STRATIGRAPHY, CARBONATE PETROLOGY, PALEOENVIRONMENTAL ANALYSIS, AND GEOLOGIC CONTROL ON MINERALIZATION OF THE JONES CAMP DIKE REGION, SOCORRO COUNTY, NEW MEXICO

Reid S. Allan

Submitted in partial fulfillment
of the requirements for the degree of
Master of Science in Geology

New Mexico Institute of Mining and Technology

Socorro, New Mexico

1988

ACKNOWLEDGEMENTS

I would like to thank my advisor, Dr. Clay T. Smith, for his patient guidance and support throughout this project. Dr. David Johnson provided much help, particularly with paleontologic and stratigraphic concerns. I am sorry that the stable isotope study to be conducted with Dr. Andrew Campbell could not be undertaken due to technical problems.

I appreciate the aid of several fellow students. Ted Jochems introduced me to the Jones Camp region and gave helpful advice. Stan Krukowski aided in conodont identification and laboratory techniques. Joan Gabelman provided field assistance and moral support.

I thank Mr. N. Edward Bottinelli, president of Zia Steel, Inc., for financial support during this research.

My parents, Craig and Audrey Allan, were instrumental in the completion of this research, supplying understanding, support, and love.

ABSTRACT

The Jones Camp Iron District is characterized by discrete pods of magnetite located longitudinally along the Jones Camp intrusive dike. The iron ore has replaced carbonate, gypsum and sandstone host rocks. The host sediments are upper Permian in age, and the dike is late Oligocene.

Two stratigraphic sections were measured through undisturbed host rock sediments, one section to the south of the dike, and one section north of the dike. Formations encountered in the study area, from oldest to youngest, are the upper Yeso, Glorieta, and lower San Andres. The stratigraphic sections were correlated across the dike/iron deposit area. Correlation of the undisturbed stratigraphic sections, comparison of biotic assemblages, and geologic relations allowed identification of the altered sediments along the dike. It was determined that the primary host rock in surface exposures is the upper most carbonate bed in the Torres Member of the Yeso Formation, designated C1.

Study of the carbonate beds of the Torres Member revealed that most are composed of mudstone/micrite, with occasional fossiliferous beds. The fossiliferous beds occur primarily high in the section, with wackestones and rare packstone beds occurring in C1. The biotic assemblage consists of pelecypods, gastropods, ostracods, algal oncolites, algal strands, globigerinid foraminifera, conodonts, fish teeth, and possible bone fragments. The biota elements are characterized by low diversity, small individual size, and an abundance which varies locally from nil to quite high.

The paleoenvironment of deposition of the Torres Member, and more generally, all the strata exposed in the study area, is a high salinity, nearshore, restricted marine environment. This conclusion is based on biotic, stratigraphic, and petrologic evidence. The region was subjected to cyclic transgressions and regressions, with the environment subsequently varying from the intertidal to supratidal zones.

The diagenetic history of the Torres Member carbonates is determined to be as follows: micritization of mud sized sediment; regression causing solution of unstable fossil grains, creation of vuggy and channel porosity, and neomorphism of micrite to microspar; and transgression, with subsequent dolomitization, filling moldic and some vuggy porosity with dolospar.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF APPENDICES

LIST OF PLATES

INTRODUCTION

LOCATION AND ACCESSIBILITY

The Jones Camp dike is located in eastern Socorro County, New Mexico. The dike crops out on Chupadera Mesa in T5S, from the eastern part of R6E to the western part of R8E. The iron mine area is most easily reached by the old Socorro-Carrizozo highway, which is referred to as Iron Mine Road on United States Geological Survey topographic maps. The old Socorro-Carrizozo highway can be reached by turning north from highway 380 about 1 km east of Bingham, New Mexico.

Access to the two measured sections on the face of Chupadera Mesa is from the south by unimproved ranch roads. Stratigraphic Section I, to the south of the dike, is located in east central Section 24, T5S, R6E. Stratigraphic Section II, on the north of the dike, lies in west central Section 7, T5S, R7E. The ranch roads lead northeasterly from highway 380 approximately 5.6 km southeast of Bingham (Figure 1). These roads are unmaintained dirt tracks which require a four wheel drive vehicle in some sections, especially under muddy conditions.

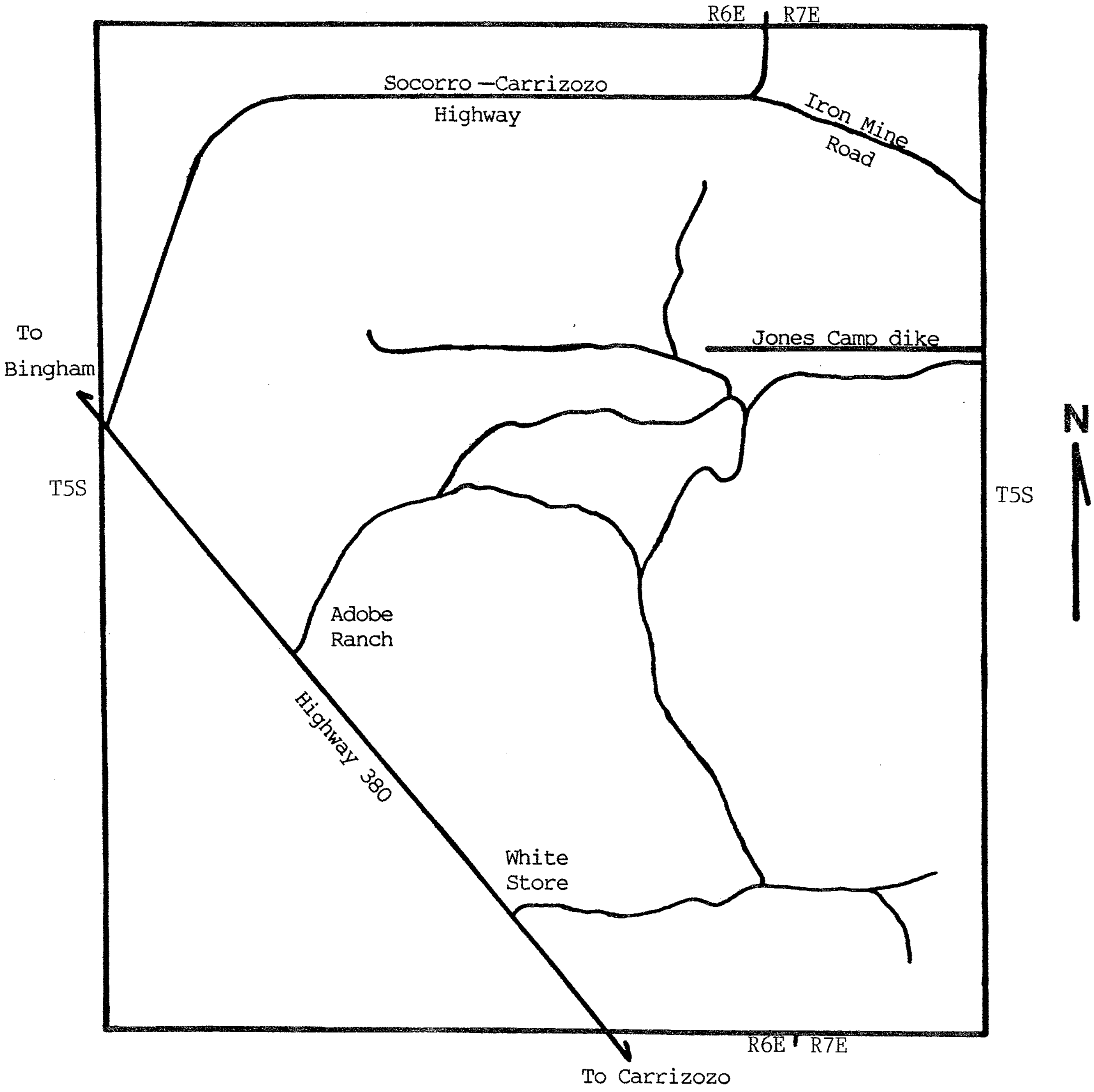


Figure 1: Location map of Jones Camp dike region.

PURPOSE AND SCOPE

The purposes of this geologic study of the Chupadera Mesa and Jones Camp dike are: to measure a detailed stratigraphic section of the sedimentary rocks surrounding the Jones Camp dike; to determine where iron ore occurs within this section; to determine the paleoenvironment of deposition of the Torres Member of the Yeso Formation; to examine the biota and petrology of the carbonates in the Torres Member; and to provide additional details for the existing surficial geologic map of the area.

Data was collected using the following methods: field stratigraphic measurement and rock description; geologic mapping; thin section analysis; and studies of conodont biostratigraphy.

HISTORY OF THE JONES CAMP MINING DISTRICT

The Jones Camp iron deposits were first discovered by P.C. Bell and Fred Schmidt in 1902. The area was named after the president of the New Mexico School of Mines at that time, Fayette A. Jones. Mining claims were initially staked in 1927.

The deposits were mined in 1963 by Carl Dotson of the International Mining Company of Socorro. Approximately

100,000 tons of ore were produced from 1963 to 1969. The ore was primarily used in the manufacture of high density cement.

Aweco International acquired Dotson's claims in 1977, with plans for a drilling program and billet mill. The claims are presently controlled by Zia Steel, Inc., N. Edward Bottinelli, president. Future plans include an exploratory drilling program and a on-site mini steel mill.

Additional details of early exploration and claim ownership history may be found in the Master of Science theses of Nogueira (1971), Jenkins (1985), and Jochems (1987).

PREVIOUS WORK

Studies of the Jones Camp region's geology and mineralization may be roughly divided into three periods: the early 1900's; the period around World War II; and from approximately 1970 to the present. Early accounts describing the mineralization and geology of the Jones Camp dike include Jones (1904), Keyes (1904), Emmons (1906), Schrader (1910), Lindgren, et al (1910), and Laskey (1932).

During World War II, the United States Bureau of Mines carried out exploration work while cataloguing the country's iron ore reserves. The Bureau of Mines study, published by Grantham and Soule (1943), included ore sampling, chemical analyses, and exploratory trenching on the site. Kelley (1949) included the Jones Camp region in his survey of New

Mexico iron deposits. He provides a good description of the geology, a geologic map, and ore reserve calculations. Data from the previous U.S. Bureau of Mines chemical analyses were included in Kelly's report, indicating ore grade and tenor from various ore bodies along the dike. Kelley recognizes the complex nature of the dike, suggesting that three types of igneous rock are present: the hornblende monzonite of the central dike; light green monzonite in surrounding facies; and diabase sills extending laterally outwards from the dike.

The most recent period of work at the Jones Camp district consists of a series of Master of Science theses from the New Mexico Institute of Mining and Technology. These examine various geologic, geochemical, and geophysical properities of the site. A summary of the work conducted during this period follows.

The first of these theses is that of Noguiera (1971). The paper is a mineralogical and geochemical study of the origin of iron mineralization, environment of ore deposition, and the relationship between the dioritic dike and the ore mineralization. Noguiera (1971) indicates that the deposits are of hydrothermal origin in the sedimentary units, while ore bodies in diabase sills result from crystal settling. The ore was deposited at a temperature between 450 and 550^{o}C under oxidizing conditions. The iron bearing fluids were probably acidic and precipitated the ore upon contact with reactive limestones.

Nogueira (1971) states that the dike is dioritic, with these diorites providing the probable source of iron. The iron was leached out of the intrusives by the hydrothermal fluids as they moved up along the borders on the dike.

The dike is divided into three igneous facies based on texture, mineralogy, and field relationships. These facies are: the central dike; the mottled border facies; and diabase sills.

Bickford (1980) conducted a geological and geophysical study of the Jones Camp iron deposits to determine the economic potential of the site. The petrology of the igneous dike was analyzed as varying in composition from quartz diorite to granodiorite. The diabase sills of Kelley (1949) and Noguiera (1971) are further classified as being composed of pyroxene syenodiorite. Bickford (1980) indicates that the magnetite mineralization occurs as pods along the length of the dike. Pod location is controlled by zones of secondary permeability caused by intrusion of the diabase sills. These more permeable zones served to consolidate the hydrothermal fluids, resulting in the podiform deposits which replace the sedimentary host rocks. Bickford (1980) measured a stratigraphic section of Permian host rock sediments -- the Upper Yeso, the Glorieta, and the lower San Andres Formations.

Geological and geophysical analyses suggest that reserves total 1,117,940 to 1,575,630 tons (Bickford, 1980). An open pit mining operation could be profitable at the site, according to Bickford's economic feasibility study.

Gibbons (1981) studied the petrographic and geochemical characteristics of the Jones Camp dike and magnetite ore. Gibbons states that the intrusive is a quartz-poor hornblende-pyroxene rock which grades from monzodiorite at the center of the dike to diorite at the margins. The composite nature of the intrusive suggests an origin of multiple intrusions from a fractionating magma body. Trace element analysis was conducted and, along with field and petrographic studies, the data suggests that the ore was deposited after consolidation of the dike and sills. As proposed by Nogueira (1971), Gibbons (1981) believes that the hydrothermal fluids leached iron from the border facies rocks, indicating that these border facies are sufficiently depleted to account for the Jones Camp magnetite mineralization. Precious metal analysis showed that there is no economic concentration of gold, silver, or platinum group elements on the property (Gibbons, 1981).

Jenkins (1985) further studied the geological and geochemical aspects of the Jones Camp region. Based on geologic and major and minor trace element analysis, he suggests that the dike and sills are comagmatic, with a geologically short period between intrusive events. Depletion of iron in the leached border facies was quantified as being 3 to 4 %.

Fluid inclusion data was gleaned from calcite samples which are cogenetic with magnetite mineralization. The data indicates a non boiling saline or hypersaline fluid under a hydrostatic pressure of 154 bars. The mean trapping temperature was found to be 166 ^{o}C (Jenkins, 1985). The hydrothermal model of ore emplacement was further developed, with the suggestion that heat from the cooling intrusives established a convective hydrothermal system. Groundwater and connate water provided fluids to circulate through this convection cell which leached, transported, and deposited the iron. Complexing of iron with chlorine and sulfate anions allowed transportation (Jenkins, 1985).

A geological, paleomagnetic, and geophysical study by Jochems (1987) is the most recent work on the Jones Camp property summarized in this review. Jochems (1987) proposes that at least 6 dioritic intrusions formed the dike. In addition to the central dike, mottled border facies, and diabase sills delineated by Kelley (1949), and further classified by the authors summarized above, Jochems suggests three other facies: mica synenodiorite, hornblende diorite, and albitite.

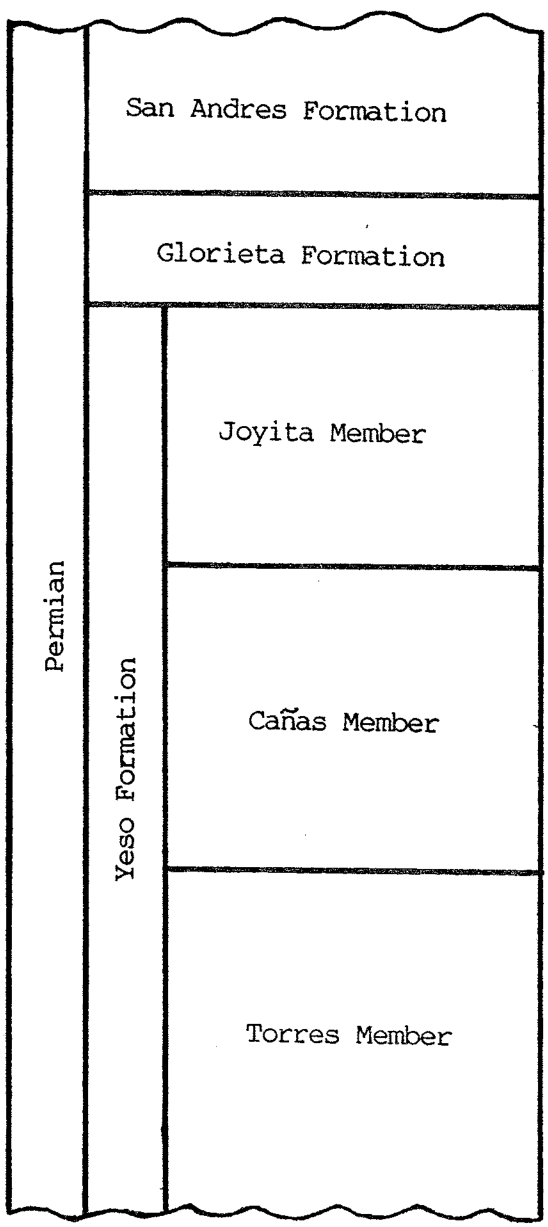
Paleomagnetic data indicates a wide range of remanent field directions at most sites. This wide range results from the effect of hydrothermal activity on chemical remanent magnetizations. The earth's magnetic field is suggested to have reversed during the emplacement of the dike (Jochems, 1987).

Geophysical magnetometer surveys produced a wide range of values at each survey site, resulting in unreliable quantitative data. The geophysical study did result in the proposal of unknown ore pods buried beneath the surface on the west end of the dike (Jochems, 1987).

GEOLOGIC SETTING

Sediments exposed on Chupadera Mesa are Permian in age: upper Yeso Formation; the Glorieta Formation; and the lower San Andres Formation (Figure 2). The Yeso Formation consists of four members: at the base, the Meseta Blanca, which is not exposed; the Torres Member, of which only the middle to upper section is exposed; the Cañas, and the Joyita Members.

The three formations were originally described in the early 1900's. Lee (1909) named the Yeso Formation after the Mesa del Yeso which is located 19.5 km northeast of Socorro, New Mexico. Lee's section was measured about 3 km southeast of this mesa, where exposures were better. Needham and Bates (1943) redescribed the Yeso in approximately the same location, separating the Yeso from the Glorieta sandstone and the San Andres Formation. The type section is 181.25 m in total thickness. The Yeso Formation varies in thickness on a regional scale, becoming thicker to the southeast and to the



Thicknesses to scale

1 cm = 15 m

Figure 2: Stratigraphic section of upper Permian sediments in the Jones Camp dike region.

northwest from the type section locale (Needham and Bates, 1943).

The Glorieta Formation was originally described by common usage as the sandstone which separates the Yeso and San Andres Formations on the Glorieta Mesa. Hager and Robitaille (1919) designated the Glorieta as Permian in age. A type section was established on Glorieta Mesa 1.6 km west of Rowe, New Mexico by Needham and Bates (1943). The type section is 41.6 m thick. The unit is thickest in northern New Mexico, thinning to the south.

Lee (1909) named the San Andres Formation after the San Andres Mountains in southern Socorro County, New Mexico. Needham and Bates (1943) designated the type section of the San Andres in Rhodes Canyon, near Engle, New Mexico. The section is 181.5 m thick. Thickness varies regionally -- the formation is as thin as 4.6 m in the north, and thickens to 367 m in southern New Mexico. The San Andres is widespread throughout New Mexico, forming a resistant cap on large topographic features, including Chupadera Mesa (Needham and Bates, 1943).

The Jones Camp iron district is found along an east-west trending lineation defined by the Jones Camp dike. The dike crops out for approximately 17.74 km through the sediments of Chupadera Mesa. Kelley and Thompson (1964) describe Chupadera Mesa as a 10 to 15 mile wide structural platform bounded on the east by the Chupadera anticline and on the west by the Chupadera fault scarp. The platform extends north to south for about 45 miles, between the Estancia Valley on the north and the Oscura uplift on the south. The Chupadera platform dips gently to the east or southeast. Kelley and Thompson (1964) state that this dip is generally 1^{o} or less, however, in the vicinity of the Jones Camp dike, dips of up to 10^{o} east have been measured.

The Jones Camp dike complex is Tertiary in age, strikes N75^{o}W, and dips between 82^{o}S and vertical. A smaller dike, the Iron Horse,strikes parallel to the Jones Camp dike and is exposed to the south (T6S, R7E). Later diabase sills and dikes were intruded after the dike rocks. These diabase intrusions occur close to the dike contact, extending up to 1 km to the south.

