GEOLOGY OF THE CORRAL CANYON AREA
CHURCHILL COUNTY, NEVADA

A THESIS

SUBMITTED TO THE FACULTY OF THE UNIVERSITY OF NEVADA

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

MASTER OF SCIENCE

BY

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ABSTRACT

Low-grade titanium deposits in Corral Canyon, Churchill County, Nevada, occur in dikes which cut genetically related diorite. Alteration of the diorite and the dikes is extensive. The titanium is present as anatase, an alteration product of sphene in the aplitic dike rocks. Gold was deposited in some of the dikes during the last stage of mineralization.

PURPOSE

The purpose of this paper is to describe the geology of the titanium deposits in Corral Canyon, Churchill County, Nevada. It is done in partial fulfillment of the requirements for a degree of Master of Science in Geology.

ACKNOWLEDGMENTS

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My thanks go to Phyllis, my wife, who by her patience, consideration, and help, allowed this paper to be written.

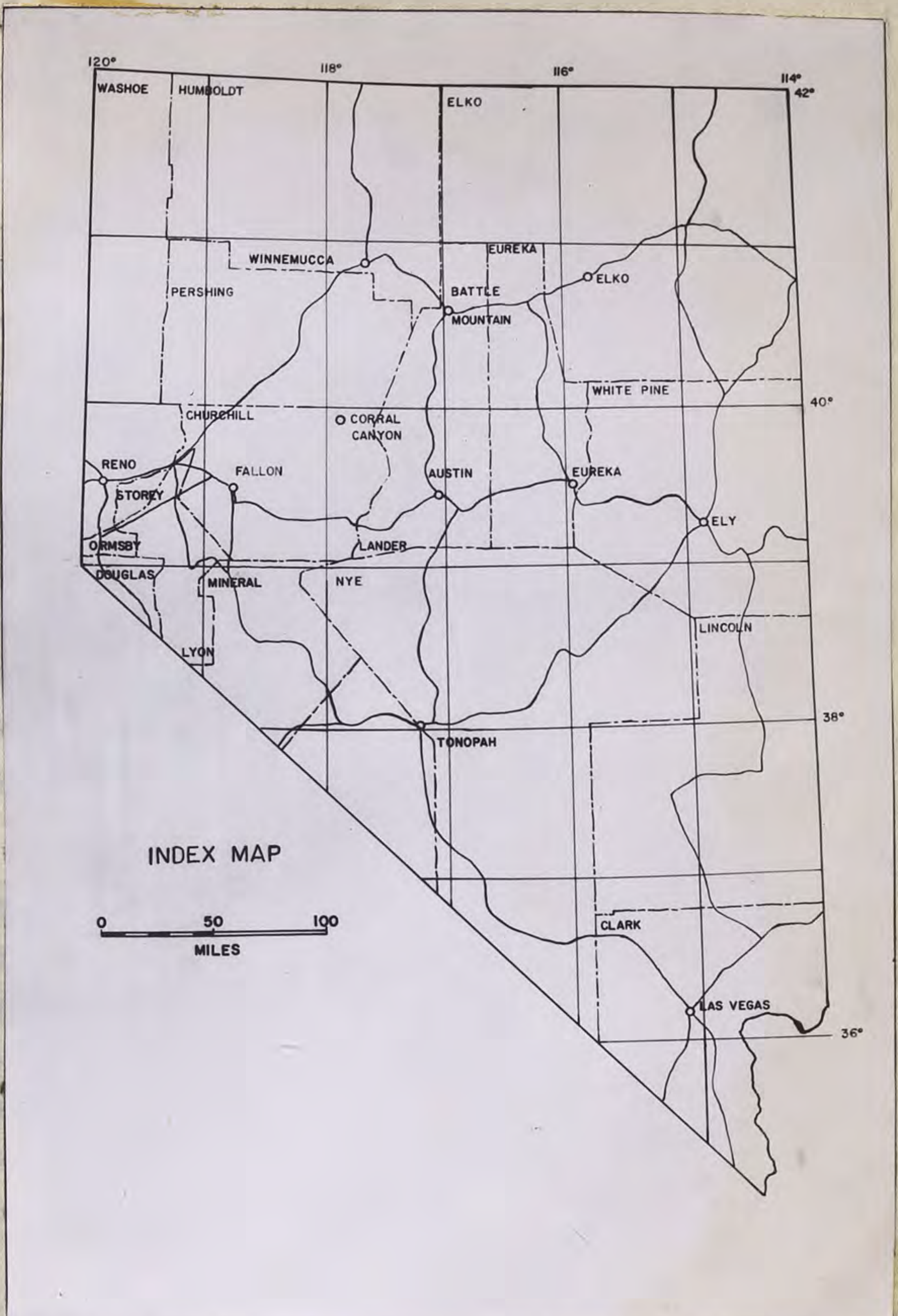

Figure 1

INDEX MAP SHOWING LOCATION OF CORRAL CANYON

LOCATION, CLIMATE, AND TOPOGRAPHY

Corral Canyon, about twenty miles north of the settlement of Dixie Valley in Churchill County, Nevada (Fig. 1) cuts the rugged eastern flank of the Stillwater Range and trends northwestward into the range. The titanium deposits are in the eastern face of the range, particularly in Corral Canyon. The area can be reached by automobile with little difficulty in good weather, but the roads may be muddy after storms. The most direct route to Corral Canyon is Highway 50 to the Dixie Valley-Wonder turnoff five miles east of Frenchman Station, then fifty-three miles north through Dixie Valley. Most of the dirt road from Highway 50 to Corral Canyon is kept in good condition but the final one and one-half miles are rough.

The climate is arid, with only small amounts of rain and snow through the year. Vegetation varies from the sagebrush and desert shrubs of the flats, to the willows and cottonwoods along the stream, and junipers on the higher peaks. The streams in Corral Canyon and in the large unnamed canyon to the south flow throughout the year; Bell Mare Creek, to the north, flows only during the winter and spring. The water in all of the streams is slightly brackish but it is potable.

The topography is steep and rugged. Elevations range from 3900 feet at the top of the alluvial fan to over 5000 feet on the highest points in the map area.

GENERAL HISTORY OF THE AREA

Corral Canyon is on the eastern flank of the Stillwater Range in northeastern Churchill County. The range consists of folded sediments and volcanics of Pennsylvanian (?) to Triassic age which have been intruded by Jurassic (?) diorites.

Faulting has obscured the stratigraphic relationships and rendered interpretation more difficult. Faulting was responsible for the uplift of the range and controls many of the canyons cutting through it.

Prospectors were first attracted by gold-bearing rocks in Corral Canyon. The area has been worked since the early 1930's.

Limestone, the only sedimentary rock in the area, forms several small patches along the eastern flank of the range. This was thoroughly silicified during the intrusion of the underlying diorite. Zones of weakness developed which evidently controlled the emplacement of an aplitic differentiate during the crystallization of the intruding diorite.

