Christopher L. Bergren. Petrology and depositional environment of the Girkin and Cove Creek Limestones (Mississippian) in Washington County, Virginia. (Under the direction of Dr. Donald W. Neal) Department of Geology, April 1985.

The Upper Mississippian (Chesterian) carbonate sequence in the Greendale Syncline of Washington County, Virginia, is a thick (580m) accumulation of shallow water mixed siliciclastic-carbonate sediments characterized by the cyclic deposition of four facies. Point-count data and cluster analysis were used to identify these four facies based upon 21 carbonate and non-carbonate components. The facies include 1) calcareous mudrocks, 2) calcareous sandstones, 3) oosparites, and 4) biomicrites.

The data suggest deposition of the Girkin and Cove Creek Limestones on a homoclinal ramp on which subtidal, low-energy biomicrites grade up slope into oolitic sediments characteristic of a shallow, highly agitated shoal. The nearshore calcareous mudrocks represent intertidal to tidal-flat environments. Calcareous sandstones were deposited in a high energy nearshore environment, possibly tidal channels or strandline accumulations.

Diagenetic processes began shortly after deposition in the marine environment and include micritization, compaction, pyrite formation and isopachous cementation. As burial continued, syntaxial, drusy and blocky cementation occurred as well as dolomitization and pressure solution. Microspar formation and silicification are also present in

Girkin and Cove Creek sediments.

Cyclic depositional patterns formed in response to changing environmental parameters. Periodic uplift of a southeast highland, episodes of basin subsidence, and fluctuations in eustatic sea-level contributed to the environmental changes recorded in this sequence.

PETROLOGY AND DEPOSITIONAL ENVIRONMENT OF THE COVE CREEK AND GIRKIN LIMESTONES(MISSISSIPPIAN) IN WASHINGTON COUNTY, VIRGINIA

A Thesis

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The Faculty of the Department of Geology

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In Partial Fulfillment

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Master of Science in Geology

by

Christopher L. Bergren

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INTRODUCTION

Sedimentary petrology is traditionally divided into two separate fields of study: siliciclastic and carbonate petrology. As such, most petrologic work is concentrated on the "pure" sediment end members, commonly ignoring the vast spectrum of mixed sediments that lie between. Likewise, most sedimentary petrology texts are divided into sections dealing with clastics and carbonates, ignoring the rocks of mixed composition and the problems inherent in their study. Investigation of these hybrid sediments is further complicated by the lack of a refined nomenclature for mixed siliciclastic-carbonate sediments. In spite of the complications, these sediments recently have generated much interest (Colacicchi et al. 1982; Hubbard,1982; Ball, 1983; Ginsburg et al. 1983; Mount,1984). Continued interest in the sedimentology of these mixed composition rocks eventually may result in a more complete understanding of the dynamics and interactions of facies, organisms and the tectonic history of depositional basins. This will come, however, only after we understand the sedimentology of numerous small areas, both modern and ancient.

The Upper Mississippian (Chesterian) Girkin and Cove Creek Limestones of the Central Appalachians represent one such mixed siliciclastic-carbonate interval. These units are located within the Greendale Syncline of southwest Virginia and northeast Tennessee and represent the thickest and possibly best exposed sections of Chesterian strata within the Central Appalachians. Detailed studies of the sedimentary and mineralogic characteristics of the units are lacking.

OBJECTIVES

The objectives of this study are: 1) to characterize the texture and composition of the Girkin and Cove Creek Limestones; 2) to characterize diagenetic features within these mixed siliclastic-carbonate units; 3) on the basis of these descriptions, to interpret the depositional environments; and 4) to evaluate changes in textures and diagenetic effects relative to depositional environment and tectonic history.

GEOGRAPHIC AND GEOLOGIC SETTING

The Girkin and Cove Creek Limestones outcrop in a northeast-southwest trending outcrop belt in Washington County, Virginia. Two locations in this belt were chosen for this investigation (Fig. 1). The Holston sampling location is located along U. S. 58A in the Brumley Quadrangle, approximately 3.9 miles northwest of Abingdon. The Hayters Gap sampling location is situated along Virginia State Route 80, approximately 4.3 miles northeast of Abingdon in the Hayters Gap Quadrangle.

The major structural features in the Washington County, Virginia, area consist of portions of the Greendale and Beaver Creek Synclines and of the Saltville, Pulaski-Staunton, Spurgeon, and Bristol Fault Blocks

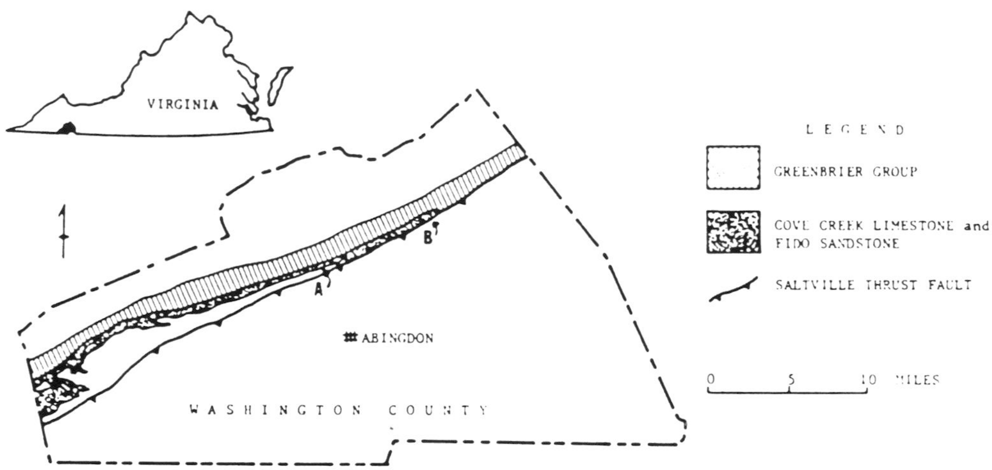

Figure 1. Study Area.

A--Holston sampling location.
B--Hayters Gap sampling location.

(Bartlett and Webb, 1971). Outcrop belts and major fault traces are aligned northeast-southwest, maintaining a southeasterly dip.

The stratigraphic units in the study area (Fig. 2) include the Lower Mississippian Big Stone Gap Shale, Price Formation, Maccrady Shale, Little Valley Limestone, Hillsdale Limestone, and the Ste. Genevieve Limestone. The Upper Mississippian (Chesterian) units include the Girkin Limestone, Fido Sandstone, Cove Creek Limestone and Pennington Formation.

The contact of the Ste. Genevieve with the Girkin is at the top of a distinctive 4.5-6m thick bed of maroon, crinoidal carbonate with varying amounts of ooliths. This bed has been previously used for locating the Ste. Genevieve-Girkin boundary in the Greendale Syncline (Butts, 1940; Averitt, 1941; Bartlett and Webb, 1971). The Fido Sandstone (Butts, 1927) is a thin (9-15m) dark-maroon sandstone which subdivides the Girkin (303.3m) and Cove Creek Limestones (272.8m). This lithologically distinct bed is important as a marker so that its recognition and description as an independent unit is justified (Butts, 1927).

The Girkin Limestone (Butts, 1917) is described as having two facies (Butts, 1940). The first is a pure limestone found along the northwestern portion of the Valley and Ridge Province, and the second, a predominantly argillaceous limestone and shale, is found in the Greendale Syncline. In eastern West Virginia and Virginia, the Girkin is correlated, in part, to Greenbrier strata (de Witt and McGrew, 1979).

The Cove Creek Limestone was named by Butts (1927) for exposures of argillaceous limestone along Cove Creek in Washington County, Virginia.

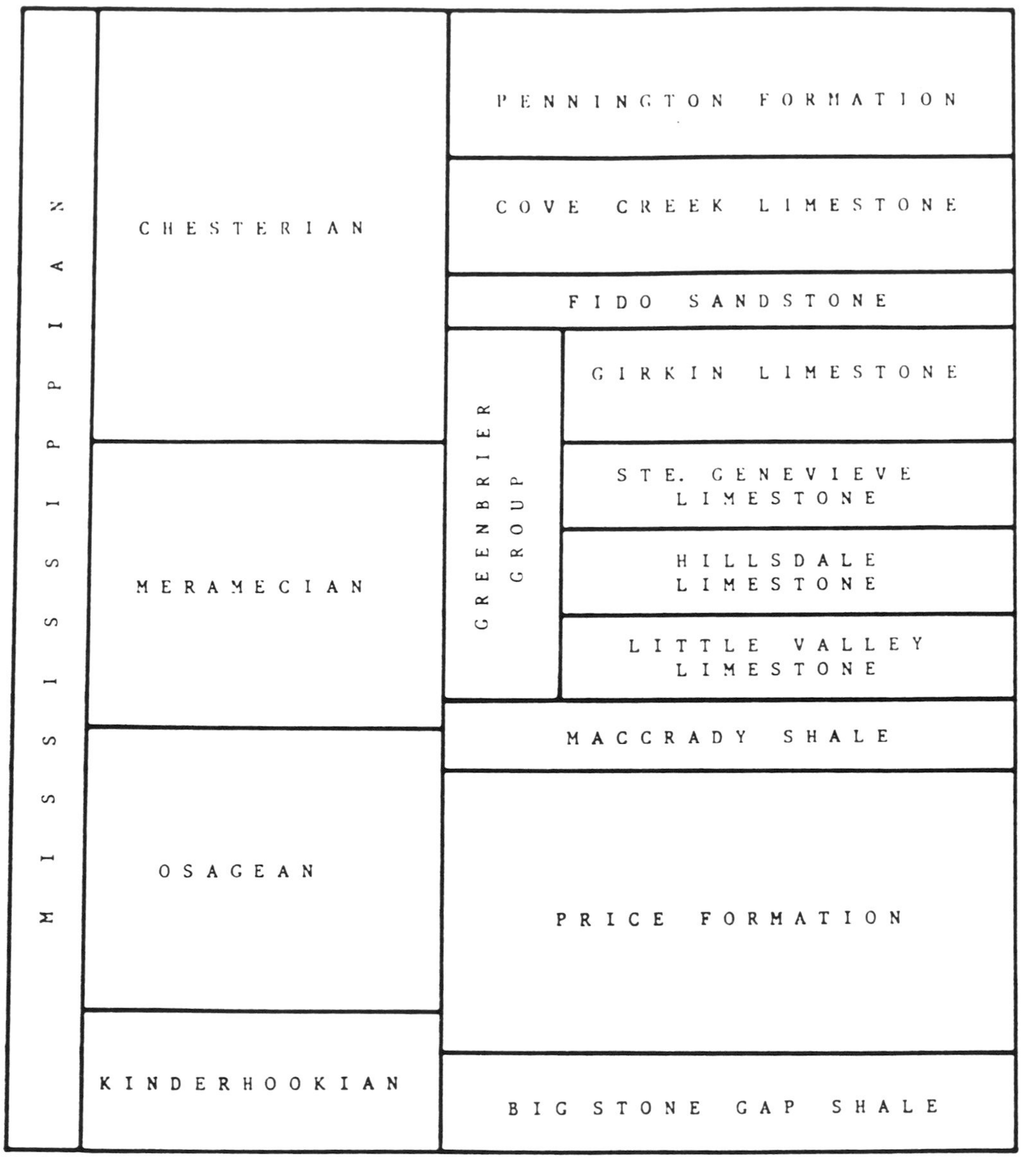

Figure 2. Mississippian stratigraphy of the Greendale Syncline.

He described the Cove Creek, the Glen Dean of Eastern Kentucky and the Bluefield Formation of the western Valley and Ridge as three different facies of what is believed to be the same stratigraphic unit. In the western Valley and Ridge, the Cove Creek equivalent is underlain by the Girkin and overlain by the Stony Gap Sandstone, the basal member of the Pennington Formation. In the Greendale Syncline, the Cove Creek overlies the Fido Sandstone and is bounded above by the shales and siltstones of the Pennington Formation. Butts (1940) described the Cove Creek as occurring only in a single belt in the Greendale Syncline, extending from the Virginia-Tennessee state line in Scott County, northeast to the Saltville Thrust Fault just north of Lindell, Washington County. Wilpolt and Marden (1959) suggested abandoning the name "Cove Creek" in favor of "Bluefield". Due to the imprecise correlation of the units, the Cove Creek nomenclature is retained and used in this study.

PREVIOUS INVESTIGATIONS

The Girkin Limestone was originally referred to as the Gasper Limestone (Butts, 1917) for its similarity to the partly oolitic limestones exposed along the Gasper River in Warren County, Kentucky. Sutton and Weller (1932) considered the Gasper Limestone to be inadequately defined. Butts (1940), however, continued to use the name Gasper for rocks in southwest Virginia considered equivalent to those found in Kentucky. The name Gasper persisted until 1963 when Rainey redefined the formation in its type area and named the unit the Girkin Limestone. The change in nomenclature is followed in this investigation.

Butts (1927) named the Cove Creek Limestone for exposures of argillaceous limestone along Cove Creek in Washington County, Virginia. Detailed investigations of this unit are lacking.

Although correlative units in Kentucky and West Virginia have been studied in some detail, Upper Mississippian carbonates exposed within the Greendale Syncline have not. Reconnaissance and field mapping studies by Butts (1917, 1927, 1940), Averitt (1941), Bartlett and Webb (1971), Bartlett and Biggs (1980) and Bartlett (1981), provide only very general descriptions of the Girkin and Cove Creek Limestones.

METHODS

Sampling

Two partial sections of the Girkin and Cove Creek Limestones were sampled at approximately 6m intervals (more frequently in heterogeneous lithologies). The samples were labled "E" (for Girkin along U. S. 58A, near Holston), "A" (for Cove Creek along U. S. 58A), "C" (for Girkin along State Route 80, in Hayters Gap) and "D" (for Cove Creek along State Route 80) followed by numerals identifying the sample. Sections were measured and described with the results in Appendix A.

Mineral Identification

One hundred and sixty three thin-sections were prepared and stained with a solution of Alizarin Red S and potassium ferricyanide in dilute hydrochloric acid (Evamy, 1963; Katz and Friedman, 1965; Friedman, 1971). With these stains calcite stains red, ferroan calcite stains purple, dolomite does not stain and ferroan dolomite stains light blue. In addition, X-ray diffractometry was employed to aid in determination of mineralogy. All 163 thin-sections were examined and point counted using 300 points per slide. Point count data is presented in Appendix B. Cement filled voids within allochems were counted as allochemical constituents (Dunham, 1962). The petrologic data was analyzed by multivariate statistical tests (cluster analysis) to aid in microfacies determination and the interpretation of depositional environments.

Each of the 163 samples was subjected to acid treatment to isolate non-carbonate material. Samples of approximately 15g to 25g were crushed and added to diluted hydrochloric acid. After allowing sufficient time for dissolution, the excess acid was decanted, the sample was washed in distilled water, filtered, dried in an oven at 75° C for 3 hours and weighed. Calculated percentages are listed in Appendix B.

Statistical Analysis

Cluster analysis is a statistical method used to place objects into groups or clusters suggested by the data, where no "a priori" knowledge exists. If the nature of the measurable distinguishing parameters are properly selected, objects in a given cluster tend to be similar to each other in some sense, and objects in differing clusters will tend to be dissimilar (SAS Institute, 1982).

CONSTITUENTS

INTRODUCTION

Compositional elements recognized from samples taken from the Girkin and Cove Creek Limestones are catagorized into two groups, carbonate and non-carbonate constituents. Carbonate constituents are further subdivided into the various allochemical components. Figures 3 and 4 illustrate Girkin and Cove Creek lithologies and constituents.

