MACROFOSSIL DISTRIBUTION IN THE STANTON LIMESTONE (UPPER PENNSYLVANIAN) IN EASTERN KANSAS

by

Michael A. Senich

An Abstract

Of a thesis submitted in partial fulfillment
of the requirements for the degree of
Doctor of Philosophy in Geology
in the Graduate College of
The University of Iowa

May, 1978

Thesis supervisor: Associate Professor Philip H. Heckel

ABSTRACT

The Stanton Limestone is a well-defined unit of alternating limestone and thin shale members marking the top of the Missourian Stage. It is typical of the laterally persistent limestone formations that alternate with thick shale formations to form the characteristically cyclic limestone-shale sequence of the Upper Pennsylvanian Series in eastern Kansas.

Abundant and diverse invertebrate fossil biotas are well developed in the Stanton. Earliest paleontological efforts attempted to describe the occurrence of individual taxa, and subsequent contributions have emphasized study of specific fossil groups. However, no attempt has been made to re-examine and interpret biotic distributions with respect to increasingly refined stratigraphic information.

Recent studies recognize a basic transgressive-regressive sequence of depositional phases in Upper Pennsylvanian cycles, consisting of outside (nearshore) shale--middle (transgressive) limestone--core (offshore) shale--upper (regressive) limestone--outside (nearshore) shale. Application of these depositional-stratigraphic studies to the Stanton Limestone establishes a basic framework for

study and documentation of macrofossil composition and distribution throughout the entire formation, and for evaluation of physical factors that may have governed recognizable distribution patterns in the Stanton throughout eastern Kansas.

Biotas of early portions of transgressive limestones are generally low in abundance and diversity, commonly with spiriferid brachiopod and phylloid algal dominance. Abundance and taxonomic diversity increases with continued transgression, and reaches maximum development at the tops of transgressive limestones, where phylloid algae, *Enteletes* (Captain Creek Member), *Meekella* (South Bend Member), *Hystriculina*, *Chonetinella*, *Rhipidomella* and *Girtyocoelia* locally dominate. During maximum transgression, development of benthic biotas is sharply reduced or completely inhibited by deposition of offshore, low oxygen gray shale or anoxic black shale. Slow recovery from low oxygen or anoxic conditions is characterized by gradually increasing abundance and diversity through early regression; faunas are locally dominated by brachiopod-echinoderm assemblages or, southward toward the detrital source, by distinctive molluscan assemblages that include *Glabrocingulum*, *Euphemites*, *Trepospira*, *Phestia*, *Paleoneilo* and *Eoasianites*. Middle regression (base of regressive limestone) is marked by the greatest abundance and diversity in the regressive phase, and

"mirrors" biotic composition of the late transgressive phase in all major taxa. Late regression is generally characterized by gradual reduction in numbers of species and total taxa, but carries local highly diverse and abundant brachiopod-echinoderm dominated assemblages with *Schizophoria*, *Derbyia*, *Meekoporella*, *Edmondia*, *Septimyalina*, *Erisocrinus* and ubiquitous spiriferids. Maximum regression reflects harsh nearshore environmental conditions, and associated lithologies carry only extremely sparse marine invertebrates.

The bulk of the nearly 200 genera and species recognized in the Stanton, occur as rare or sporadically distributed elements that do not provide enough information to evaluate environmental factors that may have affected them. Ubiquitous spiriferids *Composita*, *Phricodothyris*, *Punctospirifer*, *Neospirifer* and *Hustedia* are unrestricted in distribution, and are considered eurytopic. Fourteen genera appear to be sediment-substrate specific, and are unaffected by paleogeography or changes in depositional phase. An additional eight genera are independent of paleogeography or substrates, but are affected by physical factors associated with depositional phase. None of the taxa recognized in the Stanton seem to be restricted by paleogeography.

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PH.D. THESIS

This is to certify that the Ph.D thesis of

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ABSTRACT

The Stanton Limestone is a well-defined unit of alternating limestone and thin shale members marking the top of the Missourian Stage. It is typical of the laterally persistent limestone formations that alternate with thick shale formations to form the characteristically cyclic limestone-shale sequence of the Upper Pennsylvanian Series in eastern Kansas.

Abundant and diverse invertebrate fossil biotas are well developed in the Stanton. Earliest paleontological efforts attempted to describe the occurrence of individual taxa, and subsequent contributions have emphasized study of specific fossil groups. However, no attempt has been made to re-examine and interpret biotic distributions with respect to increasingly refined stratigraphic information.

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The bulk of the nearly 200 genera and species recognized in the Stanton, occur as rare or sporadically distributed elements that do not provide enough information to evaluate environmental factors that may have affected them. Ubiquitous spiriferids Composita, Phricodothyris, Punctospirifer, Neospirifer and Hustedia are unrestricted in distribution, and are considered eurytopic. Fourteen genera appear to be sediment-substrate specific, and are unaffected by paleogeography or changes in depositional phase. An additional eight genera are independent of paleogeography or substrates, but are affected by phsical factors associated with depositional phase. None of the taxa recognized in the Stanton seem to be restricted by paleogeography.

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INTRODUCTION

The Stanton Limestone is a well-defined unit of alternating limestone and thin shale members marking the top of the Missourian Stage (Fig. 1). It is typical of the laterally persistent limestone formations that alternate with thick shale formations to form the characteristically cyclic limestone-shale sequence of the Upper Pennsylvanian Series in eastern Kansas.

Regional subdivision of the formation along outcrop (Heckel and Cocke, 1969; Heckel, 1977) shows three generalized facies belts in eastern Kansas (Fig. 2): 1) northern open-marine facies belt, 2) algal-mound and mound-associated facies belt, and 3) southern terrigenous-detrital facies belt. Lithologies in the open-marine facies belt are generally uniform and laterally persistent thin skeletal calcilutites and shales. Localized thickening of limestone members to algal calcilutites and complementary thinning of shales characterizes the algal-mound facies belt. Mound-associated facies are roughly contemporaneous channel and rim deposits, which range from well-washed to muddy skeletal calcarenites. Limestones of the terrigenous-detrital facies are again thin skeletal calcilutites or

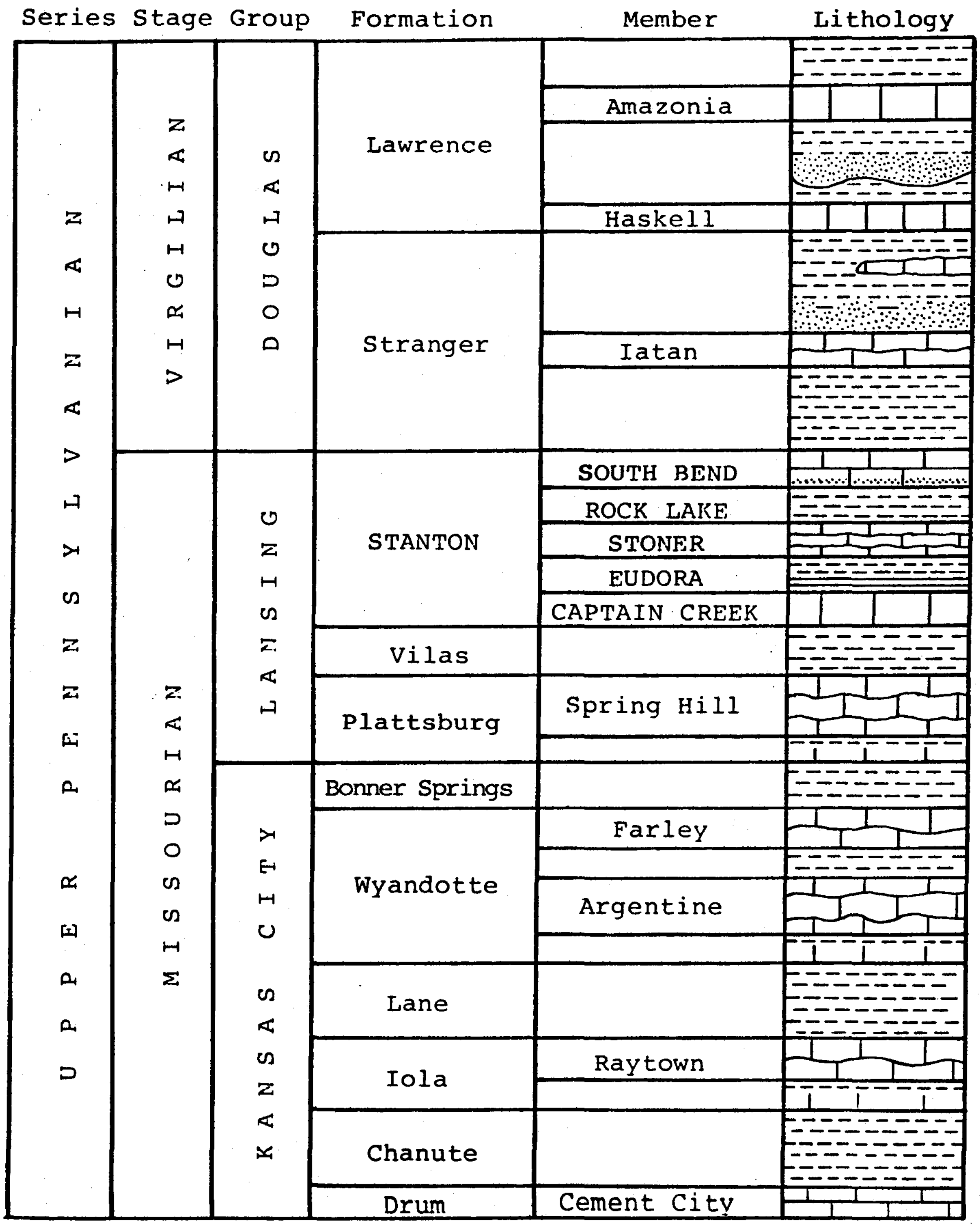

Figure 1--Generalized stratigraphic column of part of the Upper Pennsylvanian section in eastern Kansas. All lithologies are generalized. Some member names omitted outside the Stanton Formation.

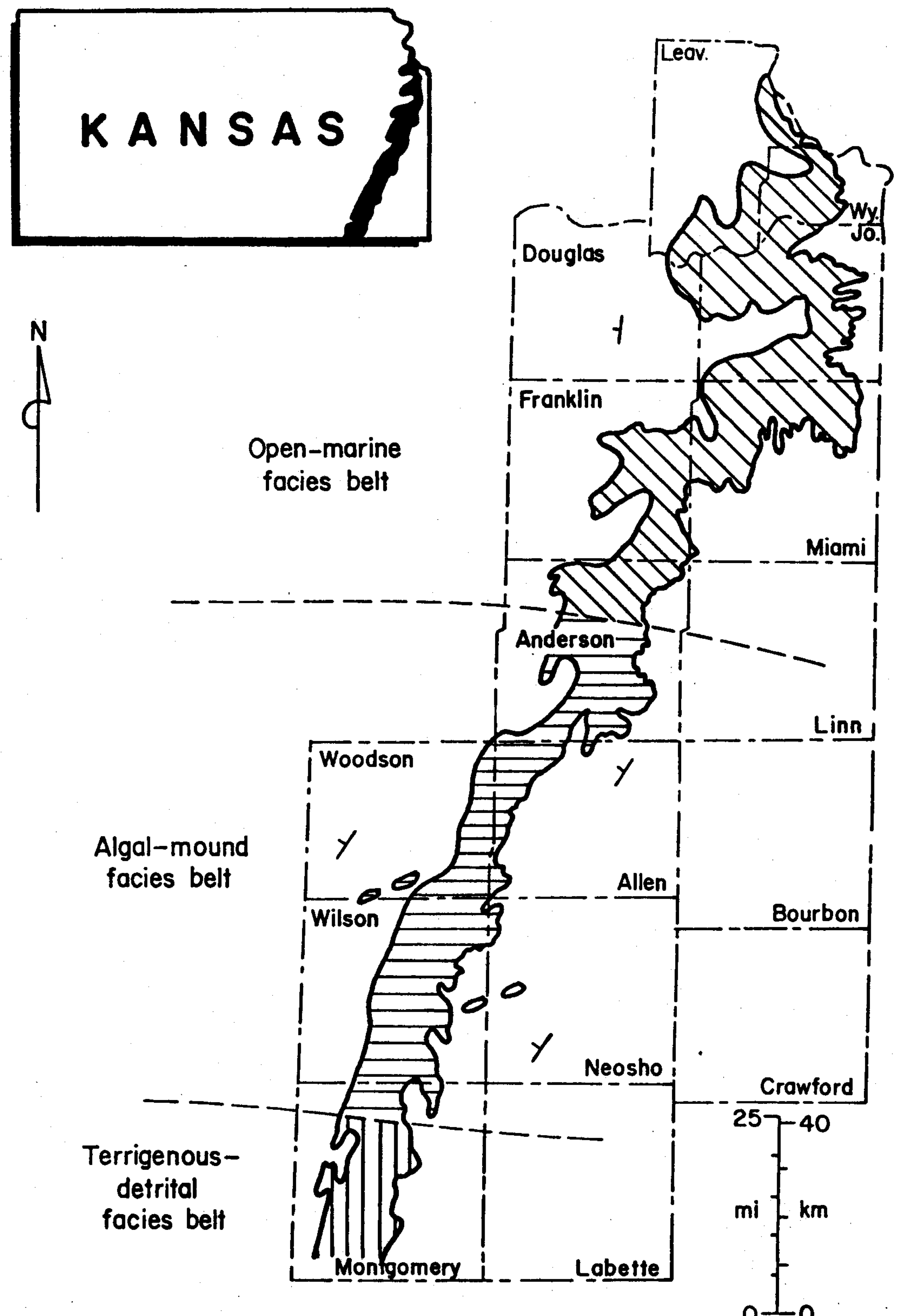

Figure 2--Stanton outcrop belt in eastern Kansas. Outcrop pattern is generalized north of Anderson Co.

sandy calcilutites to calcarenites. Shales are substantially thicker and often contain massive sand bodies, which become more prominent approaching the Oklahoma detrital source.

Abundant and diverse invertebrate fossil biotas, characteristic of the entire Mid-Continent Pennsylvanian, are well developed in the Stanton. Limestone members in northeastern Kansas yield a conspicuous marine assemblage dominated by brachiopods and fusulinids. Generalized shale biotas are complicated by lithologic variation: black fissile shales primarily contain conodonts and rare orbiculoid brachiopods; gray calcareous shales have scattered molluscs and brachiopods; light brown silty shales display unusual assemblages of plant fragments and tracks, trails and burrows. Within algal-mound facies, buildup calcilutites are dominated by phylloid algal blades, and, generally less frequent invertebrates. Calcarenite lithologies generally yield common invertebrates, but lack appreciable phylloid algae. Shales retain basic faunal characteristics developed in the open-marine facies. Southward into the terrigenous-detrital facies, major limestone members display faunas that are dominated locally by sponges and other less frequent invertebrate groups, or by distinct brachiopod-echinoderm assemblages with subordinate elements from most other major invertebrate phyla. Thickened argillaceous shales are generally dominated by molluscan assemblages, which may also be rich in other invertebrates, particularly brachiopods. Sandy and silty shales yield extremely sparse faunas, and thick sandstone bodies are virtually barren of all fossil material.

Previous Work

Paleontology

Continued interest in Stanton paleontology has produced an extensive literature. Earliest efforts by Girty (1903), Beede and Rogers (1908) and Beede (1909) listed the occurrence of individual taxa in the Kansas Carboniferous section, and attempted to recognize stratigraphic distributions of major taxonomic groups. Since then, many paleontological contributions have emphasized systematic study of specific Stanton fossil groups. Notable among these are: Bridwell (1939), brachiopods; Moore (1941), gastropods; Moore and Dudley (1944), bryozoans; Johnson (1946, 1947, 1963), algae; Cridland, et al. (1963), plants; Grinnell and Andrews (1964), brachiopods; Haglund (1967), brachiopods; Cocke (1970), corals; Pabian and Strimple (1977), echinoderms.

Newell's paleontologic and stratigraphic studies of the entire Missourian section in eastern Kansas produced several significant papers (Newell, 1931, 1934, 1937, 1942) describing many Stanton invertebrates including: schizophoriid and other brachiopods, fusulinids, a trilobite, and pectenid and myalinid bivalves. Newell (1933) also presented detailed descriptions of faunal distributions in all Missourian formations of Kansas. Stanton faunal distribution was well described, and several unusual faunal associations were noted. Particularly interesting was the discovery of an "exotic" fauna in the upper Stanton in southeastern Kansas. Newell termed the fauna "exotic" because many genera and species had not been previously reported from the Mid-Continent region.

Subsequent to Newell's original faunal descriptions, few attempts have been made to re-examine Stanton faunal distributions, particularly with respect to increasingly refined stratigraphic information. Heckel (1972) made preliminary observations on the distribution of major taxonomic groups, and Senich (1975) examined biofacies distribution in contemporaneous lithofacies of the lower Stanton in Wilson County, Kansas.

Stratigraphy

Since Hinds and Greene's (1915) correction of Swallow's (1865) mis-application of the term Stanton, there has been little confusion recognizing the Stanton as the next limestone formation above the Plattsburg. Newell (1933) effectively summarized early recognition of the Stanton, and through extensive field mapping refined basic correlations within the three limestone and two shale members, particularly in northeastern Kansas.

Until recently, further evaluation of Stanton stratigraphy has been limited to individual county reports (Newell, 1935, Johnson and Miami Cos.; Jewett and Newell, 1935, Wyandotte Co.; Wagner, 1954, 1961, Wilson Co.; Ball, et al., 1963, Franklin Co.; Miller, 1969, Allen Co.), theses (Wilson, 1957), or as mentioned in papers describing the cyclothemic sequence in the Kansas Pennsylvanian (Moore, 1936, 1949, 1950). Heckel (1972, 1975a,b) has re-examined Stanton stratigraphic relationships in terms of depositional environments. His detailed field mapping has resolved complex lateral and vertical facies relations which remained unrecognized by Newell. Heckel (1972) demonstrated that Newell's "Fredonia facies", with the exotic fauna, represents a calcarenite channel facies that transects the algal-mound facies belt and is contemporaneous with more extensive algal calcilutites. The significance of the associated exotic fauna remained essentially unexplained until Senich (1975) documented the restricted distribution of many of the faunal elements within the channel facies.

The most recent effort to understand the significance of Stanton stratigraphic relationships employs independent lithologic, invertebrate and conodont data to interpret phases of cyclothemic deposition (Heckel, 1977). Within each of the three generalized facies belts, one complete (Stanton) and one abbreviated (South Bend) Kansas-type cyclothem can be recognized in the formation. The basic vertical cyclic pattern is characteristically an ascending sequence of outside (sandy nearshore) shales--middle (transgressive) limestone--core (offshore) shale--upper (regressive) limestone--outside (sandy nearshore) shales. The significance of Heckel's interpretation is recognition of maximum transgression and stillstand during deposition of the black facies in the core shale and not in the upper limestone as previously regarded (Weller, 1956).

Paleoecology

Recent expansion of paleoecologic thought has prompted several studies on the Stanton within the past five or six years. However, despite recent advances, early works by Wilson (1962) and Moore (1964) have made important fundamental contributions to the understanding of Stanton faunas and their relation to the physical environment. Wilson interpreted algal mound complexes in southeastern Kansas as barrier reefs with reef-associated deposits formed under organic (probably algal) influence. He noted algal stromatolite development associated with a "lagoonal fauna" in the basal Stanton near Fredonia, but did not mention specific organisms or their distribution. Moore summarized his knowledge of the paleoecology of several different types of marine assemblages within Pennsylvanian and Permian cyclothems of Kansas. He briefly described a lower Stanton Captain Creek-type (*Enteletes*) assemblage from northeastern

Kansas, but mentioned only the occurrences of <u>Enteletes</u>, <u>Hystriculina</u> and associated fusulinids. Extensive faunal lists were presented for formations above and below the Stanton, but detailed descriptions of Stanton faunas were not included.

With the exception of Wray's (1964) paleoautecologic interpretation of the red alga, <u>Archaeolithophyllum</u>, recent studies of Stanton paleoecology have emphasized depositional features, either through independent sedimentological/sedimentary petrological studies, micro-paleontological studies, or both. Two separate studies have focused on the Rock Lake Shale Member in the upper Stanton. Russell (1972) used sedimentologic characters from the Rock Lake, the underlying Stoner and the overlying South Bend to interpret the dominantly red-brown shale and mudstone in the Nebraska area as regressive intertidal mudflat. Absence of an appreciable fully marine fauna was used as an indicator of marginal marine deposition, perhaps too harsh for marine organisms to survive. Hakes (1976) approached the Rock Lake from a different perspective and made interpretations in northeastern Kansas from a distinctive suite of trace fossils. He suggested that the wide variety of freshwater, brackish and normal marine indicators suggest a euryhaline environment, possibly a marginal marine lagoon. Distribution of trace fossil types was controlled by fluctuations in the "schizohaline" environment and ultimately by lithology. Hakes' conclusion is consistent with Moore's (1964) interpretation of marginal marine lagoonal deposition. Moore's evidence is a unique assemblage of land plants, arthropods, amphibians, reptiles and coelocanths found near Garnett, Kansas.

Heckel and Baesemann (1975) have recently compared distributions of Upper Pennsylvanian Kansas City and Lansing Group conodonts with observations of probable environmental significance and current paleoecological models in an effort to produce more integrated environmental interpretations of Missourian cyclothems. Although they used data from only northeastern Kansas, Wood (1977) investigated Stanton conodont distributions in southeastern Kansas within the algal-mound and terrigenous-detrital facies belts. His data corroborate the vertical trends noted by Heckel and Baesemann (1975), and show that vertical change in conodont abundance and diversity within the cyclothem sequence is much more marked than lateral facies change within each member. Wood's data also lend support to the pelagic model of conodont distribution (Seddon and Sweet, 1971) in the Kansas Pennsylvanian, suggest relative water depth distributions for individual taxa, and offer strong evidence for Heckel's (1977) interpretation of black shale deposition in Kansas-type cyclothems (see Wood and Heckel, 1977). M. D. Brondos (PhD. dissert. in progress, Univ. of Kansas) is examining aspects of Stanton micropaleontology in an attempt to document distributions and associations of ostracodes and foraminifers, and evaluate possible effects of lithologic and stratigraphic variation on microfossil assemblage changes.

Purpose and Scope

With the exception of Newell's original faunal lists, there has been little effort to thoroughly study macrofossil paleoecology of any Missourian limestone formation in eastern Kansas. Recent depositional-stratigraphic studies (Heckel, 1977, 1975a,b) and recognition of local biotic variation (Senich, 1975) have established a basic framework for paleoecologic study of the Stanton Limestone. Primary objectives of the present study are documentation of macrofossil composition and distribution in Stanton environments throughout eastern Kansas, and evaluation of physical factors that may have governed recognizable distributions. Determinable factors affecting observed patterns probably include: 1) paleogeography (facies belts), 2) lithofacies, and 3) depositional phase of the cyclic sequence. Paleogeography and lithofacies should reflect regional and local sedimentary environmental influence over biotic composition respectively. Understanding the phase of cyclic deposition within major transgressive-regressive sequences should enable evaluation of fossil distribution with respect to less readily determinable factors that are influenced by water depth, such as salinity, bottom oxygenation, light penetration and temperature. Knowledge of organic distributions in relation to the determinable factors should enable evaluation of the relative importance of the various less determinable environmental factors in limiting the distribution of major taxonomic groups, and increase understanding of relationships between organic development and Upper Pennsylvanian Mid-Continent deposition.

Methods

Field investigations were undertaken during the summers of 1975 and 1976, and for a short period during the Fall of 1976. All exposures were examined for macrofossil content, and then collected for preparation and identification of fossil specimens. To minimize collecting biases, exposures were either "picked clean" or collected until no new major elements appeared in the fauna. In the latter case, the remainder of the exposure was scanned for additional rare faunal elements. Attempts were made at all times to collect all identifiable fossil material. In instances when a particular taxon was unusually abundant and difficult to collect completely (eg. pelmatozoan debris), an estimate of its relative abundance was noted. As a precaution against float contamination, limestone and sandstone blocks were cracked and the faunal content retrieved for comparison. Bulk shale samples (minimum 2 kg) were also collected and analyzed for comparative macrofossil content. Additional representative lithologic samples were selected from all Stanton horizons, regardless of biotic content, for laboratory sedimentologic and petrographic thin-section preparation. Wherever possible, at least two or three samples were taken at each locality; in places with several lithologies, enough samples were collected to effectively cover the range of variation in the exposure.

Laboratory preparations and analyses were completed during the academic years 1975-76 and 1976-77. Fossil specimens were cleaned, and identifications attempted to generic or specific levels wherever possible. Successively higher taxonomic levels were assigned to large broken fragments and highly fragmented and abraded bioclasts. Efforts were made in most cases to use current taxonomies, but this was not always possible. For example, productoid brachiopods, which are generally poorly preserved in the Stanton, were necessarily identified according to Dunbar and Condra (1932). The more recent and comprehensive productoid classification of Muir-Wood and Cooper (1960) was considered impractical, as it relies on delicately preserved internal morphologies, which are not generally recognizable in the Stanton specimens. When in doubt concerning proper taxonomic assignment, specialists were consulted for confirmation or correction of identifications, particularly in groups such as echinoderms, cephalopods and corals, which remain less familiar to the author.

A two-fold petrographic and sedimentologic approach was established for lithologic analysis. Approximately 250 limestone, sandstone and siltstone thin-sections were prepared for examination of characteristics indicative of original sediment type. A standard 350 point-counts per slide served to determine relative proportions of major components, including all skeletal grain types and non-skeletal mud, micrite, interstitial spar, void-filling spar, dolomite, quartz, pellets, ooliths and clasts. Corresponding polished slabs were examined macroscopically for sedimentary features and textures such as bioturbation, lamination, graded bedding, sorting and color. Shale samples were randomly split and dried for 24 hours in an oven. Each sample split was weighed and the dry weight recorded. One split was immersed in Stoddard's solvent for disaggregation of clays and the other in 10% formic acid for removal of carbonate material. Samples were later washed through a nest of standard 10, 20 and 60 mesh sieves. No effort was made to retrieve size fractions less than 60 mesh (2ϕ) as this was considered repetitive of the micropaleontological studies mentioned previously. Trapped residues were recovered from sieve screens, dried overnight in an oven, and the dry weight recorded. All residues were examined under a binocular microscope for skeletal and non-skeletal constituents. Estimates of relative abundances of constituent grains were recorded, but there was no effort to treat the residues quantitatively, or for clay mineralogy.

Study Area: Geographic and Stratigraphic

The Stanton Limestone crops out in roughly a linear pattern in eastern Kansas from Leavenworth County to southwesternmost Montgomery County (Fig. 2). Excellent exposures of open-marine facies occur in northern Anderson, Franklin, and Johnson Counties. Thickened algal-mound facies are best developed in northern Montgomery and Wilson Counties, and thin laterally through Woodson and Allen Counties. The thick clastic sequence of the terrigenous-detrital facies begins at the southern extent of the mounds and continues into Oklahoma where individual Stanton members become indistinct.

Generally excellent exposure, well-known and abundant fossil biotas and a detailed stratigraphic framework make eastern Kansas a particularly interesting area in which to study vertical and lateral biotic distribution, and evaluate biotic responses to lithologic, paleogeographic and phase changes within the depositional cycles. Emphasis in this study is focused on the terrigenous-detrital and algal-mound facies of Montgomery, Wilson and southern Woodson Counties, as greatest biotic and lithologic change occurs in all members across the transition of these facies belts. Selected sections in the open-marine facies belt will be examined to generalize the more laterally persistent character of the Stanton in this area.

STRATIGRAPHY AND PETROGRAPHY

The Stanton Limestone along outcrop in eastern Kansas ranges from about seven meters in the northeast to 36 meters in the thickest known exposure in Montgomery County (Heckel, 1975a). Gradual westward regional dip produces outcrop widths of up to 15 kilometers normal to depositional strike. The Stanton has been traced northward into northwestern Missouri, and equivalent strata have been recognized in the Wann Formation of northeastern Oklahoma (Cocke, 1970; Heckel, 1975a). Condra (1930) also recognized members of the Stanton in an isolated inlier in the Platte Valley region of southeastern Nebraska. Throughout the major portion of outcrop, the Stanton is readily divisible into five members, in ascending order: Captain Creek Limestone, Eudora Shale, Stoner Limestone, Rock Lake Shale, and South Bend Limestone (Fig. 3).

In the open-marine facies belt of northeastern Kansas, the Stanton persists as a fairly uniform sequence of open-marine limestones and shales. Individual members can be easily delineated and maintain their character laterally for many kilometers with only minor variation (Heckel and Cocke, 1969). South of Anderson County in east-central Kansas, poorly known lateral relations between open-marine and algal-mound facies make identification of members less easy.

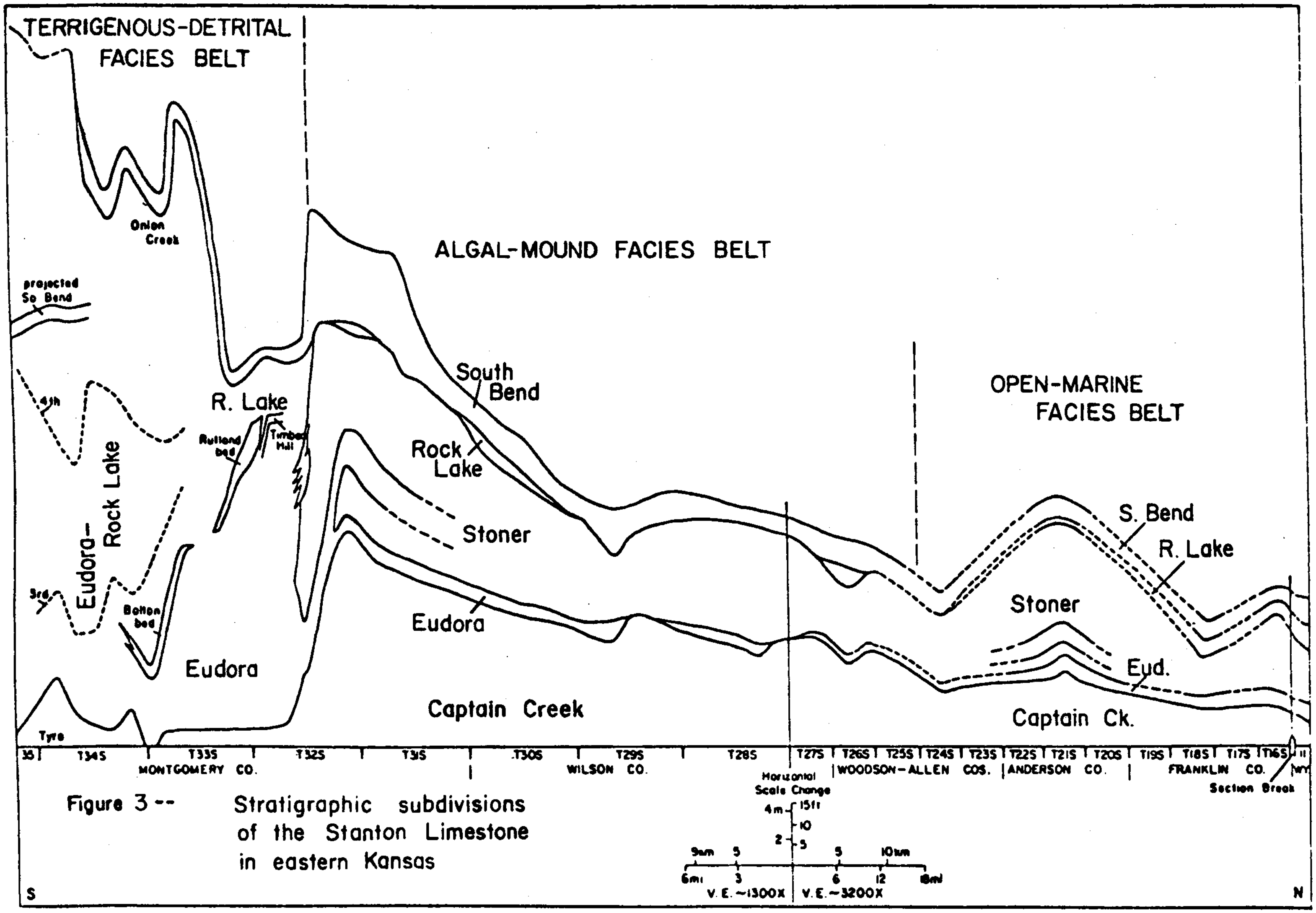

Figure 3 -- Stratigraphic subdivisions of the Stanton Limestone in eastern Kansas

Great local variations and abrupt lateral facies changes characterize limestones where algal-mound complexes are transected by contemporaneous channels. Mound thicknesses increase locally to ten meters or more and are several times thicker than normal non-mound equivalents (Heckel and Cocke, 1969). Shale members thin markedly and locally pinch out over the tops of the mounds. South of the mound complex, limestones in the Stanton thin and grade abruptly into a thick sequence of shale, siltstone, sandstone and other thin limestones in Montgomery County (Heckel, 1975a). Approaching the Oklahoma border, the five-fold member subdivision becomes less applicable. Within this area, Heckel (1975a) has traced the southern continuation of the Captain Creek and South Bend, the southward disappearance of the Stoner into shale, and the appearance of several informally named limestone, sandstone and siltstone beds in the generalized Eudora-Rock Lake interval in southernmost Kansas.

