PETROLOGY AND STRATIGRAPHY OF THE COLINA LIMESTONE (PERMIAN) IN COCHISE COUNTY, ARIZONA

by

Jan Carol Wilt

A Thesis Submitted to the Faculty of the

DEPARTMENT OF GEOLOGY

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

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SIGNED: Jan Carol Wilt

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

JOSEPH F. SCHREIBER, JR.
Professor of Geology

Date

ACKNOWLEDGMENTS

The writer is indebted to Dr. Joseph F. Schreiber, Jr., University of Arizona, for the many hours spent checking the petrography and revising the manuscript in his capacity as thesis director. Drs. D. L. Bryant and R. F. Wilson critically read the paper and made useful suggestions which are greatly appreciated by the author.

The field assistance given by the author's husband Nelson and brother, Gary Rasmussen, will always be gratefully appreciated because it made possible the writing of this thesis.

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ABSTRACT

The Colina Limestone is 622 feet thick where measured on Colina Ridge and is 947 feet thick one mile east on the southeast ridge in sec. 36 in the Tombstone Hills. The type section on Colina Ridge is compared with the sections above and with other nearby partial sections by means of a detailed correlation cross-section. The lower part of the Colina in the Tombstone Hills contains medium-bedded micrite with a few intervals of alternating covered zones and thin-bedded micrite. When the prominent cliffs of biomicrite in all sections are aligned, other units are approximately aligned.

The correlation cross-sections through northern and southern Cochise County indicate that the Colina Limestone contains more clastics in the eastern, northern, and western edges of the county. The sections to the south are the thickest (950 feet), most fossiliferous, and least clastic; therefore these were near the center of the Pedregosa Basin.

Fossils indicate a Wolfcampian age for the lower part of the Colina Limestone and a Leonardian age for the upper part. A petrographic study reveals the abundance

of organisms in the bottom sediments of the warm, shallow, slightly restricted Pedregosa basin during Colina sedimentation.

INTRODUCTION

An investigation has been made of the petrology and stratigraphy of the Colina Limestone of Permian age, a dark gray micrite to biomicrite, in Cochise County, Arizona. The study concentrated in the type area of the formation on Colina Ridge, five miles south of Tombstone, Arizona, and several outcrops east of Colina Ridge (Figure 1). This area includes sections 25, 35, and 36 of T. 20 S., R. 22 E. and sections 30, 31, 33, and 34 of T. 20 S., R. 23 E. In this area the Colina Limestone forms steep cliffs that include several 20 to 30 foot, massive, nearly vertical cliffs, other thinner bedded ledges, and steep slopes composed of very thinly bedded silty micrite.

Purpose

The purpose of the study was to re-examine the type section of the Colina and sections in the surrounding area, using the more modern limestone classification devised by Folk (1959) and modified by Wobber (1965) (Table 1). Thus more accurate correlations and conclusions concerning the depositional environment were made possible. It was hoped that fusulinids could be used to precisely date the formation; but in spite of diligent searching by many persons, none were found.

Tombstone Quadrangle

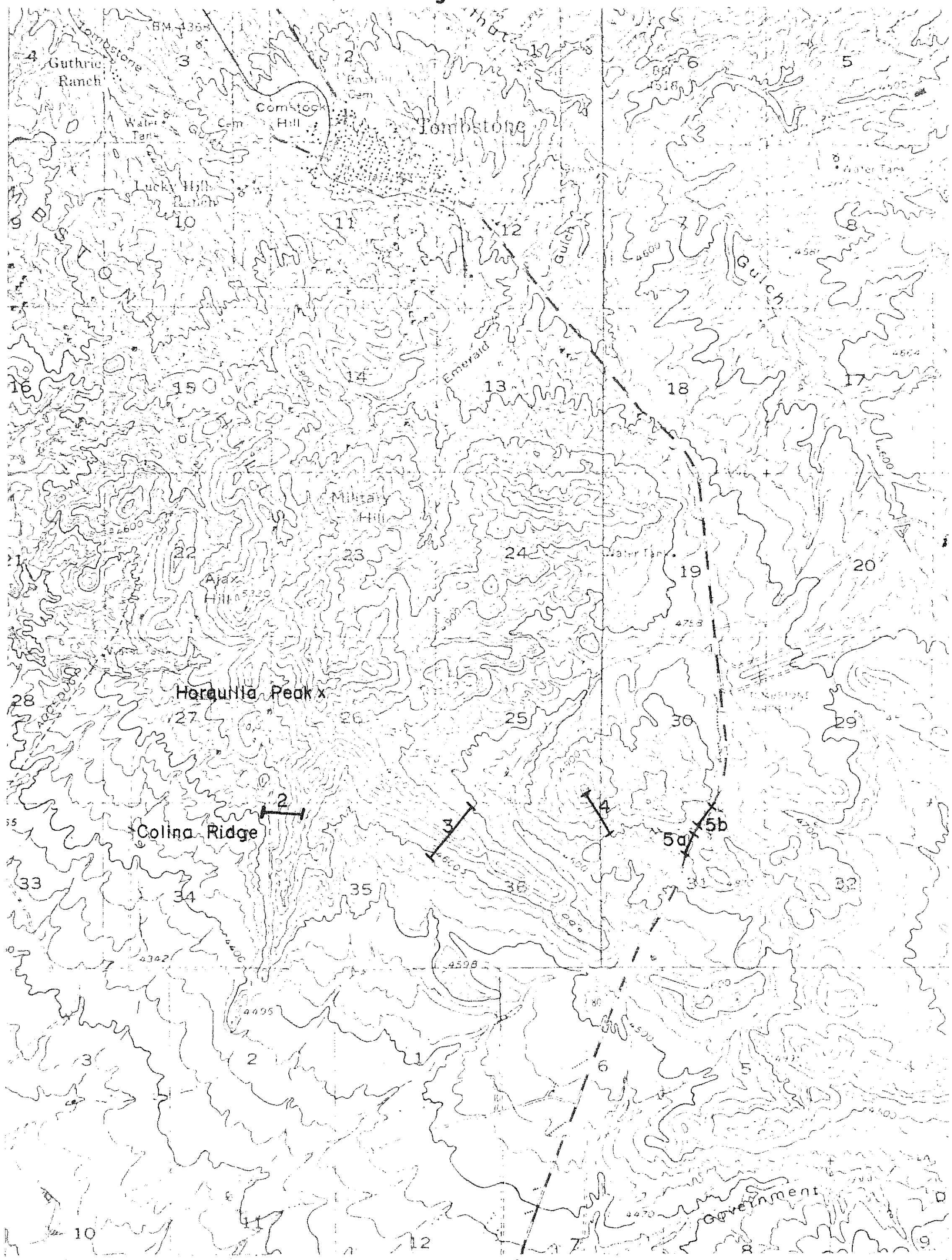
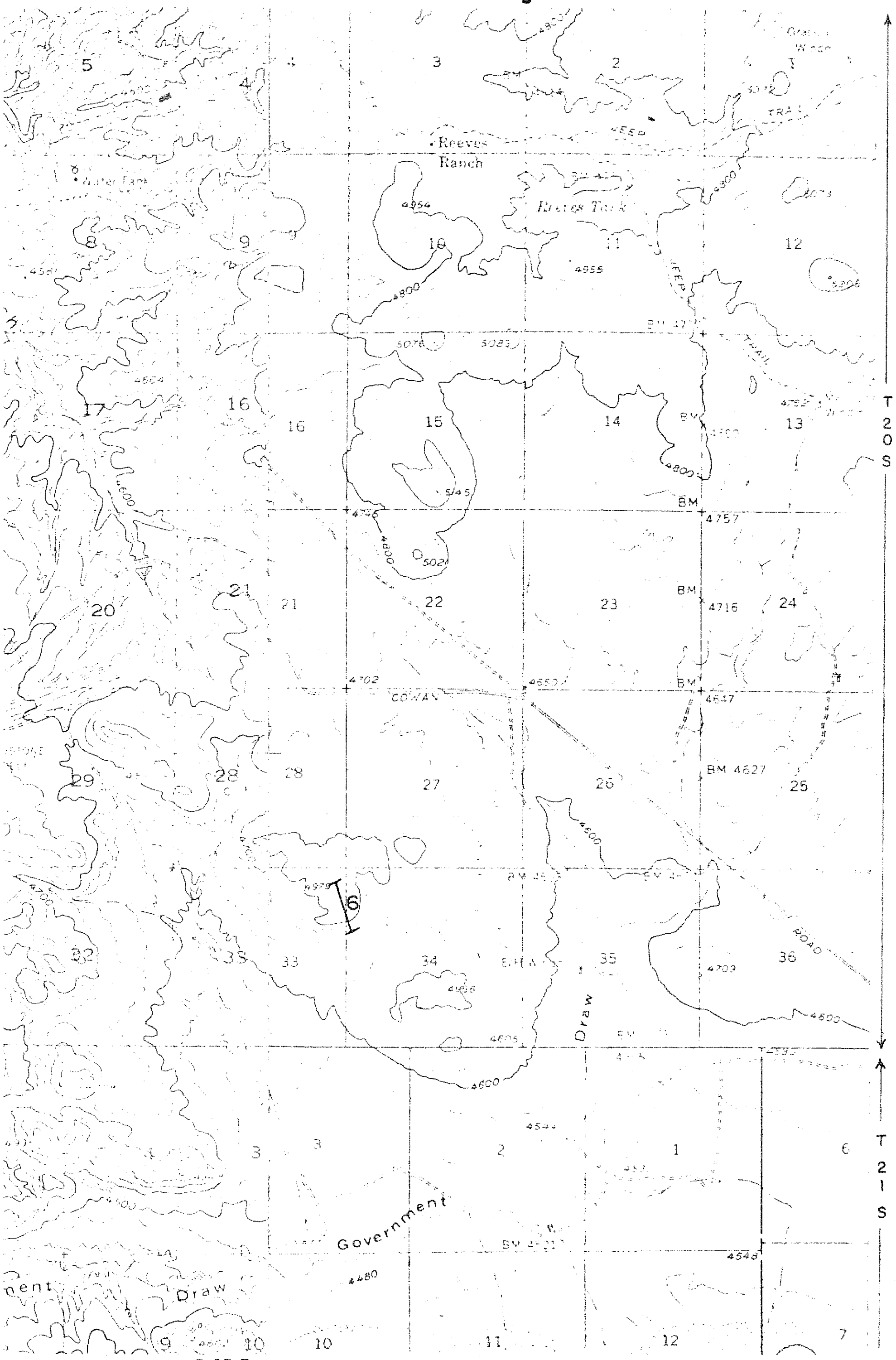


Figure I. MAP OF STUD'

Gleeson Quadrangle



OF STUDY AREA

Scale 1 inch = 1 mile

Table 1--CLASSIFICATION OF CARBONATE ROCKS[1]
(Modified from Folk, 1959 and Wobber, 1965)

Lime Mud Matrix or Spar Cement	Allochems				
	Volume % Allochems	Fossils	Pellets	Intraclasts	Oolites
Dominantly Lime Mud Matrix	0-1 %	Micrite	Micrite	Micrite	Micrite
	1-10 %	Fossiliferous micrite	Pellet-bearing micrite	Intraclast-bearing micrite	Oolite-bearing micrite
	10-50 %	Sparse biomicrite	Pelmicrite	Intramicrite	Oomicrite
	50 %	Packed biomicrite			
Subequal Sparry Cement & Lime Mud		Poorly winnowed biomicrite	Sparry Pelmicrite	Sparry Intramicrite	Sparry Oomicrite
Dominantly Sparry Cement		Biosparite	Pelsparite	Intrasparite	Oosparite

Matrix or Cement	Limestone Lithoclasts	
	0-50 % Limestone rock fragments	50 % Limestone rock fragments
Lime Mud Matrix	Lithoclast-bearing micrite	Lithomicrite
Sparry Cement	Lithoclast-bearing sparite	Lithosparite

[1] Intraclasts - represent pieces of penecontemporaneous, weakly consolidated carbonate sediment that has been torn up and redeposited to form new sediment.

Biolithite - in place reef rock, non-fragmented (Ex: algal biolithite).

Lithoclasts - rock fragments of pre-existing lithified carbonate rocks. The rock, calcithite, (Folk, 1959) is composed of more than 50 % lithoclasts. (Ex: lithomicrite)

Dismicrite - a micrite containing patches or centers of sparry cement.

The dominant fossil name may be prefixed to "bio" rocks as in "Fusulinid biomicrite". For allochems and lithoclasts that are greater than 2 mm, the word "rudite" should be added to the name (Ex: biomicrudite, lithosparrudite).

Method of Study

Five sections were measured in the field using a Brunton compass, Jacob staff, and tape. Samples of every unit in the type section on Colina Ridge and samples at intervals of five to ten feet on the ridge immediately east of Colina Ridge were collected for study in the laboratory. Laboratory study included optical identification of minerals and rocks by thin sections, size analysis by thin-section point counts, identification of insoluble residues, staining to identify carbonate minerals and to show textural relationships, and acetate peels to supplement the thin section petrography. Rock color names in this report were assigned in accordance with the colors in the National Research Council's Rock Color Chart (Goddard, 1948). The measured sections were compared to each other by a detailed lithologic correlation chart (Figure 2) and compared to other previously measured sections by less detailed correlation charts (Figures 3 and 4) to show regional thickness and lithologic trends.

Previous Investigations

The rocks of the Colina Limestone were first measured in the Tombstone Hills by Gilluly as the black limestone member of the Naco Formation in a report on the ore deposits of the Tombstone district by Butler, et al. (1938). This black limestone was later named the Colina Limestone by Gilluly, Cooper, and Williams (1954, p. 23) for its excellent exposure on the west side of Colina Ridge, which is a mile south of Horquilla Peak in the Tombstone Hills. Gilluly (1956, p. 42) and Cooper and Silver (1965, pp. 65, 66) further discussed the formation in central Cochise County and in the Dragoon Quadrangle. In the Mule Mountains, 20 miles south of the type section, Hayes and Landis (1965) studied several partial sections of Colina Limestone. Partial sections were also measured by Sabins (1957) and Sabins and Ross (1965) in the Dos Cabezas and Chiricahua Mountains. Epis (1956) measured a nearly complete Colina section in the Pedregosa Mountains. Dirks (1966) described sections of Colina Limestone in the Quimby Hills in the southeast corner of the state using Folk's terminology. Detailed sections have also been described by Gillerman (1958) in the Peloncillo Mountains, by Zeller (1965) in the Big Hatchet Mountains of New Mexico, and by Tyrrell (1957) in the Whetstone Mountains.

In older unpublished theses rocks that would now be called Colina Limestone were included in the Andrada Formation. This name was first used by Galbraith (1940) and by Wilson (1951) in a briefly described section in the Empire Mountains. Since the Earp Formation, Colina Limestone, and Epitaph Dolomite could not be differentiated in the Empire Mountains, a type section was described near the Andrada

Ranch by Bryant (1955) in his doctoral thesis on the Permian stratigraphy in southern Arizona. With increased knowledge of the Earp, Colina, and Epitaph, the use of the term Andrada Formation has been discontinued.

The following authors have included the Colina Limestone in the Andrada Formation or have used another field designation for the Colina Limestone in their theses: Alexis (1949) and Weber (1950) in the Huachuca Mountains; Cederstrom (1946) in the Dragoon Mountains; Brittain (1954) and Papke (1952) in the Chiricahua Mountains; Loring (1947) in the Swisshelm Mountains; Feth (1948) in the Canelo Hills; Anthony (1951) in the Santa Rita Mountains; Galbraith (1940), Gillingham (1936), Alberding (1938), Alexis (1939), Sears (1939), Sopp (1940), Marvin (1942), and Mayuga (1942) in the Empire Mountains; Layton (1957) and Kerns (1960) in the Rincon Mountains; and McClymonds (1957) and Ruff (1951) in the Waterman Mountains.

GENERAL DESCRIPTION OF THE COLINA LIMESTONE

The Colina Limestone is composed of micrite, which is a dull, very fine grained (1-4 microns) calcite, and of biomicrite with varying amounts of fossil hash. This hash consists of broken brachiopod and gastropod shells and ranges in size from fine sand to very coarse gravel; the fragments are commonly about one-fourth inch in length. In several beds the fossil fragments are coated with calcium carbonate. Echinoid spines are very common; oblique sections of these spines can be confused with fusulinids at first glance. Although fossil hash is more common than unbroken fossils, small turreted gastropods and large flat-coiled gastropods occur in certain beds. The most characteristic fossil in the formation is *Omphalotrochus*, a very large obtuse-angled gastropod which may attain a diameter of four inches. Fossils similar to *Composita* and *Dictyoclostus* and lacy bryozoans are fairly common; a nautiloid cephalopod and algae-like forms were also observed, but crinoids and corals were not seen.

Chert nodules are scattered throughout a few beds in the formation. Near the top of the formation chert forms an irregular shell around calcite nodules; possibly this chert has partially replaced the calcite. Zeller

(1965, p. 49) also noted these small knots of intergrown quartz and calcite, which are common in the Epitaph Dolomite, in the upper beds of the Colina Limestone in the Big Hatchet Mountains of New Mexico.

Color

The Colina Limestone is dark gray to medium dark-gray on a fresh fracture and weathers most commonly to light gray and less commonly to medium light-gray or to light olive gray if there is an abundance of fossil hash. A moderate-red silty material occurs between some bedding planes; the covered intervals are generally pale-red silty micrite. Orange or pink fine-grained sandstones and siltstones occur in the measured sections on the southeast ridge in sec. 36, above the intrusion in sec. 31, and near the Cowan Ranch road. These fine-grained clastics are either grayish orange to brownish gray, weathering to a moderate orange pink, or are pale yellow brown and grayish red to moderate pink, weathering pale red. The uniform dark-gray color on a fresh fracture is one of the principal identifying features of the Colina Limestone.

Nature of Bedding

The Colina Limestone commonly has thin to thick beds, which form one- to three-foot ledges. Short covered intervals of thin- to very thin-bedded silty micrite alternate with the thick bedding. Several massive beds 20 to 40 feet thick form conspicuous vertical cliffs which can be traced along the hillside. Although most ledges have flat bedding surfaces, the layers in the gently sloping and covered areas have slightly wavy bedding surfaces and contain silty material between the layers (Figure 5). The ledge and steep slope topography which is typical of the Colina is shown in Figure 6. The following terminology, which was originally devised by McKee and Weir (1953, p. 383) and modified by Harshbarger, et al. (1957, p. 58), is used in this report.

Table 2. Bedding terminology.

Bedding	Thickness
Very thick to massive	More than 4 feet
Thick	2 to 4 feet
Thin	2 inches to 2 feet
Very thin	1/2 to 2 inches
Laminated	2 mm to 10 mm
Thinly laminated	Less than 2 mm

Thickness

The total thickness of the Colina Limestone in the type section on Colina Ridge is 622 feet. On the ridge one mile east of Colina Ridge the thickness is 947 feet, although the thickness of this section probably has been somewhat increased by faulting. Other sections in Cochise County are about 400 to 600 feet thick; in the southeastern corner of the county the Colina is 950 feet thick.

Figure 5. Wavy bedding surfaces.

This interval of thin-bedded micrite, which is located about halfway up the south side of the southeast ridge in sec. 36, contains silty micrite between the layers.

Figure 6. Typical Colina ledge and slope topography.

This photograph was taken looking southeast into Government Draw from a point along the section measured on the southeast ridge in sec. 36. The ledge near the top of the ridge in the upper left portion of the photograph is unit 20.

Figure 5. Wavy bedding surfaces.

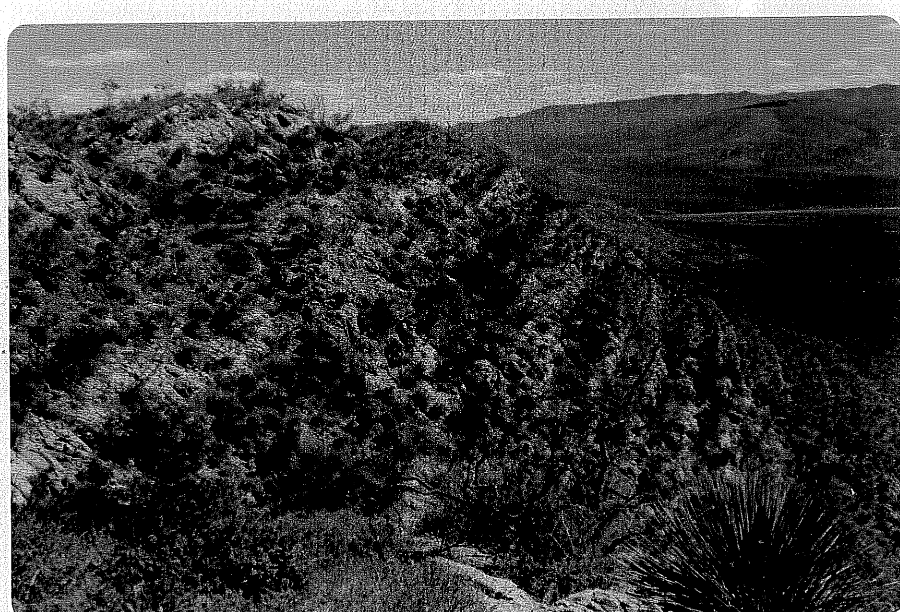


Figure 6. Typical Colina ledge and slope topography.

Lower Contact

The Colina Limestone conformably overlies the Earp Formation, which consists of thin-bedded pinkish-gray limestone and maroon or reddish-brown sandstone and shale. The top of the Earp Formation is placed above the last orange-weathering dolomite or at the base of the lowest dark-gray limestone characteristic of the Colina Limestone. In Section 2 on Colina Ridge and in Section 3 on the southeast ridge, which are the only sections including parts of the Earp Formation, the contact was placed immediately above the last orange-weathering dolomite. The Earp Formation is generally low in the valleys or on the lower, more gentle slopes of the ridges as a result of low resistance to erosion. Some of the limestones and dolomites in the upper part of the formation are more resistant and form ledges which gradually increase in steepness up to the Colina Limestone.

Upper Contact

The upper contact of the Colina Limestone with the overlying Epitaph Dolomite is also conformable. The base of the Epitaph Dolomite is taken at the base of the first massive dolomite above the partially dolomitized limestone at the top of the Colina Limestone.

In the type section of the Epitaph Dolomite, which is directly above the type section of the Colina Limestone on Colina Ridge and down the dip slope into Epitaph Gulch, there is a 200 foot section of finely crystalline dark-gray dolomite followed by an alternating sequence of sandy red limestone, cream or pink dolomite, and red mudstone. The lower part is fairly resistant and forms the dip slope on Colina Ridge; the upper part is less resistant and forms the saddle at the base of the dip slope. In the southeast ridge section and the Cowan Ranch road section the Epitaph Dolomite forms the base of the dip slope and is covered by alluvium in the valley.

The upper part of the Colina Limestone is characterized by beds of gray micrite mottled with four- to eight-inch areas of pale yellowish brown dolomite. In some areas a bed of dolomite occurs below a layer of Colina-like dark-gray micrite. In the Colina Ridge section and the southeast ridge section the contact between the micrite and dolomite does not follow one bedding plane; it is highly irregular and variable within ten feet or more. This same irregularity can be observed between the Colina Limestone and Epitaph Dolomite in the Quimby Hills (Dirks, 1966) and other places. Certain features characteristic of the Epitaph Dolomite, such as the presence of silica nodules with central cavities and silica nodules with euhedral prismatic quartz crystals coating them, are found in the upper part of the Colina Limestone in the southeast ridge section but not in the Colina Ridge section. These features may indicate that the upper part of the Colina Limestone on the southeast ridge is an undolomitized equivalent of the lower part of the Epitaph Dolomite in the type section on Colina Ridge. This interpretation would partially account for the difference in thickness of the Colina Limestone between the Colina Ridge section, which is 622 feet thick, and the southeast ridge section, which is 947 feet thick.

PETROLOGY OF THE COLINA LIMESTONE

Thin sections and acetate peels of several rocks in each unit on Colina Ridge and the southeast ridge in sec. 36 were studied in order to determine in more detail the nature of the depositional environment.

Micrites - Type III Limestones

Micrite is defined as a microcrystalline calcite ooze with grains ranging in size from one to four microns in diameter (Folk, 1959); it is dull and opaque in hand specimens and subtranslucent in thin sections. Half of the units in both measured sections appeared to be micrite according to field identification methods. However, under laboratory examination nearly all were shown to be more complex. Quite a few of the micrites have been partly recrystallized to microspar, which is slightly coarser (5 to 15 microns), clear calcite. Although a few were nearly pure micrites (Figure 7), many contained small amounts of silt, dolomite, or pellets, and a few were dismicrites.

Microcrystalline rocks that have been disturbed by burrowing organisms or by soft sediment deformation commonly have the resulting openings filled with sparry calcite. The dismicrite from some layers of the Colina

Figure 7. Micrite from unit 18 on Colina Ridge. (x 28.3)

Figure 8. Open cluster of micrite intraclasts.

This sample from unit 32 on the southeast ridge in sec. 36 contains intraclasts of micrite with sparry calcite grains inside them. Some dolomite rhombs occur in the matrix. (x 28.3)

Figure 7. Micrite from unit 18 on Colina Ridge.

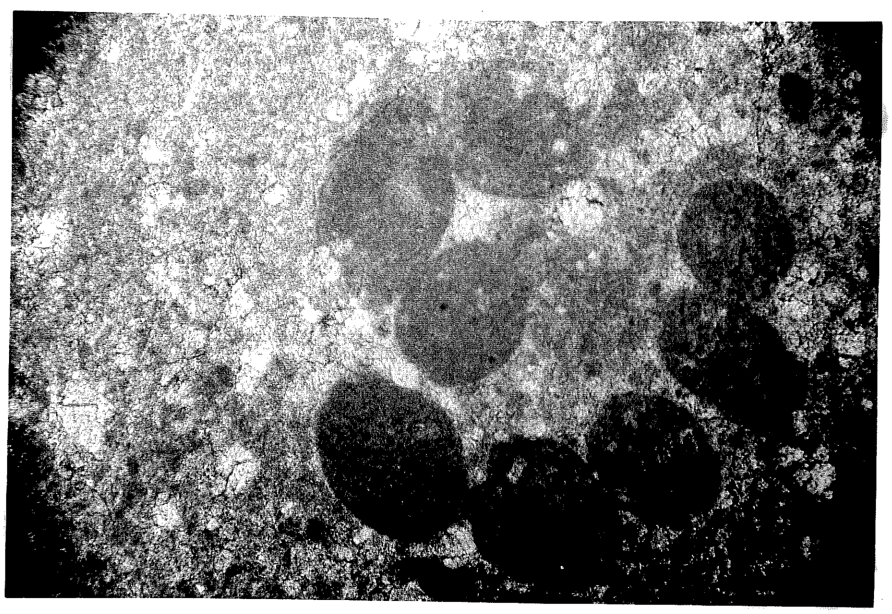


Figure 8. Open cluster of micrite intraclasts.

generally contain thin and irregularly jagged stringers of sparry calcite. The openings are filled with sparry calcite, and in some more indistinct stringers, with microspar of different sizes. The disturbed areas occupy from 3 to 35 percent of the thin sections that contain them. Some disturbed areas also occur in fossiliferous rocks. The disturbed areas filled with microspar may be a result of recrystallization of micrite to microspar and thus not reflect the original environment. However, those filled with sparry calcite may be more significant.