CARBONATE CONSTITUENTS

Fossils

Algae

Sedimentary fabrics which include cryptalgal laminations (Fig. 11), microborings of bioclastics and dark brown patches of micrite with faint structure, suggest the presence of algae in the Girkin and Cove Creek sediment. Although no algal remains were observed, several authors have indicated the presence of calcareous algae in Upper Mississippian sediments in West Virginia (Leonard, 1968; Blancher, 1974; Wray, 1977; Gray, 1985).

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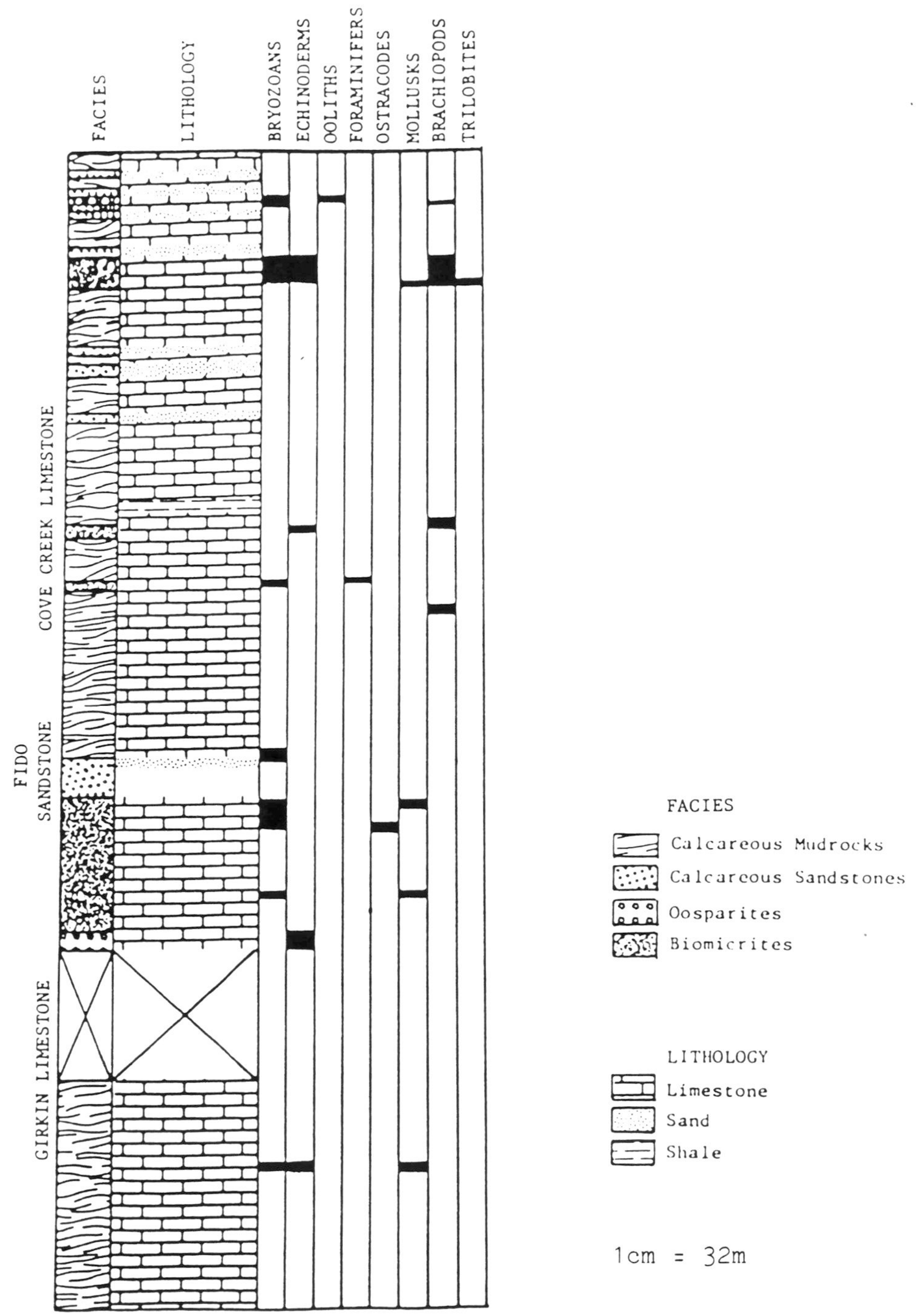

Figure 3. Girkin and Cove Creek lithologies and constituents from the Holston sampling location.

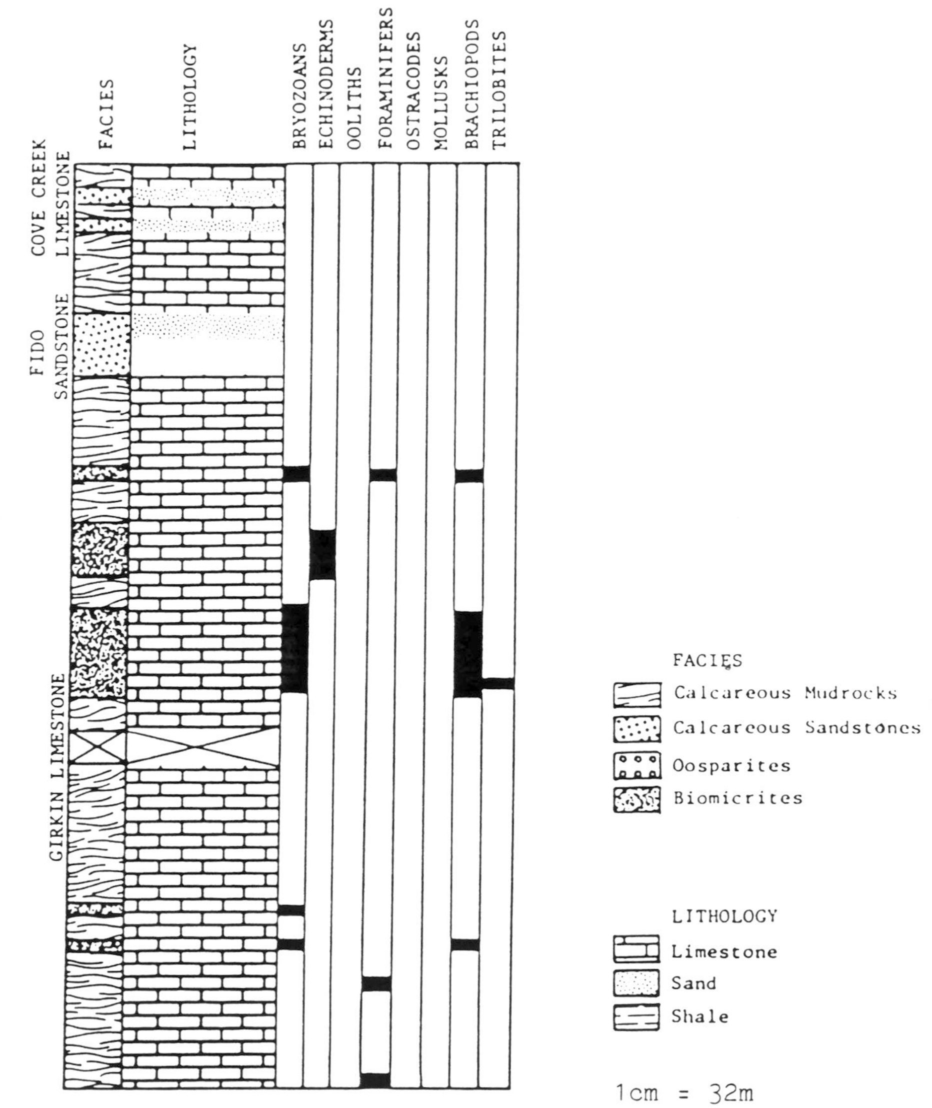

Figure 4. Girkin and Cove Creek lithologies and constituents from the Hayters Gap sampling location.

Arthropods

Arthropod bioclasts in the Girkin and Cove Creek are represented by trilobites and ostracodes. Trilobite fragments exhibit a fine, prismatic microstructure with extinction bands that sweep across the fragment as the stage is rotated. Tangential sections reveal the characteristic "Shepard's Crook" shape. Ostracodes are recognized by their typical morphology, small size, and thin, homogenous prismatic wall structure. Valves are generally less than 0.5mm in length.

Brachiopods

Brachiopods (Fig. 5) occur in minor amounts in both the Girkin and Cove Creek Limestones and are easily recognized in thin section by their laminated wall structure. The parallel laminated wall structure often contains small plications (punctate or pseudopunctate) which are oriented perpendicular to laminated wall structure through the shell. Brachiopod spines are identified by the presence of concentric parallel laminated inner, and radial-laminated outer wall layers as well as a hollow central canal. Both articulate and inarticulate forms are present.

Bryozoans

Bryozoans are the most abundant fossil group recognized within the Girkin and Cove Creek Limestones. They consist primarily of fenestrate

Figure 5. Brachiopod and Echinoderms.

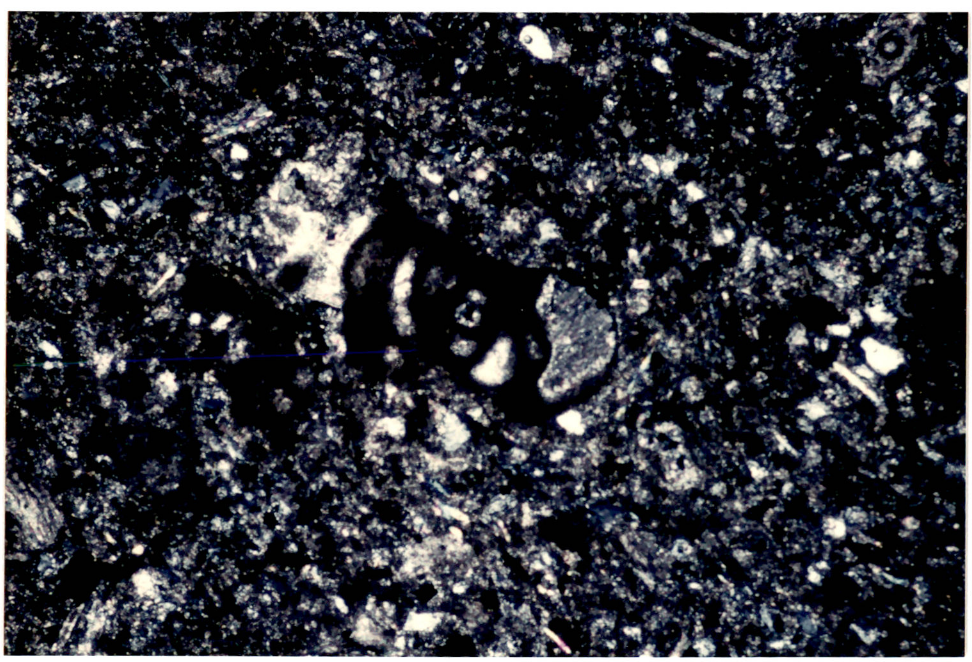

Figure 6. Endothyrid-type Foraminifera

forms, although ramose and encrusting varieties are apparent. In thin section, fronds are frequently micritized, suggestive of algal encrustations.

Echinoderms

The echinoderms, which approach bryozoans in abundance, are recognized in thin section by their characteristic unit extinction (Fig. 5). Blastoids, echinoids and crinoids are all composed of plates and columnals, making identification difficult. Therefore, they were identified as echinoderms. Echinoiderms are occasionally micritized, suggestive of algal activity.

Foraminifers

The foraminifers occur in minor amounts in the Girkin and Cove Creek and are primarily of endothyrid types (Fig. 6). Climacamina sp. has also been identified. Their distinctive chambered tests are filled with micrite or spar, while outer walls are commonly micritized.

Mollusks

Fragments of bivalves, and low spired gastropods (Fig. 7) are sparsely distributed in micritic sediments. In thin section, fragments are commonly recrystallized, making identification difficult.

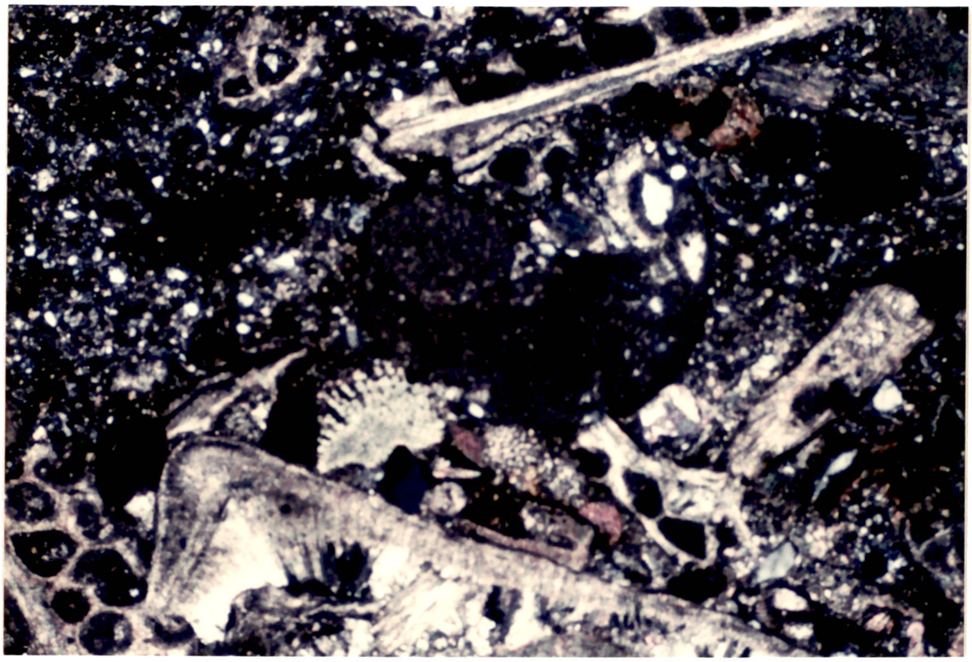

Figure 7. Gastropod.

Figure 8. Isopachous Cement and Syntaxial Cement.

Intraclasts

Intraclasts are penecontemporaneous reworked fragments of locally accumulating sediments. Although rare, in the Girkin and Cove Creek, they are generally rounded, range in size of 0.5-4mm in diameter, and often contain inclusions of skeletal remains.

Pellets

Pellets are very rare in the Girkin and Cove Creek sediments. They are spherical, micritic aggregates lacking any obvious structure, and are less than 0.5mm in diameter. Pellets may represent fossilized fecal matter of burrowing organisms or they may have resulted from abrasion of lithified micrite, i.e. small intraclasts.

Ooliths

Normal ooliths are spherical accretionary grains built of several layers of concentric carbonate laminae around a central core. Individual laminae are indistinct; radial texture, however, is well developed, forming "Maltese crosses" under crossed nichols except in cases where micritzation has obliterated all structures. Ooliths in the Girkin and Cove Creek range in size from 0.8 to 3.5mm with a mean diameter of 1.5mm. Nuclei occur as subrounded to subangular fragments of bryozoans, echinoderms, rock fragments, quartz and brachiopods.

Superficial ooliths (Carozzi,1960; Bathurst, 1967; Flugel, 1982) are generally smaller than normal ooliths with very few (1-3) laminae. In the Girkin and Cove Creek, superficial ooids range from 0.2 to 1.3mm in diameter (averaging 0.4mm) and are recognized by a thin film of iron oxide coating subrounded quartz, rock fragments, echinoderms and feldspars.

NON-CARBONATE CONSTITUENTS

Quartz

Detrital quartz occurs as subangular to subrounded grains ranging in size from fine silt to fine sand. Most quartz grains exhibit straight to slightly undulose extinction and are relatively free of inclusions. Rarer polycrystalline forms are present.

Feldspars

Feldspars form only a small percentage of the detrital grains, either within the calcareous mudrocks or calcareous sandstones. Orthoclase, plagioclase (approximately An40 to An60), and microcline can be distinguished in thin section.