Petrographic examination of Stanton lithologies reveals a variety of textures and compositions. Limestones display the greatest variability across all major facies belts, and range from mudstones and wackestones to more mud-free packstones and grainstones. Skeletal and non-skeletal constituents characterize local lithofacies, and are primarily responsible for observed lateral and vertical stratigraphic variation. Excluding black, fissile facies, shales generally appear more homogeneous along outcrop than limestone. However, the presence or absence of skeletal material immediately distinguishes gross compositional differences. Sedimentological analysis of shales (see Appendix E) reveals further variation in proportions of detrital sand, silt, clay, and skeletal carbonate content. Sandstones are least lithologically variable, and can be generally recognized as calcareous or non-calcareous quartz arenites. Local oolitic and/or minor skeletal content is common in calcareous sandstones that occur primarily as lithofacies variants of major limestone units. Non-skeletal and non-calcareous sandstones are more common in shale members, particularly in the terrigenous-detrital facies belt.

Discussion of lithologies in individual members or beds is generalized in an effort to convey major compositional and textural trends throughout the major facies belts. In all instances, diagenesis has been minimal, and lithologic characters are considered to be reasonable indicators of original sediments and substrates. Figure 4 accompanying petrographic discussions is an attempt to relate sediment-substrate distributions. Mudstones and wackestones are figured as lime mud sediments, packstones and grainstones are lime sands, and oolitic limestones are illustrated as oolitic sands. Shales in both the Eudora and Rock Lake are figured as silty, argillaceous mud sediments. Shales containing potentially significant amounts of sand-size detrital material (greater than 25% by volume) are figured as sandy, argillaceous mud sediments. Non-skeletal carbonate is insignificant in any shale, and does not warrant further recognition. Quartz arenites are displayed as either quartz sand or calcareous quartz sand sediments, depending on the presence or absence of sparry calcite matrix.

Captain Creek Limestone Member

Stratigraphy

The Captain Creek Limestone is the most easily recognizable unit of the Lansing Group in northeastern Kansas (Newell, 1935). In Leavenworth County, the Captain Creek is typically one meter of even, thin-bedded, dense, blue-gray calcilutite, which thickens southward, reaching three meters or more in Anderson, Allen and northern Woodson Counties. The uniformity of the member in northeastern Kansas, along with a diverse marine biota suggests normal open-marine shelf deposition in this area.

Southward from the open-marine facies belt, marked thickening characterizes the Captain Creek in the algal-mound facies belt of southern Woodson, Wilson and northern Montgomery Counties. It appears as an irregular thick-bedded to massive, light to dark gray, often mottled and vuggy algal calcilutite approaching 15 meters in thickness at the southern end. Lithologies are variable and grade from non-algal to algal and sparry algal calcilutites and algal calcarenites. Algal structure is usually obliterated by recrystallization, and accordingly, all algae are collectively described as leaf-like phylloid algae. In instances of exceptionally good algal preservation, green codiaceans and the red coralline alga Archaeolithophyllum have been identified locally.

Southward into the detrital facies belt of Montgomery County, the Captain Creek thins abruptly to less than two meters of dominantly calcisponge-rich calcilutite. Thin oolite marks the base in the northern end of the detrital belt, and is separated from the main calcilutite ledge by a fossiliferous sponge-rich shale, which is approximately 0.5 meters thick. Phylloid algae disappear in the sponge calcilutites, but algal-foraminiferal encrustations surround some of the macrofossils.

Petrography

The basal member of the Stanton is dominated by a suite of texturally variable mudstones and wackestones that suggest an original carbonate mud sediment. Both lithologies are similar, and contain comparable proportions of mud and spar matrix. The only appreciable difference is in the greater abundance of skeletal grains in wackestones

(Appendix D, Table 9). Mudstones and wackestones are the only lithologies in the open-marine and algal-mound facies belts, but are stratigraphically limited to the uppermost bed in the terrigenous-detrital facies belt (Fig. 4). In general, slightly more skeletal-rich lithologies occur in basal and local upper portions of the member in the two northern facies belts, wheras low skeletal content (less than 10%) characterizes middle and upper portions in the same area. In all carbonate-mud-dominated lithologies of the northern facies belts, constituent grains are primarily sinuous blades and fragments of phylloid algae, pelmatozoan debris and foraminifers. Subordinate, but locally significant skeletal grains include bryozoans, brachiopods and ostracodes. Skeletal grains are typically fragmented and/or disarticulated, but show no appreciable evidence of abrasion. Thin, algal-foraminiferal Osagia laminations encrust larger skeletal grains in local basal lithologies. Constituent grains in mud-supported lithologies of the terrigenous-detrital facies belt comprise a distinctively different association of skeletal grains. Beaded sponges (frequently Osagia-encrusted) are the dominant skeletal grains, with common pelmatozoan and bryozoan debris, brachiopods, and rare gastropods and bivalves occurring as subordinate constituents. As in the northern facies belts, skeletal constituents are fragmented, but not abraded. Mud in most

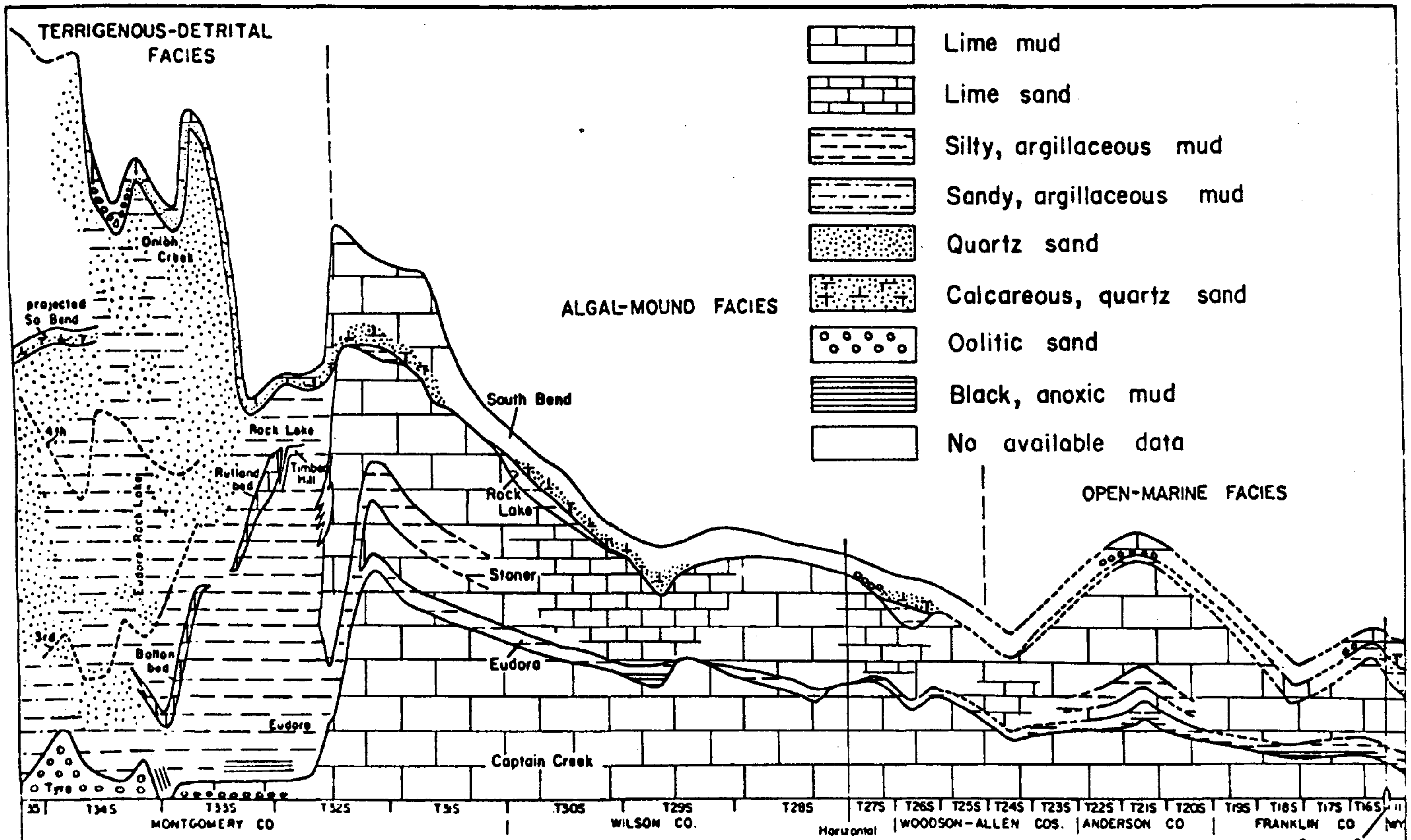

Figure 4 -- Distribution of major sediment types in the Stanton Limestone

Captain Creek lithologies, regardless of facies belt or stratigraphic level appears mottled or disturbed, which may suggest intense bioturbation of the sediment.

Packstones and grainstones representing carbonate sand sediments are geographically and stratigraphically limited to the basal portion of the Captain Creek in the terrigenous-detrital facies belt (Fig. 4). Constituent grains are overwhelmingly more significant than matrix, which consists of sparry calcite cement and rare, minor amounts of interstitial mud. Ooliths are the most abundant constituent grains, and only rarely are non-oolitically coated skeletal grains present. Oolitic nuclei are primarily detrital quartz grains, with less common mud pellets and skeletal grains (pelmatozoans, bryozoans, brachiopods, foraminifers and gastropods). Ooliths are frequently distorted showing interpenetrated margins, but this likely developed due to pre-lithification close packing compaction of grains.

Solvent-insoluble weight percent suggests that more than 70% of the Captain Creek shale in the detrital facies is clay/silt and fine sand-size material less than 0.25 mm. Formic acid treatment reveals an even lower percentage (0.19%) of insoluble constituents that are medium sand-size or coarser. The difference between both fractions suggests that nearly 29% of the shale is sand-size skeletal and non-skeletal carbonate. The sand-size carbonate fraction is entirely skeletal debris, including abundant pelmatozoan and sponge fragments and less common brachiopods, bryozoans, ostracodes and foraminifers. The small percentage of acid-insoluble grains coarser than 0.25 mm consists of non-descript irregular, gray aggregates of clay/silt-size material.

Tyro oolite

Stratigraphy

The Tyro oolite is a persistent bed that can be traced from the northern end of T34S (Montgomery County) southward into Oklahoma. It is generally a yellowish to orangish-brown or light gray weathering cross-bedded oolite that varies in thickness from less than 60 cm to more than 4.5 meters at the type section. Skeletal debris is most conspicuous in concentrated bands that accent cross-bedding. Whole shells are generally less prominent, and occur as scattered elements throughout the oolite. An exceptionally well-preserved abundant and diverse fauna characterizes local calcilutitic zones at the top of the oolite. Typical Eudora black shale overlies the Tyro, and suggests that the oolite is stratigraphically equivalent to the Captain Creek. However, the Captain Creek disappears nearly 2 km north of northernmost oolite exposure, and no known lithologic transition exists between these units to prove stratal continuity. Therefore, the Tyro is considered a distinct lithologic unit marking the base of the Stanton in southern Montgomery County. The name Tyro oolite was first mentioned by Strimple and Cocke (1969), and has been formally named by Heckel (1975a) for the type section (Loc. TyQ) and other exposures near the village of Tyro, Kansas.

Petrography

The Tyro oolite is petrographically the most homogeneous unit in the Stanton, and most frequently appears as a dense, well-washed, spar-cemented, oolitic grainstone. Ooliths (average 0.7 mm) are the only significant constituent, and frequently constitute more than 70% of the rock. Oolitic nuclei are rounded to angular quartz grains, carbonate mud pellets and rare indeterminate skeletal fragments. Extremely rare non-oolitically coated skeletal grains comprise the remaining non-matrix constituents, and include pelmatozoans, ostracodes, foraminifers, brachiopods and bryozoans. Localized limonitic mud matrix, slight north to south increase in oolith size, and scattered concentrations of non-oolitically coated skeletal grains are the major lithologic variations in the bed.

Eudora Shale Member

Stratigraphy

The Eudora Shale is a persistent shale that separates the Captain Creek from the overlying Stoner Limestone Member.

In the open-marine facies belt of northeastern Kansas, it is characteristically argillaceous, greenish-gray to gray in color, and averages approximately two meters in thickness. The most distinctive feature of the Eudora is the presence of a fissile, black shale that contains phosphatic nodules and occupies a major portion of the lower half of the unit (Moore, 1936; Newell, 1935). Although it thins locally to less than 30 cm in northern Anderson County, the black shale seems continuous southward through central Anderson County where approximately one meter is exposed (Heckel, 1975a). Miller (1969) reports gray shale with black fissile lenses at the base in northern Allen County.

Within the algal-mound facies belt, the Eudora thins to a few centimeters, and locally pinches out over the top of the Captain Creek mound complex. Where present, it appears typically as a bluish-gray to gray limy shale over the Captain Creek mound. The black fissile facies is not known over the mounds, but does occur as a thin unit in the bottoms of the major channels. Unlike the more argillaceous gray shales to the north, the limy shales over the mounds generally contain a diverse marine invertebrate fauna. The black facies in both areas is generally barren except for a few organisms considered to be pelagic or epipelagic.

South of the mound complex the Eudora thickens to a maximum of 21 meters within the detrital belt. The shale is generally a gray or light brown fossiliferous limy to silty unit with a thin zone of black fissile shale reappearing at the base. Molluscan-dominated faunas generally characterize gray shales, and a brachiopod-bryozoan dominated fauna commonly occurs in the light brown shale, particularly at the top of the Eudora in the northern end of the detrital belt, where the brown shale is believed to be the southern gradation of the overlying Stoner Member (Heckel, 1975a). The Eudora thins through central Montgomery County to 5.5 meters of dominantly gray clayey shale. Thin sandstone units appear in this area and become more prominent toward Oklahoma, particularly south of the last persistent thin limestone (Bolton bed), which readily separates the Eudora from the Rock Lake. Faunas, where present, remain molluscan or brachiopod-dominated throughout the Eudora in southern Montgomery County.

Petrography

Eudora shales in the open-marine facies belt are notoriously non-descript, gray shales (excluding the fissile black platy facies), which on outcrop are characterized by a paucity of fossils. An average of slightly less than 10% of the shale remains as a solvent-insoluble residue greater than 0.25 mm, whereas a much greater percentage of the shale that is medium sand-size or coarser (average of 52%) remains insoluble in formic acid. Binocular examination of insoluble fractions reveals dark gray, slightly micaceous clay/silt grain aggregates grading southward to irregularly shaped, well-indurated silty-micaceous grains, reddish-brown to buff micaceous clay/silt grain aggregates, buff to gray clayey clasts, and locally sub-rounded to rounded, medium sand-size (0.3-0.5 mm) detrital quartz. Skeletal grains are extremely rare throughout the facies, and so far as known, consist only of scattered planispiral, discoid-shaped foraminifers. The low solvent-insoluble residue content, the inability of formic acid to significantly reduce the shale, and the lack of carbonate skeletal grains indicate that gray Eudora shales of the open-marine facies belt are highly argillaceous and lack significant carbonate.

The appearance of abundant skeletal and non-skeletal carbonate marks the transition from the open-marine to the algal-mound facies belt, and characterizes gray Eudora shales throughout the member. Dark gray shales overlying black fissile shales are generally characterized by dark gray carbonate mud aggregates, disseminated pyrite and scattered black platy chips with conspicuous irregular-shaped burrows appearing as gray muddy traces. These dark gray shales are also significantly lower in skeletal content than upper Eudora shales, and contain only rare pelmatozoan ossicles, indeterminate bryozoans and orbiculoid brachiopods.

Lower shales in the southern part of the facies belt are relatively more skeletal-rich than northern equivalents. Upper Eudora gray shales contain an average of more than 30% solvent-insoluble residue content, and an extremely small acid-insoluble fraction greater than 0.25 mm (less than 0.25 %). Binocular examination of acid- and solvent-insoluble residues reveals extremely rare pyrite crystal aggregates as the only non-skeletal constituents. This low acid-insoluble percentage and the absence of non-carbonate and non-skeletal carbonate grains suggest that almost all of the solvent insoluble residue coarser than 0.25 mm is skeletal. Pelmatozoan ossicles are abundant, and echinoids, low-spired gastropods, brachiopod fragments and fenestellid and rhomboporid bryozoan pieces are rare to common.

In the terrigenous-detrital facies belt, lower buff to light gray shales above the black platy facies are on the average slightly less than 8% solvent-insoluble, whereas an average of 3.5% remains as acid-insoluble residue coarser than 0.25 mm. Insoluble non-skeletal grains consist of flat, discoid clay/silt grain aggregates that appear slightly micaceous; scattered, rare molluscs, brachiopods, bryozoans and worm tubes constitute the entire sand-size carbonate fraction. The bulk of the shale appears to be non-carbonate clay, silt and fine sand. Above the lower light-colored shale, the Eudora becomes a darker gray shale with a somewhat greater percentage of fine, non-skeletal silt/clay, and skeletal content consisting of abundant pelmatozoan ossicles, ostracodes, foraminifers and less common molluscs, brachiopods and bryozoans. Solvent-insoluble residues reflect the low percentage of sand-size material (less than 2.5%, most of which is skeketal, or non-skeletal grains of aggregated clay-size carbonate), and acid-insoluble residues average less than 0.2% sand-size material that is mostly rare silt/clay and pyrite-crystal aggregates and undissolved skeletal grains.

Southward, in the central part of the terrigenous-detrital facies belt (below the Bolton bed), the entire non-black Eudora becomes another lithofacies variant that appears distinctive in outcrop expression, but is sedimentologically similar to shales in the northern part of the facies belt. Approximately 5.5% of the shale remains as sand-size material after solvent treatment, and primarily consists of limonitized quartz-sand aggregates, well-rounded medium sand-size (0.3-0.5 mm) frosted, detrital quartz grains, and rare molluscan, pelmatozoan and brachiopod debris (despite abundant outcrop appearance). Average sand-size acid-insoluble weight percent of 0.5%, solvent-insoluble weight percent, and general appearance of residues suggests that this shale represents a clay/silt environment that contained minor detrital quartz sand and supported a diverse macrofauna that contributed only minor sand-size skeletal material to the sediment.

Light gray shales at the southern end of the detrital facies belt characterize another lithofacies variant. Breakdown of these shales is most complete in solvent, although an average of more than 15% usually remains as sand-size aggregates and individual grains. Carbonate skeletal constituents are unknown in any residues, but conspicuous common to abundant uniserial, agglutinate foraminifers are present in coarse sand-size fractions. Most prevalent in all residues greater than 0.25 mm are micaceous quartz silt-grain aggregates. The absence of carbonate skeletal grains and the inability of acid treatment to affect further shale breakdown suggests that there was little, if any, available carbonate in the environment.

South of the disappearance of the Bolton bed, the Eudora and Rock Lake are inseparable. Southward thinning of the Eudora beneath the Bolton bed combined with the position of the two major calcareous zones in the Rock Lake, suggests that the great majority of the Eudora-Rock Lake interval of southern Montgomery County consists of strata equivalent to the Rock Lake Member (Heckel, 1975a). Dark shales at the base of the Eudora-Rock Lake interval, which are considered equivalent to the Eudora are characterized by a lack of skeletal grains and an apparent absence of non-skeletal carbonate. Toward the northern part of the detrital basin, shales are finer grained (0.17% sand-size solvent insoluble) than southern equivalents (14% sand-size solvent insoluble). Plus 60-mesh sand-size non-skeletal grains in northern shales are slightly micaceous quartz-silt and clay aggregates, wheras southern shales are distinctly more micaceous quartz-silt aggregates. Fine sand-size detrital quartz also occurs as small aggregates with silt matrix in coarsest sand fractions of southern Eudora-Rock Lake shales.

Stoner Limestone Member

Stratigraphy

The Stoner is typically thin to wavy-bedded, light gray, fine-grained skeletal calcarenite to calcilutite in northeastern Kansas. Thin shaly partings separate individual beds that normally range from five to 20 cm thick (Moore, 1935). Total thickness of four to five meters and a brachiopod-bryozoan-echinoderm fauna characterizes the Stoner throughout much of the open-marine facies belt.

Southward, the member thickens to as much as 7.5 meters at the northern end of the algal-mound facies belt in central Anderson County. The lower half is thin- to medium-bedded skeletal calcilutite, similar to that of the open-marine facies belt, but with increasing shaly interbeds toward the base and increasing phylloid algae toward the top. The upper half maintains general characteristics of northern facies but develops a small phylloid algal mound. A 1.5 meter gray fossiliferous shale, formerly recognized as "Eudora" because of gross lithic and faunal similarities (Heckel, 1975a,b), but now regarded as a bed within the Stoner (Heckel, pers. commun., 1976), occurs near the base, and is separated from the underlying Eudora Member by a 70 cm ledge of poorly fossiliferous calcilutite. Southward from central Anderson County to the southern limit of the mound tract in northern Montgomery County, few complete sections of Stoner are available to determine total thickness. Wherever exposed, at least 4.5 meters of thin- to medium-bedded calcilutite can be recognized, and as much as 12 meters is estimated in the Elk River Valley of northern Montgomery County. Throughout the mound tract of southern Woodson and Wilson Counties, the Stoner is primarily medium-bedded algal and invertebrate calcilutite, which becomes more shaly and invertebrate-rich toward the base.

Marked lithologic and biotic variability associated with local facies development is characteristic of the upper Stoner in Wilson County. A rim along the northwestern edge of the mound tract is primarily spar-cemented, abraded-grain skeletal calcarenite, which may be locally cross-bedded, and contains a diverse marine biota. Muddier variants in the rim contain a variety of different biotic associations (Senich, 1975), and likely reflect small-scale local environmental differentiation within rim facies. Contemporaneous channels up to one kilometer wide and 30 km long transect the mounds and represent a second major lithic variant. In the Wilson County channel, the lower meter of channel fill is skeletal calcilutite with abundant bryozoans and echinoderms. The upper part of the channel contains up to six or seven meters of massive spar-cemented skeletal calcarenite, consisting of abraded algal and invertebrate debris, which locally displays bi-directional cross-bedding, suggestive of tidal currents.

At the south end of the mound facies in northern Montgomery County, the Stoner becomes less shaly throughout and thins rapidly before it finally pinches out into shale. Heckel (1975a,b) assigns all Stoner-equivalent shale to the Eudora because of the position of thin siltstone and limestone marker beds that appear above the shale just south of the pinchout. The marker beds separate the Eudora and the Rock Lake Shale Members in central Montgomery County, and seem equivalent to parts of the Stoner, but are not continuous with the Stoner along outcrop.

Petrography

Wackestones and mudstones characterize the Stoner in the open-marine facies belt (Fig. 4, p. 24). proportions of mud to spar matrix remain fairly constant laterally and vertically throughout the facies, and the only significant difference is in the abundance and composition of skeletal constituents. Skeletal-poor mudstones generally appear in middle to upper portions of the member, and vary from low diversity pelmatozoan, bryozoan and foraminiferal lithologies to more diverse lithic types in the southern part of the facies belt where they also contain phylloid algal fragments, brachiopods, ostracodes and rare trilobites. Wackestones occur throughout the member, and are more skeletal rich, but show little compositional difference from mudstones. Phylloid algal blades and fragments are more conspicuous in wackestones, and gradually increase in abundance southward through the facies belt. Other skeletal constituents are only locally more abundant than algal remains, and consist of pelmatozoan, bryozoan and brachiopod fragments, with rare to common ostracodes, foraminifers, molluscs, and algal-foraminiferal Osagia laminations. Skeletal constituents are most commonly fragmented and disarticulated, but all lack any indication of abrasion. Mud matrix dominates all constituents and averages 65-70% by volume, but is locally as much as 95% of the total composition (Appendix D, Table 10). Clear calcite spar matrix is sporadically distributed throughout individual lithologies, but is generally not as common as void-filling spar in fractures and skeletal cavities. Unlike the Captain Creek, sediment mottling and clotting structures are uncommon in the Stoner.

Wackestones of the algal-mound facies belt are characterized by marked textural and compositional variation both laterally and vertically. Mudstones are generally less common, but similar to mudstones of the open-marine facies. In both major lithologies skeletal grains are the only non-matrix constituents except for rare, fine sand-size detrital quartz in the basal wackestones near the southern end of the facies belt and in muddy lenses of the rim lithofacies. Phylloid algal blades and fragments remain the most conspicuous and abundant constituents throughout most of the facies belt. Remaining skeletal grains in algal-mound wackestones are diverse, although individual grain types rarely occur as more than common constituents. Local concentrations of pelmatozoan and bryozoan debris are subequal to algal content, but neither is individually more significant than algae. Brachiopod-dominated wackestones that completely lack algal and pelmatozoan debris occur as rare lithic types at the southern end of the facies belt. Dense, bioturbated carbonate mud is the only significant matrix component in algal-mound wackestones, and may constitute more than 65% by volume.

Unlike algal-mound lithologies, wackestones of the rim lithofacies are characterized by skeletal-sediment proportions that approach packstone fabric. Mud matrix predominates in most instances, but is less conspicuous in extremely skeletal-rich lithologies (Appendix D, Table 10). Phylloid algae are minor skeletal elements, whereas pelmatozoan and bryozoan debris overwhelms all other constituents. All other skeletal grains are less common, but remain more abundant than in algal-mound wackestones. All skeletal grains (except foraminifers) are disarticulated and/or fragmented, and many grains, particularly pelmatozoans, show signs of abrasion. The overall muddy, skeletal-rich packstone texture may be due either to mud deposition after periods of agitation, or prolific local invertebrate productivity in muddy protected areas of the rim lithofacies.

Except for pelmatozoan-bryozoan-rich packstones in the base of the member in Allen, Woodson and Wilson Counties, Stoner packstones are limited to unique topographic features in Wilson County. In the major channel that transects the algal-mound tract, coarse pelmatozoan and bryozoan-pelmatozoan packstones are dominant lithologies (Fig. 4, p. 24). Pelmatozoan and fenestellid bryozoan debris overwhelmingly dominate skeletal constituents, but disarticulated brachiopods and bivalves, gastropods, ostracodes and foraminifers are locally abundant. All skeletal material is fragmented, and most grains show evidence of abrasion. Grain-supported fabrics are cemented by sparry calcite, and locally approaches grainstone in appearance, but are considered packstones because they have at least a small amount of interstitial mud. This mud probably resulted from incomplete winnowing during agitation, and interbedded muddy lenses likely represent slack-water mud deposition during lesser periods of agitation.

The second major packstone occurrence in Wilson County occurs in the rim lithofacies (Fig. 4, p. 24). Rim packstones are similar to channel packstones, but appear to be generally more well-washed, show more grain abrasion, and are geographically less extensive. Perhaps the most diverse association of skeletal grains in the Stoner occurs in rim packstones. All major invertebrate phyla are represented, but pelmatozoans, fenestellid and rhomboporid bryozoans, and foraminifers dominate. Other skeletal constituents are more scattered and include occurrences of extrmemely rare trilobites, partially preserved Archaeolithophyllum and the solenoporid red alga Parachaetetes. Sparry calcite cement is the only matrix filling interstices of rim packstones, and appears to be more extensive than in channel packstones. Mud appears rarely as abraded, irregularly shaped clasts.

The discontinuous gray-green shale bed in the lower Stoner at the southern end of the algal-mound facies and in Anderson County (Loc. MI) contains faunal elements that also appear in the Captain Creek shale bed of central Montgomery County. Solvent-insoluble residue data show that on the average, less than 12% of the shale by weight is coarser than fine sand (greater than 0.25 mm). Formic acid treatment of a similar original sample size reveals an acid-insoluble fraction of approximately 0.4% (Appendix E, Table 16). Although the shale is richly fossiliferous in outcrop, only slightly more than 11% of the shale is medium sand-size or coarser skeletal carbonate. Observation of non-skeletal acid-insoluble fractions reveals common buff-colored, slightly micaceous silt/clay chips and flat clasts that are frequently limonitized. Plus-60 mesh carbonate skeletal composition displays slight local variation, but generally shows an abundance of pelmatozoan debris, common to abundant bryozoan fragments, common brachiopods, rare to common ostracodes and foraminifers and rare gastropods.

Bolton limestone bed

Stratigraphy

The Bolton bed is the southernmost limestone marker unit in the detrital facies, which arbitrarily separates the Eudora and Rock Lake Shale Members. Heckel (1975a) proposed the name for the arcuate band of exposures cropping out near the settlement of Bolton, Kansas. The Bolton bed is a lenticular body ranging from 30 cm to 1.4 meters and locally thins almost to zero. It is dominantly a yellowish-orange to yellowish-gray weathering whole-shell skeletal calcarenite with local lenses of oolite and common quartz sand. Its northernmost exposure is approximately 2.5 km south of southernmost exposures of the Rutland bed, and there is no known surface connection between the two beds (Heckel, 1975a). The base of the Bolton is stratigraphically six to 7.5 meters lower than basal Rutland, and thus the Bolton is regarded as stratigraphically distinct from the Rutland bed. A similarity in conodont faunas (Wood, 1977) suggests that the Bolton bed is stratigraphically equivalent to the lower Stoner.

Petrography

The Bolton bed comprises several gradational packstone and grainstone lithologies including oolitic grainstone and pelmatozoan-oolitic and quartz-skeletal packstones (Fig. 4, p. 24). With the exception of quartzose lithologies in northern and southern exposrues, none of the lithic variants can be readily segregated either geographically or stratigraphically. Calcite spar-cemented oolitic grainstone is most similar to the Tyro oolite, and is characterized by medium sand-size ooliths (0.4-0.6 mm) that frequently constitute as much as 45% of the rock. Nuclei are most commonly sub-rounded to angular quartz grains and rare skeletal grains. Non-oolitically coated skeletal grains include foraminifers, pelmatozoan ossicles and bryozoan fragments. Pelmatozoan-oolitic packstones differ from oolitic grainstones only in the amount of mud matrix and skeletal content. Mud is subordinate to calcite spar, but may be as much as 10% of the total volume. Skeletal grains are significantly more abundant (average 30%) and more diverse, including pelmatozoans, bryozoans, brachiopods, ostracodes, foraminifers and *Osagia* encrustations on larger skeletal grains. Ooliths are the same as in the grainstone, but skeletal grains are more frequent as nuclei, although not as abundant as quartz grains. Quartz-skeletal packstones are gradational to pelmatozoan-oolitic packstone, but are generally more skeletal rich and less oolitic. Angular to sub-rounded, fine to medium sand-size quartz grains constitute approximately one-third of the total composition, and are rarely oolitically coated. Skeletal grains are frequently an equal third of the bulk composition, and comprise the most diverse association of skeletal grains in the Bolton bed. This includes all grains commonly found in pelmatozoan-oolitic packstones, and rare gastropods, bivalves and corals. However, unlike the previous skeletal association, a significant number of grains occur as whole-shell constituents. Remaining grains are only moderately fragmented, and none appear to be abraded.

Timber Hill siltstone bed

The Timber Hill is a thin 0.5 to 1.5 meter-thick bed of tan to light gray siltstone. It is generally unfossiliferous, although rare molluscan fragments and brachiopods are known. Stratigraphically it overlies Stoner-equivalent shale, and at its southernmost exposure it is overlain by the Rutland bed. The name Timber Hill was proposed by Heckel (1975a) for excellent exposures along the east side of Timber Hill (Loc. TH, see Appendix C). It occurs in limited exposure in the northern portion of the terrigenous-detrital facies belt.

The Timber Hill is lithologically a thin-bedded, quartz siltstone that is composed almost entirely of sub-angular to sub-rounded quartz grains, which average about 0.04 to 0.06 mm in size. Other constituent grains are exceedingly rare, and include only small flakes of muscovite, and echinoderm, bivalve and brachiopod fragments. Sparry calcite matrix contributes to the hard, dense nature of the bed.

Rutland limestone bed

Stratigraphy

The Rutland bed is the first limestone unit above the Captain Creek in the northern end of the detrital facies belt. It is a lenticular body of tan to orange-brown weathering, cross-bedded, bioclastic calcarenite, which attains a maximum thickness of 2.5 meters at its type section. An abundant and diverse marine biota including several red (coralline and solenoporid) and green (codiacean and dasyclad) algal types characterizes the bed. It is stratigraphically higher than any other Stoner equivalents, as it overlies the Timber Hill, which in turn overlies shales known to pass into definite Stoner lithologies. It is also separated from the Stoner by more than three kilometers of shale and siltstone, and is lithologically unlike any of the nearby Stoner. Heckel (1975a) proposed the name Rutland bed for the type-section and other exposures of the unit in Rutland Township, Montgomery County, Kansas (Loc. RB_t, see Appendix C).

