THE STRATIGRAPHY AND STRUCTURE OF THE WATERMAN MOUNTAINS, PIMA COUNTY, ARIZONA

by

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ABSTRACT

The Waterman Mountains are located about 35 miles west of Tucson in Pima County, Arizona. In the Central and Eastern portion of the range the Pinal schist and Apache group are missing and a pre-Cambrian (?) granite underlies the Paleozoic sediments. The stratigraphy in the mountains includes the Cambrian Troy quartzite and Abrigo formation, the Devonian Martin formation, the Mississippian Escabrosa limestone, the Pennsylvanian Horquilla formation, the Pennsylvanian-Permian Andrada formation, the Permian Scherrer, Concha, and Rainvalley formations, and Cretaceous (?) strata. The sediments were deposited in a shallow, fairly stable basin. The Watermans were probably uplifted during the Laramide orogeny, when compressive stresses from the southwest pushed wedges of Paleozoic strata through the overlying Cretaceous (?) beds. The trends of the major faults within the mountains support the southwestern origin of compression with relatively older faults trending N. 45° W. and dipping southwestward. Relatively younger faults, probably tensional, trend N. 60°-70° E. and N. 85° W. Later Tertiary igneous intrusions are represented by rhyolite sills and dikes in the Cretaceous (?) sediments north of the range. The mineralization in the Watermans is probably related to the Tertiary igneous activity.

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ILLUSTRATIONS

INTRODUCTION

PURPOSE AND SCOPE OF STUDY

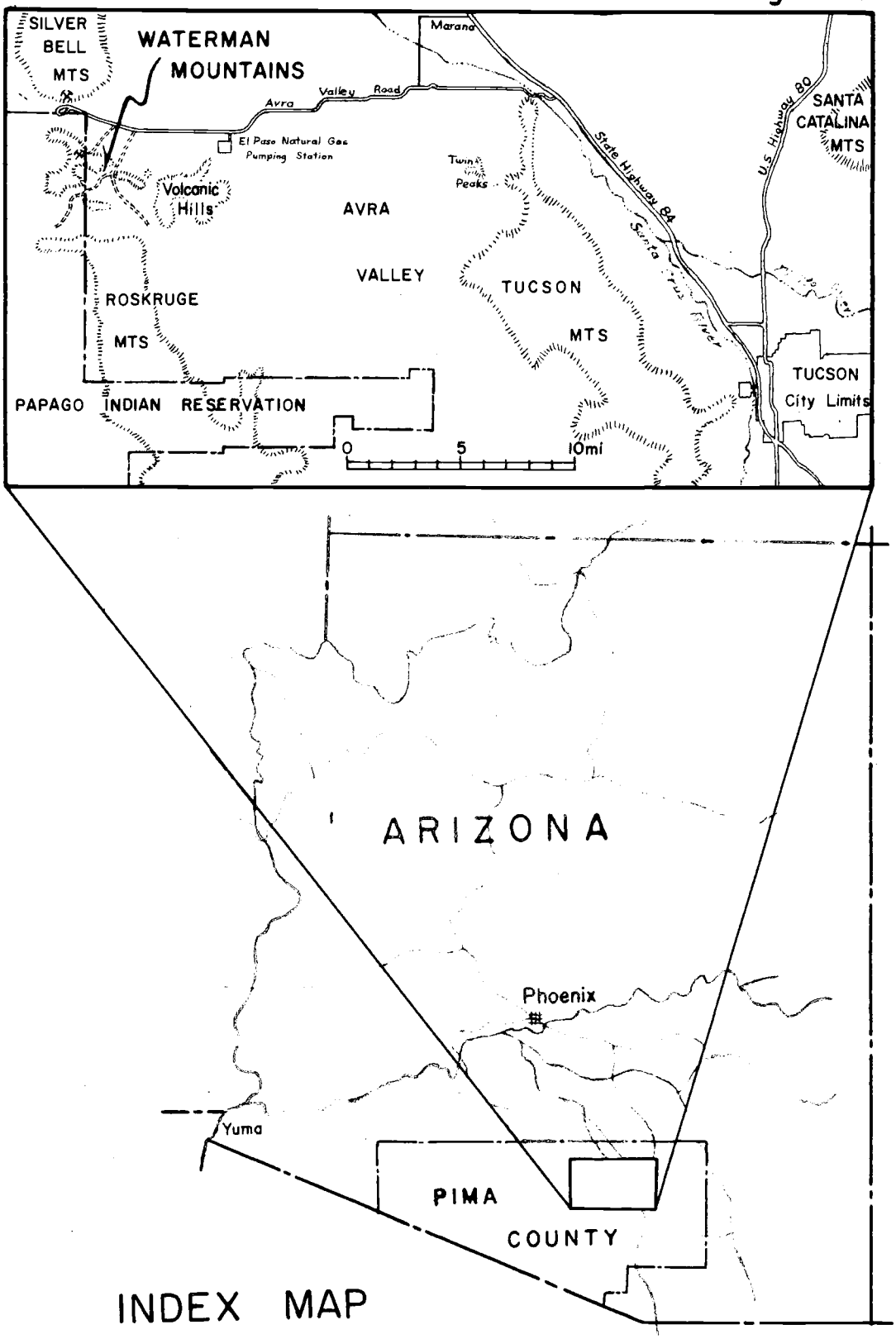
The Waterman Mountains, located about 35 miles west of Tucson, Arizona, are the resistant remnants of Paleozoic formations upthrown by high angle thrust faults. The formations present in the central and eastern portions of the mountains contain beds ranging in age from Cambrian through Cretaceous, with the usual exceptions, in southern Arizona, of the Ordovician, Silurian, Triassic, and Jurassic Systems. The structural complexity of the range was caused by the shearing and stresses of differential pressures during movement of the thrust block.

The purpose of this thesis is to map and study the geology of a portion of the Waterman Mountains. More specifically, the thesis includes a detailed section of Paleozoic and Cretaceous (?) beds involved in the faulting and uplift of the central and eastern portions of the range. Interpretation of the history of each unit, as to mode of deposition, paleogeography, and age, is discussed. Structural mapping and the interpretation of surfical features within the range were also accomplished.

LOCATION AND ACCESS

The Waterman Mountains, as defined in this report, are

Figure 1



INDEX MAP
of ARIZONA showing location
of WATERMAN MOUNTAINS

the range of hills extending southeastward from the Silver Bell mining camp (Figure 1). The central and eastern portions of the mountains are included in sections 25 and 36, T. 12 S., R. 8 E., and in sections 29, 30, 31, 32, and 33, T. 12 S., R. 9 E. The area covered in the thesis problem is about 3 miles long in an east-west direction and 1.6 miles wide, narrowing to 0.8 miles wide at the eastern end. The hill to the west was studied in a general reconnaissance and the geology is represented on the geologic map (Plate I), but it is not considered as part of the thesis area.

The Waterman Mountains are easily accessible from Tucson. Proceeding northward on Highway 84, from the Tucson city limits, one drives 15 miles to the junction with the Avra Valley road, which is a wide, paved road directed westward for 15.2 miles across the Avra Valley. On the west edge of the valley is the El Paso Natural Gas Company pumping station. Beyond the road turning into the pumping station, the main road narrows but remains paved to the Silver Bell mining camp. From a point 3.8 miles west of where the road narrows, an unimproved road leads southward through a gap which divides the thesis area into two parts. The road forks at several places providing access to various parts within the area; other roads continue into the Papago Indian Reservation to the west and to Mr. F. O. Bone's ranch to the south. Old mine roads, which lead to the unpatented, abandoned mine (Plate I) are presently impassable

for automobiles.

The town nearest the area is Marana, situated 20 miles northwest of Tucson on Highway 84. A shopping center and community of homes and trailer houses are located at the Silver Bell mining camp.

TOPOGRAPHY

The Waterman Mountains are located in the eastern part of the Sonora Desert Region. This region has many of the characteristics of the Basin and Range Province. Generally, the Sonora Desert Region is made up of basins and a series of small mountain ranges trending northward to northwestward. The basins are broad alluvial outwash plains and pediment slopes; they usually make up over 70 percent of the total area.

The Waterman Mountains are bounded on the north by the pediment slope of the Silver Bell Mountains and a few volcanic hills projecting above the alluvium; on the northwest by the north-south trending Silver Bell Range; and on the west and southwest by a basin, which is part of the Papago Indian Reservation. To the south is a low, east-west ridge of Permian limestone, which has been thrust onto Cretaceous red beds along a low angle thrust plane. Further southeast lie the Tertiary (?) volcanic rocks of the Roskruge Mountains. East of the Waterman Mountains is a low range of hills composed of volcanic and shallow intrusive rocks, which are

possibly related to the igneous rocks in the Roskruge Range. Although these hills to the east are topographically continuous with the Waterman Mountains, they are not included as a part of the Watermans in this report.

The Waterman Mountains are roughly triangular in outline. The east end of the range trends nearly east-west and the west end trends more toward the northwest. The mountains may be divided into four parts: Eastern, Central, Southwestern, and Northwestern portions. The Eastern portion is a hogback of late Paleozoic rocks which rises to an elevation of more than 2,900 feet above sea level, or about 600 feet above the surrounding lowland. The Central portion of the range is 3,200 feet in elevation at the eastern end and 3,700 feet in the western part. Waterman Peak, the highest point in the area, is 3,820 feet above sea level. The early Paleozoic rocks in the hills forming the Southwestern portion of the triangle are 3,600 feet high immediately south of the thesis area and decrease in elevation toward the southwest. The fourth division is the Northwestern extension of the range, lying between the Silver Bell mining camp and the Indiana-Arizona mine. This ridge is from 300 to 500 feet above the lowlands.

There are no permanent streams in the area. Some of the larger washes have cut valleys along major faults and some follow the less resistant shale and sandstone beds. The courses of the

minor streams on the hills are commonly controlled by faulting.

CLIMATE

The climate of the Waterman Mountains area is like that of the other parts of the Sonora Desert Region. Normal rainfall is up to 12 inches per year, the greatest amount falling during July and August. The temperature ranges from more than 110° F. during the day to about 60° F. at night in the summer months. The temperatures during the winter season are usually less than 80° F. during the day and more than 20° F. at night.

METHOD OF STUDY

Field work in the Central and Eastern portion of the Waterman Mountains made up the major portion of the study for this thesis. The field work was done throughout the 1955-1956 school year. Mapping was done on aerial photographs to the scale of 1:3,350. The photographs were taken April 23, 1956. The final map was reduced to a scale of 1:6,000 (1" equals 500') when transferred from the photographs to the base map.

No large scale topographic map of the Waterman Mountains is available. The contours on the base map were adapted from aerial photographs (Soil Conservation Service, February 1936, scale - 1:12,000), with elevations obtained by a Paulin altimeter. The contour lines were drawn with the aid of a pocket sterescope and can be con-

sidered no more accurate than their interval, 50 feet. Horizontal control is completely lacking; therefore, the distortions of the photographs were transferred onto the topographic map.

The Paleozoic formations were measured in detail. The sections of the Cambrian Troy and Abrigo, Mississippian Escabrosa, and Permian Concha and Rainvalley formations were taken from continuous outcrops, for the most part. The Devonian Martin, Pennsylvanian Horquilla, Pennsylvanian-Permian Andrada, and Permian Scherrer formations, though, are crumpled to some extent; therefore, composite sections had to be taken.

PREVIOUS WORK

The Waterman Mountains were mapped in 1924 by E. D. Wilson and C. Lausen. The results are presently shown on the State of Arizona Geologic map at a scale of one inch equals eight miles (about 1:500,000). A detailed study of the Northwestern extension of the range, primarily a study of the Indiana-Arizona mine, was accomplished by A. W. Ruff (1951, thesis). No detailed geologic mapping has been completed previously on the Central and Eastern portions of the Watermans nor on the Southwestern portion.

ACKNOWLEDGMENTS

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thesis. Acknowledgment is due F. W. Galbraith for assistance given during the course of the study and also due the members of the faculty and the graduate students of the geology department for their constructive comments and criticisms.

STRATIGRAPHY

GENERAL

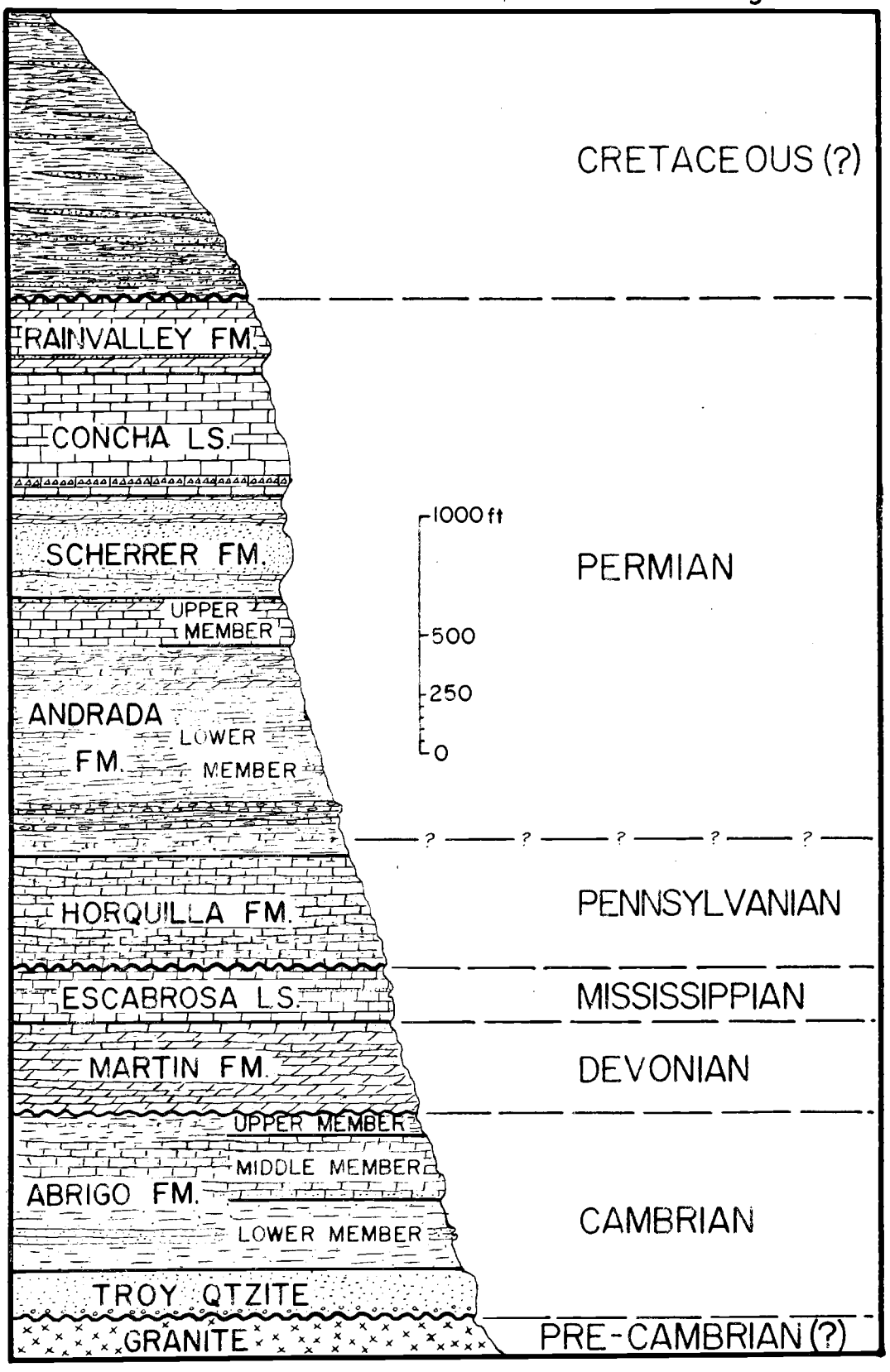
The entire sequence of Paleozoic formations lies in apparent conformity in the Waterman Mountains (Figure 2). Intervals between depositional periods have left no mark at the top of the older beds nor at the base of the younger. A prominent exception to this generalization, and the only apparent exception, is the red chert layer between the Mississippian Escabrosa limestone and the Pennsylvanian Horquilla formation. Plate III is an idealized columnar section at the Waterman Mountains.

The older rock formations within the thesis area are confined to the western part of the Central portion of the Waterman Mountains. Progressively younger beds crop out eastward and northward, with a few reversals due to the large fault displacements.

The Troy quartzite of the Middle Cambrian Series is the oldest sedimentary formation in the Waterman Mountains. The quartzite has coarse to medium sized, poorly rounded sand grains and is stained reddish by iron oxides. It apparently overlies a granite of undetermined, but probably pre-Cambrian, age.

The Abrigo formation of Middle and Upper Cambrian age lies above the Troy quartzite in conformable sequence. In the

Figure 2



Generalized Geologic Column at the Waterman Mountains

Waterman Mountains, the Abrigo may be divided into three members: the greenish-brown, micaceous shale lower member, the limestone middle member, and the green shale upper member.

The Upper Devonian Martin formation contains chiefly light brown to gray and rust-colored silty dolomites. The Martin lies with apparent conformity on the Cambrian Abrigo formation.

The Escabrosa limestone of Lower Mississippian age forms a prominent cliff wherever present in the Waterman Mountains. This formation is composed of nearly pure, massive limestone and is capped by a thick layer of crinoidal limestone.

The Horquilla formation is Pennsylvanian in age. It contains alternating resistant and non-resistant beds of predominantly limestone and silty limestone. At the base of the Horquilla is a 15- to 20-foot thick bed of red chert in a pebble conglomerate. The upper boundary of the formation was picked, arbitrarily, below the first mottled green and red shale layer of the Andrada formation.

The Andrada formation may be divided into two members in the Waterman Mountains. The lower member consists of interbedded limestones, dolomites, shales, siltstones, and limestone conglomerates. The upper member is composed of dark gray fossiliferous limestone and a few dolomite beds. The Pennsylvanian-Permian time boundary probably exists somewhere in the lower part

of the Andrada formation. The contact between the upper member of the Andrada and the Scherrer formation is usually obscure; it is commonly faulted or covered by talus.

The Scherrer formation contains a lithologically complex group of siltstones, silty limestones, and limy sandstones near the base and more homogeneous beds of sandstones and silty dolomites in the upper part. The upper contact is placed below the first massive, cherty limestone of the Concha formation.

The Concha and Rainvalley formations are composed chiefly of dark gray, fossiliferous limestone. The Rainvalley is characterized by thinner beds and dolomite layers, which are lacking in the Concha section.

As far as can be determined through fossil evidence, the Rainvalley limestone represents the uppermost Permian unit in the Waterman Mountains. About 1,200 feet of quartzitic sandstones and shales overlie the Rainvalley along the north front of the range. These beds appear to have the same attitude as the Permian formations below them, but a considerable portion of the sandstone is missing toward the west, probably due to faulting. These sandstones and shales have been tentatively dated as Lower Cretaceous because of their resemblance to the Amole arkose beds in the Tucson Mountains. To the north of the Watermans on the lowlands, and to the south, Cretaceous (?) red beds crop out in patches where erosion has cut through the Recent alluvial cover.

CAMBRIAN SYSTEM

Troy Quartzite

The Middle Cambrian Troy quartzite crops out at several localities near the west end of the thesis area (Plate V B.). The outcrops are discontinuous because of major fault displacements. The quartzite is commonly fractured by minor normal faults and bedding plane faults. At most localities the Troy forms a sloping cliff of prominent reddish-brown hue and is easily recognizable.

The Troy quartzite is made up of poorly rounded quartz grains cemented by silica. The cement is firm enough to cause the grains to break upon fracture of the rock. The grains range from granule to silt size and are clear to milky white. The red or brownish color of the rock is due to the iron content, present either as iron stains or in the form of limonite and small pseudomorphs after pyrite. The iron minerals exist throughout the thickness of the formation, although some layers have a greater concentration. The lower 20-foot unit of Troy is partially conglomeratic, with a larger accumulation of granule-sized quartz grains. Between the larger grains are sand and finer-grained material that make up the bulk of the rock. The weathered surface of the quartzite is from white to brown, glassy in appearance, and blackened by desert varnish in places.

The greatest thickness of the Troy quartzite is in the appar-

ently complete section northwest of Waterman Peak, where the Troy is about 220 feet thick. Ruff (1951, p.14) stated that the thickness of the quartzite is 185 feet in the Northwestern portion of the range, though he notes a thinning to the west. Thinning of the formation or faulted contacts may cause the differences in the thickness. Wherever the contact between the Troy and underlying greenish granite is exposed, there is evidence of faulting. However, there is no known evidence in the Central portion of the Waterman Mountains to indicate the displacements of the faults or the amount of strata missing due to the faulting. Because of the conglomeratic unit at the base, though, it is interpreted in this report that the faulting is either of small displacement or in the nature of a bedding plane fault, with little or none of the section missing. In other places in the Central portion of the range where the Troy is exposed, the thickness is always reduced by faulting.

Cross-bedding is common throughout the formation, but the cosets are rarely over 4 feet thick and extend laterally with little change of thickness. The cross-bedded laminae are thin, from 0.5 to 5 mm thick, and faint, usually accentuated only by concentrations of iron minerals or differential weathering on the surface. Looking at the formation from a short distance away the cosets of the cross-beds appear to be bedding planes, and probably are.

No fossils were found in the Troy quartzite within the thesis area. The formation was identified by its stratigraphic position and lithologic character. The age was presumed to be the same as the Troy quartzite in southern and central Arizona where fossils have been identified as Middle Cambrian.

Abrigo Formation

Where the contact is not covered by debris, the Abrigo formation appears to be conformable on the Troy quartzite. The three members of the Abrigo crop out along the western edge of the thesis area (Plate VI A.) and on the east-west ridge to the northeast of Waterman Peak. The upper and lower members, composed of siltstone and shale, form partly covered slopes, whereas the limestone middle member forms a prominent cliff. Other outcrops of the limestone member are wedged into the Andrada formation in the interior area of the Central portion of the Waterman Mountains, as are the Devonian Martin and Mississippian Escabrosa formation. The Abrigo formation is 708 feet thick at the west end of the thesis area.

Lithologically the Abrigo may be divided into three members in the Waterman Mountains: the greenish-brown, micaceous shale lower member, the limestone middle member, and the green shale upper member. The nomenclature used by Ruff (1951, pp. 16-24)

for the Cambrian system is not used in this report, although direct correlations may be made between the Central and Northwestern portions of the Waterman Mountains. The lower and middle members of the Abrigo formation as used here are equivalent to Ruff's Cochise formation. The upper member of the Abrigo is equivalent to his Abrigo formation.

Lower member. - The lower member of the Abrigo formation lies with apparent conformity on the Troy quartzite, although at most localities the contact is faulted. The lower member is 275 feet thick and contains siltstone, shale, and sandstone. The lower 180-feet of the member is composed of alternating beds of green shale and yellowish-green to brown siltstone. Thin sandstone beds are scattered throughout this portion. A 5-foot thick unit of sandstone is present about 130 feet above the base of the Abrigo formation. The sandstone unit has beds from 0.2 to 1 foot thick, and is very light brown to dark reddish-purple. This unit seems to grade laterally into siltstones. Within the 180-foot portion of the lower member, shale predominates below the 5-foot sandstone unit and siltstone predominates above.

This lower 180 feet of Abrigo formation is similar to the lower sequence of the lower Cochise formation in Ruff's (1951, pp. 16-21) report on the Northwestern portion of the Waterman Mountains. Also this sequence of rocks may be correlatable with the Santa

Catalina formation as described by Stoyanow (1936, P. 476) in the Santa Catalina Mountains, north of Tucson; and the Santa Catalina formation as described by Carpenter (1947) in the Vekol Mountains, 40 miles west of the Waterman Mountains.

Overlying the 180-foot portion of the lower member are two sandstone units separated by brownish and greenish shales and silt beds. The sandstone units form small ridges in the generally non-resistant lower member. The lower sandstone unit is 11 feet thick, with beds from 0.2 to 1.5 feet thick. The beds are predominantly grayish-brown, medium- to fine-grained sand near the base and grayish-green, fine-grained sand near the top. The sandstone weathers light brown and gray to black, with a glassy surface. Vague ripple marks exist on the upper surface of several of the sandstone beds and at the top of the lower sandstone unit the ripple marks are well developed. Cross-bedding is also best developed in the upper part of the unit.

The middle shale and siltstone beds are 13.5 feet thick with individual beds 0-1 to 0.6 feet thick. The upper sandstone is predominantly silty with scattered medium- to coarse-grained particles. The upper part of this 5-foot thick unit weathers dark gray and is visibly porous on the surface.

The two sandstone units with the middle shale and siltstone beds are about 30 feet thick and seem to correlate with the Southern

Belle quartzite of the Santa Catalina Mountains (Stoyanow, 1936, p. 476) and the Vekol Mountains (Carpenter, 1947). However, overlying the sandstone in the Waterman Mountains are more siltstones and shales instead of the limestone of the Abrigo formation that occurs in the localities just mentioned. These siltstones and shales, though, are calcareous and may represent a facies change from the lower part of the Abrigo limestone in the Santa Catalina and Vekol ranges.

The upper part of the lower member of the Abrigo formation is about 65 feet thick and is composed primarily of olive gray siltstones interbedded with green shales. The upper one-half is more limy and slightly more resistant than the lower half. Both parts usually are slope-forming, but a few fairly resistant beds form ledges in places. The lower member of the Abrigo formation is perfectly conformable and grades into the middle member.

No fossils were found in the lower member of the Abrigo formation except for vague outlines of worm borrows in the siltstones of the lower part of the section.

Middle member. - The middle member of the Abrigo formation is chiefly a massive gray limestone, pock-marked by brown silt concentrations. The weathered surface is usually light gray to blue with the silt concentrations weathering rust-colored. Thin beds of flat pebble conglomerate exist in the upper part of the

member. The middle member is 262 feet thick near the western margin of the Central portion of the Waterman Mountains.

The lowermost 26.5 feet of the member is composed of very silty, very finely crystalline, thin-bedded limestone. The beds are usually from 0.1 to 0.8 feet thick. The limestone is dark gray, with a yellowish tinge where the silt content is high. Overlying the silty limestone is a relatively more pure, thicker-bedded limestone, which is 65 feet thick. The beds are from 5 to 15 feet thick and fracture into rectangular blocks. The limestone is dark gray and very finely crystalline. In part, the limestone appears conglomeratic on the weathered surface, with connected silt stringers encircling pebble-sized limestone nodules. Above the blocky limestone beds is a 4.5-foot unit of very silty limestone, colored dark gray with a yellowish tinge, and very finely crystalline. This unit has beds from 0.3 to 1.5 feet thick and weathers from gray to brown and yellow with a granular texture. The 65 feet of limestone, with the 4.5-foot cap, forms a prominent cliff.

Immediately above the silty limestone unit is 166 feet of limestone with green shale partings. The shale is predominant in the lower 20 feet of section, and bedding plane thrusting is common in this weak zone. The limestone resembles the underlying 65-foot cliff-forming section, except that it is thinner bedded and crops out as a sloping, many-ledged cliff. A few beds of pebble conglomerate,

usually less than 0.5 foot thick, are in the upper part of the 166-foot unit. The pebbles are flat, rounded ovoids in a silty limestone matrix. Near the top of this unit, shale beds again become thicker. The upper boundary of the middle member was placed below a 33-foot green shale layer which is assigned to the upper member.

No fossils were located in the middle member. A direct correlation can be made between this member of the Abrigo in the Central portion of the Waterman Mountains and the upper part of the Cochise formation mapped by Ruff (195, pp.16-22) in the area to the northwest. The middle member may correlate with the Abrigo formation in the Santa Catalina Mountains (Stoyanow, 1936, p.476) and in the Vekol Mountains (Carpenter, 1947).

Upper member. - The upper member of the Abrigo formations is a 171-foot thick section of shales with intercalated limestone beds in the lower two-thirds and silty, calcareous to dolomitic, marl-like material in the upper third. The lower 33 feet, lying conformably on the middle member, is composed of olive gray, micaceous, silty shale with a few beds of flat pebble limestone conglomerate usually less than 0.5 foot thick.

The succeeding unit is 85 feet thick and consists of interbedded limestones and shales. The shale is olive gray to green and silty, usually in beds from 3 to 10 feet thick in the lower part, be-

coming thicker in the upper part. The limestones are of three types: massive limestone, mottled with concentrations of silt in stringer form; thin-bedded, flat pebble limestone conglomerate; and beds of granule-sized limestone nodules with a silty lime matrix. All three types are in the lower 35 feet, but only the massive limestone is present in the upper 50 feet of the 85-foot unit. The limestone weathers gray, partly light olive gray, and the silty portion weathers light brown to brownish-black. The limestone beds are usually from 0.5 to 1.5 feet thick and are resistant, forming small ledges in the generally non-resistant upper member. The shale becomes calcareous near the top of the unit.

