of the geology was made that assumed (1) the oxide tactite ore body in the Lakeshore Pit had been overturned by tilting to the northwest, (2) that these metasediments would be in place underlying the andesite west of the pit and would trend generally northwest parallel to the trend of the Slate Mountains, and (3) that the strong northwest and north-south fault and fracture system which was exposed in the pit would offer channels for migrating mineralized solutions permitting the deposition of sulphides at depth.

A proposed correlation of this interpretation with Induced Polarization anomalies involved an area that extended to the south and northwest of the Lakeshore Pit. This area was recommended for deep drilling to test the weak I. P. anomalies for sulphide mineralization.

Contour maps based on assay and geological data from gyroscopically surveyed drill holes offered control for delineation and computer evaluation of the discovered ore body.

INTRODUCTION

The Lakeshore mineral deposit outcrops on the southwest piedmont of the Slate Mountains in Section 25, T10S, R4E, Pinal County, Arizona. This location is in the Papago Indian Reservation, approximately 30 miles south of Casa Grande, Arizona.

In the Basin and Range Province of southwest Arizona, the Slate Mountains form an arcing outcrop that trends from northwest to north, and reaches an elevation of 3330 feet at Prieta Peak near the center of the range. The Lakeshore Mine, about 2 miles south of Prieta Peak, is at an elevation of approximately 1800 feet. Vegetation in the valley is of the desert variety, capable of surviving in the hot summer temperature and the few inches of annual precipitation.

PREVIOUS WORK

Rocks in the Slate Mountains were described in an unpublished thesis by Hogue (1) in 1940. The Lakeshore copper deposits were investigated by the U. S. Bureau of Mines (2) in 1950. Precambrian and Paleozoic sedimentary rocks of the area were described by McClymonds (3) in 1959. Geologic maps prepared by the Arizona Bureau of Mines (4) in 1960 show rocks in the Slate Mountain area range in age from Precambrian to Quaternary. Sedimentary rocks of the northern Slate Mountains have been described in detail in an unpublished thesis by Hammer (5) in 1961. Other work describing surface geology and sub-surface data obtained from shallow drilling is contained in several unpublished reports made by consultants for Transarizona.

HISTORY

The mineral outcrop, consisting primarily of copper silicates and iron oxides, was located by Trout and Atchison in the early 1880's. Abandoned in 1884, the property was relocated by B. S. Wilson in 1905. In 1914 Wilson sold the property to Frank M. and Charles Leonard.

The Leonards, who developed the ore body on three levels while working through a 225 foot vertical shaft, leased the property in 1917. This lease was terminated in 1919. The next noteworthy work to be conducted was an examination of the property by the U. S. Bureau of Mines in 1942 which initiated an investigation that started in 1948 and concluded with a report in 1950.

In November 1955, the three patented claims of the Lakeshore property and the Drake claims, consisting of three patented and 19 unpatented claims, were obtained by George Freeman under a lease-option agreement from Treasure State Mining Company. In 1956, a 580 acre lease surrounding these claims was obtained from the Bureau of Indian Affairs by Dwight McClure and George Freeman. In 1960 the Bureau of Indian Affairs approved an assignment of the lease to Transarizona Resources Inc.

El Paso Natural Gas Company's interest in the property was initiated by an invitation to examine the property in September 1962. At that time, the writer made an examination of the mine and plant. Transarizona had developed the mine as a small open pit. Exploration drilling on a closely-spaced drill pattern indicated ± 1.5 million tons of ± 1.75% copper oxide. Level maps and cross-sections prepared from the drill data indicated the mineral deposit formed a V-shaped trough that plunged to the southwest, and was controlled by faults.

The Plant had been designed for a copper segregation process that was followed by flotation.

As a result of the examination, a recommendation for a more complete evaluation of the property was made but the request was not approved. However, in June 1963, a limited amount of drilling was conducted in the open pit and a feasibility study of the segregation process was made.

In August 1966, under the direction of the Mining Division of El Paso Natural Gas Company, an induced Polarization survey was conducted on the Lakeshore property by McPhar Geophysical Limited and, at the same time, the writer began a general geological survey of the area.

In September 1966 a core drilling program was initiated to investigate the I. P. anomalies that were discovered on the property.

In February 1969, El Paso Natural Gas Company announced an agreement with Hecla Mining Company for development of a major new copper discovery made by the Mining Division on the Lakeshore property.

GENERAL GEOLOGY

Reconnaissance of the Slate Mountain Area

The Slate Mountains (Fig. 1), composed primarily of the Pinal Schist formation of Precambrian age (4), strike N $\pm$ 45W and dip $\pm$ 50° NE. Near the center of the mountains, an elongated mass of quartz diorite has intruded the schist. This intrusive mass tends to parallel the foliation of the schist and was identified as being Precambrian in age (4). However, recent work by P. E. Damon and R. L. Mauger (6) has dated this intrusive by the potassium-argon process as Laramide (Cretaceous-Tertiary). Along the northeast slopes of the mountains, the schist dips under the alluvium and fanglomerates at the edge of the valley.

At the north end of the Slate Mountains, the Pioneer Shale, the Dripping Springs Quartzite, and the Mescal Limestone of the Precambrian Apache Group (4) strike N $\pm$ 40° E and dip $\pm$ 45° NW. These northwest dipping metasediments overlie the northwest trending Pinal Schist with angular unconformity. Overlying the Apache Group is the Abrigo Limestone and Troy Quartzite of Early Cambrian age (4) and the limestone, quartzite and shales of Devonian and Carboniferous age (4). Along the southwest slope of the Slate Mountains and to the southeast, outcrops of these formations generally dip to the southwest and strike parallel with the trend of the mountains.

Around the southwest periphery of the Slate Mountains and protruding through the valley fill, are outlying hills of Devonian and Carboniferous limestone, Cretaceous volcanic and sedimentary rocks and Tertiary andesite and breccia (4). The Devonian

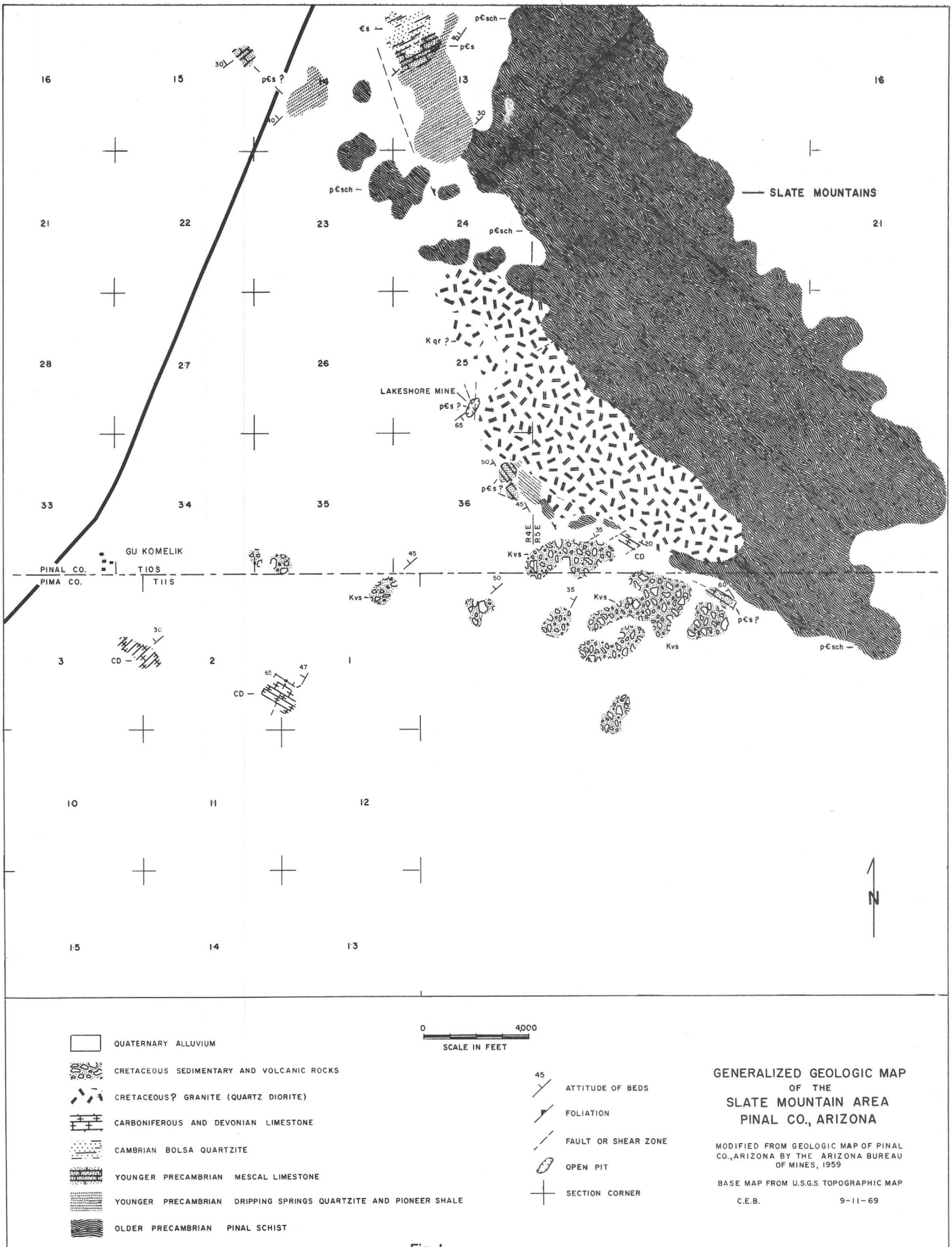

SLATE MOUNTAINS
LAKESHORE MINE
GU KOMELIK
PINAL CO.
PIMA CO.
T10S
T11S
R4E
R5E
p€sch
p€s
€s
Kqr ?
Kvs
CD
QUATERNARY ALLUVIUM
CRETACEOUS SEDIMENTARY AND VOLCANIC ROCKS
CRETACEOUS? GRANITE (QUARTZ DIORITE)
CARBONIFEROUS AND DEVONIAN LIMESTONE
CAMBRIAN BOLSA QUARTZITE
YOUNGER PRECAMBRIAN MESCAL LIMESTONE
YOUNGER PRECAMBRIAN DRIPPING SPRINGS QUARTZITE AND PIONEER SHALE
OLDER PRECAMBRIAN PINAL SCHIST
0 4000
SCALE IN FEET
ATTITUDE OF BEDS
FOLIATION
FAULT OR SHEAR ZONE
OPEN PIT
SECTION CORNER
GENERALIZED GEOLOGIC MAP
OF THE
SLATE MOUNTAIN AREA
PINAL CO., ARIZONA
MODIFIED FROM GEOLOGIC MAP OF PINAL CO., ARIZONA BY THE ARIZONA BUREAU OF MINES, 1959
BASE MAP FROM U.S.G.S. TOPOGRAPHIC MAP
C.E.B.
9-11-69

Fig. 1

and Carboniferous limestone and dolomite have been folded along an apparent northwest trending axis and then tilted to the northwest. In the area southwest of the Lakeshore mine, the breccia and the underlying Cretaceous volcanic and sedimentary rock strikes N $\pm$ 50° E and dips $\pm$ 45° NW.

Small faults have apparently displaced sedimentary bedding and igneous and sedimentary contacts in these outlying hills. However, any evidence of large faults has been covered by the alluvium. The poles of the measured attitudes of joints and fractures, plotted on a stereographic projection, indicates a preferred orientation of N 30° E with 45° SE dip, N 40° E with 45° NW dip, and N 65° E with 66° SE dip.

Geology of the Lakeshore Pit

At the Lakeshore Mine, a small open pit was excavated by Transarizona (Fig. 2). Near the center of the pit, mineralized banded tactite overlaid by a fine-grained quartzite, striking N $\pm$ 50 E and dipping $\pm$ 60° SE, was exposed. These metasediments terminate on the east side of the pit where they are in contact with diorite along a very strong oblique slip dip fault that strikes NW and dips 65° SW. Merging with this fault is a strong north-south fault that dips 74° W.

Along the west wall of the pit, altered and fractured andesite occurs on the footwall of an andesite and metasediment contact which shows slickensides. This contact, striking N $\pm$ 40° E and dipping $\pm$ 50° SE, forms the footwall of the oxide ore body.

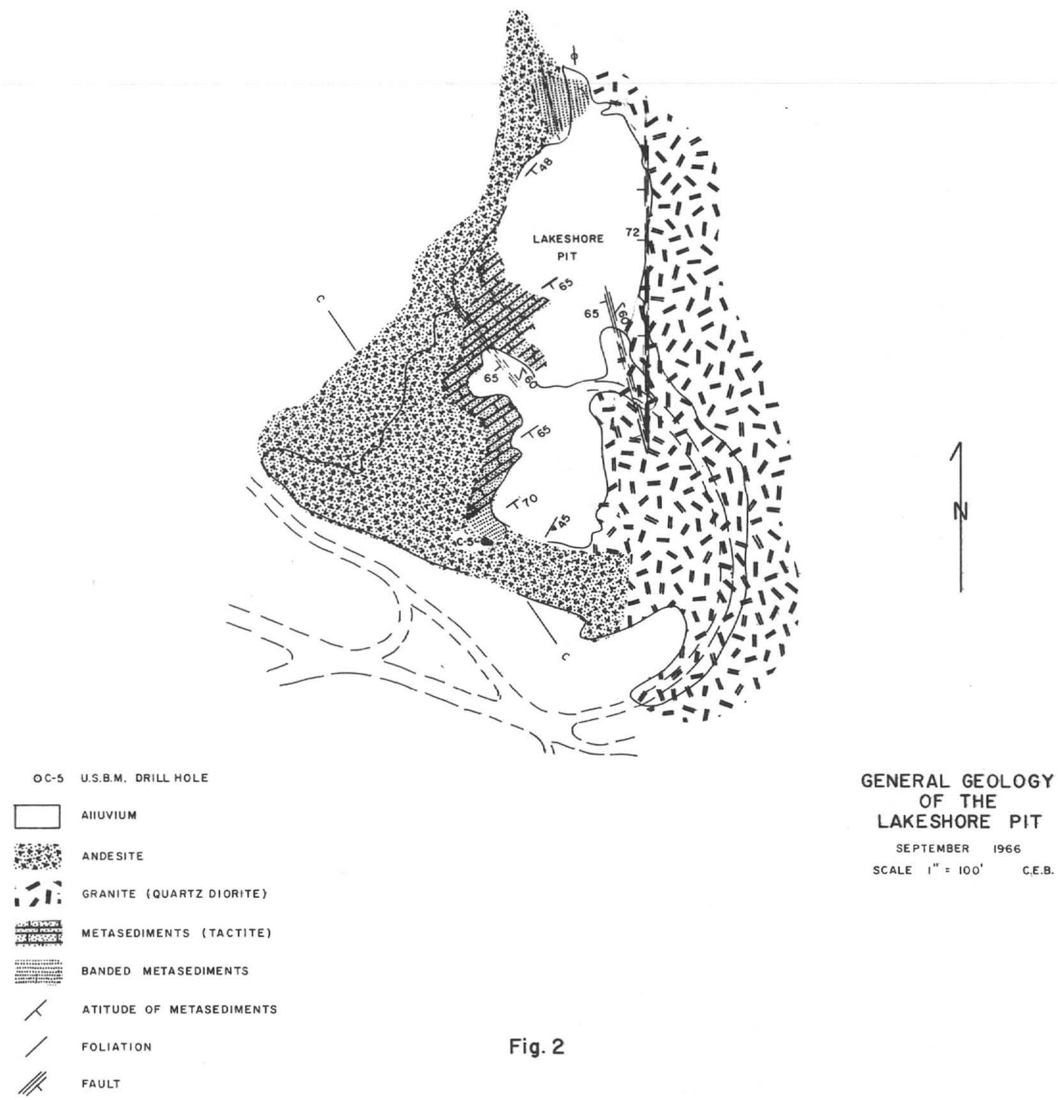

LAKESHORE
PIT
72
48
65
65
60
65
60
65
70
45
OC-5
C
C
N
OC-5 U.S.B.M. DRILL HOLE
AIIUVIUM
ANDESITE
GRANITE (QUARTZ DIORITE)
METASEDIMENTS (TACTITE)
BANDED METASEDIMENTS
ATITUDE OF METASEDIMENTS
FOLIATION
FAULT
GENERAL GEOLOGY
OF THE
LAKESHORE PIT
SEPTEMBER 1966
SCALE 1" = 100' C.E.B.