Petrography

The Rutland bed is predominantly an algal-skeletal to algal-oolitic packstone to grainstone in the upper part of the bed (Fig. 4, p. 24). Skeletal grains are the most conspicuous constituents (Appendix D, Table 11), and in both lithologies most are fragmented and highly abraded.

Small, medium sand-size ooliths (0.3-0.4 mm) are present throughout the bed, but are more abundant than skeletal grains only in packstone. Oolitic nuclei are most commonly a variety of skeletal fragments and rare quartz grains. Remaining non-skeletal grains are rare, mud intraclasts that occur scattered throughout the lower part of the bed.

Algal grains are the most abundant skeletal constituents, and although most are indeterminate phylloid fragments, *Archaeolithophyllum*, *Parachaetetes*, and the green dasyclad *Epimastopora* have been identified. Remaining skeletal constituents represent a diverse invertebrate association dominated by pelmatozoan and bryozoan debris.

Mud matrix in algal-skeletal packstones averages more than 40% of the bulk composition, whereas it rarely exceeds 2-5% in algal-oolitic packstone. Sparry matrix averages slightly more than 10% in packstone, and averages only a fraction more than 20% in grainstone. The relatively low matrix content in grainstone is attributed to the higher percentage of skeletal and non-skeletal constituents.

Rock Lake Shale Member

Stratigraphy

The Rock Lake is perhaps the most lithologically variable of the Stanton members, and is also one of the most difficult to study, as its outcrop expression is sporadic. In eastern Kansas, it appears as a gray to olive-gray argillaceous to sandy shale, usually less than one meter thick but occasionally as thick as four meters. In local areas it may contain a thin coal smut overlain by thin, laminated gray limestone (Zeller, 1968). It appears as a medium gray, clayey shale with distinct siltstone lenses in Wyandotte County. Southward through the open-marine facies belt in Franklin County, the Rock Lake begins to display increased variability. Shaly limestones with molluscan-brachiopod faunas overlain by gray-green clayey shale or brachiopod-rich shale can be found in inactive quarries near Princeton, Kansas (Ball, et al, 1963). Near Garnett in Anderson County, the Rock Lake appears as a whitish calcareous shale with intercalated shaly limestones in the lower part, and is overlain by a brownish sandstone containing a marine fauna (Moore, et al., 1936). The lower calcareous units are well-known for the unique and famous Walchia flora, and insect fauna (Carpenter, 1940) and a vertebrate fauna (Peabody, 1952, 1957, 1958) as well as marine invertebrates commonly found in other Stanton members.

Within the mound tract, the Rock Lake thins appreciably and is poorly exposed. Where present, it is typically thin, rarely exceeding 30 cm to one meter of light gray to gray-green sparsely fossiliferous shale with local thin sandstone beds. Channels transecting the mound tract of Woodson and Wilson Counties are often filled or partially filled with reddish-brown cross-bedded Rock Lake sandstones, which sometimes approach several meters in thickness.

Southward into the detrital belt of Montgomery County, the Rock Lake thickens substantially reaching 30 meters and perhaps as much as 60 meters of only sporadically fossiliferous shales and sandstones. Immediately south of the mounds, it appears as three meters of tan unfossiliferous shale overlain by 60 cm of red-brown sandstone. The sandstone thickens rapidly to six meters and the shale to five meters in a short distance south and westward.

A reddish-brown to yellowish-brown sandstone, informally termed the Onion Creek sandstone body (Heckel, 1975a), constitutes the bulk of the Rock Lake interval in the northern portion of the detrital belt. Excellent exposures of thick-bedded to massive, unfossiliferous and locally cross-bedded sandstone attain a thickness of approximately 30 meters along Onion Creek in T33S. South of T33S, the Onion Creek sandstone grades into a thick sequence of interbedded sandstones and shales with thin limy horizons termed the 3rd and 4th oolitic zones. The sandstones are generally thin-bedded, reddish-brown to reddish-orange, friable and sometimes contain a sparse molluscan fauna dominated by infaunal bivalves. Shales are gray to buff, sandy, and effectively unfossiliferous.

Petrography

Most of the Rock Lake in the open-marine facies belt is gray to light gray-brown, non-descript shale, but local facies appear as light yellowish-brown clayey shale or light-gray shaly mudstone (Fig. 4, p. 24). Mud sediment lacking significant amounts of detrital sand or non-skeletal carbonate characterize the gray shales. Coarser than 0.25 mm sand-size fractions average slightly less than 21% by volume, and are primarily granular aggregates of clay and coarse silt. Skeletal constituents are extremely rare, and when present, consist of ostracodes, foraminifers, several low- and high-spired gastropods, and scattered woody fragments. Acid-insoluble residues average approximately 12%, and suggest that additional volume loss of the shale may be due to removal of minor amounts of carbonate matrix. This would cause further disaggregation of clay/silt aggregates.

Within the open-marine facies belt, shaly mudstone in the Rock Lake is presently known only from the base of the member at Locality PQ's. Skeletal grains are the only non-matrix constituents, and are rare despite the richly fossiliferous outcrop expression. Brachiopod, echinoderm and molluscan fragments are scattered throughout the mud matrix. Thin, discontinuous clayey shale seams impart a somewhat brecciated appearance to the mudstone. Overlying the mudstone is a thin (8-10 cm) yellowish-brown clay shale. This unit is relatively solvent-insoluble (45% coarser than 0.25 mm), and consists of clay/silt-size grain aggregates and skeletal debris in the coarser sand fractions. Unlike gray shales, skeletal grains are abundant and include pectenid bivalves, brachiopods, pelmatozoans, bryozoans and ostracodes. Acid-insoluble content is less than 0.1%, and likely reflects the loss of skeletal grains and a significant amount of non-skeletal carbonate matrix in clay/silt aggregates.

Southward into the algal-mound facies belt, poor exposure and modern erosion limit observation of the Rock Lake. Gray to gray-green silty shales crop out in Woodson County at the northern end of the mound tract. Less than 5% of these shales are solvent-insoluble sand-size residues consisting of scattered skeletal material and fine sand-size quartz and clay/silt aggregates. Skeletal material differs from that of northern shales, and is locally characterized by either common caniniid corals, echinoid debris and ostracodes, or extremely rare gastropods, ostracodes and nuculanid bivalves. Sand-size acid-insoluble residues average less than 1%, and reflect the loss of skeletal content. Unlike these shales, the Rock Lake at the southern end of the mound tract appears as gray-brown to reddish-brown silty shales. Solvent-insoluble sand-size fractions are proportionally equal to northern mound facies shales, but are compositionally distinct. Skeletal grains are conspicuously lacking, and non-skeletal material consists of silty aggregates and fine sand-size detrital quartz. Acid treatment fails to significantly further reduce the shales, and likely represents loss of only minor carbonate matrix that binds the silty aggregates.

Reddish-brown, friable, quartz arenites occur as Rock Lake detrital fill in major channels of the mound tract. Skeletal material is entirely lacking, and only rare, indeterminate trace fossils occur as scattered structures on bedding plane surfaces. Matrix appears to be minimal or absent in hand specimen. No effort was made to examine these sandstones petrographically because of the extremely friable nature of the rock.

South of the mound tract, variable tannish-gray to reddish-brown Rock Lake shales remain characteristically skeletal poor, and contain greater proportions of silt and fine sand-size material than northern equivalents. Medium and coarse sand content averages approximately 7% (increasing southward through the facies belt), and consists of solvent insoluble quartz-silt aggregates, flat, roughly disc-shaped, silty plates with rare micaceous flakes, and scattered quartz grains. Matrix includes carbonate, clay and hematite, but stratigraphic or geographic trends are not apparent for any of these matrix components. Quartz sand grains when present are typically rounded to sub-rounded, slightly frosted, and rarely coarser than medium sand-size. Sand-size skeletal material is sparse, and consists of whole and fragmented molluscan shells, and scattered echinoderm, bryozoan and brachiopod debris. Woody plant fragments are also rare and scattered, but are generally more common than invertebrate skeletal debris.

The Onion Creek sandstone body is the most laterally traceable unit in the Rock Lake of the terrigenous-detrital facies belt. It is generally a friable, yellowish-tan to reddish-brown quartz arenite (Fig. 4, p. 24). Quartz grains range from very fine to medium sand-size (0.1-0.4 mm), are generally sub-rounded, and do not appear to be etched, pitted or frosted, although some grains are hematite stained. Skeletal and other non-skeletal grains are entirely absent, with the exception of an occasional, isolated woody fragment. South of the Bolton bed in T34S and T35S, the Onion Creek grades into a sequence of sandstones and more typical Rock Lake shales. Sandstone beds are also quartz arenites that range from light brown to reddish-brown, thin- to thick-bedded, and appear to be somewhat finer grained than typical Onion Creek. Quartz grains range from very fine to fine sand-size (0.1-0.25 mm), and are sub-rounded to sub-angular. Unlike the Onion Creek, many of these sandstones are well-cemented by extremely coarse calcite spar, contain sparse molluscan and brachiopod fragments, and may have subordinate plagioclase, orthoclase and muscovite.

3rd oolitic zone

Exposures assigned to the informally named 3rd oolitic zone (Heckel, 1975a) constitute the lower of two thin, calcareous horizons appearing in the Rock Lake in the southern portion of the terrigenous-detrital facies belt. Lateral continuity of exposures remains conjectural, but similar lithologies appear approximately 3 to 7 meters above the level of the Bolton bed throughout T35S, T34S and southern T33S, suggesting a continuous outcrop.

Calcareous quartz arenites, with local variations displaying more skeletal and oolitic characteristics are the most common lithology in the 3rd oolitic zone. Arenites are overwhelmingly composed of angular to rounded, very fine to coarse sand-size (0.1-0.6 mm) quartz grains. Scattered, rare quartz grains occur as nuclei in both thinly and thickly coated ooliths. Skeletal constituents are rare or entirely absent (averaging less than 2% by volume), and consist of foraminifers and fragmented and abraded pelmatozoan, bryozoan, brachiopod and indeterminate molluscan debris. Matrix is primarily clear calcite spar, with insignificant amounts of mud.

Skeletal-oolitic quartz arenites are gradational from calcareous arenites, and differ only in the relative abundance of skeletal grains and quartz-nucleated ooliths. Medium to coarse sand-size quartz grains remain the most abundant constituent, but skeletal fragments and ooliths may be as much as 30% of the total composition. Skeletal grains are most frequently pelmatozoan ossicles and rare bryozoan, brachiopod and bivalve fragments. Matrix material is sparry calcite.

4th oolitic zone

Heckel (1975a) notes that exposures of this oolitic zone are locally more limy than the 3rd zone, although generally less laterally traceable. This engenders a degree of uncertainty in assigning some exposures to this horizon, but lithologic similarities between outcrops, dissimilarities with other Stanton horizons, and stratigraphic position below the South Bend and above the horizon of the third oolitic zone all suggest that these limy horizons may have represented a nearly laterally continuous unit before modern erosion.

Oolitic grainstones are texturally and compositionally similar to grainstones of the third zone, but contain greater variation in constituent grains. Coarse sand-size ooliths (0.5-0.7 mm) with quartz nuclei are the most conspicuous grains, and they frequently constitute more than 80% of the total composition. Non-oolitic constituents are rare skeletal grains, including articulated ostracodes and pelmatozoan and brachiopod fragments. Less oolitic lithologic varieties contain a correspondingly higher percentage of skeletal and non-oolitically coated quartz grains. Skeletal grains average nearly 17% in skeletal-oolitic grainstones, and include a diverse association of most major skeletal groups. Most skeletal grains show evidence of mild abrasion, but intense fragmentation is minimal, as many bivalves occur as very coarse sand-size pieces. The quartzose-oolitic grainstone variant, retains all the textural characteristics of oolitic grainstone, but contains rounded to sub-rounded fine to medium sand-size (0.2-0.4 mm) non-oolitic quartz grains that frequently constitute as much as 20% of the total composition. Skeletal grains are extremely rare in these grainstones. All grainstone variations have a coarse, sparry calcite matrix that is partially dolomitized.

Skeletal quartz arenite is the second major lithology in the 4th oolitic zone, and is characterized by fine to very fine sand-size (0.1-0.4 mm) angular to sub-rounded quartz grains and small to large (up to 0.5 cm) skeletal fragments. Oolitically coated quartz grains are rare (less than 5%), and when present, coatings are thin and superficial (0.1 mm or less in thickness). Skeletal grains are most commonly a mixture of pelmatozoan, bryozoan and brachiopod fragments, and more locally common gastropods, bivalves, ostracodes and foraminifers. All skeletal material is fragmented, but there is little evidence of abrasion on any grains. In rare instances, skeletal content is slightly greater than quartz content, and this imparts an appearance approaching Bolton bed characteristics. As in grainstone lithologies, the matrix in skeletal-quartz arenites is coarse, partially dolomitized sparry calcite.

South Bend Limestone Member

Stratigraphy

The uppermost member of the Stanton in northeastern Kansas is generally a medium to thick-bedded, dense, fine-grained, medium to dark-gray or bluish-gray skeletal calcilutite that is typically arenaceous or conglomeratic in its lower part, and weathers yellowish-gray to yellowish-brown. Locally in Johnson and Miami Counties the member is made up of two thin beds of limestone and an included thin bed of buff sandstone and arenaceous shale (Zeller, 1968). Where the limestone is arenaceous near the base, it is also noticeably unfossiliferous (Newell, 1935). Southward toward Franklin County, the South Bend is discontinuous, owing to erosion and subsequent channel filling by Tonganoxie Sandstone of the overlying (Virgilian) Stranger Formation. In Franklin County, however, excellent exposures may be found in several quarries. The South Bend remains a dense, dark-gray to bluish-gray medium-bedded calcilutite with an average thickness of 1.2 meters. Individual beds are thinner in the poorly fossiliferous arenaceous lower part, whereas an abundant fauna, frequently appearing as shell pavements, characterizes the upper part. Color, extremely dense texture in the upper part, even bedding, and an arenaceous lower part serve to distinguish the South Bend from calcareous horizons of the Rock Lake in this area (Ball, et al.,1963).

The South Bend maintains its characteristic two-fold lithologic subdivision southward into the mound tract. Where exposed in Woodson and Wilson Counties, the typically sandy lower part is often conglomeratic or oolitic, and may contain an abundant bivalve-brachiopod-dominated fauna. The upper calcilutite portion remains essentially the same as in central and northeastern Kansas. The South Bend also occurs as fill in the Wilson County channel, where it is as much as 4.5 meters of sparsely fossiliferous, conglomeratic, calcareous sandstone. Along the rim of the mound tract, only the lower 60 cm layer of sandy conglomerate with scattered infaunal bivalves is present in incomplete exposures.

At its maximum development in northwestern Montgomery County, the South Bend forms a small six-meter-thick mound complex, which is composed primarily of algal and sparry algal calcilutites and rare calcarenites. The mound is underlain by 1 to 2 meters of basal South Bend interbedded calcilutites and sandstones, which locally contain oolitic and conglomeratic facies. Southward, the complex thins rapidly to less than one meter of skeletal calcilutite overlying a similar thickness of basal locally conglomeratic sandstone. Toward south-central Montgomery County, the calcilutite becomes a dense calcisponge-rich calcilutite reminiscent of similar Captain Creek lithology, and the conglomeratic aspect of the basal sandstone becomes more prominent. This distinct two-fold lithologic subdivision persists across the entire detrital basin and permits easy tracing of the South Bend into Oklahoma.

Petrography

The lower bed of the South Bend in the open-marine facies belt is characterized by lithologic variability, and includes quartz arenite, oolitic packstone and grainstone, and quartzose skeletal wackestone (Fig. 4, p. 24). Quartz arenite is composed of angular to sub-rounded, fine sand-size (0.05-0.2 mm) quartz in a sparry calcite matrix. Additional constituents are exceedingly rare, and are known only as small (0.05 mm) feldspar grains and mica flakes. Skeletal grains are noticeably lacking in quartz arenite. The abundance of sand-size quartz in this lower bed is also apparent in limestone lithologies. Oolitic packstone and grainstone consist of abundant quartz-nucleated ooliths and scattered skeletal grains including echinoderms, bryozoans, brachiopods and foraminifers. Non-oolitically coated quartz grains are scattered and constitute less than 5% of the total composition. Matrix in both lithologies is clear sparry calcite, with sub-equal amounts of mud differentiating packstone from grainstone. Fine sand-size quartz is the most common single grain constituent in wackestone, but skeletal grains (primarily brachiopods and bryozoans) are collectively more significant. All skeletal grains are fragmented, but only rare grains are slightly abraded. Mud matrix in wackestone overwhelms constituent grains, and constitutes more than 65% by volume.

In contrast to the lower bed, lithologies of the upper unit in the open-marine facies belt are with rare exception, quartz-free skeletal wackestones (Fig. 4, p. 24). Skeletal grains are the most significant non-matrix component (averaging 15% by volume), and are characteristically a diverse association that includes all major skeletal groups and rare occurrences of bivalves, trilobites, phylloid algae and <u>Osagia</u> laminations. All grains are fragmented, but none show any evidence of abrasion. Remaining constituent grains are quartz-nucleated ooliths and rare non-oolitically coated medium sand-size quartz grains that constitute slightly less than 25% of the total composition, and are known only from a single locality (Loc. PQ's). Mud matrix is the most abundant constituent averaging 65% of the total composition, with less common sparry calcite occurring as matrix, or as void-fill.

Southward into the algal-mound facies belt, poor exposures limit observation of the South Bend to the sandy to oolitic basal bed throughout most of Woodson and Wilson Counties. The basal bed is lithologically similar to equivalent strata in the open-marine facies belt, and is either calcareous quartz arenite or oolitic packstone. Quartz arenite is primarily composed of angular to rounded, medium sand-size quartz in a sparry calcite matrix. However, unlike northern equivalents, quartz arenite in the algal-mound facies belt has a significant skeletal content that can exceed 17% of the total composition in some samples. Skeletal grains are varied, but only pelmatozoan, bryozoan, brachiopod and isolated bivalve fragments occur as common skeletal constituents. Local common occurrences of shale pebble clasts impart a conglomeratic texture to these sandstones. Oolitic packstone is also similar to equivalent units in the northern facies belt, but is generally less oolitic, and by average, slightly more skeletal rich. Quartz-nucleated ooliths are the most abundant constituent grains, although non-oolitically coated quartz grains are frequently sub-equal in abundance. Skeletal grains remain relatively rare (average approximately 7%), and are primarily slightly abraded pelmatozoan ossicles. Packstone matrix is predominantly clear calcite spar with minor amounts of interstitial mud (typically 5% or less).

Upper South Bend exposures in the algal-mound facies belt are known only from the southern end of the mound tract in northern Montgomery County, and are relatively quartz-free and non-oolitic mudstones and wackestones (Fig. 4, p. 24). Matrix is always dominated by dense mud and/or micrite, with subordinate amounts of sparry calcite. Skeletal grains are the only significant non-matrix constituents, and consist of varying proportions of pelmatozons, bryozoan, brachiopod, ostracode and foraminiferal debris. Bivalves and phylloid algae are less frequently represented, but are locally abundant. Unlike algal material in the Captain Creek and Stoner, phylloid algae in the South Bend are always small, broken fragments and are not widely distributed throughout the mound facies. Remaining constituents are rare quartz grains that never exceed 5% of the total composition, and appear locally only near the base of the upper unit.

Southward through the terrigenous-detrital facies belt, oolitic, sandstone and conglomeratic lithologies of the basal South Bend maintain the same characteristics as equivalent strata in the northern facies belts. Quartz arenite persists as medium to coarse sand-size, angular to sub-rounded quartz grains in sparry calcite matrix, with extremely rare skeletal fragments. Oolitic grainstone and packstone consist of abundant quartz-nucleated ooliths and subordinate non-oolitic quartz and skeketal grains in a predominantly sparry calcite matrix (mud matrix is 5% or less). Clast-rich quartzose packstone represents the conglomeratic aspect of the basal South Bend, and is characterized by a mixed spar/mud matrix with abundant quartz, common skeletal grains (primarily pelmatozoans), and distinctive shale pebble clasts.

Throughout the northern part of the terrigenous-detrital facies belt, the upper calcilutitic unit of the South Bend is a skeletal wackestone that is essentially the same as skeletal wackestones in the open-marine facies belt. Skeletal grains are primarily pelmatozoan, bryozoan and brachiopod fragments, which are sub-equal in abundance with quartz-skeletal-nucleated ooliths in the mud matrix. Sponge-skeletal wackestone characterizes the upper unit in south-central Montgomery County, and is the only occurrence of a sponge-rich lithology in the South Bend. The calcisponge Girtyocoelia is the most abundant and characteristic element of a diverse and abundant skeletal association that constitutes more than 27% of the total composition and includes pelmatozoans, bryozoans, brachiopods, bivalves, ostracodes, foraminifers and possible phylloid algae. Fragments are most common, but whole-shell skeletal elements also occur as scattered constituents in the mud matrix.

Cyclothems and Depositional Phases

The Upper Pennsylvanian of eastern Kansas is characterized by a repetitive sequence of limestone and shale formations described as cyclothems. A single cyclothem is an ascending sequence of thin limestones and shales consisting of "outside" (nearshore) shale--"middle" (transgressive) limestone--"core"(offshore) shale--"upper" (regressive) limestone--"outside" (nearshore) shale (Heckel, 1977). "Outside" and "core" designations for the shales are assigned as descriptive terms for the position of the shale within the cyclothem. Outside shales lie "outside" the limestone formations, and core shales lie at the "core" or depositional middle of the transgressive-regressive cycle. "Middle" and "upper" limestone terminology is a remnant of Moore's (1936) classification describing the position of each limestone within a cycle of cyclothems that he termed the "megacyclothem". When the depositional environment of a lithologic member is reasonably well understood, terms describing the depositional phase (i.e., nearshore, transgressive, offshore, regressive) are more appropriate than positional terminology. Nearshore shales reflect periods of greatly increased detrital influx, as prodeltaic to delta-front sediments accumulated rapidly in a shallow restricted sea (Weller, 1957; Moore, 1929). Transgressive limestones record marine inundation of nearshore environments and suggest deposition in the open-marine environment below effective wave base. At maximum transgression, deepest water environments of the cyclothem are characterized by a lack of benthic fossils, and the presence of phosphorite laminae and nodules in black fissile facies of the offshore shale. The regressive limestone effectively "mirrors" the transgressive limestone, and records successively shallower water deposition that grades upward into shoreline environments of the succeeding nearshore shale.

The vertical stratigraphic and lithologic sequence of the Stanton in eastern Kansas contains characteristic features indicative of cyclothemic deposition. Each member represents a single depositional phase, and collectively they record a complete lower cycle, the Stanton cyclothem, and an abbreviated upper cycle, the South Bend cyclothem (Fig. 5). The Stanton cyclothem consists of the upper Vilas Formation (nearshore shale), Captain Creek (transgressive limestone), Eudora (offshore shale), Stoner (regressive limestone) and lower Rock Lake (nearshore shale). The incomplete South Bend cyclothem begins in the upper part of the Rock Lake, continues through the South Bend

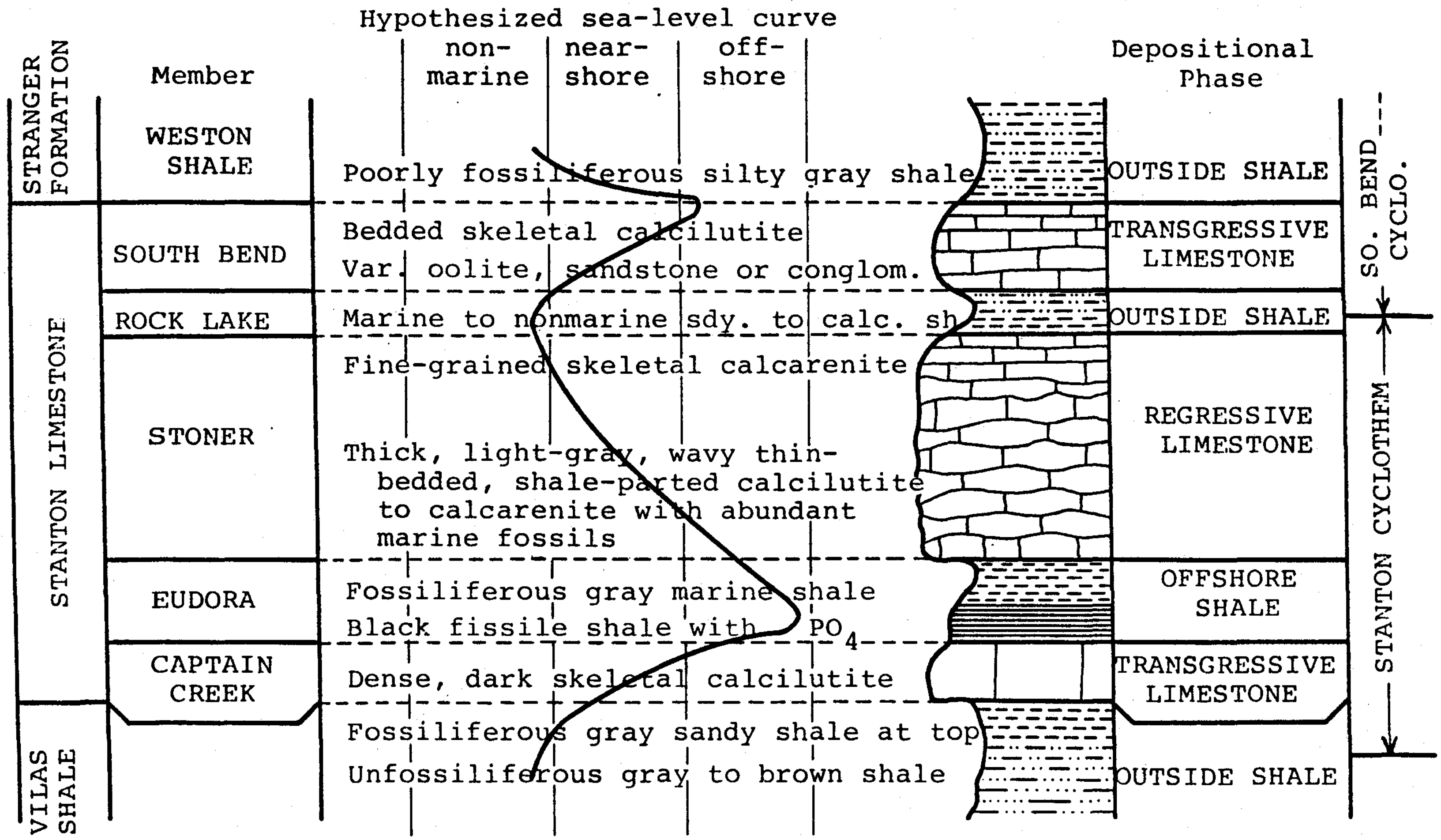

Figure 5--Relation of Stanton members to basic cyclothem terminology. Lithologic descriptions indicate general characteristics. Sea-level curve modified after Heckel and Baesemann (1975); non-marine environment includes marginal marine shoreline deposition.

(transgressive limestone), and is terminated shortly after initial offshore shale deposition (basal Weston Shale, Stranger Formation) by an overwhelming influx of Douglas Group (Virgilian) clastic sediments (Heckel, 1978).

Throughout the open-marine and algal-mound facies belts, both cyclothems in the Stanton can be more or less readily observed (Fig. 6). However, the lack of a laterally persistent regressive limestone (Stoner) in the terrigenous-detrital facies belt makes it difficult to completely delineate the boundary between the cyclothems in this area. The Bolton and Rutland limestone beds are the only significant limestones between the Captain Creek and South Bend, and although no lateral continuity exists between these beds and the Stoner, conodont evidence (Wood, 1977) suggests that the Bolton is equivalent to the lower Stoner. The thickened Eudora-Rock Lake interval south of the disappearance of the Bolton bed indicates that overwhelming detrital clastic influx prevented formation of a regressive limestone, just as much greater detrital influx of Weston Shale prevented formation of a regressive limestone for the South Bend cyclothem throughout the Kansas outcrop.

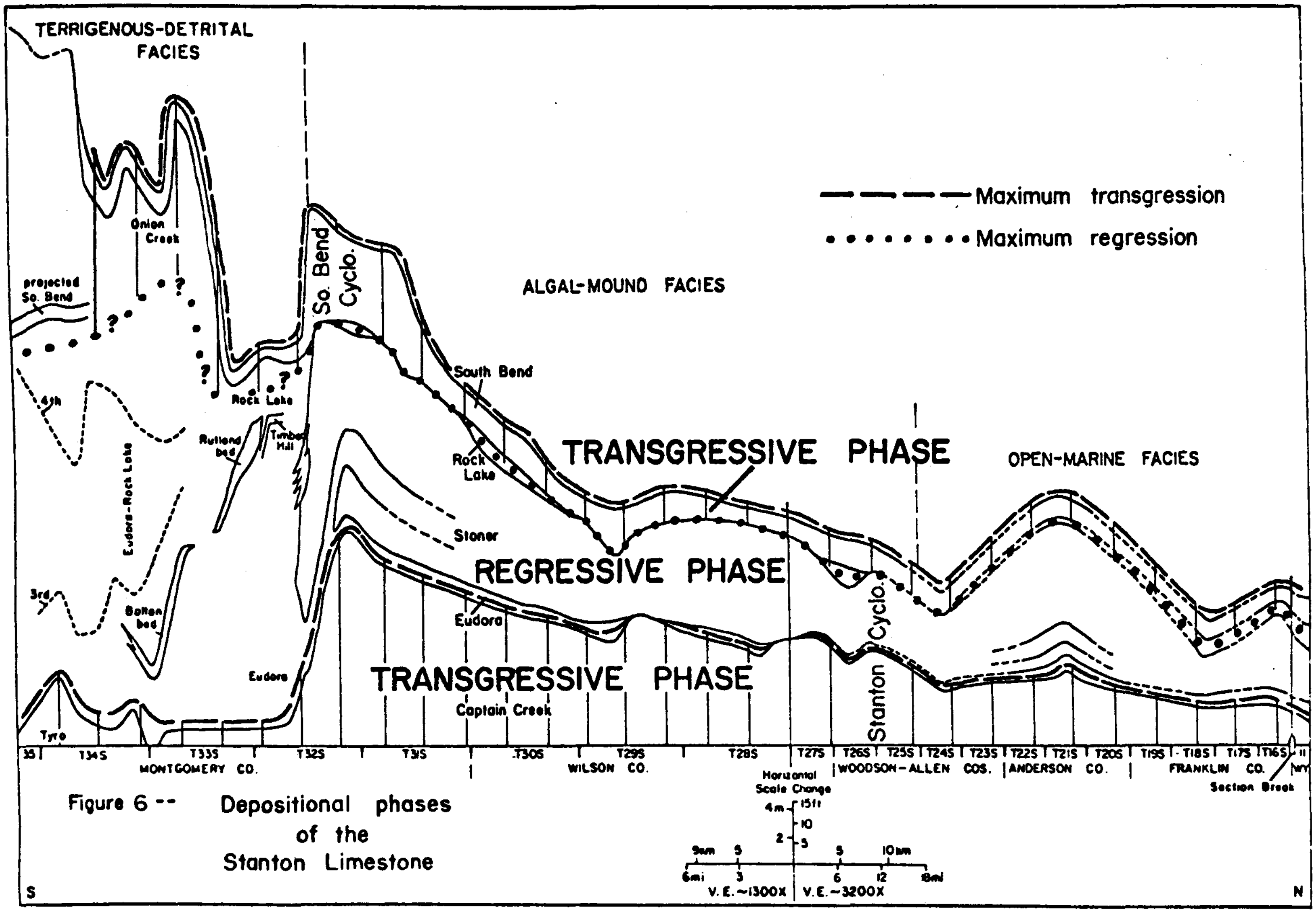

Figure 6 -- Depositional phases of the Stanton Limestone

PALEONTOLOGY

Recent studies have shown that a laterally extensive and homogenous fauna in a given environment is unrealistic. Modern environments support a pattern of contemporaneous biotic assemblages, each of which exists in response to critical biological and/or physical factors. Similarly, the picture for ancient environments can be visualized as a temporal mosaic of interrelated lithofacies and biotas. Data from all members and beds of the Stanton suggest this mosaic pattern. Sponge-echinoderm dominated assemblages are contemporaneous and probably gradational with algal-choked mounds, and these likely grade into other biotic associations. No single assemblage occupies the complete range of variation in an environment over its lateral areal extent.

Newell (1933) noted that dissimilar biotas characterize different major lithofacies in the Kansas Pennsylvanian As lithologic units undergo change along strike, biotas show an equally marked alteration. This suggests significant biotic change in response to regional geographic change in a given lithologic unit. Newell also recognized the presence of localized faunal change, perhaps due to temperature, salinity and water toxicity, but did not visualize local lithofacies and associated biofacies changes. Stanton lithologies and biotas display well-developed facies relationships. Regional geographic lithofacies change across facies belts is generally accompanied by gradual faunal replacement and overall biofacies alteration. Within given lithologic units in a particular facies belt, rapid local lithofacies changes are generally marked by abrupt biofacies changes. In addition, vertical phase change within members, in response to major transgressive and regressive changes of sea level is accompanied by marked alteration in biotic composition, organism density and overall organic diversity.

