GEOLOGY OF THE MORGAN MINE AREA
TWIN BUTTES, ARIZONA

by

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I

ABSTRACT

The Twin Buttes mining district lies at the base of the eastern flank of the Sierrita Mountains. The rocks of the region are essentially complexly folded and faulted Paleozoic and Mesozoic (?) limestones and quartzites. A post-Cretaceous (?) granite stock with attendant igneous dikes and sills further complicates the structure and has produced widespread metamorphism of the sediments. Post-granite faulting, probably of a gravitational nature, followed the cooling and shrinking of the magmatic body. Subsequent erosion has removed many of the older sedimentary rocks and has revealed the underlying granite.

Ore deposition in the district accompanied the intrusion and is typically contact metamorphic in character. The ore bodies are almost invariably associated with garnetized zones in the limestone near the granite contact. The ore is predominantly chalcopyrite with some galena and sphalerite. A variety of typically contact metamorphic minerals are closely associated with the ores.

Mining operations are dormant at the present time, and future activity in the district is problematical.

II

ACKNOWLEDGMENTS

Credit for any success that this work has attained is due in large part to the advice and criticism proffered by the members of the staff in the Department of Geology. Dr. B. S. Butler, director of the thesis, gave unstintingly of his time and knowledge, not only to the writing of the thesis but to the field preparation as well. Dr. M. N. Short supervised the preparation and study of thin sections. Dr. A. A. Stoyanow was the authority in determining the ages of such recognizable fossils as were found.

In addition, the writer wishes to express his appreciation to Mr. E. D. McKee and Dr. F. W. Galbraith for reviews of the paper and valuable criticisms, to Dr. E. D. Wilson of the Arizona Bureau of Mines for much information pertaining to the mines of the district, and to Mr. William Foy of Twin Buttes for mine production figures and personal reminiscences.

The author was fortunate in being able to work in close cooperation with Fredrick Houser, a fellow graduate student, who is preparing a report on the western portion of the Twin Buttes district.

III

HISTORICAL SKETCH OF PIMA COUNTY, ARIZONA

This historical sketch of mining activities in Pima County must necessarily be very brief; neither time nor space permits anything approaching a complete recital of the events of its exciting and romantic past. For such an account the writer bows to the far superior narrative ability of another and infinitely more capable geologist, Fredrick L. Ransome, and recommends to the reader his brief, though complete and highly interesting, history of the early Southwest which serves as an introduction to the water supply paper, "Papago Country," by Kirk Bryant.[1]

The following records were obtained from Articles appearing at various times in the Arizona Mining Journal by authors R. B. Leach,[2] M. M. Carpenter,[3] and M. A. Allen.[4]

The history of Arizona is divisible into three periods: the era of Spanish exploration 1539-1823, the 28 years of Mexican control 1825-1853, and the past 94 years, since the Gadsden Purchase, as a part of the United States.

Pima County embraces the greater part of the area which

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1 Bryan, Kirk, The Papago country: U. S. Geol. Survey Water Supply Paper 499, 438 pp., 1925.

2 Leach, R. B., Pima county review: Ariz. Min. Jr., vol. 2, no. 1, pp. 35-39, 1918.

3 Carpenter, M. M., Beginning of mining in Pima county; Ariz. Min. Jr., vol. 11, no. 2, pp. 5-7, 1927.

4 Allen, M. A., Mines of Pima county: Ariz. Min. Jr., vol. 3, no. 1, pp. 76-77, 1919.

was the earliest mining district of the United States. Its fame as a source of gold and silver was a strong lure to the many Spanish expeditions to this country in the 16th century and resulted in the attempted colonization of this part of Arizona by the mission fathers after 1687.

Though Spaniards, both conquistadores and padres, had entered Arizona years before, it was not until 1582 that ore was discovered. In that year one Antonio de Espojo, a Spaniard, owning rich mines at Santa Barbara, Mexico, headed an expedition into what is now Arizona and reported finding deposits of precious metals. A vein of silver ore, near where the town of Prescott now stands, was specifically mentioned. More than 100 years elapsed before any attempts at mining were made.

Tumacacori Mission, 50 miles south of Tucson, was the center of early day mining operations in this section. Legends of a large and rich Tumacacori mine persist even today.

Previous to its becoming a territory, Arizona was attached to Dona Ana County, New Mexico. The Territory of Arizona was created by an act of Congress in 1863.

In 1864 Pima County was made one of the four original counties of the Territory of Arizona, its boundaries then being the Gila River to the north, New Mexico on the east, Mexico on the south, and Yuma County to the west. Pima County has been greatly reduced in size since Arizona became a state in 1912; the original area included, in addition to the present Pima County, the counties of Santa Cruz and Cochise, and parts of Pinal, Graham, Maricopa, and Greenlee.

With the completion of the Southern Pacific Railroad into Tucson on March 17, 1880, daily communication was at last established with the outside world. From this time on mining machinery and supplies were shipped in and ore and metals began to pour out. Pima County was launched on the road to its goal as one of the major metal producing counties of the state.

IV

INTRODUCTION

This report is the result of a field and laboratory study of the geology and ore deposits of the area in the vicinity of the now abandoned Senator Morgan mine. The Morgan Mine is located in the southern extension of the Pima mining district which also includes the mines of the Twin Buttes area.

Field work was conducted during the first semester and early part of the second semester of the school year 1947-1948. The remainder of the second semester was devoted to the laboratory examination of thin sections and writing the report.

Topographic mapping was accomplished in conjunction with Fredrick Houser who is submitting a similar study on the adjoining Contention Mine area. Both areas are included in the map submitted with this report. Dr. B. S. Butler, head of the Department of Geology at the University of Arizona, supervised the work of both parties.

The region mapped lies just to the south of the once bustling mining camp of Twin Buttes. It involves an area of approximately four square miles, lying principally in sections 1 and 2 of T18S, R12E. Figure 1 on the following page gives a more precise picture of the location and dimensions of the area.

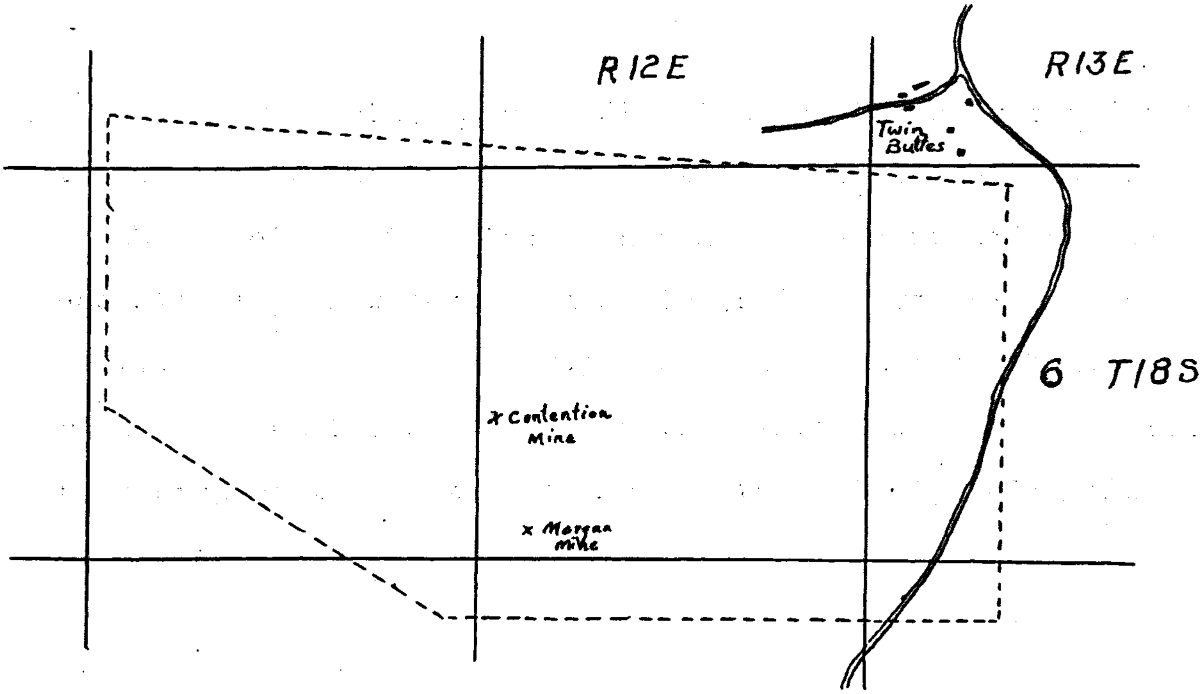

Figure 1. Location of the Twin Buttes Area

The settlement of Twin Buttes is connected by a dirt and macadam road with the city of Tucson 25 miles to the north. About 2 miles to the north a branch road swings east to connect with the Nogales highway at the little settlement of Sahuarita, 12 miles away.

During the years when the camp was producing, a branch line of the Southern Pacific Railroad ran from Tucson to Twin Buttes itself, but this has long since been abandoned and removed. The nearest railroad siding at present is that at Sahuarita, where the Eagle Picher Mining and Smelting Company operates a concentrator capable of handling 500 tons of copper, lead, and zinc ore daily.

The town of Twin Buttes is now largely abandoned, only a half dozen families being left of the once populous mining camp.

The Twin Buttes mining district and its neighbor 6 miles to the north, the San Xavier district, lie in the eastern foothills of the Sierrita Mountains whose serrated crests are occasionally snow capped on a winter day. To the east a gently sloping pediment drops away to the broad, flat, and rich alluvium-filled valley of the Santa Cruz. The towering back drop of the Santa Ritas completes a truly delightful panorama.

V

CLIMATE, FLORA, AND FAUNA

The climate in the valley of the Santa Cruz River is typically arid and supports a wide variety of desert flora. The high mountains surrounding this desert basin intercept a majority of the infrequent rain clouds depriving the valley of all but a few inches of rainfall. However, abundant sub-surface water reaches the valley from the precipitation on the mountain slopes, and where the soil is suitable a large variety of agricultural products can be raised with the assistance of irrigation.

The average distribution of rainfall for a 50 year period ending December 31, 1947, is shown in the chart below.*

January	0.90
February	0.96
March	0.74
April	0.33
May	0.18
June	0.27
July	2.24
August	2.34
September	1.18
October	0.54
November	0.82
December	1.00
Average Yearly	11.50

*Station data for normal monthly precipitation, U. S. Weather Bureau Records. Tucson, Arizona, 1948.

A wide range in temperatures, both daily and annual, is characteristic of this arid climate. Temperatures of 20°F are not uncommon in winter while summer readings often reach 110°F and occasionally 120°F. In all fairness, however, it must be added that winter weather, as a rule, is delightful, with cold brisk nights and warm sunny days. Also, in spite of the high summer temperatures, the aridity does much to alleviate the discomfort of the intense heat. Daily temperature ranges vary from 35°F in summer to 50°F during the winter months.

The average humidity for the 11 year period ending December 31, 1947, was 40%.*

The climatic conditions of the Tucson area apply generally to the higher elevations of the foothills, though temperatures are usually a few degrees lower. There is no water available in this area except at isolated cattle tanks where it is pumped to the surface by windmills. One should never travel far into these hills without carrying an adequate supply of water.

The vegetation of the foothills is typical of an arid environment. The common desert trees are the mesquite, the palo verde, ironwood, and catsclaw or acacia. The creosote bush, the desert saltbush, and the ocotillo are the principal shrubs. A wide variety of cacti include the

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*U. S. Weather Bureau records. Tucson, Arizona, 1948.

saguaro, bisnaga or barrel cactus, cholla, and prickly pear. Several members of the lily family are native of this region, the most common of which is the yucca.

Several native plants are a source of food and water during certain seasons of the year; it would be wise for anyone who intends to spend much time wandering these inhospitable hills and valleys to become acquainted with the edible species.

It is difficult at first for the newcomer to understand how a land so apparently devoid of water and herbage could possibly support any form of animal life except the indigenous rattlesnake, lizard, scorpion, and centipede. However, an observant traveller will soon discover that wild life is abundant and obviously quite prosperous.

Two types of deer habitually roam the foothills and slopes of the Sierritas and are frequently observed in the heavier brush of the lower pediment. The desert or Mexican muledeer, often erroneously called blacktail, and the diminutive whitetail provide excellent falltime hunting for the sportsman. The javelina, or wild pig, is the only other so-called big-game animal found in this section.

The predatory coyote is much more abundant than the rare glimpses of him indicate; and this is also true of the gray desert fox. The occasional mountain lion reported in the area is probably a transient rather than an inhabitant.

Two types of jackrabbit, the California jack and the antelope jack, and their smaller cousin, the Arizona cottontail, complete the list of the more conspicuous animals. However, anyone who has spent a night on the desert can affirm that these animals are only a small part of the abundant mammal life found here.

The small nocturnal creatures of primarily subterranean habits include a wide variety of rodents such as the antelope ground squirrel, or chipmunk; the rock squirrel; round-tailed ground squirrel, commonly miscalled "gopher"; pocket gophers; pocket mice; and several varieties of wood rat.

More than 100 species of birds have been identified and found to be native to this arid environment. Two varieties of quail, the Gambel quail and blue quail, and five species of doves are found in more or less abundance. The quail and and the white-wing dove are excellent game birds. The turkey buzzard, the road runner, a dozen varieties of owl, and several types of hawk make up the larger birds of the area. A large number of smaller birds complete an extensive and varied list.

The common reptiles consist of a varied lizard family which includes the colorful and much maligned Gila monster, the slender and swift collared lizard, and the formidable-appearing but harmless horned toad; and several varieties of snakes of which only two are poisonous. The rattlesnake is always dangerous, but the smaller coral snake seldom finds a victim unless the person bitten has been extremely careless.

A third member of the reptile group, the desert tortoise, is occasionally encountered on these waterless slopes. Like many of the other desert adapted creatures, the tortoise depends upon the juicy vegetation, such as the cactus, cactus fruit, and other succulents, to satisfy its moisture requirements.

A compilation of interesting facts pertaining to both the vegetable and animal life of this region is found in a publication of the University of Arizona entitled "Arizona and Its Heritage" and designated as General Bulletin No. 3, 1936.

VI

TOPOGRAPHY

The Pima district, of which Twin Buttes is the southern extension, lies at the base of the eastern slope of the Sierrita mountain system. To the west of the range lies the Altar valley while the eastern pediment terminates in the Santa Cruz valley. The mountains are about 14 miles long and the breadth varies from less than 2 miles at the northern end to roughly 5 miles in the central and southern parts. The highest peaks stand nearly 3000 feet above the upper margin of the surrounding pediment and 6500 feet above sea level. The Sierritas lack the jagged crests and precipitous slopes of their more spectacular neighbor to the north, the Tucson Mountains.

The area between the base of the Sierrita Mountains and the Santa Cruz River to the east is practically a continuous slope along the entire length of the range. The angle of inclination is greatest near the foothills, but for the middle and lower parts of the slope, from 80 to 100 feet per mile is a common gradient.