The major source of the titanium is in the dikes, where the titanium is present in the form of anatase. Specimens of the dike rock show that the anatase is an alteration product of earlier sphene, which was the first titanium mineral. The diorite contains ilmenite and rutile, which indicates that the diorite magma was also rich in titanium. Another possible source of titanium is by migration from the space lattices of biotite and hornblende, in which the titanium may proxy for Al, Fe^{++}, etc.

Continued crystallization of the magma caused deuteric alteration in both the titaniferous dikes and the diorite. The sphene in the dikes was altered to an aggregate of anatase, quartz, and calcite; the feldspar of the diorite was altered to scapolite and clay minerals.

STRATIGRAPHY

Silicified Limestone:

The silicified limestone, the oldest sedimentary rock of the area, is found only in the eastern part of the map area where it forms several small shields plastered against the intruding diorite. This limestone is the only sedimentary rock exposed in the vicinity of Corral Canyon, but portions of the rocks tentatively referred to as the Leach (?) (Muller et al, 1951) formation may be of sedimentary origin. The limestone is a reddish-brown, fine-grained rock with an extremely high silica content. Sometime after its deposition the limestone assumed its present attitude; in places a breccia zone forms the contact between the limestone and the underlying diorite, but it is not known whether the limestone was deformed before the intrusion of the diorite, or whether it assumed its present position during the intrusion of the diorite. The original strike and dip of the limestone are unknown. Limestone at the mouth of Corral Canyon has a maximum thickness of about thirty-five feet; most of the small outcrops are thinner. It is possible that some of the limestone may have been assimilated by the intruding diorite.

Leach (?) Formation:

The oldest igneous rocks mapped are the meta-volcanic rocks between Bell Mare and Coyote Canyons. These strata, at least

1,000 feet thick, have a gentle to steep dip. They consist of extensively altered andesite flows at the base, capped by relatively fresh basalt flows. These may be equivalent to the Pennsylvanian (?) Leach (?) Formation of the Mt. Tobin Quadrangle (Muller, et al, 1951).

The andesites are weathered and altered and should probably be called greenstones. Portions of the andesites in the lower part of the section have been replaced by specular hematite, which locally forms thin veins and stringers. These andesites are quite fine-grained and vary from grayish-black to grayish-white in color. No thin sections were made from this material.

The basalt is a fine-grained, brownish-red rock with euhedral phenocrysts of feldspar up to one inch in length. It has been extensively altered and is composed of labradorite, chlorite, and calcite. The vesicles have been filled with calcite.

Diorite:

Diorite is the most extensive rock type in the area from Bell Mare Canyon southward to the canyon forming the southern boundary of the area. Bell Mare Canyon forms a fault contact between the diorite to the south and the Leach (?) formation to the north. Although the diorite appears to be cut off in Bell Mare Canyon, the diorite of the Corral Canyon area may be continuous with that of the Cottonwood Canyon area, six miles to the north.