Sampling and Data Evaluation

Problems arise when trying to retrieve comparative faunas from different lithologies. Soft shales weather rapidly or are easily disaggregated in the laboratory and yield abundant fossil material. Limestones and sandstones weather less readily and produce comparatively sparse faunas. Collection of limestone faunas is limited to weathering residua of body fossils, or fossils recovered by considerable physical persuasion with a hammer. Sandstones present additional problems. If well-cemented, a fossiliferous sandstone may yield a reasonable collection of delicate thin-shelled fossils after a reasonable period of manual breaking. Porous sandstones, however, rarely yield a body fossil fauna, and only after close examination and careful cracking can a rather meager fauna of external molds be retrieved.

The problem of collecting macrofossils from different lithologies makes it virtually impossible to evaluate abundance data in a rigorous quantitative way. Shale faunas will appear considerably more abundant than either limestone or sandstone faunas, although the absolute number of individuals in fossiliferous horizons may actually be more nearly equivalent. If using raw abundance data to reconstruct and compare fossil assemblages or paleo-communities, erroneous conclusions may be reached concerning lateral geographic development and vertical stratigraphic evolution of biological organization. An apparent jump in overall fossil abundance from a dense limestone to a gray shale could be improperly described as a sudden faunal proliferation unless compensation is made for lithologic discrepancies. Efforts to compensate for artificial collecting biases, regardless of how rigorous and systematic, simply cannot eliminate all inherent biases produced in the rock record.

As an alternative to quantitative macrofossil abundance data, diversity indices can be used to evaluate biotic composition. Unlike abundance data, which must operate under the premise that collections from all lithologies reflect true proportions of all individuals present, diversity data treats equally the presence or absence of each taxon. If a collecting scheme is devised such that confidence is achieved in collecting a representative of all taxa (or all but the rarest of taxa), then faunal composition can be easily and perhaps more meaningfully compared with a diversity index. However, caution must be exercised in applying some indices, as equal weight is given to all taxa regardless of real or apparent abundance. A given taxa represented by a single specimen will be as important as another taxa reqresented by hundreds or specimens. More important is the potential for directly comparing faunas of two localities with identical indices but vastly different faunal densities. A false conclusion could be drawn from the indices that the potential for organic proliferation at each locality is identical.

In an effort to meaningfully relate the distribution and relative abundance of individual taxa, qualitative data are presented in a three-fold manner. Taxa described as "abundant" occur in numbers great enough that several tens of specimens can be easily collected at a given locality. "Common" taxa are less frequently represented, and only after a moderate amount of collecting can a dozen or more specimens be recovered. "Rare" taxa occur so infrequently that intensive collecting rarely produces more than one or two specimens. Complete lists of all taxa recovered by the author are arranged by stratigraphic unit and locality in Appendix B, Tables 2-8. Symbol codes A-C-R note distribution and relative abundance for individual taxa in each stratigraphic unit. Figures 7-40 illustrate the distribution and abundance of specific taxa, and appear at the end of Appendix B. Taxa in Table 1 are considered rare elements of the biota, which have been identified by previous authors during more intensive systematic studies, and not specifically recognized or recovered by the present author. These rare elements likely have little consequence on the gross characteristics of the biota, but they may enable a more nearly complete understanding of the full range of diversity. No attempt is made to discuss the significance of a taxon unless specifically identified during the course of this study. Brief notes concerning certain specific taxonomic usage in this report are found in Appendix A.

Captain Creek

Fossil assemblages in the lower member of the Stanton are generally dominated by abundant brachiopods. Commonly associated biotic elements are echinoderms (primarily pelmatozoan debris) and phylloid algae, both of which are usually less conspicuous but may become locally more abundant than brachiopods. All remaining taxonomic groups including sponges, bryozoans, corals, bivalves, gastropods, cephalopods and other minor groups are relatively rare, and only become significant in unusual instances when a particular genus or species may become more common.

Within the northern two-thirds or the study area, the Captain Creek is characterized by diagnostic brachiopods Enteletes pugnoides and Hystriculina wabashensis, and ubiquitous but less abundant Composita subtilita, Phricodothyris perplexa, Punctospirifer kentuckyensis, and Neospirifer dunbari. Of the remaining taxonomic groups, few, with the exception of phylloid algae, occur with sufficient frequency to be considered of major importance.

Southern biotas of the terrigenous-detrital facies are characterized by distinctively different assemblages. Brachiopods remain most abundant, but are marked by conspicuous absence of Enteletes and extremely rare occurrences of Hystriculina. Ubiquitous forms common in northern assemblages are reduced in overall abundance with Phricodothyris and Punctospirifer becoming particularly rare. Echinoderms become generally more conspicuous, with Cibolocrinus conicus and Apographiocrinus typicalis occurring frequently enough to be considered diagnostic of the southern assemblages. A sudden appearance of sponges, including the distinctive form Girtyocoelia beedei completes the list of characteristic elements of this facies.

Brachiopods

Brachiopods are the only invertebrates in the Captain Creek in appreciable numbers that can be readily identified. Most specimens are generally well-preserved, showing excellent detail, although often disarticulated or slightly crushed. Severe fragmentation and abrasion are minimal, but even in these extreme cases, enough detail is usually present to permit generic identification.

The unique and distinctively ornamented orthid, Enteletes pugnoides (Appendix A, pp. 182-183), is the most conspicuous form in the open-marine facies belt. Where present (Fig. 12, p. 236), the strongly plicate form is always found articulated and in abundance (Locs. KTPK and NP). Closely associated with Enteletes is abundant Hystriculina wabashensis (Fig. 20, p. 244). This small marginiferid often occurs articulated, although the highly concave brachial valve is usually obscured by matrix. The delicate thin shell readily exfoliates, but, when intact, spines and spine bases are easily recognized. Remaining brachiopods are dominated by common occurrences of several spiriferid genera and sporadic development of other productids. The common Mid-Continent form, Composita subtilita, occurs throughout this area (Fig. 7, p. 231), but rarely exceeds Enteletes and Hystriculina in overall abundance. Phricodothyris perplexa (Fig. 8, p. 232) may be found subequally with Composita, and together they appear as articulated, slightly crushed, 0.5 to one centimeter ovate forms. Of the productids present, only Dictyoclostus and Linoproductus occur with sufficient frequency to recognize any distribution. Rarely are either of these genera perfectly preserved. Anterior trails are frequently broken, and thin brachial valves covering deep body cavities are highly susceptible to crushing.

Little change in gross brachiopod composition transpires in the gradual transition from the open-marine to the algal-mound facies belt. Enteletes and Hystriculina remain abundant and most conspicuous. These forms display a general trend of increasing abundance southward through the mounds, and reach peak abundance near the southernmost extent of the facies belt (Locs. TMQ, TQ and ECR). Unusually abundant and perfectly preserved specimens of both forms may be found at Locality TMQ. Common spiriferids Composita and Phricodothyris become more common throughout the mounds, and specimens of each can be expected at any locality. Other spiriferid forms, including Neospirifer dunbari (Appendix A, pp. 184-187; Fig. 10, p. 234), Punctospirifer kentuckyensis (Fig. 9, p. 233) and Hustedia "mormoni" (Appendix A, p.184; Fig. 11, p. 235), display a more sporadic distribution. Productids are also sporadic in distribution, and are rare in abundance when present.

However, despite rarity, several productid forms including Antiquatonia, Reticulatia and Pulchratia appear for the first time in this facies belt. None of them exhibits excellent preservation as all are at least partially broken and most have been crushed. Remaining taxa are extremely rare, usually occurring as one or two poorly preserved specimens having no easily delineated distribution.

Marked change in brachiopod composition characterizes the transition from the mound facies to the terrigenous-detrital facies belt. Most notable is the dramatic decline in taxonomic diversity. Extensive searching at several localities failed to produce any specimens of Enteletes south of the mound termination. Hystriculina is also absent south of the mounds, with the exception of two rare occurrences in shaly lithofacies equivalents (Locs. WM and PHF). Productids diminish in abundance as well as taxonomic diversity. Three widely separated occurrences of fragmented Linoproductus and one appearance of Pulchratia represent the remaining productid forms in this facies. Spiriferids, Composita and Neospirifer, seem to be the only forms relatively unaffected by the transition. Both remain as rare elements, but they can be found at any locality. Composita is usually a whole-shell form slightly crushed, whereas the deep body cavity and fragile cardinal extremities of Neospirifer make it highly susceptible to fragmentation and crushing. Brachiopod composition in the detrital facies belt is completed by the first appearances of *Chonetinella flemingi* (Appendix A, pp. 187-190; Fig. 23, p. 247) and *Rhipidomella carbonaria* (Fig. 16, p. 240). Both occur as complete specimens (*Rhipidomella* is crushed) appearing as rare elements in shaly lithofacies near the top of the member.

Algae

Algal development in the Captain Creek is mainly in the form of large blades of phylloid algae. Red algal encrustations and blue-green algae associated with stromatolites are common locally, but are minor compared to the overall abundance of phylloid algae. Pray and Wray (1963) first applied the term "phylloid" to leaflike red and green algae in which diagenetic alteration has obliterated all internal structure. In some instances, internal structure may be preserved showing characteristics of the hypothallus and perithallus. The red alga *Archaeolithophyllum* is the most commonly preserved type, although green algal forms have been recognized (Johnson, 1946). No definite green algal forms were encountered in the present study.

Phylloid algae in the Captain Creek are most conspicuous in the mound facies belt (Fig. 40, p. 264), where prolific growth dominates mound assemblages, occasionally almost to the exclusion of all other elements. Two rare fragments have been observed in detrital facies rocks (Locs. NE-23-32-14 and SW-SE-SW-7-33-15), but both are small pieces that appear to be abraded, suggesting possible transport from the mounds. Throughout the mounds, algal development is common to abundant, frequently exceeding 75% of the total biota at a single locality. Unlike the brachiopods, algal abundance decreases from a maximum in the northern Woodson-Wilson County area southward to the mound termination.

Some algae are conspicuous in the open-marine and detrital facies of the Captain Creek. Although rarer and apparently randomly distributed, crinkly laminations of red algae encrust a variety of different invertebrates in both facies. An algal-foraminiferal encrustation, Osagia, also randomly encrusts invertebrates, particularly bryozoans and inorganic clasts at several localities.

Echinoderms

Echinoderms, particularly pelmatozoans, are perhaps the most abundant and widely distributed elements in the Captain Creek. Unfortunately, few taxa can be identified as most material occurs as disarticulated pelmatozoan debris. Column ossicles and small brachial plates are most common, but larger primibrachs and dorsal cup ossicles are also common. Virtually all Captain Creek localities in the study area contain at least minor amounts of echinoderm material.

Throughout the open-marine and mound facies, recognizable echinoderms are limited to a few *Erisocrinus* dorsal cups, two infrabasal circlets belonging to *Ulocrinus*, and isolated plates possibly of the echinoid *Archaeocidaris*, all occurring in the central portion of the mound tract. With a single exception, the distribution of identifiable echinoderms in the detrital facies is equally as scattered. Isolated rare specimens of *Cibolocrinus conicus*, *Graffhamicrinus* sp. and indeterminate pirassocrinids occur in shaly lithofacies immediately south of the mound termination. A single locality (Loc. PHF) contains the bulk of all pelmatozoan material recovered in the member. Literally hundreds of well-preserved dorsal cups can be found in this small exposure of a sponge-echinoderm-rich assemblage. Particularly abundant are small (0.5 mm diameter or less) dorsal cups of *Apographiocrinus* (Fig. 25, p. 249) and slightly larger (10 mm in diameter or less) specimens of *Cibolocrinus* (Fig. 24, p. 248). Common *Erisocrinus* and *Endelocrinus* also occur as small forms, but are not as abundant as the previously mentioned forms. Remaining elements at this locality are relatively rare, frequently represented as partial cups or as distinctive isolated cup ossicles.

Sponges

Throughout the northern and central facies belts sponges are unknown in the Captain Creek. However, a distinctive association of calcisponges and demosponges suddenly appears in the upper shaly and calcilutitic beds of the member in the detrital facies belt. The thalamid calcisponge Girtyocoelia (Fig. 37, p. 261) is a common to abundant element at all Captain Creek localities south of the mounds. The distinctive chain of perforate spheres weathers easily from the shales, and also is somewhat more resistant to weathering than enclosing calcilutite as it often appears in relief on exposed surfaces. Associated with Girtyocoelia are the less common but equally distinctive forms Maeandrostia and Heliospongia. Maeandrostia is of uncertain taxonomic affinity, and is a rare element appearing primarily as circular transverse sections with characteristic irregular canal structure. The lithistid demosponge, Heliospongia, is equally a rare element, but the distinctive size and shape (often several centimenters in length and one to two centimeters in diameter) make it unmistakable when observed in weathered relief on exposed surfaces.

Minor Elements

By comparison, all remaining taxonomic groups are rare in overall occurrence through all facies of the Captain

Creek. Individual genera and species may be abundant at any locality, but few appear with any consistency from place to place. Scattered fragments of bryozoan debris are ubiquitous throughout the study area, but large identifiable specimens are relatively rare. Most common are small fragments of fenestellid fronds, likely representing several species, as suggested by differences in size and shape of fenestrulae and arrangemant of zooecia. Corals are rare elements and appear to be fairly restricted geographically within the Captain Creek. All specimens recovered are from the mound facies, particularly near the northern end of the mound facies belt. Preservation is generally good with fine details of the calyx and other external morphology readily visible in most specimens.

Within the Captain Creek, gastropods are represented by isolated single occurrences of *Trepospira*, *Trachydomia* and *Glabrocingulum*, all of which are from localities near the mound facies termination or within the detrital facies belt. Bivalves and cephalopods are represented by even fewer specimens. A single indeterminate orthoconic nautiloid is the only known cephalopod from the Captain Creek (Loc. EQ). An indeterminate bivalve from the open-marine facies, myalinid and pectenid forms from the mound facies, and nuculanid and pectenid forms from the detrital facies represent all bivalve specimens recovered from the member.

Remaining groups (rostroconchs, conularids, trilobites, scaphopods and vertebrates) are unknown in the Captain Creek.

Tyro

The Tyro oolite is characterized throughout the major portion of its exposure by either absence or low density macrofaunas. Immediate impressions suggest that the Tyro is unfossiliferous, but close examination of many exposures reveals a surprising variety of taxa, all of which are rare except for pelmatozoan debris. Brachiopods are the most frequently encountered whole shells with echinoderms, bivalves and bryozoan material subordinate. All other groups are apparently unrepresented. The exceptional development of a diverse, abundant macrofauna in the top of the oolite is characterized by rare to abundant brachiopods and gastropods; several identifiable echinoderms, assorted bivalves and a variety of ammonoids are subordinate. All other major groups are either absent, or rare to common in unique occurrences.

Regardless of the assemblage and the environmental conditions commonly associated with an oolite shoal, exquisite preservation of all taxa is among the best in the Stanton. Many bellerophontid gastropods are complete to the anterior margin, frequently displaying sometimes unnoticed micro-ornamentation. Delicate spines and broken spine bases are often preserved on productid brachiopods, and when found articulated, pelmatozoan dorsal cups always display fine details of plate morphology.

The excellence of preservation and the similarity of the fauna to the skeletal nuclei of many ooliths suggests that the assemblages are indigenous to the Tyro environment. Observations of modern oolites demonstrates the ability of a sparse fauna to exist on an actively accreting shoal (Purdy, 1963). Low density faunas of the lower part of the bed appear analogous to this modern situation. The diverse assemblage in the upper part of the bed formed later during a phase of ooid accumulation in probably quieter water.

Brachiopods

Within the dense lower part of the oolite at all fossiliferous localities, brachiopods are rare, usually single specimens. No single taxon or group of taxa clearly dominates at any locality, and thus, it is difficult to evaluate which taxa may have been best suited to, or most exploitative of, the environment. Brachiopod genera include most of the widespread spiriferids including Phricodothyris, Neospirifer and Hustedia. Other forms include Derbyia, Hystriculina and Echinaria, and Cancrinella, which is an extremely rare brachiopod in the Stanton. Rhipidomella and Chonetinella are also present as single specimens. These appearances are potentially significant if consistent occurrence of these forms in other areas proves to be depositionally or stratigraphically important.

Transition to the upper portion of the oolite is marked by a significant increase in brachiopod abundance, but little change in total diversity. Greater separation of dominant and subordinate taxa also accompany this transition. Three genera, Composita, Punctospirifer and Derbyia, become common. A fourth genus, Crurithyris, which is absent in the lower part, occurs abundantly in the top. Crurithyris is not uniformly distributed throughout the upper unit, as it appears in gregarious clusters of shells, often exceeding a couple hundred specimens per square meter on exposed bedding planes. All remaining brachiopod taxa, with the addition of Pulchratia, Dictyoclostus, Juresania and Linoproductus, are rare, and have been previously noted in the lower unit.

Echinoderms

Pelmatozoan debris is the most frequent echinoderm material in the lower oolite. Ossicles are rare to common and occasionally occur in exposures where no other invertebrate material is recognized. In these instances, most ossicles are aligned along cross-beds, and when weathered in relief, they appear as conspicuous light streaks against the gray oolite. Identifiable dorsal cups are extremely rare, with Apographiocrinus and Delocrinus the only taxa recovered. These genera are well-preserved, display fine morphologic details on articular surfaces, and appear only as single specimens.

Echinoderms of the upper unit remain primarily pelmatozoan debris. Stem ossicles litter bedding planes at Locality TyQ-u, with brachials and disarticulated cup plates scattered throughout the exposure. All identifiable dorsal cups are rare, or less frequently, common constituents of the rock. Identifiable taxa are those previously mentioned in the lower unit and, in addition, include *Erisocrinus*, *Endelocrinus*, *Cibolocrinus*, *Exaetocrinus*, *Paragassizocrinus* and an indeterminate pirassocrinid. All are represented by complete dorsal cups, except *Paragassizocrinus*, which is characteristically preserved as a blunt, cone-shaped, fused infrabasal circlet. Preservation of all specimens is characteristically excellent, showing details of fine micro-morphology on articular facets.

Gastropods

The transition from the lower to the upper oolitic unit is marked by the abrupt appearance of more than a dozen distinct types of gastropods. The number of different taxa nearly equals that of brachiopods, but the overall gastropod abundance does not approach that of brachiopods. Intensive searches of the lower oolite failed to produce any gastropods including macroscopic fragments. The gastropods of the transition are dominated by Glabrocingulum grayvillense, Euphemites vittatus (Appendix A, pp. 190-192) and Meekospira choctawensis. Each is common to abundant, retains a complete shell, and has lost no detail of surficial ornamentation. Remaining gastropods are equally well-preserved, but less common. None of these taxa occur in the upper oolite as more than two or three specimens at any one place. Among these are Ianthinopsis primigenia and I. paludinaeformis, which are extremely rare and unknown with original shell material anywhere else in the Stanton. Other gastropods of the upper Tyro are known from several Stanton horizons.

Cephalopods

The change from the lower to the upper oolite is also marked by an equally abrupt appearance of several ammonoid species. Most specimens break cleanly from the weathered rock and are often complete shells, including the body chamber whorl. The generalized form Eoasianites hyattianum is the most prevalent species, occurring as a common constituent. All of the three remaining taxa are rare, and two occur as single specimens. "Bisatoceras" ?genus novum is represented by only one specimen that shows excellent preservation of sutures. Other specimens belonging to this genus are most frequently altered, with the sutural pattern obscured. *Prothallassoceras kingorum* and *Marathonites* sp. are also altered, but the dark suture can be easily recognized against light crystalline shell material. This single specimen of *Marathonites* is the only known occurrence of this taxon in the Stanton.

Minor Elements

Although somewhat more significant in the lower oolitic unit due to overall organism paucity, bivalves generally make only minor contribution to the assemblages. The lower oolite contains rare pectenids, including a possible specimen of *Aviculopecten*. Thin pectenid shells appear the most susceptible to deterioration, and are accordingly the poorest preserved taxa in the lower Tyro. Ribbing and evidence of growth lines are virtually lacking, and only the rough shell outline is usually recognizable. Preservation is better in the upper oolitic unit, enabling more immediate recognition of bivalve species. *Wilkingia* and *Myalina* are rare infaunal constituents, but are readily identified by their distinctive shape and ornamentation. *Myalina* is usually broken along the thinner anterior margin, and is rarely found articulated. *Aviculopecten occidentalis* is the only common bivalve species in the oolite. Shells are always disarticulated, but display good preservation of major and minor features.

Also preserved in the upper unit are unusual specimens of sponges and a scaphopod. Disarticulated beads and articulated chains of the thalamid sponge *Girtyocoelia* are common in weathered relief on bedding surfaces. Individual beads remain unbroken and display excellent details of external pores. Similarly preserved are common cylindrical tubes of the sponge *Maeandrostia*. Irregularly spaced pores on the cylindrical form is evidence of a highly convoluted and irregular internal canal system. Additional cylindrical or tubular structures (originally thought to be *Maeandrostia*, but lacking a porous outer wall) are actually a common and unique Stanton appearance of the scaphopod *Dentalium* (*Paleodentalium*) *kansasense*. Scaphopod shells have not been found complete, most frequently appearing as broken lengths of two to three centimeters, which are filled with muddy matrix.

All remaining invertebrates and algae are either absent or so extremely rare that they are of little consequence in the overall composition of the assemblages. Bryozoans occur as rare fenestellid debris in both the lower and upper units. Details of zooecial arrangement and structure are obscured, making further identification virtually impossible.

Eudora

Fossil assemblages in the lower shale member of the Stanton are characterized by locally abundant brachiopods, echinoderms and molluscs. Brachiopods generally remain the most abundant and best preserved, but gastropods and bivalves are also abundant, particularly in southernmost exposures of the member. In instances where gastropod-bivalve density is high, brachiopod abundance is lowered. Remaining taxonomic groups such as bryozoans, scaphopods and conularids are less common and more sporadic in distribution. Bryozoans appear to be unaffected by brachiopod or molluscan dominance, as they occur equally in assemblages dominated by either group.

The open-marine facies belt is characterized by extremely sparse faunas. Ubiquitous brachiopods, Composita, Punctospirifer and Neospirifer are the only biotic elements appearing with any consistency, but are not abundant at any locality. The few remaining taxa recovered in this facies are isolated and often single occurrences, which make no effective contribution to the recognition of a distinctive assemblage. Within the mound facies belt, brachiopod abundance increases markedly. Spiriferids found in the open-marine belt are common to abundant at virtually all localities in the mound belt. Additional brachiopods unknown in northern facies, are rare to common, and display patchy distributions that become more consistent toward the southern extent of the mound tract. Echinoderms, gastropods, bivalves and bryozoans are all rare elements that constitute virtually all of the remaining taxa in heavily brachiopod-dominated assemblages.

By contrast, assemblages of the detrital facies are characterized by abundant faunas that are dominated by molluscs. Ubiquitous brachiopods recognized in other facies belts persist into the detrital facies, mainly as common elements. Minor brachiopods recognized in the mound facies are severely reduced, but productids appear sporadically as rare elements. The slight change in total brachiopod composition is overwhelmed by sudden appearance of molluscan groups. Gastropods are present in all detrital facies localities, with individual species locally rare to abundant. Glabrocingulum grayvillense is perhaps the most characteristic gastropod as it occurs everywhere in abundance. Bivalves and cephalopods, as groups, are not as abundant as gastropods, but individuals such as the nuculid Phestia bellistriata and the ammonoid Eoasianites hyattianum may be dominant elements at certain localities. Echinoderms and bryozoans constitute the bulk of minor elements in this facies belt, with scaphopods and conularids occurring as extremely rare elements.

Brachiopods

Brachiopods are everywhere within the Eudora one of the most readily identifiable groups. Preservation of all specimens is generally excellent, with the only exceptions being occasional forms that are slightly crushed. Most specimens remain articulated, with a low percentage occurring as dissociated valves. When free of matrix, disarticulated valves frequently display fine details of internal morphology.

A rise in overall brachiopod abundance marks the transition from the open-marine to the mound facies and continues southward through the mound tract. Individual assemblages are dominated by rare to abundant occurrences of the ubiquitous spirifers Composita, Phricodothyris, Punctospirifer, Neospirifer and Hustedia, and are characterized by rare to common additions of Dielasma (Fig. 15, p. 239), Wellerella (Fig. 18, p. 242), Derbyia (Fig. 19, p. 243), Hystriculina and Crurithyris. With the exception of rare Hystriculina, productids remain conspicuously absent.

Brachiopod composition of detrital facies assemblages is characterized by marked reduction of ubiquitous forms, general absence of minor elements recognized in the mound tract and presence of rare and sporadically distributed productids. Composita and Neospirifer are common to rare elements at all localities throughout the facies belt, and, with the exception of common *Crurithyris planoconvexa* (Fig. 14, p. 238) in several central Montgomery County localities, they are the only forms appearing consistently. Other spirifers, *Phricodothyris*, *Punctospirifer* and *Hustedia*, have been recognized only as rare elements from isolated localities. The bulk of the remaining brachiopod composition is divided among several productids, which mark the first significant occurrence of this group in the Eudora. *Linoproductus* (Fig. 22, p. 246) and *Pulchratia* (Fig. 21, p. 245) are common taxa, which frequently appear together at several localities. Other productids such as *Juresania* and *Reticulatia* occur only as rare elements, and are too infrequent to have easily delineated distributions. The small inarticulate *Orbiculoidea* and *Lissochonetes plattsmouthensis* are both rare elements. *Orbiculoidea* is known only as single specimens from widely separated localities in black shale facies. *Lissochonetes* is similarly known only as single specimens, but is found with *Crurithyris* at several scattered localities in central Montgomery County.

Gastropods

Except for rare appearances in the open-marine and mound facies belts, gastropods are limited to the detrital belt. Gastropods are generally well-preserved, and most shell material frequently displays fine details of surficial ornamentation. Some exceptionally well-preserved specimens display growth lines along the selenizone.

Gastropods are the most abundant elements in detrital facies assemblages. Several genera and species are usually present at any locality, and frequently two or more taxa are abundant. Glabrocingulum grayvillense is one of the most readily recognizable species at any locality, always appearing abundantly (Fig. 27, p. 251). This distinctive low-spired species occurs with Trepospira discoidalis (Fig. 30, p. 254) and Euphemites vittatus (Appendix A, pp. 190-192; Fig. 28, p. 252). Each of the latter two species vary from locally abundant to rare. Subordinate gastropod species are more sporadically distributed, and usually occur as rare to common. Non-euphemitid bellerophontids comprise the largest percentage of subordinate gastropods, and are represented by Pharkidonotus spp., Cymatospira montfortianus, Retispira tenuilineata, and Bellerophon graphicus. All are present in unusual association at one locality (Loc. SBHM-398), where Cymatospira makes its only appearance in the detrital facies, occurring as an abundant element. In the rest of the facies only one or two different bellerophontids are normally present at any locality. Of the remaining gastropod taxa, all except Worthenia tabulata (Fig. 29, p. 253) and Phymatopleura nodosa are rare and randomly distributed. These include species of Ianthinopsis

Meekospira, *Straparollus* and *Pseudozygopleura*. *Worthenia* and *Phymatopleura* are present in almost half of the detrital facies localities, and are particularly prevalent in central Montgomery County.

Bivalves

The distribution of bivalves closely parallels that of gastropods. Very few taxa occur in open-marine and mound facies belts, where they are represented only by single, or at most, a few specimens. An abrupt increase in bivalve abundance accompanies the transition to the detrital facies. Bivalves are also generally well-preserved, particularly in Montgomery County. Concentric growth lines are sharp and distinct, ribs and ornamentation are prominent, and color mottling is preserved in specimens of *Paleoneilo taffiana* (Loc. SBHM-398). With the exception of myalinids, most specimens remain articulated. In rare instances of disarticulation, valves nevertheless display fine details of the muscle scars or dentition, even when broken. Myalinids are most frequently disarticulated and broken along the thin anterior margin.

In both northern facies belts, bivalves are represented only by single occurrences of *Astartella*, *Cypricardinia*, *Parallelodon* and *Wilkingia*. Intensive searching at several localities over a reasonably extensive area failed to produce further specimens. Newell (1933) also noted a lack of bivalves in the Eudora along the Kansas River Valley. The severe paucity of bivalves as well as other faunal elements seems genuine, and not an artifact of poor field investigation.

The sudden appearance of bivalves in the northern portion of the detrital belt marks the greatest occurrence of this group in the Stanton. *Paleoneilo* is the only bivalve that is abundant in this area (Fig. 34, p. 258). All other bivalves are rare, with a few species becoming common toward the central and southern portions of the facies. Several myalinid species including *Myalina* and *Septimyalina burmai* appear only in the northern part of the facies. The remainder of the bivalve fauna in this area is comprised of *Paleyoldia glabra*, *Astartella*, *Wilkingia* and *Phestia* "*attenuata*".

Myalinids are replaced southward through the facies by *Phestia bellistriata* (Fig. 33, p. 257). This distinctive species is consistently present at all localities. *Paleoneilo* is also present in southern localities, but in contrast to its northern detrital facies expression, it only occurs as a rare element. *Phestia* and *Paleoneilo* seem to have an inverse abundance relationship. When they co-occur at a locality, both are rare, and when *Phestia* becomes common to abundant (Loc. RFP), *Paleoneilo* is rare or absent. Conversely, when *Paleoneilo* is abundant in the northern part of the facies, *Phestia* is rare. Remaining bivalves *Paleyoldia*, *Astartella* and *Wilkingia* are rare to common and scattered throughout the south-central part of the facies belt.

Cephalopods

Cephalopods are the last molluscan group that has a distinct distribution and occurs in significant numbers. All appearances, with the exception of an indeterminate ammonoid and nautiloid in Wilson County, are limited to exposures in Montgomery County. Specimens are generally well-preserved with recognizable sutures, but nautiloids are usually found broken along the septa.

Both nautiloids and ammonoids are dominated by single species. Nautiloids are most frequently *Pseudorthoceras knoxense*, which is rare at most localities, but common at Locality SBHM-398. Of the remaining nautiloids, none occur with sufficient frequency to recognize a significant distribution. This small group is represented by a single indeterminate nautiloid, a specimen of *Mooreoceras normale*, and two single occurrences of *Brachycycloceras curtum*. Ammonoids are dominated by *Eoasianites hyattianum*, which appears as a common to abundant element in central Montgomery County, and becomes rare in more northern and southern exposures in the detrital facies (Fig. 35, p. 259). Closely associated with greatest development of *Eoasianites* are rare specimens of three other taxa: Neoaganides sp. and Prothallasoceras kingorum occur as single, excellently preserved specimens at Locality BH. The remaining ammonoid taxon is also rare, and is presently known from only two localities in the Eudora. "Bisatoceras" differs enough in fine morphologic features of the suture and conch shape that it may perhaps belong to a new genus (B. F. Glenister, 1977, pers. commun.).

Minor Elements

Echinoderms and bryozoans constitute the majority of minor forms. Pelmatozoan debris may be found at virtually all localities within the major facies belts, but recognizable taxa are known only from the detrital belt. A general pattern of rare, isolated single specimen occurrences of most taxa is broken by consistently common to abundant infrabasal circlets of Paragassizocrinus sp. at several localities in south-central Montgomery County (Fig. 26, p. 250). Unlike echinoderms, bryozoans are more evenly distributed throughout the mound and detrital facies belts. Ramose growth forms of cryptostomes and trepostomes are most widely distributed and are occasionally found as common or abundant elements. Remaining bryozoans are primarily rare forms such as globular and encrusting trepostomes, massive cryptostomes, ramose cyclostomes and several fenestrate types. None of these occur in any detectable distribution.

All other minor groups and individual forms are so exceedingly rare that, with the exception of the occurrences of a unique rostroconch and the small, distinctive scaphopod *Plagioglypta annulistriata* (Fig. 39, p. 263), none require specific mention. The rostroconch *Pseudoconocardium lanterna* is a rare to common element in detrital facies assemblages of central Montgomery County, and represents the only known occurrence of rostroconchs in the Stanton (Fig. 38, p. 262).

Stoner

Brachiopod domination of fossil assemblages continues in the Stoner throughout the open-marine and algal-mound facies belts. Pelmatozoan echinoderm and bryozoan debris contributes significantly to total skeletal volume, but in most cases, clearly identifiable taxa are rare. Corals, bivalves and gastropods are scattered and only become important locally. Of the remaining taxonomic groups, phylloid algae appear to be the most significant. Algal fragments occur at most localities in the open-marine facies, but are more abundant than other major invertebrate groups only in rare instances. Small to large, sinuous algal blades are more prevalent in buildup calcilutites of the mound facies and frequently become so abundant that all other invertebrates are either rare or entirely absent.

