PETROGRAPHY AND GEOCHEMISTRY OF THE BUTTERLY DOLOMITE, AND ASSOCIATED SPHALERITE MINERALIZATION, TURNER PROSPECT, ARBUCKLE MOUNTAINS, OKLAHOMA

By

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Bachelor of Science

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Seattle, Washington

1974

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
MASTER OF SCIENCE
December, 1978

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PREFACE

The petrology and geochemistry of the Arbuckle Group have been neglected recently, especially in light of the wealth of new information on carbonates and the tectonic history of the area. This study deals with the Ordovician Butterly Dolomite, one of seven formations of the Arbuckle Group in the Arbuckle Mountain area.

The author wishes to thank Dr. John Trammell for suggesting the problem for this thesis study, for being the principal thesis advisor even though he left the OSU Geology Department in June 1977, and for giving all his help. Appreciation is also extended to Dr. Gary F. Stewart for his helpful criticism, help with statistics, and for serving technically as principal advisor in Dr. John Trammel's absence. Thanks also go to Dr. Zuhair Al-Shaieb for his gracious help, for the use of the facilities of the geochemical lab, and assistance in the atomic absorption analysis. Appreciation also is expressed to Mr. Bob Handfield of Texasgulf, Inc. for permission to collect samples in the Turner Prospect Area, and to Mr. Fred Chapman, Jr. for giving access to the Chapman Ranch.

Finally, the author wishes to give special thanks to Peg, my wife, for her typing, help, and patience.

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CHAPTER I

INTRODUCTION

The Arbuckle Mountain region of southern Oklahoma (Fig. 1) is of great interest to geologists. In the past, the 11,000 ft. of fossiliferous Late Cambrian through Devonian strata constituted one of the best exposures in the Midcontinent region. More recently, it is recognized as a site of an ancient aulacogen and possesses elements of both the craton and aulacogen.

The present work is concerned only with the Butterly Dolomite, one of seven recognized formations in the Arbuckle Group (Fig. 2), and is restricted to Murray County.

Previous Work

The first mapping of the Arbuckle Mountains was done by Taff (1902, 1903, 1904), who delimited the boundaries of the Arbuckle Limestone and recognized the Arbuckle Anticline. During the next 50 years, stratigraphic and paleontologic work was done without the aid of additional detailed field work. Contributors were Ulrich (1911, 1932), Decker and Merritt (1928), Decker (1936, 1939a,b,c), Bridge (1936, 1937), Ulrich and Cooper (1938), and Frederickson (1941, 1948a, 1948b, 1949). Arbuckle Limestone was raised to group

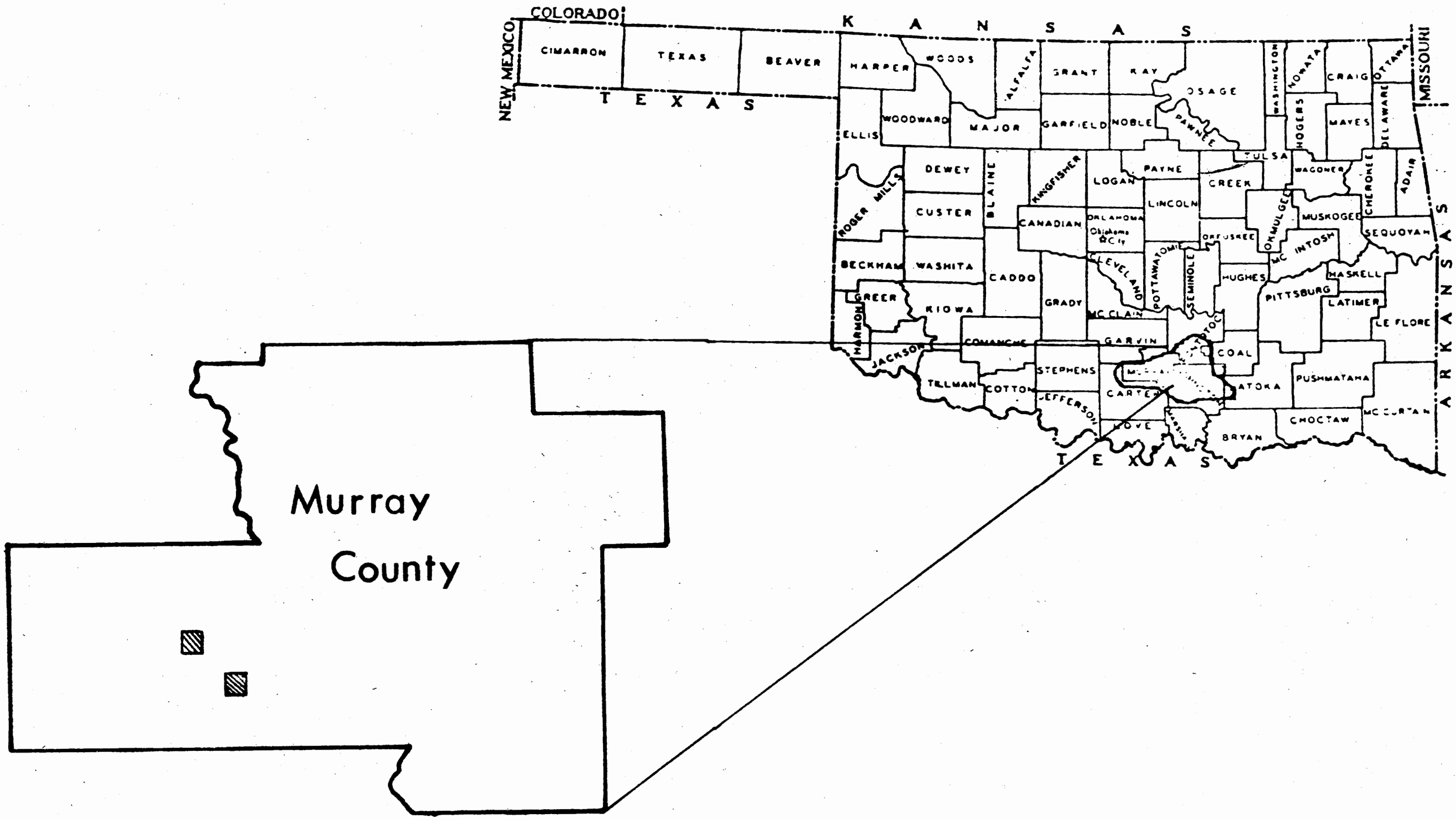

Fig. 1.-Locality of Arbuckle Mountains and study area (hachured).

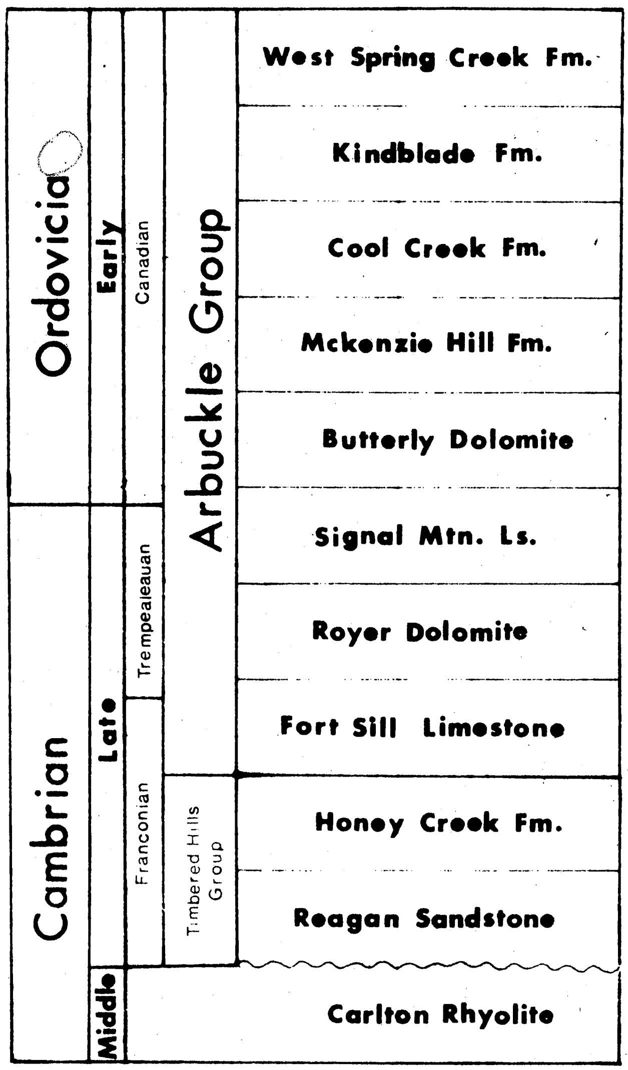

Fig. 2.-Stratigraphic units of the Timbered Hills and Arbuckle Group in the Arbuckle Anticline Area.

status by Decker.

Ham (1951, 1955) mapped the Arbuckle Mountains in greater detail. His cross-sections show the regional gradation within the Arbuckle and Timbered Hills Groups from limestone in the west to dolomite in the east.

The name Butterly Dolomite was first applied by Decker (1939a) to the dolomite unit above the Signal Mountain Limestone and below the McKenzie Hill Limestone (Fig. 2) at the southeast end of the West Timbered Hills (Secs. 28 and 29, T1S, R1E). However, the best exposures and the type section (Ham, 1951) are found on the east side of U.S. Highway 77 (Sec. 18, T2S, R2E), southeast of the Chapman Ranch buildings. The thickness of 286 ft. reported by Decker (1939a) and Ham (1951) at this locality was measured earlier by Decker and Merritt (1928).

Decker and Merritt (1928) postulated that the Butterly and the Royer Dolomites are of primary origin, due to sharp contacts among strata of limestone and dolomite, where the rock types are interlayered, and because of the great strike-length of the Butterly and Royer. They also noted two types of relatively pure dolomite. One is fine-grained, and so sandy that it can be mistaken for sandstone; the other is coarse-grained and marble-like. According to Decker and Merritt (1928) these rock types are repeated over a short vertical distance, and in the Butterly there are 16 of these alternations. Their petrographic work characterized the Butterly as pleochroic, light-brown to colorless dolomite crystals ranging in length from 0.1 to 2 mm, with angular to rounded, sand-sized quartz. The quartz has undulatory extinction, and a few grains are rhombic, indicating a secondary nature. Fabric is mosaic with no evidence of recrystallization.

Ham (1951) was the first to recognize the Butterly as a facies of the limestones in the upper Signal Mountain and lower McKenzie Hill Formations. The Butterly thins westward in the Arbuckle Mountains from a maximum of 423 ft. in the east to 148 ft. in the west.

Ham's (1951) petrographic descriptions are similar to those of Decker and Merritt (1928). Ham recognized that the Butterly is not primary, but "diagenetic dolomite" and believed that dolomitization occurred on the sea floor. He pointed out that the Butterly clasts are in limestone of the lower McKenzie Hill, indicating an early diagenetic origin of the dolomite. Ham postulated that the dolomitizational process was complete by the time of the Arbuckle Orogeny (Late Pennsylvanian) because clasts of Arbuckle dolomite are in the Vanoss (Pontotoc) Conglomerate. Ham (1951) supported the pre-tectonic origin on the basis of modification of some dolomite rhombs by stylolites. He also suggested that generally the dolomite was not subsequently recrystallized.

Since Ham's monumental work, little additional work on the Butterly has been done. Stitt (1971) briefly described a measured section of the Butterly in his paleontological study of the Cambrian-Ordovician trilobites of the Timbered

Hills. Sargent (1969, 1974) also studied a few samples of the Butterly, petrographically and geochemically. Stitt's and Sargent's determinations of lithology and petrology closely agree with Ham's work and add little new information about the Butterly. Sargent's (1974) work in geochemistry, on the other hand, is used extensively on a comparative basis in this study, although he only analyzed 12 samples of the Butterly (Appendix E).

CHAPTER II

METHODOLOGY

Sampling

The dolomites were sampled in a manner that was intended to represent best the complete section of the Butterly Dolomite. This idealistic objective was accomplished only at one locality, "S" section, described previously by Stitt (1971). This section (NW¼, SE¼, Sec. 2, T2S, R1E) is located west of the East Timbered Hills Anticline and west of U.S. Highway 77 (Fig. 3). The section was measured with tape-and-Brunton, and one sample was taken from each stratum. One hundred and sixteen samples collected from "S" section are described in Appendix A.

Five other sections were measured and sampled in Sec. 28, T1S, R1E and in the Turner Prospect area (Fig. 4). The "T" section is a partial section of the upper third of the Butterly in SE¼, SE¼, NW¼, Sec. 28, T1S, R1E. The "T" section is outside of the area of zinc mineralization and intensive fracturing and faulting. The "Z" section in SW¼, NE¼, NW¼, Sec. 28, T1S, R1E (Fig. 4) represents the unmineralized upper third of fractured Butterly. The "P" sections (P5, P6, and P9) were measured in prospect pits, and are mineralized. These sections probably are within the upper

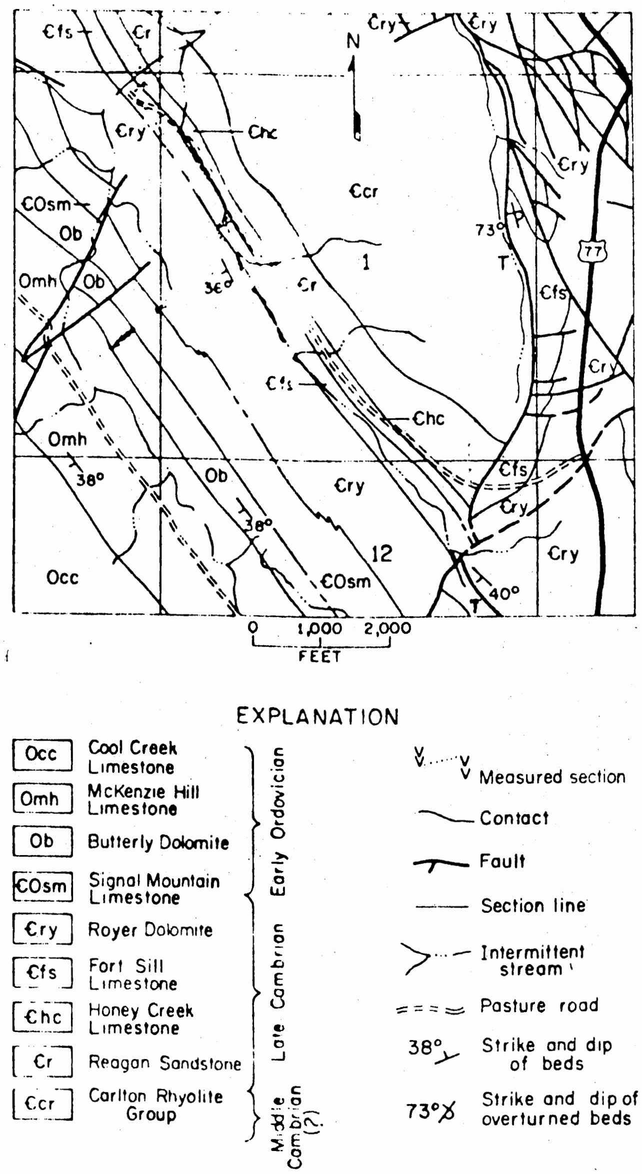

Fig. 3.-Location map of the "S" section (NW¼, SE¼, Sec. 2, T2S, R1E). Modified after Stitt (1971). Geology mapped by Ham (1951).

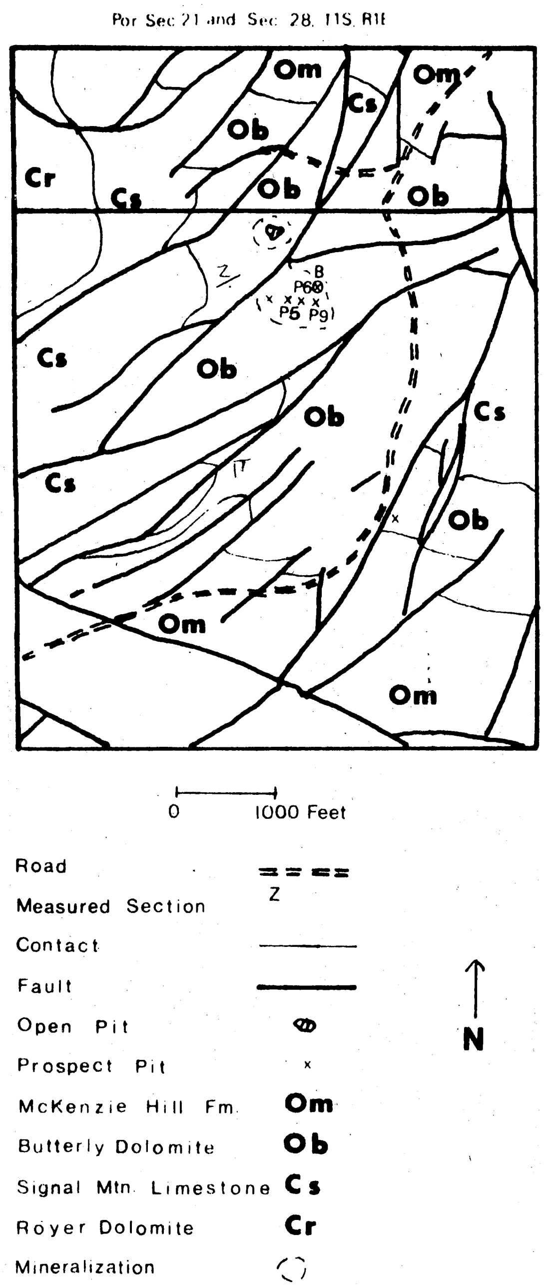

Fig. 4.-Geologic map of Turner Prospect area, showing location of the "B" drill core and the "P", "T", and "Z" sections. Modified from Ham (1951).

third of the Butterly in SW¼, NW¼, NE¼, Sec. 28, T1S, R1E.

One drill core was examined from a drill site in SW¼, NW¼, NE¼, Sec. 28, T1S, R1E. This core ("B") is now in the Oklahoma Geological Survey Core and Sample Library. The core is a sample of the lower two-thirds of the Butterly in the mineralized area. Its description is in Appendix A.

Chemical Analyses

After separating weathered material from relatively fresh material, samples were crushed in a ceramic jaw crusher, then pulverized for 10 minutes in a Spex ball mill using tungsten carbide balls and chamber. The sample were sieved to -80 mesh or finer, dried at 95^{o}C for 1 hr., and weighed.

One-gram portions of the dried samples were dissolved in 40 ml of 10% hydrochloric acid. The samples were digested for 24 hrs. in a teflon beaker; for 6 of the 24 hrs., the samples were heated on an electric hot plate. The resulting solution was filtered for removal of insoluble residue and diluted to 50 ml with deionized water. To insure accurate determinations of strontium, cadmium, and chromium, 1% lanthanum was added to the solutions to be analyzed for these elements. Five sphalerites were processed in a similar manner, but with reagent-grade nitric acid and diluted to 100 ml.

Using a Perkin-Elmer 403 double-beam atomic absorption spectrophotometer, at manufacturer's recommended instrument settings, all of the carbonate samples were analyzed for Ca, Mg, Li, Na, K, Sr, Pb, Mn, Fe, Zn, Cr, Ni, Cu, and Cd. The sphalerites were analyzed for Cu, Pb, Cd, Mn, and Fe.

The residues were dried, weighed, and checked by X-ray diffraction for carbonates and chlorides.

Clay Mineralogy

Representative samples of 25 rocks of the Butterly were crushed by hand in a mortar and pestle to -200 mesh or less. Each 20-gram sample was digested in 200 ml of sodium-acetate solution. The digested samples were stirred and allowed to settle before decanting and adding an additional 40 ml of fresh sodium-acetate solution to each sample. Each new solution was stirred and again allowed to react for 10 min. before being centrifuged for 10 minutes. Afterward, each solution was decanted and fresh sodium-acetate solution was added before repeating the centrifuging and decanting. Each collected sediment was washed twice with deionized water in a manner similar to that of the sodium-acetate solution. Each sample was mixed again with deionized water and the clay fraction was pipetted onto a clean porcelain slide and allowed to air-dry. The samples were analyzed using a Phillips-Norelco X-ray diffractometer at a rate of $^{o}2\theta/1$ min. from 2^{o}-32^{o}. Each sample was treated with ethylene glycol in a desiccator and X-rayed again to detect expandable clay. Another set of samples was heated to $450^{o}C$ for 1 hr. in a muffled oven and X-rayed for chlorite.

X-Ray Diffraction of Thin-Sections

Thin-sections and some powdered samples were analyzed using a Phillips-Norelco X-ray diffractometer at a rate of $^{o}2\theta/\frac{1}{2}$ min. with an internal standard of NaCl added. The reflection-peak positions of the (112) were measured carefully and compared to a chart for mole-percent magnesium. The chart used is from Scholle (1978, p. 228), which was modified from Goldsmith, Graf, and Heard (1961).

Petrology

Samples of the Butterly were sawed into slabs, polished with 400 and 600 grit to a smooth finish, and etched in 1.5% HCl for 5 minutes. The etched surfaces were studied under a binocular microscope with particular interest given to textures, structures, and insoluble constituents. Forty-six samples were then selected for thin-sectioning. Selected samples and thin-sections were stained with Alizarin Red-S and potassium ferricyanide by methods outlined by Dickson (1965) and Hutchison (1974).

CHAPTER III

REGIONAL SETTING

Introduction

The Arbuckle Mountain region of south-central Oklahoma is a triangular inlier of approximately 1000 sq. mi. (Ham and others, 1969). The region consists chiefly of the Arbuckle, Tishomingo, and Hunton anticlines, each bounded by faulted synclines or faults. This investigation is concerned only with the Arbuckle Anticline. The Arbuckle Anticline is separated from the other two main anticlines by the northwest-trending Washita Valley Fault, which forms the southern boundary of the Tishomingo Anticline. The Arbuckle Anticline is on the downthrown side south of the fault (Fig. 5).

The Arbuckle Anticline has an axial trend of N60°W and an areal extent of approximately 170 sq. mi. (Ham, 1951). The anticline is asymmetrical to overturned northward. On the northern limb is another northwest-trending anticline, the West Timbered Hills Anticline (Fig. 6). In the core of this doubly plunging anticline (Ham, 1951) the Cambrian Carlton Rhyolite crops out. The anticline is the northern boundary of the Arbuckle Anticline and is cut off to the north by the Washita Valley Fault (Fig. 6).