The Permian sediments arch over the dike in the east, suggesting that the unexposed intrusion extends at least another 2.6 km, before this topographic expression dies out. The dike plunges beneath the Torres Member sediments in the west, about 1.5 km west of the mesa face.

In the vicinity of the dike, the sediments have been structurally folded away from the intrusion. Small synclines and anticlines parallel the dike. Rapid weathering of the Torres Member evaporites has created small valleys on both the north and south sides of the dike. These erosional features create good exposures of the stratigraphic section parallel to the dike. Solution collapse of the evaporites causes small structural features within the section on the mesa face.

Iron ore in the form of magnetite is found along the sides of the dike and diabase sills. The mineralization occurs as discrete pods, replacing the surrounding country rock.

STRATIGRAPHY

Two detailed stratigraphic sections were measured, one approximately 2.4 km to the south of the dike, and the second approximately 1.5 km to the north. These will be referred to as Stratigraphic Section I (SSI), and Stratigraphic Section II (SSII), respectively. The sections were measured well away from the dike in order to study the sediments in their unaltered state and to obtain the most complete sections possible. The two stratigraphic sections allow correlation across the dike zone, where the sediments are often disturbed and only partial sections are availble. Total section thickness of SSI is 234 m. SSII is 324.75 m thick. Appendices I and II contain detailed descriptions of SSI and SSII, respectively.

Arroyos cut into the mesa face allow good, relatively fresh exposures of the stratigraphy. Both sections were measured by following such arroyos. The sections were measured with a Jacob's Staff and Brunton compass. Rock colors were quantified by comparison with the rock color chart prepared by Goddard, et al (1963). Field classification of carbonates is after Dunham (1962).

The formations found in the study area are all of Permian age: upper Yeso; Glorieta; and lower San Andres.

UPPER YESO FORMATION

Torres Member

The section of Yeso Formation exposed in the study area consists of the middle to upper Torres Member, the Cañas Member, and the Joyita Member. The Torres Member is made up of interbedded gypsum, sandstone, dolomitized limestone, and minor siltstone beds. Prominent carbonate beds are characteristic of the unit. The lower contact of the Torres is buried beneath alluvium eroded from Chupadera Mesa. The previously mentioned arroyos have eroded slightly deeper into the mesa to the north of the dike, so that more of the Torres Member has been exposed there than in the south. 67.54 m of Torres were measured in SSI. 121.24 m of Torres were measured in SSII. The Torres is the primary ore bearing unit of the Jones Camp district, hence it was examined in somewhat greater detail than the remainder of the section.

Five of the carbonate beds within the Torres Member are exposed in the study area. The carbonates are primarily fetid mudstones, with occasional fossiliferous beds. The uppermost carbonate interval in each stratigraphic section contains wackestones and packstones. The biotic assemblage includes gastropods, pelecypods, ostracods, oncolites, foraminifera, conodonts, algae, and occasional crinoid ossicles. Carbonate beds low in SSII are pelloidal.

The carbonates are generally blocky, cliff forming units. Bedding thickness ranges from 2 to 11 cm, often with thin silt interbeds. Carbonate composition is primarily dolomitic, suggested both by field application of dilute hydrochloric acid and laboratory thin section staining. Fractures within the outcrop are typically filled with reprecipitated gypsum, weathered from higher in the section. The carbonates frequently have a silty or sandy appearance.

Due to the importance for correlation purposes of the carbonate beds of the Torres Member, they will be referred to as labeled in Plate 1 (in pocket). SSI-C1 will describe the upper carbonate of Stratigraphic Section I, SSI-C2 will refer to the next lower carbonate in Stratigraphic Section I, et cetera.

Interbedded with the carbonates are thick intervals of massive gypsum and sandstone. The gypsum is bedded, with laminated couplets of light and dark gypsum low in the section. It crops out as a blocky cliff former within the arroyo. The sandstone is often incompetent, weathering to rounded cliff forms or slopes. It is carbonate cemented, and poorly to moderately sorted.

Cañas Member

The Cañas Member of the Yeso Formation is primarily bedded, massive gypsum with minor interbedded siltstones and limestones. The contact with the underlying Torres is determined by the top of the last prominent carbonate bed of the Torres. Above this contact, the Cañas is seen as a thick, relatively unbroken section of gypsum.

Cañas gypsum occurs as massive blocky cliffs, bedded intervals of laminated couplets, or occasionally as slopes. Minor carbonate intervals are often sandy or silty, fetid, have occasional mollusc molds, and are less than 0.5 m thick. Siltstone intervals are incompetent, fissile, and can be carbonate cemented and/or gypsiferous.

Joyita Member

The Joyita Member is a reddish sandstone with minor interbeds of carbonates and gypsum near the top of the unit. The Joyita is in sharp contact with the Cañas Member.

The Joyita is composed primarily of carbonate cemented, thinly bedded, poorly to fairly well sorted, relatively incompetent sandstone. The sandstone occurs as interbedded fissile textured, slope forming rock and more massive, buttress forming rock. The result is a slope of weathered sandstone detritus broken by rounded cliff layers.

Resistant carbonate mudstones occur near the top of the Joyita. The carbonates are non fossiliferous and are interbedded with gypsum. An interval of massive gypsum marks the upper contact.

GLORIETA FORMATION

Overlying the Joyita Member of the Yeso Formation is the Glorieta Formation. The Glorieta Formation is a fairly massive, orange-buff sandstone unit. The Glorieta/Joyita contact is marked by a color change and a massive gypsum bed.

The Glorieta sandstone is well sorted, carbonate cemented, and fairly competent. The formation occurs as massive cliffs and detritus covered slopes. The Glorieta in SSII contains approximately 2.5 m of blocky weathering carbonate mudstone.

SAN ANDRES FORMATION

The final formation exposed on Chupadera Mesa is the lower portion of the San Andres limestone. In the study area, the San Andres is a fairly massive carbonate unit. It is in sharp contact with the underlying Glorieta Formation.

The San Andres limestone occurs both as cliff forming, massive beds and as detritus covered slopes. The formation is fossiliferous. The upper surface of the San Andres is an erosional unconformity. Resistant carbonate beds of the unit cap the mesa.

CORRELATION OF STRATIGRAPHIC SECTIONS

Correlation of the stratigraphic columns is based on several lines of evidence. These are field relations, relative position of uncorrelated beds to horizons that may be positively correlated, and biotic evidence. The datum chosen for correlation is a wackestone bed in the uppermost Torres carbonate bed, C1. C1 may be definitely correlated between the two sections. Common characteristics shared between the two locations are that C1 is the highest carbonate stratigraphically in each section; the most fossiliferous with wackestones, and in the case of SSI, packstones; fossil individual size is the largest found in the section; biotic diversity is the greatest in the section. Additionally, C1 is prominently exposed and traceable around the dike. See Plate 1 for graphic illustration of the correlated sections.

The datum bed is located in the 61.08 - 61.33 m interval of SSI and the 116.3 - 116.46 m interval of SSII. The bed is a prominent one, being a fossiliferous, competent cliff former. Fossils occur as dolospar filled molds in both sections. In SSI-C1, the wackestone contains mollusc fragments and well preserved oncolites approximately 2 cm in length. These prominent oncolites are an important reference point in the strata immediately surrounding the dike. The biotic elements of the datum bed in SSII-C2 do not include the oncolites, consisting of the various more common mollusc fragments.

The datum bed occurs between calcareous shale and/or mudstone beds in both sections. Additionally, the wackestone is found low in the C1 interval of both measured sections. It occurs 1.28 m above the lower contact of SSI-C1, and 2.0 m above the lower contact of SSII-C1.

This datum is necessarily somewhat speculative, as the depositional environment varied to some extent over the 4 km separating the two sections. The carbonate, sandstone, and gypsum thicknesses of the Torres Member, as well as the biotic assemblages, vary. As mentioned previously, SSI is probably more accurate in terms of overall thickness. Despite these problems, choosing the datum as a fossiliferous bed within an interval which may be accurately correlated, C1, limits possible error to the thickness of this interval. SSI-C1 is thicker than SSII-C1, hence possible error is the thickness of SSI-C1, 7.7 m.

As indicated in Plate 1, the Torres Member carbonates are correlated directly with each other. The carbonate intervals developed differently in each location, but approximately simultaneously. A comparison of the corresponding carbonate intervals follows.

C4 in both sections overlies a gypsum interval and is followed by gypsum and/or sandstone. SSI-C4 is 3.5 m thick, the carbonate beds are massive and generally interbedded with silty sand. Thin section analysis reveals mollusc fragments, gastropods, algal strands, and possibly foraminifera. If pelloids were present, they were not preserved.

SSII-C4 is 1.64 m thick, interbedded with shaly horizons, and is calcitic. In hand sample, the rock appears as a carbonate mudstone, yet thin section study yields a Dunham classification as pelloidal wackestone due to the high concentration of pelloids. Biotic elements are similar to those in SSI-C4, including mollusc fragments, ostracods, conodonts, algae, and foraminifera.

C3 overlies sandstone in each section. SSI-C3 is overlain by sandstone while SSII-C3 is overlain by a covered slope of gypsum and sandstone. SSI-C3 is 4.8 m thick, consisting of fairly massive carbonate mudstones and interbedded silts with one sandstone bed near the top of the interval. Biota include mollusc fragments, gastropods, ostracods, conodonts, and algae. Pelloids are also found but are rare.

SSII-C3 is 5.94 m thick, about 1 m thicker than SSI-C3. Carbonate beds of SSII-C3 are generally more thinly bedded (0.5 to 1 cm) than in SSI-C3, although they are still resistant layers. Interbeds are silt and a sandstone bed found near the top of the interval. Biotic elements are similar to SSI-C3, consisting of various mollusc fragments, conodonts, and algae. No definite ostracods were observed. Pelloids are common with the lowest carbonate interval of

SSII-C3 being a pelloidal wackestone.

C2 is underlain by sandstone in each section, and overlain by gypsum in SSI, with SSII-C2 being overlain by a covered slope that is either gypsum or sandstone. SSI-C2 is very thin, 0.77 m, consisting of thin beds of carbonate mudstone interbedded with gypsum. The mudstone is fissile in the lowest and uppermost beds. The lower beds are dolomitic, while the upper section of the interval is calcitic. The interval contains small recrystallized lumps and possible burrows, suggesting that some biotic activity occured.

SSII-C2 is 3.33 m thick and consists of fissile to massive carbonate mudstone interlayered with calcareous shale. The mudstone is calcitic in the lower portion of the interval. The rock is fossiliferous, containing mollusc fragments, gastropods, conodonts, and a trace of algae.

C1 is underlain by sandstone in both sections. The Cañas Member directly overlies SSI-C1, while a sandstone interval separates SSII-C1 from the Cañas gypsum. SSI-C1 is 7.7 m thick, and is made up of carbonate mudstone, wackestone and packstone. Interbeds are calcareous shale. The biotic assemblage includes pelecypod and gastropod fragments, ostracods, oncolites, condonts, and possible algal strands. The fossil size and diversity are the greatest in the section.

SSII-C1 is 4.22 m thick, consisting of carbonate mudstone and wackestone with interbeds of calcareous shale. The biotic elements, as in SSI-C1, are large in size and the diversity is greater than in the lower carbonate intervals. Along with the common mollusc fragments, gastropods, ostracods, traces of algae and foraminifera, and possible burrows were found.

General correlation of the Cañas and Joyita Members of the Yeso Formation is easily seen in the contacts between the members. These two units both contain minor carbonate beds which may provide some additional control, and are thus correlated. The Cañas Member in SSI is 61.08 m thick, consisting primarily of massive, bedded gypsum. Thin, gypsiferous, grayish green siltstone beds are found interbedded with the gypsum. The Cañas in this location contains two carbonate mudstone beds. The lower carbonate occurs 42.91 m above the Cañas/Torres contact and the upper mudstone occurs 51.52 m above the contact. The mudstones are resistant, fetid, yellowish brown units, with some recrystallized molluscan fossils in the upper mudstone. The lower carbonate has small dark spheroids, possibly of biotic nature.

The Cañas Member, as observed in SSII, is 58.01 m thick and dominantly composed of massive gypsum intervals. As in SSI, minor siltstones of a grayish green color are found, along with three carbonate mudstone intervals. The lowest carbonate occurs 42.36 m above the Cañas/Torres contact, the middle carbonate 47.64 m above the contact, and the upper carbonate 48.26 m above the contact. The two lower mudstones are resistant, sandy, fetid layers, while the upper carbonate consists of thin beds interbedded with gypsum. The carbonates are not fossiliferous and are generally a dark yellowish brown color.

The two carbonate mudstones in the Cañas at the SSI location are tentatively correlated with the lower two mudstones of the Cañas in SSII.

The Joyita Member is 52.03 m thick in SSI, and 64.7 m thick in SSII. The unit consists primarily of carbonate cemented, reddish brown sandstone in alternating massive and fissile beds. Two carbonate mudstone beds occur at the top of the member in each section, separated by bedded gypsum. These carbonates are similar in each section, being resistant, grayish layers. The upper carbonate occurs as interbedded mudstone and gypsum. These carbonates and gypsum beds are correlated.

The Glorieta and San Andres Formations may be correlated by their well defined contacts. The Glorieta is 22.34 m thick in SSI, and 28.23 m thick in SSII. The Glorieta in SSII contains a 2.45 m interval of resistant carbonate mudstone, which is not found in the SSI location. The mudstone could be covered by detritus in SSI.

The thickness of the San Andres in the study area depends on the topographic elevation of the top of the mesa, as the upper contact is an erosional unconformity. 31.01 m are exposed in SSI, while 52.57 m are exposed in SSII. The limestone occurs as alternating resistant cliff forms and detritus covered slopes.

IDENTIFICATION OF STRATA IMMEDIATELY SURROUNDING THE DIKE

The strata in the vicinity of the dike may be correlated and identified by reference to the Torres Member carbonates, as well as field relations. The strata may be traced from the mesa face, where good exposures are possible, into the dike area. The stratigraphically highest Torres carbonate bed, C1, is particularly prominent and useful for this purpose. The very fossiliferous nature, the presence of the oncolite beds, and the resistant qualities of the interval make C1 an ideal marker unit. Conodont evidence also supports the continuous nature of this marker. Similar conodont individuals, probably Neostreptognathodus (Stan Krukowski, pers. commun., 1988, and Robison, 1981), are found in samples taken from C1 both on the mesa face and along the length of the dike.

C1 occurs high enough in the section to be exposed along the most of the exposed portion of the dike to the east of the mesa face, especially on the south side. This provides a reference bed for stratigraphic identification throughout the dike area.

Field observation of the various sediments also aids in stratigraphic identification along the dike. The Cañas Member, for example, is an easily weathered unit which in general floors valleys on either side of the dike. The Joyita Member, Glorieta and San Andres Formations are relatively distinctive when observed on the sides of the mesa near the dike. General stratigraphic location may be determined by comparison of the worker's position with these units.

CARBONATE PETROLOGY AND BIOTIC ASSEMBLAGE

The carbonate petrology and biotic elements of the Torres Member were studied in detail through the use of thin sections. Samples were taken at an arbitrarily determined interval of 0.5 m through each carbonate unit of the Torres Member exposed in the measured sections. A total of 31 samples were taken from SSI. 26 samples were taken from SSII. 57 thin sections were made from these samples. The slides were stained with Alizarin Red-S to aid in the recognition of dolomite. The thin sections were analyzed quantitatively using a standard petrographic microscope and mechanical point counting stage. 500 to 700 points were counted on each slide, with most having 600 points counted.

According to Van Der Plas and Tobi (1965), a count of 600 points gives the estimated percentage by volume of a given grain type to be: the estimated percentage plus or minus 1 to 4 %, with 95 % confidence. Figure 3 (Van Der Plas and Tobi, 1965) shows this relationship. The greater the number of points counted, the greater the accuracy of the percentage estimate. Counting more than approximately 1000 points yields diminishing returns in improved accuracy. Additionally, the lower the percentage by volume of a given element, the greater the accuracy of the count.

In the carbonates that were studied, biotic elements were

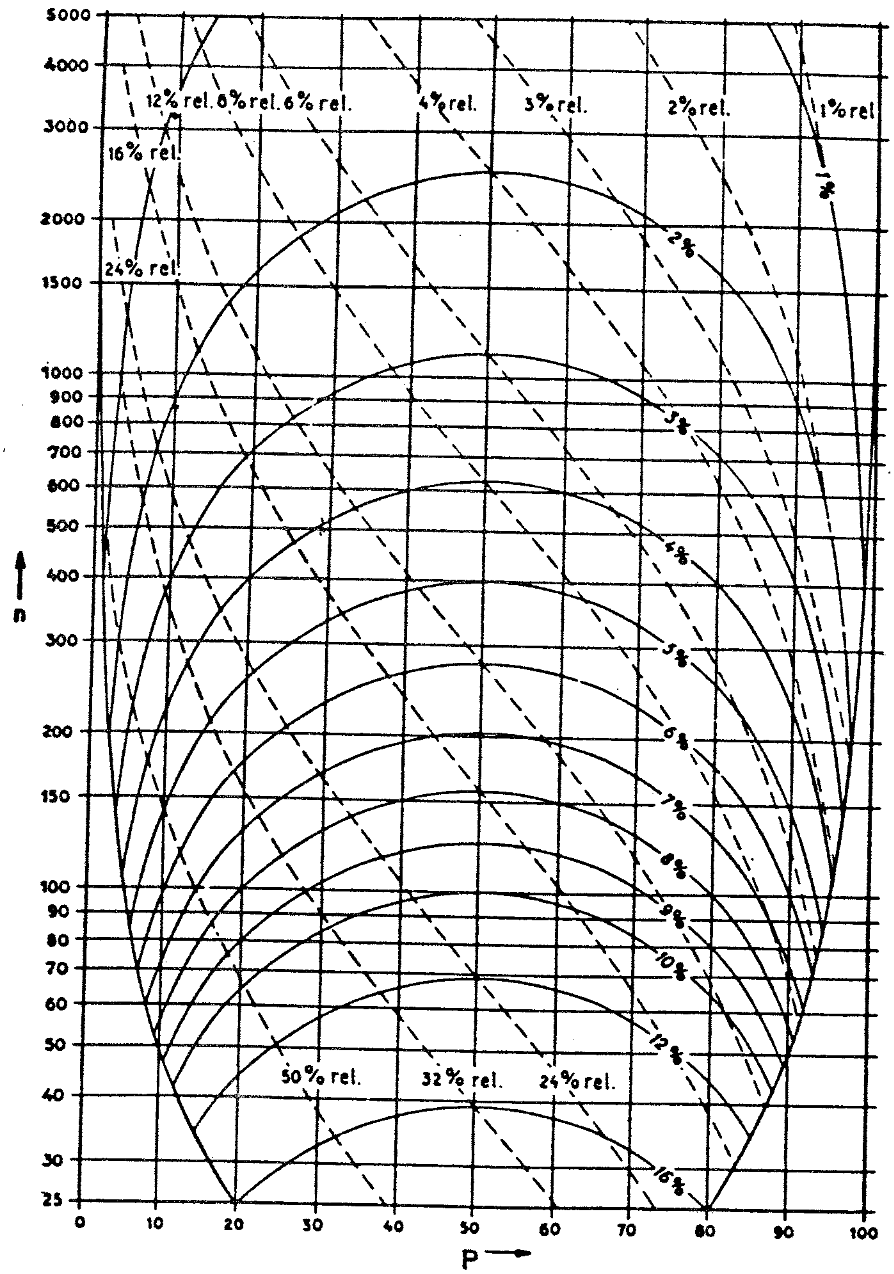


Figure 3: Relationship between points counted and actual percentage by volume of a given thin section constituent. The x-axis of the graph represents the percentage, by volume P, of the various counted elements. The y-axis represents the total number of points counted on a given thin section. (after Van Der Plas and and Tobi, 1965)

relatively rare, though very important for classification and paleoenvironmental analysis. The low percentage by volume of individuals causes the point counting data for the biotic elements to be particularly accurate.

