GEOLOGY OF THE MONTOSA-COTTONWOOD CANYONS AREA
SANTA CRUZ COUNTY, ARIZONA

by

John W. Anthony

———————

A Thesis

submitted to the faculty of the

Department of Geology and Mineralogy

in partial fulfillment of

the requirements for the degree of

Master of Science
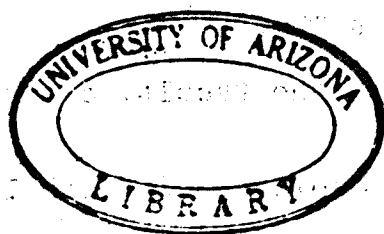
in the Graduate College

University of Arizona

1951

———————

Approved: _____*M. N. Short*_____ , _____*May 3-1951*_____

               Director of Thesis   Date

CONTENTS

ILLUSTRATIONS

Illustrations...cont.

Location of the Montosa-Cottonwood
Canyons Area

I

INTRODUCTION

The Montosa-Cottonwood canyons area, located on the southwest flank of the Santa Rita Mountains, Santa Cruz County, was suggested as an interesting region for investigation by Dr. Eldred D. Wilson of the Arizona Bureau of Mines. A variety of problems, chiefly in economic geology, structure, and petrology, is presented by the area; the purpose of this study was to clarify them in such detail as the time available permitted. The writer trusts that a beginning has been made in unraveling the extremely interesting geologic skein in this portion of the Santa Rita Mountains and that further investigations may be made from this nucleus.

The topographic base on which the geologic findings are presented was enlarged by pantograph from a map obtained from the U.S. Forest Service, prepared from the U.S. Geologic Survey Patagonia quadrangle on a scale of 1:125,000 with a contour interval of 100 feet. The final base is on a scale of 1:12,000, an increase in scale of over ten. It was felt that the original map quality was not sufficiently good to warrant the use of the more desirable 1:6000 scale on the final map. Soil Conservation Service aerial photographs were also enlarged to 1:12,000 and the geology plotted on them in the field. Contours

and drainage were adjusted to agree as closely as possible with the more accurate photographs.

Underground mine maps and the topographic map of the surface area around the Isabella mine were made with the assistance of Peter M. Mosier, then of the Copper Queen Branch, Phelps Dodge Corporation, who worked the area immediately north of that herein discussed.

The Isabella mine is located in the center of the area studied and a description of it is included. Two small properties in the Glove group of claims, owned by E.T. Sheehy of Nogales, in the southern part of the area were also investigated.

Field work was undertaken in the summer of 1947 and was continued sporadically through the spring of 1951. Laboratory studies of materials collected in the field were made mainly in 1950-51 in the Department of Geology, University of Arizona, and in the Arizona Bureau of Mines where the writer is employed.

ACKNOWLEDGMENTS

For assistance and guidance in this study the writer is indebted to members of the Department of Geology, University of Arizona. Dr. B.S. Butler assumed directorship at the outset of the work and, on his retirement in 1948, Dr. F.W. Galbraith became thesis director. Both these gentlemen gave generously of their knowledge and skills.

writer for the surface and underground geology and surveying
of the Isabella mine and will also incorporate that work
in a thesis.

LOCATION

The Montosa-Cottonwood canyons area is located on the
southwest slope of the Santa Rita Mountains, Santa Cruz
County, Arizona. It is bounded on the north by Montosa
Canyon and on the south by Cottonwood Canyon, both of which
trend approximately east-west. The area occupies the
southern halves of sections 19 and 20, the western halves
of sections 21 and 28, section 29, and the northeast half
of section 30 T.20S., R.14E. G&SRB&M. It lies entirely
within the boundaries of the Coronado National Forest.

Montosa Canyon is 50 road miles from Tucson, of which
40 miles are on U.S. Route 89 to Amado, Arizona. Ten miles
of dirt roads of varying quality connect the area with
Amado, the nearest store and post office.

II

TOPOGRAPHY AND DRAINAGE

The area studied is bounded on the north and south by east-west draining canyons. Cottonwood Canyon to the south heads on the southwest flank of Mount Hopkins, whose summit is 8072 feet above sea level, the third highest peak of the Santa Rita range. Montosa Canyon heads on the west flank of Mount Hopkins and also drains to the west. Both washes are tributaries of the northward-flowing Santa Cruz River. The western part of the area is underlain by a pediment cut on Cretaceous shales and volcanics. Limestone hills rise abruptly east of the pediment. This elevation increases irregularly to the head of the south branch of Montosa Canyon. A slope of low relief extends from Cottonwood Canyon to the base of the limestone hills, which occupy the central part of the area mapped. Abrupt cliffs and steep slopes characterize the limestone hills. Equally precipitous relief is found in the higher slopes underlain by latite in the eastern half of the region. The northern half of the limestone hills composed of Permian limestone and quartzite is completely surrounded by a 50-foot cliff of massive limestone, making the top of the mass difficult of access. Separating these hills from those composed largely of Pennsylvanian limestone to the south is a west-draining

canyon which joins Cottonwood Canyon farther west. The Pennsylvanian limestone hills form a sharp, high east-west ridge more than one mile in length.

The central highlands drain both to Cottonwood and Montosa canyons. Drainage locally is controlled by the lithology of underlying rocks and by faulting. Streams flow after a rainfall or the melting of snow.

On the north side of Montosa Canyon is an intermontane valley known as "The Devil's Cash Box." Bounded on the east by the granitic rock of the Santa Rita stock and on the west by a north-south trending ridge of Permian limestone, the valley is underlain by Cretaceous shale and limestone.

Structural disturbances have had a strong influence on physiography, as less resistant Cretaceous sediments and volcanic rocks lie under overthrust Pennsylvanian and Permian limestones which form the central high areas. The north-south contact between latite porphyry and limestone is a zone of weakness which has resulted in a saddle south of the Isabella mine from which canyons drain north and south.

Active down-cutting of the intermittent streams through quaternary gravels and "caliche conglomerate" indicates that there has been a recent lowering of base level in the region. This condition is observed throughout the southern part of the Santa Cruz valley. Terraces of recent

gravels along the slope between the Santa Cruz and the
Santa Rita Mountains are being actively dissected by ephe-
meral streams. [1]

[1] Average yearly rainfall recorded at Helvetia 16 miles
to the north at an elevation of 4300 feet is 20.15
inches as measured over a 22-year period.

The eye follows for miles the continuity of the benches
formed by these gravels. The pediment along the west
flank of the mountains slopes gently toward the Santa Cruz
River until lost under the gravels. Close to the moun-
tains the gravel cover varies greatly in thickness.

Bed rock crops out mainly in washes, but the flat
character of the cut rock surface is apparent. This sur-
face extends for some distance up the valley on either
side of Cottonwood Canyon. Bryan's observations on moun-
tain pediments in the Papago country apply generally to
this surface. [2]

[2] Bryan, Kirk, The Papago country: U.S. Geol. Survey
Water Supply Paper 499, pp. 93-100, 1925.

Here the slope angle varies up to 300 feet per mile, being
steepest opposite the smaller canyons and flatter along
the axis of the larger washes. Debris in the covering gra-
vels corresponds to the rocks in the mountains east of the
pediment.

Preceding the presently active down-cutting, there

was a period of stream aggradation during which the gravels covering the pediment were accumulated. A general rise in base level following lateral planation by streams eroding the pediment permitted rock debris from the Santa Rita Mountains to accumulate in the area between the canyon mouths and the Santa Cruz River.

The north-south trending Permian limestone ridge forming the western boundary of "The Devil's Cash Box" is being separated, by more rapid erosion of the underlying Cretaceous rocks, from the main mountain mass and can now be considered a mountain outlier.[1]

---

[1] idem, p. 96.

To the immediate north of the area studied and west of the above-mentioned limestone ridge are prominent mountain outliers of limestone and resistant volcanic rocks. Lower outliers of limestone are marked on the pediment discussed here. Total relief is not great, but the surface is rugged as a consequence of the network of actively down-cutting washes which sinuously traverse the pediment surface.

III

GENERAL GEOLOGY

The Montosa-Cottonwood canyons area is stratigraphically composed of a thick series of westward-dipping shales, limestones, quartzites, and volcanics of Cretaceous age. Over these, limestones of Pennsylvanian and Permian age have been thrust by compressive forces acting from the southwest. The overthrust sediments have been folded and sheared by high-angle faults concomitant with the thrust fault. A stock of quartz monzonite found access along the thrust plane and was emplaced in the southern part of the area.

Intrusive masses of quartz monzonite and latite porphyry invaded the eastern margin of the Cretaceous rocks, altering them strongly.

The high, central Permian limestone thrust block capped by quartzite has been folded gently into an east-west trending syncline, the southern limb of which is underlain by Naco limestone. High-angle faults of small displacement cut the Paleozoic rocks in an east-west direction. Dacite porphyry dikes intrude these limestones along their strike.

Ore mineralization in Permian limestone along the north-south trending Isabella fault is exploited by the Isabella mine, a property of small production. Minerali-

zation, mostly lead, zinc, and silver, is of the limestone replacement type. Primary sulfide minerals have been completely oxidized.

Solutions accompanying quartz monzonite sills in Naco limestone at its contact with a quartz monzonite stock have mineralized fissures along the sill edges. A number of workings constituting the Glove group of claims has produced small lots of oxidized and sulfide ore.

IV

SEDIMENTARY ROCKS

General Statement

The lithified sedimentary rocks of the Montosa-
Cottonwood canyons area range in age from Pennsylvanian
to Cretaceous, and include the Naco limestone, Snyder
Hill formation, and Cretaceous shales, limestones, and
sandstones. Sediments of Pennsylvanian and Permian age
have been thrust over strongly tilted Cretaceous rocks.

The sedimentary rocks have been intruded by igneous
masses and dikes, and have been faulted, folded, and meta-
morphosed in many localities so that the faunas have been
destroyed or strongly deformed. Fossil preservation in
them is, in general, poor.

There are no rocks present in the area older than
the Pennsylvanian Naco limestone.

Pennsylvanian

Naco limestone

Pennsylvanian Naco limestone forms a sharp, east-west
ridge marking the southern extremity of the central lime-
stone hills. Naco limestone in the area mapped is found
only in this ridge. North of and overlying it in strati-
graphic sequence are Permian limestones. Its southern

limit is delineated by a fault separating it from intrusive, fine-grained quartz monzonite.

The sedimentary sequence that makes up the Naco limestone consists of alternating limestones, shales, and hornstones. The greater part of this formation is light in color; the limestones being white, pink, and gray, and most of the shales and hornstones light green or white. A 70-foot section of crystalline limestone just below the Permian contact is dark gray. Silicification and recrystallization of beds is widespread throughout the Naco deposits. As a result, fossil preservation is poor and few forms useful for dating are found.

Unidentified large gastropods occur in a cherty limestone bed in unit 22 of the measured Naco section. Unidentifiable corals and pelecypods are also present in this limestone bed. A _Soleniscus_-type gastropod was found near the top of the Naco section together with _Composita_ sp. and large horn corals.

A section of the Naco limestone was measured just east of the West adit of the Glove group of claims. Several sills intruding the limestone cut across this section and bedding plane faulting has taken place to an undetermined extent. A complete Naco section probably is not present. No limestone stratigraphically below the Naco is exposed and the conglomerate that normally occurs at its

base does not outcrop here. A total thickness of 1199

feet of Naco strata were measured. This thickness

agrees closely with thickness trends indicated in the

Pennsylvanian isopach map of McKee. The 1500-foot iso-

pach contour passes a short distance to the east of the

Montosa Canyon area. [1]

---

[1] McKee, E.D., Sedimentary basins of Arizona and ad-
joining areas: Geol. Soc. Am., Bull., vol. 62, no.
5, 1951.

Naco Limestone Sequence

Permian

No disconformity

Pennsylvanian, Naco limestone

	feet
29. Concealed; low slope......................	137
28. HORNSTONE: white, aphanitic, thin-bedded (6" thick); forms cliff........	10
27. LIMESTONE: dark gray, uniformly colored, crystalline, moderately thick-bedded; little chert; weathers to pitted surface; strong cliff-former; large, poorly preserved fossil fragments, appear to have been corals................................	70
26. LIMESTONE: light pink and buff, fine-grained, thin-bedded (average 10'); strong cliff-former; calcified brachiopod outlines....................	85
25. HORNSTONE: green, novaculitic, very fine-grained; cross-bedded; largely concealed by limestone float..........	70

feet

24. CONCEALED: apparently underlain by
light buff to gray, thin-bedded
limestone and greenish novaculi-
tic shales; top of zone strongly
mineralized with abundant epidote
and copper carbonate stains........... 115

23. LIMESTONE: mottled, dirty gray, black
and green, speckled, thin-bedded;
chert in thin bands parallel bedding;
low cliff-former.................... 80

22. LIMESTONE: light gray to white, 2'
beds; weathers to tiny pits; low
slope-former; a few thick, cherty
bands at base contain many fossil
fragments of unrecognizable gas-
tropods and corals.................. 10   577

21. QUARTZITE: grades up into quartzite
alternating with thin beds of dark
gray limestone. Top 20 feet
are limestone...................... 40

20. QUARTZITE: dark gray, thin-bedded....... 10

19. Concealed........................ 5

18. LIMESTONE: light near-white and pink,
thin-bedded; moderately cherty, top
10 feet carrying large masses of
dark brown chert; low slope-former;
few very poorly preserved brachio-
pod fragments..................... 77

17. LIMESTONE: dark buff with darker
blotches locally, thin-bedded;
very sandy....................... 17

16. LIMESTONE: light pinkish gray, thin-
bedded; chert black on surface,
lighter on fresh surface; isolated
chert bands and masses tend to paral-
lel bedding; weathers to darker
shades and fine pitted surface........ 45

15. LIMESTONE: light buff to pink, marblized
on fresh surface; beds 1 to 3' thick;
chert present in thin, irregular seams;
weathers to pitted surface; forms
slope; very poorly preserved fossil
outlines and fragments.............. 35

feet

14. LIMESTONE: medium to light gray;
    beds 1 to 3' thick; very cherty
    in irregular masses and bands,
    black manganese dioxide stains
    some chert; forms cliff................ 50

    Andesite porphyry sill, strongly
    weathered, green with white pheno-
    crysts, low-lying...................... 10

13. LIMESTONE: light gray and pink, thin-
    bedded; cherty in tiny, abundant
    blebs; weathers darker than fresh
    surface; very poorly exposed.......... 42

12. LIMESTONE: light gray, thin-bedded;
    low-lying............................. 7

11. QUARTZITE: greenish, fine-grained,
    thin-bedded; forms slope............. 5

10. SHALE: light tan, thin-bedded;
    strongly fractured, hard, "dense"..... 4

9. Concealed.............................. 13

8. LIMESTONE: pink and white; beds 2 to
    4' thick; similar to #7, but forms
    cliff................................. 15

7. LIMESTONE: pink and white, moderately
    coarse-grained; pink on fresh sur-
    face; weathers lighter and to raspy,
    coarse surface; poor outcrops; low
    slope-former.......................... 32

6. Concealed.............................. 27

  . Basic, very highly altered dike paral-
    leling bedding of intruded sedi-
    ments; largely concealed by float
    and low-lying......................... 10

5. Concealed.............................. 20

4. LIMESTONE: buff with lenses of dark
    gray limestone, 6" to 3' beds; chert
    in interrupted, wavy bands 1 to 2'
    thick; weathers to raspy surface;
    forms slope........................... 22

feet

3. LIMESTONE: dolomitic, buff, granu-
lar; less cherty than #2; wea-
thers to raspy, coarse surface;
forms slope........................   2

2. LIMESTONE: light gray; similar to
#1; dolomitized by intrusive grani-
tic dike; iron and manganese stained
near bottom; weathers to smooth sur-
face; strong cliff-former............   50

1. LIMESTONE: light gray, crystalline,
5' beds; very cherty, chert in thin,
wavy bands; weathers darker than
fresh surface; pitted strongly on
weathered surface; forms low cliffs,
not continuous along strike...........   94

Total measured Naco limestone   1199

Fault

Quartz monzonite intrusive

Permian

Rocks of Permian age in the Montosa-Cottonwood can-
yons area are represented by the Snyder Hill formation
and by an unnamed pre-Snyder Hill formation consisting of
limestone, marl, quartzite, and gypsum. The limestone
contains a fauna consisting chiefly of mollusks but with
some brachiopods. [1]

---

[1] Stoyanow, A., Correlation of Arizona Paleozoic for-
mations, Bull. Geol. Soc. Amer., vol. 47, p. 466, 1936.