This eastward sloping pediment is covered with a thin layer of detritus which gradually increases in thickness in the direction of the valley bottom. Likewise, the detrital material becomes increasingly fine and better sorted valley-ward, grading from the unsorted mixture of boulders, gravel, and silt on the higher slopes to the stratified sands, silts, and clays of the valley floor.

The plain, subsequently, has been trenched by shallow arroyos which reveal the widespread underlying granite and remnants of Paleozoic sediments. Extensive faulting in the sediments, plus the presence of less resistant beds, has been the controlling factor in establishing the major topographic expression.

The existing drainage confines itself almost exclusively to fault zones and to easily eroded granite and shaly sediments. It is apparent from the amount of erosion accomplished that these streams are at times much more active than their present dry channels seem to indicate. It should be kept in mind that the run-off from these bare rocky slopes is characteristically rapid; an ordinarily dust dry stream channel may contain within its high banks a raging torrent in a matter of minutes after a cloudburst in the mountains. At such times they may constitute a real danger to the unwary man or beast.

Drainage is toward the east into the north flowing Santa Cruz which swings along the western margin of the Santa Cruz valley. The once perenially flowing Santa Cruz now carries water only during the rare periods of long hard rainfalls. This change in condition has taken place within the memory of the white man in the valley and, it should be added, because of the presence of the white man in the valley. The domestic demand for water has so far outstripped the supply that water is now obtainable only from deep wells. At the present time the city of Tucson is facing a serious ground water recharge problem.

Rising above the pediment surface are isolated remnants of steeply dipping Paleozoic and Cretaceous (?) sediments. These outcrops take the form of generally northwest trending ridges whose crests seldom stand more than 150 to 200 feet above the surrounding terrain. The tops of these ridges are maintained by resistant limestones and quartzites, while the low areas between consist in most places of coarse-grained deeply weathered granite. Rapid disintegration of the heterogeneous granite is characteristic of an arid climate where annual and daily temperature ranges are extreme. Inversely, the homogeneous limestones and quartzites are little affected by temperature changes. Rainfall is too slight to be an effective agent of solution for the limestone. The topographic expression is exactly the reverse of that common to more humid climate.

VII

GENERAL GEOLOGY

The Sierrita Mountains, as described by Ransome,[5]

"...consist essentially of an intrusive granitic core flanked by more or less metamorphosed rocks of sedimentary and eruptive origin. These flanking rocks are notably different in character on the two sides of the range. On the east are rather massive gray limestones, with quartzites, shales, and altered andesitic volcanic rocks. These rocks are folded and faulted, have been invaded by granite, and in places show pronounced contact metamorphism. On the west the rocks are prevailing schistose, have been more closely compressed, and have been affected by metamorphism of regional character in contrast with the more intense but local contact action on the east...."

The sedimentary rocks of this area range in age from early Paleozoic to late Mesozoic (?). These rocks, as stated above, have undergone intense folding and faulting accompanied, or closely followed, by widespread granite intrusions. At Helmet Peak the age of these intrusives has been tentatively established by Mayuga as post-Cretaceous.[6] The same relationship exists at Morgan Hill where the Cretaceous (?) sediments also dip steeply into the underlying granite.

Metamorphism in this area has been intense. The original sediments have been so altered by silicification and marbleization that certain identification is difficult if not impossible

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[5] Ransome, F. L., Ore deposits of the Sierrita Mountains: U. S. Geol. Survey Bull. 725, p. 409, 1921.

[6] Mayuga, M. N., The geology and ore deposits of the Helmet Peak area, Pima county, Arizona: Ph.D. thesis, 1942.

in some places. Recrystallization and silicification of the limestones have destroyed all but a few of the fossil remains that may have been present, effectively removing the only other possibility of determining the age relations. Garnetization is widespread, and large masses of limestone have been altered to garnet rock. The Escabrosa limestone appears to have been particularly susceptible to this type of metamorphism as well as to marbleization.

In spite of the difficulties expressed above, the following formations were identified with reasonable certainty: the Cambrian Bolsa and Abrigo formations, the Devonion Martin limestone, the Mississippian Escabrosa limestone, the Pennsylvanian Naco formation, the Permian "Manzano beds" (?), and the Cretaceous (?) quartzites, shales, and limestones.

There are several marked disconformities within both the Paleozoic and Mesozoic (?) sections. In southern Arizona the oldest formation of the Cambrian system is the upper Middle Cambrian Bolsa quartzite, which lies with angular unconformity on the eroded surface of the pre-Cambrian Pinal schist or pre-Cambrian granite. The Pinal schist is not evident in the Twin Buttes district so this relationship cannot be demonstrated; instead the Bolsa customarily exhibits an intrusive contact with post-Cretaceous granite. Disconformably overlying the Bolsa is the Upper Cambrian Abrigo formation.

Millions of years of non-deposition mark the break between the lower Upper Cambrian Abrigo formation and the

Upper Devonian Martin limestone. The Ordovician, Silurian and Early and Middle Devonian times are entirely unrepresented. A second disconformity separates the Martin from the overlying Escabrosa limestone.

The Lower Mississippian Escabrosa limestone is disconformably overlain by the Pennsylvanian Naco formation, though the disconformity is not apparent except on a faunal basis or where a basal conglomerate is present in the Naco. Ransome, in his report on the Bisbee Quadrangle,[7] failed to recognize this disconformity.

Permian strata apparently are absent in the Twin Buttes area in spite of the fact that Mayuga[8] reports a considerable thickness of "Manzano beds" and Snyder Hill limestone at Helmet Peak, only 5 miles to the north. Permian beds probably were deposited at Twin Buttes as well, but have since been removed by erosion or have been faulted out by the widespread thrusts which are common to this section. This supposition is further supported by the presence of a small isolated outcrop of Permian strata, in the extreme southeastern corner of the area mapped. Here dark gray limestone apparently underlain by red and green shales and marls is folded into a tight anticline with resulting repetition of

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7 Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 45, 1904.

8 Mayuga, M. N., op. cit., pp. 23-27.

beds. Nothing similar to this series of beds is found west of the road to Continental.

The Cretaceous (?) strata of Morgan Hill lies above and in contact with the Pennsylvanian Naco formation. The absence of a coarse conglomerate characteristic of the basal Cretaceous suggests that this contact is one of faulting rather than of deposition. It is known that no Triassic or Jurassic sediments were deposited in southeastern Arizona, so whether or not the Permian is represented here, there was a long hiatus between the deposition of the last Paleozoic strata and the beginning of the Cretaceous.

No Tertiary deposits are exposed. Any strata of this age that may be present are covered by Quaternary alluvium.

VIII

SEDIMENTARY ROCKS

PALEOZOIC ROCKS

The Paleozoic formations of southeastern Arizona were first described by Ransome[9] in his report on the Bisbee Quadrangle in 1904. All of the formational names adopted by Ransome were taken from the Bisbee area and are still in good usage, although some of the original formations have since been subdivided by later investigators. The formations found in the Twin Buttes area are essentially the equivalents of those described by Ransome at Bisbee.

Middle Cambrian

Bolsa quartzite

The Bolsa quartzite takes its name from Bolsa Canyon at Bisbee where outcrops of the rock are well exposed. The word bolsa is Spanish for purse or pouch.

The Bolsa quartzite is readily identified throughout the Twin Buttes area. The color is characteristically a shade of pink, but ranges from a rusty brown to a pale pink that is nearly white in places. The formation is increasingly arkosic upward and contains rusty brown quartzites and dark mottled shales near the top. Fresh surfaces are commonly a

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[9] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, 168 pp., 1904.

shade or two lighter than the weathered rock.

Texture of the quartzite is relatively coarse, showing rounded to subangular grains of quartz and feldspar; however, where metamorphism has been intense, the rock is almost aphanitic. As a rule, the feldspar is highly subordinate to the quartz. The base of the formation in most places is marked by a conglomerate, but in the Twin Buttes area no evidence of it has been found. Probably the true base is not exposed in this area.

Bedding in the Bolsa is characteristically thin, with much small-scale cross-bedding displayed throughout. Thin layers of slightly larger quartz grains are common. Because of its hard, brittle nature, the Bolsa quartzite is scattered widely as angular blocks in float, concealing the underlying bed rock. Outcrops are usually limited in extent even though superior resistance results in their forming many of the high points of the area. Bolsa slopes of rusty brown stand out in sharp contrast to the drab limestones of the area.

The largest outcrop of Bolsa in the region makes up most of the ridge which lies along the northern border of the Twin Buttes area. Five minor outcrops are arranged on a line extending southeast and northwest through the Contention mine.

The lower contact of the Bolsa is with the intrusive post-Cretaceous granite which obviates any attempt to determine the thickness of the formation. The writer measured nearly 700 feet of quartzite on the Bolsa ridge to the north.

The upper Middle Cambrian Pima sandstone and Cochise formation which occur in the Picacho de Calera Hills and the Whetstone Mountains respectively, and lie above the Bolsa in that order, have not been recognized at Twin Buttes. However, it is possible that either one or both are present in the series of undifferentiated Cambrian strata lying between the typical Bolsa quartzite and the unmistakable Abrigo formation. These uncorrelated thin-bedded and, in places, shaly limestones and marls were mapped with the Abrigo. The complete absence of fossils makes impossible any more precise determination of age.

Undifferentiated Cambrian

Cambrian limestones, shales, and marls

On the central northeast slope of the Bolsa Ridge a series of steeply dipping interbedded limestones, calcareous shales, and marls, nearly 600 feet thick, lie with apparent conformity on the Bolsa quartzite. Two thin beds of chert-banded Abrigo limestone separated by 10 feet of shaly limestone and marl lie above. Two hundred fifty feet of alluvium conceal the Cambrian section beyond this point. A description of the section is as follows:

Cambrian Section A

Quaternary alluvium

Upper Cambrian Abrigo formation

	Feet
1. Limestone: light blue-gray, coarse, thin-bedded (2-3 inches), chert-	

		Feet
	banded, hard, and brittle; resistant to weathering-------------	4
2.	Limestone and marl: gray, silty, shaly, soft; light-gray to nearly white, calcareous, soft--------------------	10
3.	Limestone: like No. 1------------------	3
	Total--------------------------	17

Undifferentiated Cambrian

		Feet
1.	Shales and marls: mottled blue-gray, fine, calcareous, soft; light-gray to white, calcareous, soft-----------	4
2.	Limestone: light-gray, fine-grained, thin-bedded, soft, friable-----------	6
3.	Shales and marls: like No. 1------------	12
4.	Limestone: light-gray, fine-grained, thin-bedded, hard, smooth; narrow calcite veins abundant---------------	4
5.	Shales and marls: like No. 3------------	20
6.	Limestone: white, fine-grained, thin-bedded, cherty, hard-----------------	5
7.	Shales: gray, soft---------------------	2
8.	Marls: gray to white-------------------	3
9.	Limestone: mottled pink and white, thin-bedded; contains brown shaly bands, hard; weathers white----------------	4

		Feet
10.	Limestone: light-gray, fine-grained, silty, thin-bedded, soft, friable; abundant calcite veins---------------	6
11.	Limestone: dark-gray, coarse; thin-bedded with silty bands (1/8-3/4 inches); rusty-gray on weathered surface-------------------------------	20
12.	Shales: mottled gray-green, soft--------	3
13.	Limestone: mottled pink and white, fine-grained, massive, hard, smooth; light-tan on weathered surface-------------	80
14.	Limestone: blue-black, fine-grained, massive, hard, somewhat cherty; weathers to dark-gray, rough, pitted surface--------------------------------	30
15.	Limestone: light-gray, coarse, thin-bedded, soft, friable; contains thin beds of marl-------------------------	30
16.	Limestone: light-brown, rather coarse, sandy, thin-bedded, soft, friable; weathers to rusty-brown color--------	6
17.	Shales and marls: like No. 3------------	45
18.	Limestone: mottled dark-gray and pink, fine-grained, shaly, hard; dark-gray on weathered surface----------------	4
19.	Shales and marls: like No. 17----------	50

		Feet
20.	Limestone: mottled dark-gray and red, coarse, thin-bedded, hard; weathers to rusty-brown,surface with smooth regular pits and channels----------------------------	100
21.	Alluvium---------------------------------	50
22.	Limestone: mottled gray-green, hard, rough, cherty----------------------	5
23.	Limestone: light-gray, coarse, thin-bedded, soft, silty; shows chert nodules in places; weathers to rough pitted surface----------------------	20
24.	Limestone: mottled gray-green, fine-grained, massive, hard, brittle, siliceous; weathers to a rusty-gray--	60
25.	Shales: black with greenish mottling and banding; fine, hard, brittle, somewhat micaceous; hornfelslike-----	20

Middle Cambrian Bolsa quartzite

A second, and much thinner Cambrian section, occurs on the same side of the Bolsa Ridge and a short distance east of Section A. A series of what appear to be tear faults, attendant upon thrusting from the northeast, separate the two sections. It seems probable that many of the less competent shales and marls have been faulted out between the more competent Abrigo and Bolsa.

Cambrian Section B

Lower Mississippian. Escabrosa limestone; Martin absent.

Upper Cambrian. Abrigo formation.

		Feet
1.	Limestone: light blue-gray, thin-bedded, chert-banded; typical Abrigo	150
2.	Marl: light-gray to white, soft	1
3.	Limestone: like No. 1	80
	Total	231

Undifferentiated Cambrian

		Feet
1.	Limestone: black with mottling of buff-colored silt; coarse, thin-bedded, hard; weathered surface dark-gray, pitted and channelled, showing silty bands and nodules	100
2.	Limestone: light-gray, coarse, silty, thin-bedded, soft and friable; shows dense, brown chert bands and nodules; weathers to light-gray rough pitted surface	20
3.	Limestone: dark-gray, fine, silty, thin-bedded, soft, friable; weathers to a gray-brown, smooth, regular surface	12
4.	Siltstone: drab gray, shaly	2
5.	Shale: rusty black with greenish mottling, hard, brittle, micaceous; hornfels-like	20
	Total	154

Middle Cambrian Bolsa quartzite.

Nearly 600 feet of dark-brown to black, hard, brittle, hornfels-like shales similar to those described at the base of the undifferentiated Cambrian are exposed a short distance west of the Contention shaft. Here the Bolsa and the overlying shales have apparently been thrust to the southwest onto the Pennsylvanian Naco formation.

The stratigraphic position of these shaly sediments above the Bolsa quartzite is the only basis for mapping them as Abrigo limestone. Metamorphism has destroyed any fossils that may have been present and has removed all traces of the shaly bands characteristic of the Abrigo, unless the dark-blue-green mottling and banding be taken as evidence of their earlier existence.

There is no evidence of the thin-bedded limestones and marls which lie above similar shales in the northern part of the district. Also the thickness represented here is much greater than that of the corresponding unit to the north. For both the omission and thickening of beds, faulting is probably responsible.

It has been suggested by Stoyanow[10] that these diverse sediments may be the equivalent of the Cochise formation which occurs in the Picacho de Calera Hills and the Santa Catalina Mountains to the north and northeast, respectively. The thickness observed is far in excess of the maximum of

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10 Stoyanow, A. A., personal communication.