The uppermost 53-foot unit of the upper member consists of a silty marl-like material with a light gray color. The surface is weathered to a yellowish-brown or light brown color and has a chalky appearance. The unit is mainly non-resistant, but there are some beds of more resistant silty limestone and dolomite. Two prominent beds of resistant silty dolomite crop out near the middle of the unit. These are 1 to 2 feet thick, and are useful as marker beds because of their rust-colored weathered surface. The whole unit generally grades from calcareous material near the base to dolomitic material near the top.

The contact between the Cambrian and Devonian deposits is not clear. There appears to be no unconformity between any of

the beds within the thesis area. West of the area, however, in W 1/2 NW 1/4 SE 1/4 Section 25, T. 12 S., R. 8 E., vague indications of an erosion surface exist. No positive evidence was found; the supposed erosion surface may be a minor bedding plane thrust fault.

The upper member of the Abrigo formation is equivalent to the Abrigo formation as used by Ruff (1951, pp. 23-24). Ruff described pinkish, calcareous, very fine-grained sandstone at the base of his "Abrigo formation", whereas in the Central portion of the Watermans the basal part of the upper member of the Abrigo is a greenish shale. The upper 138 feet of the Abrigo, however, is similar in both areas. Ruff described a few trilobites from the limestone beds in the lower portion of his "Abrigo". These trilobite zones were not found in the Central portion of the range. Concretions or worm borrow casts in the shale layers, as described by Ruff, also are found in the Central portion of the Waterman Mountains.

Stoyanow (1936, p. 476) described the Peppersauce Canyon sandstone as the uppermost Cambrian formation in the Santa Catalina Mountains. The sandstone is composed of alternating pink quartzites and brown, calcareous sandstone beds, 21 feet thick in the Santa Catalina Mountains. The upper member of the Abrigo formation in the Waterman Mountains may possibly be equivalent to the Peppersauce Canyon sandstone, although the lithology is not similar.

DEVONIAN SYSTEM

Martin Formation

The Martin formation overlies the upper member of the Abrigo formation in apparently perfect conformity in the thesis area. The time lapse between the deposition of the Abrigo and Martin strata is great, with the Ordovician and Silurian Systems missing. The contact between the two formations appears almost gradational; although the position of the contact itself may be subject to question. An erosion surface (or bedding plane thrust fault) which was designated as the contact by the author, to the west of the thesis area, was so chosen because beds more typical of the Abrigo formation lie below and beds more typical of the Martin lie above; thus the contact was chosen strictly by comparative lithology.

The Martin crops out beneath the Escabrosa cliff at the west end of the thesis are (Plate VI A. and B.). Also, wedges of the Martin, as well as of the Escabrosa and Abrigo limestones, are located in the interior part of the Central portion of the range. A thin wedge of questionable Martin lies north of the low ridge immediately south of the Waterman Mountains proper. The total thickness of the Martin formation is 373 feet; however, bedding plane faulting and high angle thrust faults nearly parallel to the bedding planes may have caused elimination or repetition of some beds. A composite section was measured in the attempt to establish a reasonably accurate

and complete sequence.

The lowermost 236 feet of Martin is various shades of gray, very finely crystalline, silty dolomite. The lower portion is partly calcareous. Some beds through the sequence are mottled yellow or red where silt or iron oxide is concentrated. The beds of the 236-foot sequence are from 0.2 to 7 feet thick and are from resistant to non-resistant, forming a step-like slope. The surface weathers chiefly to grayish-orange or gray and usually is smooth with a silty texture. Less resistant beds are commonly covered by talus, but some crop out in places. These beds consist of gray dolomite in the form of cobble-sized nodules enveloped in a marl-like matrix. This type of rock seems to be typical of all the less resistant, partly covered units through the sequence.

Certain beds in the 236-foot sequence have one or more of the following distinguishing characteristics: stringers and nodules of silt, calcite veins, calcite or quartz blebs, red iron oxide spots, siderite blebs and small pseudomorphs after pyrite, or peculiarities of the weathered surface. A 2-foot bed, 73 feet above the base of the sequence contains elongate, branching calcite nodules that appear to be either Cladopora, a similar tabulate coral, or possibly a trepostome bryozoan. A bed, 2.5 feet thick and lying about 85 feet above the base, appears to be conglomeratic and contains poorly preserved brachiopods and crinoid stems. A dark gray weathering bed, 7.5 feet thick and 171

feet above the base, has light brown calcite nodules which may be recrystallized fossil remains.

Much of the upper part of the 236-foot sequence has been fractured and altered by recrystallization in the Central portion of the Waterman Mountains. The section was measured below the cliff of Escabrosa limestone to the west of the area, where a nearly undeformed section of Martin formation occurs. Within the thesis area the upper 120 feet of the sequence has been replaced by orange-red, medium crystalline dolomite that is highly fractured in places. The fractures are filled by white, coarsely crystalline dolomite, which breaks into nearly perfect rhombs. White and gray siliceous material appears in stringers throughout the recrystallized section and a 4-foot thick siliceous lens is near the top at some places.

Cladopora and small brachiopods are the lowest recognizable fossils appearing in the Martin formation. They occur in a 3.5-foot thick bed about 240 feet above the base of the Devonian. In the 18-foot unit above the Cladopora zone are spiriferid, rhynchonellid, and small smooth-shelled brachiopods, gastropod outlines, horn corals, and Aulopora. The dolomite containing these fossils is gray to dark gray, finely to very finely crystalline, and silty, weathering olive gray to brown, partly pink.

Overlying the fossiliferous unit is 21 feet of less resistant silty dolomite with numerous red iron oxide spots and calcite blebs. Another fossiliferous unit, 22 feet thick, crops out above the less

resistant beds; here Cyrtospirifer whitneyi, Spirifer orestes (?), Spirifer euryteines (?), Tenticospirifer cyrtiniformis (?), Theodossia (?), Atrypa, Cyrtina (?), Schuchertella, Heterophrentis (?), Cladopora, and Aulopora were recognized.

The uppermost 42-foot unit of the Martin lies above another non-resistant layer, which 29.5 feet thick. The 42-foot unit is resistant, medium to light gray, finely crystalline, silty, limy dolomite and limestone. The rock is partly mottled and banded with concentrations of brown silt. The weathered surface is mostly yellowish-brown, generally darker than the underlying beds, and has a granular texture. The calcite blebs in these beds appear to be recrystallized fossil remains, and crinoid stems were found about 30 feet from the top of the unit.

A thrust plane separates the Martin formation from the overlying Escabrosa limestone at all points where the contact is exposed within the thesis area. At some places, the plane is a zone of thinly fractured rocks up to one foot thick; elsewhere it appears only as a wavy line marking the contact between rocks of different lithology. In both cases, little if any of the Martin or the Escabrosa appears to be missing. No conglomeratic beds were noted to indicate any soil zone or unconformity between the upper Devonian and Mississippian beds.

A considerable difference exists between the measurements

of the Martin formation in the Central and Northwestern portions of the Waterman Mountains. Ruff (1951, pp. 24-28) assigned 330 feet to the Devonian in the Northwestern portion of the range, whereas the author of this report assigns 373 feet to the Devonian. The difference apparently lies in the placement of the upper boundary of the Martin formation. The author distinguishes the Martin entirely by lithology, since fossils are rare or missing the lower and the highest units of the formation. The Martin-Escabrosa contact is placed at the base of the cliff-forming, massive limestone, the first limestone free of dolomite. Ruff evidently placed the upper 42-foot unit, assigned here to the Martin formation, in the Escabrosa. When this unit is taken out of the Martin, the measurements in the two areas differ by only 5 feet for the upper Martin.

MISSISSIPPIAN SYSTEM

Escabrosa Limestone

The Escabrosa limestone is 228 feet thick in the western part of the Thesis area. The formation is composed of massive, relatively pure limestone, cropping out as nearly vertical cliffs. Waterman Peak, the highest point in the range, has a block of this resistant limestone forming the cap. The Escabrosa cliff, a north-south sloping ridge just south of the peak, has a faulted and repeated section of the limestone. Another north-south ridge of Escabrosa lies to the northeast of Waterman Peak. A complete unbroken section of the Escabrosa is immediately west of the thesis area, southwest of the peak. The limestone also crops out in a wedge within the Andrada beds in the interior part of the Central portion of the range. A small nose of Escabrosa limestone is exposed near the west end of the Eastern portion of the range (Plate VIII B.).

The Escabrosa is not exposed in a complete or unbroken section, except in the cliffs west of the thesis area; therefore the section was measured along these cliffs (Plate VI B.). Ruff (1951, pp. 28-32) measured 316 feet of the Escabrosa limestone. The lower 40 feet of the Escabrosa in his measured section was placed in the Devonian Martin formation by the author of this report, because of the greater similarity to the Martin and because of the dolomite content of the rock. The remaining 50-foot difference

between the thicknesses in the two areas may be explained partially by thickening of section and/or by thrusting, and partially by erosion of the upper surface.

The lowermost 85 feet of Escabrosa is predominantly gray, very finely crystalline limestone, becoming reddish- and brownish-gray, asphanitic limestone near the top. The unit is massive and resistant in the lower 33 feet. The upper part is in beds 1 to 8 feet thick but remains resistant. Thin red calcite veins are in several of the beds through the member. Two prominent nodular chert zones exist about 40 and 50 feet above the base of the Mississippian formation. The chert is mostly white to gray, weathering gray and brown in elongate nodules mainly less than 1 foot long and 0.4 foot thick. Within these beds, the chert makes up nearly 50 percent of the rock. A 1.5-foot thick, calcareous sandstone bed is about 65 feet above the base of the Escabrosa. The sandstone is light gray to pink, fine-grained, poorly sorted, cemented by calcium carbonate, and weathers light brown. The lower 65 feet of the 85-foot unit weathers light gray to gray, and pinkish-gray near the top. The upper 20 feet weathers gray to light brownish-gray, partly with a rough surface.

The next overlying unit is 25 feet thick and consists of fairly resistant, gray and brownish-gray, partly pink, finely crystalline to aphanitic limestone. The rock is color banded,

mottled, or uniformly colored in various parts of the unit. The beds are from 0.2 to 3 feet thick and form a ledge in the Escabrosa cliffs at some places. Thin calcite veins are restricted to the upper 5 feet of the unit. The beds weather gray, yellow, pink, and red, depending upon the rock impurities, and most beds have rough surfaces. The upper contact of this unit has a bedding plane fault in some localities, but the displacement appears to be minor, with little or none of the unit missing.

Above the less resistant portion of the Escabrosa limestone is a 73-foot thick unit of resistant, gray and brownish-gray, partly pink, medium crystalline to aphanitic limestone with beds from 1 to 10 feet thick. Thin, light brown calcite veins exist in several of the beds. The beds are weathered light gray to brownish-gray, with yellow and pink patches. Two sandstone beds are 37 and 42 feet above the base of the unit. The thickness of the sandstone beds is variable, but generally is not more than one foot. The sand is pinkish-gray and medium-grained, with grosted, rounded grains, and calcareous cement. A limestone conglomerate lens above the lower sandstone, as well as the sandstone beds, indicate a minor break in the overall uniformity of Mississippian deposition.

Fossils are abundant within the 73-foot unit. The most common fossils are horn corals, which are very small in the upper 10 feet of the member. Syringopora is present in a bed about 15 feet

from the base of the unit (125 feet above the base of the Escabrosa) and Michelinia is about 20 feet above the base. In the middle and upper portions of the unit brachiopods and a few gastropods were found. The gastropods show only as cross-sections in the rocks.

The uppermost unit of the Escabrosa is light gray with pinkish tinges, medium to very finely crystalline limestone, 45 feet thick. The lower one-half is faintly color banded pink and gray. The upper 40 feet is mostly crinoidal limestone; the lower 5 feet has crinoid stems, but they are not abundant. This upper 40 feet of the limestone is less resistant to weathering than the underlying units of the Escabrosa. The upper surface of the top unit has been partially eroded and a red chert and shale layer, from 15 to 20 feet thick, lies on the erosion surface. This chert and shale unit is considered to be at the base of the Horquilla formation.

PENNSYLVANIAN-PERMIAN SYSTEMS -- NACO GROUP

The nomenclature of the Pennsylvanian and Permian formations in southern Arizona has been controversial during the last several years. The names of the formations used in this report will follow the proposals of Bryant (1955, pp. 31-35). Here, the Pennsylvanian-Permian Systems are represented by the Horquilla and Andrada formations placed together in the Naco group. The younger Permian formations are the Scherrer, Concha, and Rainvalley. This nomenclature may be applied quite satisfactorily in the Waterman Mountains.

The Naco group is divided into the Horquilla and Andrada formations in the Waterman Mountains. Separately, these formations are distinct from each other, but near the contact they become somewhat similar. The upper contact of the Horquilla is placed below the lowest red shale unit in the Horquilla-Andrada sequence. This contact also marks the last of the nearly continuous deposition of limestones and limy siltstones. Above the Horquilla-Andrada contact, shales and limestones are interbedded, the shale being a major constituent, at least in the lower portion of the Andrada formation.

Horquilla Formation

The Horquilla formation, which was named by Gilluly, Cooper, and Williams (1954, p. 16), overlies the Escabrosa limestone unconformably. There appears to be little change of dip between the two

formations, but a 15- to 20-foot thick, red chert conglomerate is present at the base of the Horquilla. A similar bed is at the base of the Pennsylvanian formations at many localities in southern Arizona. In the Waterman Mountains the conglomerate is made up of small pebble- to large cobble-sized, grayish-red chert and red shale. Some of the chert fragments are dark gray in the center, most are angular or only slightly rounded in form. Ruff (1951, pp. 36-37) mentions that Mississippian horn corals are embedded in the shale matrix and that they were probably eroded from the Escabrosa and deposited with the conglomerate.

The Horquilla formation crops out to the southwest and northeast of Waterman Peak (Plate 5 A.) and caps the hill to the west of the peak (Plate 6 B.). The only other outcrop of the Horquilla identified within the thesis area makes up most of the north hill of the Tri-Peak area in the Eastern portion of the Waterman Mountains (Plate 8 B.).

The Horquilla is composed of alternating beds of limestone, silty limestone, and siltstone. This alternation suggests oscillation of the seas during deposition or periods of uplift and periods of quiescence in the hinterland. The total thickness of the Horquilla, measured in the Central portion of the Waterman Mountains, is 468 feet. The difference between the 468 feet measured by the author and the 671 feet measured by Ruff (1951, pp. 32-37) is probably due entirely to the placement of the boundary between the Horquilla and the Andrada formation.

Above the basal chert conglomerate of the Horquilla formation in the Watermans are 23 feet of mottled and uniformly colored beds of light gray and dark gray, aphanitic limestone. The beds are from 0.5 to 3.5 feet thick and mainly resistant, forming a ledge above the chert conglomerate. Near the base is a bed of reddish-purple limestone. Chert nodules are near and at the base of the unit and in a zone about 16 feet above the base. Silt stringers, in the uppermost 7 feet, are less prominent than in the overlying beds. Crinoid stems, fusulinids, and fossil fragments are common in the upper 16 feet and Syringopora occurs at the top of the unit.

Above the 23-foot limestone unit of the Horquilla is a 16.5-foot thick unit of limestone conglomerate. The granules and pebbles of the conglomerate are composed of light gray, aphanitic limestone. The matrix is gray to light gray, aphanitic, partly silty, limestone. One bed of medium crystalline, silty limestone exists near the base. The beds, as a whole, are from 0.5 to 3 feet thick and generally resistant; the lowermost 1.5-foot bed is non-resistant and usually covered. The surface weathers to light gray and yellowish-gray, partly light brown. Crinoid stems are present near the base and near the top of the unit; no other fossils were noted.

The remaining 430 feet of the horquilla formation consists of alternating units of limestone, silty limestone, and limy siltstone.

The limestone is light gray to light olive gray and gray, aphanitic, and usually weathers light gray. The silty limestone gives a yellowish tinge to the gray rock mass and is partly very finely crystalline. Some of the silty limestone beds have a conglomeratic appearance where silty stringers envelop cobble-sized pieces of more pure limestone. The silty limestone weathers from light brown to rust-colored. Limy siltstones are brownish-gray to light red in color and weather light brown to very dark brown, partly black. The surfical weathering commonly penetrates up to 0.02 foot into the rock. Chert nodules and stringers of silt are scattered throughout the upper 430 feet of the Horquilla formation.

The units of the upper part of the Horquilla are from 8 to 30 feet thick, eroding to a step-like slope. In the lower portions of the sequence the limestone usually forms the ledges and the siltstone erodes to slopes or troughs. The siltstone in the upper part, however, is nearly as resistant as the limestone, and the gentler slopes are made up of thin-bedded silty limestones. The beds are generally more resistant in the lower 406 feet of the Horquilla than in the upper 62 feet. A Chaetetes zone usually forms a cap to Horquilla ridges, as to the southeast of Waterman Peak (Plate 5A.)

Two dolomite beds exist in the lower portion of the Horquilla formation. The lower one, 78 feet above the base of the Horquilla, is

8 feet of light gray, aphanitic, silty dolomite, weathering grayish-orange to gray. This bed contains limestone pseudomorphs. The upper bed is 106 feet above the base and consists of gray, partly conglomeratic, aphanitic dolomite, 9 feet thick. The weathered surface is yellowish-gray. Thin stringers of silt and silt nodules occur within the bed.

The uppermost beds of the Horquilla formation that crop out, the top of the measured section, are light gray, slightly silty limestone, 8 feet thick. The lower part of this unit contains abundant fossil fragments. The covered slope above these beds is presumed to be the non-resistant, red shale beds of the Andrada formation, since an exposed contact between the Horquilla and Andrada was not found.

Fossils are found in various beds throughout the Horquilla formation. Fusulinids are most common in the lower 118 feet of the formation and ostracods (?) occur in a few beds in the lower 182 feet. Two beds contain Chaetetes milliporaceous: one bed, 158 feet above the base of the Horquilla, has small but distinct specimens; the second, 406 feet above the base, contains massive, much weathered Chaetetes, some of which are nearly 2 feet in diameter.

Syringopora, as mentioned, are 23 feet above the base of the Horquilla formation. Horn corals were found at intervals between 115

to 160 feet above the base. Crinoid stems, commonly associated with fusulinids, are in all but the upper 150 feet of the Horquilla. Bryozoans are found in fossiliferous beds throughout the formation.

Brachiopods are usually broken into fragments, but these fossils are intact in a few beds. One such bed, 10 feet thick and 280 feet above the base of the Horquilla, contains numerous specimens of Dictyoclotus, Neospirifer, Rhipidomella, and rhynchonellids. Pelecypods are also within this bed and crinoid stems, near the top of the bed, are comparatively large, up to 3/4 of an inch in diameter.

The Horquilla formation was identified in the Waterman Mountains by its stratigraphic position, lithology, and faunal assemblage. The thickness, 468 feet, is much less in the Waterman Mountains than is some other parts of southern Arizona. Gilluly, Cooper, and Williams (1954, pp.16-18) described 999 feet of Horquilla in the Tombstone Hills, 70 miles southeast of Tucson, and 1,595 feet in the Gunnison Hills, 54 miles east of Tucson. Carpenter (1947) described only 415 feet of Naco limestone in the Vekol Mountains, but there Cretaceous red beds overlie the Pennsylvanian rocks disconformably. Britt (1955, p. 23) measured 900 feet of Naco limestone at Twin Peaks, about 16 miles east of the Watermans.

Andrada Formation

The Andrada formation is a complex stratigraphic unit

composed of shales, limestones, siltstones, dolomites, and conglomerates, and many combinations of these rock types. Except for the 207 feet of limestone at the top, the Andrada formation is generally a weak zone, forming gentle slopes. Some thin, more resistant limestone or dolomite beds crop out as ledges. The lower, more massive portion of the upper 207 feet of limestone forms a prominent cliff above thin-bedded dolomites and siltstones.

The Andrada is believed to be a time equivalent of the Earp, Colina, and Epitaph formations, which were named by Gilluly, Cooper, and williams (1954, pp.18-27) for a portion of the Naco group in the Tombstone Hills, south of Tombstone, Arizona. Northwestward from the Tombstone Hills, these formations become more difficult to recognize as individual units. Bryant (1955, pp. 37-40) described the Andrada formation in the Empire Mountains, where the Earp, Colina, and Epitaph formations could not be distinguished. The Andrada formation in the Waterman Mountains is generally similar to deposits at the type locality in the Empire Mountains.

The Andrada formation is 1, 100 feet thick in the Waterman Mountains. However, thrusting may have cut out or caused repetition of the section within some of the more incompetent beds. A composite section was taken in the attempt to avoid the deformed parts of these incompetent beds. The measured section is presumed

to be a reasonable approximation of the total thickness of the Andrada formation.

Two distinctly different types of deposits make up the Andrada formation in the Waterman Mountains. On the basis of the change of lithology between the lower and upper parts of the formation, the author has divided the Andrada into two members. The lower member includes the generally incompetent shales, limestones, siltstones, dolomites and conglomerates of the lower 893 feet of Andrada. The upper member is composed of 207 feet of thicker-bedded, more resistant limestone and dolomite.

Lower Member. - Outcrops of the lower member of the Andrada formation cross the middle of the Central portion of the Waterman Mountains in a nearly north-south band (Plate V B.). Separated blocks of the member lie in the northwest corner of the thesis area. Other outcrops are found on the lowlands north of the eastern hogback (Plate VIII B.).

The lower boundary, in contact with the Horquilla formation, was picked at the base of the lowest red shale bed. The actual contact with the Horquilla formation was not found because of covered slopes, but it is believed that the lowermost shale bed is close to the contact. A portion of either upper Horquilla or lower Andrada, though, may be hidden by faulting of unknown displacement.

The lithology of the lower member of the Andrada formation,

as mentioned, is varied. Limestone and dolomite throughout the member are gray to dark gray, and parts with a high silt content are yellowish-gray. The texture is predominantly very finely crystalline, but an aphanitic texture is not uncommon. The aphanitic texture seems more prevalent in carbonate beds with little or no silt. Limestone is more common in the lower portion of the member, whereas the dolomite becomes predominant in the upper half. The limestone and dolomite weather to a light olive gray to gray, partly to yellowish-brown where the silt content is high. One dolomite unit, about 380 feet above the base of the member, has porosity resulting in an extremely jagged weathered surface. Small chert nodules are scattered through the porous dolomite beds. This unit was used as a marker.

Thick shale beds, intercalated with limestone, are found only in the lower 63 feet of the Andrada formation. The shale is mottled grayish-red and yellowish-gray, mostly calcareous and partly silty. Siltstone is interbedded with the limestone and dolomite units upward from 63 feet above the base. Two prominent siltstone beds, from 210 to 367 feet and from 483 to 647 feet above the base, were used as marker horizona. The lower of these beds is fairly resistant, light grayish-red, limy siltstone with thin beds of silty shale. The weathered surface of the lower siltstone is light to dark brown. The upper siltstone bed is non-resistant, grayish-red material, partly thin-bedded

and partly with conchoidal shale-like fracture. The thinner beds of siltstone throughout the lower member are yellowish-brown and usually non-resistant.

Thin conglomeratic beds are at various horizona throughout the lower member of the Andrada formation. Two beds of limestone conglomerate occur at 187 and 200 feet above the base of the member; these beds are 6.5 and 10 feet thick, respectively. Both beds have gray, very finely crystalline limestone matrix with grayish-orange and light gray, aphanitic limestone pebbles and granules. These conglomeratic beds are resistant to weathering and usually form a cap or a small hogback, presenting an excellent marker in the distorted beds of the Andrada formation.

Fossils are scarce in the lower member of the Andrada formation. Within 150 feet of the base and also near the top of the member, a few beds contain brachiopods, outlines and cross-sections of bivalaves, and fossil fragments. One bed, 40 feet above the base, contains abundant fossil fragments, also bellerophontid and turreted gastropods. Bryant (1955, p. 40) mentions that fusulinids are rare in the lower part of the Andrada formation at its type locality, in the Empire Mountains; none were found in the Waterman Mountains.

Upper Member. - The upper member of the Andrada formation crops out in separated exposures east and north of the less competent lower

member through the Central portion of the Waterman Mountains (Plate V B.). A partial section of the upper member also crops out along the north slope of the hogback in the Eastern portion of the range. The upper member is 207 feet thick immediately south of East Hill in the Central portion. This section seems to be the most complete within the thesis area; but here, as elsewhere, part of the section may be missing because of the thrust faulting between the Andrada and Scherrer formations.

The upper member is dark gray, very finely crystalline, fossiliferous limestone and dark gray, very finely crystalline dolomite; The dolomite is only in the upper half of the member in units 10 to 20 feet thick. The beds throughout the member weather from light olive gray to gray, partly yellowish-gray. The limestone is fairly massive in the lower 115 feet of the member, forming a cliff above the thin-bedded strata of the lower member. Limestones and dolomites of the higher portion of the upper member have beds from 0.2 to 4 feet thick and form dip slopes. Near the top, the beds contain stringers and concentrations of silt and are less resistant than the underlying units. A few calcite and quartz blebs are in certain beds throughout the section. Scattered chert nodules are confined to a 20-foot thick bed, 80 feet above the base of the member. Except for the difference in the fauna and the general lack of chert, the upper member of the Andrada formation is somewhat similar to the Concha formation.

Fossils in the upper member are abundant in variety as well as number. The recognizable fossils, though, are restricted to the limestone beds of the member. Meekella (?) is found in a bed about 10 feet above the base. Other fossils in various beds throughout the member are Dictyoclotus and productid spines, Composita, Phricodothyris (?), Worthenia, Glabrocingulum, Amphiscapha, euomphalids, bellerophontids, trochoid and turreted gastropods, straight nautiloid cephalopods, small pelecypods, tabulate corals, echinoid spines, crinoid stems, and Bryozoa.

PERMIAN SYSTEM

Gilluly, Cooper, and Williams (1954, p. 27 & p. 29) named the Scherrer and Concha formation and assigned them to the Naco group. Bryant (1955, p. 51) proposed to restrict the Naco group to more closely follow Ransome's (1904, pp. 44-54) original definition of the Naco formation. The younger Permian strata, the Scherrer, Concha, and Rainvalley formations, were assigned to the Snyder Hill Group by Bryant (1955, p. 51), but the term "Snyder Hill" has been variously interpreted, therefore it seems wiser to drop the term and describe the Scherrer, Concha, and Rainvalley formations separately, without grouping.

Scherrer Formation

The Scherrer formation was first described by Gilluly, Cooper, and Williams (1954, p. 27) in the Gunnison Hills, 55 miles east of Tucson. At the type locality the Scherrer is composed of 65 feet of siltstone at the base, then 29 feet of gray limestone, 272 feet of sandstone, 165 feet of limestone, and 156 feet of sandstone; a total of 687 feet. The Scherrer formation in the Waterman Mountains has a somewhat similar section as that of the type locality; but the thickness of each unit is less. A composite section measures 422 feet thick at the east end of the Central portion of the range. Faulting in the sequence of rocks made an accurate measurement of the

formation difficult to obtain, but most of the deposits are believed to be represented.

Outcrops of the Scherrer formation are located south and west of the peak of East Hill (Plate VII A.) across a ridge in the interior part of the Central portion, and on the south side of the Front Ridge of the Waterman Mountains (Plate V B.). In the Eastern portion of the range the Scherrer crops out in the middle part of the Tri-peak area and on the northern slopes of the eastern hogback.

The Scherrer formation has been divided into seven units in this report for convenience of description. The lower four are combined as one unit on the geologic map (Plate I.). These include a basal siltstone unit, 61.5 feet thick, a 12.5-foot limestone, a 15-foot sandstone, and a 204-foot more massive sandstone. The massive sandstone is designated as the "lower sandstone unit" within the thesis area, for it is rarely cut out by faulting as the underlying units are. The succeeding three units are, respectively: the dolomite unit, 39 feet thick; the upper sandstone unit, 72 feet thick; and the upper carbonate unit, 18 feet thick. These three are grouped together on the map.

The Scherrer lies with apparent conformity above the limestones and dolomites at the top of the Andrada formation. The lower unit is 61.5 feet of red, limy siltstone with yellow bands in the lower portion and greenish-gray, sandy siltstone near the top. Intercalated

with the siltstone are thin beds of gray, very finely crystalline, silty dolomite in the lower 40 feet. Cross-bedded sandstone with a silty matrix exists in a 1-foot thick bed about 18 feet from the top of the unit and in a 5.5-foot thick bed at the top. The sandstone is gray with pinkish streaks, very fine-grained, and partly quartzitic. The unit, as a whole, is weakly resistant and forms a sag or valley between the carbonate beds above and below.

Overlying the clastic beds is 12.5 feet of dark gray to gray, very finely crystalline, silty limestone. The beds are from 0.3 to 1.5 feet thick and weather light yellowish-brown to yellowish-gray. They are fairly resistant to resistant and erode to a step-like slope. The limestone sequence is topped by 15 feet of yellowish-gray, partially cross-bedded, slightly resistant sandstone. The sand is very fine-grained to silty, and has poorly sorted and poorly rounded grains. A 1.3-foot thick bed of silty limestone occurs near the middle of the sandstone.