Fig. 2

At the north end of the pit, a fine-grained, banded quartzite, striking N $\pm$ 10° W with vertical dip, has been exposed in contact with the diorite on the footwall side of the NW striking fault zone.

The south end of the pit has been cut through highly altered and fractured andesite with foliation striking N $\pm$ 30° E and dipping $\pm$ 45° SE. This andesite overlays the metasedimentary rock and forms the hanging wall of the oxide ore body.

Drill hole data from close space drilling, conducted by Transarizona, indicated that the northeast end of the ore body had been offset to the northwest on the footwall side of the NW striking fault zone.

Drilling conducted by the U. S. Bureau of Mines (2) in 1948 had encountered quartzite underlying andesite at 460 feet in hole C-2, and at 270 feet in hole C-4. In hole C-5, from 455 feet to 545 feet, copper oxides were encountered in a section described by the Bureau as a shear zone (Fig. 3).

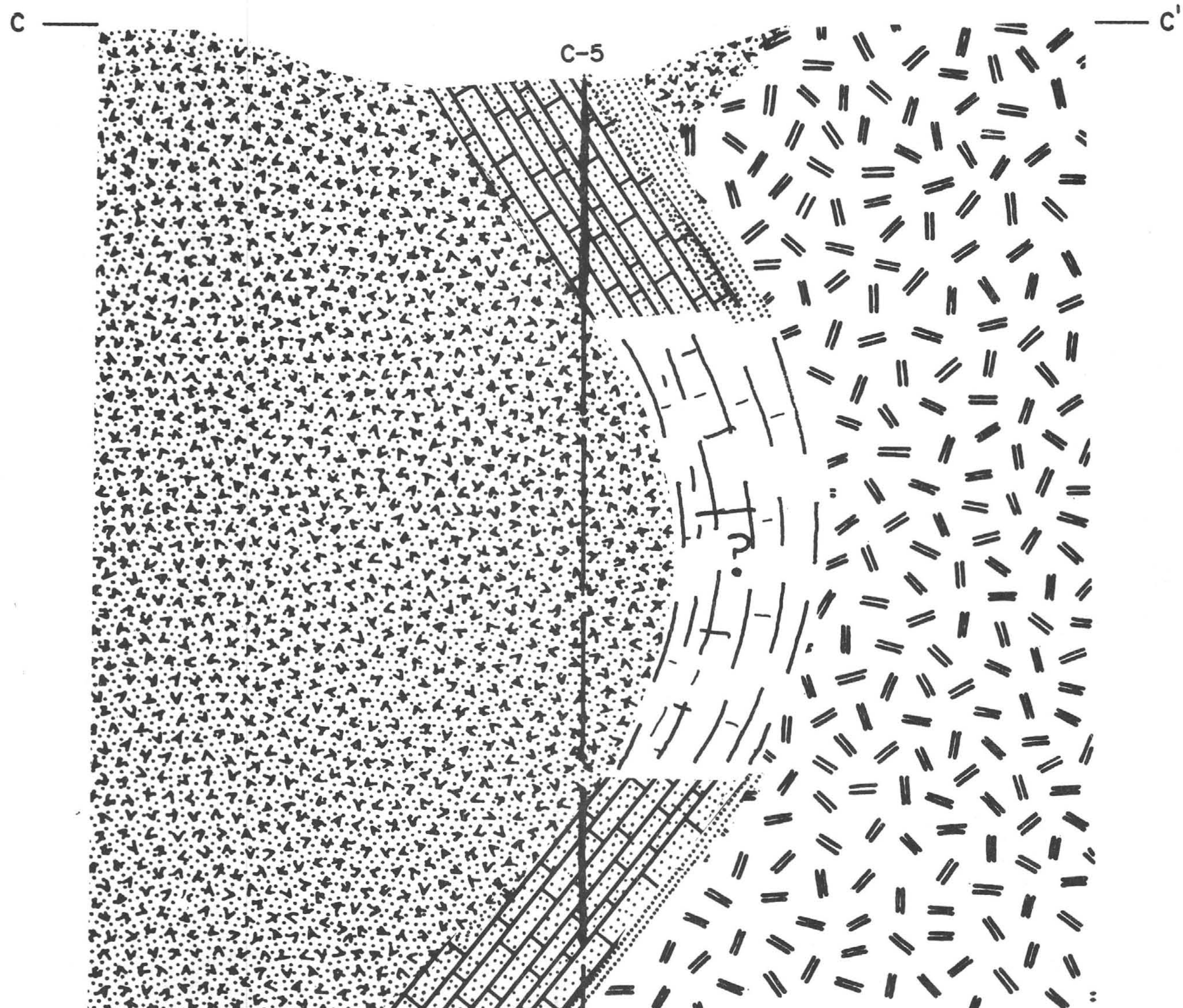
GEOPHYSICAL SURVEY

Induced Polarization Survey

During August and September of 1966, a combined resistivity and induced polarization survey was conducted on the mineral lease and the claims southwest of the Slate Mountains (Fig. 4).

A dipole-dipole electrode configuration, with 500 foot electrode spread length, was used to apply current and measure potential along parallel north-south lines, with $\pm$ 1200 foot east-west separations. Alternating current of 0.3 and 5 cycles per second were used to determine the I. P. effect. In addition to the north-south survey, an east-west survey, using shorter electrode spread lengths, was made over the Lakeshore fault system.

Fig. 3



CROSS-SECTION C-C'
LOOKING N 55 E
SCALE 1" = 100'

INTERPRETATION, BY THE WRITER, OF THE MINERALIZATION ENCOUNTERED BY THE U.S.B.M. IN CHURN DRILL HOLE No. C-5

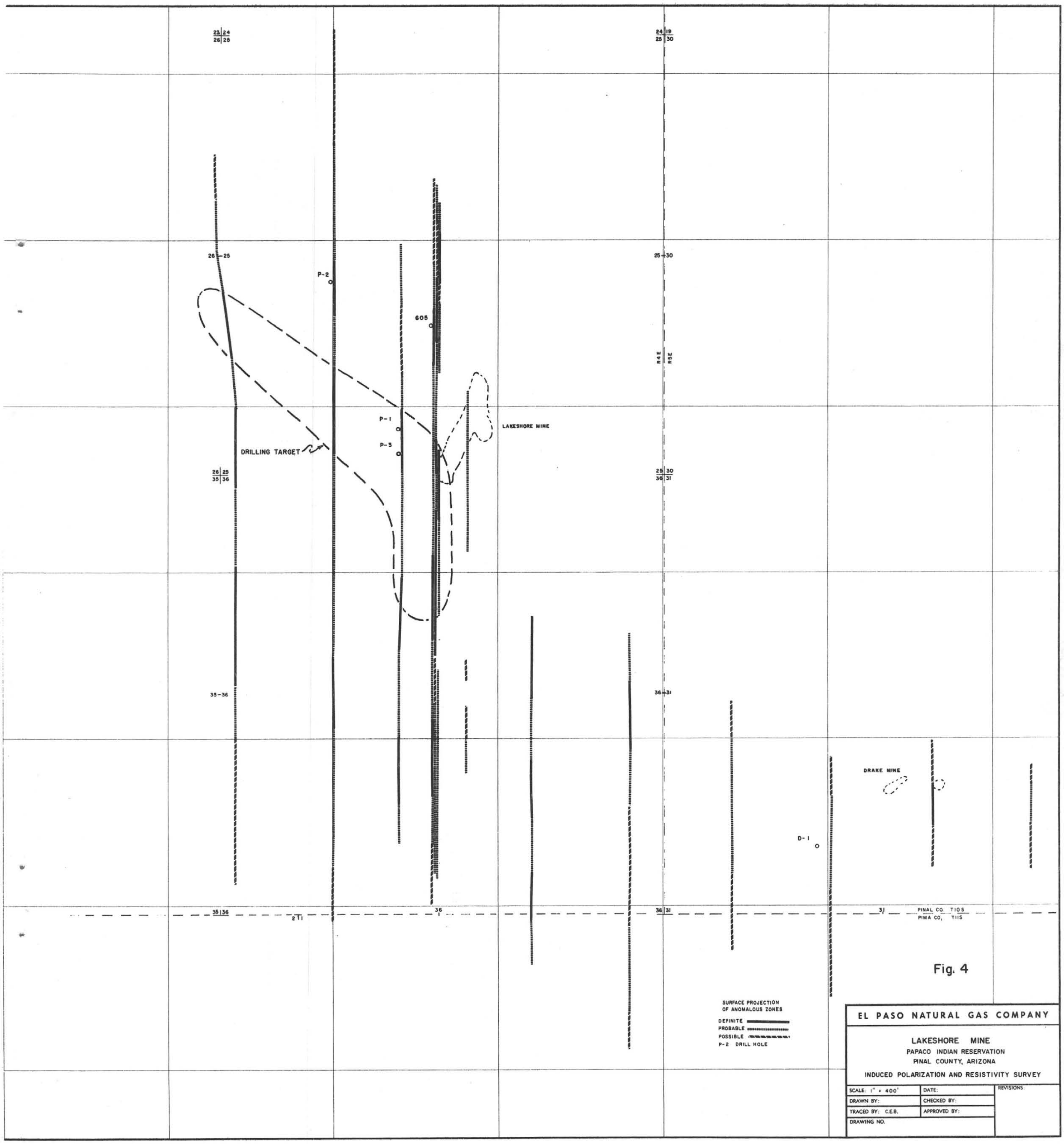


Fig. 4

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPACO INDIAN RESERVATION
PINAL COUNTY, ARIZONA

INDUCED POLARIZATION AND RESISTIVITY SURVEY

SCALE: 1" = 400'	DATE:	REVISIONS:
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TRACED BY: C.E.B.	APPROVED BY:	
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Testing I. P. Anomalies

Several I. P. anomalies were recorded along the north-south survey lines. To test the anomalies, core drilling began at locations D-1 and 605 (Fig. 4). Core hole D-1 was located in the area of a reported anomaly ± 1200 feet southwest of the Drake oxide pit. This test hole was cored for 500 feet through andesite breccia without encountering sulphide mineralization and then abandoned. Hole 605 was an old rotary drill hole which had been terminated in a weakly mineralized porphyry at a drill depth of ± 288 feet. This location was on an I. P. anomaly ± 750 feet north of the Lakeshore pit. Core drilling began at 288 feet and copper oxide mineralization was encountered along fractures in an altered biotite porphyry and in and near the contacts of the biotite porphyry and sections of altered andesite of varying thickness. This hole was anandoned at 790 feet because of drilling conditions without encountering sulphide mineralization.

With the completion of D-1 and 605, the testing of two additional I. P. anomalies began at locations P-1 and P-2 (Fig. 4). Drill hole P-2 was located on an I. P. anomaly ± 1500 feet northwest of hole 605. Core drilling was conducted through 800 feet of fanglomerate without encountering oxide or sulphide mineralization, and the hole was abandoned. The fanglomerate consisted of angular to sub-angular fragments of sedimentary and volcanic rock that was weakly cemented but did not display the prominent high-angle slickenside fracture system that had been encountered in hole 605.

At Hole P-1, located on an I. P. anomaly ± 700 feet west of the Lakeshore pit, low grade copper oxide mineralization was encountered in a fractured and altered andesite and andesite breccia. These andesites had been intruded by a few thin sill-like masses of biotite porphyry. At a drill depth of 750 feet where the drill was still in oxides, a re-evaluation of the I. P. data and a review of the geology was made.

INTERPRETATION OF GEOLOGY

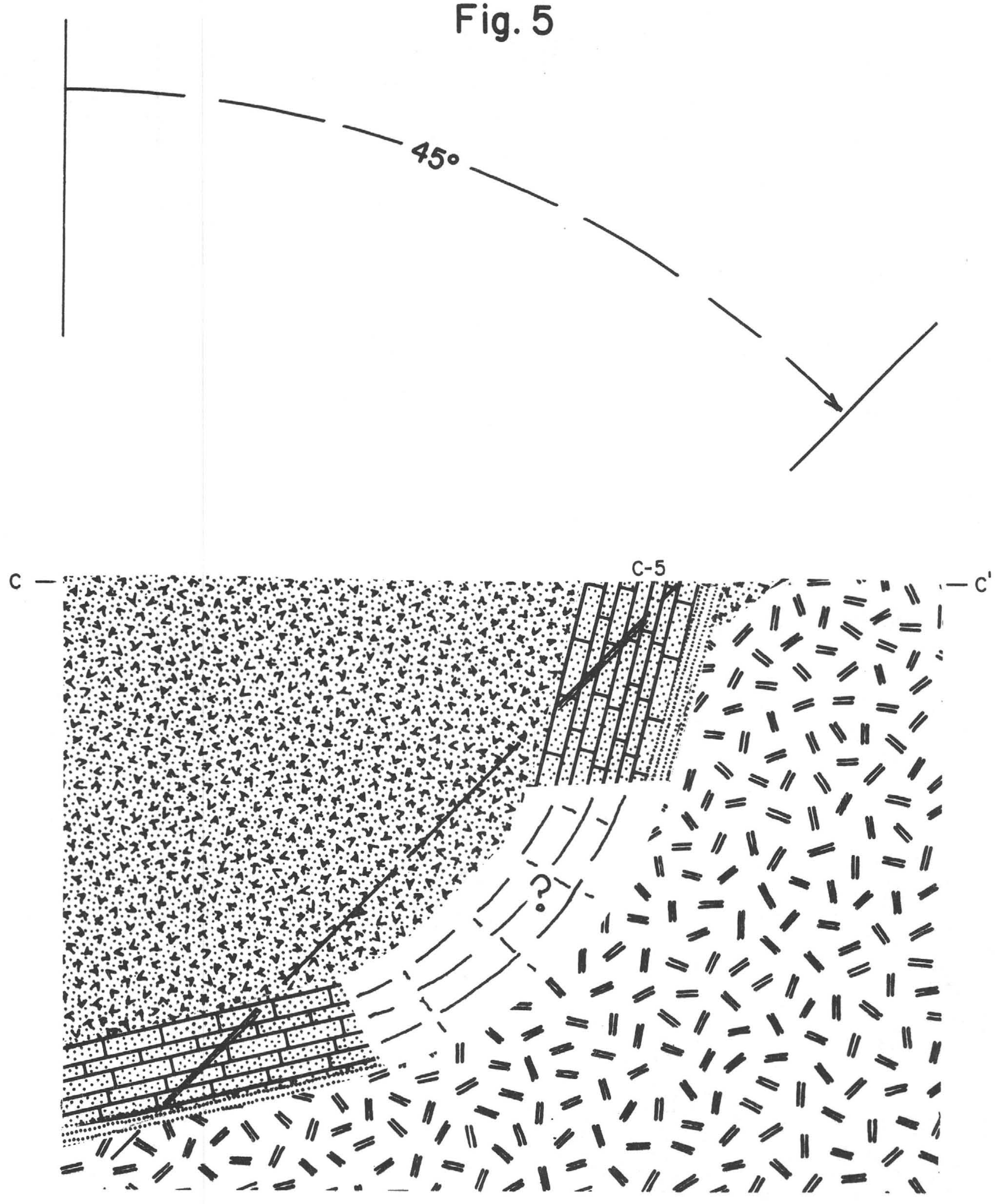
In an attempt to correlate surface geology with subsurface data obtained from core holes, the writer assumed:

(1) The andesite and breccia encountered in drill hole P-1 are extrusive and the biotite porphyry encountered in hole 605 and P-1 is younger than the andesite and younger than the biotite hornblende porphyry that has intruded the Pinal Schist to the east;

(2) The high angle slickenside fracture system encountered in hole P-1 and 605 is parallel to the fault and fracture system observed in the Lakeshore pit;

(3) The present attitude of the Cretaceous volcanic and sedimentary rocks cropping out southwest of the Slate Mountains represents the youngest structural trend in the area, and that this trend, striking N ± 50° E and dipping ± 45° NW, has been superimposed on the older structural system in the area;

Fig. 5



CROSS-SECTION C-C'
LOOKING N 55 E
SCALE 1" = 100'

ASSUMED ATITUDE OF THE METASEDIMENTS
PRIOR TO TILTING TO THE NORTHWEST

(4) If the metasediments outcropping in the Lakeshore pit were rotated about a horizontal axis trending N 50° E to a pre-45° tilt attitude, the metasediments would then be dipping steeply to the northwest and be overlaid by the andesite (Fig. 5).