The pelletiferous micrites, silty micrites, dolomitic micrites, and fossiliferous micrites will be discussed in the sections describing each constituent. Micrites result from very rapid precipitation of microcrystalline ooze and a lack of persistent strong currents which would wash away the ooze. Environments which have these characteristics include shallow, sheltered lagoonal areas, very wide and moderately deep shelves, and even deeper offshore areas.

<u>Allochemical Micrites - Type II Limestones</u>

Allochemical constituents include intraclasts, oolites, fossils, pellets and any other organized carbonate material which has not been precipitated in place (Folk, 1959). Allochemical constituents in a matrix of micrite are called intramicrite, oomicrite, biomicrite, biopelmicrite, and pelmicrite, depending upon the abundance of the various allochems. Modifying terms can be added for more accurate and detailed descriptions. In order to avoid repetition the following discussion is organized according to the allochemical constituents rather than according to the detailed rock types.

Intraclasts.--Intraclasts are fragments of carbonate sediments which have been eroded and redeposited before they were completely consolidated. They range in size from very fine sand to pebbles and boulders and are commonly well rounded. The intraclasts may be composed of homogeneous micrite, but they more commonly have a complex internal structure of fossils, oolites, quartz silt, pellets, and smaller intraclasts. The inclusive term intraclast covers many different types of fragments such as grapestone, bahamite, and coprolite. Intraclasts are distinguished from pellets by size (greater than 0.2 mm) and by internal structure.

The Colina Limestone does not include any intraclasts which obviously formed by the erosion of weakly consolidated carbonate sediment from the ocean floor. However, many discrete areas with circular to oval boundaries in the intraclast size range are common in the Colina. Some of these areas are composed of micrite and many of fossil hash. These may represent material that has been ingested and excreted by bottom scavenging organisms. Some of the excreted material would retain its cohesion by mucoid organic substances; some less strongly bound material would disaggregate. Another possible explanation of these large discrete particles of micrite and fossil hash involves agglutination of grains from the sea floor. These particles of micrite or fossil hash are described under intraclasts since they probably are coprolites or "grains of matrix" (Illing, 1954, pp. 27, 37), which are formed somewhat like lumps or grapestones. This interpretation of intraclasts includes all material which was "essentially unlithified, and nearly contemporaneous, when it was reworked" (Folk, 1962, p. 65); it excludes oolites, pellets, and fossils. This is in agreement with Folk's suggestion that "intraclast should be used as a broad class term without specifying the precise origin" (Folk, 1962, p. 64).

Fragments of micrite ranging in size from coarse sand to fine gravel occur in many Colina samples. Figure 8 shows an open cluster of rounded micrite intraclasts of the same size. However, their roundness cannot be attributed to reworking by persistent currents, because smooth, elliptical micrite intraclasts on the same thin section have a nearly interlocking relationship. The micrite could have been eroded or stirred up by organisms while it had a jelly-like consistency; it would then acquire a round shape with the least possible surface area. The interlocking intraclasts may have been slightly compressed under the weight of micrite ooze while the round intraclasts hardened before being buried by ooze. It is also quite possible that the micrite intraclasts originated as coprolites and then were compressed.

Micrite intraclasts in the Colina generally vary in size from fine sand to fine gravel within a sample, and they are most commonly subrounded. Most micrite intraclasts are darker gray than the micrite matrix surrounding them; a few contain isolated grains of sparry calcite or dolomite, which are probably a result of recrystallization (Figure 8). In many intraclasts the boundaries are not perfectly smooth because the micrite matrix has altered to microspar which projects into the intraclasts.

Some Colina intraclasts are composed of dark micrite surrounding silt- and sand-size fossil fragments. The fossils in the hash have sharp edges, indicating that they have been broken but not abraded. The shell material has recrystallized to sparry calcite. Although fragments in the hash cannot be identified generically, the chambered fragments probably are derived from foraminifera or gastropods and the long, thin fragments from brachiopods, pelecypods, or echinoids. The fossil hash intraclasts contain either one or several fossil fragments (Figures 9, 10). The intraclasts with only one fossil fragment generally have

Figure 9. Fossil hash intraclasts from unit 38 on the southeast ridge in sec. 36. (x 28.3)

Figure 10. More fossil hash intraclasts from unit 38 on the southeast ridge in sec. 36. (x 28.3)

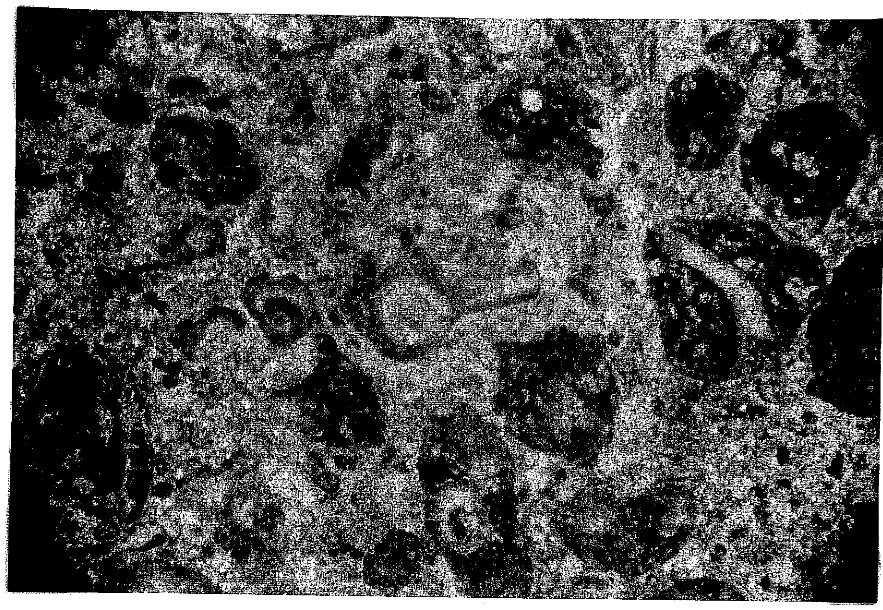


Figure 9. Fossil hash intraclasts from unit 38 on the southeast ridge in sec. 36.

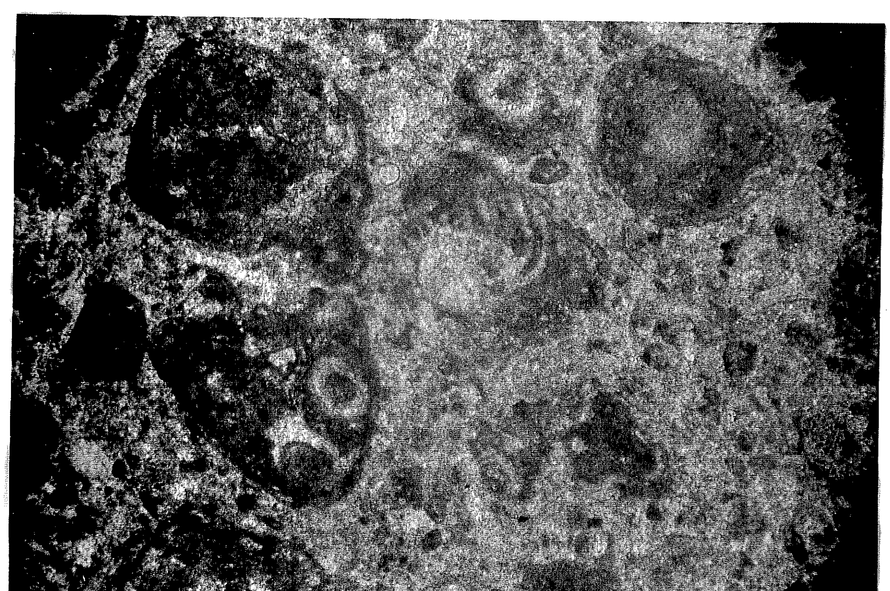


Figure 10. More fossil hash intraclasts from unit 38 on the southeast ridge in sec. 36.

concentric layers and are therefore discussed under coated grains.

The fossil hash intraclasts are commonly of coarse sand size, although a few are of fine gravel size. The intraclasts are moderately well sorted, but the spaces between the intraclasts contain very poorly sorted mixtures of quartz silt, pellets, fossil fragments, and micrite matrix. The fossil hash intraclasts are rounded, but some do not have smooth outlines. Perhaps this is the result of some micrite altering to microspar with the crystal mosaic intruding into the intraclasts.

The fossil hash intraclasts could have been eroded from local concentrations of semi-consolidated packed biomicrite by storm waves, underwater slides, or by wave action at low tide on exposed lime-mud flats. In one intraclast the fossil fragment and the micrite surrounding it are both eroded; however, the boundary of this intraclast is very jagged, perhaps as a result of alteration to microspar.

A more probable origin of the fossil hash intraclasts is biogenic; shelled animals may have been eaten by bottom scavengers and the fossil hash expelled as coprolites. The variety of sizes and shapes of fossil hash intraclasts precludes the conclusion that one type of organism produced all the intraclasts. Whether the intraclasts achieved their final form as coprolites or by erosion of biomicrites and redeposition, the broken, but not abraded, nature of the fossil hash indicates that burrowing scavengers were important in at least one phase of their formation.

Oolites and Coated Grains.--True subspherical oolites with concentric or radial structure are not present in the samples collected from the Colina Limestone. However, many fragments with white coated zones around a fossil fragment nucleus can be identified in the field. Leighton and Pendexter (1962, p. 36) define coated grains as "those having concentric or enclosing layers of calcium carbonate around a central nucleus. These include oolites, pisolites, and algae-encrusted or foraminifera-encrusted skeletal grains." The coated grains of the Colina are characterized by irregularly concentric layers, which have a non-uniform thickness from 50 to 80 microns, and are composed of dark-gray and some light-gray micrite (Figures 11, 12). The surfaces of the coated grains are not smoothly ovoid, but have many irregular projections and a few embayments of microspar. The coated grains are all similar in size, but the quartz silt, fossil fragments, pellets, and micrite that fills the spaces between them are very poorly sorted. Some coated grains contain a faintly discernable micrite core, but layers occupy the greater part of each of the

Figure 11. Coated grains from unit 20 on Colina Ridge. (x 28.3)

Figure 12. Coated grains from unit 38 on the southeast ridge in sec. 36. (x 28.3)

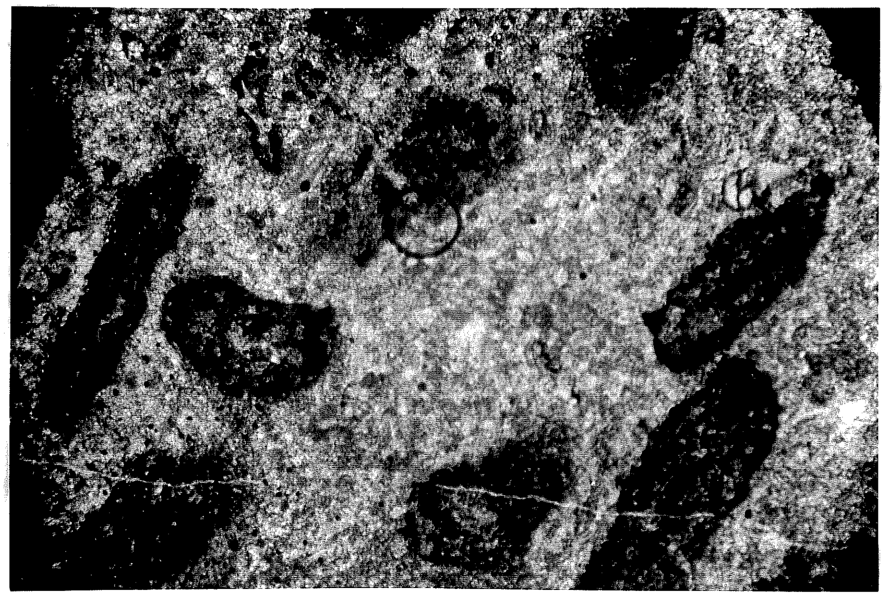


Figure 11. Coated grains from unit 20 on Colina Ridge.

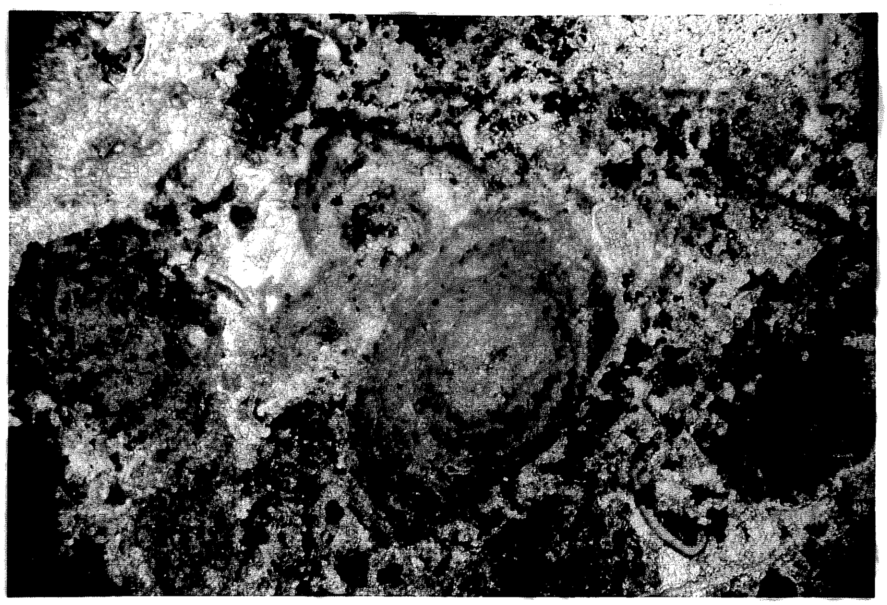


Figure 12. Coated grains from unit 38 on the southeast ridge in sec. 36.

coated grains. A few of the coated grains contain an angular piece of sparry calcite either as a core or near one end. The sparry calcite may be a result of recrystallization after the coated grain formed or it may be a shell fragment which was the original core.

The coated grains in the Colina could have been formed either by accretionary processes on the sea floor involving some type of motion or by encrustations by algae or foraminifera. The presence of a micrite matrix, which indicates a lack of persistent currents, and the similarity to photos of algal-encrusted limestones (Leighton and Pendexter, 1962, p. 42, I) points more to the latter explanation.

Pellets.--Pellets are rounded, structureless, spherical or oval aggregates of micrite; within one rock they are of a uniform size and shape, commonly between coarse silt and fine sand size (Folk, 1962, p. 64). Since these are probably invertebrate fecal pellets, they are richer in organic matter and therefore appear darker than the surrounding material. Leighton and Pendexter (1962, p. 36) stated that some pellets may also form by a "process of accretion whereby fine particles adhere to each other during alternate periods of transporation and deposition." Pellets are not abundant throughout the Colina, although a few occur scattered between intraclasts and other allochems.

These pellets are 0.08 to 0.15 mm in diameter and are generally well sorted; they are dark brown to black and have an indistinct ovoid or circular shape.

Fossils.--The biomicrites and fossiliferous micrites in the Colina Limestone locally contain whole fossils; generally from 2 to 50 percent of the rock is fossil fragments (Figures 13, 14). These fragments range from small sizes of 0.01 to 0.04 mm to large sizes of 0.5 mm by 2 mm with an average size of 0.1 mm by 0.5 mm. The fossil fragments are composed of 10- to 30-micron clear sparry calcite, although a few of the chambered fragments have dark inclusions that make them black. Fossil fragments from the insoluble residue of a sample in the upper 20 feet of the Colina include foraminifera?, productid brachiopod fragments and spines, echinoid spines, algae plates, serpulid worm tubes, and several species of Bryozoa. In surface samples the most abundant organisms are gastropods, pelecypod or brachiopod shell fragments, and echinoid spines. In thin sections and peels, pelecypod or brachiopod shell fragments are very abundant. Chambered forms from foraminifera or gastropods are also common; many of the chambers are filled with micrite or microspar. The shell fragments have sharp broken edges which are not abraded, and they are commonly imbedded in a micrite or microspar matrix. Both these facts indicate a lack of persistent currents and suggest that the bottom

Figure 13. Biomicrite from unit 21 on the southeast ridge in sec. 36. (x 28.3)

Figure 14. Coated zones around fossil fragments from unit 14 on the southeast ridge in sec. 36. (x 28.3)

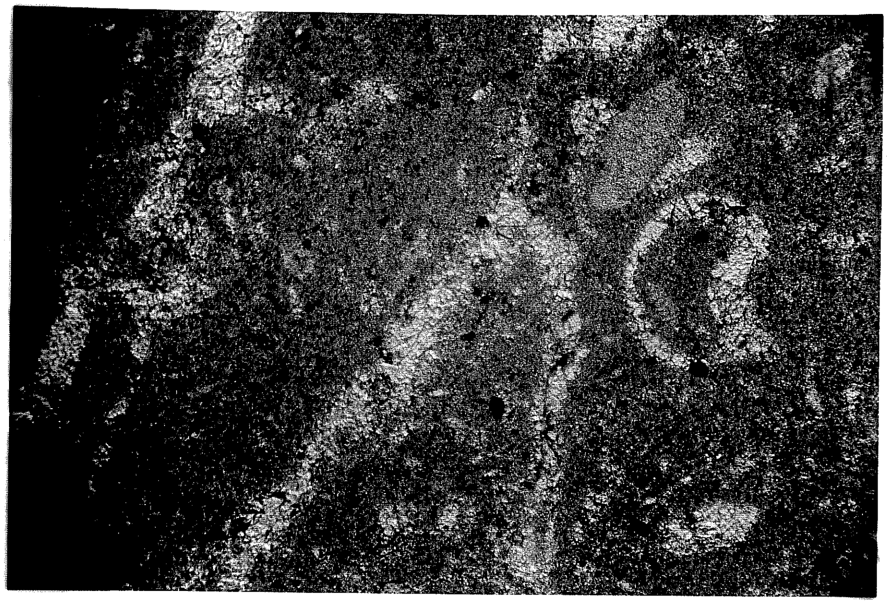


Figure 13. Biomicrite from unit 21 on the southeast ridge in sec. 36.

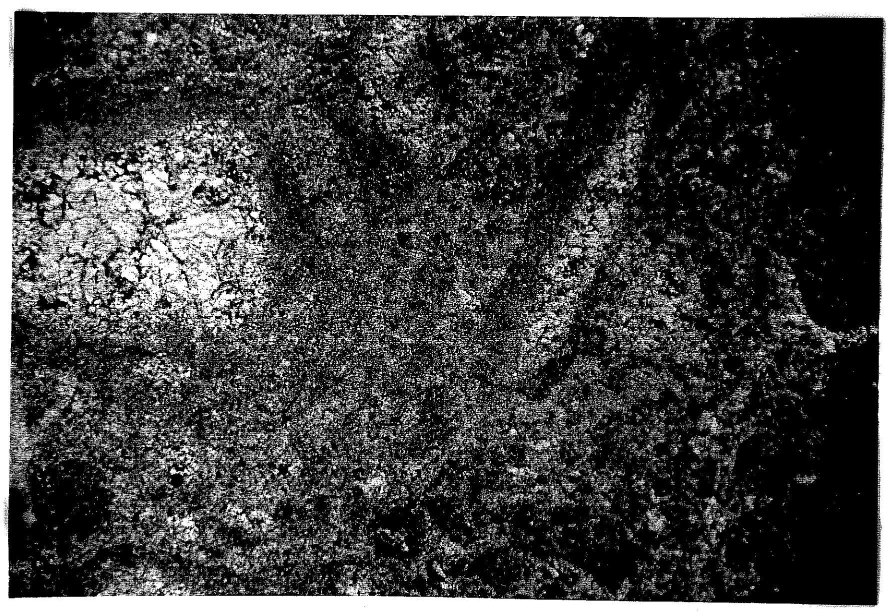


Figure 14. Coated zones around fossil fragments from unit 14 on the southeast ridge in sec. 36.

sediments were modified by the crunching and churning action of burrowing scavengers.

Sparry Allochemical Rocks - Type I Limestones

Sparry calcite is defined as calcite grains or crystals 10 microns or more in diameter (Folk, 1959). It has a sparkling, sugary texture in hand specimen and is clear in thin section. It generally occurs as pore-filling cement which is precipitated after the microcrystalline ooze has been washed away. Thus it indicates the presence of persistent currents which could be present on beaches, bars, or submarine shoals. However, some sparry calcite also forms by recrystallization.

Sparry calcite rocks are very rare in the Colina, although a few specimens of biosparrudite and intrasparite were examined. The biosparrudite contains whole brachiopods filled with sparry calcite and surrounded by finer sparry calcite. This could represent a locality where currents were persistent enough to winnow away the micrite mud, but not strong enough to break up the brachiopod shells. Some sparry calcite grains which are interspersed throughout the micrite or microspar matrix could be the result of recrystallization.

Terrigenous Admixtures

Small amounts of quartz silt are quite common in Colina rocks; these generally comprise between 1 and 15 percent of the rock and even range to as much as 25 or 30 percent. The quartz grains are medium to coarse silt scattered randomly throughout the rock. In several samples clear, euhedral quartz crystals of medium to coarse silt-size are abundant (Figure 15). In many samples subrounded coarse silt grains occur with finer grained quartz crystals; however, the subrounded grains may be short, stubby crystals.

Clastic Rocks

The clastic rocks that readily yield samples from the Colina are either calcareous sandstone or calcareous siltstone (Figure 16). They are generally stained by hematite or limonite, which imparts a red or brown hue to the rock. The quartz grains are very fine-grained sand and coarse-grained silt; generally both are present in different amounts. The grains are subangular to subrounded and are moderately well sorted. Other covered zones from which samples were not obtained may contain shale or claystone. The section measured in the roadcut along U. S. Highway 80 indicates that shale is present in the Colina. The clastic rocks probably represent intervals of greater transport of clastics.

Figure 15. Micrite with euhedral quartz crystals from unit 15 on the southeast ridge in sec. 36. (x 28.3)

Figure 16. Calcareous sandstone from unit 5 on the southeast ridge in sec. 36. (x 28.3)

Figure 15. Micrite with euhedral quartz crystals from unit 15 on the southeast ridge in sec. 36.

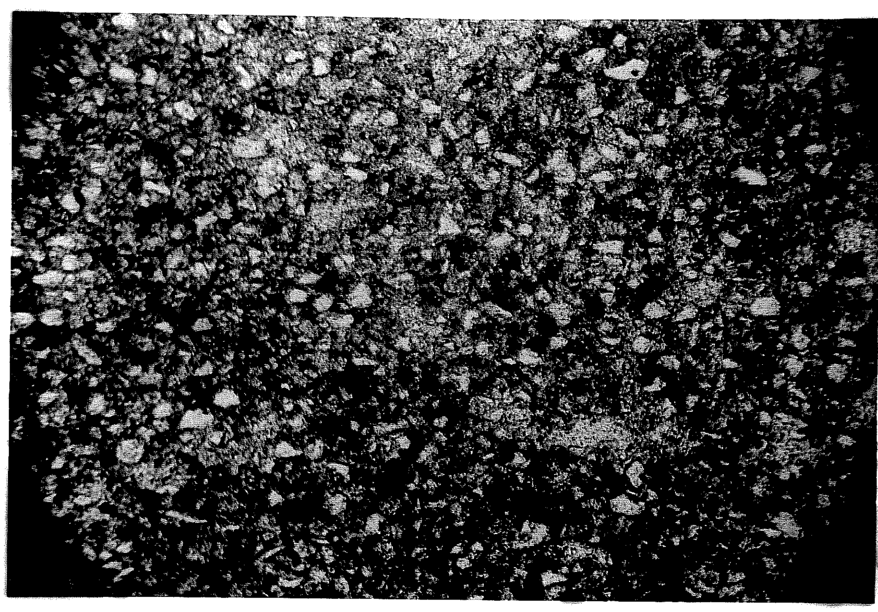


Figure 16. Calcareous sandstone from unit 5 on the southeast ridge in sec. 36.

Recrystallized or Replaced Rocks

Recrystallization is a process whereby the original crystal units change grain size and shape, but remain the same mineral species (Folk, 1959, p. 29). This includes changing micrite to microspar or to sparry calcite. Replacement is a process whereby the original constituents are replaced, usually with the same volume of material, by another mineral of a different composition (Folk, 1965, p. 158). This includes the replacement of calcite by dolomite and calcite by chert or quartz.

Sparry Calcite.--The aragonitic shell material of pelecypods, gastropods, and others in time inverts from a delicately fibrous or prismatic shell structure to a structureless, interlocking, semi-equigranular mosaic of anhedral sparry calcite (Folk, 1959, p. 32). Nearly all the fossil fragments in the Colina have been recrystallized in this manner.

Microspar.--Microspar is recrystallized micrite forming an irregular mosaic of clear crystals from 5 to 15 microns in size (Folk, 1959, p. 32). Many of the micrites and biomicrites in the Colina have been partly recrystallized to microspar. The amount of recrystallization is commonly between 15 and 30 percent, although several samples contain 75 to 80 percent microspar in irregular patches. The microspar in many samples is not uniform in crystal size and decreases in grain size towards areas of micrite. In many specimens where allochemical grains are present, the micro-spar crystal mosaic projects into the allochems.

Dolomite.--Scattered white sand-size specks are common in the upper units of both measured sections where the Epitaph is exposed. In thin sections these were revealed as dolomite rhombs and scattered patches of aphanocrystalline dolomite (Figure 16). Many of these upper units contain 30 to 50 percent very finely crystalline to aphanocrystalline dolomite. A few layers near the Epitaph contact are composed of dolomite with some patches of sparry calcite and some of quartz.

Chert.--Nodular masses of chert and sparry calcite are common in the uppermost layers of the Colina near the contact with the Epitaph Dolomite in the section on the southeast ridge in sec. 36. One sample contains quartz and sparry calcite in a 6 mm oval area. The quartz in this area is composed of 0.25 to 1.7 mm mosaic grains of different undulose extinction. The quartz is surrounded on one side by a large amount of very coarsely crystalline sparry calcite and on the other side by a thin layer of medium crystalline sparry calcite. This can be used as evidence for the replacement of calcite by chert.

DISTRIBUTION OF COLINA LIMESTONE IN SOUTHEASTERN ARIZONA

Carboniferous limestones or the Naco Limestone, which at one time included all Pennsylvanian and Permian rocks in southeastern Arizona, was noted by Ransome (1904), Darton (1925), Butler, et al. (1938), Wilson (1951), and Galbraith and Loring (1951) in the following places: Bisbee and the Mule Mountains, Tombstone Hills, Dragoon Mountains, Whetstone Mountains, Swisshelm Mountains, Huachuca Mountains, Empire Mountains, Santa Rita Mountains, Sierrita Mountains, Tucson and Amole Mountains, Silver Bell Mountains, and the Waterman Mountains. Although these reports do not mention the Colina Limestone by name, it is described in some of these localities in more recent reports. See Figure 17 for the locations of these mountain ranges.