The point counting process was biased in favor of the recognition of biotic elements in deference to diagenetic products. For example, if the point to be counted was in the mold of a mollusc shell that had been filled with spar, the point was counted as a mollusc. This practice reflects the major emphasis of this research on the paleoenvironment of deposition, rather than the diagenetic history.

The results of the point count analysis are found in Appendix III. The slides were given rock names after the classification schemes of both Dunham (1962) and Folk (1962). Dolomitization is pervasive throughout the section. The term "dolospar" is used to describe the sparry dolomitic cement found as fracture, void, and fossil mold fill. Descriptions of the bulk petrologic and biotic characteristics of the various carbonate units follow.

In addition to thin section study, samples were digested with acid, and the residues picked. Conodonts, fish teeth, and rare crinoid ossicles were found.

STRATIGRAPHIC SECTION I

SSI-C4

The lowest carbonate unit of SSI, SSI-C4, is a carbonate mudstone by Dunham's (1962) classification scheme. The Folk (1962) method describes SSI-C4 as a micrite or fossiliferous micrite. As suggested by these names, the main component of the rock is calcareous mud or micrite. Microspar is also found in abundance, being greater by volume than micrite in two cases (samples SSI-3a and SSI-4). Small amounts of sparry cement occur as equant, intergranular cement.

Field observations showed that dolomitization had occurred, but that some calcitic rock remained. The thin sections in general did not accept the ARS stain, indicating a dolomitic composition. Thin sections SSI-4 and SSI-5 do show some calcite, with < 5 % of the grains by volume being stained. Trace amounts of opaque minerals were also noted.

The rare fossil grains observed in SSI-C4 are very small in size, and occur as dolospar filled molds. Fossil types consist of gastropods, mollusc fragments (probably a mixture of pelecypod and gastropod fragments), ostracods, algal strands, globigerinid foraminifera, and possibly tubiphytes. A trace of pelloidal grains was found in thin section SSI-3a.

Figure 4 shows a sample of fossiliferous micrite from SSI-C4. Matrix material includes dolomitized micrite and microspar.

SSI-C3

SSI-C3 is classified as mudstone by Dunham (1962) and contains microspar micrites and fossiliferous microspar micrites after Folk (1962). Mud/micrite is the dominant

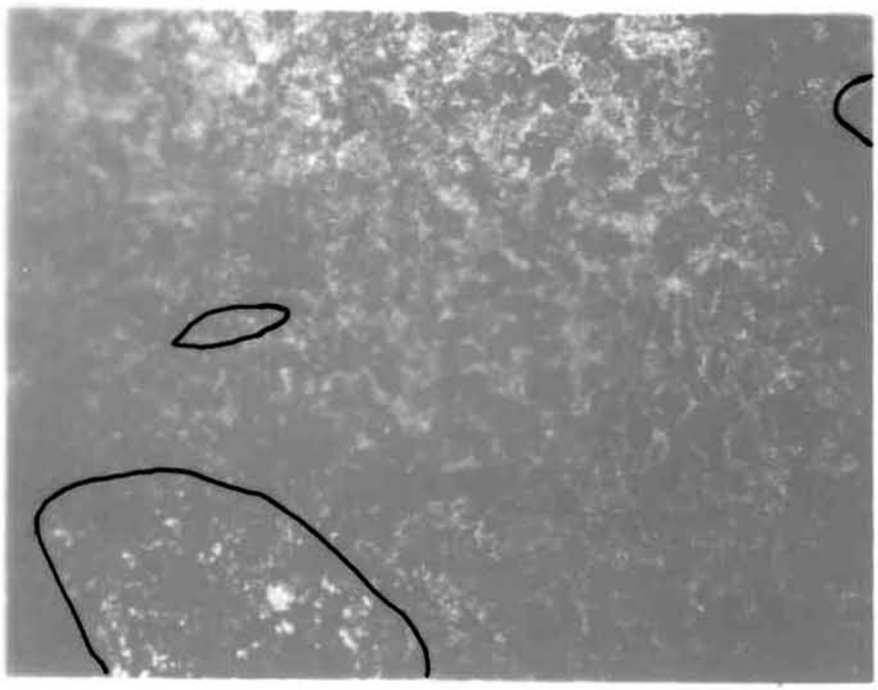


Figure 4: Photomicrograph of fossiliferous micrite from SSI-C4. Matrix material includes dolomitized micrite and microspar. Pelloids and fossil grains are evident. The oval fossil grain to the upper left of center is yellow in plane light, indicating the chitinous admixture of an ostracod shell (Scoffin, 1987). Void fill in the lower left is gypsum, while the void in the upper right is rimmed with equant dolospar. Crossed polarizers, 20X.

constitutent of SSI-C3. Microspar is the second most prevalent grain type, occuring in subequal amounts with the mud. Dolospar fills fractures, vugs and fossil molds. The spar crystal form is blocky and equant. The rock is dolomitized, with only sample SSI-10 showing trace amounts of calcite. Gypsum also fills some fractures, vugs and some fossil molds. Opaque grains comprise up to 0.5 % of the samples analyzed from SSI-C3.

Figure 5 displays a sample of fossiliferous microspar-micrite from SSI-C3.

The trace amounts of fossil grains are very small, consisting of gastropods, mollusc fragments, ostracods and algal strands. The mollusc fossils were dissolved and filled with dolospar or gypsum. Pelloids are found in trace amounts.

SSI-C2

The single sample taken from SSI-C2 is a mudstone (Dunham, 1962) or microspar-micrite (Folk, 1962). Figure 6 shows this laminated microspar-micrite. Mud and microspar occur in subequal amounts. The mud is laminated and shows possible fenestral void spaces. Dolospar and gypsum are found as void space fill. Opaque grains occur in trace amounts. SSI-C2 shows no sign of fossil grains or biotic action.

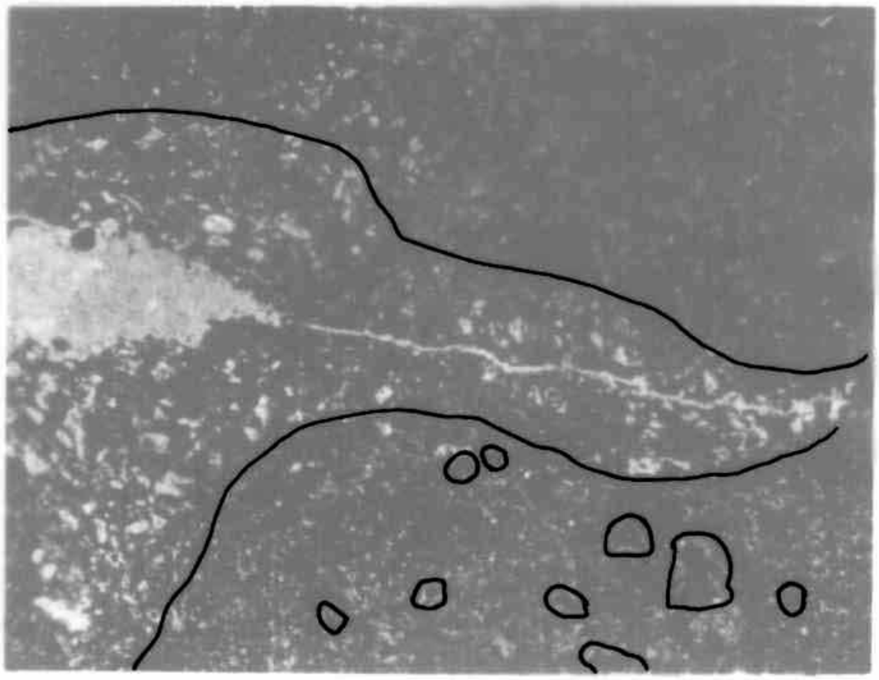


Figure 5: Photomicrograph of fossiliferous microspar-micrite from SSI-C3. Gypsum fills the prominent fracture and surrounding vuggy pore space. Dolomicrite and dolomicrospar form the matrix material. Vugs are lined with equant dolospar crust. Crossed polarizers, 20X.

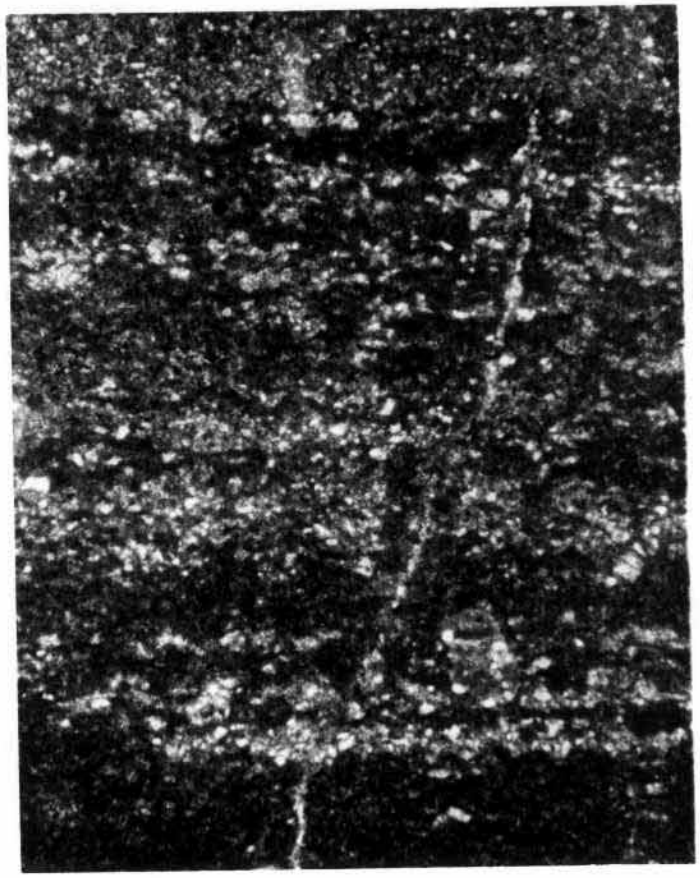


Figure 6: Photomicrograph of laminated microspar-micrite from SSI-C2. Crossed polarizers, 20X.

SSI-C1

Mudstone, packstone, wackestone, and pelloidal wackestone are present according to Dunham's (1962) classification of samples from SSI-C1. Folk's (1962) classification of the same rocks yields micrite-microsparite, microspar-micrite, fossiliferous micrite, fossiliferous microspar-micrite, sparse biomicrite, and sparse bio-microspar-micrite. Folk's (1962) classification is more specific because it is designed for microscope analysis, where greater detail is revealed. As with the other carbonate units of SSI, mud/micrite is the dominant constituent by volume, with microspar generally in somewhat lesser abundance. Thin section SSI-15 is anomalous in that microspar accounts for 51.4 % of the volume of the sample, with mud/micrite occuring as 46.6 %. The mud is occasionally laminated, and possible intraclasts are found. Dolospar is generally blocky and equant in crystal form. ARS stained calcite is found in trace amounts in sample SSI-29. SSI-C1 is otherwise thoroughly dolomitized. Opaque grains are found in trace amounts.

Figure 7 displays a fossil grain (mollusc or ostracod) with a void lining of equant to bladed dolospar followed by a filling of blocky dolospar mosaic. The rock displays round void spaces, possibly gas bubbles, filled or lined with equant dolospar or gypsum. Fossil grains are filled with dolospar. Several of the thin sections reveal laminations with void

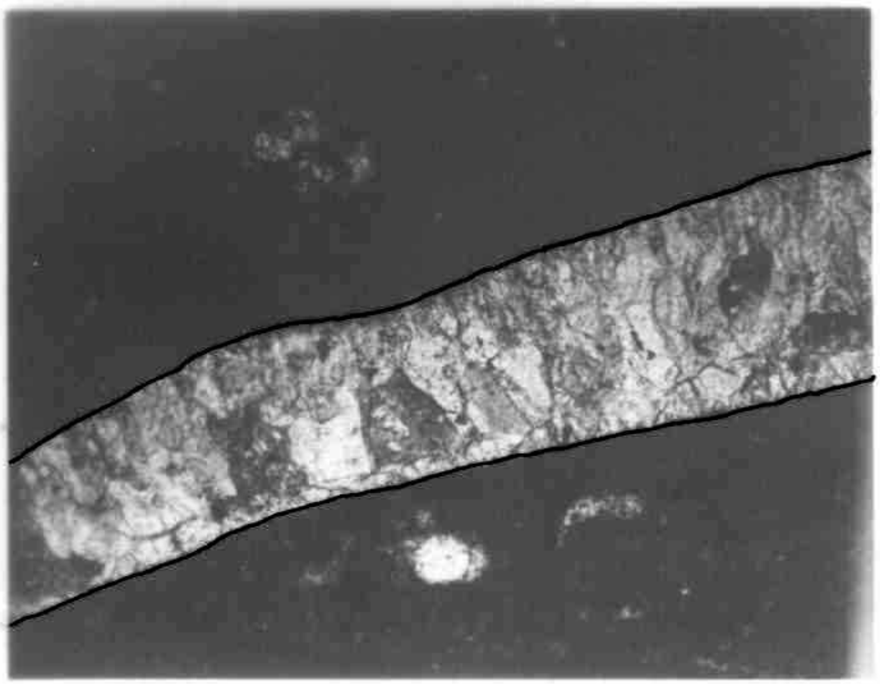


Figure 7: Photomicrograph of fossil grain with void lining of equant to bladed dolospar followed by a filling of blocky dolospar mosaic from SSI-Cl. Crossed polarizers, 100X.

spaces and fossil fragments oriented parallel to bedding (Figure 8).

The biotic assemblage of SSI-C1 consists of gastropods, mollusc fragments, ostracods, oncolites, algal strands, globigerinid forminifera, conodonts, fish teeth, and possible bone fragments. Figure 9, from the packstone/sparse biomicrite bed near the base of SSI-C1, shows a large oncolite (8 mm) in a fossil hash/mud matrix. Figures 10 and 11, are typical of samples taken from the packstones and wackestones near the top of SSI-C1. With the exception of the algal oncolites, fossil size is small, most fragments being less than 3 mm. In rare cases, ostracod and mollusc molds up to 15 mm were found. Despite this small individual size, SSI-C1 has the largest individual size and greatest diversity of the Torres Member carbonates. Pelloids are found in several samples, comprising up to 6.0 % of the rock in sample SSI-29, a pelloidal wackestone.

The sediments of SSI-C1 show characteristics of bioturbation including swirled sediment, aligned fossil grains, and burrows. Figure 12 displays what may be cross sections of horizontal, lined burrows in a finely laminated carbonate mud.

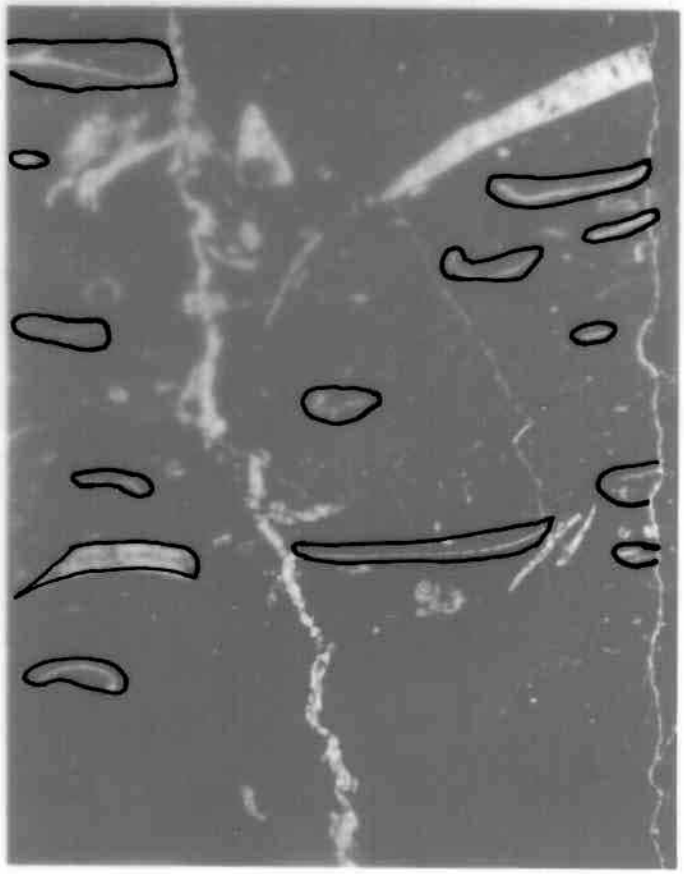


Figure 8: Photomicrograph of laminated void spaces and fossil fragments oriented parallel to bedding from SSI-C1. Crossed polarizers, 20X.

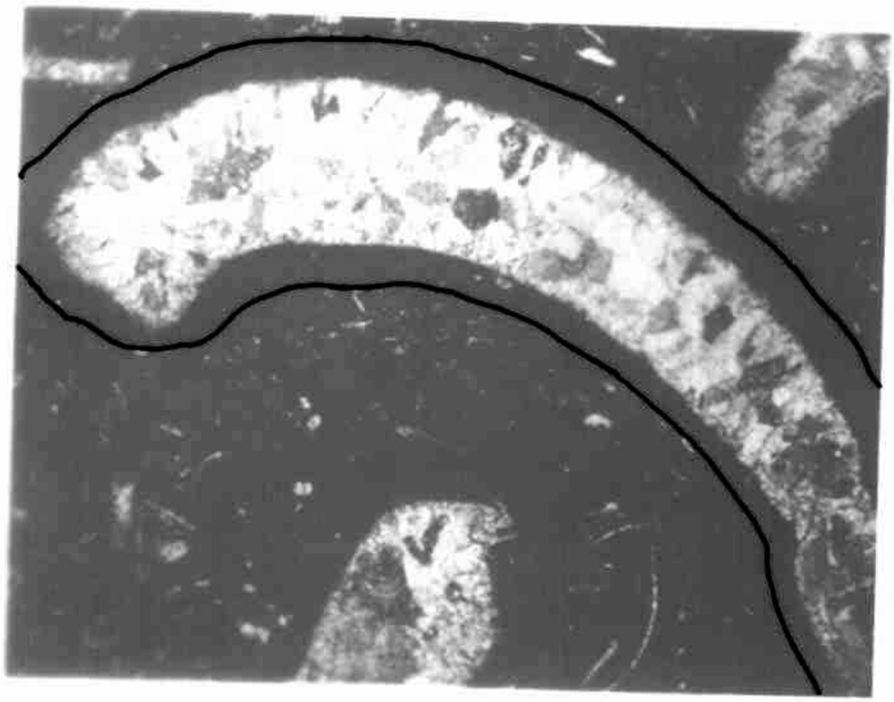


Figure 9: Photomicrograph of large oncolite in a fossil hash/mud matrix from SSI-C1. Crossed polarizers, 20X.

Figure 10: Photomicrograph of packstone/wackestone from SSI-C1. The gastropod in the upper left hand corner is approximately 1 mm in diameter. Crossed polarizers, 20X.