(5) The mineralization, encountered by the U. S. Bureau of Mines (2) in churn drill hole C-5 at a drill depth of 455 feet to 545 feet, is the continuation down dip of the mineralized metasediments and these metasediments would continue to the northwest to underlie the andesite (Fig. 3).

In summation then, this interpretation requires that the metasediments extend down dip from the oxide outcrop and lie under the andesite to the northwest. The trend of the metasediments is controlled by the northwest trend of the Slate Mountains, the strong northwest and north-south fault and fracture system, and the intrusive. Movement of mineralized solutions were controlled by this physical environment and sulphide mineralization should be encountered at depth.

RECOMMENDED DRILLING TARGET

To try to correlate this interpretation with the indicated I. P. anomalies, the plotted anomalies extending to the south of the Lakeshore pit and the anomalies in echelon to the northwest of the pit were encircled. This enclosed an area $\pm$ 1000 feet wide extending from near the center of Section 36 north to Section 25, then northwest to the west line of Section 25 (Fig. 4). This area offered the best possible correlation of projected geology and plotted I. P. anomalies. The enclosed area was recommended as the drilling target for the Lakeshore project.

DISCOVERY OF SULPHIDE MINERALIZATION

Following the review of I. P. and geological data, the decision was made to continue drilling P-1 and preparations were made to drill an offset hole 300 feet south of hole 605. However, before a drill could be moved to this location, sulphide copper mineralization was encountered in P-1 at a depth of ± 850 feet in andesite and andesite breccia. The prepared drill location south of hole 605 was abandoned and a drill was moved to location P-3, 300 feet south of P-1. Drilling at P-1 continued to a depth of ± 1100 feet where it was abandoned because of drilling conditions.

On location P-3, drilling conditions were the same as those encountered in hole P-1. Fractured and altered andesite and andesite breccia was difficult to drill but core recovery was consistently high. Mineralization consisted of low grade copper oxide and silicate plus hematite, calcite, and gypsum occurring along fracture planes. Silification seems to be the dominate type of alteration. Andesite and breccia continued to a drill depth of 1080 feet where the drill penetrated a thick section of sericite and then entered highly altered limestone or dolomite. These altered carbonate rocks continued to a drill depth of 1147 feet.

At 1147 feet, massive magnetite with pyrite and chalcopyrite in banded tactite was encountered. This marked the discovery of sulphide mineralization in meta-sediments west of the Lakeshore pit. The mineralization continued for 90 feet and had an average assay value of 1.75% copper.

DELINEATION OF MINERALIZATION

Drilling and Recording of Data

With the encounter of sulphide mineralization in metasediments, an accelerated drilling program began. Rotary drilling was used to penetrate the andesites and breccias. When the rotary hole was completed to a pre-determined depth, casing was set and a wire line diamond drill was then moved onto the prepared location. NX size tools (2-1/8 inch core diameter) were used until drill depth or drilling conditions required the hole diameter to be reduced; then BX size tools (1-5/8 inch core diameter) were used. Average recovery of core was over 90%.

From the recovered core, the following data and observations were recorded and sketched on the logs: rock type, alterations, mineralization, amount of fracturing, angle of fracturing and pitch of the slickensides, fault breccia and gouge, and contacts of major rock type changes.

When core holes were completed, they were surveyed for drift and inclination with a multiple-shot gyroscopic survey instrument. Degree of inclination and bearing of drift were recorded on 100 foot intervals and at major contacts.

With this drill hole survey data, the assay and geological data could be plotted in both vertical and horizontal positions with a high degree of accuracy (Fig. 6).

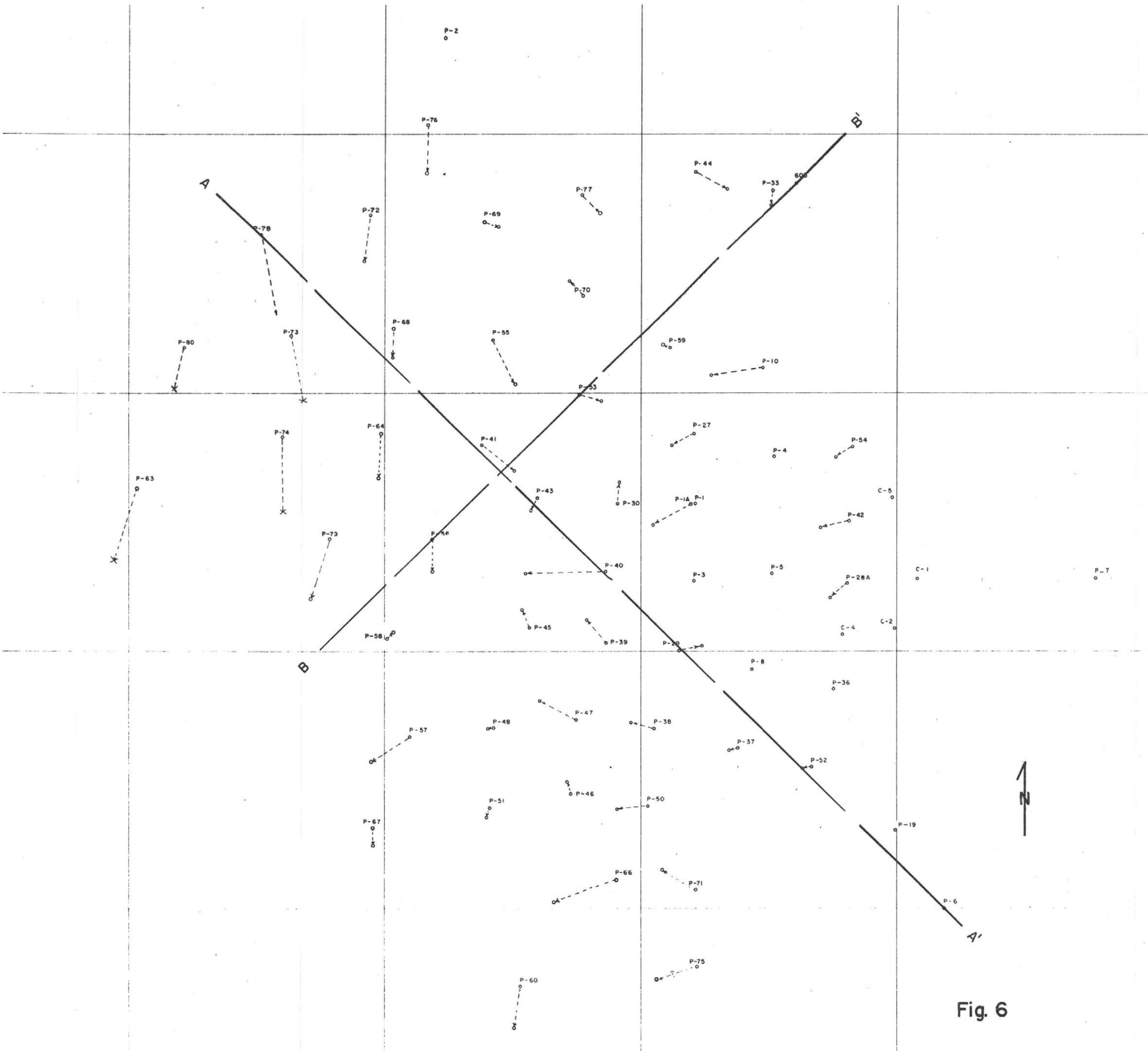


Fig. 6

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE

PAPAGO INDIAN RESERVATION

PINAL COUNTY, ARIZONA

MAGNETIC AND GYROSCOPIC DRIFT SURVEY

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
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Subsurface Mapping

To maintain control of drilling and indicate attitude and limits of assay and geological data, the following subsurface contour maps were prepared:

(1) The andesite-tactite contact

(2) The tactite-quartzite contact

(3) The quartzite-diorite contact

(4) The top and bottom of mineralization within the tactite

(5) The upper contact of the mineralized biotite porphyry

(6) The top and the lower drilling cut off of sulphide

(7) The top and bottom of oxide

(8) Base of the fanglomerate

With the above contoured data, isopach maps were drawn indicating direction and thickness of high grade oxides, sulphides, tactite, and mineralization within the tactite.

With the same contour maps, cross-sections could be drawn in any direction without regard to drift or alignment of core holes.

Interpretation of Subsurface Data

From the subsurface data, the following interpretations were made:

(1) The contours of the andesite-tactite contact form a subsurface that strikes ± north and dips ± 30° W (Fig. 7).

(2) The contours at the tactite-quartzite contact form a subsurface that strikes N ± 20° W and dips ± 20° SW, then turns to the northeast and dips to the northwest (Fig. 8). The curving contours

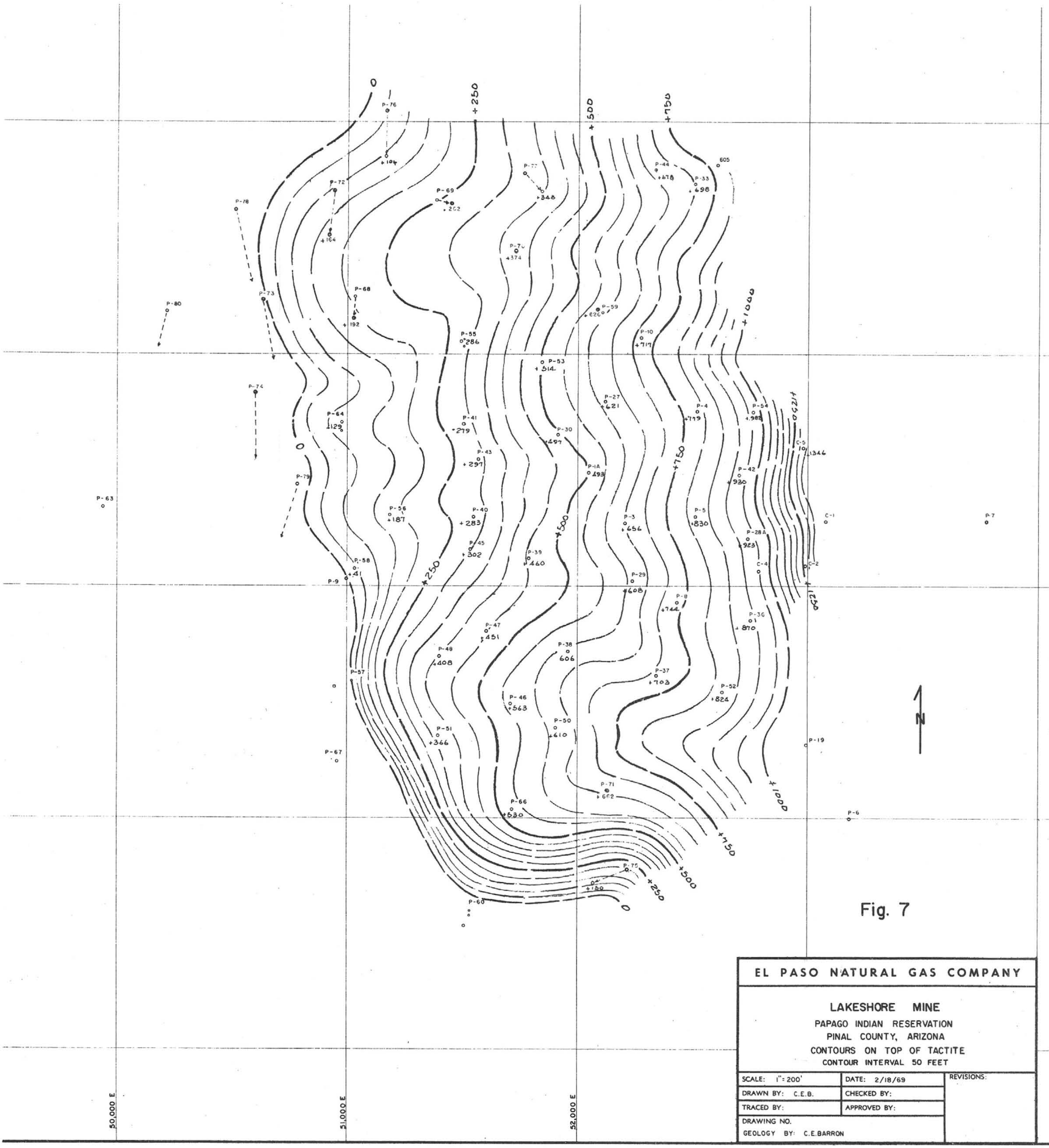

Fig. 7

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE

PAPAGO INDIAN RESERVATION

PINAL COUNTY, ARIZONA

CONTOURS ON TOP OF TACTITE

CONTOUR INTERVAL 50 FEET

SCALE: 1" = 200'	DATE: 2/18/69	REVISIONS:
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GEOLOGY BY: C.E.BARRON		

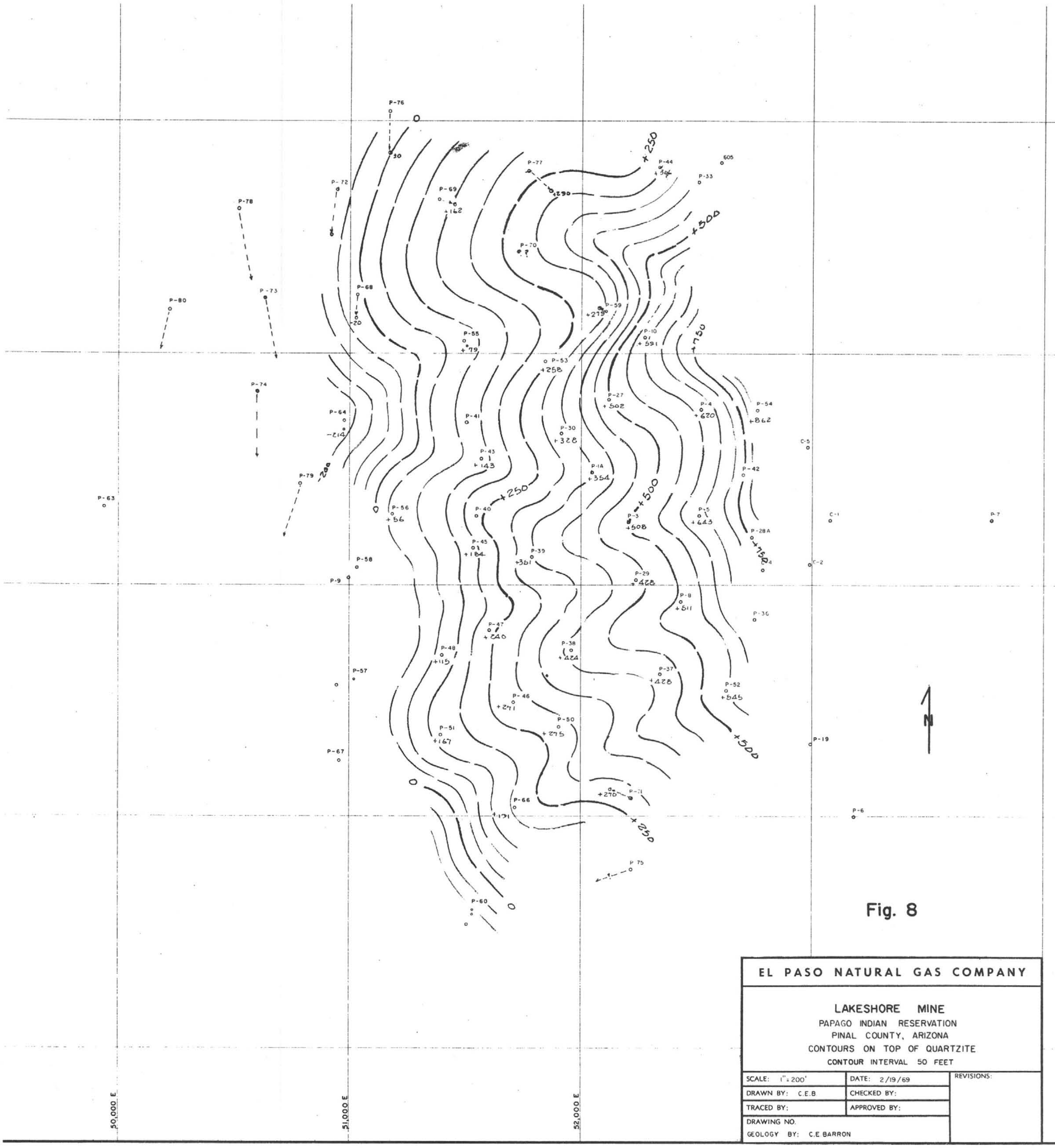

Fig. 8

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
CONTOURS ON TOP OF QUARTZITE
CONTOUR INTERVAL 50 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
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GEOLOGY BY: C.E. BARRON		

form a weakly nosing subsurface structure that plunges to the southwest. As the overlying andesite-tactite contact approaches this plunging structure, a thinning of the tactite occurs along a northeast trend and wedge-like thicknesses of tactite occur to the northwest and southeast of this zone of thinning. This thickening and thinning is best illustrated by an isopach of the tactite (Fig. 15).