Cochise County

Tombstone Hills.--Gilluly, Cooper, and Williams (1954) described widespread outcrops of Colina Limestone in the southern Tombstone Hills and eastward into Government Draw in the Earp Hills. In the type area on Colina Ridge they measured 633 feet of Colina Limestone; in this study 622 feet of the formation was measured. The slight difference in thickness may result from measuring sections

EXPLANATION

Location of Measured Sections of Colina Limestone in the Correlation Cross-Sections B and C

Approximate 5000 foot contour or other contour to outline mountain ranges

Arizona base map Scale 1:1,000,000
1 inch = approximately 16 miles

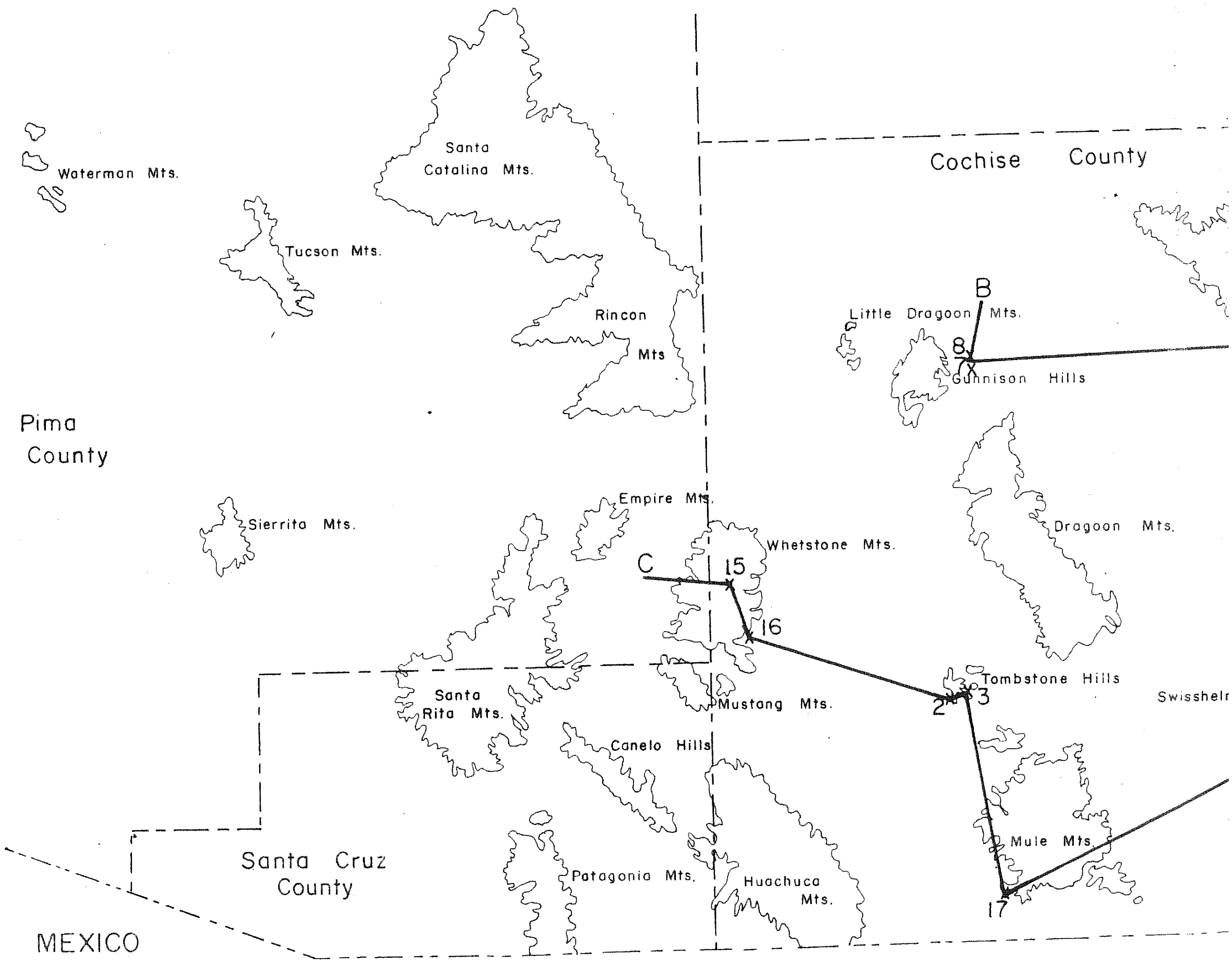
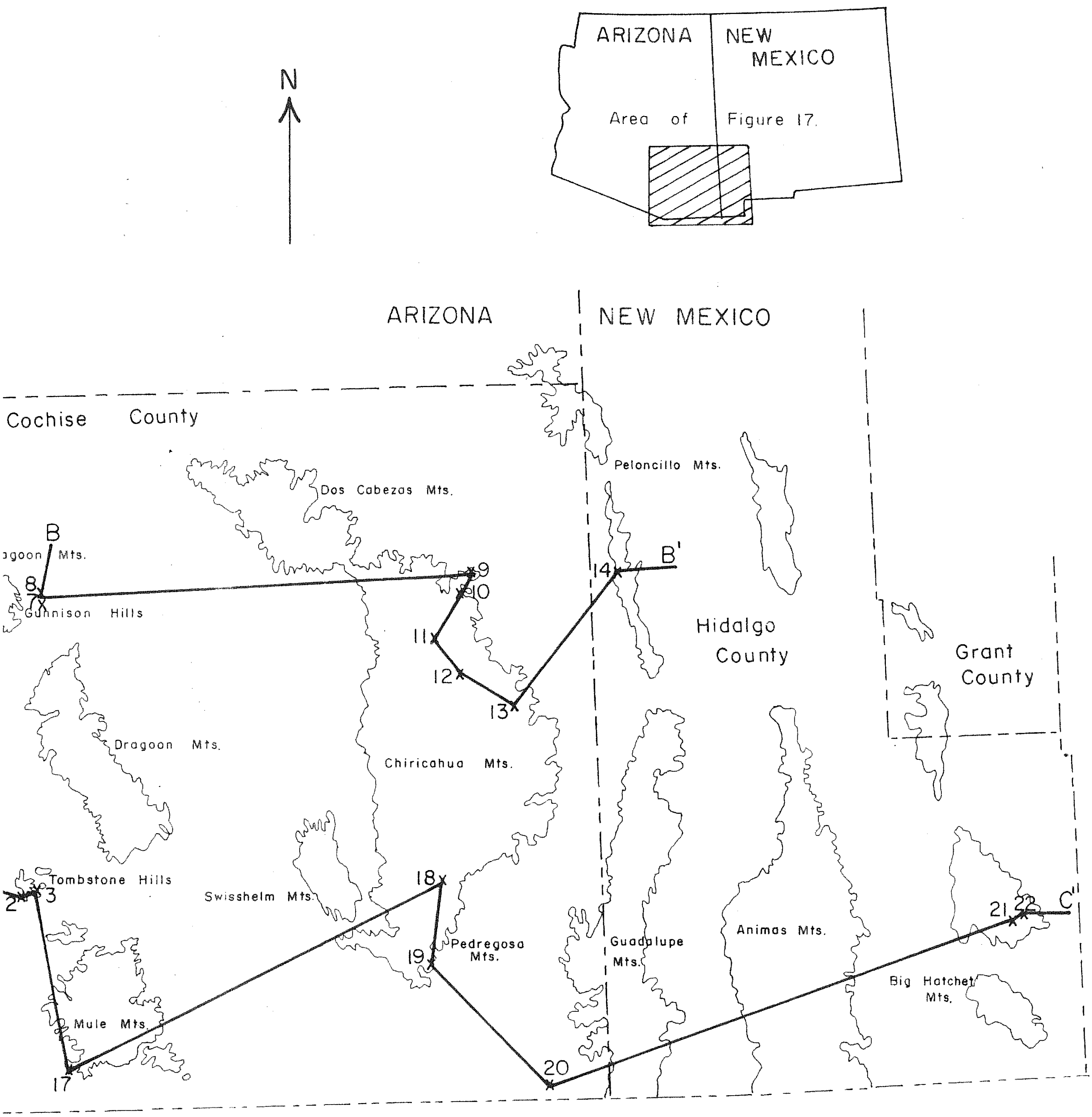


Figure 17. LOCATION MAP



LOCATION MAP

in slightly different places or from operator error. The varying level of the Colina-Epitaph contact could also account for the 11 foot difference.

Mule Mountains and Naco Hills.--Gilluly (1956) also mapped extensive outcrops of Colina in the northwestern foothills of the Mule Mountains. This area is extensively faulted, but the Naco Hills area to the south and east is less disturbed. Even in the Naco Hills area complete sections could not be measured as the Colina Limestone is unconformably overlain by Mesozoic deposits or by Cenozoic alluvium. Bryant (1955, p. 62) measured a partial section of Colina, 250 feet thick, in the Naco Hills and noted it was lighter in color and contained slightly thinner units than in the type area.

Hayes and Landis (1965, p. F29) measured a 495 foot thick section less than a mile west of the section measured by Bryant. They noted that the color is most commonly light olive gray or light brownish gray on fresh fracture rather than the dark gray of the type section and that a few beds are brownish or reddish gray. They chose the basal contact with the Earp Formation at the horizon where thick-bedded light-gray weathering limestone becomes dominant over red impure limestone and clastic rocks.

Huachuca Mountains.--Alexis (1949, p. 14) described several outcrops of massive, black, fetid limestone with

Euomphalus and *Omphalotrochus* in Garden Canyon and Lone Cabin Valley in the northern part of the Huachuca Mountains. Although he did not name or measure these outcrops since there were no continuous sections, these outcrops are probably Colina Limestone.

Weber (1950) found similar outcrops at Crump Hill, Wisconsin Canyon, Pat Scott Canyon, and Miller Canyon in the east-central part of the Huachuca Mountains; however, these beds were somewhat deformed and altered. Several outcrops contain abundant black chert in partially bedded lenses and nodules; this differs from the small amount of brown chert nodules in the type area of the Colina and suggests the possibility that it is not Colina.

Bryant (1955, p. 73) reported that "The section measured by Ogle and Taylor in Tanner Canyon has about 250 feet of gray limestone with a few interbeds of red shale and siltstone and red shaly limestone, overlain by nearly 600 feet of black limestone. The Colina aspect of this dark limestone is confirmed by an abundance of *Omphalotrochus* near the middle. The lower 250 feet is probably also Colina but fossils are rare and not diagnostic."

Whetstone Mountains.--H. R. Wanless in 1949 and a Shell Oil Company field party (Jones and Bacheller) in 1952 measured sections which were not too badly faulted in the Whetstone Mountains. Bryant (1955, p. 67) and Graybeal

(1962) reviewed these sections and reported a thickness of 700 feet for the Colina Limestone west of the Sands Ranch. The lower 200 feet consists of thin- to medium-bedded medium- to dark-gray limestone interbedded with gray and red sandstones and siltstones and buff-weathering dolomites. Graybeal (1962) noted that the sandstones contain limonite specks and that the limestones are dolomitic and coarse grained in some places. Bryant (1955, p. 67) noted rare specimens of Omphalotrochus in this lower part. The upper 420 feet is a high cliff of massive medium- to dark-gray limestone, which is silty and dolomitic in places. Brown chert occurs in this upper part. Stylolites occur here and in the Naco Hills at about the same stratigraphic position. The upper contact with the Epitaph Dolomite is very sharp, rather than transitional as it is in the Tombstone Hills.

Tyrrell (1957) reported excellent exposures of Colina Limestone along Montosa Canyon, in the east flank of the Whetstone Mountains, and in the southeast fault block. In these areas Tyrrell also noted numerous beds of dolomite and fewer fossils in the lower half of the formation, although rare specimens of Omphalotrochus and local concentrations of echinoid spines occur. The upper 50 feet contains beds of dolomitic limestone and medium-gray dolomite which are more common upward and grade into the Epitaph Dolomite. The lower contact with the Earp Formation was placed, not at the top of the last orange-weathering dolomite, but above this at a topographic break separating dominantly calcareous beds from the underlying dominantly clastic beds. Tyrrell's measured sections show a variation in thickness from 570 feet in Montosa Canyon to 630 feet on the east side of Apache Peak.

Little Dragoon Mountains.--In the Johnny Lyon Hills, Silver (1956) found that the Colina Limestone does not crop out either because it is faulted or covered by alluvium. The Little Dragoon Mountains have also been eroded deeply and no Colina Limestone outcrops are known (Bryant, 1955, p. 60).

Gunnison Hills.--Gilluly, Cooper, and Williams (1954, p. 25) published a measured section in the Gunnison Hills which contained 414 feet of the lower Colina; the upper part is covered by alluvium along a fault in Walnut Gap. A short distance across the fault to the northeast, questionable Colina strata, which measure 327 feet, are conformably overlain by the basal red siltstones of the Scherrer Formation rather than the Epitaph Dolomite. Bryant (1955, p. 59) tentatively assigned this upper 327 feet to the Epitaph on the basis of its similarity to the upper Epitaph in the Whetstone Mountains. The many possible interpretations of this Epitaph problem will be discussed in greater detail in a later section.

Bryant (1955, p. 58) noted much more dark limestone in the upper Earp Formation in the Gunnison Hills than in the type section in the Tombstone Hills. The poorly preserved molluscan fauna in these dark limestone beds closely resembles the fauna in the overlying Colina. This may indicate that the depositional conditions typical of the Earp persisted for a longer time in the Gunnison Hills. If this explanation is true, the upper part of the Earp Formation in the north is contemporaneous with the lower part of the Colina Limestone in the south.

Cooper and Silver (1965, p. 66) reviewed the sections published by Gilluly, Cooper, and Williams (1954) and noted that the formation in the Gunnison Hills is very similar to that in the type section except for a few light-gray dolomitic beds and two beds of pinkish-gray or rusty-brown sandstone high in the formation in the Gunnison Hills.

Dragoon Mountains.--The upper Paleozoic formations crop out only in incomplete and faulted sections in the Dragoon Mountains and to the southeast in the Courtland-Gleeson area. Bryant (1955, p. 57) reported relatively less disturbed sections at the northwestern edge of the range south and west of the Golden Rule mine. The Colina Limestone is about 400 feet thinner there than in the type section, but the top and bottom show evidence of shearing and thrust faulting. Cederstrom (1946) reported 250 feet of thin-bedded blue-gray limestone (possibly Colina) overlying 750 feet of sandstone and shale (possibly Earp).

Dos Cabezas Mountains.--Jones and Bacheller (Bryant, 1955, p. 101) measured a section of Colina about three miles northwest of the town of Dos Cabezas. The top 150 feet of this section is massive dark-gray fossiliferous limestone containing *Omphalotrochus* and was assigned by Bryant (1955, p. 101) to the Colina. Above this unit the section is eroded and overlain by alluvium.

Chiricahua Mountains.--In the Portal-Paradise area the Colina Limestone is similar to that of the type section, and has a thickness of at least 500 feet and possibly more than 700 feet, and is overlain by the Epitaph Dolomite. Bryant (1955, p. 104) reported numerous megafossil zones that contain abundant echinoid spines, brachiopods, corals, and gastropods including *Omphalotrochus*.

In the Hilltop mine area, Brittain (1954, p. 30) described 480 feet of dark-gray limestone below the Hilltop quartzite member. He called this black limestone the Footwall limestone and equated it to the Colina Limestone; he equated the overlying Hilltop quartzite member of the Permian system to the Scherrer Formation.

Papke (1952, pp. 29-31) also measured this section in the Hilltop mine area; he designated the 473 feet of medium- to dark-gray thin-bedded limestone the Hardluck member. This member overlies what he called the Naco Formation and underlies the Hilltop quartzite member (Scherrer). The lithology of the Hardluck limestone closely resembles that of the Colina Limestone.

Sabins (1957, p. 1324) found good exposures of the Colina Limestone in the Chiricahua Mountains at Portal, AVA Ridge, and south of Fox Canyon. The only complete section measured was 535 feet thick on the southeast edge of Timber Mountain; other nearby sections with alluvium at the base or top were within 100 feet of this thickness. In all sections where the upper contact is visible, the Colina Limestone is conformably overlain by the basal redbeds or sandstone of the Scherrer Formation.

Swisshelm Mountains.--In the nearby Swisshelm Mountains, southwest of the Chiricahua Mountains, Loring (1947, p. 42) described a section which includes 215 feet of medium-gray, fine-grained limestone with a few thin interbeds of brown limy siltstone in the lower part, and that contains *Euomphalus* and other typical Colina fossils. Below this limestone are brick red shales and sandstones that weather pale reddish brown and a red stained conglomerate; these are all typical lithologic types of the Earp Formation. The upper beds of the Colina have been eliminated by Recent erosion.

Pedregosa Mountains.--Nearly complete sections of the Colina were measured in the Pedregosa Mountains a few miles east of the Swisshelms. On Limestone Mountain, Epis (1956, p. 118) measured a nearly complete section of 1,000 feet of Colina Limestone with probably tens of feet removed by Recent erosion. Bryant (1955, p. 110) noted evidence of some bedding plane faulting in the upper part of the section and drew attention to the possibility that such repetition by faulting may have increased the apparent thickness. The formation becomes more dolomitic and varicolored toward the top of this section, and contains cherty zones throughout.

Epis (1956, p. 96) measured 950 feet of Colina Limestone on Beacon Hill, about eight miles south of Limestone Mountain, but the base of the section is covered by Tertiary rhyolite. The formation at this place is slightly different from the type section in that it contains more echinoid spines, productids, and omphalotrochids. Epis noted several beds containing black chert nodules and white calcite stringers, but he did not mention any sandstone or siltstone beds. Bryant (1955, p. 110) described this section as 400 feet of dark-gray limestone, which is slightly dolomitic in the lower part and sparsely fossiliferous in the upper part; 300 feet of similar but mostly concealed limestone with *Omphalotrochus*, *Composita*, and echinoid spines;

200 feet of dark-gray limestone with scattered chert nodules; and the top ten feet is a bed of partly dolomitized limestone with echinoid spines. The Colina in this section is overlain by 1,300 feet of Epitaph Dolomite.

San Bernardino Valley.--Dirks (1966) noted fewer clastic beds and a greater abundance of fossils, including fusulinids, in the Colina Limestone sections measured in the Quimby Hills. He used a cherty fossiliferous marker bed in two partial sections to arrive at a total thickness of 950 feet. In the nearby Pickhandle Hills, Kelly (1966, p. 13) measured only 400 feet of the lower part of the Colina in fault contact with the Epitaph Dolomite.

New Mexico

Peloncillo Mountains.--Gillerman (1958, pp. 125, 138) found outcrops of Colina Limestone on the western slope of the Peloncillo Mountains south of the Silver Hill mine, and described a 504-foot partial section north of Cienega Peak. In this area the formation forms gentle slopes with ledges and small cliffs rather than the moderately steep ridges typical of the Tombstone Hills. The lower part of the measured section is similar to the type section, but the upper part contains brown-weathering dark-gray and red siltstone and thin beds of sandstone interbedded with the black limestone. The upper 120 feet is gray to pinkish gray friable calcarenite conformably overlain by the red orthoquartzite of the Scherrer Formation.

Big Hatchet Mountains.--Zeller (1965, p. 97) found that the Colina Limestone crops out in stepped hillsides or steep bluffs in the southwestern part of the Big Hatchet Mountains of New Mexico. He attributes the difference in thickness between the Lower Sheridan Tank section of 355 feet and the Mine Canyon section of 505 feet less than a mile away "to variation in the stratigraphic level of dolomitization." He traced individual limestone beds from the Mine Canyon section into dolomite beds in the Lower Sheridan Tank section. He also recorded a thickness of 808 feet of Colina Limestone in a nearby well drilled by Humble Oil and Refining Company. Zeller also reported lower Colina in the Animas Mountains, 15 miles to the west, and in Mexico in the Sierra Boca Grande and near the village of Barreal, 70 miles southeast of the Big Hatchet Mountains.

Pima and Santa Cruz Counties, Arizona

To the west of the type area in Pima and Santa Cruz Counties the Earp Formation, Colina Limestone, and Epitaph Dolomite are more difficult to distinguish from one another. These rocks were commonly assigned to the Andrada Formation (Bryant, 1955). However, the Andrada Formation is not a useful stratigraphic name; therefore rocks within this formation should be assigned to the Earp, Colina, or Epitaph Formations.

Patagonia Mountains.--Bryant (1955, p. 75) observed 1,300 feet of Andrada Formation about two miles south of Harshaw in the Patagonia Mountains. The upper 800 feet of this section consists of medium- to dark-gray limestone which is dolomitic in many places; this can probably be correlated with the Colina Limestone. It overlies 200 feet of interbedded limestone and siltstone above a red chert conglomerate and underlies a quartzite now considered the lower quartzite of the Scherrer Formation.

Canelo Hills.--Feth (1958) measured a section in the Canelo Hills that includes about 370 feet of dark-gray limestone between an upper dominantly dolomite unit and a lower sequence of tan and reddish-gray limestone and dark-red siltstones and sandstones. This unit probably is Colina Limestone overlain by Epitaph Dolomite and underlain by Earp Formation. Bryant (1955, p. 77) pointed out that this range consists of a thrust block which has overridden Cretaceous rocks; thus the measured sections may not be representative as the accompanying faulting may have produced repetition or omission of beds.

Santa Rita Mountains.--Anthony (1951, p. 17) discussed Permian rocks in the Montosa Canyon area of the Santa Rita Mountains that include a dark-brown quartzite (possibly equivalent to part of the Scherrer Formation), light-buff to gray limestone and marly beds (possibly equivalent to the Epitaph Dolomite), light-gray to dark-gray, fossiliferous limestone (possibly equivalent to the Colina Limestone), and thin-bedded light-gray to buff limestone (possibly equivalent to part of the Earp Formation).

Empire Mountains.--Galbraith (1940) recognized 10 to 200 feet of dense, dark blue-gray limestone in the middle of the Andrada formation in the Empire Mountains. Sections of the Andrada formation measured by Jones and Bacheller on Cienega Ridge (1900 feet), by Feth (1948, p. 97) on Eagle Bluff (400 feet), and by Bryant (1955, p. 82) near the Andrada Ranch (1,600 feet) were not subdivided into Epitaph, Colina, or Earp Formations. In the Cienega Ridge section the upper part of the Andrada is similar to the Epitaph Dolomite in the Sands Ranch section in the Whetstone Mountains.

In the area southeast of the Andrada Ranch near the Sonoita road, Gillingham (1936, p. 21) described outcrops of a dark-blue, generally finely crystalline limestone with yellow to white calcite developed in small cracks. He noted several intervals of abundant fossils in the limestone. This limestone could be Colina Limestone.

Alberding (1938, p. 22) included a tentative correlation chart between the California mine area, the northern

Empire Mountains, the Whetstone Mountains (after Laursen), and the Tombstone area (after Gilluly). He erroneously correlated Gilluly's "black limestone" series (Colina) with the dark limestones (Concha Limestone) above the quartzite (Scherrer) in the northern Empire Mountains and California mine area.

Various theses concerning the ore deposits in the Empire Mountains have mentioned the presence of a dark-gray, massive bedded limestone which is dolomitic in places, below a sequence of quartzite, limestone and quartzite (Scherrer). Each author has placed this limestone in a different formation--Snyder Hill Formation, San Andres (?) Formation, Manzano Group, and upper Cienega; none of these are valid names for this formation in this area and should be disregarded. These incompletely described rocks, as listed in the next five paragraphs, might belong to either the Colina Limestone or the Epitaph Dolomite, or even to the Concha Limestone.

Alexis (1939, p. 9) described about 300 feet of massive blue limestone containing Bellerophon, some productids, echinoid spines, and other gastropods in the Lead Mountain area in the southern Empire Mountains in beds exposed along the southern slopes of Jordan Valley.

In the Pantano Hills in the northeastern Empire Mountains Sears (1939) observed about 200 feet of dark-blue, medium- to thick-bedded limestone that is light gray toward the top.

Sopp (1940) described about 90 feet of gray to blue, thin-bedded limestone on the west side of Eagle Bluff in the Montana mine area.

Marvin (1942, p. 21) observed 320 feet of blue limestone in the Hilton Ranch area; it is conformable above shales, limestones and gypsum and is in bedding plane fault contact with the overlying yellow quartzite of the Scherrer Formation. He described the limestone as blue to light gray, thin-bedded, and somewhat dolomitic. Since the only known gypsum in the Empire Mountains occurs in the Epitaph Dolomite, this limestone may not be Colina.

Mayuga (1942) worked in the Empire Peak area east of Hilton Pass in the southern part of the Empire Mountains and in the Lead Mountain area. He described outcrops of a bluish-gray, massive limestone containing cavities filled with calcite or silica, and noted such fossils as *Bellerophon* sp., a few productids, echinoid spines, and other gastropods.

Rincon Mountains.--Layton (1957, pp. 70, 84) found no complete sections of Colina Limestone or upper Andrada formation, although he described several partial sections south of the Colossal Cave Road in the southern foothills of the Rincon Mountains.

Kerns (1958, pp. 29, 30) described the upper Andrada (Colina Limestone and Epitaph Dolomite) in the Agua Verde Hills in the southwestern foothills of the Rincon Mountains as gray to black, fine-grained carbonates, mostly dolomite. He noted one inch wide, white crystalline dolomite stringers and white to tan chert. Fossils such as crinoid stems, echinoid spines, brachiopod and pelecypod valves, and gastropods are abundant, but poorly preserved.

Tucson Mountains.--Blocks of Rainvalley Formation, Concha Limestone, and Scherrer Formation are the only Permian rocks that have been indentified in the Tucson Mountains. Only the Concha Limestone and Rainvalley Formation occur at Snyder Hill, ten miles southwest of Tucson along Ajo Road (Bryant, 1955).

Waterman Mountains.--McClymonds (1957, p. 42) measured 207 feet of dark-gray, fossiliferous limestone in the upper member of the Andrada Formation (Colina) in the southern Waterman Mountains. The lower 115 feet is a massive cliff and the upper part is thinner bedded and includes several dolomite layers. A similar sequence occurs at Koht-Kohl Hill where the Colina is 220 feet thick (McClymonds, 1959, p. 81). He noted a lower carbonate-to-clastic ratio in the Waterman Mountains than in the Tombstone Hills.

Ruff (1951, p. 38) described some undifferentiated Permian sediments in the Indiana Mine area in the northern

Waterman Mountains which includes 250 feet of medium light gray, thick-bedded limestone that is probably equivalent to the Colina Limestone.

AGE

Review of Fauna

The most distinctive fossils in the Colina Limestone are the gastropods; echinoid spines and brachiopods are also quite common, especially in the upper half of the formation. Most of the fossils are exposed as cross-sections of white shelly material in dark gray micrite. Since the fossils are not harder than the surrounding rock, they do not weather out of the rock and cannot be leached out of it. These fossil cross-sections are difficult to assign to specific genera and species, but some of the better exposed fossils can be identified to genera.

Table 3 lists the fossils from the Colina Limestone and from what is assumed by the author to be Colina Limestone from descriptions in earlier reports. The gastropods and brachiopods include more identified genera than any other group. This is an indication of the abundance and variety of these animals in the seas when the Colina Limestone was deposited. Echinoid spines are very abundant, but they are difficult to assign to species because of the lack of detail in preserved specimens or because of the lack of variety in echinoids living in the Colina seas.

Table 3. Fossil distribution.