The red, massive, lower sandstone unit of the Scherrer formation is 204 feet thick, lying above the gray sandstone. The lower 116 feet of this unit is light red to yellow, fine- to very fine-grained sandstone, which is cross-bedded in places and mostly quartzitic. The beds are from 1 to 3 feet thick and resistant, forming a cliff in most parts of the thesis area. The next 70 feet in the sequence is light red to white, and partly yellow sandstone. These

beds have broad color bands. The sandstone is fine- to very fine-grained and has poorly rounded and fairly well-sorted grains. Some of the beds are quartzitic, some have limonite pseudomorphs after pyrite. The beds are from 1 to 2 feet thick, but the color bands are from 10 to 15 feet wide. The upper 14 feet of the unit is yellowish-gray, partly limy, siltstone. Between the siltstone and the sandstone is a 2-foot thick bed of dolomitic limestone. The upper portion of the unit is less resistant than the lower 186 feet, forming gentle slopes and saddles.

A thin-bedded, 39-foot thick unit of dolomite overlies the lower sandstone unit of the Scherrer. The dolomite is gray to dark gray and very finely crystalline, partly limy and partly silty. The weathered surface is light olive gray to gray with silt stringers that weather light brown in some beds. Calcite blebs, scattered through the unit may be re-crystallized remains of fossils. Spines of Permocidaris, so typical of this unit in areas east of the Waterman Mountains, were not found in any of the outcrops observed by the author.

The upper sandstone unit of the Scherrer formation is 72 feet thick. The beds are grayish-orange near the base and orange-yellow in the upper 58 feet. The sandstone is medium- to fine-grained with a slightly calcareous, silt matrix, and is made up mainly of well-sorted, fairly well-rounded milky quartz grains.

The sand grains are usually in thin laminae separated by a silty band and are cross-bedded with cosets about 2 feet thick. A unique weathering property of the upper sandstone are the small pebble-sized concretions of siltstone which occur in some of the beds.

The uppermost 18-foot thick unit is composed of dark gray, very finely crystalline, silty and limy dolomite in the lower 10 feet and gray to light brown, finely crystalline, sandy limestone in the upper 8 feet. This unit is believed by the author to be equivalent to a sequence of calcareous sandstones placed at the base of the Concha limestone in the Gunnison Hills by Gilluly, Cooper, and Williams (1954, pp. 27-29). Bryant (1955, pp. 47-48), when describing the Concha limestone at the supplementary type locality in the Mustang Mountains, proposed that the sandstone sequence be placed in the Scherrer formation, retaining the term "Concha" for the unbroken series of limestones overlying the clastics of the Scherrer. In the Waterman Mountains, the upper carbonate unit is placed in the Scherrer formation, following the precedent of Bryant, and because the unit more closely resembles the lithology of the Scherrer.

Concha Limestone

The Concha limestone is a gray, mainly massive, cliff-forming limestone which conformably overlies the Scherrer formation throughout much of southeastern Arizona. The Concha was

named by Gilluly, Cooper, and Williams (1954, p. 29) for 130 feet of limestone and calcareous sandstone in the Gunnison Hills. The top of the Concha at the type locality has been eroded and Cretaceous beds lie unconformably above. Bryant (1955, pp. 45-46) proposed a supplementary type locality in the Mustang Mountains, 45 miles southeast of Tucson, where over 1,000 feet of Permian carbonates overlie the clastic material of the Scherrer formation. He redefined the Concha limestone, excluding the lower sandstone unit of the Gunnison Hills type locality. At the supplementary type locality Bryant placed the lower 560 feet of limestone in the Concha and named the Rainvalley formation to include the upper, thinner-bedded limestones and dolomites. About 830 feet of carbonates lie above the Scherrer in the Waterman Mountains. The lower 510 feet of these beds are Concha. A few faunal zones which were described in the supplementary type locality were also observed in the Concha limestone of the Watermans. The stratigraphic section in general is similar in the two areas.

In the Waterman Mountains, the Concha limestone forms the high point on East Hill (Plate VII A.) and most of the ridge along the north front of the range (Plate V B.), caps the two southern hills of the Tri-peak area, and forms the ridge and most of the southern slope of the eastern hogback (Plate VIII A. and B.). The lower portion of the formation is massive, gray limestone which crops out

as 100- to 200-foot cliffs, nearly vertical in places. The upper portion of the Concha forms the tops and the dip slopes of the hills.

The lower unit of the Concha is resistant, dark gray, finely crystalline, fossiliferous limestone, 246 feet thick. The beds are from 1 to 4 feet thick in the lower part and mainly massive in the upper 160 feet. The weathered surface is light olive gray to gray. Chert nodules occur throughout the unit, but are especially abundant in a 60-foot thick band about 50 feet above the base of the Concha. The chert comprises over 60 percent of the rock mass within this band. The nodules are elliptical and irregular-shaped, about 1 foot long and 0.3 foot thick, gray chert which weathers from light brown to dark brown and black.

A fairly resistant, 13.6-foot thick bed of dark gray, very finely crystalline limestone with tan to light brown weathering chert nodules overlies the 264-foot unit. This bed is correlated with the "tan chert zone" that Bryant (1955) notes in all outcrops of the Concha from the Chiricahua Mountains, about 95 miles east of Tucson, to the Wasterman Mountains.

The upper 232 feet of the Concha limestone is dark gray, finely crystalline, and fossiliferous with a gray to light gray, commonly rough, weathered surface. The beds are from 1 to 10 feet thick and fairly resistant to resistant. The lower 70 feet of this unit has a few beds of brownish-gray, very finely crystalline

limestone interbedded with the dark gray limestone. Chert nodules are scattered through the 232-foot unit. Neospirifer occurs about 10 feet above the base and fusulinids are in two beds, each about 1 foot thick, 43 and 67 feet above the base. These faunal zones have been identified in the Concha at several localities throughout southeastern Arizona by Bryant (1955).

In the thesis area, the Concha-Rainvalley contact is placed at the top of the nearly continuous sequence of dark gray, finely crystalline limestones. The lowermost bed of the Rainvalley formation is dolomitic limestone containing numerous clusters of calcite blebs. Above the contact, the Rainvalley is generally more thin-bedded than the Concha, and has dolomite and dolomitic limestone interbedded with limestone beds.

Fossils are abundant and commonly well-preserved in the Concha limestone of the Waterman Mountains. Dictyoclostus bassi, D. occidentalis, rhynchonellid brachiopods, bellerophontid gastropods, crinoid stems, echinoid spines and plates, and Bryozoa occur throughout the Concha sequence. Fenestrellina and trepostome Bryozoa were found only in the lower portion of the formation; Neospirifer, Buxtonia, Derbya, Meekella, and fusulinids in the middle portion; and Composita, Dielasma, small brachiopods, turreted gastropods, and Malonophyllum and other horn corals in the upper third of the formation. Marginifera, Amphiscapha, and Aviculopecten were identified only in the upper 65 feet of the Concha.

Rainvalley Formation

Bryant (1955, pp. 48-51) named the Rainvalley formation from the 400 feet of limestones and dolomites overlying the Concha limestone on the Rain Valley Ranch in the Mustang Mountains. In general, the stratigraphic section of the Rainvalley in the Waterman Mountains is similar to that of the type locality. The thickness, 321 feet in the thesis area, is not as great as at the type locality but the difference can probably be explained by post-Permian erosion.

The Rainvalley formation crops out on the northeast side of East Hill (Plate VII A. and B.), along the northern slopes of Front Ridge, and also caps the ridge at the east end. Separated outcrops of the formation are located at the east end of the eastern hogback (Plate VIII A.). The Rainvalley usually erodes to slopes, topographically lower than the Concha limestone. At the east end of the Front Ridge a resistant, chert-bearing bed, 115 feet above the base of the formation, forms the high point.

The lower unit of the Rainvalley contains interbedded limestones and dolomites, about 106 feet thick. The basal bed, in contact with the Concha limestone, is 12 feet thick and composed of dolomitic limestone with small clusters of calcite blebs and granule-sized quartz grains. The limestones of the unit are dark gray, finely crystalline to aphanitic, and partly dolomitic. The dolomites are dark gray, aphanitic, and mostly limy. The beds, as a whole, weather light

gray to dark gray and are partly banded. Nearly pure dolomites in the upper part of the unit commonly have a light gray to almost white weathered surface. The beds vary in thickness from 0.5 to 4 feet and are fairly resistant, generally less resistant than the underlying Concha beds. Calcite blebs, replaced partially or entirely by quartz, are scattered and in clusters in the lower 73 feet of the unit. A few chert nodules occur in some of the beds throughout the unit, commonly in narrow bands.

Two clastic beds are 54 and 74 feet above the base of the 106-foot lower unit. The lower bed is about 3 feet thick and consists of light brown, sandy siltstone. The upper bed, 2.9 feet thick, has yellow siltstone at the base and yellowish to clear sandstone in the upper portion. The sandstone has well-rounded, well-sorted grains cemented with silica.

Some calcite blebs appear to be recrystallized fossil remains. Distinct fossils occur in few beds in this lower unit of the Rainvalley. Dictyoclostus, Rhipidomella, Astartella, Amphiscapha, turreted gastropods, and scaphopods exist in a bed 2.4 feet thick and 12 feet above the base of the unit. A 3-foot thick bed at the top of the unit contains Composita, spiriferid brachiopods, echinoid spines, Bryozoa, and fossil fragments.

The overlying unit, 99 feet thick, is dark gray to nearly black, finely crystalline to aphanitic, fossiliferous limestone. The

unit weathers from light gray to light olive gray and most of the beds have a rough to jagged surface. The beds vary from 0.5 to 5 feet thick and are more resistant than the beds above and below. Chert nodules are present throughout the unit. One resistant, 8-foot thick bed which is 9 feet above the base, has abundant chert nodules -- the chert making up about 50 percent of the rock mass. This bed usually forms a ridge in the Rainvalley outcrop. The nodules are up to 1 foot long and 0.3 foot thick and weather from light gray to brown to black. The chert partly occurs in stringers and lenses. Abundant fossils in this 99-foot thick unit include Dictyoclostus bassi, D. occidentalis, productid spines, Marginifera, Avonia, Composita, Phricodothyris, spiriferid and rhynchonellid brachiopods, unidentified pelecypods, Euphemites, Amphiscapha, several types of turreted gastropods, horn corals, echinoid spines and plates, crinoid stems, and several genera of Bryozoa.

The upper 116 feet of the Rainvalley formation is inter-bedded limestone and dolomite, usually forming a gentle slope and partially covered in the uppermost part. The carbonates are quite similar in appearance, being dark gray, finely crystalline to aphanitic, and weathering to light gray, partially with a rough surface. The thickness of the beds varies from 0.5 to 4 feet thick and the beds are fairly resistant to resistant. Calcite blebs, found only in the lower half of the unit, are partly concentrated in clusters and partly

scattered. A few chert nodules and scattered clusters of granule-sized quartz grains occur in the upper part of the unit. The only fossils recognized were in the 3.7-foot thick bed, 44 feet from the base of the unit (about 250 feet above the base of the Rainvalley). This bed contains Composita, Euomphalus, turreted gastropods, and fossil fragments, forming almost a coquina in the middle of the bed.

The uppermost exposure of the Rainvalley dips under a talus slope near the base of East Hill, where the section was measured. No Cretaceous nor Rainvalley crop out beyond the measured section, but the Permian formation may be much thicker than is recorded, as higher beds may be covered by alluvium.

CRETACEOUS SYSTEM

Over 1,600 feet of clastic sediments crop out along the lower slopes on the north side of Front Ridge. These clastics resemble the Cretaceous Amole arkose of the Tucson Mountains described by Brown (1939, pp. 715-718); however, the lithology of the clastic sediments in the Waterman Mountains and those described by Brown in the Tucson Mountains are similar only in that shales and arkosic sandstones are present at both localities. These sediments in the Waterman Mountains are tentatively assigned to the Cretaceous system, although no fossils were found to substantiate this designation. Other deposits of Cretaceous (?) age crop out on the lowlands south of the thesis area, but these were not studied.

The Cretaceous (?) sediments are in fault contact with the Permian limestone beds to the north of the Waterman Mountains (Plate VII B.). The fault is mainly covered by talus along the north slope of Front Ridge, but wherever the contact was observed no indication of dip of the fault was evident.

In this report the Cretaceous (?) sediments are divided into a lower unit about 1,200 feet thick and an upper unit 441 feet thick. The lower 1,200 feet are exposed at places through alluvial cover on the lower slopes north of Front Ridge. The sediments are predominantly reddish-purple silty shale interbedded with grayish-

brown to grayish-green siltstone and thin beds and lenses of light gray, arkosic sandstone. The shale is commonly mottled with irregular yellowish-green patches in the lower portion of the sequence. The siltstone beds make up about one-half of the section at some parts of the sequence and the sandstone beds are up to 4 feet thick but thin laterally or grade into siltstone. In the lower portion of the sequence the sandstone makes up about 5 percent of the section, increasing somewhat in the upper portion. Lateral lithologic change is rapid in the lower 1,200 feet of the Cretaceous (?), correlation being difficult to maintain for even as little as 200 yards.

The uppermost exposed section of the clastic deposits, 441 feet thick, comprises sandstones and shales in a nearly cyclic order. These deposits are generally more resistant to erosion that the lower portion of the Cretaceous (?), but they are commonly covered by talus from the Permian limestone cliffs along Front Ridge. The sandstone is light gray, partly with a pinkish or yellowish cast, medium- to very fine-grained, and arkosic, usually with poorly sorted and poorly rounded grains. Near the top of the Cretaceous (?) sequence some of the sandstones have a calcareous cement. The shale is reddish-purple and silty. The sandstone occurs in beds 2 to 15 feet thick between shale beds 4 to 50 feet thick. Many of the sandstone beds are cross-bedded, but the laminae are usually indistinct on the

weathered surface and completely obscure on the fresh surface of the rock. A few beds of light gray, aphanitic, silty limestone and grayish-brown siltstone occur in the upper portion of the sequence.

STRUCTURE

GENERAL

The Waterman Mountains are intensely thrust and block faulted with numerous minor shear faults. The whole of the Central portion of the range is believed to be a faulted anticline, trending approximately west-northwest and plunging east-southeast, but no refection of this anticlinal structure was recognized in the Eastern portion of the range. Minor folds were noted only in the incompetent Andrada formation, and the trends of these folds are the same as the trends of the anticline. Two periods of faulting were recognized in the Watermans, but neither period could be dated more closely than post-Cretaceous (?). The initial faulting appears to have been high angle thrusts and normal faults striking N. 45° W. and dipping, for the most part, to the southwest. Later movement caused vertical, normal, and reverse faults, probably relief fractures, which strike about N. 65° E. and N. 85° W. and dip at high angles mainly southeastward and southward.

The Central and Eastern portions of the Watermans appear to be structurally unrelated; the Central portion being more complexly fractured by thrust and normal or reverse faults, often with displacements of hundreds of feet, whereas the Eastern portion is a simple tilted fault block slightly thrust and cut by high angle faults with lesser displacements.

FOLDING

Few beds throughout the thesis area are noticeably folded. The broad anticline of the Central portion of the Watermans was probably the initial yield of the strata to compressive stresses which later ruptured along a northwest trend. The southwest half of cross-section B - B' shows the general nature of the anticline. Toward the northeast the beds continue to steepen, as shown in cross-section B - B' and also in cross-section A - A' (Plate II). The overturned beds along Front Ridge may be the northeast limb of the anticline, but their attitude was probably accentuated after the anticline had ruptured. The minor folds in the lower member of the Andrada formation seem to be related to the initial stress which caused the flexure of the anticline and the northwest trending faults, and are probably drag structures of the larger flexure. Three of these minor folds are located in NW 1/4 NW 1/4 NE 1/4 of section 31, the NE 1/4 NE 1/4 NW 1/4 of section 31, and the NE 1/4 SE 1/4 SW 1/4 of section 30. These folds, which may be followed from syncline to anticline in less than 200 feet, trend west-northwest and plunge steeply to the east-northeast.

FAULTING

Three major fault sets are recognized in the Waterman Mountains (Plate I). The strikes and dips of the faults and amount

and direction of the displacements are largely inferred, for the fault planes are mostly covered by rubble. Two ages of stress, possibly one age of compression and one of release, appear to have caused all the faulting of the range. The initial or older stress period caused fractures that strike N. 45° W. and dip mainly to the southwest. Faults dipping northeastward are mainly bedding plane thrusts and the larger thrusts at the eastern end of the Central portion of the range. A few thrusts in the southeast corner of the Central portion dip gently, about 20° to 30°, to the north and northeast. The eastern part of the Central portion may have been distorted after the initial compression by the inferred fault, which strikes N. 75° E. and separates the Central and Eastern portions of the range. The greatest displacement of the N. 45° W. faults occurs along the fault immediately north of Waterman Peak where the Cambrian Troy lies below the Escabrosa limestone; the apparent movement is over 1,000 feet. Other displacements are from tens to hundreds of feet.

The fault separating the pre-Cambrian (?) granite from the Paleozoic formations along the south margin of the Central portion and the fault separating the Permian and Cretaceous sediments north of Front Ridge are assumed to be of the same age as the N. 45° W. fault set. These marginal faults, though, trend

closer to N. 60° W.; however, they are displaced by the younger faults and conform with the movements of the older set.

The major N. 45° W. faults are generally downthrown on the south side of the Central portion of the Watermans and upthrown on the north side of the range, thus causing a block mountain effect. Toward the east end of the Central portion, however, this effect is lost, or at least obscured, by thrust faults dipping toward the northeast.

The N. 45° W. faults imply a compressive stress from the southwest or northeast. The dips of the faults seem to indicate that the stress was from the southwest, which agrees well with Wilson's (1949, p. 11) regional trends in southern Arizona during the Laramide orogeny.

The Eastern Hogback appears to be a simple block, faulted along the northern edge and tilted up, or thrust in from the south on a high angle thrust plane (cross-section G - G', Plate II). If the strike of the beds on the hogback reflects the strike of the fault along its northern edge then the fault trends about N. 75° W. The smaller thrust faults in the Concha limestone strike N. 75° - 80° W. The difference of strike on the faults to the east and those in the Central portion of the area is probably caused by the inferred fault which separates the two portions of the range. The inferred fault also may have caused the greater distortion in the Tri-Peaks area.

The two major sets of younger faults trend about N. 60° - 75° E. and N. 85° W.; two minor sets, probably closely related to the major sets, strike about N. 40° E. and N. 5° E. Many of these faults are normal, dipping eastward or southward with the east or south side downthrown, but this is not invariable since some of the faults have reverse movements, some dip to the west or north, and others are vertical. The fault set trending N. 60°-75° E. may have been tear faults related to the initial compression but their major movements seem to be normal and to have occurred later during the period of relaxation. The other three sets are probably caused by shear as the result of the release of stress. This would indicate that the tension stress comes from the southwest or northeast, probably the same direction as the stress causing the compression fractures -- from the southwest.

The younger faults across Front Ridge mainly trend N. 35° E. and dip steeply toward the southeast. These faults are believed to be directly related to the set trending N. 40° E. in the hills south of the ridge, and the slight difference of strike may be explained by the rotational movement of the fault hidden beneath the alluvium in the stream valley immediately south of the ridge. This hidden fault has a slight displacement at the west end, but the south side was downthrown about 1,000 feet at the east end as indicated by the position of the Rainvalley formation on either side of the valley.

Two sets of younger faults are recognized on the Eastern hogback: one trending about N. 35° E. and dipping to the southeast; the other trending about N. 25° W., apparently vertical. The faults that trend N. 35° E. are more conspicuous and seem to be the younger of the two sets. These faults form a series of horsts and grabens throughout the length of the hogback (cross-section F - F', Plate II). The faults that strike N. 25° W. have minor displacements and are restricted to the northeast part of the hogback.

SUMMARY

The Waterman Mountains appear to have been uplifted along a high angle thrust plane trending approximately northwest-southeast and dipping to the south. The compressive stress that wedged the pre-Cambrian (?) and Paleozoic rocks through the Cretaceous (?) sediments probably came from the southwest. The wedge is well defined near the west end of the thesis area where a major fault lifts Cambrian strata and pre-Cambrian (?) granite to the level of the Mississippian limestone (cross-sections A - A' and B - B', Plate II). North of this fault the Paleozoic sequence is repeated.

The inferred fault between the Central and Eastern portions of the range may be traced from north of the Tri-Peaks area along a line directed S. 75° W. between the Waterman Mountains proper

and the low ridge south of the range and on along the southeast margin of the Southwestern portion (Plate I). This fault trends approximately the same as the younger set of faults in the Central portion of the range that strike N. 60°-75° E. Southeast of the inferred fault, the Eastern Hogback, the low ridge south of the Watermans proper, and an east-west trending ridge of late Paleozoic rocks about 1 mile south of the thesis area may be blocks that have been projected through the Cretaceous (?) strata.

The age of the compression and tension stresses is unknown, but it is later than the Cretaceous (?) deposition. Wilson (1949, p.11) states that much of the thrusting in southern Arizona took place during the Laramide orogeny, with the prevalent trend of the folds striking northwestward and the thrusting directing northeastward. The trend of the folds and the direction of movement in the Waterman Mountains agree very well with Wilson's observations. However, Wilson also mentions that later Cenozoic orogenies had subparallel trends to the Laramide structures. Some of the faulting in the Watermans may be related to these later orogenies.

GEOLOGIC HISTORY

The Paleozoic rocks of the Waterman Mountains were probably deposited in a shallow marine basin from which the sea intermittently withdrew and advanced again. In the Vekol Mountains, 40 miles west of the Watermans; in the Slate Mountains, 25 miles west of the range; and in the Santa Catalina Mountains, 35 miles east of the Watermans the pre-Cambrian Apache group overlies the Pinal schist and is overlain by the Troy quartzite. At Twin Peaks, 15 miles east of the Watermans, the Troy lies directly on the Pinal schist. The Troy in the Waterman Mountains overlies the pre-Cambrian (?) granite with both the Apache group and the Pinal schist missing. This may indicate that the Waterman Mountains area was high during pre-Cambrian time and little or no sediments equivalent to the Apache group and Pinal schist were laid down, or that during late pre-Cambrian and early Cambrian time the area was uplifted and these sediments were eroded. A third possibility exists: that the granite underlying the Troy is not pre-Cambrian but was intruded at a later date. Rather negative evidence tends to disprove this possibility; that is, there are no granitic or equivalent intrusives in the Paleozoic rocks. The relations of the contact between the Troy and the granite along the central part of the western edge

of the thesis area, where the Cambrian beds appear to be separated from the granite only by a minor bedding plane thrust, also supports the possible pre-Cambrian age of the granite, but does not prove this age.

The Troy quartzite was laid down in an apparently stable shallow sea into which clastic material was being supplied from a fairly nearby highland. The Abrigo formation, with shales and siltstones in the lower portion, limestones in the middle, and shales and thin limestone beds in the upper portion appears to represent a transgression then a regression of the sea. The regression was complete before Ordovician time and the area apparently remained above sea level through Silurian and lower Devonian time. The amount of erosion during this withdrawal of the sea is indeterminable, but by the nature of the Abrigo-Martin contact the erosion seems to have been minor with the land area probably quite low throughout the span of time.

The sea returned in upper Devonian time and the Martin formation was deposited. The Escabrosa limestone accumulated in a shallow sea, as did the Martin formation, but by Mississippian time the shore must have been further from the Waterman Mountains area or the hinterland was low and erosion at a minimum. Later in Mississippian time the area was uplifted and eroded. Again the erosion must have been slight for the erosional contact between the

Escabrosa and the overlying red chert conglomerate at the base of the Horquilla has little relief.

The sea returned during Pennsylvanian and evidently remained through early and middle Permian time. After the Horquilla formation was deposited the sea retreated but did not completely withdraw. Into this shallow, probably oscillating sea, the shales, siltstones, and carbonates of the lower member of the Andrada formation were deposited. Later, during early Permian time, the basin deepened somewhat while the carbonates of the upper member of the Andrada accumulated.

The siltstones and sandstones of the Scherrer formation were probably deposited in a shallow regressive sea. For the last time during the Paleozoic the basin deepened and the limestones and dolomites of the Concha and Rainvalley formations accumulated. By late Permian the sea had apparently withdrawn from southern Arizona and the area remained positive until Lower Cretaceous time. The shales and sandstones of Cretaceous (?) age were apparently deposited in a shallow oscillating basin.

The Waterman Mountains were probably uplifted and faulted during the Laramide orogeny in late Cretaceous and/or early Tertiary. Rhyolite sills, intruded between the bedding planes of the Cretaceous (?) strata, and dikes, also intruded into the Cretaceous (?), occur at

several places north of the Front Ridge and one small intrusion forms a hill northeast of the Eastern Hogback. These intrusions may have accompanied the uplift of the range, but are more probably related to the later Tertiary vulcanism of southern Arizona. Silicification of some of the Paleozoic sediments and the minor mineralization in the Central portion of the range also probably occurred during later Tertiary volcanic activity. Ruff (1951, p. 56) considered the mineralization at the Indiana-Arizona mine as mesothermal and dated it as probable Tertiary.

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APPENDIX

DESCRIPTION OF MEASURED SECTION

The rock units of the Waterman Mountain were measured in detail with a tape. The descriptions of the rocks were made after megascopic observation, using a 10-power hand lens to determine the texture and impurities and checking the calcium carbonate content with a 20 per cent hydrochloric acid solution. The distinction between limestones, dolomitic limestones, limy dolomites, and dolomites was determined by the relative reactivity of the acid with the rocks. Most of the description, below, is self-explanatory. The color shades were determined by comparison with the National Research Council Rock-Color chart. Particle size of the clastic rocks are based on Wentworth's Classification. The properties of the beds to resist weathering are distinguished as resistant, fairly resistant, slightly resistant, and non-resistant.

Composite section of Cretaceous (?); upper 441 feet near middle and north of Front Ridge in W 1/2 NE 1/4 SE 1/4 Sec. 30, T. 12 S., R. 9 E.; lower 1,200 feet at west end of Front Ridge in SE 1/4 NW 1/4 and SW 1/4 NE 1/4 of Sec. 30.

Talus

Cretaceous (?): 1,641 feet thick

(Dip, 76° S. 40° W.)

		Feet
54.	Sandstone: light gray, partly yellowish-gray, medium to fine-grained, and arkosic; poorly sorted and poorly rounded grains. Mainly massive. Slightly to non-resistant.....	6
53.	Sandstone and shale, interbedded: Sandstone - grayish-green and pink, medium to fine-grained, and arkosic; with poorly sorted, fairly well-rounded grains, and calcareous cement; beds 0.3 to 1 foot thick with shale partings, and fairly resistant. Shale - reddish-purple and silty; mainly massive, non-resistant.....	15
52.	Covered (probably red shales).....	33
51.	Limestone, dolomitic: light gray, partly brownish-gray, aphanitic, and silty. Weathered surface light yellowish-gray with silty to powdery texture. Limestone pebbles in limestone matrix near base. Mainly massive. Fairly to slightly resistant.....	4.5
50.	Siltstone, sandy: light gray. Sandstone fine-grained. Yellow, coarsely crystalline limestone nodules, scattered. Mainly massive. Fairly resistant.....	3
49.	Siltstone, sandy: grayish-pink and limy. Sand fine-grained. Massive. Fairly resistant.....	4
48.	Limestone: light gray, partly brownish-gray, aphanitic, and silty. Weathered surface light yellowish-gray with silty to powdery texture. Red shale envelops limestone pebbles near top. Mainly massive. Slightly resistant.....	3
47.	Shale: reddish-purple with very light green stringers. Lenses of light gray, partly pinkish-gray, silty limestone. Non-resistant.....	25

46. Sandstone and siltstone, interbedded: Sandstone - light gray, partly pinkish- and yellowish-gray, and medium- to very fine-grained; with calcareous cement. Siltstone - grayish-red and limy. Beds 0.2 to 0.8 foot thick. Resistant to slightly resistant..... 8.5

45. Shale: reddish-purple, grades to pinkish-orange near top, and partly sitly. Non-resistant..... 20

44. Sandstone, silty: purplish-red and fine- to very fine-grained; with calcareous cement. Beds about 0.5 foot thick, with red shale partings. Fairly to slightly resistant..... 5

43. Sandstone: grayish-red, partly greenish-gray, very fine-grained, and slightly arkosic. Cross-bedding vague. Massive. Resistant to fairly resistant..... 3.5

42. Shale: purplish-red and partly silty. Non-resistant; mostly covered..... 4

41. Sandstone: light gray, partly yellowish-gray, fine- to very fine-grained, and partly arkosic; with calcareous cement. Beds 0.2 to 3 feet thick. Resistant to slightly resistant..... 15

40. Shale: reddish-purple, mottled with pinkish-orange and very light green, and partly silty. Non-resistant; partly covered..... 24

39. Siltstone: grayish-grown and limy. Mainly massive. Fairly to slightly resistant..... 2.5

38. Shale and siltstone: shale - reddish-purple. Siltstone - grayish-brown and limy. Shale envelops siltstone nodules. Mainly massive. Slightly to non-resistant..... 5

37. Shale: reddish-purple and partly silty. Non-resistant; mostly covered..... 18

36. Sandstone: light gray, partly yellowish-gray, fine- to very fine-grained, and slightly arkosic; with calcareous cement. Massive. Fairly resistant..... 3.5

35. Covered (probably red shale)..... 13.5

34. Sandstone: light gray, partly yellowish-gray, fine- to very fine-grained, and slightly arkosic; with calcareous cement. Massive. Fairly resistant..... 2

33. Covered (probably red shale)..... 7

32. Sandstone: light gray, partly pinkish-gray, medium, to very fine-grained, and slightly arkosic; with calcareous cement near top. Beds 0.5 to 2 feet thick. Resistant to slightly resistant..... 12

31. Shale: reddish-purple, mottled with yellowish-green, and partly silty. Non-resistant; mostly covered..... 56

30. Sandstone: light gray, partly yellowish- and pinkish-gray, medium- to very fine-grained, and arkosic. Beds 0.4 to 2 feet thick. Resistant..... 6

29. Shale: reddish-purple, mottled with yellowish-green, and silty. Non-resistant..... 30

28. Sandstone: light gray, partly yellowish-gray, fine- to very fine-grained, and slightly arkosic. Grades laterally into reddish-orange siltstone. Massive. Resistant..... 4.5

27. Shale: reddish-purple, mottled with yellowish-green, and partly silty. Non-resistant..... 20

26. Sandstone: light gray, partly yellowish-gray, fine- to very fine-grained, and arkosic. Beds 1.5 to 2 feet thick. Resistant..... 9

25. Shale: purplish-red and partly silty. Non-resistant; mostly covered..... 25

24. Sandstone: light gray, partly yellowish-gray, medium-to very fine-grained, and arkosic. Cross-bedding vague. Beds 0.2 to 2 feet thick, with red shale partings. Slightly resistant..... 6

23. Shale: reddish-purple, mottled with yellowish-green, and partly silty. Non-resistant; mostly covered..... 15

22. Sandstone: light gray, partly yellowish-gray, medium- to very fine-grained, and arkosic. Cross-bedding vague. Beds 0.2 to 2 feet thick, with red shale partings. Slightly resistant..... 6.5

21. Covered (probably red shale)..... 8

(Dip, 80° S. 25° W.)