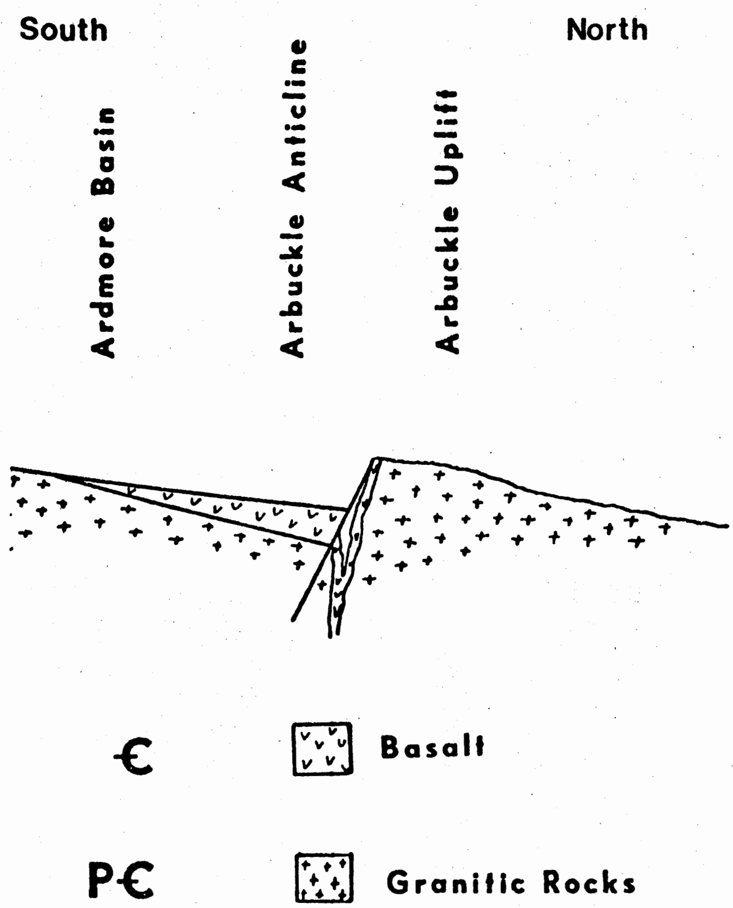

Fig. 5.-Reconstruction of the Arbuckle Anticline Region prior to extrusion of the Carlton Rhyolite. Modified after Pruatt (1975).

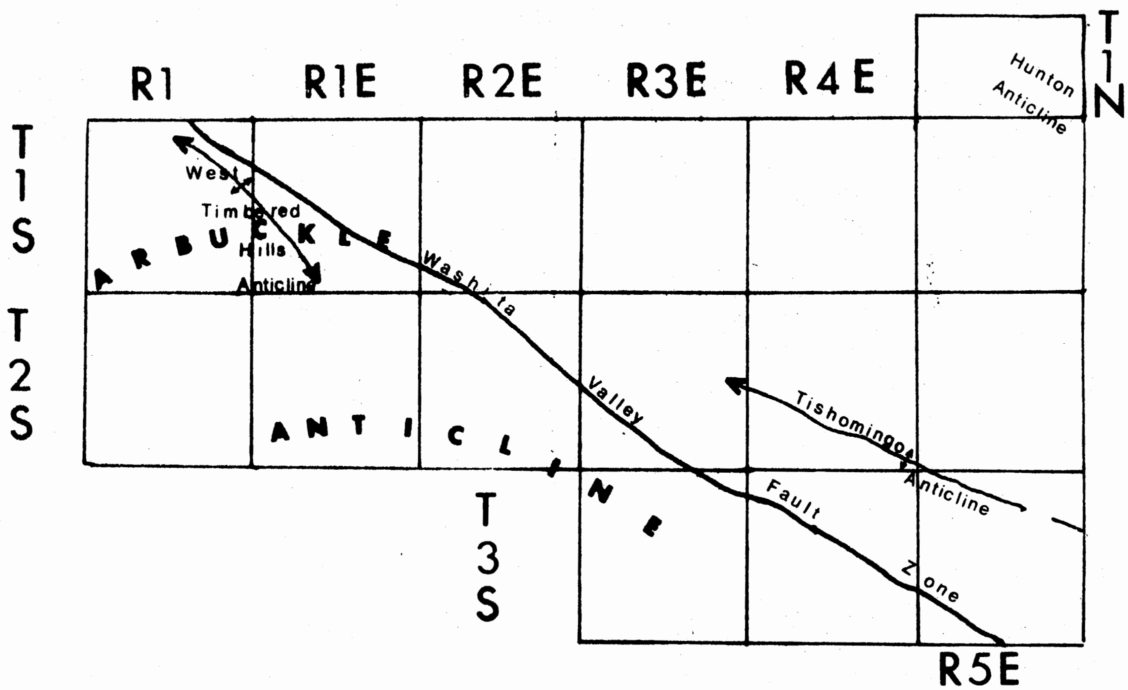

Fig. 6.-Important structures of the Arbuckle Mountains. Modified after Ham and others (1969).

This study is limited to the Butterly Dolomite, in the west limb of the East Timbered Hills Anticline and the intermediate area between the two Timbered Hills anticlines in Murray County.

Tectonic Evolution

The tectonic evolution of the study area was dominated by the Southern Oklahoma Aulacogen. Pruatt (1975) concluded that the aulacogen originated during the Late Precambrian or the Cambrian as a cratonic rift valley. According to plate tectonics theory, the aulacogen formed as a failed arm of a triple junction associated with the opening of an ocean basin to the southwest (Hoffman and others, 1974; Pruatt, 1975). During the Late Cambrian, the rift valley and the adjacent cratonic platform began to subside, and formed a deep structural trough that persisted until Late Mississippian (Pruatt, 1975). This trough was filled with 11,000 ft. of Cambrian to Devonian marine sediments, twice as thick as their facies equivalents on the craton.

During Pennsylvanian time compressive tectonism affected the aulacogen. Ham and others (1969) recognized that the epeirogenic rise of the Hunton Anticline commenced early in Desmoinesian time. The uplift was slow, pulsating, without intense deformation (Fig. 7), and concluded early in Virgilian time. Ham also recognized two main periods of tectonism in the formation of the Arbuckle and Tishomingo Anticlines during Virgilian time. The stronger of the two periods

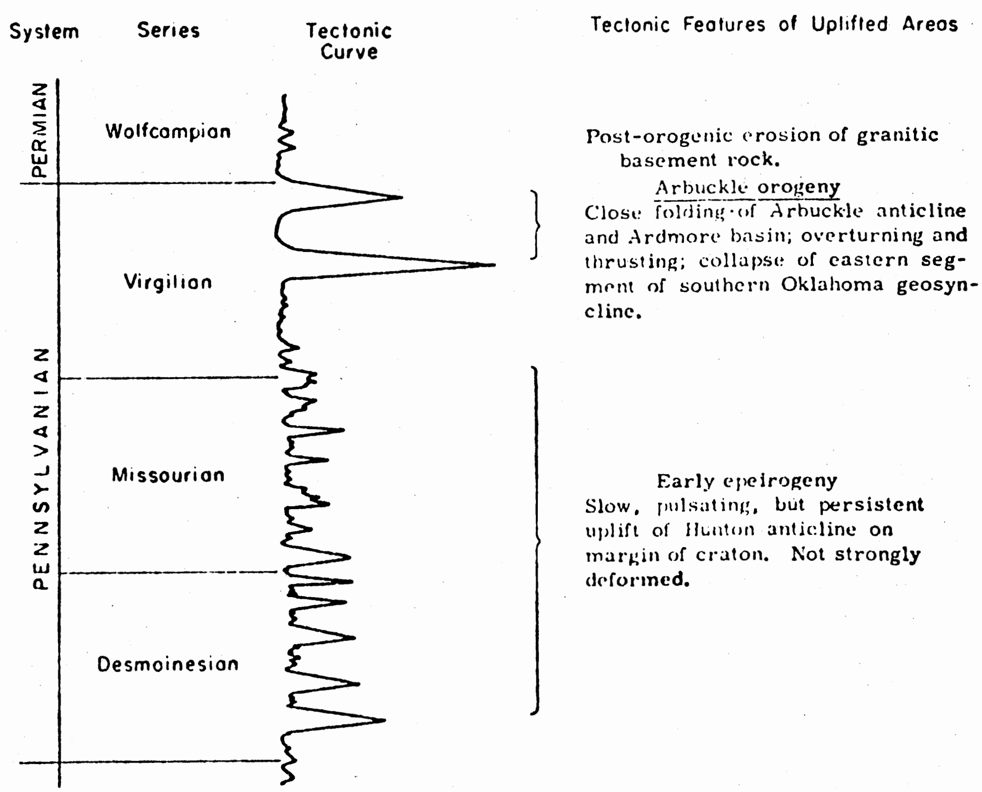

Fig. 7.-Tectonism of the Arbuckle Mountains during Pennsylvanian time. Modified after Ham and others (1969).

occurred during medial Virgilian time, producing the intense deformation of the two anticlines (Fig. 7). The folding was associated with reverse faults. These zones of weakness are postulated to have been the same as those present at the time of the original rift system (Pruatt, 1975).

The second main tectonic event is recorded in the 650 ft. of boulder-conglomerates of the Vanoss Formation. In this final tectonic event, the anticlines were faulted and uplifted with only minor folding. Although low-intensity faulting and folding continued through early Permian time, this second period of tectonism of late Virgilian time marked the culmination of the Arbuckle Orogeny (Fig. 7) and the beginning of its erosional cycle.

CHAPTER IV

PETROLOGY

Lithology

The Butterly Dolomite is a typical stratigraphic dolomite as defined by Sargent (1969, p. 10):

> . . . a dolomite occurring in bedded sequences of regional extent and having pre-tectonic stratigraphic characteristics such as stromatolitic structures, fossils, and conformance to the local and regional structure.

The Butterly dolomite replaced the Signal Mountain Limestone and the McKenzie Hill Formation. The contact between these two formations and the Butterly is irregular and interfingered. This is evident in the "S" section (Appendix A) where the remnant McKenzie Hill is only partially dolomitized, resulting in dolomitic limestones with a few interbeds of dolomite in the upper Butterly. These dolomitic limestone remnants exist in most complete sections of the Butterly. Although the contacts of these rock types are irregular, they are easily spotted in the field by the dramatic change in color and outcrop pattern.

The Butterly is characterized by light to dark brown honeycombed weathering and by medium to coarse crystallinity with scattered finely crystalline dolomite beds. In contrast, limestones of the McKenzie Hill and Signal Mountain are fine- to medium-crystalline intrasparite or pelsparite.

Butterly strata are laminated to massive with lamination being more common in the upper one-third of the section; the rock is massive in the lower two-thirds of the unit. A few pre-tectonic stratigraphic structures also are preserved, mainly in the laminated and flaggy strata. These include small-scale cross-lamination, soft-sediment deformation, bioturbation, scour-and-fill, and storm layers. Storm layers (Fig. 8) are defined as follows:

> . . . widespread, commonly unfossiliferous and well-marked layers result from major storms and are deposited when rising tides and high winds mobilize mud on bottoms of normally quiescent shallow ponds and lakes and deposit single thick layers on shoal areas (Wilson, 1975, p. 81).

The most pervasive structures are related to dolomitization and include vugs, fractures, and breccias. The very common stylolites represent tectonism.

Petrography

Fabric

The fabric of the Butterly is a monotonous medium-crystalline recrystallized dolomite with sutured and embayed grain-contacts. The only observed variation of this fabric is in sizes of dolomite crystals.

Laminae in the upper one-third of the Butterly are alternately sandy and sand-free. Vugs with protruding

Fig. 8.-Photograph of storm layers in the "T" section. The field of view is approximately 4 x 6 inches.

rhombs of coarsely crystalline dolomite are the most abundant structure. Bioturbation is observable in a few of the thin-sections of both the dolomite and dolomitic limestone. Most of the bioturbation consists of one or two straight burrows that may be vertical, horizontal, or at an acute angle to bedding. The burrows generally are filled with detrital material and/or coarser cement, but burrows in the dolomite do not contain any detrital material and contain larger crystals than the rest of the rock (Fig. 9). In a few beds bioturbation is pervasive.

Allochems

The typical precursor to dolomitization was sandy pelletiferous intrasparite (grainstone) to sandy pelsparite (wackestone). Allochems generally are replaced in dolomite beds, except for rare allochem ghosts in a few thin-sections. Therefore, most of the following part of the text is drawn from the partially dolomitized limestones of the "S" section.

Pellets are the most common allochem (Folks, 1959, 1962). Diameters of pellets in sections studied in this research range from 0.05 to 0.2 mm, and average approximately 0.15 mm. The poorly sorted pellets are elliptical to spheroidal and are composed of micrite and microsparite. They are structureless and generally contain no detrital material. Contacts show replacement of pellets by cement. In one sample the micrite envelopes are preserved. The

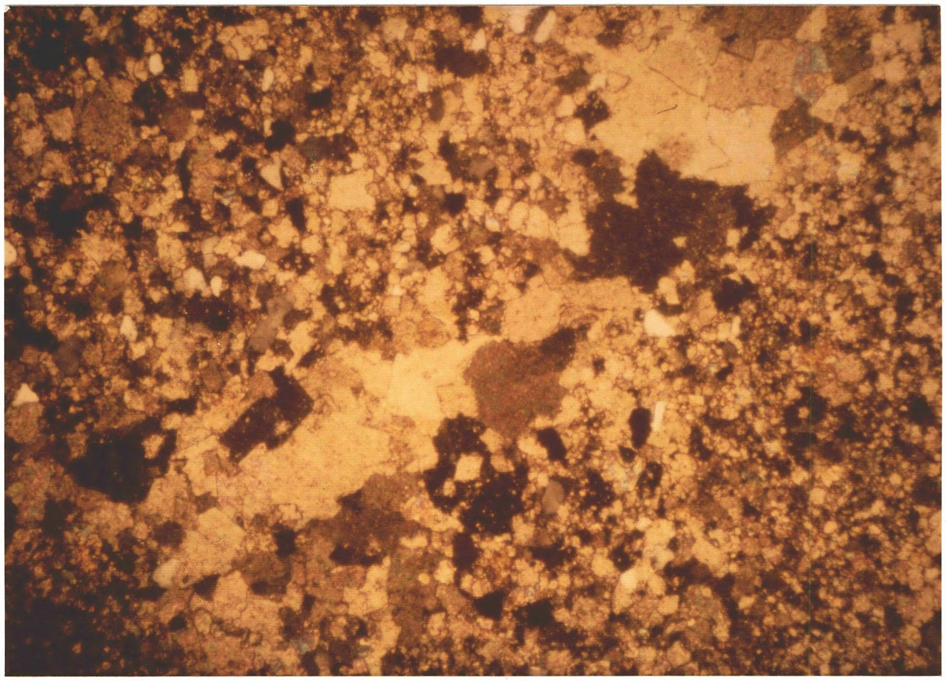

Fig. 9.-Burrow (coarser grain) in pervasively altered dolomite. Note sutured fabric. 25X; X-nicols.

pellets are more resistant to dolomitization than is the sparry calcite cement or the intraclasts.

Intraclasts are the second most common allochem. They range in length from 0.2 mm to 2 cm with the average being approximately 1 mm. Intraclasts generally show decreased rounding with increased size. The average intraclast is ellipsoidal with the larger intraclasts being almost tabular. Intraclasts, like the pellets, are poorly sorted and they grade continuously from small to large. Composition of intraclasts includes micrite, pelsparite, dolomitic pelsparite, and dolomite. The intraclasts commonly contain detrital material of quartz, potassium feldspar, and chert, with authigenic overgrowths on the quartz and potassium feldspar. The intraclasts also commonly contain dolomite rhombs.

Ooids represent only a small percent of the modal analysis; in no samples did they exceed 1 percent of the rock. The ooids are approximately 0.7 mm in diameter and commonly have pellets as their cores. The ooids have radiating, microsparite structure. The oolites appear to be more resistant to replacement by both calcite and dolomite than are the intraclasts.

Two slightly dolomitized phosphatic conodonts were found. They were 0.6 mm by 0.1 mm and were cigar-shaped.

Noncarbonate Grains

The principal noncarbonate material in the Butterly is quartz. Quartz was found in almost all the rocks examined and it averaged approximately 4% in the Butterly as a whole and approximately 5% in the thin-sections examined. It ranges in diameter from 0.03 mm (coarse silt) to 2.0 mm (very coarse sand) and averages 0.3 mm (medium sand). The dolomitic limestones contain more and coarser-grained quartz. The grains are subangular to rounded, with most being subrounded. Most of the quartz grains have authigenic overgrowths (Fig. 10). In rare instances the authigenic overgrowths produce an idioblastic quartz crystal. The original quartz detritus and the overgrowths are corroded and show evidence of replacement by both calcite and dolomite cements. The quartz grains normally have undulatory extinction. A few were fractured, with calcite in the fractures.

Inclusions in the quartz mostly are isolated vacuoles and fluid. Other inclusions, in order of decreasing abundance, include apatite, zircon, biotite, and chlorite. These minerals are only in trace amounts and seem to have been unaffected by post-depositional events.

The Butterly averages about 1% feldspar with the range being from 0 to 7 percent. Microperthite and microcline are in many of the dolomite samples. The feldspars range in length from 0.05 to 2.5 mm, with the average being 0.5 mm. Shape ranges from subrounded to angular, but predominantly is subangular. Most of the feldspars grains are unclouded by vacuoles and/or kaolinite, but many are clouded. The feldspars have clear authigenic overgrowths of potassium

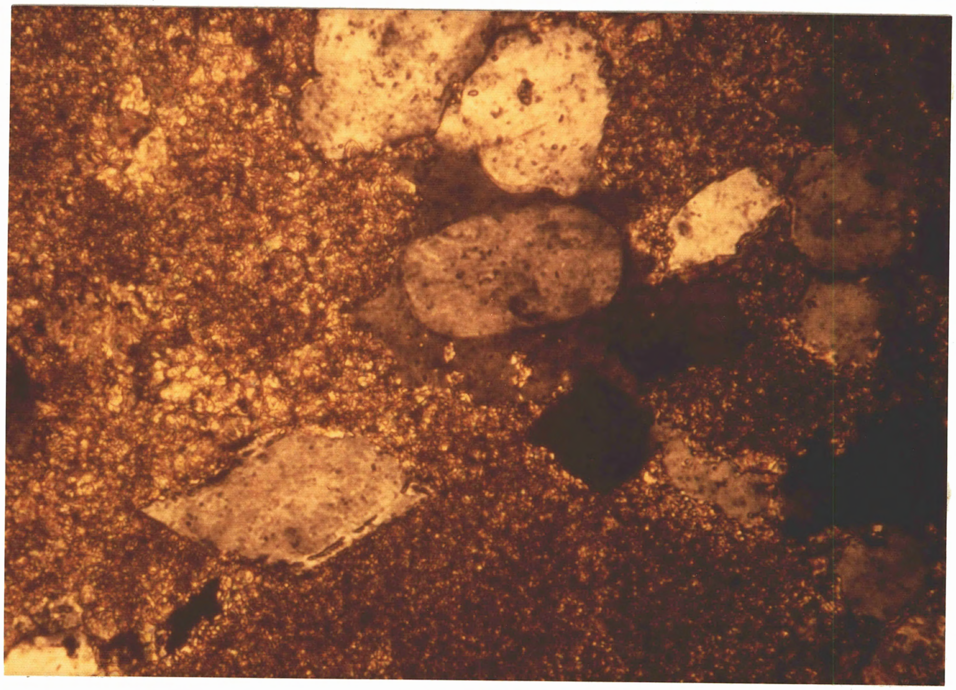

Fig. 10.-Detrital quartz (rounded upper center) with authigenic overgrowth. Detrital feldspar (lower left) with authigenic overgrowth resulting in rhombohedral cross-section. Note the inclusions of carbonate in both authigenic overgrowths and their embayed contacts of the overgrowths. 100X; X-nicols.

feldspar with inclusions of calcite (Fig. 10). These overgrowths give many feldspar grains rhombohedral cross-sections that aid in their identification. The authigenic overgrowths are more susceptible to replacement by calcite or dolomite than are the original detrital grains, although both show corrosive contacts and have been replaced by the carbonates. Some feldspars are fractured, and fracturing occurred both before (Fig. 11) and after the authigenic overgrowths.

Detrital chert does not exceed 1% of the rock. The original sizes and shapes of the grains of detrital chert are difficult to estimate, owing to extensive replacement by both calcite and dolomite. Most detrital chert grains that exceed 0.5 mm in diameter probably were rounded originally. Chert grains commonly have inclusions of carbonate (Fig. 12).

Zircons were found in a few thin-sections. The angular grains commonly display one or more of their original tetragonal crystal faces. Zircons range in diameter from 0.03 to 0.2 mm and average 0.05 mm. No overgrowths of zircon nor any indications of fracturing were seen.

The remaining detrital mineral is rare grains of glauconite, which range in diameter from 0.03 to 0.05 mm and average 0.04 mm. Rounded flakes of glauconite show no indication of abrasions or replacement.

Fig. 11.-Fractured detrital feldspar with calcite (red) filling. Note that authigenic overgrowth (clear, upper-right) has closed the fracture. Dolomite (yellow) has replaced the feldspar in the lower left corner. 100X; stained with Alizarin Red-S and potassium ferricyanide; plane-polarized light.

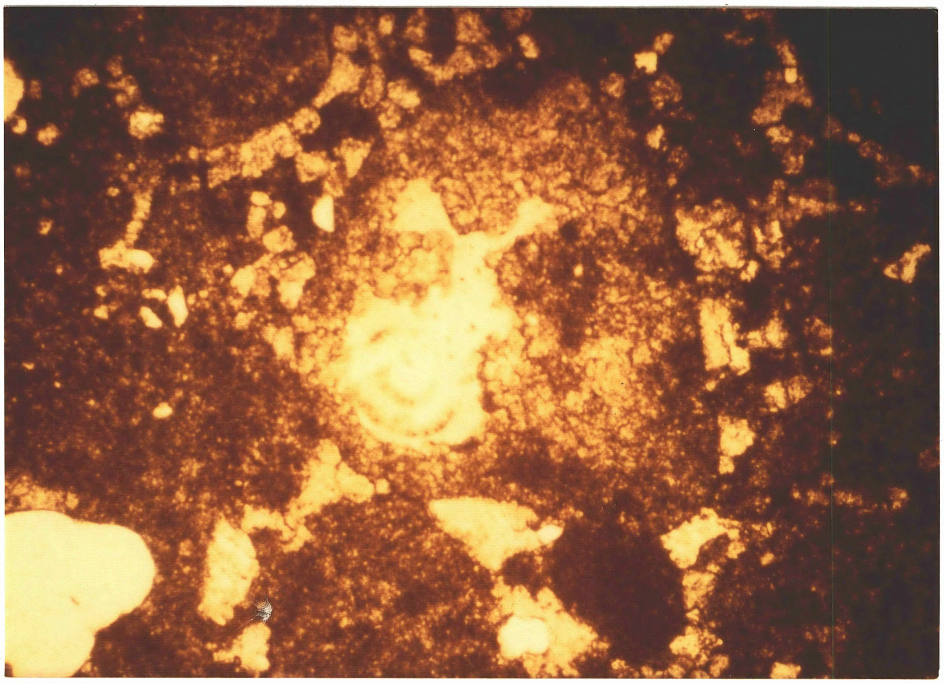

Fig. 12.-Dolomite intraclast with fibrous chert (clear) filling in dolomitic limestone of the "S" section. Note the inclusions of calcite (red) in the chert. 40X; stained with Alizarin Red-S and potassium ferricyanide; plane-polarized light.