These two formations make up the northern portion of
the central limestone hills immediately south of Montosa

Canyon and stand up in a high, mesa-like mass above the Cretaceous shales over which they have been thrust. The Permian sediments form a gently folded, synclinal structure, the trough of which strikes nearly east-west. Strata of the northern limb of the syncline dip gently to the south, while those of the southern limb dip more steeply to the north. Thin-bedded limestones and other beds exposed above the Naco limestone on the southern limb are concealed on the northern limb. They probably are at the thrust plane of the overthrust limestones.

Unnamed formation

Unnamed pre-Snyder Hill formation: Galbraith [1] has proposed the name "Andrada" for the pre-Snyder Hill rocks of Permian age in the Empire Mountains. Equivalent strata

---

[1] Galbraith, F.W., Geology of the Empire Mountains, Arizona, unpublished MS, pp. 15-18.

---

constituting a thick series of beds underlying the Snyder Hill limestone occur in the northern half of the central limestone hills. No detailed lithologic correlation has been made between the Permian "Andrada" beds of the Empire Mountains and those of the Montosa-Cottonwood canyons area. In both localities the sequence is characterized by weak, light-colored, thin-bedded limestone, marl, and gypsum, which grade upward into thick-bedded, gray lime-

stone. In the area studied the section is capped by a thick, brown quartzite.

Three gypsum beds are described in the "Andrada" formation of the Empire Mountains; only two are known to occur in the central limestone hills. These include small lenses of crystalline, white gypsum that crop out at the base near the western end of the Devil's Seat syncline and also just above the Naco limestone at the base of the southern limb of the syncline. The second exposure of gypsum is about 100 feet higher stratigraphically, but is largely concealed. Gypsum lenses are extremely irregular along their strike. In the Helmet Peak area [1] and at Helvetia [2] in the Santa Rita Mountains north of the area studied, gypsum is also present in the Permian rocks.

---

[1] Mayuga, M.N., The geology and ore deposits of the Helmet Peak area, Pima County, Arizona, Univ. Ariz. thesis, pp. 23-25, 1942.

[2] Jones, W.R., Geology of the Sycamore Ridge area, Pima County, Arizona, Univ. Ariz. thesis, 1941.

Feth [3] and Bryant [4] report an absence of gypsum in the pre-Snyder Hill Permian strata of the Canelo Hills and Mustang Mountains, respectively.

---

[3] Feth, J.H., Permian stratigraphy and structure, northern Canelo Hills, Arizona, Bull., Amer. Assoc. Petroleum Geol., vol. 32, no. 1, 1948.

[4] Bryant, D.L., personal communication.

About 400 to 500 feet above the base of the Permian section a massive limestone cliff encircles the Devil's Seat syncline. Seen from a distance, this cliff suggests, paradoxically, a monk's tonsure. A thick bed of brown Permian quartzite which caps the mesa resembles a sunburned pate.

Faunal remains are abundant in the pre-Snyder Hill Permian beds, but, as in the Naco limestone, preservation is poor owing to intense silicification and recrystallization.

The following brachiopods and pelecypods are present:

Dictyoclostus bassi McKee
Dictyoclostus occidentalis (Newberry)
Composita subtilita Girty
Composita mexicana Hall
Composita sp.
Nucula sp.

A number of gastropods, of which generic and specific classification was not made, are also represented. Large horn corals, distinguishing characteristics of which have been obliterated by metamorphism in most cases are present and small Composita-like brachiopods are not uncommon. Crinoid stems and bryozoa are abundant throughout many parts of these beds.

Several sections of the lower pre-Snyder Hill formation were measured. Because of faulting, no complete, continuous section could be obtained. The section that follows is a composite, measured in two places. The mea-

surements were made on the south side of Montosa wash up
the northern limb of the Devil's Seat syncline to the
south.

Unnamed pre-Snyder Hill formation

Measured section no. 1

Snyder Hill formation

Unnamed formation, partial section

feet

23. QUARTZITE: dark brown, fine-
grained; very hard...................... 425

22. Concealed................................ 45

21. LIMESTONE: white and buff, fine-grained,
thin-bedded; intercallated with marly
beds; weathers to soft, powdery sur-
face; very poorly preserved brachiopod
fragments............................... 40

20. LIMESTONE: light buff to gray, fine-
grained; forms slope.................... 3

19. Largely concealed; apparently under-
lain by soft, marly beds............... 23

18. LIMESTONE: light buff to gray, fine-
grained; forms cliff; poorly pre-
served brachiopods..................... 4

17. Concealed................................ 16

16. LIMESTONE: light gray, fine-grained;
weathers to raspy surface; forms low
cliffs; contains many large Dictyo-
clostus bassi........................... 22

15. LIMESTONE: light buff and gray;
forms low cliff......................... 4

14. LIMESTONE: light gray, fine-grained;
weathers to raspy surface; forms low
cliffs; contains few Dictyoclostus
bassi and gastropods.................... 20

feet

13. LIMESTONE: dark gray to blue-gray,
    massive beds; weathers to pitted
    surface in places, smooth in
    others; forms heavy cliff about
    60' high; contains many fossils,
    largely poorly preserved; _Dictyo-_
    clostus bassi, high-spired
    gastropods............................... 60 plus

12. LIMESTONE: medium gray, thin beds
    (6" to 2' thick); weathers to
    strongly pitted surface; forms low
    cliff; contains few poorly preserved
    Dictyoclostus bassi, _Composita subti-_
    lita, _Composita mexicana_, Crinoid
    stems, small gastropods, _Nucula_ sp.;
    a pectin................................ 30

11. Largely concealed, with few scattered
    outcrops of soft, white marly
    limestone.............................. 212

10. LIMESTONE: light gray, fine-grained;
    thin-bedded............................ 5

9. LIMESTONE: light buff, marly, soft,
    friable, thin-bedded; interbedded
    marls brownish gray, very soft........ 10

8. LIMESTONE: light buff and brownish,
    fine-grained, thin-bedded; forms
    low slope,............................. 4

7. LIMESTONE: light buff, marly, thin-
    bedded; weathers to soft, powdery
    surface, soft and friable; inter-
    bedded marls brownish gray, very
    soft; forms low slope................. 38

6. LIMESTONE: light buff, fine-grained,
    thin beds 2" to 2' thick; strongly
    fractured with small-scale folding
    and twisting, largely covered;
    sharply pitted on weathered surface;
    forms low slope....................... 35

5. Concealed............................... 5

4. LIMESTONE: like #6, but reddish brown
    and buff, mottled..................... 3

3. LIMESTONE: like #6........................ 107

2. Concealed, gentle slope................... 25

1. LIMESTONE: light gray, massive, thick-
       bedded; contains abundant chert no-
       dules, some black on surface; weathers
       to raspy surface; strong cliff-former;
       contains few, very poorly preserved
       fossils................................ 65
                                              _____

            Total measured partial section   1201

Base concealed by recent alluvium

A second section of pre-Snyder Hill Permian deposits

was measured on the northern wall of a declevity at the

Naco limestone-Permian contact near the steeply-dipping

southern limb of the Devil's Seat syncline. The total

thickness of Permian sediments from the Naco limestone

contact to the base of the massive limestone cliff des-

cribed above is 403 feet. The corresponding thickness

on the northern limb of the syncline is 539 feet. Gypsum

is not exposed in the thicker section, hence, a thickness

of more than 136 feet of strata appears to be missing on

the southern limb of the syncline.

Unnamed pre-Snyder Hill formation

Measured section no. 2

Massive Permian limestone cliff

Unnamed pre-Snyder Hill formation,
partial section

feet

12. LIMESTONE: gray, coarsely crystal-
    line, heavy beds 4' thick; mode-
    rate chert content; weathers to
    coarse, raspy surface; forms low
    cliff; fossils poorly preserved
    with chert centers...................... 60

11. LIMESTONE: mottled pink, tan, and
    gray, thick-bedded; chert present
    in tiny blebs and thin, irregular
    veinlets and 4" horizontal bands;
    weathers to pitted surface; forms
    low cliffs.............................. 8

10. Concealed................................ 16

9. LIMESTONE: buff and pink, broadly
   mottled, crystalline, beds 3' thick;
   fractured, cut by thin veinlets of
   white calcite; pitted on weathered
   surface; low cliff-former............. 14

8. LIMESTONE: buff, thin-bedded;
   largely concealed...................... 15

7. Concealed................................ 55

6. LIMESTONE: white and light buff,
   thin-bedded (6"); partially
   concealed.............................. 20

5. Concealed................................ 70

4. LIMESTONE: light buff, thin-bedded;
   forms low cliff........................ 12

3. Concealed: poor exposures of gypsum,
   marly, soft white, tan, and gray
   material; slope former................ 98

2. LIMESTONE: white, thin-bedded (less
   than 1' thick); interbedded with
   light gray limestone; smooth on
   weathered surface; forms low slope..... 13

1. GYPSUM: dirty tan; clean, glistening,
   coarse,friable white where fresh;
   partially concealed, but exposed
   in gullies............................. 22 plus

Total measured partial section   403 plus

No disconformity
Pennsylvanian, Naco limestone

A section measured at the extreme western extremity
of the syncline south of Montosa follows.

Unnamed pre-Snyder Hill formation

Measured section no. 3

Recent erosion surface

Lower Permian, partial section

                                                              feet
6. LIMESTONE: very dark gray, nearly
      black, coarsely crystalline, 3'
      beds; strongly fractured, white
      calcite along breaks; few heavy
      bands of chert up to 1' thick
      paralleling (?) bedding; weathers
      to rough, pitted surface; forms
      slope.................................. ?

5. LIMESTONE: pinkish-gray, crystalline,
      10' beds; weathers to rough, raspy
      surface; forms low cliffs............... 162

4. LIMESTONE: buff, mottled with darker
      brown spots, thin-bedded; white crys-
      talline calcite along fractures; man-
      ganese dioxide dendrites abundant;
      intercallated with marly beds 10 to
      15' thick; weathers to soft, powdery
      surface................................ 61

3. LIMESTONE: white, marly, thin-bedded....... 25

2. GYPSUM: white, coarsely crystalline;
      dirty gray on surface; varies in
      thickness along strike; weathers to
      small spires and rills; forms low
      slope and depressions.................. 25

1. LIMESTONE: light buff to white, fine-
      grained, thin-bedded; interbedded
      with yellowish marls; forms slope....... 40

      Total measured partial section   313 plus

Base concealed under recent alluvium

No conglomerate is present above the Pennsylvanian-
Permian contact in the declevity separating the northern
and southern halves of the central limestone hills, nor is
there evidence of disconformity or unconformity. Lacking
faunal evidence, the writer places the contact at the top
of a white hornstone bed underlying the lowest gypsum to
coincide with environmental change.

Snyder Hill formation

The Snyder Hill limestone occurs in three widely
separated places in the Montosa-Cottonwood canyons area.
It lies conformably above a massive quartzite at the top
of the unnamed pre-Snyder Hill beds and is 240 feet thick.
The upper limit is terminated by a surface of recent ero-
sion.

Dark blue gray Snyder Hill limestone rests in thrust-
fault relationship against strata of the Devil's Seat syn-
cline. A third block of Snyder Hill limestone is exposed
at the west end of the east-west Naco limestone ridge,
north of Cottonwood Canyon.

The Snyder Hill limestone capping the Devil's Seat
syncline contains Meekela pyramidalis (Newberry), Meekela
sp., Dictyoclostus bassi McKee, Dictyoclostus occidentalis
(Newberry), Marginifera sp., Chonetes sp., and Lophophylum
sp.

Snyder Hill limestone at the imbricate thrust block described above contains an assemblage similar to that above. In addition, <u>Euomphalus</u> sp. and <u>Bellerophon</u> sp. were recognized.

A measured section was made of the Snyder Hill limestone where it rests conformably on the Permian pre-Snyder Hill formation.

Snyder Hill formation

Measured section no. 4

Recent erosion surface

Snyder Hill formation

feet

5. LIMESTONE: dark gray, finely crystalline; cherty in bands and irregular masses; weathers to smooth surface; forms massive, vertical cliff; contains a number of large productids (<u>Dictyoclostus bassi</u>, <u>Derbya regularis</u>, <u>Chonetes kaibabensis</u>)........................... 60 plus

4. Concealed: apparently underlain by limestone.............................. 65

3. LIMESTONE: brownish gray, thinbedded; very sandy, banded; stained by iron oxides......................... 9

2. LIMESTONE: light gray, massive, thickbedded; cherty in irregular masses; fossils cherty; cherty, unrecognizable brachiopod fauna very poorly preserved, <u>Squamularia</u> (?)......................... 56

1. LIMESTONE: buff, fine-grained, beds 1 to 3' thick; cherty; brownish yellow on fresh surface; weathers to smooth surface; forms low cliff......... 50

Total Snyder Hill formation   240

Unnamed formation

Cretaceous Strata

The beds of Cretaceous age in the area mapped form the western flank of the large anticlinal structure of the Santa Rita Mountains. This structure is breached by intrusive rocks. The Cretaceous beds, dipping at about 60 degrees to the southwest, form the basement on which the older Pennsylvanian and Permian sediments have been thrust. The Cretaceous beds are in contact with "coarse" intrusive quartz monzonite at their eastern margin. To the west the contact is hidden under alluvial cover.

There are estimated to be 10,000 feet of Cretaceous rocks exposed in the section from the Cretaceous-quartz monzonite contact in the eastern part of Montosa basin westward to the alluvial cover on the pediment. The total thickness reported does not, however, represent a continuous section. Shales, limestones, and quartzites exposed below the overthrust Permian limestone north of Montosa wash represent a stratigraphically higher sequence than those Cretaceous rocks exposed west of the north-south limestone ridge. At the base of the latter Cretaceous sequence, a conglomerate varying in thickness from a few feet to 150 feet, rests on an erosion surface of upper Permian red shale and limestone. This conglomerate is very thin or missing immediately north of and in Montosa wash. On the other hand, a few hundred feet north along

the contact its maximum thickness is exposed. Pebbles, cobbles, and boulders averaging about four inches in long dimension, but as large as two feet in diameter of quartzite, chert, sandstone, and limestone are imbedded in a well-indurated, coarse sandstone matrix. Quartzite and chert are most abundant among the gravels. Red shale fragments which are also common, apparently have been derived from the soft, light pink to red shales of probably Permian age below. No fossils have been found in the highly silicified limestone cobbles. All gravels are well rounded and are flattened. Shear and tension breaks are ubiquitous. Their significance in the structural picture is discussed at a later place.

This basal conglomerate of the Montosa-Cottonwood canyons area undoubtedly is the correlative of that described in the Santa Rita Mountains near Helvetia and in the Empire Mountains by Schrader. [1]

---

[1] Schrader, Frank C., Mineral deposits of the Santa Rita and Patagonia Mountains, Arizona: U.S. Geol. Survey Bull. 582, pp. 51-52, 1915.