	Waterman Mountains	Empire Mountains	Rincon Mountains	Gunnison Hills	Whetstone Mountains	Canelo Hills	Huachuca Mountains	Tombstone Hills	Mule Mountains	Southeast of Gleeson	Swisshelm Mountains	Pedregosa Mountains	Chiricahua Mountains	Quimby Hills	Peloncillo Mountains	Big Hatchet Mountains
FUSULINIDS													x			
Staffella												x				
Schwagerina												x		x		
Schubertella												x				
Pseudofusulina												x				
Triticites californicus												x				
Triticites ventricosus									x							
Parafusulina														x		
FORAMINIFERA																
Climacammina									x							
?Chusenella														x		
ECHINOID SPINES	x	x	x				x	x		x			x			
Echinocrinus				x				x	x	x						
Echinocrinus cratis									x							
Echinocrinus trudifer									x							
Archaeocidaris						x						x				
PELECYPODS			x		x			x	x	x			x			
Myalina													x			
Nucula							x						x			
Astartella			x													
Pleurophorus			x													
AMMONITE CEPHALOPODS																
Metacoceras sp.										x						
Perrinites								x								
Perinites hilli													x			
SCAPHOPODS															x	
Plagioglypta									x							
Plagioglypta canna													x			
CORALS																
zaphrentoid								x								
tabulate corals	x															

Table 3. (Continued)

	Waterman Mountains	Empire Mountains	Rincon Mountains	Gunnison Hills	Whetstone Mountains	Canelo Hills	Huachuca Mountains	Tombstone Hills	Mule Mountains	Southeast of Gleeson	Swisshelm Mountains	Pedregosa Mountains	Chiricahua Mountains	Quimby Hills	Peloncillo Mountains	Big Hatchet Mountains
BRYOZOANS	x					x	x					x				
Fenestella?																
Fistulipora									x	x						
Microdoma n. sp.										x						
Proretepora									x							
Retispira					x											
Septopora?								x	x							
CRINOID STEMS	x	x	x			x		x					x			
NAUTILOIDS	x							x								
TRILOBITE																
Ditomopyge									x							
GASTROPODS	x	x	x					x	x	x			x			x
Omphalotrochus					x		x	x				x			x	
Omphalotrochus obtusispira							x	x				x				
Euomphalus sp.	x			x			x	x	x	x	x	x	x			
Bellerophon sp.	x	x	x			x	x	x	x				x			x
Worthenia sp.	x							x								
Murchisonia sp.			x									x	x			
Murchisonia gouldi								x								
Goniasma sp.								x	x			x				
Naticopsis sp.								x	x			x	x			
Orthonema sp.			x	x				x	x				x			
Anomphalus									x							
Meekospira									x							
pleurotomarians				x												
Euphemites									x				x			
Bucanopsis													x			
Yunnania								x	x			x				
Glabrocingulum	x		x													
Pseudozygopleura			x													
Amphiscapha	x															

Table 3. (Continued)

	Waterman Mountains	Empire Mountains	Rincon Mountains	Gunnison Hills	Whetstone Mountains	Canelo Hills	Huachuca Mountains	Tombstone Hills	Mule Mountains	Southeast of Gleeson	Swisshelm Mountains	Pedregosa Mountains	Chiricahua Mountains	Quimby Hills	Peloncillo Mountains	Big Hatchet Mountains
Warthia									x							
Strobeus										x						
BRACHIOPODS																
Avonia								x								
Phricodothyris	x						x						x			
Strophalosia								x	x		x					
Strophalosia slocumi								x				x				
Composita	x	x	x			x	x	x			x	x	x	x		
Composita mexicana								x	x	x						
Crurithyris								x								
Wellerella texana								x	x			x				
Dictyoclostus	x		x				x		x							
Dictyoclostus ivesi								x		x		x				
Dictyoclostus occidentalis								x	x	x						
Dictyoclostus bassi		x						x								
Dielasma								x				x				
Meekella	x						x	x								
Meekella pyramidalis				x				x								
Derbyia										x						
Derbyia multistriata									x							
Productus		x		x												
Spirifer													x			
Pseudomonotis hawni													x			
Cleiothyridina (?)			x													
Camarophoria deloi											x					
Buxtonia?										x						
SOURCES																
McClymonds, 1957	x															
Feth, 1948		x														
Alexis, 1939		x														

Table 3. (Continued)

	Waterman Mountains	Empire Mountains	Rincon Mountains	Gunnison Hills	Whetstone Mountains	Canelo Hills	Huachuca Mountains	Tombstone Hills	Mule Mountains	Southeast of Gleeson	Swisshelm Mountains	Pedregosa Mountains	Chiricahua Mountains	Quimby Hills	Peloncillo Mountains	Big Hatchet Mountains
Mayuga, 1940		x														
Layton, 1957			x													
Kerns, 1958			x													
Gilluly, et al., 1954				x												
Tyrrell, 1957					x											
Ross and Tyrrell, 1965					x											
Feth, 1948						x										
Alexis, 1949							x									
Weber, 1950							x									
Gilluly, et al., 1954								x		x						
Gilluly, 1956								x	x							
Hayes and Landis, 1965									x							
Loring, 1947											x					
Epis, 1956												x				
Bryant, 1955													x			
Brittain, 1954													x			
Papke, 1952 (ident. by Bryant)													x			
Sabins and Ross, 1965													x			
Sabins, 1957													x			
Dirks, 1966														x		
Gillerman, 1958															x	
Zeller, 1965																x

Pelecypods are locally present in the Colina Limestone, but scaphopods, bryozoans, cephalopods, corals, and trilobites are rare. Gilluly (1956, p. 50) stated, "Fusulinids are common and fairly scattered stratigraphically, ...but unfortunately all of the fusulinid collections from the Colina and Epitaph Formations in the Pearce and Benson quadrangles were misplaced or lost. None were obtained from beds of this age in the nearby Dragoon quadrangle." Because of this statement all subsequent workers have searched for fusulinids in the Colina Limestone.

Bryant (1955, p. 125) and the Shell Oil Company field party did not find any fusulinids in the Colina sections described by Gilluly. Ross and Tyrrell (1965, p. 618) did not find any fusulinids in the Colina in the Whetstone Mountains. Sabins and Ross (1963, p. 152) stated that fusulinids are absent in the sections of Colina they studied in the Chiricahua Mountains. Zeller (1965, p. 49) could not find any fusulinids in the Colina in the Big Hatchet Mountains of New Mexico.

Fusulinids have been identified by Hayes and Landis (1965, p. F30) in the Mule Mountains three feet above the base of the Colina Limestone, by Epis (1956, p. 103) at the base of the Colina in the Pedregosa Mountains, and by Dirks (1966, p. 23) throughout the Colina in the Quimby Hills. These three localities are in southeasternmost Arizona, and the only occurrence of fusulinids above the basal beds of the Colina is in the Quimby Hills, which is the farthest southeast.

Perhaps the living conditions favorable for fusulinids, which were present at times during the deposition of the Earp Formation, persisted in southeastern Arizona only until the basal beds of the Colina Limestone were deposited. This favorable environment may have remained longer in the southeasternmost corner of Arizona. It would be interesting to examine the limestone equivalent to the Colina Limestone in Mexico; perhaps it contains a more complete fusulinid record.

Age According to Fossils

Knight (*in* Gilluly, Cooper, and Williams, 1954, pp. 39-40) stated that gastropods from the Colina Limestone indicate a Wolfcampian age. This conclusion is based primarily on the abundant specimens of *Omphalotrochus obtusispira* (Shumard). He also stated on page 39 of the same work, "The restricted genus is highly characteristic of beds of Wolfcampian age occurring abundantly in the central Texas Permian as high as Leuders, in the type Wolfcamp of the Glass Mountains, in the Hueco Limestone of the Sierra Diablo, the Hueco and Sacramento Mountains, and of equivalent beds in southeastern California. Indeed, its range appears to coincide throughout the world with that of

Pseudoschwagerina." He also reports that other gastropods such as Yunnania sp. A, Taosia crenulata (Girty), and Euomphalus, n. sp. A occur in the middle Hueco of Wolfcampian age in Texas. Some of the gastropods, such as the genera Meekospira, Anomphalus, and Microdoma are characteristically Pennsylvanian forms and do not occur above the Wolfcamp. However, a few specimens, such as Murchisonia cf. M. gouldii and Euomphalus sp. B suggest a younger age.

The brachiopod fauna as studied by Williams (in Gilluly, Cooper, and Williams, 1954, p. 40) indicates a Wolfcampian or younger age. The specimens of Wellerella cf. W. texanus Shumard and Composita mexicana Hall, which are longer ranging forms, occur throughout the Colina. The fossils which are found only in the upper part of the Colina--Meekella cf. M. pyramidalis (Newberry), Dictyoclostus occidentalis (Newberry), Dictyoclostus cf. D. ivesi (Newberry), Linoproductus (Cancrinella) cf. L. villersi (D'Orbigny), and Derbyia multistriata (Meek & Hayden)--suggest a post-Wolfcampian age for the upper part.

The cephalopod Perrinites, which was found in the upper part of the Colina, indicates a Leonardian age according to A. K. Miller (in Gilluly, Cooper, and Williams, 1954, p. 40). Sabins (1957, p. 494) also found Perrinites hilli in the Chiricahua Mountains; this substantiates the Leonardian age for the upper Colina.

The fusulinid of Wolfcampian age, Triticites sp. aff. T. ventricosus (Meek & Hayden), was found three feet above the base of the Colina in the Mule Mountains by Hayes and Landis (1956, p. F30). Epis (1956, p. 103) found the Wolfcampian fusulinids, Staffella sp., Schwagerina, Schubertella, Pseudofusulina, and Triticites californicus near the base of the Colina Limestone in the Pedregosa Mountains. Dirks (1966, p. 23) stated "An Early Leonardian age is clearly indicated by the first appearance of Parafusulina approximately 320 feet above the base of the formation. Parafusulina marks the Wolfcampian-Leonardian Series boundary of the Permian System." He also found Schwagerina, Staffella and Chusenella scattered throughout his sections in the Quimby Hills.

Thus the evidence of the gastropods indicates a Wolfcampian age although a few suggest a younger age. The brachiopods indicate the upper half of the Colina Limestone is Leonardian in age. The ammonite cephalopod Perrinites hilli also indicates that the upper half of the Colina is Leonardian. The fusulinids found in the basal beds of the Colina are of Wolfcampian age and the fusulinids found in the upper half are of Leonardian age. Thus the entire fauna indicates that the lower half of the Colina Limestone is of Wolfcampian age and the upper half is of Leonardian age.

CORRELATIONS

Correlations in the Tombstone Hills

The sections measured in the Tombstone Hills, which are described in the Appendix, are compared to the type section on Colina Ridge (Gilluly, Cooper, and Williams, 1954, p. 24) by means of a detailed correlation cross-section (Figure 2). The sections on Colina Ridge (Figure 18) and the southeast ridge one mile east of Colina Ridge (Figure 19) are quite similar in topographic expression, probably because their angles of dip (30 to 55 degrees) are similar. A greater abundance of microspar was noted in thin sections and peels from Colina Ridge. This recrystallization from micrite (one to four micron calcite) to microspar (5 to 15 micron calcite) may be related to the closer proximity to igneous activity as evidenced by the sills on Colina Ridge. The problem of recrystallization in limestone in southern Arizona deserves further study, but it is beyond the scope of this study.

The section on Colina Ridge contains fewer biomicrites than the section on the southeast ridge, although many whole fossils were observed on Colina Ridge. The greater abundance of fossil hash and also of coated grains in the southeast ridge is a reflection of the greater

Figure 18. Section measured on Colina Ridge.

This photograph of Colina Ridge was taken looking north-northeast towards Horquilla Peak. The section was measured up the ridge in the center of the photograph. Photograph by Joseph F. Schreiber, Jr.

Figure 19. Section measured on the southeast ridge in sec. 36.

This photograph was taken from Colina Ridge looking northeast at the southeast ridge across the saddle of siltstones in the Epitaph Dolomite in Epitaph Gulch (Strikes N. 45°W.). The section was measured on the west (left) side of the small gully right of center. The lower contact of the Colina Limestone with the Earp Formation is near the lowest thin light colored ledge one third of the distance up the hill. Photograph by Joseph F. Schreiber, Jr.

Figure 18. Section measured on Colina Ridge.

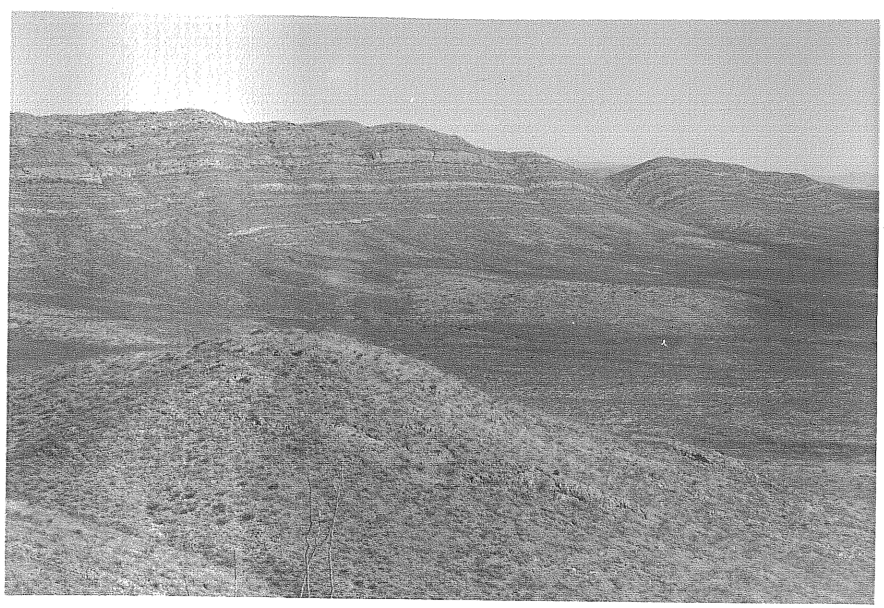


Figure 19. Section measured on the southeast ridge in sec. 36.

amounts of these materials in the upper part of the formation. The lower part of the columnar sections of Colina Ridge and the southeast ridge (Figure 2) are quite similar. The extra 325 feet in the upper part of the southeast ridge could be equivalent to the lower 200 to 270 feet of dolomite below the clastics of the Epitaph Dolomite on Colina Ridge. Zeller (1965, p. 97) traced individual limestone beds in one section into dolomite beds in a section a mile away. He thus accounted for 150 feet of extra thickness by variation in the stratigraphic level of dolomitization.

Some of the extra thickness in the southeast ridge could also be accounted for by repetition of beds as a result of faulting. Evidence for faulting, such as large, white chunks of sparry calcite and covered zones, was found in unit 36 (see Appendix), which is 158 feet below the Epitaph Dolomite. The repetition of whole units is not obvious in the columnar section of the southeast ridge (Figure 2). However, many faults of small displacement along bedding planes or at a low angle to the bedding would be invisible in a weathered hillside and could greatly increase the thickness if the faults were abundant. The geologic map of the Tombstone area (Gilluly, Cooper, and Williams, 1954) depicts the abundance of easily recognizable faults. The bedding plane faults, which are generally difficult to recognize, are much more common. Several are exposed in the roadcut through the Colina Limestone along U. S. Highway 80.

The traverse along which the section above the intrusion in sec. 31 was measured had to be offset many times in order to avoid obvious faults. The large cliff in the left part of the hill (Figure 20) was avoided because of a fault in which the limestone had fused so that the fault can only be discerned by attempting to match bedding planes. The layers in the northern part of the hill (right side of the hill in Figure 20) were measured because no faults were recognized. The upper and lower contacts were not found here or in the Cowan Ranch road section (Figure 21). The Epitaph Dolomite was mapped (Gilluly, Cooper, and Williams, 1954) at the top and forming the dip slope of both hills. However, only Colina Limestone is present at the top of each of the hills along the line of section. The angle of slope on the dip slopes indicates that the rocks are lower in the Colina farther down slope. Both the section in the cliff above the intrusion in sec. 31 and the Cowan Ranch road section have similar low dips (5 to 15 degrees) and both have an abundance of fossil hash and coated grains. This again reflects the greater abundance of these materials in the upper part of the Colina. The correlation cross-section (Figure 2) indicates that the other sections contain younger rocks than the type section on Colina Ridge.

Figure 20. Section measured above the intrusion in sec. 31.

This photograph was taken from U. S. Highway 80 looking northwest. The section was measured beginning at the lowest gray limestone on the right (east) side of the hill and proceeding to the top of the hill with offsets to the left.

Figure 21. Section measured near the Cowan Ranch road.

Photograph looking northwest; section measured along left side of hill.

Figure 20. Section measured above the intrusion in sec. 31.

Figure 21. Section measured near the Cowan Ranch road.

The outstanding feature of the columnar sections in the correlation cross-section of the Tombstone Hills (Figure 2) is the 70-foot layer of massive bedded, sparse to packed biomicrite that commonly forms a cliff. When the biomicrite units are aligned, the thin pale-red sandstone unit 80 to 100 feet above the top of the thick biomicrite unit is also aligned. This alignment of the red sandstone is true for all measured sections except the Colina Ridge section; here this stratigraphic position is occupied by the lowest bed in the Epitaph Dolomite. When both the thick biomicrite unit and the pale-red sandstone unit are aligned, two other intervals also line up approximately across the correlation cross-section. One of these is the interval of alternating covered beds and thin-bedded micrite to fossiliferous micrite, which begins about ten feet below the biomicrite unit. The other is the silty micrite which forms a prominent indentation at the base of a cliff about 95 feet below the thick biomicrite unit.

The comparison of the section measured in the road cut along U. S. Highway 80 with the section measured on the slope next to it (Figure 22) is an excellent lesson in the errors inevitably made when a completely exposed outcrop is not available. The most obvious error is the omission of all the pinkish and greenish-gray siltstones and shales in the lower part of the section. Many of the thin micrite

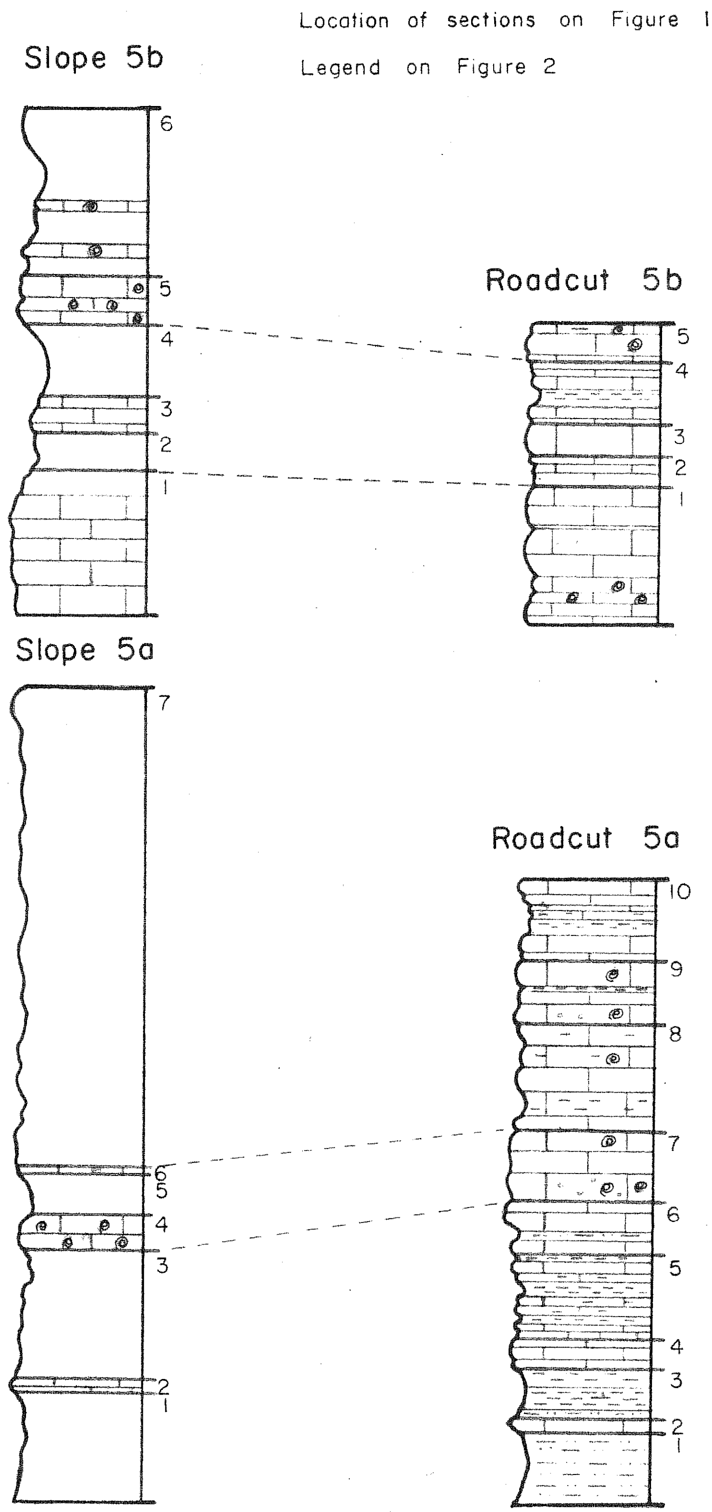


Figure 22. COMPARISON OF SLOPE AND ROADCUT SECTIONS ALONG U.S. HIGHWAY 80

beds are also covered by debris from the siltstone beds and thus appear as covered intervals in the section measured on the slope. In southern Arizona small faults and folds complicate the picture and often lead to erroneous thicknesses in section measurements. For example, the decrease in dip toward the top of Section 5a in the roadcut was not observed on the slope over the roadcut; therefore the measured thickness on the slope was greater. The photograph of the roadcut (Figure 23) shows a small fault which would increase the thickness on the slope where it could not be observed.

Correlations in Cochise County

The correlation cross-sections through northern and southern Cochise County (Figures 3 and 4) contain several quite detailed measured sections and many less detailed measured sections. The only section, other than those from this report, in which Folk's (1959) terminology is used is Dirks' (1966) section from the southeastern part of the county (Figure 17, sec. 20). Some of the columnar sections were taken from drawings and others from descriptions of measured sections. The location of the measured sections is precisely listed in Table 4. Some authors did not mention either the presence or absence of chert. Most authors did not specifically delimit the occurrence of fossils; a few simply stated that fossils occur scattered

Figure 23. Fault in road cut along U. S. Highway 80.

Outcrop on west side of highway four miles south of Tombstone illustrates a reverse fault (on the far right) at an angle to the bedding plane which increases the thickness on top of the slope where the fault cannot be detected.

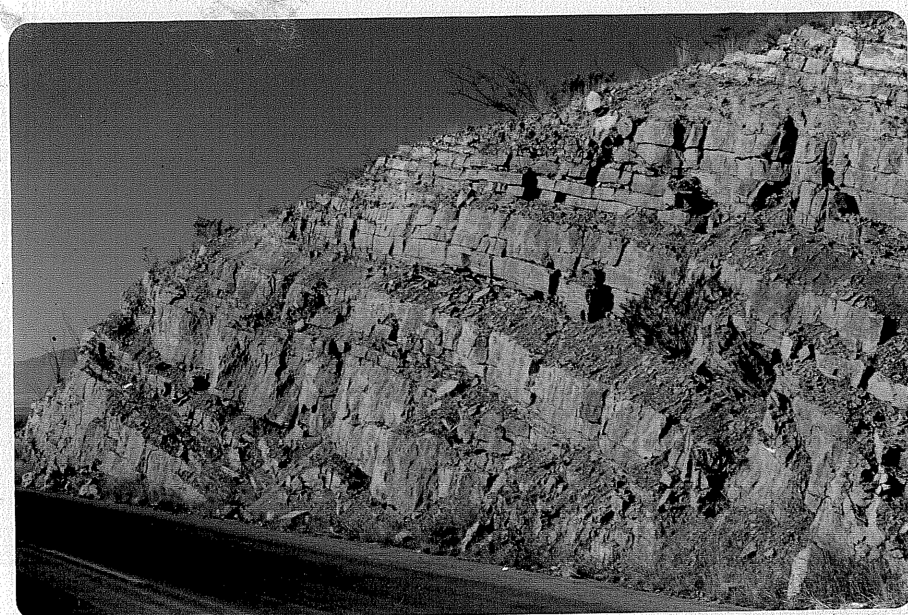


Figure 23. Fault in road cut along U. S. Highway 80.

Table 4. Location of measured sections used in cross-sections.

Author	Date	Mountains	Area	Sec.	T.	R.	No.
Gilluly, et al.	1954	Tombstone	Colina Ridge	34	20 S.	22 E.	1
Wilt	1969	Tombstone	NE¼, NE¼, NE¼	34	20 S.	22 E.	2
Wilt	1969	Tombstone	NW¼, NW¼, NW¼	36	20 S.	22 E.	3
Wilt	1969	Tombstone	NW¼, NW¼, NW¼	31	20 S.	23 E.	4
Wilt	1969	Tombstone	Hwy. 80 roadcut	31	20 S.	23 E.	5
Wilt	1969	Tombstone	NW¼, SW¼, NW¼	34	20 S.	23 E.	6
Gilluly, et al.	1954	Gunnison Hills	SE¼	29	15 S.	23 E.	7
Gilluly, et al.	1954	Gunnison Hills	NE¼	29	15 S.	23 E.	8
Sabins	1957	Chiricahua	SW¼	14	15 S.	30 E.	9
Sabins	1957	Chiricahua	NW¼	27	15 S.	30 E.	10
Sabins	1957	Chiricahua	SE¼	18	16 S.	30 E.	11
Brittain	1954	Chiricahua	Hilltop mine		16 S.	30 E.	12
Sabins	1957	Chiricahua	NE¼	21	17 S.	31 E.	13
Gillerman	1958	Pelòncillo	center	21	25 S.	21 W.	14
Tyrrell	1957	Whetstone	NE¼	33	18 S.	19 E.	15
Tyrrell	1957	Whetstone	SE¼	14	19 S.	19 E.	16
Hayes & Landis	1965	Mule	NW¼, SE¼	27	23 S.	23 E.	17
Epis	1956	Pedregosa	Limestone Mtn.	25	20 S.	29 E.	18
Bryant	1955	Pedregosa	Beacon Hill		22 S.	29 E.	19
Dirks	1966	Quimby Hills	SE¼, NE¼	15	24 S.	31 E.	20
Zeller	1965	Big Hatchet	Sheridan Tank	36	31 S.	15 W.	21
Zeller	1965	Big Hatchet	Mine Canyon	36	31 S.	15 W.	22

throughout the formation. The limitations of such rudimentary sections must be taken into account when interpreting the correlation sections.

The northern line of sections (Figure 3) contains more clastic rocks and covered intervals than the type section, which is closer to the center of the Pedregosa Basin. The greatest amount of clastics appears in New Mexico; perhaps this area was closer to positive elements supplying clastics to Permian seas. Sand is more predominant in the clastic rocks in the eastern part of the area; siltstones and covered intervals are more abundant in the western part of the area. As in the Tombstone Hills, fossils are more abundant in the upper or middle parts of the Colina; fossils are virtually absent in the lower parts of the sections in the northern correlation cross-section. The thicknesses are quite similar throughout the northern area and vary between 400 and 500 feet. The upper contact of the Colina Limestone is always with the Scherrer Formation in the northern area. In the western part of the cross-section in the Gunnison Hills and northern Chiricahua Mountains the contact is with the basal siltstones of the Scherrer. In the eastern part of the cross-section the Scherrer sandstone or quartzite is in contact with the Colina. The Epitaph, which forms the upper contact of the Colina in the type area in the Tombstone Hills, does not occur in northern Cochise County along the line of sections in Figure 3. The lower contact of the Colina Limestone in the northern correlation chart is either with the sandstones and siltstones of the Earp Formation or is covered by alluvium.

