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GEOLOGY OF THE CENTRAL DRAGOON MOUNTAINS,

ARIZONA

by

D. John Cederstrom

A Thesis

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in partial fulfillment of

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INTRODUCTION

Purpose of the Investigation

The part of the Dragoon Mountains described in the following paper was selected by the writer with the approval of the faculty of the Department of Geology at the University of Arizona as a suitable subject for a geologic study to be submitted as a thesis in partial fulfillment of the requirements for the degree of Doctor of Philosophy. Field work was carried on during parts of the summers of 1932, 1933, 1934 and 1936.

Acknowledgements

The writer is greatly indebted to the faculty of the Department of Geology of the University of Arizona for encouragement, help, and advice given him during the course of this work. In particular, Dr. B. S. Butler and Dr. M. N. Short visited the area with the writer several times and made helpful observations and suggestions and later checked some of the more important findings. Dr. Eldred Wilson and Mr. J. B. Tenney of the Arizona Bureau of Mines rendered valuable assistance in a like manner. Dr. Short gave helpful criticism and advice on microscopic study of specimens from the area. Dr. Alan Bateman of Yale University had a series of polished sections of ore minerals prepared for the writer and obligingly checked some of the writer's observations and offered further information and advice.

The writer is likewise indebted to residents of Cochise County, Arizona, who willingly gave much material assistance. Mr. Adam Dodd and Mr. E. J. Kelley of Pearce freely gave the use of their properties,

Fig. 3. Outline map of Arizona showing location of Dragoon Mountains.

respectively the Black Diamond and Middlemarch camps, as living quarters. Mr. John Sala of Tombstone provided living quarters for the writer the summer of 1936 and further gave the use of a horse during that season. Without these kindnesses this investigation would have been practically impossible.

Various other individuals have contributed by comment, constructive criticism and in other ways. Acknowledgements are also made to Dr. A. A. Stoyanow, Prof. E. D. McKee, and Dr. F. W. Galbraith of the University of Arizona and to Dr. J. W. Peoples of Wesleyan University, Middletown, Connecticut. Mr. Charles E. Schott of Shafter, Texas, went over a limited portion of the ground with the writer.

Location and History

The Dragoon Mountains are in Cochise County in southeastern Arizona and lie largely within Township 23 N, Range 18 E of the Gila and Salt Rivers Base and Meridian. The Dragoon Mountains extend from the mining towns of Gleeson and Courtland north-northwestward to Dragoon on the Southern Pacific Railroad, a distance of twenty-five miles. Historically famous Tombstone lies thirteen miles to the southwest and Bisbee, the important copper district, is located twenty-eight miles to the south. Pearce, a silver camp in the years 1895 to 1929, is eight miles east of the Dragoons.

Near both ends of the range granitic rock masses form outstanding peaks and rugged terrane. Within the northern mass is located Cochise's Stronghold, a natural fortress wherein during the 1870's the Chiricahua Indian chieftain Cochise and his tribesmen retreated when hard pressed.

It may be noted that the name of the range resulted from the fact that the First Regiment of the New York State Dragoons was sent to this region in the 1860's to capture Cochise and terminate a series of Indian massacres. The Stronghold figured in the encounters which followed.

Southeast of the pinnacled Stronghold country lies a strip of sedimentary rocks nine miles long. This paper deals with the larger, expanded northwestern portion of that strip. It extends from a point a mile southeast of Dragoon Camp to a point one mile northwest of Cochise Peak and is from two to three and one-half miles wide. Middle Pass trail, converted to a road to the head of Sorens Canyon in 1945, connects Tombstone with Pearce and divides the area into two equal halves.

The ghost towns, Middlemarch and Black Diamond, lie within the area. Activity ceased at the former around 1923 and at the latter around 1905. In many other places abandoned shacks and dump heaps testify to the former presence of equally short-lived but less pretentious operations. In the summer of 1936 no prospect was being worked regularly.

The area, therefore is truly productive only as a range land at the present time and four-fifths of the area mapped is used as grazing land by two ranchers.

Climate

Due to a higher elevation the climate of the Dragoon Mountains is somewhat colder than that of nearby Tombstone for which records are available. In summer only a few days are uncomfortably hot and the nights are cool. In the winter a large part of the range may be covered with several inches of snow which, in places, remains for weeks.

The average range in temperature at Tombstone for a period from 1902-1928 inclusive has been listed as follows:[1]

Month....................	Jan.	Feb.	Mar.	Apr.	May	June
Average extreme minimum..	20.8	24.8	28.6	33.8	40.8	50.4
Average extreme maximum..	72.4	75	81.7	87.4	94.3	101.9
Month....................	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average extreme minimum..	58.7	58	51.6	37.9	29.8	22.6
Average extreme maximum..	101	97	95.3	89.4	79	71

It is believed that on account of the higher elevation the region has a slightly greater rainfall than Tombstone. At Tombstone the following record for 1898-1928 inclusive has been listed:[2]

Month....................	Jan.	Feb.	Mar.	Apr.	May	June
Average precipitation....	0.84	0.87	0.79	0.34	0.24	0.46
Month....................	July	Aug.	Sept.	Oct.	Nov.	Dec.
Average precipitation....	3.52	3.41	1.69	0.66	0.78	0.88
Annual precipitation....	14.48					

1. Butler, B. S., Wilson, E. D. and Rasor, C. A., Geology and ore deposits of the Tombstone district, Arizona: Arizona Bur. Mines Bull. 143, p. 9, 1938.
2. Idem.

Vegetation

The lower pediments are characteristically grass lands which gradually merge upward into sparsely forested areas. In addition to various grasses, prickly pear, ocotillo, yucca, cat's claw and mesquite are commonly found. On the higher elevations oak trees and manzanita are most common and here is found the small ball or pin cushion cactus. In the more inacessible regions in the mountains or in places which are distant from water supplies grass may be found two feet in height. On some of the higher slopes are stands of pine trees with trunks several inches in diameter, and the many stumps two feet or greater in diameter attest to a once more impressive forest cover.

Work of Earlier Investigators

In describing the Santa Rita Mountains, 55 miles to the west of the Dragoons, Schrader[1] states that "the mountains are largely due to faulting". In one of the sections[2] taken across the Helvetia district in the northwestern part of the Santa Rita Mountains low-angle thrusts are featured. Although Schrader states that "the main structural feature is a thrust fault dipping to the west"[3] the section accompanying the text clearly indicates that the over-thrust plane is strongly folded.

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1. Schrader, F. C., Mineral deposits of the Santa Rita and Patagonia mountains, Arizona: U. S. Geol. Survey Bull. 582, p. 38, 1915.
2. Idem, Pl. III.
3. Idem, p. 93.

The same section crosses the Empire Mountains to the east and shows upper Paleozoic limestones thrust westward on Cretaceous sediments.

Roy A. Wilson[1] has made a detailed study of the sixteen square miles in the Empire Mountains and given a concise statement of the structural history. He includes in his report the thrust mapped by Schrader, brings out its detail and maps a new large thrust whose plane is shown to dip gently to the west. The overthrusting was followed by a period of high angle faulting. Wilson states that "the overthrusting followed the granite intrusions."

Later work[2] in the Empire Mountains indicates that most of the overthrusting preceded the igneous intrusions although part of the overthrusting took place in late Tertiary time.

The Bisbee area, 28 miles south of the Dragoon Mountains, has been described by Ransome.[3] The structural history, outlined by Tenney[4], is as follows:

1. Post Permian pre-Comanchean normal faulting (Dividend fault).
2. Compressive stresses of the Laramide Revolution resulted in doming of the sediments around a resistant core of pre-Cambrian granite. South of the Dividend Fault the massive

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1. Wilson, Roy A., Thrust faulting in the Empire Mountains of southeastern Arizona: Jour. Geology, vol. 88, p. 422, 1934.
2. Galbraith, F. W., Empire Mountains, southeastern Arizona (abstract): Geol. Soc. Am., Proc., 1940, Vol. 51, p. 1927.
3. Ransome, F. W., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 132, 1904.
4. Tenney, J. B., Ore deposits of the southwest: Guidebook 14, XVI Int. Geol. Congress, pp. 48-51, 1932.

Paleozoic beds resisted doming and folding but developed large block faults (Copper Queen Block).

(b) Low angle overthrust faulting (Queen Hill Block).

(c) Intense shattering by normal faults.

The Courtland-Gleeson area, 12 miles to the southeast of the area considered in this paper and at the end of the Dragoon Range, has been described by Eldred Wilson[1]. Here thrust faulting of possible late Tertiary age was preceded by a post-Cretaceous period of normal faulting. At Courtland the overthrust plane is approximately flat whereas at Gleeson it dips 20° to the southwest.

It is interesting to note that in the Courtland-Gleeson area as in the Empire Mountains, the thrusting is judged to be much later than at Bisbee. Here "supposedly Tertiary" rhyolite[2] has been involved. Physiographic evidence also indicates that the thrusting may be late.

The recent detailed study of the geology of the nearby Tombstone area made by Butler and Wilson has been helpful in the interpretation of various geological features in the Dragoons and many references to that work are made in this thesis.

The structural events which took place in the Tombstone area are summarized[3] in part as follows:

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1. Wilson, Eldred D., Geology and ore deposits of the Courtland-Gleeson region, Arizona: Arizona Bur. Mines Bull. 123, Geol. Series 5, 1927.
2. Wilson, Eldred D., op. cit., p. 28.
3. Butler, B. S., Wilson, E. D., Rasor, C. A., Geology and ore deposits of the Tombstone district: Arizona Bur. Mines Bull. 143, pp. 29-30, 1938.

1. Probable mild Mesozoic vulcanism.
2. Laramide folding along a southeast-northwest axis, accompanied by faulting.
3. Dike fissures develop trending N 16°E.
4. Strong faulting in approximately an east-west direction.
5. Fissuring along a southwest-northeast axis. These fissures localized the ore solutions.
6. Normal faulting of post valley-fill age.
7. Intrusion of basaltic dikes.

Darton[1] has written briefly on the Dragoon Mountains. His cross-sections B and C correspond most closely with sections C-C' and H-H' in this paper. Darton recognized the structure here designated as the Sala anticline and the general southwest dip of the sediments making up both walls of Middlemarch Canyon. In section C the easterly dipping Paleozoics lying upon "Pinal schist" are shown to make up the high ridge in the southerly part of the area covered by this paper. Their relation to the folded Mesozoic sediments on the east is not clearly brought out. Porphyry dikes are shown, as is the general relationship of the Stronghold granite to the sedimentary rocks. No suggestion of overthrust faulting is indicated. The map and sections are generalized.

GEOMORPHOLOGY

Structural Summary

Following pre-Cambrian events, of which but an inkling may be

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1. Darton, N. H., A resumé of Arizona geology: Arizona Bur. Mines Bull. 119, pp. 292-294, 1925.

gained in this area, the deposition of Paleozoic and Mesozoic sediments took place. Towards the end of the Mesozoic era folding and faulting and igneous intrusion took place on a grand scale. The mountains thus formed have since suffered much erosion. In Recent times the debris-filled valleys were trenched, probably due to over-grazing.

Larger Physiographic Forms

The portion of the Dragoon Mountains discussed in this paper consists of a belt of sedimentary rocks trending northwest-southeast which is dominated by a granite mass at its northerly end (Fig. 1).

The belt of sedimentary rocks forms a single high ridge. The easterly slope of this ridge is steep due to more rapid erosion resulting from shales at the foot of the mountain, whereas the westerly slope, made up largely of massive limestones, is more gentle. In the central portion of the area the simplicity of the range is lacking. Due to the northward pitch of an anticline whose west limb forms the single ridge to the south, massive limestones forming the crest of the fold descend to lower elevations and form prominent spurs extending westward. The shaly rocks on the east side of the range are overlain by quartzite beds forming Black Diamond Peak.

In the northerly part of the area the expanded belt of sediments making up the high land splits into three prongs pointing toward the Cochise Stronghold granite mass. The sediments here are more or less metamorphosed and very resistant. The widest prong of sediments forms a continuation of the higher ridges to the south (interrupted by Santa

Anna gulch) and extends to the northwestern limit of the map area. The west wall of Middlemarch Canyon is made up in greater part of massive limestone that forms the east limb of a syncline embracing Middlemarch and Sorens Canyons.

The longitudinal valleys are cut mainly in granitic rock and appear to have been controlled by extensive fissuring and faulting along the igneous-sedimentary boundaries. Where the granitic masses are free from closely spaced joints and fissures, they form outstanding blocks such as Cochise Peak, Sheepshead, and many unnamed lesser monoliths in the Stronghold to the north.

Short transverse canyons are almost lacking on the eastern side of the range due to the prevalence there of uniformly non-resistant shaly beds. On the western side of the range Santa Anna gulch makes a deep canyon which heads into Middle Pass. This canyon is characterized by a steep wall on the south and a gradual slope on the north except at its very head. It is suggested that Santa Anna gulch received the drainage from Sorens Canyon in an early stage of erosional history. During its downcutting it slipped progressively southward down the pitch of the folds. However, headward erosion of a tributary to the Middlemarch Canyon made rapid progress through fissured or jointed granite and shales lying between the Sentinel and the Middlemarch Camp and captured the Sorens Canyon stream. Thus Middle Pass remains high and dry as a wind gap, relict of a major drainage line.

It does not seem likely that the Sorens Canyon - Santa Anna gulch system was consequent upon the original structure. Since the folded rocks trend northwest-southeast it is more probable that Sorens Canyon drainage extended southward consequent upon the folds and through the saddle now remaining as a wind gap above Black Diamond Mine. At this latter point the presence of porphyry dikes and of a once more extensive quartzitic mass retarded the normal downcutting and shortening of the drainage by piracy from the east. In the meantime a stream from the west worked headward, pirated the main drainage line and thus reinforced, rapidly trenched itself. Evidence of this stage of drainage is seen in a deep steep-walled transverse canyon which extends southwestward from Black Diamond Peak, the location of which does not appear to be determined by any major structural feature. The gradient of the original major stream is believed to have been steep enough to make impossible any capture of the down stream portion of the drainage line. Drainage through the Silver Cloud gulch did not persist long. Had it been maintained longer, the pass west of Black Diamond Peak would be appreciably lower than the pass south of the peak which marks the original drainage consequent upon the structure. At present both passes or wind gaps are approximately the same elevation, about 6,100 feet.

The Santa Anna stream had been working headward simultaneously with the Silver Cloud stream and the former soon added the Sorens Canyon stream to its length, held it for a somewhat longer period than did its predecessor, during which interval Middle Pass was cut to 5,900 feet. Finally the Sorens Canyon system was taken by a tributary of the Middlemarch Canyon drainage system which was downcutting rapidly in shales and granite. The suggestion is made also that at the northern end of the area mapped the Stronghold Canyon drainage system made inroads on both the Sorens Canyon and Middlemarch Canyon systems.

The notches across the long spurs extending westward from Aerie and China peaks and the peak west of Black Diamond are considered to mark the locus of older streams, consequent upon folded structure, which now have been lost in the development of short deep canyon-forming streams running in a westerly direction. One minor consequent stream still remains near the head of Santa Anna gulch and heads south of Aerie Peak. Transverse streams have not yet progressed sufficiently to breach the protecting west wall near its head. Even the one consequent stream is but a remnant of a once longer system which extended northward at least across the west face of China Peak and southward to the Silver Cloud gulch.

Minor Features

The most conspicuous of the minor topographic features are the porphyry dikes. Although some of the dikes have no topographic expression, many stand out as ridges as much as a mile in length and from a few feet to tens of feet in height. A very prominent dike crosses Santa Anna gulch and on the down slope side shows about thirty feet of vertical face. Others are conspicuous on the floor and on either wall of Middlemarch Canyon. On the slopes and pediment below the Black Diamond camp the dikes attain their greatest prominence for here the featureless topography developed in the shales is relieved by elongate ridges whose backbone is a porphyry dike. Many other dikes have somewhat less topographic expression.

The resistance of large unbroken granitic units has been mentioned. A study of the structure in the igneous rock shows the controlling factor in physiographic development to be the well-defined joint system that breaks the continuity of the great mass. It is along these jointed areas that the streams have carved deep canyons and gorges.

The granitic units are rudely circular or ellipitical masses and elongate masses with steep sides. The circular or ellipitical masses appear to have two joint sets, approximately at right angles to one another. Where the joints are closely spaced pinnacles may form. Where the joints are widely spaced rounded domes of variable size, dependent on the spacing of the joints, form the crest of the hill. If one set is closely spaced and the other less so, a series of sharp knife edges or rounded parallel ridges appear.