The conglomerate is not exposed in the Montosa-Cottonwood canyons area. Its projected strike places it under the thickest part of the Paleozoic rocks of the central limestone hills. A section measured from east to west along Montosa wash including the conglomerate and overlying

rocks follows.

Covered by alluvium

feet

Porphyritic andesite, highly
altered, thick flows....................... 1870

Conglomerate, red, white, brown and
yellow chert and quartzite peb-
bles in a coarse-grained sand-
stone matrix.............................. 50

Red shales and sandstones and arkoses,
white hornstone, highly fractured......... 570

White quartz rhyolite porphyry flows......... 130

Brown, coarse-grained sandstones and
arkosic sandstones and red shales,
one thin, unfossiliferous lime-
stone bed................................. 460

Conglomerate, pebbles, cobbles, and
boulders of quartzite, chert, and
limestone in coarse sandstone matrix.... 0-150
                                           _____

                                           3230

Erosional unconformity

Permian limestone

Scattered small outcroppings of arkose, sandstone,
and red shale of Cretaceous age are in the washes cutting
into the pediment west of the national forest boundary
and south of Montosa Canyon. The attitude of beds in
these exposures is like that of the sequence described
above.

An extensive area immediately north of Cottonwood
Canyon is underlain by a thick series of undifferentiated

volcanic rocks and shale beds of Cretaceous age. They
are largely covered by alluvium; hence, exposures are small
and scattered. The strike and dip of these layered rocks
conform with those of the better exposed Cretaceous se-
quence north of Montosa Canyon (i.e., strike N 35° W, dip
55-60 degrees southwestward). Schrader interprets
these rocks as being of Tertiary age [1] but the presence

[1] idem, p. 75.

of two thin limestone beds near their contact with "fine"
quartz monzonite suggests that they are of Cretaceous age
and are identical with the rocks of this age to the north
and west.

A section was measured up from the base of the slope
to the base of the massive Permian limestone cliff on the
east slope of the Permian limestone-capped ridge connec-
ting Agua Caliente Canyon and Montosa Canyon. This sec-
tion is the only one sufficiently well exposed to warrant
detailed measurements. It contains the only abundant
limestone observed in the Cretaceous rocks.

Partial Sequence, Cretaceous

Permian, Snyder Hill formation

Fault

feet

26. SHALE: purple, sandy at top,
          strongly fractured................ 45

31

feet

25. SANDSTONE: arkosic..................... 10

24. SHALE: sandy with arkosic frag-
    ments; grades into sand-
    stone at top...................... 117

23. SANDSTONE: reddish gray, arkosic;
    contains shale fragments............... 20

22. SANDSTONE: thin-bedded; forms slope...... 50

21. SHALE: purple, strongly fractured....... 10

20. LIMESTONE: light buff, fine-
    grained, thin-bedded.................. 1

19. SHALES: green and red; interbedded
    with purple sandstones................ 105

18. SANDSTONE: purple...................... 10

17. LIMESTONE: greenish and buff, crys-
    talline, thin-bedded.................. 1

16. SHALE: purple, strongly fractured........ 51

15. LIMESTONE: purplish, coarsely crys-
    talline; dark gray on fresh
    surface................................ 9

14. SHALE: yellow and red; interbedded
    with yellow and brown sandstone....... 27

13. LIMESTONE: buff, thin-bedded; oyster
    shell fragments to extent of being
    a bed; other fossil fragments
    unrecognizable......................... 7

12. LIMESTONE: brownish yellow, fine-
    grained, dense, shaly in part......... 3

11. SHALE: dark purple, thin-bedded;
    hard, dense, strongly fractured;
    weathers to flat slope................ 120

10. LIMESTONE: medium gray, thin-
    bedded; heavily epidotized............ 9

<div align="right"><u>feet</u></div>

9. LIMESTONE: light buff, recrystal-
    lized, thin-bedded.......................   1

8. LIMESTONE: gray, thin-bedded; cut
    by calcite stringers; lighter
    gray on weathered surface..............   12

7. LIMESTONE: buff, thin-bedded; con-
    tains few unrecognizable fossil
    fragments...............................   1

6. SHALE: purple, strongly fractured;
    weathers to low slope..................   3

5. LIMESTONE: gray, thin-bedded;cut by
    calcite stringers; weathers to
    raspy surface; abundant fossil
    fragments poorly preserved; present
    are "oysters," gastropods, and
    brachiopods (?)........................   9

4. SHALE: alternating bands of red and
    yellow; strongly fractured; forms
    low slope..............................   26

3. LIMESTONE: light yellow and gray;
    forms low cliff; replete with
    "oyster" fragments.....................   4

2. LIMESTONE: light gray, dark gray on
    fresh surface; thin-bedded; cut by
    white calcite stringers and contains
    limonite cubes pseudomorphic after
    pyrite; forms low cliff; poorly pre-
    served gastropod fauna and abundant
    fragments of unrecognizable fossils....   7

1. Undifferentiated shales, sandstones,
    and quartzites......................... 3200
                                    ———————

      Total measured partial section   3858

Intrusive quartz monzonite

The lower limestone beds contain fragments of poorly
preserved, unidentifiable brachiopods and gastropods re-

placed by calcium carbonate. Some of the lower limestone beds are "oyster" reefs composed very largely of a hash of valve fragments. Alexis describes similar "oyster" beds in the Lower Cretaceous "limestone formation" of the Huachuca Mountains. [1]

[1] Alexis, C.O., The geology of the northern part of the Huachuca Mountains, Arizona, Univ. Ariz. thesis, 1949.

Below the measured section, Cretaceous beds composed of alternating shales, quartzites, and arkoses are strongly epidotized and bleached near the quartz monzonite intrusive contact. This section is about 3200 feet thick and grades directly upward into the measured limestone section.

Recent

A large volume of semi-consolidated and loose gravels covers an appreciable percentage of the surface mapped. Largely unstratified, this cover ranges in thickness from zero to 40 or more feet. Where exposed in the steep walls of washes, the gravels locally show bedding with cross-sections of fore-set beds an inch or so thick. All rock types observed in the area are represented in the alluvium, although limestone is predominant. Huge boulders up to 20 feet across rest in washes near the highlands, indicating the terrific competency of intermittent streams during times of flood.

Gravel terraces are locally capped by caliche conglo-
merate, in few places more than one foot thick, most com-
monly composed of limestone pebbles an inch or so in dia-
meter. This capping, formed prior to the downcutting of
now-active streams in the region, forms an effective man-
tel under which small terraces have retained their integ-
rity to stand as high as 30 feet above less favorably si-
tuated related gravels.

V

STRUCTURE

Regional Relationships

Considered in the regional picture, the Montosa-
Cottonwood canyons area is an isolated geologic unit.
The sedimentary rocks underlying a large portion of the
mapped area have no counterparts within a distance of
seven or eight miles in the Santa Rita Mountains. The
closest rocks of similar age are on the opposite side of
the range to the northeast. Small scale mapping of the
Santa Rita Mountains by Schrader [1] reveals a cross-section

---

[1] Schrader, op. cit., plates II and III.

---

suggestive of a breached anticlinal structure with the
rupture occupied by intrusive granite rocks. Underlying
Cretaceous sediments and volcanics, which dip in a south-
westerly direction in the Montosa area, dip to the north-
east on the northern portion of the eastern flank of the
Santa Rita Mountains. To what extent this structure has
resulted from the stresses accompanying the intrusion of
the central Santa Rita stock is not known. The Cretaceous
rocks underlying the region mapped in the present study,
then, are considered part of the western limb of a very
large, breached anticlinal structure trending generally
northwest-southeast.

Certainly few conclusions regarding the structural origin of the central Santa Rita Mountains can be deduced from the study of such a small section of them. The only major faulting in the Montosa-Cottonwood canyons area is the thrust faulting which contributed in part to the elevation of the mountain mass by building up the thicknesses of sedimentary rocks. This movement presently affects only the flank of the range in the area mapped; the central heights are composed of igneous rocks. Evidence pointing to typical "basin and range" high-angle fault structures was not found. If they exist, gravity faults of the necessary magnitude will most likely be found west of the pediment from which the range rises, perhaps covered by gravels near the Santa Cruz River.

Summary of Structural Events

The discussion of structural changes in the area may be followed more easily with a picture of the sequence of events in mind.

1. Sedimentation during the Pennsylvanian, Permian, and Cretaceous eras.

2. Tilting of the Cretaceous sequence.

3. Thrusting, from the southwest, of Pennsylvanian, Permian, and older Cretaceous rocks over younger Cretaceous rocks and associated folding of Permian sediments.

4. Shear faulting accompanying thrusting.

5. Intrusion of "fine" quartz monzonite along lower thrust plane and intrusion of "coarse" quartz monzonite into eastern margin of younger Cretaceous shales, limestones, and arkoses.

6. Intrusion of latite porphyry into limestones, shales, and "coarse" and "fine" quartz monzonites.

7. Possible further tilting of overridden Cretaceous rocks and high-angle reverse faulting along igneous-sediment contacts, resulting from intrusion of igneous rocks.

Thrust Faulting

Sedimentary rocks of Pennsylvanian and Permian age rest unconformably on the younger Cretaceous shales and volcanics. The Carboniferous rocks strike, in general, in a more westerly direction than the Cretaceous rocks and dip to the north, except where locally folded. The thrust fault surface, along which the Carboniferous rocks moved over those of Cretaceous age, is not well exposed over most of its extent south of Montosa Canyon. Talus, gravels, and caliche conglomerate have accumulated to conceal it. Cretaceous red shales and arkoses are seen through fensters in the thrust plate west of the central limestone hills, south of Montosa Canyon, and also immediately north of Cottonwood Canyon. The attitude of the beds here is the same as that of the Cretaceous bedded rocks north of Montosa wash.

Where exposed at the mouth of the draw in which the

Isabella mine is situated, the fault dips about 45 degrees
south. The fault surface is much flatter to the south,
however. Paper-thin maroon shales of Cretaceous age are
overlain by Permian limestone. The strikes of the two
formations are similar and both dip southwest. Strong
crumpling of the shales is in evidence here but little
gouge has formed.

The fault, where exposed under the massive Permian
limestone cliffs girdling the ridge between Agua Caliente
and Montosa Canyon, is unspectacular. The Permian here
might well be in conformable sequence as little physical
evidence of a major movement is apparent. The southern
extremity of this ridge, however, is capped by a striking
overturned, isoclinal fold, the limbs of which dip south-
west. It plunges sharply northwest. This structure,
lying north of the mapped area, was not examined in de-
tail, but its nature seems obvious, particularly at a
distance from the elevations to the east (Plate VII).

Dips of the fault plane revealed at a few exposures
and the attitude of the folded limestone bed described
above suggest that compressive forces moved the thrust
plate from the southwest toward the northeast. Movement
from the opposite direction would necessitate a strong
tilting of the whole series of sedimentary rocks, a mini-
mum of 45 degrees to the south, to reconcile the present
attitude of the fault surface which dips southward. No.
evidence of such tilting was observed (Plate II, sect. A-A').

Well-rounded chert, limestone, and quartzite pebbles,

cobbles, and boulders in the basal Cretaceous conglome-
rate have a remarkably well-developed set of tension
cracks and shears. The tension cracks strike about
S 45° W, and shears later than and displacing the tension
breaks have developed at acute angles to them. The abun-
dance of the fractured rocks, an appreciable percentage
of which display these structures, is taken as corrobera-
tive evidence of the direction of dominant thrust movement.

Rattlesnake Wash Fault

A fault striking N 60° W passes down Rattlesnake
Wash and outlines the northeast edge of the Devil's Seat
syncline. The Permian limestones forming the hill on its
northeast side strike in the same direction as the trace
of the fault and dip 50 to 55 degrees southwest. The
limestones southwest of the fault and those to the north-
east dip together at the fault in a V-shaped structure.
While the dip of this fault could not be determined, it is
thought that it represents an imbricate plane of the
thrust movement on which the folded sediments southwest
of the fault slid against younger, southwesterly-dipping
Permian limestone northeast of the fault (Plate II, sect.
B-B').

As a structural unit, the limestone northeast of the
Rattlesnake Wash fault is related to the Permian limestone
north of Montosa Canyon. The limestone of that ridge

north of Montosa wash, striking to the northwest and
dipping southwest, represents the faulted base of Snyder
Hill sediments which are overlain in erosional unconfor-
mity by Cretaceous rocks. The whole mass has ridden over
the younger Cretaceous sediments exposed in the Devil's
Cash Box. Permian and Pennsylvanian limestones south of
Montosa wash have, in turn, moved over the lower thrust
block so that older Permian sediments are now above youn-
ger Permian sediments.

This second overthrust block has slid over the older
Cretaceous sequence exposed in the low area between the
Naco limestone and Cottonwood Canyon.

A third imbricate thrust plate is represented by a
block of Permian limestone resting on the western end of
the north-south Naco ridge immediately north of Cottonwood
Canyon. This sheet, containing a large, poorly preserved
Euomphalus fauna not observed elsewhere in the mapped Per-
mian sediments, strikes northwest and dips about 55 degrees
southwest at its southwestern half. The northeastern half
dips to the north. The opposed dipping rocks represent
the limbs of a small northwesterly trending folded struc-
ture cut by small high-angle faults striking to the north-
west. The attitude of this block is congruent with the
thrust pattern established above. The limestones of the
thrust block are highly metamorphosed; the beds are sili-
cified and recrystallized. Lithologic dissimilarity be-

tween this limestone and the lower Permian sediments to
the north suggests that it is higher in the Permian se-
quence. It has also slid over the underlying Cretaceous
rocks and rests above the Naco limestone thrust block to
the north. It is separated from the Cretaceous sequence
to the south by the fine quartz monzonite which is exposed
at the base of the Permian limestone at its eastern,
southern, and western extremities (Plate II, sect. B-B').

Devil's Seat Syncline

The Naco limestone of which the southern half of the
central limestone hills is composed dips about 55 degrees
north and strikes from east-west to N 70° W.

Above the Naco limestone Permian rocks rest in appa-
rent conformity. The contact of lower Permian sediments
with the Naco limestone forms the southern edge of an east-
west striking, asymmetrical synclinal structure. The
gypsum, marls, and limestones at the base of the southern
limb dip about 50 degrees north. The equivalent beds on
the northern limb, exposed south of Montosa wash, dip less
steeply--about 25 degrees--south. The axial plane of
this structure, which rests on the base of the Permian
sequence, strikes about N 75° W. Its axial line is essen-
tially horizontal. The structure is about 4500 feet long
and 2500 feet across. The southwestern lip has been
turned down so that this segment of the basin-like struc-

ture forms a dip slope with the lower Permian limestone dipping to the southwest. A small anticlinal fold has formed on the southeastern shoulder of the syncline. The axial line of this structure parallels that of the syncline. High-angle faults have cut the syncline in several places.

Standing above the surrounding country, the syncline resembles a vast basin whose thick rim is formed by a massive gray Permian limestone cliff. The synclinal, basin-like structure is a folded segment of the thrusted block (Plate II, sect. B-B').

North-South Shear Faults

High-angle faults accompanied or followed closely the thrust faulting. This set of faults strikes north-south and has caused generally little horizontal or vertical displacement. Several of these rupture along their strikes both the Pennsylvanian and Permian rocks. They are regarded as being shear breaks at an angle to the direction of thrusting, i.e., the direction of greatest stress. Where these faults transect the Devil's Seat syncline, small vertical displacements, measured in tens of feet, can be seen. The western segments were dropped relative to the eastern segments in the case in which evidence could be seen, and rocks on the east side of the faults moved north relative to those on the west.

