STRATIGRAPHY OF THE JARILLA MOUNTAINS
OTERO COUNTY, NEW MEXICO

by

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ABSTRACT

Approximately 6,930 feet of Paleozoic strata is preserved in the area of the Jarilla Mountains and has been affected in varying degrees by Tertiary intrusion and metasomatism. Surface exposures represent 4,405 feet of Gobbler Formation (Desmoinesian), Laborcita Formation (Virgilian?-Wolfcampian), and Hueco Limestone (Wolfcampian). Underlying Mississippian and lower Paleozoic Formations do not outcrop, except for a small exposure of possible Percha Shale (Devonian) in the southern Jarilla Mountains.

The Gobbler Formation is a minimum of 1,600 feet thick in the Jarilla Mountains, including approximately 475 feet of unexposed Morrowan(?)-Atokan strata. Limestone, predominantly cherty wackestone, wackestones, cherty micrites, and micrites, comprise 87% of the exposed Gobbler Formation in the Jarilla Mountains. The remainding 13% are sandstones (quartz wackes, subarkosic wackes, quartz arenites, subarkoses) that decrease in volume upward in the section.

The Laborcita Formation is approximately 2,229 feet thick, of which a minimum of 859 feet is Wolfcampian and a maximum of 1,370 feet is Virgilian. Sandstones (predominantly subarkoses), meta-sediments, argillaceous micrites, and mudrocks comprise the bulk of the Laborcita Formation. Albite is the most abundant feldspar in the subarkoses; orthoclase and microcline are present only in trace amounts. Sedimentary

structures, current directions, and repetition of strata indicate the Laborcita Formation in Monte Carlo Gap contains at least 13 preserved tidal channel-"starved" basin-tidal channel-lagoonal depositional cycles.

The Hueco Limestone is 1,040 feet thick in the northern Jarilla Mountains, and is informally divided into the lower Hueco limestone, the distal Abo tongue, and upper Hueco limestone. The upper and lower limestones are predominantly wackestones and micrites. Mudrock and subordinate amounts of wackestone and grainstone comprise the lithologies of the distal Abo tongue.

Diagenesis has extensively altered the original limestone textures in the Gobbler Formation and in the Hueco Limestone by the introduction of calcite cement and neomorphic spar. Sandstones of the Gobbler and Laborcita Formations have undergone widespread diagenetic replacement of silicates by carbonates and nearly complete albitization of detrital potassium feldspar.

Metasomatic zonation in limestone host rocks near the monzonites has previously been described as clinozoisite-actinolite, andradite-grossularite, wollastonite, and calcite (marble). The metasomatic mineral assemblage in sandstone, mudstone and argillaceous host rocks is described in this study as scapolite (marialite), andradite-uvarovite, cordierite, actinolite, and wollastonite. This second mineral assemblage is suspected to be the result of metasomatism during intrusion of granodiorite.

The Jarilla dome is a Tertiary structure associated with the intrusions of granodiorite and later monzonites. The Brice Anticline in the southern Jarilla Mountains is of Laramide age, and parallels a small horst in the same area. Interpretation of the anticline is based upon the use of sandstone beds (Gobbler Formation) for correlation across the southern part of the range.

Stratigraphic correlations of meta-sedimentary rocks in the southcentral area (Figure 3) suggest the skarns there are altered equivalents of the Gobbler, Rancheria, and Lake Valley Formations. Based on these correlations, the diopside-andradite bearing mineral assemblages of these skarns are a result of magnesian and iron metasomatism.

ACKNOWLEDGMENTS

The inspiration for this study came from the ideas and project requirements of Dr. Richard Beane, who contributed freely his time and knowledge throughout this study. Dr. John MacMillan was of invaluable help throughout this study, especially so toward the latter stages of analysis and writing.

James Lyons and Michael Martineau, both geologists with Bear Creek Mining Co., Tucson, offered needed services and data liberally over the two year period of our association. Discussions with them and Mark Bloom, presently with the University of British Columbia, Vancouver, added otherwise unattainable directions and insights during the course of this study.

Donald Myers of the U. S. Geological Survey, Denver, received and identified fusulinid samples, often on short notice, without which this study would have suffered. Thanks also to Christina Balk of New Mexico Institute of Mining and Technology for brachiopod identifications at critical periods during this study.

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INTRODUCTION

Background and Geologic Setting

The Jarilla Mountains lie 40 miles north of El Paso, Texas, and 35 miles south of Alamagordo, New Mexico (Figure 1) in the Tularosa graben, a major structure within the Rio Grande tectonic province (Woodward and others, 1975). Drill cores and outcrops within the Jarilla Mountains reveal Ordovician through Wolfcampian sedimentary rocks (Figure 2) that have been domed, contact metamorphosed, and mineralized during intrusion of porphyritic and equigranular igneous rocks. The igneous rocks range in age from 47.1 ± 1.8 million years to 32(?) million years (Bloom, 1976, p. 13). Folding observed in the southern Jarilla mountains, other than doming associated with intrusion, is of Laramide age (page 58).

Inspiration for this study has come from two different sources. The first is the suspicion that skarn mineralization in outcropping Pennsylvanian-Wolfcampian rocks and in older buried strata varies as a function of host rock lithology and structure. This lithostratigraphic control of base metal mineralization has been confirmed in studies by Jaramillo (1973), Bloom and Martineau (1975, unpublished), and Bloom (1976).

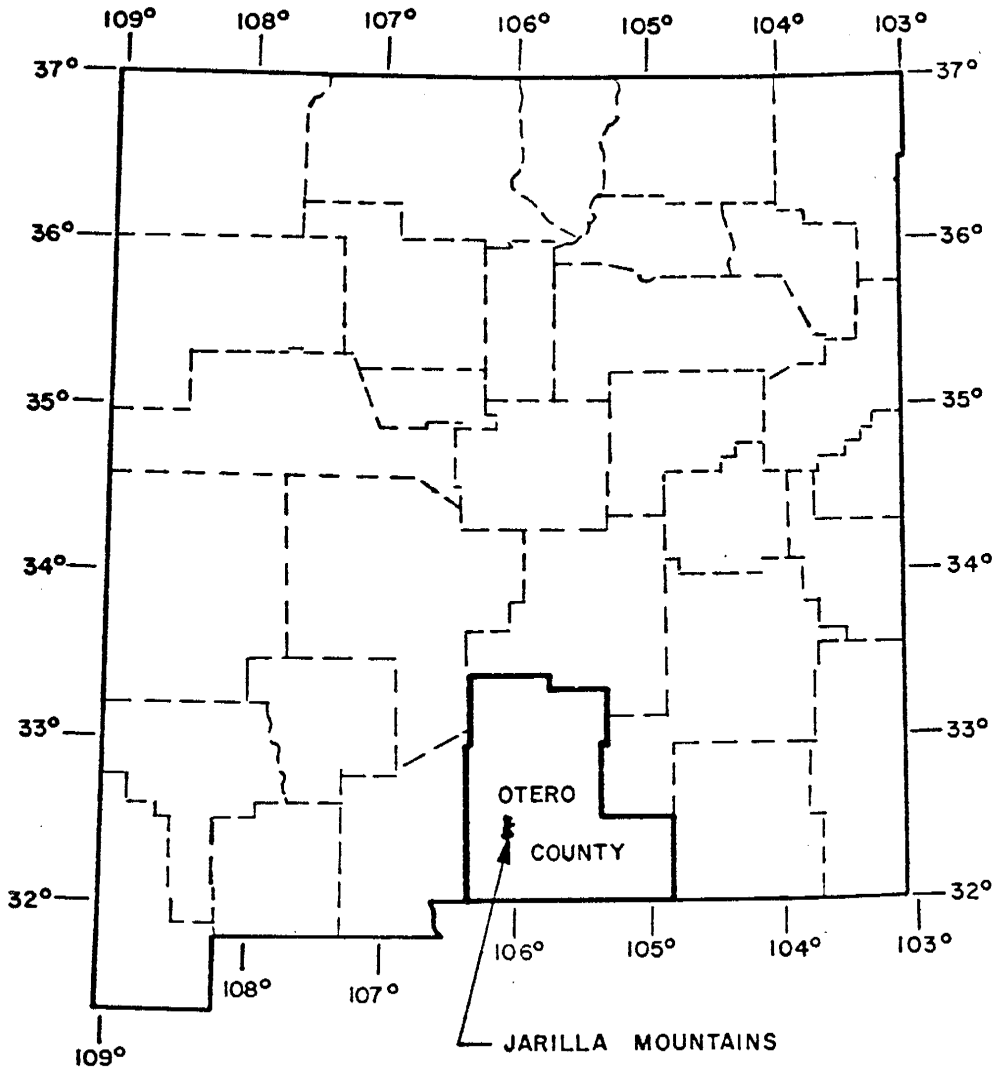


FIGURE I

INDEX MAP SHOWING THE LOCATIONS OF OTERO COUNTY AND THE JARILLA MOUNTAINS IN NEW MEXICO

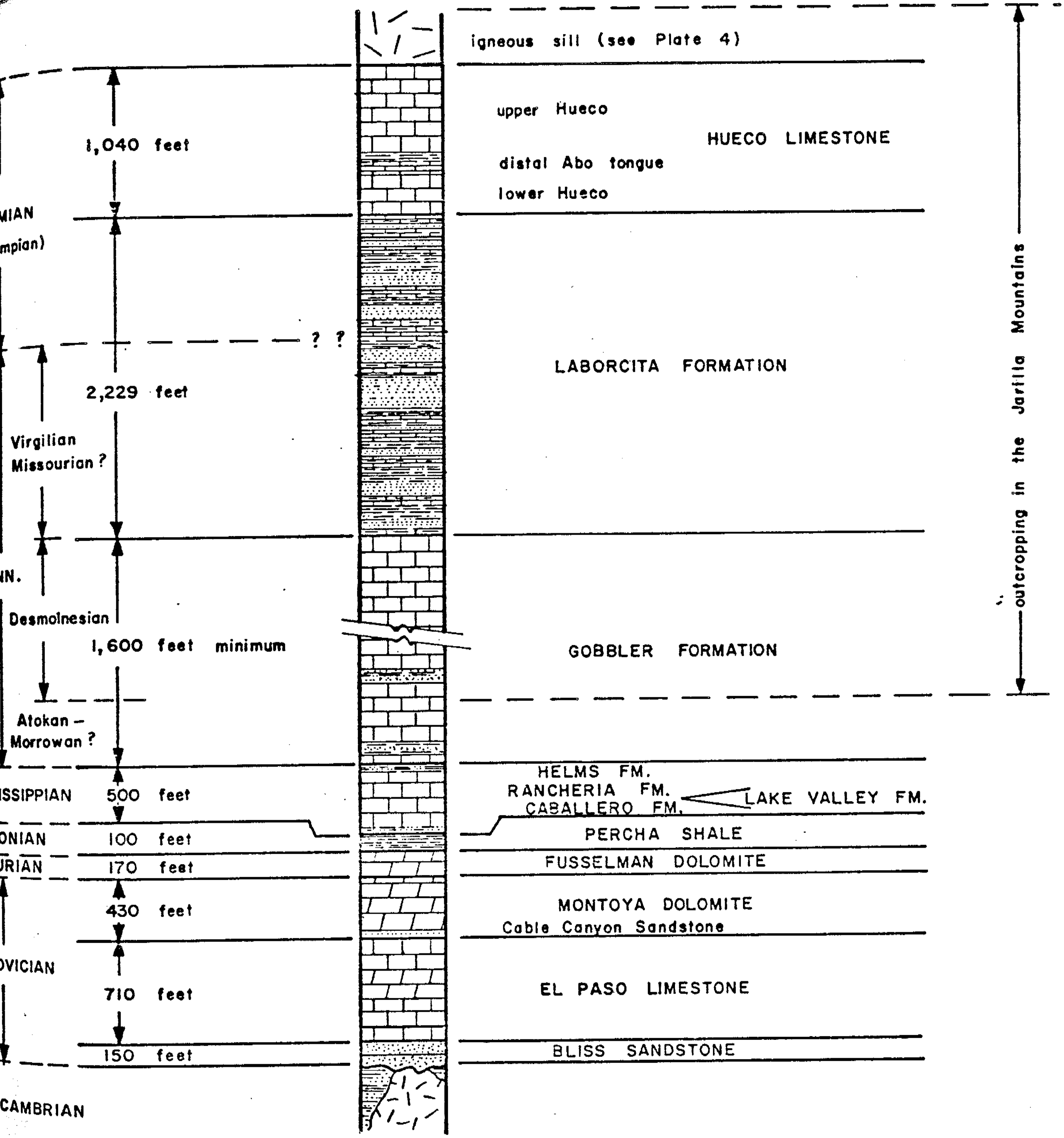


FIGURE 2

GENERALIZED STRATIGRAPHIC SECTION OF THE SEDIMENTARY ROCKS IN THE JARILLA MOUNTAINS

VERTICAL SCALE : 1 inch = 1,000 feet

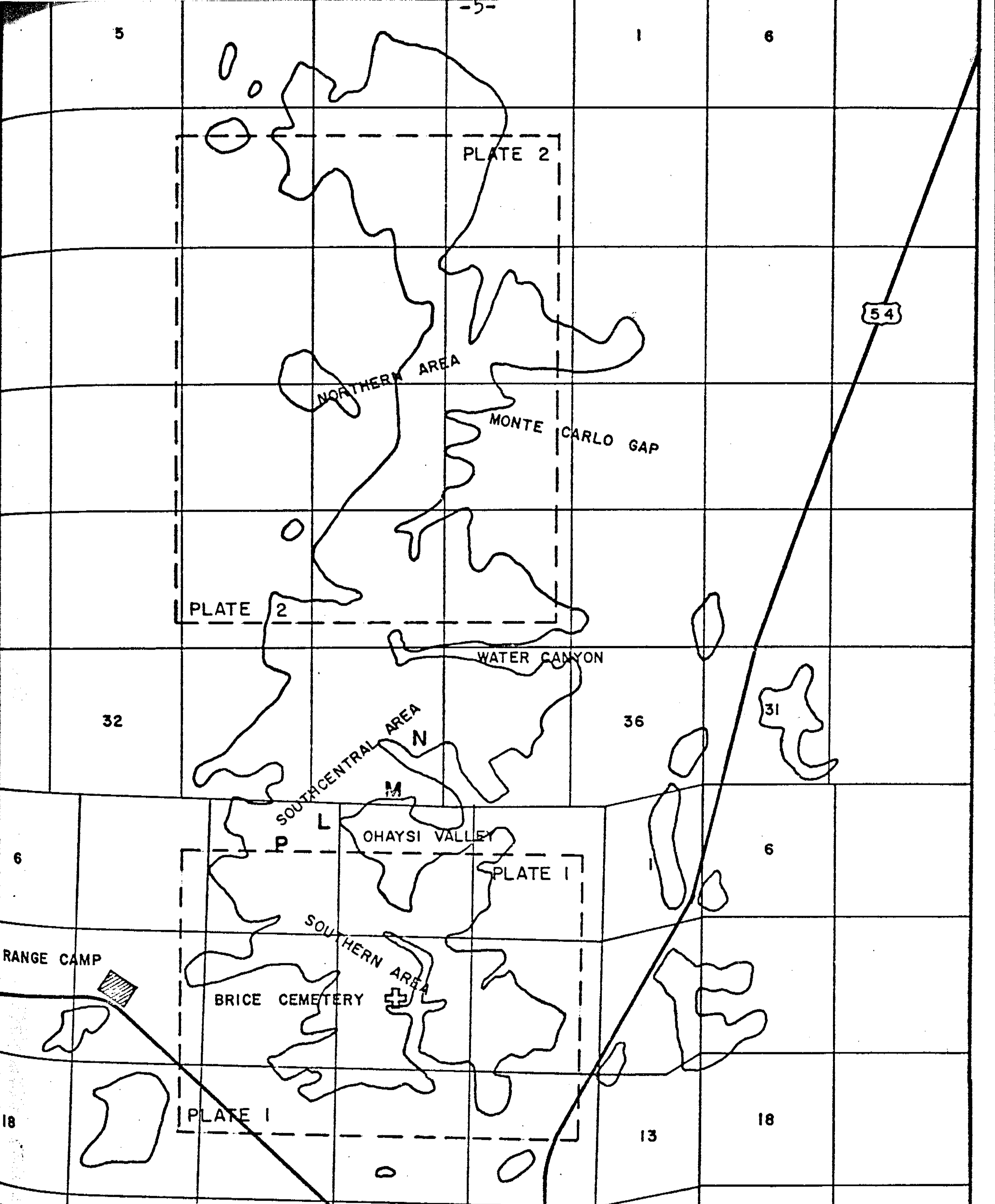
The second source has been the fortuitous location of the Jarilla Mountains. The outcrops of Pennsylvanian-Wolfcampian rocks in the Jarilla Mountains are the only accessible representatives of the eastern, inner margins of the Orogrande Basin described by Kottlowski (1963, p. 40).

Purpose

The specific purposes of this thesis are the compilation of a composite stratigraphic section and the correlation of outcropping sedimentary rocks with their metamorphic equivalents throughout the range. A result of this work is a detailed geologic map showing the general structure and intrusive patterns within two areas of the Jarilla Mountains (Figure 3).

Methods

Initial field work consisted of mapping the position, extent, attitude, and general lithologies of the sedimentary rocks at a scale of 1:6,000. Subsequent field work consisted of the measurement of five stratigraphic sections. Unit descriptions within each section were compiled at the outcrop and supplemented with descriptions of 98 slab sections and 55 thin sections. Mineral identifications in metamorphosed parts of the measured sections were supplemented by x-ray diffraction analyses.



INDEX MAP SHOWING LOCATIONS OF AREAS DISCUSSED WITHIN THE JARILLA MOUNTAINS

FIGURE 3

Previous Investigations

Interest in the geology and economic potential of the Jarilla Mountains and surrounding area has periodically waxed and waned since 1893 when Hidden reported the existence of abundant turquoise, pyrite, chalcopyrite, gypsum, jarosite, limonite, and kaolin. Since this initial report, published investigations concerning the Jarilla Mountains may be summarized in terms of three periods.

During the first period from 1910 to 1957, most reports were concerned with the quantities of gold, copper, iron, silver, and tungsten produced from existing mines. Geological summaries accompany production figures, but are general and limited to description of ore localities (Lindgren, Graten, and Gordon, 1910; Finlay, 1922; Lasky and Wootton, 1933; Kelley, 1949; Anderson, 1957). Significant exceptions are Darton (1928), who mapped the area on a scale of 1:500,000 and Needham (1937), who identified Wolfcampian fusulinids from the basal units of the Permian (Hueco Limestone) four miles north of Orogrande.

During the second period of investigation from 1959 to 1964, published reports were of a general geologic nature. These publications provided reconnaissance maps and stratigraphic sections, recognized general intrusive patterns and relationships, and established regional stratigraphic correlations (Reynolds and Craddock, 1959; Seager, 1961; Schmidt and Craddock, 1964).

Seager (1961) primarily described and interpreted the igneous rocks. He also recognized the need for stratigraphic control, but did not measure sections or attempt correlations. Schmidt and Craddock (1964) measured partial sections and made valid correlations within the Hueco Limestone and locally within the Gobbler Formation. They did not attempt to measure the complete section or to correlate the Gobbler Formation across the southern part of the range.

The third period of published investigation was begun in 1973 and presently consists of a series of three graduate theses (of which this is the third) completed at New Mexico Institute of Mining and Technology. A fourth thesis is in the data analysis stage. All four are under the direction of Dr. Richard Beane.

Jaramillo (1973) described the igneous petrology, hydrothermal alteration, and mineralization within hornblende monzonite and granodiorite intrusives. He emphasized hypogene hydrothermal alteration zoning within the hornblende monzonite and the spatially associated skarns and copper mineralization. Jaramillo confined his investigation to approximately one square mile in sections 34 and 35, T.21S., R.8E.

Bloom (1976) describes the mineral paragenesis within the calc-silicate skarns immediately south of the area studied by Jaramillo. Bloom (1976, p. 1) emphasizes the "temporal and spatial relationships between intrusive bodies and structure, alteration, and fluid flow...". He also identifies zonation of minerals in calc-silicate skarns adjacent to multiple monzonite intrusives, and describes the genesis of the observed zonation using the geochemical principles of mass balance and mass transfer. A summary and further interpretation of the studies by Jaramillo and Bloom, with emphasis on mineral zonation and paragenesis, has been published by Beane et al (1975).

Geography and Access

The Jarilla Mountains are located in southcentral New Mexico, midway between El Paso, Texas, and Alamagordo, New Mexico in the southern half of the Tularosa Valley. The Sacramento Mountains lie 35 miles to the northeast. At the southwest end of the Jarilla Mountains is the Orogrande Range Camp of the White Sands Missile Range. The Organ and San Andres ranges are 40 miles to the west, trending north-south roughly parallel to the Sacramento Mountains.

The town of Orogrande lies at the southern end of the Jarilla Mountains on U.S. Highway 54. North of Orogrande stretch the hills and peaks of the Jarilla Mountains, with numerous access roads from the east which lead to most of the areas considered in this investigation. Maximum relief is about 1,100 feet in the center of the range, with generally steep slopes and cliffs to the west and gentler slopes to the east.

STRATIGRAPHY

Introduction

The stratigraphic section in southcentral New Mexico ranges from Precambrian sedimentary and metasedimentary rocks (Kottlowski, 1956, p. 5 and Pray, 1961, p. 22) through Quaternary basalts (Kottlowski, 1956, p. 72). In the area of the Tularosa Basin and the Jarilla Mountains, the sedimentary rocks pertinent to this study (Figure 2) range from the Early Ordovician Bliss Sandstone (Kottlowski, 1956, p. 14 and Pray, 1961, p. 25) to the Wolfcampian Hueco Limestone (Kottlowski, 1960, p. 98). Unmetamorphosed sedimentary rocks exposed in the Jarilla Mountains are essentially restricted to the Pennsylvanian and Wolfcampian, except for a small upfaulted(?) block of probable Devonian Percha Shale in the extreme southern end of the range (Plate 1).

At the time of Early Tertiary intrusion (page 1), approximately 8,000 feet of Paleozoic sedimentary rocks and possibly 1,000 additional feet of Late Cretaceous sedimentary rocks were present in the area of the Jarilla Mountains (Kottlowski, 1963, pp. 9 and 72). No evidence of a thick Tertiary sedimentary or volcanic pile for the Jarilla Mountains or the surrounding area is indicated in the literature. Only a few tens of feet of Quaternary graben fill overlie

Wolfcampian limestones in the Sun Oil Co. No. 1 Pearson oil test 17 miles northeast of the Jarilla Mountains (Kottlowski, 1960, p. 98).

Ordovician - Silurian

Data on the unexposed lower Paleozoic formations present in the Jarilla Mountains are taken from the isopach maps of Kottlowski (1963) and drill core information supplied by Bear Creek Mining Company (Bloom and Martineau, 1975, unpublished). Kottlowski suggests that 150 feet of Early Ordovician Bliss Sandstone, 710 feet of Ordovician El Paso Limestone, 430 feet of Ordovician Montoya Dolomite, and 170 feet of Silurian Fusselman Dolomite are present in the area of the Jarilla Mountains. The above total of 1,310 feet of dolomite and dolomitic limestone suggested for the area by Kottlowski is not in agreement with 910 feet of magnetite-serpentine altered dolomites overlying the glauconitic sandstones and metasiltstones of the Bliss Sandstone present in the Bear Creek drill core (Bloom and Martineau, 1975, unpublished). Numerous gouge zones and intervals of Tertiary igneous rock within the drill core indicate that the 400 foot difference between expected and observed thicknesses is structurally imposed and probably not a local stratigraphic anomaly.

Devonian

A maximum of 100 feet of Devonian Percha Shale has been recognized in drill core by Bloom and Martineau (1975, unpublished) and further examined by this author. The core is predominantly metamorphosed, thinly laminated shales underlain by a few feet of metasiltstones. The metasiltstones contain thick to thin laminae of very fine sand and silt and lenticular bedding with isolated lenses of fine sand and silt in mud. Reineck and Singh (1975, p. 101) suggest the environment of such structures is one meager sediment supply and alternating conditions of current flow and slack water; in this case probably a marine delta front.

The lenticular, basal siltstones and mudstones are probably representative of distal Onate-Sly Gap facies. They were previously thought to be absent from the area (Kottlowski, 1963, p. 27)

Mississippian

The Mississippian strata in the area of the Jarilla Mountains are, in ascending order, the Caballero Formation of Kinderhook age, the Lake Valley Limestone of Osage age, the Rancheria Formation of Osage(?)-Meramec age, and the Helms Formation of Chester age (Kottlowski, 1963, p. 33). In the Sacramento Mountains south of Nigger Ed Canyon, Armstrong (1962) includes the Lake Valley Limestone within the basal units of the Rancheria Formation. This convention has been adopted by the author for the Jarilla Mountains.

Kottlowski (1963, p. 34) proposes the Rancheria and Helms Formations total 500 feet in the Jarilla Mountains, and excludes the Caballero Formation from the area. There is, however, a maximum of 45 feet of metamorphosed calcareous siltstone and shale in drill core overlying the Percha Shale (Bloom and Martineau, 1975, unpublished) that conforms to Kottlowski's (1963, p. 35) description of the Caballero Formation as a "limy clastic" facies. A maximum of 110 feet of garnet-diopside skarn with chert nodules and chert bands, also in drill core interpreted by Bloom and Martineau, is the metamorphosed equivalent of the Rancheria Formation. In addition, an overlying 30 feet of interbedded garnet bands, garnet-diopside bands, and diopside-actinolite-clay bands are probable metamorphic equivalents of the Helms Formation.

In all, 185 feet of probable Mississippian age rocks occur in drill core, 315 feet less than indicated by Kottlowski (1963, p. 34). Numerous, thick intervals of Tertiary igneous rock and several brecciated zones within the core indicate that the 315 foot difference between expected and observed thicknesses is structurally imposed, rather than a local stratigraphic anomaly. In all drill cores, hundreds of feet of Tertiary igneous rocks occupy the approximate position of the Pennsylvanian-Mississippian contact, making an accurate measurement of Mississippian thickness impossible.

Pennsylvanian Gobbler Formation

Outcrop Locations

Both Seager (1961, p. 8) and Schmidt and Craddock (1964, p. 6) determined that a complete stratigraphic section of the Gobbler Formation is not exposed within the Jarilla Mountains; the results of this study are in agreement with their determinations. There are, however, partial stratigraphic sections exposed throughout the southern part of the range in Secs. 3, 4, 9, 10, 11, 14, 15, and 16, T.22S., R.8E. (Plate 1). These exposures permit limited lithostratigraphic correlation and have allowed the author to approximate the thickness of the Gobbler Formation and the general structure of the area. One small outcrop of metamorphosed cherty limestone of the Gobbler Formation also occurs one mile south of Monte Carlo Gap (NE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 27, T.21S., R.8E.) in the northern part of the range (Plate 2).