Detrital Clay Minerals

The results of the 25 samples analyzed are presented in Table I. Clay minerals were not seen in thin-section except along a few stylolites and as alterations of feldspar. They constituted only trace amounts of the total rock and appeared to be residual clay. Most samples analyzed showed some clay minerals, and even though they were observed only in samples with stylolites, this common occurrence suggests that they are dispersed throughout the rock.

The most abundant clay mineral is illite, followed by kaolinite and Fe-chlorite. The kaolinite is from alteration of feldspar and the Fe-chlorite probably is from alteration of the mafic fraction of the igneous source rock. These findings are similar to those of previous clay-mineral studies of carbonate rocks (Grim and others, 1937).

Cements

Predolomitization cements are micrite (microsparite), sparite, and drusy sparite. The micrite cement has undergone some recrystallization and therefore can be classified as microsparite.

Microsparite is the most common cement. It is nearly opaque in thin-section and seen at high magnification (320X) is a mosaic of very finely crystalline calcite. The microsparite is more susceptible to replacement by dolomite than are the allochems.

Sparite cement was observed in two modes, drusy and

TABLE I

DETRITAL CLAY MINERALS OF THE BUTTERLY DOLOMITE

Sample	Illite	Fe-Chlorite	Kaolinite	No Clays Detected
B050	58%	-	42%	-
B078	100	-	-	-
B090	80	-	20	-
B096	-	-	-	x
B130	83	-	17	-
B210	50	25	25	-
B248	-	-	-	x
P560	-	-	-	x
P646	-	-	100	-
P610	-	-	-	x
P901	-	-	100	-
P932	-	-	100	-
S038	-	-	-	x
S054	-	-	-	x
S125	73	27	-	-
S224	-	-	-	x
S565	-	-	-	x
S608	-	-	100	-
T025	74	-	26	-
T189	53	-	47	-
T199	50	50	-	-
Z065	70	30	-	-
Z113	100	-	-	-
Z206	100	-	-	-
Z225	100	-	-	-
$\bar{x}$	39.6	5.3	23.1	-
s	41.3	13.0	36.9	-

mosaic fabric. The mosaic sparite is fine to medium crystalline, limpid, and nonferroan. The drusy sparite is fibrous, with increased crystal size toward centers of filled spaces. The drusy sparite is also limpid, nonferroan, and is uncommon.

Rock Fragments

Rock fragments are granophyric and other quartz-feldspar igneous-rock fragments. These fragments are only in trace amounts and range from 0.1 to 1 mm in diameter. They are rounded and some show evidence of fracturing. The rock fragments show the same replacement and other characteristic features as their respective mineralogical detrital counterparts.

Sulfides and Oxides

Pyrite and sphalerite are present in the Butterly. The more common pyrite is discussed in this section, whereas sphalerite is discussed in the chapter on zinc mineralization. Pyrite grains from 0.03 to 0.1 mm in diameter are disseminated in the rock. Amount ranges from 0 to 9%, averaging less than 1% for all samples of the Butterly. Shapes of the pyrite vary from cubes to irregular masses. Pyrite commonly is variably oxidized to hematite.

Hematite is also associated with zoned dolomites. It occurs in distinctive zones, which may be completely hematite or which may be both hematite and dolomite. The zones average 0.01 mm in thickness and are rhombohedral in cross-section.

Porosity

Porosity of the Butterly is intercrystalline and vuggy. The vugs are characterized by coarsely crystalline dolomite rhombs that project into the cavity. They are generally about a half a centimeter in diameter and represent as much as 5% of the rock. The vugs generally are associated with fracturing and several vugs may have a linear arrangement.

Porosity in thin-section is intercrystalline. Intercrystalline porosity generally is very low and, like the vuggy porosity, is more common in the dolomite than in the dolomitic limestone.

Replacement Dolomite

Evidence of two periods of dolomite replacement is observed in thin-section. These periods were separated by a period of corrosion of the dolomite. The first episode of dolomite replacement was early diagenetic, and is the most widespread. The second period was restricted to development in paleochannelways through which the dolomitizing fluids traveled. Therefore, its impact on the Butterly is less apparent and has been overlooked.

Fabric of the dolomitized rock is sutured to mosaic, and is medium-crystalline. The most common type of early diagenetic dolomite is a massive sutured fabric of pleochroic brown to clear crystals. The dolomite has resorbed and shows curved contacts with a low percentage (5%) of enfacial triple junctions. Sizes of dolomite crystals vary considerably in any thin section. Contacts with relic allochems are gradual with intermingling of fine and coarse crystals making it difficult to draw a line of separation.

The second morphologic type is zoned with clear and opaque (hematitic) dolomite. These rhombs are generally smaller than the other early diagenetic dolomite crystals. Like the other early diagenetic dolomite crystals, they have corroded and embayed contacts. Botryoidal zoned dolomites are in vugs in a few samples.

The third type of early diagenetic dolomite is coarsely crystalline, similar to the massive early-diagenetic dolomite, but it occurs in burrows that cut the dolomitized rock (Fig. 9). Therefore, it is older than the other morphologies, but its sutured fabric suggests that it is also early-diagenetic.

Late-stage diagenetic dolomite comprises about 10% of the dolomite in the Butterly, which probably accounts for low porosity. It is characterized by highly irregular morphology and by crystallinity equal in size to the paleochannelways, with a range from fine to extremely coarse crystals. Late-stage diagenetic dolomite is restricted to channelways, fractures, intercrystalline porosity, and vugs (Fig. 14). The late-stage diagenetic dolomite is found in corroded and embayed early-diagenetic dolomite, and is distinguished by its optical discontinuity (Fig. 13) and more limpid character. It fills fractures and also cements brecciated rocks. In vugs it has the coarsest crystallinity. The highly irregular shape of this replacement dolomite is due to a period of corrosion that occurred between the early and late diagenetic dolomitization. Channelways used by corroding solutions were filled by the late-diagenetic dolomite.

X-Ray Diffraction and Cathodoluminescence

Results of X-ray diffraction of thin-sections and selected samples show that there is no variation in magnesium content of the dolomite or calcite. The mineral dolomite consistently produced a (211) peak at 30.95 $^{o}2\theta$ and the calcite a (211) peak at 29.5 $^{o}2\theta$. These peaks indicate that the calcite is low-magnesium calcite and the dolomite is ordered (Scholle, 1978; Lippmann, 1973).

Cathodoluminescence of the Butterly thin-sections confirmed previous petrographic findings and added information to others. Quartz, feldspar, zircon, and dolomite are all luminescent.

Detrital quartz and feldspar grains have dull and bright blue luminescence respectively. Their respective overgrowths, on the other hand, are not luminescent. Therefore, the detrital grains were formed at high temperatures and the overgrowths at low temperatures (i.e., authigenic) (Thomas, 1974). Nonluminescent secondary overgrowths also

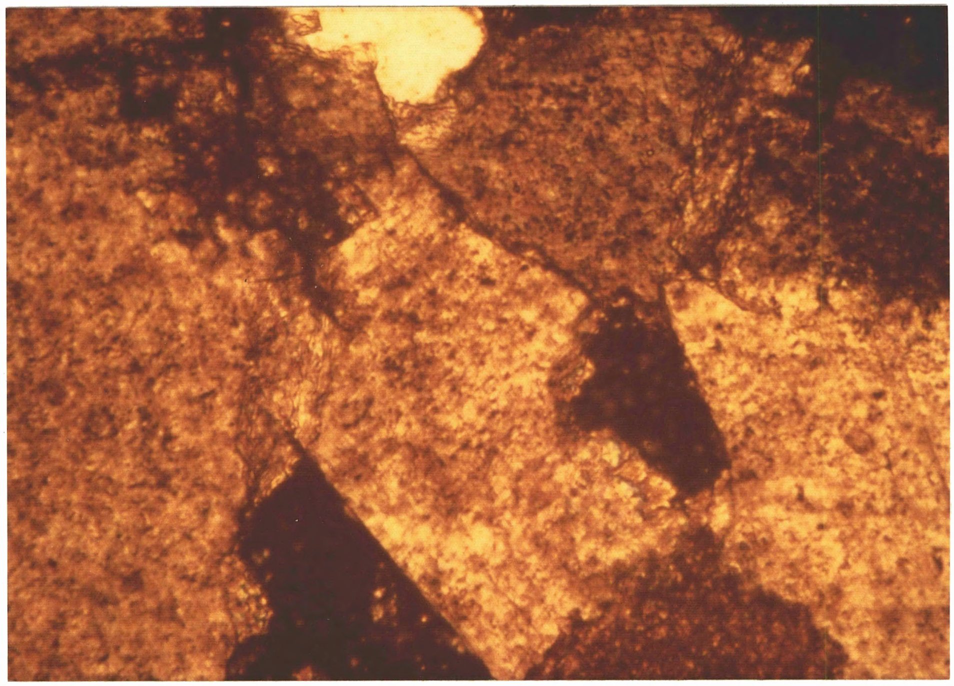

Fig. 13.-Late-stage diagenetic dolomite (black, right-center) filling corroding early-diagenetic dolomite (yellow). 128X; X-nicols.

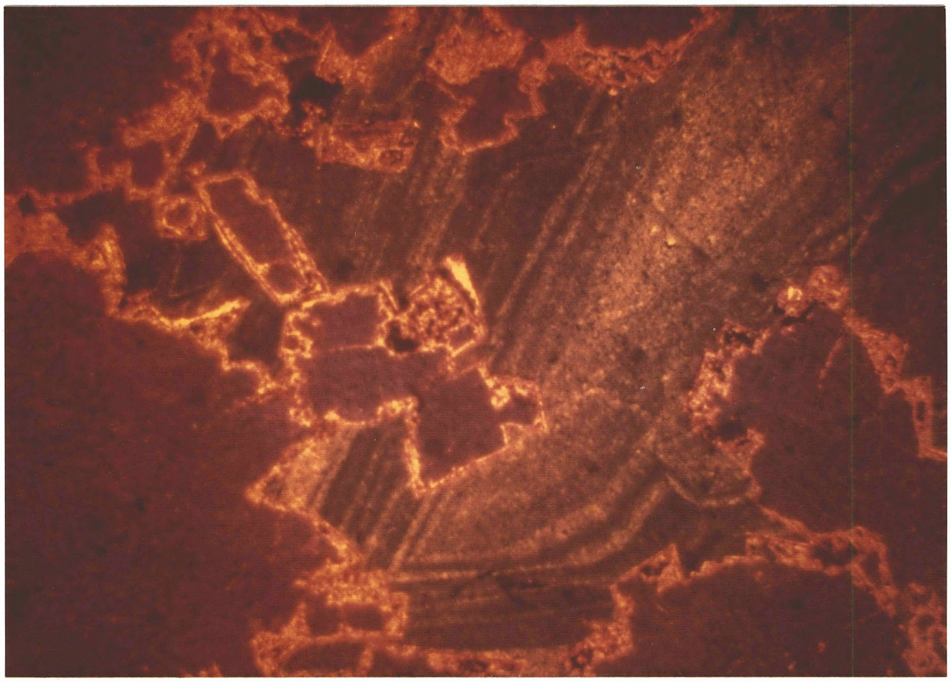

Fig. 14.-Cathodoluminescence of late-stage diagenetic dolomite filling a vug. Fifteen generations of dolomite are present and the first and third generations are bright red and yellow. Rhombs of the first generation fill the corroded contact of the early diagenetic dolomite (dull red). 20X.

fill fractures in both the quartz and feldspar. Bright yellow luminescence aided in the identification of detrital zircons.

Carbonate luminescence varied from nonluminescent calcite and allochems to brightly red-luminescent late-stage diagenetic dolomite. The nonluminescent calcite cement and allochem indicate a low concentration of Mn (activator) and higher concentration of Fe, Ni, and Co (quenchers) (Sipple and Glover, 1965). Early-diagenetic dolomite varied from no luminescence to dull red luminescence. This indicates that the dolomitizational fluids varied in trace-element chemistry especially in Mn, Fe, Ni, and Co. Late-stage diagenetic dolomite also showed variation in luminescence. The corroded and embayed contacts of the early-diagenetic dolomite were filled with bright red, late-stage diagenetic dolomite.

In one section, a large vug was filled with the late-stage diagenetic dolomite. In this vug are 15 generations of dolomite cement (Fig. 14). More importantly, this vug shows that only the first and third generations have bright red luminescence, so commonly seen in other thin-sections, whereas the remaining generations are either nonluminescent or have dull red luminescence. These 15 generations indicate periodic cementation within which the trace-element chemistry varied. Meyers (1974) postulated that periodic cements can be correlated from sample to sample. They also can be related to tectonism and erosion. Furthermore, the red luminescence is related to an average valency of Mn greater than two (Sommer, 1972). The tectonic dolomite and sphalerite of the Turner Prospect area were not luminescent.

CHAPTER V

ZINC MINERALIZATION

Introduction

The Turner Prospect in Sec. 28, T1S, R1E consists of numerous prospect pits and one open pit. Production of sphalerite stopped before 1920 and the open pit is filled with water. The open pit is approximately 180 ft. wide and 40 ft. deep. Approximately 32,000 short tons of rock were mined, most of which is in the nearby dump. The Turner Prospect has been investigated frequently by mining companies in the past two decades. The prospect has been drilled recently by the American Zinc Company, which reportedly drilled 100 shallow holes in the prospect area. The prospect is currently leased by Texasgulf, Incorporated, which plans to drill several exploratory holes in the area. The prospect is typical "Mississippi Valley Type" and is very similar to the ore deposit of the Mascot-Jefferson City Zinc District in east Tennessee, described by Crawford and Hoagland (1968).

Description

The zinc mineralization is in the upper half of the Butterly Dolomite. In the mineralized area the rock is finely crystalline and averages about 7% insoluble residues. These residues are mainly quartz and feldspar. The rock generally is laminated but massive bedding also occurs. Soft-sediment deformation in the laminated strata is common, but not necessarily associated with mineralization.

The prospect is in the area of the West Timbered Hills Anticline. Abundant faulting and fracturing characterize the prospect area. The faults and fractures contain brecciated rock fragments in a coarsely crystalline white tectonic vein-dolomite matrix (Sargent, 1969). The zinc mineralization is found in a coarsely crystalline white tectonic vein-dolomite, very similar to that found in the faults and fractures (Fig. 15). White dolomite veins cut the sphalerite mineralization, an indication that mineralization occurred before the end of precipitation of the dolomite.

The mineralized rock is in mantos and collapse breccias. Mantos are "horizontal" stratiform bodies between bedded replacement dolomite and are conformable to bedding. Thickness ranges from a few inches to 3 ft. The areal extent is difficult to estimate but probably is relatively small (i.e., thousands of sq. ft.). Most mining was in the collapse breccia. The area of the single collapse breccia coincides with that of the open pit, and extends to an unknown depth.

The mineralogy of the prospect is uncommonly simple, with as much as 25% colloform sphalerite, but it averages about 10%. The sphalerite commonly coats the breccia

Fig. 15.-Sphalerite (yellow-brown), tectonic vein dolomite (white), and brecciated host rock (gray). Note that the brecciated host rock is laminated and that sphalerite does not coat all the visible sides. Also note that the tectonic vein dolomite cuts the sphalerite mineralization. (Scale is in cm.)

fragments or the walls of the manto. The sphalerite is light brown and on the average, contains less than one percent Fe (Table II). Other trace elements in the sphalerites include on the average, 0.3% Cd, 0.005% Mn, 0.02% Cu, and 0.3% Pb. Pyrite is the next most abundant sulfide, but it rarely exceeds 5% of the rock. Galena has been reported (Becker, 1914; Ham, 1951), but no galena was observed in any of the samples collected.

Dolomite is the most abundant gangue mineral. The white dolomite has sharp contacts with the host rock and seems to be similar to the tectonic vein dolomite described by Sargent (1969, 1974). The brecciated host rock is found in both the manto and collapse breccia. The dolomite host rock commonly is laminated but it is massive at some places. The fragments are rimmed by sphalerite and white tectonic dolomite on one or more sides (Fig. 15). Tectonic dolomite is also in cross-cutting veins in the host dolomite and the sphalerite. Close scrutiny of the contacts between the sphalerite and host dolomite sometimes shows tectonic dolomite, indicating that tectonic dolomite was precipitated before the sphalerite. However, most of the tectonic dolomite precipitated after the sphalerite mineralization.

TABLE II

TRACE ELEMENTS IN SPHALERITES AND SUMMARY STATISTICS IN PPM

	n	Mean	Standard Deviation
Insoluble Residue	5	0.1148	0.0658
Fe	5	6342.8	2045.3
Mn	5	49.8	35.2
Cd	5	3184.0	973.0
Pb	5	803.6	127.4
Cu	5	197.4	117.0

CHAPTER VI

GEOCHEMISTRY

Statistical Treatment of Geochemical Data

Introduction

The geochemical data were analyzed by two statistical techniques, both nonparametric; they were the Kolmogorov-Smirnov test and the Mann-Whitney U-test. The Kolmogorov-Smirnov test was used to test the hypothesis that samples concerned were random samples from a normally distributed population, whereas the Mann-Whitney U-test was applied to evaluate the hypothesis that two sets of samples showed no significant differences on the basis of attributes measured.

The Kolmogorov-Smirnov Test

The Kolmogorov-Smirnov test can be used to evaluate goodness of fit to a normal distribution. The test is applicable to continuous frequency distributions and in many cases is more useful than a Chi-square test (Sokal and Rohlf, 1969). The test is "based on the absolute differences between observed and expected cumulative frequency distributions. These differences are expressed as differences between relative cumulative frequencies." (Sokal and Rohlf, 1969). Kolmogorov-Smirnov analysis tested the geochemical data by location and as a whole. Furthermore, the "S" section was divided into dolomitic limestones and dolomites. A significance level of 5% was used in all the tests. For each of the tested groupings, 14 elements (all except Li) and crystallinity were tested for conformity with normal distributions. The majority of the elements failed to pass the test of conformity to normality, even after having been transformed to logarithms and other forms of measurement. Iron and insoluble residue both showed evidence of lognormal distributions for all of the groupings. The dolomitic limestones also showed evidence of normal or lognormal distributions for all components tested.

The failure of the majority of the data to fit a normal distribution even after transformation indicates one of the following: (1) the sampling procedures used did not produce random samples; (2) the original limestone did not have normal distribution of its chemical components; or (3) the original limestone did have a normal distribution, but the components of Butterly Dolomite are non-normally distributed, which, if true, may be a result of several diagenetic alterations. The petrographic evidence of two periods of dolomitization and evidence from cathodoluminescence both support the third possibility.

Mann-Whitney U-Test

The Mann-Whitney U-test can be used without assuming that the data were drawn from a normal distribution (Sokal and Rohlf, 1969). The null hypothesis is that the two samples being compared were derived from the same populations. (Note that 10% significance levels were used in two of the tests (Table III). These are the lowest significance levels available (Sokal and Rohlf, 1969) for the small sample size used.)

The Mann-Whitney U-test is used in instances where the larger sample size is less than 20. This test was used to compare analyses of 12 samples (Appendix E) of the Butterly (stratigraphic dolomite), taken from Sargent's (1974) dissertation, with the samples of this study. Sargent's samples were collected from three localities in the Arbuckle Mountains. The averages for each of his localities were compared to the averages of dolomite from the "B," "T," "Z," and "S" stratigraphic sections. The Mann-Whitney U-test was also used to test distributions of the various "P" sections against one another and to test the vein dolomite against the brecciated host dolomite.

The Wilcoxon Two-sample Test was used for comparison of the distributions of other sections. Results of these tests are in Table III and the salient features of these tests are discussed below.

The test between Sargent's analyses of the Butterly and analyses of this study is important. This comparison stratigraphic dolomite = Butterly Dolomite) shows evidence to conclude that 90% of the compared element-means were drawn

TABLE III

MANN-WHITNEY U-TEST OR WILCOXON TWO-SAMPLE TEST RESULTS

Stratigraphic Sections	Butterly Dolomite = Stratigraphic Dolomite	"S" Dolomites = "S" Dolomitic Limestone	"S" Dolomites = "B"	"S" Dolomites = "Z"	"Z" = "T"	"Z" = "P"	"Z" = "B"	"P5" = "P6"	"P5" = "P9"	"P6" = "P9"	Vein = Host
Significance Level	10%	5%	5%	5%	5%	5%	5%	5%	5%	5%	10%
Mg	-	R	N	R	R	R	R	N	N	R	N
Ca	-	R	R	R	R	R	N	N	N	R	N
Fe	N	N	N	N	N	R	N	R	R	R	R
Mn	N	N	R	R	N	N	N	R	R	R	N
Sr	N	R	N	R	R	N	R	N	N	R	N
Na	N	R	R	R	N	N	N	R	R	R	R
K	N	R	R	R	N	N	N	R	R	R	R
Cu	R	N	N	R	R	N	R	R	N	R	R
Pb	N	N	N	R	R	R	N	R	R	R	R
Zn	N	R	R	R	R	R	N	N	R	R	R
Cd	-	R	N	N	N	R	N	N	R	R	R
Cr	-	R	R	N	N	N	R	R	N	R	R
Ni	N	R	R	R	N	N	R	R	R	R	N
Li	N	N	N	N	N	N	N	N	N	N	N
Insoluble Residue	-	R	N	R	R	N	R	N	N	R	R
Crystallinity	-	R	R	N	N	R	N	N	N	N	N

N = Not Reject H_o
R = Reject H_o
- = No Data

H_o : Two samples were drawn from the same population, variables measured in ppm.

from a common population. Sargent's discriminant analyses showed that the most reliable variables for discriminating stratigraphic dolomite from tectonic dolomite are Li, Na, Ni, and Cu, discriminating at the 93%, 99%, 100%, and 100% confidence levels respectively (Sargent, 1974). The rejection of Cu in the comparison of stratigraphic dolomite and tectonic dolomite (Table III) may be the result of a wider range of Cu values (0-32 ppm) found in this study compared to those reported by Sargent (2-6 ppm). The findings present evidence that the Butterly is stratigraphic, as defined by Sargent. Furthermore, the findings suggest that the distribution of elements in the Butterly is similar throughout the Arbuckle Mountains.