Isabella Fault

The most prominent fault of the north-south type forms the contact between the central limestone hills and the contiguous latite porphyry. Little evidence of the magnitude or direction of movement of this fault was observed except in the vicinity of the Isabella mine. The fault here dips about 60 degrees east and has developed up to four feet of white clay gouge in which are fragments of limestone and latite porphyry. A wedge of lower Permian limestones and marls lies between younger Permian limestone to the west and the latite porphyry to the east. The segment is delineated by a bifurcation of the northern end of the Isabella fault. The Isabella fault is lost in the Cretaceous shales at the mouth of northern Isabella Canyon but is traced continuously southward for nearly a mile and one half to Cottonwood Canyon (Plate II, sect. A-A'). In effect, this fault divides the mapped area into two parts. Local alteration of the limestone at the contact was not observed. The idea that the latite porphyry was intruded at some more or less distant place and then brought into contact with the limestone by this fault does not seem logical and there is no good evidence to support it. The presence of latite dike apophyses petrographically similar to the "parent" latite porphyry stock tends to refute this supposition. Such intrusive bodies are found

in limestone immediately north of the Isabella mine and in the south slope of the Naco limestone ridge a short distance west of the Isabella fault. These intrusive bodies may be of post-latite porphyry stock age, however.

The Isabella fault was probably caused by post-latite porphyry compressive forces.

East-West Faults

A prominent east-west striking fault called the Glove fault is of importance. It forms the contact between the Naco limestone and the quartz monzonite south of it. The Glove fault dips about 55° north, paralleling the average dip and strike of the Naco limestone. Where exposed in the East adit of the Glove group of claims the last movement, as interpreted in drag folding of the Naco sediments, was that of a high-angle reverse fault on which the Naco rode up relative to the intrusive quartz monzonite. Approximately 50 feet of crumpled sediments lie in the hanging wall. A number of parallel bedding plane breaks are exposed in the workings of the West adit, indicating that movements paralleling the contact have taken place along bedding planes up the Pennsylvanian section.

Quartz monzonite sills intrude the Naco along the strike of the beds at the Glove claims, proving that the monzonite stock intruded the limestone. An embayment in

the sedimentary contact at the southwesternmost extremity
of the central limestone hills is underlain by fine
quartz monzonite. It is thought that the thrust fault pro-
vided an entranceway for the intrusion of the quartz mon-
zonite. The southern extent of the thrust plane is obs-
cured by the intrusion of this rock, which dips under the
Naco limestone for an undetermined distance.

VI

IGNEOUS ROCKS

Igneous rocks in the area mapped include quartz monzonite of two types, latite porphyry, dacite porphyry, small basic dikes, and various lavas of the Cretaceous sequence.

INTRUSIVE QUARTZ MONZONITES

Two different textural varieties of quartz monzonite occur in the area as intrusive masses. It is likely that these rocks have been derived from the same magmatic source and that the textural difference represents a difference in igneous facies. The two types are, for convenience, designated as "coarse" and "fine" quartz monzonites.

Coarse quartz monzonite

An intrusive body of coarse quartz monzonite occurs along the eastern boundary of the Montosa-Cottonwood canyons area forming an intrusive contact with Cretaceous shale and post-Cretaceous latite porphyry, which intrudes it. The contact between the Cretaceous shale and quartz monzonite swings in an irregular bowed arc, concave to the west from Agua Caliente Canyon to the north, southward to Montosa Canyon where the shales give way to latite porphyry. The quartz monzonite contact with latite por-

phyry swings sharply eastward and is traced up the north side of the southern branch of upper Montosa Canyon for a distance of about 3500 feet. At this point it swings southward, cutting across the head of Montosa Canyon, and makes a sharp turn eastward to the headwaters of Cotton-wood Canyon. Shales along the northern portion of the quartz monzonite periphery are strongly bleached by solutions accompanying the igneous intrusion. Epidote is abundant in the shales, but is not at all common in the quartz monzonite.

This intrusive mass is part of the central Santa Rita stock mapped by Schrader in 1915. He places the northern extremity of his quartz diorite, of which specific rock unit this quartz monzonite is a part, at Agua Caliente Canyon. [1]

---

[1] Schrader, op. cit., pp. 62-64.

The mass extends southward in an irregular belt for nearly 20 miles to Sonoita Creek and is about six miles across, east-west, in its widest dimension. The contention that the rock mapped in this immediate study is a more acidic variety of Schrader's quartz monzonite will be discussed shortly.

Field appearance: The coarse quartz monzonite has withstood degradation by the elements better than have the

Cretaceous rocks to the west; the steep slopes of the
Santa Rita Mountains start immediately east of the quartz
monzonite-shale contact. The rock forms rugged, steep
slopes, commonly covered with detritus. The weathering of
the rock is controlled in part by a poorly developed joint
system, the dominant set of which strikes N 80° E and dips
62° northwest. Rounded weathered forms are typical.
Weathered outcrops of the rock are generally reddish in
color.

Megascopic description: In hand specimen the rock is
medium-grained and presents a mottled appearance, white
and pink and green cut by fine lines of green. The rock
is composed predominantly of quartz, pink feldspar, and
chlorite grains of equal size, averaging about five milli-
meters in diameter, cut by a fine network of fractures and
thin seams of chlorite. Quartz makes up about one half of
the rock, potash and plagioclase feldspar and chlorite
the remainder, with occasional grains of magnetite. Pyrite
is present locally. Aside from the abundant chlorite, the
rock gives no particular indication of being altered.

Microscopic description: In thin section the rock
is composed of quite equigranular grains of quartz, plagi-
oclase feldspar (andesine, $Ab_{68}An_{32}$), microcline-ortho-
clase, and smaller amounts of hornblende, biotite, and
chlorite. Accessory minerals are magnetite, hematite,
and, locally, pyrite. Zircon and apatite are rare. The
grains are strongly strained and somewhat fractured.

The oligoclase-andesine ($Ab_{68}An_{32}$) is consistently
altered throughout the rock so that about one half of the
plagioclase has been converted to sericite. The euhedral
crystals are strongly warped, and curved lamellae give
"wavy" or progressive extinctions. Average grain size of
crystals and grains is 2.5 mm.

Microcline and orthoclase are perthitic, having in
them wormy replacements or intergrowths of sericitized
albite. The texture of the potash feldspars in this rock
is peculiar in that the large anhedral grains appear to
be an intimate association of microcline and orthoclase.

The microcline "gridiron" twinning structure is irregularly distributed in orthoclase. The aggregate has a "dusty" surface resulting from kaolinization. Grains may be up to five millimeters in their longest dimension.

Quartz is present in anhedral, equigranular grains averaging about 1.5 mm. in size.

Hornblende and biotite have been largely altered to chlorite. Rare subhedral crystals of hornblende and biotite are present, as are minute fissure fillings. The grains average about 0.75 mm. in size.

The accessory minerals which account for less than one percent of the rock are zircon, apatite, magnetite with alteration rings of hematite, and red hematite which forms a tenuous, lacy network through the rock.

Approximate percentages of constituent minerals are as follows:

Quartz...............................46%

Andesine............................16%

Microcline-orthoclase perthite....30%

Chlorite............................ 7%

Accessories........................ 1%

The rock is, after Grout,[1] on the borderline between

granite and quartz monzonite.

---

[1] Grout, Frank F., Petrography and petrology, 1st ed., McGraw-Hill Co., New York, 1932.

Schrader describes the central Santa Rita stock as composed of a multitude of rock varieties, the most abundant being quartz diorite, which he describes from a fresh specimen taken near Nogales.

It is composed principally of oligoclase-andesine in small prisms and short prismatic laths. It contains considerable brown biotite in relatively large

foils, mostly altered to pale-green chlorite, a
nearly equal amount of hornblende, a moderate
amount of orthoclase and quartz, nearly all in-
terstitial, a little augite, considerable magne-
tite, and accessory apatite. Magnetite is un-
doubtedly a primary constituent, but in the
altered forms of the rock much secondary magne-
tite is also present. The rock in general is low
in dark minerals, especially in the forms most
nearly approaching a true diorite, which in gene-
ral are the finer grained. It is commonly rather
siliceous. The feldspars are locally more or less
muscovitized or altered to sericite and kaolin-
like material, and the ferromagnesian minerals to
chlorite and epidote. Here and there the rock
contains considerable orthoclase, epidote, and
some titanite. [1]

---

[1] Schrader, op. cit., p. 63.

Schrader further states, in discussing the local va-

rieties of the rock:

More commonly, however, the variations lie on the
siliceous side of the type form, to the extent
that the rock becomes a more or less typical quartz
monzonite..., being composed of oligoclase or oli-
goclase-andesine and orthoclase in about equal
amount, with a subordinate amount of quartz, bio-
tite, a little hornblende, magnetite, and apatite,
and the rock as a whole throughout the area shows
a very pronounced leaning toward monzonite. [2]

---

[2] idem, p. 64.

The quartz monzonite discussed by the present writer,

then, is probably a magmatic facies of Schrader's larger

batholithic mass. Mapping was not carried into the main

range sufficiently far to determine specifically the gra-

dations which Schrader notes in a broad way.

The intrusive quartz monzonite is clearly of Creta-

ceous age, or younger, intruding as it does Cretaceous
sediments. It can probably be best ascribed to the
Laramide orogeny.

Fine quartz monzonite

Underlying a sporadic alluvial cover south of the
Naco limestone ridge, north of Cottonwood Canyon and west
of the southern extension of Isabella Mine Canyon is a
large mass of low-lying quartz monzonite which under the
microscope is revealed as being very similar in composition
to the coarse quartz monzonite just discussed. As noted
previously under physiographic observations, a pediment
has been developed on this surface. The basement rock is
exposed largely only in washes and where the alluvial co-
ver is thin. This rock is intrusive against the Naco and
Permian limestones which bound it on the north. Two adits
in the Glove group of claims driven in Pennsylvanian lime-
stone cut the contact. Appreciable movement has taken
place on the contact at which strong drag folding has de-
veloped. The dragged sediments suggest high-angle reverse
faulting by which the sedimentary rocks have moved up
relative to the quartz monzonite. This movement is thought
to be a last and reversed effort on the part of the dis-
placed rocks, however, as the most logical component of
movement resulting from the intrusion of a magma into
other rocks would be an upward movement of the intruding

rock relative to the intruded rock.

Megascopic description: In hand specimen the fine-grained quartz monzonite is medium- to fine-grained equigranular and very light gray to pinkish on the fresh surface. Quartz is glassy. Feldspars appear fresh, showing cleavage and twinning distinctly. No mafic minerals are seen. The surface is stained by limonite. Along the contact with the limestone the rock differs in appearance from the fresher material to the south. It is light tan with a greenish cast and is very fine-grained. A distinct lineation of quartz grains is commonly seen.

Microscopic description: Under the microscope the fine-grained quartz monzonite resembles the coarse quartz monzonite in mineral composition. The average grain size is about 0.4 mm., considerably smaller than the coarse-grained rock.

Quartz is more abundant than in the coarse-grained quartz monzonite and appears to have formed in part at the expense of feldspars. Some of the quartz may be secondary. The grains are always anhedral and very irregular in shape.

Plagioclase is andesine ($Ab_{68}An_{32}$), near oligoclase, and is identical in composition with that in the coarse-grained variety. The andesine is lightly sericitized throughout the rock.

Microperthite is the most abundant mineral after quartz. It is composed of an intimate association of albite in orthoclase in nearly equal proportions. Albite is more extensively sericitized than orthoclase.

Muscovite in elongate masses is present and while not abundant it is ubiquitous, filling voids between other mineral grains. It appears to be of the same generation as the shreddy sericite which lightly spots the feldspars.

Limonite is present as filaments between mineral grains.

Mafic minerals are absent in the sections studied.

An unidentified silicate mineral comprises about one percent of the rock.

Quantitative estimates of the mineral constituents

are as follows:

> Quartz....................50%
>
> Andesine-oligoclase......17%
>
> Microperthite............30%
>
> Limonite................. 2%
>
> Unknown silicate......... 1%

Thin sections of samples taken along the northern contact of the quartz monzonite show strong alteration near the intruded limestones. Feldspars have been completely sericitized. This replacement is interesting in that alternate lamellae of albite twinning have gone to coarse muscovite, and intercalated between them are bands of fine, typical sericite. Lineation of anhedral quartz grains showing embayments suggests incipient schistosity not present in the main monzonite mass. Kaolinite, earthy hematite and limonite have developed. Chlorite is present as fine shreds and flakes. The advanced stage of alteration along the contact and in the dike apophyses, and the similarity of alteration in the two rocks, warrant the assumption that solutions which ascended along the fault at the contact and in the limestone, forming the ore mineralization in the limestones, were the agency responsible for the rock alteration in apophyses and parent stock.

Dikes or sills of the fine quartz monzonite have intruded the Naco limestone near the southern edge of the

sedimentaries. These dikes parallel the strike of the beds and the limestone-quartz monzonite contact. Ore mineralization is associated with them in the Glove claims. The rock is altered as intensely as the northern periphery of the large parent intrusive. Chlorite forms stringers throughout the rock, and sericite has developed extensively at the expense of the feldspars.

Large, isolated masses of coarse quartz monzonite identical with the rock described from the eastern part of the area occur in the fine quartz monzonite. Contacts are largely concealed by alluvium and talus but the general similarity of the fine and coarse varieties leads the writer to believe that the coarse rock is not a later intrusive into the finer type, but is, rather, a local variation of the same intrusive.

The contact between this rock and the latite porphyry which delineates it to the east has proferred no evidence as to which is the older. No apophyses of either have been found in the other rock, and the contact is quite regular, trending north-south. The age is questionable but relating it to the coarse quartz monzonite which is intruded by the latite porphyry, it may be considered of Laramide age, and pre-latite porphyry.

Schrader [1] has mapped the fine quartz monzonite as a

[1] idem, p. 75 and plate II.

part of the Tertiary andesite which covers an extensive area on the west and southern flanks of the Santa Rita and Patagonia Mountains.

Latite porphyry

Latite porphyry intrudes the coarse quartz monzonite (see below) and probably intrudes the fine quartz monzonite. It occupies the southeastern quarter of the area mapped and lies between the coarse and fine quartz monzonite intrusives. Rugged topography is characteristic of the latite porphyry surface, which commonly weathers to rough, blocky masses, and, less commonly, to rounded forms. The rock is, like the coarse quartz monzonite, fairly resistant to weathering. Poorly developed jointing is found throughout the mass; the dominant member, found in several places in the latite porphyry, strikes N 85° E and dips 80° west. A weaker member strikes N 10° E and dips 65° east.

The latite porphyry varies in color from green mottled with red to dark gray-green spotted with chalky white feldspar phenocrysts. Weathered surfaces are reddish-brown in the northern part of the intrusive mass as seen from some distance away. The gray-green color is the dominant hue near Cottonwood Canyon. Weathered surfaces are lighter, generally, than fresh surfaces. Along the contact with the fine quartz monzonite the groundmass is

bleached light gray.

Megascopic description: In hand specimen the rock varies in color locally. Variegated green and red with white specks grading into rectangular chalky feldspar phenocrysts is a common type. The rock in the hills immediately east of the Isabella mine is greenish with large reddish-brown areas. One half mile south it is, as described above, gray-green with well-developed rectangular phenocrysts which make up about 35 percent of the rock. Epidote is so abundant locally as to color the rock green.

Microscopic description: In thin section the rock is composed of abundant plagioclase, orthoclase, and quartz phenocrysts in a very fine groundmass of orthoclase and quartz. Quartz is not abundant; it is rare as phenocrysts. Epidote is abundant in clumps of tiny grains and as individual grains. Phenocrysts vary greatly in size, ranging from a maximum of 3 mm. down into the groundmass and averaging about 0.5 mm. in length. They occupy about 50 percent of the volume and show no orientation.

Oligoclase, in part sericitized, is the most abundant phenocryst. Orthoclase, "dusty" from clay mineral alteration, is common, but is more abundant in the groundmass.