The equivalent of the Stoner in the terrigenous-detrital facies is the upper part of the shale assigned to the Eudora, which is known to grade into Stoner limestone in the northern part of the facies belt. The assemblage within the shale is wholly unlike algal-mound or open-marine assemblages. Several brachiopod and massive bryozoan types dominate the assemblage, which also contains abundant bivalves and gastropods. Remaining groups, including echinoderms, are extremely rare. Additional Stoner shale equivalents likely occur southward through the detrital belt in the upper Eudora Shale. However, the exact stratigraphic position of this interval is difficult to recognize with certainty. Consequently, the composition and relationships of Stoner equivalent assemblages remain indefinite throughout the major portion of the detrital facies belt.

Brachiopods

Overall brachiopod abundance and diversity is greater in the Stoner than in the Captain Creek, and is more widespread throughout the northern facies belts. Large numbers of articulated and frequently undistorted spirifers lend the impression of generally excellent preservation. However, the greatest majority of specimens are most often disarticulated, broken or crushed to some degree. Individual fragments or disarticualted valves usually display at least one or two well-preserved morphologic features that enable ready identification.

The open-marine facies is characterized by common occurrences of several ubiquitous spiriferids, particularly Composita, Phricodothyris, to a lesser degree Punctospirifer, and also by scattered rare to common occurrences of several productids, particularly Hystriculina. Other spirifers such as Neospirifer and Hustedia, which are ubiquitous throughout major facies in the Captain Creek and Eudora Members, are sporadically distributed in this facies belt. Neospirifer is common only at two localities (Locs. QWW and MI), and Hustedia is represented by only two specimens near the southern extremity of the facies belt (Loc. CBQ).

The only Stoner occurrences of Enteletes are in the lower portion of the member at several localities in the northern part of the open-marine facies (Locs. KTPK, BS and EGS). Haglund (1967) reports the stratigraphic range of Enteletes pugnoides as throughout the Upper Missourian and Lower Virgilian, from the Iola to the Oread Limestone. The Stoner occurrences of Enteletes are significant in that they represent the youngest known appearance of this form in any facies of the Stanton. Extensive searching has failed to produce any specimens in Stoner mound facies or in any facies of the South Bend.

Hystriculina is the most common and widely distributed of all remaining brachiopod taxa. Unlike its close parallel distribution with *Enteletes* in the Captain Creek, *Hystriculina* is more geographically and stratigraphically widespread in the Stoner. Occurrences are characteristically common to rare, but become abundant in the northern part of the facies. Localities that yield specimens of *Enteletes* also contain common to rare occurrences of *Hystriculina*. Other productids are generally rare and scattered throughout the facies. This group includes *Echinaria*, *Echinoconchus*, *Dictyoclostus* and *Linoproductus*. Unusually common *Antiquatonia* and *Pulchratia* occur in the upper part of the member at Localities KTPK and MI. The MI locality is particularly interesting in that eight of nine recognized brachiopod taxa, including *Antiquatonia* and *Pulchratia*, are common or abundant.

The remaining taxa that complete the brachiopod fauna of the open-marine facies belt are isolated, rare specimens of the terebratulid *Dielasma*, the small orthid *Rhipidomella*, the rhynchonellid *Wellerella* and *Derbyia*. *Rhipidomella* and *Wellerella* are single specimens, occurring in the lower Stoner at Localities EGS and CBQ, respectively. *Dielasma* and *Derbyia* are more frequent, and most often appear as rare elements or unusually as common forms.

The most distinguishing features of the brachiopod fauna in the algal-mound facies belt are the appearance of several taxa that are unknown in the open-marine facies, and the marked increase in overall abundance and distribution. This change is most likely influenced by the development of mound-associated calcarenitic lithofacies. Most of the newly appearing taxa occur in either rim of channel calcarenites. Faunas in mound calcilutites do not follow this general trend, and appear somewhat like faunas in the open-marine facies belt. Many brachiopod taxa are reduced in numbers and appear to have limited distribution in buildup calcilutites of the algal-mound facies belt.

Brachiopods of the mound-associated channel calcarenite lithofacies are characterized by the enteletacean Schizophoria "texana" (Appendix A, pp. 180-182; Fig. 13, p. 237). In its adult form, the subelliptical shell possesses a broad, shallow, ventral sinus which imparts a slightly bilobed appearance at the anterior margin (Newell, 1931). Juvenile specimens are virtually indistinguishable from those of Enteletes, but the lack of adult Enteletes in these calcarenitic lithologies permits ready recognition of juvenile Schizophoria. Most specimens occur near the center of the channel in well-washed, locally cross-bedded, coarse, granular calcarenite. Disarticulated shells and fragments predominate over complete articulated specimens.

The most frequently occurring brachiopods in the channel lithofacies are again the spiriferid genera Composita, Phricodothyris and Punctospirifer. All are rare to common and are found occasionally in gregarious concentrations near the channel margin. Other spirifers, (Neospirifer and Hustedia) and Dielasma most often occur as rare elements, but become common in more favorable marginal portions of the channel. Remaining non-productid brachiopods of the channel are known only as single specimens of well-preserved Derbyia and Crurithyris, and a single fragment of Meekella striatocostata. The Meekella occurrence is significant in that it is the oldest appearance of this form in the Stanton, and the only known Stanton appearance below the South Bend (Fig. 17, p. 241). Productids do not occur anywhere within the channel as more than rare elements. Specimens are most often broken and/or abraded and do not seem to be concentrated in either central or marginal portions of the channel. Hystriculina, Echinaria and Linoproductus are the most recognizable taxa, as all other specimens are indeterminate fragments.

Biotas of the rim calcarenite lithofacies are perhaps the most laterally variable anywhere within the Stanton. Brachiopods are found in a variety of lithofacies, and individual taxa may be abundant in one lithofacies and rare in another. No single taxon can be considered characteristic of the entire lithofacies, but Derbyia comes closest, as specimens have been found in coarse skeletal calcarenite as well as muddier lithologies. The largest portion of the brachiopod fauna is composed of the same five ubiquitous spirifers recognized in previous facies. All are rare to abundant, depending on particular lithofacies. Rare occurrences of *Dielasma*, *Schizophoria* and *Streptorhynchus affine* complement the large spiriferid fauna. Individual productid taxa remain rare throughout the rim, but the number of recognizable taxa are significantly greater than in the channel, particularly in muddy calcarenites. Productids include *Hystriculina*, *Antiquatonia crassicostata*, *Pulchratia symmetrica*, *Reticulatia americana*, *Linoproductus prattenianus*, *L. platyumbonus* and *Echinaria semipunctata*.

Brachiopods in the buildup calcilutite lithofacies are markedly reduced in both density of individuals and taxonomic diversity. Ubiquitous spiriferids are reduced to scattered rare occurrences of *Composita* and *Phricodothyris*. Remaining brachiopod composition is unlike that of buildup lithofacies in other limestone members. Productids remain typically rare, and are represented by scattered fragments of *Linoproductus* and more widespread *Hystriculina*. Those non-productids that are typically rare and subordinate to more abundant taxa in the Captain Creek, are absent in the Stoner.

Near the southern extent of the mound facies belt, the Stoner contains a thin shale bed that has many biotic and lithologic characteristics reminiscent of the Eudora. The bed was originally believed to be Eudora, but the presence of three meters of Stoner calcilutite between this shale and true Eudora convinced Heckel (1975b) that this bed belongs stratigraphically within the Stoner. The significance of the shale bed is that it contains some of the most abundant faunas in the entire formation, and carries several taxa that are either restricted to this facies of the lower Stoner, or facies of the uppermost Captain Creek.

Brachiopods completely dominate the fauna in this shale bed. Many of the taxa are present in other mound facies exposures of the Eudora, but the overall density of organisms in the Stoner shale bed is much greater. Additional brachiopod taxa that are unknown in the Eudora, occur as common or abundant elements in this bed. Most conspicuous is the abundant occurrence of *Rhipidomella* and *Chonetinella*. Both appear as articulated, well-preserved forms, although slight crushing has distorted features on most specimens. These genera only occur as rare elements at several Eudora exposures. In addition, they have a curious stratigraphic distribution, appearing in significant numbers only in this shale bed, in the top of the Captain Creek and the top of the South Bend Limestone Member.

The greatest portion of the remaining brachiopods in this shale bed are common occurrences of *Composita*, *Neospirifer* and *Hystriculina*. All occur at every exposure of this bed and show some distortion due to crushing. *Punctospirifer*, *Phricodothyris*, *Hustedia* and *Derbyia* are rare to common, but are more sporadically distributed, never appearing in more than one or two exposures. *Cancrinella boonensis*, *Crurithyris* and *Lissochonetes* generally occur as rare specimens, but may be common in isolated exposures.

Echinoderms

Volumetrically, echinoderms are the second most abundant group throughout the Stoner. At all localities in each of the three major facies belts, pelmatozoan debris is common to abundant. Unfortunately, very little material remains articulated, and only in rare instances are specimens readily identifiable to generic or specific levels. Ossicles are generally well-preserved and frequently display fine details on articular surfaces. Occurrences of less well-preserved ossicles are most common in the mound-associated rim calcarenite. Highly abraded ossicles found in spar-cemented grain calcarenites of the rim lithofacies frequently display unit crystal growth into the spar cement (Loc. NBRC). Unusual occurrences of articulated column segments up to 10 centimeters long are common in well-washed calcarenite of the mound-associated channel lithofacies.

Pelmatozoan material in the open-marine facies belt is so highly disarticulated that even familial identification of individual plates is practically impossible. The transition from open-marine to mound facies does not appreciably affect the expression of echinoderms. Buildup calcilutites contain scattered pelmatozoan debris, but recognizable forms have not been recovered. Mound-associated rim calcarenites, with a single exception, are also poor in recognizable pelmatozoan taxa. Locality DQSR displays a muddy skeletal calcarenite rim lithofacies that contains several forms including Erisocrinus, Graffhamicrinus, Cibolocrinus, Stellarocrinus, Aesiocrinus and Anobasocrinus, all of which are rare. Channel calcarenite lithofacies are similarly poor in recognizable taxa, but a few localities in the axial portions of the channel do yield specimens of one or two taxa (Locs. ACS-ACN and QEWW). An unusual channel occurrence of Erisocrinus typus appears in an encrinite near the top of the inactive northeast wall of the Fredonia Cement Plant quarry (about one kilometer east of Newell's original "Fredonia facies" locality). Abundant dorsal cups (25-30/m^2) and assorted ossicles litter bedding plane surfaces. Associated with these are rare specimens of Apographiocrinus, Cibolocrinus and Perimestocrinus. The only echinoderm appearing with any consistency in both the channel and rim lithofacies is the echinoid Archaeocidaris. Dissociated plates and spines are rare to common on bedding plane surfaces, and may occasionally be found in clusters most likely representing in situ disarticulation of a single echinoid.

Echinoderm remains in the thin Stoner shale bed near the southern end of the mound facies belt are dominated by uniformly common occurrence of pelmatozoan debris and rare occurrence of *Archaeocidaris*. *Cibolocrinus*, *Apographiocrinus* and indeterminate pirassocrinid ossicles are rare, but are always in association with each other. Remaining pelmatozoans in this unit are rare single specimens of *Parulocrinus*, *Euonychocrinus* and *Paramphicrinus*.

Algae

Phylloid algal blades and fragments occur throughout the geographic extent of the Stoner, but are prominent in outcrop expression only in the mound facies belt. Preservation in individual fragments is generally poor, with only rare specimens displaying faint cellular structure suggestive of *Archaeolithophyllum*. None of the algal material recovered from the Stoner in this study possesses internal cellular structure suggesting green algae, but *Eugonophyllum* has been identified from the upper Stoner (Loc. ECR) by J. L. Wray (P. H. Heckel, pers. commun., 1977).

Outcrop expression of phylloid algae in the open-marine facies belt is extremely poor. Long sinuous blades are rare, and small sparry fragments are difficult to definitely recognize as algal material. Common sparry grains do not display characteristic features of *Archaeolithophyllum*. Crinkly laminations of encrusting red algae and *Osagia*-type algal-foraminiferal encrustations have not been observed anywhere in this facies.

Outcrop occurrences of phylloid algae are restricted to buildup calcilutites in the algal-mound facies belt. Abundant to common thin blades occur in all mound exposures and seem to follow a distribution pattern similar to that recognized in the Captain Creek. Most abundant algal proliferation appears in more northern exposures of the facies and decreases somewhat toward the southern extent of the mound tract. Recrystallization has again obliterated internal cellular structure in most cases, but a few blades retain faint hypothallic structure, the only occurrence of such preservation in the Stoner.

Mound-associated rim and channel lithofacies lack visible algal grains in outcrop, but often contain sparry fragments and abraded grains that display distinctive algal features and structures when observed petrographically. In most instances partially preserved algal material can be identified as <u>Archaeolithophyllum</u>, but extremely rare specimens of the green dasyclad <u>Epimastopora</u> have been identified from the channel, and exceptionally well-preserved fragments of the solenoporid red alga, <u>Parachaetetes</u>, have been observed in samples from Locality NBRC in the rim lithofacies. Appearance of skeletal grains with shapes similar to those of co-occurring algal types suggests that algal content in mound-associated lithofacies may be more common than can be proved. The fragmented and abraded nature of most grains suggests that much of the algal material in these lithofacies may have been transported from the mounds and is not necessarily indigenous.

Bryozoans

With rare exception, little bryozoan material appears readily amenable to generic identification. Fenestrate as well as more massive and ramose growth forms frequently display details of the zooecia and other morphology, but all are most often found fragmented. In all major facies expressions of the Stoner, indeterminate fenestellid debris is the dominant bryozoan element. Within the open-marine facies it is common to abundant, but is not distributed uniformly throughout the facies. Scattered rare encrusting and globular trepostomes are the only other recognizable forms in the open-marine facies.

Fenestellid debris is ubiquitous throughout the algal-mound facies, and is rare to abundant depending on carbonate lithofacies. Fenestellid debris is virtually the only bryozoan material found in buildup calcilutites. The only other known forms are rare indeterminate encrusting trepostomes and cylindrical rhomboporids. Diversification of carbonate lithofacies in the mound-associated rim calcarenite is accompanied by a slight increase in the number of bryozoan types. Fenestellid material is usually highly fragmented, individual pieces rarely exceeding 15 mm in maximum dimension, but may also appear rarely as large, lacey fronds up to several centimeters across. Ramose and encrusting trepostomes, ramose cyclostomes, and questionable specimens of Fenestella, Fenestrellina, Rhombopora, and Polypora all occur as rare elements in the rim, mostly in muddy skeletal calcarenite. Fenestellid fragments are common in marginal areas of the channel lithofacies, and are particularly abundant as small 5-10 mm pieces in clean calcarenites near the center of the channel. All other bryozoan material with the exception of the distinctive cyclostome Meekoporella dehiscens is noticeably lacking. The zoarium of thin bifoliate sheets forming deep six-sided subpyramidal chambers make Meekoporella an unmistakable form in this lithofacies. Only one rim lithofacies occurrence (Loc. BB) is known outside the channel, and there are no other known occurrences of Meekoporella anywhere in the Stanton (Fig. 36, p. 260).

Bryozoans are extremely rare in the thin Stoner shale bed near the southern extent of the mound facies belt. Ramose growth forms of cryptostome and trepostome bryozoans are the most widely distributed in this bed. Remaining bryozoans are primarily single specimen occurrences of a fenestrate cryptostome and a ramose cyclostome.

Coelenterates

The distribution of corals in the Stoner is similar to that of bryozoans, but abundance is much lower. Solitary rugose corals are the most frequently encountered forms, whereas colonial tabulates are found only as rare or single specimens. Overall preservation is generally excellent in all lithofacies, although retrieving specimens from unweathered limestone frequently destroys juvenile portions of the coral.

Within the open-marine facies, corals are characteristically scattered rare to common occurrences of *Lophophyllidium*. Extensive searching at exposures in this facies belt failed to produce additional coral taxa. The transition from the open-marine to the algal-mound facies is marked by a gradual increase in coral diversity without a significant increase in abundance. In all instances (except one occurrence of common *Lophophyllidium*) corals are rare. *Dibunophyllum valeriae* is the most frequently recovered form in buildup lithofacies, but is never more than rare. Extremely rare occurrences of *Neokoninckophyllum* and *Geyerophyllum* comprise the remaining coral expression in the mound tract. *Lophophyllidium* is the most widely distributed coral in the rim lithofacies, despite overall sporadic appearance. All remaining taxa recovered from the rim appear only in single exposures. These taxa include *Dibunophyllum*, Geyerophyllum, Stereostylus, Lophamplexus, and one species Caninia torquia, which is presently known from only this facies in the Stoner, but does occur elsewhere in the Stanton. The only significant tabulates in the Stoner are also found in the rim. Extremely rare specimens of Syringopora multattenuata and Michelinia, displaying no visible signs of abrasion, are known only from abraded-grain calcarenite lithofacies. Small nut-sized specimens of Sutherlandia, showing fine details of individual corallites, have been recovered from muddy skeletal calcarenite. Several coral genera that have been previously noted in the rim lithofacies are also recognized in the channel lithofacies. However, unlike the rim, the most frequently recovered genus from the channel is Neokoninckophyllum. Stereostylus and Lophamplexus are similarly distributed throughout the channel, but are less common than Neokoninckophyllum. The only significant occurrence of Lophamplexus is that of common large three to four centimeter long specimens in a small muddy calcarenite branch of another large channel in Woodson County. Lophophyllids in the Wilson County channel are extremely rare and presently known from a single exposure.

Minor Elements

All remaining taxonomic groups are comparatively rare in the Stoner, with only unusual local occurrences of individual taxa worth mentioning. Trilobites occur as single specimens at Locality NBRC in the rim lithofacies. Both specimens are small incomplete forms identified as *Ameura missouriensis* and ?*Paladin*, which is a new species and may be a new genus (R. K. Pabian, 1977, pers. commun.). Trilobites are significant in the Stoner, as they represent one of only two known occurrences of this group in the entire Stanton.

Throughout the open-marine facies, buildup lithofacies and the major portions of the rim and channel lithofacies, bivalves are insignificant contributors to biotic assemblages. However, in one small area of the rim (Loc. NW-SW-24-27-15) myalinid bivalves are unusually abundant, and frequently appear as shell pavements. Most specimens are broken, and much of the shell material is not preserved. Better preserved specimens have been identified as *Septimyalina*, and rare, excellently preserved forms are recognized as *S. burmai* (Fig. 31, p. 255). Significant bivalves in the channel lithofacies are limited to common occurrences of the pholadomyoid genus *Edmondia* in the channel center (Fig. 32, p. 256). Specimens are preserved only as internal molds, but the distinctive shell outline and coarse concentric banding make it readily identifiable. This is the only occurrence of *Edmondia* in all facies of the Stoner.

Taxonomic groups such as gastropods, cephalopods, conularids, sponges, scaphopods and rostroconchs are either extremely rare or entirely absent in Stoner assemblages.

Bolton

When not an oolitic lithofacies, the Bolton bed is a richly fossiliferous unit characterized by an assemblage of geographically and stratigraphically widespread constituents. Brachiopods and echinoderms are the most prevalent forms, although echinoderms are rarely more identifiable than pelmatozoan debris. Minor elements include rare gastropods, bivalves and bryozoans, and extremely rare single specimens of corals, sponges and cephalopods.

Unlike the preservation in other Stanton members, Bolton bed fossils are frequently fragmented, but rarely abraded. Fine morphologic features are usually present regardless of the size of the skeletal piece. In addition to the abundance of skeletal fragments, whole shells are common. Most specimens are slightly crushed or distorted, but virtually all diagnostic morphologic features are distinguishable.

Although the high degree of fragmentation might be considered strong evidence for a transported fauna, several reasons argue against this for accumulation of the Bolton bed. Foremost is the lack of abrasion on both whole shells and fragmented material. Even minimal transport cannot account for the presence of a substantial number of whole shells that are exceptionally well-preserved (ignoring post-depositional crushing and distortion). Presence of larger specimens such as Septimyalina and Neospirifer also argues against transport, as the exceptional current required to move these taxa any distance, would probably have fragmented all other skeletal material. A second line of evidence against transport is faunal composition of major constituents. Even considering ubiquitous forms that might be capable of transport, abundance and dominant brachiopod-echinoderm composition in the Bolton bed is imcompatible with that of laterally adjacent of subjacent strata. Shales to the north contain productids whereas the Bolton virtually lacks productids. Immediately subjacent Eudora shales yield common Crurithyris, but no specimens of this taxon have been found in the Bolton. In addition, the Bolton contains a distinctive suite of articulated pelmatozoan dorsal cups that are unknown in any adjacent strata. Finally, the similarity between Osagia-encrusted skeletal nuclei and uncoated grains found elsewhere in the rock further refutes transport from outside the general Bolton environment. Henbest (1963) states that access to open water, capable of rolling potential nuclei, and depths within the photic zone are essential for growth of algal-foraminiferal Osagia on all sides of a nucleus. Mild wave or current action could provide this necessary overturning of nuclei, winnow carbonate mud, agitate sand-size grains for the formation of oolites, and still remain ineffective in removing indigenous skeletal material or introducing allochthonous elements.

Brachiopods

With rare exceptions at individual localities, the Bolton brachiopod fauna is primarily composed of common to occasionally abundant spiriferid taxa Composita, Phricodothyris, Punctospirifer, Neospirifer and Hustedia. The remaining brachiopods are generally rare: single specimen occurrences of Dielasma, Linoproductus and an extremely rare Schizophoria, one of only two specimens found outside the Wilson County channel and the only one known from Montgomery County. The Bolton also yields unusual rare to common occurrences of Chonetinella and Rhipidomella (Loc. GP), both of which occur elsewhere mainly in uppermost Captain Creek and lower Stoner limestone and shale facies, and spotty rare to common Derbyia.

Echinoderms

Without exception, all skeletal-rich exposures of the Bolton yield common pelmatozoan debris. Stem ossicles are most frequently recovered with assorted brachial plates and disarticulated dorsal cup plates. Identifiable echinoderms are rare to common, and are most frequently Erisocrinus and Delocrinus, with isolated occurrences of Perimestocrinus, Cibolocrinus and an indeterminate pirassocrinid, possibly Schistocrinus. Locality GP yields specimens of all Bolton echinoderms, except Delocrinus, and also contains a singular appearance of common Erisocrinus and Cibolocrinus.

Minor Elements

The remaining fauna of the Bolton consists of isolated rare to unusual common occurrences of various bryozoans, gastropods, bivalves, sponges and single specimens of an indeterminate rugose coral and an ammonoid cephalopod. Bryozoans represent the greatest proportion and include fenestellid debris, possibly a rare specimen of *Fenestrellina*, and ramose trepostomes and cryptostomes. Gastropods are mostly rare indeterminate steinkerns, but at one locality (Loc. TB, type section of the Bolton bed) *Glabrocingulum wannense* appears as common well-preserved specimens. Two isolated specimens of *Septimyalina* and a badly broken fragment of an indeterminate bivalve are the only specimens of this group found in the Bolton. Single specimen appearances of the thalamid sponge *Girtyocoelia* complete the fauna of this bed.

Rutland

Macrofaunal associations in the Rutland bed are difficult to evaluate. Most of the biota consists of highly fragmented and abraded bioclastic skeletal grains, which suggest either allochthonous origin or considerable *in situ* tumbling. Presence of thin oolitic coatings at northern and southern extremes of Rutland exposure support effective water agitation.

The preservation and type of algal fragments may support an essentially indigenous origin. Algal fragments are conspicuous on outcrop as common to abundant dark, oatmeal-flake-shaped grains, which have been identified petrographically as _Archaeolithophyllum_, _Parachaetetes_ and _Epimastopora_. Petrographic observation reveals excellent preservation of internal cellular structure in many algal grains despite severe fragmentation. The nearest external source for abundant algae would be the southern end of the mound tract, a distance of about three kilometers to the north. If transported across this distance, most delicate algal blades would be expected to have completely disintegrated, yielding nothing but carbonate mud. Furthermore, dasyclad and solenoporid algae are unknown in the algal mounds. If algal material had been transported from a distance and preserved in the Rutland environment, it seems unreasonable to believe that more durable skeletal invertebrates associated with the algae (or derived from laterally adjacent shale environments along the way) wouldn't also be transported with the algae and preserved as nearly whole-shell skeletal constituents. Without additional unequivocal evidence however, it is difficult to prove or disprove an indigenous Rutland assemblage. Perhaps the only evidence for a non-transported biota is the presence of algal groups that are unknown in Rutland equivalent rocks.

Recognized Taxa

Identifiable non-algal skeletal material is limited to a meager representation of rare to occasionally common brachiopods, gastropods, bryozoans, corals and echinoderms. *Phricodothyris* and common *Punctospirifer* are the only brachiopods recognized. All other brachiopod material is too fragmented to attempt further identification. Specimens of *Punctospirifer* are surprisingly well-preserved, perhaps due to the small size and somewhat inflated form. *Phricodothyris* shells are badly battered, particularly along the commissure, but remain intact, perhaps due to the roughly convex lens-shape of the shell. Gastropods comprise the greatest number of different taxa recovered from a single major group. *Worthenia* is most prevalent, occurring as common abraded shells lacking most surficial ornamentation. Other gastropods, including *Naticopsis*, *Pseudozygopleura* and an indeterminate murchisoniid, are rare and also lack prominent ornamentation. Identification of these taxa, although worn and abraded, is relatively easy as general shapes are immediately recognizable and not easily confused with other taxa. Remaining macrofaunal material consists of assorted bryozoan and pelmatozoan debris. As in most other facies, pelmatozoan debris is primarily an accumulation of stem ossicles, dorsal cup and brachial plates. Bryozoan debris includes common fragments of indeterminate fenestellid types and thin stick-like ramose growth forms of *Rhombopora*.

Rock Lake

Notwithstanding the unusual development of a marginal marine lagoonal assemblage of arthropods, amphibians, reptiles and land plants (Moore, 1964), the Rock Lake Shale is monotonously unfossiliferous throughout most of its outcrop. Intensive searching at most localities failed to produce even small fragments of skeletal debris. The major exceptions are a local extremely fossiliferous limestone in Franklin County, a coral-rich shale in Woodson County, and isolated sparsely fossiliferous sandstones and shales in the detrital facies belt of central and southern Montgomery County. Extreme lithologic variability along outcrop, the general lack of macrofossils and comparatively poor exposures makes the Rock Lake the most difficult member to interpret. Paucity of appreciable and consistent fauna make it difficult to recognize biotic trends through the three major facies belts. Accordingly, discussion of Rock Lake faunas is limited to individual associations at widely separated localities throughout the study area.

In Franklin County the Rock Lake contains an unusual basal limestone unit overlain by more typical unfossiliferous gray-green silty shales (Loc. PQ's). The limestone is locally brecciated and is marked by an encrinite layer at the top. Pelmatozoan debris is the only skeletal material observable in this basal unit, and none of it remains articulated for identification. Overlying this unit is another limestone that contains an unusual and abundant fauna. Pelmatozoan debris is common throughout the unit and is associated with an abundant brachiopod-gastropod fauna. Composita, Neospirifer and Linoproductus are the most conspicuous forms, all of which are common; Phricodothyris, Punctospirifer, Dielasma, Meekella and Antiquatonia are rare. Gastropods characterized by common Straparollus reedsi and bellerophontids, all of which lack shell and remain indeterminate. Subordinate to these are extremely rare specimens of Pharkidonotus, Trepospira and Straparollus catilloides. Pharkidonotus and Trepospira do not retain any shell material, but distinctive shape and vestiges of ornamentation allow them to be recognized. All remaining elements of the fauna are rare bivalves and corals including several myalinids, Geyerophyllum, Michelinia, and a questionable auloporid. Another notable aspect of this unusual fauna is that most gastropods are uncharacteristically oversized. Composita and Neospirifer are almost twice normal size, and exceptional bellerophontids are dramatically larger, frequently approaching three to four centimeters in greatest dimension.

Southward into the mound facies, unfossiliferous gray-green clayey to silty shales and buff to gray siltstones characterize the Rock Lake. A single shale locality poorly exposed in a roadside ditch (Loc. CSL-12-26-16) contains the only known Rock Lake fauna in this facies. Abundant rugose corals, belonging to the species Caninia torquia, are the only fossils found. Most corals are conical forms two to three centimeters in length. Less common large forms approach 10 centimeters in length and two centimeters in maximum diameter. Washed residues of the shale fail to produce any other macrofossils. Similarly, the reddish-brown to orange-brown Rock Lake shales of the southern portion of the algal-mound facies do not yield any macrofossils.

In the terrigenous-detrital facies belt of southern Montgomery County, two sparse sandstone faunas and one equally sparse shale fauna comprise the only known macrofaunal development in the member. The single shale fauna (Loc 75SB) contains only rare Composita, Neospirifer and Hustedia, a few pelmatozoan ossicles and one specimen of Nuculopsis ventricosus. None of the specimens are exceptionally well-preserved, but all display one or two distinctive features that prompt easy identification. Faunas of the sandstones (Locs. NWC-30-34-15 and HR_n) are compositionally different from the shale, and are poorly preserved as limonitized external molds. Hustedia and Punctospirifer are rare, and Juresania occurs as a single specimen. Pelmatozoan material, at Locality NWC-30-34-15, consists of rare column ossicles, whereas at Locality HR_n, it consists of abundant ossicles and other small plates. None of this material lends itself to generic or specific identification. Bivalves constitute most of the remaining fauna. Rare *Paleoneilo taffiana* have been found at both localities, a single *Paleyoldia* is known from NWC-30-34-15, and extremely rare indeterminate myalinids and a single *Parallelodon* specimen have been found at HR_n. The remaining skeletal material from these exposures is indeterminate. Fenestellid fragments are scattered throughout both localities, and a single bellerophontid and an extremely poorly preserved coral have been recovered from HR_n.

3rd oolite

Whole shell faunas of the 3rd oolitic horizon are extremely rare, and as presently known, are limited to a single horizon (Loc. HR). None of the fossil material is well-preserved. Most specimens are fragmented, or lack shells as a result of diagenetic alteration or removal from the limestone matrix. Smaller specimens, particularly a few brachiopods, display somewhat better preservation, often remaining articulated and unbroken. None of the specimens exhibit evidence of extensive abrasion or transport, and it is assumed that this is effectively an *in situ* accumulation of skeletal material.

The fauna is characterized by brachiopods and gastropods, with minor bivalves, echinoderms and single specimens of an indeterminate orthoconic nautiloid and an undistorted conularid, Mesoconularia. Representatives of other major groups have not been recovered from this horizon, despite extended search and intensive observation of rock and fossil fragments.

Brachiopods are represented by an unusual association of relatively few forms occurring as rare to common constituents. The typical appearance of spiriferids in other Stanton horizons is reduced to Composita and a single articulated specimen of Hustedia. Composita is common and remains articulated and undistorted, but is represented entirely by smaller than average specimens (one centimeter or less maximum dimension). The significance of small size may be attributed to several physical or biological factors, which remain unresolved at this time. Also common is Echinaria semipunctata. Although all specimans are poorly preserved and fragmentary, this occurrence is noteworthy because Echinaria is not normally a major constituent of the brachiopod fauna. Remaining brachiopods are represented by single poorly preserved fragments of Derbyia crassa, Linoproductus, and an indeterminate productid.

Gastropods are equally as rare as the minor brachiopod taxa. Two specimens of Straparollus catilloides are the most significant, but are imbedded in matrix and extremely difficult to retrieve intact. Single specimens of Trepospira and Meekospira comprise the remaining identifiable gastropods.

Most surface morphology and other distinguishing features are observable in both, although all details are not preserved. The remaining gastropods are a group of indeterminate steinkerns, all of which are rare to common. Two types of steinkerns include a low-spired turbinate form, and a high-spired variety. The turbinate form might be Trepospira, whereas the high-spired type is most likely Meekospira.

The 3rd oolite assemblage is completed with the addition of previously mentioned conularid and cephalopod taxa, and rare bivalves and echinoderm debris. Bivalves are represented by poorly preserved myalinid fragments and disarticulated and fragmented Aviculopecten valves. Echinoderm material is unidentifiable pelmatozoan ossicles and plates.

4th oolite

Exposures of the 4th oolitic horizon are generally more fossiliferous than the 3rd oolitic zone, frequently with distinctive gastropod or brachiopod-rich assemblages at different localities. Preservation of either of these faunas varies from good undistorted and unabraded whole shells to very poor fragmented and battered skeletal debris, which is identifiable only when a distinctive morphologic feature can be discerned. Individual assemblages in the 4th zone also show some preference for either dominantly calcareous sandstones or oolite, but are not completely restricted to a particular lithology.

The gastropod-rich assemblage is present in relatively few exposures, and is most notably developed at Locality CP near the Oklahoma border. The pleurotomariacean Hypselentoma perhumerosa is an overwhelmingly abundant form, comprising nearly 75% of several hundred macrofossils recovered. It always retains original shell material, but ranges in overall preservation from poor weathered fragments to perfectly preserved whole shells replete with all morphologic features, including faint striate patterns representing growth increments. Subordinate forms that are common include Naticopsis meeki and an indeterminate high-spired form, probably Murchisonia. Each form retains original shell material on all specimens, but crushing distorts many distinctive features, particularly in Murchisonia. All remaining gastropods are rare taxa represented by only one or two specimens. Two forms, Bellerophon graphicus and Goniasma, are well-preserved and complete in all details.