(3) The more consistent thickness of mineralization, within the tactite, occurs in the wedge-like thickness southeast of the zone of thinning. Contours on the top and bottom of this mineralized thickness conform with the N 20 W strike and 20° SW dip of the underlying quartzite. The line of intersection of this mineralization with the overlying andesite trends NE and plunges SW, and terminates this thickness of mineralization in the zone of thinning. To the south and southeast of the zone of thinning, an increasing thickness of massive garnet and epidote occurs over the mineralization, and the mineralized horizon is divided into an upper and lower mineral thickness by an interbedded, fine-grained quartzite. Underlying this sulphide mineralization, a black and gray banded tactite is in contact with the underlying quartzite. This sequence of metasediments, which has been intruded by diabase and biotite porphyry, continues to the south and southeast until it has apparently been displaced by a major fault that trends N $\pm$ 20 W.

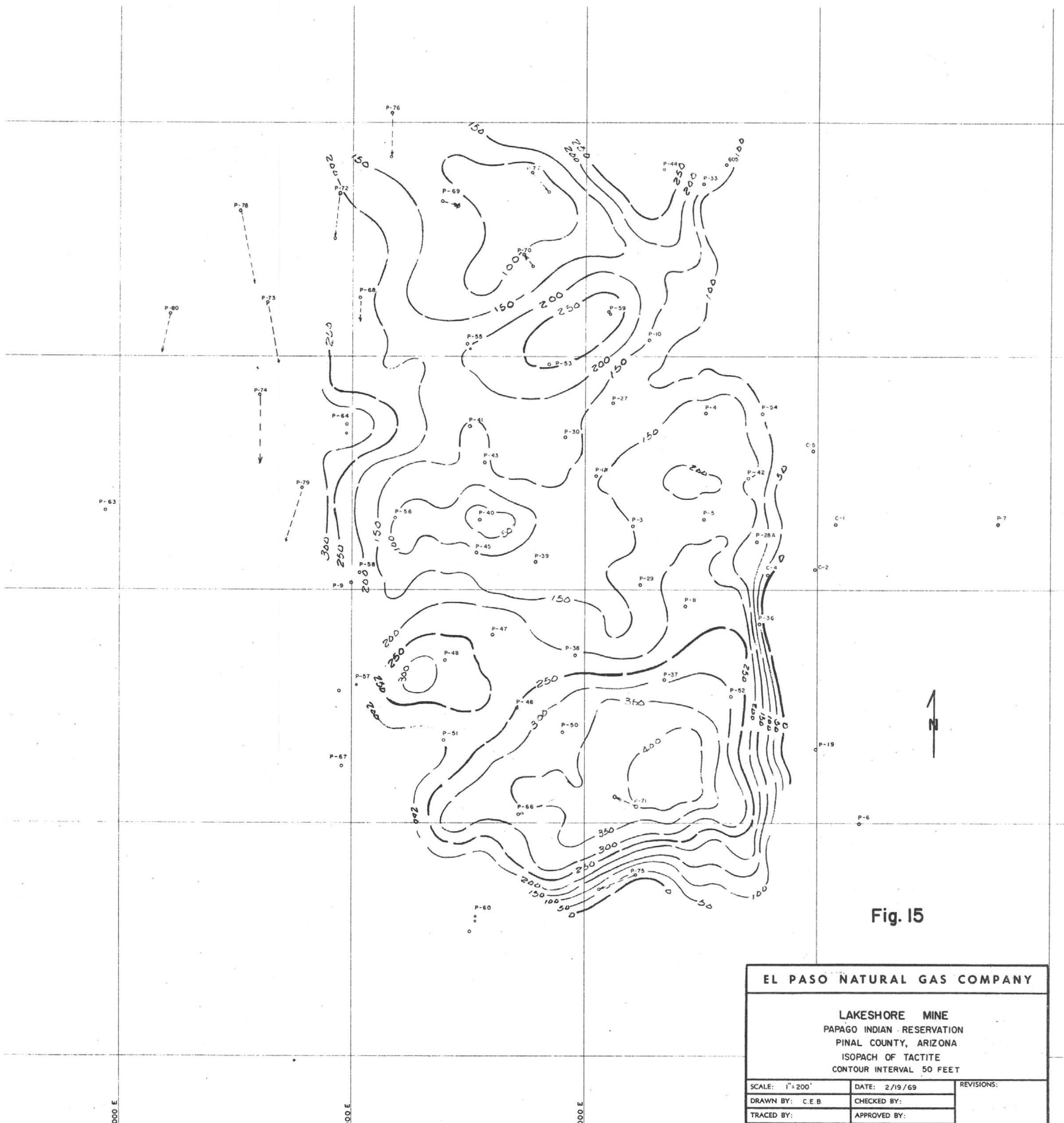

Fig. 15

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
ISOPACH OF TACTITE
CONTOUR INTERVAL 50 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
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DRAWING NO.		
GEOLOGY BY: C.E.BARRON		

(4) To the east the metasediments are in contact with the diorite. Contours on this contact form a north trending subsurface that dips ± 60° W (Fig. 9).

(5) To the west the metasediments have been intruded by the biotite porphyry along a northeast trending contact zone. Along this contact zone the intrusive forms sills of irregular masses that occur in both the metasediments and the andesite. Better grade mineralization occurs along this zone of multiple sills (Fig. 16).

(6) Northwest of this contact zone the stock-like intrusive forms a more homogenous emplacement within the andesite but continues to form sills within the metasediments. Further to the northwest, the intrusive again forms a contact zone of multiple sills within the andesite (Fig. 16).

(7) Contours on top of the oxidized intrusive trend N 55 E and form a ± 40° slope along the northwest side (Fig. 10). On the southeast side the contours indicate a much steeper slope, and to the southwest, the intrusive apparently has been displaced in this horizon by a high angle normal fault that strikes ± N 20 W. Limits of the intrusive have not been determined to the north and northeast.

(8) Contours on top of the oxide mineralization form an irregular horizon in the subsurface west of the Lakeshore pit; then this horizon forms a northwestern dip and passes through the top of the mineralized intrusive. As the oxide zone passes through the

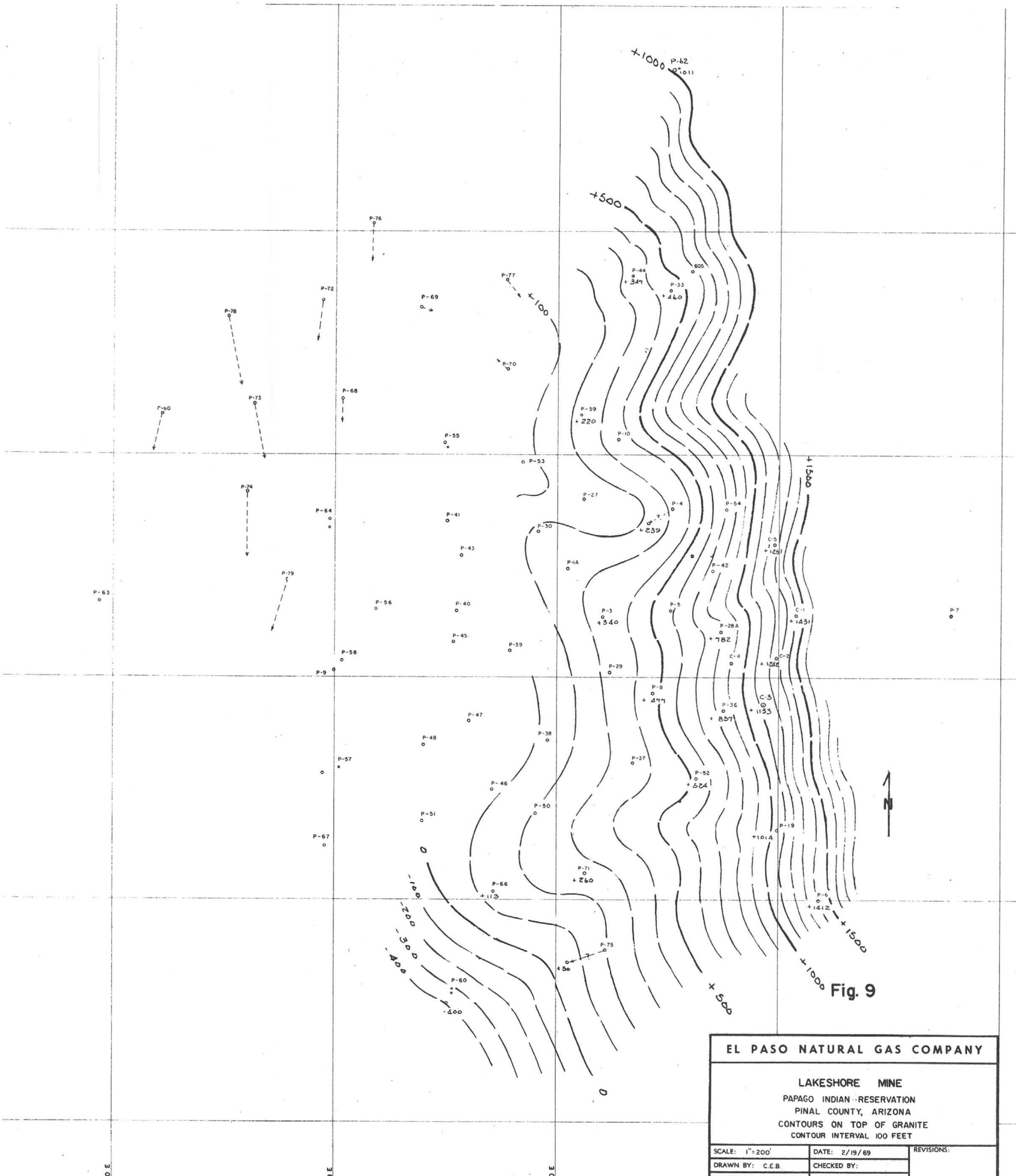

Fig. 9

EL PASO NATURAL GAS COMPANY		
LAKESHORE MINE PAPAGO INDIAN RESERVATION PINAL COUNTY, ARIZONA CONTOURS ON TOP OF GRANITE CONTOUR INTERVAL 100 FEET		
SCALE: 1"=200'	DATE: 2/19/69	REVISIONS:
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GEOLOGY BY: C.E.BARRON		

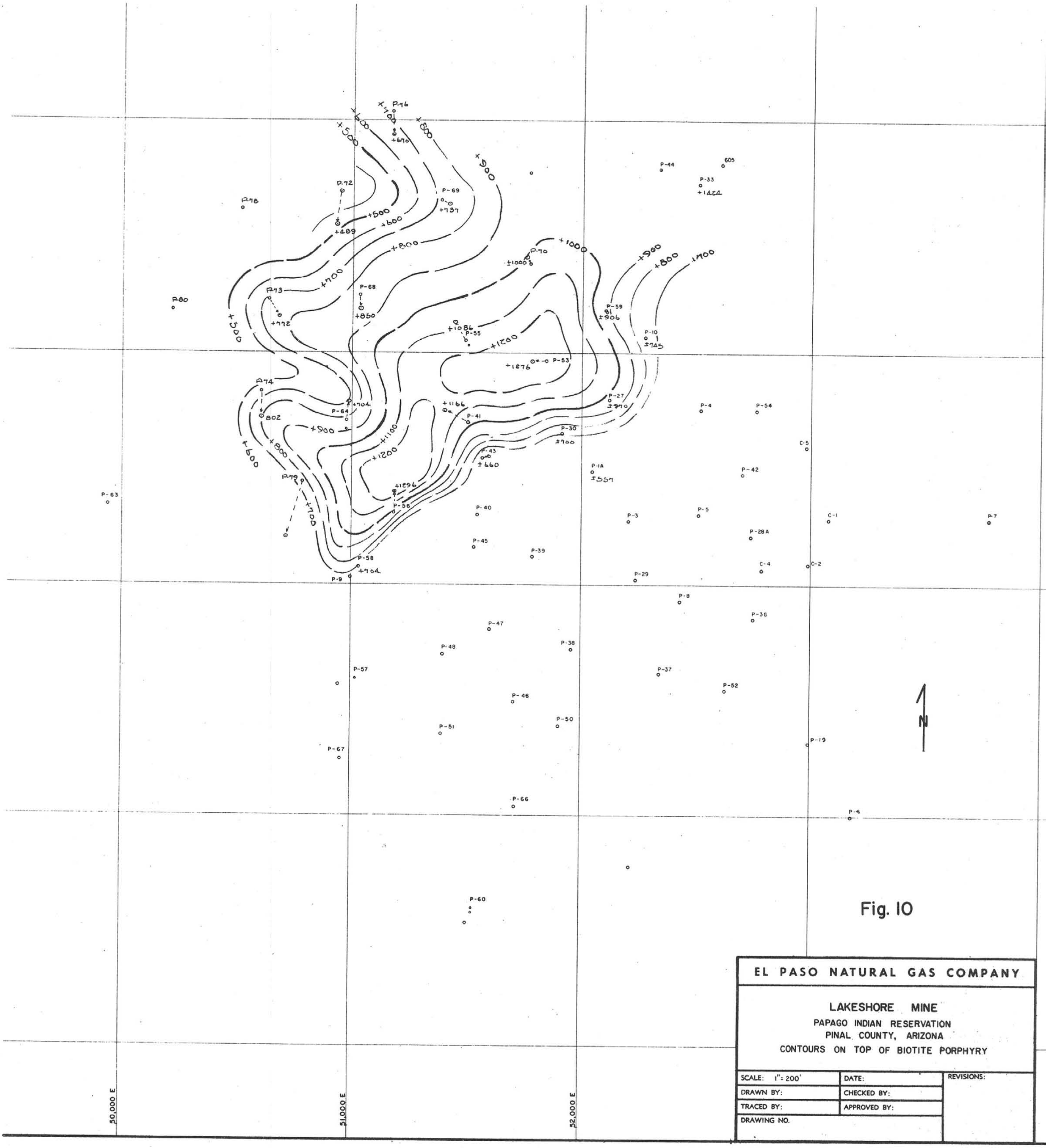

Fig. 10

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
CONTOURS ON TOP OF BIOTITE PORPHYRY

SCALE: 1" = 200'	DATE:	REVISIONS:
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upper part of the intrusive, a ± 100 foot thick blanket of ± 1.5% copper oxide mineralization occurs at the base of the oxides. This mineralization trends to the northeast along the top of the intrusive and dips to the northwest. As the dip of the oxide mineralization increases to the northwest, the high grade oxide mineralization thins and a zone of chalcocite has formed an enriched upper thickness of sulphide mineralization (Fig. 11).

(9) Contours at the top of sulphide mineralization form a low trough that plunges to the southwest along the southeast flank of the biotite porphyry intrusive. This oxide-sulphide transition horizon then climbs to its highest elevation within the top of the intrusive and forms a northeast trend that dips to the NW. To the southwest the contours turn sharply to the northwest or southeast and form a N ± 20° W trending horizon that dips ± 70° SW (Fig. 12).

(10) The isopach of the sulphides indicates a wedge-like thickness of mineralization. The thin edge, ± 300 feet thick, occurs along the northeast trending contact zone of the intrusive and the metasediments. To the northwest of this contact zone and along the apparent fault zone, the mineralized zone thickens to over 1000 feet. Some core holes in this zone have an average assay value of .85% copper for 1000 feet of recovered core. The limits of mineralization to the northwest and north of this area have not been determined (Fig. 14).