The latite porphyry is propylitically altered over large areas. Epidote is nearly everywhere present, and chlorite is abundant in the area north of Cottonwood Canyon near the fine quartz monzonite contact.

A dike in limestone of Permian age north of the Isabella mine is composed of latite of similar composition and is thought to be an apophysial offshoot of the latite porphyry stock. It is intensely sericitized and contains more quartz phenocrysts than the parent (?) body. What few mafic minerals were present have altered to chlorite, which is abundant. Feldspar phenocrysts have a distinct

lineation, the nature of which could not be determined because of the completeness of sericitic alteration.

Origin of the latite porphyry: The writer believes that the latite porphyry exposed in the mapped area is an intrusive stock on the following evidence:

1. No bedding or other phenomena associated with flows were observed in the field. With minor variations the latite porphyry is essentially homogeneous over large areas. The contact between the latite porphyry and limestone is, near the Isabella mine, a fault which obscures the intrusive nature of the contact. The dike in limestone north of the Isabella mine is considered an offshoot of the latite porphyry mass as its composition is very similar to that of the parent body.

2. Irregular masses of coarse quartz monzonite are found in the latite porphyry which show no elongate or dike-like forms. They are irregularly distributed in the latite porphyry, ranging in size from a few inches to many feet across. These are regarded as xenolithic in nature. The monzonite fragments show no indications that they are fensters, i.e., an older monzonite erosion surface peeping through superimposed lava flows; the masses are too irregular in shape, show microscopically sharp contacts, and there is no evidence of "onlap" of lavas onto quartz monzonite. Thin sections of these boundaries reveal little useful data of a positive nature. There is a suggestion

of alignment in the latite porphyry parallel to the boundary between included and including rocks. Smaller, angular fragments of monzonite are imbedded in the latite porphyry away from the contact. No significant local alteration in the quartz monzonite ascribable to the latite porphyry is seen.

The large size of some xenolithic masses of monzonite makes untenable the assumption that they have been picked up by flows. This is also true of large masses of gray limestone occluded by latite porphyry (Plate I). These are less common than monzonite xenoliths but are generally larger. One such block in the southeastern branch of Montosa Canyon is over 100 feet across and is roughly equidimensional in plan. It seems unlikely that these masses are calcite dikes. The topographic situation of some of the limestone bodies is such that it would be impossible for them to have been emplaced by the overthrusting of limestone onto the latite porphyry.

While the andesite in the belt to the south described by Schrader was not examined, his description of the rock leaves no doubt that it is largely a flow or series of flows.[1] It follows, then, that the rock exposed in the

[1] idem, p. 75.

area mapped in this study may be an exposed magma source

from which at least part of the flow andesite was de-
rived. Daly discusses a number of examples illustrating
a process he terms "deroofing" or "areal" eruption to
account for the observed phenomena of very thick flows
grading into rock of the same composition exhibiting no
features ascribable to eruptive causes. [1]

---

[1] Daly, R.A., Igneous rocks and the depths of the
earth, McGraw-Hill Co., 2nd ed., pp. 141-147, 1933.

The latite porphyry here may be considered as a source
which was uncovered over an undetermined area at the time
the lavas were extruded from it. Further work covering
a large area to the south would be necessary to substan-
tiate this possibility.

Relative age of the latite porphyry: The relative
ages of the latite porphyry and the coarse quartz monzo-
nite are not clearly shown in the area. Field data can
be interpreted to favor an earlier age for both intrusive
rocks. Arguments favoring an early (pre-coarse quartz
monzonite) age for the latite porphyry follow first be-
low.

The picture presented by rock alteration suggests an
early age for the latite porphyry. Ore and other minera-
lization in the limestones appear to have resulted from
the quartz monzonite intrusion at the Glove claim. Quartz
monzonite intrusion has also bleached and developed consi-

derable epidote in Cretaceous shales. Epidote has formed extensively in the latite porphyry together with sericite. The juices which caused the later rock alteration could likely have been associated with the quartz monzonite. As it seems well established that at least part of the epidote resulted from the quartz monzonite emplacement, the question arises as to whether or not all of it did. Of course, the solutions causing some of the mineralization and alteration may have ascended after the magma was intruded, but certainly not all.

Another factor favoring a pre-quartz monzonite age for the latite porphyry is that the usual sequence of intrusion, as observed in many areas, is first basic rocks followed by more acidic types.

The writer believes, however, that the latite porphyry is younger than, and intrudes, the coarse quartz monzonite because of the presence of xenoliths of quartz monzonite in the latite porphyry as described under Origin of the latite porphyry above. The writer can see no process by which the quartz monzonite xenoliths could have been emplaced unless they were picked up during the intrusion of the latite porphyry into the coarse quartz monzonite.

The latite porphyry is assumed, then, to be younger than the coarse quartz monzonite and of post-Cretaceous age.

Dacite porphyry

Large dikes of dacite porphyry intrude sediments in the central limestone mass and, to a lesser extent, the latite porphyry. The two main dikes are roughly parallel, striking east-west. The northern dike intrudes Permian limestone, the southern dike Pennsylvanian limestone and shales. They are both about 2500 feet long and vary in width from 10 to 40 feet. Little alteration of the intruded sediments was observed and no ore mineralization is associated with them.

Megascopic description: The rock is composed of a medium gray, aphanitic groundmass with abundant, poorly formed, chalky white phenocrysts about 3 mm. long. Glassy round quartz phenocrysts of smaller size and a few large (over one cm.) pink orthoclase euhedral crystals are characteristic. Phenocrysts occupy about 60 percent of the total volume; andesine makes up over 45 percent of the phenocrysts, orthoclase less than five percent, and quartz about 10 percent.

Microscopic description: In thin section the dacite porphyry is composed of a fine-grained groundmass, highly altered, in which are strongly sericitized plagioclase (andesine, $Ab_{62}An_{38}$) and less abundant kaolinized and sericitized orthoclase phenocrysts, as well as large anhedral quartz phenocrysts, resorbed in part, with smooth, regular curved outlines. Small muscovite phenocrysts are present but not common.

The average size of phenocrysts is about 2 mm. Quartz phenocrysts have a maximum diameter of 4.3 mm. and average 1 mm. A few large phenocrysts of what were originally biotite and/or hornblende have been completely converted to chlorite. Secondary calcite has developed.

The mineral constituents are estimated to be present in the following percentages:

Andesine..............60%

Quartz...............15%

Orthoclase...........10%

Muscovite............ 5%

Chlorite............. 8%

Magnetite............ 1%

Calcite.............. 1%

These dikes are post-Cretaceous in age and are younger than the latite porphyry which they intrude.

Quartz dikes

Several dikes composed of milky white quartz have intruded the latite porphyry near the point at which Cottonwood wash swings sharply to the north at the eastern extremity of the mapped area. They are parallel and strike nearly east-west. The dikes are irregular in width and are up to 50 feet across. Little significant ore mineralization was observed. The hanging wall of one of the dikes is composed of a solid, four-foot servage of schorlite. Scattered large crystals of potash feldspar are present in this dike which should properly be termed pegmatite.

VII

ECONOMIC GEOLOGY

Glove Group of Claims

History

The Glove group, also called the Sheehy-O'Donnell, consisting of fifteen unpatented claims, is situated on the south side of the east-west trending Naco limestone ridge, north of Cottonwood Canyon. The claims are located in section 30, T 20 S, R 14 E at an elevation of about 4200 feet. Schrader errs in his location of the property, placing the claims in the Devil's Cash Box, about one and one half miles north of their true location. [1]

---

[1] Schrader, op. cit., p. 185.

He did not himself visit the property.

The group was located in 1907 by Edward T. Sheehy, at present of Nogales, Arizona, who has owned the claims, with various associates, continuously since then. Of the five shafts and two adits in the group, four have produced shipping ore in varying quantity. In the early days of the mine, ore containing lead, zinc, and silver was hauled by mule team to Chavez, Arizona, a station of the Tucson-Nogales line of the Southern Pacific Railroad about five miles west of the claims. Silver-lead ore was

thence shipped to the American Smelting and Refining Co. works at El Paso, Texas; zinc-lead ore to the Ozark Smelting and Milling Co., Coffeyville, Kansas, and to U.S. Zinc Co., Colorado.

Sheehy states that metals mined in early days of the property came from "sand carbonate" and galena combined. [1]

---

[1] Sheehy, E.T., personal communication.

Dry bone (zinc carbonate) ore was thrown on the dump until it later was recognized as being of value. Zinc carbonate was an important source of zinc, according to DeKalb, who examined the claims in 1913. [2]

---

[2] DeKalb, Courtenay, Report on Sheehy-O'Donnell zinc-lead group, unpublished report.

Production

The incomplete (Sheehy) summary of shipments to smelters from 1911 to 1917 shown on the accompanying tables was obtained from a report compiled in 1918 on the Glove group by Hugo W. Miller of Nogales. The largest quantity of ore mined during the period 1911-17 was produced by Thomas M. Park in 1914. Most of Park's production was from the 125-foot shaft, now connected by the West adit, but he also mined ore from the 50-foot and 67-foot shafts. Schrader reports that forty men were employed at the mine,

known as the O.K., which produced "20 tons a day of chief-
ly shipping ore." [1] Production on this scale could not

---

[1] Schrader, op. cit., p. 185.

---

have been made for long, according to available smelter
returns. Hand sorting was done.

Three lots of ore shipped to El Paso by Jerry Sheehy
in 1925 showed (1) 19,170 pounds containing 7.8 ounces of
silver per ton and 32.8 percent lead, returning $339.27;
(2) 15,060 pounds containing 9.4 ounces of silver per
ton and 39.2 percent lead, returning $337.65; and (3)
29,880 pounds containing 5.8 ounces of silver per ton,
25.8 percent lead, and returning a total of $387.13.

E.J. Sikes of Globe, leasing in 1949, shipped ore
from the 67-foot shaft on the Rover claim. Returns from
A.S. &R.'s El Paso works showed 77,900 net pounds assaying
5.05 ounces of silver per ton, 29.45 percent lead, and
0.38 percent copper. Total payments were $2028.16.

Estimates indicate that at least 683 tons of ore
have been shipped from the group.

It is interesting to note that litigation between
Park and the Sheehys resulted in the first enforcement of
the then new Miners Lien Law. As a direct result of this
litigation, an amendment to the law rendered effective
the recording and posting of non-liability notices. [2]

---

[2] Sheehy, E.T., personal communication.

Date of settle-ment	Net dry tons	Ozs. Ag per ton	Total ounces silver	Percent lead	Tons lead	Percent zinc	Tons zinc	Percent iron	Percent lime	Percent insols.	Net cash rec'd
July 3, 1911	34.813	8.0	282.00	38.0	1.325	11.6	.405	9.8		11.6	$700.34
" 26, 1911	29.190	6.8	198.50	30.7	.895	12.5	.305	7.4		11.0	379.50
Oct. 15, 1912	26.918	6.0	163.30	28.6	.772	13.3	.359	7.1		14.4	279.76
Jan. 9, 1914	47.170	8.8	415.00	27.5	1.295	12.9	.610	8.3	3.5	8.2	375.58
Sept. 4, 1914	8.860	6.4	56.70	27.8	.246	18.8	.166	4.3	6.5	13.8	35.86
" ", "	19.700	9.4	191.00	29.3	.578	16.3	.321	6.3	5.3	8.2	199.50
" 12, 1914	24.750	8.2	203.00	32.1	.795	13.8	.342	6.6	6.8	5.2	267.34
" 25, "	32.500	7.4	240.00	29.0	.942	13.0	.423	7.7	6.1	7.6	376.42
Oct. 6, "	34.296	8.1	278.00	28.0	.961	14.8	.508	8.6	3.8	10.2	287.96
July 7, 1916	7.994	18.5	148.00	69.9	.559			1.0	0.4	2.0	518.00
" ", "	21.240	8.5	172.00	33.0	.702	10.7	.228	8.6	3.4	9.2	534.78
Jan. 4, 1917	0.673	14.8	10.00	62.2	.042	8.0	.005	1.7	1.0	3.5	34.00
" ", "	14.187	7.9	112.00	33.3	.472	9.2	.131	8.8	1.6	12.0	384.22
" ", "	37.620	3.3	124.00	18.8	.708	10.0	.376	14.8	4.6	13.0	132.50
" 15, "	9.831	6.2	61.00	39.6	.390	7.4	.073				301.46
Total	349.750		2654.50		10.682		4.252				$4807.22
Average		7.5		30.6		12.2					

Average net value per ton....$13.20

Summary of Silver-Lead Ore Shipped to A.S.&R.'s El Paso Works
(data incomplete according to E.T. Sheehy)

Date		Tons	Percent lead	Tons lead	Percent zinc	Tons zinc	Value per ton	Freight paid	Net returns
Nov. 19,	1914	49.88	19.7	.983	21.5	1.072	$15.73	$329.30	$454.69
" 22,	1914	46.92	18.6	.872	17.0	.796	13.49	307.00	325.79
Dec. 2 ,	1914	44.79	26.0	1.165	14.0	.628	15.20	296.80	303.00
" 11,	1914	37.66	21.9	.825	16.8	.632	14.75	251.90	386.81
" 30,	1914	39.52	22.5	.890	15.2	.602	14.33	261.00	261.43
Sept. 8,	1912	20.76	4.4	.088	33.8	.680	19.04	127.00	268.52
" " ,	1912	22.54	16.3	.368	35.5	.800	21.60	137.00	361.19
Totals		262.07		5.191		5.210	--#	1710.00	2361.43
Average			19.8		19.85				

Average freight per ton....$6.50

Average net returns per ton....$9.05

Summary of Zinc-Lead Shipments
First five to Ozark Smelt. & Min. Co.,
Coffeyville, Kas.; last two to U.S. Zinc Co., Colo.
(data incomplete according to E.T. Sheehy)

West Adit

The only workings examined by the writer were the West adit and connecting "125-foot" shaft on the Glove and Jerry claims, and the East adit and connecting "50-foot" shaft on the Rover claims.

Naco limestones and shales have been intruded by quartz monzonite dikes or sills parallel to the strike of the beds. The dip of the sills is the same as or slightly steeper than the dip of the sedimentary rocks. The contact between the Naco limestone and the quartz monzonite is a fault zone exposed in both the East and West adits. Drag folding exposed in the East adit indicates a final upward movement of the sediments relative to the quartz monzonite. About 50 feet of crumpled and disturbed sediments exposed in the East adit indicate a strong displacement on a high-angle reverse fault similar to the Isabella mine fault.

The southernmost sill in the West adit is about 80 feet in width. The northern sill is about 60 feet wide as exposed in the mine. Seventy-five feet of Naco separate them where observed in the mine. The sill-limestone contacts are delineated by faults generally dipping with or steeper than the sediments.

Mineralization: Ore mineralization in the West adit, on the adit level and the level 225 feet above, makes

along fault fissures paralleling bedding in the sediments
and at the sill-sediment contacts. No replacement of
limestone was observed. The ore where exposed on these
levels replaces limestone and shale along fissures adja-
cent to sills. Thickness of ore-mineralized fissures
ranges from one inch to about 1.5 or two feet. Two stopes
paralleling fissures on the upper level are flat-tabular
voids. The stopes are on opposite sides of the sediment
wedge between the two quartz monzonite sills.

While most of the mineralization observed in the
lowest two levels is of the sulfide type, DeKalb reports
that the ore in upper levels occurred largely as oxidized
lead and zinc minerals. [1] The surface rocks around the 125-

[1] DeKalb, op. cit.

foot shaft are stained with manganese dioxide, iron oxides
and a little copper carbonate. Oxidized ores extended to
a depth of at least 98 feet, the shaft bottom at the time
of DeKalb's examination. The bottom of the shaft at that
time apparently corresponds with the level above the adit
level, but no oxidized lead or zinc minerals were seen by
the writer in the ore. A brecciated zone along a fault
exposed in the extreme northern end of the West adit level
contains wulfenite crystals remarkable in that they are so
light as to be practically colorless.