20. Sandstone: light gray, partly yellowish-gray, medium- to very fine-grained, and arkosic. Beds 1 to 2 feet thick. Resistant..... 7

19. Shale: mottled reddish-purple and light yellowish-green. Mainly massive. Non-resistant..... 9

(Dip, 73° S. 25° W.)

18. Sandstone: light reddish-gray, fine-grained, and arkosic; fairly well-sorted and fairly well-rounded grains. Cross-bedding vague. Beds 0.5 to 4 feet thick. Resistant..... 12

(Fault plane)

17. Siltstone and shale, interbedded: Siltstone - reddish-purple and silty; beds up to 2 feet thick, fairly resistant. Shale - red, pink in lower 5 feet; beds up to 2 feet thick, non-resistant..... 23

16. Sandstone: light grayish-brown, fine- to very fine-grained, and slightly arkosic. Cross-bedding vague. Beds 0.6 to 2 feet thick. Resistant to fairly resistant..... 3.3

15. Siltstone: reddish-purple and shaly. Beds 0.1 to 0.8 foot thick. Slightly to non-resistant..... 14

14. Sandstone: grayish-red, fine- to very fine-grained with shale matrix, and arkosic. Beds 0.5 to 2 feet thick. Resistant to fairly resistant.... 20

13. Shale, sandy: red. Sand medium-grained. Beds 0.2 to 0.6 foot thick. Fairly to non-resistant..... 8

12. Siltstone: grayish-green, partly brownish-gray. Weathered surface orange-red to dark brown. Beds 0.5 to 2 feet thick. Fairly to non-resistant..... 80

11. Shale, silty: moderate yellowish-green, interbedded with reddish-gray, sandy siltstone. Weathered surface of shale and siltstone orange-red to dark brown. Beds 1 to 10 feet thick. Mainly non-resistant..... 36

10. Shale, silty: moderate yellowish-green, interbedded with siltstones and sandstones. Beds 0.5 to 2 feet thick. Slightly to non-resistant; sandstones partly fairly resistant..... 100

9. Shale and sandstone, interbedded: Shale - moderate yellowish-green and silty; beds 5 to 30 feet thick, non-resistant. Sandstone - greenish-gray, fine- to very fine-grained, and partly silty; beds 1 to 3 feet thick, fairly resistant..... 250

8. Shale, silty: moderate yellowish-green. Beds 0.5 to 2 feet thick. Slightly to non-resistant..... 70

7. Sandstone: light greenish-gray to yellowish-gray, fine- to very fine-grained, and arkosic. Beds 0.4 to 0.8 feet thick. Fairly resistant..... 1.5

6. Shale, silty: moderate yellowish-green. Beds 0.5 to 2 feet thick. Slightly to non-resistant..... 7.7

5. Sandstone: light greenish-gray, fine- to very fine-grained, and arkosic. Beds 0.2 to 0.6 feet thick. Fairly resistant..... 1

4. Shale, silty: moderate yellowish-green. Beds 0.5 to 2 feet thick. non-resistant..... 26

3. Sandstone: greenish-gray, very fine-grained to silty, and arkosic. Beds 0.5 to 1.5 feet thick. Fairly resistant..... 2.5

2. Shale, silty: moderate yellowish-green. Beds 0.5 to 2 feet thick. Slightly to non-resistant..... 45

(Dip, 75°S. 25° W.)

1. Shale and siltstone, interbedded: Shale - yellowish-green and partly silty; beds 2 to 20 feet thick, non-resistant. Siltstone - yellowish-green and partly arkosic; weathers grayish-brown to dark brown; beds up to 2 feet thick, slightly resistant. Few sandstone lenses light gray to yellowish-gray, medium- to fine-grained, and arkosic; weather light gray with glassy surface; lenses up to 5 feet thick, fairly resistant..... 500

Covered lowlands.

Section of Rainvalley formation on northeast slope of East Hill, near center of NE 1/4 Sec. 31, T. 12 S., R. 9 E.

Alluvium

Permian:

Rainvalley formation: 321 feet thick

(Dip, 45° N. 75° E.)

		Feet
39.	Limestone and dolomite, interbedded: Limestone - dark gray, very finely crystalline, slightly dolomitic; weathering light to medium olive gray with a jagged surface. Dolomite - olive gray, aphanitic, and limy; weathering yellowish-gray with a jagged surface. Calcite blebs scattered near base. Coarse to very coarse sand grains in scattered clusters in some dolomite beds. Chert nodules small (0.01 by 0.05 feet) and scattered, dark gray, and weathered from pale brown to black. Beds 0.5 to 2 feet thick. Fairly resistant; partly covered near top. Fossils: few bryozoans in zones throughout.....	58.0
38.	Limestone: medium dark gray and finely crystalline. Weathered surface medium light gray with silty texture. Grades upward into unit 39. Thickens laterally. Chert nodules few and scattered. Massive. Resistant.....	1.6
37.	Limestone: grayish black and aphanitic. Weathered surface medium light gray, with powdery texture. Thins laterally. Beds 0.4 to 0.8 feet thick. Resistant.....	3.0
36.	Limestone: medium dark gray and finely crystalline. Weathered surface medium light gray with silty texture. Calcite nodules few and scattered. Massive. Resistant.....	3.2
35.	Covered.....	2.0
34.	Limestone: dark gray and nearly aphanitic at top and base, medium gray and fine to medium crystalline with fossil fragments abundant near middle. Weathered surface medium light to medium gray with silty texture. Mainly massive. Resistant. Fossils: Composita, Euomphalus, turreted gastropods, and fragments.....	3.7

33. Dolomite: medium dark gray and aphanitic. Weathered surface medium light gray with powdery texture. Lenses of very sandy dolomite weather dusky yellowish-brown. Calcite nodules scattered. Beds 1 to 4 feet thick. Fairly resistant..... 33.0

32. Limestone: dark gray and finely crystalline. Weathers medium light gray with silty texture and a jagged surface. Calcite nodules in clusters. Mainly massive. Resistant..... 4.6

31. Covered..... 2.5

30. Limestone, dolomitic: dark gray and nearly aphanitic. Weathered surface medium light gray with powdery texture. Upper portion less dolomitic. Calcite nodules scattered through certain beds. Beds 0.5 to 1 foot thick. Fairly resistant..... 4.0

29. Limestone: grayish black and very finely to finely crystalline. Weathers medium light gray and light olive gray with silty texture and rough to jagged surface. Calcite nodules in clusters and chert nodules in certain beds, throughout. Beds 0.5 to 5 feet thick. Resistant. Fossils usually confined in zones. Fossil: Dictyoclostus bassi, Composita, rhynchonellid brachiopods, Euphemites, Amphiscapha, several genera of turreted gastropods, horn corals, echinoid spines, crinoid stems, and several gerera of bryozoans..... 67.0

28. Limestone: dark gray and very finely crystalline to aphanitic. Weathered surface medium light gray to yellowish gray with silty to powdery texture. Chert nodules weather light brown to black. Beds 1 to 2 feet thick. Resistant. Fossils: Composita, rhynchonellid brachiopods, echinoid spines and plates, crinoid stems (large - 1/2 inch diameter in 0.5-foot bed, 2.8 feet from base), and bryozoans..... 9.0

27. Limestone: medium dark gray, parts with yellowish tinge, and finely crystalline. Weathered surface medium light gray and light olive gray with silty texture. Chert in massive 0.2- to 0.7-foot bed near top, weathers light gray and light brown. Beds 1 to 1.5 feet thick. Fairly resistant. Fossils: Dictyoclostus, Chonetes, spiriferid brachiopods, and echinoid spines..... 2.5

26. Limestone: medium dark gray and finely crystalline. Weathered surface medium light gray with silty texture. Chert nodules in bands, commonly contain fossils. Mainly Massive. Fairly resistant. Fossils: Dictyoclostus bassi, spiriferid brachiopods, echinoid spines, and bryozoans..... 3.7

25. Limestone: medium dark gray, medium gray near base, very finely crystalline. Weathers medium light gray with silty texture and rough surface. Chert nodules abundant, commonly containing fossils. Less chert near base. Beds 1 to 4 feet thick. Resistant. Fossils: Dictyoclostus bassi, D. occidentalis, Marginifera, Avonia, Composita, Phricodothyris, spiriferid brachiopods, pelecypods, bryozoans, and fragments..... 8.0

24. Limestone: dark gray and very finely crystalline. Weathered surface medium light gray with yellow silt, and with silty texture. Beds 0.5 to 1 foot thick. Fairly resistant. Fossils mainly indistinct; few Dictyoclostus, producted spines, Composita, and crinoid stems..... 3.0

23. Limestone: medium dark gray and finely crystalline. Weathered surface yellowish-gray to yellow with silty texture. Grades to above. Chert nodules small (0.1 to 0.2 foot) and mainly near base. Beds 0.5 to 2 feet thick. Fairly resistant. Fossils: Dictyoclostus, Composita, spiriferid brachiopods, echinoid spines, and bryozoans. Fragments and indistinct fossils near base..... 6.0

(Dip, 77° N. 50° E.)

22. Limestone, dolomitic: medium dark gray, parts with yellowish tinge, and very finely crystalline. Weathered surface medium light gray with yellow silt, and with silty texture. Chert bed at base. Massive. Resistant. Fossils mainly indistinct; few Composita, spiriferid brachiopods, echinoid spines, bryozoans, and fragments..... 1.5

21. Limestone, dolomitic: medium dark gray, very finely crystalline, and silty. Weathered surface yellowish-gray to yellow with powdery texture. Silt concentrations weather out in brown nodules. Massive. Resistant. Fossils: Composita, echinoid spines, and bryozoans..... 1.5

20. Limestone, dolomitic: medium dark gray and nearly aphanitic. Weathered surface medium light gray with silty texture. Very coarse sand grains scattered near top. Yellow silt band in middle. Massive. Resistant..... 1.2

19. Limestone, dolomitic: banded medium dark to medium gray and aphanitic. Weathered surface very light gray to yellowish-gray with powdery texture. Very coarse sand grains near base. Few chert nodules in middle. Beds 0.1 to 0.2 foot thick. Resistant in upper portion, thin-bedded and less resistant near base..... 6.0

18. Covered..... 2.5

17. Dolomite: medium dark gray and aphanitic. Weathered surface very light gray with powdery texture. Chert nodules weather reddish-brown. Massive. Resistant... 1.2

16. Dolomite: medium dark gray and aphanitic. Weathered surface medium light to light gray with powdery texture. Yellow silt band near top. Chert nodules in middle portion, weather light brown to black. Beds 0.3 to 3 feet thick. Resistant..... 15.3

15. Sandstone: yellowish to clear, medium grained, with siliceous cement. Grains well-rounded and well-sorted. Mainly massive. Slightly resistant..... 1.9

14. Siltstone: yellow. Massive. Fairly resistant..... 1.0

13. Dolomite, limy: medium gray and aphanitic. Weathered surface very light gray with powdery texture and dark bands. Massive. Fairly resistant..... 0.8

12. Dolomite, limy: medium dark gray and very finely crystalline. Weathered surface medium to medium light gray with silty to powdery texture. Calcite blebs 12 feet above base. Two-foot chert nodule band 6 feet above base. Beds 0.5 to 4 feet thick. Resistant; basal 6 feet less resistant and partly covered. Fossils indistinct..... 16.0

11. Covered (probably siltstone)..... 2.8

10. Siltstone, sandy: light brown. Sand grains fairly well-rounded, well-sorted, and fine-grained. Massive. Resistant..... 0.5

9. Limestone, dolomitic: medium dark gray and nearly aphanitic. Weathered surface medium gray with powdery texture. Grades upward into unit 10. Calcite blebs in lower part. Beds 0.5 to 1.5 feet thick. Resistant..... 10.0

8. Limestone: medium and medium dark gray, parts with yellowish tinge, and nearly aphanitic. Weathered surface light gray to yellowish-gray with powdery texture. Beds 0.4 to 0.8 feet thick. Fairly resistant..... 2.0

7. Limestone, dolomitic: dark gray and very finely crystalline. Weathered surface medium gray with powdery texture. Massive. Slightly resistant..... 0.8

6. Limestone, dolomitic: medium gray and aphanitic. Weathered surface very light gray with powdery texture. Massive. Fairly resistant..... 1.5

5. Dolomite, limy: dark gray and nearly aphanitic. Weathers medium light to medium gray in bands, with powder texture and rough surface. Grades upward into unit 6. Calcite blebs and granule-sized quartz grains scattered. Chert in darker bands. Beds 0.5 to 1 foot thick. Fairly to slightly resistant; partly covered..... 12.5

4. Limestone, dolomitic: medium dark gray and nearly aphanitic. Weathered surface light gray with silty to powdery texture. Calcite blebs and granule-sized quartz grains scattered. Mainly massive. Fairly resistant. Fossils mainly indistinct; few bellerophontid gastropods..... 2.2

3. Dolomite, limy: medium dark gray and nearly aphanitic. Weathered surface medium gray to medium olive gray with silty to powdery texture. Calcite blebs (possibly fossil replacements) commonly have quartz outer crust. Mainly massive. Fairly resistant; lower part more resistant..... 10.6

2. Limestone: dark gray and very finely crystalline. Weathered surface medium to medium dark gray with silty texture. Calcite blebs scattered. Beds 0.3 to 1 foot thick. Fairly resistant. Fossils: Dictyoclostus, Rhipidomella (?), Astartella, Amphiscapha, turreted and other gastropods, and scaphopods..... 2.4

1. Limestone, dolomitic: medium dark gray and finely crystalline, upper 0.7 feet more dolomitic. Weathered surface medium light gray with powdery texture. Calcite blebs in clusters, partly with quartz outer crust. Quartz grains of granule size. Beds 1 to 4 feet thick. Resistant. Fossils indistinct..... 12.0

Concha limestone - conformable contact.

Section of Concha limestone on East Hill, in W 1/2 NE 1/4 Sec. 31, T. 12 S., R. 9 E.

Permian:

Rainvalley formation:

Concha limestone: 510 feet thick

(Dip, 77° N. 50° E.)

		Feet
23.	Limestone: medium dark gray and finely crystalline. Weathered surface medium light gray with yellow silt in some layers, and with powdery to silty texture. Chert nodules (0.3 by 1 foot) scattered. Beds 1 to 4 feet thick. Resistant. Fossils: Dictyoclostus, productid spines, Dielasma (?), Composita, rhynchonellid brachiopods, turreted and bellerophontid gastropods, horn corals, and echinoid spines.....	10.8
22.	Limestone: dark gray and finely crystalline. Weathered surface medium light gray with powdery to silty texture. Chert nodules few. Quartz blebs (may be fossil replacement). Mainly massive. Fairly resistant. Fossils indistinct.....	5.0
21.	Limestone: medium dark gray and finely crystalline. Weathered surface medium light gray with yellow silt in some layers, and with powdery to silty texture. Chert nodules scattered. Beds 1 to 4 feet thick. Resistant. Fossils: Dictyoclostus occidentalis and horn corals.....	15.0
20.	Limestone: medium dark gray and finely crystalline. Weathered surface medium gray with obscure yellow silt, and with silty texture. Few chert nodules. Beds 1 to 4 feet thick. Resistant. Fossils: Dictyoclostus occidentalis, Marginifera, Dielasma (?), Aviculopecten, bellerophontid gastropods, Amphiscapha, Malonophyllum and other horn corals, and bryozoans.....	34.0
19.	Limestone: dark gray and finely crystalline. Weathered surface medium gray with silty texture. Chert nodules scattered. Beds 0.4 to 1 foot thick. Fairly resistant. Fossils: Dictyoclostus, small brachiopods and fragments and bellerophontid gastropods.....	3.7

18. Limestone: dark gray and finely crystalline. Weathered surface medium gray with silty texture. Beds 1 to 4 feet thick. Fairly resistant. Fossils: Dictyoclostus, small brachiopods and fragments, and bellerophontid gastropods..... 6.5

17. Limestone: medium dark gray to brownish-gray and nearly aphanitic. Weathered surface mottled medium light gray and medium yellowish-gray, with powdery texture. Chert nodules (0.1 by 0.2 to 0.5 feet) medium gray, weather light brown to moderate yellowish-orange. Mainly massive. Fairly resistant. Fossils: Dictyoclostus, small brachiopods and fragments, and crinoid stems..... 23.0

16. Limestone: medium dark gray and finely crystalline. Weathers medium to medium light gray with silty texture and rough surface. Beds 2 feet thick, laterally massive. Fairly resistant. Fossils: Dictyoclostus, small brachiopods, and fragments, and bellerophontid gastropods..... 12.0

15. Limestone: medium dark gray to brownish-gray and nearly aphanitic. Weathered surface mottled medium light gray and medium yellowish-gray, with powdery texture. Chert nodules weather light brown. Beds 0.5 to 1 foot thick. Fairly resistant. Fossils: Dictyoclostus, small brachiopods and fragments, and crinoid stems..... 8.0

14. Limestone: dark gray and finely crystalline. Weathered surface medium gray with silty texture. Chert nodules scattered near base. Beds 1.5 to 2.5 feet thick. Fairly resistant. Fossils: Dictyoclostus occidentalis, productid spines, small brachiopods and fragments, Euphemites, Glabrocingulum, turreted gastropods, and Malonophyllum..... 10.0

13. Limestone: medium dark gray to brownish-gray and nearly aphanitic. Weathered surface mottled medium light gray and medium yellowish-gray, with powdery texture. Chert nodules weather light brown. Mainly massive. Resistant. Fossils: Dictyoclostus, small brachiopods and fragments, and crinoid stems..... 11.0

12. Limestone: medium gray and very finely crystalline. Weathered surface medium light gray with silty texture. Grades upward into unit 13. Chert nodules weather light brown to black. Massive. Resistant. Fossils: Dictyoclostus bassi, D. occidentalis, Dielasma (?), horn corals, crinoid stems, and fragments..... 20.0

11. Limestone: medium dark gray and finely to very finely crystalline. Weathered surface light olive gray to medium gray with rough silty texture. Chert nodules scattered. Beds 1 to 2 feet thick. Resistant. Fossils: fusulinid zone in middle; Dielasma (?) and bryozoans in upper part..... 5.0

10. Limestone: medium dark gray, parts with pinkish tinge, and very finely crystalline. Weathered surface medium light gray with silty texture; bands grayish-orange with powdery texture. Chert nodules weather light brown. Beds 1 to 4 feet thick. Fairly resistant. Fossils: Composita, horn corals, and crinoid stems..... 19.5

(Dip, 60° N. 50 ° E.)

9. Limestone: medium gray, parts with pinkish tinge, and finely crystalline. Weathers medium to medium light gray with yellowish tinge, and with silty texture and rough surface. Chert nodules in bands, weather light brown to brown, darker in lower part. Mainly massive. Resistant. Fossils: Dictyoclostus, Composita, Neospirifer (10 feet above base), Meekella (about 10 feet above base), Derbyia (about 10 feet above base), fusulinid zone (43 feet above base), and crinoid stems..... 45.5

8. Limestone: medium brownish-gray and very finely crystalline. Weathers light brownish gray with silty texture. Thickness of unit irregular, thins and thickens laterally. Chert nodules weather light brown to brown. Mainly massive. Resistant. Fossils indistinct..... 3.4

7. Limestone: medium dark gray and nearly aphanitic. Weatherer surface medium gray with silty texture. Chert nodules weather tan to brown. Mainly massive. Fairly resistant. Fossils: Dictyoclostus, gastropod outlines,and fragments..... 5.8

6. Limestone: medium dark gray to medium gray with pinkish tinge and nearly aphanitic. Weathered surface light gray to medium gray, mottled near base, with silty to powdery texture. Grades upward into unit 7. Chert nodules weather tan to brown. Beds 0.7 to 1.5 feet thick. Fairly resistant. Fossils: echinoid spines, crinoid stems, Fenestrellina, and small or fragmental indistinct fossils..... 7.8

5. Limestone: medium dark gray and finely to medium crystalline. Weathers medium gray to light olive gray, parts with tan cover, with silty texture and rough surface. Several bands of chert nodules, throughout; bands 1 to 20 feet thick. Mainly massive. Resistant. Fossils: Dictyoclostus bassi, productid spines, Buxtonia, rhynchonellid brachiopods, bellerophontid gastropods, echinoid spines (mostly near base), crinoid stems, Fenestrellina and other bryozoans (commonly associated with chert bands), and fragments..... 160.0

4. Limestone: medium dark gray, parts with pinkish tinge, finely crystalline, and slightly silty. Weathered surface medium light gray, parts with tan silt, with silty to powdery texture. Chert nodules (up to 0.3 by 1 foot) weather brown to black. Beds 0.5 to 2 feet thick. Fairly resistant. Fossils: Dictyoclostus, rhynchonellid brachiopods, echinoid spines and plates, crinoid stems, Fenestrellina, and fragments..... 11.8

3. Limestone: medium dark gray near base, grading to medium light gray, and finely crystalline. Weathers medium gray at base, grading to light tan-gray, with rough surface. Chert nodules numerous, except in lower 15 feet. Beds 1 to 4 feet thick; laterally massive. Resistant. Fossils: Dictyoclostus bassi, crinoid stems, Fenestrellina, and trepostome bryozoan (associated with chert)..... 78.0

2. Limestone: medium dark gray with bands of medium gray dolomitic limestone, both finely crystalline. Weathered surface medium olive gray with bands yellowish-gray, both with silty texture. Chert nodules weather light brown to brown. Mainly massive. Resistant. Fossils: Dictyoclostus, Fenestrellina, and trepostome bryozoans..... 11.9

1. Limestone: medium gray and finely crystalline. Weathers medium light gray with rough surface. Massive. Resistant. Fossils: Dictyoclostus, bryozoans, and fragments..... 2.3

Scherrer formation - conformable contact.

Composite section of Scherrer formation; upper 129 feet in saddle south of East Hill, W 1/2 NE 1/4 Sec. 31, T. 12 S., R. 9 E.; lower 293 feet across valley north of East Hill, near center of section line between sections 30 and 31.

Permian:

Concha limestone :

Scherrer formation: 422 feet thick

(Dip, 62° N. 55° E.)

		Feet
35.	Limestone, sandy: medium gray to light brownish-gray and finely crystalline. Sand grains poorly rounded, fairly well-sorted, and fine-grained. Weather surface light olive gray with pinkish tinge in parts, and with silty texture. Beds 1.5 to 4 feet thick. Resistant.....	8.2
34.	Dolomite, silty: medium dark gray, finely crystalline, and limy; medium gray where silt concentration is high. Weathered surface medium olive gray, silty concentration moderate brown, both with silty texture. Massive. Resistant.....	0.6
33.	Dolomite, limy: dark gray and nearly aphanitic. Weathered surface medium gray with powdery texture. Lower surface uneven. Massive. Resistant.....	1.3
32.	Dolomite, limy: medium gray and very finely crystalline. Weathered surface light olive gray with powdery texture. Upper surface uneven. Silt lens (0.03 foot thick) 0.8 foot above base. Mainly massive. Resistant.....	1.7
31.	Dolomite, limy: medium dark gray, finely crystalline, and silty. Weathered surface medium light gray, silt concentrations brown to yellow, both with silty texture. Mainly massive. Fairly resistant. Fossils indistinct.....	3.0
30.	Dolomite: medium gray and very finely crystalline. Weathered surface medium light gray with powdery texture. Beds 0.4 to 1 foot thick. Fairly resistant. Fossils indistinct.....	3.2

29. Sandstone: pale orange-yellow, and medium-grained; with well-sorted, fairly well-rounded, and frosted milky quartz grains and calcareous silt cement. Sand and silt in bands (up to 0.02 foot thick). Small (up to 0.01 foot) round concretions in some beds, throughout. Cross-bedded in part. Beds 0.5 to 2 feet thick. Fairly to slightly resistant..... 58

28. Sandstone: moderate grayish orange, and medium- to fine-grained; with poorly sorted, fairly well-rounded, and frosted milky quartz grains and silt cement. Weathered surface grayish-red. Sand and silt in poorly defined bands. Cross-bedded in part. Beds 0.5 to 2 feet thick. Slightly resistant..... 12.3

27. Sandstone: pale yellowish-orange and medium-grained; with well-sorted, fairly well-rounded, and frosted milky quartz grains and silt cement. Sand and silty in bands. Cross-bedded. Massive. Slightly resistant..... 1.7

26. Dolomite, limy: medium gray, finely crystalline, and partly sandy. Weathered surface light gray with granular to silty texture. Chert nodules irregular and grade to silt concentrations. Beds 0.2 to 1 foot thick. Fairly resistant..... 6.0

25. Dolomite: medium dark gray, very finely crystalline, and silty. Weathers moderate olive gray with silty texture and rough surface. Calcite blebs, partly replaced by quartz. Beds 0.2 to 3 feet thick. Fairly resistant. Fossils indistinct.. 9.0

24. Limestone, dolomitic: medium dark gray and nearly aphanitic. Weathered surface yellowish-gray with powdery texture. Quartz blebs. Massive. Resistant..... 1.3

23. Dolomite: medium dark gray and nearly aphanitic; becomes silty, limy, and very finely crystalline near base. Weathers light olive gray with powdery texture and rough surface; yellow silt near base. Quartz blebs. Chert lens in middle, about 0.1 foot thick. Massive. Resistant..... 2.2

22. Limestone, dolomitic: medium gray and nearly aphanitic. Weathers moderate yellowish gray with powdery texture and rough surface. Quartz blebs and granule-sized grains. Massive. Resistant..... 1.3

21. Dolomite, limy: medium dark gray and nearly aphanitic. Weathered surface medium light gray with silty to powdery texture. Massive. Fairly resistant..... 0.7

20. Dolomite: medium dark gray and very finely crystalline. Weathered surface olive gray with silty texture; silt concentrations near top brown. Beds 0.3 to 1 foot thick. Resistant..... 2.7

19. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface moderate to light olive gray with silty and powdery texture; silt concentrations throughout yellow and brown. Beds 2 to 5 feet thick. Resistant to non-resistant... 15.8

(Dip, 60^{0} N. 85° E.)