311 feet measured by Stoyanow in the type locality, the Whetstone Mountains. Faulting, which has elsewhere resulted in the thinning and deletion of beds, may have, in this case, produced a thickening of the section. However, if the 230 feet of exposed Abrigo is added to the nearly 600 feet of Undifferentiated Cambrian, the total thickness compares remarkably well with the slightly over 800 feet of Cambrian limestone mapped by Johnson in the Helvetia district.[11]

Stratigraphically, and, to some extent, lithologically, there appears to be some basis for correlating these undifferentiated sediments with the Cochise formation and also, perhaps, with the Pima sandstone. The main objections seem to be (1) the relatively great thickness in comparison to that of all other known sections of the Cochise formation in southeastern Arizona, and (2) the absence of the characteristic upper blue oolitic limestone member. However, neither of these objections is necessarily valid in the light of the widespread faulting in the area.

Until definite fossil evidence is obtained, strata that are between the Bolsa quartzite and the Abrigo limestone must continue to be designated as Undifferentiated Cambrian.

Upper Cambrian

Abrigo formation

The Abrigo formation is named for Abrigo Canyon, 3 miles southwest of Bisbee. The term is Spanish for shelter. At

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11 Johnson, V. H., The geology of the Helvetia mining district, Arizona: Doctor's thesis, p. 20, 1941.

Bisbee Ransome describes it as "...a thin-bedded, impure, in part shaly, in part aranaceous, very cherty dolomitic limestone...."[12]

There is very little typical Abrigo limestone in the Twin Buttes area. The only outcrop found lies at the foot of the north slope of the Bolsa ridge in the vicinity of the town of Twin Buttes. Here the Abrigo consists of a light blue-gray, rather coarse, thin-bedded limestone with narrow closely spaced and persistent chert bands. The chert bands are rusty brown and stand above the softer limestone surface to create a gnarled appearance. Occasional chert nodules increase the gnarled effect. The chert layers average 1 to 2 inches in thickness and are spaced a slightly greater distance apart. These chert layers probably were originally thin shale beds that were laid down alternately with limestones. They have since become metamorphosed. The effect of this banding is very striking; it is difficult to confuse the typical Abrigo with any other formation.

The banding on fresh surfaces appears as dark reddish-brown layers in light gray limestone. Broken faces are extremely hard, aphanitic, and siliceous.

A careful examination of the Abrigo formation produced no fossils; evidently intense metamorphism has destroyed any Upper Cambrian fossils that may have been present. Mayuga[13]

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[12] Ransome, F. L., Some Paleozoic sections in Arizona and their correlation: U. S. Geol. Survey, Prof. Paper 98-K, p. 25, 1916.

[13] Mayuga, M. N., op. cit., p. 15.

reports a similar situation at Helmet Peak. Elsewhere in southern Arizona Tricrepicephalus texanus and Hesperaspis butleri of early Upper Cambrian age have been identified from this formation.

Upper Devonian

Martin limestone

The Martin limestone receives its name from Mount Martin on Escabrosa Ridge near Bisbee where Ransome describes it as "...dark-gray, hard, compact limestones which are generally well provided with fossils...."[14] In the type area, it lies disconformably on the Upper Cambrian Abrigo limestone and is conformably overlain by the Lower Mississippian Escabrosa limestone.

The Martin limestone at Twin Buttes has little in common with that described by Ransome. Metamorphism has altered it to a light-gray or tan, coarse-grained, thick-bedded, soft, friable, calcareous rock. Garnetization accompanied by the development of chert bands and nodules is relatively rare in comparison to that in the shaly members of the section.

No well-defined, persistent contact between the Martin and the Escabrosa has been found. The white marbleized limestone characteristic of the Escabrosa interfingers with light gray Martin limestone and isolated marbleized outcrops

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[14] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey, Prof. Paper 21, pp. 32-42, 1904.

occur in it. In many places the contact between the two is gradational. It is very possible that much of that which has been mapped as Escabrosa is in reality marbleized Martin. Consequently, only an arbitrary contact could be placed.

The coarse-grained marble weathers to smooth, rounded, low-lying outcrops while the less intensely altered limestone stands higher in the area and exhibits a rough, pitted and fissured surface.

The abundant and varied Hackberry shale fauna that elsewhere is characteristic of the Martin formation is not in evidence in the Twin Butte area. A few isolated remnants of a silicified Cladopora reef, which is one of the outstanding features of the Martin limestone in the Santa Rita Mountains to the east and the Santa Catalinas to the north are present. This coral reef usually occurs at, or near, the top of the Martin and attains a thickness of nearly 10 feet in places. For mapping purposes in the Twin Butte district, it is considered to be the topmost member of the Martin.

The most extensive outcrop of the reef is found on the crest of a low ridge adjacent to and west of the Contention shaft. The resistant silicified bed appears to have been instrumental in preserving the elevated surface. The corals have been insufficiently well-preserved to permit specific identification; however, Mayuga, in his work at Helmet Peek, was able to determine Cladopora limitaris, an intermediate form between Cladopora and Favosites.[15] He cites Rominger as his authority. Several other minor and probably displaced remnants of the coral reef are found in the area.

The thick-bedded nature of the Martin plus widespread recrystallization make strikes and dips extremely difficult to determine with accuracy. Faulting and an indeterminable Martin-Escabrosa contact precludes any possibility of an accurate measurement of the thickness of Martin limestone represented in this area. However, the maximum thickness mapped, 275 feet, compares quite favorably with the 250 feet of Martin estimated by Mayuga at Mineral Hill.[16]

The Martin limestone appears to be the only Devonian represented in this part of Arizona. Calcareous shales characteristic of the lower part of the Martin at Bisbee and Tombstone have not been recognized. A Devonian formation older than the Martin limestone is found in the Picacho de Calera Hills 25 miles northwest of Tucson, and has been named Picacho de Calera formation by Stoyanow.[17] It also appears to be absent at Twin Buttes. A formation younger than the Martin occurs in Peppersauce Canyon on the north flank of the Santa Catalina Mountains, 25 miles north of Tucson. These beds which conformably overlie the Martin and have been

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15 Mayuga, M. N., op. cit., p. 17.

16 Ibid.

17 Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Geol. Soc. Am., Bull., vol. 47, p. 488, 1936.

correlated with the Elbert formation and the lower Ouray limestone of Colorado are not known to occur at Twin Buttes.[18]

Lower Mississippian

Escabrosa limestone

The Escabrosa Ridge at Bisbee is the type area of the Escabrosa limestone where it crops out very prominently. The name is Spanish for cliffy which seems particularly appropriate in the Bisbee region where this thick, massive, white limestone towers above the less resistant Martin.

The Escabrosa limestone of the Twin Buttes district is a massive light-gray to white limestone with few dark-gray zones where metamorphism apparently has been less intense. The dark-gray phase is definitely granular, and the degree of coarseness appears to have increased with metamorphism so that large calcite rhombs are characteristic of the nearly pure white marbleized variety. In the latter occurrence calcite crystals 2 inches in diameter are common. Ransome characterized the Escabrosa as a pure, non-magnesian limestone.[19]

The marble is characteristically coarse-grained and friable. Ants of the vicinity spend endless hours collecting

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[18] Ibid., p. 489

[19] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey, Prof. Paper 21, p. 42-54, 1904.

the loose calcite crystals and heaping them up in mounds. Solution pits in the rock are usually filled with crystals, the work of ants and rainwash.

Because of its extreme softness, the metamorphosed Escabrosa at Twin Buttes, unlike that at Bisbee, generally forms gentle, smoothly rounded slopes which lie below the more resistant Naco formation. Evidence of bedding has been completely obliterated by recrystallization, so strike and dip are obtained with difficulty and with questionable accuracy.

Garnetization is common along fracture zones in the Escabrosa, but is not as widespread nor on such a large scale as in some of the other limestones.

Relatively rare, dark-gray zones appear isolated within the white marble. Why such areas of little alteration should exist in the midst of large masses of highly metamorphosed limestone is not known. Bedding is evident in the many narrow veins of white calcite which project more or less persistently along the strike. In places these bands form swirls and knots on the surface indicating that even this apparently normal phase did not entirely escape the disturbing effects of folding and faulting. Chert bands and nodules are present but not common.

In the dark-gray limestone the only recognizable fossil remains have been found. Large horn corals are present, but metamorphism has been so severe that even generic identification is not possible.

The thickness of the formation, like that of the Martin limestone, is indeterminable, although in some areas it appears to be considerable. A maximum of 500 feet of Escabrosa has been measured in both the northern and southern parts of the area, but it is doubtful that this figure represents the true thickness. In every exposure thrust contacts have replaced either one or both of the normal sedimentary contacts. The difficulty of distinguishing between the Martin limestone and the Escabrosa where both have undergone metamorphism further complicates the problem.

The following thicknesses for the Escabrosa were obtained from Mayuga's report on the Helmet Peak area:[20] Bisbee, 700 feet; Little Dragoons, 750 feet; Helvetia, 700 feet; and the Empire Mountains, 600 feet.

Lower Pennsylvanian

Naco limestone

Limestone of Pennsylvanian age in the Bisbee area outcrops most prominently in the Naco Hills, near the little town of Naco, which stands astride of the International boundary between Arizona and Sonora, Mexico. It is from this locality that the Naco limestone received its name.

The Naco limestone rests disconformably on the Lower Mississippian Escabrosa throughout most of southeastern Arizona. No Upper Mississippian strata are known in this

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[20] Mayuga, M. N., op. cit., p. 20.

region except in the Chiricahua Mountains. However, apparent conformity between the Escabrosa and Naco at Bisbee kept Ransome from recognizing any break between these formations.[21] In addition, the Naco limestone as described by him included beds now known to be of Permian age. Stoyanow[22] restricts Naco limestone to those strata which carry a Pennsylvanian fauna.

There is no evidence of a Pennsylvanian-Permian contact in the Twin Buttes area. Where the Naco does have an upper contact, it is apparently one of structural disconformity with the overlying Cretaceous (?) quartzites. The presence of an isolated outcrop of Permian in the area further suggests that the Pennsylvanian-Cretaceous (?) disconformity is one of faulting rather than deposition.

In the vicinity of the Morgan Mine the Naco limestone, like nearly all the other sediments of the region, is scarcely recognizable from its description in the type locality. Metamorphism has so thoroughly altered color, texture, and structure of the limestone that stratigraphic location is the only reliable method of determining its age.

Naco limestone in this area, once identified, is not readily mistaken for anything else. Although the characteristic

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[21] Ransome, F. L., Geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 45, 1904.

[22] Stoyanow, A. A., op. cit., p. 523.

thin, shaly layers are not present or are masked by metamorphism, the definite mottling that has been imparted to this fine-grained, hard, brittle, siliceous limestone is very striking. The general effect of the weathered surface is a smoothly pitted, rusty-brown crust partly covering a blue-green limestone base. In the more shaly parts of the Naco, mottling is light gray and blue green, but the characteristic color is unmistakable.

It is on fresh surfaces that the mottling is probably most striking. The shaly constituents have imparted blotches of tan or reddish brown to the deep blue-green background. A uniform dark blue green to gray green is still more common.

Thin-bedding, extreme hardness and brittleness, aphanitic texture with characteristic conchoidal fracture, combine with the striking color to distinguish the Naco limestone from any other formation in the area.

Due to its resistance, the siliceous Naco limestone forms the crests of many ridges in the district and its angular float bestows a rusty-brown color to the slopes for some distance below the outcrop. Exposures vary considerably in thickness, but probably at no place include the full thickness of the Naco. This conclusion is based on evidence of widespread faulting within the formation. The characteristic "basal" conglomerate is entirely absent in the southern part of the area except for a small outcrop east of the Morgan shaft; a structural disconformity exists between the Naco and rocks above.

The conglomerate near the base of the Naco formation, in reality, lies about 40 feet above the lithologic boundary of the Escabrosa and Naco. It crops out on both sides of the old railroad cut on the east end of the long, low ridge extending eastward from the Morgan Mine, and consists of subangular to rounded quartzite and Naco limestone pebbles ranging from 10 mm. to 150 mm. in diameter. A much finer conglomerate, descriptively termed "black-and-white", occupies a similar stratigraphic position in the Naco on the south slope of Queen Hill. It appears again in the Naco of Foy Hill to the north.

The greatest thickness of Naco limestone in the Twin Buttes area lies at the base and extends part way up the north slope of Morgan Hill. About 400 feet of shale and limestone were measured here as compared with 900 feet estimated by Mayuga at Helmet Peak.[23]

No fossils were found in the Naco, although _Stromatopora_ have been reported from the base of the Naco on the south slope of Queen Hill.

Permian

Undifferentiated shales, limestones, and marls.

A series of sedimentary rocks outcropping in the southeast corner of the mapped area forms an inconspicuous north-

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[23] Mayuga, M. N., op. cit., p. 22.

west trending ridge completely isolated by alluvium. Dips and repetition of beds indicate a tight anticline subsequently breached by erosion. If this interpretation is correct, the lower members of the series consist of red and green shales alternating with white marls and shaly limestones. Above these softer beds lie rather massive light to dark-gray limestones.

Allowing for the difficulty of determining just where a complete series begins the section through the south limb of the anticline is as follows:

Quaternary alluvium.

Permian. (Undifferentiated)

	Feet
1. Limestone: dark-gray; fine-grained, rather thick-bedded, hard; contains many small chert nodules and narrow calcite veins; abundant unrecognizable silicified fossil remains; weathers to a rough pitted and fissured surface----------	70
2. Limestone: light-gray, fine-grained, thick-bedded, hard; contains great profusion of tiny silica nodules, in many places concentrated in beds; beds and pockets of <u>Archaeocidaris</u> spines--------------------------------	40
3. Limestone: dusty light-gray, fine-grained, thin-bedded, hard; contains	

		Feet
	many narrow calcite veins; cherty in places; weathers to give a rough pitted and fissured surface with small, rough, protruding chert nodules----------------------------------	30
4.	Shales and marls: red, green, gray, soft; white, soft----------------------	160
5.	Limestone: light-tan, fine, shaly, brittle----------------------------------	25
6.	Concealed, probably shale-----------------	15
7.	Limestone and shales: rusty-brown, thin-bedded, soft; brown, soft--------	75
8.	Shales: soft, rusty-brown----------------	15
9.	Limestone: reddish-brown, fine-grained, thin-bedded, hard, and brittle; fragmental and shaly in parts; weathers smooth----------------------	35
10.	Limestone: rusty-brown, shaly------------	20
11.	Shales: soft, red and green--------------	15

Apparent repetition of beds.

A comparison with the description of the Permian section in the Whetstone Mountains by Stoyanow[24] suggests that these beds may be a part of the Lower Permian "Manzano beds", locally

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24 Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Geol. Soc. Am., Bull., vol. 47, p. 530, 1936.

known as "Manzano B", as defined by him. The presence of limestones containing abundant <u>Archaeocidaris</u> spines and what appear to be remains of unidentifiable silicified fossils further point to Permian age. Except for the absence of quartzites and gypsum, the sequence is comparable to that described by Mayuga at Helmet Peak.[25]

The term "Manzano Beds" is applied by Stoyanow to that part of the Permian system in Arizona, which lies below the Snyder Hill limestone and contains fauna similar to that occurring in the Manzano group of the Permian in New Mexico.