Micas

Muscovite is a common accessory mineral of many argillaceous samples. The mica flakes tend to be oriented parallel to depositional surfaces. For purposes of point-count analyses, micaceous grains less than 0.06mm were classified as matrix.

Clay Minerals

Terrigenous clays are very common in Girkin and Cove Creek sediments, and are classified as matrix in point-count data (Appendix B). X-ray data suggest chlorite and illite are the predominant forms. Due to the small crystal sizes of both clays and carbonate mud, insoluble residue calculations proved useful in distinguishing between the two. Clays also occur in trace amounts as thin, platy flakes replacing feldspars along cleavage planes.

Pyrite

Pyrite is common in many samples as small, opaque grains generally less than 0.2mm in size. Pyrite is found in the matrix, in pressure solution seams and in wall linings of skeletal fragments. Framboidal forms are also present.

DIAGENESIS

INTRODUCTION

All the chemical, physical and biologic changes a sediment undergoes after its deposition, exclusive of metamorphism, is considered diagenesis. It embraces processes such as compaction, cementation, replacement, crystallization, authigenesis and bacterial action which occur under conditions of pressure (up to 1kb) and temperature (maximum range of 100°C to 300°C) which are normal to the Earth's crust.

The following discussion focuses on post-depositional changes which have effected mixed siliciclastic-carbonate sediments in the Girkin and Cove Creek Limestones. Where applicable, the timing of diagenetic events is given.

MICRITIZATION

Micritization is an early diagenetic process and entails the replacement of original carbonate grains by microcrystalline carbonate at the sediment-water interface (Kobluk and Risk, 1977) from the intertidal zone to depths of at least 780m (Perkins and Halsey, 1971).

Two processes are recognized. Degrading micritization is the result of algal, fungal or bacterial borings into carbonate particles whereby the skeletal grain is bored, the boring organism dies and decays, and the vacated tubes are filled with micrite (Bathurst, 1966;

Klement et al., 1967). Aggrading micrite envelopes form from the growth of micro-organisms on the surface of carbonate particles which subsequently protect the grains from being destroyed (Kobluk and Risk, 1977).

Allochems within the Girkin and Cove Creek are affected by degrading micritization and exhibit a wide range of alteration from thin micritic envelopes to completely micritized grains. Echinoderms and bryozoans appear to be the most affected by micritization in which a thin, micritic envelope develops. Total micritization affects foraminifers and some ooliths where original structures are obliterated.

ISOPACHOUS RIM CEMENT

A finely crystalline, isopachous, sparry calcite crust is formed around many allochems in the oosparite microfacies. Isopachous fibrous to bladed crystals grow normal to the surfaces of grains into available pore space. The small, isopachous fibrous or prismatic crystals are generally 0.01 to 0.1mm in length, whereas the larger bladed crystals are approximately 0.4 to 0.8mm. This rim cement is equivalent to cement A of Graf and Lamar (1950). Cement A is common in shallow marine environments and appears in beachrocks and in deeper marine environments with restricted sedimentation (Flugel, 1982).

Isopachous rim cements form under marine phreatic conditions (Longman, 1980). In the Girkin and Cove Creek Limestones isopachous cement preceeds syntaxial and drusy cementation (Fig. 8).

SYNTAXIAL CALCITE CEMENT

Syntaxial cement, sparry calcite formed in optical continuity with a host grain, precipitated into pore spaces and commonly form overgrowths on echinoderm fragments (Fig. 8). Syntaxial overgrowths within Girkin and Cove Creek sediments developed after the formation of a micrite rim. It has been noted, however, that no overgrowths are present on echinoiderm ossicles where such rims are thick. Syntaxial cements also formed after the precipitation of isopachous rim cements. Evamy and Shearman (1965), Land (1970) and Longman (1980) have interpreted syntaxial cements as being an early diagenetic event which occurs in a meteoric phreatic zone.

PORE FILLING CEMENTS

Sparry calcite commonly fills the pore spaces between carbonate and non-carbonate grains in the calcareous sandstones of the Girkin and Cove Creek Limestones. This cement is blocky or granular and commonly forms a poikilotopic texture surrounding terrigenous grains. Crystals are equant, anhedral to subhedral, generally 20 to 50um in size.

Drusy cement is an early diagenetic texture with anhedral to subhedral calcite crystals increasing in size outward from pore walls. This cement is common within the Girkin and Cove Creek oosparites and forms after isopachous cementation and possibly synchronous with syntaxial cement development. Longman (1980) has interpreted drusy cementation as a product of freshwater cementation.

DOLOMITE

Dolomite formation within the Girkin and Cove Creek Limestones is a secondary process, forming as a replacement of earlier blocky calcite cement in calcareous sandstones, as silt-sized rhombs scattered throughout the matrix of calcareous mudrocks and rarely as rhombs in bryozoan zoecia.

Models of dolomitization are numerous. In the Girkin and Cove Creek sediments it is difficult to postulate if any one model was responsible for dolomitization. The most likely model, however, is that proposed by Badiozamani (1973) in which a mixing environment of freshwater and seawater occurs. It is evident that freshwater conditions did occur in the Girkin and Cove Creek, recognized by characteristic meteoric cements.

MICROSPAR

Folk (1959, 1965, 1974) characterized microspar as equant, euhedral to subhedral crystals generally 5-10um in diameter. A size range of 4-30um corresponds to the micrite II of Bosselini (1964). The wider range is used for the size range of microspar. In Girkin and Cove Creek sediments microspar takes the form of scattered, variable sized crystals within mudrocks and biomicrites.

Two methods of microspar formation have been proposed. The first is an aggrading process whereby available Mg^{++} forms a "cage" around microcrystalline calcite crystals, preventing a growth larger than 2-3 microns. The removal of Mg^{++}, initiated in a brackish water or freshwater environment, allows for the growth of calcite crystals to microsparite (Folk, 1974). Lasemi and Sandberg (1984), however, suggest a one step origin in the formation of microspar from an aragonitic mud. They do not envision the mud first calcitizing to micrite and then altering to microspar by aggrading neomorphism.

SILICIFICATION

Silicification is the introduction of, or the replacement by silica, resulting in the formation of fine-grained quartz, chalcedony or opal. Silicification within the Girkin and Cove Creek affects echinoderms, brachiopods, mollusks and bryozoans whereby replacement is characterized by chalcedony and, in rarer cases, microquartz. Possible sources for silica include 1) biogenic material, 2) dissolution of feldspars and volcanic fragments, 3) pressure solution, and 4) alteration of clays.

One of the most important sources of silica is biogenic material. Two ways in which this may occur are 1) from siliceous organisms such as sponges, diatoms and radiolarians and 2) as varying proportions of silica within calcareous organisms. This is especially true of the echinoderms, in which ancient forms contain as much as 29% silica (Clarke and Wheeler, 1922).

Dissolution of volcanics (Berner,1971) and feldspars (Fuchtbauer, 1979) can be an important source of silica. Volcanic rock fragments have been identified within the intervening Fido Sandstone (Neal, 1984), however, volcanics are not recognized in the Girkin and Cove Creek Limestones. Therefore, volcanic material is not thought to be a primary producer of silica. Since feldspars account for less than one percent of total rock volume they are considered insignificant as a contributor.

Investigations by Heald (1959), Sibley and Blatt (1976) and Fuchtbauer (1979) indicate that pressure solution may contribute to silicification. Authigenic overgrowths are lacking in the Girkin and Cove Creek and it is uncertain if pressure solution provided silica.

Some investigations indicate the alteration of clays may produce silica. The smectite to illite transformation in shales (Fuchtbauer, 1979) and the alteration of illite to muscovite (Towe, 1962) can contribute to silica production.

COMPACTION

Compaction refers to any process that decreases the bulk volume of sediments. Compaction is generally considered an early diagenetic change. Some carbonate sediments, however, are only affected by compaction in a deep burial stage (Flugel, 1982). Compaction features in the Girkin and Cove Creek include ooid deformation and pressure solution. Prior to isopachous cementation, some of the ooid lamellae were spalled (Fig. 9), perhaps by overburden pressures.

Pressure solution is the preferential dissolution of mineral material at points of stress. Two styles of pressure solution (Wanless, 1979) are observed in the Girkin and Cove Creek Limestones. Sutured seam solutions occur in the oosparites which lack significant amounts of matrix. Stylolites and grain-to-grain contact sutures form irregular interpenetrating surfaces, shortening parallel to the direction of maximum stress. Grain-to-grain contacts are easily recognized where loss of material at point contacts is evident (Fig. 10). These contacts

Figure 9. Ooid Deformation.

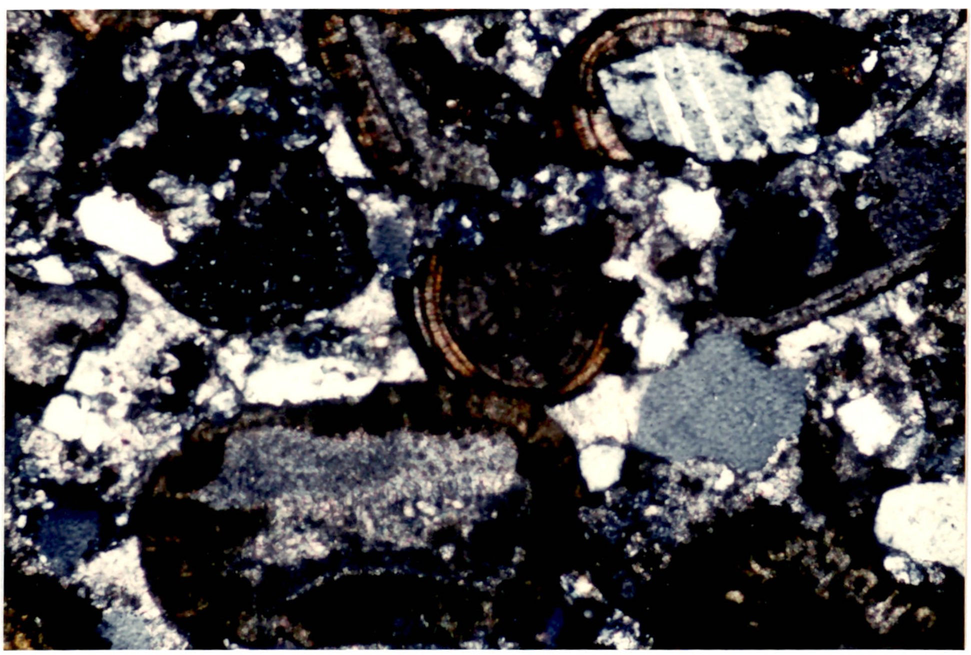

Figure 10. Grain-to-Grain Pressure Solution.

are both planar and sutured. Bathurst (1971) indicated the timing of grain-to-grain sutures as prior to the emplacement of a second generation cement.

Non-sutured seam solution occurs where significant portions of clay or platy silt are present. This solution feature is common in the calcareous mudrocks, where pressure solution produces fine clay seams. These seams have been described as clay seams (Barrett, 1964), horsetails (Roehl, 1967), wispy laminae (Lucia, 1972), wavy laminae (Reinhardt and Hardie, 1976), pseudo-stylolites (Shinn et al., 1977) and microstylolites (Wanless, 1979).

Depth of burial and pressures capable of producing pressure solutions are variable. Dunnington (1967) reported in many instances that overburdens of 500-800m were required for pressure solution, however, Schlanger (1964) reported formation of clay seams at depths of 82m or less.

PYRITE AND HEMATITE

Pyrite in the Girkin and Cove Creek Limestones is a widely distributed, isometric, opaque mineral. It commonly oxidizes to hematite and iron hydroxides which often form pseudomorphs after the common pyrite forms. Pyrite forms under a large range of geologic conditions. It is most commonly formed early during diagenesis, under reducing conditions. In these units, localized pyrite probably formed in a stagnant marine environment, possibly influenced by the action of microorganisms.

SUMMARY

The diagenetic sequence interpreted for Girkin and Cove Creek Limestones is summarized in Table 1. Diagenesis within these mixed siliciclastic-carbonate sediments began shortly after deposition in the marine environment with micritization of carbonate grains and the formation of pyrite. Mechanical compaction and initial cementation began soon after deposition with the formation of isopachous rim cements that loosely bound the sediments. With subsequent burial, several diagenetic processes were active including pressure solution and the precipitation of syntaxial, drusy and blocky cements. These cements may have been related to continued development of the Upper Mississippian-Pennsylvanian clastic wedge and an associated freshwater lens. As burial continued, dolomitization, pressure solution and fracturing developed. Microspar formation and silicification may occur under various conditions, where precise timing is uncertain.

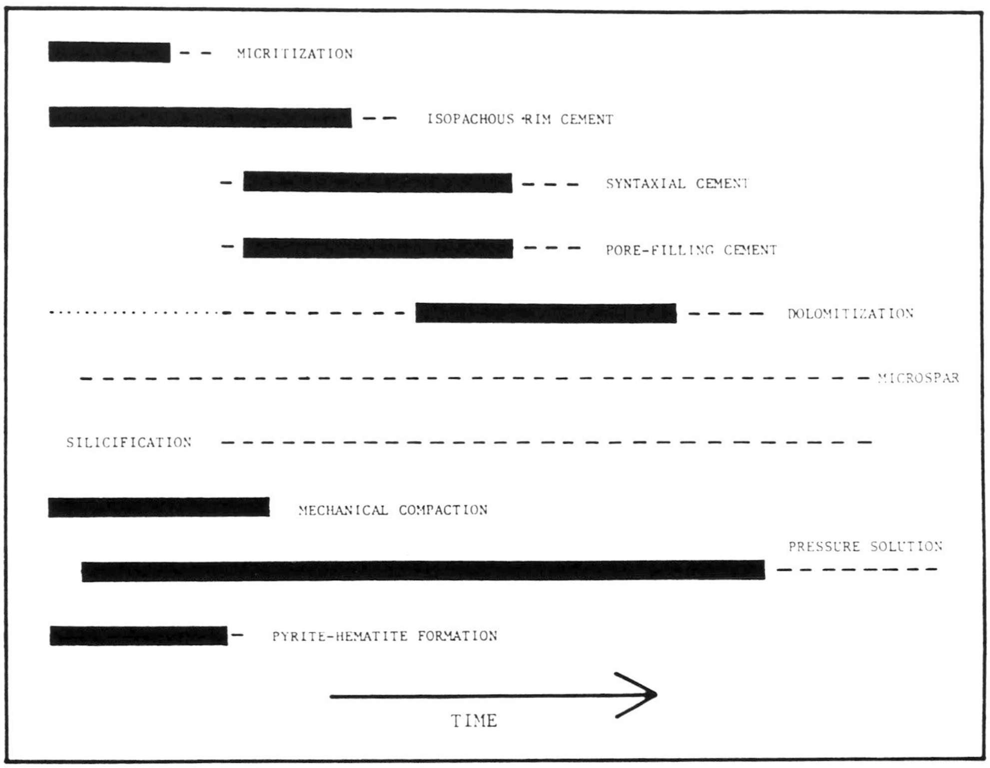

Table 1. Diagenetic sequence in the Girkin and Cove Creek Limestones.

FACIES

INTRODUCTION

Four facies are recognized within the Girkin and Cove Creek Limestones. They are 1) calcareous mudrocks, 2) calcareous sandstones, 3) oosparites, and 4) biomicrites. These facies are divisible on the basis of point-count and insoluble residue data. The data were also analyzed by cluster analysis as a suppliment to petrographic subdivision. Criteria for subdivision include, for calcareous mudrocks, the high percentage of matrix; for calcareous sandstones, the high percentage of terrigenous minerals; for oosparites, the high percentage of ooliths; and, for biomicrites, the high percentage of fossils and carbonate matrix. A graphic comparison of constituents for each facies is given in Table 2.