Another hypothesis of interest is that, in terms of the elements compared, the "S" dolomites are no different than "S" dolomitic limestones. The dolomitic limestones were defined by two criteria: the Mg/Ca ratio is less than 90 (an ideal ordered dolomite would have a ratio of 99 (Deer and others, 1964)), and the rocks are composed predominantly of calcite rather than dolomite. Twenty samples of a possible 116 were thus classified as dolomitic limestones. The results show that the dolomitization made little difference in distribution of the trace elements Fe, Mn, Cu, Pb, and Li. These tests and the element-means (Table IV) also suggest that the distributions of insoluble residues are different, signifying either a change in depositional energy, a change in source area, or that quartz and feldspar are

TABLE IV

MEANS FOR CHEMICAL DATA

Elements (ppm)	All Samples Analyzed	"S" Dolomitic Limestone	"S" Dolomite	Sargent's 1974 Butterly Samples	Weber-1964 Secondary Dolomite	Weber-1964 Primary Dolomite	Rosler & Lange-1974 All Carbonate Rocks
Ca	175755.0	248550.0	163739.6	-	-	-	302300.
Mg	110738.0	27850.0	119364.6	-	-	-	47000.
Li	1.0	1.0	1.0	0.18	8.99	20.00	5-20.
Na	156.3	15.7	119.3	220.70	257.00	391.00	400.
K	96.6	97.6	53.0	212.50	3970.00	6550.00	2700.
Ni	10.1	13.8	9.8	1.30	41.00	126.00	20.
Cu	6.0	5.3	5.4	3.10	6.74	5.72	4.
Sr	42.2	153.1	28.8	18.40	187.00	174.00	610.
Mn	259.9	123.4	443.2	196.40	237.00	245.00	1100.
Fe	1607.2	1100.8	1819.2	1350.70	1980.00	2790.00	3800-13000
Pb	35.8	33.2	32.5	1.42	18.20	68.20	9-27.
Zn	742.0	2.0	15.8	0.18	550.00	1100.00	20.
Cd	10.0	8.0	5.8	-	-	-	0.0035
Cr	10.0	7.5	10.1	-	23.40	21.30	11.
Xl	4.0	2.6	4.5	-	-	-	-
Residue	0.062	0.111	0.047	-	-	-	-

Note that Xl is for crystallinity, as explained in Appendix D.

less resistant to replacement by dolomite than by calcite. The petrographic study indicates that authigenic overgrowths are more susceptible to replacement in dolomites than in dolomitic limestones. Another interesting relationship observed from comparison of "S" dolomitic limestones and "S" dolomites and the element-means (Table IV) suggests that dolomitization increased crystallinity.

The remaining tests of distribution in Table III are comparisons of the different stratigraphic sections with one another except for the vein-to-host comparison. In this comparison, the vein-dolomite chemistry is compared with the brecciated host-dolomite chemistry found in the vein. These tests are based on a small sample size of 5 and therefore, are not very sensitive. These tests and the raw chemical data (Appendix C) suggest that the Zn concentrates in the host rock rather than the vein material. The observed lithologic association of sphalerite and brecciated host rocks supports this hypothesis. Furthermore, these tests suggest that the mineralizing dolomitizing fluids have different distributions for many of the trace elements compared. On the other hand, Ca, Mg, Sr, Mn, Ni, and Li distributions are similar for brecciated host rocks and vein dolomite. This may indicate that the brecciated host rocks were strongly influenced by the dolomitizing fluids. The fluids also may have influenced the various "P" sections, reflected in the diversity of distributions of the "P" sections. Furthermore, they may also reflect differences in porosity, permeability, and fracturing of these sections or that each section is from a different stratigraphic and chemical horizon.

The other sections compared indicate that the Butterly is composed of a diverse chemical make-up, possibly due to a heterogeneous chemistry of the original rock, with different degrees of influence by the different diagenetic alterations. Another possible explanation is that at the 95% significance level, the Butterly is not chemically homogeneous both horizontally and vertically. A third possibility is that variation is due to sampling. All three explanations may be valid.

Major Elements

Analyses suggest that average rock of the Butterly contains 11.9 weight percent Mg and 16.9 weight percent Ca, values too low for ordered dolomite (13.18% Ca and 21.7% Mg (Deer and others, 1964)). However, X-ray analysis of the samples indicates that the analyzed material is ordered dolomite. Therefore, these low values are probably erroneous, caused by saturation of the atomic absorption spectrophotometer by extremely concentrated solutions. Therefore, these elements will not be discussed except in relation to the trace elements where there is supporting evidence that they are of the correct magnitude.

Trace Elements

The trace-element impurities in the dolomite samples of this study may be present as structural impurities, as inclusions, or as intergranular absorbates on dolomite or noncarbonate grains. Pb, Sr, Na, and K have radii too large to substitute appreciably in the dolomite structure, but they do substitute in the aragonite structure. In the conversion of aragonite to calcite, these ions are excluded appreciably. Their concentrations also may be reduced (to a lesser extent) on the conversion of calcite to dolomite. The ionic radii of Cu, Ni, Zn, Fe, and Mn are within the range for substitution for Mg in the dolomite structure.

The alkali elements, Li, Na, and K are most likely to be absorbed on the carbonate or noncarbonates grains, or to occur as inclusions. Surface absorption is related directly to the concentration of ions in solution and to the type of material on which it is absorbed. The alkali-element abundances are reflections of their concentrations in the diagenetic solution, of the insoluble residue, and of the percent of clay minerals in relation to other insoluble minerals. Complete evaluation of these complex interrelationships was not made in this study. However, some inferences will be attempted.

Lithium

No relationship exists between Li and insoluble residue in stratigraphic dolomites (Sargent, 1974). The uniformity of Li content in this study is also worth noting (Table IV and Appendix C). It has been suggested by several authors (Weber, 1964; Horstman, 1957) that Li is associated with the clay fraction, since it does not enter into the dolomite lattice. However, the variable mineralogy of Butterly clays argues against this in the Butterly. Therefore, from the lack of relationships between the insoluble residue and the Li content, the uniformity of Li content, and the variation in clay mineralogy of the Butterly, the conclusion can be drawn that Li is not related to the clay minerals or to quartz and perthite. Therefore, Li occurs either as an absorbate on the dolomite or as inclusions in the dolomite. Inclusions were not observed in thin-section, suggesting that Li occurs as a surface absorbent (Sargent, 1974).

Potassium

The higher K concentration of primary dolomites relative to secondary dolomites was attributed by Weber (1964) (Table IV, this report) to higher clay-mineral content of the primary dolomites. Sargent (1974) found that stratigraphic dolomites have less K than tectonic dolomites or limestones. In the samples analyzed in this study, K ranged from 0 to 816 ppm. The average value is 97 ppm, considerably less than that determined by Sargent or Weber (Table IV). However, the Wilcoxon two-sample test results indicate that there is no significant difference in distribution of K in Sargent's samples of the Butterly and those of this study (Table III). Therefore, it is reasonable to consider that the K values reflect the clay mineralogy.

Sodium

Sodium is more concentrated in the dolomites than in the dolomitic limestones. This relationship was reported by Sargent (1974) in his comparison of limestones and dolomites and also by Fritz and Katz (1972). They also reported no correlation between Na and Al or insoluble residue. This suggests that Na is not related to clay mineralogy, but probably was related to dolomitizing solutions more saline than normal sea water (Land and Hoops, 1973). Therefore Na probably is mainly in fluid-inclusions (Sargent, 1974).

Nickel

The ionic radius of Ni is similar to that of Mg; thus it could be accommodated in the dolomite lattice by substitution. Ni has been reported to correlate with organic content in carbonates (Krauskopf, 1956). In this study Ni averaged 10 ppm (Table IV) and Sargent (1974) reported an average of 1.3 ppm (Table IV). The Mann-Whitney U-test suggests no significant difference in the distribution of the element-means between Sargent's samples and samples tested in this study. There is no direct petrographic evidence of organic materials in rocks analyzed in this study, but perhaps a few samples of the Butterly had higher organic content than those sampled by Sargent.

Copper

Copper also may be substituted into the dolomite lattice and in rocks it commonly is correlated with organic material (LeRiche, 1959). The distribution of Cu is different than that reported by Sargent (1974, p. 70), but the results are similar to Weber's (1964, p. 1824) for secondary dolomites; these data may also reflect a higher organic content of rocks sampled in this study than of Sargent's samples.

Strontium

The large Sr ion is best accommodated in the aragonite structure rather than in that of calcite or dolomite. Strontium content decreases in the replacement of aragonite by calcite or of calcite by dolomite (Kingsman, 1969; Begrens and Land, 1972). This relationship seems to be supported by results of comparison of the Sr distributions of "S" dolomites and "S" dolomitic limestones. The average Sr concentrations (42 ppm) of this study are similar to those of Sargent's (27 ppm), but are considerably lower than those reported by Weber for secondary dolomite (214 ppm) (Table IV). Therefore, these lower results may indicate that corrosion and late-stage dolomitization leached Sr.

Manganese

Increase in Mn with dolomitization has been reported by

Atwood and Fry (1967). They attributed this to higher concentrations of Mn in the dolomitizational fluids. Sargent (1974) supported these findings, but in this study the Wilcoxon two-sample test for Mn (Table III) suggests that there is no significant difference in the distributions of Mn in "S" dolomites and "S" dolomitic limestones. Therefore, results of this study are in agreement with Land and others (1975) and Till (1971), and suggest that content of Mn is not necessarily affected by dolomitization.

Lead and Zinc

Lead and zinc were found in most of the samples analyzed. Both Pb and Zn may be substituted in the dolomite lattice (Deer and others, 1962). The Wilcoxon two-sample test for the "S" dolomites compared to dolomitic limestones (Table III) suggests that dolomitization did not affect the distribution of Pb, but increased Zn. The noted association of sphalerite with the tectonic vein dolomite in the Turner Prospect and the Wilcoxon two-sample test strongly suggest that Zn concentrations are related to the Zn concentration of the dolomitizational fluids.

Iron

The ionic size of Fe is between those of Ca and Mg; therefore iron substitutes for Mg, and less commonly for Ca (Deer and others, 1964). In this study content of iron ranged from 404 ppm to 11,413 ppm. Generally it is distributed log-normally in all the sections compared, except for the sections in the area of the zinc mineralization ("P" sections). Distribution in the "P" sections may reflect the effects of sampling, but probably the distribution is related to zinc mineralization.

Variation in content of Fe is attributed by Katz (1971) to changes in Fe^{2+}/Mg^{2+} of the dolomitizational fluids. Probably each period of dolomitization had its own Fe^{2+}/Mg^{2+} ratio and the late stages of dolomitization were poorer in iron. This hypothesis is based on cathodoluminescence, which shows that the early-diagenetic dolomite is dull or nonluminescent, indicating a higher content of quenchers, and iron is the most abundant quencher in samples documented this study. The late-stage diagenetic dolomite is more luminescent (Fig. 14), indicating a lower content of quencher (iron).

Chromium

Weber (1964) found no significant variation in Cr between "primary" and "secondary" dolomites. Sargent (1974) failed to detect Cr, because of calcium interference. In this study Cr was detected, with large variation in amounts. The Wilcoxon two-sample test for Cr suggests that it is significantly different in distributions for "S" dolomites and "S" dolomitic limestones (Table III). The Cr content averages 10 ppm and 7 ppm for "S" dolomites and "S" dolomitic limestones respectively. These averages and the

Wilcoxon two-sample test results suggest enrichment of Cr with dolomitization. The average Cr value (10 ppm) for all of the Butterly carbonate rocks is very near the 11 ppm reported by Rosler and Lange (1972) for all carbonate rocks.

Cadmium

Cadmium averaged 6 ppm for the "S" dolomites and 8 ppm for "S" dolomitic limestones. These averages and the Wilcoxon two-sample test suggest that the dolomitizational fluids depleted Cd in limestone. The decrease in Cd and increase in Zn with dolomitization are conflicting. This relationship is not understood. The average Cd value (10 ppm) is approximately 3000 times greater in samples of Butterly than the average value for all carbonates (0.0035 ppm) reported by Rosler and Lange (Table IV). Furthermore, in the "P" section, vein and host are even more enriched in Cd, averaging nearly 50 ppm. The common association of Cd with Zn and the geochemistry of the sphalerites suggest that high Cd values indicate zinc mineralization.

Stehli and Hower (1961) analyzed Recent carbonate sediments and Pleistocene carbonate rocks for Mg, Sr, Ba, and Mn; Land and others (1975) analyzed Recent and ancient dolomites for Na and Sr. Both concluded that diagenesis caused a marked decrease in abundance of these elements. Sargent (1974) also showed these results with his chemical analysis. In this study the Wilcoxon two-sample test of "S" dolomites and "S" dolomitic limestones suggests that there are significant variations in distributions of Ca, Sr, K, Cd, Ni, Mg, Na, Zn and Cr (Table III). The averages for the element (Table IV) suggest that dolomitization of these limestones caused decreases in Ca, Sr, K, Cd, and Ni and an increase in Mg, Na, Zn, and Cr.

CHAPTER VII

PETROGENESIS

Evidence of depositional environments of the predolomitized sediments is observed in thin-sections of dolomitized limestone. The environment best fits that of a restricted marine-shelf lagoon, as described by Wilson (1975).

Detrital quartz, feldspar (microperthite and microcline), and zircon suggest an igneous source of noncarbonate grains. Furthermore, inclusions in the quartz also point to a plutonic igneous source area (Folk, 1974). Because grains of feldspar are slightly larger, on the average, than grains of quartz, and because the granophyric rock fragments indicate that this immature sediment was deposited near its source, the source area probably was tectonically active (Folk, 1974). Sea level was shallow during depositon and the energy level fluctuated tremendously, as indicated by the storm layers, rhythmite, and massive beds. Soon after deposition of the sediments, diagenetic events began (Fig. 16).

"Early diagenesis" in this study means diagenetic alterations of the sediment while still under the influences of the sea above. The first diagenetic event recognized was

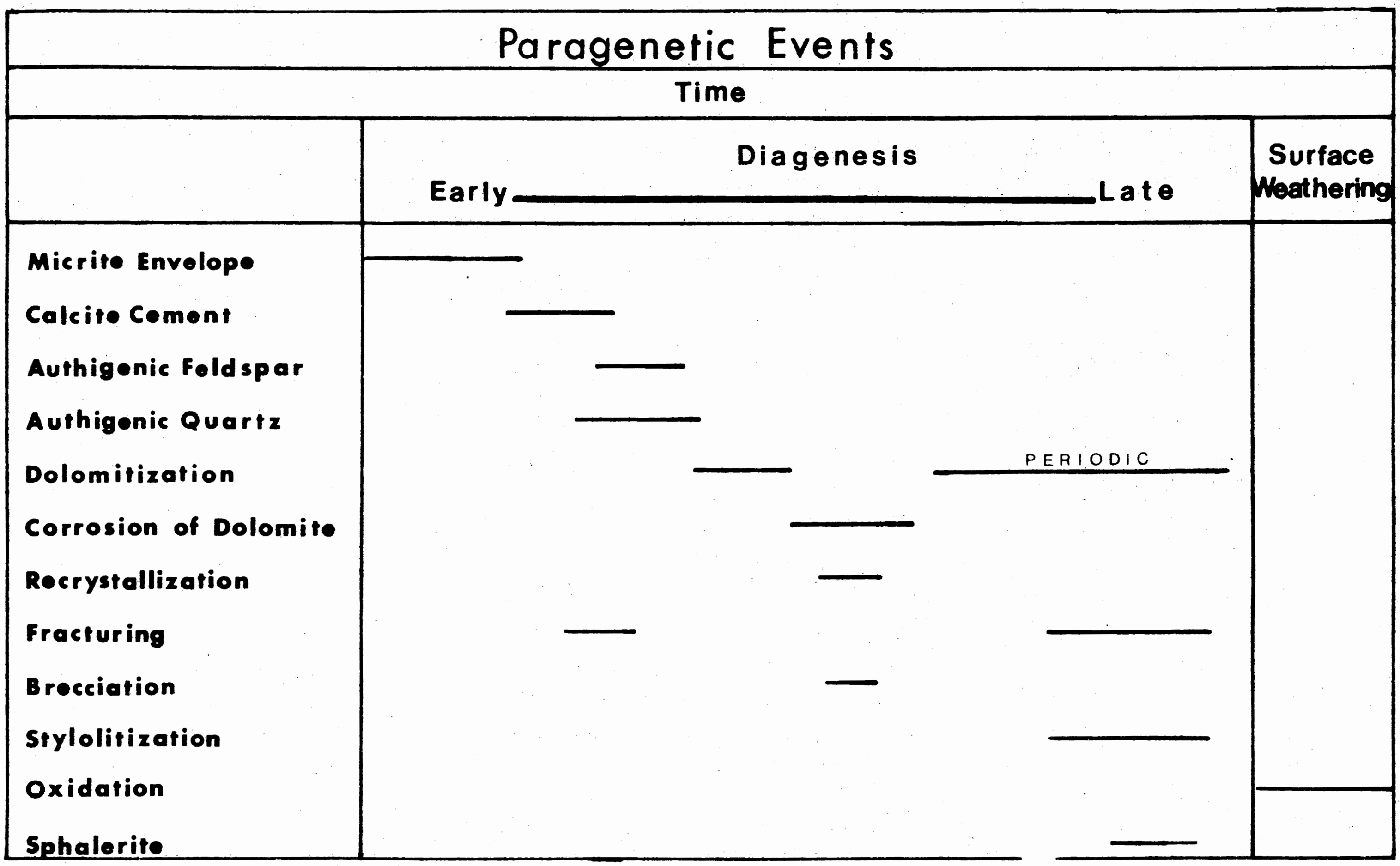

Fig. 16.-Paragenetic events of the Butterly Dolomite and the sphalerite mineralization of the Turner Prospect.

the development of micrite envelopes. Toward the end of micritization or soon thereafter, the sediments were cemented by sparry calcite.

During and following cementation, grains of quartz and feldspar were fractured. The authigenic enlargement of quartz began first and continued after authigenic feldspar overgrowths had stopped. These enlargements indicate that the sea water (or connate water) was saline to hypersaline and saturated in SiO_2 (Buyce and Friedman, 1975). Overgrowths replaced calcite cement and the allochems, as indicated by inclusions of carbonate in the overgrowths. During this episode, quartz filled uncemented cavities, producing fibrous chert (Fig. 12).

Early-diagenetic dolomitization commenced in the waning stages of growth of authigenic quartz. It is the more abundant dolomite in the Butterly. Ham's (1951) early-diagenesis hypothesis was drawn from his observation of dolomite detritus in the Lower Signal Mountain Formation. Dolomite detritus is also in the dolomitic limestones of the "S" section (Fig. 12). Even more convincing evidence of the early-diagenetic dolomitization are worm-burrows in a pervasively dolomitized rock (Fig. 9).

The mechanism for dolomitization probably was the mixing of fresh ground water with the sea water (Badiozamani, 1973). Zoned dolomites reflect changes of the dolomitizational fluids (Katz, 1971) which may have been due to changes in salinity, and/or changes in the oxidation tendency, or changes in the iron content of the water (Folk and Siedecka, 1974). The pervasive dolomite replaced the micritic cement and envelopes first, followed by the replacement of intraclasts, oolites, and pellets. Since it was selectively replaced, evidently micrite was the high-magnesium variety (Buchbindert and Friedman, 1970). The corrosional event is recorded by the resorbed contacts of the early-diagenetic dolomite. Concurrent with corrosion, recrystallization and brecciation occurred. The recrystallization is postulated from observations of texture, including presence of microsparite, low percent of enfacial triple junctions, and the occurrence of islands of sparite around detritus (Folk, 1959; Bathurst, 1971).

An effect of the corrosion and the early diagenetic dolomitization is the occurrence of collapse breccia, observed in the "P" and "B" sections. These brecciated rocks were embayed by the corroding fluids. Therefore, the breccia fractures and intercrystalline porosity appear to have been the channelways of the corroding fluids. Burial and decreasing influence of sea water probably caused these late-diagenetic events. With increasing depth of burial, the interstitial water became less saline, due to increase influence of ground water. The ground water was undersaturated with respect to magnesium (Back and Hanshaw, 1970), causing corrosion of the dolomite and collapse breccias. This undersaturation with respect to magnesium may have been caused by mixing of two subsurface waters with different dissolved sodium chloride contents. These fluids corroded the channelways (i.e., fractures, intercrystalline porosity, and breccias), increasing permeability of the rock. The late-diagenetic dolomite was then precipitated along these paleochannelways. The late-stage diagenetic dolomitization was episodic, comprising more than 15 generations. The first and third generations are depleted in Fe, Ni, and Co (quenchers) relative to manganese (activator), whereas the later and second generations have opposite relationships.

The 15 generations may reflect the tectonic history of the Arbuckle Mountains, suggested by tectonic events through the Arbuckle Orogeny (Fig. 7), 15 observed generations of dolomite, and Meyers's (1974) conclusion that periodic cements can be related to tectonic events. These 15 periodic dolomites show a general trend of decreasing luminescence in the younger generations, signifying an increase in Fe in the younger generations.

The author hypothesizes that the sphalerite mineralization and associated tectonic vein dolomite are also associated with this trend. The associated dolomites are enriched in Fe ("V" group, Appendix D) and are nonluminescent. Sargent (1974) concluded from field and petrographic evidence that the tectonic dolomite is post-Arbuckle Orogeny. The author concludes they formed after the second main tectonic event (late Virgilian) in the post-uplift tectonism, suggested by Ham's (1969) tectonic curve (Fig. 7).

Faults and fractures provided the channelways for the mineralizing fluids. Heyl and others (1974) concluded that "Mississippi Valley" type mineralizing fluids originated as heated oil-field brines. In this case brines were probably from the Ardmore Basin and migrated along aquifers in the basin. The Reagan Sandstone, nonconformably above the Carlton Rhyolite (Fig. 2), may have provided a pathway for the brines.

The Carlton Rhyolite contains more than twice the average abundance of zinc relative to other granitoid rocks of the world (Hanson, 1977). The author hypothesizes that the oil-field brines leached the Carlton Rhyliote of zinc; this supposition is supported by low amounts of zinc in the Carlton Rhyolite of the East Timbered Hills, compared to average amounts in the Carlton Rhyolite (Hanson, 1977). Furthermore, these zinc-rich brines could have migrated toward low-pressure zones through the Reagan Sandstone aquifer and then up faults and fractures. These ascending fluids might have mixed with descending meteoric water (Hall and Freidman, 1963) causing precipitation of tectonic dolomite, followed by sphalerite (Fig. 15). The colloform sphalerite indicates that the mineralization was also periodic, possibly due to tectonic disturbances of post-Arbuckle Orogeny time.

The author suggests that the mantos were created by the mineralizing fluids replacing remnant limestone beds in the Butterly. This hypothesis is based on higher average Sr content of the "P" and "Z" sections (Appendix D), 37 ppm and 38 ppm respectively (compared to the average Sr value for all analyzed samples minus the "P", "Z", and "S" dolomitic limestones of 30 ppm), and on the observation that limestone remnants are found in the upper Butterly. Fluids could then have fractured surrounding host rock, enlarging the manto. This would have resulted in brecciated host rock with sphalerite mineralization on one or more sides in a matrix of dolomite (Fig. 15). Laminated sandy dolomite makes up the most common breccia fragments. This may be a function of fissility, rather than of a chemically more favorable host rock. The collapse breccia may have formed from the thinning of the underlying beds by subsurface draining. The sphalerite mineralization and tectonic dolomite lithologies are similar to those of the manto form. The collapse breccia was filled with mineralizing fluids and the sphalerite and dolomite were precipitated in a similar manner as in the manto form.