18. Siltstone: pale yellowish-gray and partly limy. Weathered surface light gray; limy parts pale yellowish-brown. Mainly massive. Slightly to non-resistant..... 14.0

17. Limestone, dolomitic: medium gray, nearly aphanitic, and silty. Weathered surface light olive gray with silty texture. Mainly massive. Slightly resistant... 2.0

16. Sandstone, limy: medium gray and very fine-grained. Weathered surface light gray with pinkish tinge. Deeply weathered parts appear silty and are grayish-orange to black on surface. Mainly massive. Fairly resistant..... 1.5

15. Sandstone: pale red to white to yellow and fine- to very fine-grained, parts quartzitic; with fairly well-sorted and poorly rounded grains. Weathered surface pinkish-gray to yellowish-gray. Colors mainly consistent in broad bands (10 to 15 feet wide). Limonite pseudomorphs after pyrite in certain beds, throughout. Beds 1 to 2 feet thick. Resistant to slightly resistant... 70

(Fault Plane)

14. Sandstone: pale red to yellow and fine- to very fine-grained, mainly quartzitic. Weathers pink to yellowish-gray, partly brown, with glassy surface and desert varnish. Cross-bedded and flat-bedded with thin (up to 0.02 foot) laminae. Beds 1 to 2 feet thick. Resistant to slightly resistant..... 100

(Fault Plane)

13. Sandstone: pale brownish-yellow and very fine-grained to silty, mainly quartzitic. Weathered surface yellow to pinkish-gray with dark gray patches. Upper part cross-bedded with thin (up to 0.02 foot laminae. Beds 1 to 2 feet thick. Resistant to slightly resistant..... 16.5

12. Sandstone: yellowish-gray and very fine-grained to silty; with poorly sorted and poorly rounded grains. Weathered surface moderate yellowish-gray with dark gray specks. Beds 1 to 3 feet thick. Slightly resistant..... 5.7

(Dip, 58° due east)

11. Limestone: medium light gray, nearly aphanitic, and silty. Weathered surface light olive gray with silty texture. Silt stringers weather light brown. Beds 0.2 to 0.5 foot thick. Slightly resistant..... 1.3

10. Sandstone: yellowish-gray and very fine-grained to silty; with poorly sorted and poorly rounded grains. Weathered surface moderate yellowish-gray with dark gray specks. Cross-bedded. Beds 1 to 4 feet thick. Fairly to non-resistant..... 8.0

9. Limestone: medium gray, nearly aphanitic, and silty. Weathers pale yellowish-brown with powdery texture and light olive gray with silty texture, and with rough surface. Massive. Resistant..... 1.3

8. Limestone: medium dark gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with silty texture and grayish-orange with powdery texture. Mainly massive. Resistant..... 1.5

7. Limestone: medium gray, very finely crystalline, and silty; silt concentrations yellowish-gray. Weathered surface pale yellowish-brown with silty texture; silt concentrations light brown to grayish-brown; less resistant portions light gray. Beds 1 to 2 feet thick. Fairly to non-resistant..... 6.5

6. Limestone: dark gray, very finely crystalline, and silty; dolomitic in part - medium dark gray, very finely crystalline, and silty. Weathered surface moderate yellowish-gray with silty texture; dolomitic parts grayish-yellow with powdery texture. Beds 0.3 to 0.8 foot thick. Fairly resistant..... 1.4

5. Limestone: medium dark gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with gray streaks, and with powdery texture. Beds 0.02 to 0.3 foot thick. Slightly resistant..... 1.8

4. Sandstone: light to medium gray, with pinkish tinge in bands, and very fine-grained to silty, partly quartzitic; with calcareous silt cement. Weathered surface moderate yellowish-gray with dark gray specks. Somewhat cross-bedded. Beds 1 to 2 feet thick. Fairly resistant..... 5.5

3. Siltstone: moderate greenish-gray to yellowish-gray and partly limy; more resistant parts quartzitic. Weathered surface pale yellowish-brown. Mainly massive. Slightly to non-resistant..... 10.5

2. Siltstone: grayish-pink to grayish-yellow and partly limy. Weathered surface light brown to brown. Middle portion contains very fine- grained, fairly well-sorted, angular sandstone. Somewhat cross-bedded. Beds 1 to 1.5 feet thick. Resistant to slightly resistant..... 5.5

1. Siltstone: moderate red with yellowish-gray bands and slightly limy. Few dolomite beds (0.2 to 1 foot thick), thinly banded medium gray and medium light gray and very finely crystalline. Mainly massive. Slightly to non-resistant..... 40

Upper member of Andrada formation - fault contact, but apparently conformable.

Composite section of Andrada formation; the upper 467 feet southwest of East Hill, W 1/2 NE 1/4 Sec. 31, T. 12 S., R. 9 E.; the underlying 200 feet across the valley northwest of East Hill, NW 1/4 NE 1/4 Sec. 31; the underlying 66 feet southwest of East Hill, near middle of line between NW 1/4 and NE 1/4 Sec. 31; the underlying 156.5 feet in NW 1/4 SE 1/4 SW 1/4 Sec. 30; the underlying 60 feet in NW 1/4 SE 1/4 NW 1/4 Sec. 31; and the lowermost 150.5 feet in SW 1/4 NE 1/4 NW 1/4 Sec. 31.

Permian:

Scherrer formation:

Pennsylvanian-Permian -- Naco Group:

Andrada formation: 1,100 feet thick

Upper member: 207 feet thick

(Dip, 50° N. 77°E.)

		Feet
160.	Dolomite, limy: medium dark gray and nearly aphanitic. Weathers moderate yellowish-gray with powdery texture and rough surface. Beds 0.5 to 1 foot thick. Resistant.....	3.0
159.	Limestone, dolomitic: dark gray and very finely crystalline. Weathers light olive gray with silty texture and rough surface. Beds 0.5 to 1 foot thick. Resistant.....	2.5
158.	Dolomite: medium dark gray, very finely crystalline, and silty; upper portion somewhat limy; lower portion silty with yellowish tinge. Weathered surface pale yellowish-brown with silty texture; silt concentrations light brown to brown. Beds 0.5 to 2 feet thick. Fairly to non-resistant; upper portion partly covered.....	15.0
157.	Limestone: dark gray and very finely crystalline. Weathered surface medium light gray with silty texture. Silt band (up to 1 foot thick) 1 foot above base. Beds 1 to 3 feet thick. Resistant. Fossils: Dictyoclostus, Phricodothyris (?), euomphalid and bellerophontid gastropods, and bryozoans.....	17.0

156. Limestone: dark gray and nearly aphanitic. Weathered surface medium light gray with powdery texture. Calcite blebs. Massive. Resistant. Fossils: bryozoans (?)..... 2.0

155. Limestone: medium to dark gray, very finely crystalline, and silty in part. Weathered surface medium light gray to moderate olive gray with silty texture. Massive. Resistant..... 2.5

(Fault plane)

154. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with powdery texture; silt bands light brown to brown, somewhat cross-bedded. Quartzitic stringers associated with silt bands. Beds 1 to 2 feet thick. Resistant..... 12.2

153. Dolomite: medium dark gray, nearly aphanitic, and silty. Weathered surface pale yellowish-brown with powdery texture. Grades upward into unit 153. Quartz blebs in upper half. Beds 1 to 3 feet thick. Resistant..... 5.8

152. Limestone: medium dark gray and nearly aphanitic. Weathered surface light olive gray with silty to powdery texture. Beds 0.1 to 0.8 feet thick. Resistant..... 1.4

151. Limestone: medium dark gray and nearly aphanitic. Weathers medium gray and grayish-orange with rough surface. Grades upward into unit 151. Silty in part. Massive. Resistant. Fossils: fragments numerous and euomphalid gastropods..... 0.8

150. Limestone: medium dark gray and nearly aphanitic. Weathered surface light olive gray with silty to powdery texture. Upper part silty. Beds 0.4 to 3 feet thick. Resistant. Fossil fragments at top.... 7.3

149. Limestone: medium dark gray and very finely crystalline. Weathered surface medium light gray to pale yellowish-brown with silty texture. Grades upward into unit 150. Silt concentrated in bands. Beds 0.4 to 1.2 feet thick. Fairly resistant. Fossil fragments..... 2.0

148. Limestone: dark gray and very finely crystalline. Weathered surface light olive gray with silty texture. Silty near base. Beds 0.3 to 1.5 feet thick. Resistant; less resistant near base. Fossils: Worthenia, small bivalves, and fragments.... 6.5

147. Limestone: dark gray and nearly aphanitic. Weathered surface moderate olive gray with silty texture. Beds 1 to 1.5 feet thick. Resistant. Fossils: small bivalves and fragments (numerous near top)..... 3.0

(Fault plane)

146. Dolomite: dark gray and nearly aphanitic. Weathers medium gray with powdery texture and jagged surface. Calcite blebs, commonly replaced by quartz. Quartzitic stringers in apparently minor thrust planes. Beds 0.2 to 2 feet thick. Resistant..... 11.0

145. Limestone: medium dark gray and very finely crystalline. Weathered surface mottled light olive gray and medium light gray with silty and powdery texture. Silty near base. Beds 0.2 to 1.5 feet thick. Resistant. Fossils: productid brachiopod spines, Composita, small turritellid gastropods, small pelecypods, echinoid spines, crinoid stems, and fragments..... 4.0

144. Limestone: medium gray, nearly aphanitic, and silty. Weathered surface pale yellowish-brown and light brown with silty texture. Grades upward into unit 145. Mainly massive. Fairly resistant..... 3.5

143. Limestone: medium dark gray and nearly aphanitic. Weathered surface light olive gray with powdery texture. Beds 0.1 to 0.5 feet thick. Slightly resistant..... 2.5

142. Limestone: medium dark gray, very finely crystalline, partly silty. Weathered surface medium light gray to light olive gray with silty texture. Beds 0.4 to 1 foot thick. Fairly resistant. Fossils: Amphiscapha, small turreted gastropods, small pelecypods, straight nautiloid cephalopods, echinoid spines, crinoid stems, and fragments..... 4.4

141. Limestone: medium dark gray, very finely crystalline, partly silty. Weathered surface medium light gray to light olive gray with silty texture. Few chert nodules. Beds 0.4 to 1 foot thick. Resistant to fairly resistant. Fossils: Dictyoclostus, Glabrocingulum, euomphalid, turreted, and trochoid gastropods, echinoid spines, crinoid stems, and bryozoans..... 22

(Dip, 55° N. 80° E.)

140. Limestone: medium dark gray, very finely crystalline to nearly aphanitic, and partly silty. Weathered surface medium light gray with silty texture; silty parts yellow. Beds 0.5 to 2 feet thick. Resistant to fairly resistant. Fossils: Dictyoclostus, Composita, turreted gastropods, tabulate corals, echinoid spines, and crinoid stems... 60

139. Limestone: medium dark gray with pinkish splotches, very finely crystalline, and silty. Weathered surface medium gray with silty texture. Massive to thin-bedded (0.02 foot thick). Fairly resistant... 3.5

138. Limestone: dark gray and very finely crystalline. Weathered surface medium gray with silty texture. Beds 1 to 4 feet thick. Resistant. Fossils (in zone 2 feet above base): Meekella (?) and crinoid stems..... 8.4

137. Limestone: medium dark gray, very finely crystalline, and silty. Weathered surface light olive gray to pale yellowish-brown, banded pink near base, with silty texture. Massive to thin-bedded (0.02 footthick). Fairly resistant..... 2.4

136. Limestone: dark gray, with yellowish tinge in silt lenses, nearly aphanitic, and silty. Weathered surface medium light gray with powdery texture; silt lenses banded medium light gray and pale yellowish-brown. Beds 0.2 to 0.5 foot thick. Resistant..... 4.3

Conformable contact.

Lower member: 893 feet thick

135. Covered (probably siltstone)..... 1.5

(Dip, 55° N. 80° E.)

134. Limestone, silty: light olive gray and grayish-orange and nearly aphanitic. Weathered surface grayish-orange with powdery texture. Beds 0.5 foot thick. Fairly resistant..... 1.0

133. Dolomite, silty: medium dark gray with yellowish tinge and very finely crystalline. Weathered surface light olive gray with powdery texture; silty bands moderate brown. Beds 0.05 or about 0.8 feet thick, depending on weathering. Slightly resistant..... 7.5

132. Dolomite: medium dark gray, nearly aphanitic, and silty. Weathered surface light olive gray with powdery texture. Silt stringers. Beds 0.2 to 1 foot thick. Fairly resistant..... 7.0

131. Dolomite, silty: medium dark gray and nearly aphanitic. Weathered surface light olive gray with yellow silt, and with powdery texture. Beds 0.1 to 0.5 foot thick. Fairly resistant..... 1.0

130. Siltsonte: moderate yellowish-orange and slightly limy. Beds 0.05 foot thick to conchoidal fracture. Non-resistant; partly covered..... 20

129. Shale, silty: grayish-green and yellow. Non-resistant; mostly covered..... 3.0

128. Limestone, silty: grayish-orange and nearly aphanitic. Massive. Fairly resistant..... 0.5

127. Shale, silty: grayish-green and yellow. Weathers nodular. Non-resistant; mostly covered..... 3.4

126. Limestone, silty: medium gray with yellowish tinge and very finely crystalline. Weathered surface moderate olive gray with silty texture. Beds 0.1 to 0.4 foot thick. Fairly resistant..... 5.0

125. Dolomite: dark gray, nearly aphanitic, and silty. Weathered surface medium light gray to light olive gray with powdery texture and banded appearance. Beds 0.1 to 1 foot thick. Fairly resistant..... 2.3

124. Siltstone: moderate yellowish-orange and slightly limy. Beds 0.05 foot thick to conchoidal fracture. Non-resistant; partly covered..... 5.8

123. Dolomite: medium dark gray, parts with yellowish tinge, very finely crystalline, and silty. Weathered surface light olive gray with silty texture; silty parts pale yellowish-brown to brown. Beds 0.5 to 2 feet thick. Slightly resistant. Fossils (in zone 13 feet above base): brachiopods, mostly fragments..... 18

122. Dolomite: medium dark gray and nearly aphanitic. Weathered surface light olive gray with powdery texture. Calcite blebs, commonly replaced by quartz. Beds 0.3 to 2 feet thick. Fairly resistant. Small fossils and fragments numerous; fewer near top..... 8.5

121. Siltstone: moderate yellowish-orange and slightly limy. Mainly massive. Non-resistant..... 4.5

120. Limestone: medium dark gray, nearly aphanitic, and silty. Weathered surface moderate olive gray with silty to powdery texture; silt stringers through middle and near top pale yellowish-brown to brown. Beds 0.5 to 1.5 feet thick. Fairly resistant..... 6.7

119. Limestone: medium gray, nearly aphanitic, and silty. Weathered surface light gray to light olive gray with silty texture. Beds 0.3 to 0.5 foot thick. Slightly resistant..... 1.8

118. Limestone: dark gray and finely crystalline. Weathered surface medium dark gray with yellowish tinge, and with silty texture. Mainly massive. Resistant..... 0.9

117. Dolomite: dark gray and very finely crystalline. Weathers olive gray with light brown specks, and with silty to powdery texture and jagged surface. Grades upward into unit 117. Beds 0.2 to 1 foot thick. Fairly resistant..... 2.0

116. Limestone, dolomitic: medium dark gray, nearly aphanitic, and silty. Weathered surface moderate olive gray with powdery texture; silt concentrations near base light brown. Beds 0.1 to 1 foot thick. Resistant..... 2.4

115. Limestone, silty: medium dark gray and nearly aphanitic. Weathered surface pale brownish-yellow with powdery texture. Massive. Resistant..... 0.7

114. Siltstone, limy: grayish-orange to pale pinkish-orange. Slightly and non-resistant; mostly covered..... 16

(Dip, 60° due east)

113. Limestone, silty: medium gray with streaks of light olive gray and very finely crystalline. Weathered surface moderate olive gray with silty and powdery texture; silt streaks light brown. Beds 0.1 to 0.3 foot thick. Resistant in part..... 0.6

112. Dolomite, silty: medium gray with yellowish tinge and very finely crystalline. Weathered surface light olive gray with light brown streaks, and with silty to powdery texture. Beds 0.1 to 0.8 foot thick. Slightly resistant..... 2.6

111. Dolomite: medium dark gray, nearly aphanitic, and silty. Weathered surface light olive gray with light brown streaks, and with silty to powdery texture. Beds 0.1 to 1 foot thick. Resistant..... 2.1

110. Dolomite, silty: medium gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray with silty texture. Mainly massive. Resistant..... 1.4

109. Limestone: medium dark gray, very finely crystalline, and slightly silty. Weathers moderate olive gray with silty texture and rough surface. More silty near base. Beds 0.4 to 1 foot thick. Resistant..... 3.8

108. Dolomite, silty: medium dark gray with yellowish tinge and very finely crystalline. Weathered surface grayish-orange to brown with silty texture. Grades upward into unit 108. Beds 0.2 to 0.4 foot thick. Fairly resistant..... 1.0

107. Dolomite, silty: medium dark gray with yellowish tinge and very finely crystalline. Weathered surface light olive gray with light brown streaks, and with silty to powdery texture. Beds 0.1 to 0.8 foot thick. Slightly resistant..... 1.4

106. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray with powdery texture; irregular-shaped silt stringers light brown. Massive. Resistant..... 0.4

105. Dolomite, silty: medium gray and nearly aphanitic. Weathered surface pale yellowish-brown to brown with silty texture; silt in prominent bands. Beds 0.1 to 0.8 foot thick. Slightly resistant..... 1.2

104. Dolomite, silty: medium dark gray and nearly aphanitic. Weathered surface light olive gray with powdery texture. Beds 0.3 to 3 feet thick. Resistant..... 4.1

103. Limestone: moderate greenish-gray, nearly aphanitic, and slightly silty. Weathered surface moderate yellowish-gray, faintly banded, and with powdery texture. Massive. Resistant..... 0.8

102. Covered (probably siltstone)..... 4.0

101. Dolomite, silty: medium dark gray and nearly aphanitic. Weathered surface pale yellowish-brown with silty texture. Beds 0.1 to 0.8 foot thick. Slightly resistant..... 1.6

100. Dolomite, silty: banded medium dark gray and yellowish-gray and nearly aphanitic. Weathered surface pale yellowish-brown to brown with silty texture; silt in prominent bands. Mainly massive. Resistant..... 1.3

99. Dolomite, silty: medium gray with yellowish tinge and very finely crystalline. Weathers moderate olive gray with powdery texture and rough surface. Mainly massive. Resistant..... 2.6

98. Dolomite, silty: medium dark gray and nearly aphanitic. Weathered surface light olive gray with powdery texture. Beds 0.1 to 0.8 foot thick. Slightly resistant; less resistant near base.. 2.1

97. Dolomite, silty; medium dark gray and nearly aphanitic; silt content high. Weathered surface pale yellowish-brown with silty to powdery texture. Beds 0.1 to 0.4 foot thick. Non-resistant..... 1.0

96. Dolomite, silty: medium dark gray and nearly aphanitic. Weathered surface light olive gray with powdery texture. Beds 0.1 to 0.8 foot thick. Slightly resistant..... 4.5

95. Siltstone, limy: grayish-orange. Weathered surface dark yellowish-brown. Massive. Fairly resistant..... 0.5

94. Siltstone: grayish-orange and slightly limy. Grayish-red, silty shale in part. Non-resistant; mostly covered..... 22.5

93. Limestone, silty: moderate olive gray to brownish-gray and finely crystalline. Weathered surface pale yellowish-brown to light brown with silty texture. Becomes interbedded with siltstone below and above. Mainly massive. Fairly resistant... 2.0

92. Siltstone: grayish-orange to light brown and slightly limy. Non-resistant; mostly covered..... 25

(Fault plane)

91. Siltstone, dolomitic: moderate olive gray with dark specks. Weathered surface moderate yellowish-gray with faint grayish bands, and with silty to powdery texture. Beds 0.2 to 0.5 foot thick. Slightly resistant..... 1.0

90. Dolomite: dark gray, aphanitic, and silty. Weathers moderate olive gray with powdery texture and jagged surface; silt bands near top light brown. Beds 0.2 to 0.8 foot thick. Resistant.. 3.0

89. Limestone, silty: medium dark gray with yellowish and pinkish tinges and nearly aphanitic. Weathers moderate olive gray with powdery texture and rough and jagged surface. Beds 0.4 to 0.8 foot thick. Resistant..... 1.9

88. Dolomite: medium dark gray, aphanitic, and silty. Weathers moderate yellowish gray with powdery texture and jagged surface. Few silt bands. Beds 0.2 to 0.5 foot thick. Fairly resistant..... 8.9

87. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface pale yellowish-brown with silty to powdery texture. Grades upward into unit 87. Beds 0.4 to 1 foot thick. Fairly to slightly resistant..... 2.2

86. Dolomite: medium dark gray, aphanitic, and silty. Weathers light olive gray with silty texture and jagged surface. Silty near base. Beds 0.1 to 0.4 foot thick. Resistant..... 2.5

85. Siltstone, limy: yellowish-olive gray. Weathered surface grayish-orange to brown. Thin-bedded (0.02 foot thick) to conchoidal fracture. Non-resistant..... 2.7

84. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathers light olive gray with silty to powdery texture and jagged surface. Beds 0.2 to 0.5 foot thick. Resistant..... 2.3

83. Dolomite: medium dark gray, nearly aphanitic, and silty. Weathers medium gray with silty to powdery texture and jagged surface. Beds 0.2 to 0.5 foot thick, laterally massive. Resistant..... 7.8

82. Limestone, silty: medium dark gray and pale yellowish-brown and nearly aphanitic. Weathered surface moderate yellowish gray with silty to powdery texture. Less silty near top and base. Beds 0.1 to 0.6 foot thick. Fairly resistant..... 4.2

81. Siltstone: grayish-orange and limy. Non-resistant.... 2.0

80. Dolomite: medium dark gray, nearly aphanitic, and silty. Weathered surface moderate olive gray to light brown with silty to powdery texture. Beds 0.1 to 1 foot thick. Fairly resistant..... 1.5

79. Siltstone: grayish-orange and limy. Non-resistant; mostly covered..... 5.0

78. Limestone, silty: medium gray with yellowish tinge and nearly aphanitic. Weathers medium light gray and yellow sith powdery texture and jagged surface. Massive. Resistant..... 1.0

77. Siltstone, limy: grayish-orange with pinkish tinge in places. Non-resistant; mostly covered..... 8.0

(Dip, 53° S. 85°E.)

76. Siltstone: grayish-red. Thin-bedded (0.02 foot thick) to conchoidal fracture. Non-resistant..... 140

75. Covered (probably siltstone)..... 10

74. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface grayish-yellow with silty to powdery texture. Beds 1 to 2 feet thick. Fairly resistant..... 5.0

73. Limestone, silty: medium gray with yellowish tinge and nearly aphanitic. Weathered surface light yellowish-brown with silty and powdery texture. Beds 1 to 3 feet thick. Fairly resistant..... 6.5

72. Limestone, silty: medium gray with yellowish tinge and nearly aphanitic; silt stringers pale yellowish-brown. Weathered surface light yellowish-brown and light brown to brown with silty texture. Few conglomeratic limestone beds. Beds 1 to 3 feet thick. Resistant..... 22

71. Covered (probably siltstone)..... 7

70. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface grayish-yellow with silty to powdery texture. Beds 1 to 2 feet thick. Fairly resistant..... 4.5

69. Limestone, silty: medium gray with yellowish tinge and nearly aphanitic; silt stringers pale yellowish-brown. Weathered surface light yellowish-brown and light brown to brown with silty texture. Beds 1 to 2 feet thick. Resistant.... 5.0

(Dip, 42° N. 85° E.)

68. Dolomite conglomerate: medium to light gray, aphanitic pebbles in limy cement. Pebbles somewhat angular. Weathered surface grayish-yellow to pale yellowish-brown. Beds 1 to 3 feet thick. Fairly resistant..... 8.0

67. Dolomite, silty: medium dark gray, nearly aphanitic, and porous. Marker bed. Weathers moderate olive gray with powdery texture and jagged surface. Chert nodules small (0.05 to 0.2 foot diameter) and scattered. Beds 0.5 to 1.5 feet thick. Resistant..... 5.0

66. Covered (probably siltstone)..... 5.5

65. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray with silty to powdery texture. Massive. Fairly resistant..... 1.0

64. Covered..... 0.7

63. Dolomite, silty: medium dark gray with yellowish and pinkish tinges and nearly aphanitic. Weathered surface light olive gray with silty texture; silt stringers light brown. Beds 0.3 to 0.5 foot thick. Resistant..... 1.2

62. Dolomite, silty: medium dark gray, nearly sphanitic, and porous. Weathers moderate olive gray with powdery texture and jagged surface. Chert nodules small and scattered. Beds 0.5 to 1.4 feet thick. Resistant..... 5.0

61. Covered..... 2.5

60. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray with silty texture; silt yellow. Small quartz blebs. Beds about 0.5 foot thick. Resistant..... 1.1

59. Covered..... 2.0

58. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray with silty to powdery texture. More silty near top. Beds about 0.5 foot thick. Resistant..... 1.1

57. Covered..... 1.0

56. Dolomite, silty: medium dark gray and nearly aphanitic; silt yellow in small splotches. Weathered surface light olive gray to pale yellowish-brown with silty to powdery texture; silt stringers brown. Silt blebs partically quartzitic. Beds 0.3 to 1 foot thick. Resistant..... 2.5

55. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface grayish-orange to light brown with silty texture. Beds 0.5 to 1.5 feet thick. Fairly resistant..... 3.2

54. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface grayish-yellow with silty to powdery texture. Beds 1 to 2 feet thick. Fairly resistant; less resistant in lower half..... 9.6

53. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface light olive gray and grayish-yellow with silty to powdery texture; appears fragmental. Beds 0.1 to 0.5 foot thick. Slightly resistant..... 2.8

52. Dolomite, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathered surface grayish-orange to light brown with silty texture. Mainly massive. Slightly to non-resistant; partly covered..... 3.0

51. Dolomite, silty: medium dark gray, nearly aphanitic, and porous. Weathers moderate olive gray with powdery texture and jagged surface. Chert nodules small and scattered. Beds 0.5 to 1.5 feet thick. Resistant; lower part less resistant and partly covered..... 5.6

50. Dolomite: dark gray and nearly aphanitic. Weathered surface moderate olive gray with powdery texture. Flat quartz blebs, possibly fossil replacements. Beds 0.5 to 1 foot thick. Resistant..... 4.5

49. Dolomite: dark gray, nearly aphanitic, and silty. Weathered surface light olive gray with powdery texture. Quartz blebs and silt stringers. Massive. Resistant..... 0.7

(Dip, 85° N. 85° E.)

48. Siltstone: grayish-orange and limy. Non-resistant; mostly covered..... 12

47. Dolomite conglomerate: medium dark gray, nearly aphanitic, and silty matrix; light olive gray, limy mudstone fragments. Weathered surface: matrix pale yellowish-brown and pebbles grayish-orange; both with powdery texture. Massive. Fairly resistant..... 1.2

46. Siltstone, limy: moderate yellowish-gray. Non-resistant; mostly covered..... 13.1

45. Siltstone: light olive gray and nearly quartzitic. Weathered surface light olive gray with black specks; appears quartzitic. Cross-bedded. Beds 0.02 to 0.1 foot thick. Slightly resistant..... 3.2

44. Siltstone: interbedded light grayish-red limy siltstone and grayish-red silty shale; few green shale beds. Siltstone weathers pale yellowish-brown to light brown to brown. Partly cross-bedded, throughout. Beds 0.02 to 2 feet thick, depending upon weathering. Fairly resistant; shale layers mostly covered..... 127

(Dip, 58° S. 28° E.)

43. Limestone conglomerate: purplish, nearly aphanitic matrix; varicolored limestone granules and pebbles - yellow, orange, pink, and gray. Weathered surface mainly same but lighter color than fresh surface; silt stringers light brown to brown. Thickness variable. Limestone cobbles near base. Beds 0.5 to 1 foot thick. Resistant..... 2.0

42. Limestone conglomerate: medium gray, very finely crystalline matrix; grayish-orange and light gray, aphanitic limestone granules and pebbles. Marker bed. Weathered surface: matrix moderate olive gray with silty texture and rough surface; silt stringers light brown. Lenses of medium to medium light gray limestone and silty limestone weather pale yellowish-brown with silty texture. Beds 0.5 to 1.5 feet thick. Resistant..... 8.0

41. Siltstone, limy: banded moderate reddish-purple. Weathered surface banded yellowish-pink and brown. Bands less than 0.01 foot wide. Thickness variable. Beds 0.1 to 0.3 foot thick. Fairly resistant..... 2.0

40. Limestone, silty: medium light gray with yellowish tinge and nearly aphanitic. Weathered surface pale yellowish-brown with silty texture; silt bands (0.01 to 0.1 foot thick) moderate yellowish-brown. Thickness variable. Mainly massive. Resistant..... 0.8

39. Siltstone, limy (lenses): banded moderate reddish-purple and very pale orange with dusky red spots. Weathered surface banded light yellowish-pink and brown. Conglomeratic lenses. Beds 0.1 to 1 foot thick. Fairly resistant..... 4.2

38. Limestone conglomerate: medium gray, very finely crystalline matrix; grayish-orange and light gray, aphanitic limestone granules and pebbles. Marker bed. Weathered surface: matrix moderate olive gray with silty texture and rough surface; silt stringers light brown. Lenses of medium to medium light gray limestone and silty limestone weather pale yellowish-brown with silty texture. Beds 0.5 to 1.5 feet thick. Resistant..... 6.5

37. Siltstone, shaly: grayish-red, becomes yellowish-red near weathered surface. Mainly massive. Fairly resistant..... 1.8

36. Siltstone, shaly: pale orange to pinkish. Non-resistant; mostly covered..... 14

35. Limestone: yellowish-gray, parts pale red, and aphanitic. Weathers light yellowish-brown, parts grayish-orange pink and parts grayish-orange, with silty to powdery texture and rough surface; silt band near top yellow. Beds 0.3 to 1.5 feet thick. Resistant..... 5.6

34. Limestone, silty: moderate olive gray, and nearly aphanitic. Weathered surface light brown to brown with silty texture. Mainly massive. Resistant..... 1.8

33. Limestone, silty and Shale, silty, interbedded: Limestone - moderate greenish-gray; weathering light grayish-brown with powdery texture. Shale - pink to pale reddish-purple. Limestone beds less than 0.5 foot thick and fairly resistant. Shale non-resistant..... 6.7

32. Limestone, silty: moderate olive gray and nearly aphanitic. Weathered surface light brown to light olive gray with silty texture. Mainly massive. Fairly resistant..... 1.3

(Fault plane)

(Dip, 52° S. 35° E.)