CALCAREOUS MUDROCKS

The calcareous mudrocks are the most abundant facies present within the Girkin and Cove Creek. Field descriptions of this facies are varied. Generally, these rocks are medium-light to medium-dark gray, often weathering to a shaly appearance. Most samples exhibit horizontal, planar to wavy laminations averaging 0.3mm in thickness. Sedimentary features include cryptalgal laminations (Fig. 11), flaser and cross stratification, and wisps. Evidence of bioturbation is common

	CALCAREOUS MUDROCK (n=128)	CALCAREOUS SANDSTONE (n=4)	OOSPARITE (n=4)	BIOMICRITE (n=27)
Quartz	8.8	33.3	5.2	3.9
Feldspar	0.2	3.2	0.7	0.2
Rock Frags.	0.6	11.6	2.1	0.5
Matrix	83.2	14.7	10.2	59.5
Intraclasts	0.2	0.0	1.7	4.3
Echinoderms	0.3	0.6	3.2	7.3
Brachiopods	0.1	0.07	0.5	1.8
Bryozoans	1.1	0.07	7.1	18.4
Ostracodes	0.004	0.0	0.0	0.1
Foraminifers	0.02	0.0	0.0	0.2
Mollusks	0.006	0.0	0.0	0.06
Trilobites	0.0	0.0	0.0	0.04
Ooliths	0.0	0.25	55.6	0.3
Spar	4.1	26.87	13.3	2.2
Microspar	0.01	0.0	0.3	0.0
Dolomite	0.4	6.75	0.0	0.1
Pyrite	0.7	0.43	0.0	0.5
Hematite	0.2	2.97	0.1	0.3
Unknown	0.06	0.0	0.0	0.3
Insolubles	55.3	68.2	18.8	36.4
Carbonate	44.7	31.75	81.2	63.6

TABLE 2. Mean values(percentages) of constituents of the Girkin and Cove Creek Limestone facies.

in many samples. Interbedded within the mudrocks, are thin beds (less than 1.5m thick) of shale and siltstone reflecting variations in energy and terrigenenous input. Allochems are represented by bioclastic fragments of bryozoans (1.1%), echinoderms (0.3%) and brachiopods (0.1%) generally 0.5mm in length. Rarer forms include foraminifers (0.02%), ostracodes (0.004%), and mollusks (0.006%).

Non-carbonate grains include subangular to subrounded silt- and sand-sized quartz, feldspar and rock fragments. Feldspars include untwinned potassium feldspar, microcline and plagioclase. The plagioclase feldspars range in composition from approximately An40 to An60 as determined by the Michel-Levy method (Phillips and Griffin, 1981).

For the purpose of point-counting, materials less than approximately 0.005mm were classified as matrix. Terrigenous clays and microcrystalline calcite are the dominant matrix constituents. X-ray data suggest chlorite and illite are predominant clays. Due to the small crystal sizes of both clays and carbonate mud, insoluble residue calculations proved useful in distinguishing between the two (Table 2). Pyrite and hematite are found in most samples in the form of framboids, as small opaque grains disseminated throughout the matrix, along pressure seams, and in wall linings of skeletal fragments.

The calcareous mudstones have undergone a variety of diagenetic alteration. Micritization, a syn-depositional process which commonly forms micrite envelopes, is perhaps the most evident form of diagenesis in these rocks. Other diagenetic processes include the precipitation of sparry calcite, (both poikilotopic and syntaxial forms), microspar formation, silicification and dolomitization.

The calcareous mudstones are fine-grained, argillaceous rocks with less than 2% bioclastic material. The paucity of bioclastics may suggest conditions were unsuitable for many organisms. Restrictive currents may have failed to supply the nutrients required for survival. Abnormal salinities and/or the excellerated input of terrigenous material also may have prohibited organic activity. The presence of bioturbation features indicate, however, that some organisms survived under such conditions.

Cryptalgal laminations are present (Fig. 11), and are an important environmental indicator. Modern algal-laminated sediments are formed by the sediment trapping and binding action of blue-green algal mats, as commonly found in the intertidal and supratidal zones of Shark Bay (Davies, 1970), the Persian Gulf (Purser, 1973) and the Bahamas (Shinn et al., 1969). Algal-laminated sediments are affected by burrowing and browsing organisms. Only under specific environmental conditions are these laminae preserved. Algal-laminated deposits of the intertidal zone of Shark Bay are preserved in hypersaline areas (greater than 56% salinity), where burrowing and browsing organisms are limited by high salinities. The rare occurrences of algal-laminated sediments of the calcareous mudstones may indicate local areas of higher salinity or some other factor limiting burrowing and browsing.

The mudstones could be of subtidal origin or could represent sediments of shallower, perhaps intertidal muds. A shallow water genesis is supported by cryptalgal features and lack of bioclastic material. The absence of mud cracks (Shinn, 1964) and well developed stromatolitic features such as found in modern laminated muds (Laporte, 1967; Illing et al., 1965) would seem to argue against a supratidal

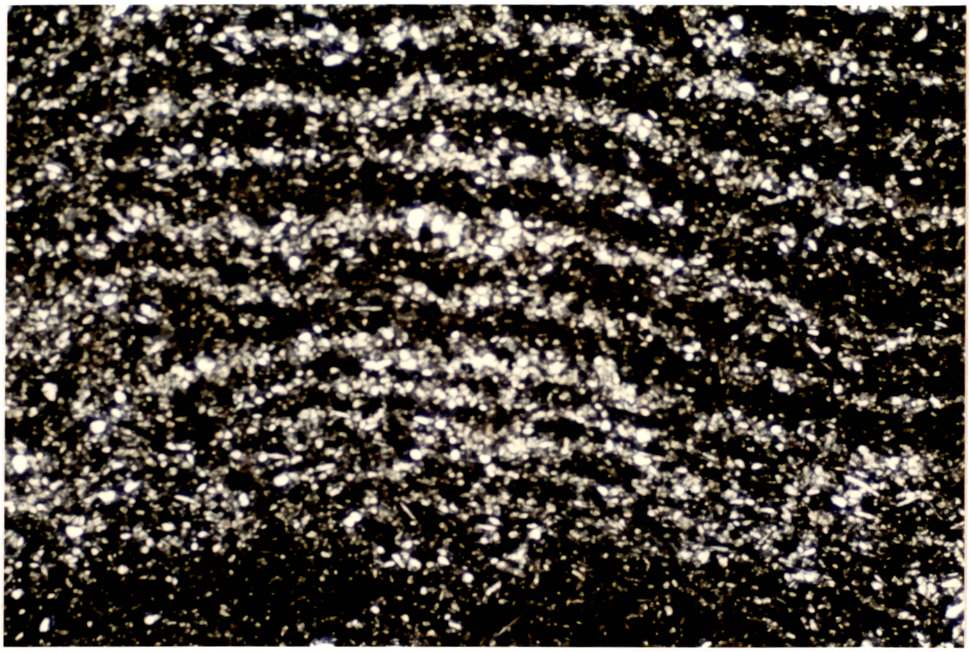

Figure 11. Cryptalgal Lamination.

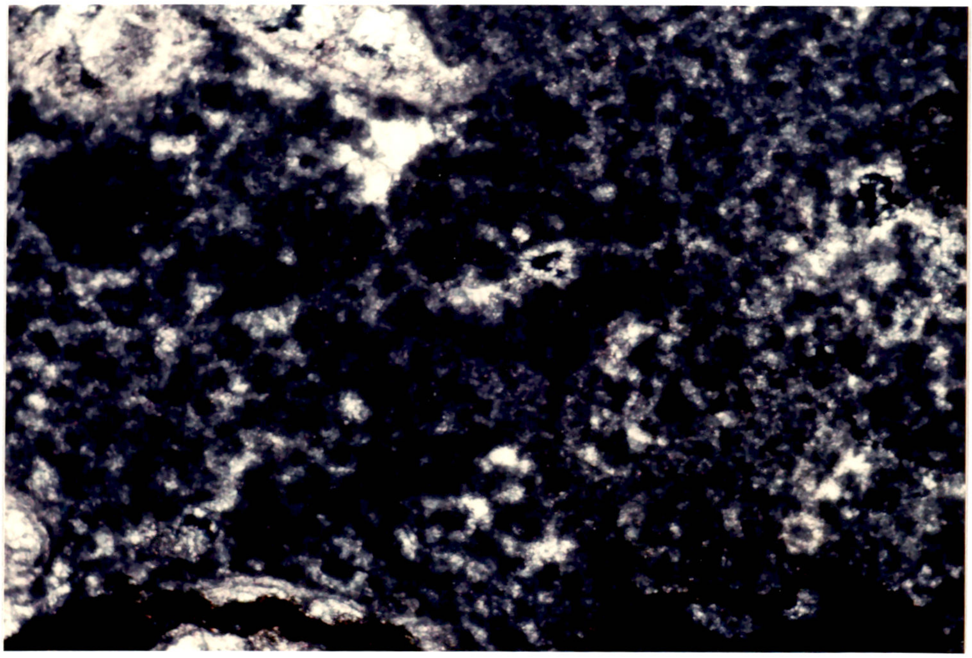

Figure 12. Clotted Texture.

origin. Ginsburg et al. (1957), attribute the absence of these features to extended periods of emergence. However, Simonson and Walker (1984) note that mixed carbonate-siliciclastic sediments may lack characteristic tidal-flat features due to an abundance of clay material. Therefore, the mixed carbonate-siliciclastic tidal-flat behaves as a soft sediment, having high water content far longer than pure carbonates. Whatever their mode of origin, continued subsidence was necessary to account for the thick accumulation of the calcareous mudrocks.

CALCAREOUS SANDSTONES

The calcareous sandstones contain varied amounts of terrigenous and matrix material Table 2. Matrix ranges from 5% in clean, moderately sorted sands to as much as 15% in gradational calcareous sandstones-mudrocks. Residue bulk consists of clear, inclusion free, subangular to subrounded quartz. The quartz grains exhibit straight to slightly undulose extinction and lack evidence of secondary overgrowths. The skeletal-carbonate components (less than 2%) include fragmented fossil debris which is commonly micritized.

Distribution and degree of dolomitization (0-26%) is variable from sample to sample. Stylolites and microstylolites are pervasive throughout the calcareous sandstones. Pyrite and hematite are common.

The calcareous sandstones accumulated by major influxes of terrigenous material at the expense of carbonate deposition. Tidal currents appear to have prevented carbonate muds from settling so that later sparry calcite cement precipitated in interstitial pores. This facies interfingers with calcareous mudstones and appears to have been deposited above wave base in a rather moderate to high energy environment.

OOSPARITES

Oosparites are composed of approximately 67% allochems consisting of 11% fossils, 11% normal ooids and 45% superficial ooids. Macroscopically, the oosparites are dark-red-brown, moderately sorted and medium- to thick-bedded.

Pore filling cements include isopachous radial rim, drusy and syntaxial cements. The results of compaction are pronounced, and include the spalling of ooid corticies (Fig. 9). Pressure solution features in the form of microstylolites and stylolites, are common (Fig. 10).

The oosparites interfinger with the calcareous mudstones and biomicrites. High-energy, shallow subtidal conditions of deposition are indicated by the grain-supported framework, the lack of carbonate mud, and the abundance of ooids.

Modern marine ooids form in shallow, well agitated environments where water depths are generally less than 2 meters (Newell et al, 1960). Conditions for growth include warm water, calcium carbonate supersaturation and normal to high salinity (Flugel, 1982). Ooid accumulations occur in a variety of geometries and most often form at a break in slope. The presence of ooid micritization also indicates shallow water deposition. The commonly recognized formational processes are limited to the photic zone, specifically in shallow current swept areas.

The oosparites of the Girkin and Cove Creek Limestones developed on a shallow carbonate shoal over which ocean waters flowed turbulently. Environmental stresses, including high-energy conditions, quartz sand influx and a shifting substrate, were the primary causes for the absence of organisms. The abundance of superficial ooids suggests that currents were not capable of keeping the substrate mobile. The fact that micritization is present attests that grains were exposed on the seafloor for periods of time sufficient to allow grain degradation.

BIOMICRITES

The second most abundant facies in the Girkin and Cove Creek is the biomicrites. Fossil content averages 28%, including whole and fragmented bryozoans (18.4%), echinoderms (7.3%), brachiopods (1.8%) mollusks (0.06%), trilobites (0.04%) foraminifers (0.2%) and ostracodes (0.1%). Other allochemical constituents include intraclasts (4%) and ooliths (0.5%). Sediments are poorly to moderately sorted with varying proportions of clay and quartz silt.

In outcrop, the biomicrites are thick-bedded, medium to medium-light gray, and weather to light-olive gray. In hand sample, bryozoans and pelmatozoans are easily recognized.

Micrite is the pervasive interstitial matrix in the biomicrites. Some samples exhibit a "clotted" texture which designates structureless micritic lumps. These "clots" are 50 to 125 microns in size, exhibit indistinct boundaries and have the appearance of being fused (Fig. 12). At present, there are two theories proposed for this texture. First, the micrite matrix recrystallizes (Schwarzacher, 1961) and secondly, the mud particles disintegrate early and fuse during compaction. The latter theory is commonly preferred (Illing, 1954; Bachmann, 1973; Flugel, 1982). It has been postulated that boring organisms and detritus-feeders may contribute significantly to the origin of the clotted structure (Flugel, 1982).

Micritization is an early diagenetic condition which affects most skeletal material. A wide range of alteration occurs, from thin micritic envelopes to completely micritized grains. Other diagenetic processes include patchy spar cementation and recrystallization, silicification, stylolitization and microspar formation.

The biomicrites are characterized by a high faunal content, abundant lime mud and micritization of allochems. The skeletal fauna characteristically inhabit a low-energy, well-oxygenated, normal salinity environment. Based on the preserved fauna, the environment was conducive to attached organisms. The abundance of lime mud also suggests that the biomicrites probably accumulated under low-energy subtidal conditions below wave base.

Recent investigations include several different interpretations for the accumulation of lime mud. Modern lime muds are accumulating below wave base in low-energy environments of Shark Bay (Davies, 1970), the Persian Gulf (Purser, 1973), the Bahamas (Shinn et al., 1969; Cloud, 1962) and British Honduras (Matthews, 1966). These modern muds are commonly derived from the breakdown of skeletal material (Cloud, 1962; Matthews, 1966; Stockman et al., 1967; Davies, 1970). Stockman et al. (1967) discussed the importance of micrite production by algae in the Florida Bay. In addition to algal influences, other organic processes are thought to exist. Biological abrasion, such as rasping by gastropods and the intestinal grinding of sediment-injesting organisms might produce significant amounts of fine material (Stieglitz, 1973; Flugel, 1982). Two principle bacterial processes, sulfate reduction and ammonia formation, can result in the formation of excess HCO3 aq in sediment pore waters from the reaction of sulfide and ammonia with bacteriogenic CO2. This excess bicarbonate may cause the precipitation of CaCO3 (Berner, 1971).

Davies (1970) noted that sea grasses in Shark Bay influence the depositional environment by: 1) accumulating skeletal carbonate material from the seagrass community, 2) reducing current movement near the bottom forming a layer of still water in which clay- and silt-sized particles can accumulate and, 3) the binding of sediments by seagrass root systems. It may be possible that dense stands of fenestellid bryozoan communities in the Girkin and Cove Creek could have served as limited baffles which may have contributed to lime mud accumulation.

DEPOSITIONAL MODEL

Four facies, representing distinct environmental conditions, have been identified in the Girkin and Cove Creek Limestones of Washington County, Virginia. It is suggested that these Upper Mississippian carbonate-siliciclastic sediments were deposited on a homoclinal carbonate ramp.