Terminology, Thickness, and Age

The Gobbler Formation has been described in the Sacramento Mountains by Pray (1961) and Benne (1975) and in the northeast Otero Platform area by Black (1975) (Figure 1). It ranges in age from Morrowan(?) to middle Missourian (Figure 2), in thickness from 1,200 to 1,600 feet, and changes from a dominantly clastic facies in the north and northeast to a dominantly limestone facies in the south and southwest (Pray, 1961, p. 80). Thompson (1942, p. 12) suggests the facies change reflects a large deltaic complex, an interpretation supported by the work of Benne (1975, p. 39) and the conclusions of Black (1975, p. 326). Black suggests that the Orogrande Basin, and thus the area of the Jarilla Mountains, was a shallow, subsiding carbonate shelf during early and middle Pennsylvanian time over which detrital clastic material moved. These deltaic sediments were deposited as lithostromes within the dominant limestone facies of the Gobbler Formation.

The Gobbler Formation in the Jarilla Mountains is dominantly a limestone facies, and has been measured and described in four, partial stratigraphic sections. They are named, in ascending stratigraphic order, the Nannie Baird, Nannie Baird North, Garnet Dike South, and Range Camp sections (Appendices B, C, D, and E; Plates 1 and 3). The composite thickness of 707 feet measured in the overlapping lower three sections cannot be correlated with the upper 428 feet of Gobbler Formation measured at the Range Camp section, suggesting there are strata missing between the measured sections (Plate 3).

As an indirect method of approximating the total thickness of the Gobbler Formation, the ages of the Range Camp and stratigraphically lower sections may be bracketed and compared with similar Pennsylvanian sections in the surrounding region. A Desmoinesian brachiopod, Antiquatonia inflata (identification by Christina Balk, 1975, oral communication) and a probable early Desmoinesian tabulate coral, Chaetetes eximus(?) (Schmidt and Craddock, 1964, p. 7) occur at 90 feet and 375 feet respectively, in the Nannie Baird section (Plate 3).

Approximately 160 stratigraphic feet below the Gobbler-Laborcita contact at Location A, Sec. 9, T.22S., R.8E. (Plate 1) is a late Desmoinesian fusulinid horizon, Beedeina sp. (formerly Fusulina, Donald Myers, 1976, written communication). The upper 100 stratigraphic feet or so of the Range Camp stratigraphic section may be early Missourian as are the upper units of the Gobbler Formation in the Sacramento Mountains (Pray, 1961, p. 80), although interpretation of the Sun Oil Co. No. 1 Pearson oil test (Kottlowski, 1963, p. 98) suggests the top of the Gobbler Formation is latest Desmoinesian nearer the Jarilla Mountains.

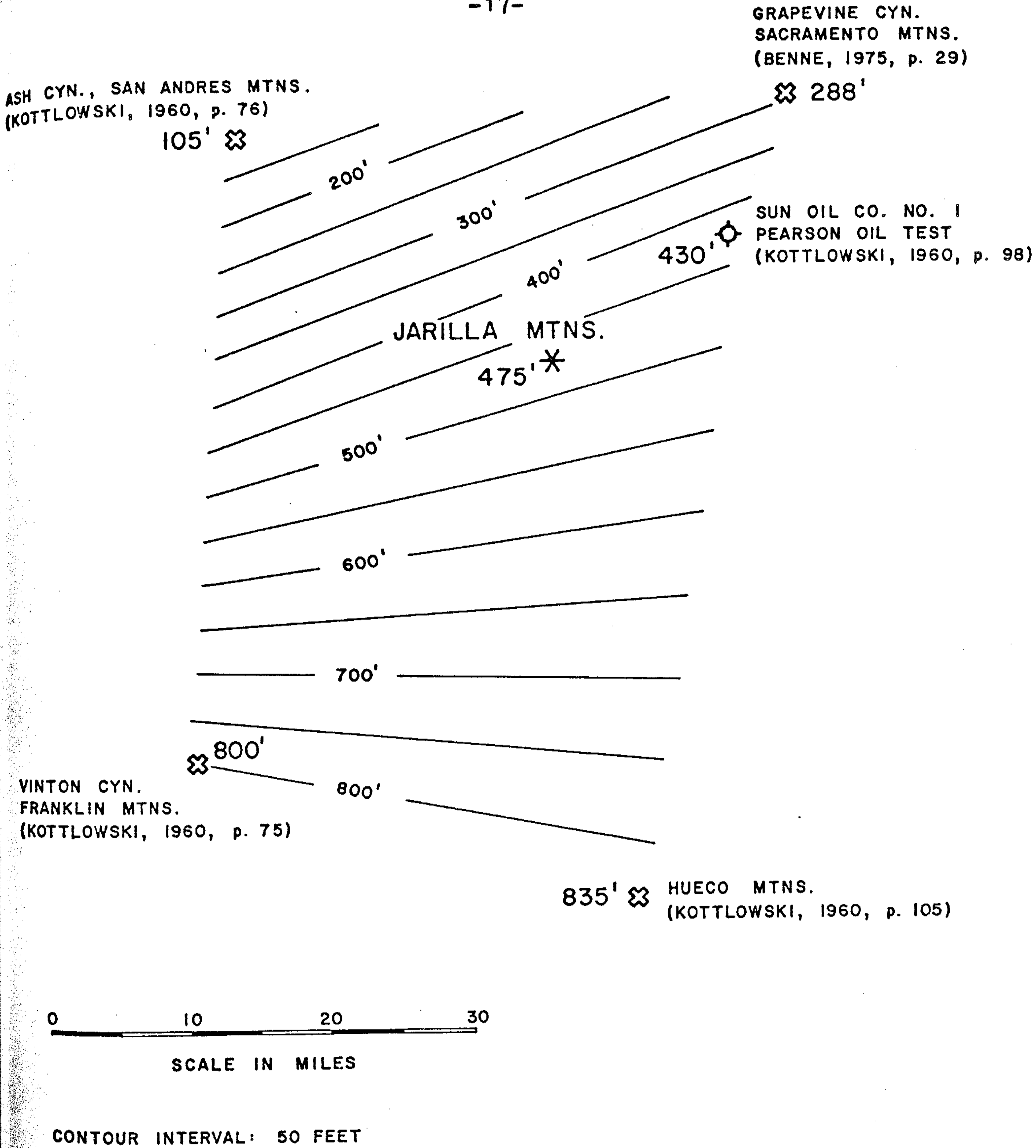
Consideration of the above lithostratigraphic and faunal evidence suggests that all of the exposed Gobbler Formation in the Jarilla Mountains is probably of Desmoinesian age and is in excess of 1,135 feet thick (Plate 3). This is at least 370 feet thicker than the Desmoinesian strata recognized in the Sun Oil Co. No. 1 Pearson oil test 17 miles to the northeast (Kottlowski, 1963, p. 98) and at least 365 feet thicker than the Desmoinesian described in the Plymouth No. 1 Federal oil test 13 miles to the north-northeast (Pray, 1961, p. 85).

Thickness data from Kottlowski (1960, pp. 75, 76, 100, and 105) and the Grapevine Canyon section (Benne, 1975, p. 38) are used to interpolate (Figure 4) that sediments of Morrowan(?) and Atokan age total approximately 475 feet in the Jarilla Mountains. Thus, based upon measured sections of most of the Desmoinesian and estimates of the Morrowan(?) and Atokan from previously published data, the total thickness of the Gobbler Formation in the Jarilla Mountains is a minimum of 1,600 feet.

The 1,600 feet in the Jarilla Mountains and 1,190 feet in the Sun Oil Co. No. 1 Pearson oil test agree with the thicknesses of 1,200 to 1,600 feet assigned to the Gobbler Formation in the Sacramento Mountains by Pray (1961, p. 80). The Gobbler Formation in the Jarilla Mountains may be expected to be slightly thicker than 1,600 because of its basinward position with respect to the Pennsylvanian Orogrande Basin as described by Kottlowski (1963, p. 9).

Lithology

Of the 1,135 stratigraphic feet of Gobbler Formation exposed in the Jarilla Mountains, 975.5 feet (87%) is lime-



INTERPOLATED THICKNESS OF THE MORROWAN–ATOKAN IN THE JARILLA MOUNTAINS

FIGURE 4

stone (including an estimated 47 covered feet at the top of the Range Camp section), 123.5 feet (11%) is sandstone, and 26 feet (2%) is mudrock. No dolomite or gypsum is present. Limestones containing more than 5% bedded and irregular chert nodules total 385 feet, or 39% of the limestones in the Gobbler Formation.

Exposed limestones of the Gobbler Formation are predominantly cherty wackestone and wackestone (400 feet), cherty micrite and micrite (264 feet), with subordinate grainstone (96.5 feet) and packstone (82 feet). Marble (85 feet) is present at the base of the Nannie Baird section in contact with a monzonite sill (see Appendix A for explanation of descriptive terminology).

Most limestones form thick and very thick ledges and characteristically weather light gray and medium light gray. A few micrite units (NB-7, RC-5) have a characteristic gray mottled appearance that is laterally traceable over thousands of feet of outcrop. Chert nodules weather grayish orange, dark yellowish brown, and dusky brown.

Allochemical material in the Gobbler limestones is dominantly biogenetic, consisting of echinoid fragments with subordinate amounts of brachiopod, bryozoan, rugose and tabulate coral, fusulinid, gastropod, and ostracode whole and fragmental material. Pellets and intraclasts are rare.

Sandstones occur in the lowermost 487 feet of the exposed Gobbler Formation, and are best exposed in the Nannie Baird section (Plate 3). The thickest and lowermost exposed sandstone unit is NB-4. It consists of 113.5 feet of subarkosic wacke, quartz wacke, quartz arenite, subarkose, and mudstone weathering blackish red and yellowish brown.

Fine to very coarse grained, angular, poorly sorted quartz, chert, and feldspar grains comprise a maximum of 45% of the wackes. The grains are surrounded by finely crystalline, chlorite-illite interstitial material that appears to have replaced many original feldspars and commonly embays quartz grains. Internal bedding structures (laminae, cross-stratification) are preserved in the arenites and are indistinct or absent in the wackes.

Sandstone units interbedded in the limestones stratigraphically above unit NB-4 are fine to very coarse grained, angular, poor and moderately sorted quartz arenite (unit NB-5d) and subarkose (unit GDS-5). Chert and illite comprise the interstitial material in these arenites, and are probably of diagenetic origin. Calcite spar is present in varying amounts up to 30% as a replacement of the feldspar grains and the interstitial chert and illite, and rarely as a partial replacement of quartz. Thicknesses of individual sandstone units range from 1.5 to 6 feet. Some units present in the Nannie Baird stratigraphic section pinch out or undergo lateral changes in facies (Plate 3) or internal bedding structures (NB-11b).

Summary

The Gobbler Formation was originally described by Pray (1961, pp. 70-84) in the Sacramento Mountains and assigned an age ranging from Morrowan (?) through middle Missourian. In the Jarilla Mountains, only Desmoinesian age units of the Gobbler Formation are recognized in outcrop, although Morrowan(?)-Atokan strata are suspected in the subsurface. The Gobbler Formation is a minimum of 1,600 feet thick in the Jarilla Mountains, similar in thickness to the 1,200 to 1,600 feet described by Pray along the length of the Sacramento Mountains.

Of the 1,600 feet of Gobbler Formation estimated in the Jarilla Mountains, 1,135 feet were described in measured sections during this study. Limestone comprises 975.5 feet (87%) of the outcropping stratigraphic section, and is dominantly cherty wackestone, wackestone, cherty micrite and micrite. Sandstones total 123.5 feet, and are dominantly quartz wackes, subarkosic wackes, quartz arenite, and subarkoses. Some of the sandstone units have been used as marker beds to aid in correlation and structural interpretation in the southern part of the range.

Pennsylvanian-Wolfcampian Laborcita Formation

Outcrop Locations

The Laborcita Formation within the Jarilla Mountains outcrops in the Monte Carlo Gap area (Secs. 15, 22, 23, and 27, T.21S., R.8E.), at the mouth of Water Canyon (NW¼, Sec. 36, T.21S., R.8E.), as a few small xenoliths within hornblende monzonite (NE¼, Sec. 33, T.21S, R.8E.), and along the lower, western slopes of a hogback 3 miles north of Orogrande (Sec. 12, T.22S., R.8E.)(Figure 3).

Terminology, Thickness, and Age

The Laborcita Formation was originally described by Otte (1959, p. 26) in the northern Sacramento Mountains. He applied the name to a "transitional" facies of "...gray and red mudstone, gray limestones, sandstones and conglomerates between the top of the Holder formation [Virgilian] and the top of the highest marine limestone underlying the main mass of the Abo red beds [Wolfcampian] .". The Laborcita Formation in Fresnal Canyon, Sacramento Mountains, was first mentioned in the literature as an un-named sequence of "questionably Pennsylvanian" beds by Thompson (1942, p. 82). Lloyd (1949) and Pray (1952) include the same beds within the Bursum Formation, originally defined by Wilpolt _et al_ (1946). Pray (1961, p. 91) later acknowledged that the Laborcita Formation should be regarded as distinct from the Bursum Formation, and applied the name

Laborcita to his "Bursum" strata in the area of the Sacramento Mountains.

The age of the Laborcita Formation in the Sacramento Mountains is stated by Otte (1959, pp. 57, 58) as "older than the Hueco Limestone, ...the bulk of the Laborcita is probably older than the Powwow conglomerate...the Laborcita Formation is considered to be of latest Virgilian and early Wolfcampian age.".

The oldest age obtained for the Laborcita Formation in the Jarilla Mountains is early Wolfcampian, based upon abraded fusulinids in unit MC-45 of this study (Plate 4, Appendix F). Schmidt and Craddock (1964, p. 18) identified fusulinids from strata equivalent to unit MC-45 as Schwagerina emaciata, Triticites ventricosus sacramentoensis, T. gallowayi, T. cellemagnus, and T. rhodesi. More recently, Donald Myers (1976, written communication) recognized Triticites cellemagnus, Schwagerina(?) sp., and Millerella(?) sp. from a sample of unit MC-45.

A Virgilian age for strata equivalent to unit MC-83 of this study was obtained by Seager (1961, p. 16), but this Virgilian date is questionable. Samples taken from Location B, Sec. 10, T.21S., R.8E. (Plate 2)(mapped as Panther Seep by Seager) contain Pseudoschwagerina uddeni, P. morsei, and P. texana, all Wolfcampian fusulinids typical of the lower part of the Hueco Limestone.(identification and age determination by Donald Myers, 1975, written communication).

The base of the Laborcita as defined by Otte (1959, p. 26) at the top of the Holder Formation is clear only along the northeast margins of the Orogrande Basin. Pray (1961, p. 94) discusses this problem and observes that sharp lithologic breaks between the Holder Formation (Virgilian) and the Laborcita Formation occur only locally in the vicinity of his measured section in Fresnal Canyon in the Sacramento Mountains. Traced laterally, lithologic distinctions of the contact are not sharp, leading Pray to interpret the contact in the vicinity of Fresnal Canyon as a diastem. Pray (1961, p. 90) further suggests that deposition was continuous from Pennsylvanian through Permian time along the margins of the Orogrande Basin.

The problem of determining the base of the Laborcita Formation was not pursued by Pray. Pray's observation that the base of the Laborcita Formation in Fresnal Canyon is a diastem was proven by the work of Wilson (1967) in nearby Dry Canyon. The results of Wilson's study indicate Pray's Virgilian-Wolfcampian diastem is the base of a preserved depositional cycle typical of Virgilian deposition throughout the Orogrande Basin and along its margins (Wilson, 1967, p. 810).

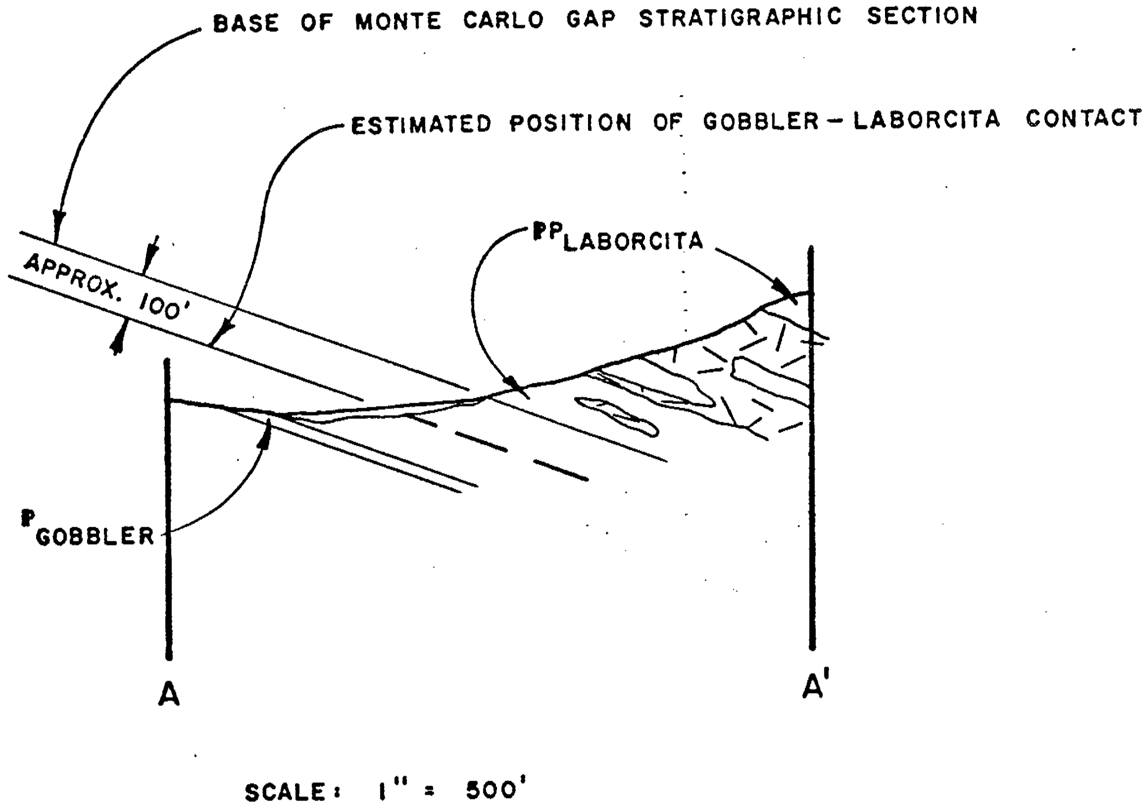
Wilson (1967, p. 815) uses the term Panther Seep Formation (Virgilian) for the cyclic beds he describes in Monte Carlo Gap in the Jarilla Mountains. From his description and general location data, this author concludes that

Wilson observed beds somewhere within the interval bounded by units MC-20 and MC-33 of this study (Plate 4). These beds lie stratigraphically below the oldest fossil bearing unit recognized in Monte Carlo Gap; an early Wolfcampian fusulinid bearing conglomerate (MC-45). Although the beds in Monte Carlo Gap described by Wilson may be Virgilian, no conclusive faunal evidence was found during the course of this study. Furthermore, no lithostratigraphic differences above or below unit MC-45 are apparent, suggesting that the entire Monte Carlo Gap measured section should be regarded as Laborcita Formation.

The total measured thickness of the Laborcita Formation in the Monte Carlo stratigraphic section (including two sill totaling 377 feet) is 2,309 feet. The upper sill (unit MC-30, 180 feet thick) displays planar upper and lower contacts with the Laborcita Formation and contains no xenoliths, indicative of forceful intrusion between competent beds, suggesting that 180 feet has been added to the stratigraphic section. The lower sill (units MC-3 and MC-5, 197 feet thick) contains numerous non-rotated xenoliths, of which MC-4 appears to be one, suggesting that 197 feet of Laborcita Formation was assimilated by the molten monzonitic intrusive. Subtracting the thickness of the upper sill, the total exposed thickness of the Laborcita Formation may be estimated at 2,129 feet.

In addition to the total of 2,129 feet of Laborcita Formation described in the Monte Carlo stratigraphic section, 100 feet of covered Laborcita Formation is estimated to underlie unit MC-1.(Plate 3), providing no structural complications exist beneath the Quaternary alluvium (Figure 5). From consideration of all of the above, the total thickness of the Laborcita Formation is estimated to be 2,229 feet.

The Virgilian-Wolfcampian boundary cannot be located precisely within the Laborcita Formation in the Jarilla Mountains. Unit MC-45 contains the oldest fauna identified within the Monte Carlo stratigraphic section; abraded fusulinids of early Wolcampian age (p. 22). The lithology and fauna of unit MC-45 suggests it is near the Virgilian-Wolfcampian boundary, occupying much the same stratigraphic position as the conglomeratic units near the Virgilian-Wolfcampian boundary in the Sun Oil No. 1 Pearson oil test (Kottlowski, 1960, p. 98). Using this assumption, the 859 feet of sandstone, mudrock, and argillaceous limestone overlying unit MC-45 (Plate 4) represents the minimum thickness of Wolfcampian Laborcita Formation present in the Jarilla Mountains. Also using the above assumption, the 1,370 feet of sedimentary and metasedimentary rocks underlying unit MC-45 (Plate 4) represent the maximum thickness of upper Pennsylvanian (Virgilian, Missourian?) rocks in the Jarilla Mountains. With the addition of the minimum of



CROSS-SECTION OF THE LOWER PART OF THE MONTE CARLO GAP STRATIGRAPHIC SECTION

FIGURE 5

1,600 feet of Gobbler Formation estimated in the southern Jarilla Mountains (p. 16), the total thickness of Pennsylvanian rocks is approximately 2,970 feet. This figure is is close agreement with the 3,125 feet estimated by Kottlowski (1963, p. 40).

The 2,970 feet of Pennsylvanian strata in the Jarilla Mountains is 740 feet thicker than the Pennsylvanian strata in the Sun Oil Co. No. 1 Pearson oil test located 17 miles northeast toward the margin of the Orogrande Basin (Kottlowski, 1960, p. 98). Significant basinward thickening of Wolfcampian Laborcita strata occurs between the 470 feet present in the Sun Oil Co. No. 1 Pearson oil test and the minimum of 859 feet of Laborcita Formation in Monte Carlo Gap (p. 25).

Lithology

Of the 2,229 stratigraphic feet included within the Laborcita Formation, 475 feet (21%) is sandstone, 429 feet (19%) is metamorphosed sandstone, mudrock, and limestone, 352 feet (16%) is sandy and argillaceous micrite, 269 feet (12%) is completely covered, 251 feet (11%) is mudrock, 235 feet (11%) is micrite, 197 feet (9%) is replaced by hornblende monzonite sill, 11 feet is wackestone and grainstone, and 10 feet is chert-limestone-quartz pebble conglomerate. No gypsum is present, although it is found within beds equivalent to the Laborcita in the southwestern part of the Orogrande Basin (Wilson, 1967, p. 816; Kottlowski, 1963, p. 42).

Units of the Laborcita Formation have a variety of outcrop characteristics. The lower 700 feet of metamorphosed sediments and igneous sills weather blackish red, dusky brown, and pale yellowish brown and form very thick ledges, medium ledges, and barely exposed, discontinuous low ridges. Sandstones tend to weather pale yellowish brown, grayish orange, and dusky brown and form medium and thick ledges. Sandstones with higher percentages of intergranular calcite (greater than 20%) tend to weather predominantly dusky brown. Mudrocks, sandy argillaceous micrites, and micrites weather grayish orange, pale yellowish brown, medium light gray, and grayish brown and form thin and medium ledges with wide exposures of upper bedding surfaces; thick ledges are rare. Thin bedded and laminated units often are covered by slabby rubble.

Exposed sandstones are predominantly subarkoses (324.5 feet) with subordinant arkose (133 feet) and quartz arenite (17.5 feet). Well to moderately sorted, quartz and feldspar grains are angular, subangular, and rarely subround. Plagioclase (albite and oligoclase?) and minor amounts of potassium feldspar (microcline ± orthoclase) comprise the feldspars in the sandstones of the Laborcita Formation. Minor detrital grains include chert, magnetite, hematite, muscovite, and zircon. Biotite and hornblende are conspicuously absent. Matrix material in all the sandstones is chert with minor amounts of illite. Calcite spar is ubiquitous in the sandstones, but is variable in amount and replaces the interstitial chert and detrital grains. Some sandstones in the middle of the Laborcita Formation in Monte Carlo Gap have as much as 65% calcite spar.

Allochems in the few beds of wackestone and grainstone are predominantly intraclasts of two types. The most common type of intraclast is angular, irregularly shaped, calcirudite-sized and has been derived locally by bioturbation or from mudcracks. Less common are rounded, calcarenite and calcirudite-sized intraclasts that occur with subordinate amounts of terrigenous sand grains, oolites, pellets, and fossil fragments (units MC-33, MC-74). Minor accumulations of gastropod fragments occur rarely within thin beds in units MC-16 and MC-35. The matrix of unit MC-45, a chert-limestone-quartz pebble conglomerate, contains fossils, intraclasts, and rare oolites. The fossil material of MC-45 is predominantly rounded and angular fragments of stromatolitic algae with subordinate amounts of abraded, whole and fragmental fusulinids and brachiopods.

<u>Sedimentary structures</u>

Numerous internal and bedding plane sedimentary structures occur in the sandstones, mudrocks, and limestones of the Laborcita Formation. Parallel and rare cuspate (unit MC-40) current ripple marks, cross-stratification, mudcracks, bioturbation, burrows, parallel lamination, convoluted bedding, and normally graded bedding are all common. Less common structures include superimposed current ripples (units MC-53, MC-68), rip-up clasts (units MC-52, MC-62, MC-74), flaser and lenticular bedding (units MC-14, MC-38), reverse graded bedding (unit MC-36), crawling trails (units MC-18, MC-46, MC-53), load structures (unit MC-36), birdseye structures (unit MC-35), thin limestone pebble lenses in sandstone (unit MC-42).

Point bar sequences of fining-upward, medium scale cross-stratification, parallel lamination, and current ripple stratification (in ascending order) as described by Visher (1965, p. 132) and Reineck and Singh (1975, p. 240) occur as thick and very thick beds of subarkose (units MC-22, MC-28, MC-32, MC-34, MC-62). The upper few feet of these point bar sequences often display extensive burrowing completely destroying current ripple stratification, parallel lamination, and occasionally the underlying medium scale cross-stratification. Some individual burrows are as much as five centimeters in diameter.

Desiccation cracks are commonly superimposed upon current ripple marks (units MC-15, MC-48), and less commonly upon two sets of superimposed, parallel current ripple marks (unit MC-53).

Thick and very thick, lenticular, flat-topped, and cross-stratified sandstone bodies occur in units MC-62, MC-68, and MC-69. Slump structures and convoluted bedding are common features and are syndepositional with the cross-stratification. Mudcracks occur at the tops of some thick sets in unit MC-62.