31. Limestone: moderate olive gray, nearly aphanitic, and slightly silty. Weathered surface mottled pale yellowish-brown and light gray with silty to powdery texture. Beds 0.5 to 1.5 feet thick. Resistant..... 2.7

30. Limestone: moderate olive gray, nearly aphanitic, and silty. Weathered surface light olive gray to grayish-yellow with silty texture. Beds 0.5 feet thick. Slightly resistant..... 2.5

29. Covered (probably siltstone)..... 5.0

28. Dolomite, silty: dark yellowish-gray and nearly aphanitic. Weathered surface grayish-orange to brown with powdery texture. Silt concentration near top. Mainly massive. Resistant..... 6.0

27. Limestone, silty: moderate yellowish-gray and nearly aphanitic. Weathered surface light yellow to pale yellowish-brown with silty to powdery texture. Beds 0.1 to 0.2 foot thick. Non-resistant; mostly covered..... 5.0

26. Limestone, silty: greenish-gray, faintly banded with light brown, and nearly aphanitic. Weathered surface yellowish-gray with silty to powdery texture; silt bands light brown; quartzitic stringers pale yellowish-brown. Beds 0.3 to 1 foot thick. Slightly to non-resistant; partly covered..... 4.4

25. Limestone, silty: moderate yellowish-gray with greenish-gray and pale yellowish-brown parts, and nearly aphanitic. Weathered surface grayish-orange to moderate yellowish-brown to brownish-black, banded in part, with silty texture. Beds 0.01 to 0.2 foot thick. Slightly resistant; partly covered..... 2.8

24. Limestone: pale yellowish-brown, very finely crystalline, and silty. Weathers pale yellowish-brown with silty texture and rough surface. Beds 0.2 to 0.4 foot thick. Resistant. Fossils: bivalve outlines..... 0.8

23. Limestone, silty: greenish-gray and nearly aphanitic. Weathered surface pale yellowish-brown to moderate brown with silty texture. Thin beds of non-resistant siltstone interbedded. Beds 0.6 to 2 feet thick. Fairly resistant..... 10.0

22. Siltstone: yellowish gray and pink. Non-resistant; mostly covered..... 7.0

21. Limestone, silty: light greenish-gray and nearly aphanitic. Weathered surface pale yellowish-brown to brown with silty texture. Beds 0.6 to 2 feet thick. Fairly resistant..... 10.0

20. Limestone conglomerate: medium light gray and nearly aphanitic matrix; yellow and orange, coarse-grained limestone fragments. Weathers moderate yellowish-gray with silty texture and rough surface; silt stringers moderate brown to brown. Massive. Resistant. Fossils: bivalve cross-sections..... 1.2

19. Limestone, silty: medium light gray with yellowish silt and nearly aphanitic. Weathered surface moderate brown to brown with silty texture. Massive. Resistant..... 1.8

18. Limestone, silty: dark yellowish-gray and nearly aphanitic. Weathered surface moderate grayish-orange and light gray with silty texture; silt nodules brown. Beds 3 to 4 feet thick. Fairly to slightly resistant; covered in lower part..... 10.5

17. Limestone: pale yellowish-brown, very finely crystalline, and silty. Weathers pale yellowish-brown with silty texture; silt band near base light brown to brown. Beds 0.2 to 1 foot thick. Resistant. Fossils: bivalve outlines..... 2.0

16. Siltstone, limy: yellowish-gray. Non-resistant; mostly covered..... 12

15. Limestone conglomerate: medium to light gray, medium crystalline matrix; grayish-orange and light gray, aphanitic limestone granules and pebbles. Weathered surface mainly same but lighter color than fresh surface. Silty limestone pebbles more resistant. Beds 0.2 to 1 foot thick. Resistant..... 2.5

14. Limestone: medium light gray with dark gray streaks, dendrites, and spots, nearly aphanitic, and silty. Weathered surface pale yellowish-brown with silty texture; silt bands light brown to brown. Mainly massive. Resistant..... 1.5

13. Limestone: moderate light greenish-gray and aphanitic. Weathers moderate yellowish-gray with silty texture and rough surface; less resistant parts light gray. Silt concentrations and conglomeratic lenses in lower part. Unit thins laterally. Beds 0.2 to 1 foot thick. Resistant..... 5.0

12. Shale: mottles, and somewhat banded, grayish-red purple and dusky yellowish-green, partly silty and partly limy. Non-resistant; mostly covered..... 12.5

11. Dolomite, silty: moderate greenish-gray and aphanitic. Weathered surface grayish-orange to brown with powdery texture. Mainly massive. Resistant..... 0.7

(Dip, 25° S. 55° E.)

10. Limestone: moderate olive gray with dark gray streaks and specks, aphanitic, and slightly silty. Weathered surface moderate yellowish-gray with silty to powdery texture. Beds 0.2 to 0.6 foot thick. Fairly resistant..... 1.3

9. Shale: moderate greenish-gray and silty. Non-resistant; partly covered..... 1.0

8. Limestone: moderate olive gray with dark gray streaks and specks, aphanitic, and slightly silty. Weathered surface moderate yellowish-gray with silty to powdery texture. Beds 2 and 3 feet thick with thin green shale bed between. Slightly resistant 5.0

7. Shale: moderate greenish-gray and silty. Non-resistant; partly covered..... 2.0

6. Limestone: medium gray to medium light gray with yellowish tinge, nearly aphanitic to medium crystalline. Weathers light olive gray to medium dark gray with silty texture and rough surface. Fossils cause conglomeratic appearance. Beds 0.2 to 1.5 feet thick. Resistant. Fossils: bellerophontid and turreted gastropod and bivalve outlines..... 4.8

5. Shale: mottled pale reddish-purple to grayish-red purple and pale pink, partly silty. Non-resistant; mostly covered..... 11.2

4. Limestone, silty: moderate grayish-orange pink and nearly aphanitic. Weathered surface grayish-orange to pale yellowish-brown. Bed 0.3 to 0.6 foot thick. Fairly resistant..... 1.5

3. Shale, silty: mottled light grayish-red and yellowish-gray and slightly limy. Slightly to non-resistant; mostly covered..... 14.0

2. Limestone: grayish-green with pinkish spots, nearly aphanitic, and silty. Weathered surface very light olive gray with powdery texture. Massive. Fairly resistant..... 1.0

1. Shale, silty: mottled light grayish-red and yellowish-gray and slightly limy. Slightly to non resistant; mostly covered..... 8.0

Horquilla formation - contact covered, apparently conformable.

Composite section of Horquilla formation; upper 125.5 feet in SE 1/4 NW 1/4 NW 1/4 Sec. 31, T. 12 S., R. 9 E.; lower 342.5 feet in N 1/2 SW 1/4 NW 1/4 Sec. 31

Pennsylvanian-Permian -- Naco Group:

Andrada formation:

Pennsylvanian:

Horquilla formation: 468 feet thick

(Dip, 43° S. 40° E.)

		Feet
81.	Limestone: very light olive gray, aphanitic, and slightly silty. Weathers light gray with rough surface. Silt stringer near base has little lime content. Beds 0.2 to 1 foot thick. Resistant...	3.5
80.	Limestone: light gray, aphanitic, and slightly silty. Weathered surface light gray with yellowish tinge. Grades upward into unit 81. Beds 0.5 to 2 feet thick. Fairly resistant. Fossil fragments numerous.....	4.5
79.	Limestone, silty: light olive gray to light greenish-gray and nearly aphanitic; lower part conglomeratic. Weathered surface grayish-orange to light brown with silty texture; silt lenses light brown to black-brown. Beds 1 to 2 feet thick. Slightly resistant.....	16
78.	Limestone: moderate olive gray, nearly aphanitic, and silty. Weathered surface light olive gray with yellowish tinge, and with silty texture. Mainly massive. Slightly resistant.....	12
77.	Siltstone, limy: pale red to light brownish-gray. Weathered surface light brown to black-brown with silty texture; weathering may penetrate up to 0.01 foot. Cross-bedded in part. Circular outlines near top may be fossil remains. Beds 0.02 to 2 feet thick, depending upon weathering. Resistant.....	23

76. Limestone: medium gray and aphanitic. Weathers light gray with rough surface. Medium light gray chert nodules (up to 0.4 by 1 foot), mainly near top, weather grayish-yellow to black. Beds 0.2 to 2 feet thick. Resistant. Fossils: Chaetetes milleporaceus (from 0.3 to 2 feet diameter) and bivalve fragments..... 7.5

75. Limestone: medium dark gray and aphanitic; silt nodules moderate olive gray. Weathers medium light gray with rough surface; silt nodules light brown to brown. Appears conglomeratic with silty limestone matrix and limestone cobbles. Beds 1 to 6 feet thick. Fairly resistant; less resistant in lower 6 feet; partly covered... 15

74. Siltstone, limy: pale red to light brownish-gray. Weathered surface light brown to black-brown with silty texture; weathering may penetrate up to 0.01 foot. Grades upward into unit 75. Cross-bedded in part. Beds 0.02 to 2 feet thick, depending upon weathering. Resistant..... 32

73. Limestone: medium gray with pinkish tinge to medium light gray with yellowish tinge, nearly aphanitic to aphanitic, and silty. Weathered surface light gray with silty to powdery texture; silt nodules and stringers grayish-orange. Beds 0.4 to 0.8 foot thick. Resistant..... 12

72. Limestone: light brownish-gray, nearly aphanitic to aphanitic, and silty. Weathers light pinkish-gray with rough surface. Grades upward into unit 73. Unit thins laterally. Silt stringers in upper part. Beds 0.3 to 1 foot thick. Resistant. Fossils: brachiopod fragments..... 4.2

71. Limestone: medium gray, nearly aphanitic to aphanitic, and silty; silty parts lighter. Weathered surface grayish-orange, light gray in lower part, and with silty to powdery texture. Appears conglomeratic with silty limestone matrix and limestone cobbles. Beds 0.2 to 1 foot thick. Fairly resistant..... 2.3

70. Siltstone, limy: pale red to light brownish-gray. Weathered surface light brown to black-brown with silty texture; weathering may penetrate up to 0.01 foot. Cross-bedded in part. Beds 0.2 to 2 feet thick. Resistant..... 9.0

(Dip, 57° S. 25° E.)

69. Limestone, silty: moderate olive gray with yellowish tinge and nearly aphanitic. Weathered surface mottle grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic with silty limestone matrix and limestone cobbles. Beds 0.2 to 1 foot thick. Slightly resistant; lower part covered..... 8.0

68. Limestone, silty: moderate olive gray to moderate yellowish-brown, partly pinkish, and nearly aphanitic. Weathered surface mottled grayish-orange to brown and medium light gray with silty texture; silty stringers light brown. Appears conglomeratic with silty limestone matrix and limestone cobbles. Silt more concentrated near base and forms cap at top. Beds 0.5 to 1 foot thick. Fairly resistant..... 2.5

67. Limestone, silty: moderate olive gray, partly with yellowish tinge, and nearly aphanitic. Weathered surface pale yellowish-brown with silty texture; silt stringers grayish-orange to dark brown. Appears conglomeratic with silty limestone matrix and limestone cobbles. Beds 0.02 to 1 foot thick, depending upon weathering. Resistant..... 4.5

66. Limestone, silty: moderate olive gray with yellowish tinge and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic with silty limestone matrix and limestone cobbles. Beds 0.2 to 1 foot thick. Slightly resistant; upper part covered..... 13

65. Siltstone, limy: pale red to light brownish-gray. Weathered surface light brown to black-brown with silty texture; weathering may penetrate up to 0.01 foot. Cross-bedded in part. Beds 0.02 to 2 feet thick, depending upon weathering. Slightly to non-resistant..... 15

64. Limestone, silty: medium gray, partly with light brown tinge, and nearly aphanitic to aphanitic. Weathered surface mottled grayish-orange to light brown and light olive gray with silty to powdery texture; silt nodules light brown to brown; chert nodules light brown. Mainly massive. Resistant. Fossils (mainly in upper 10 feet of unit): Dictyoclostus, Neospirifer (0.3 foot hinge line), Rhipidomella, rhynchonellid brachiopods, pelecypods, and crinoid stems (up to 0.05 foot in diameter)..... 30

63. Siltstone, limy: medium light gray with brownish tinge. Weathered surface black-brown with glassy appearance. Massive. Fairly resistant..... 1.6

62. Limestone, silty: dark yellowish gray, partly medium gray, and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic with silty limestone matrix and limestone pebbles. Partly dolomitic - weathered pale reddish-brown with dark yellowish-orange pebbles. Beds 0.1 to 1 foot thick. Fairly to slightly resistant; partly covered..... 17.2

61. Limestone, silty: medium gray and nearly aphanitic; silty parts pale yellowish brown. Weathers light gray and grayish-orange with silty texture and rough surface; silty stringers light brown. Appears conglomeratic with silty limestone matrix and limestone cobbles. Lower surface uneven. Silty more concentrated near base. Massive. Resistant..... 3.2

60. Limestone, silty: moderate olive gray with yellowish tinge and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic. Grades upward into unit 61. Beds 0.2 to 1 foot thick. Slightly resistant.... 2.0

59. Siltstone, limy: light grayish-green; nearly quartzitic near top - light brownish-gray with limonite pseudomorphs after pyrite. Weathered surface light brown to black-brown with silty texture; quartzitic part dark yellowish-gray with black specks. Beds 0.1 to 0.5 foot thick. Slightly to non-resistant; mostly covered..... 13

58. Limestone: light gray to light olive gray, aphanitic, and silty. Weathers light gray with yellowish tinge, and with rough surface. Few silt stringers and chert nodules. Beds 1 to 5 feet thick. Resistant..... 8.5

57. Covered (probably siltstone)..... 1.5

56. Limestone: medium light gray with yellowish tinge, nearly aphanitic, and silty. Weathered surface dark yellowish-gray with silty texture. Massive. Resistant..... 1.5

55. Limestone, silty: medium gray with yellowish tinge, partly medium dark gray, and nearly aphanitic. Weathered surface mottled grayish-orange and medium light gray with silty to powdery texture. Appears conglomeratic with silty limestone matrix and limestone pebbles. Massive. Fairly resistant..... 2.2

54. Limestone: medium gray and nearly aphanitic to light gray and aphanitic, and silty. Weathers medium light gray to moderate yellowish-gray with silty texture and rough surface; lighter in patches in upper 3.5 feet. More silty and darker limestone in lower 1 foot. Chert nodules partly large and irregular-shaped. Beds 2 to 3 feet thick. Resistant. Fossils: crinoid stems in upper part and fragments in lower..... 6.1

53. Limestone: medium light gray, pinkish in places, nearly aphanitic, and silty. Weathers medium olive gray with silty texture and rough surface. Upper surface uneven. Chert nodules scattered. Massive. Resistant..... 3.2

52. Limestone, silty: moderate olive gray with yellowish tinge and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic. Beds 0.2 to 1 foot thick. Slightly to non-resistant; partly covered..... 2.5

51. Siltstone, limy: light brownish-gray to orange-gray. Weathered surface pale brown to grayish-orange to brown with silty texture. Beds 0.02 to 0.5 foot thick, depending upon weathering. Slightly to non-resistant; lower part covered..... 9.0

50. Limestone: light gray in lower portion, medium gray in upper, and aphanitic. Weathers pale yellowish-brown to medium light gray with silty and/or rough surface. Light band is from 1 to 6 feet wide; contains large irregular chert nodules. Upper-most 1.5 feet silty with chert nodules and weathers yellowish-gray. Mainly massive. Resistant. Fossil fragments..... 7.5

(Dip, 52° S. 65° E.)

49. Limestone: medium light gray with yellowish tinge, aphanitic, and silty. Weathers light gray with rough surface. Uppermost 1 foot more silty, capped by light brown weathering silty concentration. Beds 1 to 2 feet thick. Resistant. Fossils: Ostracods (?) and fragments..... 3.5

48. Limestone, silty: light olive gray, partly yellowish-gray, with medium gray and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and moderate olive gray with silty texture. Appears conglomeratic with silty limestone matrix and limestone cobbles and pebbles. Upper 3 feet shaly. Beds 0.2 to 1 foot thick. Slightly to non-resistant; partly covered..... 10.5

47. Limestone, silty: medium dark gray with yellowish tinge and nearly aphanitic. Weathers light olive gray with silty texture and rough surface. Silicified silt lenses in middle. Massive. Resistant..... 2.5

46. Limestone: medium gray to medium light gray, nearly aphanitic, and silty. Weathers moderate olive gray to light gray with silty texture and rough surface; silty parts yellowish. Grades upward into unit 47. Chert nodules scattered. Mainly massive. Resistant. Fossils: spiriferid brachiopods, Chaetetes milleporaceus, and black fragments..... 1.1

45. Limestone: medium gray, aphanitic, and slightly silty. Weathers medium light gray with rough surface. Grade upward into unit 46. Upper surface uneven. Mainly massive. Resistant. Fossils: brachiopods, crinoid stems, and fragments..... 1.7

44. Limestone: medium light gray, aphanitic, and slightly silty. Weathers light gray with rough surface. Uneven upper surface. Silty in lower 1 foot. Massive, except for lower 1 foot. Resistant. Fossils: horn corals and fragments..... 3.2

43. Siltstone, limy: light brownish-gray and pale red. Weathered surface grayish-orange to light brown with silty texture. Beds 0.02 to 0.5 foot thick, depending upon weathering. Slightly to non-resistant; partly covered..... 13.8

42. Covered (probably siltstone)..... 5.5

41. Limestone: medium light gray, nearly aphanitic, and silty. Weathers light olive gray with silty texture and rough surface. Small chert nodules. Beds 0.8 foot thick. Fairly resistant..... 1.6

40. Limestone: medium light gray with yellowish tinge, nearly aphanitic, and silty. Weathers light gray with yellowish tinge and rough surface. Chert lenses and base and top. Massive. Resistant. Fossil fragments..... 1.6

39. Siltstone conglomerate: light brown siltstone matrix; light olive gray, aphanitic, and silty limestone pebbles. Weathered surface - light brown to brown matrix; grayish-yellow to light gray limestone with silty texture and rough surface. Mainly massive. Slightly resistant..... 1.0

38. Limestone, silty: moderate olive gray with yellowish tinge and nearly aphanitic. Weathered surface mottled grayish-orange to light brown and light gray with silty to powdery texture. Appears conglomeratic. Beds 0.2 to 1 foot thick. Slightly resistant; partly covered..... 11.5

37. Limestone: medium light gray, aphanitic, and silty; lower 0.5 foot pale red. Weathers light gray with rough surface; lower 0.5 foot light olive gray with silty texture. Silt nodules near top. Chert lenses cap unit, up to 1 foot thick. Massive, except basal 0.5 foot. Resistant. Fossils: horn corals, crinoid stems, and fusulinids..... 3.2

36. Dolomite: medium gray with yellowish-gray angular fragments, aphanitic, and silty. Weathers yellowish-gray with powdery texture and rough surface; silt stringers and nodules light brown to brown. Mainly massive. Resistant to non-resistant; upper 5 feet partly covered..... 9.0

35. Limestone: medium light gray with yellowish tinge, aphanitic, and silty. Weathers light gray with rough surface. Few chert nodules. Mainly massive. Resistant..... 1.1

34. Limestone: banded very light gray and aphanitic, and mottled medium light gray to medium dark gray and aphanitic; light parts appear crushed with silt seams between angular pebble-sized fragments. Weathered surface: light parts grayish-yellow with rough surface, silty seams are light brown; dark parts medium light gray with rough surface, appear fractured with 0.002 foot veins. Thickness of unit variable. Mainly massive. Resistant..... 1.2

33. Limestone: medium light gray with brownish tinge, aphanitic, and slightly silty; lighter in lower part. Weathers medium light gray with yellowish tinge, and with rough surface. Upper surface uneven. Lower part more silty. Chert nodules in lowest bed. Beds 0.4 to 1.2 feet thick. Resistant. Fossils: Dictyoclostus, fusulinids, and bryozoans..... 4.5

32. Limestone: medium gray, aphanitic, and silty; medium light gray with brownish tinge near top. Weathered surface medium light gray, with silty texture; light grayish-brown near top. Chert lenses between beds and small (up to 0.06 foot) chert nodules scattered. Beds 0.3 to 0.6 foot thick. Resistant. Fossils: Phricodothyris (?), horn corals, fusulinids, and ostracods(?)..... 3.0

31. Limestone conglomerate: grayish-orange, nearly aphanitic silty limestone matrix; medium light gray, aphanitic limestone granules and small pebbles. Weathered surface same but lighter color than fresh surface. Mainly massive. Nonresistant; partly covered. Fossils: crinoid stems and fusulinids..... 3.5

30. Siltstone, limy: pale yellowish-brown to gray. Weathered surface moderate grayish-orange to light brown. Beds 0.3 to 1 foot thick. Fairly to non-resistant; partly covered..... 6.0

29. Dolomite, silty: medium light gray and aphanitic. Weathers grayish-orange to gray with rough surface; silt concentrations light brown to brown; chert light gray. Chert in layer at base and in lenses in upper portion. Limonite pseudomorphs after pyrite. Beds 0.5 to 2 feet thick. Fairly resistant..... 8.0

28. Limestone: medium light gray with brownish tinge, darker near base, nearly aphanitic to aphanitic, and slightly silty. Weathered surface pale yellowish-brown to gray with silty texture. More silty near top. Beds 0.3 to 0.6 foot thick in lower 1.5 foot, massive in upper part. Resistant. Fossils: fusulinids..... 5.0

27. Limestone: medium gray with brownish tinge, aphanitic, and silty; silt lens near middle moderate grayish-orange. Weathered surface light gray with powdery texture; silt lens yellowish-gray to light brown to brown. Silt stringers near base. Massive. Fairly resistant..... 4.0

26. Limestone, shaly: yellowish-brown and brownish-yellow, and aphanitic. Weathered surface grayish-orange and light brown with powdery texture. Beds about 1 foot thick. Resistant to non-resistant; partly covered..... 3.0

(Fault plane)

25. Limestone: medium gray with black specks (fossil fragments (?)), nearly aphanitic, and silty. Weathered surface medium light gray with silty texture. Silty near top. Beds 0.2 to 1 foot thick. Resistant..... 4.3

24. Limestone: medium gray, nearly aphanitic, and silty; silt stringers light brown. Weathers medium light gray with brownish tinge, and with rough surface; silt stringers light brown. Calcite veins brown. Massive. Resistant..... 1.7

23. Limestone (lens): medium gray, moderate grayish-yellow, and yellowish-red, aphanitic, and silty. Weathered surface mottled medium light gray and grayish-orange with powdery texture. Massive. Resistant. Fossils: crinoid stems and fusulinids..... 1.0

22. Limestone: mottled medium dark gray and medium gray with brownish tinge, aphanitic, and silty; band of moderate yellowish gray, nearly aphanitic limestone at top. Weathered surface light gray with yellowish tinge and medium gray, and with wilty to powdery texture; band near top light yellowish-gray with rough surface. Silt stringers near base. Chert lenses near top. Beds about 2 feet thick. Resistant. Fossils (mainly in upper band): crinoid stems and ostracods (?)..... 5.2

21. Limestone: medium light gray with brownish tinge and aphanitic. Weathers very light gray with rough surface; silt stringers light brown. Grades upward into unit 22. Mainly massive. Resistant. Fossils: crinoid stems..... 2.5

20. Limestone: medium gray, aphanitic, and silty; silt stringers yellowish-brown. Weathered surface medium light gray with silty texture; silt stringers very light brown. Upper surface uneven. Beds 0.2 to 0.6 foot thick. Fairly resistant..... 1.8

19. Claystone, limy: moderate grayish-orange. Weathered surface pale yellowish-orange with powdery texture. Beds 0.1 to 0.4 foot thick. Slightly to non-resistant; partly covered..... 5.0

18. Limestone, shaly: grayish-orange and aphanitic. Weathered surface light grayish-orange with silty to powdery texture. Beds 0.5 to 1 foot thick. Fairly to non-resistant; partly covered..... 5.0

(Dip, 70° S. 87° E.)

17. Limestone, silty: pale yellowish-brown and aphanitic. Weathered surface light gray with brownish tinge, and with silty texture; partially rust-colored at top. Massive. Resistant. Fossils: crinoid stems.... 1.2

(Fault plane)

16. Limestone conglomerate: light brown, nearly aphanitic silty limestone matrix; medium light gray, aphanitic limestone granules. Weathers light to medium gray with yellowish tinge, and with rough surface. Massive. Resistant..... 2.0

15. Limestone conglomerate: banded yellowish-brown and dark gray, aphanitic silty limestone matrix; brownish-yellow, aphanitic limestone granules and pebbles. Weathered surface moderate yellowish-gray and medium gray with silty texture. Unit thickness variable. Massive. Resistant..... 1.4

14. Limestone conglomerate: medium gray, aphanitic silty limestone matrix; light gray, aphanitic limestone granules; few grayish-orange pebbles. Weathered surface medium light gray with yellowish tinge, and with silty texture. Massive. Resistant..... 2.2

13. Limestone conglomerate: medium gray, aphanitic silty limestone matrix; light gray and pinkish, aphanitic limestone granules. Weathered surface medium light gray and grayish-orange with silty to powdery texture. Silt nodules (very coarse grain-sized) weather out. Beds 0.5 to 1 foot thick. Fairly resistant..... 2.7

12. Limestone: light gray with yellowish tinge, aphanitic, and silty. Weathered surface yellowish-gray with powdery texture; silt stringers light brown, partially connected. Appears conglomeratic. Massive. Resistant. Fossils: Syringopora and crinoid stems..... 1.6

11. Limestone: medium light gray, yellowish-gray in lower half, medium crystalline, and silty. Weathers moderate yellowish-gray with rough surface. Massive. Resistant..... 3.0

10. Limestone conglomerate: light gray, aphanitic limestone matrix; brownish-yellow limy siltstone pebbles. Weathered surface: light olive gray limestone with silty texture; pale yellowish-brown siltstone. Massive. Fairly resistant..... 0.9

9. Covered (probably siltstone)..... 1.5

8. Limestone: light gray, aphanitic, and silty. Weathered surface light gray and light brown with powdery texture. Massive. Fairly resistant. Fossils: Syringopora and minute fragments..... 0.6

(Dip, 37° S. 60° E.)

7. Limestone: dark gray, aphanitic, and silty. Weathers mottled medium and medium light gray with rough surface. Unit thickness variable. Massive. Resistant. Fossils: crinoid stems and fusulinids..... 1.5

6. Limestone: medium light gray, aphanitic, and silty. Weathers medium light gray with yellowish tinge and rough surface. Upper surface uneven. Chert lenses near base. Beds 0.5 to 2 feet thick. Resistant. Fossils: crinoid stems and fragments..... 5.0

5. Limestone: grades from very light brownish gray at bottom to medium light gray at top, and is aphanitic. Weathers from pale yellowish-brown at bottom to medium gray at top, with rough surface; lower part has silty texture; silt stringers near base, light brown. Grades upward into unit 6. Beds 0.5 to 2 feet thick. Resistant. Fossils: crinoid stems (mainly near top) and fusulinids (few, near base)..... 6.2

4. Limestone: mottles medium dark gray and medium light gray, and aphanitic. Weathered surface mottled medium gray and light gray with silty to powdery texture. Massive. Resistant. Fossils: crinoid stems, fusulinids, and fragments..... 3.4

3. Limestone: mottled yellowish-gray and pale reddish-purple, and aphanitic. Weathered surface mottled yellowish-gray and very light reddish-purple with powdery texture. Grades upward into unit 4. Appears conglomeratic with silty limestone matrix and limestone fragments (large pebble-sized). Mainly massive. Resistant..... 2.5

2. Limestone: medium light gray, aphanitic, and silty. Weathered surface pale yellowish-brown with silty texture. Chert nodules small (up to 0.01 foot) and chert lens at top, about 0.005 foot thick. Massive. Resistant..... 2.0

1. Limestone: very light gray and aphanitic. Weathers yellowish-gray with rough surface. Grades upward into unit 2. Chert nodules numerous at base, nearly lenticular (up to 0.01 foot thick). Massive. Resistant..... 1.8

Chert conglomerate: grayish-red chert of small pebble- to large cobble size in a matrix of red shale. Chert fragments partly medium to dark gray in center. Mainly massive. Slightly to non-resistant; covered in most places.....15 - 20

Escabrosa limestone - erosion surface.