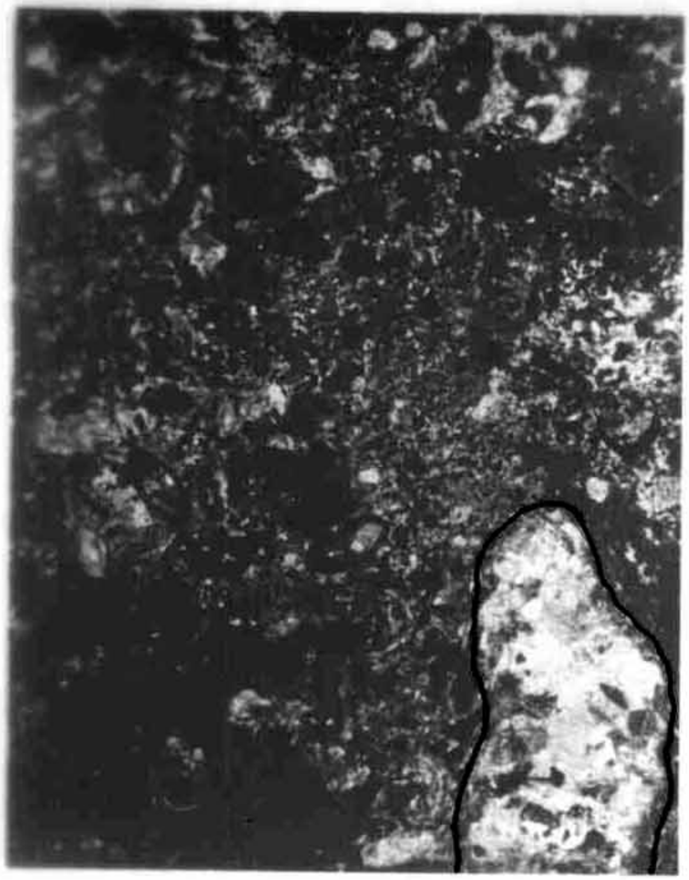


Figure 11: Photomicrograph of packstone/wackestone from SSI-Cl. Void space is approximately 2 mm long. Crossed polarizers, 20X.

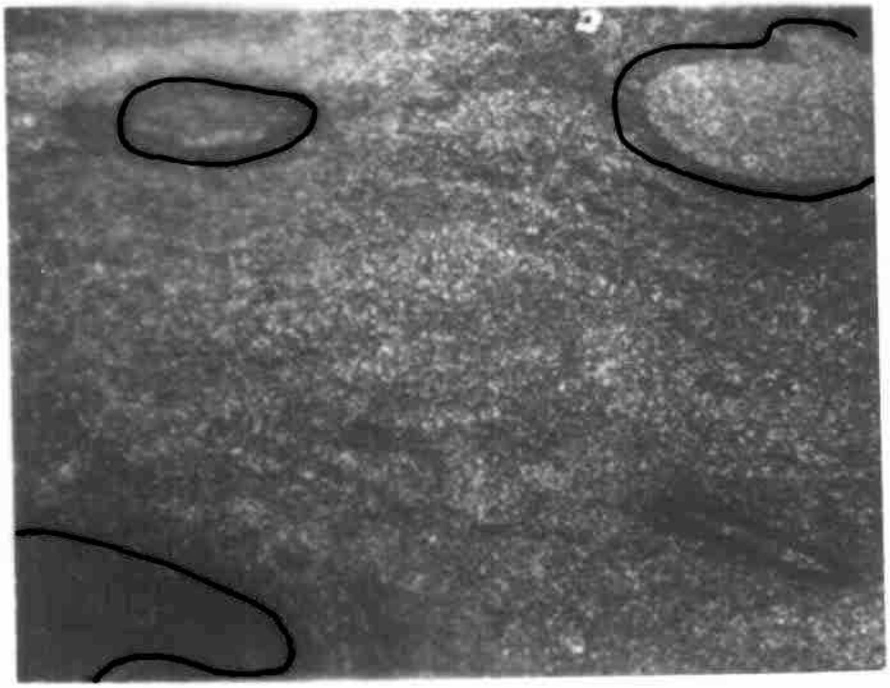


Figure 12: Photomicrograph of possible burrows from SSI-C1. Note the apparent piercement nature of the structure in the lower left of the figure. Plane light, 20X.

STRATIGRAPHIC SECTION II

SSII-C4

The lowest carbonate bed of SSII is classified by Dunham's (1962) method as containing pelloidal wackestone, mudstone, and fossilliferous mudstone. Classification by the Folk (1962) method yields the rock names of sparse pelmicrite and fossiliferous micrite-microsparite. Microspar is more prevalent than micrite, comprising 42.6 to 57.2 % by volume of the samples. Dolospar occurs as equant crystals of blocky rim cement surrounding pelloids and as replacement of fossil grains.

SSII-C4 is dolomitized throughly, showing no sign of calcitic material. Gypsum is found as fracture fill in samples SSII-2 and SSII-3. The opaque mineral content ranges from 1.5 to 2.1 %.

The biotic assemblage of SSII-C4 consists of various mollusc fragments, gastropods, ostracods, foraminifera, and algal strands. These biotic elements are found in SSII-2 and SSII-3 only. Fossil grains have been dissolved and the molds filled with dolospar. Individual size is small. Pelloids compose 26.6 % of sample SSII-1, resulting in a pelloidal wackestone by Dunham's (1962) classification. The pelloids are generally shaped like rectangles, with rounded corners. Figure 13, taken from sample SSII-1, shows this pelloidal

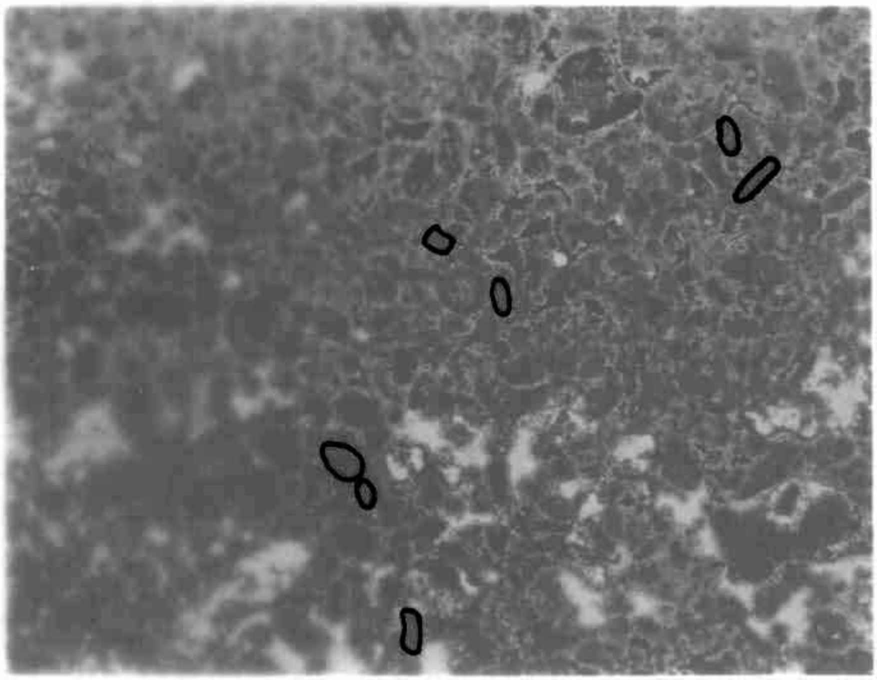


Figure 13: Photomicrograph of pelloidal wackestone/sparse pelmicrite from SSII-C4. Note the oval to somewhat rectangular shape of most of the pelloids. Some of the pelloids are composed of micrite with equant sparry rim cement. Crossed polarizers, 20X.

wackestone/sparse pelmicrite.

SSII-C3

SSII-C3 is made up of pelloidal wackestone and mudstone, as classified by Dunham's (1962) method. Folk (1962) rock names for SSII-C3 include sparse pelmicrite, pel-opaque-biomicrite, opaque-micrite, pelmicrite, and micrite. Microspar is common in all samples, occuring in subequal amounts with micrite. In sample SSII-4, microspar accounts for 52.0 % of the rock's volume, over two times the amount of micrite. Nonetheless, micrite/mud is the dominant grain type in most samples. In the mudstone/micrite samples, alternating dark and light colored laminae are apparent. The darker laminations are composed of micrite, while the lighter colored laminae are coarser grained microspar. Blocky and bladed dolospar crystals replace fossil grains and line vesicles. Some void spaces are lined with microspar.

SSII-C3 is dolomitized. Only one sample, SSII-10, has calcitic grains, and they are in trace amounts. Gypsum is common as fossil mold and fracture fill. As suggested by the Folk (1962) name of opaque-micrite, opaque grains are found in relatively large amounts, comprising up to 4 % of the samples. The opaque grains are small and may occur both in the matrix and as sparry fracture fill. In the laminated mudstone sample SSII-12, the opaque grains occur along the contact between coarse and fine grained laminae.

The biotic assemblage of SSII-C3 includes molluscan fragments, gastropods, and algal strands. Individual size is small, with the maximum length of the mollusc fragments being 2 mm. These 2 mm long fragments are from sample SSII-5. Fossil grains are rare, composing at most 3.3 % of the rock, usually less. Despite the lack of fossil grains, pelloids are common. Pelloid shape is similar to those in SSII-C4, with most having oval to rounded rectangular forms. Some round pelloids are found which may be ooids. Sample SSII-9 may contain burrows.

SSII-C2

SSII-C2 is classified as mudstone after the method by Dunham (1962). Folk's (1962) method results in the rock names of pelmicrite, micrite, and fossiliferous micrite. Microspar is the most common grain type in SSII-C2. Microspar accounts for up to 73.8 % by volume of the carbonate. Mud/micrite occurs in subequal amounts, giving the samples the overall appearance of fine grained, relatively featureless carbonate. Some of the mudstones are faintly laminated. Dolospar cement occurs in small amounts as blocky crystals dispersed throughout the matrix and as fossil grain replacement.

The carbonate beds of SSII-2 are dolomitized. Four samples in the middle of the SSII-C2 interval contain calcitic grains. These samples contain up to 5 - 10 % calcite. Gypsum is found as fracture fill material. Opaque mineral grains are generally rare, but can account for up to 2.0 % of rock volume (sample SSII-16).

The biotic assemblage of SSII-C2 consists of mollusc fragments, gastropods and possibly foraminifera. Sample SSII-20, at the top of the interval, is the most fossiliferous. The fossil grains of SSII-C3 are generally faint ghosts, having been dissolved and replaced by microspar and dolospar. Pelloids are found in only two samples, SSII-13 and SSII-20. SSII-13 contains 6.3 % pelloids by volume, giving the sample a mottled appearance. Possible burrows were noted in several slides.

SSII-C1

SSII-C1 is made up of mudstones according to Dunham's (1962) classification scheme. Folk's (1962) method classifies SSII-C4 as fossiliferous micrite with one sample (SSII-26) being classified as dismicrite. Mud/micrite is generally the most common grain type, occuring in the rock as up to 78 % of the total volume. Microspar occurs in greater amounts than mud in several samples from SSII-C1. Microspar accounts for 52.7 % of the volume of sample SSII-29. The mud/microspar matrix of the SSII-C1 carbonates is often vuggy and fractured. The mud in some samples is laminated.

Dolospar occurs as blocky crystals replacing fossil grains and pelloids, and filling vugs. Sample SSII-27 contains the most dolospar, 10.2 %, which occurs as pore fill and pelloid replacement. Other samples generally have much less dolospar, only trace amounts in some cases.

SSII-C1 is dolomitized, with only one slide, SSII-26, having any calcitic grains. SSII-26, a dismicrite, contains approximately 5 % calcite, and is also the least fossiliferous sample from SSII-C1. Gypsum is fairly common, filling vuggy pore spaces and fractures. Opaque mineral grains are relatively common, comprising up to 1.8 % of the rock volume. Figure 14, taken from sample SSII-22, shows large, hexagonal grains of the opaque mineral. The opaque material typically occurs in pore spaces or fractures.

The biotic assemblage of SSII-C1 consists of mollusc fragments (pelecypod and gastropod), definite gastropods, ostracods, and possible forams and algal strands. 3 to 4 types of mollusc shells were observed in SSII-29. Fossil individual size is up to 5 mm, found in SSII-21. Most individuals are smaller, 1 mm or less measured along the greatest dimension. The fossil grains are generally replaced with dolospar with some molds being filled by a single, optically continuous crystal of dolospar. Other fossil grains occur as faint ghosts, replaced by microspar and micrite. Pelloids are relatively rare, comprising a maximum of 4.4 % of the rock, with most samples having less than 1 % pelloids. Sample SSII-31 has an overall mottled pelloidal appearance, and, like several other SSII-C1 samples, is burrowed.

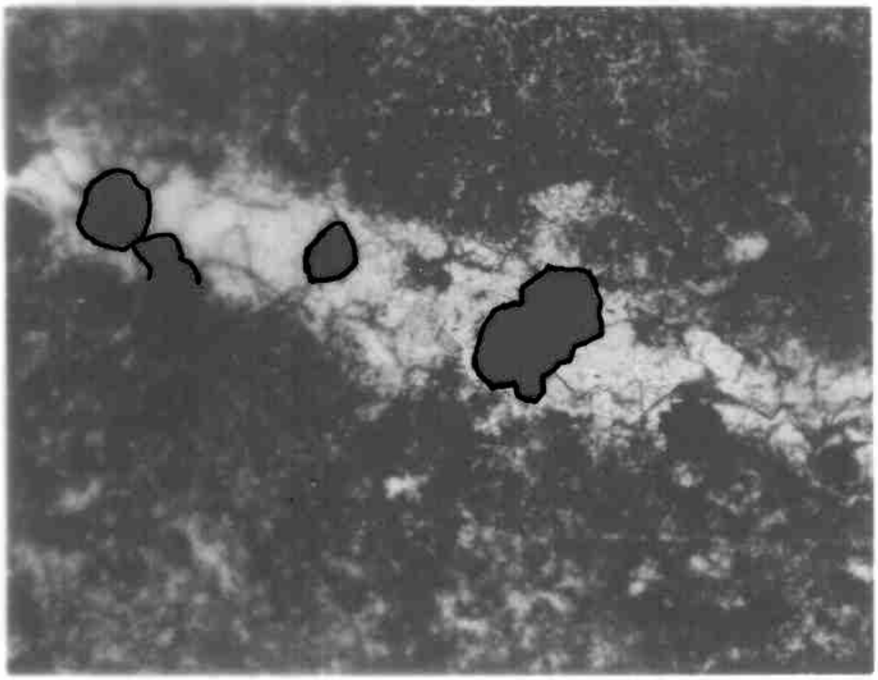


Figure 14: Photomicrograph of opaque mineral from SSII-Cl. Plane light, 100X.

CARBONATE 5

Carbonate 5 (C5) is the stratigraphically lowest exposed carbonate unit of the Torres Member in the study area. The unit is found west of the last exposure of dike rock. C5 is only partially exposed, as the topography is much more gentle in this area than on the mesa face. Thin sections were not made for this carbonate unit, hence the following description is of hand samples only. Due to the poor exposure a stratigraphic thickness was not obtained.

C5 consists of mudstones and occasional wackestones. The rock is brownish gray to grayish black. Beds are massive in some locations, ranging from 15 to 30 cm thick. The carbonate is fetid and occasionally has a crystalline appearance on fresh surfaces. A bed of mudstone was found which contained definite interclasts of carbonate mud within a somewhat grainy, perhaps pelloidal, matrix.

The biologic assemblage includes large pelecypods, up to 12 cm in longest dimension, gastropods, worm tubes, ostracods, crinoids, and possibly algae. The crinoid ossicle observed was small, approximately 3 mm in diameter.

PALEOENVIRONMENT OF DEPOSITION

The biotic, petrologic, and stratigraphic data presented previously suggest that the paleoenvironment of deposition for the Torres Member was a high salinity, nearshore, restricted marine environment. More specifically, the data suggest that deposition occurred in the intertidal to supratidal zones of an ancient sea. The Torres, with it's interbedded limestones, sandstones, and gypsum layers, may be viewed as a small scale model for the depositional environment of the thicker, more consistent sandstone, gypsum, and limestone units which lie above the Torres. An interpretation of relevant data appears below.

BIOTIC EVIDENCE

The biota of the upper Torres carbonates are characterized by low diversity, small individual size, and an abundance which varies locally from nil to quite high. These general characteristics are indicative of an unstable, stressed environment (Dr. D. Johnson, pers. commun., 1987). The fossil assemblage consists of gastropods, pelecypods, ostracods, foraminifera, algal oncolites, algal strands, conodonts, and possibly tubiphytes. Sizes of individuals range from the majority being 2 mm or less to rare cases of 10 to 20 mm individuals.

With the exception of the San Andres Limestone, other stratigraphic units in the study area are nonfossiliferous. The San Andres contains gastropods, pelecypods, and other organisms. Individual size may be quite large -- up to 3-4 cm diameter gastropods were found. A more stable, less stressed environment is proposed for the San Andres. The small rounded bumps found within the limestone beds of the Cañas Member may suggest biotic activity of a limited extent.

Heckel (1972) published a diagram (Figure 15) which shows the relationship between fossilizable organisms and salinity. Euryhaline fossilizable organisms such as algae, ostracods, molluscs, and foraminifera listed in Figure 15 as being able to exist in high salinity, restricted marine waters match closely with the types of organisms found in the upper Torres carbonates. More significantly, none of the stenohaline fossilizable organisms which exist solely in normal marine waters (including corals, bryozoans, echinoderms, for example) are found in the Torres Member.

As noted in the section on the biotic assemblage, study of acid digested carbonate residues revealed various fish teeth, conodonts, and rare crinoid ossicles. The conodonts and crinoids were very small, again suggesting the harsh, restricted environmental conditions considered previously. The crinoids may have existed outside a restricted embayment and were washed in by storm waves, deposited out of life position. The relatively large crinoid ossicle (3 mm

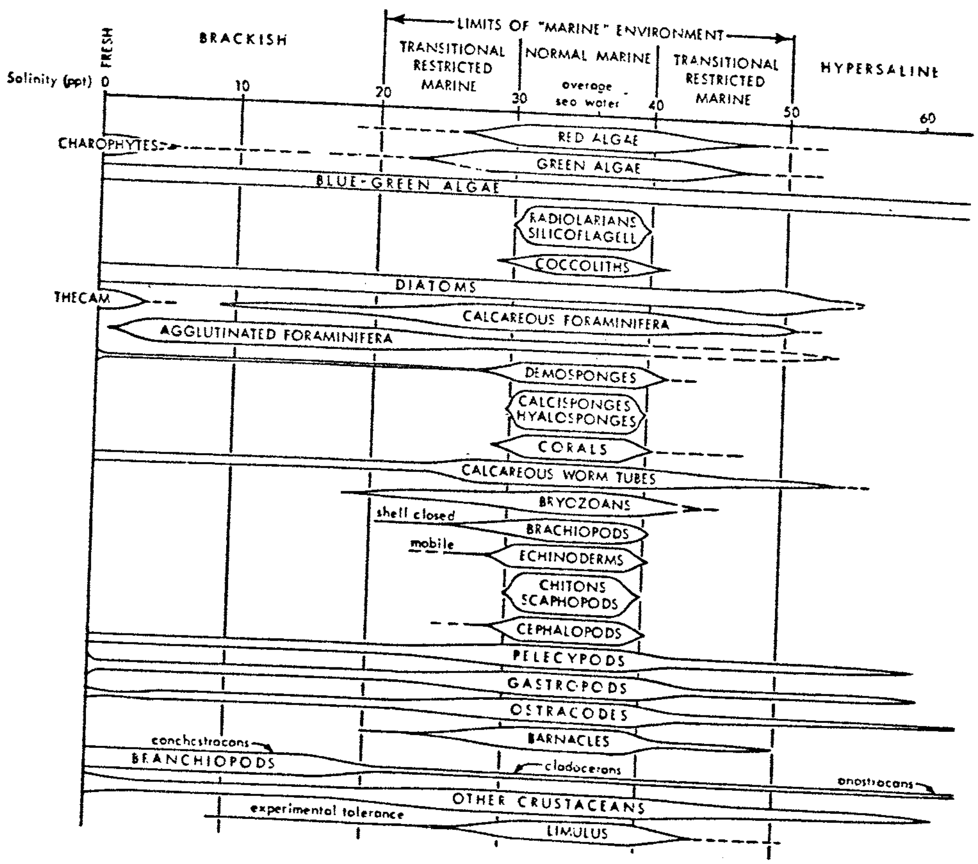


Figure 15: Relationship between fossilizable organisms and salinity. (after Heckel, 1972)

diameter) found in C5, the lowest exposed Torres carbonate, may indicate a somewhat lower salinity environment than the upper carbonate units. C5 also contained very large pelecypods, and a bed of interclastic mudstone. The large individual size of the pelecypods suggests a less stressed environment where nutrients were more abundant. The interclasts indicate a relatively high energy environment.