Many gray, medium and thick micrite beds from 768 feet to 1,203 feet in the Monte Carlo Gap stratigraphic section are capped by thin, grayish orange beds weathering grayish orange. The contact between the two beds is characteristically erosional and irregular with approximately three millimeters maximum relief. The grayish orange capping bed is mudcracked and bioturbated, with a maximum of 30% angular pebble and granule intraclasts of medium gray or grayish orange, micrite and clayed micrite. Mudcracks commonly occur in the oxidized cap and tend to be filled with grayish orange micrite. In some instances, the mudcracks penetrate as much as ten centimeters into the underlying medium gray micrite (unit MC-19).

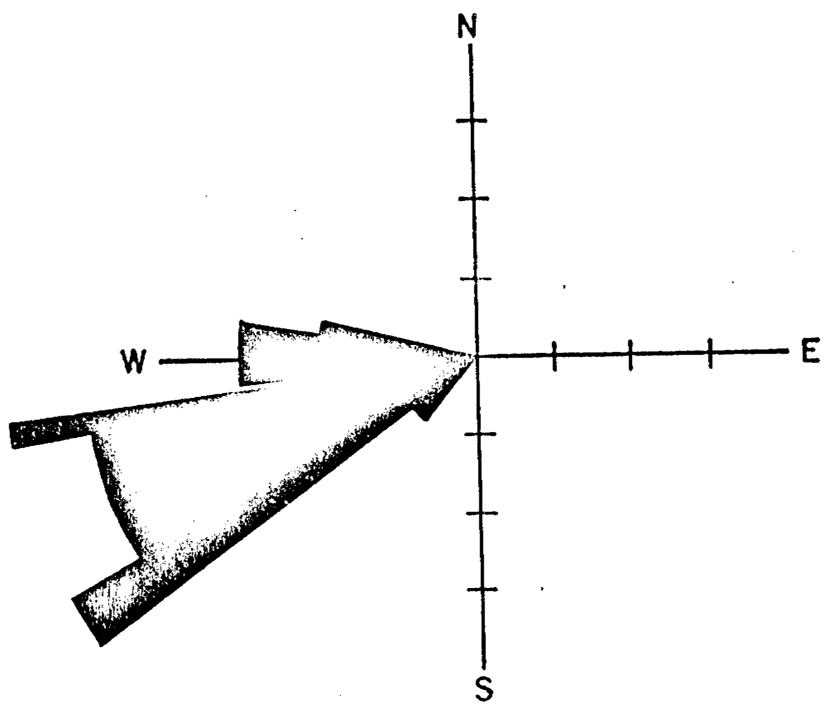
Current directions taken from medium scale cross-stratification, parallel current ripple marks, and ripple cross-stratification are listed in Table 1 and are shown graphically in Figure 6. These measurements do not represent an exhaustive study of directional structures, but rather those measured within approximately 100 lateral feet of the line of section.

The results of the measurements of medium scale cross-stratification indicate a westerly current direction. The

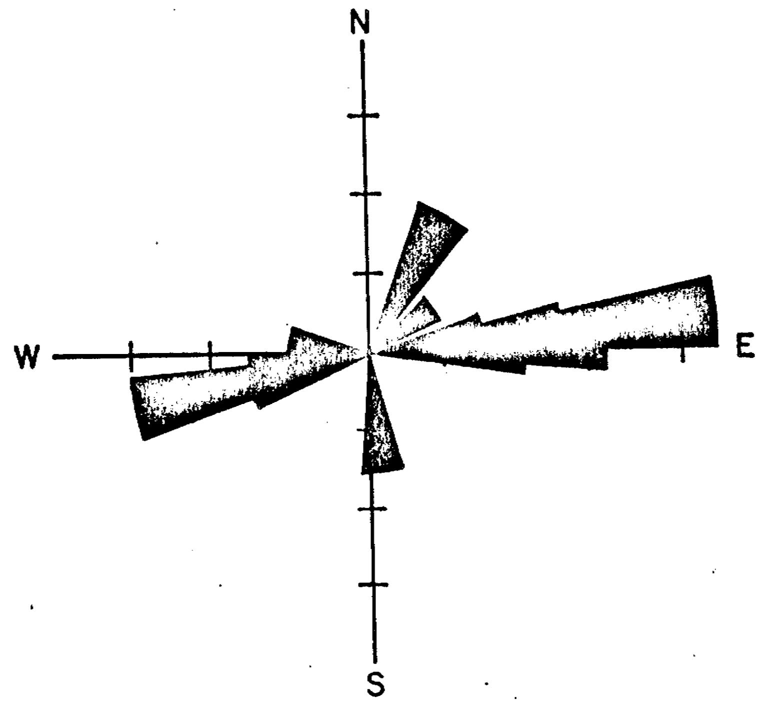
TABLE 1

CURRENT DIRECTION DATA - LABORCITA FORMATION
(presented graphically in Figure 5)

Medium scale cross-stratification			Ripple marks and ripple stratification		
current direction	unit	number of measurements	current direction	unit	number of measurements
N86°W ± 10°	MC-22	2	N30°E ± 10°	MC-23	2
N90°W ± 10°	MC-28	1	N80°W ± 10°	MC-25	1
S50°W ± 10°	MC-34	1	N60°E ± 5°	MC-28	1
S68°W ± 15°	MC-62	5	N85°E ± 10°	MC-36	1
			N50°E ± 5°	MC-38	1
			S80°W ± 10°	MC-48	3 (bimodal)
			N80°E ± 10°		
			S75°W ± 10°	MC-68	3 (bimodal)
			S5°E ± 10°		
			N88°E ± 10°	MC-69	2



MEDIUM SCALE CROSS-STRATIFICATION



RIPPLE MARKS AND RIPPLE STRATIFICATION

CURRENT DIRECTION DIAGRAMS, LABORCITA FORMATION

(DATA FROM TABLE I)

FIGURE 6

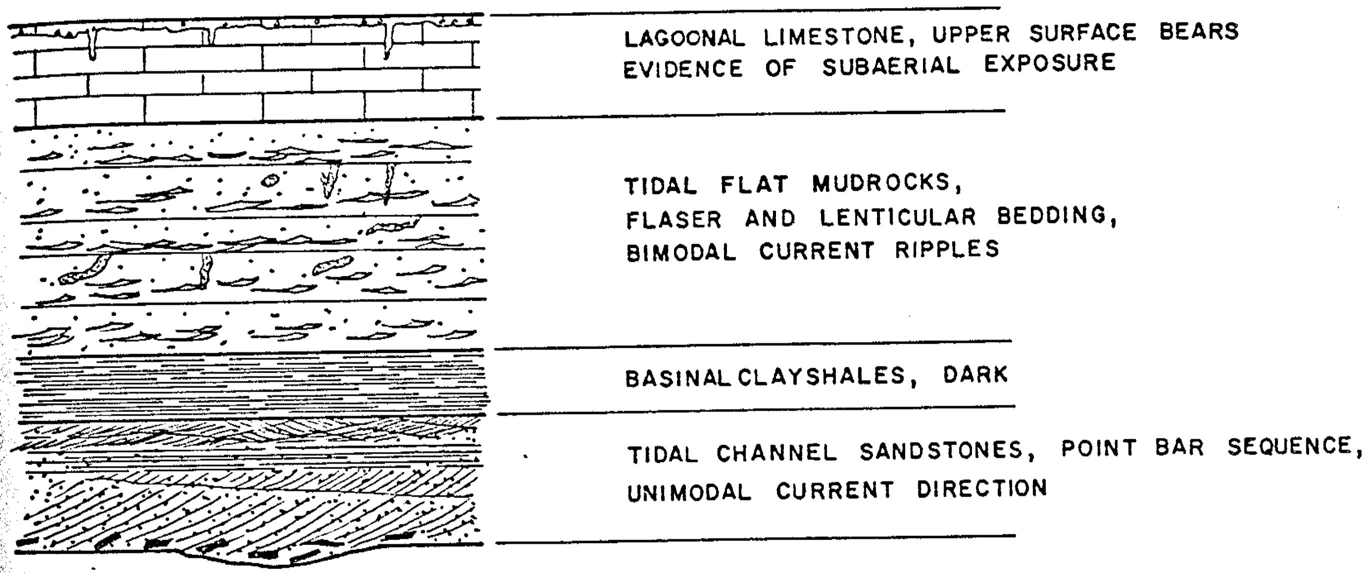
ripple marks and stratification indicate bimodal flow directions to the west and to the east-northeast.

Environment of Deposition

Although the interpretation of environments of deposition is not a primary objective of this study, features indicative of environments of deposition are so abundant in Monte Carlo Gap that they deserve some comment.

The area now occupied by the Jarilla Mountains was within the Orogrande Basin during Virgilian and Wolfcampian time (Kottlowski, 1963, p. 40). The source area for clastic sediments lay to the east in the Pedernal Landmass (Kottlowski, 1960, p. 147). A cyclical alternation of sedimentation between the Orogrande Basin and the surrounding shelf margins during Virgilian and early Wolfcampian time is recognized by Wilson (1967). He suggests clastic sediment bypassed the shelf margins and was deposited within the basin at times of raised sea level, the shelves received clastic sediment and the basin was "starved".

Each cycle of lowering and rising sea level in the area of the Jarilla Mountains produced a similar repetition of sediments corresponding to a succession of depositional environments.(Figure 7). Wilson (1967, p. 105) generally describes these basin cycles that begin with "...cross-bedded sandstone and grade upward through relatively thick shale to a dark, tidal flat lime mudstone and shale.". Using the



TYPICAL DEPOSITIONAL CYCLE WITHIN THE LABORCITA FORMATION

FIGURE 7

criteria of Reineck and Singh (1975) and Wilson (1967), thirteen depositional cycles may be recognized within the upper 1,425 feet of unmetamorphosed Laborcita Formation in Monte Carlo Gap (Plate 4).

The basal sandstones of most cycles in Monte Carlo Gap were deposited by meandering tidal estuaries at the mouths of small rivers flowing from the east. The sandstone deposits show structures typical of point bar sedimentation, including angular, argillaceous limestone and mudrock pebbles at the base of thick beds. Slump and load structures penecontemporaneous with deposition are common. The upper zones of the point bars are usually bioturbated. Measured current directions indicate a dominant flow direction to the west within most medium scale crossbeds, but a few thin, poorly preserved cross-beds show foresets dipping to the east.

At the base of the uppermost cycle in the Laborcita Formation (Plate 4), some of the sandstone bodies within units MC-68 and MC-69 are lenticular over a few tens of feet but none exhibit ideal point bar sequences, although medium scale cross-stratification and fining upward of grain size are well developed. These youngest sandstone bodies of the Laborcita Formation represent channels formed during a final, minor drop in sea level which preceded a slow change to the more permanent shelf conditions recognizable in the overlying Hueco Limestone.

The thick sequence of basinal mudshale and clayshale suggested by Wilson as typical of basinal cycles is not always present in the depositional cycles in Monte Carlo Gap. Although talus usually covers slopes above the ledgy outcrops of channel sandstones, basinal shales often seem to be missing and instead the channel sandstones are overlain by tidal flat or lagoonal sediments.

Tidal flat mudrocks, sandy mudrocks, argillaceous limestones, and sandstones are ubiquitous throughout the Laborcita Formation. Mudcracks superimposed on current ripple marks, flaser and lenticular bedding, current ripple cross-stratification, and occasional burrows are typical of the tidal flat environments. Reineck and Singh (1973, p. 139, Figure 214) discuss crawling traces in tidal flat areas that are similar to those in unit MC-53. Current directions of ripple marks form a bimodal, opposed pattern, also typical of tidal deposits.(Figure 6).

Lagoonal, argillaceous limestones and limestones are usually at the top of the depositional cycles. The limestones are thinly and thickly laminated, but almost always are extensively bioturbated and weather to medium or thick ledges. Burrows are abundant (units MC-29, MC-35, MC-58, MC-70, MC-71, and MC-74). At the top of some of the limestones is a thin cap of grayish orange weathering limestone (p. 31) that was subaerially exposed prior to lithification, indicating brief periods of lowered sea level. Similar features are described by Wilson (1967, p. 808, 809) at the tops of Virgilian shelf cycles in the Sacramento Mountains.

Summary

The Laborcita Formation, originally described by Otte (1959, p. 26), is of latest Virgilian and early Wolfcampian age. The thickness of the Laborcita Formation in the Monte Carlo Gap stratigraphic section is estimated to be 2,229 feet thick, of which a minimum of 859 feet is Wolfcampian strata and the lower part a maximum of 1,370 feet of Virgilian strata.

Sandstone, meta-sediments, argillaceous micrite, mudrock, micrite, conglomerate, wackestone, and grainstone, in decreasing order of abundance, comprise the Laborcita Formation. Plagioclase is the dominant feldspar in the sandstones, and biotite and hornblende are conspicuously absent.

The dominant sedimentary structures are ripple marks, ripple and medium scale cross-stratification, mudcracks, burrows, parallel lamination, convoluted bedding, and normally graded bedding. Point bar sequences occur in many of the thicker sandstone units. Current directions in medium scale cross-strata are westerly. In ripple marks and ripple stratification current directions are bimodal to the west and east-northeast.

The Laborcita Formation is indicative of repeated cyclical sedimentation during the Virgilian and Wolfcampian. A typical cycle consists of basinal shales, tidal channel sandstones, tidal flat mudrocks, and lagoonal, argillaceous limestones. The tops of some of the limestones exhibit features indicative of subaerial exposure.

Wolfcampian Hueco Limestone

Outcrop Locations

Resistant units of the Hueco Limestone form hills at the northern end of the Jarilla Mountains and a line of conspicuous hogbacks two miles southeast of the main part of the range. The stratigraphic section of Hueco Limestone described and measured in this study is exposed along the northern side of Monte Carlo Gap. The line of section is essentially the northern continuation of that used to measure the Laborcita Formation (Plate 2).

Terminology, Thickness, and Age

The total thickness of Hueco Limestone described during this study in the northern Jarilla Mountains is 1,040 feet. This is in close agreement with the earlier reported thicknesses of 986 feet measured by Schmidt and Craddock (1964, p. 20) and 1,075 feet estimated by Seager (1961, p. 21) in the same area. For the purposes of this study, the Hueco Limestone in Monte Carlo Gap is subdivided into three informal members; the lower Hueco limestone, the distal Abo tongue, and the upper Hueco limestone.

Schmidt and Craddock (1964, p. 16) have assigned a Wolfcampian age for the entire Hueco Limestone section in Monte Carlo Gap based on fusulinids and macrofossils. Seager (1961) also assigns a Wolfcampian age to the entire Hueco Limestone section. Myers (1975, written communication) assigns fusulinids from unit MC-83 of this study to the lower Hueco limestone, a conclusion in agreement with lithostratigraphic correlations to the lower Hueco of the Sun Oil Co. No. 1 Pearson oil test (Kottlowski, 1960, p. 98) suggested in this study.

Lower Hueco Limestone

The measured thickness of the lower Hueco limestone (units MC-75 through MC-84) in the northern Jarilla Mountains is 264 feet. Of this total thickness, 156 feet (59%) is wackestone, 64 feet (24%) is micrite, 26 feet (10%) is covered mudrock, and 18 feet (6%) is packstone, grainstone, and boundstone. Limestones containing 5% or more chert nodules (units MC-86, MC-94) total 88 feet (33%) of the lower Hueco limestone.

Most of the units weather as medium and thick ledges, although a few units characteristically form very thick ledges. Unit MC-76, near the base of the lower Hueco limestone, forms cliffs up to 20 feet high. Typically, weathered surfaces are medium light gray and medium gray. Chert nodules weather grayish orange and dusky brown. Covered areas within described units total 35% of the measured lower Hueco limestone section.

The base of the lower Hueco limestone is concealed beneath rubble from units MC-75 and MC-76. It is a sharp lithologic change from argillaceous micrites, calcareous siltstones, and oolitic grainstones (unit MC-74) of the Laborcita Formation to algal wackestones and boundstones (unit MC-75) of the lower Hueco limestone. A similar sharp lithologic change at the Laborcita-Hueco contact is found on Hard Luck Tank Hill, one mile to the west (Plate 2).

Allochemical material in the lower Hueco limestone is composed predominantly of intraclasts with subordinant amounts of fragmental and whole fossils, pellets, and oolites. The fossils are algal fragments and fusulinids with minor amounts of echinoid(?) spines, gastropods, brachiopods, ostracodes, bryozoans, and rugose corals. Pelletal material, although uncommon overall, makes up as much as 40% of some beds in unit MC-84. Oolites comprise 5% of one bed at 2,525 feet, also in unit MC-84.

Distal Abo Tongue

Units MC-85 through MC-90 comprise the distal Abo tongue and total 163 stratigraphic feet. Of this total thickness, 82 feet (50%) is mudrock or suspected mudrock, 23.5 feet (14%) is wackestone, 23 feet (14%) is grainstone, 17.5 feet (11%)

is micrite, 9 feet (6%) is sandy packstone, and 8 feet (5%) is sandstone.

Medium and thick ledges and low ridges characterize 12% of the weathered outcrops of the otherwise covered or barely exposed distal Abo tongue. Typically, weathered surfaces are pale yellowish brown, grayish orange, medium gray and dark yellowish brown.

The base of the distal Abo tongue is a sharp, erosional contact with a maximum of five centimeters of relief in the area of the measured section. It represents a sharp lithologic change from the algal and fusulinid bearing, cherty wackestones and micrites of the lower Hueco limestone to overlying mudrocks and argillaceous intraclastic and sandy grainstones and packstones.

Allochemical material is composed predominantly of intraclasts and fossil fragments with subordinant pellets and minor oolites. The fossil material is composed of fragments and rare whole forms of brachiopods and gastropods with minor numbers of fusulinids, stromatolitic and coralline algal fragments, foraminifera, echinoid(?) spines, bryozoans, and rugose corals.

Detrital materials of the distal Abo tongue are predominantly very fine to coarse, angular, quartz sand grains. One lenticular bed in unit MC-88 contains 15% rounded chert and quartz granules and pebbles in a medium grained sand and brachiopod shell matrix. Quartz sand grains comprise up to 30% of the packstones and basal grainstones of unit MC-85, the basal unit of the distal Abo tongue. Rare, well rounded quartz sand grains occur with the predominantly angular grains in unit MC-85. Angular, poorly sorted silt and very fine sand of subarkosic composition occurs in some beds of unit MC-87.

Upper Hueco Limestone

The measured thickness of the upper Hueco limestone (units MC-91 through MC-109) in the northern Jarilla Mountains is 613 feet. Of this total thickness, 397 feet (64%) is wackestone, 121.5 feet (20%) is micrite, 48 feet (8%) is packstone, 24.5 feet (4%) is grainstone, and 22 feet (4%) is mudrock. None of the described units in the upper Hueco limestone contain more than 5% chert nodules.

Most units in the upper Hueco limestone form thick and medium ledges with subordinate very thick ledges. Unit 91 (a grainstone), the basal unit of the upper Hueco limestone section, forms a 10 foot sheer cliff (Plate 4). Typical weathered surfaces are medium gray and medium light gray. Intraclastic wackestones and grainstones in the lower part of the upper Hueco limestone (units MC-93, MC-96, MC-97) tend to have grayish orange mottling on their weathered surfaces. Covered areas estimated within each described unit total 67% of the measured upper Hueco limestone.

The base of the upper Hueco limestone is concealed, but is placed in this study at the base of a very thick bedded, cliff-forming grainstone (unit MC-91) overlying a 52 foot thick covered interval, probably mudrock, of the distal Abo tongue.

Allochemical material in the upper Hueco limestone is predominantly biogenetic with subordinate intraclasts, pellets, and oolites. Intraclasts and pellets, however, are the predominant allochems in units MC-93, MC-96, and MC-97 (59 total feet) in the lower part of the upper Hueco limestone. Biogenetic allochems are predominantly whole and fragmental foraminifera, gastropods, and brachiopods, with less common amounts of echinoid(?) spines, oncolites, fusulinids, bryozoa, ostracodes, echinoids, and coralline algal fragments. Oncolites, although rare overall within the upper Hueco limestone, are abundant within unit MC-102 and somewhat less so within the lower beds of unit MC-105. The predominant biogenetic allochems in the lower Hueco are algae and fusulinids, in sharp contrast to the foraminifera, gastropods, and brachiopods prevailing in the upper Hueco limestone.

Summary

The Hueco Limestone (Wolfcampian) is exposed in the northern part of the Jarilla Mountains and in hogbacks two miles to the east. A total of 1,040 feet of Hueco Limestone was measured on the northern side of Monte Carlo Gap, and was subdivided into three informal members; the lower Hueco limestone, the distal Abo tongue, and upper Hueco limestone.

The upper and lower Hueco members are predominantly wackestones and micrites. Allochems in the lower Hueco limestone are mostly intraclasts, algal fragments, and fusulinids. In contrast, fragmental and whole forminifera, gastropods, and brachiopods form the dominant allochemical materials in the upper Hueco limestone. Mudrock and subordinate amounts of intraclastic wackestone and grainstone dominate the lithologies of the distal Abo tongue.

POST-DEPOSITIONAL ALTERATION

Introduction

The sedimentary rocks in the Jarilla Mountains have been altered by diagenetic processes since the time of their deposition. Additional alteration of the sedimentary rocks occured during the early and middle Tertiary, when intrusion by silicic igneous rocks created favorable conditions for metasomatism. The preserved textures and mineralogies of diagenetic and metasomatic origin observed in outcrops of the Gobbler, Laborcita, and Hueco Formations have been described in outcrop and hand specimen, and analyzed in thin section and by x-ray diffraction. Only limestones and sandstones are discussed in terms of diagenesis; mudrocks and argillaceous limestones are not considered for lack of data. The terminology used in the following discussion is strictly descriptive, and is not intended to imply genetic processes unless specifically stated as such in the text.

Limestone Diagenesis

Discussion of the diagenesis in limestones will generally follow a sequential format as inferred from textural relationships observed in thin section. The diagenetic histories of the limestones of the Gobbler and Hueco Formations appear to be similar, and will be discussed together. Much of the terminology for describing diagenetic textures in limestones is taken from Bathurst (1971).

The formation of micritic envelopes around skeletal fragments is the earliest recognizable diagenetic effect in the grainstones (rarely in the packstones) of the Gobbler and Hueco Formations. Bathurst (1971, pp. 381-383) labels this effect "micritization" and attributes it to the boring action of algae and possibly fungi, followed by infilling of algal boreholes with micritic carbonate. He does not specify the process of infilling nor the source and original mineralogy of the micritic material.

An initial, or first generation of calcite spar cement is ubiquitous in grainstones of the Gobbler and Hueco Formations. It occurs as elongated crystals on the outer and inner walls of allochems radiating away from the allochem surface. Blatt _et al_ (1964, p. 464) use "drusy" as a general term for elongate or acicular crystals whose long axes are oriented perpendicular to the substrate. Bathurst (1971, p. 547) terms it radial-fibrous cement. Both authors suggest this first generation cement forms early in the diagenetic history of the rock.

Geopetal structures in brachiopod and gastropod shell cavities (unit MC-91) enable the relative diagenetic age for first generation spar cement to be estimated in the Hueco Formation. Geopetal detritus overlies first generation spar cement in the interiors of shell cavities. Subsequently, the shells have been rotated by currents or bioturbation so that geopetal surfaces are not uniformly oriented. Additional "drusy" spar cement was precipitated within the part of the shell cavities not filled by geopetal detritus subsequent to rotation. This sequence of events suggests that first generation spar cement was formed during deposition and reworking of the grainstone. A similar, non-rotated, alternation of spar cement and geopetal detritus is illustrated by Bathurst (1971, p. 432, Figure 311).

Precipitation of second generation spar cement has completely filled the pore spaces in grainstones. It is recognizable, according to Bathurst (1971, pp. 417-419), by planar intercrystalline boundaries, abundant enfacial junctions among triple junctions, and a uniform distribution of crystal size. Blatt et al (1964, p. 464) refer to this type as "blocky" cement. Second generation cement is a minor constituent in packstones, wackestones, and micrites where it occurs in shell cavities, tests, and burrows.

Neomorphic spar is formed both before and after the second generation spar cement described above. Bathurst (1971, p. 476) uses the term "neomorphic spar" to include "...all spar which has formed as an in situ replacement of a more finely crystalline crystal mosaic.". This convention is adopted for this study as is Bathurst's (1971, p. 502) arbitrary subdivision of neomorphic spar into three crystal-size categories: micrite (0.5 to 5 microns), microspar (5 to 50 microns), and pseudospar (50 to 100 microns). The major criteria used for recognition of neomorphic spar in this study is also drawn from Bathurst (1971, pp. 484-493) and includes: the general lack of plane intercrystalline boundaries; an irregular and patchy distribution of crystal sizes; a low percentage of enfacial junctions among triple junctions; replacement of original fabrics of allochems by microspar and pseudospar; and the occurence of relict structures, outlines, and "ghosts" of allochems within the spar.

Partial or complete replacement of skeletal fabrics by pseudospar and microspar marks the earliest appearance of neomorphic spar, and occurs both before (unit MC-91) and after (units MC-92 and MC-99) the second generation of spar cement described previously. In unit MC-91, brachiopod shells have been broken during compaction after replacement of their internal fabric by neomorphic spar but before precipitation of the second generation of pore-filling cement. In unit MC-91 and other grainstones, the evidence that a pre-existing shell fragment has been replaced by neomorphic spar is often only the dark, cloudy remains of a micritic envelope.

A later stage of neomorphic spar formation occurs as patchy to complete microspar and pseudospar replacement of micrite. The micrite itself is neomorphic spar, presumably it replaced clay-sized particles of carbonate very early in the sequence of diagenetic events. Pseudospar and microspar have almost completely replaced micrite in some packstones of the Hueco Limestone (unit MC-101), making them difficult to distinguish from grainstones in hand specimen.

Microstylolitic contacts are present between allochems (unit RC-2), between an allochem and spar cement (unit RC-2), between crystals of neomorphic spar (unit NBN-4b), and between quartz grains in limestones (unit MC-97). Stylolites occur in outcrop as horizontal, undulating surfaces tens of feet wide. Both stylolites and microstylolites are attributed to pressure solution (Blatt et al, 1964, p. 470; Bathurst, 1971, p. 462-464), and the truncation of all primary and diagenetic textures by these features indicates that pressure solution is a late event in the diagenetic history of the limestones.

Evidence for the timing of the appearance of chert nodules during the diagenetic history of the limestones of the Gobbler and Hueco Formations was not observed during this study. There are, however, relationships observable in outcrop that may be significant to future studies of the stratigraphy or silica content of the limestones in the Jarilla Mountains.

Almost all chert nodules in the limestones of the Jarilla Mountains occur in wackestones, micrites, and packstones; few occur in grainstones. Although chert nodules in unit

NB-8 (wackestone) form exclusively on the sites of undisturbed skeletal remains of colonial corals and cherty limestone nodules in unit RC-6b (micrite) appear to be localized around whole rugose corals, most chert nodules do not seem to bear any spatial relation to organic debris. The only consistent features of chert nodules, particularly in the Gobbler Formation, are their tendencies to be elongated parallel to bedding and to be of similar size and shape within individual beds.