Stylolites and fractures are observed mainly in the Turner Prospect area and are associated with faulting. The most recent event was the oxidation to hematite of pyrite and of the ferroan dolomite zones (Katz, 1971). Pyrite is oxidized throughout the Butterly.

CHAPTER VIII

CONCLUSIONS

The principal conclusions of this study are:

1. The Butterly Dolomite is a typical stratigraphic dolomite; it is medium-crystalline with about 5% sand of quartz and feldspar.

2. Detrital quartz and feldspar have authigenic overgrowths, indicating that the overlying sea was hypersaline and saturated in SiO_2.

3. Detrital clay minerals include illite, kaolinite, and Fe-chlorite in order of decreasing abundance. All were found only in trace amounts and were not observed by ordinary petrographic techniques.

4. Chemical elements of the analyzed samples do not fit a normal distribution, even after transformation. This may be due to the Butterly having a non-normal distribution, which could be the product of several diagenetic alterations.

5. The comparison of "S" dolomites and "S" dolomitic limestone suggests that distributions of insoluble residue and crystallinity change with dolomitization. These results for insoluble residue indicate that quartz and feldspar are less resistant to replacement by dolomite than by calcite.

The results for crystallinity suggest dolomitization did increase crystallinity.

6. The Wilcoxon two-sample test of "S" dolomites and "S" dolomitic limestones and of the means for these two groups suggest that dolomitization of these limestones caused decrease in Ca, Sr, K, Cd, and Ni and increase in Mg, Na, Zn, and Cr.

7. The results of the Mann-Whitney U-test for the vein ("V") and host ("H") rocks and the raw chemical data (Appendix C) signify that Zn was concentrated in the host-breccia fragments. The similar distributions of Sr, Mn, Ni, and Li may be the results of the dolomitizational fluid's stamping its composition on the host rock.

8. Results of the Wilcoxon two-sample test reflect the diverse chemical makeup of samples of the Butterly. This may be explained by one of the following: (1) variation in sampling; (2) chemical distributions of the Butterly are homogeneous neither horizontally nor vertically; and (3) chemical distributions of the original rocks were heterogeneous and were complicated further by the various diagenetic alterations. The author recognizes all three as possibly valid.

9. The Butterly has been subjected to recrystallization and two periods of dolomitization separated by a period of corrosion. The first dolomitization (early diagenetic) occurred only inches below the sea-sediment interface. Corroding fluids traveled through intercrystalline pores and

fractures embaying the early diagenetic dolomite.

10. The late-diagenetic dolomite precipitated in the intercrystalline porosity, fractures, faults, and vugs enlarged by the corroding fluids. Its trace-element chemistry changed from iron-poor (oldest) to iron-rich (youngest). The precipitation was periodic and may reflect the tectonic history of the Arbuckle Mountain region in Pennsylvanian and Permian time. Fifteen generations of dolomite were observed in one sample.

11. The tectonic dolomite and associated sphalerite of the Turner Prospect may be associated with the iron-enrichment trend of the late-diagenetic dolomite. This author's hypothesis is that the zinc mineralization is a product of heated oil-field brines from the Ardmore Basin that migrated through the Reagan Sandstone. These brines leached zinc from the Carlton Rhyolite, mixed with descending meteoric water, and precipitated both dolomite and sphalerite. The sphalerite was localized by the replacement of remnant limestone beds.

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APPENDICES

APPENDIX A

STRATIGRAPHIC SECTION

List of Symbols Used

Carbonates	C
Fractured	F
Graded Bedding	G
Orange	O
Red	R
Yellow	Y

Laminated

Flaggy

Massive

Fractured Core

Dolomitic Limestone

Dolomite

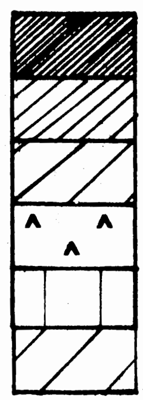


Fig. 17.-List of Symbols Used

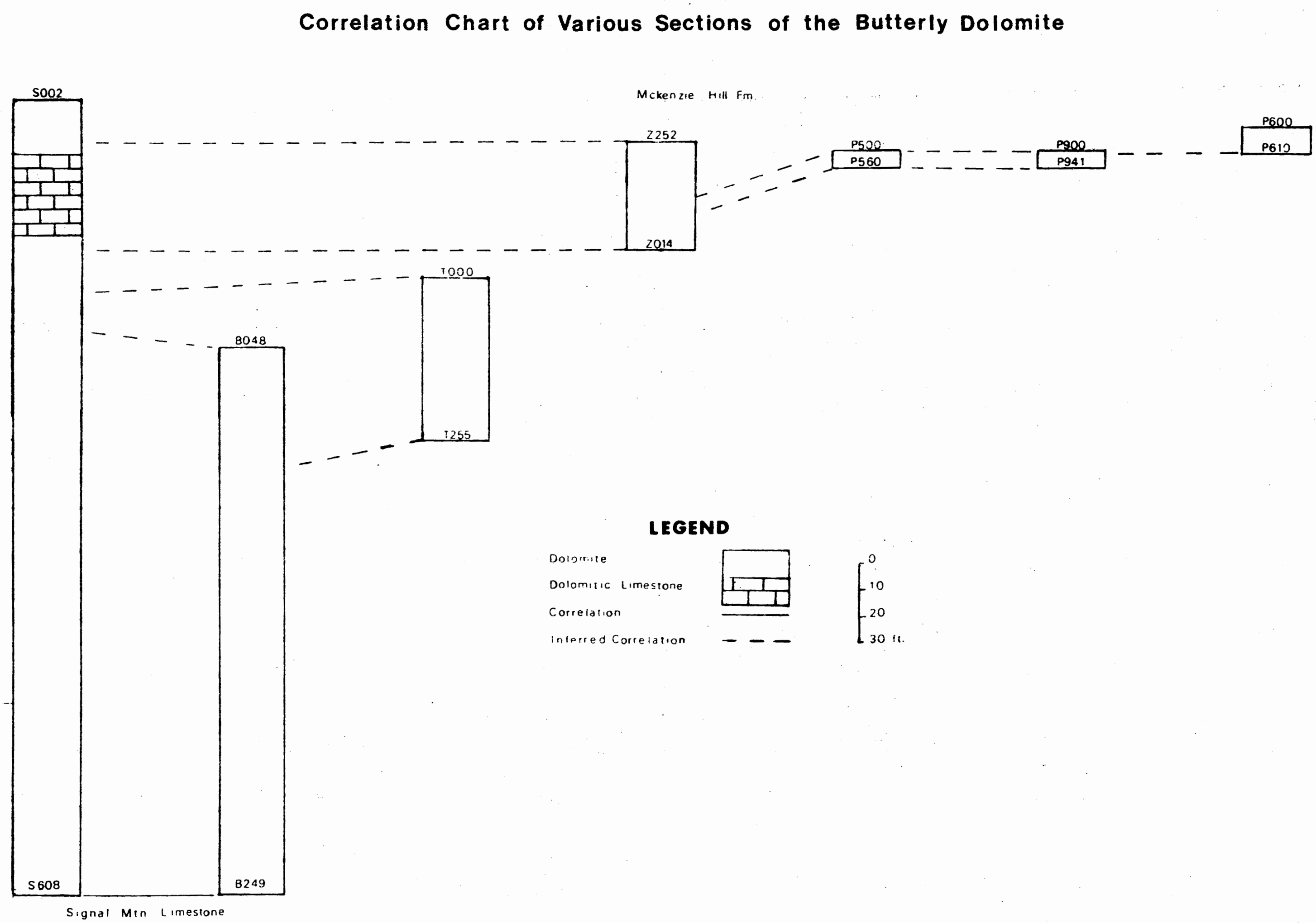
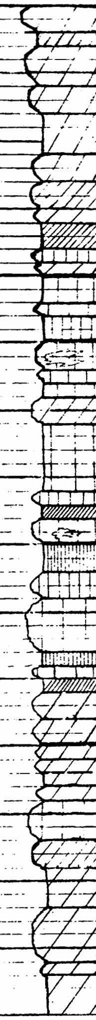


Fig. 18.-Correlation chart of the Butterly Dolomite.

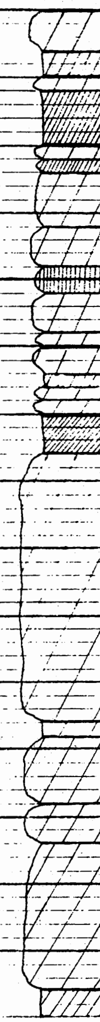
Footage	Pellets	Intraclasts	Whole	Fragment	Quartz Sand	Feldspar	Clay	Other (Terrigenous)	Structures Other	Color Other	Color	Pyrite	Sample Number	Remarks
1		2									N6		S002	
3											N6		S007	
6		10			3					R	5R 4-5 & N5	2	S012	
8		5									N6	tr	S017	
10	10				3						N7		S022	
13											N7		S029	
15							tr				N7		S033	
16					5						N9 & N6		S035	
17					2						N6 & N8	1	S038	
					13	4	1							
19	13	39		tr	15						5YR 4/1	tr	S043	
20											N8		S045	
22	25			tr	3		1				10YR 2/2		S048	
23	60				1		1				5YR 4/1		S052	
24	10	1			5		1				5YR 4/1		S054	
26	30	1			10		1				N6		S056	
27		60			10	1					N5		S056a	
28	60						1				5YR 4/1		S059	
29		20			10	1					N6		S062	
30		1			3						N7		S065	
34	5	20			5		1				5YR 4/1		S071	
37	60	1			tr		1				10YR 4/2		S081	
38		tr			10	tr					N6		S083	
39	60	5		tr	1						5YR 4/1		S085	
40		70						C	G		N6		S088	Calcarenite
41					5						10YR 4/2		S091	
43		40			5						5YR 4/1		S095	
45	60	10		tr	tr						5YR 4/2		S099	
49					5						N7	1	S106	
50	40			tr							10YR 2/2		S108	
51		5			10						N7 & N5		S110	
52											N8		S112	
55					1						N8	tr	S119	
56					1						N8		S123	
57					2						N7		S125	
58		1			15						N7	tr	S128	
59					5						N7		S130	
61	50	tr	1		tr						5YR 4/1	3	S135	
63					10	1					N7	tr	S140	
66											5R 6/2	tr	S145	
68											N5	1	S150	
72											N3	tr	S157	
73													S160	

Lithology & Weathering Profile



Footage	Allochems	Terrigenous (Quartz Sand)	Color	Mineralization	Sample Number
76	2		N3		S166
79	5	5	N8		S173
81			N6&10YR66		S176
83		1	N7		S183
86			N7		S187
87		1	N7		S190
88	3	1	N4&N8		S192
93			N9 & N7		S203
95	tr	tr	N8 & N7		S208
97			N6		S211
100			N8		S215
101			N9& N5		S221
103			N7	3	S224
104			N9& N5		S226
105			N9 & N5		S228
108			N7		S235
113			N7		S245
124			N7		S265
129			N4	1	S277
130			N6&5YR7/4		S279
135			N8		S290
140			N7		S301
149			N8		S319

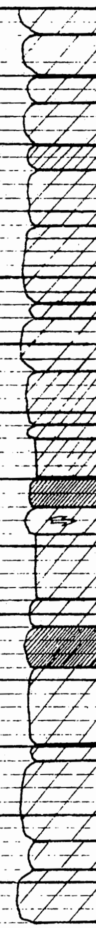
Lithology & Weathering Profile



Footage	Dolomitic	Limestone	Crystallinity	Recrystallized / Micrite / Sparite	Allochems	Size	Terrigenous	Structures	Stratification	Color		Mineralization	Locality	Sample Number	Remarks
151		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N7			S322	
153		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N6			S325	
157	X	X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N6			S333	
158	X	X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N8			S335	
160															
162		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N6			S346	
165		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N7			S350	
170		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N7			S360	
175		X	V. Coarse X	X X				Other X	Massive X	Lt. Gray X	N7			S371	
178		X	Fine X	X X					Massive X	Other R	5R6/2	Pyrite tr		S376	
180		X	Fine X	X X				Other X	Massive X	Lt. Gray X	N5			S379	
183		X	Fine X	X X					Massive X	Lt. Gray X	N6			S386	
185		X	Fine X	X X		Arenite X	Quartz 1		Massive X	Lt. Gray X	N7	Pyrite tr		S389	
189		X	Fine X	X X		Arenite X	Quartz tr		Massive X	Lt. Gray X	N6			S399	
194		X	Fine X	X X	Intraclasts 5	Lutite X	Quartz tr		Massive X	Lt. Gray X	N6			S409	
196	X	X	Medium X	X X	Intraclasts 1	Lutite X			Massive X	Dk. Gray X	N4			S413	
198		X	Medium X	X X				Other X	Flaggy X	Lt. Gray X	N6	Pyrite tr		S415	
200		X	Medium X	X X				Stylolites X; Other X	Massive X	Dk. Gray X	N4			S419	
201		X	V. Coarse X	X X				Other X	Massive X	Brown X	5YR4/1			S423	
204		X	Medium X	X X				Other X	Massive X	Brown X	5YR3/4			S429	
205		X	Medium X	X X	Intraclasts 1	Lutite X		Other X	Massive X	Brown X	5YR4/1			S431	
212		X	Coarse X	X X					Massive X	Brown X	5YR4/1			S445	
213		X	Medium X	X X		Arenite X	Quartz tr		Massive X	Dk. Gray X	N4			S446	
215		X	Fine X	X X	Intraclasts 1	Lutite X			Flaggy X	Lt. Gray X	N6			S450	
219		X	Fine X	X X	Intraclasts 1	Lutite X			Flaggy X	Lt. Gray X	N6			S458	
224		X	Fine X	X X				Other X	Massive X	Lt. Gray X	N6	Pyrite 1		S467	

Column headings: Footage; Dolomite; Limestone; Crystallinity (V. Coarse, Coarse, Medium, Fine, V. Fine, Aphanitic, Recrystallized); Micrite; Sparite; Allochems (Oolites, Pellets, Intraclasts, Fossils: Whole, Abraded, Fragment); Size (Lutite, Arenite, Rudite); Terrigenous (Quartz Sand, Feldspar, Clay, Other); Structures (Stylolites, Pseudo Bx, Tectonic Bx, Soft Sed Def, Cross Beds, Initial Dip, Vugs, Other); Stratification (Massive, Flaggy, Laminated); Color (Variegated, Lt. Gray, Dk. Gray, Brown, Orange, Pink, White, Black, Other); Mineralization (Pyrite, Sphalerite, Other); Locality; Sample Number; Lithology & Weathering Profile; Remarks

Footage	Intraclasts	Quartz Sand	Color	Sample Number
229	3		N5	S478
232	5		N4	S483
234	5		N6	S489
236			N5	S494
238	3		N4	S497
243			5YR4/1	S507
248	1	3	5YR4/1	S516
249			N5	S518
252			5YR4/1	S524
255			N5	S532
257	1		N6	S536
259	1		N5	S540
261			N4	S544
263	1		5YR4/1	S548
264	1		10YR4/2	S548a
267	5		N4	S551
271	1		N5	S563
272	2		N5	S565
276			N5	S574
281	3		N4	S584
285			N4	S590
289	5		N7	S598
290			5YR4/1	S601
293			5YR4/1	S608



Signal Mtn. Ls.

Footage	Sample Number	Color (code)	Mineralization	Color	Stratification	Structures	Terrigenous	Size	Crystallinity	Rock
48	B048	N6& N9	Sphalerite 3	White; Lt. Gray / Variegated	Massive	Stylolites	Quartz Sand tr	Arenite	Sparite / Recrystallized; Coarse	Dolomite
50	B050	N6	Pyrite 1	Lt. Gray	Laminated	Stylolites	Feldspar tr; Quartz Sand 1		Sparite / Recrystallized; Medium	Dolomite
54	B054	N7		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
58	B058	N7		Lt. Gray	Massive	Vugs			Sparite / Recrystallized; Coarse	Dolomite
66	B066	N8		Lt. Gray	Massive	Vugs			Sparite / Recrystallized; Coarse	Dolomite
71	B071	N7		Lt. Gray	Massive	Stylolites			Sparite / Recrystallized; Coarse	Dolomite
74	B074	10 YR 6/2 & 5 YR 6/1		Brown; Lt. Gray / Variegated	Massive	Stylolites			Sparite / Recrystallized; Coarse	Dolomite
78	B078	N8		Lt. Gray	Laminated	Stylolites	Quartz Sand tr	Arenite	Sparite; Fine	Dolomite
79	B079	N7		Lt. Gray	Massive	Vugs			Recrystallized; Medium	Dolomite
80	B080	N8		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
84	B084	N7		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
86	B085	N8		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
87	B087	N7		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; V. Fine	Dolomite
90	B090	N7		Lt. Gray	Massive	Vugs; Tectonic Bx; Stylolites	Clay tr	Lutite	Sparite / Recrystallized; V. Coarse	Dolomite
93	B093	N9	Pyrite 3	White; Lt. Gray	Massive	Vugs; Tectonic Bx; Stylolites	Feldspar tr; Quartz Sand 1	Arenite	Sparite / Recrystallized; Coarse	Dolomite
95	B095	N8	Pyrite 1	Lt. Gray	Massive	Vugs; Tectonic Bx; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
96	B096	N8		Lt. Gray	Massive	Vugs; Stylolites	Feldspar tr; Quartz Sand tr	Arenite	Sparite / Recrystallized; Coarse	Dolomite
99	B099	N8		Lt. Gray	Massive	Vugs; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
101	B101	N7		Lt. Gray	Flaggy	Vugs; Stylolites			Sparite / Recrystallized; Medium	Dolomite
108	B108	N8	Pyrite 3	Lt. Gray	Massive	Vugs; Tectonic Bx; Stylolites			Sparite / Recrystallized; Coarse	Dolomite
111	B111	N7	Pyrite tr	Lt. Gray	Laminated	Stylolites	Quartz Sand tr	Arenite	Sparite / Recrystallized; Coarse	Dolomite

Footage	Dolomite / Limestone	Crystallinity	Micrite / Sparite	Allochems: Intraclasts	Size	Structures	Stratification	Color	Color code	Mineralization: Pyrite	Locality	Sample Number	Remarks
125	Dolomite	Coarse	X (Sparite, Recrystallized)			Vugs, Stylolites	Massive	Lt. Gray	N8	3		B125	
130	Dolomite	V Coarse	X (Sparite, Recrystallized)			Vugs, Stylolites	Massive	Lt. Gray	N6			B130	
163	Dolomite	V Fine	X (Sparite, Recrystallized)	3	Rudite	Vugs	Massive	Lt. Gray	N6	tr		B163	
167	Dolomite	Coarse	X (Sparite, Recrystallized)	25	Rudite	Soft Sed Def	Massive	Dk. Gray	N4	tr		B167	
170	Dolomite	Fine	X (Sparite, Recrystallized)				Massive	Dk. Gray	N4	tr		B170	
178	Dolomite	Fine	X (Sparite, Recrystallized)				Massive	Lt. Gray	N4	3		B178	
181	Dolomite	Medium	X (Sparite, Recrystallized)	10	Rudite	Vugs, Stylolites	Flaggy	Dk. Gray	N4			B181	

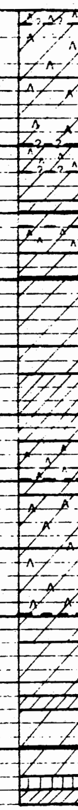
Footage	Limestone	Dolomite	Crystallinity: E. Coarse	V. Coarse	Coarse	Medium	Fine	V. Fine	Aphanitic	Recrystallized	Sparite	Micrite
191		X					X			X	X	
194		X				X				X	X	
202		X		X						X	X	
203		X				X				X	X	
205		X					X			X	X	
206		X					X			X	X	
209		X			X					X	X	
210		X			X					X	X	
213		X					X			X	X	
218		X				X				X	X	
226		X				X				X	X	
227		X				X				X	X	
236		X		X						X	X	
240		X					X			X	X	
242		X			X					X	X	
243		X			X					X	X	
246		X		X						X	X	
248	X	X						X			X	
249		X					X				X	

Footage	Allochems: Oolites	Pellets	Intraclasts	Fossils: Whole	Abraded	Fragment	Size: Rudite	Arenite	Lutite	Terrigenous: Quartz Sand	Feldspar	Clay	Other
191			tr				X						
194							X						
202			tr				X						
203													
205			tr				X						
206													
209													
210													
213			tr				X						
218								X		1	tr		
226													
227			1				X						
236													
240								X		1	tr		
242								X		tr			
243			tr				X						
246								X		tr			
248													
249			tr				X						

Footage	Structures: Stylolites	Pseudo Bx	Tectonic Bx	Soft Sed Def	Cross Beds	Initial Dip	Vugs	Other	Stratification: Massive	Flaggy	Laminated
191	X								X		
194	X								X		
202							X		X		
203									X		
205									X		
206	X						X		X		
209	X						X		X		
210	X						X		X		
213	X		X				X		X		
218										X	
226	X						X		X		
227	X						X		X		
236	X						X		X		
240	X								X		
242			X							X	
243	X						X		X		
246	X						X		X		
248	X									X	
249	X									X	