The conodonts, although they could have lived in the euryhaline conditions, could also have been carried in by currents. The restricted conditions, with an associated poor supply of nutrients could account for the small conodont size. Dr. D. Johnson (pers. commun., 1987) has suggested that the conodonts are juveniles which died before full growth was attained.

Worm tubes are also listed in the restricted marine section of Heckel's (1972) diagram (Figure 15). It is not known whether or not the burrows of the Torres carbonates were caused by worms. However, Wilson (1975), and Lucia (1972) both state that burrowed sediment in general is indicative of an intertidal environment. Wilson (1975) makes the distinction that vertical burrows imply that the preserved sediment was from the intertidal zone, while horizontal burrows suggest the supratidal zone. Both vertical burrows (Figure 16) and possibly horizontal burrows (Figure 12) occur in the upper Torres section.

A final piece of biotic evidence for a restricted marine

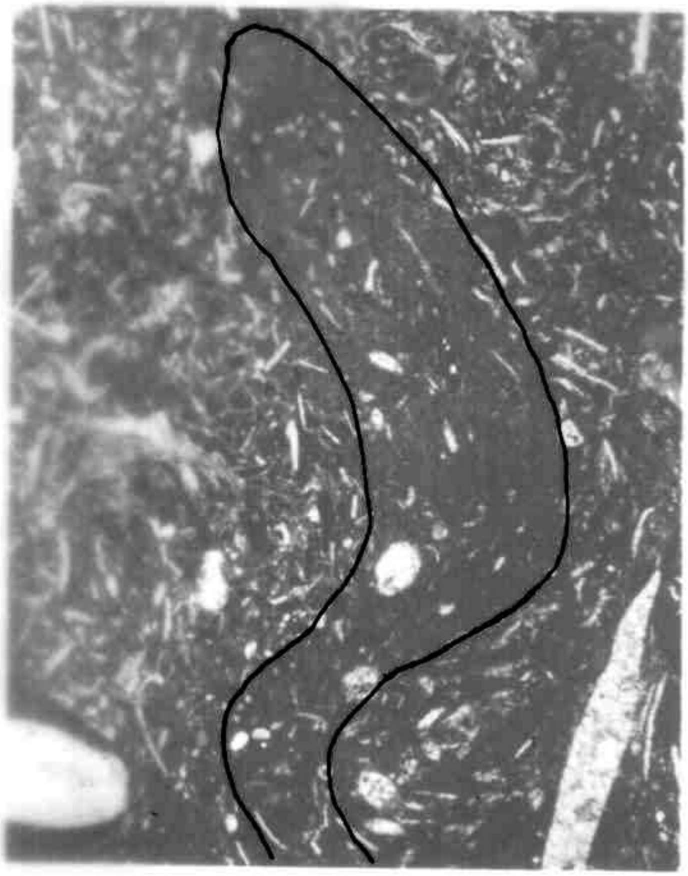


Figure 16: Photomicrograph of vertical burrow from SSI-Cl.
Crossed polarizers, 20X.

intertidal/supratidal paleoenvironment concerns the fine laminations and fenestral fabric which occurs in some of the Torres carbonate beds. Such laminae can be caused by algal mat formation in very shallow water (Wilson, 1975). The algal growth traps fine layers of carbonate mud. Periodic subaerial exposure causes drying of the sediment and the production of gas bubbles through putrefaction of organic matter within the sediment. The gas bubbles within the sediment are preserved as fenestral textures. Wilson (1975) contends that such dessication by subaerial exposure occurs in tidal flats.

STRATIGRAPHIC EVIDENCE

The stratigraphic section of the upper Torres Member (Appendices I and II) shows a package of sediments which may be interpreted as a repetitive sequence of small scale transgressions and regressions. The thick gypsum beds were likely deposited in a very shallow, low energy environment with high evaporation rates. To deposit the limestones, and for the biota to survive, a deeper environment is required, hence a transgression. The deposition of fine grained sandstone is perhaps due to an increased supply of terrigenous sediment, overwhelming carbonate sediment production. The lack of ripple marks and other sedimentary structures in the sandstone indicates a low energy environment of deposition. To return to evaporite deposition, a regression would have to occur.

Slight transgressions and regressions would change the environment from an evaporative zone to the deeper intertidal zone. The presence of evaporites, in particular, indicates a shallow, high salinity, restricted marine environment. Wilson (1975) notes that evaporites are associated with carbonate shoreline (intertidal) deposits.

PETROLOGIC EVIDENCE

Dolomite dominates the carbonates of the upper Torres Member. Both the seepage reflux and evaporative pumping models for dolomitization require marine waters close to a source of hypersaline waters with a high Mg/Ca ratio. The close association of apparently restricted marine carbonates and evaporites in the upper Torres fits these models. Elf-Aquitane (1982) states that "the necessary conditions for dolomitization are usually found in very shallow, low-energy environments." A nearshore, shallow environment is implied for the Torres sediments.

DIAGENETIC HISTORY

The diagenetic history of the carbonates in the upper Torres Member is fairly simple. (Note: The terminology used in the following discussion of diagenetic environments is after Longman, 1980). Micritic Mg-calcite cementation of the mud sized sediment probably occurred soon after deposition in the active marine phreatic zone. Micritization would stabilize the shape of the fossil grains that were subsequently dissolved away.

A slight fall in sea level (regression) moved the carbonate into the freshwater phreatic zone or the freshwater vadose zone. Solution by meteoric water undersaturated with respect to calcite preferentially leached the unstable aragonitic mollusc and ostracod grains, resulting in moldic porosity. The extensive solution also caused the formation of vuggy porosity and channel porosity along fractures in the limestone.

Neomorphism of the micrite to the abundant microspar occurred in response to a marine transgression, which moved the carbonate from a zone of solution into the stagnant freshwater phreatic environment.

A further relative rise in sea level resulted in the vuggy porous carbonate being moved beneath the freshwater vadose or phreatic zone. Dolomitization of the sediment took place here, filling moldic porosity with dolospar and causing replacement of the aragonitic matrix to dolomite. The seepage reflux model (Figure 17) for dolomitization seems to apply fairly well to the upper Torres carbonates. The environment of evaporite formation, further inland from the environment of carbonate deposition, produced dense brines relatively enriched in Mg^{++} due to the removal of Ca^{++} as gypsum and other salts. The dense brines with their elevated Mg/Ca ratio displaced the pore waters of the carbonate, flushing out Ca^{++} to the marine environment and replacing the Ca^{++} with Mg^{++}. Longman (1980) notes that mixing zones between the freshwater phreatic and marine phreatic environments are conducive to dolomitization even without associated evaporites. The upper Torres, however, with the abundant nearby evaporites, would not need to enter such a mixing environment for dolomitization to occur. Hence, the simplest answer is the seepage reflux model.

The possibility of two cemetation stages exists, as seen in Figure 7. The equant/bladed crust of dolospar formed inside the mold first, followed by precipitation of the blocky dolospar mosaic filling the center of the mold. Some voids, as in Figure 4, upper right, contain only the crust of equant dolospar. Void filling was not pervasive, however, due to the vuggy nature of the carbonates in outcrop at the present time. The gypsum filling of some pores almost certainly occurred after diagenesis, because of its high solubity. Gypsum void filling probably occurred in recent times, upon subaerial

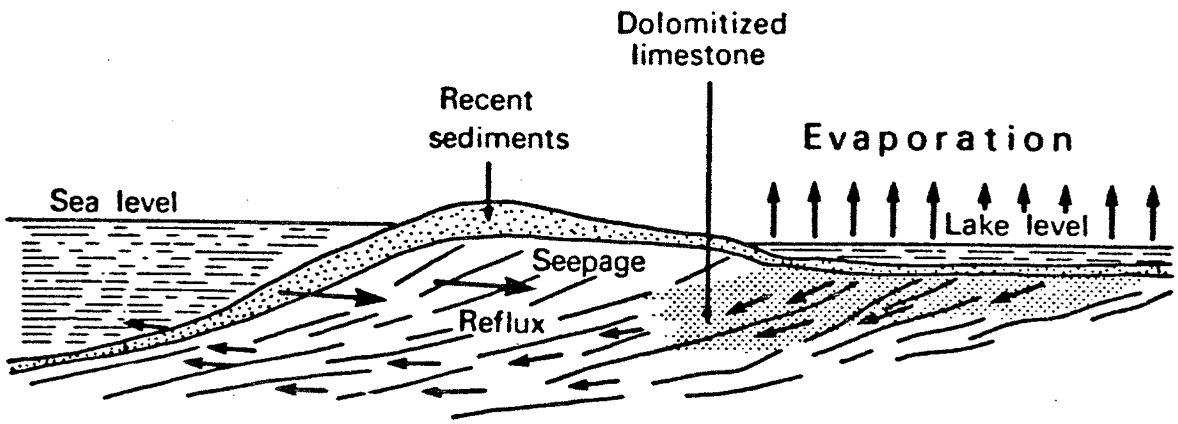


Figure 17: Seepage reflux model for dolomitization. (after Zenger, 1972)

exposure when meteoric waters flushed the evaporite from overlying beds into the carbonate. This process is continuing at the present.

FIELD GEOLOGIC OBSERVATIONS

During the course of this research, additional mapping of the dike area was conducted. This mapping concentrated on the Torres Member, with the goal of identifying the previously ambiguous carbonate beds. The results of this mapping may be seen in Plate 2, which is a revised version of the geologic map developed by Jochems (1987), Jenkins (1985) and other previous workers. Cross sections of the Jones Camp dike and the surrounding sediments are displayed in Plate 3 (after Jenkins, 1985)

Reconnaissance mapping was carried out in the area west of the dike, in search of the lower contact of the Torres Member with the Meseta Blanca. This contact was not found, despite the topographic relief of Antelope Mound and other such features located approximately 11 - 12 km north west of Chupadera Mesa. Speculatively, the formations exposed in these topographic features are the Cañas Member of the Yeso Formation, the Joyita Formation, and the Glorieta Formation, and, as in the study area, a section of lower San Andres Formation.

Drilling data, taken from a hole some 3.5 km east of

Antelope Mound in Section 28, Township 4S, Range 6E, indicates that the top of the Torres lies several hundred feet below the surface. The hole has been plugged and abandoned.

THERMAL COLOR ALTERATION OF CONODONTS

Conodonts collected from C1 in the immediate vicinity of the dike were noticeably darkened due to the heat of dike intrusion. Epstein, et al (1977) give approximate temperature ranges for various degrees of color alteration due to heating. Comparison of the Jones Camp conodonts to these colors/temperature ranges suggests that the host rocks were heated to approximately 190 to 300 ^{o}C. It should be noted that other factors in addition to temperature affect conodont color alteration. These factors include the effects of hydrothermal fluids.

GEOLOGIC CONTROL ON MINERALIZATION

The detailed study of the Jones Camp area stratigraphy allows positive identification of mineralized host rock beds. The upper limestone bed, C1, was identified along the length of the dike by stratigraphic relations, the biotic assemblage, general appearance, and by tracing bed continuity. C1 proved to be an excellent reference bed for stratigraphic orientation in the field.

The highest grade iron ore is localized in the upper limestone bed, C1, of the Torres Member. Along the western region of the dike, lower Torres carbonate beds such as C3 and C4 also host iron ore.

Due to the fact that lower Torres Member carbonate beds are often not exposed along the eastern region of the dike, it is impossible to determine if they host high grade iron ore in this area without an exploratory drilling program. If, however, relatively pure carbonate was the factor which caused precipitation of high grade ore, it is possible that further ore pods would be found in carbonate beds in the subsurface. Jochems (1987) found geophysical magnetic anomalies on the far west end of the dike, where dike rocks have not yet been exposed by weathering. Beds in the lower section of the Torres, or Meseta Blanca which are not exposed in the study area could host ore.

Lower grade iron ore is also found in Torres Member sandstone and gypsum beds. The sandstones are cemented with carbonate, providing a catalyst for ore precipitation. Gypsum, composed of $CaSO_4$, is also an ore host.

FUTURE WORK

Further study of the Jones Camp iron region should include stable isotope work, an exploratory drilling program, and a subsequent economic feasibility study of the site's potential for profitable mining.

Stable isotope geochemistry was originally proposed to be part of this study, but was curtailed due to the lack of necessary analytical equipment. The proposed research plan was to sample the Torres carbonate beds at regular intervals, moving laterally away from the dike. Mass spectrometer analysis of the samples for O_{18} would have revealed any fractionation of the ore bearing hydrothermal fluids as they penetrated the host rocks. This documenting of the evolving ore fluid would allow greater understanding of the hydrothermal system and mechanism of ore deposition.

An exploratory drilling program should concentrate initially on delimiting the thickness of known ore bodies so that accurate ore tonnages may be estimated. Further drilling should be directed towards determining if additional ore pods occur at depth. The logical places for this drilling would be on Jochems' (1987) magnetic anomalies. With the drilling data, a more accurate assessment of the economic potential of the Jones Camp deposits could be made.

CONCLUSIONS

Study of the stratigraphic, geologic and paleontological characteristics of the Chupadera Mesa and Jones Camp dike has resulted in the following conclusions:

1) Surficially exposed iron ore is confined to the upper part of the Torres Member of the Yeso Formation. The highest quality ore is hosted by C1, the uppermost carbonate unit of the Torres Member. Additional ore pods may be located lower in the section, but this cannot be determined without exploratory drilling.
2) The paleoenvironment of deposition of the sedimentary rocks of Chupadera Mesa is a confined basinal, near shore, shallow marine environment which experienced several transgression/regression cycles.
3) The biotic assemblage of the Torres Member consists of hypersaline, near shore, intertidal organisms. The organisms lived in a stressed environment. Some of the fossil remains, such as the conodonts, fish teeth, and crinoid ossicles, may have been washed into the confined basin to be deposited out of life position.
4) Petrologic analysis of Torres Member carbonates revealed that most of these rocks are mudstones/micrites, with occasional beds of fossiliferous wackestone/biomicrite.

The rocks range from very clean carbonate to silty carbonate. The carbonates of the Torres Member are pervasively dolomitized. The seepage reflux model of dolomitization is proposed as the most likely mechanism for dolomitization.

5) The carbonate beds of the Torres Member provide good marker units for stratigraphic orientation along the length of the Jones Camp dike. The uppermost carbonate unit, C1, is particularly useful due to the characteristic fossiliferous horizons.

6) The host rocks in the immediate vicinity of the dike were heated by the intrusion to approximately 190 to 300 $^{\circ}C$, as suggested by color alteration of conodonts.

BIBLIOGRAPHY

Bickford, D. A., 1980, Economic geology of the Jones Camp iron deposit, Socorro County, New Mexico: unpublished Master of Science thesis, New Mexico Institute of Mining and Technology.

Dunham, R. J., 1962, Classification of carbonate rocks according to depositional texture: in Ham, W. E., ed., Classification of Carbonate Rocks, AAPG Mem. 1, p. 108-121.

Elf-Aquitane, 1982, Exploration for Carbonate Petroleum Reservoirs: Reickmann, A. and Friedman, G. M., translators, p. 213.

Emmons, N. W., 1906, The Jones iron fields of New Mexico: Mining Magazine, v. 13, p. 109-116.

Epstein, A. G., Epstein, J. B., Harris, L. D., 1977, Conodont Color Alteration -- an Index to Organic Metamorphism: Geological Survey Professional Paper 995, U. S. Government Printing Office, Washington, 27 p.

Folk, R. L., 1962, Spectral subdivision of limestone types: in Ham, W. E., ed., Classification of Carbonate Rocks, AAPG Mem. 1, p. 62-84.

Gibbons, T. L., 1981, Geochemical and petrographic investigation of the Jones Camp magnetite ores and associated intrusives, Socorro County, New Mexico: unpublished Master of Science thesis, New Mexico Institute of Mining and Technology.

Goddard, E. N., Trask, P. D., DeFord, R. K., Rove, O. N., Singewald, J. T., Jr., and Overbeck, R., M., 1963, Rock-Color Chart: The Geological Society of America, New York, New York.

Grantham, R. M., and Soule, J. H., 1947: Jones iron deposit Socorro County, New Mexico, U. S. Bureau of Mines, Report of Investigation 4010, 4 p.

Heckel, P. H., 1972, Recognition of ancient shallow marine environments: in Rigby, J. K. and Hamblin, W. K., eds., Recognition of ancient sedimentary environments, SEPM Spec. Pub. 16, p. 226-286.

Jenkins, J., 1985, Geology and geochemistry of the Jones Camp magnetite deposits, Socorro County, New Mexico: unpublished Master of Science thesis, New Mexico Institute of Mining and Technology.

Jochems, T. P., Jr., 1987, Geological, paleomagnetic and geophysical studies at Jones Camp Dike, Socorro County, New Mexico: unpublished Master of Science thesis, New Mexico Institute of Mining and Technology.

Jones, F. A., 1904, New Mexico Mines and Minerals (1904 World's Fair edition): the New Mexico Printing Co., Santa Fe, New Mexico, p. 102-103.

Kelley, V. C., 1949, Geology and economics of New Mexico iron ore deposits: University of New Mexico Publications in Geology n. 2., The University of New Mexico Press, Albuquerque, New Mexico, p. 213-222.

Kelley, V. C. and Thompson, T. B. 1964, Tectonics and general geology of the Ruidoso-Carrizozo region, central New Mexico: New Mexico Geological Society Guidebook, 15th Field Conference, p. 110-121.

Keyes, C. R., 1904, Iron deposits of the Chupadera mesa: The Engineering and Mining Journal, v. 78, p. 632.

Lasky, S. G., 1932, The ore deposits of Socorro County, New Mexico: New Mexico Bureau of Mines and Mineral Resources, Bulletin n.8, p. 137-139.

Lee, W. T. and Girty, G. H., 1909, The Manzano Group of the Rio Grande Valley, New Mexico: U. S. Geological Survey Bulletin 389, 141 p.

Lindgren, W., Graton, L. C., and Gordon, C. H., 1910, The ore deposits of New Mexico: U. S. Geological Survey Professional Paper 68, p. 203-204.

Longman, M. W., 1980, Carbonate diagenetic textures from nearsurface diagenetic environments: AAPG Bulletin, v. 64, n. 4, p. 461-487.

Lucia, F. J., 1972, Recognition of evaporite--carbonate shoreline sedimentation: in Rigby, J. K. and Hamblin, W. K., eds., Recognition of ancient sedimentary environments, SEPM Spec. Pub. 16, p. 160-191.

Needham, C. E. and Bates, R. L., 1943, Permian type sections in central New Mexico: Geological Society of America Bulletin, v. 54, p. 1653-1668.

Noguiera, A. C., 1971, Mineralogy and geochemistry of contact metasomatic iron deposits at Jones Camp, Socorro County, New Mexico: unpublished Master of Science thesis, New Mexico Institute of Mining and Technology.

Robison, B. A., ed., 1981, Treatise on invertebrate paleontology, part W, Supplement 2, Conodonta.

Schrader, F. C., 1910, Iron deposits of the northern Sierra Oscura: in Geological Survey Professional Paper: The ore deposits of New Mexico, n. 68, p. 203-205.

Scoffin, T. P., 1987, An introduction to carbonate sediments and rocks: Blackie and Son, Glasgow, 274 p.

Van Der Plas, L. and Tobi, A. C., 1965, A chart for judging the reliability of point counting results: American Journal of Science, v. 263, p. 87-90.

Wilson, J. L., 1975, Carbonate facies in geologic history: Springer-Verlag, New York, 471 p.

Zenger, D. H., 1972, Dolomitization and uniformitarianism: J. Geol. Educ., v. 20, p. 107-124.