The diorite varies considerably, both in texture and in composition, but it is generally medium- to coarse-grained except where intense silicification has taken place; there it is extremely fine-grained. The major constituents of the diorite, in order of decreasing abundance, are plagioclase, hornblende, biotite, augite, and orthoclase. Common accessory minerals are apatite, magnetite, ilmenite, zircon, and some rutile.

The diorite has been extensively altered and the original minerals have been replaced by scapolite, clay minerals, epidote, chlorite, sericite, and calcite.

Ferguson (1939, p. 9) states that sphene is a minor constituent of the diorite in Cottonwood Canyon. Although this mineral is not common in the diorite of the Corral Canyon area, it is probable that the two diorites are portions of the same intrusive body.

<u>Titaniferous Dikes</u>:

The titaniferous dikes are the second most extensive rocks in the area. These trend slightly west of north and cut through the diorite. In the southern portion of the area, where they cut the limestone, it is difficult to recognize the contacts because of extensive alteration. The dikes are fine-grained and are almost snow-white in color, except for areas of intense iron mineralization. The major minerals, in order of decreasing abundance, are albite, calcite, anatase, sericite, quartz, and iron oxides. They were evidently emplaced as aplite dikes during an early stage of crystallization of the dioritic magma and have been extensively altered by deuteric processes associated with the further consolidation of the magma. Anatase, disseminated throughout the dikes, is an alteration product of early-formed sphene as is shown by well-developed sphene-shaped envelopes enclosing spongy aggregates of anatase and quartz.

The position of the dikes is apparently controlled by a zone of weakness that closely parallels several shear zones in the diorite. Replacement probably played a lesser part in controlling the dikes; however, it evidently played an important part in later mineralization.

The last stage of mineralization was auriferous pyrite, now altered to limonite. It occurs in elongate stringers of quartz and calcite associated with the dikes.

Diabase Dikes:

A number of diabase dikes ranging from a few inches to fifty feet in width cut the area. These are the youngest rocks of the area. The dikes range from extremely fine-grained grayish-black, unaltered rocks composed mainly of andesine and pyroxene, to crumbly, greenish-brown, extremely altered ones. The latter are spheroidally weathered. The rock is quite compact where fresh; where it has been extensively altered it is quite friable.

STRUCTURE

There are major faults in the larger canyons that transect the range, as well as faults parallel to the range. Coyote Canyon, which forms the northernmost boundary of the area, and Bell Mare Canyon are controlled by faults. The Bell Mare Canyon fault, which forms the contact between the volcanic section to the northeast and the intrusive diorite to the southwest, has had considerable displacement. Coyote Canyon fault is in the Leach (?) formation and, though it controls the topography, it probably does not have a large displacement. Corral Canyon has the same general trend as Coyote Canyon and Bell Mare Canyon and is assumed to follow a fault zone. The unnamed canyon that forms the southern boundary of the area is controlled by jointing or shearing within the diorite.

The diabase dikes or sills appear to have been controlled by a number of shear zones which cut the diorite. Several brecciated zones were also noted but it was not possible to find the amount of displacement, if any. Several small faults seen in the drifts do not extend to the surface.

Although the geomorphology of the area indicates a number of faults parallel to the range, they exert no control on the titanium-bearing dikes.

PETROLOGY AND PETROGRAPHY

Silicified Limestone:

The silicified limestone is a reddish-brown, extremely fine-grained rock which forms small shields on the diorite. The limestone has been thoroughly silicified and, at first glance, appears to be a quartzite.

No thin sections were made of this rock but an examination with a binocular microscope showed that major constituents are, in order of decreasing abundance, calcite, quartz, and magnetite.

Leach (?) Formation:

These rocks are largely altered andesites with somewhat fresher basalts capping them. They range in color from grayish-black to grayish-white, and vary in texture from fine-grained to porphyritic.

Hand specimens of the basalt show large euhedral phenocrysts of labradorite set in a fine-grained groundmass. Microscopic studies show that the basalt is composed of labradorite phenocrysts set in a groundmass of microcrysts of labradorite, epidote, chlorite and magnetite. Original vesicles and fractures in the rock have been filled with calcite.

No thin sections of the andesite were made but they have been extensively silicified.

Diorite:

Diorite, the most common rock in the area, varies considerably both megascopically and microscopically. It is generally medium- to coarse-grained in texture and ranges in color from light brownish-gray to greenish-black. Near many of the shear zones and near the dikes, the diorite has been extensively silicified and can be identified as diorite only by the gradational nature of the alteration.

Megascopically the diorite resembles a light-colored granodiorite and is composed of, in decreasing order of abundance, plagioclase, hornblende, biotite, augite, and in some places, large fibrous masses of scapolite. Near the dikes and in most of the map area the diorite seems to be made up of plagioclase and orthoclase with minor bleached ferromagnesian minerals, but other portions of the diorite are characterized by large masses of hornblende and biotite with some scapolite.