The precise age of these beds of variegated shales, marls, and dark colored limestones must be open to question until further investigation uncovers more definite proof.

MESOZOIC ERA

Cretaceous (?)

Strata of Cretaceous (?) age occur only in the extreme southern end of the Twin Butte district. Here a considerable thickness of continental deposits consisting of alternating quartzites, shales, and thin-bedded limestones overlies a thick, coarse, poorly sorted basal conglomerate. By far the greater part of Morgan Hill consists of Cretaceous (?) sediments which lie disconformably on the Naco limestone of Lower Pennsylvanian age. Beds dip steeply into the post-

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25 Mayuga, M. N., op. cit., p. 23-25.

Cretaceous granite to the south.

To the east of Morgan Hill shales and quartzites with a few thin beds of limestone are exposed southward for several thousand feet beyond where they are buried by alluvium. At the bottom of this nearly complete section the basal conglomerate is found.

Relatively few outcrops of Cretaceous (?) strata are found on the Morgan ridge. An abundance of angular fragments forming float are scattered from crest to base, effectively concealing all but a few good exposures. The rock consists essentially of light-gray to rusty-brown quartzites that are fine-grained to aphanitic in texture and show fine stratification, including, in places, small scale cross-bedding. Outcrops weather to a rough, rounded, granite-like surface. Epidotization is common, the degree varying from thin films on the surface and in joints to an epidote content which makes up a large percentage of the rock. Thin shale beds are interbedded with the quartzites.

On fresh surfaces colors vary from shades of light-gray and tan through blue gray to reddish brown and pale green. Mottling is common. The fresh surface is characteristically shiny and vitreous and exhibits a conchoidal fracture. Dark fracture faces of unrecrystallized quartz grains are scattered over the surface.

In the more extensive section to the east exposures are more plentiful at both the bottom and the top of the series although intermediate beds are obscured by float.

The lower part of the section appears as follows:

Obscured

Lower part of Cretaceous (?) section

		Feet
1.	Quartzite: light-gray to tan, fine-grained	Indeterminable
2.	Limestone: black, brittle, shaly	1-1/2
3.	Conglomerate: coarse; grades upward into fine quartzites above	60
4.	Limestone: mottled gray-green, thin-bedded, shaly, hard	30
5.	Quartzite: gray-brown, fine-grained	15
6.	Shale: soft, gray, calcareous	4
7.	Quartzite: tan	150
8.	Limestone: gray-green, fine-grained, thin-bedded, shaly, hard	8
9.	Limestone: alternating beds; light-tan to brown, soft, shaly	40
10.	Conglomerate: coarse, poorly sorted, at the base; consists of pebbles and boulders ranging from 5 mm. to 125 mm. in diameter; finer pebble conglomerate above grading upward into coarse-grained and fine-grained quartzites	400

Quaternary alluvium

Approximately 2500 feet south of the base of the Cretaceous (?) section a fine black and white pebble conglomerate is overlain by a 4-foot bed of edgewise, limestone conglomerate and approximately 70 feet of coarse arkose. Alluvium conceals all outcrops beyond this point.

The Cretaceous section in the Empire Mountains near Hilltano Mine, as described by W. H. Brown,[26] appears to correspond lithologically with that found in the Twin Buttes district. At neither location is the complete thickness exposed, but in both places it is known to be great, perhaps 10,000 to 15,000 feet.

J. H. Feth describes Cretaceous (?) deposits in the Northern Canelo Hills as consisting of a coarse basal conglomerate overlain by sandstones, quartzites, and shales with thin limestones interbedded.[27] The section to which he has given the name Canelo Red Beds measures 1360 feet. The lithologic similarity to the Twin Buttes Cretaceous (?) is apparent.

Andesitic flows and tuffs placed by W. H. Brown at the base of the Cretaceous strata in the Tucson Mountains and recognized by Mayuga as also being present at Helmet Peak,[28] are either entirely absent or unexposed in the Twin Buttes

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[26] Brown, W. H., Tucson Mountains, an Arizona basin range type: Geol. Soc. Am., Bull., vol. 50, pp. 716-718, 1939.

[27] Feth, J. H., Geology of the Northern Canelo Hills, Santa Cruz county, Arizona: Ph.D. thesis, p. 40.

[28] Mayuga, M. N., op. cit., p. 27.

area. Above these volcanics both Brown and Mayuga describe great thicknesses of conglomerates, quartzites, arkoses, shales, and thin limestone beds. These deposits were subdivided by Brown into a lower series called Recreational Red Beds and an upper series termed the Amole Arkose.[29] A study of the detailed sections of these two formations leads the writer to believe that the upper part of the Recreational Red Beds and a part or all of the Amole Arkose are represented in the Twin Buttes area. No fossils have been found, however, so precise correlation is impossible at present. Brown reports finding a mactra and a gastropod fauna in the Amole Arkose.

CENOZOIC ROCKS

Quaternary Alluvium

The mountain slopes and valley floors of arid southeastern Arizona are characteristically covered by alluvial deposits ranging from thinly spread, poorly sorted, generally coarse detritus of the upper bajada slopes to fine sands and silts of the intermontane valley bottoms.

The low areas of the Twin Buttes region are almost entirely covered by detrital accumulations washed out of the Sierrita Mountains to the west. The alluvium is commonly thin in the foothills, but thickens rapidly in the direction of the Santa Cruz valley to the east. These recent deposits have been cut by shallow washes and arroyos which reveal the

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[29] Brown, W. H., op. cit., p. 716-718.

underlying Paleozoic sediments and intrusive granite. The sorting is poor and the arroyo walls reveal rudely stratified deposits ranging from boulders several inches in diameter to fine sands and silts. Broad stream beds are characteristically made up of fine gravels and sands.

Alluvium in many places is cemented by caliche to form a fairly resistant caliche conglomerate. This caliche is nearly pure calcium carbonate which has been precipitated from a calcium bicarbonate solution by evaporation of water and escape of carbon dioxide. The bicarbonate solution was obtained from leaching of the Paleozoic limestones by carbon dioxide charged rain water. The calcium carbonate is a natural cement and acts as a binder between the fragments of clastic material. Such conglomeratic beds are usually thin, varying from a few inches to a foot or two. Seldom are they of any considerable extent areally.

The alluvial deposits consist of an aggregate of all the rocks of the region: Paleozoic and Mesozoic (?) limestones and quartzites, post-Cretaceous intrusives, and fragments of the crystalline granite which makes up the core of the Sierritas.

IX

IGNEOUS ROCKS

Post-Cretaceous granite

The entire Twin Buttes district is apparently underlain by a post-Cretaceous granite stock. A similar intrusive was found at Foy Hill, and Mayuga reports a granite of like age in the Helmet Peak area. Post-Cretaceous intrusion is indicated by the fact that the Cretaceous (?) sediments on the south flank of Morgan Hill dip steeply into the underlying granite.

Under arid climatic conditions coarsely crystalline rocks which consist of a variety of minerals are much more vulnerable to the forces of weathering than are the more homogeneous limestones and quartzites. In consequence the low areas of the region are characteristically underlain by the granite. The granite crops out most prominently in the western part of the area while alluvial deposits largely conceal it east of the Contention mine. South and west of Morgan Hill outcrops are predominantly post-Cretaceous granite and later intrusives.

This so-called granite, which is perhaps more specifically a quartz monzonite, is a rusty-gray, soft, friable rock which has been cut by numerous rusty quartz veins and later intrusives. In the hand specimen the minerals appear to be essentially coarse crystals of quartz and orthoclase feldspar with a little biotite and an occasional crystal of pyrite and magnetite. It has the appearance of a coarse-grained granite.

Microscopic examination reveals that the rock contains the following minerals:

	Per Cent	Size
Quartz	40%	0.05 to 2 mm.
Orthoclase	35%	0.4 to 2 mm.
Oligoclase	20%	0.2 to 1.5 mm.
Biotite	5%	
Pyrite	- 1%	
Magnetite	- 1%	

In accordance with Grout's classification, the rock is transitional between a granite and a quartz monzonite.

Granite

A coarse-grained granite dike of indeterminable, though considerable, dimensions cuts the post-Cretaceous granite east of the Contention mine. It is a hard, rather resistant, pinkish tan rock which weathers to a rough pitted surface. Fresh surfaces are pinkish gray from the abundant orthoclase and quartz. This intrusive granite is rather widespread throughout the area.

Microscopic examination reveals the following minerals:

	Per Cent	Size
Orthoclase	± 60%	0.5 to 2 mm.
Quartz	± 40%	0.05 to 0.5 mm.
Biotite	- 1%	average 0.05 mm.
Magnetite	- 1%	average 0.05 mm.

Alteration of the orthoclase has resulted in widespread kaolinization and some sericitization.

Aplite

This rock occurs as a medium gray, fine-grained dike in the granite east of the Contention mine. A hand lens reveals equigranular feldspars and quartz with a few scattered grains of biotite or some other dark colored mineral.

A thin section shows the following minerals:

	Per Cent	Size
Quartz	70%	0.1 to 0.4 mm.
Orthoclase	20%	0.5 to 1 mm.
Oligoclase	10%	0.05 to 0.5 mm.
Muscovite	- 1%	0.1 to 0.4 mm.
Biotite	- 1%	

Quartz andesite

A dark gray to nearly black, fine-grained rock containing abundant gray feldspars, some quartz, and considerable ferro-magnesian minerals forms an intrusive contact with the granite in both banks of the large wash west of the Bolsa ridge. The dike forms one wall of the arroyo for nearly 700 feet. In the hand specimen it has the characteristics of an andesite.

In a thin section the rock is found to consist of:

	Per Cent	Size
Andesine	55%	0.1 to 1.5 mm.
Hornblende	30%	0.05 to 0.5 mm.
Quartz	10%	0.05 to 0.5 mm.
Biotite	5%	0.05 to 0.2 mm.
Magnetite	- 1%	

The hornblende has been altered to biotite to some extent. Andesine shows extensive kaolinization.

Rhyolite

An isolated outcrop of granite east of Morgan Hill has been intruded by a light colored dike which appears to be rhyolitic in composition. Phenocrysts of pink orthoclase and quartz are contained in a rather dark gray groundmass. Flakes of biotite and an occasional pyrite cube are visible.

Microscopic examination reveals that the groundmass which makes up approximately 75% of the rocks is essentially fine interlocking crystals of orthoclase and quartz containing larger crystals of:

	Per Cent	Size
Orthoclase	20%	0.25 to 0.5 mm.
Quartz	5%	0.2 to 0.6 mm.
Biotite	- 1%	0.1 to 0.5 mm.
Chlorite	- 1%	

Kaolinization obscures much of the feldspar.

X

METAMORPHIC ROCKS

There are four general types of metamorphism exhibited in the Twin Buttes area: (1) marbleization which is widespread and occurs to a greater or less degree in practically all the limestones in the district, (2) garnetization which is perhaps equally widespread but more confined to regions of faulting and fracturing, (3) epidotization which is confined almost exclusively to the Cretaceous (?) quartzites of Morgan Hill, and (4) silicification characteristic of all the sandstones in the region and, to varying degrees, of the shaly limestones.

Marble

Marbleization is most pronounced in the Escabrosa limestone where the intense pressure and heat of folding and granitic intrusion have brought about almost complete recrystallization. The resulting nearly pure white, extremely coarse-grained, massive, soft, and friable marble is very striking. In places the Martin limestone appears to have been equally highly marbleized, and is distinguished with difficulty from the Escabrosa. Marbleization in various stages is apparent throughout the entire limestone sequence.

The lack of minerals other than calcite in the marble testifies to the purity of the original limestone.

Garnet

Extensive fracturing and fissuring in the Paleozoic sediments of the Twin Buttes area, produced by widespread faulting, intense folding and igneous intrusion, have provided many channels of easy access for the mineralizing fluids which subsequently penetrated them. The surface evidence of this fracturing and of the succeeding mineralization are the numerous resistant belts of garnetized limestone which parallel the faults that localized them.

As in the case of marbleization, some of the limestones appear to be more susceptible to garnetization than others. This seems particularly true of the Escabrosa and Naco limestones. On the other hand, these are far more abundant in the area than are any other limestones, so the difference in garnetization may be more apparent than real.

In the process of garnetization of limestones the heat of the solutions rich in silica drove off the CO_2, and the carbonates were converted to silicates. To form the andradite type of garnet found in the limestones of the area iron must have been present either as an impurity in the limestone or as a constituent of the invading solutions. The latter source of the iron seems to be indicated for three reasons: (1) the garnet occurs abundantly in what was originally a pure limestone, (2) garnetization is adjacent to channels in fracture zones, and (3) other iron minerals are associated with the garnet in the contact zone.

Garnetization in the Twin Buttes area characteristically produces a rusty-brown, coarse-grained, extremely hard rock, which weathers to a rough, pitted surface.

Epidote

The epidote which occurs in the Cretaceous (?) quartzites is characteristically a product of alteration of other minerals. In this case alteration has been due to the subjection of mixed sedimentory beds containing calcareous matter, with sand, clay, and limonite to intense contact metamorphism. A yellowish green, finely crystalline, hard, brittle, vitreous mineral results. The process requires the subjection of rocks containing calcium, alumina, silica, and iron to intense heat and action of solutions.

Quartzite

The Cambrian and Cretaceous (?) quartzites are both the end product of metamorphic processes. Heat and pressure have altered the original sandstones to a pink and white, fine-grained to aphanitic, dense, hard, brittle rock which breaks with a conchoidal fracture. Not only has the original calcareous cement been replaced by silica, but even many of the quartz pebbles have undergone recrystallization.

Minor contact Metamorphic minerals

The minerals of the contact metamorphic zone are commonly tremolite, hedenbergite, diopside, and chlorite. The first three are common products of alteration of crystalline limestone in which the carbonate radical has been replaced by silica and magnesium and iron added. The magnesium and iron may be supplied by impure limestones or by the mineralizing solutions themselves. Chlorite is a common alteration product of any one or all three of the other silicates.

XI

STRUCTURE

Little is known of the structural history of the Sierrita Mountains previous to the post-Cretaceous granitic intrusion. The large igneous mass which now underlies and surrounds most of the older sediments of the region has almost completely obliterated any earlier structural evidence. The work of Brown in the Tucson Mountains, however, reveals a sequence of geologic events which could apply equally well to the Sierrita Mountains.[30]

Brown found that the Paleozoic and Mesozoic sedimentary rocks had undergone intense folding and thrust faulting by the end of the Cretaceous and that erosion had reduced their surface to a near peneplane. In Tertiary time--probably Late according to plant remains--volcanic activity poured out great flows of lava which came to rest with marked angular unconformity on the sedimentary series below. The Tertiary extrusives were subsequently block faulted and tilted to the east at angles ranging from 10 to 20 degrees. Younger basaltic rocks are found in a few limited areas to be lying almost horizontally on the tilted volcanic blocks.