In polished section galena and sphalerite are the

abundant ore minerals, honey-yellow sphalerite being more common than galena, which replaces it. Chalcopyrite is disseminated through all sphalerite as minute blebs. Pyrite occurs as euhedral cubic crystals. It is not abundant. Covellite, which tarnishes galena, is rare.

The sequence of mineralization as ascertained from the examination of polished sections follows. Earlier quartz is replaced by a member of the chlorite family. [1]

---

[1] This mineral could not be positively identified but had such extremely low birefringence as to be essentially isotropic. Index of refraction, ($n=1.608$).

Calcite forms a central core in some vein-like masses of this mineral, which is light to very dark green. Pyrite cubes and irregular stringers are scattered throughout quartz and chlorite. Clear, honey-yellow sphalerite replaces these minerals. Disseminated in the sphalerite are very tiny blebs of chalcopyrite which, in portions of the sections examined, are oriented in lines suggesting cleavage traces in sphalerite. No relationships were observed to prove that chalcopyrite is replacing sphalerite, that chalcopyrite is residual, having been nearly completely replaced by sphalerite, or that the texture is due to unmixing of a solid solution. Bastin and others point out that either is possible, but that no satisfactory criteria have been developed for differentiating

between the possible origins without supporting evidence. [1]

[1] Bastin, et. al., Criteria of age relations of minerals, Econ. Geol. vol. xxvi, no. 6, pp. 570-71.

The extremely uniform size and shape of the chalcopyrite grains suggest unmixing of a solid solution, as one would expect more shape and size variations if replacement were the cause of this phenomenon.

Galena replaces sphalerite, chlorite, and pyrite. Covellite is rare and replaces galena.

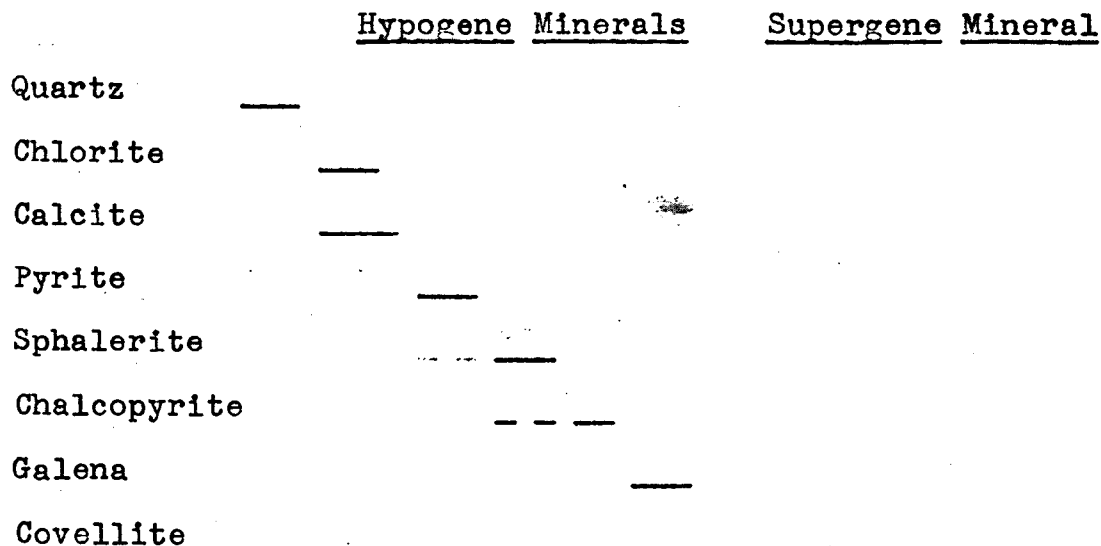|	Hypogene Minerals	Supergene Mineral
Quartz	—	
Chlorite	—	
Calcite	—	
Pyrite	—	
Sphalerite	—	
Chalcopyrite	— — —	
Galena		—
Covellite		—

Diagram showing the sequence of
mineralization, West adit, Glove claims

East Adit

No ore mineralization was observed in the adit level of the East adit. Sheehy reports that no ore was shipped. [1]

_____

[1] Sheehy, personal communication.

_____

Conclusions and suggestions

Production of the group has not been large although the grade of ore shipped has been good, especially in the light of prevailing lead and zinc prices.

The veins now exposed are narrow and considerable development work would have to be done with no guarantee that ore obtained during the work would defray more than a fraction of the cost. Underground diamond drilling might prove some ore if holes were drilled in a southerly direction to cut across the east-west striking, northerly dipping faults and limestone-sill contacts. Assuming an average dip of 55° N for the quartz monzonite-Naco fault contact, the depth to quartz monzonite from the bottom of the 125-foot shaft would be about 170 feet. Lateral exploration on the faults and sill-Naco contacts might be as rewarding as prospecting at depth.

Isabella Mine

Location

The Isabella mine is in the Tyndall mining district on the south side of Montosa Canyon. The mine is at an elevation of about 4900 feet on the southern edge of Montosa Basin, also called "The Devil's Cash Box." The shaft of the Isabella mine is located in the northwest quarter of section 29, T 20 S, R 14 E on the Isabel claim. A discrepancy exists between the General Land Office survey plats of the Isabel and Black Diamond claims and the location observed by the writer. The plats show the Isabel claim in section 17 and 20, T 20 S, R 14 E. A quarter corner on the property shows it to be located as stated above. As the section corners were located several years (1923) subsequent to this claim survey, the error may lie with the latter. Bearings and distances given on the survey plats do not agree with the U.S. Geological Survey Patagonia quadrangle as to the correct location.

History and Production

The Isabel claim, one of a group of fourteen known as the Montosa group, was located in 1896 and patented in 1912 together with the adjacent Black Diamond claim, located in 1904. Schrader states that the mine, then known as the Amado mine, was worked principally about 1901. [1]

[1] Schrader, op. cit., p. 186.

Shortly thereafter Capt. John D. Burgess of Tucson, employed by the Calabasas Mining Co., Ltd., of New York City, leasing from Smith and Freeman of Tucson, owners of the mine, conducted operations at the property. Reportedly 2000 feet of underground drifting was done, largely on the Isabel claim, and the shaft was deepened to a 250-foot depth. [1] It is questionable that this much work was

[1] idem, p. 186.

accomplished as there are no dumps in evidence to account for such extensive mining. Some dump material is reported to have been shipped during the late 1940's, however, and this may have been the fate of some earlier extracted material. At the time the present writer examined the Isabella mine the inclined shaft was open a short distance below the 38-foot level and shortly thereafter was lagged off at the 38-foot level so that the lower workings are no longer accessible. Wilson and Butler further state that the patent survey plats show a total of only 275 feet of underground workings on both the Isabel and Black Diamond claims. [2]

[2] Wilson, E.D., and Butler, B.S., report of condition of Isabel and Black Diamond claims to the President of the University of Arizona, 1946.

In 1901 Burgess erected a 36-inch 30-ton water-jacketed smelter a few hundred feet west of the mouth of

the draw in which the Isabella mine is located and, although it was operated for a total of only four and one half days, $9600 worth of bullion was shipped to Ledoux and Co., New York. [1]

[1] Schrader, op. cit., p. 186.

Mr. Fred G. Hawley of Tucson, who was employed at the mine as an assayer during 1901-2, reports that a few bars each of copper-lead and lead-copper bullion were extracted from the small tonnage of copper-lead ore treated by the Burgess smelter. [2]

[2] Hawley, F.G., personal communication.

Schrader was informed that minerals mined at this time included malachite, chalcopyrite, bornite, cerussite, galena, magnetite, specular hematite, and epidote. [3]

[3] Schrader, op. cit., p. 186.

When its bond expired in February, 1902, the Calabasas company gave up the property.

In 1912 ore was mined from the Isabella by Robert O. Boykin, who is quoted below from a letter to the President of the University of Arizona, Dec. 6, 1946. Boykin wrote that he shipped ore containing about 40% lead, 2% copper, and low gold-silver values produced from the property to the El Paso smelter.

I used native Tubac miners and selectively mined
and hand sorted to produce that grade of ore.
At that time lead was about 5¢ per pound and cop-
per was about 14¢. Labor was about $2.00 per
day. I had a short-term lease and after my dis-
covery and production of this high-grade ore Mr.
Freeman thought the mine could be sold immediately
for cash after I placed it in production and re-
fused to grant an extension of my lease. The
lease was the O'Hara and Boykin and we called it
the Double O mine at that time. Having a short-
term lease, I could not put equipment in the
mine and was unable to go deeper than 125 feet.
The production was all from the 'Isabella' and
occurred as small pockets and lenses of lead
and copper carbonate ore. The location of these
lenses was unpredictable and when my lease ex-
pired there was no profitable ore in sight.

Wilson and Butler state:

Harvey Saxby is reported to have sunk a shaft
65 feet deep on the Isabel claim in 1917 and
to have shipped a car of sand carbonate lead
ore from a pocket that was found at a depth
of 30 feet.

They continue:

During 1927-28, H.S. Hillman and associates
deepened Saxby's shaft to 125 feet and at a
depth of 80 feet drove a drift southwestward
for approximately 211 feet. This drift was
for the purpose of testing the area down the
dip beneath Boykin's stope, but it encoun-
tered very little ore. [1]

---

[1] Wilson and Butler, op. cit.

Since 1930 the Board of Regents of the University of

Arizona has had part ownership of the Isabel and Black

Diamond claims through the bequest of Merril P. Freeman

of Tucson.

In 1947 and 1948 C.H. and S.A. McIntosh of Lordsburg,

New Mexico, to whom a lease was transferred from C.W. Walker of Patagonia, drifted south from the bottom of the vertical shaft on the 38-foot level and encountered small pockets of ore averaging about 17% lead, 2% copper, and four ounces of silver, with very low values in gold. About 102 tons of this ore were shipped to the El Paso smelter. No work has been done on the property since the McIntoshes ceased operations in 1948 after drifting and cross-cutting about 380 feet southward in limestone.

During the last operation (1947-48) a new road was constructed from the base of the mine canyon to the Isabella mine and the mine was re-equipped throughout. At the present time some repair work would be required on the road to make it serviceable.

Geology

The Isabella mine is located entirely in limestone of Permian age at a fault contact between intrusive latite porphyry and the limestone.

Permian limestone and marls form the west side of the small north-south trending canyon in which the mine is located. The limestone and marls strike generally east-west to northwest-southeast and dip to the south. Locally the limestone is silicified or dolomitized and manganese-stained. Red shales of Cretaceous age occur at the base

of the draw at the junction of the mine canyon and Montosa Canyon beneath the limestone which has been thrust over them from the south. The latite porphyry has been faulted against the limestone by a high-angle fault dipping on the average 60° to the east and striking N 35° E. Just north of the Isabella shaft this fault splits, one segment striking about N 12° E and the other N 50° E. The block of limestone and marls between these fault segments may have been moved up with respect to the Permian limestone to the west. No evidence of the dominant direction of movement on the Isabella fault was obtained underground. Slickensides in gouge show movement in numerous directions in the plane of the fault. The latite porphyry, however, was most likely moved up to the limestone. This relative movement, reflected in the position of the marls in the lower part of the canyon to the north, would make the Amado fault a high-angle reverse fault.

A break 500 feet to the east of and approximately parallel to the Isabella fault has displaced the limestone at least 100 feet horizontally. Local topography is controlled by weaknesses resulting from these breaks.

About 300 feet south of the Isabella shaft a segment of the Isabella fault swings sharply westward. At least one other east-west cross fault intersects this segment.

Strong iron mineralization is found along this inter-section and the limestone to the west has been dolomitized and stained by manganese dioxide along east-west fissures.

Underground, the Amado̶ [Isabella] fault is exposed in drifts on both the 38- and 80-foot levels. It dips 62° east on the 38-foot level near the shaft and 50° east on the 80-foot level, forming a surface concave upward. To the south the curve is reversed, the steeper portions being general-ly deeper. The altitude of the fault varies considerably, however, along its strike where exposed underground. To the south, underground, several branching segments are present, showing the fault to be a fault zone locally. White clay gouge up to four feet thick is present on the hanging wall, which is limestone, in all accessible parts of the workings. Slickensides are abundant but give no indication of the directions of major displacement.

Mineralization

Heavy specular hematite masses occurring mainly in the footwall are prominent on the 38-foot level. Some of these masses have malachite, azurite, lead carbonate, and sulfate and plumbojarosite associated with them.

The ore shipped during McIntosh's operation yielded lead, copper, and silver, with low gold (values quantita-tively similar to those shipped during the early days of

the mine). Burgess' ore was supposed to be sulfides, however. Lead occurred as cerussite--the typical "sand carbonate" of the miner, being extremely friable and sandy. Plumbojarosite has contributed to the lead content. Very few residual masses of galena were observed in the workings, surrounded by anglesite and cerussite, indicating that the oxidized lead minerals were formed, at least in part, from galena. Malachite, azurite, and rare brochantite, associated with lead minerals and specular hematite, have probably accounted for the lion's share of the ore's copper content. Some zinc occurs in the oxidized ore and in specular hematite. Ultra-violet light reveals a very small quantity of willemite, but not enough to account for the zinc present in assays. The mineral nature of the preponderance of the zinc present is not known.

While no sulfides, aside from galena mentioned above and a little covellite, are found in the accessible portions of the mine, a reconstruction of the original minerals from the oxidized end products would suggest that the stoped ores were originally sulfides (galena, sphalerite, perhaps chalcocite and chalcopyrite, and some silver sulfide such as argentite). A relatively small amount of iron oxide staining is present. Iron is present in vivid yellow plumbojarosite. The abundant primary specular

and micaceous hematite in the mine has not resulted from
contact-metamorphism. Lime silicates, garnet, and the re-
mainder of the contact mineral assemblage are missing.

Small massive pieces of a chlorite group mineral are
found irregularly in the clay gouge filling the fault
zone. Powdery plumbojarosite coats some of these, and
small plates of specularite are scattered through the
chlorite.

Polished sections of ore minerals and gauge were
prepared to obtain genetic relationships between ore mine-
rals and ore minerals and gangue minerals. A few sections
showed that specular hematite replaced quartz, suggesting
that there was an early stage of silicification. What
little silica was observed in the workings seems to be
confined to the areas containing massive hematite.

A thin section of one of a few fragments of latite
porphyry found in the gouge formed in the fault shows it
to have been intensely altered with the formation of
secondary quartz veinlets, which are quite probably of
the same generation as the quartz replaced by specular
hematite. Intense sericitization and chloritization have
taken place.

Azurite and malachite are intimately mixed with spe-
cular hematite. Quite possibly they have been derived
in place from sulfides which replaced hematite. These

copper carbonates fill triangular interstices between intersecting tabular crystals of hematite and cut across hematite in veinlets. Not uncommon is the replacement of copper carbonate veinlets by parallel veinlets of plumbo-jarosite.

The sequence of oxidation of lead minerals is clearer than that of the copper minerals. Galena is clearly the first lead mineral deposited. It was later than specular hematite and possibly later than copper sulfides. In polished section reaction rims of anglesite are seen surrounding residual islands of galena. Smooth, wavy boundaries between anglesite and galena are remarkably sharp. Anglesite replaces galena both along cleavage traces and in irregular patterns. Under high magnification residual galena blebs can be seen disseminated throughout anglesite and later cerussite. Anglesite has been replaced by cerussite, which is considerably more abundant. After the development of anglesite and cerussite, but prior to the formation of plumbojarosite, covellite replaced galena, anglesite, and cerussite. A reversal from an oxidizing to a reducing environment is patently necessary here for the formation of the sulfide, covellite. It is postulated that, subsequent to the oxidation of lead sulfide, the water table rose, meeting solutions bearing copper sulfate. These precipitated on encountering the reducing

environment provided by the water table with the formation

of covellite. Copper sulfate may have been derived from

residual copper sulfides which had not been entirely oxi-

dized at that time and which were destroyed by oxidation

following a later lowering of the water table.