Where one set of joints is well developed and a cross set is poorly developed or absent, ridges develop parallel to the dominant set. These ridges may have a sheer wall which represents erosion to a joint and may have a rounded top. An excellent example is the ridge forming the western edge of the basin south of Gordon's Claims.

The surface of the granite is almost everywhere rounded. Spires are rare. Several instances were noted where small granite ridges, ten to twenty feet wide present rounded wind-eroded surfaces facing the prevailing wind, the southwest, and vertical faces to the lee.

SEDIMENTARY ROCKS

The consolidated sedimentary rocks making up the Dragoon Mountains range in age from Cambrian through Mesozoic. They overlie pre-Cambrian granite and are overlapped by unconsolidated late Tertiary or Pleistocene gravels.

To relate the rocks in the Dragoon Mountains to those in adjacent areas a brief discussion of Paleozoic paleogeography will be helpful.

"In dealing with the paleogeography and lithology of the Paleozoic deposits of Arizona, it is well to keep in mind the presence of a land mass in the central part of the state, which, possibly with maximal submergence during the Mississippian, acted as a barrier all through the Paleozoic."[1] This land mass, named "Mazatzal Land" by Stoyanow, is made up of Archeozoic schists, granite, and unaltered sedimentary beds which are older than the pre-Cambrian Apache group. Mazatzal Land is believed to have extended from southwestern Arizona to central Arizona and in that area the presence of Paleozoic deposits has not been established.

Although recent work[2] appears to show that Mazatazal Land was not always completely effective as a barrier, the concept of a southeastern depositional basin, more or less separated from a northern Arizona basin by a line of shoals and islands throughout most of Paleozoic time, remains. The concept is, in fact, emphasized by a geologic cross section in the work referred to. Hence the discussion of rocks found in the Dragoon Mountains may be limited to comparisons with rocks found in the southeastern part of the state.

Pre-Cambrian

The Apache group of rocks of pre-Cambrian age in central Arizona

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. Amer., Vol. 47, p. 461, 1936.
2. Huddle, J. W., and Dobrovolney, E., Late Paleozoic stratigraphy and oil and gas possibilities of central and northeastern Arizona: U. S. Geol. Survey Oil and Gas Investigations; Preliminary chart no. 10, 1945.

were so named by Ransome[1] in 1916. At that time the group was known to be present as far south as the Santa Catalina Mountains near Tucson. Ransome[2] had assigned all these to the Cambrian, or even younger strata. Darton[3] in 1925 definitely correlated the Apache group with the pre-Cambrian Grand Canyon series but also noted that the Troy member was deposited unconformably upon and overlapped the older members of the group and "becomes the basal formation of the sedimentary series, corresponding to the Bolsa quartzite......not far southeast......" which he[4] considered to be Cambrian in age. In this inconsistency Darton seems to have approached but did not quite arrive at a valid concept of the true age relationship of these rocks. In 1936 the uppermost member of Ransome's Apache group, the Troy quartzite, was separated from that group and assigned to the Cambrian on paleontologic evidence by Stoyanow[5]. Members of the Apache group of rocks have been found as far south as the Little Dragoon Mountains, 12 miles north of the area covered by this report[6]. The distinctive lithology of the Apache group and the excellent exposures where pre-Cambrian granite is overlain by Cambrian Bolsa quartzite in the area covered by this present report indicate that the Apache group is entirely absent in the central part of the Dragoon Mountains.

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1. Ransome, F. L., Some Paleozoic sections in Arizona and their correlation: U. S. Geol. Survey Prof. Paper 98-K, pp. 136-141, 1916.
2. Idem, p. 166.
3. Darton, N. H., A resumé of Arizona geology: Arizona Bur. Mines Bull. 119, p. 36, 1925.
4. Idem, p. 45.
5. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. Amer., Vol. 47, p. 474, 1936.
6. Cook, Frederick Stearns, The geology of the Seven Dash area, Cochise County, Arizona: Master's Thesis, Univ. of Arizona, 1938.
7 Enlows, Harold Eugene, Geology and ore deposits of the Little Dragoon Mountains: Doctor's Thesis, Univ. of Arizona, 1939.

Cambrian

In northwestern Arizona[1] deposition began in Lower Cambrian time and ceased in middle Cambrian time but in southeastern Arizona[2] the invasion of Cambrian waters began in Late Middle Cambrian time. In the southeastern part of the state the seas successively younger than Late Middle Cambrian were progressively more limited in areal extent. The influence of Mazatzal Land is seen in the kind of rocks; in the Tucson-Globe area the Cambrian strata are predominantly clastic whereas in the Bisbee-Tucson area the rocks consist of basal clastics and succeeding limestone.[3]

The basal Cambrian Bolsa quartzite of the Bisbee region might well have been known as the Dragoon quartzite. Dumble[4] had applied the name to pre-Devonian strata which he saw well exposed in the vicinity of South Pass near the southern end of the Dragoon Mountains only a few miles south of the area covered by this report. He gave no indication of their probable age, however. Ransome[5] did not feel certain that the Dragoon quartzite of Dumble was a correlative of the Cambrian quartzites of Bisbee and therefore introduced the term "Bolsa quartzite", which is now in general use.

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1. McKee, Edwin D., and Resser, Charles E. E., Cambrian history of the Grand Canyon Region: Carnegie Institution of Washington Pub. 563, pp. 12, 30, 1946.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, pp. 1261-1262, Figs. a-f, Pl. V, 1942.
3. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 465, 1936.
4. Dumble, E. T., Notes on the geology of southeastern Arizona: Trans. Am. Inst. Min. Eng., Vol. 31, p. 711, 1902.
5. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, p. 132, 1904.

Bolsa quartzite

In the extreme southerly part of the area mapped (Fig. 1) the Bolsa quartzite of late Middle Cambrian age lies unconformably upon pre-Cambrian granite and is about 325 feet thick. Elsewhere in the area faulting, erosion or igneous intrusion have acted upon the Bolsa quartzite and the full thickness is not present. It forms a prominent hill at the foot of the mountain on the west side of the range to the south and is present as broken but fairly continuous masses on the slope southwest of Salas Peak and on the small hill southwest of the Gordons claims. At the latter two localities it is intruded by granite.

The Bolsa quartzite attains its greatest areal development as almost horizontal overthrust masses. It caps the Sentinel and Black Diamond Peak, and a smaller but conspicuous mass is present on the slope southeast of Black Diamond Peak. Several much smaller patches are mapped at intermediate points. The Abrigo limestone overlies a quartzite thrust mass on Grants Hill and a patch of Abrigo limestone is present above the quartzite making up the Sentinel. These occurrences of Abrigo limestone identify the Bolsa as such. The quartzite is underlain by younger intrusive granite, Mesozoic shale or Paleozoic limestone indicating an overthrust relationship.

Along Escabrosa Ridge, in Bisbee, the lowest member of the Bolsa quartzite[1] is a bed of conglomerate from six inches to a foot in thickness, the pebbles of which are rarely over three inches in diameter. This

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1. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 28-30, 1904.

conglomerate is overlain by coarse-grained sandstone beds from ten to twenty feet thick. The coarse sandstones pass upward into thinner bedded, vitreous, fine-grained quartzites. The description is applicable also the Bolsa quartzite in the Dragoon Mountains. The basal conglomerate is well developed in the quartzite forming Black Diamond Peak and in the isolated masses between that and the Sentinel. In these places the conglomerate is about two feet thick, but pebbles contained in it are not greater than 1½ inches in diameter. Layers of smaller pebble conglomerate are present in the middle part of the section. These layers are brownish when fresh and weather to a dirty gray. Two layers are known, each about three feet thick.

The quartzite is more blocky than slabby and, although white when fresh, is yellow to pink on weathered surfaces.

The Bolsa quartzite, widely distributed in the Bisbee-Tucson area, has been correlated with the Troy quartzite[1] of the Santa Catalina Mountains. Formerly considered part of the Apache group, the Troy quartzite has been separated from that group because the Troy carried Cambrian fossils and also because it underlies younger Cambrian strata conformably and overlaps the members of the older Apache group.

The overlapping relationship of the Troy quartzite to the Bolsa quartzite in southeastern Arizona has been mentioned by Stoyanow[2]. Cook[3] describes the occurrence in the Little Dragoons as follows:

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 474, 1936.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, p. 1262, 1942.
3. Cook, Frederick Stearns, The geology of the Seven Dash Ranch area, Cochise County, Arizona: Master's Thesis, Univ. of Arizona, p. 9, 1938.

"Resting with angular unconformity on the slightly eroded surface of the Dripping Spring quartzite (of the Apache group) is a quartzite formation composed of two members, both Middle Cambrian in age. At the base of the two members is a conglomerate consisting of pink, flat, angular slabs of Dripping Spring quartzite in a matrix of purple quartsite......and is undoubtedly the Troy quartzite as defined by Ransome."

In the Seven Dash Ranch area the lower reddish Troy has a maximum thickness of 30 feet and thins to the southeast and disappears. The overlying member, which is white with a purplish cast, strongly resembles the Bolsa quartzite of the Bisbee quadrangle.

"The sediments of the two quartzite formations were deposited at approximately the same time. However, no interbedding of the two formations occurred in this area......the red quartzite......is overlapped by the white quartzite......The difference in color and lithology indicates that the sediments were derived from different sources, the red (Troy quartzite) from the north and west, the white (Bolsa quartzite) from the south......

This then appears to be the meeting and overlap of the basal members of the Cambrian......"

All of the basal Cambrian quartzite in the Dragoons is considered referable to the Bolsa. There is no suggestion within the area mapped that the Troy might be present nor would it be expected on the basis of Cook's findings in the area to the north. Only the Bolsa has been recognized in Tombstone and Bisbee[1].

Pima sandstone

In the Whetstone Mountains, 25 miles west of the Dragoons, the Bolsa quartzite is overlain by the Pima sandstone,[2] " a buff hard sandstone with inclusions of Bolsa quartzite in places. It contains

1. Butler, B. S., Wilson, E. D., Rasor, C. A., Geology and ore deposits of the Tombstone district: Arizona Bur. Mines Bull. 143, pp. 29-30, 1938.
Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 28-30, 1904.
2. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 466, 1936.

Micromitra (Iphidella) pannulla (White)." Although only four feet thick, this sandstone has been traced more than 60 miles to the northeast but is probably absent east of the Whetstones. The Pima sandstone is absent in the Dragoon Mountains, in Tombstone, and in the Little Dragoon Mountains.

Cochise formation

The Cochise formation[1] overlies the Pima sandstone in the Whetstone Mountains. There

> "it consists of three distinct members: 1. at the base are pink and reddish, thin-bedded sandstones, 30 feet thick, 2. Then follow 116 feet of yellow, pink, gray, white, purple, buff, and red shales, which in the upper horizons alternate with calcareous shale and then rubbly limestone...... 3. the upper division is characterized by blue limestone. At the base, the limestone, rather grayish, brownish, and mottled, alternates with shale. Higher in the section, the blue limestone predominates and is quite conspicuous."

In the upper division the lower beds are fragmental in places and layers with flat-pebble conglomerate are common. This division is further easily recognizable in that the blue limestone is more resistant to weathering than the beds of the other divisions. Included sandy strata contain Olenoides pugio (Walcott). Above are beds of oolitic and pisolotic blue limestone carrying "small spherical bodies resembling algae" and in the uppermost part of the formation are thin-bedded, gray arenaceous limestones alternating with thin-bedded pink and gray limestone.

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 466, 1936.

The Cochise formation is correlated with the Santa Catalina formation of the Tucson-Globe area.[1] This formation has been found to extend as far south as the Little Dragoons.[2] In the Seven Dash Ranch area[3], where it is approximately 100 feet thick, it is characterized by six feet of pink and red fine-grained sandstone at the base, followed by fifteen feet of dominantly pink sandstone with lenses of pebbly conglomeratic material. This is overlain by four feet of hard, fine-grained, purple quartzite and the remainder of the section is made up of highly colored sandy rocks. In the Little Dragoon area, the Santa Catalina formation is overlapped by its correlative, the Cochise formation.

In the most southerly portion of the Dragoons about fifty feet of poorly exposed yellow and red sandy shales are present at the base of the Abrigo. Fragments of what were probably brachiopods have been found in them. The shale is not exposed elsewhere. Southwest of Sala Peak the overlying Abrigo limestone is folded but the Bolsa quartzite beneath is faulted against it and at one place where a good exposure of the contact between the two formations was found, the shales are not present.

It seems likely that these shales belong to the Cochise formation in view of their similarity to known occurrences and their stratigraphic position. Dr. Stoyanow has examined samples of these rocks submitted to him and stated[4] that these are entirely similar lithologically to rocks of the Cochise formation known elsewhere in southeastern Arizona.

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 466, 1936.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, p. 1262, 1942.
3. Cook, Frederick Stearns, The geology of the Seven Dash Ranch area, Cochise County, Arizona: Master's Thesis, Univ. of Arizona, 1938.
4. Oral communication.

Abrigo formation

The Abrigo formation is well developed on the southwestern side of the range and fine outcrops are seen in several places. A broad, unbroken exposure extends from the southernmost portion of the area to the Silver Cloud Claims. It is well developed again on the slope west of Sala Peak. The hill south of the Gordons Claims is largely made up of Abrigo limestone. At these places it is underlain by the Bolsa quartzite or Cochise sandstone and overlain by the Martin limestone.

The Abrigo limestone is present in thrust blocks in several places. On Grants Hill and on the Sentinel the Abrigo limestone overlies the Bolsa quartzite. On the spur north of Cochise Peak two isolated outcrops of Abrigo limestone are underlain by younger intrusive granite. Typical Abrigo cherty limestones, well exposed in Sorens Canyon opposite Cochise Peak, are structurally related to the rocks capping Grants Hill (Section A-A', Fig. 2).

In the Dragoon Mountains, as at Bisbee, the typical Abrigo formation consists of a series of slabby, thin-bedded limestones separated by still thinner layers of chert, many of which are only a fraction of an inch thick. The limestone weathers to a gray color. In places several feet of blocky chert-free limestone is intercalated between the typical Abrigo cherty limestones. The blocky beds have a layered appearance in some places but in others they are mottled.

The measured total thickness of the Abrigo formation in the southern part of the area is 400 feet. The exposure below Sala Peak is about 275 feet thick.

Copper Queen and Rincon limestones

Local facies of Cambrian strata younger than the Abrigo[1] are found in several localities. In Bisbee 81 feet of Copper Queen limestone is recognized. A six-foot, hard, gray, cliff-forming limestone which occurs at the base contains Billingsella coloradoensis (Shumard) as well as many trilobites. The upper beds are softer grayish limestone.

In the Whetstone Mountains, the Rincon Mountains, and in the Picacho de Calera Hills, the Rincon limestone[2] rests upon the Abrigo. It is a "pink mostly crystalline limestone that is in places oolitic and often contains accumulations of green matter, glauconite or epidote." Billingsella coloradoënsis (Shumard) is found in the upper part of the formation but a distinct triolbite faunule distinguishes these strata from the Copper Queen limestone, and from the underlying uppermost Abrigo with which it is coextensive.

The Copper Queen limestone is not as widely distributed as the Rincon limestone and appears to represent a deposit of the retreating Cambrian sea. It is restricted to southeasternmost Arizona.

Nothing comparable to the Copper Queen limestone of Bisbee, the lowest member of which is cliff-forming and a good key horizon, is present and it is believed to be absent although 8 feet of pink and white cross-bedded sandstone lying between known Abrigo and Martin limestone are suggestive of the parting quartzite member of the Copper Queen limestone in this area. The distinctive lithology of the Rincon

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, pp. 469-472, 1936.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, pp. 1262-1263, 1942.

limestone, pink mostly crystalline and in places oolitic, is such that it may be safely said to be absent.

Ordovician

Ordovician strata were mentioned in 1875[1] from the Dos Cabezas Mountains 50 miles northeast of the Dragoons. However, to date Ordovician strata have not been proven to extend west of that area.[2] The Ordovician limestones of the Dos Cabezas Mountains are correlated with the Longfellow limestones of the Clifton - Morenci district because Raphistoma trochiscus White is common to both areas.

The Ordovician strata found in the nearby Dos Cabezas Mountains are described by Darton[3] as follows:

> "The limestone under the Martin has all the characteristics of the Abrigo beds at Bisbee but Ordovician fossils were found in the upper beds. Most of the limestone of the formation has slabby bedding, weathers to a light blue-gray color and has brown reticulating stems of supposed seaweed on many of the bedding planes."

Nothing at all similar lithologically to the formation described above is present immediately beneath the Martin in the Dragoon Mountains as is evident from inspection of the section given below.