Other taxa of the gastropod assemblage vary from extremely rare to common, but generally remain unidentifiable. An indeterminate orthoconic nautiloid fragment completes the molluscan portion of the fauna, and an indeterminate productid and specimens of Neospirifer constitute all the brachiopod remains. Representatives of other major phyla have not been observed, and are assumed to be absent in this fauna.

Two distinctive variations in major constituents characterize the brachiopod-rich assemblage. One variant (Loc. ESL-6-35-14w) is distinguished by abundant *Composita*, *Punctospirifer*, *Hustedia* and *Derbyia*. Subordinate brachiopods include rare *Dielasma* and *Streptorhynchus*. Notably absent are productids. Other groups never occur as more than rare constituents. This small complement includes pelmatozoan debris, a single *Delocrinus*, fenestellid debris, encrusting trepostome bryozoans, *Septimyalina*, *Acanthopecten*, an indeterminate nautiloid and a bellerophontid gastropod. Various degrees of preservation prevail, with all taxa showing at least some degree of crushing or fragmentation. Larger brachiopods are frequently an assortment of articulated and disarticulated valves. Only small forms such as *Hustedia*, *Streptorhynchus* and *Punctospirifer* remain articulated and relatively well-preserved. *Punctospirifer* is unusually abundant and displays a marked size and shape range from less than 0.5 mm to more than one centimeter, and from an inflated to an alate body outline. Remaining non-brachiopod constituents are moderately well to poorly preserved and are most often fragmented. In most instances, a fortuitous fragment with recognizable features serves to identify the taxon. Evidence of abrasion was not observed in any specimens.

The other variant of the brachiopod-rich assemblage is generally distinguished by rare spiriferids, an absence of derbyids and the presence of scattered productids. None of the taxa are consistently distributed and different combinations of the same seven taxa were encountered at different localities. *Composita*, *Phricodothyris*, *Puncto-spirifer* and *Hustedia* are the most prevalent forms; all are rare, except for one occurrence (Loc. NWC-20-34-14) of abundant *Composita* and common *Hustedia*. The remaining brachiopods include scattered rare *Dielasma*, *Dictyoclostus*, *Juresania*, and indeterminate productids. Other groups cannot be characterized by any particular group or taxon. Pelmatozoan debris is rare at all localities, and none of it is identifiable. Other readily recognized taxa usually occur at only one or two localities. These include the gastropods *Glabrocingulum*, *Straparollus* and indeterminate steinkerns, fenestellid debris and an orthoconic nautiloid. Preservation of individual taxa is extremely variable in different taxa at a single locality. The range of variability includes poorly preserved crushed and broken specimens to moderately well-preserved, undistorted whole shells, none of which show observable signs of abrasion regardless of the condition of preservation.

South Bend

Fossil assemblages in the upper member of the Stanton are generally dominated by common to abundant brachiopods. Commonly associated constituents are echinoderms and bivalves. Phylloid algae are relatively inconspicuous, but are represented locally by abundant blades and fragments. Gastropods and bryozoans are rare to common and constitute most of the remaining faunal elements. Other groups such as corals, sponges, cephalopods, trilobites and vertebrates are rare.

Within the open-marine facies belt, the entire South Bend is generally characterized by omnipresent Composita, Phricodothyris and Punctospirifer. Pelmatozoan echinoderm material is equally common or abundant, but not as identifiable taxa. Phylloid algae are scattered, but locally are subequal with dominant brachiopods. Of the remaining taxa, none occur with sufficient frequency or are unique in distribution to be considered indicative of this facies belt.

Assemblages in the transition to the algal-mound facies belt are comparable in composition to those of the open-marine facies, but taxa are more spotty in their distribution. Brachiopods remain the most numerous constituents, with Composita the only widespread form in the facies that is common to abundant. Bivalves are the most significant of the subordinate constituents, approaching parity with brachiopods in taxonomic diversity, but are only rare to common, and sporadically distributed. All remaining groups are either extremely rare on outcrop, or common to abundant but with spotty distribution.

Southward into the terrigenous-detrital facies belt, the overall character of South Bend assemblages does not change significantly. Two distinctive assemblages appear laterally along outcrop in the upper unit of the member, whereas the lower sandy and conglomeratic unit loses any recognizable assemblage. Brachiopods remain most conspicuous in all assemblages, particularly in the upper unit at the southern end of the mound tract. Bivalves and sponges are locally as significant as brachiopods in the upper assemblage, but appear in this assemblage only in west-central Montgomery County. Except for one unique echinoderm fauna in the upper unit, this group is unusually rare in both major assemblages of this facies. Remaining groups, including gastropods, corals, bryozoans, cephalopods and vertebrate fish remains, are extremely rare, and only scattered.

Brachiopods

As in previous members and assemblages, brachiopods are the most readily identifiable macrofossils, due both to their good preservation and to the large number of recoverable specimens. Overall preservation is generally good to excellent, with most morphologic features clearly discernible. Fragmentation is negligible, except on very thin shells, and effects of extended abrasion have not been recognized. Specimens usually remain articulated, and observable distortion is limited to slight crushing of some forms.

The two-fold lithologic subdivision of the South Bend is readily recognized in the open-marine facies belt, but associated brachiopod faunas are less readily distinguished from one another. Both faunas are generally dominated by common to abundant Composita, Phricodothyris and Puncto-spirifer. Subordinate and somewhat more sporadic in distribution are rare to common Derbyia and Meekella in both assemblages. Specimens of Derbyia are usually distorted due to crushing, but are readily recognized by a distinctive radially lirate pattern that is crossed by a weaker and irregular concentric lirate pattern. Also, a unique pedicle cardinal area morphology consisting of an arched deltidium, an inner vertically striate perideltidial area and a horizontally striate outer area aid in identifying Derbyia. The shape and ornamentation of Derbyia make it difficult to retrieve specimens from dense matrix, and as a result, most specimens are broken in the collection process. The distinctive shell morphology, however, enables even small fragments to be identified with confidence. Meekella is similarly distinct morphologically and can also be identified from small fragments. Coarse sharp-crested radial plications and broad interspaces are marked by fine radial lirae which parallel plications on the umbonal region and converge toward plicate crests nearer the anterior edge and on lateral slopes. The strongly biconvex inflated shell possesses a somewhat subpyramidal pedicle valve and a cardinal area that also contains an arched deltidium and a vertically striate perideltidial region. Similiarity between cardinal area morphology in Derbyia and Meekella is distinguished by invariable ontogenetic distortion near the apex of the deltidium in Meekella.

Two small forms, Chonetinella flemingi and Rhipidomella carbonaria, are the most diagnostic taxa for distinguishing the upper and lower faunas. Both species occur only in the upper fauna, and are most prevalent near the top of the upper lithic unit. Rhipidomella is never more than a rare constituent and may not be present in the upper assemblage at every locality. When present, it is always as well-preserved, articulated specimens. Chonetinella is more prevalent within the upper fauna than Rhipidomella. Wherever the upper fauna is found, Chonetinella is abundant, and frequently as a shell pavement (Locs. KTPK and PQ's). Individuals usually remain articulated, frequently display excellent preservation (including delicate spines along the hinge line), and, despite the thin, fragile shell, specimens are unbroken and undistorted.

Of the remaining taxa in the open-marine facies belt, none are restricted to either fauna, or even consistently present. Hystriculina is common, whereas Neospirifer and Linoproductus are rare, but all occurrences (except for a single Linoproductus) are found at a single locality in both the lower and upper brachiopod faunas (Loc. BS). The distribution of Hystriculina is particularly noteworthy as it is one of only two occurrences of this form in the open-marine and algal-mound facies belts. It is common throughout these facies in both the Captain Creek and Stoner, but has not been found at any other localities in the South Bend despite thorough search. Rare to common Dielasma in the upper fauna at Locality PQ's and in the lower fauna at Locality QWW complete the brachiopod fauna in the open-marine facies belt.

Brachiopod faunas of the algal-mound facies belt are generally comparable to faunas of the open-marine facies, but lack any productids or chonetids. Composita remains the most widespread element, and is rare to abundant at all localities. Other spiriferids are uncharacteristically sparse, and are found at only one or two localities, although they are often abundant when present. Punctospirifer, which is usually found at most exposures in other major Stanton units, is known in the South Bend only from basal sandstones at Locality SWC-22-30-15.

Derbyia and *Meekella* remain the most characteristic elements throughout the algal-mound facies belt. They vary from rare to abundant at individual localities, but overall distribution is not widespread throughout the facies. However, as the association of *Derbyia* and *Meekella* is unknown in lower members of the Stanton, recognition of these forms as indicators of South Bend brachiopod faunas seems justified. Individual specimens are frequently broken during removal from the rock, but there is no evidence of pre-burial fragmentation.

The notable absence of *Chonetinella* and *Rhipidomella* in South Bend algal-mound facies warrants further consideration. In previous South Bend occurrences, both taxa appear only within the upper portion of the member in an assemblage slightly different from that of the lower unit. Most fossil collections in the algal-mound facies belt are from the lower unit of the South Bend. Recent erosion and limited exposure of the upper unit in this facies are likely responsible for the absence of *Chonetinella* and *Rhipidomella*. There seems to be little reason to doubt that if the uppermost South Bend were exposed, both forms would be present.

Brachiopod faunas in the terrigenous-detrital facies belt remain distinct and closely associated with the prominent two-fold lithologic subdivision of the member in this region. Faunas of the lower sandy to conglomeratic unit are characteristically sparse, and are represented by only one or two elements at any locality. Fossiliferous lower South Bend exposures at two localities (Locs. SE-SE-SE-28-32-14 and SCWL-4-34-14) respectively yield only rare specimens of articulated, well-preserved *Punctospirifer* and a single, battered valve of *Pulchratia*.

Faunas of the upper limestone unit are substantially more abundant, and are represented by a variety of brachiopods. Ubiquitous *Composita*, *Phricodothyris*, *Punctospirifer*, *Neospirifer* and *Hustedia* once again dominate, and in one quarry (Loc. H160Q) all five genera are common to abundant. Characteristic genera *Derbyia* and *Meekella* continue to display spotty distribution. However, in contrast to previous facies, they are only rare or common. Presence of uppermost South Bend beds marks the reappearance of *Chonetinella* and *Rhipidomella*. Both types occur again as whole-shell, uncrushed forms, which are locally rare to common, except for an unusually abundant occurrence of *Rhipidomella* (Loc. NEC-34-32-14).

The remaining constituents of the upper fauna are a variety of rare to abundant brachiopod types, most of which occur only in the extremely fossiliferous exposure at Locality H160Q. Many forms at this locality are recognized throughout the Stanton, and others are extremely scarce. The presence of *Hystriculina* in the northern end of the detrital facies is the only other South Bend occurrence of this genus. It is typically a rare specimen, but is abundant at H160Q. Preservation is exceptional (ignoring minor effects of crushing), with short one to two millimeter broken spines readily observable on most specimens. Scarce taxa include *Streptorhynchus* and *Orbiculoidea*, both of which are known only as single specimens, and the small, distinctive rhynchonellid *Wellerella osagensis*, which occurs as a common element. All of these genera have been found from only one or two other Stanton horizons, and their exceptional preservation as well as occurrence make them particularly noteworthy.

Bivalves

Although represented by relatively few taxa, low numbers of individuals, and overall spotty distribuiion, bivalves are perhaps the most common group of subordinate taxa that are readily identifiable in South Bend assemblages. Individual specimens are never as well-preserved as brachiopods, and most frequently appear either broken, somewhat corroded, or as molds lacking any shell material. None of the taxa occur with sufficient frequency to be characteristic of a particular assemblage, but in association with other subordinate groups, they serve to distinguish compositional variations in major South Bend assemblages.

Within the open-marine facies belt, bivalve distribution is effectively limited to exposures at the southern end near the transition to the mound facies belt (Loc. QWW). The greatest number of bivalve types occur in the basal South Bend, associated with relatively sparse brachiopods of the lower assemblage. Three genera are recognized, two of which, Septimyalina and Edmondia, are infaunal to semi-infaunal types, and Aviculopecten which is interpreted as a nekto-benthic form. Septimyalina is common, but the thick shell is typically broken along somewhat thinner margins. Aviculopecten and Edmondia are considerably more deteriorated. Ribbing on rare Aviculopecten specimens is always abraded, thin auricles are broken, and valves are disarticulated. Preservation of rare Edmondia specimens is also poor, with most represented by internal molds and little shell material. The molds of Edmondia suggest that specimens were articulated and unbroken prior to loss of shell material. It should also be noted that this is the only occurrence of Edmondia outside the Stoner channel calcarenite lithofacies, and further indicates the preference of this bivalve for coarse sand-size sediments. Bivalves of the upper South Bend assemblage in this facies belt are extremely rare, and are represented by scattered indeterminate myalinids.

The transition to the algal-mound facies is characterized by the appearance of additional infaunal and pectenid genera. All are scattered within the lower assemblage, and are preserved much the same as specimens in the open-marine facies. Septimyalina is again the most prevalent genus, and is found at more than half of the localities where the basal unit is exposed. Additional infaunal genera are single occurrences of Parallelodon, Paleyoldia and indeterminate nuculanids. The appearance of Parallelodon in the lower South Bend and its lower Stanton occurrences is interesting in that it is found only in detrital, quartz-rich lithologies. Pectenids in the lower assemblage are represented by rare Aviculopecten and Pseudomonotis. Specimens are always disarticulated, but shell deterioration is generally not as severe as in the open-marine facies belt. Most ornamentation is distinct, and only in a few instances are delicate shell morphologies such as the auricles found broken.

Bivalves in the detrital facies belt display the poorest distribution and lowest abundance of this group in the entire South Bend. Individual taxa occur as rare specimens, but have distinct distribution in the lower and upper assemblages. The greatest number of genera are typically associated with sparse brachiopod faunas of the lower assemblage, whereas isolated single taxa are found with rich brachiopod faunas of the upper assemblage. Septimyalina, Paleyoldia, and Aviculopecten constitute the only recognizable taxa within the lower assemblage. Other fragments can be found at most exposures, but these are often so badly broken that confident identifications cannot be made. Infaunal types characterize the upper assemblage, and include *Paleoneilo* and *Septimyalina*. Extreme brachiopod domination of the assemblage probably posed severe limitations on the development of a substantial bivalve fauna.

Echinoderms

Although identifiable taxa are extremely rare throughout most of the South Bend in all major facies belts, pelmatozoan debris frequently contributes significantly to the total biovolume at any locality. Within the open-marine facies belt, unidentifiable ossicles and dissociated calyx plates are common to abundant. In some instances, a distinctive plate or spine enables recognition of a higher taxonomic category such as rare pirassocrinids, but generic or specific identification remains impossible. Pelmatozoan concentration is somewhat more sporadic in the algal-mound facies belt, and varies from locally rare to abundant. A single pirassocrinid spine and a partial dorsal cup of ?*Sciadiocrinus* (Loc. NE-NE-SE-33-26-16) are the only identifiable pelmatozoan remains in this facies. Except for an *Erisocrinus* specimen (Loc. SE-SW-SE-28-32-14), exposures of the basal South Bend are effectively lacking in any echinoderm material, including pelmatozoan stem ossicles. However, pelmatozoan debris is common to abundant at all exposures of the upper South Bend. At Locality H160Q a crinoid fauna has been collected that contains more identifiable genera and species than any other member or locality in the entire formation. Particularly interesting is that all of the genera and species are rare, and none of the taxa commonly recognized in lower members of the Stanton are present, except for Apographiocrinus. Unique South Bend and Stanton occurrences include Isoallagecrinus, Contocrinus and Exoriocrinus, and those also not represented elsewhere in the Stanton include single specimens of Elibatocrinus and Laudonocrinus.

Algae

Of the three Stanton limestone members, the South Bend has the poorest outcrop expression of phylloid algae. This is likely attributable to the nature of South Bend exposures across the algal-mound facies belt. Buildup calcilutite containing phylloid algae only occurs in the upper lithic unit, which is rarely exposed in the mound facies belt, except at the southern extremity in northern Montgomery County. Furthermore, not all exposures at the southern end of the mound tract display distinct blades or fragments of phylloid algae. Petrographic observations reveal phylloid algal fragments and verify significance of the algae in the mound sediment, but on outcrop, algae remains for the most part inconspicuous. A significant outcrop occurrence is at

Locality H160Q in the north wall of the quarry where a massive algal-mound complex is exposed. The algae are discontinuous sinuate blades and fragments, which are locally so abundant that they appear to be the only biotic constituents in the rock. Less algal lithofacies at the same exposure contain common spiriferids and locally common Meekella.

Minor Elements

Of the remaining taxonomic groups, only bryozoans and sponges display slight distributional differences that aid in recognizing local variations in South Bend assemblages. Specimens within this category are typically rare, and frequently poorly preserved, but distinctive morphologies enable ready identification, even from small fragments.

Bryozoans are the most significant of the minor elements. Fenestellid debris occurs in both open-marine and algal-mound facies assemblages, but is only rare to common. Size, shape and arrangement of zooecia and fenestrulae suggest that several types of fenestellid bryozoans may have existed at any locality, but most specimens are considerably fragmented and unidentifiable. Fenestellids diminish in the detrital facies, and bryozoans in general disappear from the basal unit. The upper unit contains a variety of ramose, globular and encrusting trepostomes that are rare to common at any particular locality in this facies, but are unknown throughout the open-marine and algal-mound belts. The only readily identifiable taxon is the cryptostome Rhombopora, which appears as thin, delicate, cylindrical branches and fragments.

The beaded calcisponge, Girtyocoelia, is locally significant in calcilutites of the upper South Bend in west-central Montgomery County. Specimens appear in weathered relief on outcrop exposures and are the most conspicuous forms of the assemblage. Presence of the sponges produces an as emblage that is reminiscent of the sponge-echinoderm dominated assemblage in the Captain Creek. However, distinction between the two assemblages is easily made, as echinoderm debris is less common and sponges are not as dominant in the South Bend assemblage.

Of the remaining major taxonomic groups, none of the identified taxa occur with sufficient frequency to recognize any distribution or assemblage preference. All are single specimens, and most represent either unique South Bend or additional isolated Stanton occurrences. The nautiloid Metacoceras and isolated teeth of Orodus and Petalodus destructor represent the only known occurrences of these taxa in the Stanton. An unusual and interesting occurrence of color banding is preserved in specimens of the gastropod Euconospira turbiniformis at Locality H160Q.

PALEOECOLOGY

In order to evaluate lateral and vertical distributions of fossil organisms, it is necessary to know the factors possibly controlling their presence or absence. These factors can be biological, physical or any combination of both. Biological influences affecting distributions can include a variety of organism-organism interactions such as commensal, symbiotic and competitive relationships, as well as biological characteristics inherent in individual species. However, even under close observation in modern environments, it is frequently difficult to positively identify biological influences controlling the presence or absence of a particular organism. In ancient environments living interactions obviously cannot be observed, and most hypotheses suggesting biological control must necessarily be tempered with a degree of caution. A large number of organism associations might be influenced partially or entirely by biological factors, but the nature of the rock record simply does not permit positive recognition.

Modern marine invertebrates are also strongly influenced by the physical environment. A variety of environmental factors including salinity, temperature, substrate, water depth, turbulence, light penetration and dissolved oxygen content have all been shown to affect modern distributions (Hoskins, 1964). The existence of an organism is not however, so much dependent upon average or dominant conditions in an area, as upon the tolerance of the organism for a limiting factor (Weller, 1957). However, it is often difficult to recognize the effects of a single factor in the modern environment, as different physical effects may control the presence or absence of a species over different parts of its distribution, e.g., oxygen in one place, temperature in another and turbidity elsewhere (Mulicki, 1957). Furthermore, observed distributions may also be influenced by complex interactions of several factors (such as relationships between water depth, wave agitation and substrate character), and only through detailed observation can the relative importance of any single factor be recognized (Mayou, 1972; Jones, 1950).

As with modern marine invertebrates, ancient organisms were probably affected similarly by the physical environment. However, unlike the modern environment where most factors can be monitored, the ancient record only permits evaluation of environmental factors in relative terms. Paleoenvironmental change is usually indicated by abrupt lithologic change, and is frequently accompanied by equally abrupt faunal change. Independent stratigraphic and petrographic interpretations provide estimates of the relative effect certain physical factors have on lithologic change, and on the composition and distribution of associated fossil organisms. Stenotopid taxa survive only within narrow limits of environmental change, and are accordingly most susceptible to variations in limiting physical factors. Eurytopic organisms are more tolerant of wide environmental variation, and are more likely to be ubiquitous in their distribution.

The current depositional framework for the Stanton Limestone (Heckel, 1977, 1978) and data from this report suggest general environments and associated physical factors that may have affected biotic distribution. Individual taxa with recognizable distribution may have been limited by general paleogeography (facies belts), lithofacies (substrate) or depositional phase. Specific physical factors affecting individual taxa are difficult to evaluate, but may be inferred from stratigraphy and petrography. None of these specific factors can be definitely recognized as ultimately responsible for observed distributions.

Organisms Restricted to Geographic Facies Belts

Several dozen genera and species in the Stanton appear to be restricted to particular facies belts or limited by major topographic features. However, virtually all observed patterns seem to be artifacts of other factors influencing distribution rather than actual paleogeography. Most of the taxa displaying apparent geographic distribution are an assortment of rare forms that represent several major invertebrate phyla. These organisms are typically single specimen occurrences at one or two isolated localities. The scarcity of their occurrence does not provide enough data to evaluate any trends, but the possibility remains that distinctive distributions may be recognizable with more information.

A smaller group of common to abundant taxa also appears to be restricted to particular facies. Molluscan forms including _Worthenia_, _Paleoneilo_, _Phestia_, _Plagioglypta_ and _Pseudoconocardium_ occur only in Eudora shales in the northern end of the terrigenous-detrital facies belt. The limited stratigraphic occurrence and lithologic association of these taxa suggest a relation to other environmental factors such as substrate or depositional phase, rather than geographic restriction. Also limited to the detrital facies belt are locally common to abundant _Crurithyris_, _Trepospira_, _Euphemites_, and with rare exception, _Eoasianites_ and _Glabrocingulum grayvillense_. Most occur in shales, but none are restricted to a single lithology. As a result, it does not appear that substrate limits their distribution. However, none of these taxa occur in early transgressive or late regressive phases. All appear only at the tops of transgressive limestones in both cyclothems, in basal regressive limestone equivalent (Bolton bed), or within the non-black offshore shale. This strongly suggests that these taxa are more affected by depositional phase and the specific factors associated with deeper water. If related to depositional phase, the question remains as to why these taxa are effectively restricted to the terrigneous-detrital facies belt. Comparable lithologies are found in the same phases of deposition throughout the northern facies belts, but none of these taxa occur any farther north than the southern extremity of the mound facies. Perhaps the southern end of the mounds may have acted as a topographic barrier that effectively altered hydrographic conditions, and inhibited any northward migration of these detrital facies taxa.

Organisms Limited by Sediment Substrates

The majority of Stanton taxa either provide little information as to substrate requirements, or occur with equal frequency in several primary lithofacies types. Only a small number of taxa have recognizable distributions that suggest sediment-substrate specificity. Of the major sediment types previously discussed, only lime muds, lime sands, silty, argillaceous muds, quartz sand and possibly calcareous quartz sands contain taxa that are limited to substrates and environments that these sediments represent. Sandy argillaceous mud, oolitic sand and black anoxic mud either completely lack faunas, or are inhabited by generally low density faunas consisting of taxa that are equally as common or more prevalent in other lithofacies.

Lime mud is the most common sediment type in the Stanton and contains greater overall taxonomic diversity than any other lithofacies. However, few taxa are unique to this sediment. Productid brachiopods in general are widespread in lime mud, but are often equally as common in other lithofacies, particularly argillaceous muds. Most other brachiopods are either so extremely rare as to preclude any definite statement, or are abundant, but ubiquitious throughout lime muds and ohter sediment types. Echinoderms, bryozoans, rare molluscs, and sponges occur as common to sporadic elements, and also appear with greater or lesser frequency in other sediments. The only taxa that are commonly recognized and effectively limited to lime muds are the brachiopods Enteletes and Hystriculina. Neither of these taxa has been found in argillaceous or sandy sediments, and furthermore, their distributions suggest that they preferred relatively pure algal-carbonate muds.

Lime sands are essentially restricted to the Stoner member in the rim and channel calcarenite lithofacies, and in Stoner equivalents of the terrigenous-detrital facies belt (Bolton and Rutland beds). Local lithofacies variations were favorable for the development of abundant and diverse faunas along the rim and channel, but as with lime muds, few taxa were limited to these lime sand sediments. The pholadomyoid bivalve Edmondia, the hexagonellid bryozoan Meekoporella and the brachiopod Schizophoria are the only taxa restricted to lime sand, and all occur in well-washed granular sediments of the channel lithofacies. Edmondia is unusual in that as a probable slow-burrowing form, it differed from most Paleozoic bivalves, which burrowed rapidly to maintain a buried life position in similar environments (Stanley, 1970). Considering the instability of shifting lime sand sediments in the channel environment and the burrowing rate of Edmondia, it is unlikely that this bivalve would be able to maintain a completely buried position, and may have adapted to a semi-infaunal life mode. An alternative is that Edmondia may have burrowed more rapidly than shell form suggests. Brisk currents are commonly cited as necessary for bryozoan growth, and may have had a major affect in limiting the distribution of Meekoporella to the channel environment. Unlike delicate fenestellid bryozoans from other quieter environments, thick zoarial wall structure and massive colonial form suggest that Meekoporella is particularly suited to more turbulent conditions, and is unlikely to have been transported from less agitated channel margins. Schizophoria is somewhat anomalous in that general shell morphology does not suggest a turbulent life habitat. However, specimens are at most only disarticulated, and show no signs of extended abrasion. Perhaps Schizophoria became adapted to this environment as a result of other physical or biological pressures.

Silty, argillaceous muds of the terrigenous-detrital facies belt contain the largest number of taxa that are restricted to a particular sediment-substrate, and all but a single echinoderm taxon are molluscan forms. The nuculanids Phestia and Paleoneilo are infaunal bivalves that only occur in Eudora muds. Both are locally common to abundant, but in inverse relationship to one another. Paleoneilo is more prevalent in silty muds in the northern end of the facies belt, whereas Phestia is most common in muds below the Bolton bed that contain a greater percentage of coarse silt and fine sand. Perhaps both were limited to a general argillaceous mud environment, and it was other pressures, possibly biological (? competition), that influenced observed distributions and relationships. Plagioglypta is also limited in distribution to this sediment type, particularly in the northern end of the facies belt. Yochelson (1957) suggests that these Paleozoic scaphopods were semi-infaunal organisms, living on moderately soft substrates. This soft bottom interpretation is compatible with the substrate requirements of the rostroconch *Pseudoconocardium*, which also occurs only in these silty, argillaceous muds. Pojeta and Runnegar (1976) suggest from general shell morphology that these rostroconchs were mobile forms living wholly or partially buried in the mud. The gastropods *Worthenia* and *Trepospira* and the crinoid *Paragassizocrinus* are the remaining taxa that are limited to this sediment type. All occur in muds that have a greater coarse silt and fine sand content. The gastropods were likely vagrant on the moderately soft substrate, whereas *Paragassizocrinus* was a stalkless, sessile organism that probably stabilized itself by partial burial in the sediment (Moore and Strimple, 1973). However, *Paragassizocrinus* is unusual in that its restricted occurrence in these muds is in sharp contrast to Moore and Strimple's (1973) suggestion that it preferred environments associated with calcareous buildups on shallow sea floors.

Quartz sands are generally characterized by a paucity of invertebrates, possibly due to rapid sediment accumulation or shifting substrate. Rarely are abundant faunas found in calcareous quartz sands, and never in non-calcareous sands. Taxa that do occur are likely eurytopic forms that are more common in other Stanton sediments. Two molluscan taxa, the bivalve *Parallelodon* and the gastropod *Hypselentoma*, are however restricted to these quartz sands. *Parallelodon* is extremely rare (known only from isolated molds), but is consistent in its appearance in non-calcareous quartz sand of the southern part of the detrital facies belt. Its general shell morphology suggests that it may have been an exceedingly slow burrower, and may have lived only partially buried in the sandy substrate (Stanley, 1970). Hypselentoma is an abundant, well-preserved gastropod, but is only known from one locality of calcareous quartz sand (Loc. CP). Similar to Worthenia and Trepospira, it was probably vagrant on a moderately soft substrate, but there is no additional evidence to suggest a reason for its limitation to this sand substrate.

Organisms Affected by Depositional Phase

For some taxa, it is difficult to differentiate between the effects of substrate specificity and the influence of environmental factors associated with phases of deposition. Other taxa are distinctly related to depositional phases and apparently unaffected by lithologic change. These phase-associated invertebrates were likely more strongly influenced by specific environmental factors (salinity, temperature, oxygenation, agitation, etc.) or combinations of these factors, all of which generally vary with water depth.

Early transgressive phases (lower Captain Creek and lower South Bend) probably presented extreme conditions for Stanton invertebrates, and were characterized by factors associated with environments at or just below effective wave base. Fully marine waters were likely well-oxygenated and warm, although probably affected by periodic agitation, turbulence and possibly fluctuating salinity (particularly basal units). None of the taxa recognized in this study are restricted to early transgressive phases. However, some gastropods, particularly bellerophontids, and Archaeocidaris (echinoid) are unusually common, and may have been tolerant of somewhat harsh environments. Other associated taxa are generally widespread and more abundant in other parts of the Stanton, and were apparently unaffected by environmental extremes.

Late transgressive phases (upper Captain Creek and upper South Bend) were associated with deepening water that was well below effective wave base, but still within the photic zone for luxuriant algal growth. Environments probably remained well-oxygenated with stable, fully marine salinities, and were unaffected by agitation or strong currents. Nine taxa representing several major invertebrate groups are effectively restricted to this quiet water phase of deposition. The brachiopods Rhipidomella and Chonetinella only occur at the tops of the transgressive limestones (and other comparable phases), and are most characteristic in non-algal lithofacies. Other brachiopods including Linoproductus, Cancrinella, and Enteletes and Meekella

(Captain Creek and South Bend respectively) also show restricted distribution in late transgressive phases, but are more characteristic of algal-rich lithofacies. *Girtyocoelia*, *Cibolocrinus* and *Apographiocrinus* are the only other taxa with recognizable distribution that are limited to transgressive and comparable phases, and are also found only in non-algal lithofacies. Remaining taxa are also widespread in other phases of deposition, or seem more directly influenced by substrate. However, in association with these restricted taxa, they constitute some of the most taxonomically diverse assemblages, and suggest that late transgressive environments are some of the most conducive for invertebrate proliferation in the Stanton.

During maximum transgression (lower Eudora) the marine environment deepened below the photic zone (loss of algal-carbonate mud), and with restricted circulation, marine waters became extremely oxygen-poor or anoxic during deposition of black shale lithofacies (Heckel, 1978). Oxygen depletion is probably the most limiting factor during this phase of deposition, as all benthic invertebrates are either dramatically reduced in abundance, diversity and size of individuals, or, more commonly, are completely eliminated.

With the initiation of regressive deposition (upper Eudora), re-established vertical circulation replenished bottom oxygen, and enabled certain benthic invertebrates to re-occupy probably cool, deeper marine environments, which likely remained below the photic zone. Most benthic invertebrates occurring in these environments are also common in other phases. However, several molluscan taxa that are restricted to this phase likely occur due to a preference for silty, argillaceous substrates, which are deposited in the absence of algal-carbonate mud. The only brachiopod that is restricted to this phase is the small rhynchonellid *Wellerella*. This distinctive deeper water Stanton occurrence is interesting in view of Alexander's (1975) shallow water interpretation of *Wellerella*. *Crurithyris* is also common in these argillaceous sediments, although not restricted to this phase, and is also an interesting occurrence in light of a shallow, brackish water interpretation favored by Mudge and Yochelson (1962).

In the middle regressive phase (lower Stoner and equivalents), resumption of algal-carbonate mud deposition indicates water depths within the photic zone, but probably well below effective wave base (lack of shoal water lithologies). Biotic assemblages associated with this phase are comparable to assemblages of the late transgressive phase in terms of taxonomic diversity and overall abundance. Geographically and stratigraphically widespread taxa that comprise the largest part of late transgressive assemblages similarly constitute the bulk of middle regressive assemblages. Specific taxa that favored late transgressive environments reappear during middle regression, and do not occur in any other part of the entire regressive phase. These taxa include distinctive brachiopods Rhipidomella, Chonetinella, Cancrinella and Linoproductus, and the echinoderms Cibolocrinus and Apographiocrinus, and the unique thalamid sponge Girtyocoelia. In all biotic aspects, middle regressive assemblages are effectively "mirror" images of late transgressive assemblages. The same physical factors that controlled the distribution of restricted taxa during late transgression, affected the same taxa in a similar manner during the middle regressive phase.