The southern line of sections (Figure 17) zigzags from the western border of Cochise County, through the middle of the Pedregosa Basin south of the Pedregosa Mountains, to the eastern border of the basin in New Mexico. The clastics in the southern correlation cross-sections (Figure 4) are composed primarily of siltstones. In the western part of the southern area clastics are more abundant in the lower Colina; in the eastern part clastics are more abundant in the upper Colina. The sections in the Pedregosa Mountains and Quimby Hills contain the least amount of clastics, probably because they were closer to the center of the Pedregosa Basin. Fossils are found throughout the Colina in these areas, whereas they are more abundant in the upper part of the Colina west of the center of the basin. The thickness is quite variable in the southern area, although a thickening trend toward the center of the Pedregosa Basin is discernable. Thicknesses of 400 feet increase to more than 600 feet in the type section at Colina Ridge; the maximum thickness of more than 950 feet occurs in the Pedregosa Mountains and Quimby Hills.

Thicknesses decrease eastward to 500 feet and 300 feet in the Big Hatchet Mountains of New Mexico. Most of the Colina sections are more dolomitic near the upper contact with the Epitaph Dolomite, although some upper contacts are erosion surfaces. The lower contact of the Colina is with Earp Formation sandstones or siltstones.

Correlations with Central Arizona

The Colina Limestone can be correlated with the Fort Apache Member of the Supai Formation in central Arizona, both lithologically and chronologically. Sabins (1957, p. 499) made this correlation on the basis of rock types and the ages of the rocks above and below both formations. Since most of the Supai Formation below the Fort Apache Member is Wolfcampian in age, Sabins (1957, p. 500) suggested that this part (the Big A Butte Member) extends south as the Earp Formation. The Supai above the Fort Apache Member (the Corduroy Member) may extend south as the basal redbeds of the Scherrer Formation.

Frazier (1961, p. 33) stated that the lithologies of the Colina Limestone and the Fort Apache Member as found on the Fort Apache Indian Reservation are quite similar; both are hard, blocky, dark gray to black and very fossiliferous. He noted that sponge spicules and echinoid fragments were abundant in both formations and that certain fossils, such as *Echinocrinus cratis*, *Orthonema* sp., *Plagioglypta* sp., *Chonetes* sp., *Meekella* sp., and *Naticopsis*, are common to both formations. Frazier (1961, pp. 32-33) assigned a Wolfcampian and lower Leonardian age to the Fort Apache Member because of the presence of Wolfcampian fossils and Leonardian *Meekella difficilis* and because of the absence of the upper Leonardian fossil, *Dictyoclostus bassi*.

Winters (1963, p. 15) stated that the Fort Apache Limestone fauna is probably Leonardian because its species are limited to Leonardian and younger beds in the standard sequence in west Texas. The only exception is *Meekospira knighti* which has been tentatively recognized in the Wolfcampian Hueco Limestone. Winters (1963, p. 15) stated, "Probably the northward-advancing sea that produced the Colina Limestone in late Wolfcampian-early Leonardian time in southeastern Arizona reached and receded from the reservation in early Leonardian time."

Correlations in Surrounding Areas

Partial time equivalents of the Colina Limestone include all those formations which are late Wolfcampian and early Leonardian in age. Some of these in the surrounding areas are as follows: the upper Supai Formation in northern Arizona; part of the Cutler Formation below the De Chelly Sandstone Member in northeastern Arizona; the Supai or Queantoweap Sandstone in western Clark County, Nevada; the upper part of the Bird Spring Formation in eastern Clark County, Nevada; the Abo Formation in northwestern New Mexico; the Hueco Limestone in central eastern New Mexico; and the Wolfcamp Formation in the Glass Mountains of Texas (McKee, 1967, pp. 208-210 and Table 1).

SUMMARY OF DEPOSITIONAL ENVIRONMENT

Interval A in Paleotectonic Investigations of the Permian System in the U. S. (McKee, 1967, p. 209) includes the Wolfcampian part of the Earp Formation and the entire Colina Limestone, even though part of it is probably of Leonardian age. The paleogeography of interval A is described in the following excerpt from McKee (1967, p. 213) from the investigation mentioned above.

> In the southeastern Arizona basin, referred to as the Pedregosa trough (Kottlowski, 1958, p. 84), interval A consists of relatively pure carbonate rocks near the center or deepest part but contains progressively more mudstone and siltstone toward the margins, especially westward. Some fine-grained detrital sedimentary rock near the east edge (Big Hatchet Mountains) may have been derived from the "Florida Island" positive element in New Mexico (Kottlowski, 1958, p. 83), but most of the detritus, as indicated by its present distribution, seems to have come from the west or northwest.
>
> An uplift northwest of the Pedregosa basin may have been a source of local conglomerate cobbles in the Gunnison Hills area, Arizona (J. R. Cooper, in Gilluly and others, 1954, p. 21). Some of the fine-grained detrital sediment might have come from highlands far to the northeast, such as the Uncompahgre and San Luis elements of Colorado, as suggested by Sabins (1957, p. 501); but this seems unlikely for interval A because (1) the intervening Defiance and Zuni positive elements were still partly above base level, (2) extensive areas of salt and gypsum accumulated in east-central Arizona (Little Colorado River area), and (3) the north margin of the basin in northeastern Arizona was apparently in central Arizona, far north of the Pedregosa basin.

> The upper beds of interval A (Colina Limestone) are mostly dark-gray to black uniformly thick bedded limestone containing mollusks and echinoids. These deposits are apparently not normal marine. They accumulated in relatively quiet water under slightly reducing conditions (Tyrrell, 1957). Farther east, rocks of interval A contain less detrital material, less dolomite, but a more open-sea fauna. Westward, in the Empire Mountains, the rocks are largely detrital (Bryant, D. L., 1955), which suggests proximity to the west edge of the basin.

The early Leonardian seas transgressed northward from areas of Colina deposition producing the Fort Apache Member of the Supai Formation. Gerrard (1966, p. 2441) stated in his discussion on paleogeography that "the Fort Apache sea advanced across a broad, low-gradient alluvial plain which had been partly flooded several times previously by marine waters. The principal drainage from the Uncompahgre-San Luis positive area on the northeast carried sediment southwest across the plain. However, streams that transported detritus from the plain to the Fort Apache sea margin appear to have flowed toward the south to southeast." Paleomagnetic studies have determined that southern Arizona may have been about 10° S. latitude during the early Permian (DuBois, 1964, p. 42); thus southern Arizona might have been in the tropical to subtropical climate zone.

The petrographic studies of the Colina have revealed many interesting details of the depositional environment. The great preponderance of micrites compared to the scarcity of sparites indicates that the bottom sediments of the Colina seas were not winnowed by strong or persistent currents. This lime mud may have originally been formed of aragonite needles similar to the acicular and prismatic aragonite needles a few microns long which are presently forming west of Andros Island in the Bahamas (Cloud, 1962, p. 1). These aragonite needles are accumulating where the water temperatures are generally higher than 27°C and salinites are greater than 39 parts per thousand. The bank waters vary in pH from 8.02 to 8.15 and oxidation-reduction potentials (Eh) average about 0.3 volts (Cloud, 1962, p. 14). These values are significant if the lime mud in the Colina has formed in the same manner. Cloud (1962, p. 25) stated that "aragonite needles are known to be formed by purely physiochemical processes and internally by codiacean and dasycladacean algae." The original aragonite mud of the Colina may have been in some other form. Matthews (1966, p. 428) found that aragonite needles were not common in the Recent lime muds from the southern British Honduras; rather the aragonite was in granular and prismatic particles. The factors he lists as most important in the production of lagoon lime muds in that area are "(1) the inherently fragile nature of the shells of molluscs and tests of foraminifera that inhabit this environment; (2) the removal of the binding organic matter from mollusc shells; (3) the weakening of larger skeletal particles by the activity of boring micro-organisms; and (4) the mastication, ingestion, and perhaps even simple movement of sediment by the vagrant benthos" (p. 452).

The rarity of corals and fusulinids in the Colina may indicate that the ocean waters were not well circulated and that they were possibly of a slightly higher salinity than normal marine waters. The absence of fusulinids may signify that the Colina seas were not as deep as 160 to 180 feet, which is the fusulinid zone of Elias (1937, p. 410). The abundance of mollusks and the presence of calcareous algae, bryozoans, and calcareous brachiopods indicates the depth of the Colina seas was between 60 to 100 feet or as deep as 160 feet according to Elias' zonations (Elias, 1937, p. 410). Since changes in water temperature and salinity affect the depths at which organisms live, the slightly higher salinity in the Colina seas would affect the depth designations.

The large amount of broken, but not abraded, fossil hash in the Colina Limestone indicates that bottom scavenging organisms of many kinds were very abundant. The coprolite intraclasts of micrite and fossil hash and the pellets also emphasize the abundance of organisms. The bottom sediments must have been teeming with detritus feeders such as worms, crustaceans, echinoids, and holothurians. These animals would ingest lime mud and whatever was with it and excrete it as fecal pellets of coprolites in varying degrees of cohesion and in sizes and shapes which varied according to the organism. Of course fecal pellets could be produced by any type of organism, whether or not it was a detritus feeder. Some organisms in the Colina seas probably resorted to the chemical boring and mechanical crunching of shells in order to obtain the nourishment inside them. Larger predators such as crabs and gastropods would be the principal crunchers and the worms, molluscs, sponges, and algae would be the chief chemical borers (Ginsburg, 1957, p. 83). The abundance of organic matter, which imparts a dark gray color to the Colina Limestone, and the common odor of hydrogen sulfide given off by Colina rocks when they are struck with a hammer, indicate that bacteria preserved organic matter by sulfate reduction. These factors do not necessarily require a deep stagnant basin where oxygen is absent from the deeper waters. Shallow Florida Bay, which is only slightly restricted by the Florida Keys, contains carbonate muds with a strong odor of hydrogen sulfide extending from near the surface down to the rock floor. However, the top-most fraction of an inch is light in color indicating a well oxygenated bottom (Ginsburg, 1957, p. 88).

In summary the Colina Limestone was deposited in the center of the Pedregosa Basin, with moderate depths and waters of normal salinity (possibly because it was connected to the Sonoran geosyncline open ocean to the south) and also in the more restricted, shallower, and slightly more saline western, northern, and eastern portions. The environment was characterized by a lack of persistent currents and by an abundance of scavenging bottom life.

APPENDIX

LOCATION AND DESCRIPTION OF MEASURED SECTIONS

SECTION 2

Colina Ridge

Section of the Colina Limestone at the type section on Colina Ridge. The base of the measured section is at the top of the Earp Formation in the NE¼, NE¼, NE¼, sec. 34, T. 20 S., R. 22 E. The top of the section is in the NE¼, NW¼, NW¼, sec. 35, T. 20 S., R. 22 E., elevation 4900 feet, at the base of the Epitaph Dolomite at the top of the ridge north of Epitaph Hill.

	Thickness (feet)
Epitaph Dolomite (unmeasured):	
24. Dolomite, slightly silty, medium-gray (N 4) to medium light gray (N 5), weathering yellowish-gray (5Y 7/1 to 5Y 8/1); aphanocrystalline, contains medium silt; forms ledges; some echinoid spines at base; dolomite rhombs weathering out on surface 10 feet above contact.	
Colina Limestone:	
23. Micrite, slightly silty and dolomitic, medium dark gray (N 4), weathering light-gray (N 7); fine quartz silt, subrounded and more finely crystalline dolomite; forms ledges	5.5
22. Dolomite, medium dark gray (N 4), weathering light olive gray (5Y 6/1); aphanocrystalline; forms ledges	6.0
21. Micrite, medium dark gray (N 4) to medium-gray (N 5), weathering light gray (N 7); thin beds 3 to 4 inches at 10 feet above base; forms ledges and slopes; at 5 feet above base is locally a packed biomicrite with <u>Dictyoclostus</u>-like and <u>Aviculopecten</u>-like fossils; large calcite pods at 10 feet above base; white grains at 15 feet are dolomite rhombs	25.0

20. Micrite, slightly silty and dolomitic, medium-gray (N 4), weathering medium light gray (N 7); quartz silt, medium to coarsely crystalline dolomite; micrite locally altered to microspar; some intraclasts of micrite present locally; medium bedded, forms ledges and slopes; some fossiliferous micrite at 45 feet above base; white sand-size grains scattered throughout; disseminated quartz stringers in beds 30 feet above base; much scattered chert and a 4 inch chert marker bed 37 feet above base 62.0

19. Micrite to fossiliferous micrite, slightly dolomitic, medium dark gray (N 4), weathering light-gray (N 7); medium to coarsely crystalline dolomite; locally micrite is extensively replaced by microspar; some intraclasts; forms ledges and slopes; some echinoid spines, gastropod and pelecypod or brachiopod fragments, and bellerophontid gastropods; fossils increase toward top 26.0

18. Micrite, slightly dolomitic and intraclastic, medium dark gray (N 4) and some-dark gray (N 3), weathering medium light gray (N 6); medium to coarsely crystalline dolomite, locally altered to microspar; massive bedded broken cliffs alternate with laminated 3 to 5 foot zones producing uneven slopes; contains sand-size square white grains; a few echinoid spines near top; several light brownish gray (5YR 6/1) brecciated zones at top 45.5

17. Sparse biomicrite to fossiliferous micrite to micrite near top, very slightly silty, medium dark gray (N 4), weathering light-gray (N 7); medium silt-size quartz; lower 36 feet is partly covered; upper 20 feet has massive bedding; chert is in small crystals near the base; pronounced weathered chert seam occurs in the cliff at 45 feet above base; the 10 feet above the chert is a massive cliff. 56.0

16.	Fossiliferous micrite, slightly pelletiferous, medium dark gray (N 4), weathering light olive gray (5Y 6/1); pellets are variable in size but average fine sand-size; locally micrite is altered to microspar; thin to very thin bedding, partially covered; breaks easily and shatters	9.0
15.	Sparse biomicrite to fossiliferous micrite, medium dark gray (N 4), weathering light-gray (N 7) to medium light gray (N 6); thin to thick bedded; partly covered and forms slope in lower part. Fossil content increases to 40% above 15 feet, then decreases to 10% above 27 feet, then increases above 40 feet then decreases in size and amount above 42 feet. Fossils include gastropod and brachiopod fragments and outlines of omphalotrochoid gastropods, echinoid spines, and spirifer-like brachiopods. Fossils in upper part are coated with white-weathering material. Widely scattered branching chert occurs in lower part	57.0
14.	Covered, limestone rubble and red to brown soil	25.0
	Sill, granite porphyry, thickens and thins laterally; 20 feet thick approximately 25 feet to the north	12.0
13.	Sparse biomicrite, medium dark gray (N 4), weathering medium light gray (N 6) to light brownish gray (5YR 6/1); locally altered partly to microspar; fossils are brachiopod and pelecypod fragments	4.0
12.	Covered by red to brown soil. Upper 3 feet is silty micrite, pale reddish brown (10R 5/4), weathering light olive gray (5YR 6/1); mottled white and gray with caliche coating; very well weathered	13.0

11.	Micrite, slightly silty, medium dark gray (N 4), weathering light-gray (N 7); coarse quartz silt, subrounded to subangular; locally microspar is interspersed in micrite; 2 to 6 inch beds form ledges; red silty material occurs between beds	7.0
10.	Fossiliferous micrite, very slightly silty, dark-gray (N 3), weathering light-gray (N 7); coarse quartz silt to fine quartz sand, subangular and poorly sorted; micrite is abundantly altered to microspar; one foot thick bedding forms slopes in the lower half, massive beds form ledges in the upper half; upper part contains some high spired turritellid gastropods. At base is fossiliferous micrite, medium dark gray (N 4), weathering grayish-orange (10YR 7/4) to very pale orange (10YR 8/2); one foot thick, thins laterally and is discontinuous; contains 3 inches of white calcite crystals in gray matrix. Near middle is silty micrite, grayish-red (5R 4/2); 6 to 8 inch bed, finely laminated. Some intraformational conglomerate occurs discontinuously 1.5 feet above the silty material. Top 1 foot is fossiliferous micrite, weathering very pale orange (10YR 8/2)	24.0
9.	Covered	9.0
8.	Micrite, dark-gray (N 3), weathering light-gray (N 7); 2 to 5 inch laminations	7.0
7.	Micrite, black (N 1), weathering medium light gray (N 6); 2 to 3 foot beds. Sill, covered to north and south, 3 feet thick, at 5 feet above base. Chert nodules, 1 by 1 to 1 by 3 inches in diameter, at 33 feet above base and scattered through the unit up to 58 feet. Oolitic limestone, medium dark gray (N 4), weathering light-gray (N 7); 8 inch thick bed at 58 feet and 18 inch thick bed at 60 feet	103.0

6.	Sandstone, calcareous, dark yellowish brown (10YR 4/2), weathering pale yellowish brown (10YR 6/2); very fine quartz sand with some coarse silt, subangular to subrounded, moderately well sorted, contains some clay or biotite; 1 to 3 inch beds, ripple laminated	3.0
5.	Micrite, black (N 1), weathering medium light gray (N 6); massive bedding greater than 4 feet becoming 1 to 2 feet thick towards middle; rough weathered surface. Sparse biomicrite beds scattered throughout	33.0
4.	Micrite, black (N 1), weathering medium-gray (N 5); 1 to 8 inch beds. Alternates regularly with claystone and siltstone, greenish-gray (5GY 6/1) to brownish-gray (5YR 4/1); 1 to 2 inch beds. Clastics make up 10% of unit and are visible only in washes	40.0
3.	Micrite, black (N 1) to dark-gray (N 3), weathering light-gray (N 7); 2 to 4 foot beds are easily seen along strike across the hillside	24.0
2.	Micrite, black (N 1), weathering dark-gray (N 3); 6 to 12 inch beds with some laminated and some massive bedding, slope former; contains a brownish-gray (5YR 6/1) weathering bed at 15 to 16 feet	16.0
1.	Sparse to packed biomicrite, poorly winnowed, dark-gray (N 3), weathering medium-gray (N 5); hashy, very small to ¼ inch brachiopod shells weathering on surface as chert replacements, shells filled with sparite; some brachiopods have both valves intact; some brachiopods are concentrated in layers	9.5
	Total of Colina Limestone	621.5

Earp Formation (incomplete):

– Sandstone and calcareous siltstone, pale yellowish orange (10YR 8/6), weathering dark yellowish orange (10YR 6/6); sandstone is fine grained and very fine-grained with small scale cross-bedding; beds 1 to 8 inches thick	9.5
– Siltstone and claystone, brownish-gray (5YR 4/1); contains scattered 6-inch-thick dark-gray (N 3) micrites which weather light-gray (N 7); prominent cross-bedded calcarenite in middle of unit	28.5
– Sparse biomicrite, dark-gray (N 3), weathering light-gray (N 7); 6 to 12 inch beds make a prominent outcrop . . .	11.0
Total of incomplete Earp Formation	49.0

Base of section, not base of exposure.

SECTION 3

Southeast Ridge in Section 36

Section of the Colina Limestone on the southeast trending ridge in sections 35 and 36. The base of the section is at the top of the Earp Formation on the south line of the SE¼, NE¼, NE¼, sec. 35, T. 20 S., R. 22 E., elevation 4600 feet. The section was measured across the top of the ridge through the notch at the south line of the NW¼, NW¼, NW¼, sec. 36, T. 20 S., R. 22 E., elevation 5050 feet. The top of the section is at the base of the Epitaph Dolomite in the valley at the north line of the NE¼, NW¼, NW¼, sec. 36, T. 20 S., R. 22 E., elevation 4725 feet. The strike varies from N. 52° W. to N. 55° W.; the dip varies from 30° N. to 56° N.

	Thickness (feet)
Epitaph Dolomite (unmeasured):	
42. Dolomite, calcitic and quartzose, medium-gray (N 5), weathering light olive gray (5Y 6/1); aphanocrystalline dolomite; coarse sand size areas of mosaic quartz and sparry calcite; slightly covered; contains unidentified black specks and calcite vugs.	
Colina Limestone:	
41. Biomicrite to micrite, dolomitic, medium light gray (N 6), weathering light olive gray (5Y 6/1); abundant finely crystalline dolomite increases upward; intraclastic in lower 5 feet; forms ledges and slopes; contains clusters of radiating prismatic quartz	18.0

40. Covered zones, 2 to 5 feet thick, alternate with micrite, dolomitic, medium dark gray (N 4), weathering medium light gray (N 6); abundant white specks are circular areas of aphanocrystalline dolomite; a few large areas of quartz and sparry calcite. Upper 5 feet is sparse biomicrite, grayish-red (5R 4/2) to brownish-gray (5YR 5/1), weathering pinkish-gray (5YR 7/1) to pale yellow brown (10YR 6/2); coated grains at 6 and 10 feet 25.0

39. Sparse biomicrite, dolomitic and slightly disturbed, light brownish gray (5YR 6/1), weathering pale yellow brown (10YR 6/2) or light olive gray (5Y 6/1); finely crystalline dolomite rhombs; fossil and micrite fragments coated with sparry calcite; partly covered; echinoid spines, Bryozoa, crinoid stems, with fossils becoming smaller toward top. Coated grains of ¼ inch diameter in upper 5 feet; calcite veins and large nodules throughout 20.0

38. Fossiliferous intramicrite, slightly dolomitic, medium dark gray (N 4), weathering light-gray (N 7); finely crystalline dolomite; ledges up to 5 feet thick; mottled slightly brown in places; pelecypod and brachiopod fragments, echinoid spines, and coated grains; coated grains are abundant in lower 5 feet and upper 2 feet; fossils are absent in upper 5 feet. Chert present on top of uppermost bedding plane 30.0

37. Micrite, slightly dolomitic, medium dark gray (N 4), weathering medium light gray (N 6) and light olive gray (5Y 6/1); very finely crystalline dolomite; massive beds in lower 22 feet; large chert nodules; at 7 feet up are mottled zones of brownish-gray dolomitic micrite; at 10 feet up are crystals of quartz. Covered zone at 22 feet up is 3 feet thick. Upper 6 feet

is fossiliferous micrite, brownish-gray (5YR 4/1), weathering light olive gray (5Y 6/1); bedding is thinner than lower part, in 1 to 2 foot ledges; some beds more dolomitic; scattered chert nodules 31.0

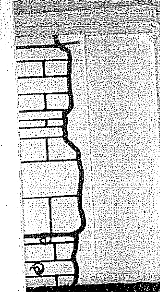
36. Micrite, medium-gray (N 5), weathering light-gray (N 7); forms thick ledges; covered zone about 8 feet thick 55 feet above base of unit may be a fault; some zones with long, thin echinoid spines at about 15 feet and 40 feet. At 25 feet are large calcite nodules with diameters larger than 1 inch; some calcite is replaced by chert; chert present in cracks near middle of unit; white specks, probably dolomite, are abundant in lower half 89.0

35. Biogenic intrasparite, brownish-gray (5YR 5/1) and medium dark gray (N 4), weathering light brownish gray (5YR 6/1) and some light-gray (N 7); 1 to 2 foot beds; echinoid spines, calcite vugs lined with ¼ inch diameter crystals, and coated grains are present . . 6.0

34. Micrite, dolomitic, grayish-red (5R 4/2), weathering light-gray (N 7) to light olive gray (5Y 6/1); very fine to coarsely crystalline dolomite; locally micrite is entirely altered to microspar; forms rounded ledges; finger-size glassy chert with a shape like staghorn corals present on bedding planes and through them; white specks are dolomite 14.0

33. Sparse to packed biomicrite, intraclastic and some dismicrite, medium dark gray (N 4) to medium-gray (N 5), weathering light-gray (N 7); locally sparry calcite and microspar matrix; forms ledges and cliffs; shell fragments are surrounded by white coated zones; echinoid spines are larger at top; contains white, fine sand-size particles, possibly dolomite. Concentrations of chert veins occur on

top of bedding planes in lower part of unit; less chert higher in unit; chert is light brown (5YR 6/4). N. 54° W., 56.5° N. 29.0



32. Intramicrite, dolomitic and slightly disturbed, medium-gray (N 5), weathering light-gray (N 7); medium-crystalline dolomite; forms thick ledges and slopes; contains *Omphalotrochus*; chert, pale yellow brown (10YR 6/2), occurs abundantly in uppermost bedding plane and in lesser amounts throughout the unit 28.0

31. Biogenic intramicrite, silty, grayish-red (5YR 4/2), weathering light brownish gray (5YR 6/1); coarse quartz silt, subangular; locally contains much sparry calcite matrix; forms ledges; contains large 5 inch diameter *Omphalotrochus*, crinoid stems?, large echinoid spines; chert, moderate-brown (5YR 4/2), in large 2 inch diameter nodules, concretions, and stringers 9.0

30. Cover. Fossiliferous micrite, intraclastic with some dismicrite, blackish-red (5R 2/2), weathering medium light gray (N 6); 1.5 foot ledge in middle of unit is covered in many places; fragments of pelecypods and gastropods 13.0

29. Micrite to fossiliferous micrite, slightly disturbed, medium dark gray (N 4), weathering light-gray (N 7); forms small ledges; thin bedded near top; middle ledges weather smoothly; small chert nodules on bedding surface in lower part; chert is in short cylinders in middle part; upper 4 feet contains echinoid spines, gastropods, and bryozoan stems replaced by chert; upper part is very hard 18.0

28. Biomicrite, slightly disturbed, medium-gray (N 5), weathering medium light gray (N 6); forms 2 foot ledges; tops of bedding planes form cliffs; very small broken shells and echinoid spines and small trochoid gastropods; stringers of chert. N. 56° W., 55° N. 7.0

27. Cover and silty micrite, grayish-red (10R 4/2), weathering to pale-red (5R 6/2); 4 to 6 inch beds, mostly covered; one layer crops out regularly and is smooth weathering. Above this is calcareous sandy siltstone, moderate red orange (10R 6/6), weathering light-brown (5YR 6/4); coarse quartz silt and very fine quartz sand, angular, white with some limonite stains, moderately sorted; forms slope, but a 3 foot bed was uncovered. Above this is calcareous sandy siltstone, moderate orange pink (5YR 8/4), weathering grayish-orange (10YR 7/4); same characteristics as lower siltstone 20.0

26. Fossiliferous micrite to sparse and packed biomicrite, silty, medium dark gray (N 4), weathering light olive gray (5Y 6/1) to light brownish gray (5YR 6/1) in the upper part; subrounded quartz silt; some coated grains and a few dismicritic areas; 1 to 2 foot bedding forms ledges and slopes; small Omphalotrochus and echinoid spines with a coated zone around them are common; dark yellow orange (10YR 6/6) chert forms smooth and elongate masses in lower part; gastropods, a few small pelecypods, and brachiopods near the top 13.0

25. Micrite, very slightly silty, medium dark gray (N 4), weathering light-gray (N 7) to very light olive gray (5Y 7/1); euhedral quartz crystals, coarse silt-size, some subrounded quartz; locally micrite is extensively replaced by microspar; thick bedded, forms ledges and cliff; a few long

echinoid spines and rough, crystal-like chert are in lower 5 feet. Middle 5 feet is covered. Upper 4 feet is micrite, dark-gray (N 3), weathering medium-gray (N 5); medium bedded, forms ledges 28.0