Devonian

South of Mazatzal Land the Devonian limestone strata are found only in the southeastern part of the Paleozoic trough.[4] Northward toward the

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1. Gilbert, C. G., Report on the geology of portions of New Mexico and Arizona: U. S. Geog. Survey, W. 100th Meridian (Wheeler), Vol. 3, pp. 511-513, 1875.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, p. 1265, 1942.
3. Darton, N. H., A resumé of Arizona geology: Arizona Bur. Mines Bull. 119, p. 296, 1925.
4. Stoyanow, A. A., Correlation of Arizona Paleozoic formations. Bull. Geol. Soc. America, Vol. 47, p. 485, 1936.

ancient shore-line of Mazatzal Land arenaceous limestones and sandstone take their place.

Martin limestone

The Martin limestone is well developed in the southern part of the area (Fig. 1) and has been traced about two and one half miles northwestward. It is well exposed in both limbs of the Silver Cloud anticline, but disappears beneath Mississippian strata with the plunge of the fold to the northwest. More limited exposures are present southwest and west of Sala Peak and south of the San Juan claims.

The Martin has been described by Ransome as consisting of dark gray, hard, compact limestones in moderately massive beds with some slabby and shaly members, particularly in the lower part.[1] Associated with the dark limestones are few beds of lighter hue and in some places calcareous shales of pinkish tint. Ransome assigns a thickness of 300 to 350 feet to the Martin limestone.

Between the thin-bedded cherts of the Abrigo formation below and the massive blue Escabrosa limestone above, the following section is found in the southerly part of the Dragoons:

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1. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 33-35, 1904.

Section of Martin limestone in the Dragoon Mountains

Mississippian. Escabrosa limestone.

Devonian. Martin limestone.

	Feet
Pink and buff limestone. Atrypa reticularis common...........................	40
Gray-green, pink, bright yellow, yellow-brown limestone carrying reef of Cladopora prolifica, Acervularia davidsoni, Pachyphyllum woodmani..................	40
Sandstone................................	2
Brown limestone, upper part dusty yellow.	25
Limestone containing sandy lenses.......	8
Brown and bluish limestone..............	12
Pinkish and brown limestone containing some sandy lenses.......................	6
Sandy limestone.........................	18
Shale...................................	6
Pink sandstone..........................	4
Brown limestone with subordinate shale..	35
White quartzite.........................	3
Black limestone containing layers of fine pebbles................................	25
Brown limestone.........................	10
Pink cross-bedded quartzite.............	3
Brownish limestone grading up through gray to rich brown at top...............	108
	355

Upper Cambrian. Copper Queen (?) formation

Pink and white cross-bedded quartzitic sandstone..........................	8

It is pointed out that the upper part of the section contains several of the characteristic fossils present in the Martin limestone of Bisbee.[1]

An outstanding feature of the Martin limestone as found in a number of outcrops in southern Arizona is the presence within it of a silicified reef of colonial corals which in some places is as much as ten feet thick.[2] This reef occurs near the top of the Martin limestone section as shown above. Even in those places where metamorphism and recrystallization of the Devonian rocks has been intense, some vestiges of Cladopora generally remain and permit positive identification of the strata.

The Martin limestone above the typical Abrigo formation developed southwest of Sala Peak is less than 275 feet thick and consists of a series of gray, moderately thick-bedded limestone which weather grayish-brown. Poorly preserved specimens of Cladopora have been found in the lower part of the section. A striking series of siliceous beds is developed here. They are well exposed and form bold cliffs whose light color contrasts sharply with the drab background. The lowest siliceous layer is 75 feet above the base of the section and is four feet thick. Five layers in all are present, the thickest of which is 20 feet. The fourth layer forms a prominent shoulder immediately northwest of Sala Peak. At its base profuse impressions of Cladopora are found. It thus appears that these layers are silicified limestone. Why certain beds were almost completely silicified and adjacent beds entirely unaffected is not known.

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 486, 1936.
2. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 33-35, 1904.

The low spur south-southwest of Sala Peak shows a more limited development of Martin limestone in which a broad, siliceous band is intercalated.

Since no fossils were found in the lower 300 feet of the Martin section as given, only the upper portion may be safely assigned to the Martin limestone. This lower part of the section appears to contain more quartzite sandstones and highly colored limestones than have been mentioned in descriptions of the Martin in nearby areas. It is possible that these lower unfossiliferous beds may belong to the Picacho de Calera formation[1], found in the Picacho de Calera Hills northwest of Tucson and traced 75 miles eastward to the Rincon and Whetstone Mountains. However, that formation is very fossiliferous and, in particular the upper two feet of the formation is a "brown calcareous sandstone replete with fish teeth." Nothing suggestive of these distinctive strata was found in the Dragoons and they are presumed to be absent.

The presence in the Martin limestone of more sandy material in the Dragoons than at Bisbee is considered due to the fact that this area was somewhat closer to the Devonian shore-line.

Mississippian

Escabrosa limestone

The Escabrosa limestone of Lower Mississippian age overlies the Devonian with [illegible] conformity in southeastern Arizona. The gray cliff-forming limestones in the southwestern part of the area and most of the

1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 488, 1936.

massive beds making up the high southeast wall of Santa Anna Gulch belong to this formation. In the area south of Sala Peak it likewise overlies the Devonian in normal sequence. At this locality a reef-like mass of poorly preserved <u>Syringopora</u> was found. Massive beds stratigraphically below the Permian (?) limestones that make up the northeast wall of Middlemarch Canyon are also believed to be Mississippian in age.

Recrystallization of the limestone strata has taken place in many parts of the area, particularly near granite intrusions. Tremolite has been produced locally. Where recrystallization has taken place the Escabrosa is distinguished from the overlying limestones with difficulty. It is entirely possible that some of the limestone mapped as Permian (?) in Middlemarch Canyon, at the head of Stronghold Canyon and in the extreme northern part of the area is really Escabrosa.

The Escabrosa limestone in the area mapped is similar in all respects to the typical Escabrosa of Bisbee, described[1] as consisting of "rather thick-bedded, nearly white to dark gray, granular limestones" which in places are largely made up of fragments of crinoid stems. Its cliff-forming character is conspicuous and, in the Dragoons, its position in the section and its massive aspect are sufficient to identify it in most places. In the southern part of the area the cliff-forming limestones are about 300 feet thick.

<u>Paradise formation</u>

In the Chiricahua Mountains, immediately to the east of the Dragoons,

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1. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 42-44, 1904.

Upper Mississippian limestones, the Paradise formation, have been found.[1] The basal member is somewhat similar to the Escabrosa limestone but the upper members are "markedly different, both lithologically and paleontologically from anything so far described from the Carboniferous of Arizona. These beds consist of black and gray, moderately thick- and thin-bedded crystalline limestone, olive green and yellow when weathered, alternating with sandstone, shale, oolite, cross-bedded calcareous sandstone, and arenaceous limestone. The preponderant color is distinctly yellow......so much so that when looked upon at a distance it appears as a yellow band between the dark beds of the underlying Escabrosa and higher Naco."

A characteristic fauna is found. It includes "Archimedes, invariably accompanied by a diminutive brachiopod fauna, which recurs four times. Two beds of limestone, several feet in thickness, are practically made up of the bryoza and fully deserve the name 'Archimides limestones'. In each case, associated fossils are diminutive brachiopods and trilobites."

This formation has not been recognized in the Dragoons. Such a distinctive formation could scarcely pass unnoticed; hence it is considered absent.

Permian (?)

"Naco" Limestone

The Naco limestone rests upon the Escabrosa limestone with marked

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1. Stoyanow, A. A., Notes on recent stratigraphic work in Arizona: Am. Jour. Science, Vol. 12, p. 315, 1926.
   Hernon, R. M., The Paradise formation and its fauna: Jour. Paleontology, Vol. 9, No. 8, pp. 653-696, 1935.

disconformity in the southern Arizona [1]. In the Dragoons, also, the relationship is one of apparent conformity.[2]

In the Bisbee region the original "Naco" limestone has been described[3] as "similar to those of the underlying limestone (Escabrosa), but some of the bedding is thinner and texture generally is finer grained." Some beds also have a pinkish hue. Chert is common and occurs in irregular bunches and nodules and also in thin layers.

This description is roughly applicable to the strata above the cliff-forming Escabrosa which make up the crest of the range from Silver Cloud southeastward. Similar strata are also found on Sala Peak and south of there along Santa Anna gulch.

The thin-bedded characteristic is readily apparent when dip and strike measurements are desired; in this formation they may be secured without great difficulty. In the underlying Escabrosa limestone it is generally impossible to determine the attitude of an individual member by detailed observation.

The strata, in general, are bluish in color, but gray, pink or red beds are common in some places, particularly one-half mile northwest of Kelley's Ranch and on the east side of the ridge in the southern part of the area. Recrystallization has taken place as far south from the granitic mass as Mount Noonan and Aerie Peak. Here the recrystallized

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 521, 1936.
2. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, p. 1274, 1942.
3. Ransome, F. L., Geology and ore deposits in the Bisbee quadrangle: U. S. Geol. Survey Prof. Paper 21, pp. 44-46, 1904.

strata have lost their dull yellow and pink tints and are a monotonous succession of white and pale bluish strata with a more massive aspect.

Recrystallized strata making up parts of both walls of Middlemarch Canyon and extending over into the head of Stronghold Canyon probably are Permian (?) limestone, although positive proof is lacking. Other smaller areas of these rocks are mapped in the northwesterly portion of the area, the determination of which is likewise open to question.

The original Naco limestone of Ransome is now known[1] to include (1) strata of Lower Pennsylvanian age (2) Permian strata equivalent to the Manzano formation in New Mexico, (3) the Snyder Hill formation of Permian age and (4) beds equivalent to part of the Permian Kaibab limestone of the Grand Canyon.

Manzano and Snyder Hill formations

Above the Pennsylvanian rocks in the Whetstone Mountains section are Permian beds. These beds contain a fauna similar to that of the Manzano formation in New Mexico. The Manzano equivalent strata are 250 feet of thin-bedded, bluish-gray limestones which overlie 750 feet of sandstones and shales. The Snyder Hill formation which overlies the Manzano beds, is described as "thin-bedded, black limestone beds with a wide array of gastropods, both large and small." Several poorly preserved fossils collected in the southern part of the Dragoon Mountains were submitted to Dr. Stoyanow by the writer. These were termed suggestive[2] of the Manzano or Snyder Hill rather than the Pennsylvanian

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1. Stoyanow, A. A., Correlation of Arizona Paleozoic formations: Bull. Geol. Soc. America, Vol. 47, p. 522, 1936.
2. Oral communication.

(restricted) Naco. For this reason the strata between the Mississippian and Cretaceous beds are tentatively assigned to the Permian.

Pre-Mesozoic Erosional Interval

The relationship of the Mesozoic rocks to the underlying rocks is of a great significance in southeastern Arizona. At Bisbee faulting took place at the close of Paleozoic time.[1] Erosion then removed such great thicknesses of Paleozoic rocks that in places the Mesozoic was deposited upon pre-Cambrian rocks. No such obvious and spectacular result of pre-Mesozoic deformation and erosion is seen in the Dragoons. Mesozoic strata immediately northeast of Sala Peak rest on upper Paleozoic limestones, the combined thickness of which (Escabrosa and Permian (?)) is 200 feet. However, since the older Paleozoic strata are also somewhat thinner in this area the thinning here is not considered indicative of post-Permian erosion but is ascribed to differences within the depositional area. Further, the strata are on an anticlinal limb, and folding may have caused some thinning. Immediately to the southeast of Sala Peak a greater thickness of Permian (?) limestone is easily apparent.

In conclusion, no positive evidence such as selective erosion has been found within the area studied pointing to Pre-Mesozoic deformation.

Mesozoic Rocks

Mesozoic rocks underlie a relatively large portion of the area. They occupy much of the country east of the crest line and also make up the ridge on which Aerie Peak is located. Smaller patches are found southwest of Aerie Peak and south of China Peak.

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1. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geol. Survey Prof. Paper 21, pp. 106-107, 1904.

In some places the lower portion of the Mesozoic section, at least, is apparently simple to recognize as such. In most other places it is not certain that the rocks are not repeated by faulting or close folding and little can be said of the exact position in these rocks in the column.

Along the Dragoon fault, east of the Sentinel and at the lower end of the northeast wall of Middlemarch Canyon, the base of the Mesozoic is marked by a limestone conglomerate which lies unconformably upon the Paleozoic limestones. It is made up of well-rounded, gray, light blue and light red Paleozoic limestone cobbles up to six inches in diameter in a limy matrix. Its thickness is variable, but east of the Sentinel it may be 100 feet. It is absent in the base of the Mesozoic in other parts of the area.

In one place at least, a fault breccia intersects the limestone conglomerate in such a way that the one appears to grade into the other. However, the thickness of the conglomerate, its tendency to stand out topographically and the presence in it of various pebbles of local origin is sufficient to permit identification.

Darton[1] states that "the limestone succession exposed in the northern end of the Dragoon Mountains......is mainly Naco limestone......In the higher part of the succession is a red sandstone member and much coarse limestone conglomerate. The latter appears to grade into a fine-grained limestone and also into gray shale, otherwise it might be regarded as post-Carboniferous. The boulders are limestone. Another mass of the conglomerate was noted west of Dragoon Camp".

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1. Darton, N. H., A resumé of Arizona geology: Arizona Bur. Mines Bull. 117, p. 295, 1925.

Within the area studied the limestone conglomerate does not appear to grade into finer sediments; rather, it appears to be absent in places because of non-deposition.

Above the limestone conglomerate, as in the Middlemarch syncline, or directly upon the Permian limestone where the conglomerate is absent, as southeast of Sala Peak, lies a series of sandstones and shales whose maximum thickness is unknown. It has not been ascertained whether or not the Mesozoic section is repeated by faulting, but a minimum of 1000 feet is represented and a thickness of 3000 feet may be present.

The lower 100 feet of sediments above the limestone conglomerate is predominantly quartzitic. Near the base, conglomerate is present in which quartz pebbles up to an inch in diameter are present. Subordinate shales are also present.

The higher strata are predominantly shale. The shales are thicker than intercalated sandstones; individual shaly members may be 100 feet thick, whereas the sandstone members are rarely more than twenty feet thick. Red and reddish-brown are the dominating colors but some of the shale, dark on fresh fracture, weathers yellow. In most places the shales tend to be minutely fractured as a result of deformation; they have nowhere been observed to be slaty. A feature of the chocolate-colored sandy shales in the vicinity of Dragoon Camp is the presence in them of small nodules of gray limestone. Sandstone members are numerous and are generally quartzitic. Some are cross-bedded.

The Mesozoic formations described above resemble the Bisbee group as described by Ransome.[1] At Bisbee these have been subdivided into four formations: The basal Glance conglomerate, the Morita sandstones and shales, the Mural limestone and the Cintura shales and sandstones. The Glance conglomerate is made up of local underlying materials. The Morita formation presents a dull red or yellowish-brown appearance. It consists of dull-red shales and red or tawny sandstones with occasional layers of small pebble conglomerate and lenses of impure limestone. The red shales are mostly hard and compact, and the presence of small, light gray, calcareous concretionary nodules is characteristic, especially on weathered surfaces. Some of the sandstone is cross-bedded and some of the upper beds are quartzitic. The Mural limestone consists mostly of limestones, some members of which are sandy. In the middle of the section is a 25-foot buff sandstone member. The Cintura formation resembles the Morita.

The Mesozoic formations in the Dragoon Mountains thus far described are tentatively correlated with the Bisbee group as a whole. Darton[2] reports fossils in shales southwest of Pearce determined, by T. W. Stanton, as Cretaceous.

The southwest wall of Sorens Canyon between Santa Anna gulch and Aerie Peak is made up of a series of epidotized, garnetized and highly silicified rocks in which wide streaks of black hornfelsic material is intercalated. These beds lie above less than 200 feet of quartzitic and shaly material which in turn rests upon Paleozoic limestones.

More abundantly distributed is a massive rock, blue or gray on fresh fracture, fine-grained, and extremely hard. It appears to be a completely silicified limestone. Some beds are cherty and mottled and

1. Ransome, F. L., The geology and ore deposits of the Bisbee quadrangle, Arizona: U. S. Geological Survey Prof. Paper 21, pp. 56-69, 1904.
2. Darton, N. H., Resume of Arizona Geology, Univ. of Ariz., Bull. 119, p. 142, 1925.

contain dark limy nodules set in a matrix of apparently pure silica. Epidotization and garnetization of these beds is common and much of the weathered rock is pitted.

The black hornfelsic rock occurs as continuous bands in white silicified limestone several feet wide but it also occurs as highly irregular nodules in the white matrix. Stringers or projections of the hornfelsic rock into the matrix are common. The dark hornfels is largely argillaceous, but contains clusters of garnet.