Sandstone Diagenesis

The grains, matrix, and cements within the sandstones of the Gobbler and Laborcita Formations show abundant evidence of diagenetic alteration. However, a consistent sequence of diagenetic effects cannot be reconstructed, possibly because of the effects of metasomatism.

Detrital grains within the Gobbler and Laborcita sandstone units show evidence of loading, cementation, ion substitution, and replacement. Many sand grains exhibit line and concavo-convex contacts with adjacent grains. A few quartz grains display syntaxial quartz overgrowths which appear to replace the interstitial chert common within the sandstones of the Gobbler and Laborcita Formations. Local areas of interstitial material are chert with as much as 60% illite. Also occuring within the interstitial material are minor amounts of hematite both as isolated masses of clay-sized particles and as fine crystalline pseudomorphs after pyrite.

Very fine to medium crystalline calcite spar is the most ubiquitous diagenetic mineral within the sandstones. It occupies as much as 65% of the total volume of some sandstones (unit MC-44) and replaces, in seeming order of preference, interstitial chert, feldspar grains, illite, and quartz grains. The abundance of the spar is not readily discernible in hand specimen or in slab section, as it tends to leave the outlines of replaced sand grains intact. The spar in most instances appears to be a diagenetic mineral, although its abundance increases in the Laborcita sandstones near the metasomatically altered units at the base of the Monte Carlo Gap stratigraphic section (Plate 2; Appendix F).

X-ray analysis indicates most feldspars are sodium plagioclase, except for minor amounts of microcline in a few beds within the middle and upper units of the Laborcita Formation (units MC-34 and MC-62). This apparent lack of potassium feldspar is anomalous considering the source area for the sandstones is considered to be the granitic upland of the Pedernal landmass to the east (Figure 6 and Kottlowski, 1960, p. 145). A probable explanation for the lack of potassium feldspar in the sandstones of the Jarilla Mountains may involve diagenetic substitution of sodium ion for potassium ion. Similar diagenetic replacement of sodium for potassium in feldspars has been observed within the Abo Formation in central New Mexico (Cappa, 1975).

Metamorphism

Southern Area

The occurence, paragenesis, and spatial zonation of metasomatic minerals within the altered units of the Gobbler Formation and older formations have already been described by Jaramillo (1973) and Bloom (1976). The zonation they recognized (moving away from the intrusive contact) may be summarized by listing the predominant minerals within each zone: clinozoisite-actinolite, andradite-grossularite, wollastonite, and calcite (marble).

In addition to the above sequence of four zones, a fifth zone has been interpreted from thin section observation of seemingly unaltered limestones sampled near the outer margins of metasomatic aureoles and also near relatively "dry" intrusives. Within this outermost zone, very fine to medium crystalline, euhedral quartz crystals have nucleated spontaneously or grown upon chert or quartz silt or sand substrates. This quartz tends to occur as isolated crystals or more commonly as groups of two to four euhedral crystals radiating from a common substrate, and comprises less than one percent of the host limestone. These euhedral quartz crystals are described under "porphyroblasts" in thin section descriptions in the appendices (p.). Some of the coarser examples of the minute quartz crystals are visible in hand specimen.

A second type of metasomatic alteration not documented by earlier studies in the southern area is the replacement of interstitial material, feldspar, and pre-existing cement by chlorite in unit NB-4. The spatial distribution and mineral zonation within this one sandstone unit are discussed further on page 59.

Northern Area

Mineralogic description of metamorphism in the northern area of the Jarilla Mountains (Plate 2) is limited in this study to the lower 700 feet of the Monte Carlo Gap stratigraphic section (Plate 4). A combination of thin section and x-ray analysis has yielded a metasomatic alteration assemblage in the more terrigenous Laborcita Formation that is strikingly different from the assemblage occuring in the limestones of the Gobbler Formation.

The lower 250 feet of the Monte Carlo Gap stratigraphic section (Plate 4) is extensively pyrometasomatized sandstone, mudrock, and limestone. This interval contains abundant andradite-uvarovite garnet, scapolite, cordierite, and actinolite. Common accessory minerals include diopside, idocrase(?), calcite, and quartz. Of special interest is the lowermost outcropping unit (MC-1), a meta-sandstone which contains the assemblage iron-rich orthoclase, wollastonite, and quartz, with lesser amounts of diopside and uvarovite. Orthoclase is not found anywhere else within the metasedimentary or sedimentary column described in this study.

The upper 310 feet of metasediments (overlying a propylitically altered monzonite sill, Plate 4) contain a quartz-calcite-plagioclase-wollastonite-chlorite mineral assemblage. Scapolite is abundant along thick horizons in the lower 150 feet and disappears upward. Calcite and wollastonite decrease upward within the interval, with a reciprocal increase in detrital quartz and plagioclase. All three trends indicate a decrease in metamorphism upwards. In all samples analyzed, scapolite appears to be the extremely low birefringent, sodium rich, marialite end-member.

Mineralization of direct interest to the economic geologist is sparse, consisting of small outcroppings of gossan with traces of copper carbonates near the base of the Monte Carlo Gap stratigraphic section and barite-galena -pyrite-chalcopyrite veins less than one foot thick located 800 feet south of the base of the section (Plate 2). No base metal mineralization was detected within the skarn developed in the Laborcita Formation.

<u>Summary</u>

Limestones of the Gobbler Formation and the Hueco Limestone have been indurated by calcite cement and the textures have been extensively altered by neomorphic spar ranging in size from micrite to pseudospar. Sandstones of the Gobbler and Laborcita Formations have also been altered during diagenesis; the two most outstanding effects being extensive replacement of silicate detrital minerals by calcite spar and nearly complete albitization of detrital potassium feldspar.

The mineral zonation in metasomatically altered limestones (moving away from intrusive contacts) in the southern area (Plate 1) has previously been described as clinozoisite-actinolite, andradite-grossularite, wollastonite, and calcite (marble) (Jaramillo, 1973; Bloom, 1976). In otherwise unaltered limestone peripheral to the marble zone, a scattered growth of fine crystalline, euhedral quartz appears to indicate a fifth zone of metasomatism. This fifth zone has been detected hundreds of feet from the nearest marble or wollastonite altered limestones.

In the northern area (Plate 2) the mineral assemblage in metasomatically altered Laborcita Formation is predominantly scapolite (marialite), andradite-uvarovite, cordierite, actinolite, and wollastonite. The presence of wollastonite seems to define the outer zone of alteration. Nearby mineralization of economic interest includes thin barite-galena-pyrite-chalcopyrite veins and small gossans with trace amounts of copper carbonates.

STRUCTURE AND CORRELATION

Introduction

This chapter is concerned with the structure and correlation of the sedimentary rocks and their metamorphosed equivalents within the Jarilla Mountains. The southern area (Plate 1) and the northern area (Plate 2) are mapped and described in terms of structure and marker horizons. Refinements of the stratigraphic correlations and structural interpretations of Seager (1961) and Schmidt and Craddock (1964) in the northern area are included. Portions of the southcentral area (Figure 2) have been mapped and described by Jaramillo (1973) and Bloom (1976). They have proposed correlations between metamorphic rocks and possible equivalents which deserve comment and reinterpretation, and are discussed below.

Southern Area

The overall structure of the Jarilla Mountains is a dome, called the Jarilla dome by Schmidt and Craddock (1964, p. 38). In addition, three smaller structural features are recognizable in the southern area. The first is a large, doubly plunging anticline, hereafter referred to as the Brice Anticline, trending approximately N50°W. The axial trace is located on Plate 1, but is only approximate owing to disruption caused by later faulting and intrusion. This large fold is parallel with, and probably of the same age as, the northwest and north trending compressional features of Laramide age (Dr. Charles Chapin, 1976, oral communication) on Otero Mesa (Black, 1975, p. 330) and in West Texas north of Sierra Blanca and Van Horn (Woodward et al, 1975).

The second structural feature is a small horst recognizable in the NE$\frac{1}{4}$, Sec. 9, T.22S., R.8E. The horst lies between two vertical faults trending N45° W, both of which have been intruded by hornblende monzonite along their entire lengths of exposure. Recognition of the horst is based on the correlation of sandstone beds at Location C with those at Location D and also by observation of large scale drag folds on opposite sides of a dike at Location E (Plate 1). The dike at Location E occupies the southwestern bordering fault of the horst and may be traced from the southeast side of the hill at Location E northwest for 4,000 feet to Location F, near the top of the Range Camp stratigraphic section. Near Location G the northeast bounding dike-fault truncates sandstone marker horizons and a quartz monzonite sill within the horst. The dike-fault may be traced for 1,500 feet along its length before it is lost in hornblende monzonite sills.

The third structural feature is a system of radiating hornblende monzonite dikes and sills centered at Location H, approximately 600 feet south of the Brice Cemetery. The center of the radiating dike system is generally on the axis of the Brice anticline.

Limestones and sandstones of the Gobbler Formation are the only units exposed in the southern area with the exception of one poorly exposed outcrop of possible Percha Shale at Location I (Plate 1). The outcrop of suspected Percha Shale is in fault contact with limestones of the Gobbler Formation, and appears to be an upfaulted block along the axis of the Brice anticline.

The sandstone beds at Locations C and D correlate with unit NB-4 of the Nannie Baird stratigraphic section (Plate 1). Correlation is based on similarity of bed thickness, grain size and angularity, and in the case of Location D, associated lithologies overlying the NB-4 equivalent.

The sandstones of unit NB-4 and Locations C and D are equivalent to glauconitic sublitharenites described by Benne (1975, p. 27) in the Gobbler Formation in the Sacramento Mountains. Unit NB-4 contains a stable quartz-chlorite -illite(?) assemblage, whereas the sandstones at Locations C and D contain a quartz-illite-calcite alteration. The localization of the iron and magnesium bearing chlorite in the area of the Nannie Baird stratigraphic section (unit NB-4) and the removal of the iron and magnesium (in glauconite) from the equivalent units one mile to the west (Locations C and D) is suggestive of a crude mineral zonation of metasomatic origin.

The contact between a non-cherty packstone and grainstone unit (NBN-6) and an overlying chert wackestone unit (NBN-7) has been correlated across part of the southern area. It is represented as a dotted line on Plate 1 and labeled accordingly. Additionally, sandstone beds occuring in the Nannie Baird stratigraphic section (units NB-9 and NB-11b) are found in similar positions in the Nannie Baird North (units NBN-0 and NBN-2) and Garnet Dike South (units GDS-5 and GDS-11) stratigraphic sections. These are also represented as dotted lines and labeled on Plate 1.

A locally traceable contact between units RC-5 and RC-6a (Plate 3) serves as a marker to correlate the upper and lower parts of the Range Camp stratigraphic section (Plate 1). A second correlation concerning strata within the Range Camp stratigraphic section is made between a thick mudrock unit (sub-units RC-2b and RC-2d) and a bed of similar thickness and lithology at Location J in the southwest corner, Sec. 10, T.22S., R.8E. Limestones equivalent to sub-units RC-2a and RC-2c were not observed at Location J, however the limestones overlying the mudrock unit at Location J are similar in thickness and lithologic succession to the upper part of the Range Camp stratigraphic section.

Northern Area

The structure of the northern area is dominated by the

Jarilla dome as described by Seager (1961, pp. 47, 48) and Schmidt and Craddock (1964, p. 40). These earlier authors described and mapped the general domal structure and placement of hornblende monzonite sills and a granodiorite stock, but both committed errors in the correlation of the Laborcita Formation - Hueco Limestone contact that led to misinterpretations of local structural details.

The maximum displacement of any fault in the northern area is approximately 150 feet, measured at Location K one mile north of Monte Carlo Gap. Seager (1961, p. 48) measured 800 feet of throw in the same area, but based his measurements on an erroneous placement of the Panther Seep (Laborcita) Formation - Hueco Limestone contact (p. 22). He did, however, place the contact correctly within Monte Carlo Gap and also one mile to the west on Hard Luck Tank Hill (Plate 2). Schmidt and Craddock (1964, Plate 1) also correctly place the contact in Monte Carlo Gap, but fail to recognize outcrops of Laborcita Formation at Hard Luck Tank Hill and along the lower slopes of the hills one to two miles north of Monte Carlo Gap. The skarn outcrops in the northern half of Sec. 9, T.21S., R.8E., mapped both by Seager, and Schmidt and Craddock, but only observed during reconnaisance in this study, are metamorphosed sandstones, mudrocks, and limestones of the Laborcita Formation.

Southcentral Area

The southcentral area covers the hills around the Ohaysi Valley (Figure 3). It was neither mapped nor studied in stratigraphic or structural detail by this author because it lacked the lithologic and structural control need to accomplish the purposes of this study. However, the extensively metamorphosed sedimentary rocks of the southcentral area have been mapped by Jaramillo (1973) and Bloom (1976) and described in terms of the occurence, paragenesis, and zonation of their alteration mineral assemblages. The following paragraphs are comments upon the probable stratigraphic location of metamorphic outcrops described by Jaramillo and Bloom.

At location L (Figure 3), Jaramillo (1973, p. 15) describes a diopside-calcite-sulfide skarn with local magnetite mineralization next to a hornblende monzonite intrusive, and interprets the original host rock to be a cherty dolomitic limestone. Jaramillo also notes a "thin" quartz siltstone which contains 17% muscovite occuring within the diopside-calcite-sulfide skarn. Possible equivalents to the quartz siltstone and the diopside-calcite-sulfide skarn are the distal Cable Canyon Sandstone, the lower beds of the Montoya Dolomite, and the upper beds of the El Paso Limestone.(Figure 2). There are faults with this interpretation, as will be seen in the following discussion.

The only observed alteration of dolomites and cherty dolomites in drill core (Bloom and Martineau, 1975, unpublished) is magnetite-serpentine-sulfide and minor magnetite-serpentine-garnet-diopside-sulfide skarn, very different from the diopside-calcite skarn described by Jaramillo. Also, the Cable Canyon Sandstone is described by Kottlowski (1963, p. 20) as "...quartz sand...washed relatively free of clay and non-resistant minerals." and thus has little original aluminum to form the muscovite. Significant amounts of aluminum are usually difficult to move under hydrothermal conditions (Beane, 1975, oral communication) and therefore are likely to have been present originally in the siltstone as a constituent of detrital feldspar, mica, or clay.

In the Sacramento Mountains, Benne (1975, p. 27) describes micaceous protoquartzites (sublitharenites) within the lower Desmoinesian intervals of the Gobbler Formation that are chemically similar to the muscovitic quartz siltstone observed at Location L by Jaramillo. This evidence indicates that the host rocks at Location L were part of the lower Gobbler Formation, and that the magnesium, iron, and sulfur in the diopside-calcite-sulfide skarn are exogenous. Nowhere else in the stratigraphic column are beds of micaceous sublitharenites interbedded with thick units of cherty carbonates.

Xenoliths described by Jaramillo (1973, p. 15) at Location M (Figure 3) are andradite-calcite-hornblende-sulfide and calcite-andradite-diopside-wollastonite-sulfide. The lack of aluminum and significant magnesium excludes all but the limestones of the Gobbler Formation and the basal units of the Rancheria Formation (Figure 2 and p. 12) from consideration as host rocks.

Jaramillo (1973, p. 15) interprets outcrops at Location N (Figure 3) as "calcareous beds" and "dolomite beds" that have been respectively altered to andradite-calcite-diopside -sulfide and diopside-andradite-sulfide mineral assemblages. Further inspection during reconnaisance be this author revealed these "beds" to be breccias occuring near the margins of the granodiorite mentioned by Jaramillo (1973, p. 15) and Schmidt and Craddock (1964, p. 22). The breccias consist of pebble and cobble sized angular fragments of thickly and thinly laminated sediments altered to the above-mentioned assemblages in a matrix of similar mineralogy.

The presence of lamination and lack of aluminum in the breccias excludes the Percha Shale, Caballero, Helms, Gobbler, and Laborcita Formations from consideration. If the original sedimentary host rock were dolomitic (no mass transfer of magnesium) it was probably the El Paso Limestone ("...irregularly dolomitized...thin to medium bedded, silty limestone...laminae..."; Kottlowski, 1963, p. 14). A second interpretation assumes mass transfer of iron and magnesium into the Rancheria Formation, the only thin bedded limestone and calcareous shale of significant thickness in the stratigraphic column (Figure 2). This second interpretation is more acceptable in a structural framework considering the probable stratigraphic position of outcrops at Locations L and M previously discussed.

At the Iron Queen Mine (Location P, Figure 3), Bloom (1976, p. 28 and Plate 6) describes alternating beds of magnetite and clinopyroxene-garnet hornfels and suggests that the Panther Seep (Laborcita) Formation is the host rock. Bedding thicknesses of the magnetite replacing carbonate and the abundance of chert nodules in the magnetite however, exclude the Laborcita Formation or its equivalents from consideration. Based on the results of this study and the known stratigraphy, the beds at Location M are either cherty limestones of the Dona Ana Member of the Lake Valley Formation interbedded with silty, thin bedded limestones of the Rancheria Formation (a relationship described by Armstrong, 1962, Figure 8) or the alternating cherty limestones and mudrocks expected in the Atokan and Morrowan(?) beds of the Gobbler Formation (Kottlowski, 1960, p. 98).

Summary

The Jarilla dome was formed during intrusion of early Tertiary igneous rocks and dominates the structure of the Jarilla Mountains. The Brice Anticline, a northwest trending fold in the southern area of the Jarilla Mountains, is subparallel to similar Laramide folds to the southeast on the Otero Platform and in West Texas, and is probably the same age. A small horst parallels the axial trace of the Brice Anticline, and is superimposed upon the fold for much of its length. Also in the southern area is a system of radiating dikes and sills centered along part of the crest of the Brice Anticline.

Correlation of sandstone beds and limestone unit boundaries provides structural control across the southern end of the range. Recognition of sandstone units near the lower part of the stratigraphic section is complicated because of post-depositional alteration of detrital minerals and interstitial material.

In the northern area of the Jarilla Mountains, the Jarilla dome is revealed by the attitudes of beds in the Laborcita Formation and the Hueco Limestone. The dome has been intruded by hornblende monzonite sills and by a granodiorite stock. A system of faults trend generally northeast (Plate 2) and displace a maximum of 150 stratigraphic feet.

Meta-sedimentary rocks in the southcentral area of the Jarilla Mountains have been previously studied in terms of their metasomatic mineral assemblages, paragenesis, and mineral zonation by Jaramillo (1973) and Bloom (1976). Interpretation of the mineral assemblages and outcrop descriptions compiled by Jaramillo and Bloom suggest all the outcropping skarns in the southcentral area are altered equivalents of the Gobbler, Rancheria, and Lake Valley Formations.

Magnesian and iron metasomatism is suggested to be a major process in the formation of diopside-andradite bearing skarns from the Pennsylvanian and Mississippian host rocks mentioned above.

REFERENCES CITED

Anderson, E.C., 1957, The metal resources of New Mexico and their economic features through 1954: New Mexico Bur. Mines Min. Res. Bull. 39, p. 100-102.

Armstrong, A.K., 1962, Stratigraphy and paleontology of the Mississippian System in southwestern New Mexico and adjacent southeastern Arizona: New Mexico Bur. Mines Min. Res. Mem. 8, 99 p.

Bathurst, R.G.C., 1971, Carbonate sediments and their diagenesis: Amsterdam, Netherlands, Elsevier Pub. Co., 620 p.

Beane, R.E., Jaramillo, L.E., and Bloom, M.S., 1975, Geology and base metal mineralization of the southern Jarilla Mountains, Otero County, New Mexico: New Mexico Geol. Soc. Guidebook, 26th Field Conf., Las Cruces Country, p. 151-156.

Benne, R.E., 1975, The stratigraphy of the lower Gobbler Formation, Sacramento Mountains, New Mexico: Univ. of Oklahoma, M.S. thesis, 141 p.

Black, B.A., 1975, Geology and oil and gas potential of the northeast Otero Platform area, New Mexico: New Mexico Geol. Soc. Guidebook, 26th Field Conf., Las Cruces Country, p. 323-333

Blatt, H., Middleton, G., and Murray, R., 1972, Origin of sedimentary rocks: Englewood Cliffs, New Jersey, Prentice -Hall, Inc., 634 p.

Bloom M.S., 1976, Mineral paragenesis and contact metamorphism in the Jarilla Mountains, Orogrande, New Mexico: New Mexico Inst. of Mining and Technology, M.S. thesis, 81 p.

Cappa, J., 1975, The depositional environment, paleocurrents, provenance, and dispersal patterns of the Abo Formation in part of the Cerro de Amado Region, Socorro County, New Mexico: New Mexico Inst. of Mining and Technology, M.S. thesis, [illegible] p.

Compton, R.R., 1962, Manual of field geology: New York, N.Y., John Wiley and Sons, 378 p.

Darton, N.H., 1928, Geologic map of the state of New Mexico: U. S. Geol. Survey.

Dott, R.L., 1964, Wacke, graywacke, and matrix - what approach to immature sandstone classification?: Jour. Sed. Petrology, v. 34, p. 625-632.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture: in Ham, W.E. (ed.), Classification of carbonate rocks: Am. Assoc. Petroleum Geologists Mem. 1, p. 108-121.

Finlay, J.R., 1922, Report of appraisal of mining properties of New Mexico: New Mexico State Tax Comm., p. 82.

Folk, R.L., 1974, Petrology of sedimentary rocks: Austin, Texas, Hemphill's, 170 p.

Geological Society of America, 1963, Rock color chart, 8 p.

Hidden, W.E., 1893, Two new localities for turquoise: Am. Jour. Sci., v. 46, p. 400-402.

Ingram, R.L., 1954, Terminology for the thickness of stratification and parting units in sedimentary rocks: Geol. Soc. America Bull., v. 65, p. 937-938.

Jaramillo, L., 1973, Alteration and mineralization in the Jarilla Mountains, Otero County, New Mexico: New Mexico Institute of Mining and Technology, M.S. thesis, 45 p.

Kelley, V.C., 1949, Geology and economics of New Mexico iron ore deposits: Univ. New Mexico Publ. in Geology, no. 2, 246 p.

Kottlowski, F.E., 1956, Stratigraphic studies of the San Andres Mountains, New Mexico: New Mexico Bur. Mines Min. Res. Mem. 1, 132 p.

______, 1960, Summary of Pennsylvanian sections in southwestern New Mexico and southeastern Arizona: New Mexico Bur. Mines Min. Res. Bull. 66, 187 p.

______, 1963, Paleozoic and Mesozoic strata of southwestern and southcentral New Mexico: New Mexico Bur. Mines Min. Res. Bull. 79, 100 p.

______, 1965, Measuring stratigraphic sections: New York, N.Y., Holt, Rinehart, and Winston, Publ., 253 p.

Lasky, S.G., and Wootton, T.P., 1933, The metal resources of New Mexico and their economic features: New Mexico Bur. Mines Min. Res. Bull. 7, 178 p.

Lindgren, W., Graten, L.C., and Gordon, C.H., 1910, Ore deposits of New Mexico: U.S. Geol. Survey Prof. Paper 68, p. 184-187.

Lloyd, E.R., 1949, Pre-San Andres stratigraphy and oil producing zones in southeastern New Mexico, a progress report: New Mexico Bur. Mines Min. Res. Bull. 29, 87 p.

Needham, C.E., 1937, Some New Mexico fusulinids: New Mexico Bur. Mines Min. Res. Bull. 14, 88 p.

Otte, C., Jr., 1959, Late Pennsylvanian and Early Permian stratigraphy of the northern Sacramento Mountains, Otero County, New Mexico: New Mexico Bur. Mines Min. Res. Bull. 50, 111 p.

Pettijohn, F.J., Potter, P.E., and Siever, R., 1973, Sand and sandstone: New York-Heidelberg-Berlin, Springer-Verlag, 618 p.

Pray, L.C., 1961, Geology of the Sacramento Mountains escarpment, Otero County, New Mexico: New Mexico Bur. Mines Min. Res. Bull. 35, 144 p.

Reineck, H.-E., and Singh, I.B., 1975, Depositional sedimentary environments: New York-Heidelberg-Berlin, Springer-Verlag, 439 p.

Reynolds, C.B., and Craddock, J.C., 1959, Geology of the Jarilla Mountains: in Guidebook to the Sacramento Mountains: Permian Basin Section, Soc. Econ. Paleontologists and Mineralogists and Roswell Geol. Soc., p. 279-283.

Schmidt, P.G., and Craddock, C., 1964, Geology of the Jarilla Mountains, Otero County, New Mexico: New Mexico Bur. Mines Min. Res. Bull. 82, 55 p.

Seager, W., 1961, Geology of the Jarilla Mountains, Tularosa Basin, New Mexico: Univ. of New Mexico, M.S. thesis, 80 p.

Thompson, M.L., 1942, Pennsylvanian system in New Mexico: New Mexico Bur. Mines Min. Res. Bull. 17, 92 p.

Visher, G.S., 1965, Fluvial processes as interpreted from ancient and recent fluvial deposits: in Middleton, G.V. (ed.), Primary sedimentary structures and their hydrodynamic interpretation: Soc. Econ. Paleontologists Mineralogists Spec. Publ. 12, p. 116-132.

Wilpott, R.H., Macalpin, A.J., Bates, R.L., and Vorbe, G., 1946, Geology of La Joya area, Los Pinos Mountains and North Chupadera Mesa: U.S. Geol. Survey Oil and Gas Inv. (Prelim.) Map 61.

Wilson, J.L., 1967, Cyclical and reciprocal sedimentation in Virgilian strata of south New Mexico: Geol. Soc. America Bull., v. 78, no. 7, p. 805-818.

Woodward, L.A., Callender, J.F., Gries, J., Seager, W.R., Chapin, C.E., Shaffer, W.L., and Zilinski, R.E., 1975, Tectonic map of the Rio Grande region, Colorado - New Mexico border to Presidio, Texas: New Mexico Bur. Mines Min. Res.