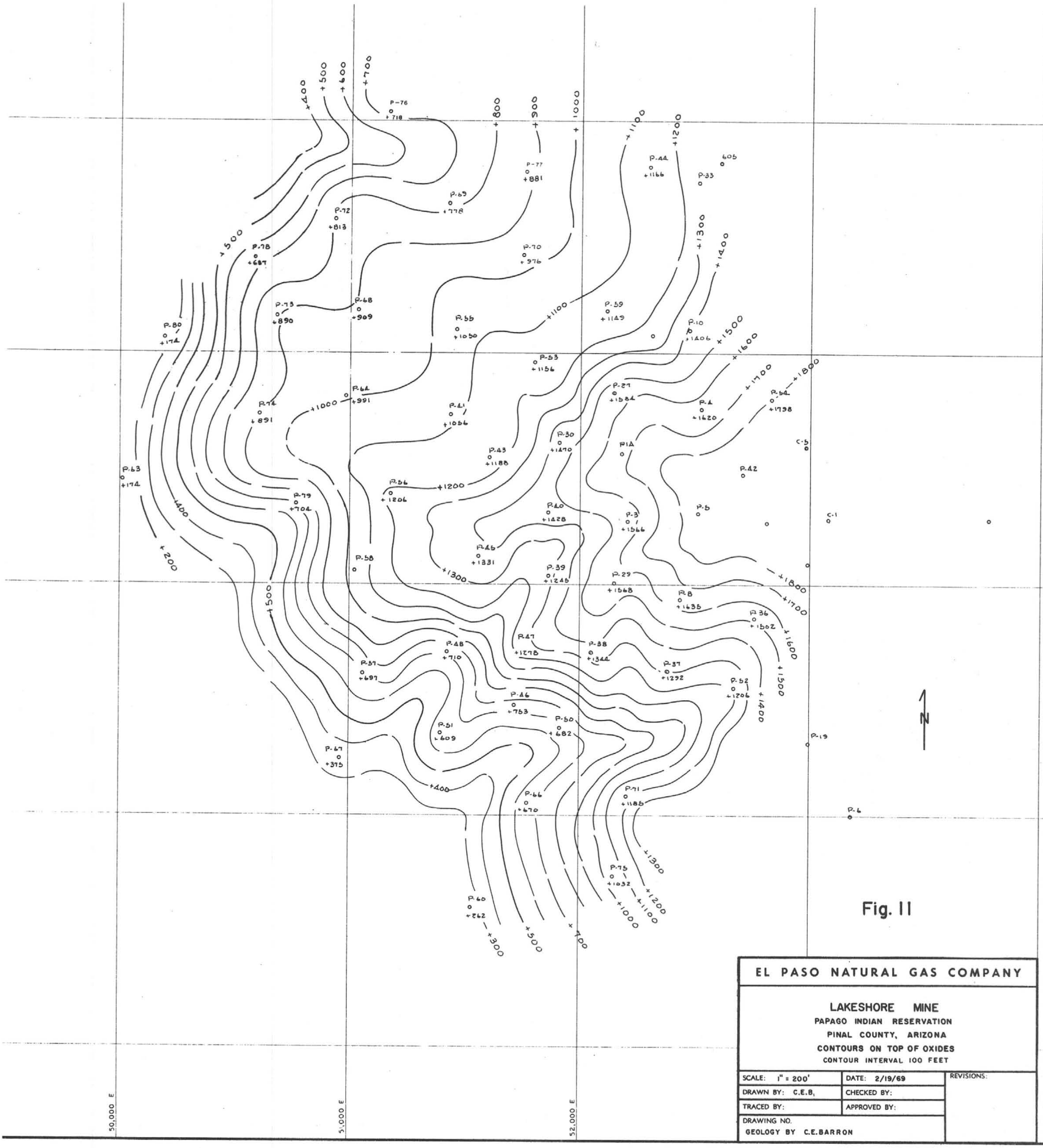


Fig. 11

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
CONTOURS ON TOP OF OXIDES
CONTOUR INTERVAL 100 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
DRAWN BY: C.E.B.	CHECKED BY:	
TRACED BY:	APPROVED BY:	
DRAWING NO. GEOLOGY BY C.E.BARRON		

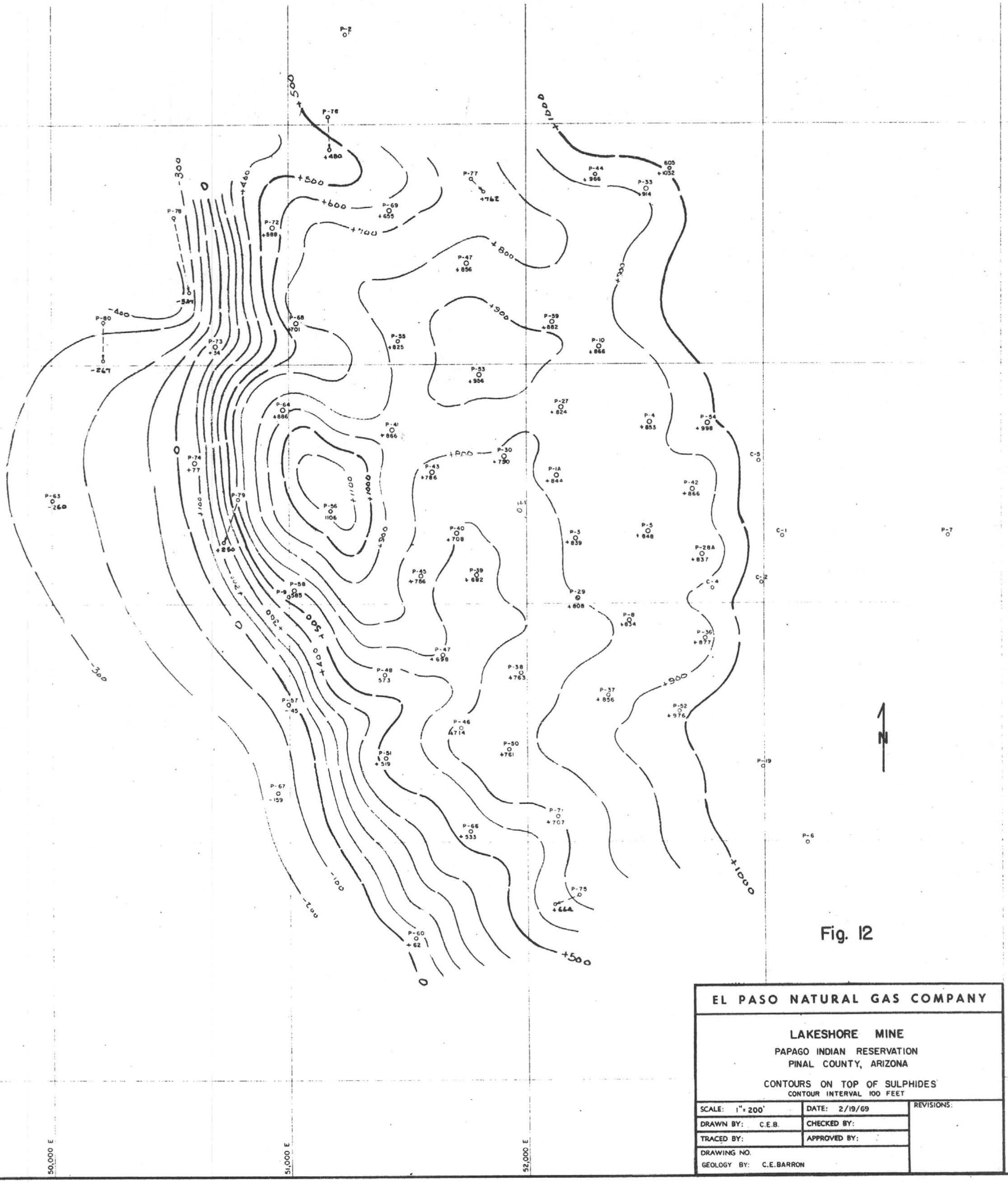


Fig. 12

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE

PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA

CONTOURS ON TOP OF SULPHIDES
CONTOUR INTERVAL 100 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
DRAWN BY: C.E.B.	CHECKED BY:	
TRACED BY:	APPROVED BY:	
DRAWING NO.		
GEOLOGY BY: C.E.BARRON		

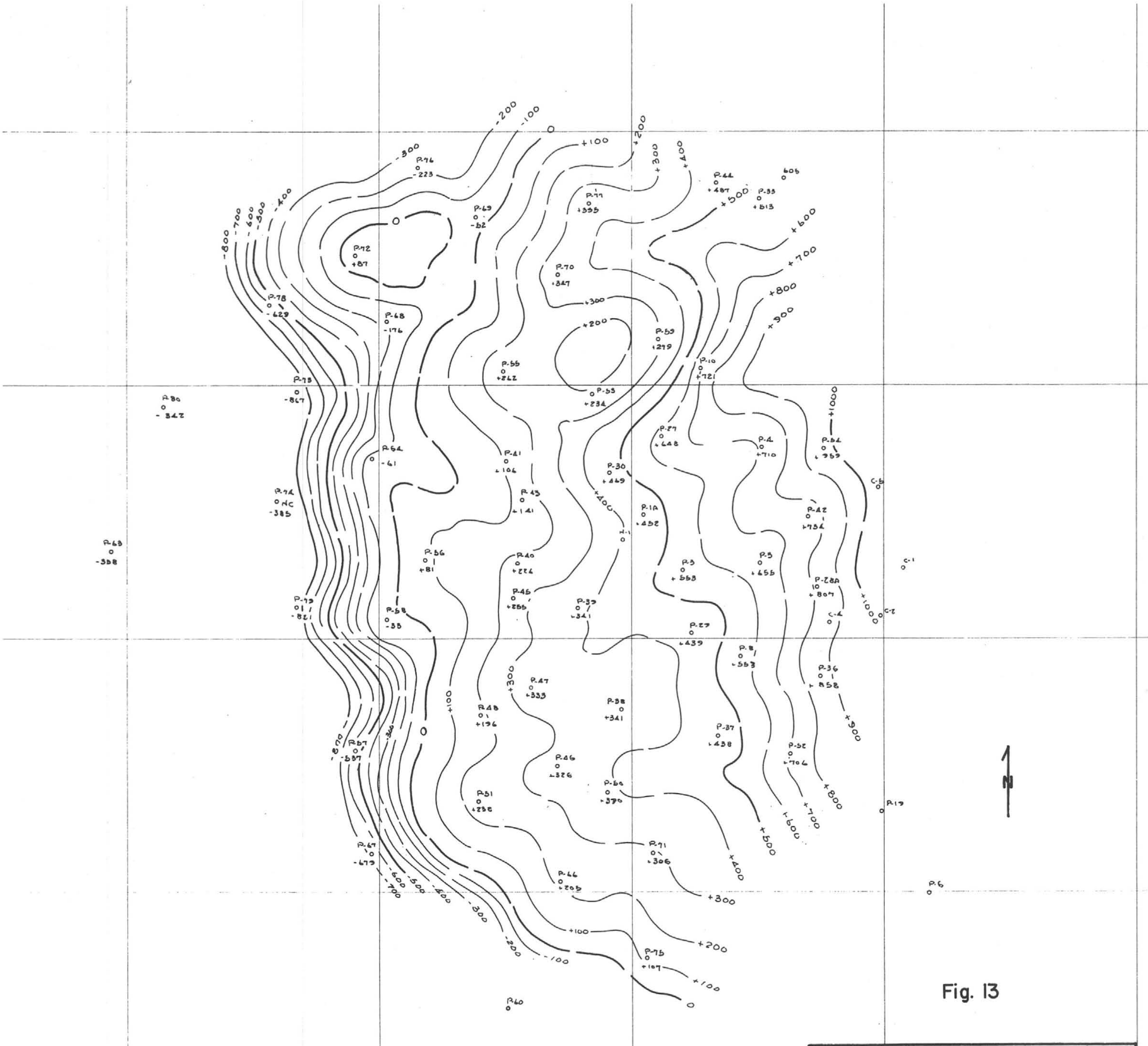


Fig. 13

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE

PAPAGO INDIAN RESERVATION

PINAL COUNTY, ARIZONA

CONTOURS AT LOWER SULPHIDE CUT-OFF

CONTOUR INTERVAL 100 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
DRAWN BY: C.E.B.	CHECKED BY:	
TRACED BY:	APPROVED BY:	
DRAWING NO. GEOLOGY BY C.E.BARRON		

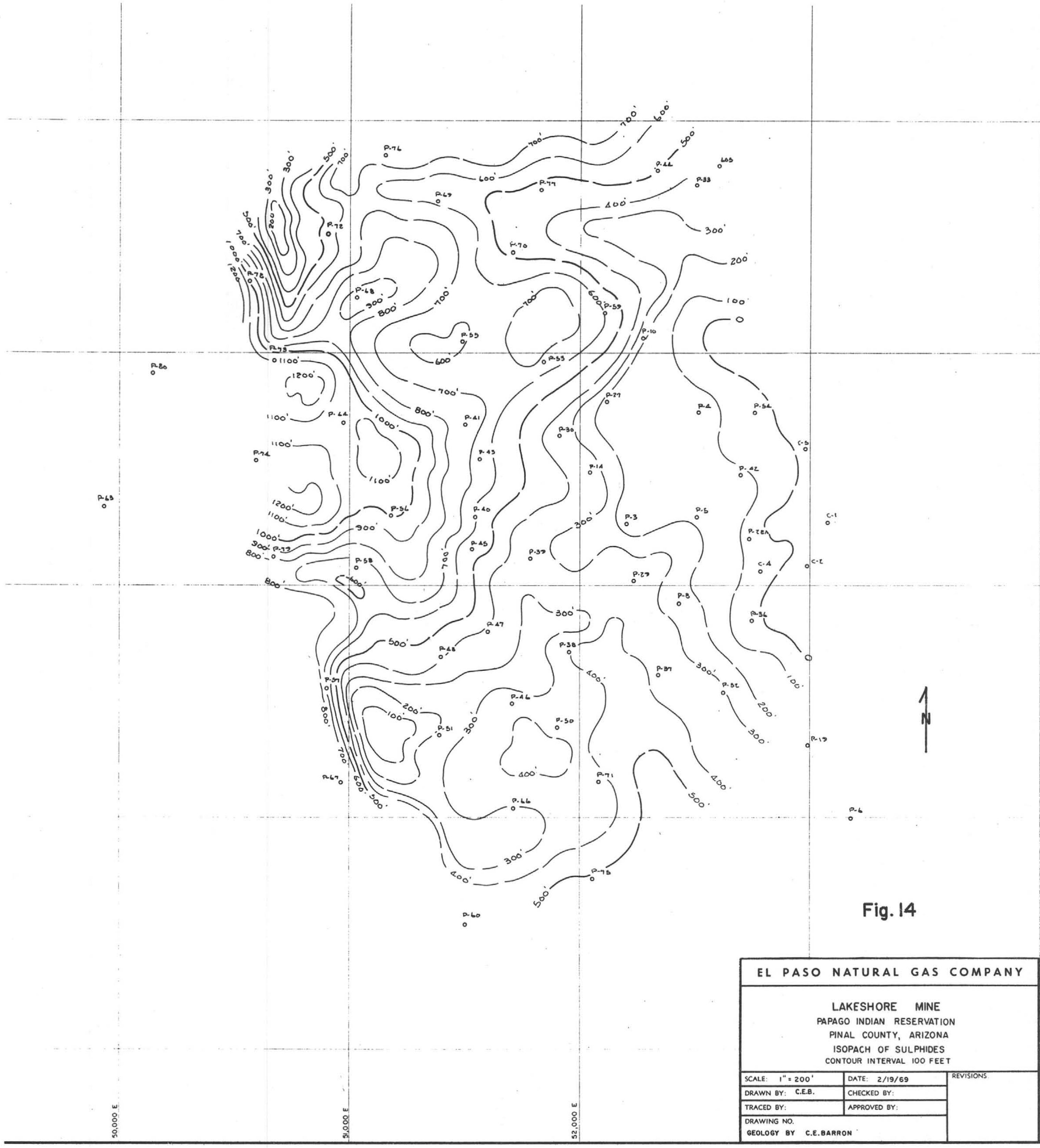


Fig. 14

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
ISOPACH OF SULPHIDES
CONTOUR INTERVAL 100 FEET

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS
DRAWN BY: C.E.B.	CHECKED BY:	
TRACED BY:	APPROVED BY:	
DRAWING NO.		
GEOLOGY BY C.E.BARRON		