The hard, white material has the appearance of dense, smooth chert. It contains clusters of epidote grains, some of which enclose grossularite. In thin-section, the presence of calcite was determined.

This rock where weathered has a brown nondescript appearance. The garnet and epidote etch out and leave the rock pitted. B. S. Butler, on a visit to the area on August 17, 1936, stated[1] that these rocks are similar to the series of strata lying above the lower shales and sandstones of Mesozoic age in the Tombstone area. The description[2] of the "Novaculite" from that area seems applicable in large part to these rocks.

The variously metamorphosed rocks making up the southwest wall of Sorens Canyon have a minimum thickness of 400 feet, but northwestward they increase to more than 1000 feet.

Other discontinuous areas of Mesozoic rocks are present in the Dragoons but age determinations relative to each other cannot be made. They are described in the following paragraphs.

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1. Oral communication.
2. Butler, B. S., Wilson, E. D. Rasor, C. A., Geology and ore deposits of the Tombstone district, Arizona: Arizona Bur. Mines Bull. 143, pp. 19-20, 1938

On the southwest wall of Middlemarch Canyon near the Cobraloma prospect about 200 feet of limestone, overlain by fifteen feet of quartzite, lie above black shales. On the spur below the Cobraloma prospect these black shales are underlain by a maximum of 100 feet of thin-bedded cherty limestones in which are four beds, each less than ten feet thick, made of almost entirely of poorly preserved oysters. These alternate with thin-bedded hard, siliceous limestones which contain many fine layers of chert. The rock weathers whitish and exhibits many black bands varying in width from that of a pencil streak up to one-inch. All show a machine-like parallelism. Their place in the section is not known and, although the fossiliferous members answer the description[1] of the Blue limestone of Tombstone in which the "upper portion is in most places crowded with poorly preserved shells of a small undetermined species of oyster......", the presence of a quartzite bed a short distance above indicates that these limestones are perhaps younger than the Blue limestone of Tombstone.

Immediately southeast of Middlemarch Mine are 300 feet of dark shales which are overlain by highly metamorphosed limestones, in part shaly and conglomeratic. The mine is located in these limestones. A single oyster was found in one of these limestone beds. These rocks cannot be assigned to any specific place in the section although both these and the beds near the Cobraloma prospect probably occur low in the section.

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1. Butler, B. S., Wilson, E. D., Rasor, C. A., Geology and ore deposits of the Tombstone district, Arizona: Arizona Bur. Mines Bull. 143, p. 20, 1938.

About 4,000 feet of Mesozoic rocks are mapped in the northwestern portion of the area. This section, like the section below Dragoon Camp, may be repeated by faulting. The rocks are dense gray to black hornfelsic shales. Limy or quartzitic rocks do not appear to be present. These rocks weather to a dull brown and many members have a "burnt" appearance.

A series of shaly rocks of Mesozoic age is present south of China Peak. These rocks are of interest in that metamorphism has created a spotted phyllite properly termed a fleckenshiefer. In the hand specimen the ground mass shows a silky luster and is gray with many dark greenish to black spots. The spots are rounded to ellipitical in section and occupy from 5 to 40 percent of the total rock surface. In places the spots exhibit a parallelism but in other places they are distributed at random.

The Mesozoic rocks, though possessed of characteristics which generally separate them sharply from the Paleozoic rocks, are difficult to study. The description of the Mesozoic strata of the Tombstone region by Butler and Wilson[1] is applicable in its entirety to the Mesozoic rocks of the Dragoon Mountains.

"In most places the Bisbee group is not well exposed. It forms rather smooth, brown or rusty slopes that are littered with fragments of the harder beds. The most abundant rocks are sandstone, quartzite, red, brown, green or black shale, and all gradations between shale or quartzite and impure limestone. Locally metamorphism has not only converted the purer sandstone to quartzite but has produced abundant epidote in calcareous sand or calcareous hornstone or novaculite. The epidote is generally in little nests or aggregates which on exposed surfaces weather

1. Butler, B. S., Wilson, E. D,, Rasor, C. A., Geology and ore deposits of the Tombstone district, Arizona: Arizona Bur. Mines Bull. 143, p. 19, 1938.

out so that the rock has a curious pitted appearance. In addition to the rocks mentioned, the formation contains some fairly pure limestone members. Lenticular beds of conglomerate, made up largely of pebbles of Carboniferous limestone and of siliceous rocks, are locally present in the lower portion.

Nowhere in the district is a complete section of the group available for study and measurement. Complexly folded, dislocated by faulting, and extensively metamorphosed by igneous intrusions, the Bisbee group has so far baffled attempts to discover the character and thick- of all its constituent parts, the total thickness of the whole, or its exact geologic age."

The writer has avoided the use of the terms Comanchean or Cretaceous in reference to the rocks described above even though it was suggested that they might be correlated in part with Ransome's Bisbee group, all of which has been [illegible] considered Lower Cretaceous in age.

Pliocene to Recent

The bedrock on the lower slopes is overlain in places by a younger alluvium composed of a heterogeneous mixture of sand and gravel. The material is of local origin and no exotic gravels have been found within it. Where plastered along the canyon sides, the alluvium contains boulders up to two feet in diameter in a sandy matrix but within the pediment area the maximum gravel size is smaller.

The greatest thicknesses exposed are in the canyons extending southwest from Black Diamond Peak and west of Sala Peak where exposures as much as fifty feet may be seen in several places. Evidence is lacking to show that this older alluvium may be correlated with the Gila conglomerate of upper Pliocene age[1] whose lacustrine deposits

1. Knechtel, M. M., Geological relations of the Gila conglomerate in southeastern Arizona: Am. Jour. Sci., 5th Ser., Vol. 31, pp.81-92, 1936.

are well displayed at Benson.[1] Tuff, diatomite or limestone, characteristic of the lake bed phase of the Gila conglomerate have not been recognized within the area mapped. Therefore the older alluvium is designated as Pliocene to Recent.

IGNEOUS ROCKS

Pre-Cambrian Granite

Pre-Cambrian granite is exposed only in an arroyo in the extreme southern part of the area. It is unconformably overlain by the Bolsa quartzite forming part of the east limb of the Silver Cloud anticline. The sediments of the west limb, however, have been faulted against the pre-Cambrian granite and on that side, therefore, the granite is overlain by Devonian limestones. The granite is a dark greenish black porphyritic rock carrying many small schist fragments. Most of the phenocrysts are small anhedra but a few large anhedral feldspar phenocrysts are present. The phenocrysts make up more than half of the rock.

Microscopic.- The coarse-textured granite contains large anhedra of perthite and microcline and somewhat smaller anhedral grains of quartz. Feldspar makes up about two-thirds of the total phenocrysts.

The ground mass contains unaltered biotite and ilmenite. The ilmenite is partly altered to leucoxene. Some muscovite is also present and within muscovite areas apatite occurs as tiny grains. Magnetite, as small grains, is also present. The feldspars have been highly sericitized. Some veinlets of secondary iron oxide are present.

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1. Gidley, J. J., Preliminary report on fossil vertebrates of the San Pedro Valley, Arizona: U. S. Geol. Survey Prof. Paper 131, pp. 119-131, 1932.

Post-Cretaceous Granite

The coarse-grained granite making up the Cochise Stronghold area, herein referred to as the Stronghold granite, extends southward as narrow bands into the area discussed in this paper and the borders of the mass itself fall within the northern and western limits of the map. The granite is considered to be intrusive into the sedimentary rocks with which they are in contact. Evidence to support this contention is seen in the metamorphism of the sedimentary rock adjacent to the granite and in the pattern made by the granite outcrops. Evidence tending to indicate that the granite has been faulted against the sedimentary rocks is seen in details of the contacts.

With one minor exception the granite-sedimentary contacts, where well exposed, indicate more or less movement along the contact. The granite is not frozen to the walls but is everywhere separated from the sedimentary rock along a sharp plane. In the few places where determination was possible the plane dips steeply toward the sediments. Apophyses or stringers nowhere extend into the sedimentary rocks. Breccia is present in the sedimentary rock at the contact of the head of Middlemarch Canyon on the northeast wall and on the southwest wall. The Cobraloma adit passes through to the contact and along it for about thirty feet exposing a face of slickensided granite on the contact. Gouge is present in many other places and shear zones along the contact are common.

Let us now consider the pattern made by the granite within the area. Beginning at the head of Stronghold Canyon a belt of granite extends southeastward into Middlemarch Canyon, gradually narrows in in that direction and vanishes beneath valley fill. Another narrow belt of granite extends southward from Cochise Peak. At its extremity it underlies the northern portion of the Black Diamond quartzite mass. Specimens from the dump of the prospect south of the Black Diamond mine indicate that the granite was probably encountered in the mine a short distance below the surface. A much smaller, but more wedge-like granite re-entrant is present one-half mile south-southwest of China Peak and a small rudely circular outcrop of granite is found on the northeast wall of Middlemarch Canyon, about one mile southeast of Mt. Noonan.

In summary, the granite occurs within the sedimentary rock area in the following structural forms; a long dike, a shorter tapering dike, a small wedge and a plug. These forms are considered to be strongly indicative that the rock is intrusive.

When the metamorphism of the sedimentary rocks in the northerly area is compared with the lack of metamorphism in the southerly area, a strong argument is thereby advanced for the intrusive nature of the granite. Metamorphism is particularly well exhibited in the shaly series making up the southwest wall and head of Sorens Canyon. The rocks are now largely hornfels. Schistose rock has been developed near the granite immediately southwest of China Peak. The Paleozoic limestone has likewise suffered greatly in the northerly area and has been recrystallized, bleached, silicified and mineralized. Grossularite, magnetite and epidote, minerals denoting contact metamorphism, are developed along the granite boundaries in Middlemarch Canyon, at the head of Stronghold Canyon, in the extreme northwestern portion of the area and elsewhere. It should be noted that while the Black Diamond mine, like the Middlemarch mine and Gordons claim, is developed within a sedimentary rock area, granite is present near by. Taking a view of the range as a whole, it is seen that the Black Diamond is the southernmost strongly mineralized locality and southward strong mineralization is not found until another granitic mass is approached.

Macroscopic.- The Stronghold granite has a medium to coarse grained texture. In most places it is prophyrtic but the porphyrtic character is not everywhere readily apparent in the hand specimen. The phenocrysts are stubby untwinned euhedral feldspar grains, the largest of which measured 2 centimeters in length. A microscopic study of crushed fragments showed that these are orthoclase.

The phenocrysts make up not more than one-fourth of the rock. Quartz is present as smaller subhedral to anhedral grains and it makes up about one third of the minerals present. The remainder of the interstitial material is feldspar which was determined in thin sections to be largely albite. The proportions of the essential minerals are, therefore; quartz, 35 percent; orthoclase, 25 percent; and albite, 35 percent. Biotite and chlorite are sparingly present and generally make up not much more than five percent of the total minerals. Muscovite is less commonly found.

Where fresh, the rock is whitish or tinged with green or yellow. On weathered surfaces it is gray in places but more commonly it is light yellow or light brown in color. In the soft light of late afternoon, particularly when the harsh rays of the sun are diffused by the moisture laden atmosphere following a heavy rain, the granite mass may take on a brilliant pink hue of great beauty.

<u>Microscopic</u>.- A specimen taken ten feet from the sedimentary contact south of China Peak appeared definitely porphyritic in thin section, as opposed to the hand specimen in which the texture seemed to be merely inequigranular. The larger feldspar grains were determined by study of crushed fragments to be orthoclase. They contain relatively few small inclusions of twinned and untwinned albite oriented parallel with and at right angles to the elongation. Small laths of albite and small anhedral quartz grains make up the ground mass. A few larger grains of albite and quartz are also present. Very little microcline was present.

Biotite makes up less than five percent of the section. Less than one percent of sphene is present; in places it is altered to leucoxene. Grains of zircon, surrounded by smoky or solid black reaction rims of magnetite, are included in biotite.

A thin section was made of a sample taken from the granite "plug" occurring on the northeast wall of Middlemarch Canyon. This rock is essentially similar to the rock described above although the textural relationships have been obscured by mylonitization. Some quartz and muscovite grains show undulatory extinction. The biotite is chloritized, however, and a small amount of magnetite is generally associated with it. Albite is both kaolinized and sericitized but orthoclase is only slightly altered.

A third thin section was made of a sample taken from Sorens Canyon. The rock here, too, has been mylonitized and the texture obscured but it was found that the proportions of the essential minerals was the same as in the sections described above. A little microcline was found in this section and the biotite was entirely chloritized.

As far as it is known to the writer, this granite massif is made up almost entirely of the rock described above and it is believed that everything mapped as Stronghold Granite is all one rock type belonging to a single period of intrusion.

Minor Intrusives

Aplite Dikes

In several places a late aplitic granite is present as small dikes generally less than a foot wide.

Dikelets extend from the granite-sedimentary contact and into the sediments on the western slope of Mt. Noonan. An intersecting system of thin dikelets is found in the granite north of Salas ranch house; one set of the system is roughly parallel to the regional trend, the other set is approximately normal to these. The dip of the dikelets is variable but they tend to be vertical. Dikelets also occur along the granite-sedimentary contact at Sorens Camp. They are found again intruding sediments north of Grants Hill.

Near the head of Sorens Canyon is a larger dike-like body of rock about 500 feet long with a maximum width of 30 feet whose texture is similar to that of the small stringers. Within this large fine-grained mass, however, are several pegmatite veinlets about an inch wide. They appear to be quartz veins but close inspection reveals the presence of subordinate feldspar.

Macroscopic.- In the hand specimen the aplite is gray to dazzling white, fine grained, inequigranular and is peppered with minute flakes of biotite. In the hand specimen the texture is fine, and the rock has more the appearance of a quartzite than a granite.

Microscopic.- In thin section the aplite at the head of Sorens Canyon shows a fine, even-grained mosaic of anhedral quartz and feldspar and minor amounts of muscovite and biotite and chlorite. The grains are about 0.1 millimeter in diameter but locally slightly larger grains appear single or in clusters. Because of their small size it is difficult to distinguish between the quartz and the feldspar. However, in plain light the quartz stands out in relief and it is apparent that it makes up half of the section. Albite twinning is rare in the feldspar grains. Scanty pale pink apatite and magnetite were noted.

The section is discolored in several places by brownish limonite strains. The feldspar is slightly kaolinized.

A thin section was also made of the fine-grained granite developed along the contact of the normal granite with the sedimentary rock on the northeast wall of Middlemarch Canyon. Although the rock here has suffered mylonitization, the proportions of the essential minerals are clearly revealed. Quartz makes up at least fifty percent of the rock and, except for about two percent of biotite, the remainder is feldspar. Orthoclase is present as grains as 0.1 millimeter in diameter and in places it contains inclusions of anhedral twinned albite grains or well rounded blebs of quartz. Scattered albite grains also occur independently of the orthoclase. Albite makes up about one-fifth of the total feldspar present. Some of the quartz grains show strain shadows.

A feature of this section is the texture created by the alternations of broken material with the more nearly intact minerals. The rock here may be aptly called a micro-gneiss.

Sanidine Rhyolite Porphyry

A short distance northwest of Salas ranch house and also a short distance to the southeast are dikes about five feet wide of rhyolite porphyry in which sanidine feldspar is present. The dikes trend northwest-southeast and intrude Paleozoic rocks. At the former locality the dike trends parallel to strong fissures which strike N55°W and dip 40°SW.

Macroscopic.- The rock is pink on weathered surfaces but gray where fresh. The phenocrysts are euhedral quartz and feldspar; the quartz phenocrysts are 3 or 4 millimeters in diameter but one of the largest feldspar phenocrysts measured only 2 by 0.5 millimeters. Both the quartz and feldspar phenocrysts are quite clear and fresh. The ground mass is microcrystalline in texture and under the binoculars a few grains of fresh quartz and kaolinized feldspar and biotite may be discerned. The feldspar weathers pink and gives the color to the rock.

Microscopic.- The large feldspar phenocrysts are sanidine as determined by the small optic angle and by indices of refraction.

The pheocrysts of sanidine and quartz are euhedral to subhedral and many of them have been partially resorbed, the feldspars more than the quartz. Some of the sanidine phenocrysts contain inclusions of myrmekitic quartz and others contain perthitic intergrowths of albite. The phenocrysts make up 50 percent of the rock. About 30 percent of the phenocrysts show characteristic multiple twinning of albite.

Smaller grains of biotite, in part altered to chlorite, are also present and magnetite is sparsely scattered throughout. The ground mass is an even, fine-grained mosaic of anhedral quartz, albite and subordinate biotite. The albite is mildly kaolinized.