In general, a ramp (Fig. 13) is a gently sloping platform (generally less than 1°) that extends basinward without a pronounced break in slope (Ahr, 1973). Shallow, wave-agitated facies of the nearshore zone pass downslope into deeper water, low energy deposits (Ahr, 1973; Read, 1982). They differ from rimmed shelves in that continuous reef trends are absent and buildups are separated and discrete. Ramps generally develop at times of tectonic or climatic crises in which reef formers are poorly represented (James, 1979).

Homoclinal ramps are characterized by uniform slopes dipping into the basin. They generally lack significant gravity flow deposits and slumps in deeper-water facies as compared to periplatform deposits (Read, 1982). Homoclinal ramps are located well landward of the continental-ocean crust boundary on continental margins, on underthrusting continental crusts in foreland basins, or in continental interiors (Read, 1985).

The calcareous mudrocks of the Girkin and Cove Creek are composed of various mixtures of carbonate and siliciclastic materials. These sediments are interpreted as shallow, nearshore, low-energy deposits

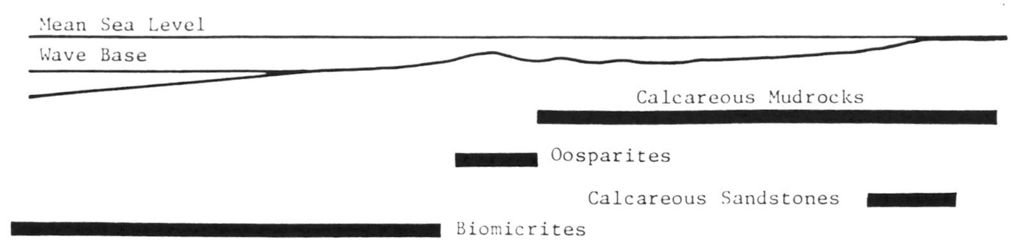

Figure 13. Homoclinal ramp model.

where coastal systems acted as a transport mechanism, mixing carbonates and siliciclastics. These sediments are similar to tidal-flat deposits, however, typical tidal-flat sedimentary and diagenetic features are lacking. It is possible that the argillaceous mud retarded early cementation, dolomitization, and extensive algal mat development. Simonson and Walker (1984) indicate mixed carbonate-siliciclastic tidal-flat complexes exhibit soft sediment deformation and diffuse burrows. These sediments had high water content far longer than would be expected of pure carbonates.

Oosparites were deposited seaward of the calcareous mudrocks in a shallow, highly agitated area of the carbonate ramp. They may have formed as discontinuous bars or shoals at or near wave base.

The biomicrites contain the most abundant remains of diverse, open marine organisms of all the other facies. The organisms served as sediment producers and, perhaps, as sediment bafflers and binders. The biomicrites formed below wave base, basinward of the oosparites and calcareous mudrocks. Micritic intraclasts may have formed when storms passed over the ramp.

Calcareous sandstones are cross-bedded quartz sediments containing a paucity of fossil material. They are indicative of a high-energy, nearshore environment and represent significant clastic input during Late Mississippian time. Due to the lack of characteristic sedimentological evidence, a definitive depositional environment is not proposed. However, they may represent tidal channel deposits or strandline accumulations.

GEOLOGIC HISTORY

The Vertical distribution of facies (Fig. 14) reflects the cyclic nature of these Upper Mississippian sediments. The cyclic pattern is the result of changing environmental parameters. The lithologic sections also illustrate the complicated lateral variations in the two sections, making correlation difficult. This complexity suggests local variation in the coastal environment rather than regional changes resulting from periodic uplift of a southeastern highland, episodes of basin subsidence, and fluctuations in eustatic sea level. The general trend of a shallowing upward sequence as demonstrated by the Girkin and Cove Creek is, perhaps, more related to these factors.

The majority of terrigenous clastics in Girkin and Cove Creek sediments was derived from the erosion of metamorphic and sedimentary highlands to the east and southeast (Cooper, 1964). As these highlands were eroded, streams swept large amounts of detritus to the west and northwest where the sediments were winnowed and sorted by waves and currents. During Girkin and Cove Creek time, broad tidal flats of mixed siliciclastic-carbonate sediments formed as terrigenous sediment from the eastern highland source mixed with basin carbonates. Minor variations in terrigenous influx could account for local coastal displacement.

As sediments were accumulating within the Appalachian basin, local areas of downwarping occurred. Isopach maps of the Greendale Syncline indicate Chester age rocks were thicker in the syncline than in adjacent

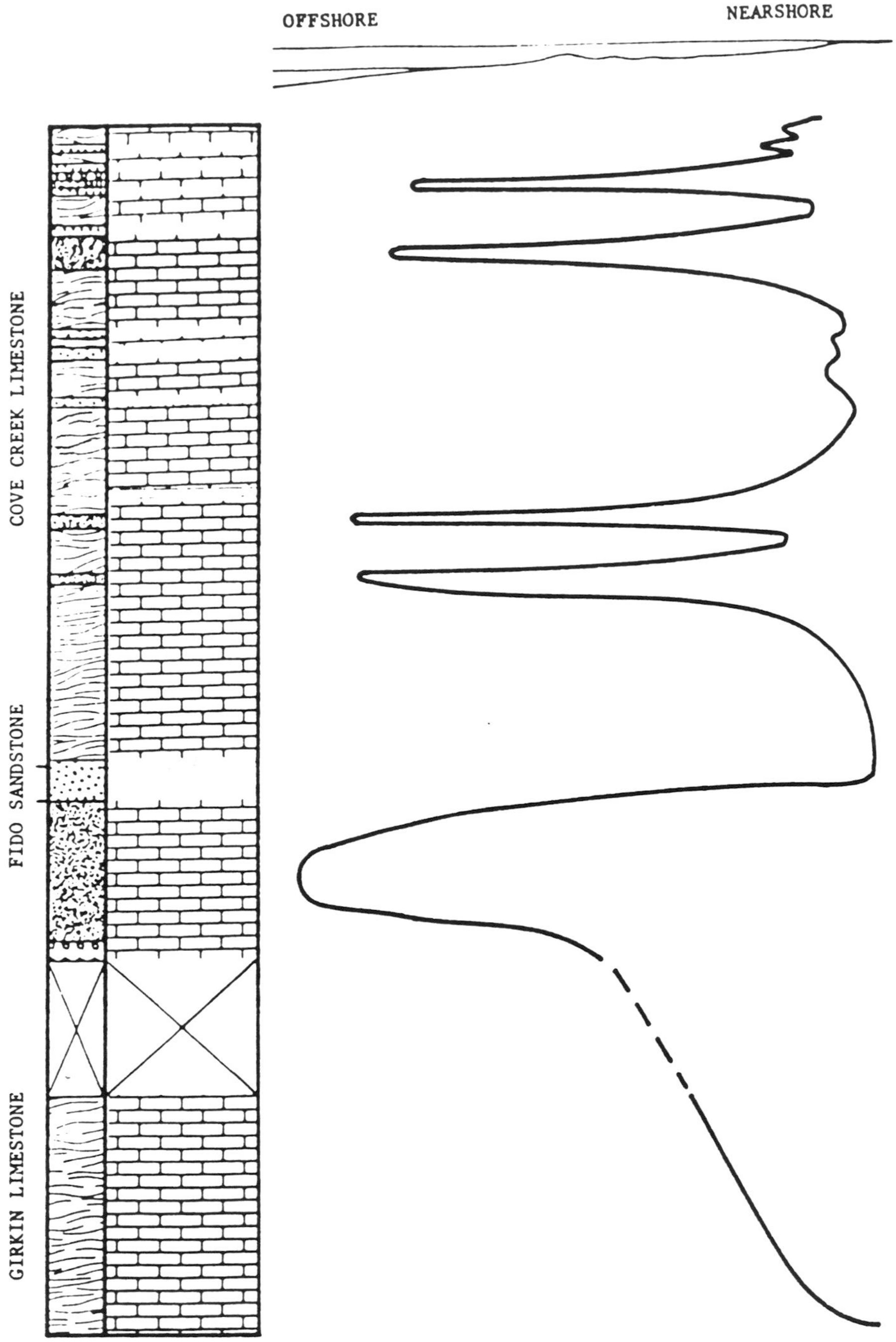

Figure 14. Vertical distribution of facies.
1cm = 32m

areas (Cooper, 1964). This suggests that local folding occurred during the deposition of the Girkin and Cove Creek strata and as the syncline increased in size, it acted as a trap for detritus eroded from the adjacent boarderlands. Fluctuations in the rate of subsidence, as well as the rate of clastic influx, may have resulted in the lateral migration of facies, thus, acting as a mechanism responsible for cyclic variations.

Regionally, it is evident that the source areas were uplifted and large amounts of material accumulated to form a large coalescing delta complex (Pennington Formation). These clastics were confined to the eastern portion of the basin during early Chester time (deWitt and McGrew, 1979). By late mid-Chester time a delta-alluvial plain was formed and the westward expanding wedge of detritus had displaced the Chester sea to the west. During late Chester time, the seas continued to retreat to the west and southwest as a result of the ever expanding delta. By the end of Chester time, the sea had withdrawn from all but the extreme western part of the basin (deWitt and McGrew, 1979).

Vail et al. (1977), devised a sea level curve which reflects global cycles of relative changes in coastal onlap through geologic time. During Late Mississippian time a second order regressive cycle is recognized. This is consistent with the present data which illustrate a prograding deltaic wedge which displaced a late Chesterian sea to the west.

Lithologic evaluation suggests that argillaceous sediments of the Girkin and Cove Creek Limestones formed in response to continued development of a delta sequence to the east. As fluvial transport systems matured, the accumulation of mixed siliciclastic-carbonate rocks resulted. Since clastics of the Pennington sequence overlie Girkin and Cove Creek sediments it is plausible to suggest these two formations represent a transition between carbonate and clastic sequences in both environment and lithology. Cyclic successions within the Girkin and Cove Creek are oscillations that represent local transgressive-regressive sequences superimposed on a broad offlapping succession.

SUMMARY OF CONCLUSIONS

1) Sediments were deposited on a homoclinal ramp on which subtidal, low-energy biomicrites grade up slope into oolitic sediments characteristic of a shallow, highly agitated shoal. The nearshore calcareous mudrocks are indicative of intertidal to tidal-flat sediments. Calcareous sandstones are indicative of a high energy, nearshore environment, possibly tidal channels or strandline accumulations.

2) Cyclic depositional patterns formed in response to changing environmental parameters. Periodic uplift of a southeast highland, episodes of basin subsidence, and fluctuations in eustatic sea level contributed to the environmental changes recorded in this sequence.

3) Diagenesis within the Girkin and Cove Creek Limestones began shortly after deposition in the marine environment with micritization of carbonate grains and the formation of pyrite. Mechanical compaction and initial cementation by isopachous rim cements began soon after deposition. With subsequent burial, several diagenetic processes were active including pressure solution and the precipitation of syntaxial, blocky and drusy cements. These cements may have been associated with freshwater lenses in connection with the development of the Upper Mississippian-Pennsylvanian clastic wedge. Dolomitization, pressure

solution and fracturing occurred with continued burial. Microspar formation and silicification are also present in Girkin and Cove Creek sediments.

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APPENDIX A

APPENDIX A

Measured Sections

Holston Section

Unit		Cumulative Thickness(meters)	Interval Thickness(meters)
Cove Creek Limestone (272.8m)			
1.	Light gray calcareous mudrock.	0-8.2	8.2
2.	Light gray calcareous sandstone.	8.2-11.3	3.1
3.	Light gray calcareous mudrock, bioturbated.	11.3-17.7	6.4
4.	Light gray calcareous sandstone	17.7-19.8	2.1
5.	Dark-Red-Brown oosparite, medium-to thick-bedded, fossiliferous.	19.8-22.9	3.1
6.	Brownish gray Biomicrite, thick-bedded, abundant bryozoans and echinoderms.	22.9-25.6	2.7
7.	Medium-light gray calcareous sandstone	25.6-28.7	3.1
8.	Light gray-medium-light gray calcareous mudrock, medium-bedded, trace fossils, bioturbated.	28.7-43.0	14.3
9.	Light gray calcareous sandstone.	43.0-44.8	1.8
10.	Medium-light gray Biomicrite, thick-bedded, abundant bryozoans and echinoderms.	44.8-61.0	16.2
11.	Medium gray calcareous mudrock, laminated, bioturbated.	61.0-87.5	26.5
12.	Medium-light gray calcareous sandstone, medium-to thick-bedded.	87.5-90.8	3.3
13.	Medium-light gray calcareous mudrock, laminated, trace fossils, N65E 25SE.	90.8-95.1	4.3
14.	Medium-light gray,calcareous sandstone, minor dolomitization, moderately-poorly sorted.	95.1-99.7	4.6
15.	Light olive gray calcareous mudrock, cryptalgal laminations, trace bryozoans.	99.7-117.9	18.2

Unit		Cumulative Thickness(meters)	Interval Thickness(meters)
16.	Medium-light gray calcareous sandstone	117.9-120.4	2.5
17.	Medium-light gray calcareous mudrock, thin, wavy, laminations, flaggey.	120.4-159.1	2.5
18.	Black,fissile shale with slickensides.	159.1-160.6	1.5
19.	Medium-light gray calcareous mudrock, trace bryozoans and echinoderms.	160.6-166.1	5.5
20.	Medium-gray Biomicrite, thick-bedded, abundant Bryozoans and echinoderms, trace foraminifers, trilobites, brachiopods, ostracodes and mollusks.	166.1-172.2	6.1
21.	Medium gray calcareous murdock, wispy laminae.	172.2-189.9	17.7
22.	Medium gray biomicrite, thick-bedded, abundant bryozoans and echinoderms, trace brachiopods, mollusks and ostracodes.	189.9-196.0	6.1
23.	light gray calcareous mudrock, finely laminated, bioturbated.	196.0-269.7	73.7
24.	medium-light gray calcareous sandstone, moderately-poorly sorted, medium-to thick-bedded.	269.7-272.8	3.1
Fido Sandstone (15.2m)			
25.	Dark-red-Brown sandstone	0-15.2	15.2
Girkin Limestone (231.6m)			
26.	Medium gray biomicrite, thick-bedded, abundant bryozoans and echinoderms, trace foraminifers and brachiopods.	0-62.2	62.2
27.	Dark-red-brown oosparite, medium-to thick-bedded, moderately sorted.	62.2-71.0	8.8
28.	Covered.	71.0-128.0	57.0
29.	Medium-light gray calcareous mudrock, finely laminated, bioturbated, trace echinoderms and bryozoans, N70E, 24SE.	128.0-231.6	103.6

Hayters Gap Section

Unit	Cumulative Thickness(meters)	Interval Thickness(meters)
Cove Creek Limestone (82.3m)		
30. Light gray calcareous mudrock, finely laminated, flaggey.	0-2.1	2.1
31. Light gray calcareous sandstone, minor dolomite, moderately sorted.	2.1-7.9	5.8
32. Light gray calcareous mudrock, finely laminated, N55E, 72SE.	7.9-14.6	6.7
33. Light gray calcareous sandstone, medium-bedded	14.6-19.8	5.2
34. Medium-light gray calcareous mudrock, finely laminated.	19.8-67.7	47.9
35. Medium-brownish-gray calcareous sandstone, trace dolomite.	67.7-82.3	14.6
Fido Sandstone (15.2m)		
36. Dark-red-Brown sandstone	0-15.2	15.2
Girkin Limestone (303.3m)		
37. Medium gray calcareous mudrock, silty, medium-bedded.	0-35.0	35.0
38. Medium-light gray biomicrite, abundant Bryozoans and echinoderms.	35.0-41.8	6.8
39. Light gray calcareous mudrock, trace intraclasts	41.8-59.1	17.3
40. Medium gray biomicrite, abundant bryozoans and echinoderms.	59.1-84.1	25.0
41. Medium gray calcareous mudrock, trace intraclasts, medium-bedded.	84.1-96.0	11.9
42. Medium gray biomicrite, abundant bryozoans and echinoderms, trace brachiopods, forams, ostracodes.	96.0-137.2	41.2
43. medium gray calcareous mudrock, finely laminated.	137.2-148.4	11.2