Whether a similar relationship between sediments and volcanics ever existed in the Twin Buttes region is not known,

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[30] Brown, W. H., op. cit., p. 748.

but there is no reason to doubt that the Paleozoic and Mesozoic rocks here were subjected to the same orogenic and erosional forces which were so effectively at work only a few miles to the north.

Generally speaking, the structure of the Twin Buttes district appears to be essentially that of a breached anticline. The original anticlinal fold was probably due primarily to compressive stress from the northeast and, perhaps, in part to the upward pressure exerted by the magmatic body from below. At the present time only remnants of the northeast and southwest limbs remain, each completely surrounded and probably underlain by the granite.

The strikes of the limbs exhibit a remarkable parallelism, and in each the average is very close to N 45°W. Nowhere do the strikes of the beds vary greatly from this average, except where dragging has resulted from faulting. Dips of the beds are universally steep; there is evidence of overturning of some beds in the northeastern limb. No evidence of plunging could be obtained.

There are two major fault systems: (1) a series of strike faults which parallel the beds and trend generally northwest and (2) a series of transverse faults which strike northeast. One minor oblique fault was mapped and several others were postulated. The writer was able to find little positive evidence of thrust faulting, although it very probably was quite prevalent, and the relationships of many of the formations strongly suggest it.

Throughout the area it is apparent that the strike faults, as a rule, preceded the dip faults and are probably pre-granite. Very possibly some transverse faulting accompanied the development of the strike faults, but few if any appear to have been mineralized, while the strike fault zones are commonly garnetized.

Transverse faults customarily manifest themselves as saddles in the ridges. Strike faults are less readily detected except where thinning of beds is pronounced or where formations are missing. Undoubtedly, many strike faults are concealed beneath the alluvium of the generally southeast trending stream beds.

For greater facility in discussing the more detailed structure of the area, it seems advisable to designate three general subdivisions: (1) the Bolsa ridge in the northeastern section, (2) Morgan Hill to the southwest, and (3) the isolated outcrop of Permian strata in the extreme eastern part of the district.

Bolsa ridge

The most prominent structural features of the Bolsa ridge are the pronounced transverse and strike faults which have offset some beds and completely cut out others. Evidently, the earliest displacement in the area was in the form of high angle faulting of the northeasterly dipping beds which resulted in the cutting out of all but a narrow remnant of the Devonian Martin between the Abrigo and Escabrosa.

Identification of the Martin limestone was made possible by the presence of the Cladopora reef at, or near, its top. Houser mapped two relatively minor outcrops of Martin which are obviously displaced in the section. East of the mid-ridge transverse fault Lower Mississippian Escabrosa is in fault contact with Upper Cambrian Abrigo. North of the Minnie mine Pennsylvanian Naco has been faulted up against the Abrigo, cutting out both Martin and Escabrosa limestones. High angle thrust or reverse faulting which accompanied the intense folding seems to be the most logical explanation of this widespread omission of beds.

Subsequent strong transverse faults along which there has been both vertical and horizontal movement have resulted in extensive offsetting of beds. The most pronounced fault of this type is one which bisects the ridge very nearly at its linear center. The entire southeastern half of the limb has moved nearly 400 feet to the southwest. No evidence of thrust-faulting, such as a basal breccia, or dragging of beds in the case of tear faulting were observed. In the absence of thrust or tear faulting the same result could have been achieved by high angle normal faulting in which the southwest side moved down.

Three complementary transverse faults parallel to, and a short distance northwest of, the fault described above permit a total displacement of about 500 feet. Bolsa, Abrigo, Martin, and Escabrosa formations have all been overturned and moved to the southwest. Dragging of beds at both ends of the fault block provide evidence of horizontal movement between bounding tear fault surfaces.

The western-most fault in the area exhibits indisputable evidence of considerable horizontal movement along its surface. This fault forms the western boundary of a second fault block and here involves the Naco limestone. Beds on opposite sides of the fault have been dragged sharply around indicating that the Bolsa, Abrigo, and Naco on the east have moved southwestward in relation to the Bolsa on the west. The irregular contact between the Bolsa and granite eliminates any possibility of determining whether it was involved in the faulting.

Three nearly parallel transverse faults involve the Naco and Escabrosa on the Queen Hill. High angle normal faulting appears to have been the dominant process which moved parts of the Naco down into the underlying Escabrosa.

Morgan Hill

The structure of Morgan Hill appears to fit into the same general pattern as that of the Bolsa ridge to the northeast. Both strike and transverse faulting have been active with results comparable to those described above; omission and offsetting of beds are prevalent.

The most persistent example of omission of beds is the faulting out of the base of the Cretaceous (?) with the resulting absence of the basal conglomerate. On the north slope of Morgan Hill the Naco limestone has the appearance of grading upward into the fine-grained Cretaceous (?) quartzites. This relationship is apparently true along the entire length of the ridge.

The almost complete absence of the basal conglomerate in the Naco, except for small remnant north of the new Morgan shaft, indicates strike faulting between it and the underlying Escabrosa. The presence of several areas of garnetized rock within the Naco limestone, the strikes of which closely parallel the strike of the beds, strongly suggests additional strike faulting within the Naco formation itself. Mineralized solutions derived from the main intrusive mass worked their way into the sediments along these earlier fault zones.

Thinning of the Bolsa quartzite and the Abrigo limestone is extreme in places. This is especially true along the strike fault trending N40°W through the Contention workings. Here a thin line of Bolsa and Abrigo remnants lie in direct contact with the Escabrosa. The Martin limestone is absent except for a single narrow sliver of the silicified Cladopora reef lying between equally thin representatives of the Abrigo and Escabrosa. Mineralization of the limestone with garnetization at the surface followed the faulting.

The attitude of the fault planes, where dips could be determined, appears to indicate high angle reverse faulting. The dips measured are consistently to the south and southwest and range from 45° to 65°.

Transverse faults striking generally northeast are numerous and most show evidence of vertical displacement at steep angle. South of the old Morgan shaft, and between it and the new shaft, a long transverse fault has permitted the Naco limestone and the Cretaceous (?) quartzite to the west to move some distance to the southwest. Dragging of the beds in the vicinity of the fault indicate the direction of movement.

A second example of transverse faulting is the movement along the major northeast fault west of the Contention mine which carried the Bolsa and Abrigo southwestward until the latter rested against the Devonian Martin. The time relationship of the two fault systems is clearly displayed here in the displacement of the older strike faults and the mineralized limestones which parallel them by the more recent transverse fault.

A relationship of formations difficult to explain, except by high angle thrust, or reverse, faulting, is the presence west of the Contention mine of Martin limestone between the Escabrosa and Naco limestones. This supposition is supported by the fact that the strike fault which cuts through the Contention workings dips at an angle of 60°-70° to the southwest.

The Cretaceous (?) strata dip steeply into the granite on the southwest slope of Morgan Hill and finger out into the encroaching granite to the west. It is believed that the intrusive completely surrounds and underlies the Paleozoic and Mesozoic sediments of Morgan Hill.

Permian beds

Sediments consisting of shales, limestones, and marls, of Permian age, form a low inconspicuous outcrop in the extreme eastern part of the area. The beds appear to have been folded into a tight asymmetrical anticline, the axial plane of which is inclined approximately 25° to the northeast. The dip of the beds range from 75° to the northeast on the northeast limb to 40° southwest on the southwest limb. At the center the dip approaches the vertical. The strike of the limbs is N50°W; no evidence of plunging was observed. A major transverse fault bisects the structure about midway of its length. Movement along the fault appears to have been essentially of a dip slip nature with the southeastern wall moving up.

The Permian beds are completely surrounded by alluvium, so it is impossible to determine their relationship to the other formations of the Twin Buttes area. No Permian rocks were observed west of this outcrop. Isolation appears to be due to faulting as well as to alluvial deposits. Until further investigation proves otherwise, the presence of these Permian strata in the Twin Buttes district will be attributed to overthrusting from the north or northeast, involving a maximum displacement of 3-1/2 to 4 miles but probably much less.

The intrusion of the post-Cretaceous granite is thought to have had little disturbing effect upon the overlying sediments. Evidence seems to indicate that the magma entered more or less quietly along weakened zones of folding and faulting, assimilating the country rock as it advanced. The sedimentary rocks have the appearance of roof pendants projecting downward into the top of the stock.

Undoubtedly some structural deformation accompanied the intrusion process, but the parallelism of the limbs of the former anticline and the more or less uniformity and persistence of strikes and dips do not seem to be compatible with the large scale upwarping and thrusting aside of sediments that the mechanical intrusion of an igneous body of this size must demand.

Cooling and shrinking of the molten mass probably produced much of the normal faulting observed in the area.

In summarizing, there appear to have been three distinct periods in the structural history of the Twin Buttes area: (1) a period of intense folding accompanied by thrust and high angle strike faults parallel to the axis of the folds, (2) granitic intrusion and mineralization along fault zones, and (3) transverse faulting normal to the axis of the folds involving both horizontal and vertical displacement.

XII

GEOLOGIC HISTORY

The oldest known rocks in southeastern Arizona consist of a thick series of sericite schists which were first described by Ransome and named Pinal schist.[31] The schists are considered to be metamorphosed sediments of Archeozoic age.

In Late Proterozoic time an arm of the sea encroached upon Arizona from the south to submerge the southeastern half of the state. In this southeastern basin the Proterozoic Apache group was deposited disconformably on the pre-Cambrian Pinal schist or pre-Cambrian granite.

Apparently the sea withdrew from southeastern Arizona at the close of the Proterozoic and did not return until late Middle Cambrian time when the Troy and Bolsa quartzites were deposited. The Troy quartzites and conglomerates were laid down disconformably on the Apache group in the Santa Catalina Mountains, while to the south and southeast of Tucson the Bolsa lies directly on the old erosion surface of the Pinal schist or pre-Cambrian granite. The Bolsa observed at Twin Buttes appears to have been deposited in a near shore environment at first, as indicated by the presence of a rather

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Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle: Arizona, U. S. Geol. Survey Prof. Paper, pp. 24-27, 1904.

coarse conglomerate at or near the base. With rising sea level the coarse clastics grade upward into fine quartz sandstones and micaceous shales.

By the close of the Middle Cambrian the sea was again withdrawing to the southeast, and no Middle Cambrian deposits are found north of the junction of the Gila and San Pedro rivers.[32] Middle Cambrian strata younger than the Bolsa quartzite are found progressively farther to the southeast as the waters retreated. The most northerly extension of the Cochise formation is the Santa Catalina Mountains and the Picacho de Calera Hills in the Tucson Mountains. No positive evidence of the Cochise has been found at Twin Buttes, however.

During Upper Cambrian time the sea continued to withdraw and the thin-bedded, shaly Abrigo formation deposited on the Middle Cambrian Bolsa, while clastics comprised most of the sediments to the north in the Santa Catalinas. Apparently subsidence was taking place to the south, and the Abrigo formation to the north represents a near shore facies. The great thickness of the Abrigo at Twin Buttes records continued subsidence for a long period. The accumulation of fine calcareous muds alternating with thin-bedded limestones suggests deposition in somewhat deeper

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[32] Stoyanow, A. A., Paleozoic paleogeography of Arizona: Geol. Soc. Am., Bull., vol. 53, p. 1262, 1942.

water at very near base level of deposition. The very uppermost Cambrian which is represented by the Rincon limestones in the Whetstone Mountains and at Picacho de Calera in the Tucson Mountains, and the Copper Queen limestone at Bisbee is entirely absent. The Copper Queen limestone is found only in the extreme southeastern corner of the state.

A long period of emergence followed the deposition of the Abrigo sediments and the seas did not return to southeastern Arizona, except for minor transgressions recorded by isolated outcrops of Ordovician age in the Dos Cabezas Mountains and the Clifton-Morenci district, until Late Devonian. The relatively pure, non-magnesian, massive Upper Devonian Martin limestone, deposited with apparent conformity on the Abrigo points to deposition in a moderately deep sea environment at some distance from shore. To the north, the limestone gives way to aranaceous limestones, shales, and sandstones. The Devonion sea occupied approximately the same basin as that in which the Cambrian strata were deposited.

Continued subsidence throughout the Late Devonian and Early Mississippian brought even deeper seas into southeastern Arizona and with them the pure massive Lower Mississippian limestone which was deposited disconformably on the Martin. Lower Mississippian fauna indicate a deep sea environment as does the complete absence of dolomite. By the close of Early Mississippian time the southeastern trough was almost completely drained and the only Upper Mississippian strata deposited in this part of Arizona is the Paradise formation in the Chiricahua Mountains.

In the Pennsylvanian transgressive seas from the southeast again covered most of southeastern Arizona. A series of shaly limestones, indicative of a moderately shallow water environment, was deposited disconformably on the Escabrosa. Abundant fauna, essentially brachiopods, suggest water that was not too deep. An intraformational conglomerate lies within the basal limestone beds of the Naco, the Pennsylvanian formation of southeastern Arizona.

In the southeastern basin the Permian sea deposited in places along its shallow margins red and green shales, thin-bedded limestones, marls, and gypsum. As the sea deepened, the marine limestone of the Snyder Hill formation was laid down.

Following the withdrawal of the Permian sea, after the end of the period, southeastern Arizona apparently remained emerged until middle Early Cretaceous time when the Trinity sea spread westward as far as Bisbee. Cretaceous sediments throughout the remainder of the state are continental in origin. There is no evidence of Triassic or Jurassic deposition in southeastern Arizona.

In Late Cretaceous time widespread volcanic activity accompanied by tremendous outflowings of lava was prevalent throughout the state. Mayuga distinguished andesite, rhyolite, dacite, and latite flows in the Helmet Peak area.[33] There is no evidence that these flows ever extended as far south as the Twin Buttes district.

Extensive folding, thrust faulting, and renewed igneous activity took place at the close of the Cretaceous. This period of general crustal unrest has been ascribed by most students to the Laramide Revolution. It was during the late stages of this severe orogenic activity, or closely following it, that the large granite mass was intruded into the overlying Paleozoic and Cretaceous strata. The ore deposits of the district are believed to have been formed at this time.

During the Late Tertiary (?) Mayuga finds evidence of another period of igneous activity in the vicinity of Helmet Peak.[34] Since this last period of basaltic flows the dominant earth shaping process has been erosion.

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[33] Mayuga, M. N., op. cit., p. 27

[34] Ibid., p. 38.

XIII

ECONOMIC GEOLOGY

The metal production of the Twin Buttes district has been predominantly copper with some lead, zinc, silver, and a little gold. The mines included in the district are the Glance which lies to the east of the Queen just outside of the area mapped, the Queen, King, Minnie, Morgan, and Contention. Of these, the Glance has been the greatest producer, closely followed by the Morgan with the Queen third in importance. The comparative production records of the mines appear below:*

Glance	$2,786,126.00
Morgan	2,035,306.00
Queen	1,747,852.00
Minnie	1,339,803.00
King	275,000.00
Contention	

The mineralization of the district is typically contact metamorphic in character, the direct result of the invasion of the sediments by a large granitic intrusive body. Deposition has been controlled almost entirely by faulting and fracturing of the Carboniferous limestones near the intrusive contact and is confined to belts or zones of

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*Records of William Foy.

altered rock in which pyrite and chalcopyrite are intimately associated with garnet, amphiboles, pyroxenes and other silicate products of contact metamorphism. Heat and pressure from the intrusive mass forced mineralizing solutions out into the surrounding country rock along fracture zones.