Plumbojarosite [1] is abundant in the mine and probably

was important as a source of lead in the ore shipped.

---

[1] Identification of this mineral is certain, perhaps,
only so far as placing it in the jarosite group is
concerned. A lead test was obtained from clean, care-
fully selected material which showed no contamination
by the lead minerals with which it is so intimately
associated. The microscopic crystals were too small
to yield diagnostic optical data, but the index range
appears rather too high for jarosite.

It is intimately associated with other lead minerals,

especially cerussite, crystals of which it coats. Polished

sections show individual euhedral, six-sided crystals of

plumbojarosite in galena, anglesite, cerussite, and covel-

lite. The mineral replaces cerussite in stringers and

veinlets. In loose, powdery masses, it fills vuggy cavi-

ties in essentially all the ore.

The nature of the origin of plumbojarosite here is

not definitely established but its occurrence suggests a

secondary origin. The mineral, as pointed out above, re-

places and coats all earlier ore minerals, and occurs

most commonly as loose, powdery crusts and minute euhed-

ral crystals in early ore minerals. The mineral is hydrous

and is generally thought to be formed at moderate to low temperatures under conditions where ferric sulfate will form.[1]

---

[1] Butler, B.S., personal communication.

The mineral is closely related to alunite,[2] however, which is known to form under both hypogene and supergene conditions, the former being probably the more common.

---

[2] Hendricks, S.B., The crystal structure of alunite and the jarosites, Am. Min., vol. 22, no. 6, pp. 773-784.

	Hypogene minerals	Supergene minerals
Quartz	___	
Specularite	___	
Copper sulfide	___	
Galena	___	
Malachite		___
Azurite		___
Anglesite		___
Cerussite		___
Covellite		___
Plumbojarosite		___

Diagram showing the sequence
of mineralization, Isabella mine

BIBLIOGRAPHY

Alexis, Carl O., The geology of the northern part of the Huachuca Mountains, Arizona: Univ. Ariz. thesis, 1949.

Bastin, E.S., et. al., Criteria of age relations of minerals: Econ. Geol., vol. xxvi, no. 6.

Bryan, Kirk, The Papago country: U.S. Geol. Survey Water Supply Paper 499, 1925.

Butler, B.S., Primary (hypogene) sulfate minerals in ore deposits: Econ. Geol., vol. xiv, no. 8, 1919.

Butler, B.S., and Gale, H.S., Alunite, a newly discovered deposit near Marysvale, Utah: U.S. Geol. Survey Bull. 511, 1912.

Daly, R.A., Igneous rocks and the depths of the earth: McGraw-Hill Co., 2nd ed., 1933.

DeKalb, Courtenay, Report on Sheehy-O'Donnell zinc-lead group: unpublished report.

Galbraith, F.W., Geology of the Empire Mountains, Arizona: unpublished MS.

Grout, Frank F., Petrography and petrology: McGraw-Hill Co., New York, 1st ed., 1932.

Hendricks, S.B., The crystal structure of alunite and the jarosites: Am. Min., vol. 22, no. 6.

Jones, W.R., Geology of the Sycamore Ridge area, Pima County, Arizona: Univ. Ariz. thesis, 1941.

Kiersch, G.A., Structural control and mineralization at the Seventy-Nine mine, Gila County, Arizona: Econ. Geol., vol. 44, no. 1, Jan.-Feb., 1949.

Mayuga, M.N., The geology and ore deposits of the Helmet Peak area, Pima County, Arizona: Univ. Ariz. thesis, 1942.

McKee, E.D., Sedimentary basins of Arizona and adjoining areas: Geol. Soc. Amer., Bull., vol. 62, no. 5, 1951.

Schrader, Frank C., Mineral deposits of the Santa Rita and Patagonia Mountains, Arizona: U.S. Geol. Survey Bull. 582, 1915.

Bibliography...cont.

Stoyanow, A., Correlation of Arizona Paleozoic formations; Bull. Geol. Soc. Amer., vol. 47, 1936.

Stoyanow, A., Lower Cretaceous stratigraphy in southeastern Arizona: Geol. Soc. Amer., Mem. 38, 1949.

Wilson, E.D., and Butler, B.S., Report of condition of Isabel and Black Diamond claims to the President of the University of Arizona, 1946.

PHOTOGRAPHIC PLATES

PLATE IV

View, looking east, of Santa Rita Mountains.
Montosa-Cottonwood canyons area is between
vertical lines.

PLATE V

View, looking southeast. Limestone in foreground
is Snyder Hill limestone of imbricate thrust
block.

PLATE VI

View southwest of Naco limestone ridge. Permian,
unnamed formation in foreground. Cottonwood Can-
yon in extreme distance.

PLATE VII

View west, taken near head of south branch of Montosa
Canyon, showing physiographic expression of mountain
outliers capped by Snyder Hill limestone to right,
north, in photograph.

Baboquivari Peak   Devil's Seat

Devil's Cash Box

Pchl

qmc

Pl

qd

PLATE VIII

A. Third imbricate thrust block of Snyder Hill lime-
   stone. Looking northwest.

B. Faulting in massive beds of pre-Snyder Hill unnamed
   limestone of Permian age.

PLATE IX

A. Permian pre-Snyder Hill formation-Naco limestone

   contact. Devil's Seat syncline to left. View

   east.

B. Pre-Snyder Hill limestone-Naco limestone contact

   passes down declevity in foreground, displaced

   by north-south shear fault. View looking west.

PLATE X

A. Chert paralleling bedding in Snyder Hill limestone.

B. Detail of folded structure in quartzite which caps
pre-Snyder Hill formation of Permian age.

PLATE XI

A. Beds of Cretaceous age at sequence measured. Oyster

beds lie near base. Cliff at top of section is

Snyder Hill limestone thrust over Cretaceous age

rocks. View looking north; west side of Devil's

Cash Box.

B. Detail of oyster bed at base of slope shown above.

PLATE XII

A. Arkose of Cretaceous age exposed in wash west of national forest boundary.

B. Caliche conglomerate capping gravels.

PLATE XIII

A. "Coarse" quartz monzonite exposed near head of south
branch of Montosa Canyon.

B. Jointing in "coarse" quartz monzonite exposed as
above.

PLATE XIV

A. Blocky character of latite porphyry.

B. Jointing in latite porphyry.

PLATE XV

A. "Fine" quartz monzonite in wash at base of Snyder
   Hill thrust block west of Glove claims, north of
   Cottonwood Canyon.

B. Central limestone hills looking west. Limestone is
   of Permian age. South Isabella Canyon at base of
   hill. Isabella fault (outlines) passes down Isabel-
   la Canyon. Latite porphyry in foreground.

PLATE XVI

A. Thrust fault exposed at base of north Isabella
   Canyon. Pre-Snyder Hill limestone at left against
   maroon shales of Cretaceous age. Dip is 45 degrees
   southwest.

B. View, looking southeast, of central limestone
   hills. Devil's Seat syncline in right, central
   part of photograph, capped by Permian age
   quartzite overlain by Snyder Hill limestone.

PLATE XVII

A. Fold in massive beds of pre-Snyder Hill limestone.
   View, northest, of Devil's Seat syncline.

B. Head frame and hoist shed, Isabella mine.

PLATE XVIII

A. Ore bin, Isabella mine.

B. West Adit, Glove claims.

PLATE XIX

Looking southwest from West Adit, Glove claims. Tumacacori
Mountains in distance across Santa Cruz River. Rocks of
Cretaceous age underly low area in background.

PLATE XX

A. Photomicrograph of "coarse" quartz monzonite
   showing straining of andesine twin lamellae.
   Crossed nichols.   X36.

B. Photomicrograph of thin section of "fine" quartz
   monzonite, showing equi-granular texture of and-
   esine-oligoclase and irregular quartz grains.
   Partially crossed nichols.   X20.
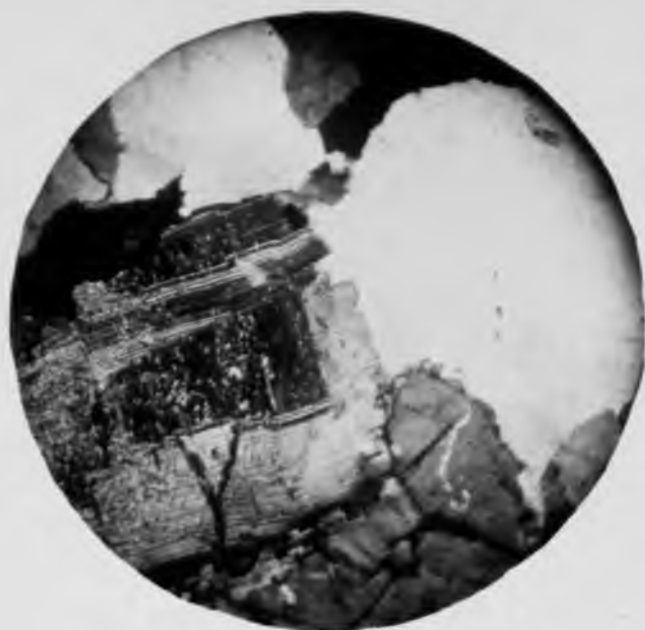
PLATE XXI

A. Photomicrograph of latite porphyry showing oligo-
clase and quartz phenocrysts in fine-grained
quartz-orthoclase groundmass. Area shown is
strongly sericitized.

Crossed nichols.   X36.

B. Photomicrograph of "coarse" quartz monzonite fragment
in latite porphyry showing extremely sharp contact.
Light area in upper right-hand section of field is
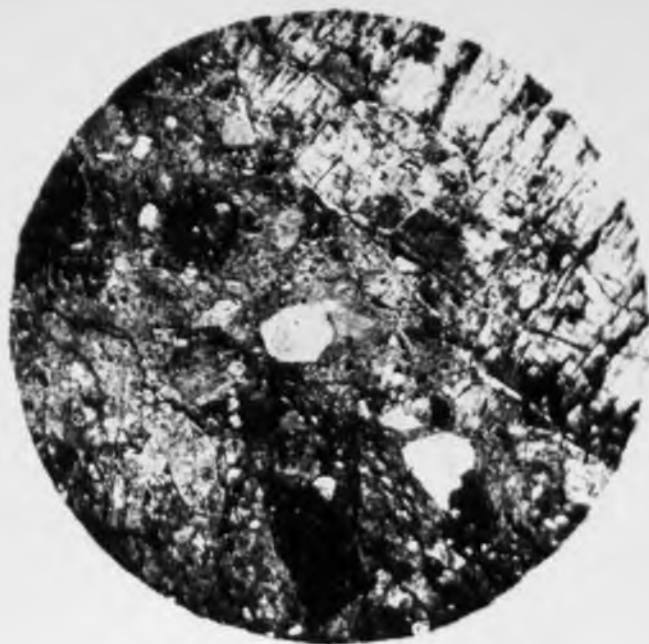microperthite grain of quartz monzonite.

Partially crossed nichols.   X20.

PLATE XXII

A. Photomicrograph of thin section of dacite porphyry.
Extensive development of sericite in phenocrysts
and groundmass causes cloudiness of photograph.
Partially crossed nichols.   X20.

B. Galena replacing sphalerite and chalcopyrite which
have replaced early quartz gangue. West Adit, Glove
claims.   X150.
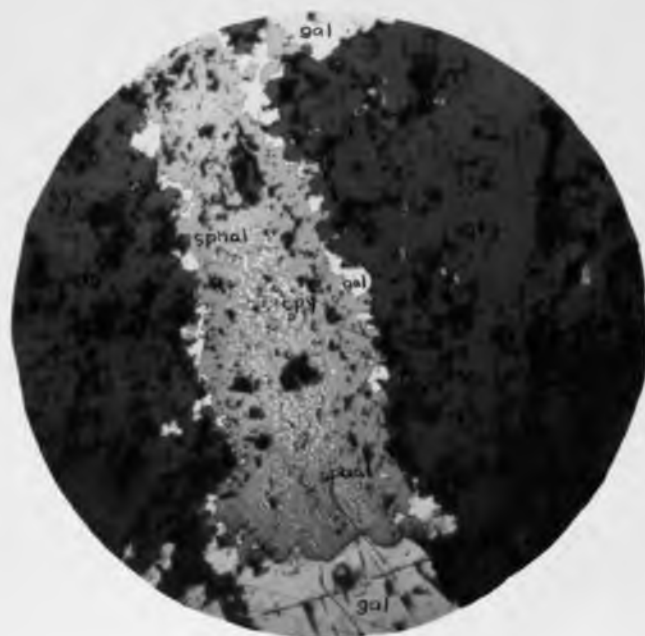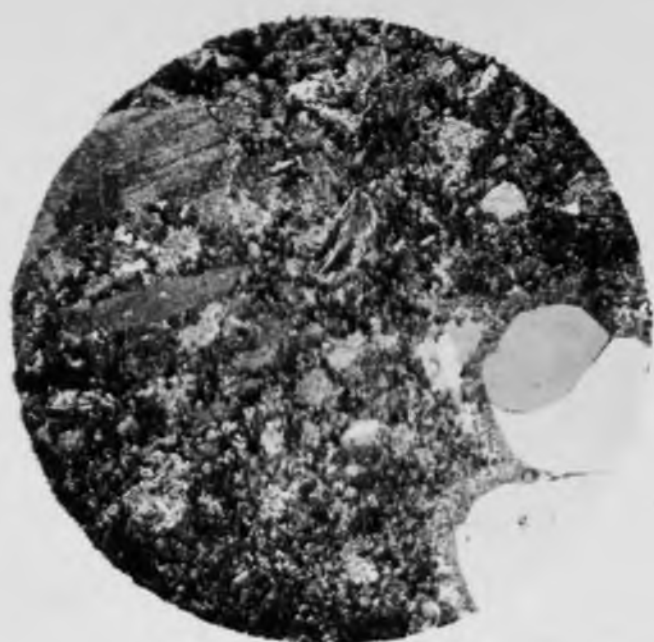
gal: galena
sphal: sphalerite
cpy: chalcopyrite
qtz: quartz

PLATE XXIII

A. Chalcopyrite blebs in sphalerite showing lineation
of grains of the former suggesting ex-solution
texture. West Adit, Glove group of claims.   X150.

cpy: chalcopyrite
sphal: sphalerite
g: qangue
py: pyrite

B. Photomicrograph of plumbojarosite in galena,and angles-
ite. Triangular pits are cleavage traces in galena.
Note euhedral crystal of plumbojarosite in anglesite
(black). Isabella mine, 32 foot level.   X750.
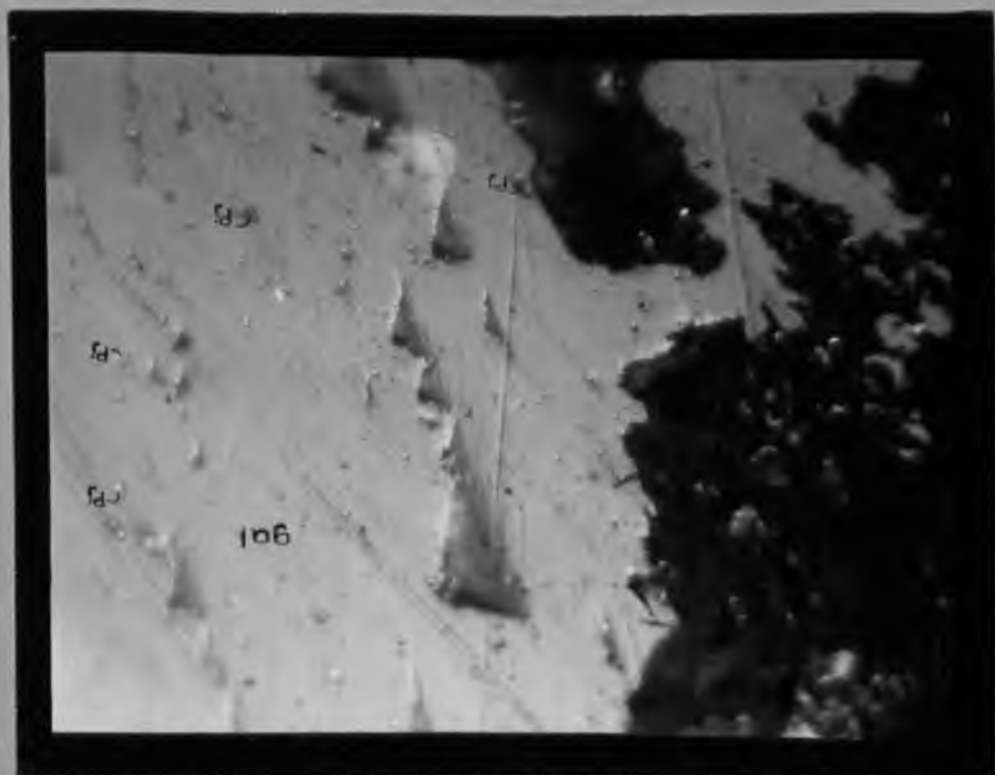
Pj: plumbojarosite
gal: galena
ang: anglesite

PLATE XXIV

Anglesite replacing galena. Later covellite (showing

little contrast in photograph) replaces both minerals.