APPENDIX I

DESCRIPTION OF STRATIGRAPHIC SECTIONS

The following written description of Stratigraphic Sections I and II (SSI and SSII respectively) follows the same labeling convention as described in the text. The sections are described from the bottom to the top, or from the oldest rocks to the youngest rocks. The Torres Member carbonates are labeled in sequence, with SSI-C4 being the lowest carbonate in SSI, SSI-C3 being the next highest, et cetera. SSI-C1 is the uppermost carbonate in SSI. SSII carbonates are labeled in the same manner.

STRATIGRAPHIC SECTION I

YESO FORMATION

TORRES MEMBER

INTERVAL	DESCRIPTION
0 - 10.5 m	15 to 50 cm thick beds of gypsum, mottled very light gray (N8) to (N3), weathering to light to moderate brown (5 YR 5/6 to 5 YR 4/4), crops out as nearly vertical blocky faces within the arroyo, weathers to a slope former outside the arroyo.
10.5 - 11.0	Soft, crumbly, well sorted sandstone, dark yellowish orange (10 YR 6/6) to moderate yellowish brown (10 YR 4/4), weathers more rapidly than surrounding gypsum, does not effervesce with dilute HCl.
11.0 - 13.6	Bedded, massive gypsum, colors are the same as the 0 - 10.5 m interval, fine laminations within the beds alternating light gray and dark gray gypsum, the couplets are approximately 0.5 cm thick, dark laminae are organic rich, light gray gypsum is organic poor.

13.6 - 17.1 SSI-C4 -- carbonate mudstone, beds 10 - 25 cm thick, interbedded with 10 - 25 cm beds of silty sand, generally dolomitic, fetid.

SUBINTERVALS OF SSI-C4

13.6 - 13.7 Carbonate mudstone, gypsiferous, slightly calcitic, fossil molds were observed in thin section, colored moderate yellowish brown (10 YR 5/4).

13.7 - 13.76 Carbonate mudstone, clean, dolomitic, fetid, dark gray (N3) fresh, weathers to light gray (N7).

13.76 - 13.8 Silty sand, unconsolidated, light brown (5 YR 6/4).

13.8 - 13.9 Carbonate mudstone, silty, dark yellowish brown (10 YR 4/2).

13.9 - 14.0 Silty sand, crumbly.

14.0 - 14.1 Carbonate mudstone, fairly clean, possible fossil grains, medium gray (N5) fresh, light gray (N7) weathered.

14.1 - 14.4 Section covered, possibly clean mudstone.

14.4 - 15.5 Mudstone, silty, very fetid, alternating 10 - 25 cm beds of light brown (5 YR 5/6) and moderate brown (5YR 3/4) rock, light brown rock is reentrant forming, moderate brown weathers to small rounded blocks or buttresses, contains molluscs, ostracods, algae, possible forams.

15.5 - 15.85 Silty sand, somewhat incompetent, overhangs previous alternating sequence.

15.85 - 15.95 Carbonate mudstone, fairly clean, medium gray (N5) fresh, weathers to light gray (N7).

15.95 - 16.5 Interbedded carbonate mudstone and shale, slope former, shale is finely laminated, colored moderate brown (5 YR 3/4).

16.5 - 16.75 Carbonate mudstone, calcitic, gastropods, mollusc fragments, algal strands were observed in thin section, light gray (N7).

16.75 - 16.95 Carbonate mudstone, dolomitic, brownish gray (5 YR 4/1) when fresh, weathers to grayish black (N2)

16.95 - 17.1 Carbonate mudstone, silty, moderate brown (5 YR 3/4 to 4/4).

END SSI-C4

17.1 - 23.3 Gypsum, similar to the gypsum lower in the section, weathers to detritus covered slope, possible bedding and lamination couplets are obscured, detritus is light gray carbonate, or moderate reddish orange (10 R 6/8) sand and silt in the upper part of the interval.

23.3 - 28.2 Sandstone, crumbly, carbonate cemented, weathers to rounded cliff forms with some interbeds of slope forming, incompetent, silty sandstone, color is pale yellowish orange (10 YR 8/6) to light gray, the bulk being yellowish -- at the 26.5 and 28.05 m levels, 15 cm beds of massive gypsum occur, resistant, blocky weathering, overhanging the sandstone.

28.2 - 33.0 SSI-C3 -- in general, SSI-C3 is more blocky and massive deep in the arroyo, and more fissile and silty along the arroyo walls due to different weathering mechanisms.

SUBINTERVALS OF SSI-C3

28.2 - 29.81 Interbedded silty carbonate mudstone and siltstone, carbonate beds are competent, blocky weathering, 5 - 10 cm thick, siltstone beds are less resistant, reentrant forming, 1 - 4 cm thick and composed of 0.3 to 1.0 cm thick laminae, biotic elements include mollusc fragments, gastropods, ostracods, rare pelloids color of the interval is medium to light gray (N5 - N7), weathering to pale yellowish orange (10 YR 8/6).

29.81 - 29.93 Carbonate mudstone, fossiliferous, mollusc fragments, algae, ostracods, rare pelloids.

29.93 - 30.6 Siltstone, fissile texture.

30.6 - 30.9 Sandstone, massive cliff former, silty, carbonate cemented, fine grain, fairly well sorted.

30.9 - 33.0 Carbonate mudstone, massive 10 to 45 cm beds, silty, occasional mollusc molds.

END SSI-C3

33.0 - 34.5 Sandstone, resistant cliff former within the arroyo, beds are 10 - 30 cm thick, weathers to flat bedding planes outside arroyo, forming a "stair step" slope, color is yellow (10 YR 8/6) to grayish orange (10 YR 7/4).

34.5 - 37.5 Sandstone, slope former, slope covered with gypsum detritus and eroded sandstone.

37.5 - 38.77 Sandstone, loose, poorly consolidated, well sorted, carbonate cemented, source of slope sand detritus.

38.77 - 39.54 SSI-C2 -- gypsiferous carbonate mudstone and gypsum.

SUBINTERVALS OF SSI-C2

38.77 - 38.87 Carbonate mudstone, finely laminated, interlaminated with gypsum, medium gray (N5).

38.87 - 38.94 Gypsum, white.

38.94 - 39.14 Carbonate mudstone, 0.35 to 2.0 cm thick beds, dolomitic, silty, slightly fetid, contains small recrystallized lumps and possible burrows, suggesting possible biotic action.

39.14 - 39.29 Gypsum, white, interlayered with 1 cm beds of silty, brownish black (5 YR 2/1) mudstone, the interval is crenulated -- gypsum layers vary in thickness and number of mudstone beds range from 2 to 4 at different locations laterally along the interval.

39.29 - 39.32 Carbonate mudstone, blocky weathering.

39.32 - 39.54 Carbonate mudstone, finely laminated, shale - like, calcitic, grayish black (N2) -- contact with underlying blocky mudstone is gradational over a few centimeters, tan gypsum from overlying beds fills 0.5 to 1.0 cm fractures in the mudstone.

END SSI-C2

39.54 - 54.25	Gypsum, bedded, forms a blocky slope/cliff within arroyo, weathers to slope outside arroyo, where exposed, the gypsum is mottled light gray/white and medium dark gray, where slope covered, the detritus is stained moderate reddish brown (10 R 4/6) to moderate reddish orange (10 R 6/6) by the overlying sandstone.
54.25 - 55.18	Sandstone, lower contact approximate, well sorted, massive 30 cm thick beds, cliff former, obscured by slope cover in some places, moderate reddish orange (10 R 6/6) with occasional splotches of grayish orange pink (10 R 8/2).
55.18 - 58.44	Sandstone, as in interval below, except colored yellow.
58.44 - 58.48	Sandstone, silty, fissile texture.
58.48 - 58.51	Carbonate mudstone, dolomitic, recrystallized, medium light gray (N6).
58.51 - 58.61	Siltstone, crumbly, reentrant forming medium light gray (N6).
58.61 - 59.4	Siltstone, fissile texture, more resistant than underlying bed, forms reentrant,becomes more resistant near the top of the interval, gypsiferous, color is dark yellowish brown (10 YR 5/4), surficially

stained light gray and reddish orange.

59.4 - 59.77 Sandstone, resistant cliff former, silty, moderate yellowish brown (10 YR 5/4).

59.77 - 59.8 Siltstone, sandy, fissile.

59.8 - 67.5 SSI-C1 -- carbonate mudstone, dolomitic, fossiliferous, fossils have been dissolved with dolomitic spar reprecipitated in the void spaces, some packestone and wackestone horizons, fossil types include gastropod and pelecypod fragments, ostracods, oncolites, condonts, possibly algae.

SUBINTERVALS OF SSI-C1

59.8 - 60.44 Carbonate mudstone, sandy, resistant cliff former, trace of mollusc fragments, fetid, crystalline appearance, color is dark yellowish brown (10 YR 4/2).

60.44 - 60.45 Calcareous shale, fissile texture.

60.45 - 60.62 Packstone, resistant, dolomitic, fetid, mollusc fragments, oncolites, ostracods, foraminifera, pelloids, algae color is brownish gray (5YR 4/1).

60.62 - 61.08 Interbedded carbonate mudstone and calcareous shale, cliff former within arroyo, slope out of arroyo, variable bed thickness -- carbonate beds vary from 2.0 to 11 cm, shale beds are 1.0 to 16 cm, mollusc and ostracod fragments were observed scattered through the interval, brownish black (5 YR 2/1).

61.08 - 61.33 Wackestone, massive cliff former, molluscs and oncolites, dissolved and molds filled with dolospar, brownish gray (5 YR 4/1).

61.33 - 62.38 Interbedded carbonate mudstone and calcareous shale, mudstone beds 2 - 7 cm thick, shale beds are approximately 0.5 cm, cliff former within arroyo, slope former outside arroyo, the interval gets more fissile and less resistant towards the top, brownish gray (5 YR 4/1) to dark gray (N3).

62.38 - 62.47 Carbonate mudstone, resistant buttress former, brownish gray (5 YR 4/1).

62.47 - 62.79 Carbonate mudstone, sandy resistant cliff former, overhangs carbonate/shale sequence in arroyo, dark yellowish brown (10 YR 4/2).

62.79 - 62.88 Carbonate mudstone, shaly, fissile texture, brownish gray (5 YR 4/1).

62.88 - 63.40 Carbonate mudstone, sandy, resistant cliff former, the upper 15 cm of the interval are thin bedded, 1 - 2 cm, weathers to 0.75 cm diameter rounded bumps.

63.40 - 63.55 Calcareous shale, weathers to a reentrant.

63.55 - 63.68 Carbonate mudstone, massive, buttress former, fossiliferous.

63.68 - 63.74 Carbonate mudstone, thin bedded, fissile texture, cave former.

63.74 - 63.89 Wackestone, massive, calcitic, mollusc fragment molds filled with spar, pelloids, medium dark gray (N4).

63.89 - 65.66 Carbonate mudstone, massive sandy to shale - like, weathers to a somewhat fissile appearance, becomes more fissile towards the top, 0.75 cm diameter bumps scattered across weathered surfaces, calcitic, occasional fossils, including oncolites.

65.66 - 65.70 Calcareous shale, transitional bed.

65.70 - 65.87 Carbonate mudstone, 4 - 7 cm beds of mudstone interbedded with thin calcareous shale, some recrystallized fossils, brownish gray (5 YR 4/1) to brownish black (5 YR 2/1).

65.87 - 66.18	Packstone, massive, fossil hash of mollusc fragments, ostracods, dolomitic spar filled molds, algae, foraminifera, medium gray (N5).
66.18 - 66.20	Calcareous shale.
66.20 - 66.78	Interbedded carbonate mudstone and calcareous shale mudstone beds are resistant, 1 - 7 cm thick, shale beds are fissile, thin, interval color is brownish gray (5 YR 4/1), weathers to light gray (N7).
66.78 - 66.87	Carbonate mudstone, less resistant than underlying interval, shaly, pinkish gray (5 YR 8/1).
66.87 - 66.90	Pelloidal wackestone, biotic assemblage is the same as in lower beds of SSI-C1.
66.90 - 67.54	Interlayered sandy fossiliferous carbonate mudstone and gypsum, resistant, overhangs underlying wackestone, brownish gray (5 YR 4/1), transitional bed to Canas Member.

END SSI-C1

CAÑAS MEMBER

67.54 - 77.18	Gypsum, bedded, resistant, forms blocky

cliffs within arroyo, weathers to slope outside arroyo, the gypsum is white with thin medium dark gray (N4) laminae.

77.18 - 77.44 Calcareous siltstone, gypsiferous, reentrant former, very light gray (N8) to light brownish gray (5 YR 4/1).

77.44 - 84.47 Gypsum, massive, bedded, white to grayish.

84.47 - 84.74 Silty rock, incompetent, weathers to cave, gypsum veins, distinct pale reddish brown (10 R 5/4) to grayish red (10 R 4/2).

84.74 - 85.45 Gypsum, massive.

85.45 - 85.63 Siltstone, incompetent, cave former, fissile texture, mottled colors -- dusky yellow (5 Y 6/4), light olive brown (5 Y 4/4), yellowish gray (5 Y 7/2), olive gray (5 Y 3/2), the bulk of the interval is greenish.

85.63 - 85.66 Gypsum, white to light gray.

85.66 - 85.88 Siltstone, cave former, fissile, as from 85.45 to 85.63.

85.88 - 94.90 Gypsum, massive, bedded, blocky cliff former.

94.90 - 95.57 Siltstone, soft, reentrant forming, gypsiferous, greenish gray (10 GY 5/2).

95.57 - 110.15 Gypsum, massive.

110.15 - 110.45 Calcareous silt, incompetent, reentrant former grayish red (10 R 4/2) to dusky yellowish brown (10 YR 2/2).

110.45 - 111.89 Carbonate mudstone, fairly resistant, is overhung by gypsum, thin 1 cm thick beds, occasional gypsum laminae within carbonate, upper 20 cm has 0.5 cm diameter dark spheroids, color is generally grayish red (10 R 4/2) to dusky yellowish brown (10 YR 2/2), the center of the interval is gray.

111.89 - 117.30 Gypsum, massive, bedded, white to gray.

117.30 - 117.41 Siltstone, fissile, approximately 0.3 to 0.5 cm thick gypsum interlaminations, silt is colored moderate yellowish brown (10 YR 5/4).

117.41 - 119.06 Gypsum, detritus covered slope.

119.06 - 119.33 Carbonate mudstone, resistant, forms rounded buttress overhung by gypsum, sandy, slightly fetid, some recrystallized molluscan fossils, colored dark yellowish brown (10 YR 4/2).

119.33 - 119.91 Laminated gypsum, 0.5 to 5 cm beds of brownish black (5 YR 2/1) gypsum interlaminated with 0.2 to 0.5 cm beds of white gypsum, less resistant than overlying massive gypsum.

119.91 - 121.65 Gypsum, massive, bedded.

121.65 - 121.90 Laminated gypsum, as from 119.33 to

119.91, less resistant than surrounding gypsum.

121.90 - 128.62 Gypsum, massive, bedded.

JOYITA MEMBER

128.62 - 131.96 Sandstone, weathers to fairly massive forms, thin, 1 to 2 cm thick beds, the rock is somewhat incompetent, crumbles easily, fairly well sorted, carbonate cemented, moderate reddish brown (10 R 4/4) to dark reddish brown (10 R 3/4).

131.96 - 133.49 Gypsum, massive.

133.49 - 142.01 Sandstone, fairly massive, thin bedded, bedding thins towards the top of the interval, porous, soft, weathers to light gray (N7) and grayish pink (5 R 8/2).

142.01 - 142.29 Sandstone, fissile texture.

142.29 - 145.42 Sandstone, fairly massive.

145.42 - 145.5 Sandstone, less resistant, thin bedded, overhung by more massive sandstone above.

145.5 - 150.0 Sandstone, massive cliff former.

fissile, thin bedded slope former, moderate reddish brown (10 R 4/4).

154.73 - 154.82 Sandstone, more resistant, overhangs interval below in arroyo.

154.82 - 156.85 Sandstone, fissile slope former.

156.85 - 158.08 Sandstone, massive outcrop former, fissile texture, but fairly resistant.

158.08 - 158.95 Sandstone, slope former, fissile.

158.95 - 160.94 Sandstone, rounded cliff former, moderate reddish orange (10 R 6/6) in exposed outcrop.

160.94 - 161.46 Sandstone, reentrant former, fissle.

161.46 - 162.24 Sandstone, massive cliff former.

162.24 - 165.5 Sandstone, fissile slope former.

165.5 - 165.6 Sandstone, resistant bed.

165.6 - 168.35 Sandstone, fissile slope former.

168.35 - 168.72 Sandstone, resistant, massive.

168.72 - 168.94 Sandstone, fissile slope former.

168.94 - 169.09 Sandstone, massive bed.

169.09 - 170.25 Sandstone, fissile, slope former.

170.25 - 173.66 Sandstone, fairly massive, less fissile, still slope former.

173.66 - 173.86 Sandstone, fissile.

173.86 - 174.35 Sandstone, massive.

174.35 - 175.29 Sandstone, massive, thinner beds.

175.29 - 175.64 Sandstone, resistant, approximately 30 cm thick beds, pinkish gray (5 YR 8/1) mottled with grayish orange (10 YR 7/4) and dusky yellowish brown (10 YR 2/2).

175.64 - 175.81 Sandstone, reentrant former, grayish orange (10 YR 7/4).

175.81 - 176.47 Carbonate mudstone, resistant, cliff former, overhangs sandstone beneath, beds are 2 to 6 cm, interbedded with gypsum laminae, light brownish gray (5 YR 6/1) on fresh surfaces, weathers to light gray (N7).

176.47 - 176.8 Interbedded carbonate mudstone and 1 cm and thicker beds of gypsum, carbonate has a blocky appearance in outcrop, dark gray (N3) fresh, light gray (N7) weathered.

176.8 - 180.65 Gypsum, bedded, massive, mottled shades of gray.

GLORIETA FORMATION

180.65 - 187.85 Sandstone, slope former, well sorted, carbonate cemented, color in outcrop varies from white (N9) to grayish orange (10 YR 7/4) to dark yellowish orange (10 YR 6/6), the overall impression is a buff color.

187.85 - 191.26 Sandstone, massive beds, cliff former, color as in interval below.

191.26 - 202.99 Sandstone, slope former, with rounded massive beds cropping out through slope.

SAN ANDRES FORMATION

202.99 - 207.0	Limestone, carbonate mudstone, massive 10 to 40 cm thick beds, cliff former, fossiliferous -- molluscs, gastropods up to 3 cm in diameter, fresh color is medium gray (N5), weathers to yellowish gray (5 Y 7/2).
207.0 - 230.25	Carbonate mudstone, detritus covered slope.
230.25 - 234.0	Carbonate mudstone, massive cliff former.
234.0	Erosional unconformity.

APPENDIX II

STRATIGRAPHIC SECTION II

YESO FORMATION

TORRES MEMBER

INTERVAL	DESCRIPTION
0 - 7.65 m	Bedded gypsum, the basal 40 cm are moderate reddish brown (10 R 4/6) to dark reddish brown (10 R 3/4), above the 40 cm level, the gypsum is mottled very light gray (N8) to brownish gray (5 YR 4/1).
7.65 - 12.0	Sandstone, well sorted, fairly competent, gypsiferous near the base, moderate reddish brown (10 R 4/6).
12.0 - 13.5	Sandstone, less competent, color changes to moderate yellowish brown (10 YR 5/4).
13.5 - 16.5	Sandstone, alluvium covered slope former.
16.5 - 16.8	Sandstone, exposed outcrop, gypsiferous.
16.8 - 19.5	Sandstone, slope former, gypsiferous.
19.5 - 21.24	Gypsum, bedded, cliff former, light gray, contact with underlying sandstone is approximate.
21.24 - 22.88	SSII-C4: Carbonate mudstone, fossiliferous

and pelloidal in thin section, contains molluscs, ostracods, algae, foraminifera, 5 - 10 cm thick beds with thin shaly interbeds, calcitic, cliff former, color is brownish gray (5 YR 4/1).