Albite Rhyolite Porphyry

Other rhyolite porphyry dikes are widely distributed throughout the area and many of these stand out conspicuously above the rocks which they intrude. In places they are as much as ten or fifteen feet wide and are continuous for considerable distances with the trend of the range. Others are only a foot or two wide and of no physiographic importance. Plotting of many of these smaller dikes added confusing detail to the map and some have been omitted.

In the southern part of the area several dikes are found east of the crest line but their development in the massive limestones on the west side is more limited. In the northern half of the area the dikes are more widely distributed and intrude both igneous and sedimentary rocks.

The dikes are vertical or almost vertical in attitude and nearly all of them trend northwest-southeast. South of Santa Anna gulch however, two dikes are plotted whose trend is north-northwest. The dikes are obviously younger than the Stronghold granite and are regarded as a late differentiation product from the same parent magma.

Macroscopic.- A typical albitic rhyolite porphyry is mainly brown to lavender, in places bluish, gray or white on fresh fracture and brown, yellow or grayish on weathered surfaces. The texture is porphyritic. The phenocrysts, quartz, feldspar and subordinate pyrite, are generally about one millimeter in diameter but larger ones have been noted. The matrix is felsitic.

The dikes generally show a chill effect and the phenocrysts are smaller near the edge of the dike. Marked flow structure has been noted in the phorphyry dikes, particularly in the prominent dikes above Middlemarch mine.

Microscopic.- The phenocrysts are mostly euhedral quartz crystals with slightly rounded edges. There are also subordinate phenocrysts of twinned albite which may show very sharp outlines or be quite rounded by resorption.

In the fine-grained ground mass orthoclase, albite, quartz and a minor ferromagnesian mineral were recognized with a fair degree of certainty. The ferromagnesian mineral was not identified. Some albite is partly converted to calcite. There has been slight chloritization of the ground.mass.

A specimen of the porphyry exhibiting flow structure was also studied. Under the microscope it appeared to be entirely similar to the specimen previously described with the exception that the phenocrysts were characterized by micro-fractures in a criss-cross pattern.

Diabase Dikes

Short diabase dikes, generally less than two feet in width were found in a number of places. Some intersect tightly folded sediments, as the Abrigo limestone of the Silver Cloud anticline and on the crest of that anticline west of Black Diamond Peak. Elsewhere the dikes do not appear to be as definitely related to any particular portion of a structural form. Near the head of Sorens Canyon the diabase intrudes the Cochise granite. It also intrudes the granite immediately north of Black Diamond Peak. A dike also appears a high-angle reverse fault on the high spur southeast of Salas ranch. A few others have been found.

Few of the dikes exceed a length of ten feet. The dike intruding the Mesozoic sediments near the head of Sorens Canyon is exceptional and is about 50 feet long.

Macroscopic.- The diabase is characteristically black or greenish-black where fresh but is lighter where weathered. In the hand specimen a white felt of tiny feldspar grains may be distinguished. These are developed in a dark ground mass.

Microscopic.- In thin section the rock is seen to consist largely of hornblende and feldspar laths in the common ophitic intergrowth. Many of the feldspars are twinned on the albite law and since their refractive indices are above that of balsam, the maximum extinction of 26° of the twinned feldspar established them as andesine.

Hornblende exhibits the typical 124° cleavage and six-sided figure in basal section. It is light brown to greenish brown in color. Under crossed nicols many of the hornblende crystals were seen to be twinned. The maximum extinction is 22°. The hornblende is pleochroic and basal sections vary from very light brown to deep, almost opaque, brown.

Some pyrite is present as small irregular grains and as larger grains with good cubic development. The feldspar is slightly kaolinized, the hornblende is chloritized in part and a little red hematite has been derived from pyrite.

A sample of diabase taken from a dike near the Silver Cloud prospect was very highly altered. Large masses of chlorite are present which give no hint of the mineral from which it was derived. A small amount of sericite is associated with feldspar residuals and a minor amount of calcite is also present. Magnetite is scattered throughout the section, in places as triangular or hexagonal shaped grains. In one place 124° cleavage was noted and it seems obvious that here the nagnetite was derived from hornblende. Epidote is in irregular masses and as veinlets.

METAMORPHIC ROCKS

As mentioned above the sedimentary rocks, within the area have been metamorphosed in part. However, it is considered desirable at this point to recapitulate briefly the areas of metamorphic rocks and to note their relation to the Stronghold granite.

The upper Paleozoic rocks are widely bleached, silicified and recrystalized in the northern portion of the area. Their pale blue, light gray and white hues contrast sharply with the darker and more varied colors of the strata in the southern less metamorphosed area. Silicification has been a dominant process. Many limestones have been almost completely silicified without greatly altering the appearance of the rock; on the other hand certain strata have been greatly changed in appearance by silicification and appear as light colored bands in a darker section. The silicified Devonian limestones below Salas Peak characteristic of this change in appearance have been described above.

Garnetization is common along igneous contacts. Only grossularite, the lime garnet, has been found. It is common along igneous-limestone contacts in Middlemarch Canyon and west of Grants Hill. Hedenbergite is common in the Salas Peak and Gordons Claims areas. Mississippian and Devonian limestones are tremolitized in several places south and southwest of Salas Peak. Magnetite occurs sporadically.

The Mesozoic rocks in the northern part of the area are likewise strongly metamorphosed. The strongly silicified and epidotized hornfelsic rocks which make up the ridge extending southeastward as far as Aerie Peak have been described in some detail. Similar rocks are present in the vicinity of Grants Hill. Fleckenschiefer or spotted phylite is present south of China Peak but is not present elsewhere.

Limy rocks in the Mesozoic section near Middlemarch mine have been greatly silicified, so much so that some of these strata are difficult to distinguish from quartzites. Above the Black Diamond mine hedenbergite is common.

Ore mineralization, either occurring as fissure filling or by replacement of the wall rock may be properly regarded as metamorphism. In the Dragoon Mountains mineralization has generally been spotty and is of little importance areally. Magnetite, barite, pyrite, galena, sphalerite, bornite and chalcopyrite are common as replacement minerals in both Paleozoic and Mesozoic limestones and vanadinite and wulfenite have been found in one place as fissure fillings in Paleozoic limestone.

Pyrometasomatic metamorphism such as silicification and bleaching is found only in the northern area and is most pronounced in the vicinity of the larger granitic masses. Sporadic mineralization is less restricted areally but the three largest mines and most of the smaller prospects are located close to outcropping granitic rock. Solutions and heat emanating from the granite therefore have quite obviously been the agencies through which metamorphism occurred.

STRUCTURAL DEFORMATION

No sedimentary rocks in the central Dragoon Mountains remain in their original undisturbed position, except for the younger unconsolidated detritus skirting the range and partly filling the deep canyons. Great stresses, acting from the southwest or northeast have crumpled and broken the strata into many units. Other stresses of lesser magnitude have also been active.

A summary of the structural events will be helpful in following and evaluating the detailed discussion of folding and faulting to follow:

1. Sedimentation in the Paleozoic and Mesozoic eras.
2. Low-angle overthrust faulting.
3. Folding of the sediments, including the overthrust blocks, into broad open folds whose axes trend northwest-southeast. Reverse faulting also took place where competent strata were unable to adjust themselves fully to the compressive forces by folding.
4. Intrusion of the Stronghold granite and associated dike rocks. A radial thrust may have been exerted by the intrusive magma. Minor normal faulting followed the cooling of the granite mass.

Folds

Folds dominate the structure of the portion of the Dragoon Mountains discussed in this paper. Later faulting has destroyed the unity of the folds and granite has occupied parts of them, but a true structural picture of the area is gained only by a detailed study of the folds.

In the southerly part of the area are two parallel anticlines whose axes fall on either side of the range. These trend northwest-southeast (Sections F-F', G-G', H-H', Fig. 2) and are in contact along a reverse fault.

Silver Cloud Anticline.- The Silver Cloud anticline, located on the western side of the range, makes up the two spurs extending west and southwestward from Silver Cloud Peak. On the southwestward spur the Abrigo, Martin, Escabrosa and part of the Permian (?) formations are well displayed (Section F-F', Fig. 2). Due to a gentle northwest pitch of the fold however, the more northerly spur does not reveal the Abrigo limestone at the surface. The massive limestones have dominated the structure and they crop out with a broad bold sweep.

Considerable solid flow from limb to crest is seen in the Mississippian rocks on the east-west spur. The southwest limb of the anticline bends quite sharply here and flow from that limb toward the crest has created a bulbous limestone mass which stands out as a conspicuous peak. Thickening may have extended over the anticlinal crest. However, the crest area now forms a topographic saddle because of the localization there of closely spaced tension joints. It is probable that flow took place early during the period of folding when the sediments were under heavy cover and jointing occurred later as the folds rose vertically.

Thin-bedded Abrigo limestones exposed in the arroyo near the Silver Cloud claims have responded differently to compression. Here is a complex system of tight, contorted and overturned drag folds which strongly contrast with the broad arch of the overlying massive limestones.

Near the Silver Cloud claims the trace of anticlinal axis trends southward and is covered by alluvium (Fig. 1). However, the northeast limb is well exposed southeastward and strata as low as the Devonian form an unbroken outcrop and extend to the most southerly portion of the map area. The Abrigo limestone, Bolsa quartzite and pre-Cambrian granite are well exposed beneath them in the most southerly area mapped. Although the northeast limb is completely developed here, the southwest limb has been downfaulted and high Devonian beds lie against the pre-Cambrian granite.

On the east slope of the range the eastern limb of the Silver Cloud anticline forms synclines, in places, along the fault contact with the Mesozoic shales (Section H-H'). The contact is a warped plane, and only where the Paleozoic rocks make a reentrant into the Mesozoic rocks is the synclinal structure observed. Two such synclinal embayments are present; one at the southeast end of the range and one above the saddle just east of Silver Cloud Peak.

To the northwest the Silver Cloud anticline is limited by a cross fault of small displacement. The evidence is considered later.

Black Diamond Anticline.- The axis of the Black Diamond anticline lies on the northeasterly slope of the range and the entire fold lies within the Mesozoic sediments (Sections F-F', G-G', and H-H', Fig. 2). The northeast limb is well expressed on the slopes below Black Diamond Camp and the southwest limb may be seen higher on the slopes beneath the northwesterly trending fault mentioned above and is present as a narrow strip only.

The Black Diamond anticline appears to be a sharp crease separating two series of isoclinal sediments unlike the broad arch of the Silver Cloud anticline. At no place on either of the limbs of the Black Diamond structure was the characteristic progressive change of dip of a fold noted.

To the northwest the axis of the Black Diamond anticline is replaced by granite but the northeast limb is seen on the prominent ridge just east of the Sentinel (Section E-E', Fig. 2). The limb is made up of a heavy limestone conglomerate underlain by limestone bearing abundant brachiopods, considered Paleozoic in age. Southeast plunge of the anticline is thus indicated.

Another clue to the make up of the range is thus revealed. It may now be surmised that the limestone conglomerate which crops out near the Sentinel lies only a short distance below the anticlinal axis southeastward. The Silver Cloud and Black Diamond folds are then seen to be part of the same structure which is now broken by a fault.

North of Section G-C', Fig. 2, the Paleozoic-Mesozoic fault contacts bends westward and the synclinal development of the northeast limb of the Silver Cloud anticline is faulted out and Section G-G', therefore, does not show all the elements of the original structure. In this section however, the presence of the limestone conglomerate lying upon the Paleozoic rocks established the fact that the full thickness of Paleozoic rocks is present here.

The northern portion of the area considered in this paper differs markedly from the southern portion discussed above. Taken as a whole the northern area may be said to consist of an anticlinorium on the southwestern side of the range, the northeastern limb of which develops into a syncline, Sec. D-D'. Northward increasingly greater portions of the structure give way to the Cochise Stronghold granite mass. This general statement does not describe all the observed structures however. Part of the folds have been telescoped by faulting, as in the area near Gordons claims, and notable omissions occur. These and other variations make a simple characterization of the northern province impossible.

Middlemarch Syncline.- The northeast limb of the Black Diamond anticline has been traced northward to a point directly west of the Sentinel in this discussion. It has been noted that the Mesozoic limestone conglomerate formed a ridge. Northeast of this point, across the mouth of Middlemarch Canyon, the conglomerate beds again crop out and the Paleozoic limestones which underlie them have a southwest dip. A syncline, here called the Middlemarch syncline, is evident (Section E-E', Fig. 2).

The Paleozoic rocks making up the walls of Middlemarch Canyon dip to the southwest (Sections D-D' and C-C', Fig. 2). Both walls of the canyon, therefore, are considered to be part of the northeast limb of the Middlemarch syncline. Locally the axis of the syncline trends west-northwest and passes under the hill which lies between the lower ends of Sorens and Middlemarch Canyons. Under this hill Mesozoic congomerate crops out and is underlain by massive limestones, probably Paleozoic in age. The beds appear to be horizontal and are considered to mark the northwestward axis of the Middlemarch syncline. A flexure along the strike, corresponding to this flexure of the synclinal axis, has been observed in the massive Paleozoic limestones on the ridge northeast of Noonan Peak. It is believed that a correspondingly greater flexure could take place in the less competent shales to the west and the structure is so indicated (Fig. 1).

The southwest-dipping series of strata making both walls of Middlemarch Canyon may be traced northwestward to Stronghold Canyon with moderate continuity. Here the entire Paleozoic sequence (and probably also the Mesozoic rocks at the Middlemarch mine) is a part of the east limb of the Middlemarch syncline. Thus an unbroken series of folds appear to extend from the southeasternmost part of the area northward to Mount Noonan. This contrasts with the dissimilar folds on either side of Santa Anna Gulch on the western side of the range and it is believed therefore, that the transverse fault mapped in Santa Anna Gulch passes into a fold eastward and is marked by the flexures in the trace of Middlemarch synclinal axis and in the beds just south of Mt. Noonan.

The relation of the thin strip of Mesozoic sediments northwest of Middlemarch Mine to the underlying Paleozoic rocks is not clear but they are thought to be faulted against the Paleozoics. The entire series dips to the southwest and is considered to be part of the east limb of the Middlemarch syncline. The area at the head of Middlemarch Canyon appears to be a greater development of the northeast limb of the Middlemarch syncline and no trace of a southwest limb is thought to be present north of the mouth of Sorens Canyon.

<u>Sala Anticlinorium</u>.- Turning now to the area south of the Aerie Peak (Sections C-C' and D-D'), we find the Sala anticlinorium which consists of three distinct anticlines with intervening synclines. It

is best observed on the lower spurs extending north and northwest from Santa Anna Gulch. These three anticlines occur within about the same distance across the strike as that required by the Silver Cloud anticline. The Sala anticlinorium and the Silver Cloud anticline are not considered to be parts of one structure. It is thought that the strata north of Santa Anna Gulch, although probably continuous with the strata to the southeast in the early stages of folding, acted as an independent unit and were shortened a relatively greater amount and are now separated from the Silver Cloud anticline by a cross fault of small displacement. The offset at the head of Santa Anna Gulch bears out this interpretation. Further, the observed low pitch of the Silver Cloud anticline does not appear to be great enough to account for the presence of Mesozoic beds at low elevations a short distance northward even though the Paleozoic section thins markedly in that direction. However, massive limestone beds are involved on both sides of the fault and the gulch is filled with alluvium as a result of which the position of the fault is indeterminate.

The folds south of Aerie Peak strike about N 45°W and plunge less than 5° to the southeast. The two higher anticlines are traced to the spur connecting Salas Peak with Aerie Peak. Their projection one half mile northwest of this point is hypothetical in part because metamorphism of the strata has largely obliterated the bedding planes and salient characteristics. Directly west of Salas Peak the simple folded structure is lacking. Bolsa quartzite of the Cambrian is brought up to a high level and a mashing of the structure by the intruding granite acting obliquely to the strike is suggested.

The lowest of the three anticlines crops out on a low hill on the pediment and passes northwestward into a series of imbricate reverse faults. They are considered in detail under "Faults."

The details of the relationship of the Sala anticlinorium to the Middlemarch syncline is uncertain because in Sorens Canyon granite has replaced a segment of the structure. However, it seems possible and even likely that in Section D-D' the restored structure would include a northward extension of the Middlemarch syncline and perhaps also the Black Diamond anticline and that the Sala anticlinorium was brought against these folds along a northward continuation of the Dragoon fault.

The folds in the area south of China Peak are not continuous with those of the Sala anticlinorium but are believed to be separated from the latter structure by a cross fault.

Within the basin-like depression of the Gordons claims area (Section B-B'), a slightly warped block of lower Paleozoic strata has been brought against Mesozoic shales by reverse faulting. The Mesozoic shales here are overlain by a small thrust mass of folded Mississippian limestones. Presumably the underlying Mesozoic strata are also folded. The strata may be considered to have been continuous with the rising Sala anticlinorium but when greater relief was gained by faulting a markedly different structure was created. In any event, the continuity of these folds with those of the Sala Peak area is broken and structural similarities are few and dubious.