Late regression (upper Stoner and equivalents) is characterized by environmental conditions that are comparable to those associated with early transgression. Shoal and non-shoal water lithologies are common throughout this phase, and record shallow water environments at or just below effective wave base. Water agitation was likely variable depending on paleotopography, particularly along the northwest rim of the mound tract. None of the taxa recognized in this study are indigenous to this phase and associated environments. However, locally favorable conditions often supported abundant and diverse assemblages. The productid Echinaria and the gastropod Straparollus, both of which are generally sporadic throughout the Stanton, reach their greatest abundance in this phase. Excluding assemblages specifically associated with calcarenitic lithofacies, late regressive assemblages are comparable to early transgressive assemblages. Calcarenitic lithofacies associated with major topographic features (channel and rim) included local microenvironments that were probably protected from intense agitation or physical extremes, and were generally more conducive to invertebrate proliferation.

The general absence of biotas during maximum regression (Rock Lake) alludes to the severity of environmental conditions associated with this phase. Environments were likely shallow marine above wave base to non-marine, suggesting fluctuating salinities and a great potential for turbid water. It is probable that most Stanton taxa required fully marine or stable marine conditions, and were consequently unable to tolerate environmental instability during maximum regression.

<u>Organisms with Unrestricted Distributions</u>

In addition to taxa that are so exceedingly rare or apparently random in their distribution, and those taxa that are likely affected by sediment-substrate requirements or depositional phase, there is a small group of genera and species that are abundant and widespread throughout the Stanton, and remain essentially unrestricted in terms of factors influencing their distributions. This group includes the ubiquitous spiriferids Composita, Phricodothyris, Punctospirifer, Neospirifer, Hustedia and two other taxa, Derbyia and Septimyalina. The two most widespread species in the Stanton, Composita subtilita and Phricodothyris perplexa, are present in greater or lesser abundance in all facies belts, depositional phases and all major and minor lithofacies, except fissile, black shales. Associated organisms appear to have had little biological affect in precluding these species from any assemblage. It is likely that Composita and Phricodothyris are the most eurytopic taxa in the Stanton, and could tolerate a full range of environmental extremes.

Similarly distributed throughout the Stanton, although somewhat more sporadically, are Punctospirifer kentuckyensis, Hustedia "mormoni" and Dielasma bovidens. They are generally less frequent in occurrence than either Composita or Phricodothyris at any locality, and are abundant only in the absence of one or both of these other genera. As these three species appear in all facies belts, depositional phases, and most lithologies, it is reasonable to assume that these taxa were also relatively eurytopic organisms. Their sometimes sporadic distribution may possibly be a result of an inability to successfully compete for limited resources with other invertebrates, particularly Composita and Phricodothyris. General paucity in mound lithofacies of the Captain Creek and Stoner may suggest that prolific algal growth could have produced more lime mud sediment in a given area at any time than any of these species were capable of tolerating.

The remaining three taxa, Septimyalina, Neospirifer and Derbyia are even more reduced in overall distribution, but occur in all facies belts and in several major lithofacies. However, all of these taxa appear somewhat restricted to certain depositional phases, and are either rare or absent in upper transgressive limestones or regressive outside shales. The disjunct and spotty distributions and the variety of lithologies in which these taxa are found, make it difficult to interpret the factors that may have affected their appearance. If totally eurytopic in their environmental requirements, it might be expected that they would have more widespread distribution with respect to depositional phases and lithofacies. As an alternative explanation, observed patterns may be a function of species recognition. As noted in Appendix A, Neospirifer dunbari encompasses a variety of alate to gibbous forms. If these varieties can be separated as distinct species, it may be that each has slightly different environmental tolerances. Derbyia is represented in the Stanton by two species, D. crassa and D. bennetti. The preservation of material in this study does not always permit ready recognition of distinctive features of each species. Consequently, there has been no separation of these forms when plotting the distribution of *Derbyia*, and unfortunately, the observed pattern may include both species, each of which may have different physical requirements. *Septimyalina* is difficult to interpret, as Newell (1942) suggests that it preferred shallow turbid waters of the shore zone. The present distribution indicates that *Septimyalina* may have also occupied offshore stable marine environments. This discrepancy may either be an extension of the range of tolerance of this genus, an effective occupation of similar substrates in different environments, or the result of an inability to sufficiently distinguish *Septimyalina* from other myalinid genera.

Ecological Replacement of Organisms

The distinctive genera *Enteletes* and *Meekella* are widespread forms that first occur stratigraphically below the Stanton and range well above the Stanton into the Virgilian and lower Permian respectively. *Enteletes pugnoides* is first reported as low as the Iola and extends up to the Oread (Haglund, 1967), whereas *Meekella striatocostata* occurs even lower in the Marmaton (Desmoinesian) and is known at least as high as the Wreford (Dunbar and Condra, 1932). As they have concurrent ranges throughout the Stanton, it is interesting that there is a disjunct distribution of the two species. *Enteletes*, with rare exception in the lower Stoner of the open-marine facies, occurs only in the Captain Creek in the algal-mound and open-marine facies belts. *Meekella*, also with rare exception in the upper Stoner of the algal-mound facies, occurs only in the South Bend in the algal-mound and open-marine facies belts. Nowhere within the Stanton are they found in association, and for the most part, they are stratigraphically separated by the entire regressive phase of the Stanton cyclothem.

Enteletes is an unattached, epifaunal form that is commonly associated with fine-grained limestones, particularly in algal calcilutites, and does not occur in sand-size sediments. *Enteletes pugnoides* reaches its greatest abundnace and distribution in these sediments in the Plattsburg and lower Stanton, and rapidly declines in abundance, becoming locally absent, during the remainder of the Missourian Stage (Haglund, 1967). *Meekella striatocostata* was probably an unattached, free-lying form as an adult (Rudwick and Cowen, 1968), and similarly occurs in fine-grained limestones, but also appears rarely in calcareous sandstones in the basal South Bend. Although *Meekella* appears stratigraphically before *Enteletes*, maximum abundance and diversity of form does not occur in *Meekella* until the early Permian (Dunbar and Condra, 1932).

Both forms are coarsely plicate and similarly ornamented with fine radial lirae. Lamont (1934) notes strong correlation between sediment size and coarseness of lirae, and suggests that the lirae may have aided maximum stability on loose substrates. Coarse plications likely strengthened thin, delicate shells, and may also have aided stabilization in the absence of functional adult pedicles (Rudwick and Cowen, 1968; Haglund, 1967).

Although sufficient data is unavailable to make a definite statement concerning the separate distributions of *Enteletes* and *Meekella*, it is reasonable to suggest that they occupied similar habitats in comparable environments of successive transgressive limestones. Biotic associations are also similar, with the exception of less abundant *Hystriculina* and less luxuriant algal content in the South Bend. Perhaps biological exchange occurred in areas peripheral to Stanton deposition during maximum regression, and permitted ecological replacement of *Enteletes* by *Meekella* in the succeeding transgression.

CONCLUSIONS

With the exception of specific eurytopic taxa that are present in all but the most severe Stanton environments, most species generally occur in disjunct distribution patterns. Except for extremely rare taxa, these appearances probably represent original distributions, rather than apparent patterns that are artifacts of sampling methods. Concurrent distributions of individual taxa create distinctive assemblage patterns that are laterally and stratigraphically discontinuous. This mosaic pattern of biotic organization stands in contrast to laterally extensive and stratigraphically recurrent paleocommunities that have been proposed in other parts of the geologic record. Local environmental differences influenced the taxonomic composition of specific assemblages in this mosaic. Individual taxa were probably influenced by specific limiting environmental factor(s), and fluctuations in these factors likely governed the presence or absence of a taxon in an assemblage. The taxonomic composition of any assemblage was therefore likely the product of a critical combination of environmental factors.

The specific factors affecting Stanton taxa are difficult to recognize and can only be inferred in most general terms from stratigraphic and petrographic observations. Gross physical features including paleogeography, lithofacies and depositional phase explain general distributional trends, but are limited in resolving complex patterns or explaining sporadic appearances of subordinate taxa. None of the taxa recognized in this study seem limited by paleogeographic control. Individual taxa may appear to be limited to a particular facies belt or major topographic feature, but other factors are more effective in explaining observed patterns. Topography may have altered local hydrographic conditions, but any taxa affected by this change were probably more strongly influenced by physical factors other than paleogeography. Sediment type and depositional phase more readily explain the distribution of specific taxa. Fourteen genera were limited by specific substrate types, and include: 1) Enteletes, Hystriculina (lime muds), 2) Edmondia, Meekoporella, Schizophoria (lime sands), 3) Phestia, Paleoneilo, Plagioglypta, Pseudoconocardium, Worhtenia, Trepospira, Paragassizocrinus (silty argillaceous muds), 4) Parallelodon (quartz sand), and 5) possibly Hypselentoma (calcareous quartz sand). An additional eight genera are independent of sediment-substrate, but were probably limited by certain environmental factors associated with depositional phases. These taxa include: Rhipidomella, Chonetinella, Linoproductus, Cancrinella, Cibolocrinus, Apographiocrinus, Girtyocoelia (late transgressive and middle regressive phase), and 2) Wellerella (early regressive phase). Environmental factors favorable to these depositional phase related taxa may have included low turbidity, stable substrates, stable marine salinity, and perhaps slightly cooler temperatures. The dominantly molluscan fauna that is limited to silty, argillaceous mud sediments also occurs only in the early regressive phase, but the lack of these elements in algal-mound and oprn-marine facies during this phase suggests that they were more directly limited by substrate and only indirectly by specific environmental factors associated with early regression. The most common taxa in all assemblages are the ubiquitous spiriferids Composita, Phricodothyris, Punctospirifer, Neospirifer and Hustedia, which occur without apparent limitations in all geographic facies belts, all sediment types and in all phases of deposition except maximum regression. This indicates that these taxa are strongly eurytopic, and are consequently little affected by environmental fluctuations. All remaining taxa are so extremely rare or sporadic in distribution that they cannot be adequately evaluated in terms of paleogeographic, substrate or depositional phase controls.

In terms of cyclothemic deposition, greatest abundance and taxonomic diversity occurs in the tops of transgressive limestones and in the base of succeeding regressive limestones, and is symmetrical with respect to maximum transgression and deposition of the offshore (core) shales. Abundance and diversity decreases toward the base of transgressive limestones and toward the top of regressive limestones (except for unusual development associated with local environments related to paleotopography in the late regressive phase). Benthic faunas are dramatically reduced or entirely eliminated by loss of bottom oxygen during maximum transgression (offshore black shale deposition). Faunas recovered slowly from the effects of low oxygen or anoxic conditions, and although locally abundant, they remained low in overall abundance and diversity during earliest regression. These trends are generally consistent with modern observations of increasing abundance and diversity in a more stable marine offshore direction, and suggest that optimum conditions for biotic development in the Stanton occurred in algal-carbonate muds deposited in quiet, fully marine waters (well below effective wave base), at or near the lower limit of the photic zone, but above the level of decreased bottom oxygenation.

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APPENDICES

APPENDIX A

TAXONOMIC PROBLEMS

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TAXONOMIC PROBLEMS

Nomenclature and its usage in paleontology are in a constant state of flux. Names are changed, definitions are re-evaluated and basic concepts of generic and specific identification are subjected to revision. Within the Mid-Continent Pennsylvanian many taxa have been restudied and the validity of many others has been questioned in light of modern practices. In the present study, the most current generic and specific names have been used wherever possible. However, nomenclatural status of many taxa is open to question. The following notes briefly describe problems with current usage of generic and specific names, and the use of these names in this report. Taxa discussed in no manner reflect the total number of taxa recognized in this study that may need nomenclatural revision. Only those taxa most familiar to the author will be mentioned.

Schizophoria "texana"

Mather (1915) described a species Rhipidomella altirostris based on a single pedicle valve. Subsequently Girty made an extensive collection of Morrowan rocks from Arkansas for the USGS, and noted several hundred specimens of *R. altirostris*, some of which were designated as topotype material. Girty (1927) then described a species, *Schizophoria texana*, from the Marble Falls Limestone of Texas, which closely resembles the form now recognized as *Schizophoria altirostris* (Mather). Easton (1962) evaluated *S. altirostris* and *S. texana*, concluding that they are indeed identical, and that by priority *S. texana* is an invalid junior synonym. However, in a footnote (Easton, 1962, p. 86) he states that the types of *S. texana* were not available for restudy, and that his conclusions concerning the identity of the two species is based on comparative material of *S. altirostris* and only the original figures and descriptions of *S. texana*. Most recently, Sutherland and Harlow (1973) examined collections of *Schizophoria* from eastern New Mexico, and although their specimens agree with Girty's description of *S. texana*, they claim that indirect evidence (unstated) tends to support Easton's conclusions.

In assigning a specific name to *Schizophoria* specimens in this study, it appears that there are several alternatives. If Easton's synonymy is invalid without restudy of *S. texana* types, then the name *S. texana* should stand until a study has been completed. If types are available for restudy, and examination does reveal the synonymy, then *S. altirostris* is the valid name by priority and Easton's contentions are correct. If however the types of *S. texana* are lost, and additional topotype material cannot be obtained, then *S. texana* should be considered a *nomen dubium*. A final alternative is acceptance of Easton's proposal as a subjective synonymy without restudy of *S. texana* types. Considering that types of *S. texana* have not been re-examined and that Sutherland and Harlow's indirect evidence is the only additional support of Easton's synonymy, *Schizophoria* "*texana*" will be used in this study until an objective evaluation of *S. altirostris* and *S. texana* has been completed and the taxonomic problems resolved.

Enteletes pugnoides

Recognition of Mid-Continent species of *Enteletes* has been based historically on typological definitions using the number of crests on the fold as a weighted character. Newell (1931) described variation in *E. hemiplicatus* (Hall) as a new bicrested species, *E. pugnoides*, and a new unicrested variety, *E. hemiplicatus* var. *plattsburgensis*, both of which were described from cotypes from the Lansing Group. Bridwell (1939) recovered two specimens of *Enteletes* from the Captain Creek Limestone in northeastern Kansas, and noted close affinities to *E. pugnoides* and *E. h.* var. *plattsburgensis*. However, his specimens possessed a distinctly tricrested fold, which led him to establish a third species, *E. costidorsitriplicatus*.

The validity of these species remained unchallenged throughout the following three decades until Haglund (1967) re-evaluated the three species through detailed stratigraphic collections and the application of biometric analyses. His data revealed no substantial external or internal differences between single and multi-crested species with the exception of crest form. In addition, he observed continuous morphologic variation from uni- to multi-crested forms, suggesting overall randomness in development. He concluded that the number of crests on the fold has little systematic importance and effectively ynonymized the two species and one variety, choosing Enteletes pugnoides Newell as name bearer for his concept of the species.

Single, multiple and transitional crest forms occur throughout the lower Stanton in the northern two-thirds of the study area. Bicrested variants are frequently recovered with sub-equal numbers of unicrested, tricrested and intermediate crest variants at several localities. These occurrences tend to support Haglund's proposal that Enteletes of the Upper Pennsylvanian Mid-Continent is a polymorphic genus. Therefore, use of Enteletes pugnoides in this text includes all Stanton variations of E. pugnoides and E. hemiplicatus var. plattsburgensis sensu Newell (1931) and E. costidorsitriplicatus sensu Bridwell (1939).

Hustedia "*mormoni*"

Virtually all post-Morrowan retziid spirifers have been referred to *Hustedia mormoni* (Marcou). In using this name most authors cite descriptions from Girty (1915a), who proposed the name *Hustedia*, or refer to the extensive survey of Dunbar and Condra (1932). The name has become well ingrained in the literature, with little effort to ascertain its validity. A recent exception is Sutherland and Harlow's (1973) study in which they mention the *Hustedia* problem.

Marcou (1858) originally described *Terebratula Mormoni* from a horizon in the Mountain Limestone in the vicinity of Salt Lake City, Utah. Sutherland attempted to restudy Marcou's collection of specimens, and found that the type specimen of *T. Mormoni* in the British Museum no longer exists. Assuming it lost, the type locality must be re-established and topotypes obtained to stabilize the name. If this cannot be done, *Hustedia mormoni* should be regarded as a *nomen dubium*. Pending further investigation, usage of *Hustedia* "*mormoni*" in this report, recognizes the insecure taxonomic status of the species.

Neospirifer dunbari

Confusion apparently still remains concerning the taxonomic relationships between *Neospirifer dunbari* (Hall) and two varieties, *N. dunbari* var. *alatus* and *N. dunbari* var. *gibbosus*. Dunbar and Condra (1932) described the *alatus* variety as having arisen from the *dunbari* stock by developing unusually transverse proportions. Shell plications maintain the subangular shape and strong fasiculation characteristic of the genus, but also develop simple plications on the extended wing-like projections. In contrast to the alate form, Dunbar and Condra state that the *gibbosus* variety is strongly convex and the ventral cardinal area is shortened from the elongate rectangular shape characteristic of *N. dunbari* to an exceptionally high triangular shape. Subsequent authors have had difficulty with these distinctions, particularly when examining large collections.

Sturgeon and Hoare (1968) note that within *N. dunbari* there is ". . . a considerable amount of variation in the number and arrangement of bifurcations of costae and costellae, and that the . . . amount of variation appears to be as great within a population as between populations." Dunbar and Condra allude to these variations in shell morphology, stating that *dunbari* and the alate variety seem to intergrade, but they maintain the distinction partially due to a more limited stratigraphic range for the alate form. Spencer (1967) describes the ranges of all three forms, listing *N. dunbari* as ranging throughout the Pennsylvanian. The alate and gibbous varieties have virtually identical ranges first appearing in the lower Kansas City Group and expiring in the Wabaunsee Group.

Sutherland and Harlow (1973) make the most recent attempt to evaluate these forms. However, their observations, based on material from eastern New Mexico and comparison with type material, remove alatus from the dunbari line, making it a separate species, and fail to mention the relation of gibbosus to either species. They consider Dunbar and Condra's variety alatus to be a juvenile form of Neospirifer latus. Since N. latus was also named by Dunbar and Condra (1932), the name alatus was chosen, by page priority in the original publication, for the "distinctive species" (Sutherland and Harlow, 1973, p. 75). Neospirifer dunbari is maintained and briefly compared with N. alatus. They state that N. dunbari differs from N. alatus in being much smaller, in having a triangular shape, with much less subdivision of the costae, and in having minor fasiculation. It is not clearly stated whether this comparison is based on their own material from New Mexico, or whether it is based on types of each form. If the latter case is true, the discrepancy between Dunbar and Condra's concept of N. dunbari and alatus and Sutherland and Harlow's concept of the two forms might be understood. Sutherland and Harlow may have compared adult dunbari with adult alatus sensu N. latus of Dunbar and Condra.

It is evident that there must be a great deal of morphologic variation in Middle and Upper Pennsylvanian Neospirifer lineages, and that there may be a large amount of character overlap between "species". Several dozen specimens have been recovered from throughout the Stanton, and although the specimens are rarely complete, enough detail remains to recognize distinct morphologic variablility. The bulk of Stanton specimens most closely resemble *Neospirifer dunbari sensu* Dunbar and Condra. Other specimens appear to be more transversely extended or more inflated. Whether these specimens should be recognized in terms of Dunbar and Condra's concept or as Sutherland and Harlow believe is uncertain at this time. Pending detailed systematic study of Upper Pennsylvanian *Neospirifer* lineages, specimens in this study are referred to *Neospirifer dunbari*. This includes alate and gibbous variants, but is not an effort to support or refute either concept of the species.

Chonetinella flemingi

Also displaying marked morphologic variation in the Mid-Continent Pennsylvanian is the genus *Chonetinella*, which is based on Norwood and Pratten's 1854 species *Chonetes flemingi*. Dunbar and Condra (1932) reviewed the generic characteristics, noting that this specialized group of Late Paleozoic chonetids is distinguished by a moderate to very strongly convex ventral valve with a narrow and pronounced sinus. The dorsal valve is strongly concave and bears a narrow median fold. Specific characteristics are given in their description of *C. flemingi* indicating that this shell is of medium size with a length about three-fifths the greatest breadth. In addition, the ventral sinus is deep and narrow, lying between a pair of sharply rounded folds that form the most convex portion of the valve. Additional morphologic features are similarly described in somewhat subjective terms, allowing for a considerable range of variation within the restrictions of the terms used in the definition.

Dunbar and Condra (1932) recognized substantial variation in collections of Upper Pennsylvanian *Chonetinella flemingi*, and within the limits of the definition established three new varieties, *C. flemingi* var. *alata*, *C. f.* var. *plebeia* and *C. f.* var. *crassiradiata*. All of these forms are based on subjectively defined variations. *Chonetinella flemingi* var. *alata* is recognized on the basis of greater elongation along the hinge, a shallower ventral sinus, a lower beak and much broader lateral folds. *Chonetinella flemingi* var. *plebeia* is noted as being much smaller, less strongly arched, and less strongly sinuate than typical *C. flemingi*. The rare variety *C. f.* var. *crassiradiata* is distinguished from the more typical form solely on coarser radial ornamentation on the beak and umbonal region. Stratigraphic ranges for *C. flemingi* and two varieties indicate presence through the top of the Missourian Stage. The *crassiradiata* variety however is known only from the Cherokee Group (Desmoinesean Stage), and is consequently of no importance with respect to Stanton *Chonetinella*.

Examination of abundant *Chonetinella flemingi*, primarily from the upper Captain Creek, lower Stoner and upper South Bend, suggests the presence of two distinct forms which most closely resemble typical *C. flemingi* and *C. f.* var *alata*. The variety *plebeia* is not definitely recognized from any Stanton horizons, although some specimens do approach *plebeia* in many attributes. Large Stanton collections of several dozens of specimens present problems in confidently identifying all forms as *C. flemingi* or *alata*. Most specimens can be placed with relative ease in either group, but there are always a number of specimens which seem to be intermediate in morphology, making it difficult to subjectively separate them as either type.

In light of other brachiopod species problems in the Mid-Continent Pennsylvanian, it is tempting to consider that *C. flemingi* and *C. flemingi* var. *alata* represent yet another morphological gradation from a more quadrate typical *flemingi* to an elongate *alata*. Considering these variations as one species would bring the problem of recognition full circle and return the concept of *C. flemingi* to its original sense. However, a recent investigation has subjected large collections of *Chonetinella flemingi* to biometric analysis. Applications of computer statistics on measurements of several morphologic features per specimen reveal distinct and consistent trends suggesting viable species of

Chonetinella flemingi and *Chonetinella alata* (R. S. Spencer, 1977, pers. commun.).

Since biometric analyses are beyond the scope of this report and visual methods cannot confidently separate the two species, all references to *Chonetinella flemingi* in this report will include all forms representing *C. flemingi sensu stricto* and those of the species *C. alata*. In establishing this practice, the author realizes the potential for misinterpreting independent geographic and stratigraphic distributions of these species and any paleoecologic implications that may result.

Euphemites vittatus

Specimens belonging to the gastropod genus *Euphemites* Warthin (1930) are locally common to abundant in the Stanton Limestone. These and similar specimens from other horizons are most frequently recognized as the species *Euphemites carbonarius* (Cox), which is known throughout the Pennsylvanian of North America. Girty (1915) described this species from the Upper Pennsylvanian of Oklahoma, and since then, this description has become one of the most widely cited references for this form in the Mid-Continent region. The name *Euphemites carbonarius* is used in subsequent publications with little regard as to the validity of the name. Consequently, the name has become well established in the North American literature. Unfortunately, little attention has been paid to King's (1940) discussion which challenges the use of this name, and his recommendation to abandon it in favor of the name Euphemites vittatus (McChesney).

King (1940) relates that Norwood and Pratten (1855) failed to describe the specimens they referred to Bellerophon urii, but figured a single specimen. Cox (1857) pointed out differences between their specimen and figures, and described the specimen giving it the name B. carbonarius. Cox unfortunately failed to mention a type locality, did not re-illustrate the specimen, and the type is now lost. McChesney (1860) described two species from Norwood and Pratten's Grayville locality (which is considered to be a logical choice for the type locality of B. carbonarius), but neither of them conforms to the type Cox described. As Cox's type was never figured, is now lost, and with no type locality, his species should be considered invalid. McChesney's E. vittatus should be recognized as the valid name for the form first noted by Norwood and Pratten. McChesney (1860) proposed this name as a substitute for B. urii, which is pre-occupied by Fleming's (1828) European species.

There are clearly two alternatives to be considered: 1) acceptance of King's recommendation that Euphemites vittatus (McChesney) is the valid name, or 2) maintain the name Euphemites carbonarius (Cox). E. carbonarius is the more commonly cited name, but the least taxonomically secure, whereas *E. vittatus* is more stable taxonomically, but at best, regarded as a junior synonym of *E. carbonarius* by most authors. Usage of *Euphemites vittatus* in this report is based on its greater taxonomic stability, and that it is becoming more widely recognized by many authors.

APPENDIX B

BIOTIC DISTRIBUTIONS

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BIOTIC DISTRIBUTIONS

The following tables present distribution and relative abundance data for all taxa recognized in Stanton members and beds. Localities are listed geographically from south to north in the study area; major taxonomic groups are listed in order of overall importance in the formation, and individual taxa are listed according to approximate importance within major groups. Abundance data is marked as previously described in the text. Abundant taxa (A) occur with sufficient frequency that several tens of specimens can be easily collected at a given locality. Common taxa (C) are less frequently represented, and only after a moderate period of collecting can a dozen or more specimens be recovered. Rare taxa (R) occur so infrequently that intensive collecting rarely produces more than one or two specimens. Taxa appearing without an abundance code symbol have not been found or do not occur at a given locality. Table 1 presents additional taxa that have been identified by previous authors in more extensive systematic investigations of particular taxonomic groups. None of these taxa have been recovered or recognized in the course of this study.

Table 1 --Additional Stanton taxa described in previous investigations. From Newell (1933, 1937, 1942).

Coelenterates

Lophophyllum profundum
Lophophyllum westi
Zaphrentis wannense
Campophyllum torquim

Brachiopods

Lingula carbonaria
Teguliferina armata
Avonia knighti
Derbyia haesitans
Linoproductus canalis

Cephalopods

Euloxoceras greenei
Dolorthoceras sp.
Kionoceras sp.
Coloceras liratum

Bivalves

Pleurophorus sp.
Deltopecten occidentalis
Entolium aviculatum
Streblopteria tenuilineata
Streblopteria hertzeri
Pteria longa
Pinna sp.
Posidonimya sp.
Myalina ampla
Myalina kansasensis
Myalina subquadrata
Myalina meeki
Solenopsis cf. *S. solenoides*
Schizodus curtus
Schizodus wheeleri

Gastropods

Lepetopsis parrishi
Helictostylus girtyi

Table 2--Distribution of biotic elements in the Captain Creek Limestone Member.

TAXON \ LOCALITY	PHF	SW-SE-SW-7-33-15	SE-NW-1-33-14	NE-23-32-14	WW-sp. clu.	WW-sh.	Loc. 14a	ECR-low	ECR-high	CCFA	TMQ	TMQ-calc.	TQ	CSL-22-30-15	QCSL-7-30-15	QNWC-23-29-15	CSL-10-29-15	WSL-6-28-17	Jct. 75-39	EQ	1QSP	MI	NP	KTFK-low	KTFK-high
BRACHIOPODS:																									
Composita subtilita	C	R	R	R	R	R	R		R	R	R	C	R	R	R	C	C	C	R	R	A		R	C	C
Phricodothyris perplexa				R	R		R		R	R	R		C	R	R			C	R	R	C				C
Punctospirifer kentuckyensis	R						R									R	C	R		R	A		R		
Neospirifer dunbari	R	R	R	R	R	R	R		R	R	R	R	R				R				C				
Hustedia "mormoni"												R					R			R					
Enteletes pugnoides								R	C		A		C	R	C	C			C	C			A		A
Schizophoria "texana"																				R					
Crurithyris planoconvexa														R				R							
Dielasma bovidens															R		R						R		
Rhipidomella carbonaria	C					R			R																
Cancrinella boonensis									R				R												
Meekella striatocostata																									
Streptorhynchus affine																									
Wellerella osagensis																									
Derbyia crassa																									
Derbyia bennetti																									
Derbyia sp.																R									
Hystriculina wabashensis	R					R		R	C		A		C	R	R		R			C	C		A	R	A
Echinaria semipunctata																				R					
Echinaria sp.																									
Echinoconchus sp.																									
Antiquatonia crassicostata														R			R								
Antiquatonia sp.										R	R												R		
Reticulatia americana														R											
Reticulatia sp.																									
Pulchratia cf. P. symmetrica																									
Pulchratia sp.			R								R		R												
Dictyoclostus sp.																									R
Juresania nebrascensis																							R		
Juresania sp.											R														
Linoproductus sp.		R			R				R														R		C
L. cf. L. prattenianus																									
L. cf. L. platyumbonus											R														
productid indeterminate														C	R					R	C				
Chonetinella flemingi	R					R					R														
Lissochonetes plattsmouthensis																									
Orbiculoidea sp.																									

Table 2 (cont'd.)

	PHF	7-33-15	1-33-14	23-32-14	WM-sp. clu	WM-sh.	Loc. 14a	ECR-low	ECR-high	CCRA	TMQ	TMQ-calc.	TQ	22-30-15	7-30-15	23-29-15	10-29-15	6-28-17	Jct. 75-39	EQ	1QSP	MI	NP	KTPK-low	KTPK-high
ECHINODERMS:																									
pelmatozoan debris	A	C	R	R	C		C	R	R	C	R	C	R	R	C	R	C	R	R	C	A		C		R
Ulocrinus sp.												R			R										
Parulocrinus sp.																									
Erisocrinus typus	C																								
Erisocrinus sp.																									
Parerisocrinus sp.																									
Delocrinus sp.																									
Endelocrinus sp.	C																								
Perimestocrinus sp.												R													
Graffhamicrinus sp.	R						R																		
Cibolocrinus conicus	A					R	R																		
Apographiocrinus typicalis	A																								
Exoriocrinus sp.	R																								
Exocrinus sp.																									
Exaeteocrinus sp.																									
Euonychocrinus dubius	R																								
Paramphicrinus poundi	R																								
Paragassizocrinus sp.																									
Laudonocrinus sp.																									
Parethelocrinus sp.																									
Contocrinus sp.																									
Elibatocrinus sp.																									
Isoallagecrinus sp.																									
Stellarocrinus sp.																									
cf. Aesiocrinus sp.																									
Anobasocrinus sp.																									
Plaxocrinus sp.																									
cymbiocrinid indeterminate																									
cromeocrinid indeterminate															R										
pirassocrinid indeterminate							R																		
?Sciadiocrinus sp.	R																								
?Schistocrinus sp.																									
?Archaeocidaris sp.														R	R	R	C	R							
GASTROPODS:																									
Glabrocingulum sp.																	R								
G. (Glabrocingulum) wannense																									
G. (G.) grayvillense								R																	
G. (Ananias) welleri																									
Euphemites vittatus																									
Pharkidonotus percarinatus																	R								
Pharkidonotus tricarinatus																									

Table 2 (cont'd.)

	PHF	7-33-15	1-33-14	23-32-14	WM-sp. clu	WM-sh.	Loc. 14a	ECR-low	ECR-high	CCRA	TMQ	TMQ-calc.	TQ	22-30-15	7-30-15	23-29-15	10-29-15	6-28-17	Jct. 75-39	EQ	1QSP	MI	NP	KTPK-low	KTPK-high
Cymatospira montfortianus																									
Retispira tenuilineata																	R								
Bellerophon graphicus																									
bellerophontid indeterminate																	R								
Worthenia tabulata																									
Hypselentoma perhumerosa																									
Phymatopleura nodosa																									
Ianthinopsis cf. I. brevis																									
I. cf. I. primigenia																									
I. cf. I. paludinaeformis																									
Ianthinopsis sp.																									
Meekospira choctawensis																									
Meekospira sp.																	R								
Naticopsis scintilla																									
Naticopsis meeki																									
cf. Murchisonia																									
murchisoniid indeterminate																									
Straparollus (Amphiscapha) reedsi																									
S. (Amphiscapha) catilloides																									
Trepospira sp.																									
T. (Trepospira) discoidalis	R					R																			
Euconospira turbiniformis																									
Pseudozygopleura sp.																	R								
Gosseletina cf. G. spironema																									
Gosseletina sp.																	R								
?Goniasma sp.																									
Trachydomia newelli											R														
Trachydomia sayrei																									
platycerid indeterminate																									
steinkern indeterminate														R											
Lepetopsis peregrina																									
BIVALVES:																									
Septimyalina cf. S. burmai																									
Septimyalina sp.																	R								
Myalina (Myalina) sp.																									
M. (Orthomyalina) slocomi																									
myalinid indeterminate																									
Wilkingia sp.																									
Edmondia sp.																									
Phestia bellistriata																									
Paleoneilo taffiana																									
Nuculopsis ventricosus																									

Table 2 (cont'd.)