22.88 - 30.06 Sandstone, carbonate cemented, partially slope covered moderate yellow brown (10 YR 4/1) on fresh surfaces, very pale orange (10 YR 8/2) on weathered surfaces.

30.06 - 36.6 SSII-C3

SUBINTERVALS OF SSII-C3:

30.06 - 33.3 Carbonate mudstone, 5 - 10 cm thick beds with thin shaly interbeds, some sand content in mudstone, cliff former, fossiliferous -- recrystallized molluscs, algae, pelloidal in thin section, weathers to small rounded bumps due to fossils, colored grayish olive green (5 GY 3/2) to dusky yellow green (5 GY 5/2) with some darker mottled areas.

33.3 - 33.6 Carbonate mudstone with fissile texture.

33.6 - 34.25 More resistant mudstone, somewhat sandy, slightly fetid.

34.25 - 35.7 Sandstone, competent, rounded cliff former, grayish olive (10 Y 4/2) fresh, yellow gray (5 Y 7/2) on weathered surfaces -- fissile, more thinly bedded towards the top, color becomes moderate brown (5 YR 3/4) fresh, dark yellowish orange (10 YR 6/6) weathered.

35.7 - 36.6 Carbonate mudstone, thin 0.5 to 2.0 cm beds, gypsiferous near top of interval, colored brownish gray (5 YR 4/1).

END SSII-C3

36.6 - 51.0 Gypsum, bedded, alluvium covered from 43.5 - 51.0 m

51.0 - 74.67 Sandstone, contact with underlying gypsum is approximate, fairly well sorted, slope former, dark yellowish brown (10 YR 4/2) fresh, grayish orange pink (5 YR 7/2) weathered, becomes fissile,more thinly bedded at 61.5 m, from 64.5 to 69 m, the color becomes mottled grayish orange pink and dark yellowish orange (10 YR 6/6), the uppermost 1.17 m is shaly, cave forming.

74.67 - 78.0 SSII-C2

SUBINTERVALS OF SSII-C2

74.67 - 75.2 Carbonate mudstone, fissile beds low in the interval, grades from 5 to 20 cm thick beds towards the top, mudstone is calcitic, cliff former, overhangs underlying sandstone, fossiliferous -- contains pelecypods and gastropod fragments, trace of algae, colored pale yellowish brown (10 YR 6/2).

75.2 - 75.37 Carbonate mudstone, shaly, cave forming, grayish orange (10 YR 7/4).

75.37 - 78.0 Interlayered carbonate mudstone and calcareous shale, mudstone is sandy, beds are crenulated, massive beds up to 10 - 15 cm cliff former, fossiliferous at top of interval -- contains mollusc fragments, gastropods, trace of algae, color is moderate yellowish brown (10 YR 5/4).

END SSII-C2

78.0 - 91.57 Alluvium covered slope, sandy soil, possibly underlain by sandstone or gypsum, soil color is very light gray (N8) to grayish orange (10 YR 7/2), covered by fossiliferous carbonate float, carbonate colors are greenish gray (5 GY 6/1) to light brownish gray (5 YR 6/1) on fresh surfaces, and pale yellow brown (10 YR 6/2) weathered.

91.57 - 91.84 Gypsum, exposed outcrop, mottled grayish orange (10 YR 7/2) to light gray.

91.84 - 100.5 Gypsum, covered by sandy soil and alluvial float.

100.5 - 107.5 Gypsum, exposed outcrop, bedded, stained grayish orange pink (10 R 8/2), section here is folded and structurally altered, perhaps due to solution collapse measurements are approximate.

107.5 - 113.3 Sandstone, somewhat competent, rounded buttress or slope former, fair to poor sorting, color is very pale orange (10 YR 8/2) to grayish orange (10 YR 7/4).

113.3 - 114.3 Gypsum, massive bedded.

114.3 - 118.52 SSII-C1

SUBINTERVALS OF SSII-C1

114.3 - 116.24 Carbonate mudstone, massive cliff former, thin bedded, sandy, fetid, contains molluscs, gastropods, ostracods, possible burrows, dark yellowish brown (10 YR 4/2), occasional 0.5 to 1.0 cm interbeds of less sandy, more competent carbonate mudstone with a crystalline appearance, interbeds are colored brownish gray (5 YR 4/1) to olive gray (5 Y 4/1).

116.24 - 116.3 Carbonate mudstone, resistant, overhangs the underlying layer, crystalline appearance, fetid, fossiliferous -- mainly mollusc fragments and ostracods, the rock is approaching a wackestone, brownish black (5 YR 2/1).

116.3 - 116.46 Wackestone, competent cliff former, sandy, fossils are recrystallized, red (10 R 2/2) to medium light gray (N6).

116.46 - 117.32 Calcareous shale, fissile texture, slope former, fossiliferous -- mollusc fragments, gastropods, possible traces of algae and foraminifera, fresh color is brownish black (5YR 2/1), weathers to light brownish gray (5 YR 6/1).

117.32 - 117.42 Carbonate mudstone, massive resistant bed, crops out through shaly slope, fossiliferous, brownish black (5 YR 2/1) to olive black (5 Y 2/1).

117.42 - 117.99 Calcareous shale, brownish black (5 YR 2/1).

117.99 - 118.52 Interbedded fissile, pale yellowish brown (10 YR 6/2) mudstone and fissile brownish black (5 YR 2/1) calcareous shale, beds are thin, 0.3 to 1.0 cm thick, contains mollusc fragments, gastropods, possibly a trace of foraminifera.

END SSII-C1

118.52 - 119.44 Interbedded sandstone and shale, sandstone beds become more massive near the top of the interval, reaching 10 cm thick, pale yellowish brown (10 YR 6/2).

119.44 - 119.54 Fissile sandstone, cave forming.

119.54 - 119.87 Massive sandstone, pale yellowish brown (10 YR 6/2).

119.87 - 120.07 Incompetent sandstone, cave forming.

120.07 - 120.17 Resistant sandstone, overhangs cave beneath.

120.17 - 120.23 Loose, incompetent sand, weathers to reentrant.

120.23 - 120.30 Resistant sandstone.

120.30 - 120.34 Incompetent shaly/sand horizon, reentrant forming, gypsiferous on weathered surface.

120.34 - 120.44 Resistant sandstone.

120.44 - 120.62 Incompetent shaly/sand horizon, reentrant forming, gypsiferous on weathered surface.

120.62 - 120.74 Resistant sandstone.

120.74 - 121.17 Incompetent sand horizon, weathers to cave, gypsiferous on weathered surface.

121.17 - 121.24 Resistant sandstone.

CAÑAS MEMBER

121.24 - 130.64	Gypsum, bedded, can be exposed as massive buttresses or weather to a slope, fresh color is very light gray (N8), weathered slope surficial colors are light brownish gray (5 YR 6/1) to grayish orange (10 YR 7/4).
130.64 - 131.0	Incompetent sandy siltstone, with 2 cm thick interbeds of white, crystalline gypsum, siltstone is mottled yellow, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4).
131.0 - 131.17	Incompetent sandy siltstone, greenish gray (5 GY 6/1).
131.17 - 148.5	Gypsum, bedded, generally a slope former, with occasional 1 m cliffs of massive gypsum cropping out.
148.5 - 150.0	Cliff of massive gypsum.
150.0 - 163.6	Gypsum, slope former.
163.6 - 163.9	Carbonate mudstone, resistant cliff former, beds are 2 to 10 cm thick, thinning towards the top of the interval, interbedded with gypsum.
163.9 - 168.1	Gypsum, bedded.
168.1 - 168.55	Gypsum, thin bedded, 0.2 to 1.0 cm beds of alternating medium dark gray (N4) and

grayish orange (10YR 7/4) or light gray.

168.55 - 168.66 Sandy incompetent rock, reentrant forming, grayish green.

168.66 - 168.8 Gypsum, fine beds 1.0 to 1.5 cm thick, alternating light and dark gray beds.

168.8 - 168.88 Sandy, gypsiferous material, grayish orange (10 YR 7/4) to moderate yellowish brown (10 YR 5/4).

168.88 - 169.01 Carbonate mudstone, sandy, fetid, various colors: dark yellowish brown (10 YR 4/2) or light brownish gray (5 YR 6/1) fresh, dark yellowish brown (10 YR 6/2) or light olive gray (5 Y 5/2) on weathered surfaces.

169.01 - 169.5 Gypsum, bedded, very light gray.

169.5 - 169.8 Interbedded gypsum and dark yellowish brown carbonate mudstone, beds are 0.5 to 2.0 cm thick.

169.8 - 179.25 Gypsum, bedded, interbedded 15 cm massive beds with 1 cm thin beds.

JOYITA MEMBER

179.25 - 193.65 (lower contact is approximate)

Sandstone, fair to poorly sorted, carbonate cemented, slope former with some beds cropping out, slope covered with alluvium, color is moderate reddish brown (10

R 4/6) to moderate yellowish brown (10 YR 5/4).

193.65 - 194.75 Sandstone, resistant massive buttress outcrop.

194.75 - 195.15 Sandstone, fissile weathers to cave.

195.15 - 195.75 Resistant sandstone, massive outcrop.

195.75 - 196.25 Less resistant sandstone, cave former.

196.25 - 196.4 Resistant sandstone, buttress former.

196.4 - 196.65 Less resistant sandstone, cave former.

196.65 - 197.25 Massive sandstone.

197.25 - 216.45 Sandstone, poorly sorted, forming alternating cliff and slope outcrop patterns low in the interval, beds are 1 to 5 cm thick, the interval turns to unbroken slope from the middle to the top, the sandstone becomes fissile near the top of the interval.

216.45 - 217.1 Massive resistant sandstone outcrop.

217.1 - 220.55 Sandstone, fissile slope former.

220.55 - 226.35 Resistant sandstone, massive cliff former.

226.35 - 234.75 Fissile sandstone, slope former with some sandstone cropping out.

234.75 - 236.63 Massive sandstone outcrop.

236.63 - 237.25 Gypsum, bedded, massive cliff former.

237.25 - 237.33 Carbonate mudstone, olive gray (5 Y 4/1) on fresh surfaces, weathers to light olive gray (5 Y 5/2).

237.33 - 239.15 Gypsum, bedded.

239.15 - 239.4 Thinly interbedded carbonate mudstone and gypsum mudstone in 0.5 to 1.0 cm beds, the interval appears laminated.

239.4 - 243.95 Gypsum, bedded.

GLORIETA FORMATION

243.95 - 256.85 Sandstone, well sorted, carbonate cemented slope former with occasional 5 cm thick beds exposed through the float, color is buff to very pale orange (10 YR 8/2) to dark yellowish orange (10 YR 6/6).

256.85 - 261.75 Sandstone, bedded, massive cliff former.

261.75 - 264.75 Sandstone, slope former.

264.75 - 266.25 Carbonate mudstone, sandy, blocky weathering, greenish black (5 G 2/1) fresh, weathers to moderate yellowish brown (10 YR 5/4).

266.25 - 267.2 Carbonate mudstone cropping out through alluvium covered slope.

267.2 - 270.75 Slope underlain by sandstone (lower contact is approximate).

270.75 - 272.18 Resistant sandstone, cliff former.

SAN ANDRES FORMATION

272.18 - 273.75 Limestone, resistant cliff former, clean, locally fossiliferous mudstone.

273.75 - 288.49 Carbonate mudstone, slope former.

288.49 - 291.75 Carbonate mudstone, resistant cliff former.

291.75 - 294.75 Carbonate mudstone, slope former with some resistant beds cropping out through the slope.

294.75 - 304.95 Carbonate mudstone, forms unbroken slope.

304.95 - 308.55 Carbonate mudstone, resistant cliff former.

308.55 - 315.75 Carbonate mudstone, slope former.

315.75 - 324.75 Carbonate mudstone, slope former with some resistant outcropping beds.

324.75 Erosional unconformity.

APPENDIX III

CARBONATE PETROLOGY AND BIOTIC ANALYSIS

POINT COUNTING DATA

The sample labeling scheme is in ascending stratigraphic order. "SSI" precedes a sample number that comes from Stratigraphic Section I, and "SSII" precedes a sample number from Stratigraphic Section II. For example, SSI-1 denotes the lowest sample taken in SSI. SSI-2 is the next stratigraphically higher sample, et cetera. Anomalous beds were sampled and labeled with a letter following the number of the sample immediately below -- sample SSII-3a is an anomalous bed between SSII-3 and SSII-4. As stated in the text, samples were taken at arbitrary 0.5 m intervals.

The samples are listed with points counted, percentages of the total points, Dunham and Folk rock names, and additional comments. The slides were stained with Alizarin Red-S (ARS) to facilitate identification of dolomite. 500 to 700 points were counted per slide.

STRATIGRAPHIC SECTION I

SSI-C4

SSI-1

POINT TYPE	POINTS COUNTED	PERCENTAGE
Fossil mold	5	0.83 %
Spar	4	0.67
Mud/Micrite	391	65.3
Microspar	199	33.2

Total points = 599

Dunham: Mudstone Folk: Micrite

Dolomitized, blocky cement.

SSI-2

POINT TYPE	POINTS COUNTED	PERCENTAGE
Fossil mold	2	0.33 %
Gypsum vein fill	7	1.2
Mud/Micrite	304	50.7
Microspar	287	47.8

Total points = 598

Dunham: Mudstone Folk: Fossiliferous micrite

Fossil molds filled with dolospar, rare grains of ARS stained calcitic spar, cement is equant and intergranular, possible algal strand

SSI-3

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	8	1.3 %
Foraminifera	1	1.7
Algae	6	1.0
Ostracod	3	0.5
Gypsum	16	2.7
Spar	5	0.83
Mud/Micrite	380	63.1
Microspar	183	30.4

Total points = 602

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, equant, intergranular cement, gypsum fills veins, fossils are micritzed.

SSI-3a

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	9	1.5 %
Algae	15	2.5
Tubiphytes	3	0.5
Fossil mold	2	0.33
Pelloids	3	0.5
Spar	1	0.17
Mud/Micrite	186	30.8
Microspar	384	63.7

Total points = 603

Dunham: Mudstone Folk: Fossiliferous microsparite

Dolomitized, equant, blocky, intergranular cement.

SSI-4

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mud/Micrite	226	37.5 %
Microspar	377	62.5

Total points = 603

Dunham: Mudstone Folk: Microspar micrite

Dolomitized, coarse microspar mottled with micrite, < 5 % ARS stained calcite, blocky, equant, intergranular cement.

SSI-5

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	1	0.17 %
Spar	2	0.33
Mud/Micrite	305	50.7
Microspar	293	48.8

Total points = 601

Dunham: Mudstone Folk: Microspar micrite

Dolomitized, homogeneous mud, smaller grain size than SSI-3, opaque grain may be iron mineral, ARS stained calcitic vein fill, equant, blocky, intergranular cement.

SSI-6

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	2	0.33 %
Mollusc	7	1.2
Algae	4	0.67
Opaque	3	0.5
Gypsum	1	0.17
Spar	6	1.0
Mud/Micrite	374	62.2
Microspar	204	33.9

Total points = 601

Dunham: Mudstone Folk: Fossiliferous microspar micrite

Dolomitized, fossil molds filled by dolospar, some fossil molds still as void space, possibly burrowed, possible globigerinid foram, blocky, equant, intergranular cement.

SSI-C3

SSI-7

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	3	0.5 %
Opaque	1	0.17
Gypsum	7	1.2
Spar	6	1.0
Mud/Micrite	362	60.7
Microspar	217	36.4

Total points = 596

Dunham: Mudstone Folk: Microspar micrite

Dolomitized, gypsum as vein fill, equant, blocky, intergranular cement.

SSI-8

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	5	0.84 %
Mollusc	19	3.2
Ostracod	3	0.5
Pelloids	6	1.0
Gypsum	44	7.4
Spar	15	2.5
Mud/Micrite	355	59.4
Microspar	151	25.3

Total points = 598

Dunham: Mudstone Folk: Fossiliferous microspar micrite

Dolomitized, some calcite, blocky, equant, intergranular cement.

SSI-9

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	1	0.17 %
Algae	2	0.34
Ostracod	2	0.34
Pelloids	12	2.0
Opaque	3	0.51
Gypsum	24	4.1
Spar	13	2.2
Mud/Micrite	348	58.9
Microspar	186	31.5

Total points = 591

Dunham: Mudstone Folk: Fossiliferous microspar-micrite

Dolomitized, fossil molds filled with dolospar, gypsum vein fill, blocky, equant, intergranular cement.

SSI-10

POINT TYPE	POINTS COUNTED	PERCENTAGE
Spar	2	0.33 %
Mud/Micrite	218	44.7
Microspar	280	55.0

Total points = 500

Dunham: Mudstone Folk: Microspar-micrite

Dolomitized, vuggy, possible algae and fossil mold casts, < 1 % stained with ARS. equant, blocky intergranular cement.

SSI-11

POINT TYPE	POINTS COUNTED	PERCENTAGE
Fossil molds	17	2.8 %
Opaque	1	0.17
Gypsum	14	2.3
Spar	20	3.3
Mud/Micrite	391	65.2
Microspar	157	26.2

Total points = 600

Dunham: Mudstone Folk: Fossiliferous microspar-micrite

Dolomitized, vuggy, fossil molds filled with gypsum, fractures filled with dolospar, fenestral structures, signs of burrowing, swirled sediment, blocky, equant, intergranular cement.

SSI-12

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	2	0.33 %
Mollusc	23	3.8
Pelloids	3	0.5
Opaque	1	0.17
Gypsum	30	5.0
Spar	26	4.3
Mud/Micrite	352	58.7
Microspar	163	27.2

Total points = 600

Dunham: Mudstone Folk: Fossiliferous microspar-micrite

Dolomitized, fossil molds filled with dolospar, blocky, equant, intergranular cement.

SSI-13

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	7	1.2 %
Gypsum	76	12.7
Spar	6	1.0
Mud/Micrite	373	62.4
Microspar	136	22.7

Total points = 598

Dunham: Mudstone Folk: Fossiliferous microspar-micrite

Dolomitized, vuggy, voids filled with gypsum, blocky, equant, intergranular cement.

SSI-14

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	3	0.5 %
Mollusc	16	2.7
Algae	2	0.33
Opaque	1	0.17
Gypsum	26	4.3
Spar	3	0.5
Mud/Micrite	503	83.7
Microspar	47	7.8

Total points = 601

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, gypsum filled pore spaces, dolospar filled fossil molds and fractures.

SSI-C3

SSI-14a

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	1	0.17 %
Gypsum	8	1.3
Spar	17	2.8
Mud/Micrite	333	55.5
Microspar	241	40.2

Total points = 600

Dunham: Mudstone Folk: Microspar-micrite

Dolomitized, laminated mud, blocky, equant, intergranular cement.

SSI-C4

SSI-15

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	4	0.67 %
Algae	1	0.17
Gypsum	1	0.17
Spar	6	1.0
Mud/Micrite	280	46.6
Microspar	309	51.4

Total points = 601

Dunham: Mudstone Folk: Micrite-microsparite

Dolomitized, fossil molds filled with dolospar, burrowed, laminated -- layers of mud/fine microspar alternate with coarser microspar, blocky, equant, intergranular cement.

SSI-16

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	5	1.0 %
Mollusc	65	13.0
Ostracod	5	1.0
Oncolite	88	17.6
Foraminifera	4	0.8
Algae	3	0.6
Pelloids	22	4.4
Spar	11	2.2
Mud/Micrite	239	47.8
Microspar	58	11.6

Total points = 500

Dunham: Packstone Folk: Sparse biomicrite

Dolomitized, oncolite hash in mud matrix, grain support.