A volumetric analysis by Chayes' method (995 points) shows the following composition for specimen A211, a dark colored diorite:

Primary minerals:	
Andesine	34%
Hornblende	24
Biotite	10
Magnetite	4
Zircon	Trace
Apatite	Trace
Secondary minerals:	
Clay, sericite, calcite	20
Chlorite	7
Epidote	Trace
	99%

where is the augite?

See p. 10

The plagioclase has been largely altered to clay, sericite, and calcite; some chlorite and epidcte are also present. The hornblende is altering to biotite.

The texture resembles the diabasic texture but in this specimen the interstices between the laths of plagioclase contain hornblende rather than pyroxene.

A volumetric analysis by Chayes' method (1204 points) gave the following composition for specimen A261, a light-colored diorite:

<u>Primary minerals</u>:		
Andesine	36%	
Orthoclase	9	
Microcline	10	
Quartz	1	Augite?
Sphene	Trace	
Apatite	Trace	
<u>Secondary minerals</u>:		
Clay, sericite	28	
Calcite/ankerite	12	
Chlorite	Trace	
Epidote	<u>Trace</u>	
	96%	

The microcline is fresh but the andesine has been largely converted to aggregates of clay, sericite, and calcite. The primary ferromagnesian has been completely converted to calcite or ankerite.

The specimen has an aplitic texture.

<u>The Titaniferous Dikes:</u>

The dikes are very light in color, almost snow-white in places, and contrast very strikingly with the surrounding diorite. They are generally equigranular, but vary locally from fine- to medium-grained in texture. Megascopically the rock appears to be an aggregation of feldspar, clay minerals, quartz, anatase, and in some places, sericite. The percentage of anatase is extremely variable.

Thin sections show that the composition is variable. Where little alteration has taken place, as in Cottonwood Canyon, about six miles to the north of Corral Canyon, fresh albite, quartz, calcite, and anatase are described by F. L. Ransome (1911). In Corral Canyon, where alteration has been more extensive, the composition of the dikes, in order of decreasing abundance, is plagioclase (albite to oligoclase), clay, calcite, sericite, garnet, quartz, anatase, and iron oxides.

The plagioclase has been partially altered to clay and sericite and has a mottled appearance. Calcite has formed in part from feldspar and sphene, and was in part introduced. The most important alteration has been the replacement of early sphene by aggregates of anatase, quartz, and calcite. The anatase is disseminated unequally throughout the dikes but occurs mainly in wedge-shaped masses. These wedge-shaped aggregates of anatase, as well as well-developed sphene-shaped envelopes surrounding the anatase-quartz aggregates, indicate that the anatase is an alteration product of early sphene. The titanium content of the dikes is variable; locally it runs as high as 30 to 40%, but the deposits average about 0.75%. Several large bodies average more than 2%.

The dikes found near the nickel deposits in Cottonwood Canyon described by Ferguson (1939, p. 9) are very similar to those of the Corral Canyon area. Steiger (Ransome, 1911) has made a chemical analysis of the dike material from the deposits in Cottonwood Canyon. This analysis follows:

CHEMICAL ANALYSIS OF AN APLITE
By George Steiger

SiO_2	61.71%
Al_2O_3	16.63
Fe_2O_3-FeO	0.40
MgO	None
CaO	5.94
Na_2O	8.52
K_2O	0.16
H_2O (-)	0.51
H_2O (+)	0.81
TiO_2	0.79
ZrO_2	0.04
CaO_2	4.05
P_2O_5	0.15
	99.71%

A norm calculated by Ransome from the above analysis follows:

Albite (approx. $Ab_{96}An_4$)	76.5%
Calcite	9.2
Quartz	8.8
Kaolinite	3.5
Anatase	0.8
Apatite	0.4
Water	0.8
	100.0%

The elongate lenses and stringers mined in the past for their gold content were not studied in thin section. Megascopically they consist largely of so-called "bull-quartz", limonite, hematite, and pyrite. The gold is in the pyrite, and mining has been restricted to a few areas where the alteration of pyrite to a mixture of limonite and hematite has been most extensive. The gold content of the quartz stringers is extremely variable; samples taken by the author average about $15 a ton, but the Shaw's report assays as high as $135 a ton. More than thirty-five tons of gold ore averaging about $35 a ton have been shipped from the property.

Diabase Dikes:

The diabase dikes are the youngest rocks in the area south of Bell Mare Canyon; their relationship to the Leach (?) formation to the north is not clear.

These dikes are quite variable in appearance. Most of them are greenish-brown in color and weather spheroidally; they are extremely friable near the surface but become quite compact two or three inches below the surface. The dikes not exhibiting the spheroidal weathering are grayish-black in color and very fine-grained in texture.