Section of Escabrosa limestone from cliff west of area in S 1/2 NW 1/4 SE 1/4 Sec. 25, T. 12 S., R. 8 E.

Pennsylvanian:

Horquilla formation:

Mississippian:

Escabrosa limestone: 228 feet thick

(Dip, 37° S. 85° E.)

		Feet
44.	Limestone: medium light gray and grayish-orange pink and medium to very finely crystalline. Weathered surface pale orange-pink, more grayish in places. Crinoid stems make up most of the rock. Massive. Slightly resistant.....	22
43.	Limestone: medium light gray and grayish-orange pink and medium to very finely crystalline; faintly color banded in places. Weathered surface plae orange-pink and light gray. Crinoid stems abundant. Chert nodules (up to 0.5 by 1.5 feet) scattered through certain beds. Beds 1 to 3 feet thick. Resistant.....	19
42.	Limestone: banded medium light gray and light brownish-gray and medium to finely crystalline. Weathered surface banded light olive gray and light brownish-gray with granular to silty texture. Beds 0.2 to 0.6 foot thick. Resistant. Fossils: crinoid stems.....	1.5
41.	Limestone: light brownish-gray and very finely crystalline. Weathers light brownish-gray with rough surface. Massive. Resistant. Fossils: crinoid stems.....	1.5
40.	Limestone: medium light gray with yellowish-gray patches and very finely crystalline. Weathers pale yellowish-brown with silty texture and rough surface. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant. Fossils: crinoid stems.....	1.0
39.	Limestone: light brownish-gray and very finely crystalline; medium crystalline near top. Weathers light brownish-gray with pink bands, and with silty texture and rough surface. Thin calcite stringers light brown. Massive Resistant. Fossils: horn corals and crinoid stems.....	19.5

38. Limestone: medium gray and grayish-orange pink in fine bands and very finely crystalline. Weathered surface grayish-orange pink and medium light gray with silty texture. Grades upward into unit 39. Thin calcite stringers light brown. Massive. Resistant..... 1.5

37. Limestone: light and medium brownish-gray and nearly aphanitic. Weathered surface light gray with whitish streaks near middle, and with silty texture and rough surface. Thin calcite stringers light brown. Mainly massive. Resistant..... 3.2

36. Limestone: pale red, mottled with medium gray near base, and nearly aphanitic. Pinkish-gray limy sandstone at top and base (beds up to 0.2 foot thick); sand is medium-grained with fairly well-rounded and frosted grains. Weathered surface: limestone - moderate orange-pink, mottled with medium light gray near base, and with silty texture; sandstone - light brownish-gray. Beds 0.1 to 0.4 foot thick. Resistant; sandstone less resistant..... 3.8

35. Limestone: moderate brownish-gray and nearly aphanitic. Weathered surface medium light gray with silty texture. Thin calcite stringers light brown. Massive. Resistant..... 0.8

34. Limestone: grayish-orange pink and finely crystalline. Weathered surface light brownish-gray with silty texture. Thin calcite stringers light brown. Small indistinct fossils in clusters near base. Massive. Resistant..... 1.2

33. Sandstone: pinkish-gray and medium grained; with fairly well-rounded and frosted grains and calcareous cement. Weathered surface light brownish gray. Unit thickness variable. Massive. Fairly resistant..... 0.5

32. Limestone: dark brownish-gray and very finely crystalline; conglomeratic near base. Weathered surface medium gray, partially brownish-gray and light gray, with silty texture. Lower surface uneven. Beds 2.5 to 3 feet thick. Resistant. Fossils: brachiopods and few horn corals..... 5.0

31. Sandstone: pinkish-gray and medium-grained; with fairly well-rounded and frosted grains and calcareous cement. Weathered surface light brownish-gray. Unit thickness uneven. Massive. Fairly resistant..... 1.0

30. Limestone: medium light gray and very finely crystalline. Weathered surface light olive gray and yellow with silty texture. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant. Fossils: brachiopods, few horn corals, and fragments.... 6.0

29. Limestone: brownish-gray and very finely crystalline in upper portion; medium dark gray with brownish-gray spots and finely crystalline near base. Weathers medium brownish-gray with smooth surface in upper portion; medium light gray with silty texture and rough surface near base. Massive. Resistant. Fossils: horn corals and fragments..... 2.2

28. Limestone, silty: brownish-gray and very finely crystalline. Weathered surface medium light gray with silty texture. Thrust faults along bedding planes, displacement appears minor. Beds less than 0.2 foot thick. Slightly resistant..... 1.0

27. Limestone: medium gray with light pinkish tinge and finely crystalline. Weathered surface medium olive gray with silty texture; silt bands light brown. Thin (less than 0.005 foot) calcite stringers light brown. Beds 0.7 to 1.2 foot thick. Slightly resistant..... 3.8

26. Limestone: mottled medium gray and brownish-gray and medium to finely crystalline. Weathered surface medium light gray with fine granular texture; partly darker gray or more pinkish and lighter, commonly with medium gray band at base. Thin (less than 0.005 foot) calcite stringers light brown. Beds 1 to 1.5 feet thick. Resistant. Fossils: Syringopora, Michelinia, and fragments..... 13.5

25. Limestone: banded medium dark gray and medium crystalline, and medium brownish-gray and finely crystalline. Weathered surface: dark gray part, medium gray with yellowish tinge; brownish-gray part, light brownish-gray; both with silty texture. Beds 0.1 to 0.3 foot thick. Fairly resistant..... 2.0

24. Limestone: medium dark gray and finely crystalline; darker gray near top and base. Weathered surface medium gray with pinkish tinge, and with silty texture; darker gray near top and base. Beds 4 feet thick. Resistant. Fossils: horn corals (in upper 1.5 feet)..... 8

23. Limestone: medium gray and very finely crystalline. Weathered surface medium light gray with silty texture. Thrust faults along bedding planes, displacement appears minor. Beds less than 0.2 foot thick. Slightly resistant..... 0.5

22. Limestone: brownish-gray and very finely crystalline in upper portion; medium brownish-gray and finely crystalline near base. Weathered surface medium light gray in upper portion; yellowish-gray near base; both with silty texture. Thin (less than 0.005 foot) calcite stringers light brown. Massive. Fairly resistant..... 1.2

21. Limestone: brownish-gray and very finely crystalline in upper portion; banded pale red and medium brownish-gray and nearly aphanitic near base. Weathered surface medium gray and yellow in upper portion; banded medium light gray and pinkish-gray near base; both with rough surface. Massive. Resistant..... 3.3

20. Limestone: medium light gray and very finely crystalline in upper portion; medium gray with pale red spots (appears conglomeratic) and very finely crystalline to nearly aphanitic near base. Weathered surface light olive gray and yellow in upper portion; mottled medium gray to grayish-pink near base; both with silty texture and rough surface. Massive. Fairly resistant..... 2.5

19. Limestone: medium dark gray and finely crystalline; very finely crystalline near base. Weathers medium dark gray with yellowish tinge, and with rough surface; medium light gray near base. Upper surface uneven. Beds 1 foot thick. Fairly resistant..... 2.0

18. Limestone: mainly medium light gray and finely crystalline layers in upper part, and mainly brownish-gray and aphanitic in lower part; bands of pale red and light grayish-red and aphanitic layers more common near base. Weathered surface: banded medium gray and medium light gray in upper part; banded medium gray, yellowish-gray, and grayish-orange pink to dark pinkish-gray in lower part; both with fine granular texture and rough surface. Beds 0.2 to 1 foot thick. Resistant..... 10.7

17. Limestone: mottled grayish-pink and blackish-red near top, and banded pale red and blackish-red in lower portion; and very finely crystalline to aphanitic. Weathers banded pale red and grayish-red with granular texture and rough surface. Beds 0.3 to 0.7 foot thick. Fairly resistant..... 1.5

16. Limestone: mottled pale red and dusky red and aphanitic; small (0.01 foot) pale red spots, appear conglomeratic. Weathers medium gray with silty texture and rough surface. Beds 0.5 foot thick. Fairly resistant..... 2

15. Limestone: moderate pink to light brownish-gray and nearly aphanitic. Weathers pale red and medium light gray with rough surface. Beds 0.2 to 0.4 foot thick. Fairly resistant..... 1.3

14. Limestone: brownish-gray and aphanitic. Weathers medium light gray with silty texture and rough surface. Thin (less than 0.002 foot) calcite stringers light brown. Beds 0.7 to 2 feet thick. Fairly resistant..... 5

13. Limestone: dark brownish-gray and aphanitic. Weathered surface medium gray and silty texture. Thin (about 0.01 foot) calcite stringers grayish-orange. Massive. Fairly resistant..... 3

12. Limestone: dark pinkish-gray and aphanitic. Weathered surface light brownish-gray with silty texture. Massive. Resistant..... 2

11. Limestone: medium gray, very finely crystalline, and silty. Weathers medium gray with silty texture and rough surface; silt concentration yellowish-gray. Thin (about 0.01 foot) calcite stringers light brown. Massive. Resistant..... 3

10. Limestone: medium light gray and aphanitic. Weathers medium light gray with rough surface. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant..... 5.5

9. Sandstone: very light gray to grayish-pink and fine-grained; with poorly sorted grains and calcareous cement. Weathered surface light brown. Massive. Fairly resistant..... 1.5

8. Limestone: moderate brownish-gray with pinkish tinge and very finely crystalline. Weathered surface moderate olive gray with silty texture. Thin (less than 0.005 foot) calcite stringers light brown, partially replaced by silica. Massive. Resistant..... 2

7. Limestone: light grayish red and very finely crystalline. Weathered surface pinkish-gray to medium light gray with silty texture. Thin (less than 0.005 foot) calcite stringers light brown. Massive. Resistant..... 8

6. Limestone: medium gray, slightly brownish, and very finely crystalline. Weathers medium gray with rough surface. Massive. Resistant..... 1

5. Limestone: medium gray and finely crystalline; with very light gray to light gray chert nodules (up to 0.4 by 1.5 feet making up about 40% of the unit). Weathered surface medium gray; chert very light gray to pale yellowish-brown. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant..... 5.5

4. Limestone: medium gray and moderate orange-pink and medium crystalline. Weathered surface pale red and medium gray with granular to silty texture. Thin (less than 0.002 foot) calcite stringers reddish-brown. Massive. Resistant..... 3.5

3. Limestone: medium gray, slightly pinkish, and nearly aphanitic; light gray, partially translucent chert (up to 0.4 by 1.5 feet, making up about 50% of the unit). Weathered surface medium light gray; chert light gray to light brown. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant..... 7.5

2. Limestone: medium dark gray and medium to very finely crystalline. Weathered surface moderate olive gray and medium dark gray with silty texture. Massive. Resistant. Fossils: small fragments..... 4.5

1. Limestone: medium gray, partially pinkish, and medium to finely crystalline. Weathered surface medium gray with silty texture. Thin (less than 0.005 foot) calcite veins reddish-brown. Massive. Resistant. Fossils fragments..... 33

Martin formation - fault contact, but apparently conformable.

Composite section of Martin formation; upper 288 feet west of area near center of line between NW 1/4 and SW 1/4 of SE 1/4 Sec. 25, T.12 S., R.8 E.; lower 85 feet southwest of Waterman Peak in NW corner of Sec. 31, T.12 S., R.9 E.

Mississippian:

Escabrosa limestone:

Devonian:

Martin formation: 373 feet thick

(Dip, 44° N. 55° E.) Feet

93. Limestone: medium dark gray and moderate orange-pink, finely crystalline, and silty. Weathered surface medium gray and pale yellowish-orange with granular texture. Massive. Resistant..... 3.0

92. Dolomite, limy: medium gray and light brown to medium light gray, finely crystalline, and silty; lighter color in lower part. Weathered surface moderate yellowish-brown with sandy texture. Mainly massive, laterally beds 1 foot thick and greater. Resistant. Fossils mainly indistinct; crinoid stems near base.... 28.5

91. Dolomite, limy: medium gray, finely crystalline, and silty. Weathered surface medium gray with silty texture. Thrust faults along bedding planes, displacement appears minor. Beds less than 0.2 foot thick. Slightly resistant..... 1.5

90. Dolomite, limy: light gray with pink calcite granules, finely crystalline, partly medium crystalline, and silty. Weathered surface light brown, banded yellowish-brown and light brown in middle, with granular texture. Mainly massive. Resistant. Fossils indistinct..... 8.3

89. Limestone: medium gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with granular texture. Massive. Fairly resistant..... 0.7

88. Dolomite: medium gray, very finely crystalline, and slightly silty. Weathered surface pale yellowish-brown with silty texture; partially weathered to soft marl-like material. Mainly massive. Non-resistant..... 15

87. Dolomite, limy: medium gray, very finely crystalline, and silty. Weathered surface light brown with silty texture; partially weathered to soft marl-like material. Mainly massive. Resistant..... 14.5

86. Dolomite, limy: brownish-gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with darker patches, and with silty texture. Beds 1 to 2.5 feet thick. Resistant. Fossils: Cyrtospirifer whitneyi, Spirifer orestes (?), Spirifer euryteines (?), Tenticospirifer cyrtiniformis (?), Schuchertella, Atrypa (?), Cladopora, and Aulopora..... 8.3

85. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with silty texture. Clacite stringers and nodules. Massive. Resistant. Fossils: Cyrtospirifer, Spirifer (?), and Aulopora..... 1.5

84. Dolomite: medium light gray with yellowish-gray streaks, very finely crystalline, and silty. Weathered surface grayish-orange with silty texture; silt streaks have red outlines. Massive. Resistant. Fossils: spiriferid brachiopods..... 2.7

83. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with silty texture. Calcite stringers and nodules. Massive. Resistant. Fossils: spiriferid brachiopods..... 2.0

82. Dolomite: medium light gray with dusty red specks, very finely crystalline, and silty. Weathered surface light brown to very light gray with silty texture; partially weathered to soft marl-like material, with elliptical more resistant nodules (up to 0.2 by 0.3 foot). Mainly massive. Non-resistant..... 2.7

81. Dolomite, limy: pale yellowish-brown and medium gray with dusky red specks, very finely crystalline, and silty. Weathered surface light brown with silty texture. Beds 0.4 to 1 foot thick. Fossils: Atrypa (?), Theodossia hungerfordi (?), spiriferid brachiopods, Heterophrentis (?), and Aulopora..... 4.0

80. Dolomite: medium gray with medium light gray streaks and moderate reddish-brown and dusky red specks (possibly iron oxide), very finely crystalline, and silty. Weathered surface light brown with silty texture. Massive. Resistant. Fossils (abundant): Theodossia (?), Cyrtina (?), other spiriferid brachiopods, Atrypa, and fragments..... 0.8

79. Dolomite: light brownish-gray with dusky red specks, very finely crystalline, and silty; darker color near base. Weathered surface light brown with silty texture; lighter near base; partially weathered to soft marl-like material, with elliptical more resistant nodules. Beds 0.3 to 1 foot thick. Non-resistant; few beds fairly resistant. Fossils indistinct, fragmental near base..... 16

78. Dolomite: light brownish-gray at base, moderate brownish-gray near middle, and pinkish-gray near top, very finely crystalline, and silty; dusky red specks in lower and middle parts. Weathered surface pale yellowish-brown, darker near base, with silty texture; partially weathered to soft marl-like material. Calcite blebs (about 0.01 foot diameter), possibly fossil replacements. Beds 0.5 to 1.5 feet thick. Mostly non-resistant..... 5.0

77. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface light brownish-gray with silty texture; thin silt stringers and quartz grains (up to 0.02 foot diameter) light brown. Massive. Resistant. Fossils: spiriferid, rhynchonellid, and small smooth-shelled brachiopods, horn corals, and Aulopora..... 2.0

76. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface light olive gray with silty texture; silt concentrations light brown. Beds about 1 foot thick. Resistant. Fossils: spiriferid brachiopods and fragments..... 5.5

75. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface light olive gray with light brown specks, and with silty texture. Massive. Resistant. Fossils: spiriferid brachiopods and fragments..... 5.0

74. Dolomite, limy: medium gray with medium dark gray patches and light brown specks, very finely crystalline, and silty. Weathered surface grayish-orange with pale yellowish-brown patches, and with silty texture. Rust-colored specks on surface may be fossil remains. Massive. Fairly resistant..... 1.5

73. Dolomite, limy: medium dark gray, finely crystalline, and silty; silt concentrations yellowish-gray. Weathered surface mainly olive gray with silty texture; silt stringers light brown. Unit thickness variable. Grades upward into unit 74. Massive. Fairly resistant..... 0.2

72. Dolomite, limy: medium dark gray with pale yellowish-brown patches, very finely crystalline, and silty. Weathered surface pale yellowish-brown with rust-colored specks, and with silty texture. Massive. Resistant. Fossils mainly indistinct; few gastropod outlines..... 3.0

71. Dolomite: medium dark gray, finely crystalline, and silty; silt concentrations pinkish-gray. Weathered surface pale yellowish-brown with light brown patches, and with silty texture. Massive. Resistant. Fossils: small smooth-shelled brachiopods, Cladopora and fragments..... 3.5

70. Dolomite: medium gray and pinkish-gray, finely crystalline, and silty. Weathered surface light brown and pale yellowish-brown with silty, nearly granular, texture; silt stringers rust-colored. Massive. Resistant. Fossil fragments..... 1.8

69. Covered (probably silty dolomite)..... 25

68. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with light brown specks and with sandy texture. Calcite blebs, possibly fossil replacements. Mainly massive. Fairly resistant..... 1.5

67. Dolomite: grayish-black with medium gray patches, very finely crystalline, and silty. Weathered surface medium dark gray with light olive gray patches, and with silty texture. Mainly massive. Fairly resistant. Fossils: conispiral gastropods..... 2.8

66. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with silty texture; silt stringers and small nodules light brown. Mainly massive. Fairly resistant..... 2.0

65. Dolomite: medium dark gray, finely crystalline, and silty. Weathered surface moderate yellowish-brown with silty to granular texture; silt nodules pale yellowish-brown. Massive. Resistant..... 1.0

64. Dolomite: medium dark gray and medium gray, very finely crystalline, and silty; lighter part limy. Weathered surface pale yellowish-brown with olive gray streaks, and with silty to granular texture. Calcite blebs, possibly fossil replacements. Massive. Fairly resistant..... 1.5

63. Dolomite: medium light gray, finely crystalline, and silty. Weathered surface pale yellowish-brown and light brown with silty texture; partially weathered to soft marl-like material, with elliptical more resistant nodules (up to 0.2 by 0.3 foot). Beds about 0.3 foot thick. Non-resistant..... 8

62. Dolomite: dark gray, very finely crystalline, and silty. Weathered surface olive gray and light brown with granular texture; silt lenses light brown. Thin (0.002 foot) calcite stringers. Massive. Resistant. Fossils indistinct..... 1.5

61. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with granular texture; silt stringers light brown. Grades upward into unit 62. Massive. Resistant. Fossils indistinct..... 1.0

60. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with gray patches, and with silty to granular texture. Massive. Fairly resistant. Fossils indistinct..... 2.0

59. Dolomite: medium gray, darker near top, very finely crystalline, and silty. Weathered surface olive gray with light brown specks, darker gray near top, and with granular texture. Grades upward into unit 60. Mainly massive. Resistant. Fossils indistinct: bryozoans (?)..... 3.5

58. Dolomite: medium dark gray, lighter near top, very finely crystalline, and silty. Weathered surface light olive gray, darker near top, and with silty texture; silt lenses (up to 0.02 foot thick) and stringers light brown. Beds 0.2 to 0.9 foot thick. Fairly resistant..... 2.0

57. Dolomite: medium dark gray, very finely crystalline, and silty; silt stringers pinkish-gray, mostly near base. Weathered surface pale yellowish-brown with silty texture; silt stringers moderate brown. Massive. Resistant. Fossils indistinct..... 1.5

56. Dolomite: medium dark gray, finely crystalline, and silty. Weathered surface pale yellowish-brown with silty to granular texture. Calcite blebs, possibly fossil replacements. Mainly massive. Non-resistant... 1.7

55. Dolomite: medium gray, finely crystalline, and silty, Weathered surface yellowish-gray with silty texture. Thin (less than 0.002 foot) calcite stringers grayish-orange. Massive. Resistant..... 1.5

54. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with silty texture. Thin (less than 0.002 foot) calcite stringers light brown. Small (about 0.01 foot) white dolomite blebs. Massive. Resistant. Fossils indistinct..... 1.5

53. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface medium dark gray with olive gray patches near base, grades to pale yellowish-brown in middle, and grayish-orange near top, all with silty texture. Massive. Resistant. Fossils indistinct..... 2.0

52. Dolomite: dark gray, very finely crystalline, and silty. Weathered surface medium dark gray with yellowish tinge, and with silty texture. Grades upward into unit 53. Thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant. Fossils indistinct..... 2.0

51. Dolomite: dark gray, very finely crystalline, and silty. Weathered surface medium dark gray with silty texture. Dolomite nodules (up to 0.02 by 0.1 foot) and thin (less than 0.002 foot) calcite stringers light brown. Massive. Resistant. Fossils indistinct..... 3.6

50. Dolomite: medium gray, very finely crystalline, and silty; silt concentrations pinkish gray. Weathered surface light to moderate brown near base and pale yellowish-gray near top, with silty to granular texture. Grades upward into unit 51. Mainly massive. Fairly resistant. Fossils: brachiopod outlines..... 2.0

49. Sandstone: medium light gray, and very fine-grained; with fairly well-sorted and poorly rounded grains, and calcareous cement. Weathered surface pale yellowish-brown to dark brown, with dusky red specks. Partially with more resistant elliptical nodules. Beds 0.7 to 2 feet thick. Non-resistant..... 4.2

48. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with silty to powdery texture. Thin (up to 0.002 foot) calcite stringers light brown. Calcite blebs, possibly fossil replacements. Partially weathered to soft marl-like material. Mainly massive. Slightly resistant..... 1.2

47. Dolomite: medium gray, aphanitic, and silty; silt concentrations grayish-red. Weathered surface grayish-orange with powdery texture. Thin (up to 0.002 foot) calcite stringers light brown. Massive. Fairly resistant..... 0.8

46. Dolomite, limy: medium gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with powdery texture. Partially weathered to soft marl-like material with more resistant elliptical nodules (up to 0.02 by 0.03 foot). Mainly massive. Non-resistant..... 3.0

45. Dolomite: medium dark gray with black specks, very finely crystalline, and silty; silt stringers reddish-gray. Weathered surface pale yellowish-brown with gray streaks, and with silty texture. Thin (up to 0.002 foot) calcite stringers light brown. Massive. Fairly resistant..... 0.4

44. Dolomite: dark gray, very finely crystalline, and silty. Weathered surface medium dark gray with lighter streaks, and with silty texture. Massive. Resistant..... 0.2

43. Dolomite: medium dark gray, aphanitic, and silty. Weathered surface pale yellowish-brown with powdery texture. Thin (up to 0.002 foot) calcite stringers light brown. Massive. Resistant..... 1.7

42. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface grayish-orange with silty texture. Dolomite nodules, possibly fossil replacements. Thin (less than 0.002 foot) calcite stringers light brown. Beds 0.3 to 0.9 foot thick. Resistant.. 1.5

41. Dolomite: medium dark gray with dusky red specks and very finely crystalline. Weathered surface pale yellowish-brown in lower part and banded medium light gray and pale yellowish-brown near top, with silty to powdery texture; silt stringers dusky red. Thin (up to 0.002 foot) calcite stringer light brown. Massive. Resistant..... 2.0

40. Dolomite: medium gray, aphanitic, and silty; silt stringers dusky red. Weathered surface grayish-orange with powdery texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive. Resistant..... 1.4

39. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface light olive gray to medium gray with black specks, and with silty texture. Beds 0.1 to 0.3 foot thick. Slightly resistant..... 1.0

38. Covered..... 11

37. Dolomite: medium gray, aphanitic, and silty. Weathered surface light olive gray with black specks, and with powdery texture. Mainly massive. Fairly resistant. Minute fossils (?)..... 1.5

36. Dolomite: medium light gray, aphanitic, and silty. Weathered surface grayish-orange to yellowish-gray with silty to powdery texture. Mainly massive. Fairly resistant..... 2.0

35. Dolomite: medium gray, aphanitic, and silty. Weathered surface grayish-orange to light gray with powdery texture. Mainly massive. Fairly resistant..... 3.5

34. Dolomite: greenish-gray, aphanitic, and silty. Weathered surface very pale orange to light brown with silty texture. Partially weathered to marl-like material. Mainly massive. Non-resistant..... 1.0

33. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown to light brown with silty texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive. Resistant..... 2.0

32. Dolomite: medium gray, aphanitic, and silty. Weathered surface grayish orange with powdery texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive. Resistant.. 3.0

31. Dolomite: medium dark gray, lighter in upper part, aphanitic, and silty. Weathered surface pale yellowish-brown to lighter brown in upper part, with silty texture. Thin (less than 0.002 foot) calcite stringers light brown. White dolomite blebs (from less than 0.01 foot to 0.01 by 0.05 foot), possibly fossil replacements. Mainly massive. Resistant..... 2.5

30. Dolomite: dark gray, aphanitic, and silty. Weathered surface moderate grayish-orange with powdery texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive. Resistant..... 1.5

29. Dolomite: interbedded medium dark gray and dark gray, both aphanitic and silty. Weathered surface banded yellowish-gray and moderate grayish-orange with powdery texture. Beds 0.5 to 1 foot thick. Resistant..... 4.0

28. Dolomite: dark gray and aphanitic. Weathered surface light olive gray with powdery texture. Massive. Resistant..... 0.5

27. Dolomite: dark gray, aphanitic, and silty. Weathered surface moderate grayish-orange with powdery texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive. Fairly resistant..... 2.0

26. Dolomite: medium dark gray, aphanitic, and silty. Weathered surface yellowish-gray with powdery texture. Beds 0.5 to 0.6 foot thick. Non-resistant..... 1.0

25. Dolomite: dark gray, aphanitic, and silty. Weathered surface moderate grayish-orange with powdery texture. Thin (less than 0.002 foot) calcite stringers light brown. Mainly massive, thin-bedded near base and top. Resistant..... 2.5

24. Dolomite: medium dark gray, very finely crystalline, and silty. Weathered surface pale yellowish-brown with silty texture. Fine-grained sand disseminated in a few bands. Mainly massive. Fairly resistant..... 1.0

23. Dolomite: medium dark gray, finely crystalline, and silty. Weathered surface olive gray with silty to granular texture. Beds 0.05 to 0.3 foot thick, depending upon weathering. Fairly resistant..... 3.5

22. Dolomite: medium light gray to olive gray, finely crystalline, and silty. Weathered surface pale brown to light olive gray with silty texture. Grades upward into unit 23. Mainly massive. Slightly resistant..... 2.0

21. Dolomite: medium dark gray, darker in middle part, very finely crystalline, and silty. Weathered surface light brown in lower 1 foot, grades to moderate olive gray in middle part, and to pale yellowish-brown near top; all with silty texture. Thin (up to 0.002 foot) calcite stringers light brown. Massive; laterally beds 0.2 to 0.8 foot thick. Resistant..... 5

20. Dolomite: medium gray near base, grades to medium dark gray near top, very finely crystalline, and silty. Weathered surface light olive gray near base, grades to brownish-gray in middle, and to pale yellowish-brown near top; silty to granular texture. Thin (up to 0.002 foot) calcite stringers. Beds 0.1 to 0.7 foot thick. Fairly resistant..... 5

19. Dolomite: dark gray and nearly aphanitic in lower part, medium dark gray and very finely crystalline near top, and silty. Weathered surface pale yellowish-brown in lower portion, olive gray near top, with silty and powdery texture; calcite nodules in middle part light brown. Beds 0.05 to 0.3 foot thick, depending upon weathering. Non-resistant..... 9

18. Dolomite: medium dark gray, very finely crystalline, and silty; silt concentrations yellowish-gray. Weathered surface light brown to pale yellowish-brown to olive gray with rust-colored patches, and with silty to granular texture. Unit appears conglomeratic. Massive. Fairly resistant. Fossils indistinct: brachiopods (?) and crinoid stems (?)..... 2.5

(Dip, 45° N. 55° E.)