24. Sparse biomicrite to fossiliferous micrite, slightly silty, medium dark gray (N 4), weathering light olive gray (5Y 6/1) to light-gray (N 7) in the upper part; subrounded quartz silt; coated grains; thin to medium bedded, forms ledges and slope; long echinoid spines near the top 24.0

23. Micrite to fossiliferous micrite, silty and locally disturbed, medium dark gray (N 4), weathering light-gray (N 7) and medium light gray (N 6) with a slight olive tinge; euhedral coarse quartz silt to fine sand-size quartz sand-crystals and some subrounded grains; ½ foot to 2 foot ledges; top of bedding planes form small cliffs; common echinoid spines; chert veins common. Upper 6 feet is covered. N. 55° W., 50° N. 25.2

22. Covered 13.5

21. Micrite, slightly silty, medium dark gray (N 4) to medium-gray (N 5), weathering light-gray (N 7); subrounded quartz silt; 1 to 2 foot beds and 2 to 3 inch irregular beds in upper part; forms top of cliff and top of ridge; contains coated grains and some small fossils. A covered interval, 5 feet thick, begins at 13 feet. Upper 5 feet is sparse to packed biomicrite, locally with dismicrite and possible pellets, medium dark gray (N 4) to medium-gray (N 5), weathering light olive gray (5Y 6/1); ½ to 1 foot bedding; forms ledges on north slope of ridge; contains coated grains and has a petroliferous odor. N. 52° W., 50° N. 23.0

20. Fossiliferous micrite to packed biomicrite, very slightly silty and intraclastic, medium dark gray (N 4) to medium-gray (N 5) weathering pale yellow brown (10YR 7/2) to grayish-brown (YR 3/2); quartz silt, subangular to subrounded and well-sorted; some disturbed areas; massive bedded, forms a long slightly sloping cliff; some irregular chert stringers; <u>Omphalotrochus</u>, gastropods, bryozoans, brachiopods, pelecypods, and echinoid spines 63.0

19. Micrite, slightly silty, medium dark gray (N 4), weathering light-gray (N 7); subrounded quartz silt; 5 to 10 inch thick beds occur in lower 4 feet along with some thinner zones and some conglomeratic limestone; the upper 7.5 feet is fossiliferous micrite, medium dark gray (N 4) to medium-gray (N 5), weathering light olive gray (5Y 6/1); 6 inch to 1 foot beds form ledges and slopes; N 52° W., 30° N. 11.5

18. Covered in lower 5 feet. Micrite to fossiliferous micrite, slightly silty, medium dark gray (N 4), weathering light-gray (N 7); silt-size euhedral quartz crystals; some disturbed areas; 1 to 4 inch beds for the next 4 feet. Then biomicrite, slightly silty, brownish-gray (5YR 4/1), weathering light brownish gray (5YR 6/1); silt-size quartz crystals; 2 feet thick. Then micrite, slightly silty, pale-red (5R 6/2), weathering pale yellow brown (10YR 6/2) or grayish orange pink (5YR 7/2); subangular quartz silt; some disturbed areas; in very thin 3 to 6 inch crumbly beds; forms slope 17.5

17. Micrite, very silty, medium dark gray (N 4), weathering light-gray (N 7); coarse silt and very fine quartz sand, poorly sorted; a few disturbed areas; massive bedded; contains chert near top 9.5

16. Covered or silty claystone, grayish orange pink (5YR 7/2); in two 8 to 9 foot intervals. Alternates with micrite, medium dark gray (N 4), weathering light olive gray (5Y 6/1); in 3 to 6 inch beds; forms small ledges and slope. Thin 4 inch beds of fossiliferous micrite and biomicrite are upper 3 feet 27.3

15. Micrite, very silty, medium dark gray (N 4), weathering light olive gray (5Y 6/1) to light-gray (N 7) in the top 2 feet; euhedral, doubly terminated prismatic quartz crystals, coarse silt to very fine sand and fine sand; massive bedding 5 feet thick; forms prominent cliff extending along ridge . 31.0

14. Micrite, grayish-red (5R 4/2), weathering pale-red (10R 6/2); variable thickness, forms prominent indentation along ridge 5.0

13. Intrasparrite, medium-gray (N 5), weathering light-gray (N 7); medium bedded; forms ledge 10.0

12. Micrite, medium-gray (N 5) to medium dark gray (N 4) to moderate orange pink (10R 7/4) in upper part, weathering light-gray (N 7) to light olive gray (5Y 6/1) to pinkish-gray (5YR 7/1); thin beds of 6 inches to 1 foot; forms slope; middle part has flat chert covering it with red silt and clay in the irregular bedding planes. Biomicrite, brownish-gray (5YR 5/1), weathering grayish orange pink (5YR 7/2) and pale-red (5R 6/2); 2.5 foot thick bed at base and at 22 feet. Upper 11 feet is covered zone, dismicrite, medium-gray (N 5), weathering pinkish-gray (5YR 7/1) 41.1

11.	Micrite to fossiliferous micrite, medium dark gray (N 4), weathering light-gray (N 7); thin to thick beds of 6 inches to 1 to 3 feet; some chert. Alternates with cover, calcareous sandstone, moderate red orange (5R 5/4), weathering grayish orange pink (5YR 7/2); very fine sand and coarse silt, subangular quartz, moderately well-sorted; an 8 foot zone begins at 6 feet and a 12 foot zone begins at 20 feet	32.2
10.	Sparse to packed biomicrite, slightly disturbed, medium dark gray (N 4), weathering light-gray (N 7) to light olive gray (5Y 6/1); thin bedded; brachiopod, pelecypod, and echinoid spine fragments	10.0
9.	Covered	18.0
8.	Micrite, silty, medium dark gray (N 4), weathering light olive gray (5Y 6/1); silt-size quartz crystals and fine sand-size subrounded quartz grains; some micrite altered locally to microspar; thin to thick bedding; some chert near middle. Basal 5 feet is micrite, medium-gray (N 5), weathering grayish orange pink (5YR 7/2). Top 1.8 feet is packed biomicrite, medium dark gray (N 4), weathering light olive gray (5Y 6/1); thin bedded; gastropods, brachiopods, pelecypods, and echinoid spines	25.8
7.	Biogenic pellitic micrite, medium dark gray (N 4), weathering medium light gray (N 6); massive bedding; forms cliff which continues in unit 6. A 1 foot bed of fossiliferous micrite, brownish-gray (5YR 4/1), weathering light-gray (N 7), occurs at 6 feet . . .	22.0

6. Fossiliferous micrite, medium dark gray (N 4) to dark-gray (N 3) at top, weathering yellowish-gray (5Y 8/1); massive bedding; forms cliff face; some chert occurs in middle; brachiopods present 24.0

5. Covered, alternating with micrite to fossiliferous micrite. Basal 7 feet is covered, silty micrite, medium-gray (N 5), weathering light-gray (N 7) with pale-red (10R 6/2) soil; coarse silt quartz. At 7 feet is a 5.6 foot unit of micrite, slightly sparry, medium-gray (N 5), weathering grayish orange pink (5YR 7/2) and related colors; very thin bedded to laminated. At 12.6 feet is a 6.8 foot layer of fossiliferous micrite, intraclastic and very slightly silty, medium dark gray (N 4), weathering light-gray (N 7); coarse, dark quartz silt, subrounded; thin bedded to laminated. At 19.4 feet is a 6 foot layer of micrite, medium dark gray (N 4), weathering light olive gray (5Y 6/1); thin bedded. The next 6 feet is alternating cover and fossiliferous micrite as below. The upper 16 feet is covered with some calcareous sandstone, pale reddish brown (10R 5/4), weathering pale-red (10R 6/2); very fine quartz sand, subangular, moderately well-sorted; stained with hematite 47.4

4. Dismicrite, brownish-gray (5YR 4/1) to grayish-red (5R 4/2) or medium-gray (N 5) higher in the unit, weathering light olive gray (5Y 6/1) and pale yellowish brown (10YR 6/2); thick to massive bedding; forms cliff 17.0

3. Disturbed pelmicrite, olive-gray (5Y 4/1), weathering light olive gray (5Y 6/1); medium to thick bedded 9.0

2. Covered 30.0

1. Dolomitic limestone, dark-gray (N 3), weathering light-gray (N 7) to light olive gray (5Y 6/1); thin bedding in 1 foot ledges; gastropods and brachiopods	12.0
Total of Colina Limestone	947.0
Earp Formation (incomplete):	
– Dolomite, grayish-brown (5YR 3/2), weathering dark yellowish orange (10YR 6/6)	1.0
– Covered, probably sandstone	17.0
Total of incomplete Earp Formation	18.0

SECTION 4

Cliff above Intrusion in Section 31

Partial section of the Colina Limestone on the cliff above the rhyolite intrusion. The base of the section is in the NW¼, NW¼, NW¼, sec. 31, T. 20 S., R. 23 E., elevation 4800 feet, at the head of a gully near the highest part of the rhyolite intrusion. The top of the section is at the top of the hill near the triangulation station in SE¼, SE¼, SE¼, sec. 25, T. 20 S., R. 22 E., elevation 5260 feet. The strike is N. 45° E. with a dip of 5° W.

	Thickness (feet)
Colina Limestone (incomplete):	
18. Sparse biomicrite, dark-gray (N 3), weathering pale yellowish brown (10YR 5/2); one to two foot bedding; ledges and cover; fossils include mainly echinoid spine fragments, ranging to packed biomicrite near the top with fragments of bryozoans, brachiopods, and large flat-coiled gastropods; coated grains are near the top	15.0
17. Micrite to fossiliferous micrite, brownish-gray (5YR 4/1), weathering light brownish gray (5YR 6/1); one-half to one and one-half foot bedding; cover near base and ledges; fine fossil hash near top; chert spheres of one-half inch diameter	13.5
16. Micrite, medium-gray (N 5), weathering light-gray (N 7); in a two foot ledge. Becomes sparse to packed biomicrite, medium-gray (N 5), weathering light brownish gray (5YR 6/1); two foot bedding; ledges; fine fossil hash, coated grains	8.5

15. Covered with ledge of silty limestone, brownish-gray (5YR 4/1), weathering pale yellowish brown (10YR 6/2); and with ledge of sandy limestone near top, moderate-pink (5R 6/4), weathering pale-red (10R 6/2) 18.0

14. Fossiliferous micrite to sparse biomicrite, medium dark gray (N 4), weathering light olive gray (5Y 7/1); five inch bedding; thin ledges. Ranges to micrite, medium dark gray (N 4), weathering light-gray (N 7); two foot bedding; ledges. Top is same as base with fine fossil hash and coated grains 17.0

13. Micrite, medium-gray (N 5), weathering light-gray (N 7.5); massive bedding; cliff; large chert nodules five by eight inches and less; top foot is fossiliferous micrite 24.0

12. Packed and sparse biomicrite, brownish-gray (5YR 4/1), weathering light brownish gray (5YR 6/1); three to five inch and two foot bedding; ledges. Alternating with micrite and fossiliferous micrite, medium-gray (N 5), weathering light-gray (N 7); two foot beds; ledges and slope; scattered chert, cmall coated grains, fine to medium sand sized fragments near top 34.5

11. Covered 10.0

10. Packed biomicrite to fossiliferous micrite, medium-gray (N 5), weathering light-gray (N 7) to light olive gray (5Y 6/1); one-half to two to six foot bedding; thin ledges to cliff at top; fossil fragments very fine sand-size, some coated grains, larger echinoid spines and gastropods, and coated grains with thicker layers at top . . . 25.0

9. Packed biomicrite, medium dark gray (N 4.5), weathering light-gray (N 7); six to eight foot bedding at base to one to three foot bedding; cliff at base to ledges with some cover near top; brachiopod and echinoid spine fragments with coated grains near base, large flat-coiled gastropods higher; coated grains near base; veinlets of chert 55.0

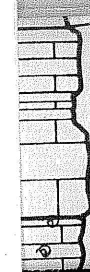
8. Silty limestone, pale-red (10R 4/4), weathering pale-red (10R 5/4); fine laminations in color; notch in cliff . . 3.0

7. Micrite, dark-gray (N 3), weathering medium light gray (N 6.5); one to eight inch to four foot bedding; cliff; bedding planes contain red silt. Upper four feet is fossiliferous micrite, medium dark gray (N 4), weathering light-gray (N 7); echinoid spines and brachiopod fragments; some coated grains 15.3

6. Calcareous sandstone, moderate reddish brown (10R 4/6), weathering pale reddish brown (10R 5/6); fine grained; slope. Upper foot is micrite, light brownish gray (5YR 6/1), weathering grayish-orange (10YR 7/4); two foot bedding; ledge at base of cliff; chert in planes at all angles 5.5

5. Micrite, medium dark gray (N 4), weathering light-gray (N 7.5); one to two foot bedding; cliff; silty laminae weathering moderate red orange (10R 6/6) in bedding planes 20.5

4. Covered with micrite, dark-gray (N 3), weathering medium light gray (N 6); three to five inch bedding; ledge three feet thick near top; fossils in float, none found in ledge 24.0



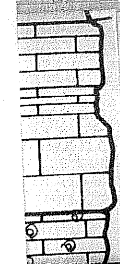
3. Micrite with two covered zones, medium-gray (N 5) to medium dark gray (N 4), weathering light-gray (N 7); bedding ranges from eight inches to two feet to five feet; ledges and slope, cliff at top; occasional fossils near base; middle ledges smooth weathering, upper cliff rough weathering; one-quarter inch diameter chert spheres in middle 55.0

2. Covered and micrite, dark-gray (N 3), weathering medium light gray (N 6); two inch beds, micrite layer is eight inches thick; covered except where exposed in road cut; limonitic blebs and cubes from pyrite. Top siltstone, weathering very light gray (N 8); three feet 5.0

1. Sparse biomicrite, medium-gray (N 5), weathering light-gray (N 7); four foot then two foot bedding; ledges and cover; fossils locally packed, brachiopods, tiny gastropods, two inch long echinoid spines; reddish chert in laminae between bedding planes 15.0

Total of incomplete Colina Limestone 363.8

Rhyolite intrusion and several feet of cover.



SECTION 5aR

U. S. Highway 80, Roadcut

Partial section of the Colina Limestone in the southern roadcut along U. S. Highway 80 between Tombstone and Bisbee. The base of the section is in SW¼, NW¼, NE¼, sec. 31, T. 20 S., R. 23 E. The strike is N. 49° W. with a dip of 37°. The section was begun on the east side of the road and moved to the west side.

	Thickness (feet)
Covered in arroyo.	
Colina Limestone (incomplete):	
10. Alternating silty shale and micrite, medium dark gray (N 4), weathering very light gray (N 8) in upper layer; very light gray (N 8), weathering yellowish-gray (5YR 8/1) in lower layer; micrite in three foot beds, shale very fissile; ledges and slope; small syncline near top of roadcut . . .	15.0
9. Sparse biomicrite, medium light gray (N 4¼), weathering light-gray (N 7); upper part in one-half to one and one-half foot beds, lower in two to three foot beds; ledges and slope in center with shaly zone; fossils include brachiopod and gastropod fragments, echinoid spines replaced by sparry calcite near the base, and very fine-grained fossil hash at the top weathering medium light gray (N 6) . . .	15.0
8. Micrite, light-gray (N 7), weathering yellowish-gray (5YR 8/1) at base; ranging to medium-gray (N 5), weathering light-gray (N 7) at center; upper fissile part weathers pale yellowish orange (10YR 8/6); bedding mostly massive in two to three foot beds, some fissile zones especially in upper part; some fossils are in the gray zones between cracks; radical dip change	22.0

7.	Sparse to packed biomicrite, medium-gray (N 5), weathering light-gray (N 7); thick bedding with some fissile layers; coated grains; dip about 16°; crossed to west side of road to measure upper part of section because of fault and flat dip	15.0
6.	Micrite, medium-gray (N 5), weathering light-gray (N 7) in upper part, lower part is lighter gray (N 7) to pinkish-white (5YR 9/1); two foot bedding except in middle pinkish and yellowish silty shale; fine fossile hash at top, bryozoans and crinoid stems in four inch shale unit at very top of unit; dip 30°	11.0
5.	Micrite, yellowish-gray (5Y 7/2) to greenish-gray (5GY 6/1) to light greenish gray (5GY 9/1); alternating with shale, medium dark greenish gray (5GY 5/1) to medium-gray (N 5) to medium light gray (N 6) at the very top; units one to two to three feet thick, laminated; slope	17.0
4.	Micrite, dark-gray (N 3), weathering light-gray (N 7); thick beds with some color lamination; ledges	6.5
3.	Shale, greenish-gray (5GY 6/1); fissile; with shaly micrite in three inch beds and with siltstone near the base	10.0
2.	Micrite, medium-gray (N 5), weathering light-gray (N 7); thick beds; ledge . .	3.0
1.	Siltstone, pinkish-gray (5YR 8/1); no obvious bedding; slope	15.0
	Total of incomplete Colina Limestone	129.5

Rhyolite intrusive which is the same as in Section 3.

SECTION 5aS

U. S. Highway 80, Slope

Partial section of the Colina Limestone on top of the southern roadcut along U. S. Highway 80 between Tombstone and Bisbee. The base of the section is in SW¼, NW¼, NE¼, sec. 31, T. 20 S., R. 23 E. The strike is N. 49° W. with a dip of 37° measured on the northwest side of the road.

	Thickness (feet)
Covered in arroyo.	
Colina Limestone (incomplete);	
7. Covered	100.0
6. Packed biomicrite, medium light gray (N 4), weathering light-gray (N 7); thin bedding; ledge; fine fossil hash .	1.0
5. Covered	9.0
4. Sparse to packed biomicrite, medium-gray (N 5), weathering light-gray (N 7); thick bedding with some shaly layers; ledge	7.0
3. Covered, with six inch ledge of gray, laminated micrite with a pinkish tinge seven feet from the top of the unit . .	26.0
2. Micrite, dark-gray (N 3), weathering light-gray (N 7) at base, upper part with more pinkish tinge; one and one-half foot beds; ledges	3.0
1. Covered	23.0
Total of incomplete Colina Limestone	169.0

Rhyolite intrusive which is the same as in Section 3.

SECTION 5bR

U. S. Highway 80, Roadcut

Partial section of the Colina Limestone in the next roadcut to the north of Section 5a. The base of the section is a short distance south of the intersection of U. S. Highway 80 with the line between sections 30 and 31, T. 20 S., R. 23 E. The dip is 10° N.

Covered in arroyo.

		Thickness (feet)
Colina Limestone (incomplete):		
5. Sparse biomicrite, medium dark gray (N 4), weathering light-gray (N 7) at the base to dark-gray (N 3), weathering medium light gray (N 6½) at the top; bedding alternates between three inches to one and one-half feet to six or more inches again; middle zone is broken in small three inch blocks; tiny fossil hash 1/8 to 1/4 inch in length; reddish silty material in bedding planes .		8.0
4. Micrite alternating with shale		
g. Shale in chips	0.17	
f. Micrite, medium dark gray (N 4), weathering light olive gray (10YR 6/1); smooth weathering	1.33	
e. Clay, white to pinkish-gray (5YR 8/1); more fissile towards top	1.75	
d. Micrite, pale-red (10R 6/2), weathering moderate orange pink (10R 7/4); one foot bedding	3.5	
c. Shale, moderate orange pink (10R 7/4); to silty micrite, pale-red (10R 6/2); bedding ¼ to two to four inches; some very fine sandy material with laminations	3.0	

b. Micrite, medium dark gray (N 4), weathering light-gray with a red tinge (N 7); one foot bedding	2.75	
a. Shaly micrite, grayish-red (5R 4/2) to medium dark gray (N 4)	0.7	
Total thickness of unit 4		13.2
3. Micrite, medium dark gray (N 4), weathering light-gray (N 7); massive bedding in four and less feet; cliff . .		7.0
2. Alternating shale and micrite, blackish-red (5R 3/2), weathering pale-red (5R 6/2); bedding two to three inches; shale, grayish-red (5R 4/2), weathering pale-red (5R 5/2); upper shale is light-red (5R 6/6), weathering slightly darker red (5R 7/6); laminated bedding of ½ inch; units five to ten inches thick		6.0
1. Micrite		
c. Micrite, medium dark gray (N 4), weathering medium light gray (N 6½); massive bedding; cliff	19.0	
b. Fossiliferous micrite, medium-gray (N 5), weathering light-gray (N 7); thick bedding in three foot layers; very tiny hashy fossils . . .	3.0	
a. Micrite, dark-gray (N 3), weathering light-gray (N 7); two to three inch bedding; ledge; silty material in some bedding planes	7.0	
Total thickness of unit 1		29.0
Total of incomplete Colina Limestone		63.2

Covered (bottom of section is below ledge which forms unit 1).

SECTION 5bS

U. S. Highway 80, Slope

Partial section of the Colina Limestone on top of the next roadcut to the north of Section 5a. The base of the section is a short distance south of the intersection of U. S. Highway 80 with the line between section 30 and 31, T. 20 S., R. 23 E. The dip is 12° N.

Covered in arroyo.

	Thickness (feet)
Colina Limestone (incomplete):	
6. Covered, with a few ledges of sparse biomicrite, dark-gray (N 3), weathering medium light gray (N 6½); three to four inch beds; ledges and slope; tiny hash	35.0
5. Sparse biomicrite to fossiliferous micrite, dark-gray (N 3), weathering medium light gray (N 6½); thin bedded; ledges with one three foot zone of cover in the middle; tiny fossil hash .	10.0
4. Covered with reddish material in float	15.0
3. Micrite, medium-gray (N 5) at base to medium dark gray (N 4) at top, weathering light-gray (N 7); two foot bedding at base, three to four inch bedding at top; ledges and covered towards top	7.0
2. Covered with reddish soil; float is shaly micrite, medium dark gray (N 4) to medium-gray (N 5), weathering pale-brown (5YR 5/2); slope	8.0

1. Micrite, dark-gray (N 3) to medium dark gray (N 4), weathering medium light gray (N 6) to light-gray (N 7); at base is thin six inch bedding, higher is thick one to three foot bedding; ledges and slope; some chert in middle; used 12° dip throughout section 30.0

Total of incomplete Colina Limestone 105.0

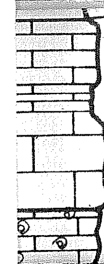
Covered (bottom of section is below ledge which forms base of unit 1).

SECTION 6

Cowan Ranch Road

Partial section of the Colina Limestone on the hill south of Cowan Road and north of Government Draw. The base of the section is immediately above the uppermost dolomite in the Earp Formation in the NW¼, SW¼, NW¼, sec. 34, T. 20 S., R. 23 E. The top of the partial section is at the top of the hill along the west line of the SW¼, NW¼, NW¼, sec. 34, T. 20 S., R. 23 E., elevation 4975. The strike is N. 42° E. with a dip of 10° N.

Top of hill, top of exposure.	Thickness (feet)
Colina Limestone (incomplete):	
15. Micrite, medium light gray (N 6), weathering light-gray (N &); one to two foot bedding; ledges and cover; chert nodules; at the base of the unit is a mottled zone of micrite, moderate-red (5R 5/4), weathering pale-red (10R 6/2), which contains a few fossils	19.0
14. Covered	10.0
13. Micrite, medium-gray (N 5), weathering light-gray (N 7); lower 20 feet is a cliff with massive bedding; upper part in one to two foot beds; covered at top; many large chert nodules four by five inches	24.0
12. Sparse biomicrite, medium dary gray (N 4) to medium-gray (N 5), weathering light-gray (N 7); one to one and a half foot bedding; ledges and cover; fossils include long echinoid spines with joints, becoming packed biomicrite near the top with brachiopod fragments ¼ inch long and zones of gastropods replaced by chert; fewer coated grains toward the top	14.0



11.	Micrite, medium-gray (N 5), weathering light-gray (N 7); one foot bedding at base and top with ledges and cover; massive bedding in cliff in between; one-half inch diameter calcite blebs; very tiny fossil fragments at base of unit	21.0
10.	Covered, with thin ledge of sandstone, fine grained, pale red (5R 6/2), weathering same; laminated; in ledge five feet above base of unit	15.0
9.	Sparse biomicrite, medium dark gray (N 4), weathering light-gray (N 7); one foot bedding; ledges and cover; large echinoid spines; amount of fossils varies from fossiliferous micrite to packed biomicrite; coated grains and calcite veins near top	20.0
8.	Micrite, dark-gray (N 3) to medium dark gray (N 4), weathering light-gray (N 7); lower 20 feet is in one foot beds; ledges and cover; notch below cliff has very thin bedding with reddish silty material in bedding planes; upper part is massive bedded cliff; cliff has very rough weathering	39.0
7.	Covered; steep slope	25.0
6.	Sparse biomicrite, medium-gray (N 5½), weathering light-gray (N 7) with slight brownish tinge; bedding ranges from four to six inches to three feet to six to eight inches; the coated grains are smaller and not as thick as below	6.0
5.	Covered	5.0
4.	Micrite, medium-gray (N 5½), weathering light-gray (N 7½); one to three foot bedding; cliff; very few to no fossils; some chert in veins; very rough weathering	14.0

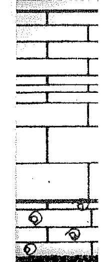
3. Packed biomicrite to sparse biomicrite, medium-gray (N 5), weathering light-gray (N 7) with a slight olive gray tinge; one-half to one to two foot bedding; ledges at base and top, ledges and cover in between; fossils include echinoid spines, brachiopod fragments, large flat-coiled gastropods; in the middle of unit where it is less fossiliferous the fossil hash is found in local concentrations; coated grains are present in the lower 20 feet with a diameter of one-eighth inch and in the upper 30 feet with a diameter of one-fourth inch; large chert nodules up to four inches in diameter are common . . . 69.0

2. Fossiliferous micrite and cover, medium dark gray (N 4) to medium-gray (N 5), weathering light-gray (N 7); one to two foot bedding; ledges and cover; very tiny fossil fragments increasing towards top; some coated grains at top; one-fourth inch calcite blebs and chert in small pieces at base of unit 33.0

1. Covered 7.0

Total of incomplete Colina Limestone 321.0

Micrite, light gray (N 7); thick bedding; ledges; local patches of dolomitic limestone; moderate-red (5R 5/4) and pale red purple (5RP 6/2); usually covered 15.0