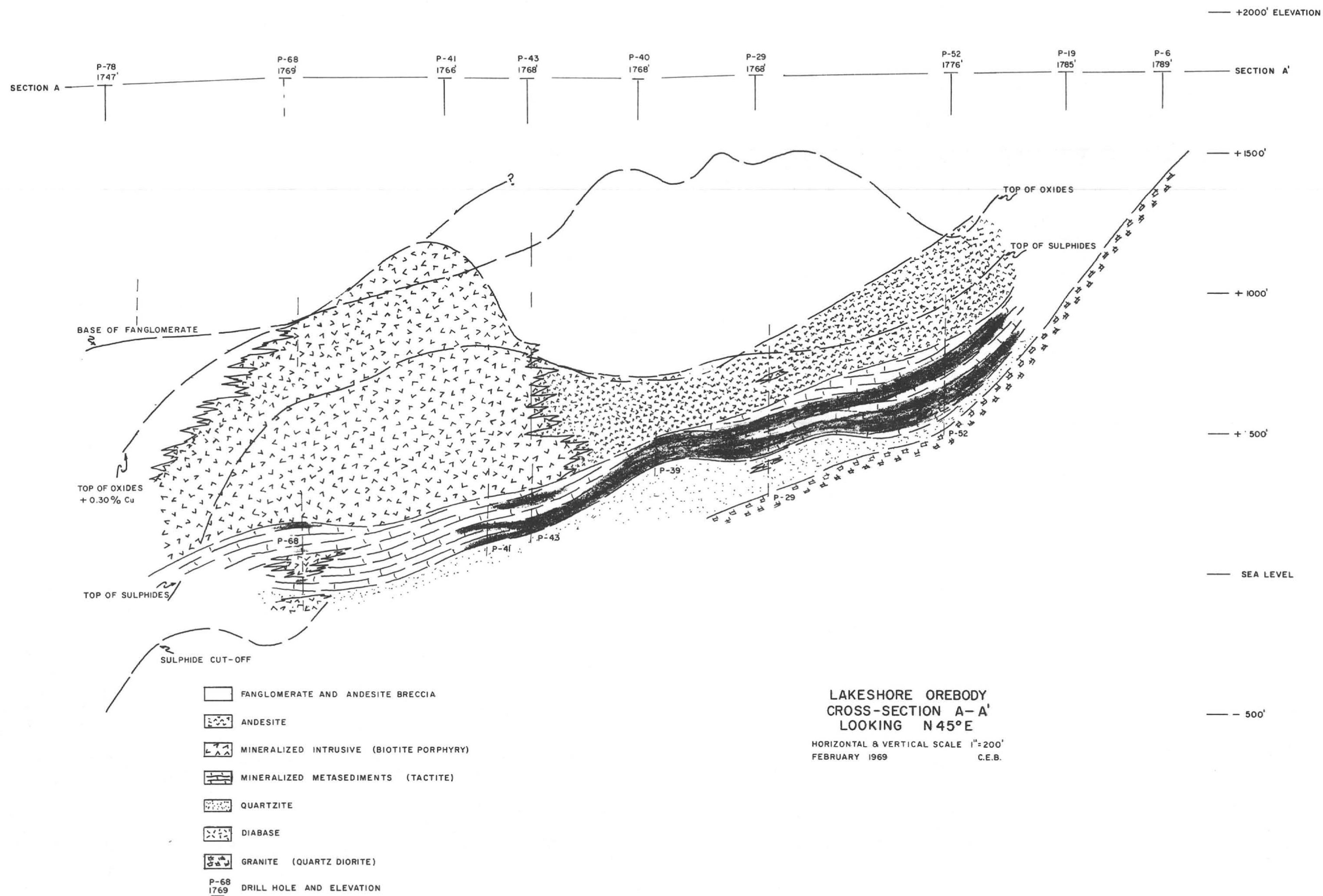
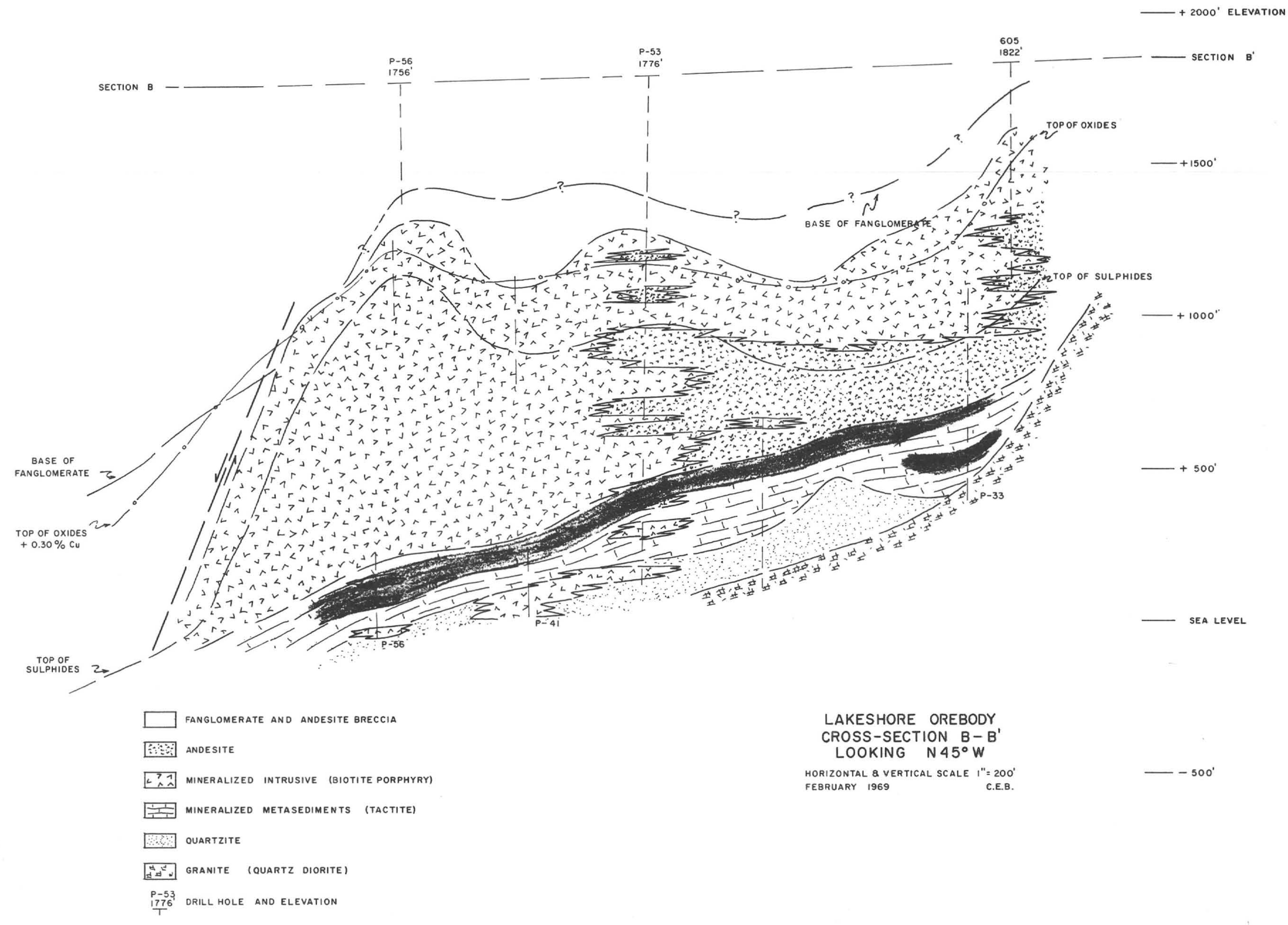

+2000' ELEVATION
SECTION A
SECTION A'
P-78 1747'
P-68 1769'
P-41 1766'
P-43 1768'
P-40 1768'
P-29 1768'
P-52 1776'
P-19 1785'
P-6 1789'
+ 1500'
+ 1000'
+ 500'
SEA LEVEL
- 500'
TOP OF OXIDES
TOP OF SULPHIDES
BASE OF FANGLOMERATE
TOP OF OXIDES + 0.30% Cu
TOP OF SULPHIDES
SULPHIDE CUT-OFF
P-39
P-52
P-29
P-43
P-41
P-68
FANGLOMERATE AND ANDESITE BRECCIA
ANDESITE
MINERALIZED INTRUSIVE (BIOTITE PORPHYRY)
MINERALIZED METASEDIMENTS (TACTITE)
QUARTZITE
DIABASE
GRANITE (QUARTZ DIORITE)
P-68 1769 DRILL HOLE AND ELEVATION
LAKESHORE OREBODY
CROSS-SECTION A-A'
LOOKING N45°E
HORIZONTAL & VERTICAL SCALE 1"=200'
FEBRUARY 1969
C.E.B.

Fig. 16



+ 2000' ELEVATION
SECTION B
SECTION B'
P-56
1756'
P-53
1776'
605
1822'
TOP OF OXIDES
+1500'
BASE OF FANGLOMERATE
TOP OF SULPHIDES
+ 1000'
+ 500'
P-33
P-41
P-56
SEA LEVEL
- 500'
BASE OF FANGLOMERATE
TOP OF OXIDES + 0.30 % Cu
TOP OF SULPHIDES
FANGLOMERATE AND ANDESITE BRECCIA
ANDESITE
MINERALIZED INTRUSIVE (BIOTITE PORPHYRY)
MINERALIZED METASEDIMENTS (TACTITE)
QUARTZITE
GRANITE (QUARTZ DIORITE)
P-53
1776'
DRILL HOLE AND ELEVATION
LAKESHORE OREBODY
CROSS-SECTION B-B'
LOOKING N45°W
HORIZONTAL & VERTICAL SCALE 1" = 200'
FEBRUARY 1969
C.E.B.

Fig. 17

(11) Overlying the highly fractured and altered andesite, biotite porphyry and tactite is a relatively unfractured, weakly cemented fanglomerate that thickens from $\pm$ 100 feet at the edge of the valley to $\pm$ 1500 feet around the southwest end of the biotite porphyry and is apparently in contact with the altered and oxidized top of this intrusive.

In summation, the geological data indicates the occurrence of mineralization at Lakeshore to be the result of the emplacement of a weakly mineralized biotite porphyry. This stock-like mass formed a multiple sill contact with eroded and deformed metasediments and the overlying andesites and breccia. The processes of contact metamorphism formed tactite or skarn in the metasediments and a higher grade of sulphide mineralization was deposited in the more favorable carbonates. Post-mineral faulting and fracturing formed channels for erosion, leaching, and enrichment of mineralization. This mineral deposit was tilted to the northwest and underwent a second period of erosion and oxidization. This oxidized and fractured surface was then buried by the present overlying fanglomerate (Fig. 17).

COMPUTER EVALUATION

During March and April of 1968, a computer evaluation of the assay and geological data from 23 core holes was performed by an independent consultant (7). This evaluation provided the following information:

(1) Ore reserves, tonnage and grade of the sulphide and oxide mineralization for various cut-off grades and thicknesses;

(2) Level plans at various vertical intervals showing contours of sulphide copper values;

(3) Vertical cross-sections of the sulphide copper values;

(4) A confidence interval analysis to determine future drilling requirements; and

(5) A financial analysis based on ore reserves of varying cut off grades, and the following parameters - mining cost and mining methods, concentrator capacity and recovery, metal prices, capital requirements and financing, royalty, sales agreements, and taxation.

In May 1968, ore reserves based on assay and geological data from 23 holes was reported as follows:

1. Tactite reserves, based on a cut-off grade of 0.75% copper, were 13.7 million tons with an average grade of 1.84% copper.
2. Porphyry reserves including tactite, based on a cut-off grade of 0.50% copper, were 59 million tons with an average grade of 0.99% copper.

During September 1968, the assay and geological data was again submitted to an independent consultant (8) for computer evaluation. The following reserves were reported:

1. Porphyry reserves based on mineralization with a thickness greater than 200 feet and a cut-off grade of 0.50% copper were 86 million tons with an average grade of 0.81% copper. This included tactite material lying under the porphyry.

2. Tactite reserves, outside the porphyry area and with a cut-off grade of 1.00% copper, were 10 million tons with an average grade of 1.73% copper.

In November 1968, with the data from 42 core holes, the following up-dated ore reserves, classified as a total of proved and probable, were reported:

1. Porphyry reserves based on mineralization with a thickness greater than 200 feet and a cut-off grade of 0.50% copper, were 132.0 million tons with an average grade of 0.81% copper. This included 9 million tons of tactite material lying under the porphyry.

2. Tactite reserves, outside the porphyry area and with a cut-off grade of 1.00% copper, were 10 million tons with an average grade of 1.73% copper.

3. Oxide reserves, based on a cut-off grade of 0.50% copper, were 85 million tons with an average grade of 0.81% copper.

On February 7, 1969, with data from 51 core holes, the following ore reserves classified as a total of proved and probable, were reported:

1. Porphyry reserves, based on a cut-off grade of 0.40% copper, were 241 million tons with an average grade of 0.70% copper.

2. Tactite reserves, based on a cut-off grade of 1.00% copper, were 24 million tons with an average grade of 1.69% copper.

3. Oxide reserves, based on a cut-off grade of 0.40% copper, were 207 million tons with an average grade of 0.71% copper.

CONCLUSION

In the opinion of the writer, the discovery of sulphide mineralization at Lakeshore was the result of a successful interpretation of combined geologic and geophysical data. The rotation of the mineralized metasediments to an assumed pre-tilt attitude gave a reason for projecting these metasediments to the northwest. The I. P. anomalies were correlated with this assumed northwest projection.

At the end of this phase of the exploration program, the majority of mineralized core holes have been collared within or near the limits of the proposed drilling target (Fig. 18). The interpretation that assumed overturning of metasediments by tilting to the northwest has been strengthened by three core holes which were collared in the oxide ore body and again entered mineralized metasediments at depth after penetrating the andesites. The discovery of the mineralized tactite led to the discovery of sulphide mineralization in the biotite porphyry intrusive and a "porphyry copper" deposit.

The gyroscopic drift survey of drill holes accurately located the subsurface position of the assay and geologic data that was obtained from the diamond drill cores, and gave the necessary vertical and horizontal control for the preparation of subsurface maps and cross sections and for computer evaluation of the mineral deposit.

Computer evaluation proved to be an efficient and rapid method of obtaining and updating grade and tonnage estimates during the exploration program.

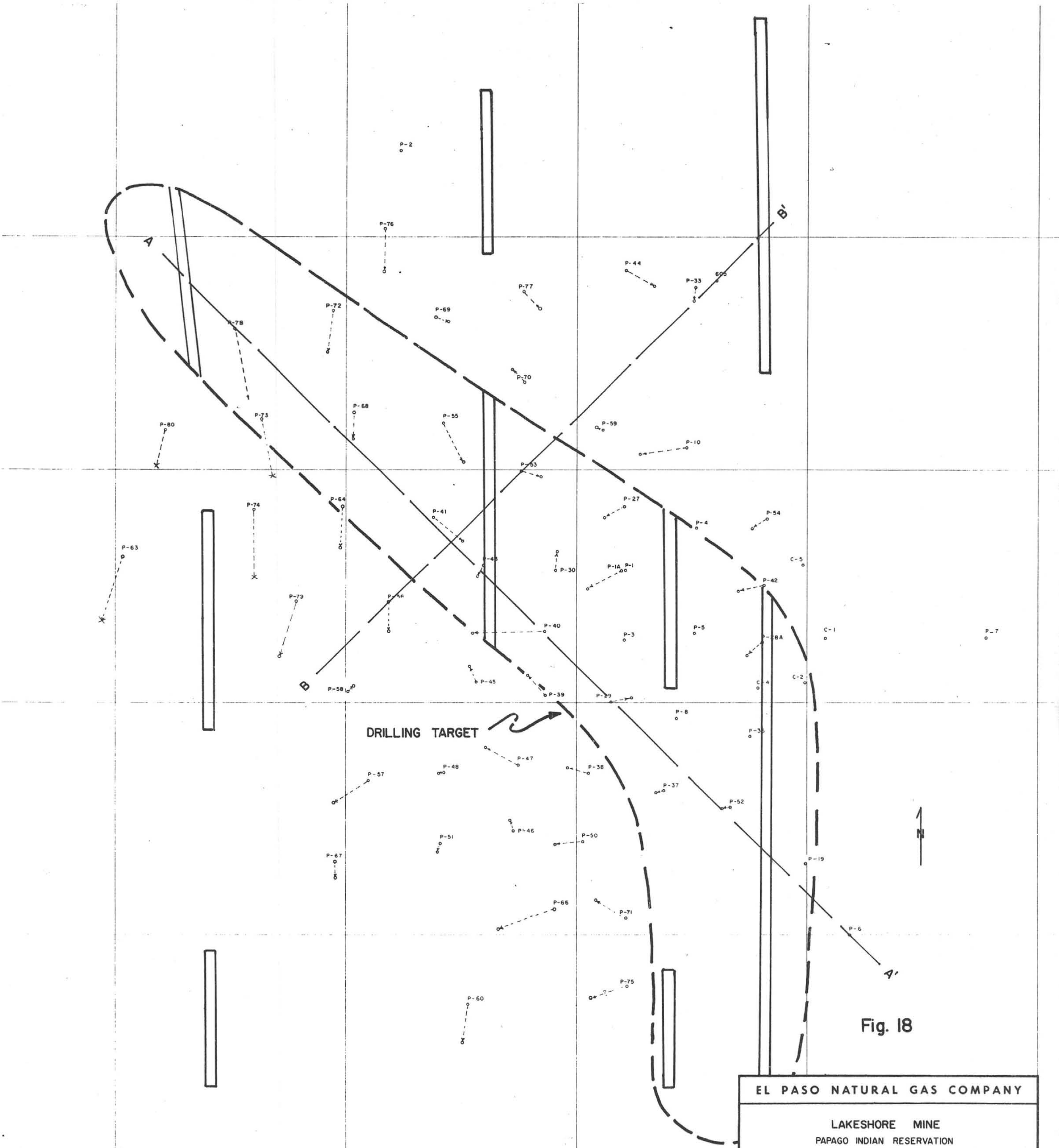


Fig. 18

EL PASO NATURAL GAS COMPANY

LAKESHORE MINE
PAPAGO INDIAN RESERVATION
PINAL COUNTY, ARIZONA
MAGNETIC AND GYROSCOPIC DRIFT SURVEY

SCALE: 1" = 200'	DATE: 2/19/69	REVISIONS:
DRAWN BY: C.E.B.	CHECKED BY:	
TRACED BY:	APPROVED BY:	
DRAWING NO.		