The main structural units seen in Sections A-A' and B-B' are quite certainly faulted against each other. The only structure which can be traced into them from the better known southeastern area is the northeast limb of the Middlemarch syncline.

Faults

High Angle Reverse Faults

Study of the structural geology indicates that in several places the strata were unable to obtain full relief by folding during periods of mountain building and further relief was gained by high-angle reverse faulting.

Dragoon Fault.- The greatest of these high angle reverse faults is the Dragoon fault which follows the trend of the range. In the southeastern portion of the map area (Fig. 1) the trace of the fault passes short distance below and to the northeast of the crest of the range and forms the Paleozoic-Mesozoic contact. Where this fault crosses the deep gulch southwest of Black Diamond Peak it dips about 75 degrees to the southwest. The hanging wall Paleozoic rocks have overridden the Mesozoic footwall. The Dragoon fault was traced northward for a distance of almost three miles from the southern limit of the map to a point one half mile north of Silver Cloud Peak where it appears to be limited by a transverse fault. It has been pointed out above that folds on either side of the transverse fault located along Santa Gulch are dissimilar.

As brought out more fully in the discussion of folding, the stratigraphic units at the head of Sorens Canyon have a relation to each other most simply explained by faulting (Sections A-A' and B-B') and a northward continuation of the Dragoon fault into that area is possible. However, since the folds on either side of the cross fault in Santa Anna Gulch have acted as independent units, and since the high angle faulting occurred during the later stages of folding, it would seem that the Dragoon fault and the faults at the head of Sorens Canyon are similar in origin but not necessarily parts of one original structure.

Near the head of Sorens Canyon Cambrian strata of the overthrust sheet abut upper Paleozoic limestones on the southwest wall. Here the fault plane dips steeply to the southwest and at the contact the dip of the Cambrian limestones of the footwall is steepened and contorted showing the effects of compression. Inasmuch as the overthrust strata are affected by this fault, it is evident that if this fault is related to the compression which created the larger folds, as it is thought to be, the overthrust sheet is younger in age than the Dragoon fault system and the large folds.

Fault in Middlemarch Canyon.- The lower ends of the spurs extending east of the Cobraloma prospect are made up of moderately thin-bedded limestones in pastel shades of pink, blue and yellow. These limestones are similar to the higher Pennsylvanian strata found elsewhere in the area and accordingly are assigned to that horizon. The limestones dip to the southwest and at the lower ends of the spur they are in contact with the granite in which the stream is cut.

Higher on the slope these Paleozoic limestones are in contact with a series of Mesozoic black shales and subordinate arkoses which also dip steeply to the southwest. A limestone member in this series, as has already been noted (page 38), is replete with fossil oysters. The shales are considered to be a higher part of the Mesozoic series and may possibly be correlated with the strongly metamorphosed strata south of the Middlemarch mine.

The contact of these shaly rocks with the underlying Paleozoics trends upstream across Cobraloma Gulch, thus indicating that the plane of contact is inclined to the southwest.

The shales appear to lie unconformably upon the Paleozoic rocks in sedimentary contact. However, the Mesozoic limestone conglomerate and lower red shales and quartzites of the Mesozoic are entirely lacking and further, directly northeast of the Cobraloma prospect, the Mesozoic strata meet the Paleozoic strata at an angle. In addition it may be noted that the Paleozoic limestones show a marked deformation. Chert bands in the massive strata are intricately folded and contorted and breccia is abundant, particularly on the north bank of Cobraloma Gulch near the contact. This indicates strong compression and the Mesozoic rocks are believed to be in contact along a high-angle reverse fault.

A short distance north of the Cobraloma prospect the fault bringing the higher Mesozoic shales in contact with Paleozoic limestones is limited by a cross fault trending southwest-northeast.

<u>Fault north of Grants Hill</u>.- In the extreme northwestern portion of the area mapped, i. e., immediately north of Grants Hill, the Paleozoic limestones are in contact with the Mesozoic hornfelsic shales. The dip of the limestones is to the northeast but near the contact their dip steepens, they become vertical and even overturn to dip steeply to the southwest. The contact is marked by strong fissuring and slicken-

sides. These data are considered evidences of compression and the fault is most logically interpreted as a high-angle reverse fault.

Fault southeast of Salas Peak.- Considering now the westerly side of the range, a well defined high-angle fault crosses the saddle of the spur extending south-southwest of Salas Peak. The trace of the fault on the surface and an exposure of the fault plane itself shows that it dips 80° to the southwest. The hanging wall consists of Cambrian sediments which lie upon footwall limestones of Mississippian age. It is, therefore, a reverse fault. The fault passes into a fold southeastward and northwestward it terminates at the granite boundary.

Fault at Gordons Claims.- The geology of the basin-like area south of China Peak has already been sketched in the discussion of folding. A warped segment of lower Paleozoic rocks lies in juxtaposition with a folded thrust mass resting upon Cretaceous sediments. The contiguity of these two masses cannot be explained by folding and, therefore, a northwest-southeast fault is mapped between them. Inasmuch as the fault is not exposed, its character may only be surmised. It is thought to be similar to the fault at the foot of Salas Peak, discussed above.

High-Angle Normal Faults

In the extreme southern part of the area, a normal fault is present along what was presumably the axis of the Silver Cloud fold. Martin limestone of the pediment lies against pre-Cambrian granite along a fault plane which dips 45° to the southwest.

The high angle faults thus far discussed are reverse faults which developed when the limit of yield by massive strata had been exceeded. Here the rise of granitic and quartzitic rock brought forth and localized a fault along a dome where tension was effective and the fault is a normal fault.

On Grants Hill, the Sentinel and perhaps Black Diamond Peak, the Bolsa quartzite masses are dropped off in successive little steps in an eastward direction. These normal faults trend with the range and regional structure. These minor normal faults are regarded as resulting from settling movements which took place after compression had ceased and perhaps even after the intrusion of the Stronghold granite.

Cross Faults

Two large cross faults are postulated in the area, neither of which has been seen. The abrupt offsetting or termination of strata, however, necessitate these cross faults and they are mapped in response to that need.

The cross fault mapped in Santa Anna Gulch separates the Silver Cloud anticline (which pitches to the northwest) from the Sala anticlinorium (which pitches to the southwest). An offset along this fault is seen at the head of Santa Anna Gulch. However, the Middlemarch syncline appears to continue unbroken across the eastward projection of this fault and the fault is considered to pass into a cross fold at the mouth of Sorens Canyon.

There is evidence of a second cross fault that extends from a point south of Gordons claims northeastward across the backbone of the range and across the southwest wall of Middlemarch Canyon.

One-half mile east of Gordons claims, the Paleozoic limestone in which several prospects are developed is abruptly terminated in a deep gulch although the attitude of the formation and the topography call for a continuation of these beds on the opposite side of the gulch. This termination is clear cut evidence of a cross fault. Lower in the same gulch the topography is more subdued and the geology is not as clearly revealed but the juxtaposition there of different structures may be well explained by a cross fault.

Further, it is believed that the northeastward continuation of this fault separates the infaulted Cambrian of the early overthrust sheet on the southwest wall of Sorens Canyon from the Mesozoic strata farther on down the canyon. The exact junction of these two segments was not found although it is close to where it is mapped.

A cross fault is clearly revealed on the wall of Middlemarch Canyon just above the Cobraloma prospect. Strong drag indicates that the southeastern block moved to the northeast. This fault may be a continuation of the fault just discussed. Extension to the northeast beyond this point has not been found.

Cross faults of smaller magnitude are mapped in the northwesterly portion of the area. They are lost upon entering the shaley Mesozoic series and hence may be of greater length than noted on the map. However, they have been mapped only as far as they have been actually traced.

Low Angle Faults Associated with Folding

When stresses were applied to this area the massive Paleozoic strata appear to have been unable to fold sufficiently to provide full relief and eventually the massive arches cracked and segments of folds slid over each other. In most places the faults thus created are high-angle faults but a few low-angle faults of minor importance also resulted.

Southwest of Sala Peak: The imbricate reverse faults seen on the spur a mile southwest of Salas Peak (Section C-C') are thought to be type examples of this class of faults.

At the very toe of the spur directly east of Salas ranch house a moderately thick section of thin-bedded Permian (?) limestones dip to the southwest. Locally the strata do not conform to the general strike and show marked divergences. Below the Pennsylvanian rocks, the more massive Mississippian is revealed on the crest of the spur apparently underlying the Pennsylvanian in conformable sequence. Detailed study, however, shows that on the northwest slope of the spur the Mississippian makes a sharp fold to the north along the strike and is slightly overturned and it is evident that here the Permian (?) strata have slipped along a fault closely parallel to the bedding and now override the crumpled Mississippian strata.

Giving out attention to the crest of the spur again we find a small infaulted anticline in the underlying Devonian rocks immediately northeast of the massive Mississippian limestones. The buckled Mississippian limestone and infaulted anticline rest on and abut against the next series of strata to the northeast in such a way that a fault contact is demanded. The brecciated fault plane is well exposed near the crest of the spur and its lower extensions traced by the lithologic anomalies, show it to be a low angle fault. This fault too appears to have begun as a bedding fault.

The Devonian strata upon which this thrust mass lies rest in turn upon Mississippian strata to the northeast and the trace of the contact shows the plane of contact inclines at a low angle to the southwest. The section then gives way to Devonian and Cambrian strata in orderly succession and at the saddle separating the spur from the steep slope below Salas Peak this section is brought against Pennsylvanian rocks by a high-angle reverse fault previously discussed.

As interesting as the imbricate faults themselves is the fact that the faults die out and appear to give way to a simple fold to the east. Eastward topographic relief is less, however, and the details of the transition cannot be observed. Enough may be seen, however, to state that these faults are not limited by any cross fault but merge into a simple fold from which they probably originated as bedding faults.

The series of strata in which Gordons and Muheims claims are located presents evidence of another well defined low angle reverse fault. Here a block of upper Paleozoic limestones about fifty feet thick passes upward into Mesozoic shales and quartzites and rests on a series of the same Mesozoic rocks. The Paleozoic limestones of the thrust block passes up into the Mesozoic shales in normal succession. Erosion has removed nearly all of the quartzite and shale lying above the overthrust limestone at Gordons claims but a considerable thickness of the overlying quartzites and shales is present below the Muheim claims (one-fourth mile east of Gordons claims) and at this place they form a prominent spur.

The thrust plane dips at an angle of about 40° to the southwest but flattens down dip. This flattening gives the limestone in which

Gordons mine is located a spoon shape. To the southeast it brings the Paleozoic limestone out from beneath the Cretaceous at the foot of the slope below Muheims claims.

On the spur immediately northwest of Gordons mine the limestone flares upward along the strike and accentuates the spoon shape of the overthrust block in this vicinity.

The thrust block is obviously cut off by a fault on the southwest and along this fault Cambrian to Mississippian strata contact the thrust block. To the southeast the limestone member of the thrust block is discontinuous and is, therefore, thought to be cut off by a cross fault. On the northwest and northeast the block is limited by its contact with the underlying Mesozoic shales.

The thrust block has been intensely mineralized. The limestone along the fault plane has been converted into a mass of solid garnet and epidote. Sulfide mineralization is seen in the prospects above the garnet zone. Solutions appear to have ascended through vertical cracks normal to the strike of the thrust plane and to have spread out into the limestone bed. The favorable character of the limestone as a locus of deposition may be due to its chemical composition, but since the mineralized bed is seen to be sheeted at a slight angle to the bedding, sheeting and ordinary brecciation are contributing if not governing factors influencing mineralization. In the prospects east of Gordons claims the intraformational movement is seen to even better advantage. Here on a slight warp, the beds have slipped and are slickensided markedly creating a formation intimately fissured and open. These structures are by-products of the force which caused the repetition of of the upper Paleozoic and Mesozoic section at this place.

The Gordons claims thrust mass does not appear to be related to the regional overthrust but is believed to be a fault associated with folding for the following reasons; (1) it is near an area of imbricate faults which have developed from an over-stressed fold, (2) the thrust mass is composed of younger rocks (Mississippian) than those of the regional overthrust sheet (Cambrian), (3) there is no reason to believe it could not have developed from a broken fold.

Middlemarch Canyon.- Mapping of the area in the vicinity of Middlemarch mine shows a wedge-shaped area of blue limestone capping the hill above the mine. The limestone is underlain by a thin siliceous bed. The contact with underlying rocks dips 20° to 30° southeastward.

The limestone bears poorly preserved horn corals, similar to those found in the Mississippian, as well as crinoid stems. Thus, from the lithology and fossil content, it is assigned to the upper Paleozoic.

These Paleozoic limestones rest on limestones in which a poorly preserved oyster was found and which are therefore, Mesozoic in age. The top of the hill, then is considered to be a small overthrust block. High-angle (normal?) faults of small displacement have somewhat destroyed the unity of the mass.

This Paleozoic mass is composed of younger strata than those making up the early overthrust sheet but its placement is similar to remnants of that sheet. It is tentatively classed with the faults developed after folding because it is composed of younger strata than the known early overthrust sheet, remnants of which entirely surround this area.

Early Overthrusting

Preceding the port-Cretaceous folding, a flat-lying sheet of lower Paleozoic rocks overrode the Mesozoic and upper Paleozoic strata. The thrust sheet was later folded and faulted, partly assimilated or stoped by a granitic intrusion and has suffered greatly from erosion. Portions of the thrust mass do remain, however, and crown the Black Diamond and less majestic peaks and lend further variety to an already complex area.

Grants Hill.- At the head of Sorens Canyon, on the northeast prominence known here as Grants Hill, a fine example of the overthrust sheet is displayed. The higher part of the hill is composed mainly of thin-bedded Abrigo limestone but on the northeast and southeast sides of the hill are outcroppings of the underlying Bolsa quartzite. These Cambrian strata rest on steeply dipping Mesozoic shales which pass entirely beneath the hill and appear again on the other side.

The strike of the thrust mass is northwesterly. On the southwest side of the hill the dip is about 45° to the southwest but on the northeast side the strata lie almost horizontally. In addition there are many local variations; an upcurling along the northwest margin and a sharp "roll" or minor fold in the center (across the strike) are the main irregularities.

The Bolsa quartzite thins from about 80 feet on the northeastern side of the hill to only a few feet on the south. It is not seen on the westerly side of Grants Hill and is thought to be sliced out. The southeastern eminence of the hill is capped by Abrigo limestone, whereas (due to the minor fold mentioned) the northwestern eminence of the hill is capped by beds thought to belong to the lower part of the Devonian.

The thrust plane itself was not observed, but the geology seen in a prospect developed in the base of the thrust block at the northeast end of Grants Hill is significant. Just west of the prospect the strata are contorted and roll considerably. In an adit extending 50 feet or more into the mountain are several zones of fissuring, both horizontal and dipping as much as 10° to the southwest. These are thought to be sympathetic with the overthrust fault. The strongest of these has been mineralized.

Above the adit a stripped face reveals interesting details. Here a flat zone of intense shear three feet thick is displaced a few feet by vertical cross faults. The strata beneath are torn and gougy while the upper material is not thus affected.

The rocks of the sole mass are a series of what appear to be metamorphosed shales; mainly black, with some ocasionally reddish in color, and having a rusty appearance. The writer believes them to be more closely similar to the Mesozoic shales than any other rock seen in the area and they are thus mapped. Eldred Wilson of the Arizona Bureau of Mines has seen these rocks and stated[1] that they do not appear to be similar to any of the pre-Cambrian of southern Arizona which he has seen.

The Grants Hill thrust mass, projected to the southwest across Sorens Canyon, is seen at the foot of the slope northeast and east of China Peak. The strata dip steeply to the southwest and indicate a fold-

1. Personal communication, Aug. 17, 1936.

ing of the thrust plane. Upper Paleozoics on the southwest are brought against these Abrigo strata by a high-angle fault which dips steeply to the southwest (Section A-A'). The Pennsylvanian limestones here are much brecciated, whereas the thin-bedded Abrigo limestone is crumpled.

The Abrigo limestone south of Grants Hill is terminated northwestward at the head of Sorens Canyon by a cross fault. The Abrigo limestone may be traced to the southeast for about half a mile where it gives way to metamorphosed Mesozoics rocks along another cross fault.

On the prominent spur extending northward from Cochise Peak are two small "islands" of thin-bedded Abrigo limestone, each of which is entirely isolated and rests on granite. They are remnants of the larger thrust sheet which covered this area; remnants in which the lower portion has been sliced off or replaced by granite.