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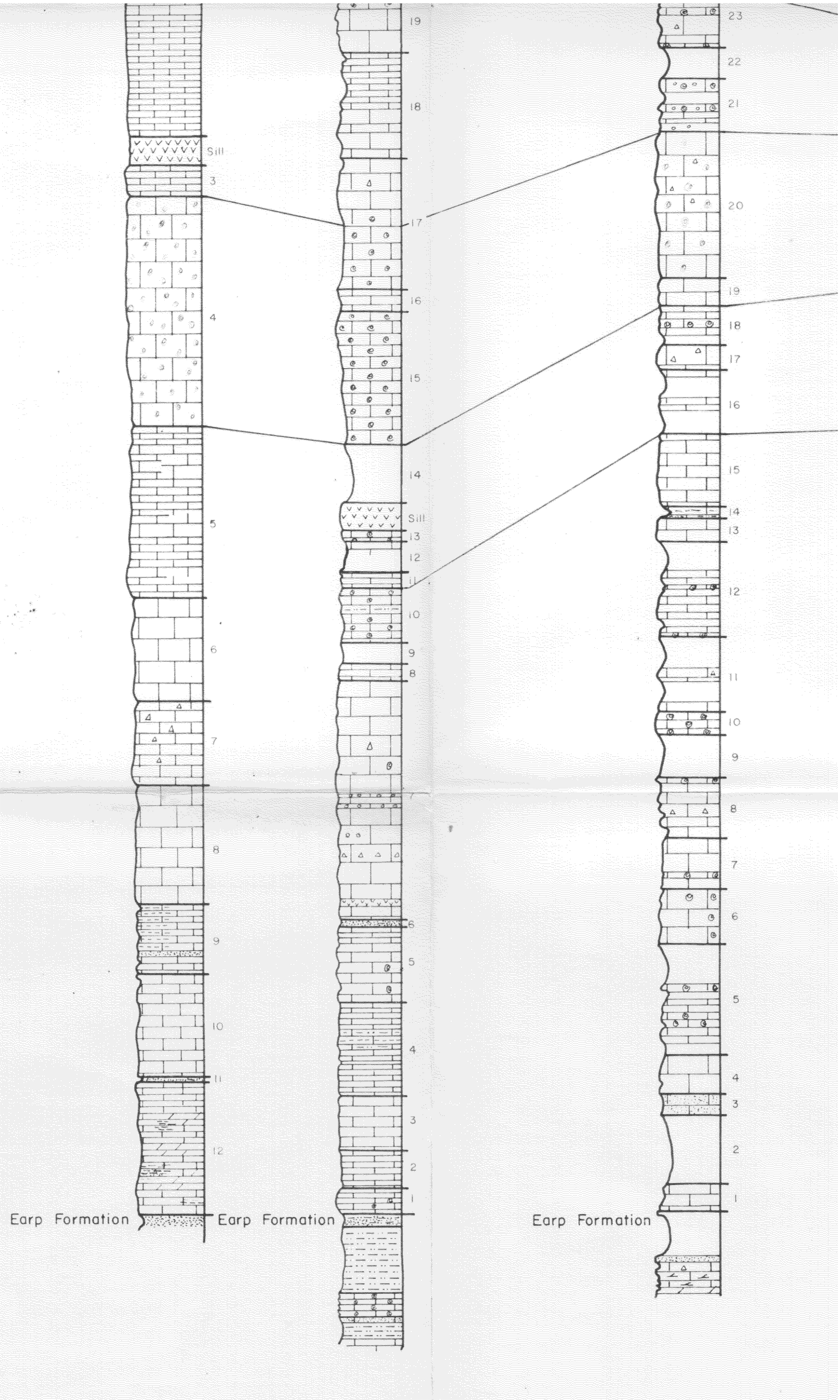
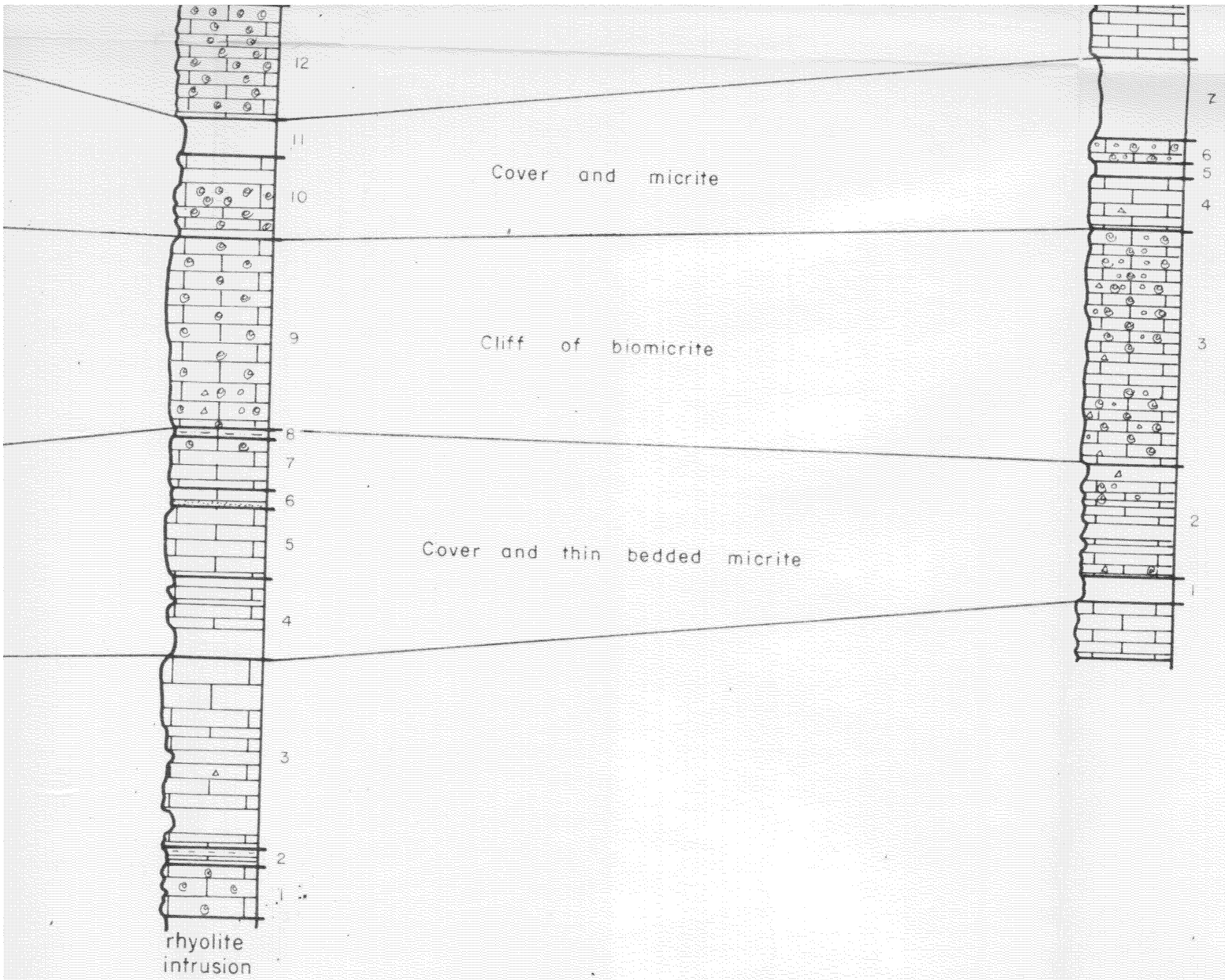


Figure 2. CORRELATION OF COLINA

WILTS 592



EXPLANATION

- cover
- thin bedded limestone (2"–2')
- thick bedded limestone (2'–4')
- massive bedded limestone (4')
- sandstone
- siltstone
- shale
- dolomite
- dolomitic limestone
- silty limestone
- chert in limestone
- fossiliferous limestone
- alluvium
- shaly limestone
- sandy limestone
- calcareous sandstone
- sandy dolomite
- coated grains in limestone
- sill

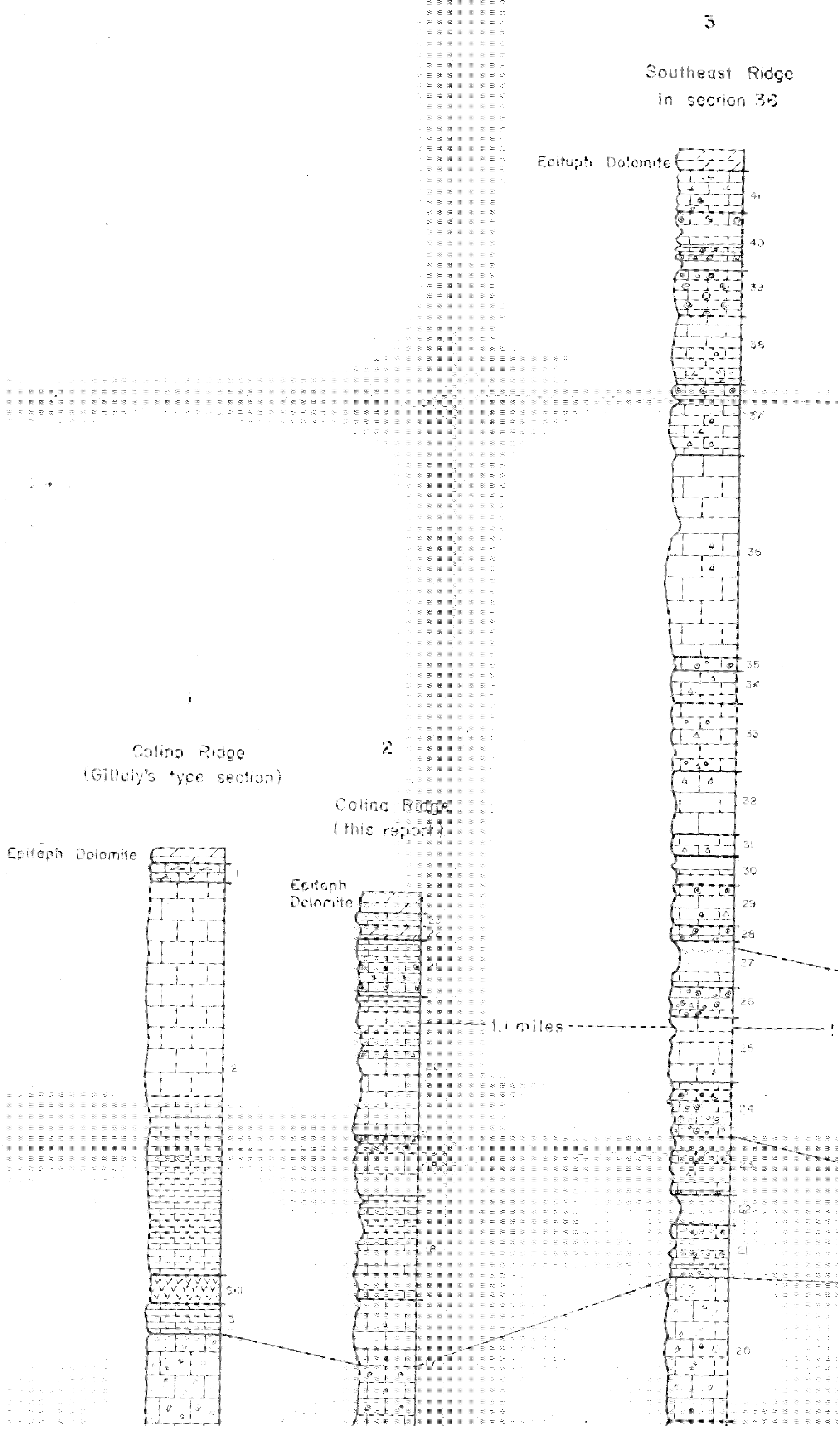
Vertical Scale 1 inch = 40 feet

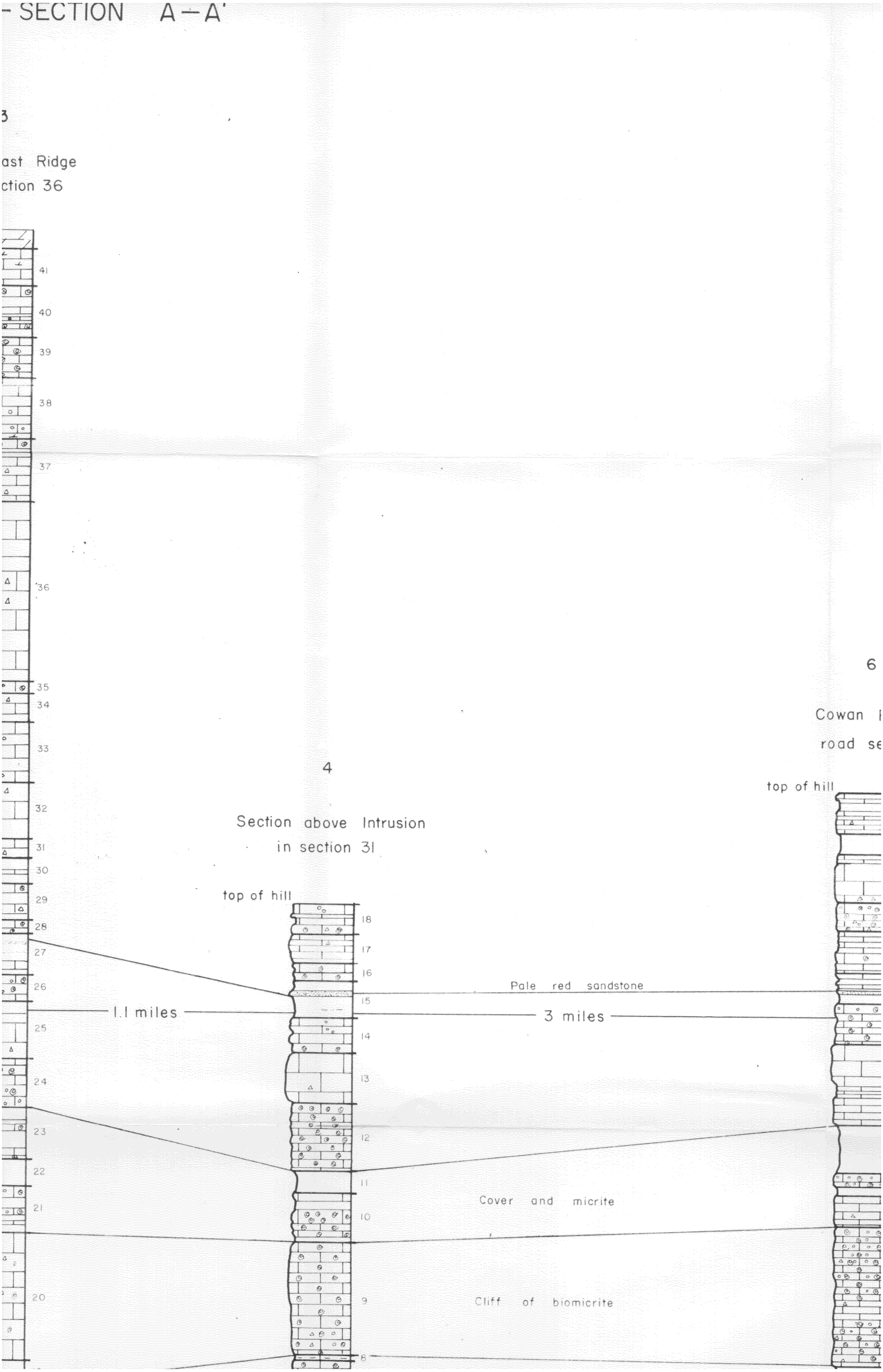
See Figure 1 for location of numbered sections

JAN CAROL WILT, 1969

IESTONE IN THE TOMBSTONE HILLS

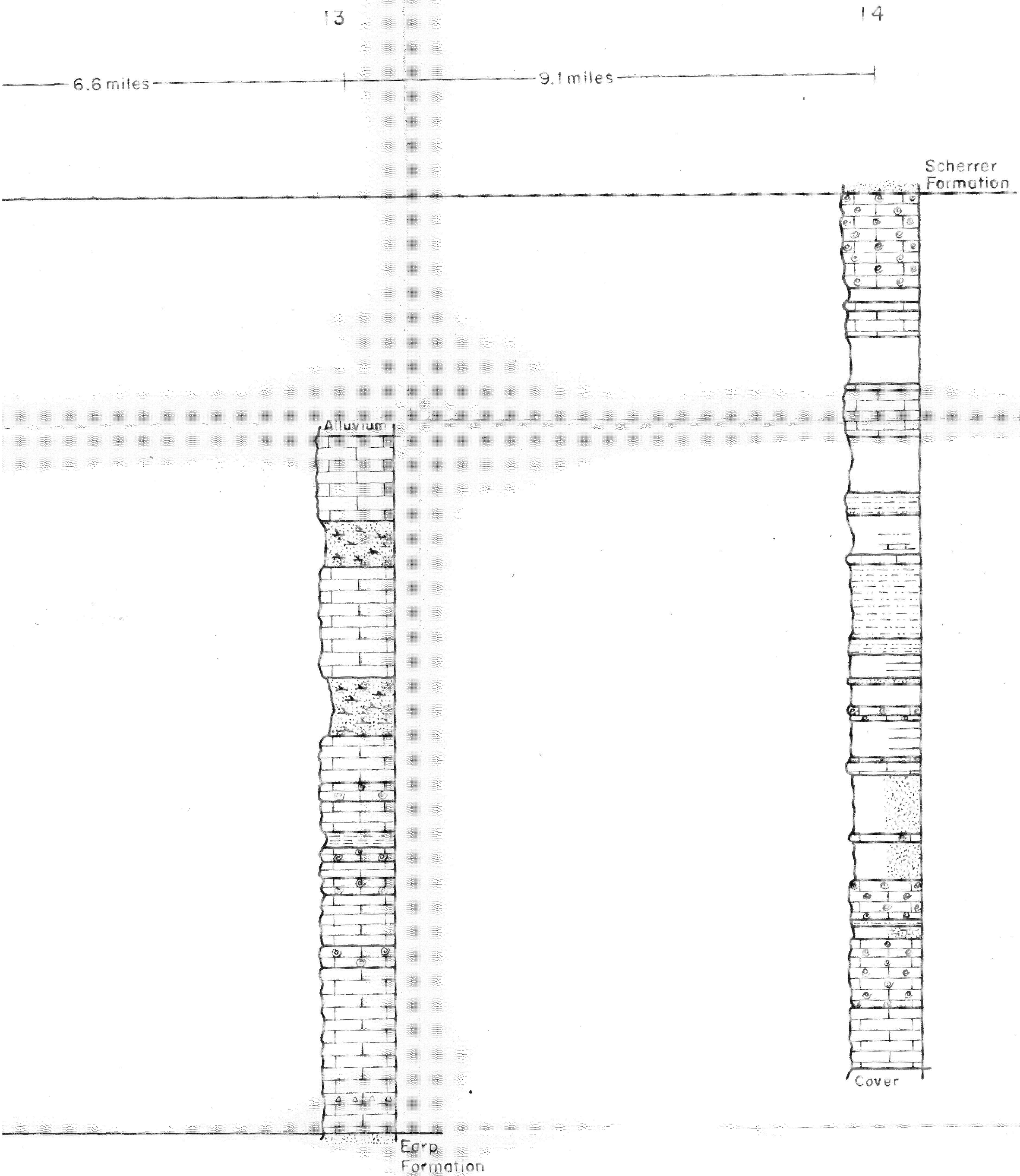
CROSS — SECTION





-SECTION A-A'
3
ast Ridge
ction 36
41
40
39
38
37
36
35
34
33
32
31
30
29
28
27
26
25
24
23
22
21
20
4
Section above Intrusion
in section 31
top of hill
18
17
16
15
14
13
12
11
10
9
8
1.1 miles
Pale red sandstone
3 miles
Cover and micrite
Cliff of biomicrite
6
Cowan
road se
top of hill

Peloncillo Mountains



reous sandstone

dolomite

d grains in limestone

omerate

Vertical Scale 1 inch = 60 feet

Data from: 7 and 8 Gilluly, Cooper and Williams, 1954
9, 10, 11, and 13 Sabins, 1957
12 Brittain, 1954 and Papke, 1952
14 Gillerman, 1958

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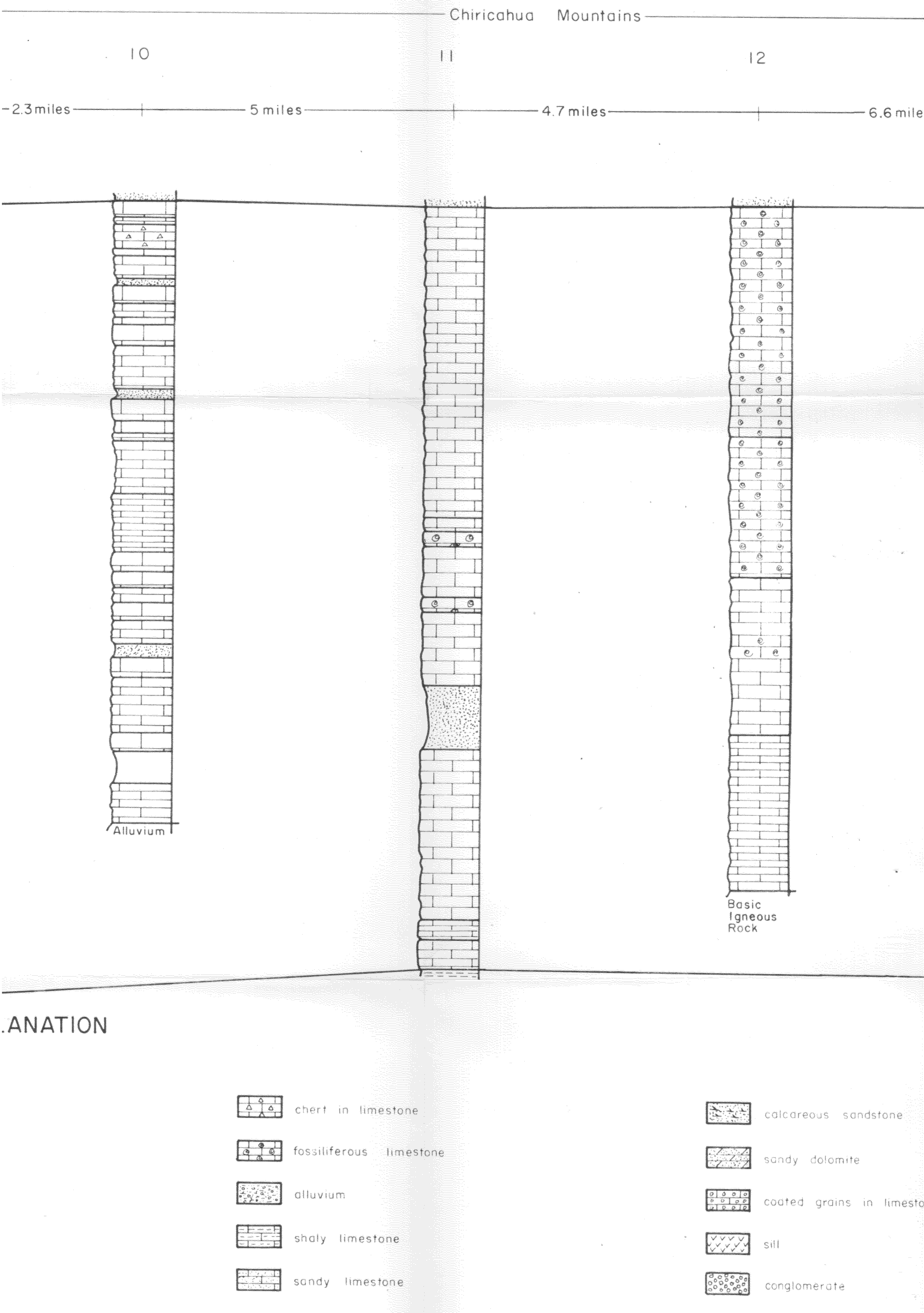
N COCHISE COUNTY