ACKNOWLEDGMENTS

The author wishes to thank the members of the Mining Division of El Paso Natural Gas Company for helpful comments and criticism on the paper; and is grateful to Doctors W. S. Strain and Earl M. P. Lovejoy of the Geology Department, University of Texas at El Paso, for reading the paper and suggesting improvements.

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(2) United States Bureau of Mines, Report of Investigations, 4706, 1950.

(3) McClymonds, N. E., 1959, Precambrian and Paleozoic Sedimentary Rocks on the Papago Indian Reservation, Arizona. Arizona Geologic Society, Guidebook II, pp. 77-84.

(4) Geologic Maps, prepared by the Arizona Bureau of Mines, University of Arizona, 1960.

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(6) Damon, P. E. and Mauger, R. L.: Epeirogeny - Orogeny View from Basin and Range Province, reprinted from Transactions of SME, March 1966, Vol. 235.

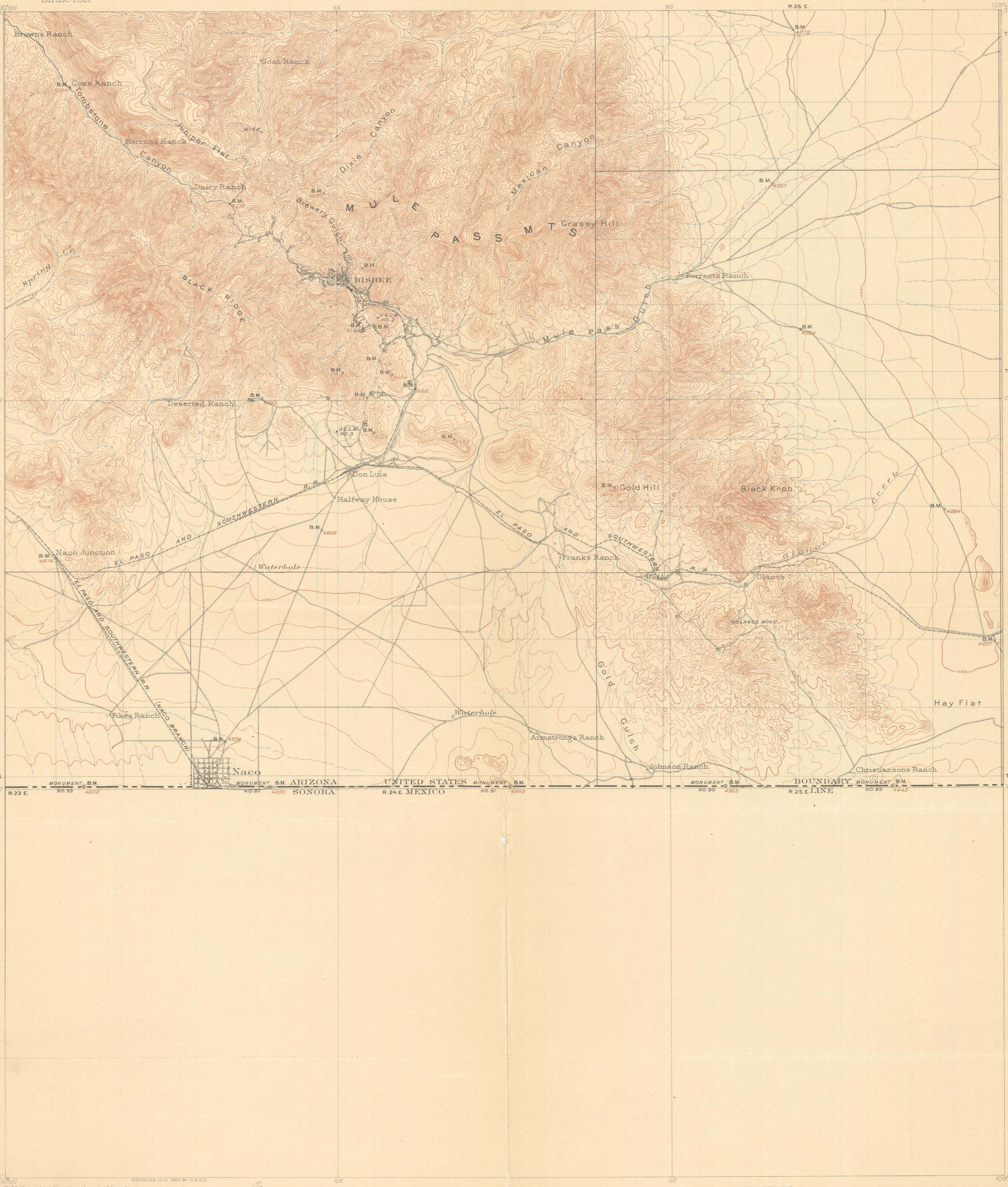
(7) Richard F. Hewlett and Associates, Computer Applications Consultants, Tucson, Arizona.

(8) Systems Development Division of Computech Research, Ltd., Tucson, Arizona.

U.S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT
DIRECTOR

TOPOGRAPHY

ARIZONA
(COCHISE COUNTY)
BISBEE QUADRANGLE



ENGRAVED JULY 1902 BY U.S.G.S.

E.M. Douglas, Geographer in charge.
Triangulation and topography by T.M. Bannon.
Surveyed in 1901-1902.

APPROXIMATE MEAN DECLINATION 1901

Scale $\frac{1}{62500}$

Contour interval 50 feet.
Datum is mean sea level.

DIAGRAM OF TOWNSHIP

6	5	4	3	2	1
7	8	9	10	11	12
18	17	16	15	14	13
19	20	21	22	23	24
30	29	28	27	26	25
31	32	33	34	35	36

Edition of Dec. 1902.

DESCRIPTION OF THE TOPOGRAPHIC MAP OF THE UNITED STATES

The United States Geological Survey is making a topographic map of the United States. This work has been in progress since 1882, and about one-fifth of the area of the country, including Alaska, has been mapped. The mapped areas are widely scattered, nearly every State being represented, as shown on the progress map accompanying each annual report of the Director.

This great map is being published in atlas sheets of convenient size, which are bounded by parallels and meridians. The four-cornered division of land corresponding to an atlas sheet is called a *quadrangle*. The sheets are of approximately the same size: the paper dimensions are 20 by 16½ inches; the map occupies about 17½ inches of height and 11½ to 16 inches of width, the latter varying with latitude. Three scales, however, are employed. The largest scale is 1:62500, or very nearly one mile to one inch; i. e., one linear mile on the ground is represented by one linear inch on the map. This scale is used for the thickly settled or industrially important parts of the country. For the greater part of the country an intermediate scale of 1:125000, or about two miles to one inch, is employed. A third and still smaller scale of 1:250000, or about four miles to one inch, has been used in the desert regions of the far West. A few special maps on larger scales are made of limited areas in mining districts. The sheets on the largest scale cover 15′ of latitude by 15′ of longitude; those on the intermediate scale, 30′ of latitude by 30′ of longitude; and those on the smallest scale, 1° of latitude by 1° of longitude.

The features shown on this map may, for convenience, be classed in three groups: (1) *water*, including seas, lakes, ponds, rivers and other streams, canals, swamps, etc.; (2) *relief*, including mountains, hills, valleys, cliffs, etc.; (3) *culture*, i. e., works of man, such as towns, cities, roads, railroads, boundaries, etc. The conventional signs used for these features are grouped below. Variations appear in some maps of earlier dates.

All water features are shown in *blue*, the smaller streams and canals in full blue lines, and the larger streams, lakes, and the sea by blue water lining. Certain streams, however, which flow during only a part of the year, their beds being dry at other times, are shown, not by full lines, but by lines of dots and dashes. Ponds which are dry during a part of the year are shown by oblique parallel lines. Salt-water marshes are shown by horizontal ruling interspersed with tufts of blue, and fresh-water marshes and swamps by blue tufts with broken horizontal lines.

Relief is shown by contour lines in *brown*. Each contour passes through points which have the same altitude. One who follows a contour on the ground will go neither uphill nor downhill, but on a level. By the use of contours not only are the shapes of the plains, hills, and mountains shown, but also the elevations. The line of the seacoast itself is a contour line, the datum or zero of elevation being mean sea level. The contour line at, say, 20 feet above sea level is the line that would be the seacoast if the sea were to rise or the land to sink 20 feet. Such a line runs back up the valleys and forward around the points of hills and spurs. On a gentle slope this contour line is far from the present coast line, while on a steep slope it is near it. Thus a succession of these contour lines far apart on the map indicates a gentle slope; if close together, a steep slope; and if they run together in one line, as if each contour were vertically under the one above it, they indicate a cliff. In many parts of the country are depressions or hollows with no outlets. The contours of course surround these, just as they surround hills. Those small hollows known as sinks are usually indicated by hachures, or short dashes, on the inside of the curve. The contour interval, or the vertical distance in feet between one contour and the next, is stated at the bottom of each map. This interval varies according to the character of the area mapped; in a flat country it may be as small as 10 feet, in a mountainous region it may be 200 feet. Certain contours, usually every fifth one, are accompanied by numbers stating elevation above sea level. Many other heights, instrumentally determined, are also given, the number in each case being placed in close proximity to the point to which it applies.

The works of man are shown in *black*, in which color all lettering also is printed. Boundaries, such as State, county, city, land-grant, reservation, etc., are shown by broken lines of different kinds and weights. Cities are indicated by black blocks, representing the built-up portions, and country houses by small black squares. Roads are shown by fine double lines (full for the better roads, dotted for the inferior ones), trails by single dotted lines, and railroads by full black lines with cross lines. Other cultural features are represented by conventions which are easily understood.

The sheets composing the topographic atlas are designated by the name of a principal town or of some prominent natural feature within the district, and the names of adjoining published sheets are printed on the margins. The sheets are sold at five cents each when fewer than 100 copies are purchased, but when they are ordered in lots of 100 or more copies, whether of the same sheet or of different sheets, the price is two cents each.

The topographic map is the base on which the facts of geology and the mineral resources of a quadrangle are represented. The topographic and geologic maps of a quadrangle are finally bound together, accompanied by a description of the district, to form a folio of the Geologic Atlas of the United States. The folios are sold at twenty-five cents each, except such as are unusually comprehensive, which are priced accordingly.

Applications for the separate topographic maps or for folios of the Geologic Atlas should be accompanied by the cash or by post-office money order (not postage stamps), and should be addressed to—