The strike of the strata making up two small islands is northwesterly. The upper mass, containing not more than thirty feet of section, has, at its upper contact, a dip to the northeast. The dip flattens in a short distance and the larger part of the rocks present have a southwesterly dip. The lower mass likewise has a northeast dip at its upper contact but the lower part passes into at least two small folds whose axial planes incline southwestward. The sole of these masses is, for the most part, horizontal. The character of these masses is considered to definitely relate them to the Grants Hill sheet.

It would appear that here the thrust plane is arched over the main crest of the range but on the other hand, the two "islands" may have been lowered from their original position relative to Grants Hill during stoping by the granite. A small mass of quartzite on the south slope of Cochise Peak rests on the granite and is inclined to the southwest. This erosional remnant is considered to be Bolsa quartzite and before erosion it was probably continuous with the Grants Hill mass, a half mile to the northwest. Half a mile down the canyon from Sorens Camp on the northeast wall is a still smaller quartzite to which the same interpretation is applied. West of the Sentinel a third small quartzite mass is entirely similar in character to the two blocks described above.

The Sentinel.- The outstanding hill east of the Middlemarch Pass road where it crosses the divide (Fig. 1) is known as the Sentinel. It is a quartzite mass. The quartzite dips to the southwest, but the northeast portions of the mass have been dropped slightly by late normal faults so that the line of outcrop of the quartzite inclines to the northeast. Concealed from the traveler on the road by the bold quartzite strata on the crest of the hill, is at least 50 feet of typical Abrigo limestone above quartzite in the down-dropped northeastern block. The quartzite on which it rests and the quartzite forming the peak is, therefore Bolsa.

These Cambrian strata rest on intrusive granite and they are interpreted as being part of the thrust mass and once continuous with the strata capping Grants Hill and the erosional remnants on the walls of Sorens Canyon.

A small quartzite mass on the southeast wall of Middlemarch Canyon (northeast of the Sentinel) rests upon limestone conglomerate. Immediately to the northwest of this mass another may be found which rests upon upper Paleozoic limestones and half a mile to the northwest a third, very small, isolated quartzite mass also rests upon Paleozoic limestones. These are all considered to be Bolsa and part of the folded overthrust sheet of which a portion forms the Sentinel.

Black Diamond Peak.- Grants Hill, and to a lesser degree, the Sentinel, readily lend themselves to proof of the former existence of a large overthrust sheet. It is not as obvious at first that the same interpretation may apply to the Black Diamond Peak but, in the opinion of the writer, this is the only possible interpretation.

The view of Black Diamond Peak from Sorens Canyon trail, about a mile northwest of the Sentinel immediately suggests a comparizon with the Sentinel in the foreground. Both are predominantly quartzite masses resting on granite and Mesozoic shales and dipping (as a whole) northeastward. With respect to the folds both are located in structural positions which demand Mesozoic, or at least, upper Paleozoic sediments. The structural similarity of Black Diamond quartzite to the rocks capping the Sentinel and Grants Hill, and the fact that the quartzites forming Black Diamond Peak extend to a lower elevation and rest with angular unconformity on Mesozoic shale, are considered by the writer as sufficient proof that these rocks are the Bolsa quartzite.

Viewed from the southwest the quartzite capping the Black Diamond Peak makes a horizontal outcrop and presents a bold cliff. Upon closer inspection it is found that the main peak forming mass has the regional strike and dips 10° to 15° to the northeast. At the northeast rim of the quartzite crown the strata abruptly become horizontal and produce there, too, a sharp cliff.

On the north and northeast slopes, lower than the peak by two to five hundred feet, are large detached quartzite masses dipping 45° or more in a northeasterly direction. They suggest immediately slump masses derived from the peak or segments lowered by block faulting. Directly east from the peak the true relationship is clearly shown. Here one spur is less deeply cut than those to the north, and the quartzite of the peak descends 1,000 feet by gradual folding. The lower tip of this spur is connected laterally northward with a "detached mass" as described above.

If the quartzite masses were considered part of the Mesozoic shale series they should, if projected down dip, crop out as part of that series of rocks. Projection of any one of the quartzite masses, with ample allowance for folding, shows that they do not reappear where they would be expected if they were part of the Mesozoic series of strata. In fact, at no place in the Mesozoic section does a quartzite bed appear which is either very similar in lithology or comparable in thickness to the quartzite on the Black Diamond Peak.

Mapping in the Black Diamond area was continued southeastward for the purpose of including another quartzite mass located a mile and a half southeastward of Black Diamond Peak. Here, near the southeast corner of the map, a massive quartzite block rests upon upper Paleozoic limestones. The quartzite is entirely similar, lithologically, to the quartzite forming Black Diamond Peak, but was eroded to a thickness of hardly more than sixty feet.

The contact with the underlying limestones is clear. The quartzite and the limestone each show a ten-foot breccia zone at the contact.

This mass, lying within a syncline of upper Paleozoic rocks, is considered a thrust block of Bolsa quartzite similar in character and history to the Black Diamond, Sentinel and Grants Hill thrust masses. However, since quartzites are present in the Permain in the Santa Rita Mountains[1] and elsewhere, the possibility is admitted that this mass may be part of the upper Paleozoic sequence instead of an overthrust block.

Time of overthrust faulting.- In summary then, five well defined thrust masses of Cambrian strata are found in the area mapped. The Grants Hill block rests upon Mesozoic shales apparently several hundred feet above the base of the Mesozoic. The block at the mouth of Middlemarth Canyon rests on basal Mesozoic and uppermost Paleozoic strata. The Black Diamond block rests on Mesozoic shales perhaps as little as two or three hundred feet above the base of the Mesozoic and the southeasternmost thrust block rests on uppermost (?) Paleozoic rocks. The sole rocks beneath the Sentinel overthrust have been stoped out by granite but presumably it rested on basal Mesozoic conglomerate or uppermost Paleozoic rocks.

The overthrust fault plane therefore intersected uppermost Paleozoic or low Mesozoic beds. This strongly suggests that overthrusting on a moderately warped plane took place before folding; otherwise it would be expected that the overthrust plane would intersect the folded strata at many different horizons.

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1. Stoyanow, A. A., Paleozoic paleogeography of Arizona: Bull. Geol. Soc. America, Vol. 53, p. 1276, 1942.

It has been pointed out above that on the west wall of Sorens canyon (Section A-A', Fig. 2) upper Paleozoic limestones are faulted against Cambrian strata which are a continuation of the Grants Hill thrust sheet. This faulting, most probably associated with the main period of folding, was certainly later than the time of thrusting.

It is probably also significant that no trace of the thrust sheet is found west of the Dragoon fault (with the one exception in the southerly area noted above). Some remnants of the thrust sheet might be expected to be found on the high elevations on westerly side of the range and the fact that the overthrust is developed only in the footwall rocks on the eastern side of the range suggests that the regional folding movement on the Dragoon fault carried nearly all of the overthrust sheet to high elevations where it was subject to more rapid erosion than those portions east of the Dragoon fault.

The structure of the thrust masses does not coincide exactly with the underlying folds which were created later in time; parallelisms exist, as in the case of the (restored) thrust sheet across the mouth of Middlemarch Canyon (Section E-E', Fig. 2) but the Black Diamond and the Grants Hill blocks truncate the underlying strata. It is believed however, that the early thrust plane itself was warped and further, after initial movement of the overriding sheet occurred, there would be a tendency for the sheet to buckle as friction increased. The overriding sheet would then tend to fold (or fault) and assume attitudes greatly divergent from the underlying horizontal or low dipping beds. It is further entirely probable that during the folding which followed the overthrusting, the underlying pliable shales folded to a greater extent than overlying brittle quartzites of the thrust sheets. Hence, the discordance of folded structure between the sole and the thrust masses cannot be considered evidence that the thrust sheet was not involved in the regional folding.

MINERAL DEPOSITS

List of Minerals

The listed minerals below have been recognized in the hand specimen or in polished or thin sections under the microscope. Although a moderate number of minerals have been recognized from a routine study of a relatively few specimens taken in place and from dump heaps, it is altogether likely that others were found during the development of the Middlemarch and Black Diamond mines of which no mineral trace may be found at the present time. This is thought to be true of native gold and silver, in traces at least, and of many oxide minerals. On the other hand, it has been fortunate that a vanadium prospect has recently opened and brought to light, minerals which a few years earlier might have been unknown in this portion of the Dragoons.

<u>SULFIDES</u>:

<u>Galena</u> (PbS).- Galena has been found in the Middlemarch and Black Diamond mines, in the Gordons claims ores, and in several prospects. Under the microscope it was found to be contemporaneous with, or more generally later than sphalerite.

<u>Chalcocite</u> (Cu_2S).- Chalococite has been recognized under the microscope in material taken from a prospect located on the ridge one half mile south of Aerie Peak. It surrounds wedge-shaped residuals of

chalcopyrite and is obviously derived from it.

Sphalerite (ZnS).- Black sphalerite is developed in large masses in the Gordons claims but is also found less abundantly elsewhere. Brown, yellow and greenish sphalerite were also found at Gordons claims.

Covellite (CuS).- Covellite was found replacing chalcocite in ore from Gordons claims.

Bornite (Cu_5FeS_4).- Bornite was found in the polished section of a sample taken from the dump at the Black Diamond mine. It occurred as tiny blebs in a larger area of chalcopyrite.

Chalcopyrite ($CuFeS_2$).- Chalcopyrite, like sphalerite and galena, is present in many places. It is associated with those sulphides in many small prospects and in the Middlemarch and Black Diamond mines. In the latter mine it also replaces magnetite.

Pyrite (FeS_2).- Pyrite is associated with the sulphide minerals but it also occurs as euhedral grains in the albitic rhyolite porphyry and as metacrysts in the hornfelsic rocks at the head of Sorens Canyon.

OXIDES:

Quartz (SiO_2).- Quartz is an essential constituent of the granite and the albitic rhyolite porphyry present throughout the area and also makes up a large proportion of the Cambrian, Mesozoic, Tertiary and Recent sediments. Quartz veins are found in many places. Quartz in the form of chert is widely developed in the Paleozoic limestone as layers, nodules and irregular masses. Thoroughly silicified ledges of Devonian limestone have been described above.

Tenorite (CuO).- Copper pitch ore or tenorite replaces copper sulphides in a prospect one half mile south of Aerie Peak.

Hematite (Fe_2O_3).- Hematite was not recognized in the igneous rocks and was doubtfully present as small grains replacing sphalerite in ore from Gordons claims.

Magnetite (Fe_3O_4).- Magnetite is commonly present in minute amounts as a primary constituent of the igneous rocks and less commonly as a secondary mineral. In the lowest level of the Middlemarch mine it is abundant as acicular crystals replacing limestone.

Limonite.- Hydrated oxides of iron derived from primary iron bearing minerals are found on the outcrops of many mineralized veins. A pseudomorph of limonite after pyrite was found in a prospect near Gordons claims. Crusts of limonite are now forming in small pools on the floor of the Cobraloma prospect. It has resulted from the oxidation of iron-bearing solutions derived from the leaching of pyrite. Great masses of limonite are present in Black Diamond mine as secondary fissure fillings.

CARBONATES:

Calcite ($CaCO_3$).- Calcite makes up the great limestone beds so well displayed in the area and is also a hypogene vein mineral associated with oxide minerals. It has also been found to be supergene. It is being deposited at a seep in the lower level of the Black Diamond mine and much secondary calcite with limonite is also found there as a fissure filling.

Siderite ($FeCO_3$).- A cleavage rhomb of siderite was found on the dump at the Silver Cloud mine.

Malachite ($CuCO_3Cu(OH)_2$).- Malachite has been found only as thin coatings derived from the leaching of copper-bearing minerals but was seen in many old prospects.

Azurite ($2CuCO_3.Cu(OH)_2$).- Azurite is less common than malachite but is associated with it in several places.

SILICATES:

Orthoclase ($K_2O.Al_2O_3.6SiO_2$).- Orthoclase is an essential constituent of the granite and of the rhyolite dikes. In the rhyolite it occurs both as phenocrysts and in the ground mass. The glassy sanidine variety of orthoclase occurs as phenocrysts and in the ground mass of the sanidine rhyolite porphyry.

Microcline ($K_2O.Al_2O_3.6SiO_2$).- Small amounts of microcline have been found in this section of the Stronghold granite as well as in the granite of pre-Cambrian age.

Plagioclase ($Na_2O.Al_2O_3.6SiO_2$).- Albite is the only plagioclase recognized in the granites of the area. The plagioclases occurring in the diabase dikes were not determined.

Hedenbergite ($(Ca,Mg,Fe)O.SiO_2$).- Hedenbergite occurs as long flat blades, brown in color at igneous contacts in many places. In the Gordons claims it is associated with grossularite.

Tremolite ($MgO.SiO_2$).- A specimen of the fibrous masses developed in the Devonian and Mississippian limestone southwest of Salas Peak was determined to be tremolite. A specimen from a prospect near Gordons claims was likewise found to be tremolite.

<u>Hornblende</u> ($Ca(Mg,Fe)_3Si_3O_{12}$).- Hornblende was recognized in a thin section of the diabase dike present on the west slope of Cochise Peak. It exhibited an extinction angle of 27°.

<u>Grossularite</u> ($3CaO.Al_2O_3.3SiO_2$).- The grossularite variety of garnet is widely developed throughout the area. Most notable occurrences are along granite-limestone contacts, in the mineralized thrust of Gordons claims, with epidote in the metamorphosed sediments near Aerie Peak and as a two-foot wide vein of pure grossularite in limestone, well exposed on both sides of the arroyo just southwest of Salas ranch house.

<u>Zircon</u> ($ZrO_2.SiO_z$).- In a thin section of the Stronghold granite, grains of zircon within biotite were noted. They were surrounded by reaction rims of magnetite as a smokiness and as a solid black border.

<u>Epidote</u> ($H\ Ca_2(Al,Fe)_3Si\ O_{18}$).- Epidote is widely developed in the metamorphosed Mesozoic rocks making up the west wall of Sorens Canyon. Here it occurs as clusters or blotches in many places enclosing a center of grossularite. In other places it is in veinlets in this rock. The lamprophyre dikes have been strongly epidotized in places.

<u>Hemimorphite</u> ($2ZnO.SiO_2.H_2O$).- Oxidized material from the Muheim claims (just east of Gordons claims) gave an excellent test for zinc on the charcoal. Inasmuch as this material did not effervesce with acid (indicating smithsonite) it is considered to be hemimorphite.

<u>Muscovite</u> ($H_2KAl_3(SiO_4)_3$).- Muscovite is a constituent of the acid igneous rocks in the area. Sericite is an alteration product of some of the feldspar.

Biotite ($(H_2K)Mg,Fe)_3(Al,Fe)(SiO_4)_3$).- Biotite is also a minor constituent of the acid igneous rocks in the area.

Chlorite ($H_8(Mg,Fe)_5Al_2Si_3O_{18}$).- Chlorite is an alteration product of biotite.

Kaolinite ($Al_2O_3.2SiO_2.2H_2O$).- Kaolinization of the feldspars of the igneous rocks has been noted in thin section.

Chrysocolla ($CuO.SiO_2.2H_2O$).- A specimen of radiating crystalline chrysocolla was found on the dump of the Silver Cloud mine.

PHOSPHATES:

Apatite ($Ca(PO_4)_3CaF$).- In a thin section of the pre-Cambrian granite grains of apatite are enclosed by muscovite. Apatite has not been found in the younger granite.

VANADATES:

Vanadinite ($Pb_4(PbCl)(VO_4)_4$).- Vanadinite occurs in fissures in Escapules vanadium prospect (in the Cambrian limestones southeast of Grants Hill) as long acicular crystals, generally golden brown in color. The crystals are prismatic and are but rarely terminated by pyramids. Squat lozenge-shaped red hexagons have also been noted.

SULPHATES:

Barite ($BaSO_4$).- Barite replaces limestone in a prospect near the head of Santa Anna Gulch.

Anglesite ($PbSO_4$).- Oxdized material on the dump at Muheims claims (just east of Gordons claims), soluble with difficulty in hot acid, gave an excellent test for lead on charcoal. The lead mineral is considered to be anglesite.

MOLYBDATES:

Wulfenite ($PbMO_4$).- Associated with vanadinite, yellow extremely thin tabular crystals of wulfenite are found in fissures at Escapules vanadium mine. The basal pinacoids are modified by prisms.

The Mines

A brief description of the more important prospects and mines is given below. The total recorded value of ore mined from the area is about $235,000, entirely from the Black Diamond and Middlemarch mines.[1] Small shipments of silver ore from the Silver Cloud claims and some copper ore from the Muheims are reported by local people.