Isabella mine, 32 foot level. Striae due to poor

polish.   X150

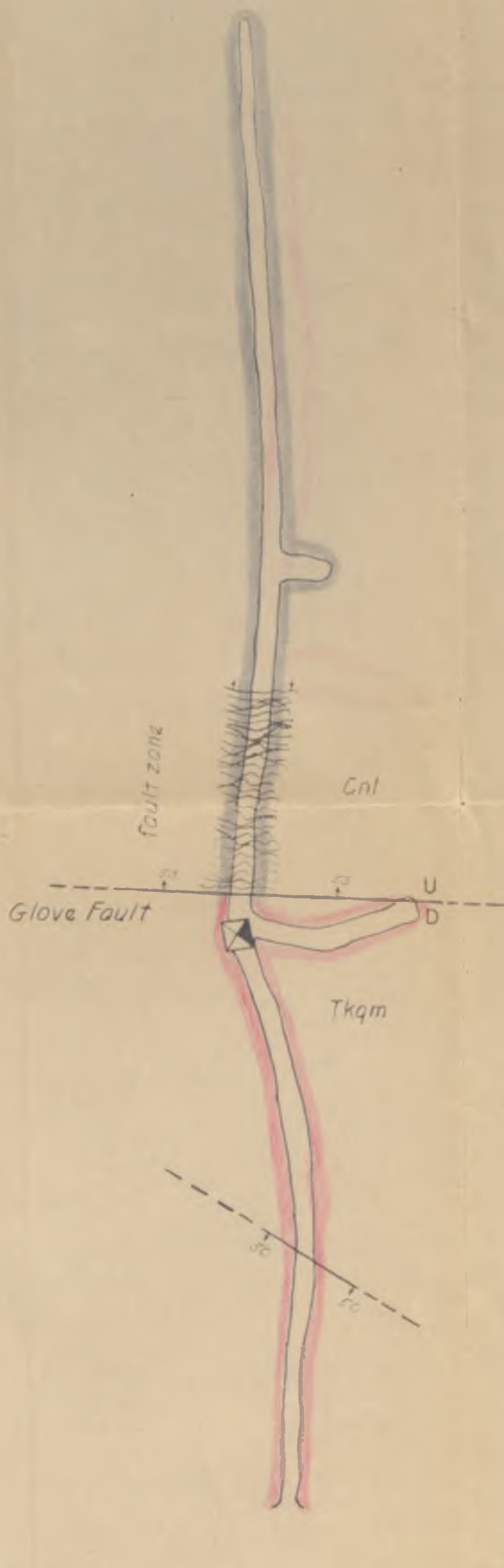 gal: galena
  ang: anglesite
  cov: covellite

8 pieces

piece the + b accessory
/ a.1.1957 - 3-

Workings, East Adit

Scale 1"= 25'

Symbols

| Cnl | Naco limestone |
| Tkqm | Quartz monzonite |

Cnl

Tkqm

Glove Fault

fault zone

U
D

A — A'

30 level

80 level

Andesite

Permian limestone

45

85

75

60

60

70

60

40

70

49

70

A

50

62

Isabella shaft

A'

Fault

Stoped area

Top of winze

Shaft bottom

Inclined shaft or winze

Adit level

30 foot level

80 foot level
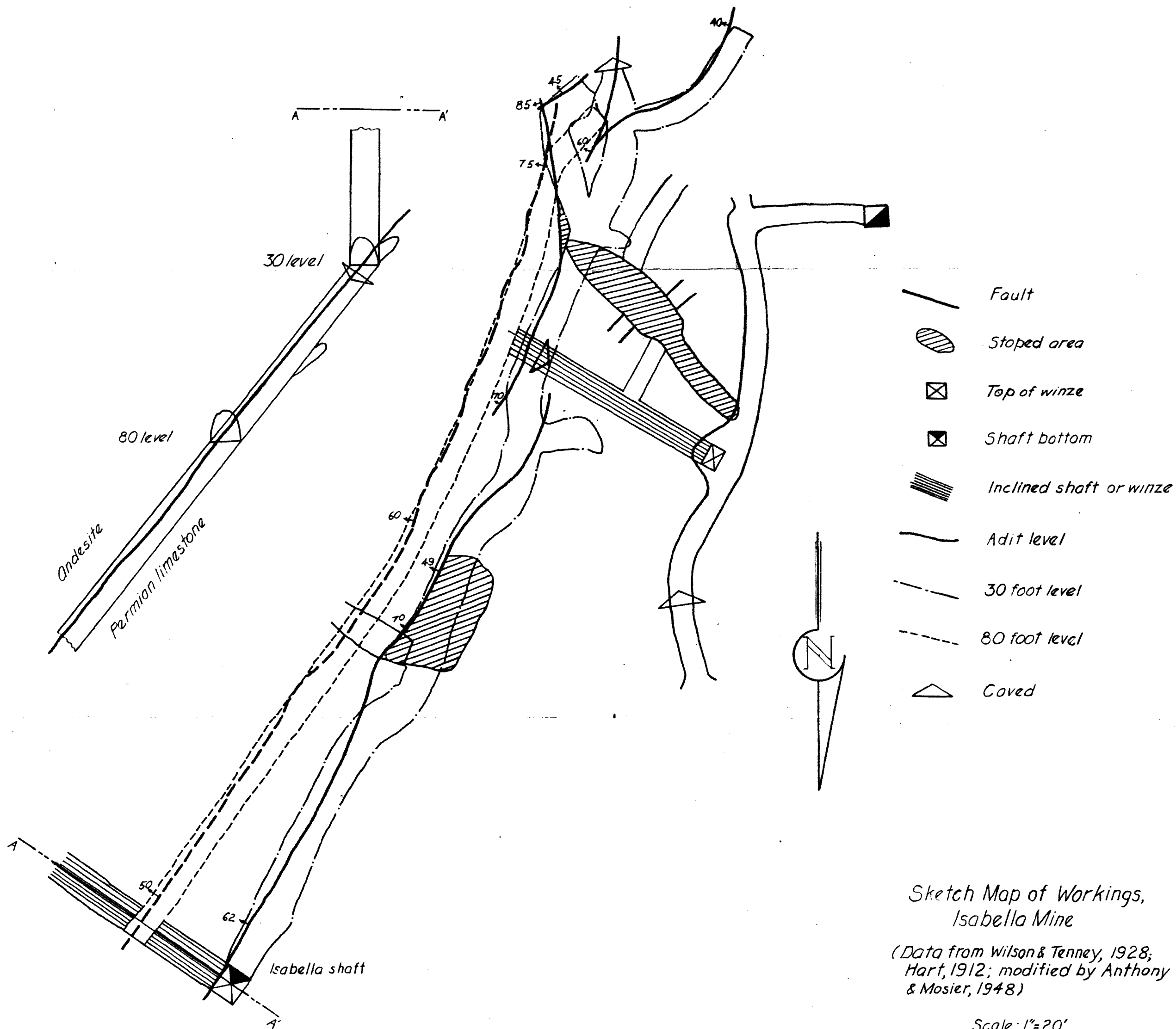
Caved

N
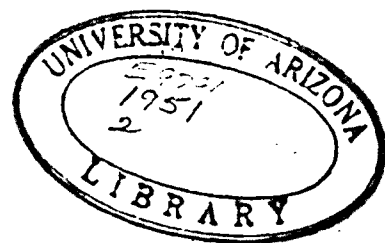
Sketch Map of Workings,
Isabella Mine

(Data from Wilson & Tenney, 1928;
Hart, 1912; modified by Anthony
& Mosier, 1948)

Scale: 1" = 20'

XXV

3

XXVI

4

Symbols

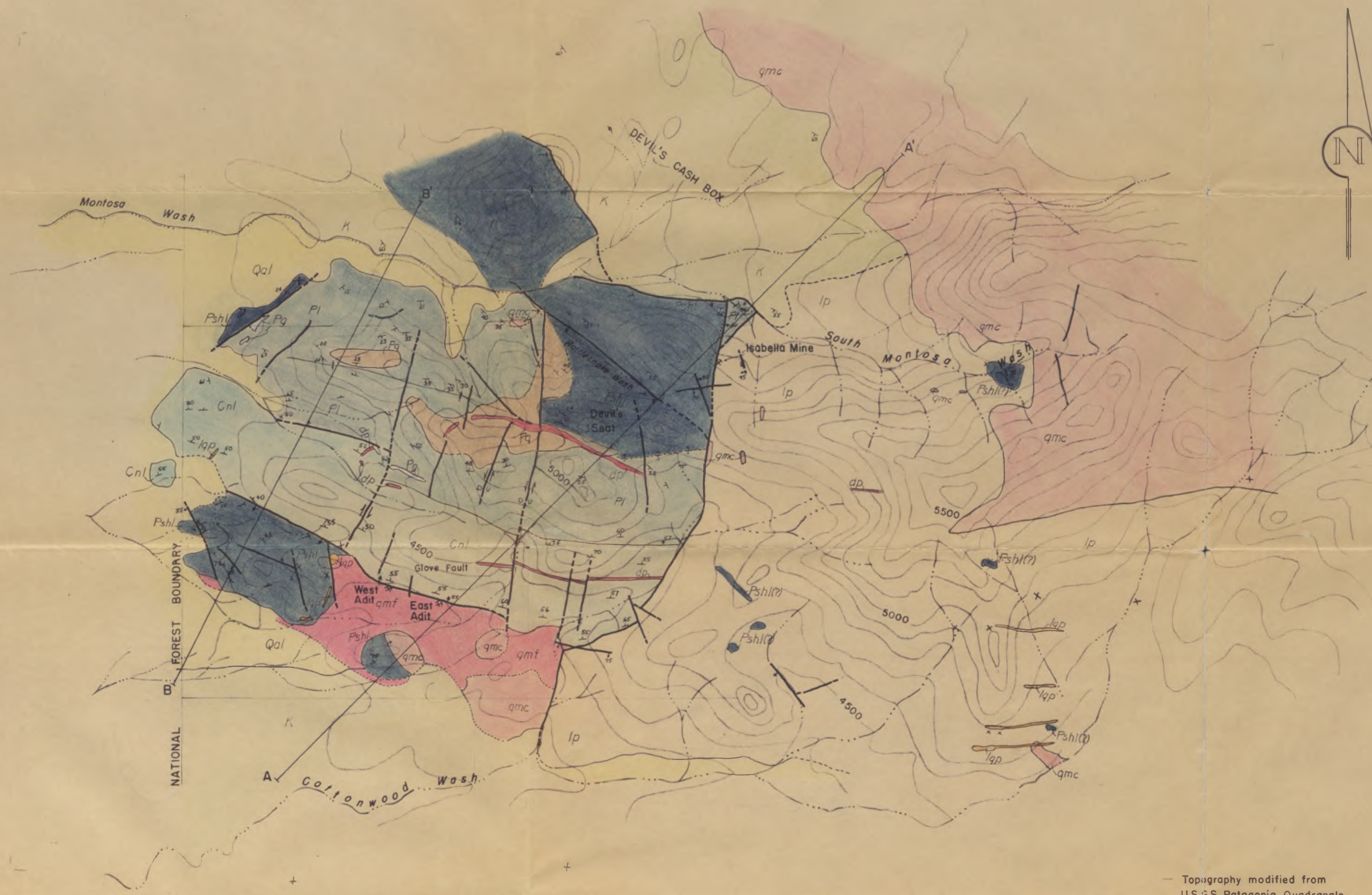Cnl   Naco limestone

Tkqm   Quartz monzonite

Cnl

75

Tkqm

Cnl

60

Cnl

Upper level 22.5 ft.
above adit.

Tkqm

Lower Workings,
West Adit

Scale: 1"=25'

Tkqm

Cnl

Tkqm

N

PLATE I

EXPLANATION

SEDIMENTARY ROCKS

Qal — Alluvium — QUATERNARY

K — Shales, limestones sandstones & volcanics — CRETACEOUS

Snyder Hill limestone — PERMIAN

Pq — Unnamed quartzite — PERMIAN

Pbg — Unnamed limestone & gypsum — PERMIAN

Cnl — Naco limestone — PENNSYLVANIAN

IGNEOUS ROCKS

dp — dacite porphyry

lp — latite porphyry

lqp — lamprophyre, quartz veins, pegmatite

qmc — "coarse" quartz monzonite

qmf — "fine" quartz monzonite

TERTIARY– CRETACEOUS

SYMBOLS

70 — Strike and dip

50 — High angle fault-dashed where inferred

Thrust fault; "T" on overthrust plate

50 — Contact - dashed where inferred

X — Prospect pit

Syncline, trace of axial plane

Topography modified from U.S.G.S. Patagonia Quadrangle.

Geology by JOHN W. ANTHONY. 1951.

GEOLOGIC MAP

MONTOSA-COTTONWOOD CANYONS AREA

SANTA CRUZ COUNTY, ARIZONA

1000 0 1000 2000 3000 FEET

1:12,000
SCALE
CONTOUR INTERVAL=100 FT.

Montosa Wash

Qal

Pshl(?)

Cnl

DEVIL'S CASH BOX

Isabella Mine

Devil's Seat

South Montosa Wash

Glove Fault

West Adit

East Adit

FOREST BOUNDARY

NATIONAL

A   Cottonwood Wash

qmc

qmf

lp

lqp

dp

5500

5000

4500

MAGGIE IGO

JIM BLAINE

ANDREW JACKSON

BANNER

SHEEHY

NELLIE FARRELL

GLOVE

ROVER

RADIUM

O'DONNELL

ALEXANDER HAMILTON

200

300

400

500

600

100

◻ 40' Shaft

◻ 125' Shaft

◻ 67' Shaft

◻ 50' Shaft

JERRY

West Adit

Assumed elev. 0'

East Adit

BELMONT

PUEBLO

TOWN

CLAIM MAP
OF THE

GLOVE GROUP OF CLAIMS

TYNDALL MINING DISTRICT
SANTA CRUZ COUNTY, ARIZONA

0 100 200   400feet

XXVIII

8

ISABEL

SURVEY NO. 2967

BLACK DIAMOND

SURVEY NO. 2966

XXIX