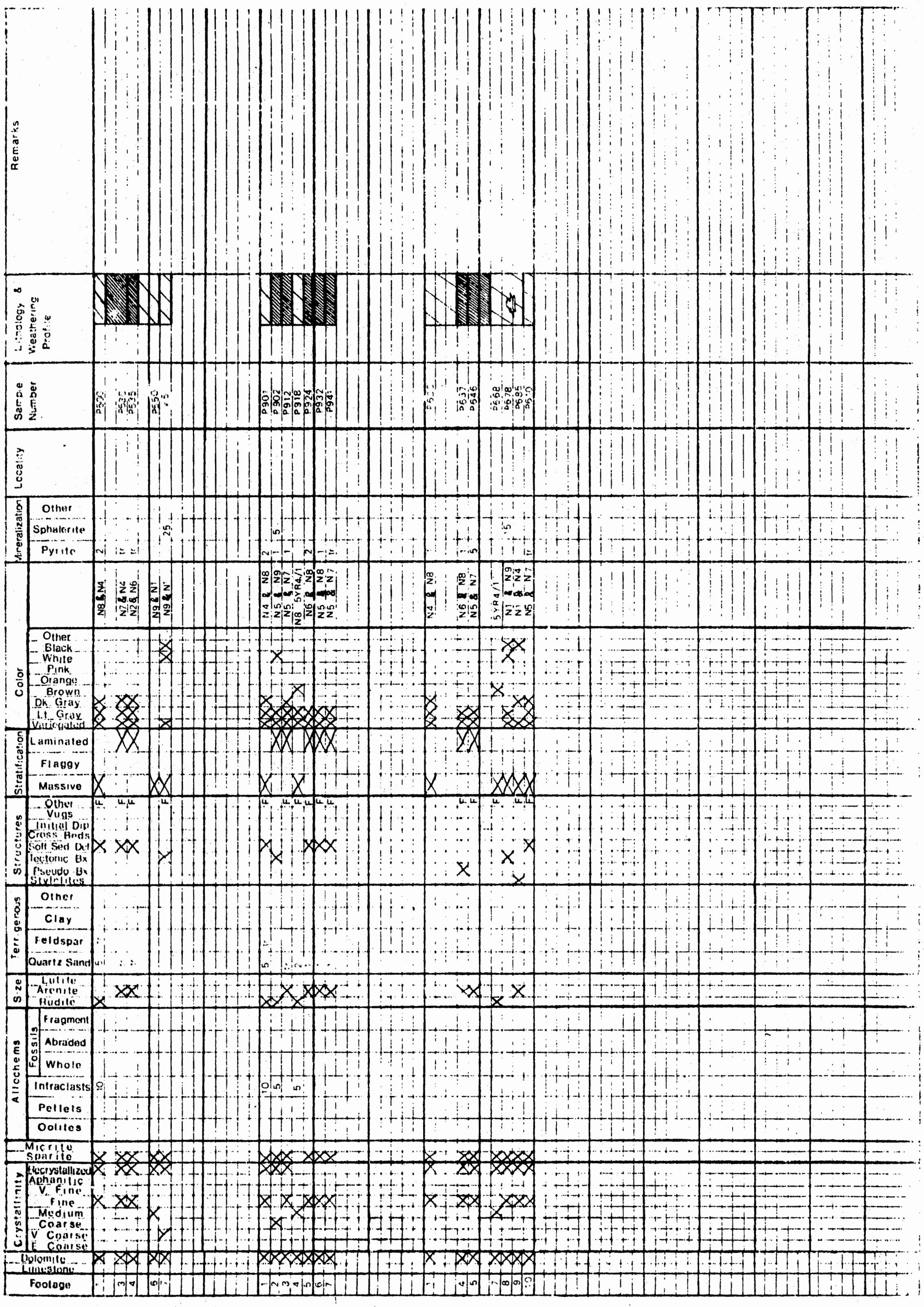
Footage	Color: Variegated	Lt. Gray	Dk. Gray	Brown	Orange	Pink	White	Black	Other		Mineralization: Pyrite	Sphalerite	Other	Locality	Sample Number	Remarks
191	X	X								N5 &N6					B191	
194		X								N6	1				B194	
202			X							N4					B202	
203			X							N4					B203	
205		X								N6	5				B205	
206		X								N7	tr				B206	
209	X	X	X				X			N4 &N9					B209	
210	X	X	X				X			N4 &N9					B210	
213		X								N6					B213	
218		X								N6	1				B218	
226	X	X								N5 &N7					B226	
227	X	X								N5 &N7					B227	
236	X	X	X							N4 &N7					B236	
240		X								N6	1				B240	
242	X	X	X							N3 &N7	1				B242	
243	X	X								N6 & N8					B243	
246	X		X				X			N4 &N9	tr				B246	
248	X	X	X							N4 &N6	tr				B248	
249		X								N5					B249	

Lithology & Weathering Profile



Remarks												
Lithology & Weathering Profile												
Sample Number												
Locality	T000	T025	T081 T088 T092	T123	T143	[illegible]	T189	T199	T213	T23[illegible]	T239	T255
Mineralization: Other												
Mineralization: Sphalerite												
Mineralization: Pyrite												
Color (code)	[illegible] & N5	N8 & [illegible]	N5 N5 N4	N9 & N5	N[illegible]	N[illegible]	[illegible]	N6	N5 & N3	N6	N6	N5
Color: Other												
Color: Black												
Color: White				X					X			
Color: Pink												
Color: Orange		X										
Color: Brown							X					
Color: Dk Gray	X		X						X			
Color: Lt Gray	X	X	X	X	X	X		X	X	X	X	X
Color: Variegated	X											
Stratification: Laminated	X							X				
Stratification: Flaggy		X	X									
Stratification: Massive			X	X	X	X	X		X	X	X	X
Structures: Other										X	X	X
Structures: Vugs		X	X									
Structures: Initial Dip												
Structures: Cross-Beds												
Structures: Soft Sed Def												
Structures: Tectonic-Bx				X			X		X			
Structures: Pseudo-Bx												
Structures: Stylolites			X					X				X
Terrigenous: Other												
Terrigenous: Clay												
Terrigenous: Feldspar												
Terrigenous: Quartz Sand								5 2			3	10
Size: Lutite	X	X	X					X	X		X	X
Size: Arenite			X		X							
Size: Rudite												
Allochems: Fossils: Fragment												
Allochems: Fossils: Abraded												
Allochems: Fossils: Whole												
Allochems: Intraclasts												
Allochems: Pellets												
Allochems: Oolites												
Micrite	X											
Sparite	X	X	X	X	X	X	X	X	X	X	X	X
Crystallinity: Recrystallized	X	X	X	X	X	X	X	X	X	X	X	X
Crystallinity: Aphanitic												
Crystallinity: V. Fine	X									X		
Crystallinity: Fine							X				X	X
Crystallinity: Medium		X	X		X			X				
Crystallinity: Coarse			X	X		X			X			
Crystallinity: V. Coarse												
Crystallinity: E. Coarse												
Dolomite	X	X	X	X	X	X	X	X	X	X	X	X
Limestone												
Footage	0[illegible]	04	[illegible]	23	28	3[illegible]	3[illegible]	4[illegible]	47	53	55	60

Footage	Intraclasts	Fossils: Fragment	Quartz Sand	Feldspar	Color (Other)	Color	Pyrite	Sample Number
01			20			5YR 4/1	1	Z252
02			1			N7	tr	Z240
03	tr		1			N6	tr	Z230
04	1		1			N8 & N4	1	Z225
06			1			N8		Z216
07	1		5		Y	5Y8/1 & N7		Z206
08			1		O	5Y6/1 & N7		Z202
09	tr		2			N8		Z191
12	1		3		O	5Y6/1 & N5		Z182
13			1			N7		Z168
14			10			N7		Z162
15	1		5			N8		Z153
16	3		20	tr		N8		Z147
18	tr		15			N7		Z139
20			1			N6 & N9		Z126
21			2			N7		Z118
22	2		1			N6		Z113
23					O	5Y6/1 & N6	1	Z109
24	1					10YR 6/2	1	Z106
25	1		15			N8		Z099
26	1		25	2		N8		Z095
27			30			N6		Z080
29					O	5Y6/1 & N6		Z071
31					Y	5YR8/1 & N6	tr	Z065
33	1		2			N8		Z057
35					O	5YR4/1 & N4		Z051
36	tr					N5 & N9		Z045
37			1			N8	tr	Z040
40						N7	tr	Z032
41	5		tr		Y	N7 & 5Y8/4		Z025
42						N8		Z023
43		tr				N7	tr	Z019
44						5Y 6/1 & 5YR 4/1	tr	Z014



Remarks
Lithology & Weathering Profile
Sample Number
Locality
Mineralization
Other
Sphalerite
Pyrite
Color
Other
Black
White
Pink
Orange
Brown
Dk. Gray
Lt. Gray
Variegated
Stratification
Laminated
Flaggy
Massive
Structures
Other
Vugs
Initial Dip
Cross Beds
Soft Sed Def
Tectonic Bx
Pseudo Bx
Stylolites
Terrigenous
Other
Clay
Feldspar
Quartz Sand
Size
Lutite
Arenite
Rudite
Allochems
Fossils
Fragment
Abraded
Whole
Intraclasts
Pellets
Oolites
Micrite
Sparite
Crystallinity
Recrystallized
Aphanitic
V. Fine
Fine
Medium
Coarse
V. Coarse
E. Coarse
Dolomite
Limestone
Footage
P901
P902
P912
P918
P924
P932
P941

APPENDIX B

MODAL ANALYSES OF THE BUTTERLY DOLOMITE

Sample Numbers	B1-48	B1-50	B1-93	B1-96	B1-111	B1-167
Allochem						
Intraclasts	-	-	-	-	-	25
Ooids	-	-	-	-	-	-
Pellets	-	-	-	-	-	-
Fossils	-	-	-	-	-	-
Cements						
Microsparite	-	-	-	-	-	-
Sparry Calcite	-	-	-	-	-	-
Dolomite	96	97	95	96	99	72
Non-Carbonates						
Quartz	tr	1	1	tr	tr	tr
Feldspar	-	tr	tr	tr	-	tr
Zircon	-	-	-	-	-	-
Chert	-	-	-	-	-	tr
Apatite	-	-	-	-	-	-
Biotite	-	-	-	-	-	-
Chlorite	-	-	-	-	-	-
Glauconite	-	-	-	-	-	-
Leucoxene	-	-	-	-	-	-
Clay	-	-	-	1	-	-
Rutile	-	-	-	-	-	-
Rock Fragments						
Granophyric	-	-	-	-	-	-
Mineralization						
Pyrite	-	1	3	1	tr	tr
Sphalerite	3	-	-	-	-	-
Porosity	tr	-	tr	1	-	2

Sample Numbers	B1-218	B1-240	B1-242	S043	S048	S052	S054
Allochem							
Intraclasts	-	-	-	13	27	12	5
Ooids	-	-	-	tr	tr	-	-
Pellets	-	-	-	39	18	37	27
Fossils	-	tr	-	-	-	-	-
Cements							
Microsparite	-	-	-	25	37	30	37
Sparry Calcite	-	-	-	-	1	2	3
Dolomite	97	96	96	5	01	7	10
Non-Carbonates							
Quartz	1	1	1	13	14	8	15
Feldspar	tr	tr	-	4	1	3	2
Zircon	-	-	-	tr	-	-	-
Chert	-	-	tr	tr	-	-	tr
Apatite	-	-	-	-	tr	-	-
Biotite	-	-	-	-	tr	-	-
Chlorite	-	-	-	-	-	-	-
Glauconite	-	-	-	-	-	-	-
Leucoxene	-	-	-	-	-	-	-
Clay	-	-	-	-	-	-	-
Rutile	-	-	-	-	-	-	-
Rock Fragments							
Granophyric	-	-	-	-	-	-	-
Mineralization							
Pyrite	1	1	1	tr	tr	tr	tr
Sphalerite	-	-	-	-	-	-	-
Porosity	-	1	1	tr	-	tr	-

Sample Numbers	S056a	S062	S065	S071	S085	S088	S095	S099
Allochem								
Intraclasts	21	13	-	62	23	30	18	28
Ooids	tr	tr	-	1	tr	-	-	tr
Pellets	16	10	-	2	28	5	2	19
Fossils	-	-	-	-	-	-	-	-
Cements								
Microsparite	21	31	-	3	27	tr	24	27
Sparry Calcite	1	5	-	11	1	18	5	-
Dolomite	16	17	76	5	10	8	22	21
Non-Carbonates								
Quartz	20	19	10	11	8	29	21	3
Feldspar	4	3	4	3	2	5	6	1
Zircon	tr	-	tr	-	-	-	tr	-
Chert	tr	-	tr	1	-	tr	1	-
Apatite	-	-	-	-	-	-	tr	-
Biotite	-	-	-	-	-	-	-	-
Chlorite	tr	-	tr	-	-	-	-	-
Glauconite	tr	-	-	-	-	-	-	-
Leucoxene	-	-	tr	-	-	-	-	-
Clay	-	-	-	-	-	-	-	-
Rutile	-	-	-	-	-	-	-	-
Rock Fragments								
Granophyric	-	tr	-	-	-	tr	-	-
Mineralization								
Pyrite	-	1	4	tr	tr	-	tr	tr
Sphalerite	-	-	-	-	-	-	-	-
Porosity	tr	tr	5	-	-	4	-	tr

Sample Numbers	S106	S110	S128	S166	S183	S190	S224	S235
Allochem								
Intraclasts	51	43	-	-	-	1	-	-
Ooids	-	-	-	-	-	-	-	-
Pellets	-	-	-	30	-	tr	-	tr
Fossils	-	-	-	-	-	-	-	-
Cements								
Microsparite	-	-	-	-	-	-	-	-
Sparry Calcite	2	-	-	-	-	-	-	-
Dolomite	30	41	65	68	98	95	98	98
Non-Carbonates								
Quartz	11	11	17	tr	1	2	tr	tr
Feldspar	3	3	7	tr	tr	1	-	-
Zircon	-	-	tr	tr	-	-	-	-
Chert	-	tr	2	-	-	-	-	-
Apatite	-	-	-	-	-	-	-	-
Biotite	-	-	-	-	-	-	-	-
Chlorite	-	-	-	-	-	-	-	-
Glauconite	-	-	-	-	-	-	-	-
Leucoxene	-	-	-	-	-	-	-	-
Clay	-	-	-	-	-	tr	-	tr
Rutile	-	-	-	-	-	-	-	-
Rock Fragments								
Granophyric	-	-	-	-	-	-	-	-
Mineralization								
Pyrite	2	1	tr	tr	tr	tr	1	1
Sphalerite	-	-	-	-	-	-	-	-
Porosity	-	-	8	1	-	-	-	-

Sample Numbers	S279	S319	S409	S423	S532	S563	S608	T5025
Allochem								
Intraclasts	-	-	15	-	-	-	-	-
Ooids	-	-	-	-	-	-	-	-
Pellets	-	-	-	-	-	-	1	-
Fossils	-	-	-	-	tr	-	-	-
Cements								
Microsparite	-	-	-	-	-	-	-	-
Sparry Calcite	-	-	-	-	-	-	-	-
Dolomite	96	98	74	90	96	88	85	98
Non-Carbonates								
Quartz	tr	tr	1	6	1	7	1	1
Feldspar	-	tr	-	-	tr	tr	tr	tr
Zircon	-	-	-	-	tr	tr	tr	-
Chert	-	-	-	-	-	2	-	-
Apatite	-	-	-	-	-	-	-	-
Biotite	-	-	-	-	-	-	-	-
Chlorite	-	-	-	-	-	-	-	-
Glauconite	-	-	-	-	tr	-	tr	-
Leucoxene	-	-	-	-	tr	-	-	-
Clay	tr	1	-	-	-	-	-	-
Rutile	-	-	-	-	-	-	-	-
Rock Fragments								
Granophyric	-	-	-	-	-	-	-	-
Mineralization								
Pyrite	-	-	-	-	1	-	9	tr
Sphalerite	-	-	-	-	-	-	-	-
Porosity	3	-	10	4	1	2	3	tr

Sample Numbers	T5199	T5213	Z023	Z065	Z090	Z113	Z162
Allochem							
Intraclasts	-	tr	-	-	tr	1	1
Ooids	-	-	-	-	-	-	-
Pellets	tr	tr	-	-	-	-	-
Fossils	-	-	-	-	-	-	-
Cements							
Microsparite	-	-	-	-	-	-	-
Sparry Calcite	-	-	-	-	-	-	-
Dolomite	90	96	90	85	78	77	80
Non-Carbonates							
Quartz	5	2	4	12	17	17	10
Feldspar	2	tr	tr	2	3	3	5
Zircon	-	tr	-	-	tr	-	tr
Chert	-	tr	-	tr	1	tr	-
Apatite	tr	-	-	tr	tr	-	-
Biotite	-	-	-	-	-	-	-
Chlorite	-	tr	-	-	tr	-	-
Glauconite	-	-	-	-	-	-	-
Leucoxene	-	-	-	-	-	-	-
Clay	-	tr	2	-	-	-	-
Rutile	-	-	-	tr	-	-	-
Rock Fragments							
Granophyris	tr	-	-	-	tr	-	-
Mineralization							
Pyrite	1	tr	tr	tr	tr	tr	1
Sphalerite	-	-	-	-	-	-	-
Porosity	1	1	13	-	tr	1	2

Sample Numbers	Z206	Z225
Allochem		
Intraclasts	-	-
Ooids	-	-
Pellets	-	-
Fossils	-	-
Cements		
Microsparite	-	-
Sparry Calcite	-	-
Dolomite	75	54
Non-Carbonates		
Quartz	21	36
Feldspar	3	5
Zircon	tr	-
Chert	tr	tr
Apatite	tr	-
Biotite	-	-
Chlorite	tr	-
Glauconite	-	-
Leucoxene	-	-
Clay	-	-
Rutile	-	-
Rock Fragments		
Granophyric	-	-
Mineralization		
Pyrite	tr	4
Sphalerite	-	-
Porosity	-	tr

APPENDIX C

CHEMICAL ANALYSES OF THE

BUTTERLY DOLOMITE

LOC=B

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
1	B	48	0.0097	167000	117000	884	91	30	177	35	1	5	43	5049	23	5	0	5	115.508
2	B	50	0.0671	211000	125000	707	102	54	305	316	1	5	38	67	3	5	0	4	97.672
3	B	54	0.0017	171000	117000	1332	80	30	175	25	1	5	35	27	3	155	65	6	112.806
4	B	58	0.0099	162000	117000	555	81	25	167	20	1	5	33	28	3	5	0	5	119.073
5	B	66	0.0053	156000	114000	633	75	30	855	10	1	5	30	18	5	10	10	2	120.482
6	B	71	0.0110	172000	114000	647	83	28	187	20	1	5	30	16	5	5	10	4	109.275
7	B	74	0.0086	188000	118000	630	81	30	106	20	1	0	25	18	8	10	10	5	103.482
8	B	78	0.0722	195000	126000	620	86	65	129	108	1	16	49	151	8	5	9	4	106.532
9	B	79	0.0026	171000	120000	947	90	27	140	5	1	5	30	11	8	5	0	4	115.699
10	B	80	0.0115	194000	117000	455	71	46	278	40	1	5	25	17	5	20	13	2	99.432
11	B	84	0.0041	166000	120000	517	80	20	159	0	1	5	35	6	5	15	8	5	119.183
12	B	86	0.0172	190000	122000	585	92	25	81	28	1	5	46	0	5	15	10	2	105.864
13	B	87	0.0080	172000	118000	872	91	20	149	5	1	5	35	7	5	10	10	2	113.109
14	B	90	0.0307	176000	115000	1233	129	31	113	103	1	5	31	23	5	5	11	5	107.728
15	B	93	0.1030	184000	109000	4013	212	39	195	485	1	6	50	11	6	22	23	2	97.668
16	B	95	0.0253	170000	114000	1257	82	21	790	226	1	5	41	15	8	5	11	4	110.560
17	B	96	0.0332	193000	123000	874	109	31	222	57	1	5	36	5	5	5	11	5	105.073
18	B	99	0.0336	177000	119000	579	103	21	127	0	1	0	36	0	5	5	11	2	110.845
19	B	101	0.0769	157000	108000	3142	60	32	347	303	1	5	49	115	5	11	12	3	113.414
20	B	108	0.0147	157000	115000	726	101	20	223	0	1	3	41	8	3	10	10	5	120.765
21	B	111	0.0393	167000	113000	1509	99	26	286	177	1	5	42	43	3	5	11	5	111.559
22	B	125	0.0114	167000	125000	713	86	20	202	25	1	5	40	4	5	10	5	5	123.406
23	B	130	0.0165	217000	130000	625	66	25	208	0	1	20	46	13	5	5	5	6	98.770
24	B	163	0.0762	185000	124000	1932	65	27	265	146	1	5	49	31	5	11	6	2	110.508
25	B	167	0.0187	169000	112000	1376	76	20	214	92	1	5	41	17	3	10	10	5	109.263
26	B	170	0.1024	196000	118000	2200	111	50	468	345	1	6	39	43	6	11	7	3	99.259
27	B	178	0.1959	212000	126000	2736	112	44	560	535	1	6	37	45	6	12	18	3	97.989
28	B	181	0.0899	199000	123000	1511	126	38	374	258	1	5	44	11	5	11	12	4	101.905
29	B	191	0.0929	182000	125000	2039	110	39	380	292	1	6	33	6	6	6	12	3	113.235
30	B	194	0.0728	184000	120000	2259	108	27	291	243	1	5	38	5	8	49	28	4	107.524
31	B	202	0.0609	154000	117000	1704	122	21	128	120	1	5	43	0	8	11	11	6	125.259
32	B	203	0.0804	169000	121000	1849	120	33	190	109	1	5	33	0	5	5	17	4	118.043
33	B	205	0.1714	193000	124000	2836	97	36	344	278	1	6	42	0	6	12	14	3	105.927
34	B	206	0.0381	150000	111000	2188	83	36	307	317	1	5	31	9	8	10	11	3	122.004
35	B	209	0.0968	160000	119000	1733	194	28	149	127	1	3	28	0	6	11	18	5	122.622
36	B	210	0.0515	169000	114000	1502	206	32	174	53	1	11	37	0	5	5	16	4	111.214
37	B	213	0.0801	168000	121000	1006	234	27	315	76	1	5	27	0	5	11	9	3	118.746
38	B	218	0.1122	180000	133000	777	90	45	293	332	1	6	39	0	8	13	18	4	121.821
39	B	226	0.0308	160000	111000	1052	134	28	160	108	1	5	34	0	5	62	31	4	114.379
40	B	227	0.0420	151000	112000	966	136	31	193	78	1	0	26	0	5	10	11	4	122.288
41	B	236	0.0212	153000	119000	1134	123	20	199	36	1	5	25	0	8	5	5	6	128.233
42	B	240	0.0879	159000	115000	1995	121	27	318	285	1	5	33	0	5	110	50	3	119.246
43	B	242	0.0452	152000	121000	1335	162	21	0	92	1	0	37	5	9	5	6	5	131.246
44	B	243	0.0897	170000	117000	1483	132	27	258	390	1	5	38	0	5	11	6	5	113.470
45	B	246	0.0377	166000	120000	2182	156	23	161	78	1	0	26	0	5	16	8	6	119.183
46	B	248	0.0933	324000	13000	739	331	116	138	171	1	17	39	3	8	6	7	2	6.615
47	B	249	0.1478	170000	124000	3638	1877	29	194	458	1	0	41	33	6	12	8	3	120.258

LOC=H

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
48	H	2	0.0712	150000	105000	1588	75	27	86	291	1	5	70	11843	86	5	6	3	115.409
49	H	5	0.0927	118000	109000	2149	118	28	83	132	1	6	72	22043	121	6	12	3	152.296