In hand specimens the diabase dikes are generally dark in color and appear to be composed primarily of ferromagnesian minerals.

A volumetric analysis by Chayes' method (1137 points) shows the following composition for specimen A411, a diabase dike:

Primary minerals:

Andesine	57%
Augite	24
Olivine	8
Ilmenite	7
Biotite	4
Apatite	Trace
	100%

The olivine has been completely altered to bowlingite. Most of the biotite has been altered to chlorite, but the unaltered patches contain lenses of sphene.

Texturally the diabase varies from intersertal to ophitic.

PETROLOGY AND PETROGRAPHY

Alteration:

There have been several stages and many types of alteration associated with the intrusion and crystallization of the diorite in the Corral Canyon area. The general sequence of alteration has been sericitization and silicification, kaolinization and carbonatization, and scapolitization. The diorite has been affected by all of these processes, and the aplite dikes have been affected by all except the scapolitization.

The most striking alteration of the diorite has been the formation of scapolite from the plagioclase of the original rock. Although most of the scapolite is fine-grained and is difficult to distinguish from the unaltered plagioclase, locally crystals attain great size. Radiating masses of scapolite up to four inches in length and one-half inch in diameter were found in some portions of the diorite, and smaller aggregates are quite common.

The indices of refraction and x-ray powder diffraction patterns both indicate that the scapolite is about $Ma_{90}Me_{10}$, or almost pure marialite, the soda end-member of the scapolite series. Comparison of x-ray powder diffraction patterns of scapolite from the Buena Vista Hills, about fifteen miles to the northwest, and the Corral Canyon area show no significant variations in composition (Shawe, F. R., 1955). During the preliminary work on the property the author felt that possibly the scapolite resulted from contamination of the intruding magma by assimilation of the overlying calcareous sediments. If this had taken place to any extent the scapolite would be meionite, or at least near the meionite (calcareous) end of the scapolite series. Since the scapolite is about $Ma_{90}Me_{10}$ it must have a deuteric origin, and metasomatism is probably the controlling mechanism for the alteration.

The mechanism for such a process of scapolitization is not clear. The only essential addition for the alteration of the anorthite molecule to marialite is chlorine. The liquid phase of the magma may have become enriched in iron chlorides and, with the formation of magnetite by the reaction of water on the iron chlorides, caused free chlorine ions to be made available for reaction with the plagioclase molecules (Shawe, F. R., 1955). This mechanism seems to be the most plausible. In some thin sections a calcic plagioclase is seen in contact with scapolite and both seem quite fresh, but this is not anomalous. Barth (1952, p. 283) considers meionite and marialite as the low temperature equivalents of anorthite and albite respectively, and states that plagioclase and scapolite can exist together, with a calcic plagioclase in equilibrium with a sodic scapolite.

Sericitization and kaolinization are both widespread but the carbonatization and silicification are restricted mainly to the dikes. Orthoclase and some plagioclase have been altered completely or partially to sericite. The reacting solutions seem to have attacked the potash feldspar first and reacted to a lesser extent with soda-lime feldspars. Some quartz is associated with the sericite. Kaolin alteration has attacked the feldspars along the sericite alteration and aggregations of the two minerals are quite common, although such associations are not the rule.

In the diorite, calcite is limited mostly to the joints and fractures near the titaniferous dikes which have a very high content of calcite. In the dikes the calcite may have resulted from the alteration of feldspars and from material introduced by magmatic emanations. The calcite formed by the breakdown of feldspar occupies the position formerly held by the feldspar and forms a mosaic of individual crystals, while the introduced material forms seams through the rock. Large masses of calcite are common in those portions of the dike that have the highest titanium content. These areas are restricted to places where the diorite has wide fractures into which the escaping volatile fraction of the solidifying dioritic magma passed and crystallized.

Silicification of the diorite has been limited largely to shear zones and contact zones along the dikes. The diorite along the margins of the dikes has been so thoroughly altered that only the gradational nature of the contact makes identification possible. Some veins and stringers of quartz seem to be controlled by jointing in the diorite, since these veins and stringers are approximately parallel to the dikes.

ORIGIN OF THE TITANIUM-BEARING DIKES

Disseminated throughout most of the altered dike rock are crystals and blebs of translucent, honey to chestnut-brown colored anatase. Megascopic studies show that the mineral is mostly in the form of acute pyramids of the tetragonal system, but that some are also tabular. The mineral has two perfect cleavages, $\{001\}$ and $\{011\}$.

In thin section the anatase is brown to yellowish-brown, and is somewhat pleochroic. The index of refraction is quite high and the birefringence is strong. All of the crystals studied were quite small, few of them more than two or three millimeters in length, though many of the aggregates are an inch or more long. Anatase was seen embedded in all of the other minerals except the apatite.