Unit		Cumulative Thickness(meters)	Interval Thickness(meters)
44.	Covered	148.4-162.5	14.1
45.	Light gray calcareous mucrock, cryptalgal laminations, bioturbated N59E,29SE	162.5-224.0	61.5
46.	Medium gray biomicrite, abundant bryozoans and echinoderms.	224.0-229.2	5.2
47.	Medium gray calcareous mudrock, trace echinoderms.	229.2-239.9	10.7
48.	Medium gray biomicrite, abundant bryozoans and echinoderms, trace brachiopods and foraminifers.	239.9-244.1	4.2
49.	Light gray calcareous mudrock, medium bedded, trace byrozoans and echinoderms, medium-bedded.	244.1-303.3	59.2

APPENDIX B

KEY TO APPENDIX B

SPAR	SPAR CEMENT
MICSPAR	MICROSPAR
DOL	DOLOMITE
OOID	OOLITHS
PEL	PELLETS
INT	INTRACLASTS
ECH	ECHINODERMS
BRACH	BRACHIOPODS
BRYOZ	BRYOZOANS
OST	OSTRACODES
FORAM	FORAMINIFERS
MOLL	MOLLUSKS
GAST	GASTROPODS
TRILO	TRILOBITES
QTZ	QUARTZ
FSP	FELDSPAR
PYR	PYRITE
HEM	HEMATITE
CHERT	CHERT
RF	ROCK FRAGMENTS
MATRIX	MATRIX
OTHER	OTHER
CARB	CARBONATE(CALCULATED)
INSOL	INSOLUBLE RESIDUES

OBS	SAMPLE	SPAR	MICSPAR	DOL	JOID	PEL	INT	ECH	BRACH
1	E2	3.0000	0.00000	0.70000	0	0	0.0000	0.0000	0.00000
2	E3	0.0000	1.30000	0.30000	0	0	0.0000	0.0000	0.00000
3	E4	1.7000	0.00000	0.80000	0	0	0.0000	0.0000	0.00000
4	E5	2.7000	0.00000	0.30000	0	0	0.0000	0.0000	0.00000
5	E6	0.0000	0.00000	0.00000	0	0	0.0000	0.0000	0.00000
6	E7	0.0000	0.00000	0.00000	0	0	0.0000	0.0000	0.00000
7	E8	0.3000	0.00000	0.00000	0	0	0.0000	2.3000	0.00000
8	E9	0.3000	0.00000	1.30000	0	0	0.0000	0.0000	0.00000
9	E10	1.0000	0.00000	0.00000	0	0	0.0000	0.0000	0.00000
10	E11	0.6000	0.00000	0.00000	0	0	0.0000	3.3000	0.00000
11	E12	1.0000	0.00000	0.70000	0	0	0.0000	0.0000	0.00000
12	E13	2.3000	0.00000	1.30000	0	0	0.0000	0.3000	0.00000
13	E14	0.0000	0.00000	0.00000	0	0	0.0000	0.0000	0.00000
14	E15	16.0000	0.70000	0.00000	62	0	0.0000	1.2000	0.00000
15	E16	20.7000	0.70000	0.00000	76	0	0.0000	0.0000	0.00000
16	E17	0.3000	0.00000	0.00000	0	0	18.3000	5.3000	0.00000

OBS	BRYOZ	CST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
1	0.0000	0.000000	0.000000	0.00000	0	0	11.0000	0.00000
2	0.0000	0.000000	0.000000	0.00000	0	0	6.7000	0.00000
3	0.0000	0.000000	0.000000	0.00000	0	0	8.2000	0.30000
4	0.0000	0.000000	0.000000	0.00000	0	0	12.0000	0.00000
5	0.0000	0.000000	0.000000	0.00000	0	0	8.7000	0.00000
6	0.0000	0.000000	0.000000	0.00000	0	0	4.7000	0.00000
7	2.3000	0.000000	0.000000	0.30000	0	0	6.0000	0.00000
8	0.0000	0.000000	0.000000	0.00000	0	0	9.7000	0.00000
9	0.0000	0.000000	0.000000	0.00000	0	0	10.0000	0.00000
10	25.0000	0.000000	0.000000	1.30000	0	0	1.7000	0.00000
11	0.0000	0.000000	0.000000	0.00000	0	0	21.0000	0.00000
12	0.0000	0.000000	0.000000	0.00000	0	0	18.3000	0.00000
13	4.0000	0.000000	0.000000	0.00000	0	0	18.0000	0.00000
14	0.0000	0.000000	0.000000	0.00000	0	0	11.3000	2.70000
15	0.0000	0.000000	0.000000	0.00000	0	0	1.3000	0.00000
16	4.3000	0.000000	0.000000	0.00000	0	0	8.0000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
1	0.30000	0.00000	0	0.00000	83.0000	0.00000	48.2000	51.8000
2	0.60000	0.30000	0	0.00000	71.1000	0.00000	48.1000	51.9000
3	0.70000	0.30000	0	0.40000	87.6000	0.00000	47.5000	52.5000
4	1.70000	0.70000	0	0.00000	82.6000	0.00000	46.4000	53.6000
5	0.70000	0.00000	0	0.00000	90.6000	0.00000	55.3000	44.7000
6	0.30000	0.00000	0	0.00000	95.0000	0.00000	55.5000	44.5000
7	0.00000	1.30000	0	0.00000	87.8000	0.00000	48.4000	51.6000
8	2.60000	1.00000	0	0.00000	86.1000	0.00000	38.8000	61.2000
9	3.00000	1.00000	0	0.00000	88.0000	0.00000	49.5000	50.5000
10	2.00000	1.00000	0	0.00000	63.0000	0.00000	54.1000	45.9000
11	0.00000	0.00000	0	0.00000	77.3000	0.00000	28.7000	71.3000
12	1.30000	0.00000	0	0.00000	76.5000	0.00000	35.1000	64.9000
13	1.60000	0.30000	0	0.00000	76.4000	0.00000	35.6000	64.4000
14	0.00000	0.70000	0	4.70000	0.7000	0.00000	85.6000	14.4000
15	0.00000	0.00000	0	0.00000	1.3000	0.00000	91.1000	8.8000
16	0.00000	0.00000	0	0.00000	63.5000	0.30000	38.9000	61.1000

OBS	SAMPLE	SPAR	MICSPAR	OOL	OOID	PEL	INT	ECH	BRACH
17	E18	0.3000	0	0.00000	0	0	0.0000	5.3000	0.00000
18	E19	17.3000	0	0.00000	0	0	41.0000	32.7000	0.00000
19	E20	1.3000	0	0.00000	0	0	0.0000	0.7000	0.00000
20	E21	3.7000	0	0.00000	0	0	0.0000	0.3000	0.00000
21	E22	1.3000	0	0.00000	0	0	0.0000	2.3000	0.00000
22	E23	1.0000	0	0.00000	0	0	0.0000	0.7000	0.00000
23	E24	0.0000	0	0.00000	0	0	2.0000	5.3000	0.00000
24	A84	0.0000	0	0.00000	0	0	0.0000	6.3000	0.00000
25	A85	0.9000	0	0.00000	0	0	0.0000	0.3000	0.00000
26	A86	4.3000	0	0.00000	0	0	0.0000	0.0000	0.00000
27	A87	0.0000	0	0.00000	0	0	0.0000	0.0000	0.00000
28	A88	0.0000	0	0.00000	0	0	0.0000	0.3000	0.00000
29	A89	1.0000	0	0.00000	0	0	0.0000	0.0000	0.00000
30	A1	1.3000	0	0.00000	0	0	0.0000	0.0000	0.00000
31	A2	0.0000	0	0.00000	0	0	0.0000	0.0000	0.00000
32	A4	0.0000	0	0.00000	0	0	0.0000	1.3000	3.70000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
17	20.6000	0.000000	0.000000	0.000000	0	0	0.3000	0.00000
18	7.0000	0.000000	0.000000	0.300000	0	0	0.0000	0.00000
19	3.0000	0.000000	0.000000	0.000000	0	0	9.7000	0.00000
20	8.7000	0.300000	0.000000	0.000000	0	0	8.3000	0.00000
21	12.6000	0.000000	0.000000	0.000000	0	0	3.0000	0.00000
22	27.3000	0.000000	0.000000	0.000000	0	0	1.3000	0.00000
23	7.3000	0.000000	0.000000	0.300000	0	0	5.6000	0.00000
24	19.3000	0.000000	0.000000	0.000000	0	0	14.3000	0.00000
25	12.3000	0.000000	0.000000	0.000000	0	0	21.0000	1.00000
26	0.0000	0.000000	0.000000	0.000000	0	0	6.0000	0.00000
27	0.0000	0.000000	0.000000	0.000000	0	0	6.3000	0.00000
28	0.0000	0.000000	0.000000	0.000000	0	0	9.7000	0.00000
29	0.0000	0.000000	0.000000	0.000000	0	0	16.0000	0.00000
30	0.0000	0.000000	0.000000	0.000000	0	0	6.0000	0.00000
31	0.0000	0.000000	0.000000	0.000000	0	0	3.7000	0.00000
32	0.0000	0.000000	0.000000	0.000000	0	0	8.0000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
17	0.00000	5.30000	0	0.00000	68.3000	0.00000	79.0000	21.0000
18	0.00000	3.50000	0	0.00000	1.0000	0.60000	96.4000	3.6000
19	0.00000	0.00000	0	0.00000	40.3000	0.00000	46.2000	53.8000
20	3.30000	0.00000	0	0.00000	74.0000	1.30000	53.9000	46.1000
21	1.00000	0.00000	0	0.00000	79.5000	0.30000	65.4000	34.6000
22	3.70000	0.00000	0	0.00000	96.3000	0.70000	68.3000	31.7000
23	0.00000	1.30000	0	0.00000	77.9000	0.30000	58.8000	41.2000
24	0.30000	0.30000	0	0.30000	58.6000	0.60000	48.5000	51.5000
25	0.00000	0.00000	0	3.00000	61.0000	0.70000	40.3000	59.7000
26	0.00000	0.70000	0	0.00000	72.3000	0.00000	41.3000	58.7000
27	0.00000	0.70000	0	0.00000	68.3000	0.00000	34.1000	65.9000
28	1.00000	0.00000	0	0.00000	83.7000	0.30000	59.4000	40.6000
29	2.00000	0.00000	0	0.00000	81.0000	0.00000	33.9000	66.1000
30	2.00000	0.00000	0	0.00000	90.7000	0.00000	68.3000	31.7000
31	2.00000	0.00000	0	0.00000	94.3000	0.00000	68.1000	31.9000
32	1.30000	0.00000	0	0.00000	35.7000	0.00000	42.1000	57.9000

OBS	SAMPLE	SPAR	MICSPAR	DOL	VOID	PEL	INT	ECH	BRACH
33	A5	0.0000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
34	A6	1.0000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
35	A7	0.0000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
36	A8	0.3000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
37	A9	0.0000	0	0.00000	0.00000	0	0.0000	7.7000	0.0000
38	A10	4.0000	0	0.00000	0.00000	0	1.0000	9.7000	0.0000
39	A11	2.0000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
40	A12	2.3000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
41	A13	1.0000	0	1.00000	0.00000	0	0.0000	0.0000	0.0000
42	A14	1.7000	0	1.30000	0.00000	0	0.0000	0.0000	0.0000
43	A15	4.3000	0	2.00000	0.00000	0	0.0000	0.0000	0.0000
44	A16	0.0000	0	0.00000	0.00000	0	30.3000	10.3000	2.0000
45	A17	0.0000	0	0.00000	0.00000	0	0.0000	0.6000	1.7000
46	A18	0.3000	0	0.00000	0.00000	0	0.0000	0.3000	0.0000
47	A19	0.3000	0	0.00000	0.00000	0	0.0000	0.0000	0.0000
48	A20	16.0000	0	1.00000	0.00000	0	0.0000	0.0000	0.0000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
33	0.0000	0	0.000000	0	0.000000	0.000000	0.0000	0.000000
34	0.0000	0	0.000000	0	0.000000	0.000000	0.3000	0.000000
35	0.0000	0	0.000000	0	0.000000	0.000000	1.3000	0.000000
36	0.0000	0	0.000000	0	0.000000	0.000000	0.0000	0.000000
37	12.7000	0	0.300000	0	0.000000	0.000000	2.0000	0.000000
38	11.7000	0	0.000000	0	0.000000	0.000000	14.0000	0.300000
39	0.0000	0	0.000000	0	0.000000	0.000000	3.7000	0.000000
40	0.0000	0	0.000000	0	0.000000	0.000000	4.0000	0.000000
41	0.0000	0	0.000000	0	0.000000	0.000000	3.0000	0.000000
42	0.0000	0	0.000000	0	0.000000	0.000000	2.7000	0.000000
43	0.0000	0	0.000000	0	0.000000	0.000000	7.3000	0.000000
44	5.3000	0	0.000000	0	0.000000	0.000000	0.0000	0.000000
45	1.0000	0	0.000000	0	0.000000	0.000000	1.7000	0.000000
46	1.0000	0	0.000000	0	0.000000	0.000000	2.3000	0.000000
47	0.0000	0	0.000000	0	0.000000	0.000000	6.3000	0.000000
48	0.0000	0	0.000000	0	0.000000	0.000000	10.7000	0.000000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
33	0.00000	0.60000	0	0.00000	99.4000	0.00000	73.4000	26.6000
34	1.00000	0.30000	0	0.00000	97.4000	0.00000	69.4000	30.6000
35	1.00000	0.30000	0	0.00000	97.7000	0.00000	68.9000	31.1000
36	0.30000	0.00000	0	0.00000	30.4000	0.00000	73.2000	26.8000
37	0.00000	0.70000	0	0.00000	76.6000	0.00000	67.9000	32.1000
38	0.00000	0.70000	0	0.70000	57.6000	0.30000	59.7000	40.3000
39	0.30000	1.30000	0	0.00000	32.7000	0.30000	67.1000	32.8000
40	2.00000	0.00000	0	0.00000	91.7000	0.00000	66.4000	33.6000
41	0.70000	0.00000	0	0.00000	94.3000	0.00000	66.4000	33.6000
42	0.00000	0.00000	0	0.00000	74.3000	0.00000	67.2000	32.8000
43	0.30000	0.30000	0	0.00000	86.1000	0.00000	65.0000	35.0000
44	1.00000	0.00000	0	0.00000	50.8000	0.30000	54.1000	45.9000
45	2.30000	0.00000	0	0.00000	92.7000	0.00000	49.5000	50.5000
46	3.30000	0.30000	0	0.00000	72.4000	0.00000	48.8000	51.2000
47	0.70000	0.30000	0	0.00000	92.7000	0.00000	48.2000	51.8000
48	1.30000	0.00000	0	0.10000	67.9000	0.00000	57.6000	42.4000