The most common evidence of contact metamorphic mineralization is the numerous outcrops of garnetized limestone. These are of no economic importance except as a possible guide to ore. The mineralized zones are generally rather narrow at the surface, limited in extent, and appear to be restricted almost entirely to the strike faults. But not all such faults are so affected.

The Carboniferous limestones are apparently more susceptible to alteration than are others. However, this may be due to the fact that there is relatively a much greater amount of Carboniferous limestone in the area rather than that they are particularly favorable, chemically or structurally, for such alteration. The Senator Morgan shaft is sunk in Lower Pennsylvanian Naco while the Contention shaft cuts the Lower Mississippian Escabrosa. At Foy Hill 4 miles to the north the Devonian Martin seemed to be most strongly garnetized. Undoubtedly the proximity of the igneous contact has had considerable influence in the location and degree of metamorphism.

The ore deposits consist essentially of chalcopyrite, galena, and some sphalerite, with abundant pyrite and magnetite and carry some silver and gold. The ores are preponderantly primary sulfides, although some supergene chalcocite and a little native copper have been mined. The original production of the area was from surface outcrops of copper carbonates and chrysocolla. Generally, oxidation of the ore has been the exception rather than the rule. The one exception was found in the Queen mine where oxidation had reached a depth of 600 feet. R. L. Brown made an extensive study of the Queen and Glance workings.[35]

Brown's work at the Queen and Glance mines further revealed that the ore bodies are characteristically irregular in outline, somewhat tabular, and of limited extent both vertically and horizontally. At depths beyond 700 feet the deposits become too low grade to mine. At the Morgan the workings were extended to 900 feet before the ore pinched out. In both cases granite was found only a short distance below the shaft bottom.

A study of Brown's underground maps indicates that the ore bodies are irregularly distributed and are confined to rather wide garnetized zones. Ore deposition appears to have been concentrated on the limestone side of the contact zone away from the granite.

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35 Brown, R. L., The geology and ore deposits of the Twin Buttes district; Master's thesis, Univ. of Ariz., pp. 34-38, 1926.

History of the Twin Buttes Area

Much of the following information was obtained from notes compiled by Dr. E. D. Wilson, geologist in the Arizona Bureau of Mines, for the purpose of publishing a brief history of mining in Pima County. All mine production figures were supplied by Mr. William Foy of Twin Buttes.

There was little or no metal production in the Pima district previous to the completion of the Southern Pacific railroad into Tucson in 1880. Transportation difficulties, further complicated by bands of marauding Apaches, served as the chief obstacle to mining in the area.

Silver deposits which had been known to the Jesuit fathers and the early Spaniards were the basis for the early production of the district. Considerable silver-lead ore was shipped, principally from the San Xavier mine, from 1880 until silver was demonitized in 1893. A little copper was mined during the first four years of this period.

The copper deposits at Twin Buttes were located in the early seventies, but little work was done in the first period of copper mining. The Twin Buttes Mining and Smelting Company acquired all the promising property in 1903 and built a standard gauge railroad from Tucson to Twin Buttes. During the eleven years of development and operation by the Twin Buttes Company the gross production amounted to $3,110,000.00.*

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*Figures from records of William Foy.

Most of the ore came from the Morgan Mine with the Copper Glance, Copper Queen, and Copper King mines contributing.

When the venture collapsed in 1914 the Southern Pacific bought the rail line from Tucson to Sahuarita to be used as part of its branch line to Nogales and Mexico. In that year the Senator Morgan Mine was leased to two of the original owners, Messrs. Bush and Baxter, who shipped a considerable tonnage of copper ore to the Copper Queen smelter at Douglas. The high copper prices during the first World War made such long distance hauling profitable. Earlier attempts to operate a smelter on Twin Buttes production had failed.

In 1915 the Morgan Mine was closed down when the ore was found to be too low grade to work. The shaft is now a source of water for stock.

The following figures on Morgan production for the years 1906-1913 were obtained from the records of William Foy who now owns the property.

TWIN BUTTES MINING AND SMELTING COMPANY

Morgan Mine

Production and Cost of Production 1906-1913*

Production			
Cars shipped, R. R.	2,694		
Wet Tons	138,775		
Dry Tons	132,502		
Moisture %	3.80		
Copper %	5.92		
Copper, lbs. gross	15,688,237		
Copper, lbs. net	1,377,922		
Copper price, average	13.0102 cts.		
Total copper value		$1,861,800.60	
Silver, oz.	254,404		
Silver price, average	68.201 cts.		
Net silver value		167,400.00	
Total receipts copper and silver			$2,029,200.60
Cost of Production		$1,973,546.60	
Credits		76,871.05	
Total cost less credits			$1,896,675.55
TOTAL NET			$ 132,525.05

*Statement condensed.

<u>The Morgan Mine</u>

At the present time the underground workings of the Morgan mine are completely inaccessible and have been so since 1941 when attempts were made to reopen one shaft to explore the mineral possibilities of some quartz veins. The only information available is that contained in past reports on the mine. F. L. Ransome included it in a general report on the geology and ore deposits of the Sierrita Mountains.[36] R. L. Brown, 5 years later, in 1926, made a rather thorough study of all the mines in the Twin Buttes district.[37] To these two earlier investigators must go the credit for many of the facts and figures obtained on the Morgan mine.

For the 11 years previous to its abandonment in 1915 the Senator Morgan mine was one of the big producers of the district. The ore was predominantly chalcopyrite which occurred in massive bodies intimately associated with abundant pyrite and magnetite, and some sphalerite and specular hematite. Galena was encountered in the upper part of the old Morgan shaft. There was little or no evidence of oxidation and secondary enrichment, galena having been noted in an outcrop just north of the original shaft. The gangue minerals consist of an abundance of garnet with lesser amounts of quartz, diopside, hedenbergite, tremolite, and chlorite.

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[36] Ransome, F. L., Ore deposits of the Sierrita Mountains: U. S. Geol. Survey Bull. 725, pp. 426-427, 1921.

[37] Brown, R. L., op. cit., pp. 31-33.

The ore body was apparently deposited along a fracture zone which accompanied northwest-southeast faulting. The mineralized zone outcrops at the surface in the form of a belt of garnet parallelling the longitudinal fault extending east of the old Morgan shaft. Ore was mined to a depth of 900 feet where it became too low grade to be profitable. It was reported that granite was encountered at that level. A second fault cuts the strike fault at nearly right angles between the old and new Morgan shaft. Apparently there was little or no mineralization along this later fault.

In 1941 the Morgan property was leased by C. M. Taylor after the discovery of scheelite in the quartz veins outcropping on Morgan hill south of the old Morgan shaft. This project was soon abandoned.

Exposures of the quartz veins at the surface have a generally westerly strike, range from a few feet to more than 50 feet in length; and vary from 1 to nearly 10 feet in width. They have cut the Cretaceous (?) quartzites and shales for a distance of over 600 feet.

The scheelite occurs as finely disseminated particles in the coarsely crystalline milky quartz. The particles are scarcely visible except under ultra-violet light. Assays of samples obtained revealed that the scheelite ore contained 0.7% to 10% WO_3.*

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*Arizona Bureau of Mines assay.

Contention Mine

The Contention mine was last operated by Mr. William Foy in 1947, and, though not abandoned, has been idle since that time. The underground workings are inaccessible due to the presence of water in the shaft to a height well above the upper level.

Development was first begun in 1919 and was carried on intermittently by Mr. Foy until 1943; the first production was in October 1944. The ore ran about 15% zinc, 2 to 3% copper, and approximately 1.5 ounces of silver. From 1944 to 1947 the mine produced about 8000 tons of ore, 780 tons of which were mined in 1947. High costs of production and the low price of zinc forced Mr. Foy to close the mine down in the latter year.

The underground workings are not extensive and attained an over-all depth of only about 210 feet. The shaft was sunk into a garnetized zone in the limestone which strikes northwest parallelling the granite contact. At 150 feet a 70 foot crosscut was driven to the southwest to intercept the contact zone which was found to be dipping in that direction at about 65°, and drifts were driven along the strike of the ore body in both directions. An early 4-inch show of sphalerite later widened to the southwest into a zone of nearly 15 feet. A block 120 feet long by 50 feet high was stoped. An inclined winze was sunk an additional 60 feet and a drift was driven for about 250 feet to the southwest. No ore was recovered from the 210-foot level.

The ore body occurs in a lenticular mass of garnet lying between the granite to the east and Carboniferous limestone to the west. A second shaft sunk about 300 yards to the west failed to reveal any extension of the ore body in that direction.

Plate VI shows a simplified sketch of the underground workings of the Contention mine.

Future of the District

The Twin Buttes mining district has been dormant, except for intermittent and short-lived minor activity, for nearly 20 years. The large mines are apparently exhausted and continued exploration with the diamond drill revealed nothing of sufficient importance to warrant further development. In most cases, the bottoms of the workings were found to be only a short distance from granite.

With the advent of World War II an exploration program was initiated by the United States Bureau of Mines and a field party was sent into the area to survey, trench, and sample the most promising parts of the district. Dr. E. D. Wilson of the Arizona Bureau of Mines and Dr. B. S. Butler of the University of Arizona mapped the geology of the region during the same summer and submitted a full report to the Bureau of Mines. The efforts of neither party were instrumental in uncovering any new ore bodies.

The structure of the district does not lend itself to the encouragement of further activity. Most of the more favorable and extensive outcrops of limestones have been rather thoroughly exploited. The exposures remaining to be explored are relatively limited areally and, probably, also vertically. The presence of large areas of granite at the surface suggests that nowhere do the sediments continue to any considerable depth. This is further indicated by the fact that the two deepest mines of the district, the Senator

Morgan and the Queen, encountered granite at 900 and 700 feet, respectively. In both cases the ore became increasingly low grade with approach to the granite. As mentioned earlier in this report, there is reason to believe that the sedimentary rocks of the area are floating in this mass of granite.

In view of the above observations, the writer is of the opinion that the Twin Buttes mining district will never again be a major contributor to the copper production of Pima County. Minor copper ore bodies of the contact type may be located by diamond drilling and developed as small leasing operations if future copper prices permit. Zinc may be profitably recovered from the Contention mine with a substantial increase in market values. Records of the district show that an appreciable amount of silver has been recovered from the copper ores, but it is doubtful if it ever occurs in sufficient quantities to permit mining for this metal alone. Further development of the scheelite deposits may reveal ores of economic importance, but to date little is known about them.

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PHOTOGRAPHIC PLATES

PLATE VIII

A. Gravel road to Sahuarita. Santa Cruz valley and Santa Rita Mountains in background. View to the east.

B. One of the larger intermittent streams of the area. Cut into Tertiary (?) granite.

Cb - Middle Cambrian Bolsa quartzite.

Tg - Tertiary (?) granite.

Plate VIII

PLATE IX

A. View to west from the Contention mine. Sierritas in background. Garnet Queen head frame in central foreground.

- Dm - Devonian Martin limestone.
- Ce - Mississippian Escabrosa limestone.
- Ca - Cambrian Abrigo (?) (Undifferentiated Cambrian)

B. View to east from Contention mine. Santa Ritas in background. Santa Cruz valley in middle distance, and eastward sloping pediment in foreground.

Plate IX

PLATE X

A. Fault west of Contention mine, looking north. Northwest side has moved southwest.

Ce: Mississippian Escabrosa limestone.

Tg: Tertiary (?) granite.

B. Typical garnet outcrop in Pennsylvanian Naco. Customarily stands well above adjacent limestone.

Plate X

PLATE XI

A. Angular Bolsa fragments mantling top of Bolsa Ridge to north.

B. Chert-banded Abrigo on north slope of Bolsa Ridge.

Plate XI

PLATE XII

A. Marbleized Martin limestone west of Contention Mine. Grass may be seen growing in solution pits.

B. Typical marbleized Escabrosa outcrop on ridge adjacent to and west of the Contention mine. The brilliant white color is common.

Plate XII

PLATE XIII

A. Marl bed adjacent to chert-banded Abrigo (?) limestone.

B. Drag fold in Manzano shales.

Plate XIII

PLATE XIV

A. Thin-section photomicrograph of post-Cretaceous granite.

Qtz: quartz

Plg: andesine

Orth: orthoclase

Magnification 55X.

B. Photomicrograph showing fine intergrown quartz crystals with larger crystals of oligoclase and muscovite. Crossed nicols. Rock is an aplite dike.

Qtz: quartz

Plg: oligoclase

Mus: muscovite

Magnification 48X.

Plate XIV

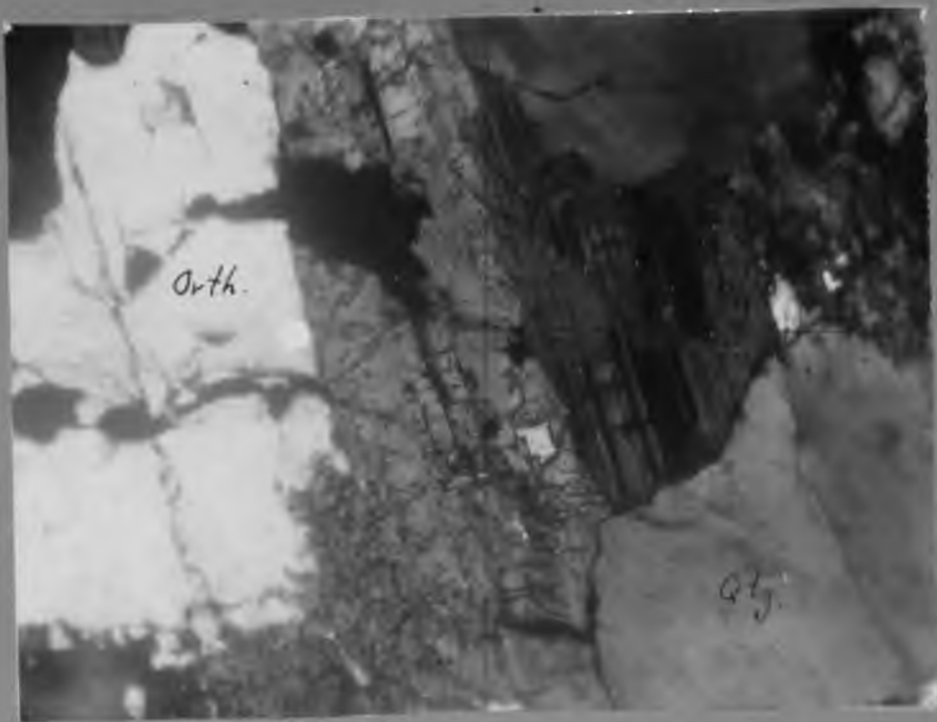


PLATE XV

A. Thin-section photomicrograph of late intrusive granite showing large kaolinized orthoclase crystals surrounded by fine-grained intergrown quartz.