LOC=P

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
50	P	500	0.0198	153000	113000	1785	250	26	0	71	1	5	36	1734	15	5	10	3	121.767
51	P	530	0.1196	170000	115000	2272	85	40	392	250	1	6	45	3862	23	6	35	3	111.530
52	P	535	0.0436	151000	106000	2536	136	37	303	201	1	5	47	4182	37	5	6	3	115.737
53	P	550	0.1035	167000	120000	2398	98	28	212	190	1	6	50	3067	14	6	12	4	118.470
54	P	600	0.0757	151000	115000	2202	130	32	168	222	1	5	32	5085	38	5	17	3	125.564
55	P	637	0.0737	162000	118000	1997	119	38	184	157	1	5	27	3886	49	5	12	3	120.091
56	P	646	0.1103	174000	129000	2079	96	45	197	107	1	6	39	1574	17	6	12	3	122.232
57	P	668	0.0208	158000	117000	817	87	31	20	0	1	5	31	286	10	5	5	4	122.088
58	P	678	0.1278	143000	109000	1777	92	34	0	115	1	0	120	71085	332	6	1	3	125.670
59	P	685	0.0483	152000	110000	2968	84	47	315	278	1	5	47	1003	24	5	1	3	119.314
60	P	610	0.0843	192000	124000	1502	71	55	306	169	1	16	44	8736	76	5	12	3	106.479
61	P	901	0.1026	196000	128000	1655	117	56	267	201	1	28	56	418	11	22	7	3	107.670
62	P	902	0.0209	154000	119000	996	82	31	163	5	1	5	46	8681	71	5	5	5	127.400
63	P	912	0.0838	158000	114000	1801	82	22	147	186	1	5	38	1473	27	5	6	3	118.957
64	P	918	0.0406	167000	113000	938	83	26	141	52	1	5	36	70	5	5	11	4	111.559
65	P	924	0.0660	166000	115000	2248	86	37	166	161	1	5	43	119	11	5	11	3	114.217
66	P	932	0.0913	188000	120000	1788	77	44	160	94	1	11	44	116	6	6	7	3	105.236
67	P	941	0.1065	179000	115000	2507	90	39	274	336	1	6	34	325	6	6	7	3	105.922

LOC=S

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
68	S	2	0.0341	155000	109000	9887	4659	41	259	52	1	5	31	8	3	5	8	4	115.941
69	S	7	0.0187	142000	108000	11413	4688	46	122	5	1	5	31	15	5	5	5	4	125.394
70	S	12	0.0665	166000	116000	1484	134	27	134	134	1	5	21	3	5	5	6	5	115.211
71	S	17	0.0295	139000	115000	1752	155	21	144	82	1	3	31	2	5	5	11	5	136.404
72	S	22	0.0180	158000	116000	1675	117	18	5	0	1	0	36	0	8	5	5	5	121.044
73	S	29	0.0340	150000	113000	1325	119	21	98	62	1	5	31	0	8	10	3	5	124.202
74	S	33	0.0287	160000	116000	1390	134	15	21	0	1	5	36	0	5	36	11	6	119.531
75	S	35	0.0250	148000	113000	2154	164	21	87	0	1	0	26	0	8	5	3	6	125.881
76	S	38	0.1803	176000	144000	3794	317	49	128	274	1	24	30	0	12	6	8	1	134.894
77	S	43	0.1333	252000	120000	923	213	115	0	0	1	6	35	7	8	6	13	2	78.510
78	S	45	0.0483	157000	114000	1786	100	21	79	45	1	0	32	0	11	11	11	4	119.715
79	S	48	0.1214	255000	20000	1337	148	250	0	57	1	6	34	3	11	11	18	3	12.931
80	S	52	0.0886	257000	9000	757	126	197	0	104	1	5	38	0	8	11	15	3	5.774
81	S	54	0.1498	308000	18000	1376	82	265	171	235	1	12	35	6	9	6	14	3	9.635
82	S	56	0.0845	262000	7000	453	115	142	0	38	1	5	38	0	8	11	17	2	4.405
83	S	56	0.2336	264000	17000	1240	104	228	0	150	1	7	46	0	20	10	29	2	10.617
84	S	59	0.0064	258000	14000	674	65	131	0	0	1	5	35	0	8	10	20	2	8.946
85	S	62	0.1940	238000	38000	1458	167	93	0	62	1	0	31	0	6	12	21	2	26.324
86	S	65	0.1478	170000	114000	2153	129	23	47	65	1	0	35	0	9	12	8	5	110.560

LOC=S

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
87	S	71	0.0261	202000	63000	1165	92	92	92	82	1	5	31	2	8	8	11	4	51.420
88	S	88	0.3052	261000	8000	439	50	160	0	144	1	7	3	0	7	7	8	3	5.053
89	S	81	0.0638	268000	11000	737	59	182	0	11	1	5	43	0	5	5	17	2	6.767
90	S	83	0.1553	161000	131000	1799	89	24	0	260	1	3	36	0	9	12	14	2	134.149
91	S	85	0.0392	250000	11000	541	57	141	0	0	1	5	47	0	5	8	8	2	7.254
92	S	91	0.1832	202000	69000	3030	135	86	0	324	1	0	37	0	6	6	5	2	56.317
93	S	95	0.1685	199000	33000	1173	156	84	6	216	1	6	2	0	6	6	8	2	27.340
94	S	99	0.0515	242000	23000	1344	90	163	0	158	1	5	32	0	5	5	6	3	15.670
95	S	106	0.1655	236000	32000	2247	102	177	24	264	1	6	30	8	12	6	13	4	22.355
96	S	108	0.0508	247000	14000	753	68	174	0	13	1	5	42	0	5	5	11	2	9.345
97	S	110	0.1477	164000	110000	5749	147	56	0	417	1	6	35	0	9	6	13	4	110.584
98	S	112	0.0307	165000	117000	3766	1702	31	170	5	1	10	31	18	8	5	16	3	116.908
99	S	119	0.0171	152000	113000	922	117	15	46	0	1	0	31	13	5	5	5	5	122.568
100	S	123	0.0199	153000	114000	4234	1837	41	92	0	1	5	26	9	5	5	8	4	122.845
101	S	125	0.0274	203000	112000	4730	2468	57	213	0	1	5	31	34	5	5	16	4	90.963
102	S	128	0.1340	173000	114000	5081	2252	40	0	35	1	3	29	10	6	6	7	4	108.643
103	S	130	0.0844	169000	116000	2933	1311	44	98	79	1	0	35	10	8	11	17	6	113.165
104	S	135	0.0289	270000	5000	407	211	124	21	0	1	5	36	0	8	5	16	2	3.053
105	S	135	0.0244	269000	9000	661	333	113	0	0	1	5	36	14	8	5	16	2	5.516
106	S	140	0.0839	192000	112000	3859	1856	49	120	71	1	3	33	7	8	5	12	4	96.174
107	S	145	0.0478	168000	110000	2636	378	21	215	24	1	5	42	70	8	5	16	4	107.951
108	S	150	0.0381	150000	119000	780	88	21	16	0	1	0	36	0	5	5	16	6	130.797
109	S	157	0.0532	164000	119000	1109	106	21	53	16	1	3	37	0	5	5	11	5	119.632
110	S	160	0.0066	146000	116000	1399	171	20	428	0	1	3	30	0	5	5	5	6	130.993
111	S	166	0.0599	165000	131000	1085	96	27	69	0	1	0	32	0	5	5	1	3	130.897
112	S	173	0.1383	180000	123000	1915	180	23	29	186	1	0	26	0	6	6	10	3	112.661
113	S	176	0.0092	156000	125000	1378	136	20	45	0	1	0	30	0	5	5	10	5	132.108
114	S	183	0.1226	177000	125000	2240	80	23	0	239	1	6	23	0	6	11	7	4	116.434
115	S	187	0.0035	140000	124000	933	65	25	133	5	1	0	20	0	5	5	5	4	146.028
116	S	190	0.0680	160000	122000	1084	75	38	182	279	1	3	27	0	5	5	11	4	125.714
117	S	192	0.0213	153000	120000	889	102	26	56	46	1	0	20	0	5	5	10	5	129.310
118	S	203	0.0186	153000	121000	1095	92	20	61	0	1	0	25	0	8	3	10	5	130.388
119	S	208	0.1296	154000	94000	4762	138	69	281	816	2	6	17	931	6	3	7	4	100.635
120	S	211	0.0303	144000	108000	1598	175	21	113	3	1	5	23	1	8	5	5	6	123.653
121	S	215	0.0312	165000	120000	1342	201	21	93	10	1	3	21	0	5	5	5	6	119.906
122	S	221	0.0193	153000	120000	1096	133	20	178	0	1	3	20	0	8	5	10	6	129.310
123	S	224	0.0959	177000	124000	1383	83	39	122	94	1	22	22	3	6	6	1	4	115.502
124	S	226	0.0174	152000	115000	1053	102	23	81	0	1	5	31	0	5	5	10	6	124.737
125	S	228	0.0137	162000	119000	938	91	20	112	0	1	3	30	0	5	5	10	6	121.109
126	S	235	0.0143	147000	103000	842	101	25	208	172	1	5	30	0	5	5	10	4	115.521
127	S	245	0.0159	163000	118000	564	94	20	117	10	1	5	25	282	5	5	15	5	119.354
128	S	265	0.0216	148000	116000	629	87	26	286	0	1	5	46	0	5	5	16	5	129.223
129	S	277	0.0160	168000	121000	478	81	25	76	0	1	5	30	0	3	5	10	5	118.746
130	S	279	0.0084	167000	126000	1059	227	25	171	0	1	5	35	0	5	5	5	5	124.393
131	S	290	0.0002	150000	120000	540	75	20	30	0	1	5	30	36	5	5	10	5	131.896
132	S	301	0.0147	147000	118000	1979	497	20	5	10	1	5	25	0	8	5	15	6	132.345
133	S	319	0.0340	160000	125000	621	78	31	171	114	1	5	36	0	8	5	11	5	128.805
134	S	322	0.0035	156000	124000	738	110	20	68	0	1	5	30	0	8	5	10	6	131.051
135	S	325	0.4245	269000	214000	1347	217	35	200	0	1	9	52	0	9	9	20	6	131.161
136	S	333	0.0006	145000	119000	585	120	20	80	0	1	5	25	0	8	5	20	6	135.307
137	S	335	0.0033	150000	119000	1575	140	20	176	10	1	5	30	0	5	196	100	6	130.797

-- LOC=S --

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
138	S	346	0.0067	151000	118000	1097	156	25	131	0	1	5	30	0	5	30	18	6	128.839
139	S	350	0.0061	151000	121000	604	86	20	75	0	1	5	35	0	5	5	3	6	132.115
140	S	360	0.0185	142000	121000	647	127	20	107	0	1	5	41	0	5	5	0	6	140.488
141	S	371	0.0040	161000	116000	547	85	20	85	0	1	5	35	0	5	5	5	6	118.789
142	S	376	0.0060	146000	119000	830	106	15	30	0	1	5	30	0	5	15	5	3	134.381
143	S	379	0.0103	152000	111000	672	101	20	71	0	1	5	30	0	5	5	5	3	120.399
144	S	386	0.0296	160000	114000	598	93	21	108	52	1	5	31	0	5	5	0	3	117.470
145	S	389	0.0194	169000	114000	642	82	20	122	31	1	5	36	7	5	5	5	3	111.214
146	S	399	0.0657	160000	125000	594	91	21	64	43	1	5	37	0	5	5	3	3	128.805
147	S	409	0.0391	167000	116000	614	88	21	104	42	1	5	31	9	5	10	6	4	114.521
148	S	413	0.1002	231000	36000	1300	94	144	0	94	1	6	33	0	6	6	9	4	25.694
149	S	415	0.0471	163000	121000	651	100	21	31	0	1	5	31	1	5	5	6	4	122.388
150	S	419	0.0089	162000	119000	762	126	20	86	0	1	5	30	0	3	5	0	4	121.109
151	S	423	0.0091	156000	121000	878	141	15	0	0	1	5	35	10	5	5	0	5	127.880
152	S	429	0.0149	152000	119000	695	91	20	102	0	1	5	30	0	3	5	5	4	129.076
153	S	431	0.0005	171000	118000	575	85	20	180	0	1	5	35	0	3	5	8	4	113.770
154	S	445	0.0244	263000	191000	1199	144	49	333	72	1	8	67	0	10	8	21	5	119.735
155	S	446	0.0227	175000	122000	496	133	31	67	0	1	5	36	0	5	5	10	4	114.938
156	S	450	0.0170	168000	117000	549	71	25	97	15	1	5	36	0	5	10	10	3	114.820
157	S	455	0.2627	224000	158000	746	136	34	424	0	1	7	47	0	7	7	7	3	116.293
158	S	458	0.0172	158000	115000	743	92	20	56	10	1	5	31	0	5	5	5	3	120.001
159	S	467	0.0206	153000	112000	842	112	26	82	15	1	5	31	0	5	10	8	3	120.689
160	S	478	0.0139	157000	103000	730	101	25	172	66	1	5	30	0	5	5	5	4	108.163
161	S	483	0.0441	151000	117000	1386	136	31	94	42	1	5	31	0	5	120	53	4	127.747
162	S	489	0.0430	157000	117000	799	125	37	235	31	1	5	37	0	5	21	16	3	122.865
163	S	494	0.0196	158000	122000	561	82	31	130	0	1	5	36	0	5	20	10	4	127.305
164	S	497	0.0097	156000	120000	581	91	25	61	0	1	5	35	0	5	5	5	4	126.823
165	S	507	0.0393	156000	112000	10565	4736	52	156	0	1	5	26	13	0	5	6	4	118.369
166	S	516	0.0639	166000	119000	988	139	27	123	69	1	5	37	0	3	5	3	3	118.190
167	S	518	0.0176	158000	120000	728	117	25	112	0	1	5	36	0	3	5	0	6	125.218
168	S	524	0.0112	157000	125000	784	142	25	101	0	1	5	35	0	5	10	0	4	131.266
169	S	532	0.0132	162000	122000	745	96	25	101	0	1	5	35	0	5	5	10	5	124.162
170	S	536	0.1656	155000	107000	485	96	30	114	132	1	6	30	2	6	6	8	4	113.814
171	S	540	0.0917	165000	117000	991	110	28	358	127	1	6	33	0	6	8	1	4	116.908
172	S	544	0.0108	167000	116000	576	91	25	111	0	1	5	35	0	5	5	10	5	114.521
173	S	548	0.0129	167000	121000	897	142	25	86	0	1	5	35	0	5	5	8	5	119.457
174	S	548	0.0165	173000	117000	1688	447	38	198	0	1	5	36	1	5	13	10	6	111.502
175	S	551	0.0405	167000	115000	938	151	21	26	0	1	5	36	6	5	8	6	4	113.534
176	S	563	0.0607	165000	112000	1810	122	21	5	27	1	32	48	8	5	5	17	5	111.912
177	S	565	0.1047	191000	121000	1614	145	45	329	168	1	6	39	0	6	6	12	3	104.447
178	S	574	0.0193	158000	114000	1371	127	25	56	25	1	10	36	0	5	5	13	4	118.957
179	S	584	0.0743	162000	110000	1485	119	38	189	286	1	5	27	0	5	5	12	4	111.949
180	S	590	0.0439	178000	118000	1700	188	31	146	52	1	10	37	0	10	5	3	6	109.296
181	S	598	0.0713	172000	111000	4469	549	75	167	145	1	5	38	0	5	5	6	3	106.399
182	S	601	0.0316	182000	108000	5989	2272	57	98	0	1	21	36	0	5	5	5	5	97.835
183	S	608	0.0363	193000	112000	6226	3165	73	213	21	1	21	42	5	5	5	6	5	95.676

LOC=T

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
184	T	0	0.0204	185000	120000	1450	71	36	245	128	1	5	36	0	3	5	16	2	106.943
185	T	25	0.1157	175000	121000	1775	102	34	277	74	1	6	34	3	6	6	7	3	113.996
186	T	81	0.0775	135000	124000	1485	108	27	130	35	1	5	38	0	5	5	4	3	151.437
187	T	88	0.0215	137000	113000	1221	92	20	56	72	1	5	31	0	5	5	10	4	135.988
188	T	92	0.0210	148000	109000	1292	158	20	123	36	1	5	36	0	5	41	21	5	121.425
189	T	123	0.0102	172000	123000	1212	136	35	207	5	1	5	45	0	5	5	3	5	117.902
190	T	143	0.0381	172000	125000	2230	338	26	234	10	1	5	42	0	5	5	0	3	119.819
191	T	150	0.0103	151000	111000	1061	111	25	106	0	1	5	30	0	5	5	0	4	121.196
192	T	189	0.0227	180000	119000	1207	368	31	246	0	1	15	31	7	5	5	5	2	108.998
193	T	199	0.1748	175000	109000	2181	203	48	0	200	1	30	42	3	12	6	5	4	102.691
194	T	213	0.0129	162000	115000	1570	117	25	76	46	1	5	30	0	5	5	0	5	117.038
195	T	231	0.0173	163000	114000	1476	191	25	76	5	1	5	31	0	5	5	0	2	115.308
196	T	239	0.0225	159000	117000	1125	97	20	5	0	1	5	31	0	5	10	5	3	121.320
197	T	255	0.1064	162000	116000	1343	112	28	375	67	1	6	28	0	6	6	12	3	118.055

LOC=V

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
198	V	2	0.0063	140000	109000	1057	101	35	126	0	1	5	40	3874	25	3	10	5	128.363
199	V	5	0.0080	151000	113000	1799	252	30	0	0	1	5	40	2419	25	5	5	5	123.380
200	V	11	0.0100	141000	112000	1465	182	30	0	0	1	5	56	9090	91	20	15	5	130.961

LOC=Z

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
201	Z	14	0.0215	180000	120000	1012	153	31	291	0	1	5	33	11	5	5	0	4	109.914
202	Z	19	0.0417	189000	127000	1195	94	31	219	130	1	5	31	6	5	5	6	4	110.786
203	Z	23	0.0202	190000	126000	893	112	31	260	77	1	5	41	3	3	5	5	4	109.335
204	Z	25	0.0573	175000	122000	1379	101	42	249	170	1	5	42	18	3	8	3	4	114.938
205	Z	32	0.0102	172000	122000	924	106	35	182	25	1	5	40	38	3	5	15	5	116.943
206	Z	40	0.0138	162000	118000	938	142	30	228	61	1	5	35	5	5	5	5	4	120.091
207	Z	45	0.0616	204000	133000	1135	117	37	336	11	1	5	37	2	0	5	14	5	107.489
208	Z	51	0.0453	179000	125000	880	84	37	162	63	1	5	37	2	0	5	6	5	115.133
209	Z	53	0.3044	283000	171000	1323	144	47	259	0	1	7	50	2	0	7	19	4	99.621
210	Z	65	0.1132	169000	113000	2988	113	34	209	248	1	6	45	14	0	6	7	3	110.239
211	Z	71	0.0168	200000	122000	1165	153	31	158	0	1	5	46	17	3	5	5	5	100.571
212	Z	80	0.1540	183000	122000	2246	106	50	491	402	1	12	47	5	3	6	14	4	109.914
213	Z	95	0.1573	172000	115000	1584	157	30	119	184	1	18	36	28	6	6	8	3	110.233
214	Z	99	0.1784	182000	120000	1887	103	49	371	438	1	6	49	2	6	6	8	3	108.706
215	Z	106	0.1088	191000	135000	1178	93	34	157	0	1	6	34	0	6	6	4	4	116.531
216	Z	109	0.0487	179000	117000	1072	84	32	89	0	1	5	37	2	5	5	6	4	107.764
217	Z	113	0.1830	197000	120000	2057	117	68	345	336	1	31	43	47	6	6	8	4	100.429
218	Z	118	0.1015	178000	124000	1692	117	36	122	83	1	6	39	11	6	6	7	5	114.854
219	Z	126	0.0179	163000	115000	1293	137	33	173	10	1	5	36	15	5	5	5	5	116.320
220	Z	139	0.1619	179000	119000	1050	95	48	167	167	1	6	48	12	6	6	2	4	109.607
221	Z	147	0.1541	171000	123000	1555	106	35	254	148	1	6	35	4	6	6	0	3	118.591
222	Z	153	0.0517	174000	123000	1260	95	40	232	84	1	5	32	9	5	5	11	4	116.546

LOC=Z

OBS	LOC	SAMPLE	RESID	CA	MG	FE	MN	SR	NA	K	LI	CU	PB	ZN	CD	CR	NI	XL	MGCARAT
223	Z	162	0.1021	190000	127000	1220	150	33	173	78	1	6	28	18	6	6	7	4	110.203
224	Z	168	0.1000	172000	127000	1006	83	47	272	117	1	6	39	28	6	6	7	5	121.736
225	Z	182	0.1797	189000	126000	1304	85	49	317	262	1	6	43	24	6	6	2	4	109.914
226	Z	191	0.0939	177000	122000	1435	99	33	226	66	1	6	28	18	6	6	1	4	113.640
227	Z	202	0.0704	189000	125000	1151	102	43	118	11	1	5	38	9	5	5	17	4	109.041
228	Z	206	0.2127	164000	115000	3620	102	38	89	451	1	19	38	60	6	13	9	4	115.610
229	Z	216	0.0219	174000	113000	971	82	36	250	41	1	5	36	7	5	5	5	5	107.071
230	Z	225	0.1309	161000	121000	2531	92	43	75	247	1	23	35	29	6	6	4	3	123.909
231	Z	230	0.0342	198000	130000	1268	104	36	119	0	1	5	36	5	5	5	0	4	108.243
232	Z	240	0.0455	173000	127000	1294	89	37	194	37	1	5	31	16	5	3	16	4	121.032
233	Z	252	0.0043	90000	61000	2139	50	25	156	603	1	10	20	32	0	5	10	4	111.746

APPENDIX D

STATISTICS

Aphanocrystalline	1
Very finely crystalline	2
Finely crystalline	3
Medium crystalline	4
Coarsely crystalline	5
Very coarsely crystalline	6
Extremely coarsely crystalline	7

Fig. 19.-Explanation of Crystallinity

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	233	0.062273	0.0626706	0.0002000	0.424500	0.424300	0.0041057	1.96800625	5.81618833
CA	233	175755.364807	32675.8541952	90000.0000000	324000.000000	234000.000000	2140.6663831	1.83731458	4.11419076
MG	233	110738.197425	29841.7543370	5000.0000000	214000.000000	209000.000000	1954.9983282	-2.14554484	6.08502473
FE	233	1607.227468	1437.9196913	407.0000000	11413.000000	11006.000000	94.2012511	3.87236095	19.91679027
MN	233	259.896996	643.9169721	50.0000000	4736.000000	4686.000000	42.1844034	5.35142122	30.73648096
SR	233	42.167382	39.1777818	15.0000000	265.000000	250.000000	2.5666218	3.33402332	12.08061735
NA	233	156.266094	126.3401863	0.0000000	855.000000	855.000000	8.2768208	1.65904425	5.84039812
K	233	96.635193	128.7990949	0.0000000	816.000000	816.000000	8.4379093	1.99525227	5.21822424
LI	233	1.004292	0.0655122	1.0000000	2.000000	1.000000	0.0042918	15.26433752	233.00000000
CU	233	6.004292	5.0124826	0.0000000	32.000000	32.000000	0.3283787	2.95799068	10.49095860
PB	233	35.781116	10.1535277	2.0000000	120.000000	118.000000	0.6651797	2.67776806	21.30762577
ZN	233	742.047210	5053.3505045	0.0000000	71085.000000	71085.000000	331.0559988	12.15995721	164.63286378
CD	233	10.008584	25.0680095	0.0000000	332.000000	332.000000	1.6422599	10.02628994	120.33189785
CR	233	10.060086	19.5630236	3.0000000	196.000000	193.000000	1.2816163	6.99333383	54.15263169
NI	233	10.137339	9.8902610	0.0000000	100.000000	100.000000	0.6479325	4.73740551	34.59578920
XL	233	3.995708	1.1762662	1.0000000	6.000000	5.000000	0.0770598	-0.00765888	-0.71724710
MGCARAT	233	108.563849	30.3995050	3.0531560	152.295561	149.242405	1.9915378	-2.50371245	5.63586258