OF COLINA LIMESTONE IN NORTHERN COC

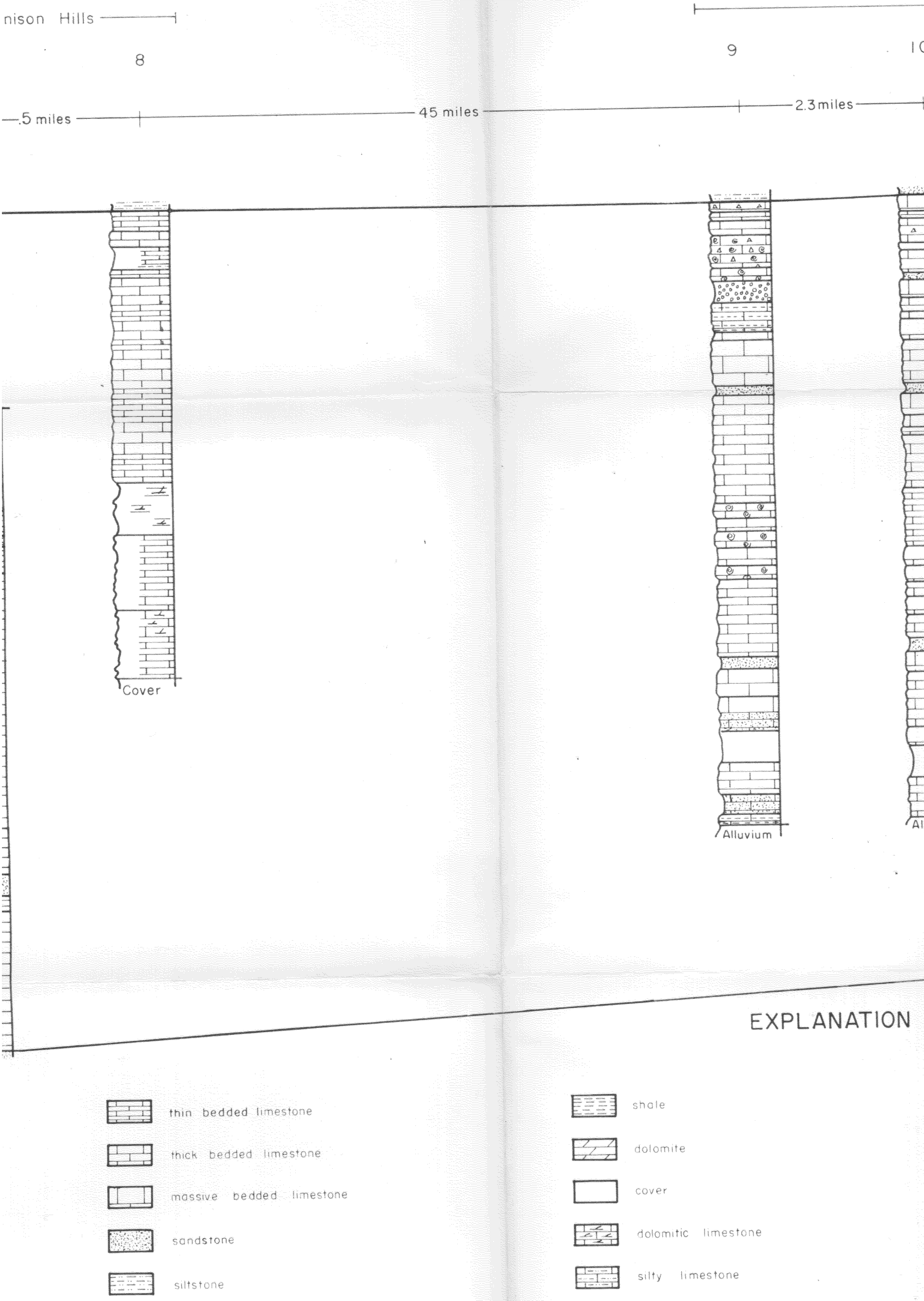
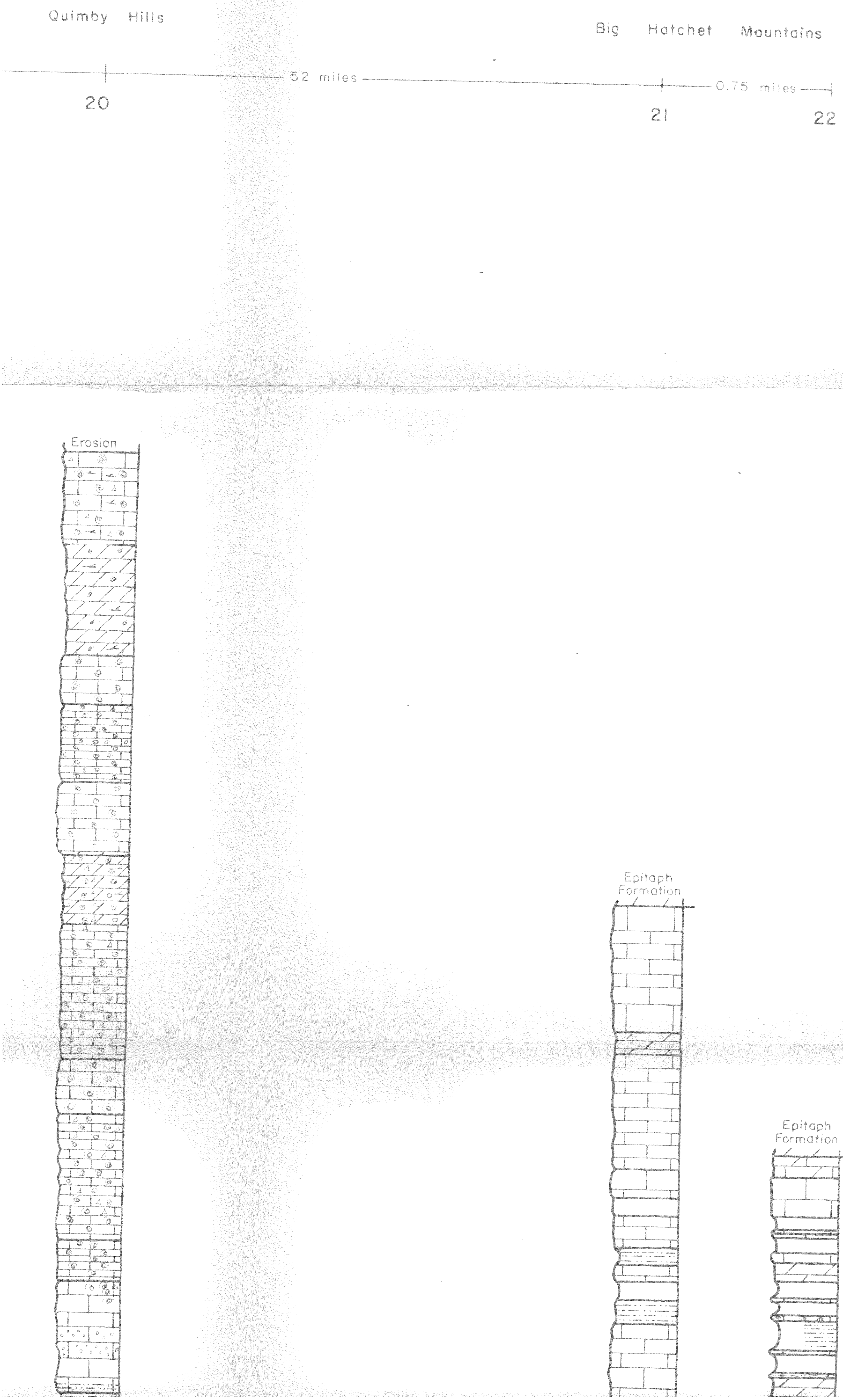
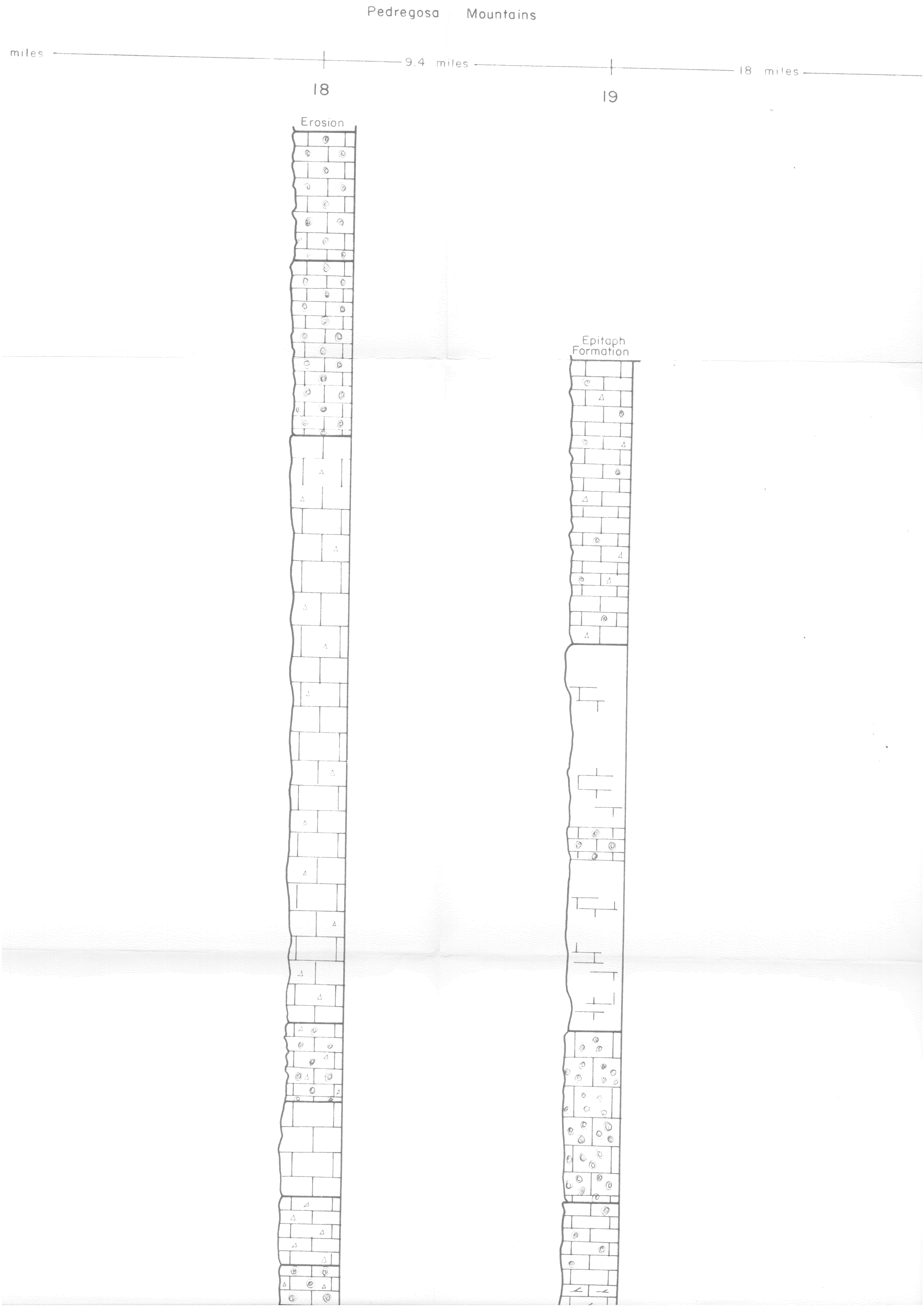
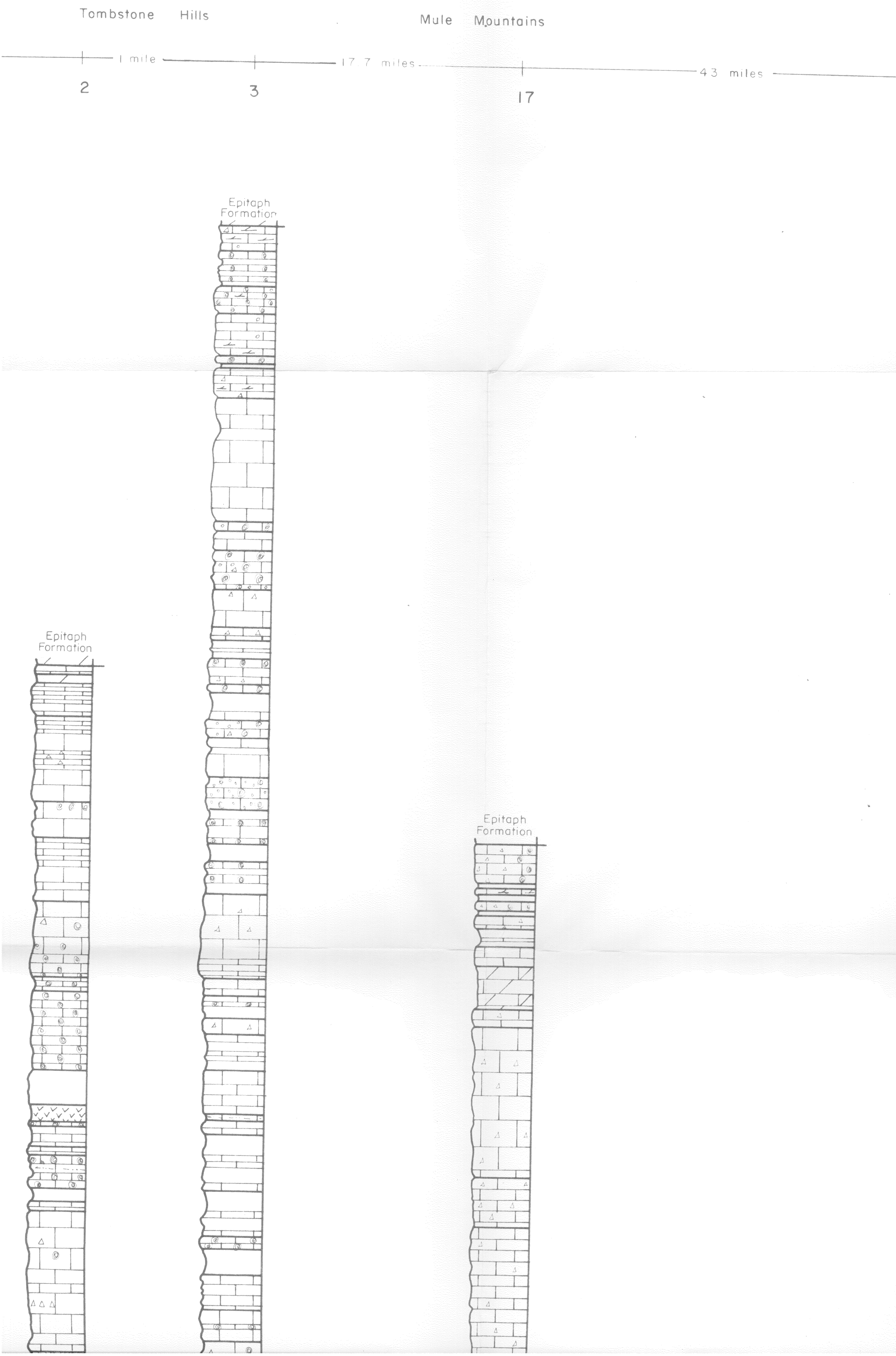


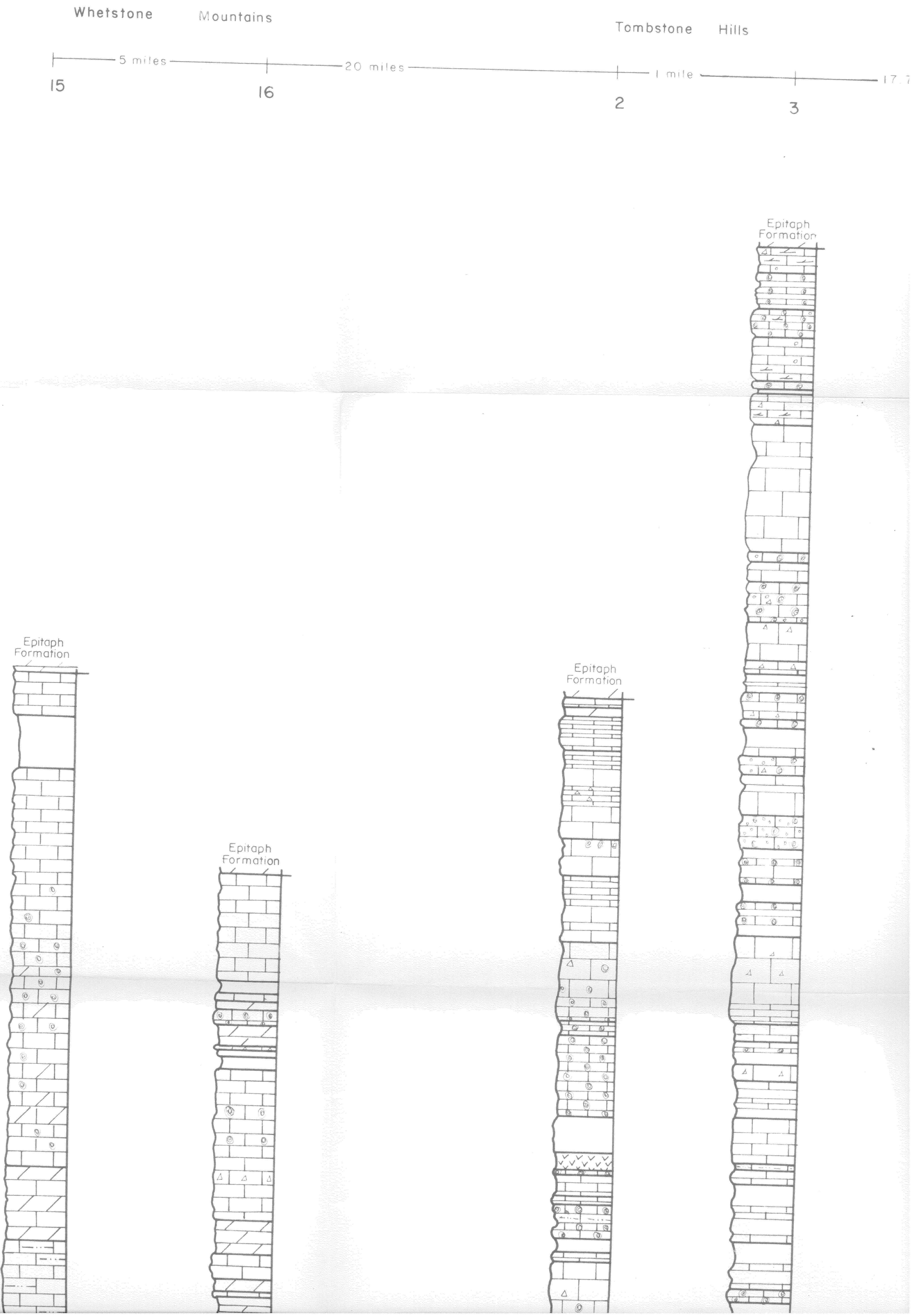
Figure 3. CORRELATION OF CO

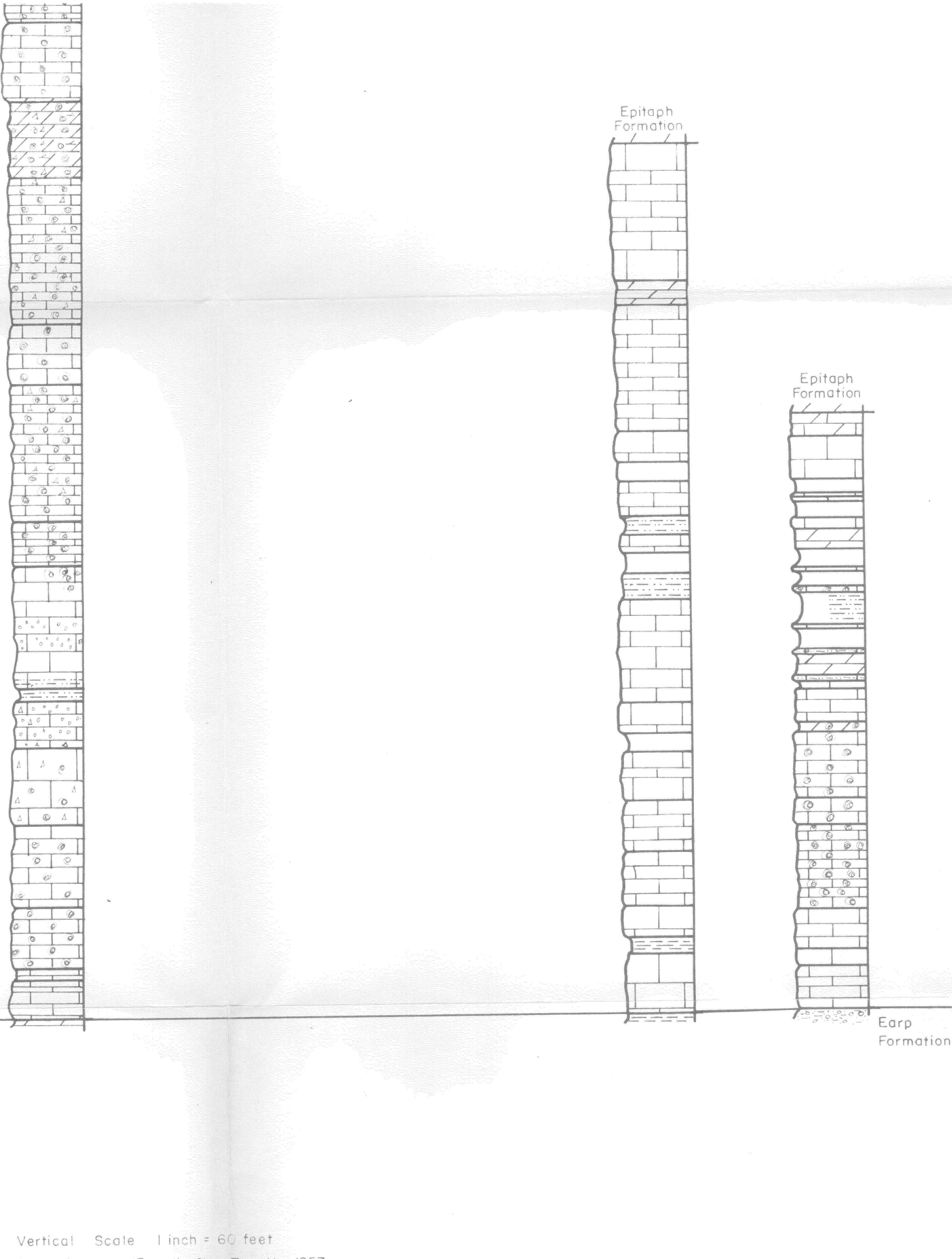

Quimby Hills
Big Hatchet Mountains
52 miles
0.75 miles
20
21
22
Erosion
Epitaph Formation
Epitaph Formation

SS – SECTION C – C'




Tombstone Hills
Mule Mountains
1 mile
17.7 miles
43 miles
2
3
17
Epitaph Formation
Epitaph Formation
Epitaph Formation


Whetstone Mountains
Tombstone Hills
5 miles
20 miles
1 mile
15
16
2
3
Epitaph Formation
Epitaph Formation
Epitaph Formation
Epitaph Formation

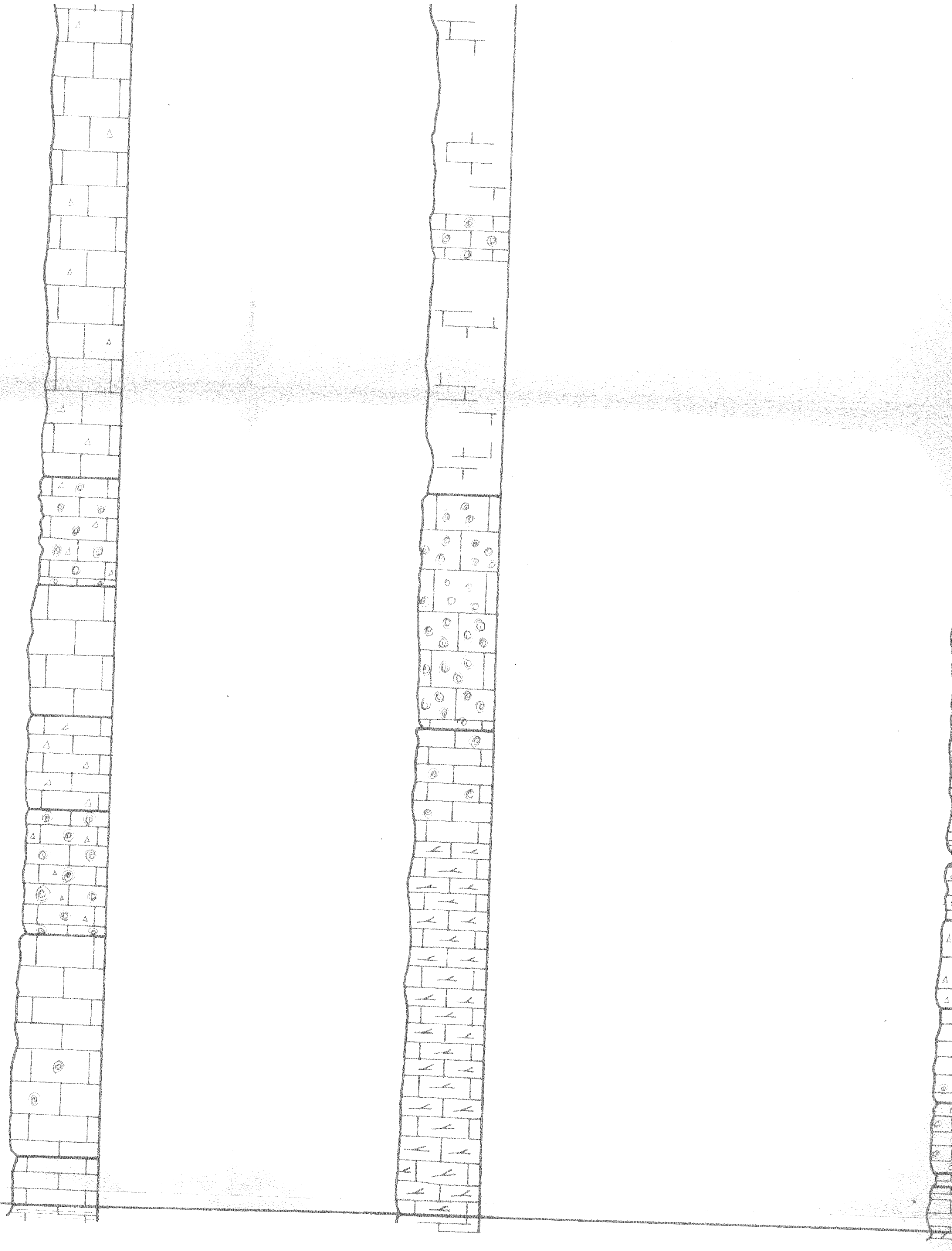


Vertical Scale 1 inch = 60 feet

Data from: 15 and 16 Tyrell, 1957
2 and 3 this report
17 Hayes and Landis, 1965
18 Epis, 1956
19 Bryant, 1955
20 Dirks, 1966
21 and 22 Zeller, 1965

JAN CAROL WILT, 1969

NTY



chert in limestone

fossiliferous limestone

alluvium

shaly limestone

sandy limestone

calcareous sandstone

sandy dolomite

coated grains in limestone

sill

conglomerate

Verti

Data

JAN

.IMESTONE IN SOUTHERN COCHISE COUNTY

gure 4. CORRELATION OF COLINA LIMEST

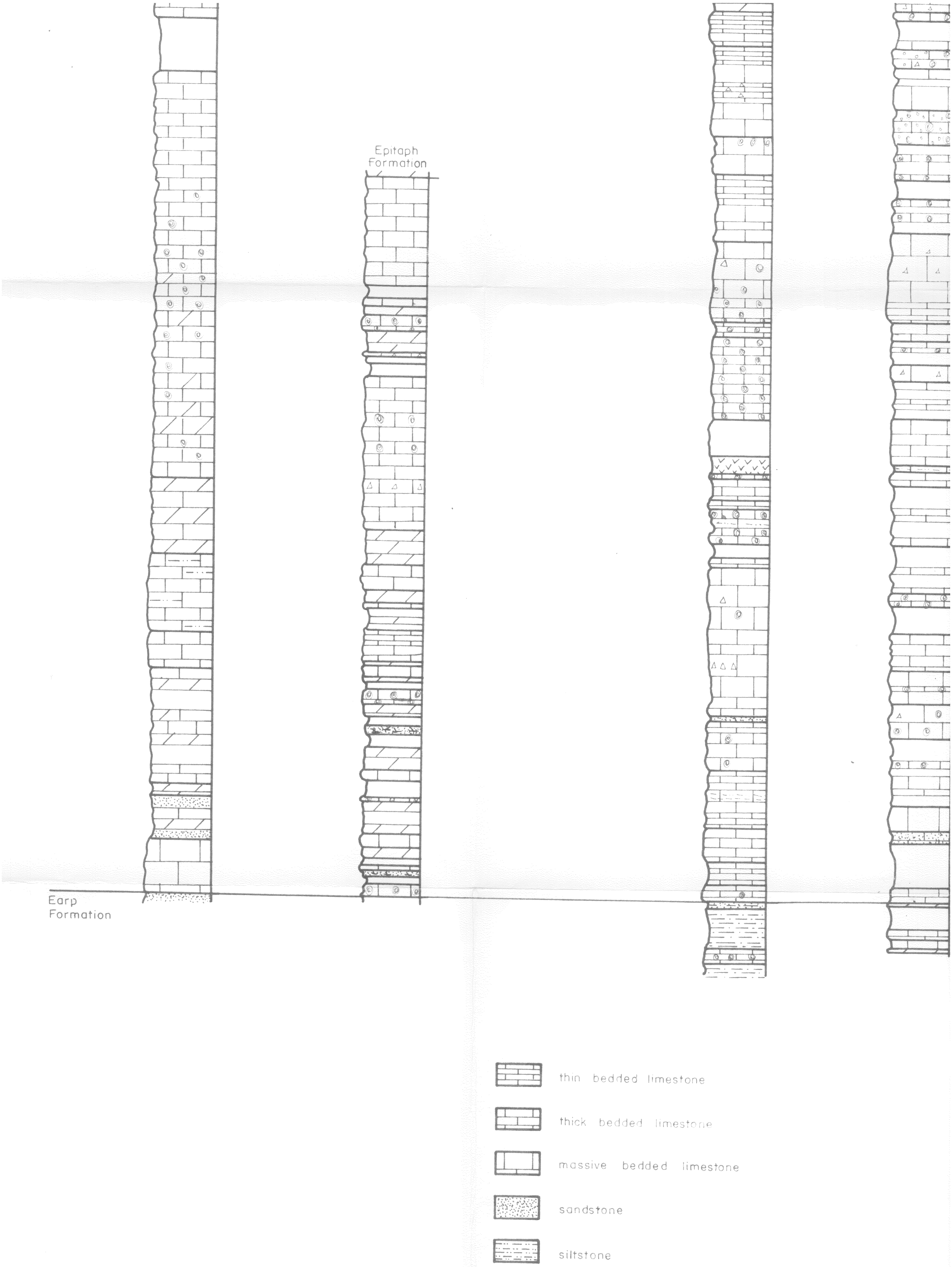

Epitaph Formation
Earp Formation
thin bedded limestone
thick bedded limestone
massive bedded limestone
sandstone
siltstone

Figure 4. COR