APPENDIX A

INTRODUCTION TO STRATIGRAPHIC SECTIONS

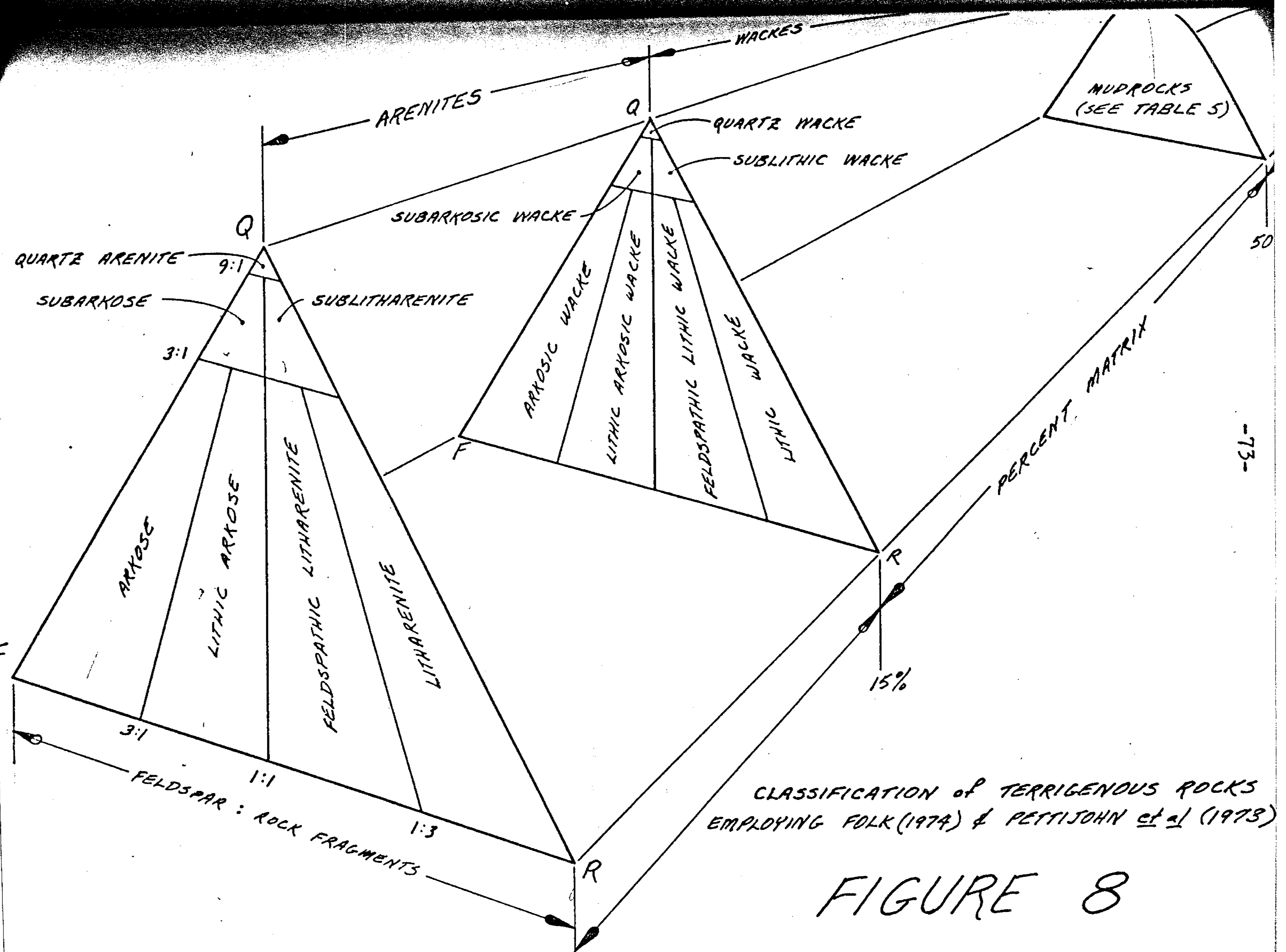
Techniques Employed

Field methods for measuring stratigraphic sections are described by Kottlowski (1965) and Compton (1962). The most common technique employed during this study was the sighting bar and simple clinometer with mirror. Rock descriptions were compiled at the outcrop following a prepared field outline, and supplemented by later slab and thin section descriptions. Identification of metamorphic minerals and fine-grained components of terrigenous sedimentary rocks were aided by x-ray diffraction analyses.

Each measured stratigraphic section is named for a nearby local feature. For example, the Nannie Baird section has been named for the nearby Nannie Baird Mine. Numbers denoting position in stratigraphic feet were painted along the line of section, usually every ten feet.

Descriptive Terminology

A classification scheme employing Folk (1974) and Pettijohn et al (1973), based on composition and texture, is used to define terrigenous rocks (Figure 8). Textural terms supplied by Dunham (1962) are slightly modified (Table 2) and used in conjunction with the textural and genetic-compositional terms



CLASSIFICATION of TERRIGENOUS ROCKS EMPLOYING FOLK (1974) & PETTIJOHN et al (1973)

FIGURE 8

Carbonate rocks > 50% carbonate

Depositional Texture Recognizable					Depositional Texture Not Recognizable
Original Components Not Bound During Deposition				Original Components Bound	
Contains Micrite			Lacks Micrite		
Micrite Supported		Grain Supported			
< 10% Grains	> 10% Grains				
Micrite	Wackestone	Packstone	Grainstone	Boundstone	Crystalline Carbonate

Textural classification of carbonate rocks (Dunham, 1962), modified

TABLE 2

of Folk (1974) to classify carbonate rocks (Table 3). Folk's terms are in parentheses in rock unit descriptions.

Grain, allochem, and crystal sizes are described according to Folk (1974) (Tables 4 and 5) and comparative scales used to delineate roundness and sorting (Table 6) are taken from Pettijohn _et al_ (1973). Terminology for bedding thickness and the thicknesses of individual ledges in outcrop conform to Ingram (1954) (Table 7).

Format of Descriptions

The descriptive format for each rock unit delineated within the stratigraphic sections (Appendices B through F) is as follows:

General lithology: limestone, conglomerate, sandstone, mudrock

Specific lithologic classification:

Topographic expression: exposed, ridges, ledges, cliffs, percent exposed vertically

Lower contact description: covered, gradational, sharp, erosional, maximum relief

Color: fresh/weathered

Grains: percent, mineralogy, size, roundness, sorting

Allochems: percent, type, size

Porphyroblasts: mineralogy, size

Matrix: mineralogy and/or texture

Cement: mineralogy and/or texture

Fossil occurences: group names(s)

Bedding and modifiers: thickness, continuity, internal structures

Nodules: mineralogy, percent

Unique characteristics, comments:

Attitude of strata:

Apparent dip along line of section: ...if line of section deviates from true dip direction

Descriptive data are listed in decreasing order of abundance within each descriptive subgroup. Thin section and slab section data is designated in brackets, fauna and flora lists in parentheses. Colors assigned to rock units conform to the Geological Society of America Rock Color Chart (1963). At times, rock units are divided into sub-units. These sub-units are individually described and separately labeled by adding a suffix to the unit number (example: MB-5f).

VOLUMETRIC ALLOCHEM COMPOSITION	LIMESTONES, PARTIALLY DOLOMITIZED LIMESTONES, AND PRIMARY DOLOMITES (see Notes 1 to 6)					REPLACEMENT DOLOMITES[7] (V)	
	>10% Allochems ALLOCHEMICAL ROCKS (I and II)		<10% Allochems MICROCRYSTALLINE ROCKS (III)		UNDISTURBED BIOHERM ROCKS (IV)	Allochem ghosts	No Allochem Ghosts
	Sparry calcite cement > Microcrystalline ooze Matrix	Microcrystalline Ooze Matrix > Sparry Calcite Cement	1-10% Allochems	<1% Allochems			
	SPARRY ALLOCHEMICAL ROCKS (I)	MICROCRYSTALLINE ALLOCHEMICAL ROCKS (II)	Most Abundant Allochem			Evident Allochem	
>25% Intraclasts (i)	Intrasparrudite (Ii:Lr) Intrasparite (Ii:La)	Intramicrudite* (IIi:Lr) Intramicrite* (IIi:La)	Intraclasts: Intraclast-bearing Micrite* (IIIi:Lr or La)	Micrite (IIIm:L); if disturbed, Dismicrite (IIImX:L); if primary dolomite, Dolomicrite (IIIm:D)	Biolithite (IV:L)	Finely crystalline Intraclastic Dolomite (Vi:D3) etc.	Medium Crystalline Dolomite (V:D4)
<25% Intraclasts; >25% Oolites (o)	Oosparrudite (Io:Lr) Oosparite (Io:La)	Oomicrudite* (IIo:Lr) Oomicrite* (IIo:La)	Oolites: Oolite-bearing Micrite* (IIIo:Lr or La)			Coarsely Crystalline Oolitic Dolomite (Vo:D5), etc.	Finely Crystalline Dolomite (V:D3)
<25% Intraclasts; <25% Oolites; Volume Ratio of Fossils to Pellets >3:1 (b)	Biosparrudite (Ib:Lr) Biosparite (Ib:La)	Biomicrudite (IIb:Lr) Biomicrite (IIb:La)	Fossils: Fossiliferous Micrite (IIIb: Lr, La, or Ll)			Aphanocrystalline Biogenic Dolomite (Vb:D1), etc.	
<25% Intraclasts; <25% Oolites; Volume Ratio of Fossils to Pellets 3:1 - 1:3 (bp)	Biopelsparite (IIbp:La)	Biopelmicrite (IIbp:La)	Pellets: Pelletiferous Micrite (IIIp:La)			Very Finely Crystalline Pellet Dolomite (Vp:D2), etc.	etc.
<25% Intraclasts; <25% Oolites; Volume Ratio of Fossils to Pellets <1:3 (p)	Pelsparite (Ip:La)	Pelmicrite (IIp:La)					

Classification of carbonate rocks (Folk, 1974)

TABLE 3

U.S. Standard Sieve Mesh #		Millimeters	Microns	Phi (ϕ)	Wentworth Size Class	
		4096		-12		
		1024		-10	Boulder (-8 to -12ϕ)	
Use		256		-8		
wire		64		-6	Cobble (-6 to -8ϕ)	
squares		16		-4	Pebble (-2 to -6ϕ)	GRAVEL
5		4		-2		
6		3.36		-1.75		
7		2.83		-1.5	Granule	
8		2.38		-1.25		
10		2.00		-1.0		
12		1.68		-0.75		
14		1.41		-0.5	Very coarse sand	
16		1.19		-0.25		
18		1.00		0.0		
20		0.84		0.25		
25		0.71		0.5	Coarse sand	
30		0.59		0.75		
35	1/2	0.50	500	1.0		
40		0.42	420	1.25		
45		0.35	350	1.5	Medium sand	
50		0.30	300	1.75		
60	1/4	0.25	250	2.0		SAND
70		0.210	210	2.25		
80		0.177	177	2.5	Fine sand	
100		0.149	149	2.75		
120	1/8	0.125	125	3.0		
140		0.105	105	3.25		
170		0.088	88	3.5	Very fine sand	
200		0.074	74	3.75		
230	1/16	0.0625	62.5	4.0		
270		0.053	53	4.25		
325		0.044	44	4.5	Coarse silt	
		0.037	37	4.75		
	1/32	0.031	31	5.0		
	1/64	0.0156	15.6	6.0	Medium silt	
Analyzed	1/128	0.0078	7.8	7.0	Fine silt	MUD
by	1/256	0.0039	3.9	8.0	Very fine silt	
		0.0020	2.0	9.0		
Pipette		0.00098	0.98	10.0	Clay	
		0.00049	0.49	11.0		
or		0.00024	0.24	12.0		
		0.00012	0.12	13.0		
Hydrometer		0.00006	0.06	14.0		

Size scale of detrital grains (Folk, 1974)

TABLE 4

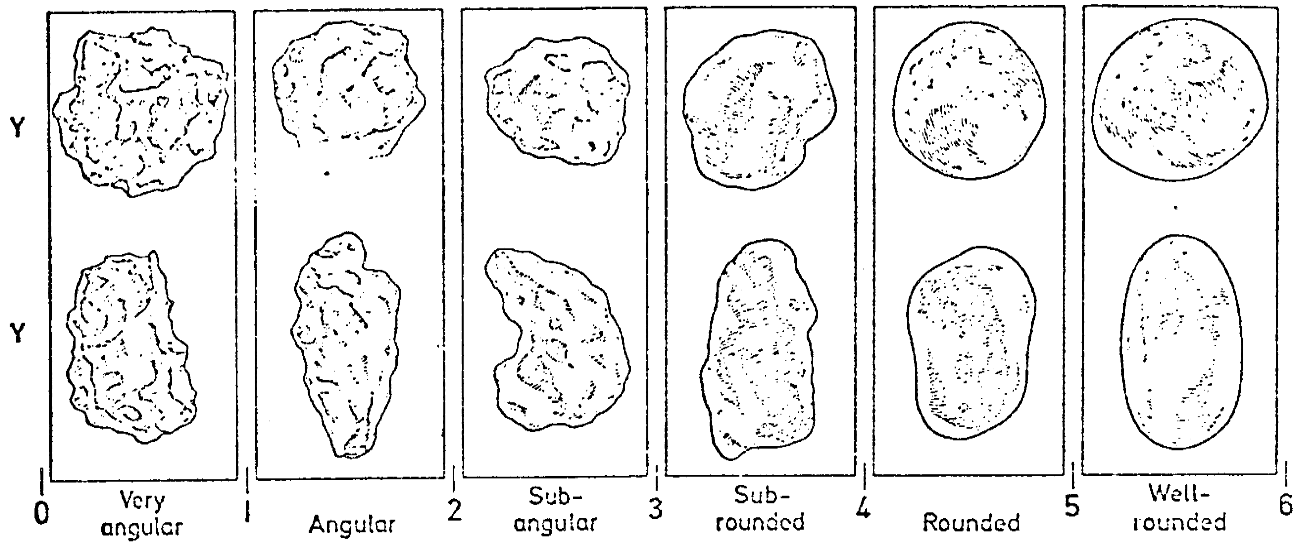
TABLE 5

Grain size	Transported Constituents	Grain size	Authigenic Constituents
	Very Coarse calcirudite		(7) Extremely coarsely crystalline
64 mm	Coarse calcirudite		(7) Extremely coarsely crystalline
16 mm	Medium calcirudite		(7) Extremely coarsely crystalline
4 mm	Fine calcirudite	4 mm	(6) Very coarsely crystalline
1 mm	Coarse calcarenite	1 mm	(5) Coarsely crystalline
0.5 mm	Medium calcarenite		(5) Coarsely crystalline
0.25 mm	Fine Calcarenite	0.25 mm	(4) Medium crystalline
0.125 mm	Very fine calcarenite		(4) Medium crystalline
0.062 mm	Coarse Calcilutite	0.062 mm	(3) Finely crystalline
0.031 mm	Medium calcilutite		(3) Finely crystalline
0.016 mm	Fine Calcilutite	0.016 mm	(2) Very finely crystalline
0.008 mm	Very fine calcilutite		(2) Very finely crystalline
0.004 mm		0.004 mm	(1) Aphanocrystalline
0.002 mm			(1) Aphanocrystalline
0.001 mm		0.001 mm	

PETROLOGY OF MUDROCKS

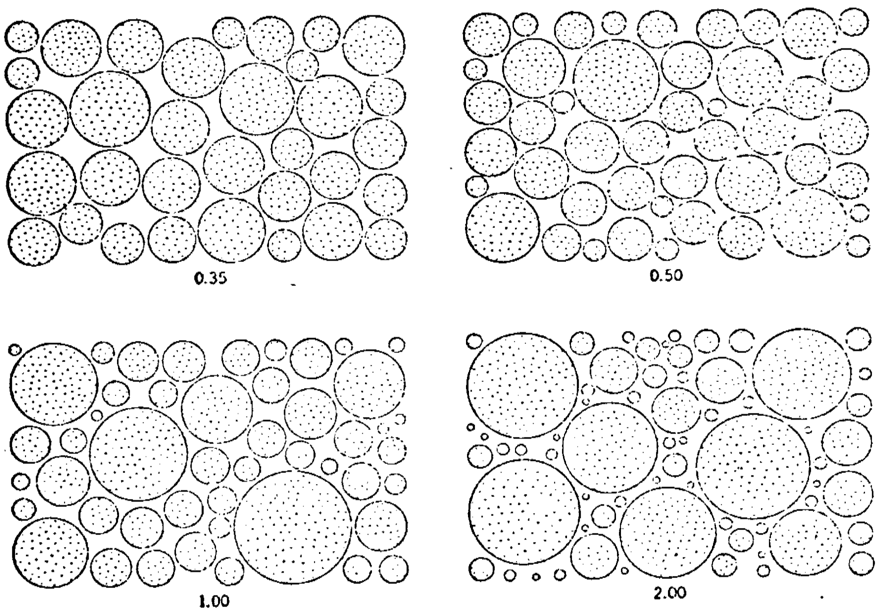
Mudrock (word coined by Ingram) is a general term used herein to cover those terrigenous rocks that contain more than 50 percent silt and/or clay. The most obvious division of mudrocks is on the basis of texture and structure:.

Grain size of mud fraction	Soft	Indurated, non-fissile	Indurated, fissile
Over 2/3 silt	silt	siltstone	silt-shale
subequal silt and clay	mud	mudstone	mud-shale
over 2/3 clay	clay	claystone	clay-shale



Roundness images and classes. Columns show grains of similar roundness but different sphericity (Redrawn from Powers, 1953, Fig. 1)

SORTING IMAGES



DIAMETER RATIO (MILLIMETERS)	PHI STANDARD DEVIATION	VERBAL SCALE	
1.0	0.00		
		very well sorted	MATURE
1.6	0.35		
		well sorted	
2.0	0.50		
		moderately sorted	SUBMATURE
4.0	1.00		
		poorly sorted	
16.0	2.00		
		very poorly sorted	

(After Folk, 1955, p. 104-105)

Comparative scales for roundness and sorting (Pettijohn et al, 1973)

TABLE 6

Beds	Very Thick	
		100 cm. (3 feet)
	Thick	
		30 cm. (1 foot)
	Medium	
		10 cm. (4 inches)
	Thin	
		3 cm. (1 inch)
	Very Thin	
		1 cm. (2/5 inch)
Laminae	Thick Laminae	
		0.3 cm. (1/10 inch)
	Thin Laminae	

Bedding thickness scale (Ingram, 1954)

TABLE 7

APPENDIX B

Nannie Baird Stratigraphic Section

Formation: Gobbler Formation

Age: Desmoinesian (Pennsylvanian)

Total thickness measured: 510+ feet

Location: NW$\frac{1}{4}$,SW$\frac{1}{4}$ Sec. 11, T.22S., R.8E. (Plate 1)

General Description:

The Nannie Baird stratigraphic section is located 1.8 miles north 15° west of Orogrande. Beginning 950 feet north 15° west of the municipal reservoir dam, and 50 vertical feet below and south of a ridge crest, the line of section climbs north to the crest and proceeds northeast along the ridge. A few offsets occur to gain exposure advantage or to cross minor faults. The effects of thermal metamorphism, hydrothermal metamorphism, and fracturing associated with faults are evident in varying degrees throughout the section. Sandstone and mudrock total 145.5 stratigraphic feet (29%) of the predominantly limestone section.

Unit	Description	Thickness in feet Unit	Cumulative
	Top of the Nannie Baird stratigraphic section. Overlying strata are structurally complex and mostly covered.		
NB-15	LIMESTONE; micrite; thick ledges; covered; medium gray (N5)/light gray (N7); thick, continuous: nodules - chert, 2%; N48°W @ 25°NE.	15+	510+
NB-14	LIMESTONE; micrite, clayey micrite, subarkose, mudshale; 40% exposed; covered; medium gray (N5)/yellow orange (10 YR 7/6), light gray (N7); upper one foot is normally graded, very fine subarkose and mudshale; medium, thick, continuous; nodules - micrite, 40%, lenticular, parallel to bedding, in slightly clayey micrite matrix; N48°W @ 25°NE.	8	495
NB-13	SANDSTONE; quartz arenite; 1% exposed; covered; mottled light olive gray (5 Y 6/1)/ mottled pale yellowish brown (10 YR 6/2), yellowish gray (5 Y 8/1), grayish orange (10 YR 7/4); grains - quartz, fine to coarse, subangular, poorly; matrix - chlorite(?); cement - calcite; N48°W @ 25°NE.	2	487
NB-12	LIMESTONE; wackestone (biomicrite, biomicrudite); thick, very thick ledges, 60% exposed; sharp; mottled light and medium gray (N7, N5)/light gray (N7); allochems - 15%, fossil fragments, fine calcarenite to fine calcirudite; matrix - micrite; echinoids, echinoid(?) spines, unidentified shell material, (fusulinids) ; thick, very thick; rare horizons with planar, microthin laminae; N48°W @ 24°NE.	15	485

Unit	Description	Thickness in feet Unit	Cumulative
NB-11b	SANDSTONE; subarkose, siltstone, siltshale; 2% exposed; sharp; medium gray (N5), moderate yellowish brown (10 YR 5/4), very light gray (N8)/pale yellowish brown (10 YR 6/2); grains - quartz, feldspar, medium sand to fine silt, decreasing upward, angular, moderate; allochems - minor, unidentified fossil fragments, coarse calcarenite; matrix - chlorite(?), limonite; cement - calcite; thick laminae, thin beds; N48°W @ 25°NE.	11±3	470
NB-11a	SANDSTONE; quartz arenite, sandy intraformational limestone conglomerate, micrite; thick ledges, 70% exposed; sharp, basal quartz arenite; white, gray mottled, medium gray (N5)/ mottled grayish pink (5 R 4/2), medium light gray (N6); arenite - fine, subangular, well; conglomerate - micrite pebbles and cobbles; matrix - quartz, fine to granule, angular, poorly; cement - calcite; medium, thick; basal quartz arenite and overlying micrite pinch out toward the southeast beneath intraformational conglomerate; N48°W @ 25°NE.	6±3	459
NB-10d	LIMESTONE; packstone (biomicrudite, biomicrite); thick ledges; 40% exposed; gradational; medium gray (N5)/light gray (N7); allochems - 65%, fossil fragments (and pellets), very fine calcarenite to medium calcirudite; matrix - microspar and pseudospar ; brachiopods, echinoids, (foraminifera, fusulinids); thick; occasional limonite stained, undulating, discontinuous, thin laminae; nodules - chert, 3%; N48°W @ 25°NE.	15	453
NB-10c	LIMESTONE; cherty micrite; thick ledges, 70% exposed; gradational; medium dark gray (N4)/ yellowish brown (10 YR 5/2); allochems - 5%, fossil fragments, fine and medium calcirudite; matrix - micrite, clay(?); echinoids, brachiopods, bryozoans, echinoid(?) spines; thick, continuous; nodules - chert, 10%; N48°W @ 25°NE.	6	438

Unit	Description	Thickness in feet Unit	Cumulative
NB-10b	LIMESTONE; cherty wackestone (cherty biomicrite), micrite; medium and thick ledges, 35% exposed; covered; medium light gray (N6)/ medium gray (N5); allochems - 15% to 30%, fossil fragments, fine and medium calcirudite; matrix - micrite; echinoids, rugose coral, brachiopods, echinoid(?) spines, fusulinids ; medium, thick; nodules - chert, 15%, commonly with thick, wavy, internal laminae; porous; N48°W @ 25° NE.	42.5	432
NB-10a	LIMESTONE; packstone (biomicrite), micrite; 10% exposed; covered; medium light gray (N6), scattered pale brown (5 YR 5/2)/very pale orange (10 YR 8/2); allochems - 45%, fragmental and whole fossils and (pellets), very fine to medium calcarenite; grains - 1%, quartz, fine, angular; porphyroblasts - (quartz, trace, fine crystalline, euhedral); matrix - (micrite, patchy microspar and pseudospar); echinoids, brachiopods, fusulinids, ostracodes ; medium, thin, continuous; N48° W @ 25° NE.	4.5	389.5
NB-9	SANDSTONE; subarkose; 10% exposed; mottled light gray (N7)/mottled grayish red (5 R 4/2), light gray (N7); grains - quartz, feldspar, fine to granule, angular, poorly; cement - silica; thick, continuous; normally graded; N48°W @ 25° NE.	2.5	385
NB-8	LIMESTONE; wackestone (biomicrudite); thick ledges, 50% exposed; covered; medium gray (N5)/ light gray (N7); allochems - 30%, fossil fragments, fine calcarenite to medium calcirudite; matrix - micrite; colonial corals (Chaetetes eximus(?), Schmidt and Craddock, 1964, p. 8), rugose corals, echinoids, brachiopods; thick, continuous; chert - 5%, thin continuous horizons and as nodules replacing corals; N48°W @ 25° NE.	17.5	382.5

Unit	Description	Thickness in feet Unit	Cumulative
NB-7	LIMESTONE; micrite, clay-bearing micrite; 50% exposed; gradational; dark gray (N3)/mottled medium gray (N5), moderate brown (5 YR 4/4); thick, continuous; nodules - 50% pebble-sized micrite nodules in clay-bearing micrite; N38°W @ 28°NE.	11	365
NB-6	SANDSTONE; quartz arenite, quartz siltstone; 10% exposed; sharp; moderate yellowish brown (10 YR 7/4); grains - very fine, subround, well; cement - silica; thin, discontinuous laminae; bioturbated, flaser bedding(?); siltstone is pyritic; N36°W @ 26°NE.	6	354
NB-5f	LIMESTONE; cherty wackestone (biomicrite); medium, thick ledges, 70% exposed; sharp, erosional, 10 cm. maximum relief; medium gray (N5) /light gray (N7); allochems - 30%, fragmental and whole fossils, fine and medium calcirudite; grains - trace, quartz, fine, very angular, embayed by spar; porphyroblasts - [quartz, 1%, very fine to medium crystalline]; matrix - [micrite, microspar, and pseudospar]; brachiopods, echinoids; medium; nodules - chert, 10%; putrid; N36°W @ 26°NE.	12	348
NB-5e	LIMESTONE; wackestone (biomicrudite, biomicrite), micrite; thick, very thick ledges, 75% exposed; covered; medium gray (N5), medium light gray (N6); allochems - 10% to 50%, fragmental and whole fossils, fine and medium calcirudite; grains - trace, quartz, fine, angular; matrix - micrite; brachiopods, echinoids, echinoid(?) spines, rugose corals, gastropods; thick, very thick; chert - minor, partially replacing fossils and 2 mm. diameter burrows in the uppermost two feet; N50°W to N36°W @ 26°NE.	69.5	336

Unit	Description	Thickness in feet Unit	Cumulative
NB-5d	SANDSTONE ; quartz arenite; 2% exposed; sharp; mottled light olive gray (5 Y 6/1)/mottled grayish red (5 R 4/2), grayish orange (10 YR 7/4); grains - quartz, feldspar, fine to coarse, angular, poorly; matrix - [10% chert, illite, hematite]; cement - [25%, calcite, medium crystalline]; thin, medium, continuous; normally graded; [subparallel illite fabric locally within chert matrix]; N50°W @ 25°NE.	1.5	266.5
NB-5c	LIMESTONE; wackestone (biomicrudite); thick, very thick ledges, 85% exposed; sharp, undulating, 15 cm. relief; medium gray (N5)/light gray (N7), medium gray (N5); allochems - 40%, fossil fragments, fine and medium calcirudite; matrix - micrite; thick, very thick; rare thin lenses of intraformational breccia with silty matrix and whole brachiopods; N50°W @ 25°NE.	10	265
NB-5b	MUDROCK; siltstone, clayshale; covered; covered; medium gray (N5)/ very pale orange (10 YR 8/4); N50°W @ 25°NE.	3	255
NB-5a	LIMESTONE; packstone (intramicrudite); thick ledge, 100% exposed; gradational, 15 cm. maximum relief; medium gray (N5)/ mottled medium light gray (N6), dark yellowish orange (10 YR 6/6); allochems - 60%, carbonaceous micrite intraclasts, coarse calcirudite; matrix - 35%, micrite, clay-bearing micrite, minor limonite pseudomorphs after pyrite; 5% phylloid(?) algae; single thick bed, continuous; N50°W @ 25°NE.	2.5	252

Unit	Description	Thickness in feet Unit	Cumulative
NB-4	SANDSTONE; quartz wacke, subarkosic wacke, quartz arenite, subarkose, mudstone; 35% exposed, thick ledges; covered; olive black (5 Y 2/1), greenish gray (5 G 6/1), medium gray (N5)/yellowish brown (10 YR 5/2), blackish red (5 R 2/2); wackes - quartz, chert, albite, fine to very coarse, angular, rarely round , moderately sorted, [matrix is chlorite-illite]; arenites - quartz, albite, chert, very fine, angular, well; cement - minor chert and calcite; medium, thick, continuous; vague thick laminae in wackes; current ripple stratigication in arenites; overall grain size decreases upward; N74°W to N50°W @ 20°NE to 42°NE.	113.5	248.5
NB-3	LIMESTONE; micrite, wackestone, marble; very thick ledges, lower 25% covered; sharp; medium gray (N5), medium dark gray (N4)/alternating horizons of medium gray (N5), medium dark gray (N6), and grayish orange (10 YR 7/4); allochems - unidentified fine and medium calcirudite; matrix - micrite; thin to thick, micrite and wackestone beds alternate with thick, irregular horizons of coarsely crystalline marble; N60°W @ 19°NE.	29	135
NB-2	HORNFELS; calcite-quartz(?); 2% exposed; sharp; light brownish gray (5 YR 6/1)/light brown (5 YR 6/4), very light gray (N8); finely crystalline with 10% very coarse calcite porphyroblasts; grades laterally to silty micrite; brachiopods (*Antiquatonia inflata*, Desmoinesian; identification by Christina Balk, 1975, written communication), fenestrate and branching bryozoa; thin, undulating; thick, discontinuous laminae; N75°W @ 24°N.	21	106

Unit	Description	Thickness in feet Unit	Cumulative
NB-1	LIMESTONE; marble; medium ledges, 15% exposed; sharp intrusive contact with underlying monzonite sill(?) subparallel with strata; five foot wide garnet-diopside-epidote exoskarn grading upward into marble; medium light gray (N6); fine to very coarsely crystalline; rare sandy horizons in upper beds; thick, medium; N70°W @ 24°N.	85	85

Base of the Nannie Baird stratigraphic section

Total thickness 510+ feet

APPENDIX C

Nannie Baird North Stratigraphic Section

Formation: Gobbler Formation

Age: Desmoinesian (Pennsylvanian)

Total thickness measured: 322+ feet

Location: SE$\frac{1}{4}$, NE$\frac{1}{4}$, Sec. 10, T.22S., R.8E. (Plate 1)

General Description:

The Nannie Baird North stratigraphic section is located 2,000 feet northeast of the base of the Nannie Baird section, and climbs up the south slope of Hill 4698 to within 50 of the crest (Plate 1). Offsets in the line of section are made to take advantage of exposures. Limestones throughout the entire section contain trace amounts of fine crystalline, euhedral quartz porphyroblasts. Silicification along fractures in the upper parts of the section are common. Sandstone and mudrock total 5 stratigraphic feet (2%) of the predominantly limestone section.