LOC=B

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	47	0.054240	0.0458927	0.001700	0.195900	0.194200	0.0066941	1.08607581	1.08685384
CA	47	177765.957447	27428.3356863	150000.000000	324000.000000	174000.000000	4000.8339517	3.46793059	17.19772528
MG	47	116510.638298	16323.9918664	13000.000000	133000.000000	120000.000000	2381.0989348	-5.73013086	36.89708679
FE	47	1409.085106	851.4708714	455.000000	4013.000000	3558.000000	124.1997914	1.24812713	1.27817874
MN	47	152.680851	261.8848989	60.000000	1877.000000	1817.000000	38.1998386	6.47789317	43.35577941
SR	47	32.361702	15.7844524	20.000000	116.000000	96.000000	2.3023990	3.58945555	17.02473704
NA	47	249.234043	159.1067748	0.000000	855.000000	855.000000	23.2081083	2.18386625	6.05090085
K	47	149.510638	146.0520861	0.000000	535.000000	535.000000	21.3038863	0.96745343	-0.01309121
LI	47	1.000000	0.0000000	1.000000	1.000000	0.000000	0.0000000	.	.
CU	47	5.340426	3.8576665	0.000000	20.000000	20.000000	0.5626985	2.05229337	6.13787450
PB	47	36.723404	6.8831935	25.000000	50.000000	25.000000	1.0040170	0.04445035	-0.66814201
ZN	47	124.680851	734.4726918	0.000000	5049.000000	5049.000000	107.1338530	6.83913178	46.84391757
CD	47	5.978723	2.9817515	3.000000	23.000000	20.000000	0.4349332	4.14798441	23.30842151
CR	47	16.446809	27.2219609	5.000000	155.000000	150.000000	3.9707311	4.02705133	17.13135121
NI	47	12.638298	11.5239364	0.000000	65.000000	65.000000	1.6809389	2.90823650	10.51816406
XL	47	3.957447	1.2676141	2.000000	6.000000	4.000000	0.1849005	-0.11771942	-1.02455224
MGCARAT	47	110.598782	17.6939351	6.615171	131.245535	124.630363	2.5809257	-4.52557251	26.49698095

LOC=H

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	2	0.081950	0.0152028	0.071200	0.092700	0.0215000	0.010750	.	.
CA	2	134000.000000	22627.4169980	118000.000000	150000.000000	32000.0000000	16000.000000	.	.
MG	2	107000.000000	2828.4271247	105000.000000	109000.000000	4000.0000000	2000.000000	.	.
FE	2	1868.500000	396.6869042	1588.000000	2149.000000	561.0000000	280.500000	.	.
MN	2	96.500000	30.4055916	75.000000	118.000000	43.0000000	21.500000	.	.
SR	2	27.500000	0.7071068	27.000000	28.000000	1.0000000	0.500000	.	.
NA	2	84.500000	2.1213203	83.000000	86.000000	3.0000000	1.500000	.	.
K	2	211.500000	112.4299782	132.000000	291.000000	159.0000000	79.500000	.	.
LI	2	1.000000	0.0000000	1.000000	1.000000	0.0000000	0.000000	.	.
CU	2	5.500000	0.7071068	5.000000	6.000000	1.0000000	0.500000	.	.
PB	2	71.000000	1.4142136	70.000000	72.000000	2.0000000	1.000000	.	.
ZN	2	16943.000000	7212.4891681	11843.000000	22043.000000	10200.0000000	5100.000000	.	.
CD	2	103.500000	24.7487373	86.000000	121.000000	35.0000000	17.500000	.	.
CR	2	5.500000	0.7071068	5.000000	6.000000	1.0000000	0.500000	.	.
NI	2	9.000000	4.2426407	6.000000	12.000000	6.0000000	3.000000	.	.
XL	2	3.000000	0.0000000	3.000000	3.000000	0.0000000	0.000000	.	.
MGCARAT	2	133.852429	26.0825276	115.409297	152.295561	36.8862643	18.443132	.	.

LOC=P

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	18	0.074394	0.0350539	0.019800	0.127800	0.1030000	0.0082623	-0.27360780	-1.14312048
CA	18	165611.111111	15224.3569898	143000.000000	196000.000000	53000.0000000	3588.4153556	0.67368972	-0.39248869
MG	18	116666.666667	6068.2393997	106000.000000	129000.000000	23000.0000000	1430.2977431	0.50898752	0.19709755
FE	18	1903.666667	580.9804087	817.000000	2968.000000	2151.0000000	136.9383956	-0.36968221	-0.19129641
MN	18	103.611111	40.9075556	71.000000	250.000000	179.0000000	9.6420033	2.98156469	10.26605291
SR	18	37.111111	9.5971129	22.000000	56.000000	34.0000000	2.2620612	0.50235128	-0.26717061
NA	18	189.722222	109.6104361	0.000000	392.000000	392.0000000	25.8354276	-0.22461195	-0.25248671
K	18	155.277778	90.7069007	0.000000	336.000000	336.0000000	21.3798215	-0.00739403	-0.29064895
LI	18	1.000000	0.0000000	1.000000	1.000000	0.0000000	0.0000000	.	.
CU	18	7.166667	6.0900111	0.000000	28.000000	28.0000000	1.4354294	2.72820354	8.42595941
PB	18	45.277778	20.0610995	27.000000	120.000000	93.0000000	4.7284465	3.30749642	12.64242790
ZN	18	6427.888889	16365.0606868	70.000000	71085.000000	71015.0000000	3857.2817954	4.05117251	16.82613622
CD	18	42.888889	75.1969093	5.000000	332.000000	327.0000000	17.7240815	3.71759914	14.73716525
CR	18	6.277778	3.9527437	5.000000	22.000000	17.0000000	0.9316706	4.13964279	17.37862214
NI	18	9.833333	7.5244699	1.000000	35.000000	34.0000000	1.7735346	2.26269554	7.31193529
XL	18	3.277778	0.5745131	3.000000	5.000000	2.0000000	0.1354140	2.07235302	3.84862268
MGCARAT	18	116.661295	7.1913932	105.236441	127.399873	22.1634322	1.6950276	-0.28074079	-1.17005565

-- LOC=S --

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	116	0.058084	0.0688186	0.000200	0.424500	0.424300	0.0063896	2.41545225	7.69895014
CA	116	178362.068966	38493.4543395	139000.000000	308000.000000	169000.000000	3574.0275106	1.54667922	1.20847735
MG	116	103586.206897	38837.0215500	5000.000000	214000.000000	209000.000000	3605.9269253	-1.31063447	1.83663969
FE	116	1695.344828	1911.8976010	407.000000	11413.000000	11006.000000	177.5152358	3.17745722	11.43958189
MN	116	388.068966	879.7466110	50.000000	4736.000000	4686.000000	81.6824222	3.77326047	14.48060533
SR	116	50.215517	53.0489202	15.000000	265.000000	250.000000	4.9254686	2.25764017	4.62983318
NA	116	101.448276	91.3584764	0.000000	428.000000	428.000000	8.4824216	1.28079585	2.07480433
K	116	60.715517	110.4575312	0.000000	816.000000	816.000000	10.2557243	3.62606371	19.11949407
LI	116	1.008621	0.0928477	1.000000	2.000000	1.000000	0.0086207	10.77032961	116.00000000
CU	116	5.396552	4.6248465	0.000000	32.000000	32.000000	0.4294062	3.18451895	13.57625668
PB	116	32.655172	7.9532366	2.000000	67.000000	65.000000	0.7384395	-0.11584002	5.31964782
ZN	116	13.396552	90.1612931	0.000000	931.000000	931.000000	8.3712659	9.56116860	95.93206987
CD	116	6.129310	2.3573389	0.000000	20.000000	20.000000	0.2188734	2.12416139	9.89834057
CR	116	9.612069	20.8717706	3.000000	196.000000	193.000000	1.9378953	7.63141714	62.38684674
NI	116	10.508621	10.7917003	0.000000	100.000000	100.000000	1.0019842	5.57683188	42.66591353
XL	116	4.155172	1.2894451	1.000000	6.000000	5.000000	0.1197220	-0.17104223	-0.81300158
MGCARAT	116	103.259523	40.2536984	3.053156	146.028090	142.974934	3.7374621	-1.68713766	1.32285355

LOC=T

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	14	0.047950	0.0508000	0.010200	0.174800	0.1646000	0.0135769	1.57863896	1.69539227
CA	14	162571.428571	15360.8607817	135000.000000	185000.000000	50000.0000000	4105.3627294	-0.50206713	-0.59331657
MG	14	116857.142857	5347.2802988	109000.000000	125000.000000	16000.0000000	1429.1207735	-0.00625286	-1.15615034
FE	14	1473.428571	363.5821173	1061.000000	2230.000000	1169.0000000	97.1714082	1.19898085	0.67941853
MN	14	157.428571	90.8851467	71.000000	368.000000	297.0000000	24.2900772	1.63174286	1.80802032
SR	14	28.571429	7.7331881	20.000000	48.000000	28.0000000	2.0667814	1.19085611	1.80080827
NA	14	154.000000	111.4429830	0.000000	375.000000	375.0000000	29.7843900	0.37887168	-0.64227878
K	14	46.428571	57.8362600	0.000000	200.000000	200.0000000	15.4573907	1.60341915	2.66225114
LI	14	1.000000	0.0000000	1.000000	1.000000	0.0000000	0.0000000	.	.
CU	14	7.642857	6.9570398	5.000000	30.000000	25.0000000	1.8593605	3.03287896	9.38977552
PB	14	34.642857	5.3436827	28.000000	45.000000	17.0000000	1.4281593	0.74303812	-0.67687860
ZN	14	0.928571	2.0555473	0.000000	7.000000	7.0000000	0.5493681	2.40523933	5.78197412
CD	14	5.500000	1.9903614	3.000000	12.000000	9.0000000	0.5319465	2.93648190	10.38917214
CR	14	8.142857	9.5503294	5.000000	41.000000	36.0000000	2.5524329	3.62341631	13.31852050
NI	14	6.285714	6.4262511	0.000000	21.000000	21.0000000	1.7174879	1.11375425	0.71106529
XL	14	3.428571	1.0894096	2.000000	5.000000	3.0000000	0.2911570	0.21248343	-1.12345679
MGCARAT	14	119.436719	12.1238323	102.690721	151.436537	48.7458163	3.2402305	1.47485221	3.18120534

LOC=V

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	3	0.008100	0.00185203	0.006300	0.010000	0.0037000	0.0010693	0.24226877	.
CA	3	144000.000000	6082.76253030	140000.000000	151000.000000	11000.0000000	3511.8845843	1.67953560	.
MG	3	111333.333333	2081.66599947	109000.000000	113000.000000	4000.0000000	1201.8504252	-1.29334278	.
FE	3	1440.333333	371.61449559	1057.000000	1799.000000	742.0000000	214.5517291	-0.29738061	.
MN	3	178.333333	75.56674754	101.000000	252.000000	151.0000000	43.6284820	-0.21783592	.
SR	3	31.666667	2.88675135	30.000000	35.000000	5.0000000	1.6666667	1.73205081	.
NA	3	42.000000	72.74613392	0.000000	126.000000	126.0000000	42.0000000	1.73205081	.
K	3	0.000000	0.00000000	0.000000	0.000000	0.0000000	0.0000000	.	.
LI	3	1.000000	0.00000000	1.000000	1.000000	0.0000000	0.0000000	.	.
CU	3	5.000000	0.00000000	5.000000	5.000000	0.0000000	0.0000000	.	.
PB	3	45.333333	9.23760431	40.000000	56.000000	16.0000000	5.3333333	1.73205081	.
ZN	3	5127.666667	3507.75146402	2419.000000	9090.000000	6671.0000000	2025.2012520	1.40286125	.
CD	3	47.000000	38.10511777	25.000000	91.000000	66.0000000	22.0000000	1.73205081	.
CR	3	9.333333	9.29157324	3.000000	20.000000	17.0000000	5.3644923	1.64220707	.
NI	3	10.000000	5.00000000	5.000000	15.000000	10.0000000	2.8867513	0.00000000	.
XL	3	5.000000	0.00000000	5.000000	5.000000	0.0000000	0.0000000	.	.
MGCARAT	3	127.568053	3.85259857	123.379853	130.960904	7.5810504	2.2242988	-0.88940750	.

LOC=Z

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
RESID	33	0.091633	0.0721102	0.0043000	0.304400	0.300100	0.0125528	0.93638339	0.67277162
CA	33	180272.727273	26609.7640999	90000.0000000	283000.000000	193000.000000	4632.1653601	0.63043349	10.15083786
MG	33	122000.000000	14794.4246255	61000.0000000	171000.000000	110000.000000	2575.3787600	-1.10260781	12.18662254
FE	33	1474.090909	629.9059138	880.0000000	3620.000000	2740.000000	109.6525449	1.98527566	3.66330507
MN	33	108.090909	24.8550342	50.0000000	157.000000	107.000000	4.3267061	0.41165171	0.07664035
SR	33	38.212121	8.4511744	25.0000000	68.000000	43.000000	1.4711606	1.50580175	3.43064925
NA	33	214.000000	91.5235625	75.0000000	491.000000	416.000000	15.9322072	0.88238240	1.21895287
K	33	137.878788	156.3571148	0.0000000	603.000000	603.000000	27.2182800	1.40953686	1.42226613
LI	33	1.000000	0.0000000	1.0000000	1.000000	0.000000	0.0000000	.	.
CU	33	7.878788	6.0712312	5.0000000	31.000000	26.000000	1.0568657	2.65507670	6.83616190
PB	33	37.727273	6.5730165	20.0000000	50.000000	30.000000	1.1442153	-0.22410870	0.52626527
ZN	33	15.121212	14.1504363	0.0000000	60.000000	60.000000	2.4632748	1.45997468	2.17581331
CD	33	4.333333	2.1164042	0.0000000	6.000000	6.000000	0.3684187	-1.24771071	0.23169699
CR	33	5.757576	1.5417179	3.0000000	13.000000	10.000000	0.2683786	3.32059403	15.66073211
NI	33	7.151515	5.0256916	0.0000000	19.000000	19.000000	0.8748606	0.71636476	-0.05085779
XL	33	4.090909	0.6306562	3.0000000	5.000000	2.000000	0.1097832	-0.06576428	-0.31283739
MGCARAT	33	112.021306	5.8751975	99.6213514	123.908828	24.287476	1.0227406	-0.13227735	0.00527868

"S" DOLOMITIC LIMESTONES

S T A T I S T I C A L   A N A L Y S I S   S Y S T E M   0:49 FRIDAY, JULY 7, 1978   2

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
FOOTAGE	20	44.700000	37.6816303	19.000000	196.000000	177.000000	8.4258687	3.71834578	15.29542505
RESID	20	0.110945	0.079643	0.006400	0.305200	0.298800	0.0178805	0.75207155	0.13212519
NA	20	15.700000	42.1951606	0.000000	171.000000	171.000000	9.4351247	3.21605209	10.51015360
K	20	97.600000	99.8527337	0.000000	324.000000	324.000000	22.3277500	0.86340083	-0.23249859
SR	20	153.050000	52.7191916	84.000000	265.000000	181.000000	11.7883696	0.65279429	-0.19647070
MN	20	123.350000	68.5767146	50.000000	333.000000	283.000000	15.3342196	1.67556670	3.49436458
FE	20	1100.750000	642.9090854	407.000000	3030.000000	2623.000000	143.7588418	1.63333477	3.40616273
CU	20	5.300000	2.4083189	0.000000	12.000000	12.000000	0.5385165	0.05978471	4.21555743
ZN	20	2.000000	3.8251247	0.000000	14.000000	14.000000	0.8553239	2.11275067	4.26838673
CD	20	7.950000	3.4255234	5.000000	20.000000	15.000000	0.7659703	2.49137847	7.89919611
NI	20	13.750000	5.8478516	5.000000	29.000000	24.000000	1.3076194	0.72715192	0.92995321
CR	20	7.450000	2.4596748	5.000000	12.000000	7.000000	0.5500000	0.66804693	-1.17773089
LI	20	1.000000	0.0000000	1.000000	1.000000	0.000000	0.000000	.	.
PB	20	33.200000	11.5193202	2.000000	47.000000	45.000000	2.5757983	-1.96206182	4.08893604
CA	20	248550.000000	26150.3245426	199000.000000	308000.000000	109000.000000	5847.3903311	-0.28297159	0.89468721
MG	20	27850.000000	28047.4691606	5000.000000	120000.000000	115000.000000	6271.6047640	2.21972340	5.52514680
XL	20	2.550000	0.7591547	2.000000	4.000000	2.000000	0.1697521	1.01651158	-0.37145377
SAMPLE	20	96.850000	79.2625710	43.000000	413.000000	370.000000	17.7236498	3.64218427	14.80973157
ND	20	96.550000	79.2625716	43.000000	413.000000	370.000000	17.7236498	3.64218427	14.80973157
TOTAL	20	277961.100000	27912.5746100	233664.000000	373327.000000	139663.000000	6241.4414255	2.40058802	7.54472909
MGCARAT	20	19.646347	20.3422323	3.053156	78.509726	75.456570	4.5486614	1.81438949	2.86749810
SRCARAT	20	0.278039	0.0790089	0.178723	0.448409	0.269686	0.0176669	0.58895727	-0.60194758
MNFERAT	20	15.092033	13.7721957	4.529243	52.701450	48.172207	3.0795566	2.16015679	4.03109461

"S" DOLOMITES

LOC=S

VARIABLE	N	MEAN	STANDARD DEVIATION	MINIMUM VALUE	MAXIMUM VALUE	RANGE	STD ERROR OF MEAN	SKEWNESS	KURTOSIS
FOOTAGE	96	148.572917	87.2058357	1.000000	293.000000	292.000000	8.9004083	-0.02302738	-1.26251737
RESID	96	0.047072	0.0611832	0.000200	0.424500	0.424300	0.0062445	3.37798546	15.80259012
NA	96	119.312500	88.7523239	0.000000	428.000000	428.000000	9.0582461	1.33635219	2.28266691
K	96	53.031250	111.4866481	0.000000	816.000000	816.000000	11.3785584	4.21173605	23.66143057
SR	96	28.791667	12.6756432	15.000000	75.000000	60.000000	1.2937024	1.79741456	3.09141742
MN	96	443.218750	958.1883257	65.000000	4736.000000	4671.000000	97.7946865	3.37689408	11.34157763
FE	96	1819.218750	2062.1099680	478.000000	11413.000000	10935.000000	210.4632173	2.90578077	9.27173217
CU	96	5.416667	4.9729091	0.000000	32.000000	32.000000	0.5075454	3.10135950	12.03413152
ZN	96	15.770833	99.0175401	0.000000	931.000000	931.000000	10.1059354	8.69692783	79.33304178
CD	96	5.750000	1.8806494	0.000000	12.000000	12.000000	0.1919430	9.77820238	1.61510221
NI	96	9.833333	11.4658914	0.000000	100.000000	100.000000	1.1702326	5.76235028	42.13720526
CR	96	10.062500	22.9116438	3.000000	196.000000	193.000000	2.3384099	6.94982109	51.50986096
LI	96	1.010417	0.1020621	1.000000	2.000000	1.000000	0.0104167	9.79795897	96.00000000
PB	96	32.541667	7.0679658	17.000000	67.000000	50.000000	0.7213712	1.28455838	5.59705672
CA	96	163739.583333	20093.0701810	139000.000000	269000.000000	130000.000000	2050.7403879	3.16482154	13.41102740
MG	96	119364.583333	14469.6559386	94000.000000	214000.000000	120000.000000	1476.8030751	4.44067242	25.01098326
XL	96	4.489583	1.1144486	1.000000	6.000000	5.000000	0.1137429	-0.27620696	-0.30992181
SAMPLE	96	313.614583	179.6093052	2.000000	608.000000	606.000000	18.3312980	-0.06697926	-1.23375740
ND	96	313.614583	179.6093052	2.000000	608.000000	606.000000	18.3312980	-0.06697926	-1.23375740
TOTAL	96	285648.12500	32400.8860994	251404.000000	484899.000000	233495.000000	3306.9015899	4.32067841	22.56033620
MGCARAT	96	120.678934	10.0136731	90.962992	146.028090	55.065097	1.0220162	-0.42900955	0.49560222
SRCARAT	96	0.079880	0.0320576	0.042879	0.204929	0.162050	0.0032719	1.93714362	3.92915073
MNFERAT	96	16.588909	11.6782681	2.599319	53.041835	50.442516	1.1919083	1.85224166	2.63744865

APPENDIX E

SARGENT'S CHEMICAL ANALYSES OF

THE BUTTERLY DOLOMITE

	Pb	Zn	Na	K	Li	Ni	Cu	Sr	Mn	Fe
TA 5-3-1	-	2	313	365	1	3	6	23	86	1212
Cb 1	-	-	188	45	-	3	2	16	54	105
Cb 2	-	-	173	165	-	1	3	22	63	439
Cb 3	-	-	238	490	-	-	3	27	54	794
Cb 4	-	-	298	150	-	1	3	23	49	397
Cb 5	-	-	196	140	-	1	3	32	45	376
Cb 6	-	-	284	375	1	1	3	34	63	836
Cb H-77-1	-	-	169	475	-	-	2	32	146	1754
Cb H-77-2	-	-	177	95	-	1	3	1	146	1253
AA 2-2-1	-	-	252	110	-	5	2	3	677	3988
AA 2-10-1	17	-	157	40	-	-	4	4	405	2527
AA 2-20-1	-	-	207	100	-	-	3	4	569	2527
$\overline{X}$	1.42	0.18	220.67	212.50	0.18	1.33	3.08	18.42	196.42	1350.67
s	4.91	0.60	53.90	165.63	0.60	1.56	1.08	12.44	223.89	1157.25

VITA 2

Peter Val Kranak

Candidate for the Degree of

Master of Science

Thesis: PETROGRAPHY AND GEOCHEMISTRY OF THE BUTTERLY DOLOMITE, AND ASSOCIATED SPHALERITE MINERALIZATION, TURNER PROSPECT, ARBUCKLE MOUNTAINS, OKLAHOMA

Major Field: Geology

Biographical:

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Education: Graduated from Cubberley High School, Palo Alto, California, in June, 1970; received Bachelor of Science degree in Geology from University of Washington in December, 1974; completed requirements for the Master of Science degree at Oklahoma State University in December, 1978, with a major in Geology.

Professional Experience: Teaching and research assistand, Oklahoma State University, Stillwater, Oklahoma, January, 1977-May, 1978; Geologist, Continental Oil Company, May, 1976-August, 1976 and June, 1975-October, 1975.