An x-ray powder diffraction pattern (Fig. 2) and an x-ray spectrometer recording (Fig. 3 & 4) were made of several of the crystals and of a concentrate obtained by crushing a random sample of the dike rock and concentrating the mineral with a Superpanner. Careful comparison of the patterns obtained with A.S.T.M. standards confirmed the observation that the titanium mineral is anatase, TiO_2, a polymorph of rutile and brookite.

Late in the crystallization of the diorite, or a concealed granodiorite, an aplitic differentiate intruded zones of weakness

ANATASE
Copper K alpha radiation (1.5405 A°)

57.3 mm Debye-Scherrer Camera
Asymmetric Film Position
Two hour exposure @ 35KV, 15ma

Line	I(visual)	20	d
1.	VS	25.70	3.468
2.	W	38.20	2.355
3.	S	48.35	1.881
4.	S	54.20	1.691
5.	S	55.40	1.657
6.	S	62.95	1.475
7.	W	69.05	1.359
8.	W	72.85	1.297
9.	S	79.10	1.209
10.	W	72.20	0.953
11.	W	65.65	0.917
12.	W	61.30	0.896
13.	W	57.35	0.878
14.	W	48.85	0.846
15.	W	42.50	0.826
16.	VW	36.0	0.810
17.	S	29.95	0.798

Figure 2

X-RAY POWDER DIFFRACTION PATTERN AND DATA

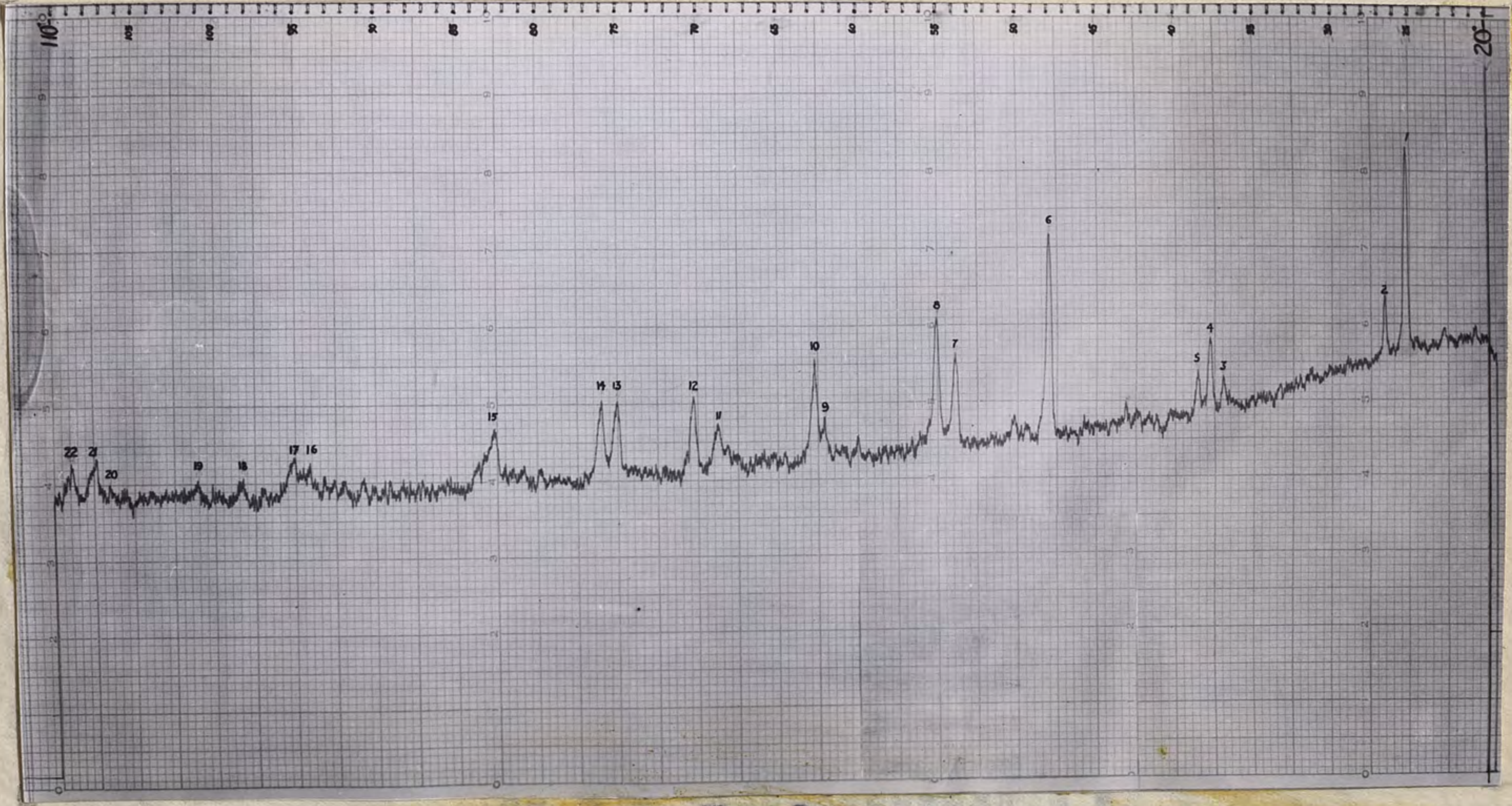

Figure 3

X-RAY SPECTROMETER RECORDING

Settings on X-ray Spectrometer
Radiation CuK at 50Kvp 16 ma
Optics 3° MR - HR - 0.2°
Range 3 RCA
Scan rate 2° 2θ deg/min