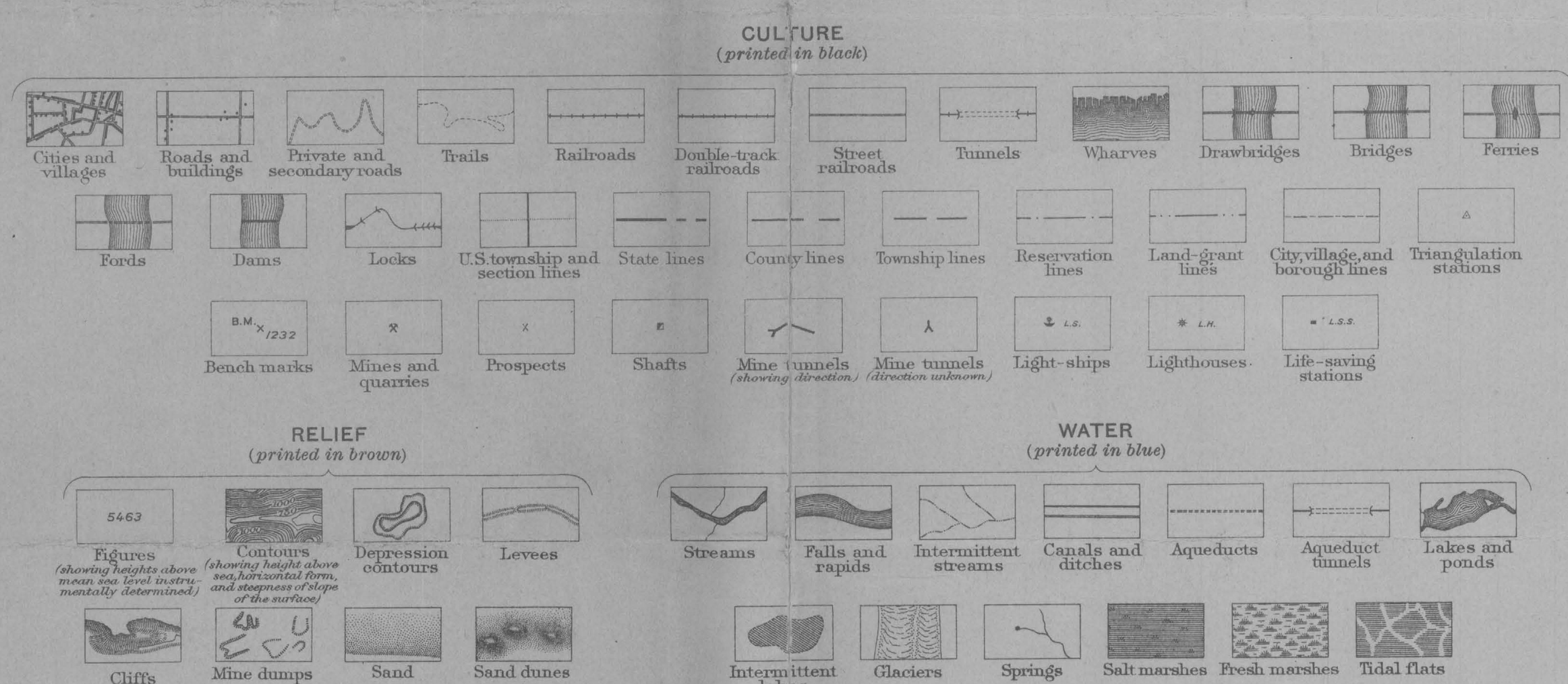
THE DIRECTOR,

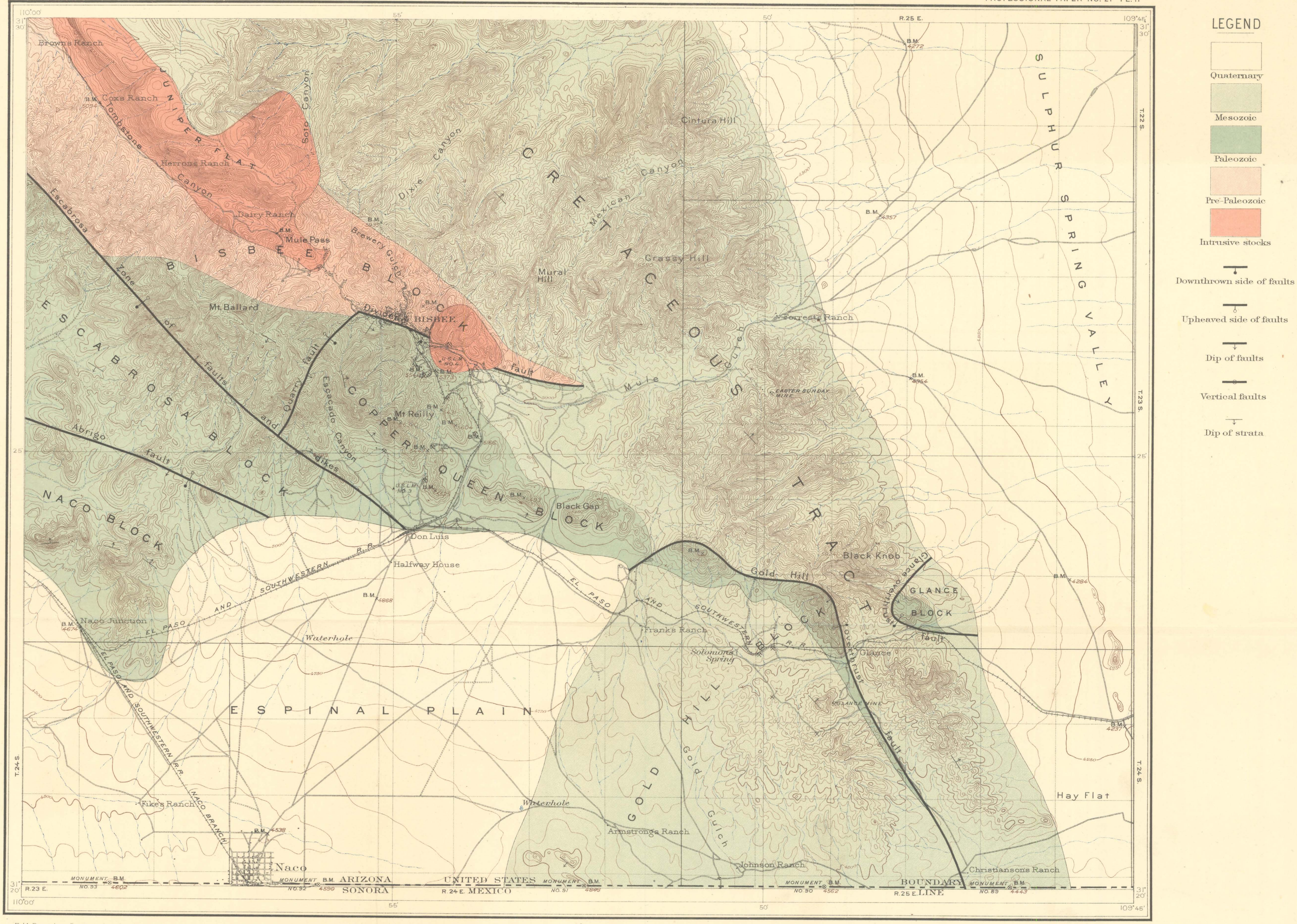
United States Geological Survey,

Washington, D. C.

September, 1899.

CONVENTIONAL SIGNS





E. M. Douglas, Geographer in charge
Triangulation and topography by T. M. Bannon
Surveyed in 1901-1902

GEOLOGIC DIAGRAM OF BISBEE QUADRANGLE, ARIZONA

F. L. Ransome, Geologist

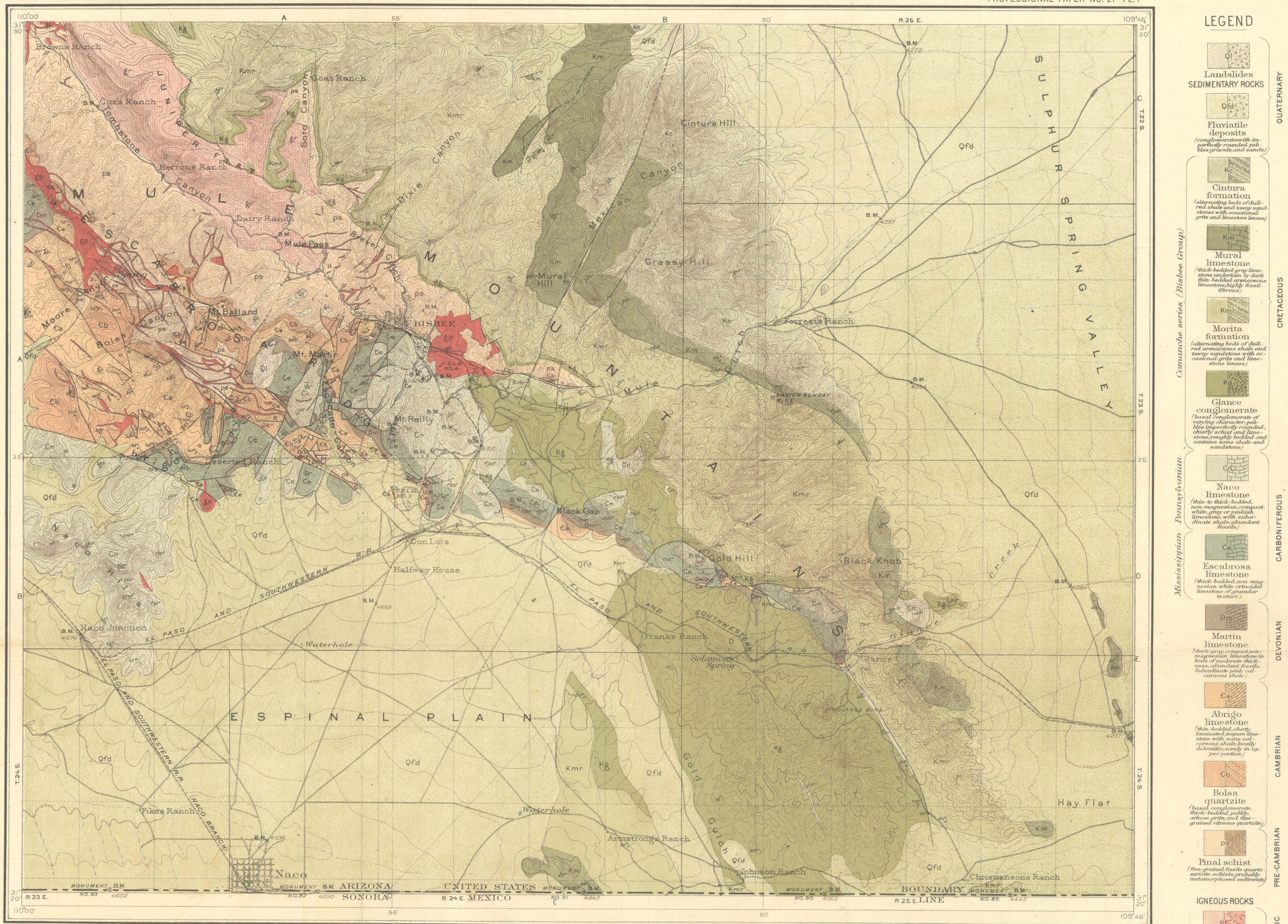
Scale $\frac{1}{62500}$

1 ½ 0 1 2 3 4 miles

1 ½ 0 1 2 3 4 5 kilometers

Contour interval 50 feet

Datum is mean sea level



E. M. Douglas, Geographer in charge.
Triangulation and topography by T. M. Bannon.
Surveyed in 1901-1902.

GEOLOGIC MAP OF BISBEE QUADRANGLE, ARIZONA

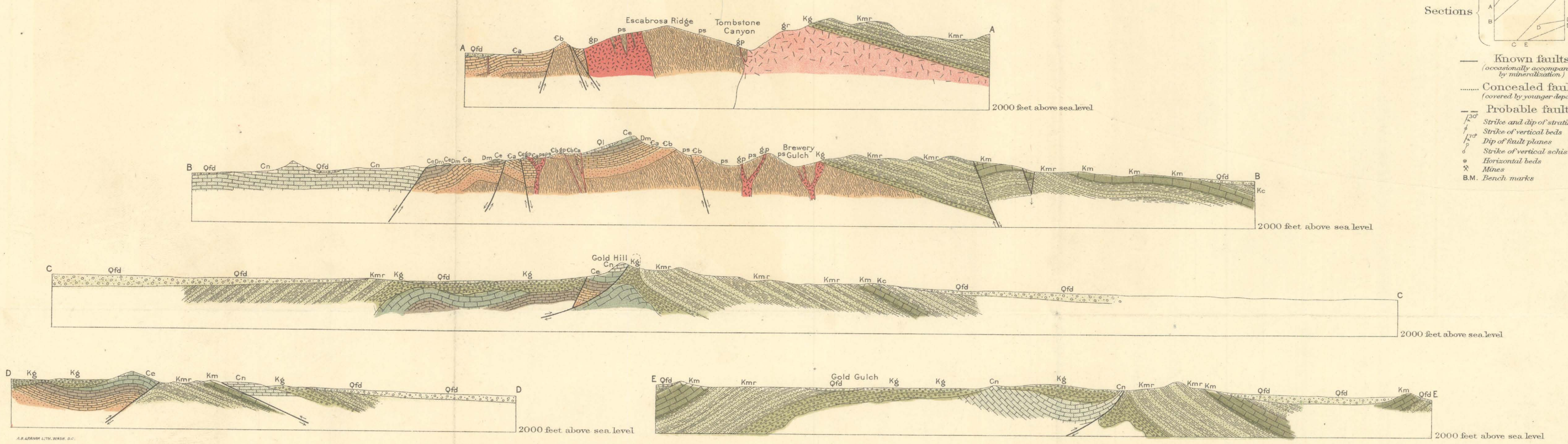
Geology by F. L. Ransome
Assisted by J. Morgan Clements
and Alfred M. Rock
Surveyed in 1902.

Scale 1/62500

1 ½ 0 1 2 3 4 miles

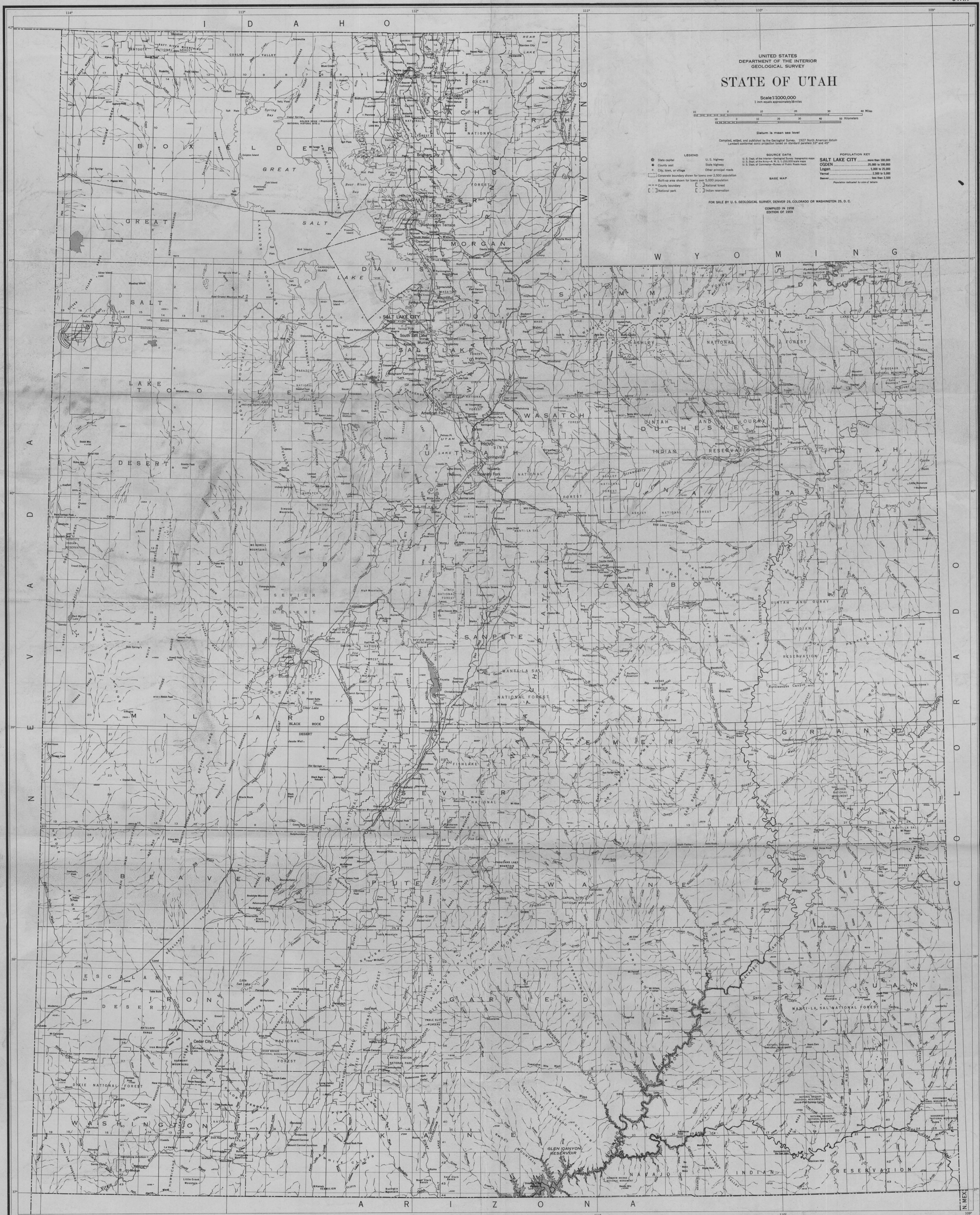
1 ½ 0 1 2 3 4 5 kilometers

Contour interval 50 feet
Datum is mean sea level



GEOLOGIC STRUCTURE SECTIONS

(Scale same as map)


UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY
STATE OF UTAH
Scale 1:1000,000
1 inch equals approximately 16 miles
10 0 10 20 30 40 Miles
10 0 10 20 30 40 50 Kilometers
Datum is mean sea level
Compiled, edited, and published by the Geological Survey. 1927 North American datum
Lambert conformal conic projection based on standard parallels 33° and 45°
LEGEND
State capital
County seat
City, town, or village
Corporate boundary shown for towns over 2,500 population
Built-up area shown for towns over 5,000 population
County boundary
National park
U. S. highway
State highway
Other principal roads
National forest
Indian reservation
SOURCE DATA
U. S. Dept. of the Interior—Geological Survey topographic maps
U. S. Dept. of the Army—A. M. S. 1:250,000 scale maps
U. S. Dept. of Commerce—Bureau of Public Roads maps
BASE MAP
POPULATION KEY
SALT LAKE CITY more than 100,000
OGDEN 25,000 to 100,000
Logan 5,000 to 25,000
Vernal 2,500 to 5,000
Beaver less than 2,500
Population indicated by size of letters
FOR SALE BY U. S. GEOLOGICAL SURVEY, DENVER 25, COLORADO OR WASHINGTON 25, D. C.
COMPILED IN 1958
EDITION OF 1959
IDAHO
WYOMING
NEVADA
COLORADO
ARIZONA
N. MEX.
BOX ELDER
CACHE
RICH
WEBER
MORGAN
DAVIS
SALT LAKE
SUMMIT
DAGGETT
TOOELE
WASATCH
DUCHESNE
UINTAH
UTAH
JUAB
CARBON
SANPETE
MILLARD
EMERY
GRAND
SEVIER
BEAVER
PIUTE
WAYNE
IRON
GARFIELD
SAN JUAN
WASHINGTON
KANE
GREAT SALT LAKE
SALT LAKE CITY
OGDEN
PROVO
Logan
Brigham City
Cedar City
GLEN CANYON RESERVOIR
FLAMING GORGE RESERVOIR
UINTAH AND OURAY INDIAN RESERVATION
NAVAJO INDIAN RESERVATION
MANTI-LA SAL NATIONAL FOREST
DIXIE NATIONAL FOREST
Mexican Hat
Aneth
114°
113°
112°
111°
110°
109°
42°
41°
40°
39°
38°
37°