Qtz: quartz

Orth: orthoclase

Magnification 48X.

B. Photomicrograph of andesine, quartz, and hornblende in a quartz andesite. Albite twinning in orthoclase crystals. Crossed nicols.

Plg: andesine

Qtz: quartz

Hbl: hornblende

Magnification 65X.

Plate XV

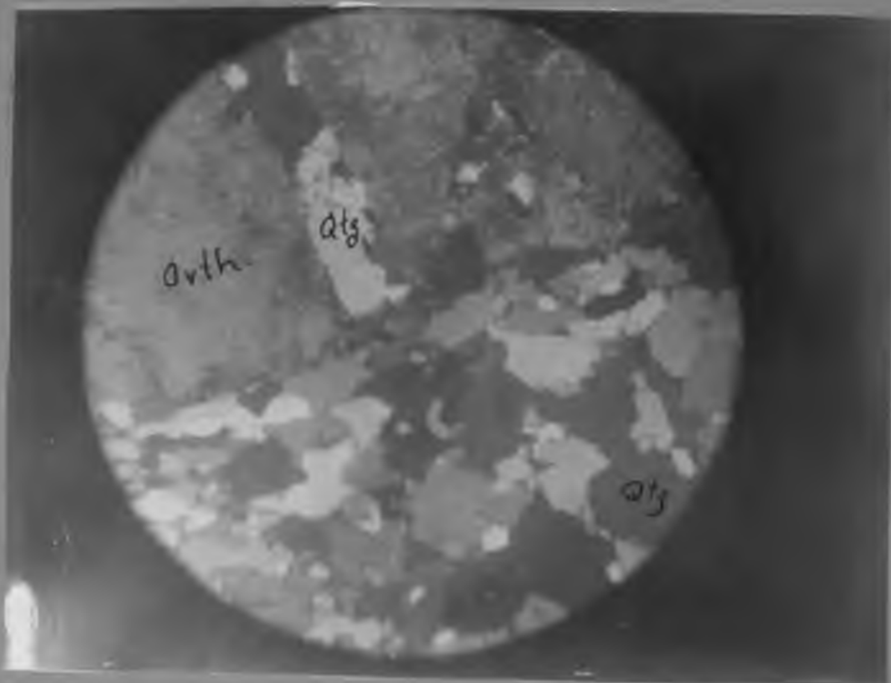


PLATE XVI

A. Thin-section microphotograph of a rhyolite dike. Groundmass consists of fine grains of quartz and feldspar. Quartz and carlsbad-twinned orthoclase crystals shown. Crossed nicols.

Qtz: quartz

Orth: orthoclase

Magnification 35X.

B. Photomicrograph showing microperthitic intergrowth of orthoclase and albite feldspars. Chlorite alteration along fracture in crystal. Crossed nicols. Rock is a trachyte dike.

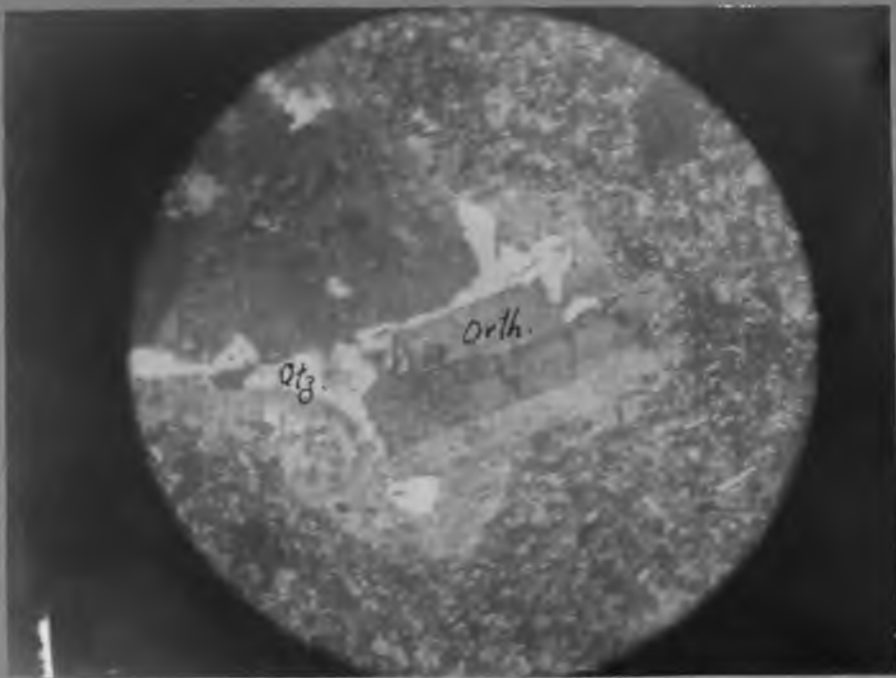
Orth: orthoclase

Ab: albite

Chl: chlorite

Magnification 35X.

Plate XVI



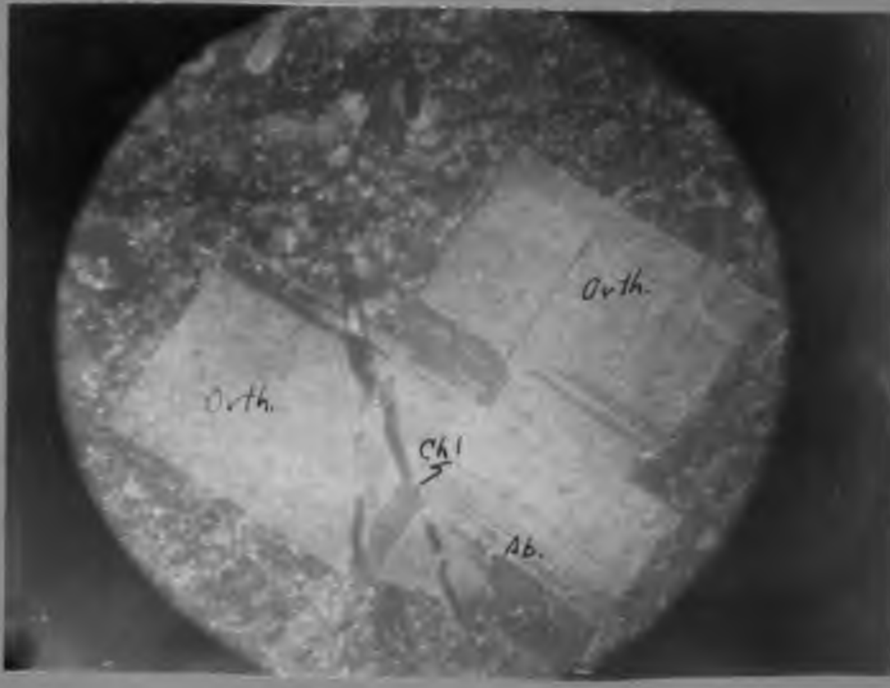


PLATE XVII

Cladopora reef in Devonian Martin limestone west of Contention mine.

Plate XVII

Panorama of Morgan Hill, Looking South.

In POCKET
7 maps

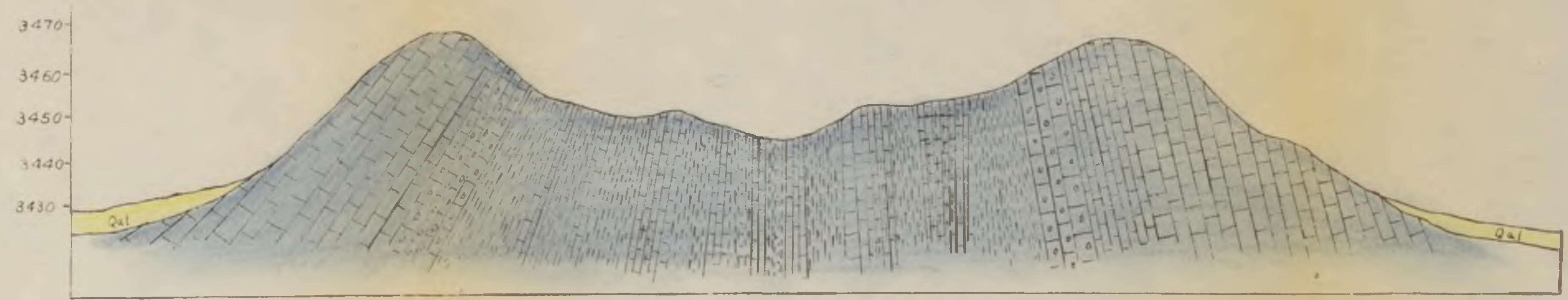
STRUCTURE of SECTIONS

The Senator Morgan Mine Area

Twin Buttes, Arizona

Section along A A'
Scale: 1in.-500ft.

Section along B B'
Scale: 1in=500ft.

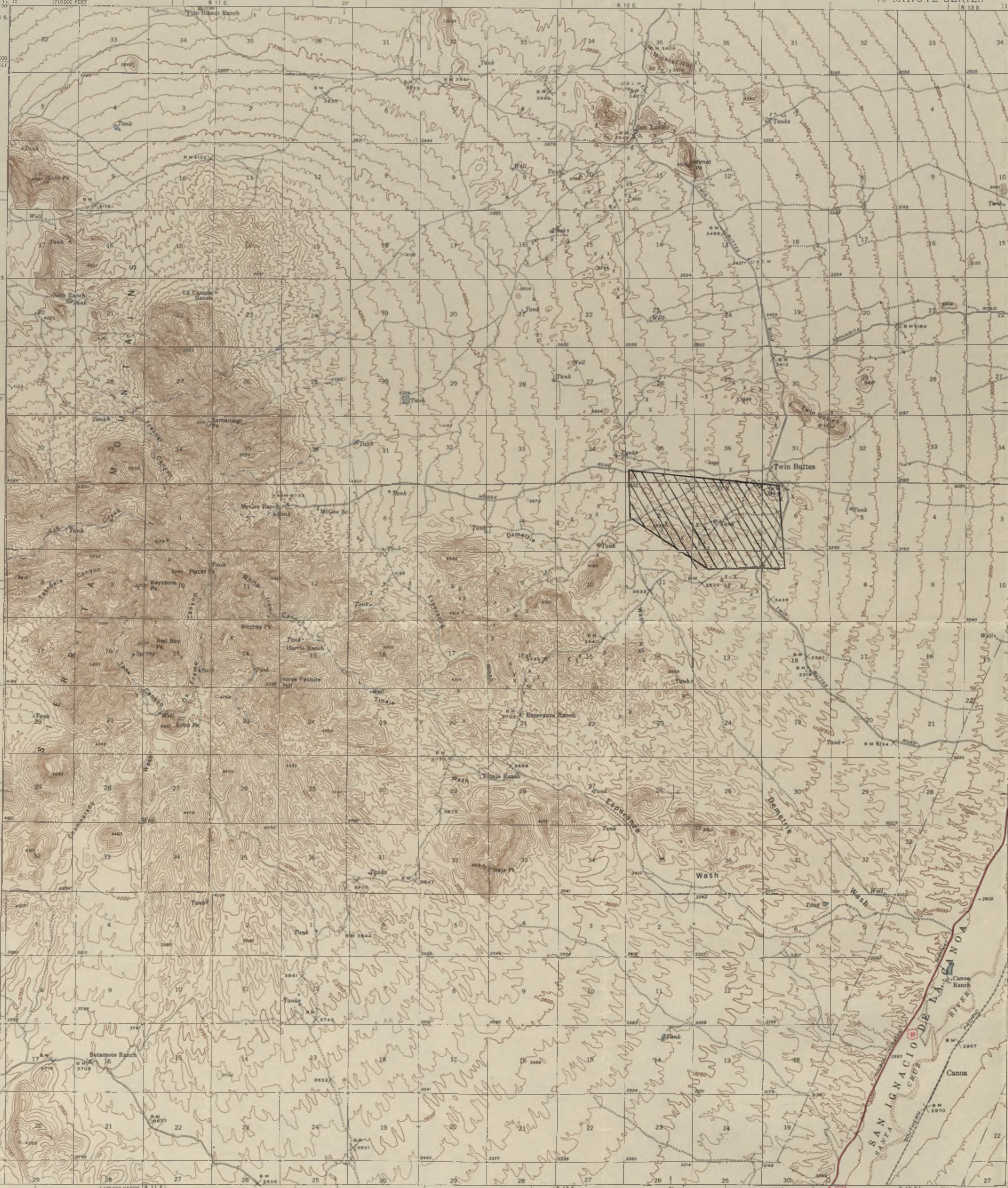


Section along C C'
Scale: 1in. =100ft.

Plate II

UNITED STATES
DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

ARIZONA
(PIMA COUNTY)
TWIN BUTTES QUADRANGLE
15-MINUTE SERIES



Topography by J. L. Lewis, F. H. Purdy, J. J. Hayes, S. M. Borrell, K. A. Bunker, P. J. Frampton, and G. B. Woolley
Surveyed in 1938-1939

APPROXIMATE MEAN DECLINATION, 1939

Scale $\frac{1}{62500}$

Contour interval 50 feet
Datum is mean sea level

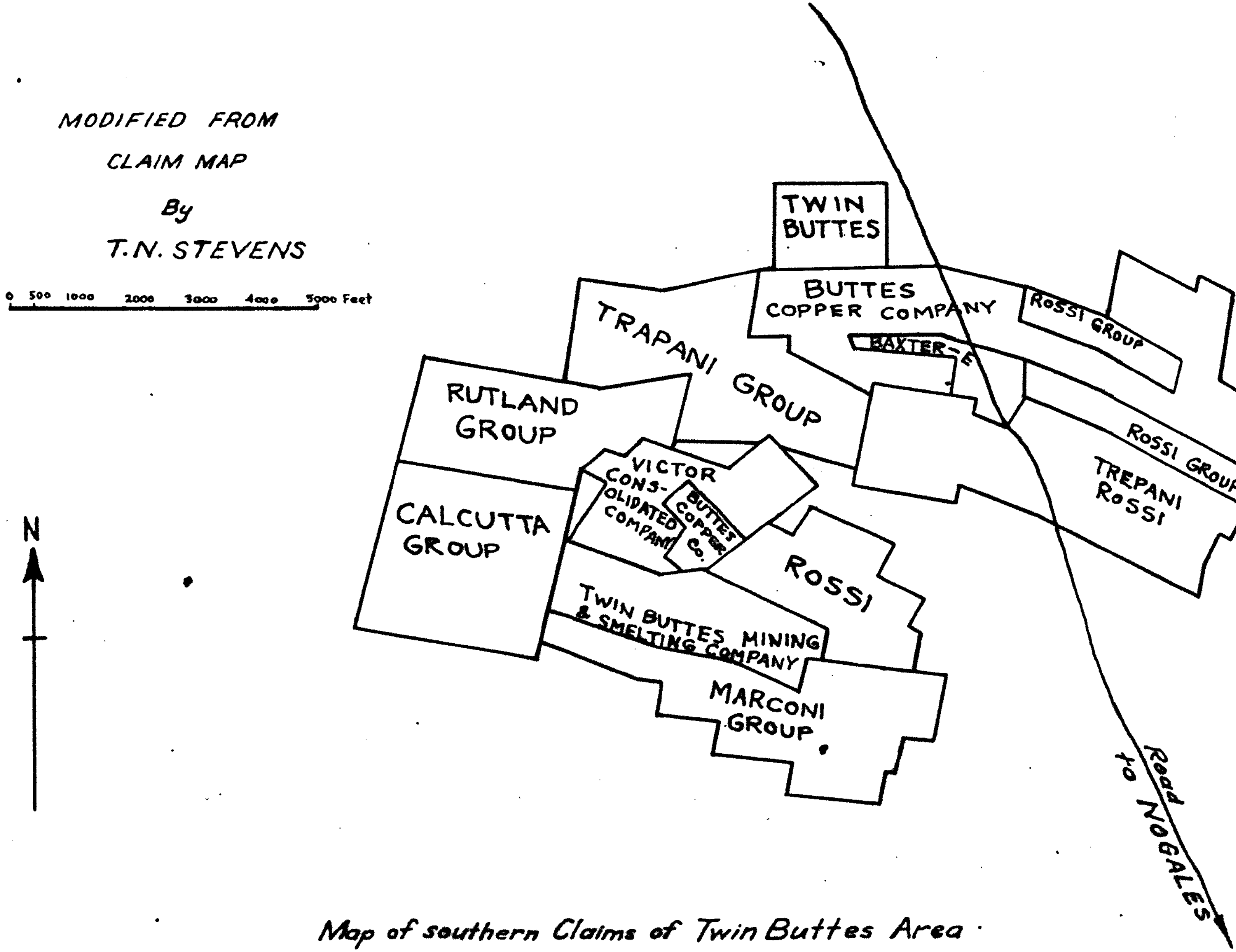
AMADO 2½ MI.
NOGALES 31 MI.