Line	2θ	θ	d	d(ideal)	(hkl)
1.	25.25	12.6	3.5309	3.51	101
2.	26.6	13.3	3.3482		
3.	36.9	18.5	2.4274	2.439	103
4.	37.8	18.9	2.3779	2.379	004
5.	38.5	19.3	2.3305	2.336	112
6.	48.0	24.0	1.8938	1.891	200
7.	53.8	26.9	1.7025	1.699	105
8.	55.1	27.6	1.6625	1.665	211
9.	62.1	31.1	1.4912	1.494	213
10.	62.7	31.4	1.4784	1.480	204
11.	68.8	34.4	1.3634	1.367	116
12.	70.3	35.2	1.3362	1.337	220
13.	75.0	37.5	1.2653	1.264	215
14.	76.0	38.0	1.2511	1.250	301
15.	82.7	41.4	1.1698	1.171	303
16.	94.1	47.1	1.0514		
17.	95.1	47.6	1.0429	1.0433	321
18.	98.2	49.1	1.0190		
19.	101.0	50.5	0.99922	1.0173	109
20.	106.5	53.3	0.96068		
21.	107.4	53.7	0.95573	0.9550	316
22.	109.0	54.5	0.94612	0.9461	400

Lines 2, 16, 18, and 20 are lines for quarts.
The other lines give good agreement for anatase (TiO_2).

Figure 4

X-RAY SPECTROMETER RECORDING DATA

in the previously crystallized portion of the diorite.

The origin of the sphene in the dikes is not clear, but it is probable that it formed early in the history of the dikes. Later hydrothermal alteration of the dikes converted the sphene to aggregates of anatase, calcite, and quartz. The presence of euhedral quartz crystals intimately mixed with the anatase, and the presence of concentrations of calcite in the immediate vicinity of the anatase, suggest that some of the quartz and calcite are the result of the breakdown of the original sphene. The alteration of the sphene was accompanied by the alteration of the feldspar to clay minerals, sericite, chlorite, and quartz.

The last stage of mineralization was the introduction of large amounts of quartz containing auriferous pyrite. This late-stage quartz forms elongate stringers and lens parallel to the dikes or along the margins of the dikes. This quartz deposition was probably accompanied by continued sericitization and carbonatization. It was these gold-bearing stringers that first attracted attention to the property and they have been worked for their gold content for many years.