The Black Diamond

The Black Diamond mine was opened on a large scale around 1900 and at one time was equipped with a mill, smelter, an aerial tram system and a power plant. It failed to yield a profit and was closed a few years later. Sporadic work by lessees has taken place from time to time.

The mine is developed in a lenticular stratum of Mesozoic limestone about 40 feet wide. Adits at two different levels have sought to strike ore. The upper or Dividend level cut the ore zone and numerous stoped areas indicate a fair sized operation.

Two stopes were developed along fractures striking about north 50° west, the regional trend of the range. The fractures dip steeply to the southwest. Two strong cross fissures were also noted, but

1. Elsing, M. J., & Heineman, R. E. S., Arizona Metal Productions: Arizona Bur. Mines Bull. 140, p. 91, 1936.

they appear to carry no primary minerals. They have been enlarged by solution by meteoric waters.

The fissure system on the lower or Bagge level is similar to that on the Dividend level.

The mineral assemblage includes pyrite, chalcopyrite, bornite, magnetite, sphalerite and galena. Production of 1,100,000 pounds of copper is reported from the Black Diamond.[1] It was probably mined as chalcopyrite and bornite. A silver production of $3,000 is also reported but the source of the silver was not determined.

It is interesting to note that pyrite and chalcopyrite are abundant on the Dividend level but a short distance below in the Bagge level sphalerite and magnetite predominate indicating higher temperature deposition and probable marked decline in ore values with depth.

Middlemarch Mine

The Middlemarch mine is filled with water to the adit level and very little is known of its mineralogy or of the structures controlling the ore. The mine is located in Mesozoic limestones on the west limb of the Middlemarch syncline. The shearing and brecciation exhibited in the glory hole above the adit, however, connote a more complex geological history than simple folding.

According to Mr. E. J. Kelley[2] the mine was opened in 1895 by Mr. M. M. Gorman who operated it until 1910. The abandoned mill and

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1. Elsing, M. J. and Heineman, R., Arizona metal production: Arizona Bur. Mines Bull. 140, p. 91, 1936.
2. Oral communication.

the tailings pile indicate a once sizeable operation. The oxidized zone which extended down to about twenty feet above the adit, yielded ore of a high copper content in which the value of the gold and silver equalled that of the copper. The primary ore was of much less value.

From 1910 to 1915 the mine was idle but was again operated by lessees from 1915 to 1921. At that time the low price of copper and the water problem combined to make further mining unprofitable. The total production is listed as 265,000 pounds of copper and $10,000 in silver.[1]

Gordons Claims

The Gordon claims area, located about a mile south of China Peak, consists of two adits driven into the spoon-shaped thrust mass of Paleozoic limestones which rest upon Mesozoic rocks. The lower or San Juan adit faces the east and the higher Silver adit faces the south.

A few hundred feet of underground development reveal several intresting features. In the San Juan adit vertical fissures striking N30°E and N5°W are well marked. The bedding here is inclined at a gentle angle to the northeast and is intersected by a strong zone of sheet faulting dipping 25° to the northwest.

Black sphalerite is abundant in this level and the walls of the adit are cut for some distance in solid sphalerite without appreciable gangue. In about 160 feet a face of ore averaging more than six feet in height is exposed on one wall.

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1. Elsing, M. J. and Heineman, R., Arizona metal production: Arizona Bur. Mines Bull. 140, p. 91, 1936.

The upper or Silver adit likewise reveals a vertical fissure which strikes N25°W. The sheeting is pronounced on this level as well and is seen to roll and vary from horizontal to 30°. Sulphides are less widespread here and oxidized ore is found in the zone of sheeting.

The limestone mass in which the adits are driven is capped by Mesozoic shales. The sole of the thrust mass is heavily silicified and epidotized.

The interpretation here adopted is that ore solutions rose along the vertical fissures and spread out along the sheeted zones and were probably aided in so doing by the relatively impervious shale cover. Whether or not the solutions given off by the nearby igneous mass ascended along the thrust fault could not be inferred but it is quite possible that they did so.

Muheims Claims

Muheims claims, located on the spur to the east of the Gordon claims, are developed in an extension of the thrust mass described above but almost entirely separated from it by erosion. This prospect was not explored but at the adit strong fissures are present which strike N65°W and dip 60° to the southwest. Vertical fissures normal to these are also present. A sample from some heaps or oxidized ore gave excellent blowpipe tests for lead and zinc. Inasmuch as it was soluble with difficulty in acid, it is considered to be hemimorphite and anglesite rather than smithsonite and cerussite.

Many other prospects within the area are located, generally , on mineralized fissures having a regional trend of N55°W or in the sediments along the granite-sedimentary contact.

RESUME' OF GEOLOGIC HISTORY

The geologic history of the area may be summarized as follows:

In pre-Cambrian times igneous intrusion of older, probably schistose rock took place, since schistose fragments in the limited exposure of pre-Cambrian granite in this area indicate the presence of a previously existing rock of that character. At the end of pre-Cambrian time the region was eroded to low relief. The Paleozoic sediments deposited are typical of those in the southern and south-central Arizona sedimentary basin which existed from late pre-Cambrian time to the end of the Paleozoic era.

In shallow seas of late Middle Cambrian time the Bolsa quartzite and shaly sandstones of the Cochise formation were deposited. These quartzites were followed by shales and thin bedded limestones of the Abrigo of early Upper Cambrian age which lie disconformably upon them.

No traces of Ordovician or Silurian strata have been recognized.

Martin limestone of Devonian age was laid down upon Cambrian shaly limestone.

In Mississippian time massive limestones were deposited upon the Devonian strata. These were followed without recognizable lithologic break by even thicker limestones of Upper Carboniferous age. The absence of the upper Mississippian Paradise formation indicates a profound hiatus that occurred between early Mississippian and Upper Carboniferous times in this area.

A period of erosion followed and in Mesozoic times the encroaching seas trapped coarse local material brought out of the higher land areas and formed a basal limestone conglomerate. Shallow inland seas or lakes persisted through much of the remainder of Mesozoic time and a great thickness of shaly sediments was deposited. The depositional basin was for the most part unstable, for quartzites, arkoses, shales and limestones were deposited alternately and no single rock type appears to attain any great unbroken thickness. Tuffs, characteristic of the Mesozoic in other parts of southern Arizona, were not recognized. These sediments are correlated with the Bisbee group of Lower Cretaceous age.

Toward the end of Mesozoic time Paleozoic sediments were projected northeastward (?) over the area by thrust faulting and in places Cambrian strata came to rest upon Mesozoic shaly rocks. Later compressive forces threw the rocks into a system of broad open folds and reverse faults.

Shortly following, or perhaps concomitant with the later period of folding, a great mass of molten rock forced its way upward, stoping out large segments of rock in its path, pushing aside others and sending forth its hot liquors and gases through fissures and openings in its confining roof. Late high-angle faults of small throw record a gentle settling at the termination of the compressive and igneous activity.

Further folding, faulting or igneous activity is not recorded in this portion of the Dragoons and orogenic forces appear to have been spent. The intense compression had raised these rocks to higher elevations. Erosion followed and in part stripped the pile to its core and buried the lower lying bases in a heavy mantle of alluvium. At a late date a slight uplift or a change in the climatic cycle gave new vigor to the streams.

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~~3~~ 2 maps

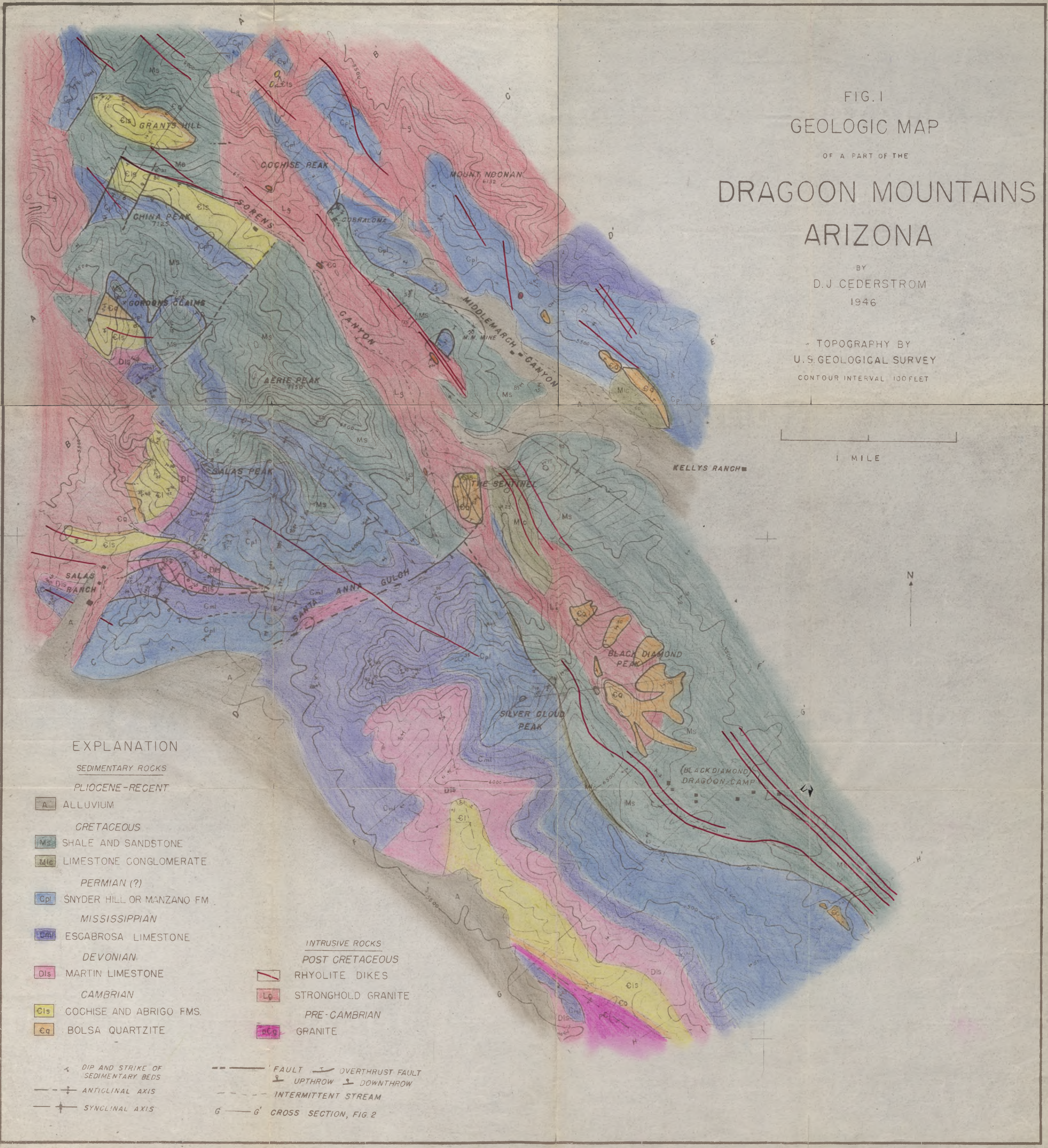
FIG. I
GEOLOGIC MAP
OF A PART OF THE
DRAGOON MOUNTAINS
ARIZONA
BY
D.J CEDERSTROM
1946
TOPOGRAPHY BY
U.S. GEOLOGICAL SURVEY
CONTOUR INTERVAL 100 FEET
1 MILE
N
GRANTS HILL
COCHISE PEAK
MOUNT NOONAN
CHINA PEAK
SORENS
CANYON
MIDDLEMARCH
CANYON
GORDONS CLAIMS
AERIE PEAK
SALAS PEAK
THE SENTINEL
KELLYS RANCH
SALAS RANCH
SANTA ANNA GULCH
BLACK DIAMOND PEAK
SILVER CLOUD PEAK
(BLACK DIAMOND) DRAGOON CAMP
EXPLANATION
SEDIMENTARY ROCKS
PLIOCENE-RECENT
A ALLUVIUM
CRETACEOUS
Ms SHALE AND SANDSTONE
Mlc LIMESTONE CONGLOMERATE
PERMIAN (?)
Cpl SNYDER HILL OR MANZANO FM.
MISSISSIPPIAN
Cml ESCABROSA LIMESTONE
DEVONIAN
Dls MARTIN LIMESTONE
CAMBRIAN
Єls COCHISE AND ABRIGO FMS.
Єq BOLSA QUARTZITE
INTRUSIVE ROCKS
POST CRETACEOUS
RHYOLITE DIKES
Lg STRONGHOLD GRANITE
PRE-CAMBRIAN
pЄg GRANITE
DIP AND STRIKE OF SEDIMENTARY BEDS
ANTICLINAL AXIS
SYNCLINAL AXIS
FAULT
OVERTHRUST FAULT
UPTHROW
DOWNTHROW
INTERMITTENT STREAM
G — G' CROSS SECTION, FIG. 2

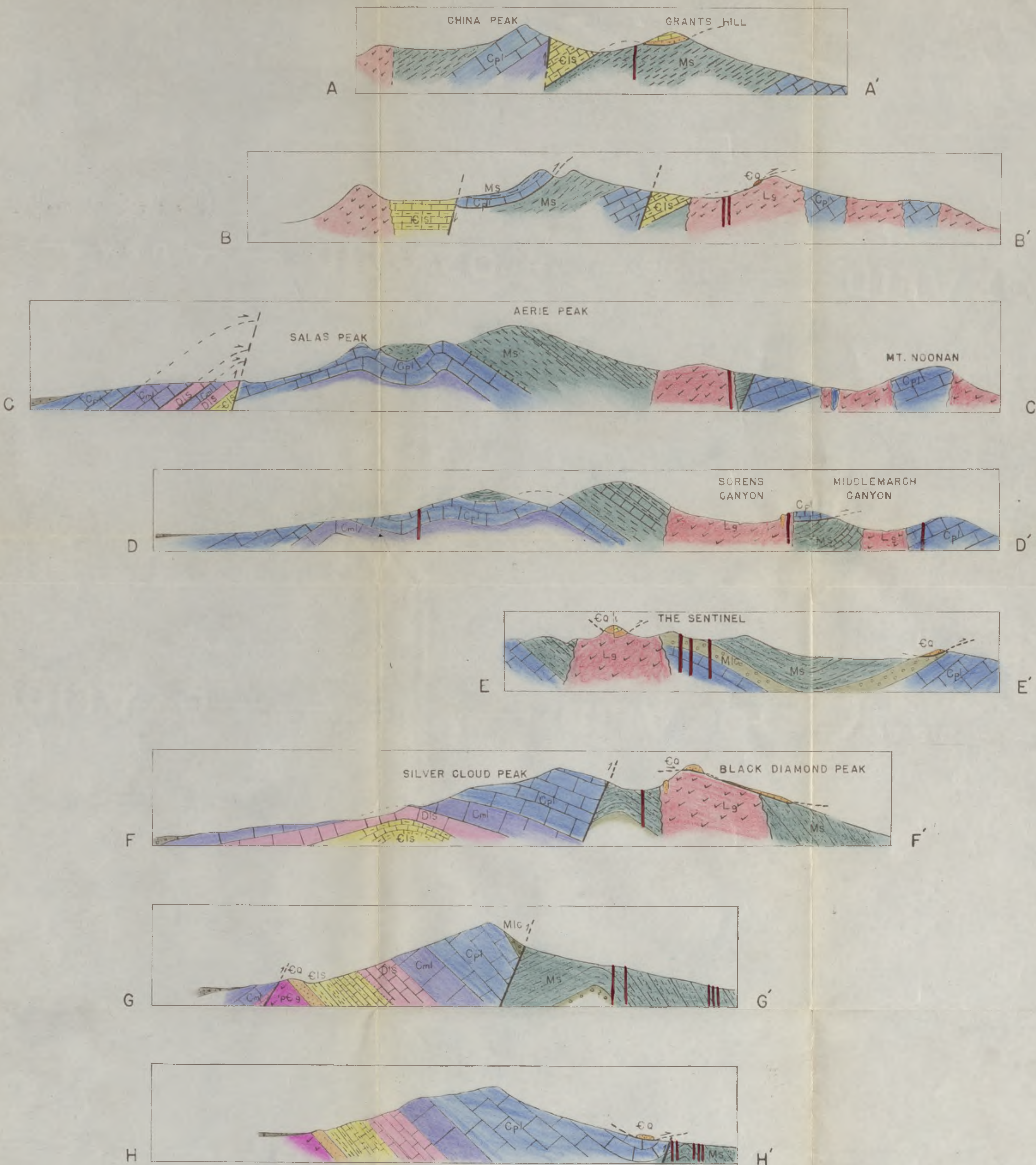

FIG. 2, GEOLOGIC CROSS SECTIONS

OF THE DRAGOON MOUNTAINS, ARIZ.

TO ACCOMPANY FIG. 1