ROUTES USUALLY TRAVELED
HARD IMPERVIOUS SURFACES
OTHER SURFACE IMPROVEMENTS
1940
U. S. ROUTE
STATE ROUTE

Polyconic projection. 1927 North American datum
5000 yard grid based on U. S. zone system, F
10000 foot grid based on Arizona (Central) rectangular coordinate system

TWIN BUTTES, ARIZ.
N3145—W11100/15

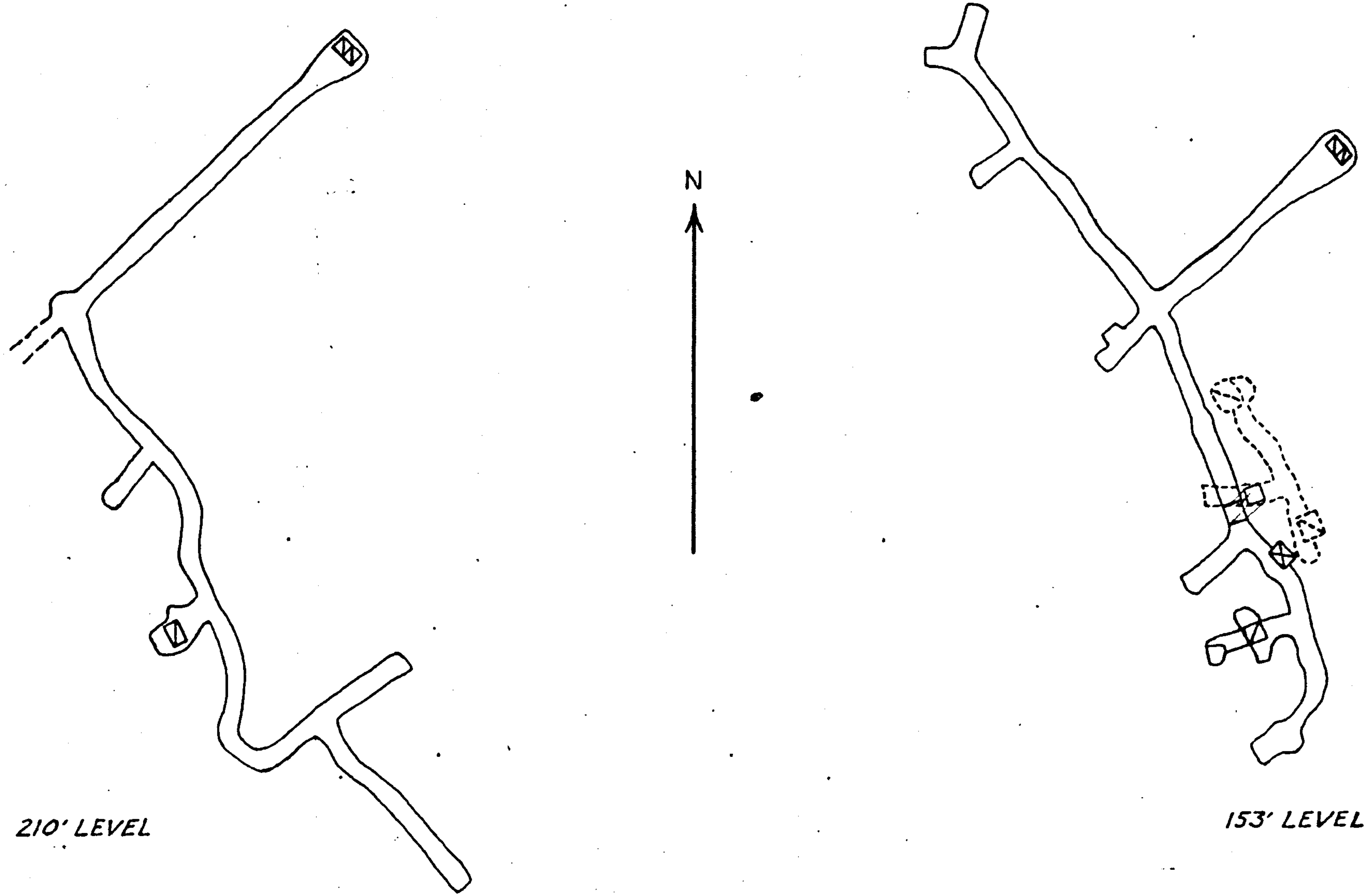
Plate III



Map of southern Claims of Twin Buttes Area

Plate IV

Plate 4



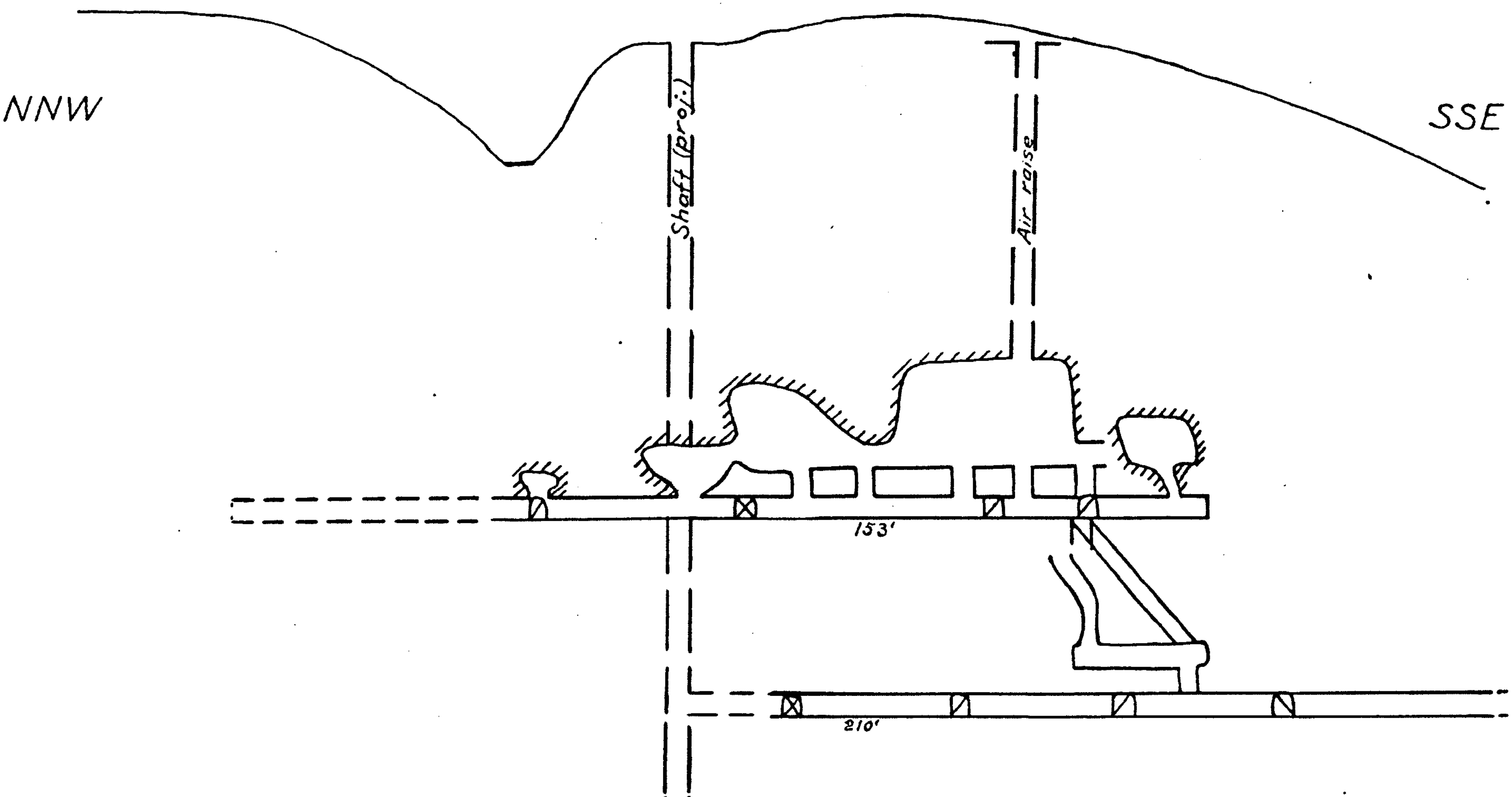
CONTENTION MINE

SCALE 1" = 100 FEET

December 1943

From map by
E.A. Stone and R.M. Hernon

Plate V



SECTION

CONTENTION MINE

SCALE 1" = 50 FEET

March 1946

From section by
E. A. Stone and R. M. Hernon

Plate VI

Plate 6


Official Precinct Map of PIMA COUNTY ARIZONA
AUTHORIZED BY THE BOARD OF SUPERVISORS OF PIMA COUNTY ARIZONA
APRIL 13 1942
R. H. MARTIN CHAIRMAN
TOM COLLINS MEMBER
J. B. MEAD MEMBER
G. MACKENZIE CLERK
MARICOPA
PINAL
COCHISE
SANTA CRUZ
MEXICO
SUPERVISOR DISTRICT NO. 1.
SUPERVISOR DISTRICT NO. 2.
SUPERVISOR DISTRICT NO. 3.
AJO PRECINCT NO. 27
QUIJOTOA PRECINCT NO. 37
INDIAN OASIS PRECINCT NO. 34
SILVERBELL PRECINCT NO. 41
MARANA PRECINCT NO. 35
CORTARO PRECINCT NO. 31
AMPHITHEATER PRECINCT NO. 28
FORT LOWELL NO. 32
TANQUE VERDE REDINGTON PRECINCT NO. 42
TUCSON PRECINCT NO. 1.
TUCSON PRECINCT NO. 3.
TUCSON PRECINCT NO. 22
NO. 21
SAN XAVIER PRECINCT NO. 40
SAHUARITA PRECINCT NO. 39
VAIL HELVETIA PRECINCT NO. 44
PANTANO PRECINCT NO. 36
TWIN-BUTTES PRECINCT NO. 43.
CONTINENTAL PRECINCT NO. 30.
GREATERVILLE PRECINCT NO. 33.
PRECINCT NO. 38. RAIN VALLEY
ARIVACA PRECINCT NO. 29
TUCSON SEE DETAIL
SILVERBELL RD.
CASA GRANDE HWY.
ORACLE RD.
COUNTRY CLUB RD.
INA RD.
GRANT RD.
BROADWAY
IRVINGTON RD.
TUCSON - AJO HWY.
U.S. 80
NOGALES HWY.
WILMOT RD.
SASABE RD.
— DETAIL — CITY OF TUCSON AND VICINITY
PRINCE ROAD
FORT LOWELL ROAD
GRANT ROAD
SPEEDWAY
DRACHMAN
CONGRESS ST.
BROADWAY
IRVINGTON RD. T15S
EMERY PARK
NOGALES-VAIL CONN. RD.
SOUTHERN-PACIFIC RAILROAD
CITY LIMITS
DISTRICT NO. 2.
DISTRICT NO. 1.
LEGEND:
SUPERVISOR DIST. BOUNDARY
PRECINCT BOUNDARY
COUNTY BOUNDARY
RAILROAD
ROAD
CITY OR TOWN
SCALE: 1" = 6 MI.
SUPERVISOR DISTRICT NO. 1.
TUCSON PRECINCT NO. 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 25, 26
AMPHITHEATER 28
CORTARO 31
FORT LOWELL 32
GREATERVILLE 33
MARANA 35
PANTANO 36
RAIN VALLEY 38
SILVERBELL 41
TANQUE VERDE, REDDINGTON 42
VAIL-HELVETIA 44
SUPERVISOR DISTRICT NO. 2.
TUCSON PRECINCT NO. 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14
ARIVACA 29
CONTINENTAL 30
SAHUARITA 39
SAN XAVIER 40
TWIN BUTTES 43
SUPERVISOR DISTRICT NO. 3.
AJO PRECINCT NO. 27
INDIAN OASIS 34
QUIJOTOA 37
DRAWN BY: F. P. COLE JULY 7, 1942.

Plate VII

Plate 7


EXPLANATION
SEDIMENTARY
QUATERNARY Qal alluvium
CRETACEOUS (?) Kqt(?) quartzite limestone shale
PERMIAN Pmb Manzano Beds, marl, limestone shale
PENNSYLVANIAN Cn Naco limestone
MISSISSIPPIAN Ce Escabrosa limestone
DEVONIAN Dm Martin limestone
CAMBRIAN Upper Ca Abrigo limestone
Middle Cb Bolsa quartzite
IGNEOUS
Tg granite
Tqd quartz diorite
Tgd granite dike
Trp rhyolite porphyry
g garnet zone
FAULTS
observed
inferred
N
To San Xavier
Magee Road
Twin Buttes
Glassford Hill
Morgan Fault
Morgan Mine
Morgan Hill
To Continental
GEOLOGIC MAP
THE SOUTHERN PART
OF
THE TWIN BUTTES AREA
PIMA MINING DISTRICT, ARIZONA
Scale = 1/3000
250 0 250 500
Feet
Contour interval 25 feet
Datum is mean sea level
May 1948
Topography & Geology by
F.N. Houser
H.A. Whitcomb
GEOLOGY
HOUSER
CONTENTION MINE
WHITCOMB

Plate 1