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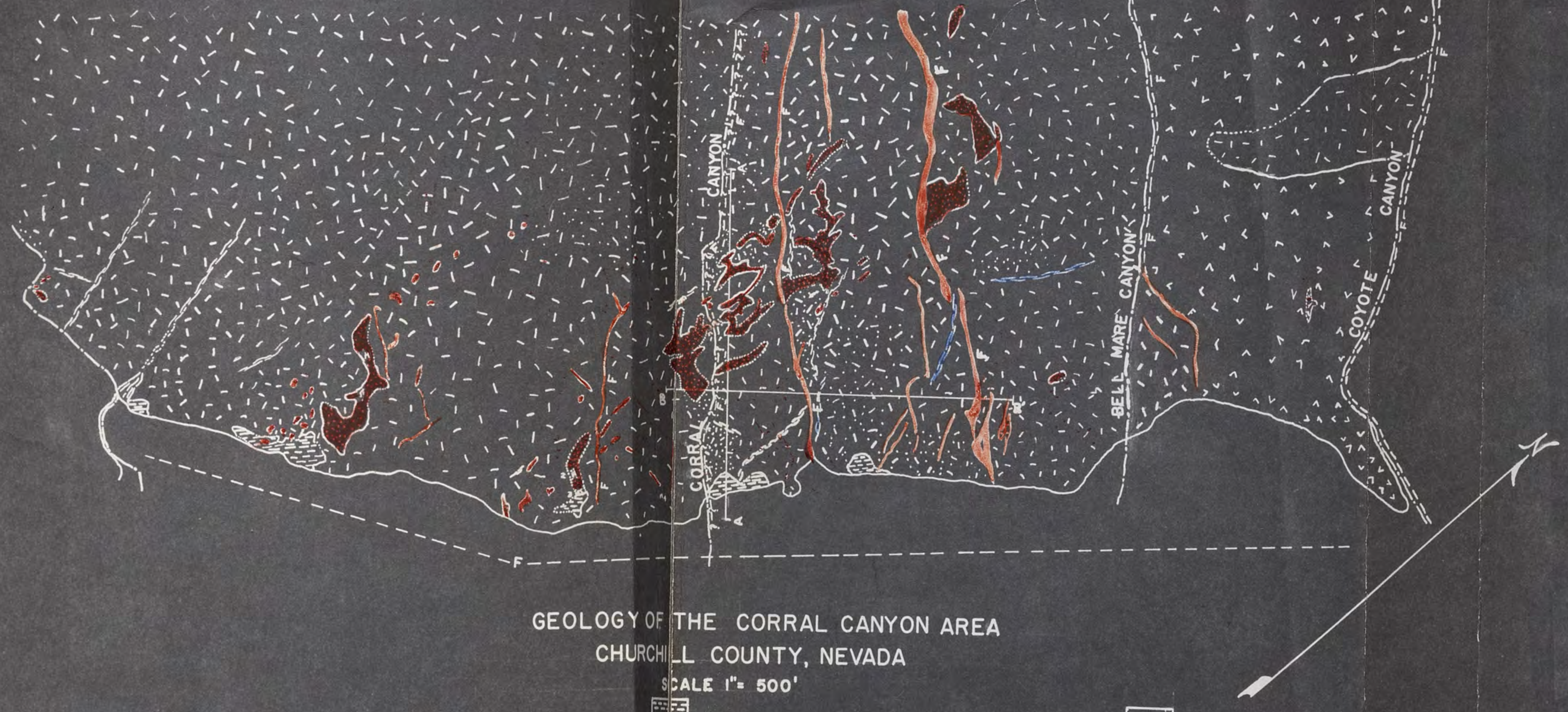
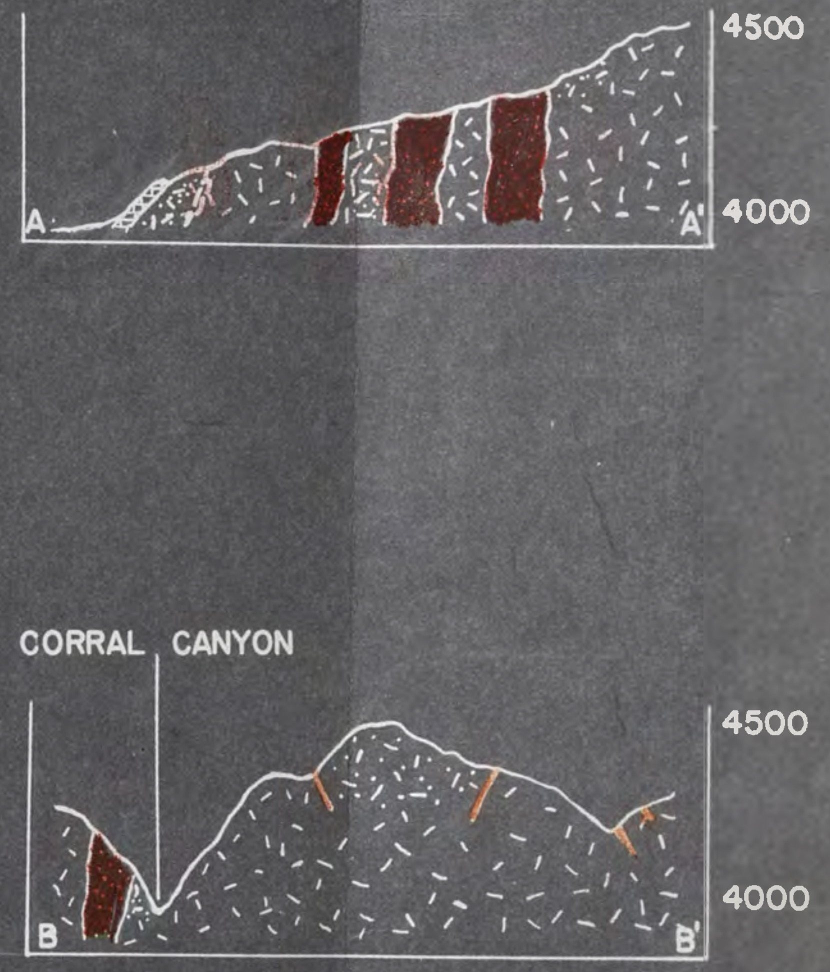


GEOLOGY OF THE CORRAL CANYON AREA
CHURCHILL COUNTY, NEVADA
SCALE 1"= 500'

LIMESTONE	▤	STREAM	☐
DIORITE light colored dark colored	▨	CONTACTS	☐
TITANIFEROUS DIKES	■	SHEAR ZONES	☐
DIABASE DIKES & SILLS	☐	FAULTS	☐
LEACH(?) FORMATION	☐	ADITS	☐

PLATE ONE



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