Unit	Description	Thickness in feet Unit	Cumulative
NBN-8	LIMESTONE; cherty wackestone, cherty packstone, (cherty biomicrudite), cherty micrite; thick, very thick ledges, 80% exposed; gradational and sharp lower contact; upper contact covered, marbled near monzonite dike outcropping along ridge crest; medium gray (N5)/medium light gray (N6), dark yellowish orange (10 YR 6/6), dusky brown (5 Y 2/2); allochems - 50%, fragmental and whole fossils, fine and medium calcirudite; matrix - micrite, trace disseminated limonite pseudomorph after pyrite; brachiopods, bryozoans, echinoids; very thick, continuous; nodules - chert, 50%; silicification along fractures; N60°W @ 26°NE.	10+	322+
NBN-7c	LIMESTONE; cherty micrite; 25% exposed; gradational; medium gray (N5), medium light gray (N6)/dark gray (N3) and light gray mottling, dark yellowish brown (10 YR 4/2); medium, thick; nodules - chert, 5% to 20%, decreasing upward; N60°W @ 26°NE.	29	312
NBN-7b	LIMESTONE; packstone (biomicrudite); 30% exposed; covered; medium gray (N5); allochems - 60%, fossil fragments, intraclasts, and pellets, medium calcarenite to medium calcirudite; porphyroblasts - [quartz, 1%, fine crystalline, euhedral]; matrix - [pseudospar, microspar]; echinoids, [fusulinids, foraminifera, gastropods, ostracodes]; thick, uneven, discontinuous over 100 feet; nodules - chert, 5%; N60°W @ 26°NE.	11	283
NBN-7a	LIMESTONE; cherty micrite; 40% exposed; gradational, continuous; medium dark gray (N4)/light gray (N7), medium dark gray (N4), dark yellowish orange (10 YR 6/6); very thick; nodules - chert, 30%; N60°W @ 26°NE.	30	272

Unit	Description	Thickness in feet Unit	Cumulative
NBN-6	LIMESTONE; packstone, wackestone (biomicrudite); 40% exposed; sharp, undulating, continuous; medium gray (N5)/medium light gray (N6); allochems - 25% to 60 %, fragmental and whole fossils, medium calcarenite to medium calcirudite; matrix - (microspar and pseudospar); cement - minor, radial and pore filling, medium crystalline ; porphyroblasts - quartz, 1%, fine crystalline, euhedral; very thick, thick, discontinuous; vague medium and large scale cross-stratification(?); N72°W @ 30°NE to N60°W @ 26°NE.	43	242
DIKE	HORNBLENDE MONZONITE dike cuts across NBN-5 - NBN-6 contact. Contact may be viewed 150 feet east of line of section.	9	199
NBN-5d	LIMESTONE; nodular, cherty, micrite; 40% exposed; covered; medium dark gray (N4)/light gray (N7), medium light gray (N6), grayish brown (5 YR 3/2), dark yellowish orange (10 YR 6/6); thick; nodules - chert, 10% to 60%; micrite retains nodular appearance in low chert zones; silicification along fractures; N72°W @ 30°N.	35	190
NBN-5c	LIMESTONE; cherty wackestone (cherty biomicrudite), cherty micrite; thick ledges, 60% exposed; covered; medium dark gray (N4)/light gray (N7), grayish brown (5 YR 3/2); allochems - 10%, fossil fragments, fine and medium calcirudite; matrix - micrite; echinoids, brachiopods, bryozoans, echinoid(?) spines; thick, continuous; nodules - chert, 15%; silicification along fractures; N65°W @ 24°N.	14	155
NBN-5b	LIMESTONE; nodular micrite; 30% exposed; covered; yellowish orange (10 YR 7/6), medium gray (N5)/moderate brown (5 YR 4/4), medium light gray (N6); 39% micrite modules in clay bearing micrite matrix; very thick; thin, wavy, discontinuous laminae; silicification along fractures; N65°W @ 24°NE.	6	141

Unit	Description	Thickness in feet Unit	Cumulative
NBN-5a	LIMESTONE; cherty wackestone, basal packstone, (cherty biomicrudite); thick ledges, 100% exposed; gradational; medium dark gray (N4)/ light gray (N7), moderate brown (5 YR 3/4); allochems - 15%, fragmental and whole fossils, fine and medium calcirudite; matrix - micrite; echinoids, brachiopods; medium, very thick; nodules - chert, 10%; N65°W @ 24° N.	11	135
NBN-4c	LIMESTONE; wackestone (biomicrudite, biomicrite); thick ledges, 80% exposed; gradational; medium dark gray (N4)/light gray (N7), pale yellowish brown (10 YR 6/2); allochems - 10%, fragmental and whole fossils, medium calcarenite to medium calcirudite; matrix - micrite, clay bearing micrite, trace medium crystalline pyrite; brachiopods, echinoids, brypzoans, echinoid(?) spines; very thick; thin, undulating, discontinuous clayey laminae, decreasing upward; N63°W @ 23°N.	14	124
NBN-4b	LIMESTONE; micrite; 70% exposed; covered; gradatonal; medium gray (N5)/pale yellowish brown (10 YR 8/6); matrix - [medium crystalline pseudospar], micrite; medium, thick, discontinuous; neospar zones cross bedding planes; nodules - cherty lime, 1%; N63°W @ 23°N.	7	110
NBN-4a	LIMESTONE; wackestone (biomicrudite, biomicrite), grainstone (biosparite); thick ledge, 80% exposed; erosional; medium gray (N5)/light gray (N7); allochems - 20%, fragmental and whole fossils, fine calcarenite to medium calcirudite; matrix - micrite; echinoids, echinoid(?) spines, brachiopods, [foraminifera]; thick; normally graded near base; nodules - cherty lime, 3%; N63°W @ 23°N.	6	103

Unit	Description	Thickness in feet Unit	Cumulative
NBN-3	LIMESTONE; wackestone, packstone (biomicrite); thick, medium ledges, 20% exposed; covered; medium gray (N5)/medium light gray (N6); allochems - 15% to 60%, fragmental and whole fossils, fine calcarenite to fine calcirudite, subparallel fabric; matrix - micrite; echinoids, brachiopods, gastropods, echinoid(?) spines; thick wackestone, medium packstone, continuous; N63°W @ 23°N.	18.5	97
NBN-2	MUDROCK; sandy siltshale; 1% exposed; covered; greenish gray (5 GY 6/1)/grayish orange (10 YR 7/4); grains - 25%, quartz, feldspar, very fine, angular; matrix - chlorite-illite(?); very thin; laminar, fissile; N63°W @ 23°N.	5	78.5
NBN-1	LIMESTONE; cherty wackestone (cherty biomicrite); medium thick ledges, 30% exposed; sharp; medium light gray (N6)/medium gray (N5), moderate brown (5 YR 4/4); allochems - 30%, fragmental and whole fossils, fine and medium calcirudite; matrix - micrite; echinoids, rugose corals, brachiopods, echinoid(?) spines; medium, thick; nodules - chert, 15%; N63°W @ 23°N.	73.5	73.5

Base of the Nannie Baird North stratigraphic section; overlies unit NBN-0, a sandstone unit equivalent to unit NB-9 in the Nannie Baird stratigraphic section 2,000 feet to the southeast.

Total thickness 322 feet

APPENDIX D

Garnet Dike South Stratigraphic Section

Formation: Gobbler Formation

Age: Desmoinesian (Pennsylvanian)

Total thickness measured: 320 feet

Location: NW¼, Sec. 10, T.22S., R.8E. (Plate 1)

General Description:

The Garnet Dike South stratigraphic section is located 1,500 feet north of the Brice Cemetery, and 3,000 feet west of the Nannie Baird North stratigraphic section. Minor offsets in the line of section are made to take advantage of exposure except at unit GDS-9, where structural control is poor. Metasomatic effects increase toward the top of the section, where abundant wollastonite reaction rims occur around the perimeters of chert nodules. Sandstone and mudrock total 20 stratigraphic feet (6%) of the predominantly limestone section.

Unit	Description	Thickness in feet Unit	Cumulative
,	Top of the Garnet Dike South stratigraphic section. Overlying strata is covered by colluvium on the north side of the gulley (Plate 1).		
GDS-19	LIMESTONE; cherty micrite; thick ledges, 30% exposed; sharp lower contact; medium dark gray (N4)/medium light gray (N6), light gray (N7), and dark gray (N3); matrix - micrite; thick, very thick, continuous; nodules - chert, 25%, wollastonite reaction rims on chert nodules; N70°E @ 23°N.	24+	320+
GDS-18	LIMESTONE; packstone, grainstone (biomicrudite); 5% exposed; covered; light gray (N7)/ mottled light to dark gray (N7 to N3); allochems - 60% to 90%, fossil fragments, coarse calcarenite to fine calcirudite; matrix - medium to very coarse crystalline calcite; echinoids, unidentified fragments; thick, continuous; N70°E @ 23°N.	14	296
GDS-17	LIMESTONE; cherty micrite; thick ledges, 40% exposed; sharp; medium dark gray (N4)/medium light gray (N7), dark gray (N3) nodules with very light gray (N8) rims; matrix - micrite; thick, very thick, continuous; nodules - chert, 25%, wollastonite reaction rims; N70°E @ 23°N.	18	282
GDS-16	LIMESTONE; micrite, wollastonite and diopside(?) hornfels; thick, very thick ledges, 50% exposed; covered; medium gray (N5), medium light gray (N6)/light gray (N7), pale orange (10 YR 8/2), dark yellowish brown (10 YR 4/2); matrix - micrite, medium to coarse crystalline calcite, fine crystalline clinopyroxenes; thick, very thick, continuous; thin, very thin hornfels beds alternate with thin micrites; N70°E @ 23°N.	67.5	264

Unit	Description	Thickness in feet Unit	Cumulative
GDS-15	LIMESTONE; wackestone, packstone (biomicrudite); 100% exposed; covered; medium gray (N5)/medium light gray (N6), medium gray (N5), grayish orange (10 YR 7/4); allochems - 15% to 80%, fossil fragments, coarse calcarenite to medium calcirudite; matrix - micrite; brachiopods, echinoids, echinoid(?) spines; medium, continuous; thin, irregular, discontinuous, packstone beds; N70°E @ 23°N.	1.5	196.5
GDS-14	Covered; N70°E @ 23°N.	7	195
GDS-13c	MUDROCK; siltstone; 10% exposed; sharp; bluish white (5 B 9/1)/light brown (5 YR 6/6); grains(?) - 15%, coarse silt-sized elongated "blebs", parallel to bedding; hornfelsic texture; thick, continuous; N70°E @ 23°N.	2	188
GDS-13b	LIMESTONE; packstone, wackestone (biopelmicrite); 10% exposed; covered; medium dark gray (N4)/medium gray (N5); allochems - 30% to 60%, pellets and fossil fragments, very fine to medium calcarenite; matrix - micrite; thick, continuous; N70°E @ 23°N.	3	186
GDS-13a	MUDROCK; clayshale, mudstone, pyritic hornfels; 5% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2), grayish orange (10 YR 7/4); thin bedded; thin and thick parallel laminae, fissile; 2% pyrite, finely crystalline; N70°E @ 23°N.	10	183
GDS-12	LIMESTONE; wackestone (biomicrite); 50% covered; gulley exposure; covered; medium dark gray (N4)/medium gray (N5); allochems - 15%, unidentified, fine calcarenite; matrix - micrite; thick; N70°E @ 25°N.	2	173

Unit	Description	Thickness in feet Unit	Cumulative
GDS-11	SANDSTONE; subarkose, siltstone; 90% exposed, gulley exposure; covered; greenish gray (5 GY 6/1)/mottled light gray; grains - quartz, feldspar, fine to granular, subangular, poorly; matrix - illite-chlorite(?); thick; medium siltstone bed at top with hornfelsic texture and sharp lower contact; N70°E @ 25°N.	2	171
GDS-10	LIMESTONE; wackestone (biomicrite); 90% exposed, gulley exposure; covered; medium gray (N5)/ medium light gray (N4); allochems - 15%, unidentified fine calcarenite; matrix - micrite; thick; N70°E @ 25°N.	4	169
GDS-9	Covered; N70°E @ 25°N to 65°N.	25	165
GDS-8	LIMESTONE; micrite, wackestone (biomicrite); 30% exposed, gulley exposure; medium gray (N5); allochems - 10%, fossil fragments, fine to coarse calcarenite; matrix - micrite; unidentified; thick, medium; N65°W @ 25°N.	10	140
GDS-7	Covered; complex structure; variable attitudes.	15	130
GDS-6	LIMESTONE; wackestone (biomicrudite), micrite; thick, very thick ledges, 60% exposed; covered; medium dark gray (N4)/medium light gray (N6); allochems - 15%, fossil fragments, coarse calcarenite to medium calcirudite; matrix - micrite; echinoid(?) spines, echinoids; very thick, continuous; N65°W @ 25°N.	16	115
GDS-5	SANDSTONE; subarkose; 5% exposed; greenish gray (5 GY 6/1)/mottled light gray; grains - quartz, feldspar, fine to granule, subangular, poorly; matrix - (5% chert, 3% illite, minor calcite); thick; vague thick laminae; vague medium scale cross-stratification; N65°W @ 25°N.	6	99

Unit	Description	Thickness in feet Unit	Cumulative
GDS-4	LIMESTONE; packstone, wackestone (biomicrudite); thick ledges, 50% exposed; covered; medium gray (N5)/medium light gray (N6); allochems - 30% to 70%, fossil fragments, coarse calcarenite to medium calcirudite; matrix - micrite; echinoids, brachiopods, colonial corals (Chaetetes?) in growth positions at 87 feet; thick very thick, continuous; N65°W @ 25°N.	17	93
GDS-3	LIMESTONE; cherty wackestone, cherty packstone (cherty biomicrudite); thick, very thick ledges, 70% exposed; gradational; medium gray (N5) /medium light gray (N6), moderate brown (5 YR 4/4), dusky brown (5 YR 2/2); allochems - 30% to 75%, fossil fragments, fine and medium calcirudite; matrix - micrite; echinoids, brachiopods; thick, very thick; continuous; nodules - chert, 10% to 25%, increasing upward; N65°W @ 25°N.	27	76
GDS-2	LIMESTONE; micrite; 30% exposed; gradational over 3 feet; medium gray (N5)/pale yellowish brown (10 YR 6/2); matrix - medium crystalline pseudospar, 0% to 30% micrite; thick; spar zones cross bedding planes; N65°W @ 25°N.	13	49
GDS-1	LIMESTONE; micrite, cherty micrite; thick ledges, 25% exposed; planar, sil-type contact with hornblende monzonite, no exoskarn or endoskarn developed; medium gray (N5)/ medium gray (N5), dark yellowish orange (10 YR 6/6), dusky brown (5 YR 2/2); allochems - 5%, fragmental and whole fossils, coarse calcarenite to coarse calcirudite; matrix - micrite; rugose corals, brachiopods; medium, thick; nodules - chert, 5%, decreasing upward; N65°W @ 25°N.	36	36

Base of Garnet Dike South stratigraphic section.

Total thickness 315 feet

APPENDIX E

Range Camp Stratigraphic Section

Formation: Gobbler Formation, lowermost Laborcita Formation

Age: Desmoinesian, Missourian(?) (Pennsylvanian)

Total thickness measured: 498 feet

Location: S½, Sec. 4, T.22S., R.8E. (Plate 1)

General Description:

The Range Camp stratigraphic section is located approximately 6,000 feet northwest of the Brice Cemetery. The upper part of the section (RC-6a to RC-14) is located 1,500 feet west of the lower part to take advantage of exposure. Structural control is good except in unit RC-13 where the Gobbler Formation - Laborcita Formation contact is hidden by colluvium. Metasomatic effects appear to minimal, althought the section is always within 500 feet of hornblende monzonite sills and dikes..

Unit	Description	Thickness in feet: Unit	Thickness in feet: Cumulative
RC-14	MUDROCK; claystone, clayey micrite, calcareous siltstone, subarkose; thin, medium ledges, 2% exposed; light olive gray (5 Y 6/1), medium gray (N5)/moderate yellowish brown (10 YR 5/4), dark yellowish orange (10 YR 6/6), dusky brown (5 YR 2/2); grains - quartz, plagioclase, fine, subangular, well; subarkose matrix and cement - 3% limonite and hematite, calcite; mudrocks - thin bedded, thick, thin laminae; subarkose - thick, medium scale cross-stratification; N87°W @ 25°N.	23	498
RC-13	Covered; 435 to 475 feet: N23°E @ 25°W. 380 to 435 feet: N3°E @ 25°W. The Gobbler Formation - Laborcita Formation contact is arbitrarily placed at 425 feet, within the covered interval.	95	475
RC-12	LIMESTONE; wackestone (biomicrudite); thick ledges, 25% exposed; covered; medium light gray (N6)/yellowish gray (5 Y 8/1); allochems - 20%, whole and fragmental fossils, coarse calcarenite to fine calcirudite; matrix - micrite, local dismicritic texture; tabulate corals, echinoids; thick, medium; thin, vague, undulating, discontinuous calcirudite lenses; N23°E @ 25°W.	13	380
	From RC-11 to RC-12, the line of section shifts north-northwest 200 feet, beginning just north of a dike trending N37°E.		
RC-11	LIMESTONE; micrite; thick capping ledge, 90% exposed; sharp; medium gray (N5)/yellowish gray (5 Y 8/1), moderate yellowish brown (10 YR 5/4), grayish orange (10 YR 7/4); allochems - 3%, whole fossils, medium calcirudite; matrix - micrite; rugose corals; thin, undulating, discontinuous bed; nodules - chert, 4%; N23°E @ 25°W.	9	367

Unit	Description	Thickness in feet Unit	Cumulative
RC-10	LIMESTONE; cherty micrite; 90% exposed; gradational; medium gray (N5)/medium light gray (N6), grayish orange (10 YR 7/4), dusky brown (5 YR 2/2); matrix - micrite; very thick; nodules - many with irregular and concentric internal banding; N17°E @ 18°W; measured along strike.	28	358
RC-9	LIMESTONE; grainstone (biosparrudite), wackestone (biomicrudite); 10% exposed; gradational; medium gray (N5)/medium light gray (N6); allochems - 80%, fossil fragments, coarse calcarenite to medium calcirudite; matrix - micrite; cement - medium and coarsely crystalline spar; echinoids, brachiopods; very thick, discontinuous, interbedded grainstone and wackestone; line of section crosses a brecciated fault at approximately 285 feet. The fault is downthrown 25 feet to the northeast, and has been compensated for by adding 25 feet to RC-9; N1°W @ 23°W; 10° along N26°W.	90	330
	The line of section shifts 100 feet uphill along a resistant bed at the contact between units RC-8 and RC-9.		
RC-8c	LIMESTONE; cherty wackestone (cherty biomicrudite); 10% exposed; gradational; medium gray (N5)/medium light gray (N6), dusky brown (5 YR 2/2); allochems - 15%, fossil fragments, medium calcarenite to medium calcirudite; matrix - micrite; echinoids, tabulate coral; very thick; nodules - chert, 5% to 20%, decreasing upward, a few 75 cm. diameter, concentrically banded chert nodules near the top; N4°E @ 17°W; 11° along N35°W.	98	240
	From RC-8b to RC-8c, the line of section shifts 175 feet downhill along a resistant, thick, cherty wackestone bed.		

Unit	Description	Thickness in feet Unit	Cumulative
RC-8b	LIMESTONE; cherty wackestone (cherty biomicrudite); thick ledges, 15% exposed; sharp, irregular with underlying grainstone; light gray (N7) /grayish orange (10 YR 7/4), dusky brown (5 YR 2/2); allochems - 15%, fragmental and whole fossils, medium calcarenite to medium calcirudite; matrix - clay bearing micrite; bryozoans, echinoids, brachiopods; thick; thin, discontinuous, internal bedding; nodules - chert, 20%; N4°E @ 17°W; 11° along N35°W.	22	142
RC-8a	LIMESTONE; cherty wackestone (cherty biomicrite), grainstone (biosparrudite); very thick ledge, 60% exposed; covered; medium light gray (N6)/ light and medium gray (N7, N5), moderate brown (5 YR 4/4); allochems - 15% to 80%, fossil fragments, fine to coarse calcirudite; matrix - micrite; cement - medium to very coarse crystalline spar; brypzoans, brachiopods, echinoids; very thick; nodules - chert, 20%; N21°W @ 16°W; 4° along N35°W.	11	120
RC-7	LIMESTONE; grainstone (biosparrudite); 10% exposed, gulley exposure; sharp, 15 cm. relief; medium gray (N5); allochems - 85%, fossil fragments, fine calcirudite; matrix - coarsely crystalline spar; echinoids, rugose corals; medium; N21°W @ 16°W; 4° along N35°W.	3	109
RC-6b	LIMESTONE; cherty micrite; very thick ledge, 100% exposed; gradational; medium gray (N5)/pale yellowish brown (10 YR 6/2), medium light gray (N6); allochems - 5%, whole fossils, coarse calcirudite; matrix - clay bearing micrite, 20% micrite as vague nodules; rugose corals; very thick bedded; nodules - cherty lime, 20%, most with rugose coral core; N21°W @ 16°W; 4° along N35°W.	5	106

Unit	Description	Thickness in feet Unit	Cumulative
RC-6a	LIMESTONE; packstone, wackestone (biomicrudite); 100% exposed, gulley exposure; sharp, undulating, 10 cm. relief; medium gray (N5)/upward increasing pale yellowish brown (10 YR 6/2); allochems - 10% to 60%, fossil fragments, coarse calcarenite to medium calcirudite; brachiopods, echinoids, tabulate corals at base, rugose corals; thick, continuous; N21°W @ 16°W; 4° along N35°W.	16.5	101
	From RC-5 to RC-6, line of section shifts west 1,500 feet. Lithologic descriptions of RC-6a and RC-6b are taken from rocks in the same location as the description of RC-5, where they are better exposed.		
RC-5	LIMESTONE; micrite; 100% exposed, gulley exposure; sharp; medium dark gray (N4)/light gray with grayish yellow tinge, medium light gray (N6) mottling; allochems - 8%, pelletal(?), coarse calcilutite; matrix - micrite; rare echinoid(?) spines; very thick, continuous; nodules - chert, 5%; N23°E @ 8°N.	8.5	84.5
RC-4	LIMESTONE; packstone (biomicrudite); 100% exposed, gulley exposure; sharp, 15 cm. relief; medium gray (N5)/medium light gray (N6), pale yellowish brown (10 YR 6/2); allochems - 65%, fossil fragments, fine calcarenite to medium calcirudite; porphyroblasts - quartz, 1%, fine crystalline, euhedral; matrix - micrite, (patchy microspar and pseudospar); echinoids, brachiopods, rugose corals, bryozoans, (coralline algae); thick, medium; N23°E @ 8°N.	9	76
RC-3	LIMESTONE; micrite, cherty micrite; 100% exposed, gulley exposure; sharp; medium dark gray (N4)/ medium gray (N5); thick; nodules - chert and cherty lime, 10%; N23°E @ 8°N.	12	67
RC-2d	MUDROCK; clayshale, claystone; 100% exposed in gulley; covered; light olive gray (5 Y 6/1)/grayish yellow (5 Y 8/4), grayish orange (10 YR 7/4); grains - minor silt; cement - silicious; thick laminae; fissile; N23°E @ 11°N.	14	55

Unit	Description	Thickness in feet Unit	Cumulative
	From RC-2c to RC-2d, line of section shifts 300 feet north to a steep gulley near a prospect pit.		
RC-2c	LIMESTONE; grainstone (fossiliferous intrasparrudite); thick ledge, 80% exposed; covered; medium light gray (N6)/light gray (N7), medium light gray (N6), moderate brown (5 YR 4/4); allochems - 90%, micrite intraclasts and fossil fragments, medium calcarenite to coarse calcirudite; grains - quartz, 5%, fine to very coarse, angular to round; cement - medium and coarsely crystalline spar; brachiopods, echinoids, fusulinids; thick, continuous; N17°E @ 12°W.	2.5	41
RC-2b	MUDROCK; clayshale, claystone; 90% exposed, gulley exposure; covered; light olive gray (5 Y 6/1)/grayish yellow (5 Y 8/4), grayish orange (10 YR 7/4); grains - minor silt; cement - silicious; thick laminae, very thin beds; fissile; N17°E @ 12°W.	4	38.5
RC-21	LIMESTONE; sandy grainstone (sandy intraclastic biosparrudite); 100% exposed; sharp, one cm. relief; medium gray (N5), mottled; allochems - 90%, fossil fragments and intraclasts, medium calcarenite to medium calcirudite; grains - quartz, 5%, fine to very coarse, angular (to round, syntaxial quartz overgrowths); cement - (10%, fine and medium crystalline spar); brachiopods, echinoids, echinoid(?) spines, (gastropods, coralline algae, foraminifera); single medium bed, continuous; (microstylolitic intergrowths of allochems); N20°E @ 11°W.	1	34.5
RC-1c	LIMESTONE; cherty micrite; thick ledges, 90% exposed; gradational; medium dark gray (N4)/medium light gray (N6), dark gray (N3); matrix - micrite; thick, medium; nodules - chert, 30%; N20°E @ 11°W.	7.5	33.5

Unit	Description	Thickness in feet Unit	Cumulative
RC-1b	LIMESTONE; micrite, wackestone (biomicrudite); 100% exposed, gulley exposure; sharp; dark gray (N3)/medium gray (N5), grayish orange (10 YR 7/4); allochems - 10%, fragmental and whole fossils, fine calcarenite to coarse calcirudite, decreasing uward; matrix - micrite; bryozoans, brachiopods, echinoids, rugose corals, algae(?), foraminifera , echinoid(?) spines, thick; thin, undulating, discontinuous, clayey laminae; vague crossbedding in allochem fabric ; burrows, 2 cm. diameter, rare; N20°E @ 11°W.	15.5	26
RC-1a	LIMESTONE; micrite, cherty micrite; very thick ledge; covered; medium dark gray (N4)/medium gray (N5), dusky brown (5 YR 2/2), allochems - 2%, whole fossils, medium calcirudite; matrix - micrite; rugose corals; thick, very thick; discontinuous, undulating laminae; nodules - chert, 15%; N20°E @ 6°W.	10.5	10.5

Base of Range Camp stratigraphic section.