OBS	SAMPLE	SPAR	MICSPAR	OOI	OOID	PEL	INT	ECH	BRACH
49	A21	3.0000	0	0.00000	0.0000	0	0.00000	0.3000	0.0000
50	A22	2.3000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
51	A23	12.7000	0	0.00000	0.0000	0	0.00000	0.3000	0.0000
52	A24	3.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
53	A25	3.7000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
54	A26	7.7000	0	0.00000	0.0000	0	0.00000	0.3000	0.0000
55	A27	7.3000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
56	A28	2.0000	0	0.70000	0.0000	0	0.00000	0.0000	0.0000
57	A29	6.7000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
58	A30	17.2000	0	0.00000	0.0000	0	0.00000	0.3000	0.7000
59	A31	1.7000	0	1.00000	0.0000	0	0.00000	0.0000	0.0000
60	A32	2.0000	0	0.30000	0.0000	0	0.00000	0.0000	0.0000
61	A33	3.3000	0	0.00000	0.0000	0	0.00000	0.3000	0.0000
62	A34	0.7000	0	0.00000	0.0000	0	0.00000	0.3000	0.0000
63	A35	7.3000	0	0.30000	0.0000	0	0.00000	0.7000	0.0000
64	A36	4.5000	0	0.30000	0.0000	0	0.00000	0.0000	0.0000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
49	0.0000	0	[illegible]	0	0.000000	0.000000	7.0000	0.00000
50	0.0000	0	[illegible]	0	0.000000	0.000000	7.0000	0.00000
51	0.0000	0	[illegible]	0	0.000000	0.000000	9.7000	0.70000
52	0.0000	0	[illegible]	0	0.000000	0.000000	3.0000	0.00000
53	0.0000	0	[illegible]	0	0.000000	0.000000	3.3000	0.00000
54	0.0000	0	[illegible]	0	0.000000	0.000000	7.0000	0.00000
55	0.0000	0	[illegible]	0	0.000000	0.000000	3.7000	0.00000
56	0.0000	0	[illegible]	0	0.000000	0.000000	1.3000	0.00000
57	0.0000	0	[illegible]	0	0.000000	0.000000	6.3000	0.00000
58	0.0000	0	[illegible]	0	0.000000	0.000000	12.7000	0.00000
59	0.0000	0	[illegible]	0	0.000000	0.000000	3.3000	0.00000
60	0.0000	0	[illegible]	0	0.000000	0.000000	6.0000	0.00000
61	0.0000	0	[illegible]	0	0.000000	0.000000	7.7000	0.00000
62	0.0000	0	[illegible]	0	0.000000	0.000000	4.0000	0.00000
63	1.0000	0	[illegible]	0	0.000000	0.000000	8.3000	0.00000
64	0.0000	0	[illegible]	0	0.000000	0.000000	6.3000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
49	0.70000	0.00000	0.000000	1.30000	87.7000	0.00000	57.6000	42.4000
50	0.70000	0.00000	0.000000	1.00000	89.0000	0.00000	55.3000	44.7000
51	0.30000	0.00000	0.000000	2.30000	74.0000	0.00000	53.7000	46.3000
52	1.00000	0.00000	0.000000	0.00000	93.0000	0.00000	56.5000	43.5000
53	1.70000	0.30000	0.000000	0.00000	91.0000	0.00000	59.5000	40.5000
54	0.30000	0.00000	0.000000	0.70000	84.0000	0.00000	60.0000	40.0000
55	0.00000	1.00000	0.000000	0.00000	88.0000	0.00000	59.1000	40.9000
56	0.70000	0.00000	0.000000	0.00000	95.3000	0.00000	63.0000	37.0000
57	0.70000	0.00000	0.000000	0.30000	86.0000	0.00000	61.2000	38.8000
58	0.00000	1.70000	0.000000	0.70000	65.4000	1.30000	48.0000	52.0000
59	0.00000	0.70000	0.000000	0.00000	93.3000	0.00000	44.5000	55.5000
60	0.00000	0.70000	0.000000	0.00000	87.3000	3.70000	29.5000	70.5000
61	0.00000	0.30000	0.000000	0.00000	88.4000	0.00000	25.3000	74.7000
62	0.00000	1.30000	0.000000	0.00000	93.7000	0.00000	24.0000	76.0000
63	0.00000	0.30000	0.000000	2.00000	80.4000	0.00000	37.0000	63.0000
64	0.00000	0.30000	0.000000	0.70000	87.7000	0.00000	33.7000	66.3000

OBS	SAMPLE	SPAR	MICSPAR	POL	OOID	PEL	INT	ECH	BRACH
65	A37	0.3000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
66	A38	1.6000	0	2.00000	0.0000	0	0.00000	0.0000	0.0000
67	A39	13.3000	0	2.00000	0.0000	0	0.00000	0.3000	0.0000
68	A40	0.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
69	A41	6.1000	0	0.70000	0.0000	0	0.00000	1.0000	0.7000
70	A42	5.4000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
71	A43	4.7000	0	1.60000	0.0000	0	0.00000	0.0000	0.0000
72	A44	1.0000	0	1.00000	0.0000	0	0.00000	0.0000	0.0000
73	A45	0.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
74	A46	0.7000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
75	A47	3.3000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
76	A48	1.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
77	A49	0.7000	0	0.00000	0.0000	0	0.00000	0.0000	0.0000
78	A50	3.3000	0	0.00000	2.3000	0	0.00000	12.3000	19.0000
79	A51	3.0000	0	0.70000	0.2000	0	0.00000	0.0000	1.7000
80	A52	2.0000	0	0.00000	4.0000	0	2.00000	23.3000	1.7000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
65	0.0000	0	0.00000	0	0.000000	0.000000	14.0000	0.00000
66	0.0000	0	0.00000	0	0.000000	0.000000	6.0000	0.00000
67	0.0000	0	0.00000	0	0.000000	0.000000	9.3000	0.30000
68	0.0000	0	0.00000	0	0.000000	0.000000	6.7000	0.00000
69	0.0000	0	0.00000	0	0.000000	0.000000	8.7000	0.00000
70	0.0000	0	0.00000	0	0.000000	0.000000	12.0000	0.00000
71	0.0000	0	0.00000	0	0.000000	0.000000	5.0000	0.00000
72	0.0000	0	0.00000	0	0.000000	0.000000	1.3000	0.00000
73	0.0000	0	0.00000	0	0.000000	0.000000	2.0000	0.00000
74	0.0000	0	0.00000	0	0.000000	0.000000	1.0000	0.00000
75	0.0000	0	0.00000	0	0.000000	0.000000	1.7000	0.00000
76	0.0000	0	0.00000	0	0.000000	0.000000	2.0000	0.00000
77	0.0000	0	0.00000	0	0.000000	0.000000	0.7000	0.00000
78	15.3000	0	0.00000	0	0.000000	0.000000	2.3000	0.30000
79	0.7000	0	0.00000	0	0.000000	0.000000	7.0000	0.00000
80	17.7000	0	0.00000	0	0.300000	0.700000	4.0000	0.70000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
65	0.00000	0.00000	0.000000	1.00000	75.6000	0.00000	34.1000	65.9000
66	1.60000	0.30000	0.000000	1.30000	68.5000	0.00000	27.5000	72.5000
67	0.30000	1.70000	0.000000	0.70000	72.1000	0.00000	39.0000	61.0000
68	0.00000	1.30000	0.000000	0.00000	92.0000	0.00000	33.4000	66.6000
69	1.30000	0.00000	0.000000	0.30000	81.2000	0.00000	34.4000	65.6000
70	0.70000	0.00000	0.000000	1.30000	83.3000	0.00000	40.8000	59.2000
71	1.00000	0.00000	0.000000	0.00000	87.7000	0.00000	42.0000	58.0000
72	1.00000	0.00000	0.000000	0.00000	85.7000	0.00000	44.9000	55.1000
73	1.00000	1.00000	0.000000	0.00000	76.0000	0.00000	43.4000	56.6000
74	1.00000	0.00000	0.000000	0.00000	77.3000	0.00000	47.5000	52.5000
75	1.30000	0.00000	0.000000	0.00000	86.7000	0.00000	46.3000	53.7000
76	2.70000	0.00000	0.000000	0.00000	84.3000	0.00000	46.2000	53.8000
77	2.30000	0.00000	0.000000	0.00000	86.3000	0.00000	44.0000	56.0000
78	3.70000	0.00000	0.000000	1.70000	40.0000	2.80000	64.5000	35.5000
79	0.70000	0.00000	0.000000	0.70000	56.5000	0.00000	42.0000	58.0000
80	0.30000	0.00000	0.000000	1.30000	42.0000	0.00000	67.0000	33.0000

OBS	SAMPLE	SPAR	MICSPAR	DOL	VOID	PEL	INT	FCH	BRACH
81	A53	2.7000	0	0.00000	0.0000	0	0.00000	0.3000	2.30000
82	A54	8.6000	0	0.00000	1.0000	0	0.00000	15.3000	6.50000
83	A55	2.0000	0	0.00000	0.3000	0	0.00000	1.3000	0.00000
84	A56	3.0000	0	1.30000	0.0000	0	0.00000	0.7000	0.00000
85	A57	1.3000	0	0.30000	0.0000	0	0.00000	0.7000	0.30000
86	A58	1.3000	0	0.30000	0.0000	0	0.00000	0.0000	0.00000
87	A59	2.3000	0	1.00000	0.0000	0	0.00000	0.3000	0.00000
88	A60	1.3000	0	0.70000	0.0000	0	0.00000	0.3000	0.00000
89	A61	5.3000	0	0.00000	0.0000	0	0.00000	1.3000	0.70000
90	A62	3.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.00000
91	A63	3.3000	0	1.30000	0.0000	0	0.00000	0.7000	0.00000
92	A64	5.0000	0	0.70000	0.0000	0	0.00000	3.0000	0.30000
93	A65	3.7000	0	0.70000	0.0000	0	0.00000	0.0000	0.00000
94	A66	6.0000	0	0.00000	0.0000	0	0.00000	0.0000	0.00000
95	A67	3.7000	0	0.70000	0.0000	0	0.00000	0.0000	0.00000
96	A68	3.3000	0	0.00000	0.0000	0	0.00000	0.3000	0.00000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
81	0.0000	0	0.00000	0	0	0.000000	10.7000	0.00000
82	14.7000	0	0.00000	0	0	0.000000	3.6000	0.00000
83	0.3000	0	0.00000	0	0	0.000000	10.3000	0.00000
84	0.0000	0	0.00000	0	0	0.000000	8.3000	0.00000
85	0.0000	0	0.00000	0	0	0.000000	4.3000	0.00000
86	0.0000	0	0.00000	0	0	0.000000	6.3000	0.00000
87	0.0000	0	0.00000	0	0	0.000000	9.3000	0.00000
88	0.0000	0	0.00000	0	0	0.000000	8.7000	0.30000
89	0.3000	0	0.00000	0	0	0.000000	4.7000	0.00000
90	0.0000	0	0.00000	0	0	0.000000	8.3000	0.30000
91	0.0000	0	0.00000	0	0	0.000000	10.7000	0.00000
92	1.3000	0	0.00000	0	0	0.000000	12.0000	0.30000
93	0.0000	0	0.00000	0	0	0.000000	10.0000	0.00000
94	0.0000	0	0.00000	0	0	0.000000	12.7000	0.00000
95	0.0000	0	0.00000	0	0	0.000000	11.3000	0.30000
96	1.0000	0	0.00000	0	0	0.000000	13.7000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
81	0.70000	0.00000	0.000000	0.30000	83.0000	0.00000	42.0000	58.0000
82	1.60000	0.00000	0.000000	0.70000	47.3000	1.00000	53.8000	46.2000
83	2.30000	0.30000	0.000000	0.00000	83.7000	0.00000	40.2000	59.8000
84	1.70000	0.30000	0.000000	0.00000	85.0000	0.00000	40.3000	59.7000
85	0.70000	0.00000	0.000000	0.30000	91.7000	0.00000	40.5000	59.5000
86	3.00000	0.00000	0.000000	0.30000	89.1000	0.00000	39.8000	60.2000
87	1.00000	0.30000	0.000000	0.00000	88.4000	0.00000	41.4000	58.6000
88	1.70000	0.00000	0.000000	0.00000	88.0000	0.00000	40.2000	59.8000
89	0.00000	1.70000	0.000000	0.00000	89.0000	0.00000	41.6000	58.4000
90	0.00000	1.00000	0.000000	0.00000	87.4000	0.00000	40.3000	59.7000
91	1.30000	0.30000	0.000000	0.00000	83.0000	0.00000	40.0000	60.0000
92	0.70000	0.00000	0.000000	0.70000	76.3000	0.00000	39.1000	60.9000
93	0.30000	0.00000	0.300000	0.70000	82.3000	0.00000	28.7000	71.3000
94	0.30000	1.00000	0.000000	1.00000	78.3000	1.70000	27.8000	72.2000
95	0.30000	0.00000	0.000000	0.00000	83.7000	0.00000	24.8000	75.2000
96	0.00000	0.00000	0.000000	1.30000	74.3000	0.00000	35.8000	64.2000

OBS	SAMPLE	SPAR	MICSPAR	OOL	VOID	PEL	INT	ECH	BRACH
97	A69	3.3000	0	1.00000	0.0000	0	0.00000	0.0000	0.00000
98	A70	3.7000	0	0.00000	5.7000	0	0.00000	1.0000	0.60000
99	A71	1.3000	0	0.00000	46.7000	0	6.70000	3.0000	0.00000
100	A72	15.3000	0	0.00000	37.6000	0	0.00000	8.7000	2.00000
101	A73	2.7000	0	0.00000	2.7000	0	7.30000	7.0000	0.30000
102	A74	3.7000	0	4.70000	0.0000	0	0.00000	0.0000	0.00000
103	A75	10.3000	0	0.30000	0.0000	0	0.00000	0.0000	0.00000
104	A76	3.3000	0	0.70000	0.0000	0	0.00000	0.3000	0.00000
105	A77	19.7000	0	0.70000	0.0000	0	0.00000	0.0000	0.00000
106	A78	7.3000	0	1.70000	0.0000	0	0.00000	0.0000	0.00000
107	A79	23.3000	0	0.30000	0.0000	0	0.00000	0.0000	0.00000
108	A80	3.7000	0	0.70000	0.0000	0	0.00000	0.0000	0.00000
109	A81	11.7000	0	0.30000	0.0000	0	0.00000	0.0000	0.00000
110	A82	24.0000	0	0.30000	0.0000	0	0.00000	0.0000	0.00000
111	A83	7.7000	0	0.00000	0.0000	0	0.00000	0.0000	0.00000
112	C1	0.0000	0	0.00000	0.0000	0	2.00000	0.3000	0.00000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
97	0.3000	0	0.00000	0	0	0.000000	10.0000	0.70000
98	14.0000	0	0.00000	0	0	0.000000	11.1000	1.00000
99	0.3000	0	0.00000	0	0	0.000000	3.3000	0.00000
100	28.0000	0	0.00000	0	0	0.000000	4.7000	0.00000
101	10.7000	0	0.00000	0	0	0.000000	7.0000	0.70000
102	0.0000	0	0.00000	0	0	0.000000	19.3000	0.30000
103	0.0000	0	0.00000	0	0	0.000000	11.0000	0.00000
104	0.0000	0	0.00000	0	0	0.000000	9.3000	0.30000
105	0.0000	0	0.00000	0	0	0.000000	15.0000	0.00000
106	0.0000	0	0.00000	0	0	0.000000	6.7000	0.30000
107	0.0000	0	0.00000	0	0	0.000000	14.3000	0.30000
108	0.0000	0	0.00000	0	0	0.000000	11.0000	0.00000
109	0.0000	0	0.00000	0	0	0.000000	10.7000	0.00000
110	0.0000	0	0.00000	0	0	0.000000	18.6000	0.00000
111	0.0000	0	0.00000	0	0	0.000000	8.7000	0.30000
112	7.3000	0	1.30000	0	0	0.000000	0.3000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
97	1.30000	0.00000	0.000000	0.70000	82.7000	0.000000	23.5000	76.5000
98	0.00000	0.30000	0.300000	4.00000	61.4000	0.000000	44.0000	56.0000
99	0.00000	0.00000	0.000000	0.70000	38.0000	0.000000	61.0000	39.0000
100	0.00000	0.00000	0.000000	3.00000	0.7000	0.000000	87.2000	12.8000
101	1.00000	0.00000	0.000000	1.30000	56.3000	0.000000	39.1000	60.9000
102	1.00000	0.00000	0.000000	1.70000	68.3000	0.000000	39.1000	60.9000
103	0.60000	0.00000	0.000000	1.70000	76.1000	0.000000	49.0000	51.0000
104	1.30000	0.00000	0.000000	1.00000	78.0000	0.000000	51.8000	48.2000
105	0.00000	0.00000	0.000000	2.30000	62.3000	0.000000	52.3000	47.7000
106	0.30000	0.00000	0.000000	0.30000	63.7000	0.000000	54.8000	45.2000
107	0.30000	0.30000	0.000000	0.30000	61.5000	0.000000	40.1000	59.9000
108	0.30000	0.30000	0.000000	1.00000	81.3000	0.000000	47.2000	52.8000
109	0.00000	0.00000	0.000000	0.70000	74.6000	0.000000	45.7000	54.3000
110	1.30000	0.00000	0.000000	0.00000	35.8000	0.000000	47.5000	52.5000
111	0.00000	0.00000	0.000000	0.70000	32.6000	0.000000	46.1000	53.9000
112	0.00000	0.00000	0.000000	0.00000	88.8000	0.000000	40.7000	59.3000