17. Dolomite: medium dark gray, finely crystalline, and silty. Weathered surface medium gray with light brown tinge, and with silty texture; silt concentrations light brown to brown. Mainly massive. Resistant..... 3.0

16. Dolomite: medium gray, finely crystalline, and silty. Weathered surface moderate olive gray with silty texture; silt bands light brown to brown. Small pebble- to granule-sized ovoids in conglomeratic lense near top; fresh surface matrix medium dark gray, pebbles medium gray; fragments slightly more resistant to weathering. Beds 0.5 to 1.5 feet thick. Resistant to fairly resistant..... 5.0

15. Dolomite: medium light gray, very finely crystalline, and silty. Weathered surface orange-gray with silty to powdery texture; elongate calcite blebs light brown. Mainly massive. Fairly resistant..... 1.5

14. Dolomite: medium dark gray with yellowish tinge and very finely crystalline. Weathered surface light gray with light brown tinge, and with silty texture. Quartz blebs. Elongate calcite blebs, possibly fossil replacements (Cladopora (?)). Beds 0.4 to 0.8 foot thick. Resistant..... 2.0

13. Dolomite: medium dark gray to light gray, very finely crystalline to nearly aphanitic, silty, and slightly limy. Weathered surface moderate olive gray to pale yellowish-brown to light gray with silty texture; silt concentrations light brown. Grades upward into unit 14. Beds 0.1 to 0.5 foot thick. Fairly to non-resistant..... 6.4

12. Dolomite: medium gray, very finely crystalline, and silty. Weathered surface light olive gray with silty to powdery texture; calcite nodules light brown. Beds 0.3 to 0.6 foot thick. Resistant..... 2.1

11. Dolomite: medium dark gray, finely crystalline, and silty. Weathered surface medium gray with light brown tinge, and with silty texture; silt concentrations light brown to brown. Grades upward into unit 12. Beds 1 to 3 feet thick. Resistant..... 7.0

10. Dolomite: medium gray, nearly aphanitic, and silty. Whethered surface pale yellowish-brown with powdery texture. Thin (up to 0.005 foot) calcite stringers light brown. Massive. Resistant..... 1.8

9. Dolomite, silty: light gray with red iron oxide specks and streaks, nearly aphanitic, and slightly limy. Weathered surface very light brownish-gray and pale brown with silty texture. Grades upward into unit 10. Beds 0.5 to 1.5 feet thick. Slightly resistant..... 5.4

8. Dolomite, silty: medium gray with yellowish-tinge and red iron oxide spots, and nearly aphanitic. Weathered surface yellowish-brown with yellowish-pink spots, and with silty to powdery texture. Massive. Fairly resistant..... 3.7

7. Dolomite, limy: medium light gray, aphanitic, and silty. Weathered surface grayish-orange to pale yellowish-brown with silty to powdery texture, Grades upward into unit 8. Small siderite blebs. Coarse sand grains near base. Massive. Resistant..... 2.6

6. Limestone, dolomitic: medium gray and aphanitic. Weathered surface grayish-yellow with powdery texture. Massive. Resistant..... 0.8

5. Dolomite: medium dark gray with red iron oxide streaks, very finely crystalline, and silty. Weathered surface olive gray with silty to powdery texture. Grades upward into unit 6. Massive. Resistant..... 0.9

4. Marl, silty: grayish-yellow green. Weathered surface very light green and light brown. Beds 0.05 to 0.2 foot thick. Slightly to non-resistant..... 1.8

3. Dolomite: medium light gray and aphanitic. Weathers light olive gray and light yellow with powdery texture and rough surface; small silt nodules rust-colored. Mainly massive. Fairly to slightly resistant..... 2.5

2. Dolomite: moderate to light greenish-gray, very finely to finely crystalline, and silty; red iron oxide spots scattered, throughout. Weathered surface pale brown with grayish tinge to light brown with silty to granular texture. Mainly massive. Fairly to slightly resistant..... 11

1. Dolomite: medium to light gray, parts with yellowish tinge, parts with pinkish tinge, aphanitic, and silty; red iron oxide specks scattered, throughout. Weathers grayish-orange to grayish-yellow with powdery texture and partially with rough surface. Beds 0.3 to 3 feet thick. Resistant; beds near top fairly to slightly resistant laterally. Fossil fragments in upper half.. 27.5

Abrigo formation - unconformable contact.

Composite section of Abrigo formation; upper 433 feet southwest of Waterman Peak in the NE corner SE 1/4 SE 1/4 Sec. 25 and the SE corner NE 1/4 SE 1/4 Sec. 25, T.12 S., R.8 E.; lower 275 feet in the SE corner of Sec. 25, and the NE corner of Sec. 36, T.12 S., R.8 E.

Devonian:

Martin formation:

Cambrian:

Abrigo formation: 708 feet thick

Upper menber: 171 feet thick

(Dip, 40° N. 85° E.) Feet

31. Marl, silty: moderate yellowish-gray to pinkish-yellow; more resistant parts - thin-bedded, medium light gray to grayish-yellow, nearly aphanitic marly dolomite. Weathered surface grayish-yellow to light brown. Beds 0.3 to 1 foot thick, partially with conchoidal fracture, depending upon weathering. Slightly to non-resistant..... 21.5

30. Dolomite, silty: medium gray with yellowish tinge and nearly aphanitic. Weathered surface moderate brown to rust-colored with silty to powdery texture; calcite blebs light brown. Beds 0.1 to 0.8 foot thick. Resistant; less resistant laterally..... 1.9

29. Marl, silty: medium light gray to moderate olive gray. Weathered surface light gray to pale grayish-orange. Beds 0.3 to 1 foot thick, partially with conchoidal fracture, depending upon weathering. Slightly to non-resistant..... 2.4

28. Dolomite, silty: medium gray with yellowish tinge and nearly aphanitic. Weathered surface banded moderate yellowish-gray and light brown to rust-colored with silty to powdery texture; silt stringers and thin silt lenses brown. Grades upward into unit 30. Mainly massive. Fairly resistant; less resistant laterally..... 1.2

27. Marl, silty: medium light gray to moderate olive gray; more resistant beds - thin-bedded, dark yellowish-gray, nearly aphanitic silty limestone with medium light gray, aphanitic siliceous limestone stringers. Weathered surface moderate yellowish-gray to grayish-orange; silty limestone with powdery texture. Grades upward into unit 28. Beds 0.3 to 1 foot thick, partially with conchoidal fracture, depending upon weathering. Slightly to non-resistant..... 26

26. Limestone and shale, interbedded: limestone (about 20%) - medium gray to light olive gray, aphanitic, and partially silty; weathering medium gray to light olive gray with silty texture. Shale (about 80%) - moderate olive gray to greenish-gray, silty, and limy. Silt stringers envelop pebble-sized limestone nodules in some limestone beds; appears conglomeratic. Limestone beds up to 2 feet thick, are mainly massive, and resistant. Shale beds up to 20 feet thick, are fairly to non-resistant; partly covered..... 50

25. Limestone and shale, interbedded: limestone (about 40%) - dark gray to light olive gray, very finely crystalline to aphanitic, and partially silty; weathering medium dark gray to medium light gray to light olive gray with rough surface. Limestone beds of three types: (1) mottled with silt concentrations, (2) granules in silty limestone matrix, and (3) silty limestone matrix with flat-pebble conglomerate; pebbles in (3) reddish-gray and yellowish-gray, aphanitic, silty limestone. Shale (about 60%) - moderate olive gray to greenish-gray, slightly micaceous, and silty. Silt lenses, common in limestone beds, weather light brown to brownish-black. Limestone beds 0.5 to 1.5 feet thick, are mainly massive and resistant. Shale beds 3 to 10 feet thick, thin-bedded to conchoidal fracture and slightly to non-resistant; partly covered..... 35

24. Shale: moderate olive gray, micaceous, and silty. Few flat-pebble limestone conglomerate beds, less than 0.5 foot thick. Shale slightly to non-resistant; partly covered..... 33

Conformable contact.

Middle member: 262 feet thick.

(Dip, 28° N. 80° E.) Feet

23. Limestone: medium dark gray and nearly aphanitic. Weathered surface medium light gray with powdery texture; silt stringers light yellow to grayish-orange. Silt stringers envelop pebble-sized limestone nodules in some beds; appears conglomeratic. Few flat-pebble limestone conglomerate beds, less than 0.5 foot thick, in upper portion of unit. Beds 0.1 to 2 feet thick, with green shale partings; shale dominant in lower 20 feet of unit. Resistant..... 166

22. Limestone: medium dark gray with yellowish tinge, finely to very finely crystalline, and silty. Marker bed. Weathered surface medium gray with light brown tinge, and with silty to granular texture. Limestone conglomerate, with pebble-sized fragments, near top. Beds 0.3 to 1.5 feet thick. Resistant..... 4.5

21. Limestone: medium dark gray and nearly aphanitic to aphanitic. Weathers medium light gray with rough surface; silt stringers light brown. Silt stringers envelop pebble-sized limestone nodules in some beds; appears conglomeratic. Silt bands near base. Beds 5 to 15 feet thick; fractured into large rectangular blocks. Resistant..... 65

20. Limestone, silty: medium dark gray to medium gray with yellowish tinge and nearly aphanitic to aphanitic. Weathered surface mottled light brown to brown and olive gray near top, and light brown to rust-colored near base; both with silty to powdery texture. Grades upward into unit 21. Beds 0.1 to 0.8 foot thick. Resistant..... 5

19. Limestone: medium dark gray and aphanitic. Weathered surface medium light gray; silt stringers light brown. Silt stringers envelop pebble-sized limestone nodules in some beds; appears conglomeratic. Grades upward into unit 20. Few siderite nodules, scattered. Beds 0.1 to 0.6 foot thick. Resistant.... 4.5

18. Limestone, silty: medium gray with yellowish tinge and nearly aphanitic. Weathered surface light brown to rust-colored with silty to powdery texture. Grades upward into unit 19. Beds 0.1 to 0.8 foot thick. Resistant..... 8

17. Limestone, silty: medium dark gray with yellowish tinge, dark yellowish-brown in part, and nearly aphanitic. Weathered surface mottled medium light gray and light brown to rust-colored with silty to powdery texture. Green shale partings. Beds 0.1 to 0.8 foot thick. Fairly to slightly resistant..... 9

Conformable contact.

Lower member: 275 feet thick

(Dip, 34° S. 50° E.) Feet

16. Siltstone, shaly: moderate olive gray to medium gray with yellowish tinge and limy. Beds 0.3 to 0.5 foot thick. Slightly to non-resistant; partly covered..... 4

15. Shale: moderate olive gray to greenish-gray, micaceous, and silty. Slightly to non-resistant; mostly covered..... 1.8

14. Siltstone and shale, interbedded: Siltstone - moderate olive gray to medium gray with yellowish tinge and limy. Shale - green to yellowish-green and limy. Siltstone beds 1 to 4 feet thick and fairly resistant. Shale beds less than 1 foot thick and non-resistant..... 27

13. Siltstone and shale, interbedded: Siltstone - moderate olive gray to yellowish-gray; interbedded with shale in upper and lower parts of unit. Shale - green to yellowish-green and silty; interbedded with siltstone in upper and lower parts of unit and mainly massive in middle portion. Siltstone beds 1 to 4 feet thick and slightly resistant. Shale beds 1 to 10 feet thick and non-resistant; partly covered..... 32

12. Siltstone: interbedded greenish-gray and reddish-gray with few medium to very coarse sand grains; partially quartzitic. Weathered surface light olive gray; partially glassy with desert varnish; partially with porosity to limit of weathering. Cross-bedded. Beds 0.1 to 1.8 foot thick, with green shale partings. Resistant..... 5

11. Siltstone and shale, interbedded: Siltstone (about 60%) - moderate olive gray to brownish-gray and greenish-gray, partly limy; weathering light brown to yellowish-brown and brownish-black. Shale (about 40%) - moderate olive gray to brownish-gray, micaceous, and silty. Very fine-grained sand lenses in upper part. Siltstone and shale beds 0.1 to 1 foot thick, and slightly to non-resistant..... 13.5

(Dip, 54° N. 42° E.)

10. Sandstone: light gray and bluish-gray green and fine-grained; with well-sorted, poorly rounded, and frosted quartz grains. Gray sandstone, in upper part, contains yellow limonite specks, is cross- bedded, and has ripple marks on upper surfaces; weathers brownish-gray with pitted surface. Green sandstone, in lower part, has high silt content, is slightly limy, and is partially quartzitic; weathers brownish-gray to brownish-black with a glassy surface. Beds 0.8 to 1.2 feet thick. Resistant..... 4

9. Siltstone, shaly: brownish-gray with yellowish-gray shale partings. Weathers light brown to brownish-black with glassy surface in part. Grades upward into unit 10. Beds 0.1 to 0.3 foot thick. Slightly resistant..... 2.8

8. Sandstone: grayish-brown with reddish tinge to greenish-yellow to light brown and medium- to fine-grained, partly silty; with poorly sorted and fairly well-rounded grains; partially quartzitic. Weathers medium light gray to light brown to brownish-black with glassy surface in part. Iron oxide pseudomorphs after pyrite. Cross-bedding vague. Beds 0.2 to 1.5 feet thick, with greenish-yellow shale partings. Resistant..... 4.5

7. Siltstone and shale, interbedded: Siltstone (about 90%) - light grayish-brown with greenish tinge to greenish-gray; weathers light brown to brownish-black. Shale (about 10%) - moderate olive gray to brownish, micaceous, and silty. Beds 0.5 to 3 feet thick, with greenish-gray shale partings. Slightly to non-resistant..... 45

6. Sandstone: grayish-brown with light green streaks and coarse- to fine-grained; with poorly sorted and fairly well-rounded grains; quartzitic. Weathers light brownish-gray with glassy surface and desert varnish. Upper surface uneven. Massive. Resistant..... 0.7

5. Sandstone: dusky red purple and medium- to very fine-grained; with poorly sorted and fairly well-rounded grains; quartzitic. Weathers dusky red purple with glassy surface and desert varnish. Upper surface uneven. Massive. Resistant..... 0.7

4. Sandstone: pale red with orange tinge and fine-grained to silty; with poorly sorted and fairly well-rounded grains; quartzitic. Weathers pinkish-orange with glassy surface and desert varnish. Upper surface uneven. Massive. Resistant..... 0.8

3. Sandstone: grayish-brown with reddish tinge, partly greenish-gray, and fine-grained to silty; with poorly sorted and poorly rounded grains; quartzitic. Weathers reddish-brown with glassy surface and desert varnish. Upper surface uneven. Mainly massive. Slightly resistant..... 0.9

2. Sandstone: pale brown with orange tinge to light grayish-brown and coarse-grained to silty; with poorly sorted and fairly well-rounded grains; quartzitic. Weathers moderate grayish-orange to medium light gray with yellowish tinge, and with glassy surface and desert varnish. Upper surface uneven. Beds 0.2 to 0.8 foot thick. Fairly resistant..... 2.3

1. Siltstone and shale, interbedded: Siltstone (about 20%) - moderate olive gray to brownish-gray, greenish-gray, and yellowish-gray; beds with olive gray shale partings; few very coarse- to fine-grained sand particles; weathers moderate olive gray to pale brown. Shale (about 80%) - moderate olive gray to brownish-gray, partly reddish-gray, micaceous, and silty. Beds 0.5 to 20 feet thick. Fairly to non-resistant..... 130

Troy quartzite - fault contact.

Section of Troy quartzite north of Waterman Peak in W 1/2 SW 1/4 SW 1/4 Sec. 30, T.12 S., R.9 E.

Cambrian:

Abrigo formation:

Troy quartzite: 220 feet thick

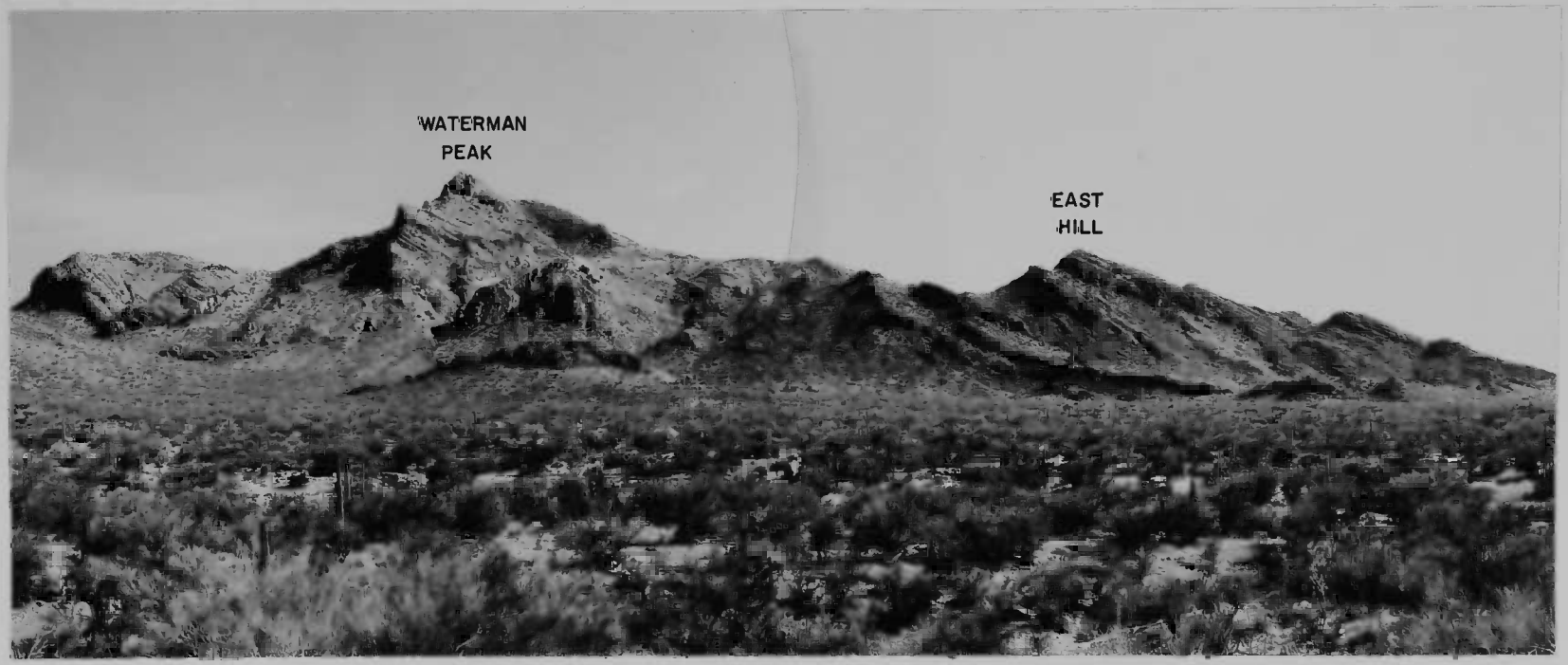
(Dip, 45° N. 70° E.) Feet

3. Sandstone: pale brown and very coarse- to fine-grained; with poorly sorted, poorly rounded quartz grains and silica cement. Weathers light gray to light brown with glassy surface and desert varnish. Beds about 2 feet thick. Resistant..... 4

2. Quartzite: white to brown, parts greenish-gray, parts reddish-gray, and granule- to silt-sized, most grains within sand size range (1/16 mm to 2 mm); poorly sorted and poorly rounded quartz grains; grains break upon fracture of rock. Weathers light gray with pinkish or yellowish tinge, and with glassy surface and desert varnish. Limonite specks and iron oxide pseudomorphs after pyrite are the probable source for the brown color. Cross-bedding common, cosets up to 4 feet thick. Beds 1 to 4 feet thick. Resistant to fairly resistant.....196

1. Quartzite: white to brown, parts reddish-gray, and small pebble- to silt-sized; with poorly sorted and poorly rounded quartz grains; grains break upon fracture of rock. Weathers light gray with pinkish tinge, and with glassy surface and desert varnish. Cross-bedded, cosets up to 4 feet thick. Unit has higher percentage of larger grains, small pebble- and granule-size, than overlying units, but not considered conglomeratic. Resistant..... 20

Pre-Cambrian (?) granite - unconformable contact.



Panoramic view of Central portion of Waterman Mountains, toward the north.

PLATE V

A. Aerial view of Waterman Peak, toward the north. Older Paleozoic strata along left margin, Mississippian and younger strata at center and right.

B. Aerial view of Central portion of range, toward the east. Strata progressively younger from right to left and foreground to background. Rotational fault down stream valley in left center, right side downthrown at far end of valley.

PLATE VI

A. Panoramic view of Waterman Peak, toward the northeast. Lower member of Abrigo through Escabrosa represented from stream in middle foreground to skyline.

B. View of Martin through Horquilla on hill west of thesis area, toward the north.

PLATE VII

A. View of East Hill, toward the south. Lower member of Andrada through Rainvalley represented from right margin to lower slope of hill at left.

B. View of eastern part of Front Ridge, toward the Southeast. Concha in hill to right. Permian-Cretaceous contact in center.

PLATE VIII

A. View of Eastern Hogback, toward the east. Concha dip slope on south side of hill.

B. View of Eastern portion of Watermans, toward the southeast. Rainvalley at peak of hill in foreground -- at east end of Front Ridge. Lower member of Andrada through Concha represented on Eastern Hogback from left to right.

GEOLOGIC MAP OF CENTRAL AND EASTERN PORTIONS OF THE WATERMAN MOUNTAINS

R. 8 E. R. 9 E.

Section 30 Section 29

Section 25

Section 36

Section 31

Section 32 Section 33

Section 6

Section 5

Section 4

T. 12 S.

T. 13 S.

INDIANA-ARIZONA MINE

WATERMAN PEAK

Abandoned Mine

FRONT RIDGE

EAST HILL

TRI-PEAKS

EASTERN FOOTHILLS

Avra Valley Road 1/2 miles

PAPAGO INDIAN RESERVATION BOUNDARY

SYMBOLS

- 60 Dip and Strike
- Strike of vertical beds
- Faults and inferred or projected faults
- Contacts and inferred contacts
- Contact with alluvium
- Roads
- Trails
- Mines
- 2510 Elevations (altimeter readings)
- A — A' Cross-section locations
- Measured section locations

EXPLANATION

SEDIMENTARY ROCKS

QUATERNARY	Qal	Alluvium	
CRETACEOUS (?)	K		
PERMIAN	Pr	Rainvalley formation	
	Pc	Concha limestone	
	Psu	Scherrer (upper) formation	
	Psl	Scherrer (lower) formation	
PENNSYLVANIAN-PERMIAN	PPau	Andrada formation, upper member	
	PPal	Andrada formation, lower member	
PENNSYLVANIAN	Ph	Horquilla formation	
MISSISSIPPIAN	Me	Escabrosa limestone	
DEVONIAN	Dm	Martin formation	
CAMBRIAN	Cau	Abrigo formation, upper member	
	Cam	Abrigo formation, middle member	
	Cal	Abrigo formation, lower member	
	Ct	Troy quartzite	

IGNEOUS ROCKS

TERTIARY (?)	Ti	Intrusives
PRE-CAMBRIAN (?)	P€	Granite

TOPOGRAPHIC BASE FROM SOIL CONSERVATION SERVICE AERIAL PHOTOGRAPHS, 1936

GEOLOGY AND TOPOGRAPHY BY N. E. McCLYMONDS, 1957

N

W E

S

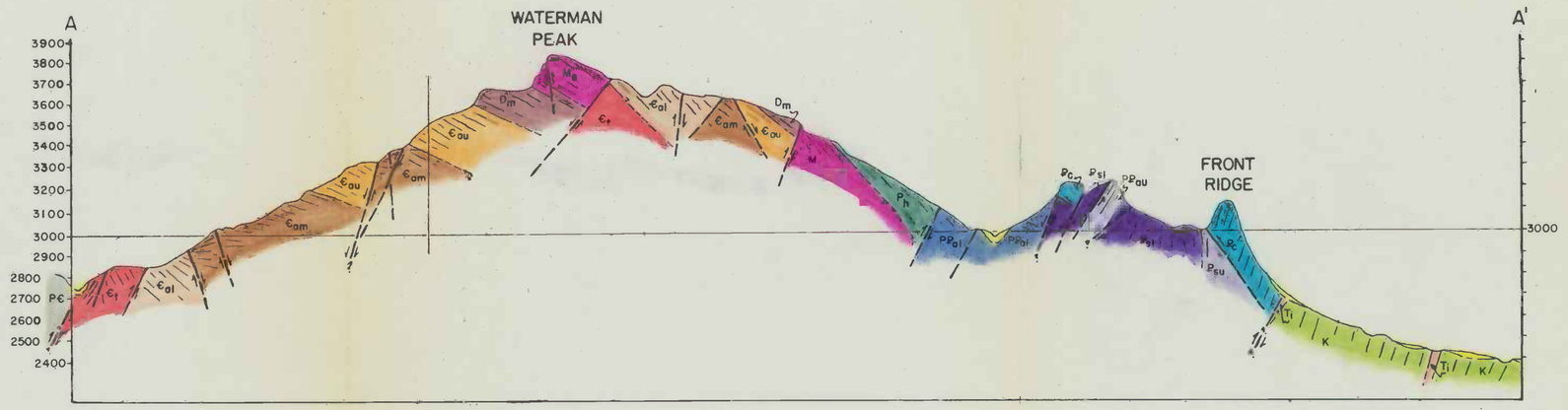
14° MAGNETIC NORTH

SCALE

0 500 1000 2000 ft

CONTOUR INTERVAL 50 FEET

GEOLOGIC CROSS-SECTIONS OF THE CENTRAL AND EASTERN PORTIONS OF THE WATERMAN MOUNTAINS



SYMBOLS

Faults and inferred faults

Contacts and inferred contacts

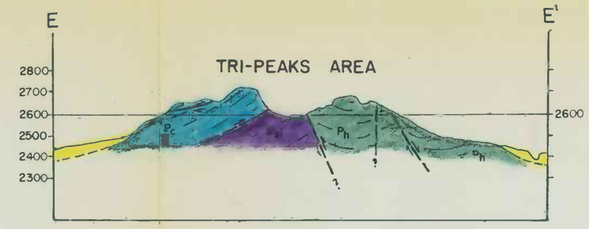
Apparent direction of movement on faults

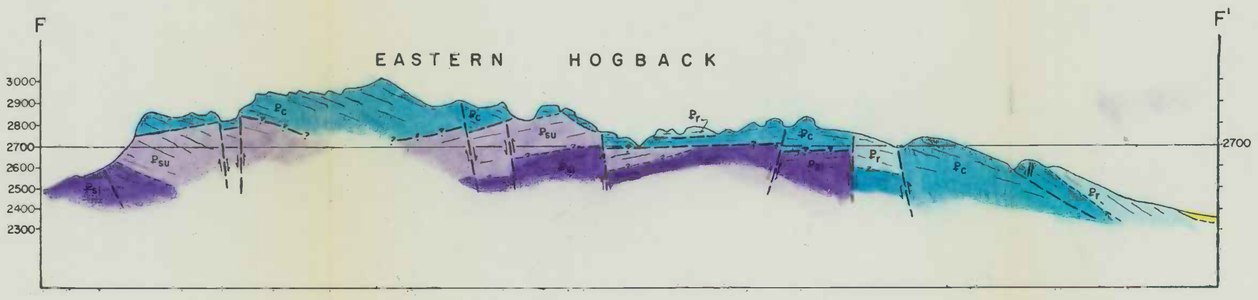
Note: Explanation of color scheme and formation symbols on Geologic Map.

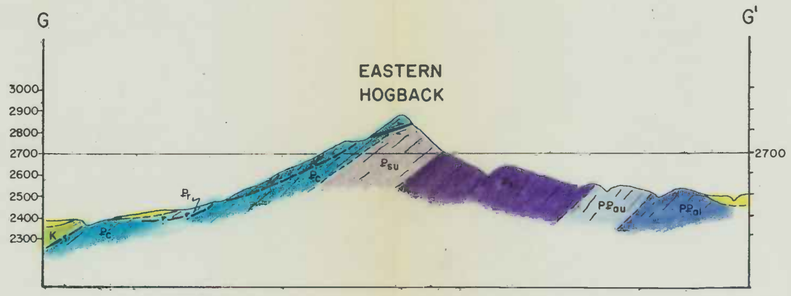
SCALE

Vertical to Horizontal, 1:1

0 500 1000 2000 ft







COLUMNAR SECTION AT THE WATERMAN MOUNTAINS

LITHOLOGIC SYMBOLS

- LIMESTONE
- dolomitic
- cherty
- silty
- conglomeratic
- DOLOMITE
- limy
- silty
- conglomeratic
- SHALE
- SILTSTONE
- limy
- SANDSTONE
- conglomeratic
- CONCEALED
- PARTIALLY CONCEALED