Total thickness 498 feet

APPENDIX F

Monte Carlo Gap Stratigraphic Section

Formations: Laborcita Formation, Hueco Limestone

Age: Virgilian(?) (Pennsylvanian), Wolfcampian (Permian)

Total thickness measured: 3,349 feet

Location: begins SE Cnr. Sec. 22, T.22S., R.8E.

ends NE¼, SW¼ Sec. 14, T.22S., R.8E. (Plate 1)

General description

The Monte Carlo Gap stratigraphic section runs generally north-south across Monte Carlo Gap in the northern Jarilla Mountains. It crosses two east-west, vertical faults of minor displacement and includes two sills (units MC-5 and MC-30). Numerous north-south faults and dikes parallel the line of section (Plate 1). Metasomatic effects are limited to the lower 700 feet of the stratigraphic section, althought trace amounts of quartz porphyroblasts (p. 53) are in limestones near the top of the section in the Hueco Limestone.

Unit	Description	Thickness in feet Unit	Cumulative
	Top of the Monte Carlo Gap stratigraphic section. Overlying unit is a biotite hornblende monzonite porphyry sill of probable Tertiary age.		
MC-109	LIMESTONE; wackestone (biomicrite), packstone (biopelmicrite), grainstone (biopelsparite); thick, medium ledges, 25% exposed; sharp, medium basal beds pinching out to the southeast; medium gray (N5)medium light gray(N6), light gray (N7); grains - (trace in grainstone, quartz, very fine, angular); allochems - 5% to 70%, fragmental and whole fossils (and pellets), fine calcarenite to coarse calcirudite; matrix - micrite; cement - (very fine to medium crystalline spar in grainstone); gastropods, (foraminifera), brachiopods; thick, medium, thinning upward, undulating, lenticular, some continuous; thick laminae; intensely bioturbated zones; N55°W @ 11°NE.	44	3,349
MC-108	MUDROCK; mudshale, mudstone; 90% exposed in gulley 100 feet southeast of line of section; covered; light olive gray (5 Y 6/1)/pale yellowish brown (10 YR 6/2); hornfelsic texture; fissile, non-fissile; N55°W @ 11°NE.	11	3,305
MC-107	LIMESTONE; wackestone (biomicrite, biomicrudite), micrite; thick, medium ledges, 70% exposed; covered; medium gray (N5), medium dark gray (N4)/medium gray (N5); allochems - 5% to 15%, fragmental and whole fossils, medium calcarenite to medium calcirudite; matrix - micrite; cement - spar cement in rare burrows; brachiopods, echinoid(?) spines, bryozoa, gastropods, (foraminifera), echinoids; thick, medium, continuous; intense to local bioturbation; N55°W @ 11°NE.	27	3,294
	From MC-106 to MC-107, the line of section shifts 500 feet north.		

Unit	Description	Thickness in feet Unit	Cumulative
MC-106	LIMESTONE; micrite, wackestone (biomicrite); very thick, thick ledges, 90% exposed; gradational; medium gray (N5)/ medium gray (N5) decreasing upward to very light gray (N8); allochems - 10%, decreasing upward, fragmental and whole fossils, coarse calcarenite and fine calcirudite; matrix - micrite, (microspar, pseudospar); gastropods, (ostracodes); thick, very thick, increasing upwards, undulating, continuous; vague, intense bioturbation in lower beds; N68°W @ 19°N.	20	3,267
MC-105	LIMESTONE; wackestone (biomicrudite, clayey biopelmicrite); thick and medium ledges, 50% exposed; gradational; medium dark gray (N4)/medium gray (N5); allochems - 10% to 40%, fragmental and whole fossils, (pellets), medium calcarenite to coarse calcirudite; matrix - micrite, minor clayey micrite; spar cement in rare burrows; brachiopods, echinoid(?) spines, (foraminifera, fusulinids); thick, medium, thickening upward, undulating, continuous; vague thick laminae; intense bioturbation in lower half; burrows and trails abundant in lower beds; rare oncholite horizons; nodules - chert, 2%, upper beds; N68°W @ 19°N.	97	3,247
MC-104	LIMESTONE; clayey micrite; 1% exposed; covered; light olive gray (5 Y 5/2)/dark yellowish orange (10 YR 6/6); allochems - minor, whole and fragmental fossils, fine calcirudite; matrix - clayey micrite; gastropods; medium(?); bioturbated; N68°W @ 19°N.	10	3,150
MC-103	LIMESTONE; wackestone (biomicrite); thick, medium ledges, 35% exposed; gradational; medium dark gray (N4)/medium gray (N5); allochems - 20%, fragmental and whole fossils, fine calcarenite to medium calcirudite; matrix - (micrite, microspar, minor patchy chert); brachiopods, echinoid(?) spines, gastropods, (fusulinids); thick and medium, continuous; putrid; nodules - chert, 4%, near base; whole brachiopods all aligned in a N30 E direction; N68°W @ 19°N.	31	3,140

From MC-102 to MC-103, line of section shifts 425 feet east.

nit	Description	Thickness in feet Unit	Cumulative
C-102	LIMESTONE; wackestone (biomicrite); medium, thick ledges, 20% exposed; gradational; medium dark gray (N4)/medium gray(N5); allochems - 15%, fragmental and whole fossils, fine to coarse calcirudite, very fine pelletal(?) calcarenite; matrix - micrite; brachiopods, echinoid(?) spines, gastropods; thick, medium, continuous; oncholites - common, 5 to 40 mm., whole and with outer layers spalled; N68°W @ 17°N.	25	3,109
C-101	LIMESTONE; micrite, wackestone (biomicrite), packstone (biopelmicrite); medium, thick ledges, 30% exposed; sharp; medium gray (N5)/ medium light gray (N6), dusky brown (5 YR 2/2); allochems - 10% to 60%, decreasing upward, fragmental and whole fossils and pellets, very fine calcarenite to medium calcirudite; matrix - (microspar, pseudospar), micrite; cement - (minor, finely crystalline); gastropods, brachiopods, (foraminifera, ostracodes), echinoid(?) spines; medium, thick, thickening upward, lower beds lenticular; undulating, uneven laminae; thick beds are extensively bioturbated; nodules - chert, 4%, upper beds; N68°W @ 17°N.	77	3,084
C-100	LIMESTONE; sandy wackestone, sandy packstone (sandy biomicrite); medium, thick ledges, 20% exposed; covered; medium dark gray (N4)/medium gray (N5) with rare grayish orange (10 YR 7/4) horizons near top; grains - 1% to 15%, increasing upward, 50% in top thin bed, quartz, minor feldspar, very fine, angular, trace siltstone lithoclasts; allochems - 15%, fragmental and whole fossils, fine to coarse calcirudite; matrix - micrite, common thin silty micrite lenses; gastropods; medium, thick, thickening upward; burrows; local, intensely bioturbated horizons; thin and thick parallel laminae; N68°W @ 18°N.	30	3,007

Unit	Description	Thickness in feet Unit	Cumulative
MC-99	LIMESTONE; wackestone (biomicrudite), minor grainstone (biosparrudite); medium ledges, 15% exposed; covered; medium gray (N5)/ medium light gray (N6); grains - [quartz, 1% in grainstone, fine, subangular]; allochems - 45% to 80%, fragmental and whole fossils, medium calcarenite to medium calcirudite; matrix - micrite, [microspar, pseudospar]; cement - [very fine to coarse crystalline spar in grainstone]; brachiopods, bryozoans, echinoids, echinoid(?) spines, [foraminifera, gastropods, fusulinids]; medium, thick, continuous; vague thick laminae; local zones of intense bioturbation; burrows - vertical, 3 cm. dia., on upper bedding surfaces; N68°W @ 18°N.	21	2,977
MC-98	LIMESTONE; wackestone, packstone (biomicrite), micrite; low ridges on dip slope, 10% exposed; covered; medium gray (N5)/medium light gray (N6); allochems -70% maximum, pellets and fragmental and whole fossils, very fine calcarenite to medium calcirudite; matrix - micrite; cement - medium crystalline spar in burrows; [forminifera], brachiopods, echinoid(?) spines, gastropods, [fusulinids], rugose corals; medium, thick, continuous; bioturbated thin beds; abundant subvertical burrows on upper bedding surfaces; N68°W @ 25°N to 18°N, dip decreasing upward.	121	2,956
	From MC-97 to MC-98, line of section shifts 75 feet east.		
C-97	LIMESTONE; sandy packstone (sandy intramicrudite), grainstone (intraclastic biosparrudite, intrasparite), quartz arenite at base; thick, medium ledges, 75% exposed; gradational and sharp, one cm. relief; medium light gray (N6)/medium gray (N5); grains - 20% to 85%, quartz, subangular, fine to granule, [syntaxial overgrowths, 2% chert, subround, granule]; allochems - 3% to 50%, intraclasts, fragmental and whole fossils, medium calcarenite to fine calcirudite; matrix - micrite, [microspar, pseudospar, rare hematite]; cement - [fine to coarse crystalline spar]; brachiopods, echinoid(?) spines, [fusulinids, gastropods, coralline algae]; thick, medium, undulating; medium scale cross-stratification; bioturbation at base; nodules - chert, 1%; N68°W @ 25°N.	10.5	2,835

Unit	Description	Thickness in feet Unit	Cumulative
C-96	LIMESTONE; wackestone (intramicrite, biomicrite), grainstone (intrasparrudite), clayey wackestone (clayey biomicrudite), sandy argillaceous micrite; thick, medium ledges, 35% exposed; gradational; medium gray (N5), light olive gray (5 Y 6/1)/ medium gray (N5), grayish orange (10 YR 7/4); grains - 50% in basal beds, 3% at top, quartz, [very fine, angular, well]; allochems - 10% to 80%, intraclasts, fragmental and whole fossils, [pellets, very fine calcarenite to fine calcirudite]; matrix - micrite, clayey micrite; cement - 15% spar in grainstone; [foraminifera], brachiopods, echinoid(?) spines, gastropods; thick, medium, thinning upward, continuous; burrows - 4 cm. dia., 10 to 100 cm. long; nodules - chert, 3% N68°W @ 23°N.	38.5	2,824
C-95	MUDROCK; mudstone; medium ledges, 45% exposed; grdational; light olive gray (5 Y 6/1)/dark yellowish orange (10 YR 6/6); thick, continuous; thin, thick, laminae; extensive bioturbation; N68°W @ 23°N.	11	2,786
C-94	LIMESTONE; silty micrite; thick, medium ledges, 40% exposed; gradational; medium dark gray (N4)/ medium light gray (N6), grayish orange (10 YR 7/4); grains - 35%, silt; matrix - micrite; medium, thin; thin, thick laminae; moderate bioturbation; N68°W @ 23°N.	8	2,775
C-93	LIMESTONE; wackestone (intramicrite); very thick, thick ledges, 70% exposed; erosional, 20 cm. relief; medium dark gray (N4), varicolored intraclasts at base/medium light gray (N6), grayish orange (10 YR 7/4); allochems - intraclasts, 60% at base, decreasing upward, fine to coarse rudite, fragmental and whole fossils, 40% at top, increasing upward, fine to medium rudite; matrix - [microspar]; brachiopods, gastropods; very thick to medium, thinning upward; thick, discontinuous laminae; slight to moderate bioturbation, increasing upward; burrows; [geopetal micrite within gastropods]; N68°W @ 23°N.	10	2,767

nit	Description	Thickness in feet Unit	Cumulative
C-92	LIMESTONE; silty micrite; thick, medium ledges, 35% exposed; gradational; medium dark gray (N4)/ medium light gray (N6), grayish orange (10 YR 7/4); grains - 40% silt; matrix - micrite; thin, medium, lenticular; thin, thick, undulating laminae; moderate to intense bioturbation; horizontal burrows; vague, low angle, medium scale cross-stratification; N68°W @ 23°N.	11	2,757
C-91	LIMESTONE; grainstone (biosparrudite); 10 foot cliff; covered; medium dark gray (N4)/medium gray (N5); grains - 4%, quartz, medium, coarse, subround; allochems - 60%, whole and fragmental abraded fossils, [trace pellets and intraclasts]; cement - [fine to coarsely crystalline spar]; brachiopods, gastropods, bryozoans, echinoids, [ostracodes]; medium, thick, vague, discontinuous; minor bioturbation; upper foot contains abundant mud-filled brachiopods; N68°W @ 21°N.	10	2,746
C-90	Covered; probably mudrock; N68°W @ 21°N.	52	2,736
C-89	LIMESTONE; grainstone (pelletal biosparrudite), silty quartz arenite; medium, thick ledges, 20% exposed; covered; medium light gray (N6)/ pale yellowish brown (10 YR 6/2), grayish orange (10 YR 7/4); grains - 70% in one thick bed, quartz, [very fine, angular, well]; allochems - fragmental and whole fossils, [pellets and trace oolites], very fine calcarenite to medium calcirudite; matrix - 5%, clayey micrite; cement - [fine crystalline spar]; brachiopods, gastropods, [fusulinids, foraminifera], echioid(?) spines; thick, medium, undulating; thick, discontinuous laminae; bioturbation; N68°W @ 21°N.	26	2,684

Unit	Description	Thickness in feet Unit	Cumulative
MC-88	SANDSTONE; silty quartz arenite, conglomeratic grainstone (conglomeratic biosparrudite); medium ledge, 35% exposed; covered; medium gray (N5), medium dark gray (N4)/grayish orange (10 YR 7/4), dark yellowish brown (10 YR 4/2); grains - 60% to 90%, quartz, fine to coarse, subangular, well and moderately ; clasts - 15%, chert, micrite, and quartz, granule and pebble, round and subround, poorly sorted; allochems - 30%, fossil fragments, medium to coarse calcirudite; cement - medium crystalline spar; brachiopods, rugose coral; medium ,discontinuous; N68°W @ 21°N.	2	2,658
MC-87	MUDROCK; sandy siltstone, micrite, clayey micrite; 2% exposed; covered; pale brown (5 YR 5/2), light olive gray (5 Y 5/2), medium gray (N5)/mottled gray, pale yellowish orange (10 YR 8/6); grains - 0% to 65%, silt, angular, poorly; matrix - micrite, clay; thin, medium; intense bioturbation; micrite filled burrows in siltstone; N68°W @ 21°N.	40	2,656
MC-86	LIMESTONE; wackestone (intraclastic biopelmicrite), micrite; medium, thick ledges, 40% exposed; covered; medium dark gray (N4)/medium gray (N5), pale yellowish brown (10 YR 6/2); allochems - 5% to 70%, [pellets, intraclasts], fragmental and whole fossils, [minor oolites], medium calcarenite to fine calcirudite; matrix - micrite; gastropods, [foraminifera, fusulinids]; medium, thick, continuous; thick, lenticular laminae; moderate to intense bioturbation; burrows on upper bedding surfaces; N68°W @ 21°N.	31	2,616

Unit	Description	Thickness in feet Unit	Cumulative
MC-85	LIMESTONE; sandy packstone; (sandy, intraclastic biomicrudite), basal grainstone (sandy intrasparrudite); 5% exposed; erosional, 5 cm. relief; medium gray (N5)/medium light gray (N6), varicolored intraclasts; grains - 30%, decreasing upward, quartz, (chert), very fine to coarse, subangular, (some well rounded), moderately; (minor granule and pebble mudstone lithoclasts); allochems - 35% to 50%, decreasing upward, fossil fragments, intraclasts, (and oolites), medium calcarenite to medium calcirudite; matrix - micrite, (microspar), clay; cement - (5% fine crystalline spar, trace silica); brachiopods, (stromatolitic and coralline algae, echinoid(?) spines, bryozoans); medium, thin; basal bed is normally graded and contains ripped-up, mudcrack laminae; N68°W @ 21°N.	12	2,585
MC-84	LIMESTONE; wackestone (biomicrite), micrite, packstone (biomicrudite, pelmicrite); medium to very thick ledges, 90% exposed; gradational over one foot; medium dark gray (N4)/medium gray (N5); allochems - 20% to 60%, fragmental and whole fossils, (pellets), intraclasts, and oolites, very fine calcarenite to medium calcirudite; matrix - micrite; fusulinids, echinoids, brachiopods, echinoid(?) spines, bryozoans, gastropods; medium to very thick, continuous; nodules - chert, 5%, and in thin continuous beds; N68°W @ 23°N.	63	2,573
MC-83	LIMESTONE; cherty wackestone (cherty biomicrite); thick ledges, 85% exposed; erosional, 8 cm. relief; medium gray (N5)/light gray (N7), dusky brown (5 YR 2/2); allochems - 10% to 60%, whole and fragmental fossils, (pellets), very fine calcarenite to medium calcirudite; matrix - micrite; fusulinids (*Pseudoschwagerina morsei*, *P. texana*, identification by Donald Meyers, 1975, written communication), phylloid(?) algae near base, brachiopods, rugose corals; medium, thick, continuous; nodules - chert, 15%; N68°W @ 25°N.	49.5	2,510

Unit	Description	Thickness in feet Unit	Cumulative
MC-82	LIMESTONE; algal boundstone, wackestone (biomicrite, pelmicrite); thick capping ledge, upper 20% exposed; gradational; medium gray (N5)/medium light gray (N6); allochems - 15%, pellets, fossil fragments, fine and medium calcarenite; matrix - micrite; rare gastropods, echinoid(?) spines; medium, thick, continuous; extensive bioturbation in upper beds; stromatolitic(?) algae in lower ten feet, abundant phylloid algae in upper one foot; N68°W @ 25°N.	12.5	2,460.5
	From MC-81 to MC-82, the line of section shifts 60 feet west.		
MC-81	LIMESTONE; wackestone, packstone (intramicrite); thick, very thick ledges, 70% exposed; gradational; medium gray (N5), medium dark gray (N4)/grayish orange (10 YR 7/4), medium light gray (N6); allochems - 10% to 80%, increasing upward, intraclasts, coarse calcarenite to medium calcirudite, subround; matrix - pseudospar(?), micrite; thick, medium, discontinuous; parallel, undulating, discontinuous laminae; rare slumping; minor bioturbation; N68°W @ 25°N.	21	2,448
MC-80	LIMESTONE; micrite, sandy micrite; thin, medium ledges, 30% exposed; covered; medium gray (N5); grains - 10%, quartz, very fine, angular, moderate, @ 2,415; matrix - micrite; very thin to medium, continuous; thick, uneven, undulating laminae; vague ripple cross-stratification; bioturbated in horizons below cross strata; rare burrows two cm. dia.; N68°W @ 25°N.	26	2,427
MC-79	Covered; N68°W @ 40°N.	26	2,401
	From MC-78 to MC-79, the line of section shifts 130 feet west.		

Unit	Description	Thickness in feet Unit	Cumulative
MC-78	LIMESTONE; clayey micrite, grainstone (intrasparrudite); thick, medium ledges, 50% exposed; sharp; medium gray (N5)/light gray (N7), grayish orange; allochems - 0% to 75%, intraclasts, whole and fragmental fossils, coarse calcarenite to medium calcirudite, subround; grains - 15% on thin laminae, rare overall, fine, subangular; matrix - micrite; cement - medium crystalline spar; thick, medium, thinning upward; moderate bioturbation in clayey micrites; N68°W @ 25°N.	33	2,375
MC-77	LIMESTONE; wackestone (biomicrudite); thick ledges, 60% exposed; covered; medium gray (N5)/light gray (N7); allochems - 15%, fragmental and whole fossils, fine to medium calcirudite; matrix - micrite; brachiopods; medium, thick, continuous; undulating, discontinuous laminae in upper beds; abundant algal platelets; N68°W @ 25°N.	6.5	2,342
MC-76	LIMESTONE; wackestone (biomicrite); cliffs to 20 feet high, 95% exposed; covered; light gray (N7) to medium gray (N5); allochems - 10% to 35%, intraclasts, fossil fragments, and pellets, very fine calcarenite to medium calcirudite; matrix - micrite, microspar, pseudospar; cement - medium and coarse crystalline spar infilling irregular cavities; algal platelets, echinoid(?) spines, brachiopods, ostracodes, foraminifera; very thick, medium, continuous; bioturbation; nodules - chert, 5% to 15%, irregular; N68°W @ 25°N.	25	2,334.5
MC-75	LIMESTONE; wackestone (biomicrudite), boundstone (algal biolithite(?)); medium ledge, 20% exposed; covered; medium dark gray (N4)/light gray (N7) with dark gray (N3) "blotches"; allochems - 50%, algal fragments, calcirudite; matrix - micrite, rare fine crystalline hematite; cement - spar infilling of irregular cavities; medium, thick, continuous; lower half bioturbated; upper half undisturbed; N68°W @ 25°N.	1.5	2,310.5

ase of the Hueco Limestone. Total measured thickness 1,040 feet

Unit	Description	Thickness in feet Unit	Cumulative
	From MC-74 to MC-75, the line of section moves east 1,400 feet.		
MC-74	LIMESTONE; clayey micrite, siltstone, sandy packstone (sandy oolitic intramicrite); medium light gray (N6)/grayish orange (10 YR 7/4), light brownish gray (5 YR 6/1); allochems - 1% to 60%, [intraclasts, pellets, oolites, fossil fragments], coarse calcilutite to fine calcirudite; grains - 5% to 60%, quartz, [rare chert], silt to fine, angular; matrix - micrite, clayey micrite; cement - (coarse crystalline spar in few burrows); echinoid(?) spines; medium, thin, continuous; mudcracks, disrupted mudcrack laminae within packstone beds; intense bioturbation within clayey micrites; N61°W @ 18°N.	11	2,309
MC-73	LIMESTONE; clayey micrite, micrite, mudstone, subarkose; 4% exposed; covered; medium gray (N5), medium dark gray (N4)/ light gray (N7), grayish orange (10 YR 7/4), moderate yellowish brown (10 YR 5/4); grains - quartz, feldspar, fine to coarse, subangular, moderate; matrix - micrite; cement - calcite; thin, very thin; thick laminae; convoluted bedding within laminated micrites; medium and small scale cross-stratification; N61°W @ 18°N.	39	2,298
MC-72	LIMESTONE; micrite; thin, medium ledges, 40% exposed; covered; medium dark gray (N4)/light gray (N7); thin, medium; laminated; slump structures and convoluted laminae; few intensely bioturbated beds; N61°W @ 18°N.	16	2,259
MC-71	LIMESTONE; micrite, clayey micrite, siltstone, subarkose at top; medium, thin ledges, 30% exposed; covered; medium gray (N5)/grayish orange (10 YR 7/4), light to medium dark gray (N7 to N4); grains - quartz, very fine, subround, well; allochems - basal siltstone contains angular rip-up intraclasts; thin, very thin; thin, fissile laminae; micrites are intensively bioturbated; burrows, 5 cm. dia, inclined; N61°W @ 18°N.	29	2,243

Unit	Description	Thickness in feet Unit	Cumulative
MC-70	LIMESTONE; micrite, clayey micrite, wackestone (intramicrite); medium, thick ledges, 40% exposed; covered; medium gray (N5)/ very light gray (N7), upper part of individual beds are grayish orange (10 YR 7/4); allochems - 0% to 60%, angular and irregular intraclasts, rare pellets and fossils, coarse calcilutite to medium calcirudite; matrix - micrite, clayey micrite; medium, thick, continuous; vague, thick laminae; intense bioturbation within individual beds; abundant burrows, 2 mm. dia., horizontal; N61°W @ 18°N.	20	2,214
MC-69	LIMESTONE; clayey micrite, subarkose; medium, thick ledges, 20% exposed; covered; medium dark (N4), light olive gray (5 YR 5/2)/grayish orange (10 YR 7/4), grayish brown (5 YR 5/2); allochems - intraclasts (carbon-rich), common, medium calcirudite; grains - quartz, feldspar, fine to coarse, subangular, moderate, rip-up clasts of clayey micrite abundant at base of sandstone beds; thin, medium, continuous micrite beds; thick, lenticular sandstone beds; medium scale cross-stratification; current ripple marks; N61°W @ 18°N.	41	2,194
MC-68	SANDSTONE; subarkose, mudstone; thick ledges, 15% exposed; covered; medium gray (N5)/moderate yellowish brown (10 YR 5/4); grains - quartz, feldspar, fine to coarse, subangular, well, few angular mudstone lithoclasts; cement - calcite; thick, discontinuous; medium scale, tabular and lenticular cross-stratification, decreasing scale upward; current ripple stratification; parallel current ripple marks, superimposed; N61°W @ 18°N.	14	2,153
MC-67	LIMESTONE; micrite; medium ledge, 100% exposed; covered; medium dark gray (N4)/medium gray (N5); thick, continuous; very thin, discontinuous laminae; N61°W @ 18°N.	1	2,139
MC-66	Covered; line of section crosses vertical fault striking N30 E, downfaulted to the east; displacement of 57 stratigraphic feet.	158	2,138

Unit	Description	Thickness in feet Unit	Cumulative
MC-65	LIMESTONE; micrite, intramicrite; thin ledges, 80% exposed; covered; dark gray (N3)/medium gray (N5); allochems - 35%, intraclasts, fine and medium calcirudite; thin, medium, continuous; horizontal.	4	1,980
MC-64	MUDROCK; mudstone, subarkose, silty micrite, micrite; medium, thin ledges, low ridges, 5% exposed; sharp; medium gray (N5)/pale brown (5 YR 5/2), dusky brown (5 YR 2/2); lithologically similar to MC-62; thickness is interpolated from thickness of the same sequence measured on Hard Luck Tank Hill, one mile to the west (Plate 2). Unit MC-64 in Monte Carlo Gap is structurally complex and 98% covered.	123	1,976
MC-63	LIMESTONE; micrite; medium ledge, 50% exposed; covered; medium gray (N5)medium light gray (N6); thick; N78°W @ 24°N.	2	1,853
MC-62	SANDSTONE; subarkose, mudstone, silty micrite; thick, very thick ledges, 30% exposed; gradational; medium gray (N5), pale yellowish brown (10 YR 6/2)/dusky brown (5 YR 2/2), pale yellowish brown; grains - quartz, plagioclase, microcline, very fine to coarse, angular, well; cement - [a maximum of 60% calcite spar]; thin to very thick, thicker beds are lenticular; cross-stratification - medium scale, lenticular, tabular; mudcracks at top of one thick set; ripple marks, ripple stratification; mudcracks; convoluted laminae in thick sets; intense bioturbation of upper parts of cross-stratified beds; mudstone lithoclasts at base of thick sets; N78°W @ 24°N.	121	1,851
MC-61	LIMESTONE; sandy micrite, silty micrite; 30% exposed; covered; medium gray (N5)/grayish orange (10 YR 7/4); grains - quartz, fine, angular; matrix - micrite, silt; medium; thick, thin laminae; thin bioturbated zones; N75°W @ 23°N.	1	1,730

Unit	Description	Thickness in feet Unit	Cumulative
MC-60	HORNFELS; calcite-quartz hornfels, silty micrite; medium ledges, 1% exposed; covered; medium light gray (N6)/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); grains -(quartz, rare plagioclase, magnetite), silt-sized, angular; matrix - (40%, calcite spar, very finely crystalline); thick, medium; ripple stratification; minor bioturbation; N75°W @ 23°N.	66	1,729
MC-59	LIMESTONE; grainstone (intrasparrudite); 100% exposed; covered; greenish gray (5 GY 6/1)/grayish orange (10 YR 7/4); allochems - (70%, intraclasts, fine to coarse calcirudite, subangular, poorly, fining upward); matrix - (10%, micrite); cement - (20%, coarse crystalline spar); thick; vague bioturbation; N75°W @ 23°N.	1	1,663
MC-58	LIMESTONE; micrite, silty micrite, mudstone; 5% exposed; covered; medium light gray (N6)/light olive gray (5 Y 6/1), pale yellowish brown (10 YR 6/2); grains - (30%, fine to coarse silt, angular); matrix - micrite; medium, thin, undulating, discontinuous; intense bioturbation; burrows - common, 3mm. dia., trace hematite infillings; N75°W @ 23°N.	18	1,662
MC-57	LIMESTONE; micrite, silty micrite; 10% exposed; covered; medium dark gray (N4)/medium light gray (N6), yellowish brown (10 YR 5/2); grains - (15%, silt, angular); matrix - micrite; thin, medium; fissile laminae; mudcracks; upper beds extensively bioturbated; small folds; N75°W @ 23°N.	39	1,644
MC-56	LIMESTONE; micrite; 30% exposed; covered; medium dark gray (N4)/medium gray (N5); medium; thick, vague laminae; N75°W @ 23°N.	1	1,604
MC-55	Covered; N75°W @ 23°N.	19	1,603

From MC-54 to MC-55, line of section shifts 450 feet east.