SSI-17

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	3	0.5 %
Mollusc	9	1.5
Algae	1	0.17
Spar	6	1.0
Mud/Micrite	505	84.2
Microspar	76	12.7

Total points = 600

Dunham: Mudstone   Folk: Fossiliferous micrite

Dolomitized, fossils oriented parallel to bedding, blocky, equant cement.

SSI-18

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	1	0.17 %
Mollusc	14	2.3
Ostracod	trace	< 1.0
Fossil molds	1	0.17
Opaque	2	0.33
Spar	8	1.3
Mud/Micrite	499	83.0
Microspar	76	12.6

Total points = 601

Dunham: Mudstone   Folk: Fossiliferous micrite

Dolomitized, fractures filled with dolospar, mollusc fragments up to 9 mm in length, some molds and fractures lined with small equant dolospar crystals, then filled by later blocky dolospar.

SSI- 19

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	2	0.33 %
Mollusc	16	2.6
Algae	3	0.5
Ostracod	2	0.33
Fossil grain	1	0.17
Spar	11	1.8
Mud/Micrite	482	79.5
Microspar	89	14.7

Total points = 606

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, fossil molds and fractures filled with dolospar, fracture fill crystal size grades from small to large from the edge to center of the fracture, fossils oriented parallel to bedding.

SSI-20

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	1	0.17 %
Opaque	1	0.17
Spar	15	2.5
Mud/Micrite	303	50.5
Microspar	280	46.7

Total points = 600

Dunham: Mudstone Folk: Microspar-micrite

Dolomitized, fenestral void spaces filled with dolomitic and calcitic spar, scattered grains of calcitic spar, equant, blocky cement.

SSI-21

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	4	0.67 %
Bone/Fish teeth	5	0.83
Spar	2	0.33
Mud/Micrite	338	56.3
Microspar	251	41.8

Total points = 600

Dunham: Mudstone Folk: Fossiliferous microspar-micrite

Dolomitized, fractures lined with dolospar, possible bone fragments, blocky cement.

SSI-22

POINT TYPE	POINTS COUNTED	PERCENTAGE
Spar	2	0.33 %
Mud/Micrite	153	25.4
Microspar	447	74.3

Total points = 602

Dunham: Mudstone Folk: Micrite-microsparite

Dolomitized, laminated mud, blocky dolospar cement lining pores, occasional calcitic grains.

SSI-23

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	3	0.5 %
Mollusc	108	18.0
Pelloid	23	3.8
Opaque	4	0.67
Intraclast	13	2.17
Gypsum	5	0.83
Spar	69	11.5
Mud/Micrite	332	55.3
Microspar	43	7.4

Total points = 600

Dunham: Wackestone Folk: Sparse biomicrite

Dolomitized, fossils replaced by dolospar with micrite envelopes, contains possible intraclasts.

SSI-24

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gypsum	2	0.33 %
Spar	6	1.0
Mud/Micrite	381	63.5
Microspar	211	35.2

Total points = 600

Dunham: Mudstone Folk: Microspar-micrite

Dolomitized, homogeneous mud with calcitic spar and microspar up to 5 %, fenestral voids oriented parallel to bedding.

SSI-25

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mud/Micrite	486	81.0 %
Microspar	114	19.0

Total points = 600

Dunham: Mudstone Folk: Micrite

Dolomitized, very similar to SSI-24, possible fenestral void spaces, occasional calcite, possible burrow.

SSI-26

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	trace	<< 1 %
Spar	trace	<< 1
Mud/Micrite	358	59.7
Microspar	242	40.3

Total points = 600

Dunham: Mudstone Folk: Microspar-micrite

Dolomitized, laminated mud/microspar, a few round voids filled with dolospar, possible lined burrows.

SSI-27

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	6	1.0 %
Mud/Micrite	458	76.3
Microspar	136	22.7

Total points = 600

Dunham: Mudstone   Folk: Fossiliferous micrite

Dolomitized, laminated mud, flattened bubble-like voids lined with equant dolospar, mollusc fragments << 1 mm with micritic rim and dolomicrospar fill, trace of opaque grains.

SSI-28

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	7	1.2 %
Mollusc	57	9.5
Foraminifera	6	1.0
Algae	2	0.33
Ostracod	4	0.67
Bone	2	0.33
Pelloid	18	3.0
Opaque	1	0.17
Spar	64	10.6
Mud/Micrite	302	50.3
Microspar	137	22.8

Total points = 600

Dunham: Packstone   Folk: Sparse bio-microspar-micrite

Dolomitized, fossil fragment hash, maximum individual size is 0.9-1.0 cm, molds filled with dolospar, some burrowing.

SSI-29

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	3	0.5 %
Mollusc	23	3.8
Ostracod	10	1.7
Oncolite	1	0.17
Algae	1	0.17
Amber grains	4	0.67
Pelloids	36	6.0
Gypsum	1	0.17
Spar	41	6.8
Mud/Micrite	419	69.8
Microspar	61	10.2

Total points = 600

Dunham: Pelloidal wackestone Folk: Sparse biomicrite

Dolomitized, laminated, fossil fragment hash, fragment size up to 1 mm, ostracods are approximately 0.4 mm, trace of ARS stained calcite, amber grains are possibly bone or conodonts.

SSI-30

POINT TYPE	POINTS COUNTED	PERCENTAGE
Gastropod	1	0.17 %
Mollusc	32	5.3
Ostracod	3	0.5
Algae	5	0.83
Amber grains	4	0.67
Pelloid	7	1.2
Opaque	1	0.17
Gypsum	2	0.33
Spar	66	11.0
Mud/Micrite	403	67.2
Microspar	76	12.7

Total points = 600

Dunham: Fossiliferous mudstone   Folk: Fossiliferous micrite

Dolomitized, fossil hash of small fragments -- 0.1 mm to 1.5 mm, laminated, burrowed, fractures filled with dolospar, amber grains may be bone, fish teeth, and/or conodonts, round void spaces, blocky cement.

STRATIGRAPHIC SECTION II

SSII-C4

SSII-1

POINT TYPE	POINTS COUNTED	PERCENTAGE
Pelloid	186	26.6 %
Opaque	15	2.1
Mud/Micrite	107	15.3
Microspar	298	42.6
Spar	94	13.4

Total points = 700

Dunham: Pelloidal wackestone   Folk: Sparse pelmicrite

Dolomitized, blocky, equant cement, equant cement in layer around neomorphosed pellets.

SSII-2

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	3	0.5 %
Pelloids	8	1.3
Opaque	9	1.5
Gypsum	18	3.0
Mud/Micrite	171	28.5
Microspar	343	57.2
Spar	48	8.0

Total points = 600

Dunham: Mudstone   Folk: Fossiliferous microsparite

Dolomitized, blocky, equant rim cement, mollusc fragments replaced with dolospar, gypsum as and fracture fill.

SSII-3

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	12	2.0 %
Gastropod	5	0.83
Foraminifera	3	0.5
Ostracod	2	0.3
Algae	3	0.5
Pelloids	14	2.3
Gypsum	37	6.2
Mud/Micrite	179	29.8
Microspar	303	50.5
Spar	30	5.0

Total points = 588

Dunham: Fossiliferous mudstone Folk: Fossiliferous microsparite

Dolomitized, blocky, equant cement, gypsum as fracture fill, fossils replaced with dolospar.

SSII-C3

SSII-4

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	1	0.17 %
Pelloids	122	20.3
Opaque	14	2.3
Gypsum	2	0.3
Mud/Micrite	109	18.2
Microspar	312	52.0
Spar	40	6.7

Total points = 600

Dunham: Pelloidal wackestone Folk: Sparse pelmicrosparite

Dolomitized, equant cement, gypsum as fracture fill, some of the pelloids may be ooids, rare mollusc fragments.

SSII-5

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	20	3.3 %
Pelloid	95	15.8
Opaque	16	2.7
Gypsum	17	2.8
Mud/Micrite	282	47.0
Microspar	170	28.3

Total points = 600

Dunham: Pelloidal wackestone Folk: Sparse pelmicrite

Dolomitized, blocky dolospar cement, gypsum as cavity fill, some pelloid cavities lined with microspar, mollusc fragments up to 2 mm in length.

SSII-7

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	1	0.17 %
Algae	5	0.83
Opaque	24	4.0
Gypsum	46	7.7
Mud/Micrite	324	54.0
Microspar	180	30.0
Spar	20	3.3

Total points = 600

Dunham: Mudstone Folk: Pel-opaque-biomicrite

Dolomitized, vesicles lined with dolospar and gypsum, ghost mollusc fragments, possible algal strands.

SSII-8

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	12	2.0 %
Mud/Micrite	306	51.0
Microspar	282	47.0

Total points = 600

Dunham: Mudstone Folk: Opaque-micrite

Dolomitized, some faint horizontal lamination.

SSII-9

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	18	3.0 %
Mud/Micrite	230	38.4
Microspar	351	58.6

Total points = 599

Dunham: Mudstone Folk: Opaque-microsparite

Dolomitized, blocky, equant cement, some lamination, posible burrows.

SSII-10

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	6	1.0 %
Gastropod	2	0.34
Pelloids	25	4.2
Opaque	8	1.4
Gypsum	3	0.51
Mud/Micrite	341	57.8
Microspar	202	34.2
Spar	3	0.51

Total points = 590

Dunham: Mudstone Folk: Pelmicrite

Dolomitized, some rare calcitic grains, bladed and blocky cement, gypsum as fracture fill, dolospar fills voids and replaces some of the fossil grains, general pelloidal appearance.

SSII-12

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	5	0.8 %
Mud/Micrite	354	59.0
Microspar	238	39.7
Spar	3	0.5

Total points = 600

Dunham: Mudstone Folk: Micrite

Dolomitized, equant cement, laminated -- light colored laminae are microspar, darker bands are micrite, opaque mineral grains found along contact between coarse and fine layers, "microspar" could contain a large percentage of gypsum.

SSII-C2

SSII-13

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	2	0.34 %
Pelloid	38	6.4
Gypsum	57	9.6
Mud/Micrite	240	40.3
Microspar	259	43.5

Total points = 596

Dunham: Mudstone Folk: Pelmicrosparite

Dolomitized, gypsum as fracture fill, mottled appearance, mollusc fragments.

SSII-14

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	16	2.6 %
Mud/Micrite	233	37.9
Microspar	349	56.8
Spar	16	2.6

Total points = 614

Dunham: Mudstone Folk: Microsparite

Dolomitized, possible burrows.

SSII-15

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	trace	<< 1 %
Opaque	4	0.67
Mud/Micrite	238	39.7
Microspar	356	59.3
Spar	3	0.5

Total points = 601

Dunham: Mudstone Folk: Microsparite

Dolomitized, blocky cement, rare ARS stained calcitic grains, rare, very small mollusc ghosts.

SSII-16

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	12	2.0 %
Mud/Micrite	221	36.8
Microspar	364	60.7
Spar	4	0.7

Total points = 601

Dunham: Mudstone Folk: Microsparite

Dolomitized, ARS stained calcitic grains approximately 5 - 10 %, possible burrow and mollusc ghost, possible small grains of gypsum.

SSII-17

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	3	0.5 %
Opaque	5	0.83
Gypsum	5	0.83
Mud/Micrite	130	21.7
Microspar	443	73.8
Spar	14	2.3

Total points = 600

Dunham: Mudstone Folk: Microsparite

Dolomitized, blocky cement, mottled appearance, some ARS stained calcite, mollusc ghosts.

SSII-18

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	trace	<< 1 %
Opaque	2	0.3
Mud/Micrite	283	47.2
Microspar	307	51.2
Spar	8	0.3

Total points = 600

Dunham: Mudstone Folk: Microsparite

Dolomitized, blocky cement, calcitic grains < 5 %, mottled appearance, rare mollusc ghosts replaced by microspar

SSII-19

POINT TYPE	POINTS COUNTED	PERCENTAGE
Opaque	6	1.1 %
Mud/Micrite	186	32.6
Microspar	360	63.2
Spar	18	3.2

Total points = 570

Dunham: Mudstone   Folk: Microsparite

Dolomitized, blocky cement, laminated.

SSII-20

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	7	1.0 %
Gastropod	7	1.0
Ostracod	trace	<< 1
Foraminifera	1	0.14
Algae	trace	<< 1
Pelloid	2	0.3
Opaque	trace	<< 1
Gypsum	3	0.5
Mud/Micrite	325	46.4
Microspar	317	45.3
Spar	38	5.4

Total points = 700

Dunham: Mudstone   Folk: Fossiliferous microsparite

Dolomitized, blocky cement, general appearance of matrix is microspar mottled with mud, mollusc and ostracod fragments replaced by dolospar with possible micrite rims, fossil size up to 2-3 mm in length.

SSII-C1

SSII-21

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	16	2.7 %
Gastropod	1	0.17
Ostracod	3	0.5
Opaque	4	0.67
Mud/Micrite	448	74.7
Microspar	117	19.5
Spar	11	1.83

Total points = 600

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, laminated mud, spar and microspar filled vugs and fossil replacement, mollusc fragments up to 5 mm.

SSII-22

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	17	2.8 %
Gastropod	1	0.17
Ostracod	1	0.17
Opaque	11	1.8
Gypsum	6	1.0
Mud/Micrite	424	70.7
Microspar	101	16.8
Spar	39	6.5

Total points = 600

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, vugs and fractures filled with dolospar and opaque mineral, opaque grains are up to .5 mm.

SSII-23

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	16	2.7 %
Ostracod	1	0.17
Opaque	4	0.7
Gypsum	11	1.8
Mud/Micrite	421	70.2
Microspar	145	24.2
Spar	2	0.33

Total points = 600

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, blocky cement, vugs filled with gypsum or dolospar, fenestral appearance, possible burrows.

SSII-26

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	2	0.34 %
Opaque	1	0.17
Mud/Micrite	382	63.7
Microspar	215	35.8

Total points = 600

Dunham: Mudstone Folk: Dismicrite

Dolomitized, vuggy, ARS stained calcitic grains approximately 5 %, mollusc ghosts.

SSII-27

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	15	2.5 %
Foraminifera	1	0.17
Algae	1	0.17
Pelloid	4	0.66
Gypsum	2	0.33
Opaque	3	0.5
Mud/Micrite	225	37.5
Microspar	288	48.0
Spar	61	10.2

Total points = 600

Dunham: Mudstone Folk: Fossiliferous microsparite

Dolomitized, large pores filled with dolospar, pelloidal shaped circles filled with dolospar.

SSII-28

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	8	1.3 %
Gastropod	8	1.3
Ostracod	1	0.17
Opaque	3	0.5
Mud/Micrite	431	71.8
Microspar	138	23.0
Spar	11	1.8

Total points = 600

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, vuggy pores, some pore space filled with dolospar, mottled general appearance, gastropods up to 0.5 mm, mollusc fragments, some fossils are faint and ghost-like.

SSII-29

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	18	3.0 %
Gastropod	3	0.5
Algae	1	0.17
Opaque	4	0.67
Mud/Micrite	250	41.7
Microspar	316	52.7
Spar	8	1.3

Total points = 600

Dunham: Mudstone Folk: Fossiliferous microsparite

Dolomitized, blocky dolospar fills pore spaces and replaces fossils, three to four individual types of mollusc shell were observed, some fossil molds replaced with a single crystal of optically continuous dolospar.

SSII-31

POINT TYPE	POINTS COUNTED	PERCENTAGE
Mollusc	8	1.3 %
Gastropod	1	0.17
Foraminifera	1	0.17
Pelloid	1	0.17
Gypsum	12	2.0
Mud/Micrite	341	56.7
Microspar	234	38.9
Spar	3	0.5

Total points = 601

Dunham: Mudstone Folk: Fossiliferous micrite

Dolomitized, vuggy pore space constituting approximately 15 to 20 % of the sample, fractured, vugs and fractures filled with gypsum, general appearance is mottled, rock looks as if it may have been pelloidal, mollusc fragments, burrows.

MEASURED STRATIGRAPHIC SECTIONS

PLATE 1

Plate 2: GEOLOGIC MAP OF THE JONES CAMP DISTRICT, SOCORRO COUNTY, NEW MEXICO.

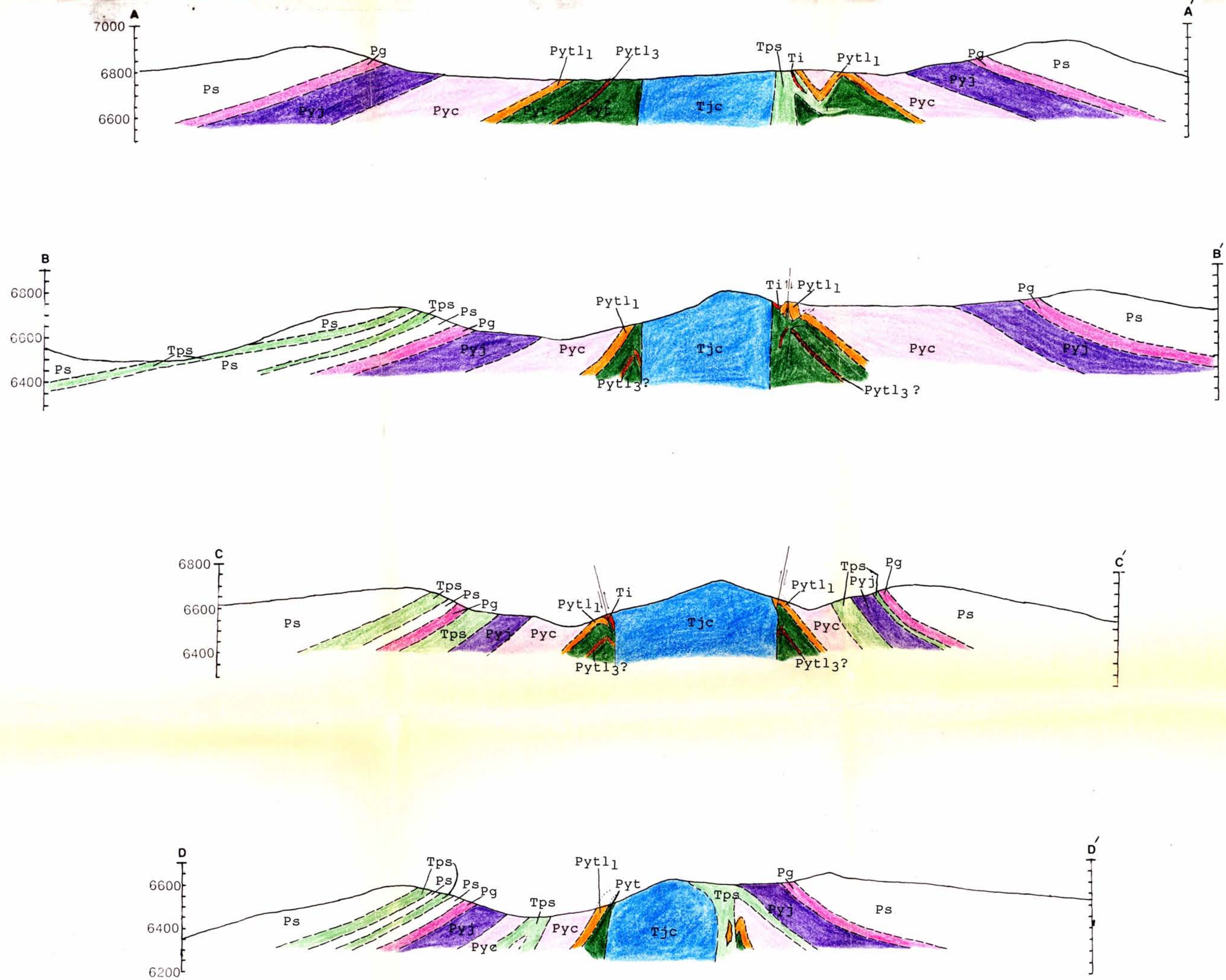


PLATE 3: GEOLOGIC CROSS SECTIONS

SCALE: ONE INCH = 400 FEET

(AFTER JENKINS, 1985)

SEE PLATE 2 FOR COLOR SCHEME