OBS	SAMPLE	SPAR	MICSPAR	DOL	OOID	PEL	INT	ECH	BRACH
113	C2	7.0000	0	0.0000	0.30000	0	0.00000	0.0000	0.00000
114	C3	5.3000	0	0.3000	0.00000	0	0.00000	0.6000	0.60000
115	C4	4.0000	0	0.0000	0.00000	0	0.00000	0.0000	0.00000
116	C5	2.0000	0	1.0000	0.00000	0	0.00000	0.0000	0.00000
117	C6	5.3000	0	0.0000	0.00000	0	0.00000	0.3000	0.00000
118	C7	[illegible]	0	[illegible]	0.00000	0	0.00000	0.0000	0.00000
119	C8	[illegible]	0	[illegible]	0.00000	0	0.00000	0.6000	0.00000
120	C9	1.0000	0	[illegible]	0.00000	0	1.00000	1.3000	0.00000
121	C10	0.0000	0	[illegible]	0.00000	0	3.30000	1.3000	1.70000
122	C11	2.3000	0	[illegible]	0.00000	0	4.00000	1.3000	0.00000
123	C12	[illegible]	0	1.3000	0.00000	0	2.30000	4.6000	0.00000
124	C13	[illegible]	0	2.0000	0.00000	0	7.00000	1.7000	0.00000
125	C14	[illegible]	0	1.3000	0.00000	0	0.00000	0.3000	0.00000
126	C15	4.1000	0	[illegible]	0.00000	0	0.70000	0.0000	0.30000
127	C16	[illegible]	0	[illegible]	0.00000	0	0.00000	0.0000	0.00000
128	C17	3.0000	0	0.3000	0.00000	0	0.00000	0.0000	0.00000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
113	0.0000	0	0.00000	0	0	0.000000	17.0000	0.70000
114	1.6000	0	0.00000	0	0	0.000000	31.1000	2.80000
115	0.7000	0	0.00000	0	0	0.000000	33.3000	1.30000
116	0.0000	0	0.00000	0	0	0.000000	21.0000	0.70000
117	0.0000	0	0.00000	0	0	0.000000	24.0000	1.30000
118	0.0000	0	0.30000	0	0	0.000000	9.1000	1.30000
119	3.8000	0	0.70000	0	0	0.000000	8.1000	0.60000
120	6.0000	0	1.70000	0	0	0.000000	5.0000	0.70000
121	11.3000	0	0.00000	0	0	0.000000	3.0000	0.00000
122	11.7000	0	0.00000	0	0	0.000000	7.3000	0.00000
123	16.7000	0	0.00000	0	0	0.000000	6.0000	0.00000
124	2.7000	0	0.00000	0	0	0.000000	8.7000	0.30000
125	0.0000	0	0.00000	0	0	0.000000	6.3000	0.30000
126	2.3000	0	0.00000	0	0	0.000000	9.0000	1.00000
127	0.0000	0	0.00000	0	0	0.000000	10.0000	0.30000
128	0.0000	0	0.00000	0	0	0.000000	8.3000	0.00000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
113	1.30000	3.7000	0	3.3000	60.7000	0.000000	35.0000	65.0000
114	0.30000	0.6000	0	3.3000	53.3000	0.300000	26.9000	73.1000
115	0.00000	0.3000	0	3.0000	57.3000	0.000000	20.6000	79.4000
116	0.70000	0.0000	0	3.3000	67.3000	0.000000	27.2000	72.8000
117	1.30000	0.0000	0	1.7000	66.4000	0.000000	37.4000	62.6000
118	0.00000	0.0000	0	0.3000	88.0000	0.000000	53.0000	47.0000
119	0.60000	0.6000	0	1.6000	82.8000	0.000000	49.1000	50.9000
120	0.00000	0.3000	0	1.7000	81.6000	0.000000	78.1000	21.9000
121	0.00000	0.7000	0	[illegible]	78.7000	0.000000	54.9000	45.1000
122	0.00000	0.0000	0	[illegible]	72.7000	0.000000	51.3000	48.7000
123	0.00000	0.0000	0	[illegible]	98.1000	0.000000	51.2000	48.8000
124	0.00000	0.0000	0	1.3000	76.3000	0.000000	45.8000	54.2000
125	0.70000	0.0000	0	0.0000	90.1000	0.000000	46.4000	53.6000
126	0.30000	0.0000	0	0.7000	51.3000	0.000000	36.7000	63.3000
127	1.00000	0.0000	0	0.0000	84.7000	0.000000	39.5000	60.5000
128	0.00000	0.0000	0	1.7000	36.7000	0.000000	40.3000	59.7000

OBS	SAMPLE	SPAR	MICSPAR	POL	OOID	PEL	INT	ECH	BRACH
129	C18	5.0000	0	2.5000	0	0	0.00000	0.3000	0.00000
130	C19	0.3000	0	0.7000	0	0	0.30000	0.3000	0.00000
131	C20	3.0000	0	0.7000	0	0	0.00000	0.6000	0.00000
132	C21	0.0000	0	0.0000	0	0	0.00000	2.3000	0.00000
133	C22	0.0000	0	0.0000	0	0	0.00000	2.0000	0.00000
134	C23	0.3000	0	0.0000	0	0	0.00000	2.7000	0.00000
135	C24	1.7000	0	0.0000	0	0	0.00000	2.0000	0.00000
136	C25	1.3000	0	0.0000	0	0	0.00000	0.3000	7.30000
137	C26	0.0000	0	0.0000	0	0	0.00000	9.3000	1.30000
138	C27	1.7000	0	0.0000	0	0	0.00000	2.7000	5.30000
139	C28	3.7000	0	0.0000	0	0	0.00000	2.3000	2.00000
140	C29	0.0000	0	0.3000	0	0	0.00000	1.0000	0.00000
141	C30	0.0000	0	0.0000	0	0	7.30000	0.7000	0.70000
142	C31	0.0000	0	0.3000	0	0	1.30000	23.3000	1.00000
143	C32	0.0000	0	0.0000	0	0	0.00000	0.3000	0.00000
144	C33	0.3000	0	0.7000	0	0	0.00000	1.3000	0.00000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
129	0.0000	0	0.000000	0	0	0.000000	8.9000	0.00000
130	0.3000	0	0.000000	0	0	0.000000	8.3000	0.30000
131	0.0000	0	0.000000	0	0	0.000000	8.3000	0.00000
132	8.3000	0	0.000000	0	0	0.000000	5.7000	0.00000
133	7.0000	0	0.000000	0	0	0.000000	9.0000	0.30000
134	27.3000	0	0.000000	0	0	0.300000	3.0000	0.00000
135	14.0000	0	0.000000	0	0	0.000000	0.0000	0.00000
136	11.1000	0	0.000000	0	0	0.000000	0.3000	0.00000
137	40.0000	0	0.000000	0	0	0.000000	0.0000	0.00000
138	18.0000	0	0.000000	0	0	0.000000	0.0000	0.00000
139	13.7000	0	0.000000	0	0	0.000000	0.0000	0.00000
140	25.0000	0	0.000000	0	0	0.000000	4.3000	1.00000
141	5.3000	0	0.000000	0	0	0.000000	7.7000	0.00000
142	50.3000	0	0.000000	0	0	0.000000	3.0000	0.30000
143	9.7000	0	0.000000	0	0	0.000000	3.7000	0.00000
144	9.0000	0	0.000000	0	0	0.000000	9.7000	0.70000

OBS	PYR	HEM	CHERT	RF
129	0.30000	0.7000	0	2.2000
130	1.20000	0.0000	0	0.0000
131	1.70000	0.0000	0	1.0000
132	0.30000	1.7000	0	1.7000
133	1.00000	1.0000	0	1.0000
134	0.30000	0.0000	0	0.3000
135	0.00000	0.0000	0	0.0000
136	0.00000	0.0000	0	0.0000
137	0.00000	0.0000	0	0.3000
138	0.30000	0.0000	0	0.7000
139	0.00000	0.0000	0	0.0000
140	3.00000	0.0000	0	1.7000
141	3.30000	0.3000	0	0.3000
142	3.00000	0.0000	0	0.0000
143	3.00000	0.0000	0	0.0000
144	0.30000	0.0000	0	2.0000

OBS	MATRIX	OTHER	CARB	INSOL
129	90.1000	0.000000	37.2000	62.8000
130	88.3000	0.000000	38.1000	61.9000
131	85.7000	0.000000	40.3000	59.7000
132	81.0000	0.000000	41.5000	58.5000
133	79.7000	0.000000	37.4000	62.6000
134	65.8000	0.000000	49.0000	51.0000
135	82.3000	0.000000	81.4000	18.6000
136	79.7000	0.000000	78.4000	21.6000
137	49.0000	0.000000	87.6000	12.4000
138	71.3000	0.000000	92.5000	7.5000
139	76.3000	0.000000	87.4000	12.6000
140	62.0000	0.000000	59.4000	40.6000
141	77.4000	0.000000	38.7000	61.3000
142	20.8000	0.000000	40.0000	60.0000
143	86.3000	0.000000	43.1000	56.9000
144	75.3000	0.700000	37.6000	62.4000

OBS	SAMPLE	SPAR	MICSPAR	DOL	VOID	PEL	INT	ECH	BRACH
145	C34	4.3000	0	0.0000	0	0	0.00000	0.00000	0.000000
146	C35	1.3000	0	0.0000	0	0	0.00000	0.00000	0.000000
147	C36	0.2000	0	0.0000	0	0	0.00000	2.30000	0.700000
148	C37	2.6000	0	0.0000	0	0	0.00000	0.30000	0.000000
149	C38	8.3000	0	0.0000	0	0	0.00000	0.00000	0.000000
150	C39	0.4000	0	0.0000	0	0	0.00000	0.00000	0.000000
151	C40	7.3000	0	0.0000	0	0	2.30000	2.40000	0.700000
152	D1	26.3000	0	1.0000	1	0	0.00000	0.00000	0.000000
153	D2	0.0000	0	0.0000	0	0	0.00000	0.00000	0.000000
154	D3	1.3000	0	0.0000	0	0	0.00000	0.00000	0.000000
155	D4	2.3000	0	0.0000	0	0	0.00000	0.00000	0.000000
156	D5	1.0000	0	0.0000	0	0	0.00000	0.00000	0.000000
157	D6	11.3000	0	0.3000	0	0	0.00000	0.00000	0.000000
158	D7	3.7000	0	3.3000	0	0	0.00000	0.30000	0.000000
159	D8	25.3000	0	0.0000	1	0	0.00000	1.30000	0.300000
160	D9	4.7000	0	0.0000	0	0	0.00000	0.30000	0.000000

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
145	0.0000	0	0.000000	0	0	0	12.0000	0.70000
146	0.0000	0	0.000000	0	0	0	4.3000	0.00000
147	26.0000	0	0.300000	0	0	0	2.3000	0.00000
148	1.3000	0	0.000000	0	0	0	11.0000	0.60000
149	0.0000	0	0.000000	0	0	0	12.7000	0.70000
150	5.7000	0	0.000000	0	0	0	3.3000	0.00000
151	3.3000	0	0.000000	0	0	0	9.3000	0.00000
152	0.3000	0	0.000000	0	0	0	23.0000	2.30000
153	0.0000	0	0.000000	0	0	0	60.5000	1.50000
154	0.0000	0	0.000000	0	0	0	8.7000	0.70000
155	0.0000	0	0.000000	0	0	0	3.7000	0.70000
156	0.0000	0	0.000000	0	0	0	4.3000	0.00000
157	0.0000	0	0.000000	0	0	0	17.7000	1.30000
158	3.3000	0	0.000000	0	0	0	8.3000	1.00000
159	12.7000	0	0.000000	0	0	0	21.7000	5.30000
160	0.0000	0	0.000000	0	0	0	16.0000	1.30000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
145	0.30000	0.3000	0	1.3000	81.4000	0.000000	27.3000	72.7000
146	0.00000	0.3000	0	0.0000	94.4000	0.000000	30.9000	69.1000
147	0.30000	0.3000	0	0.0000	59.8000	0.300000	57.0000	43.0000
148	0.70000	0.3000	0	2.7000	80.8000	0.000000	32.3000	67.7000
149	0.70000	0.0000	0	1.0000	76.6000	0.000000	36.7000	63.3000
150	0.00000	0.3000	0	0.3000	90.3000	0.000000	43.3000	56.7000
151	0.00000	0.3000	0	0.3000	80.1000	0.300000	52.2000	47.8000
152	0.70000	0.3000	0	6.0000	38.4000	0.000000	35.6000	64.4000
153	0.00000	10.3000	0	14.0000	5.5000	0.000000	7.5000	92.5000
154	0.00000	3.4000	0	1.3000	85.9000	0.000000	24.9000	75.1000
155	0.00000	0.7000	0	0.3000	92.3000	0.000000	48.5000	51.5000
156	0.30000	0.0000	0	1.7000	92.7000	0.000000	47.5000	52.5000
157	0.70000	0.0000	0	3.3000	61.4000	0.000000	40.5000	59.5000
158	0.00000	0.3000	0	2.7000	81.1000	0.000000	48.4000	51.6000
159	0.00000	1.3000	1	19.7000	7.7000	0.000000	41.8000	58.2000
160	0.00000	0.7000	0	0.7000	76.3000	0.000000	38.3000	61.7000

OBS	SAMPLE	SPAR	MICSPAR	OOL	VOID	PEL	INT	ECH	BRACH
161	D10	25.0000	0	26	0	0	0	1.30000	0
162	D11	13.7000	0	0	0	0	0	0.70000	0
163	D12	12.0000	0	0	0	0	0	0.00000	0

OBS	BRYOZ	OST	FORAM	MOLL	GAST	TRILO	QTZ	FSP
161	3	0	0	0	0	0	28.0000	3.70000
162	3	0	0	0	0	0	11.3000	0.30000
163	0	0	0	0	0	0	18.7000	0.30000

OBS	PYR	HEM	CHERT	RF	MATRIX	OTHER	CARB	INSOL
161	0	0.300000	0	7.00000	4.7000	0	42.1000	57.9000
162	0	3.700000	0	1.30000	68.0000	0	36.7000	63.3000
163	0	0.700000	0	0.00000	68.3000	0	22.3000	77.7000