Unit	Description	Thickness in feet Unit	Cumulative
MC-54	LIMESTONE; micrite; thick ledge, 100% exposed; medium gray (N5)/medium light gray (N6); thick thick laminae; N84°E @ 25°N.	2	1,584
MC-53	MUDROCK; siltshale, quartz arenite, sandy wackestone (sandy intracmicrite); 40% exposed; covered; medium gray (N5), medium dark gray (N4)/pale yellowish brown (10 YR 6/2); grains - 10% to 90%, [quartz, minor plagioclase, microcline, chert, zircon, medium silt to coarse sand, angular, moderate]; allochems - [15%, rounded intraclasts and fossil fragments], fine calcarenite to fine calcirudite; matrix - micrite, silt, clay; cement - calcite; medium, thin; flat-topped, parallel ripple marks are superimposed at right angles on an earlier set of parallel ripples, in turn both are superimposed by a set of large mudcracks; large, horizontal, branching feeding trails, rare; vertical burrows; N84°E @ 25°N.	27	1,582
C-52	SANDSTONE; subarkose, sandy grainstone (sandy intrasparite), sandy mudstone; thick ledges, 5% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - [quartz, plagioclase, chert], coarse silt to coarse sand, [subround], moderately; allochems - calcirudite, [rounded]; matrix -[patchy pseudospar and microspar replacement of micrite intraclasts]; cement -[fine to medium crystalline, radial and pore filling spar in grainstone]; thick, medium; medium scale cross-stratification; ripple marks; angular siltstone lithoclasts in sandstone beds; locally intens bioturbation; N84°E @ 25°N.	13.5	1,555
C-51	LIMESTONE; argillaceous micrite, mudstone; exposed bed surface; covered; medium dark gray (N4) /medium gray (N5); grains - 25%, silt, angular ; allochems - [2%, fossil fragments], medium calcirudite; matrix - clayey micrite; [brachiopods, bryozoans]; thin; thin, discontinuous dark gray (N3) laminae; locally intensive bioturbation; N84°E @ 25°N.	0.5	1,541.5

Unit	Description	Thickness in feet Unit	Cumulative
MC-50	SANDSTONE; subarkose, argillaceous micrite; low ridges, 5% exposed; covered; medium gray (N5)/ grayish orange (10 YR 7/4), pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, very fine, subangular, well; cement - calcite; medium, thin; current ripple marks, ripple stratification; mudcracks; N87°E @ 25°N.	33	1,541
MC-49	SANDSTONE; conglomeratic sublitharenite; medium ledges, 90% exposed; covered; medium gray (N5)/ pale yellowish brown (10 YR 6/2); clasts - 40%, chert, limestone, mudstone, granule to pebble, subround; grains - 50%, quartz, fine to medium, subangular, well; cement - calcite; thick, continuous; thin, lenticular, internal beds; vague, medium scale, cross-stratification with normally graded lenses; N87°E @ 25°N.	2	1,508
MC-48	SANDSTONE; subarkose, sandy mudstone, siltstone; thin ledges, 15% exposed; covered; medium dark gray (N4), yellowish brown (10 YR 5/2)/grayish orange (10 YR 7/4); grains - quartz, feldspar, silt and very fine sand, angular, well; cement - calcite; medium to very thin, discontinuous, fissile; mudcracks superiposed on current ripple marks indicating bimodal current flow; very thin siltstones lie above and preserve underlying ripple forms; N88°E @ 22°N.	21	1,506
MC-47	Covered; N88°E @ 22°N.	15	1,485
MC-46.5	LIMESTONE; clayey micrite; medium ledge; 100% exposed; covered; medium gray (N5)/medium light gray (N6), grayish orange (10 YR 7/4); medium; extensively bioturbated; N88°E @ 22°N.	1	1,470
MC-46	SANDSTONE; subarkose; 5% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, feldspar, medium, subangular, well; cement - calcite; medium; vague, thick laminae; moderate bioturbation; burrows - 5 mm. dia., vertical, common; N88°E @ 22°N.	9	1,469

Unit	Description	Thickness in feet Unit	Cumulative
MC-45	CONGLOMERATE; sandy chert-limestone-quartz pebble conglomerate; thick ridge, 70% exposed; covered; mottled gray/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); clasts - 25%, limestone, chert, quartz, granule to pebble, round, few angular mudstone rip-up lithoclasts, planar fabric, fining upward; grains - 20%, [quartz, chert], medium to very coarse, [angular to round], poorly; allochems - 40%, [fragmental and whole abraded fossils, intraclasts, minor oolites], medium calcarenite to medium calcirudite; matrix - [5%, micrite, microspar and pseudospar]; cement - [10%, medium to coarse crystalline pore filling cement, syntaxial quartz overgrowths on quartz grains]; fusulinids (identified, see page 22), brachiopods; very thick, thick; thin pebble lenses near top; vague cross-stratification, medium scale, becoming smaller upward; normal and reverse grading; upper beds extensively bioturbated; N89°E @ 21°N.	10	1,460
MC-44	SANDSTONE; subarkose; 30% exposed; covered; mottled gray/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); grains - 25%, quartz, orthoclase, trace muscovite, fine silt to fine sand, angular ; matrix - clay; cement - [medium crystalline calcite spar replacing silicates, carbonate rhomb "ghosts"]; medium, thin; thick and thin laminae; extensive bioturbation; N89°E @ 21°N.	6	1,450
MC-43	MUDROCK; sandy mudshale, siltstone, argillaceous micrite; 40% exposed; covered; medium dark gray (N4)/pale yellowish brown (10 YR 6/2), grayish orange (10 YR 7/4); grains - 40% to 90%, silt, [angular, poorly, planar fabric]; matrix - [micrite], clay; cement - calcite; thin, medium; thin, discontinuous laminae; extensive bioturbation of micrites, occasional gray micrite clasts in grayish orange matrix; N87°E @ 21°N.	21	1,444

Unit	Description	Thickness in feet Unit	Cumulative
MC-42	SANDSTONE; subarkose; thick ledges, ridges; 100% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); grains - quartz, plagioclase, medium to coarse, subangular, well; cement - calcite; thick, very thick, continuous; medium scale cross-stratification; thin lenses of limestone pebbles; burrows - 3 cm. dia., abundant; local intense bioturbation; N87°E @ 21°N.	5	1,423
MC-41	LIMESTONE; clayey micrite, micrite; medium ledge, 2% exposed; covered; grayish orange (10 YR 7/4), dark gray (N3)/grayish orange, medium gray (N5); matrix - micrite, [hematite concentrated within the centers of individual laminae]; cement - "birdseye" structures; very thin, medium; thick, undulating, continuous laminae [bounded by micro-thin carbon films]; extensive bioturbation in clayey micrite; N89°E @ 21°N.	30	1,418
MC-40	SANDSTONE; subarkose, sandsy siltstone; 10% exposed; covered; medium dark gray (N4)/grayish orange (10 YR 7/4), pale yellowish brown (10 YR 6/2); grains - quartz, feldspar, very fine, angular, well; cement - calcite; medium; sandy siltstone interbeds; current ripple marks and ripple stratification; mudcracks; N87°E @ 21°N.	7	1,388
MC-39	MUDROCK; siltstone, siltshale, argillaceous micrite; thin ledges, 5% exposed; covered; medium gray (N5), medium dark gray (N4)/grayish orange (10 YR 7/4), pale yellowish brown (10 YR 6/2); grains - 10% to 55%, silt, angular, moderate; matrix - micrite, clay; thin; thin laminae; fissile; vertical burrows; N87°E @ 21°N.	18	1,381

Unit	Description	Thickness in feet Unit	Cumulative
MC-38	SANDSTONE; subarkose, sandy siltstone; medium, thick ledges, 40% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); grains - quartz, feldspar, medium, subangular, well; thick, very thick; ripple stratification; flaser bedding grades upward into ripple stratification; ripple marks, current, parallel, curved, bifurcating; extensive bioturbation within upper zones of ripple stratification; N82°E @ 19°N.	32	1,363
MC-37	LIMESTONE; micrite, sandy grainstone (sandy pelsparite), clayey micrite, wackestone (intramicrudite); thick ledges, 15% exposed; gradational; dark gray (N3), medium dark gray (N4)/medium dark gray (N4), grayish orange (10 YR 7/4); grains - [0% to 10%, quartz, feldspar, coarse silt to fine sand, subangular]; allochems - [5% to 80%, intraclasts, pellets, fossil and algal fragments, coarse calcilutite to fine calcirudite]; matrix - micrite, clay, [hematite]; cement - [minor medium crystalline spar]; thick, medium, continuous; thick laminae; extensive bioturbation; N82°E @ 19°N.	35	1,331
MC-36	SANDSTONE; subarkose, mudstone; thin, medium ledges, 20% exposed; gradational; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, silt to medium sand, subangular, well, few beds with reverse grading; cement - calcite; medium, thick, continuous; thin and thick laminae; parallel current ripple marks; ripple stratification; extensive bioturbation; load ("flame") structures of clayey micrite between sand units; N82°E @ 18°N.	49	1,296
MC-35	LIMESTONE; micrite, clayey micrite, mudstone, wackestone (biomicrite); 1% exposed; covered; olive gray (5 Y 5/1), medium dark gray (N4)/grayish orange (10 YR 7/4), medium dark gray (N4); allochems - fossil fragments, medium calcarenite to fine calcirudite; matrix - micrite, clay, hematite; thin, medium; thick, very thin laminae, normally graded thick laminae; birdseye structures; burrows, 2 mm. dia.; N77°E @ 17°N.	36	1,247

Unit	Description	Thickness in feet Unit	Cumulative
MC-34	SANDSTONE; subarkose; thick ledges, 90% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, microcline; very fine to medium, subangular, well, fining upward; cement - calcite; thick, thinning upward; cross-stratification - medium scale, tabular, upper 15 cm. bioturbated; point bar; current ripple marks; convoluted laminae; N77°E @ 17°N.	8	1,211
MC-33	LIMESTONE; micrite, clayey micrite, mudstone; medium ledges, 10% exposed; covered; medium dark gray (N4)/medium light gray (N6), yellowish gray (5 Y 7/2), grayish orange (10 YR 7/4) cap; matrix - micrite, minor clay, silt; medium, thin; grayish orange upper surfaces of micrite beds are mudcracked, bioturbated, with a maximum of 30% angular intraclasts in random orientations; N73°E @ 14°N.	18	1,203
MC-32	SANDSTONE; subarkose; medium, thick ledges, 35% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, fines and medium, subangular, well; cement - calcite; thick, medium; medium scale cross-stratification; ripple stratification; individual sets fine upward; point bar; extensive bioturbation; N73°E @ 14°N.	19	1,185
MC-31	LIMESTONE; clayey micrite, quartz-calcite hornfels; thick ledge; intrusive contact with underlying sill; medium gray (N5)/yellowish gray (5 Y 8/1); thick; N73°E @ 14°N.	2	1,166
MC-30	SILL; hornblende monzonite; N86°E @ 20°N.	180	1,164
MC-29	LIMESTONE; micrite; 5% exposed; covered; medium dark gray (N4)/medium light gray (N6); medium, continuous; burrows - vertical, sub-horizontal, 5 mm. dia.; N86°E @ 20°N.	18	984

Unit	Description	Thickness in feet Unit	Cumulative
MC-28	SANDSTONE; subarkose; 30% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, feldspar, fine to coarse, subangular, moderately and well, fining upward; cement - calcite; medium and thin, thickening upward; medium scale, tabular cross-stratificaton; ripple stratification; mudstone lithoclasts in lower, coarser beds; point bar; straight, parallel current ripples; intrastratal burrows, 5 cm. dia.; N86°E @ 20°N.	21	966
MC-27	MUDROCK; siltstone, sandy micrite; 1% exposed; covered; grains - quartz, silt to very fine sand; cement - calcite; thin; current ripple marks; N86°E @ 20°N.	5	945
MC-26	LIMESTONE; micrite, clayey micrite; thick ledges, 50% exposed; covered; medium dark gray (N4) /light gray (N7), grayish orange (10 YR 7/4); thick; vague thick laminae; oxidized, mudcracked horizon, 3 cm. thick, erosional lower contact with micrite, grades upward through thin, sandy laminae to micrite; N86°E @ 20°N.	5	940
MC-25	MUDROCK; mudstone, quartz arenite; 85% exposed; covered; medium dark gray (N4), medium gray (N5) /grayish orange (10 YR 7/4), pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, fine, angular, well; cement - calcite; thin, medium, continuous; thick laminae; parallel current ripple marks; N86°E @ 20°N.	13	935
MC-24	LIMESTONE; micrite; thick ledge, 100% exposed; covered; medium dark gray (N4)/light gray (N7), yellowish gray (5 Y 7/2); thick, continuous; vague, discontinuous, thick laminae; N86°E @ 20°N.	3	922

Unit	Description	Thickness in feet Unit	Thickness in feet Cumulative
MC-23	SANDSTONE; subarkose, clayey micrite, wackestone (intrasparrudite); medium ledges, 15% exposed; covered; medium gray (N5), medium dark gray (N4)/pale yellowish brown (10 YR 6/2), grayish orange (10 YR 7/4); grains - 0% to 85%, [quartz, plagioclase, very fine, subangular, well]; allochems - [intraclasts, pellets, ooids, abraded fossil fragments], very fine calcarenite to medium rudite, [rounded]; matrix - [minor micrite, hematite]; cement - [very fine to medium crystalline spar, incomplete pore filling in intrasparrudite has left a moderate amount of porosity]; medium, thin, continuous; mudcracks superimposed upon parallel current ripple marks; angular clayey micrite lithoclasts within rippled, mudcracked beds; bioturbation and convoluted bedding within clayyey micrites; N86°E @ 20°N.	31	919
MC-22	SANDSTONE; subarkose; medium, thick ledges, 80% exposed; coverd; medium gray (N5)/pale yellowish brown (10 YR 6/2), dusky brown (5 Y 2/2); grains - quartz, plagioclase, fine to medium, subangular, well, fining upward; cement - calcite: medium, thin; thin and thick laminae; medium scale, tabular cross-stratification; horizontal, parallel laminae; current ripple stratification; point bar; intrastratal burrows, 5 cm. dia.; N86°E @ 20°N.	6	884
MC-21	LIMESTONE; micrite, sandy micrite; covered; covered; medium gray (N5)/medium light gray (N7); grains - quartz, feldspar, very fine, subangular; matrix - micrite; laminar, fissile; N86°E @ 20°N.	28	878
MC-20	SANDSTONE; subarkose; thick and medium ledges, 20% exposed; covered, medium gray (N5)/pale yellowish brown (10 YR 6/2), dusky brown (5 YR 2/2); grains - quartz, plagioclase, fine to medium, subangular, well, fining upward; cement - calcite; medium and thick, discontinuous, lentecular; parallel laminae; medium scale, lenticular cross-stratification; N86°E @ 20°N.	7	850

Unit	Description	Thickness in feet Unit	Cumulative
MC-19	LIMESTONE; sandy micrite, micrite, mudstone; thick upper ledge, 10% exposed; covered; medium gray (N5), medium dark gray (N4)/medium light gray (N6), grayish orange (10 YR 7/4); grains - 10%, quartz, very fine, angular, well, normally graded; matrix - micrite, clay; medium; thin parallel laminae in lower beds; uppermost bed is oxidized, mudcracked, clayey micrite with an erosional lower contact and ubiquitous angular intraclasts near the base; mudcracks penetrate 10 cm. into the underlying gray micrite; common micro-thin, lentecular carbon clasts; N86°E @ 20°N.	23	843
MC-18	LIMESTONE; micrite; thick ledge, 50% exposed; covered; medium gray (N5)/light gray (N7); medium, thin; vague, undulating, discontinuous laminae; N86°E @ 22°N.	2	820
MC-17	SANDSTONE; arkose, arkosic siltstone, clayey wackestone (clayey intramicrite), mudshale; medium ledges, 15% exposed; covered; medium gray (N5), light olive gray (5 Y 6/1)/dusky brown (5 Y 2/2), grayish orange (10 YR 7/4); grains - 0% to 90%, quartz, feldspar, biotite , coarse silt to medium sand, angular, well; allochems - intraclasts, very fine calcarenite to medium calcirudite, thin lenses of calcirudite in sandstone; cement - calcite; thin to thick, normally graded; undulating, parallel laminae and convoluted bedding in clayey intramicrite with broken, disturbed, micro-thin algal laminae; ripple marks and ripple cross-stratification; thin, bioturbated beds in intramicrite; highly variable dips; N86°E.	48	818
MC-16	LIMESTONE; micrite, wackestone (intramicrudite); thick ledge, 100% exposed; covered; medium dark gray (N4)/light gray (N7), grayish orange (10 YR 7/4) cap; allochems - intraclasts, fossil fragments, fine to medium calcirudite on thin horizons ; matrix - micrite; thick, continuous; thick laminae, continuous; thin, undulation, discontinuous laminae; large mudcracks; vague ripple marks; N86°E @ 22°N.	2	770

Unit	Description	Thickness in feet Unit	Cumulative
MC-15	SANDSTONE; subarkose; thick ledge, 30% exposed; covered; medium gray (N5)/pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, medium, subangular, well; cement - calcite; thick; current ripple stratification; mudcracks superimposed on ripple marks; N82°W @ 22°N.	8	768
MC-14	SANDSTONE; subarkose, siltstone, micrite; medium ledges, 20% exposed; covered; medium light gray (N4), medium gray (N5)/pale yellowish brown (10 YR 6/2), grayish orange (10 YR 7/4); grains - quartz, plagioclase, very fine to medium, subangular, well, coarsening upward; allochems - 3%, intraclasts and pellets, very fine to medium calcarenite, occur as discontinuous lenses and burrow fillings in micrite ; cement - calcite; medium; discontinuous thick and thin laminae; flaser bedding; current ripple stratification; mudcracks; intense bioturbation in basal micrite; N86°W @ 25°N.	20	760
MC-13	SANDSTONE; silty arkose, siltstone; medium ledges, 80% covered; covered; medium light gray (N6)/dusky brown (5 YR 2/2), pale yellowish brown (10 YR 6/2); grains - 85%, quartz, feldspar, [biotite], coarse silt to very fine sand, angular, moderate; cement - calcite; medium, thick; vague, undulating laminae; parallel, bifurcating current ripple marks; ripple cross-stratification, [individual laminae are normally graded]; N86°W @ 25°N.	15	740
Dike	Monzonite dike. The line of section moves across a north-northeast trending monzonite dike and begins again at the basal contact of MC-13. The metamorphic effects seen on the southeast side of this dike (lower in the section) are not apparent on the northwest side (higher in the section).		

Unit	Description	Thickness in feet Unit	Cumulative
MC-12	LIMESTONE; micrite, mudstone, quartz arenite; medium ledges, 5% exposure; covered; grains - quartz, fine, subangular, well; cement - calcite; thin, medium, continuous; mudcracks; N82°E @ 28°N.	35	725
MC-11	SANDSTONE; quartz arenite; thick ledge, 80% exposed; covered; light gray (N3)/pale yellowish brown (10 YR 6/2), grayish brown (5 YR 3/2); grains - quartz, feldspar, fine, subangular, well; cement - calcite; thick; thin and thick laminae; N82°E @ 27°N.	3	690
MC-10	MUDROCK; subarkosic sandy mudstone, micrite; thin ledges, 20% exposed; covered; medium gray (N5), light olive gray (5 Y 5/2)/blackish red (5 R 2/2); grains - 40%, quartz, feldspar, angular, very poorly; matrix - micrite, silica(?); thin; thin undulating, discontinuous laminae; N82°E @ 26°N.	35	687
MC-9	SANDSTONE; subarkose; thin ledges, 100% exposed; sharp; light olive gray (5 Y 5/2)/blackish red (5 R 2/2); grains - quartz, feldspar, fine, angular, well; cement - calcite; very thin; thick laminae; mudcracks superimposed on current ripples; N82°E @ 22°N.	2	652
MC-8	LIMESTONE; micrite, argillaceous micrite; thin ledges, 20% exposed; covered; matrix - micrite, wollastonite; thin; mudcracks; N82°E @ 23°N.	48	650
MC-7	SANDSTONE; quartz arenite, siltstone; medium ledges, 40% exposed; sharp; light olive gray (5 Y 5/2)/dusky brown (5 YR 2/2), pale yellowish brown (10 YR 6/2); grains - quartz, plagioclase, very fine to fine, subangular, well, fines upward; cement - calcite; thick, medium, thinning upward; ripple marks; N83°E @ 27°N.	6	604

Unit	Description	Thickness in feet Unit	Cumulative
MC-6	META-MUDROCK and META-SANDSTONE; blastoporphyritic hornfels; thin to thick ledges, 60% exposed; sharp, undulating, intrusive contact with hornblende monzonite sill; greenish gray (5 GY 2/2), light olive gray (5 Y 5/2)/dusky brown (5 YR 2/2), pale yellowish brown (10 YR 6/2); porphyroblasts - scapolite, wollastonite, minor andradite-uvarovite garnet, calcite; grains - quartz, fine to medium, embayed; thin to thick, continuous and lenticular; medium and large scale, very low angle cross-stratification; mudcracks; bioturbated thin beds; N75°W @ 17°N to N80°E @ 31°N.	211	598
	From MC-5 to MC-6, the line of section shifts 450 feet east-northeast.		
MC-5	Sill; hornblende monzonite; N72°E @ 20°N.	168	415
MC-4	META-MUDROCK and META-SANDSTONE; blastoporphyritic hornfels and skarn; very thick ledges, 5% exposed; sharp, intrusive ; light olive gray (5 Y 5/2), pale olive (10 Y 6/2)/pale yellowish brown (10 YR 6/2), grayish brown (5 YR 3/2); porphyroblasts - andradite-uvarovite, scapolite, cordierite, actinolite, diopside, calcite; grains - quartz; thin to thick, vague ripple stratification and ripple marks; mudcracks; N72°E @ 20°N.	47	247
MC-3	Sill; hornblende monzonite; N72°E @ 20°N.	29	200
MC-2	META-MUDROCK and META-SANDSTONE; blastoporphyritic hornfels and skarn; 5% exposed; covered; light olive gray (5 Y 6/1), greenish gray (5 G 6/1), medium gray (N5)/ dusky brown (5 YR 2/2), pale yellowish brown (10 YR 6/2); porphyroblasts - andradite-uvarovite, scapolite (marialite), cordierite, actinolite, diopside, calcite; thin to thick; thin to thick laminae; minor ripple stratification; N72°E @ 26°N to 21°N.	169	171

Unit	Description	Thickness in feet Unit	Cumulative
MC-1	SANDSTONE; subarkose; 50% exposed; covered; mottled gray-olive/mottled pale brown (5 YR 5/2); grains - quartz, iron-orthoclase, fine to medium, subround, well; porphyroblasts - wollastonite, diopside, uvarovite garnet; cement - calcite; N72°E @ 26°N.	2	2

Base of the Monte Carlo Gap stratigraphic section.

Total thickness of the exposed Laborcita Fm. 2,129 feet

Total thickness of the Monte Carlo Gap section 3,349 feet

This thesis is accepted on behalf of the faculty of the

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[illegible]

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