	PHF	7-33-15	1-33-14	23-32-14	WM-sp. clu	WM-sh.	Loc. 14a	ECR-low	ECR-high	CCRA	TMQ	TMQ-calc	TQ	22-30-15	7-30-15	23-29-15	10-29-15	6-28-17	Jct. 75-39	EQ	1QSP	MI	NP	KTPK-low	KTPK-high
nuculanid indeterminate							R																		
Paleyoldia glabra																									
Astartella sp.																									
Cypricardella sp.																									
Pseudomonotis sp.																									
Aviculopecten gradicosta																									
Aviculopecten cf. A. occidentalis																									
Aviculopecten sp.																									
Acanthopecten cf. A. meeki																									
Acanthopecten sp.								R																	
?Limipecten sp.																									
pectinid indeterminate							R																		
Parallelodon kansasense																									
Parallelodon sp.																									
bivalves indeterminate																				R					
CEPHALOPODS:																									
nautiloids indeterminate																				R					
Pseudorthoceras knoxense																									
Metacoceras cornutum																									
Brachycycloceras curtum																									
Mooreoceras normale																									
Tainoceras sp.																									
Liroceras sp.																									
Eoasianites hyattianum																									
"Bisatoceras" ?genus novum																									
Prothallassoceras kingorum																									
Neoaganides sp.																									
Marathonites sp.																									
ammonoid indeterminate																									
BRYOZOANS:																									
Fenestella sp.														R						R					
Fenestrellina sp.														R											
fenestellid debris						R	R	R	R	R	R			R						C	A		C		R
ramose cryptostome																									
massive cryptostome																									
ramose trepostome										R															
globular trepostome																									
encrusting trepostome																									
ramose cyclostome																									
ramose ? ctenostome																									
Meekoporella dehiscens																									
?Polypora sp.																									

Table 2 (cont'd.)

	PHF	7-33-15	1-33-14	23-32-14	WM-sp. clu	WM-sh.	Loc. 14a	ECR-low	ECR-high	CCRA	TMQ	TMQ-calc	TQ	22-30-15	7-30-15	23-29-15	10-29-15	6-28-17	Jct. 75-39	EQ	1QSP	MI	NP	KTPK-low	KTPK-high
?Rhombopora sp.																									
?Cyclotrypa sp.																									
COELENTERATES:																									
Sutherlandia sp.																				R					
Michelinia sp.																									
Syringopora multattenuata																									
auloporid indeterminate																									
Caninia torquia																									
Lophamplexus sp.																				R					
Stereostylus sp.																									
Lophophyllidium sp.															R		C			R					
Geyerophyllum cf. G. cylindricum															R										
Geyerophyllum sp.																									
Dibunophyllum valeriae																									
Dibunophyllum sp.															R		R								
Neokoninckophyllum heckeli															R										
Neokoninckophyllum sp.																	R								
coral indeterminate																R			R						
PORIFERA:																									
Girtyocoelia beedei	R	C	C	C	C	A																			
Girtyocoelia sp.																									
Maeandrostia kansasensis	C																								
Maeandrostia sp.							R																		
Heliospongia ramosa																									
ROSTROCONCHS:																									
Pseudoconocardium lanterna																									
CONULARIDS:																									
Conularia crustula																									
Mesoconularia sp.																									
TRILOBITES:																									
Ditomopyge scitula																									
Ditomopyge sp.																									
Ameura missouriensis																									
Paladin sp. ? novum																									
SCAPHOPODS:																									
Plagioglypta annulistriata																									
Dentalium (Paleodentalium) kansasense																									
VERTEBRATES:																									
Petalodus destructor																									
Orodus sp.																									
PHYLLOID ALGAE:		R		R				C	C	A			C	A	A	A	C	A	A	A					

Table 3--Distribution of biotic elements in the Eudora Shale Member.

LOCALITY / TAXON	RFP	RF	PGS	BH	WM-west	SCEL-35-32-14	SBHM-398	CNL-NW-25-32-14	NEC-14-29-15	NQEB	RDMQ	1QSP	MI	NP	EGS	BS	KTPK	BLACK SHALES:	ACS-ACN	EEQ	MI	NP	EGS	BS	KTPK
BRACHIOPODS:																									
Composita subtilita	R	R	R	R	R	C	C			A	C	A	R	R											
Phricodothyris perplexa					R					R	R		R												
Punctospirifer kentuckyensis		R		R		R				A	C	R		R											
Neospirifer dunbari		R	R	R	R	C	C	R	R	R		C	C	R											
Hustedia "mormoni"		R	R	R	R				R	R	R	R		C											
Enteletes pugnoides																									
Schizophoria "texana"																									
Crurithyris planoconvexa	C	C	C	C	R				R																
Dielasma bovidens									R	R	R														
Rhipidomella carbonaria									R				R	C											
Cancrinella boonensis																									
Meekella striatocostata																									
Streptorhynchus affine																									
Wellerella osagensis									R	R															
Derbyia crassa			R						R	R															
Derbyia bennetti																									
Derbyia sp.					R		R	R					R												
Hystriculina wabashensis									R				R												
Echinaria semipunctata																									
Echinaria sp.																									
Echinoconchus sp.																									
Antiquatonia crassicostata																									
Antiquatonia sp.																									
Reticulatia americana																									
Reticulatia sp.					R																				
Pulchratia cf. P. symmetrica							C																		
Pulchratia sp.			R			R						R	R												
Dictyoclostus sp.																									
Juresania nebrascensis							R																		
Juresania sp.																									
Linoproductus sp.			R			C	C																		
L. cf. L. prattenianus							R																		
L. cf. L. platyumbonus								R																	
productid indeterminate		R			R		R	R																	
Chonetinella flemingi					R																				
Lissochonetes plattsmouthensis	R	R																							
Orbiculoidea sp.			R	R			R												C						

Table 3 (cont'd.)

	RFP	RF	PGS	BH	WM-west	35-32-14	SBHM-398	25-32-14	14-29-15	NQEB	RDMQ	1QSP	MI	NP	EGS	BS	KTPK	BLACK SH:	ACS-ACN	EEQ	MI	NP	EGS	BS	KTPK
ECHINODERMS:																									
pelmatozoan debris	C	C	C	C	C	C	A	R	R	C	R	A	R	C			C								
Ulocrinus sp.																									
Parulocrinus sp.							R																		
Erisocrinus typus																	R								
Erisocrinus sp.																									
Parerisocrinus sp.																									
Delocrinus sp.	R																								
Endelocrinus sp.							R																		
Perimestocrinus sp.							R																		
Graffhamicrinus sp.							R																		
Cibolocrinus conicus																									
Apographiocrinus typicalis		R																							
Exoriocrinus sp.																									
Exocrinus sp.							R																		
Exaeteocrinus sp.																									
Euonychocrinus dubius																									
Paramphicrinus poundi																									
Paragassizocrinus sp.	A	R	C	R																					
Laudonocrinus sp.						R																			
Parethelocrinus sp.	R																								
Contocrinus sp.																									
Elibatocrinus sp.							R																		
Isoallagecrinus sp.																									
Stellarocrinus sp.																									
cf. Aesiocrinus sp.																									
Anobasocrinus sp.																									
Plaxocrinus sp.																									
cymbiocrinid indeterminate																									
cromeocrinid indeterminate																									
pirassocrinid indeterminate						R	C					R													
?Sciadiocrinus sp.																									
?Schistocrinus sp.																									
?Archaeocidaris sp.					R		C																		
GASTROPODS:																									
Glabrocingulum sp.	R					A					R														
G. (Glabrocingulum) wannense				R			R																		
G. (G.) grayvillense	A	A	A	A	A		A							R											
G. (Ananias) welleri	R		R	R																					
Euphemites vittatus	R	R	C	R	C		A																		
Pharkidonotus percarinatus					R		R																		
Pharkidonotus tricarinatus		R	R				R																		

Table 3 (cont'd.)

	RFP	RF	PGS	BH	WM-west	35-32-14	SBHM-398	25-32-14	14-29-15	NQEB	RDMQ	1QSP	MI	NP	EGS	BS	KTPK	BLACK SH	ACS-ACN	EEQ	MI	NP	EGS	BS	KTPK
Cymatospira montfortianus							A																		
Retispira tenuilineata							C																		
Bellerophon graphicus							C																		
bellerophontid indeterminate			R																						
Worthenia tabulata		R	R	R			R																		
Hypselentoma perhumerosa																									
Phymatopleura nodosa	R	R	R																						
Ianthinopsis cf. I. brevis					R																				
I. cf. I. primigenia																									
I. cf. I. paludinaeformis																									
Ianthinopsis sp.			R				C																		
Meekospira choctawensis	R						C																		
Meekospira sp.					R																				
Naticopsis scintilla																									
Naticopsis meeki																									
cf. Murchisonia							R																		
murchisoniid indeterminate		R																							
Straparollus (Amphiscapha) reedsi																									
S. (Amphiscapha) catilloides					R		R				R														
Trepospira sp.																									
T. (Trepospira) discoidalis	C	R	C	R	R																				
Euconospira turbiniformis																									
Pseudozygopleura sp.							R																		
Gosseletina cf. G. spironema										C	C														
Gosseletina sp.																									
?Goniasma sp.																									
Trachydomia newelli																									
Trachydomia sayrei																									
platycerid indeterminate																									
steinkern indeterminate	R	R	R	R																					
Lepetopsis peregrina																									
BIVALVES:																									
Septimyalina cf. S. burmai							R																		
Septimyalina sp.							R																		
Myalina (Myalina) sp.							R																		
M. (Orthomyalina) slocomi							R																		
myalinid indeterminate							C																		
Wilkingia sp.	C	C		R			R		R																
Edmondia sp.																									
Phestia bellistriata	C	R	R	R																					
Paleoneilo taffiana	R	R	R		R		A																		
Nuculopsis ventricosus																									

Table 3 (cont'd.)

	RFP	RF	PGS	BH	WM-west	35-32-14	SBHM-398	25-32-14	14-29-15	NQEB	RDMQ	1QSP	MI	NP	EGS	BS	KTPK	BLACK SH	ACS-ACN	EEQ	MI	NP	EGS	BS	KTPK
nuculanid indeterminate							R																		
Paleyoldia glabra				R	R		R																		
Astartella sp.				R			R			R	R														
Cypricardella sp.										R															
Pseudomonotis sp.																									
Aviculopecten gradicosta																									
Aviculopecten cf. A. occidentalis																									
Aviculopecten sp.																									
Acanthopecten cf. A. meeki																									
Acanthopecten sp.																									
?Limipecten sp.																									
pectinid indeterminate																									
Parallelodon kansasense										R															
Parallelodon sp.																									
bivalves indeterminate	R	R					R	R (Phestia "attenuata")																	
CEPHALOPODS:																									
nautiloids indeterminate	R										R														
Pseudorthoceras knoxense	R	R		R			C	R																	
Metacoceras cornutum																									
Brachycycloceras curtum			R	R																					
Mooreoceras normale	R																								
Tainoceras sp.																									
Liroceras sp.																									
Eoasianites hyattianum	C	C	A	A	R		R																		
"Bisatoceras" ?genus novum	R		C																						
Prothallassoceras kingorum				R																					
Neoaganides sp.				R																					
Marathonites sp.																									
ammonoid indeterminate											R														
BRYOZOANS:																									
Fenestella sp.						R																			
Fenestrellina sp.																									
fenestellid debris										C	R	R	C												
ramose cryptostome		R					C			R															
massive cryptostome																									
ramose trepostome						C	A																		
globular trepostome							R																		
encrusting trepostome																									
ramose cyclostome												R													
ramose ? ctenostome																									
Meekoporella dehiscens																									
?Polypora sp.																									

Table 3 (cont'd.)

	RFP	RF	PGS	BH	WM-west	35-32-14	SBHM-398	25-32-14	14-29-15	NQEB	RDMQ	1QSP	MI	NP	EGS	BS	KTPK	BLACK SH	ACS-ACN	EEQ	MI	NP	EGS	BS	KTPK
?Rhombopora sp.					R	C	C																		
?Cyclotrypa sp.																									
COELENTERATES:																									
Sutherlandia sp.																									
Michelinia sp.																									
Syringopora multattenuata																									
auloporid indeterminate																									
Caninia torquia									R																
Lophamplexus sp.																									
Stereostylus sp.																									
Lophophyllidium sp.										C															
Geyerophyllum cf. G. cylindricum																									
Geyerophyllum sp.																									
Dibunophyllum valeriae																									
Dibunophyllum sp.																									
Neokoninckophyllum heckeli																									
Neokoninckophyllum sp.																									
coral indeterminate									R																
PORIFERA:																									
Girtyocoelia beedei									R																
Girtyocoelia sp.												R													
Maeandrostia kansasensis																									
Maeandrostia sp.																									
Heliospongia ramosa																									
ROSTROCONCHS:																									
Pseudoconocardium lanterna	R	R	R																						
CONULARIDS:																									
Conularia crustula	R		R											R											
Mesoconularia sp.																									
TRILOBITES:																									
Ditomopyge scitula																									
Ditomopyge sp.																									
Ameura missouriensis																									
Paladin sp. ? novum																									
SCAPHOPODS:																									
Plagioglypta annulistriata					R		R	R																	
Dentalium (Paleodentalium) kansasense																									
VERTEBRATES:																									
Petalodus destructor																									
Orodus sp.																									
PHYLLOID ALGAE:																									

Table 4--Distribution of biotic elements in the Stoner Limestone Member.

TAXON \ LOCALITY	NWC-18-32-14-sh	NW-NW-NW-1-32-14	NW-NW-1-32-14-sh	ECR-sh	ECR-1	RC-sh	QSEC-25-30-14	FNW	QEWW	ACS-ACN	CSL-9-29-15	BB	RRSENQEB	DQSR	NW-SW-24-27-15	NBRC	EEQ	1QSP-1	1QSP-2	CBQ-sh	CBQ-2	MI-1	MI-sh	MI-3	QWW	PQ's	NP	EGS	BS-1	BS-2	KTPK-1	KTPK-2
BRACHIOPODS:																																
Composita subtilita	A	R	C	C	R	R	R	C	R	C		R	R	C	R	R	C	A	C	R	C	R	A		C	R	R	R	C		C	C
Phricodothyris perplexa		R	R			R	R			R		R		R	R						R		C				R				C	C
Punctospirifer kentuckyensis						C		R		R		C	R	C			R	R	C		R		C					C	C			
Neospirifer dunbari	R		R	R		C		C				R	R	R			C	C		R	R		C		C							
Hustedia "mormoni"	R					R		R				R	R	R			R	R		R												
Enteletes pugnoides																												C	C		C	
Schizophoria "texana"								C		C				R		R																
Crurithyris planoconvexa	C									R					R																	
Dielasma bovidens										R		R		R					R		R		R									
Rhipidomella carbonaria	A		C	A		A																						R				
Cancrinella boonensis	R					R																										
Meekella striatocostata								R																								
Streptorhynchus affine														R																		
Wellerella osagensis																					R											
Derbyia crassa						C				R		R																C	R	R		
Derbyia bennetti						R																										
Derbyia sp.	R			R		R						R			C	R							A									
Hystriculina wabashensis	C	R	C	R		R	R	R					R	R						R						R	C	R			C	A
Echinaria semipunctata										R				R			R						R									
Echinaria sp.										R					R																	R
Echinoconchus sp.																											R					
Antiquatonia crassicostata	C													R																		R
Antiquatonia sp.																							C									
Reticulatia americana	R			C		C						R																				
Reticulatia sp.																																
Pulchratia cf. P. symmetrica	C													R																		
Pulchratia sp.						R												R					C									C
Dictyoclostus sp.				R																							R					
Juresania nebrascensis	R																															
Juresania sp.				R														R														
Linoproductus sp.					R					R																R						C
L. cf. L. prattenianus	R									R				R																		
L. cf. L. platyumbonus														R	R																	
productid indeterminate			R				R	R	R			R		R			C															
Chonetinella flemingi	A		A	A		A																										
Lissochonetes plattsmouthensis	R											R		R																		
Orbiculoidea sp.																																

Table 4 (cont'd.)

	18-32-14-sh	1-32-14	1-32-14-sh	ECR-sh	ECR-1	RC-sh	25-30-14	FNW	QEWW	ACS-ACN	9-29-15	BB	RRSENQEB	DQSR	24-27-15	NBRC	EEQ	1QSP-1	1QSP-2	CBQ-sh	CBQ-2	MI-1	MI-sh	MI-3	QWW	PQ's	NP	EGS	BS-1	BS-2	KTPK-1	KTPK-2
ECHINODERMS:																																
pelmatozoan debris	C	R	C	C	C	C	C	A	A	A	R	A	C	A	C	A	A	A	C	R	R		A		C	R	A		C		C	C
Ulocrinus sp.										R																						
Parulocrinus sp.						R																										
Erisocrinus typus								C	R	R				R																		
Erisocrinus sp.																																
Parerisocrinus sp.										R																						
Delocrinus sp.																																
Endelocrinus sp.								R																								
Perimestocrinus sp.																																
Grafthamicrinus sp.														R																		
Cibolocrinus conicus	R					R		R						R																		
Apographiocrinus typicalis	R					R		R												R												
Exoriocrinus sp.																																
Exocrinus sp.																																
Exaeteocrinus sp.																																
Euonychocrinus dubius	R																															
Paramphicrinus poundi				R																												
Paragassizocrinus sp.																																
Laudonocrinus sp.																																
Parethelocrinus sp.														R																		
Contocrinus sp.																																
Elibatocrinus sp.																																
Isoallagecrinus sp.																																
Stellarocrinus sp.														R																		
cf. Aesiocrinus sp.														R																		
Anobasocrinus sp.														R																		
Plaxocrinus sp.																																
cymbiocrinid indeterminate																																
cromeocrinid indeterminate																																
pirassocrinid indeterminate	R					R																										
?Sciadiocrinus sp.																																
?Schistocrinus sp.								R						R																		
?Archaeocidaris sp.	R		R	R		R		R	R		R	R		R	R	R																
GASTROPODS:																																
Glabrocingulum sp.	R																				C											
G. (Glabrocingulum) wannense																																
G. (G.) grayvillense				R																												
G. (Ananias) welleri																																
Euphemites vittatus	R																															
Pharkidonotus percarinatus																																
Pharkidonotus tricarinatus																																

Table 4 (cont'd.)

	18-32-14-sh	1-32-14	1-32-14-sh	ECR-sh	ECR-1	RC-sh	25-30-14	FNW	QEWW	ACS-ACN	9-29-15	BB	RRSENQEB	DQSR	24-27-15	NBRC	EEQ	1QSP-1	1QSP-2	CBQ-sh	CBQ-2	MI-1	MI-sh	MI-3	QWW	PQ's	NP	EGS	BS-1	BS-2	KTPK-1	KTPK-2
Cymatospira montfortianus																																
Retispira tenuilineata																																
Bellerophon graphicus																																
bellerophontid indeterminate										R																						
Worthenia tabulata																																
Hypselentoma perhumerosa																																
Phymatopleura nodosa				R																												
Ianthinopsis cf. I. brevis																																
I. cf. I. primigenia																																
I. cf. I. paludinaeformis																																
Ianthinopsis sp.																																
Meekospira choctawensis																																
Meekospira sp.																																
Naticopsis scintilla																																
Naticopsis meeki																																
cf. Murchisonia																																
murchisoniid indeterminate																																
Straparollus (Amphiscapha) reedsi										R						R																
S. (Amphiscapha) catilloides																					R											
Trepospira sp.																																
T. (Trepospira) discoidalis	R																															
Euconospira turbiniformis										R									R		R											
Pseudozygopleura sp.																																
Gosseletina cf. G. spironema								R																								
Gosseletina sp.																																
?Goniasma sp.																																
Trachydomia newelli																																
Trachydomia sayrei						R																										
platycerid indeterminate										R											R											
steinkern indeterminate																		R					R		R							
Lepetopsis peregrina								R																								
BIVALVES:																																
Septimyalina cf. S. burmai								R							C								R									
Septimyalina sp.												R			A						R											
Myalina (Myalina) sp.										R																						
M. (Orthomyalina) slocomi																																
myalinid indeterminate								R	R			R	R	R	C								R									
Wilkingia sp.																																
Edmondia sp.								R		C																						
Phestia bellistriata																																
Paleoneilo taffiana																																
Nuculopsis ventricosus																																

Table 4 (cont'd.)

	18-32-14-sh	1-32-14	1-32-14-sh	ECR-sh	ECR-1	RC-sh	25-30-14	FNW	QEWW	ACS-ACN	9-29-15	EB	RRSENQEB	DQSR	24-27-15	NBRC	EEQ	1QSP-1	1QSP-2	CBQ-sh	CBQ-2	MI-1	MI-sh	MI-3	QWW	PQ's	NP	EGS	BS-1	BS-2	KTPK-1	KTPK-2
nuculanid indeterminate															R																	
Paleyoldia glabra																																
Astartella sp.																																
Cypricardella sp.																																
Pseudomonotis sp.																																
Aviculopecten gradicosta																					R											
Aviculopecten cf. A. occidentalis																																
Aviculopecten sp.																																
Acanthopecten cf. A. meeki																																
Acanthopecten sp.																																
?Limipecten sp.																																
pectinid indeterminate										R					R																	
Parallelodon kansasense																																
Parallelodon sp.																																
bivalves indeterminate																																
CEPHALOPODS:																																
nautiloids indeterminate								R		R					R																	
Pseudorthoceras knoxense																																
Metacoceras cornutum																																
Brachycycloceras curtum																																
Mooreoceras normale																																
Tainoceras sp.										R																						
Liroceras sp.																																
Eoasianites hyattianum																	R															
"Bisatoceras" ?genus novum																																
Prothallassoceras kingorum																																
Neoaganides sp.																																
Marathonites sp.																																
ammonoid indeterminate																																
BRYOZOANS:																																
Fenestella sp.				R				R						R	R																	
Fenestrellina sp.														R																		
fenestellid debris								R	C	R		C	R	A	R	C	C	C	A		C		A		C		C		C		C	C
ramose cryptostome	R		R	R	R	R																										
massive cryptostome																																
ramose trepostome			R	R										R																		
globular trepostome																			R		R											
encrusting trepostome														R					R				R									
ramose cyclostome			R											R																		
ramose ? ctenostome																																
Meekoporella dehiscens								R	R	C		R																				
?Polypora sp.														R																		

Table 4 (cont'd.)

	18-32-14-sh	1-32-14	1-32-14-sh	ECR-sh	ECR-1	RC-sh	25-30-14	FNW	QEWW	ACS-ACN	9-29-15	BB	RRSENQEB	DQSR	24-27-15	NBRC	EEQ	1QSP-1	1QSP-2	CBQ-sh	CBQ-2	MI-1	MI-sh	MI-3	QWW	PQ's	NP	EGS	BS-1	BS-2	KTPK-1	KTPK-2
?Rhombopora sp.						R						R					C															
?Cyclotrypa sp.																																
COELENTERATES:																																
Sutherlandia sp.	R		R											R																		
Michelinia sp.								R				R																				
Syringopora multattenuata																R																
auloporid indeterminate																																
Caninia torquia														R																		
Lophamplexus sp.								R		R				R																		
Stereostylus sp.								R		R				R																		
Lophophyllidium sp.								R	R	R		R			R		C	R	R	R					C		C					
Geyerophyllum cf. G. cylindricum																R																
Geyerophyllum sp.								R																								
Dibunophyllum valeriae													R																			
Dibunophyllum sp.								R								R																
Neokoninckophyllum heckeli																																
Neokoninckophyllum sp.								R		R																						
coral indeterminate					R		R		R				R	R																		
PORIFERA:																																
Girtyocoelia beedei																																
Girtyocoelia sp.																																
Maeandrostia kansasensis										R																						
Maeandrostia sp.																																
Heliospongia ramosa																																
ROSTROCONCHS:																																
Pseudoconocardium lanterna																																
CONULARIDS:																																
Conularia crustula																																
Mesoconularia sp.																																
TRILOBITES:																																
Ditomopyge scitula																																
Ditomopyge sp.																R																
Ameura missouriensis																R																
Paladin sp. ? novum																																
SCAPHOPODS:																																
Plagioglypta annulistriata																																
Dentalium (Paleodentalium) kansasense																																
VERTEBRATES:																																
Petalodus destructor																																
Orodus sp.																																
PHYLLOID ALGAE:		C			C		A				A		A								C	C		R	A	C	R		R		R	

Table 5--Distribution of biotic elements in the Bolton and Rutland limestone beds.

TAXON \ LOCALITY	BOLTON BED	GP	NW-NW-23-33-14	CWL-NW-SW-6-34-15	TB	SE-SW-NW-24-33-14	RFG	BH	NWL-25-33-14	SE-SE-SW-25-33-14	RUTLAND BED	RBt	NEC-12-33-14
BRACHIOPODS:													
Composita subtilita		C	R	C	C		C	R				R	
Phricodothyris perplexa		R				R	R					C	
Punctospirifer kentuckyensis		R	R	R	C	R	R	R					
Neospirifer dunbari		C		C	C	R	R	R					
Hustedia "mormoni"		R	R	C	C	R	R	R					
Enteletes pugnoides													
Schizophoria "texana"					R								
Crurithyris planoconvexa													
Dielasma bovidens					R								
Rhipidomella carbonaria		R											
Cancrinella boonensis													
Meekella striatocostata													
Streptorhynchus affine													
Wellerella osagensis													
Derbyia crassa		R											
Derbyia bennetti													
Derbyia sp.			C		R								
Hystriculina wabashensis													
Echinaria semipunctata													
Echinaria sp.													
Echinoconchus sp.													
Antiquatonia crassicostata													
Antiquatonia sp.													
Reticulatia americana													
Reticulatia sp.													
Pulchratia cf. P. symmetrica													
Pulchratia sp.													
Dictyoclostus sp.													
Juresania nebrascensis													
Juresania sp.													
Linoproductus sp.			R			R							
L. cf. L. prattenianus													
L. cf. L. platyumbonus													
productid indeterminate						R							
Chonetinella flemingi		R											
Lissochonetes plattsmouthensis													
Orbiculoidea sp.													

Table 5 (cont'd.)

	BOLTON	GP	23-33-14	6-34-15	TB	24-33-14	RFG	BH	25-33-14	25-33-14	RUTLAND	RB_t	12-33-14
ECHINODERMS:													
pelmatozoan debris		C	C	C	C	C	C	C				C	
Ulocrinus sp.													
Parulocrinus sp.		R											
Erisocrinus typus		C		R				R					
Erisocrinus sp.													
Parerisocrinus sp.													
Delocrinus sp.				R		R		R					
Endelocrinus sp.													
Perimestocrinus sp.		R											
Graffhamicrinus sp.													
Cibolocrinus conicus		R											
Apographiocrinus typicalis													
Exoriocrinus sp.													
Exocrinus sp.													
Exaeteocrinus sp.													
Euonychocrinus dubius													
Paramphicrinus poundi													
Paraguassizocrinus sp.													
Laudonocrinus sp.													
Parethelocrinus sp.													
Contocrinus sp.													
Elibatocrinus sp.													
Isoallagecrinus sp.													
Stellarocrinus sp.													
cf. Aesiocrinus sp.													
Anobasocrinus sp.													
Plaxocrinus sp.													
cymbiocrinid indeterminate													
cromeocrinid indeterminate													
pirassocrinid indeterminate				R									
?Sciadiocrinus sp.													
?Schistocrinus sp.		R											
?Archaeocidaris sp.													
GASTROPODS:													
Glabrocingulum sp.													
G. (Glabrocingulum) wannense													
G. (G.) grayvillense					C			R					
G. (Ananias) welleri													
Euphemites vittatus													
Pharkidonotus percarinatus													
Pharkidonotus tricarinatus													

Table 5 (cont'd.)

	BOLTON	GP	23-33-14	6-34-15	TB	24-33-14	RFG	BH	25-33-14	25-33-14	RUTLAND	RB_t	12-33-14
Cymatospira montfortianus													
Retispira tenuilineata													
Bellerophon graphicus													
bellerophontid indeterminate								R					
Worthenia tabulata												C	
Hypselentoma perhumerosa													
Phymatopleura nodosa													
Ianthinopsis cf. I. brevis													
I. cf. I. primigenia													
I. cf. I. paludinaeformis													
Ianthinopsis sp.													
Meekospira choctawensis													
Meekospira sp.													
Naticopsis scintilla												R	
Naticopsis meeki													
cf. Murchisonia													
murchisoniid indeterminate												R	
Straparollus (Amphiscapha) reedsi													
S. (Amphiscapha) catilloides													
Trepospira sp.													
T. (Trepospira) discoidalis													
Euconospira turbiniformis													
Pseudozygopleura sp.												R	
Gosseletina cf. G. spironema													
Gosseletina sp.													
?Goniasma sp.													
Trachydomia newelli													
Trachydomia sayrei													
platycerid indeterminate													
steinkern indeterminate				R	R								
Lepetopsis peregrina													
BIVALVES:													
Septimyalina cf. S. burmai													
Septimyalina sp.					R								
Myalina (Myalina) sp.													
M. (Orthomyalina) slocomi													
myalinid indeterminate								R					
Wilkingia sp.													
Edmondia sp.													
Phestia bellistriata													
Paleoneilo taffiana													
Nuculopsis ventricosus													

Table 5 (cont'd.)

	BOLTON	GP	23-33-14	6-34-15	TB	24-33-14	RFG	BH	25-33-14	25-33-14	RUTLAND	RBt	12-33-14
nuculanid indeterminate													
Paleyoldia glabra													
Astartella sp.													
Cypricardella sp.													
Pseudomonotis sp.													
Aviculopecten gradicosta													
Aviculopecten cf. A. occidentalis													
Aviculopecten sp.													
Acanthopecten cf. A. meeki													
Acanthopecten sp.													
?Limipecten sp.													
pectinid indeterminate													
Parallelodon kansasense													
Parallelodon sp.													
bivalves indeterminate								R					
CEPHALOPODS:													
nautiloids indeterminate								R					
Pseudorthoceras knoxense													
Metacoceras cornutum													
Brachycycloceras curtum													
Mooreoceras normale													
Tainoceras sp.													
Liroceras sp.													
Eoasianites hyattianum													
"Bisatoceras" ?genus novum													
Prothallassoceras kingorum													
Neoaganides sp.													
Marathonites sp.													
ammonoid indeterminate													
BRYOZOANS:													
Fenestella sp.													
Fenestrellina sp.		R											
fenestellid debris		R				R	R						
ramose cryptostome		R											
massive cryptostome					R								
ramose trepostome													
globular trepostome													
encrusting trepostome													
ramose cyclostome													
ramose ? ctenostome													
Meekoporella dehiscens													
?Polypora sp.												C	

Table 5 (cont'd.)

	BOLTON	GP	23-33-14	6-34-15	TB	24-33-14	RFG	BH	25-33-14	25-33-14	RUTLAND	RB$_t$	12-33-14
?Rhombopora sp.													
?Cyclotrypa sp.													
COELENTERATES:													
Sutherlandia sp.													
Michelinia sp.													
Syringopora multattenuata													
auloporid indeterminate								R					
Caninia torquia													
Lophamplexus sp.													
Stereostylus sp.													
Lophophyllidium sp.													
Geyerophyllum cf. G. cylindricum													
Geyerophyllum sp.													
Dibunophyllum valeriae													
Dibunophyllum sp.													
Neokoninckophyllum heckeli													
Neokoninckophyllum sp.													
coral indeterminate													
PORIFERA:													
Girtyocoelia beedei		R											
Girtyocoelia sp.								R					
Maeandrostia kansasensis													
Maeandrostia sp.													
Heliospongia ramosa													
ROSTROCONCHS:													
Pseudoconocardium lanterna													
CONULARIDS:													
Conularia crustula													
Mesoconularia sp.													
TRILOBITES:													
Ditomopyge scitula													
Ditomopyge sp.													
Ameura missouriensis													
Paladin sp. ? novum													
SCAPHOPODS:													
Plagioglypta annulistriata													
Dentalium (Paleodentalium) kansasense													
VERTEBRATES:													
Petalodus destructor													
Orodus sp.													
PHYLLOID ALGAE:												C	

Table 6--Distribution of biotic elements in the Rock Lake Shale Member.

TAXON / LOCALITY	HR-n	NWC-30-34-15	75-SB	SCWL-28-34-14	COON CRK	NW-NE-NW-34-26-16	CSL-27-26-16-1	CSL-27-26-16-2	CSL-27-26-16	SE-SE-26-26-16-1	SE-SE-26-26-16-2	CSL-12-26-16	NW-NE-9-27-16-1	NW-NE-9-27-16-2	QWW	PQ's	BS	KTPK
BRACHIOPODS:																		
Composita subtilita			R													C		
Phricodothyris perplexa																R		
Punctospirifer kentuckyensis	R															R		
Neospirifer dunbari			R													C		
Hustedia "mormoni"	R	R	R															
Enteletes pugnoides																		
Schizophoria "texana"																		
Crurithyris planoconvexa																		
Dielasma bovidens																R		
Rhipidomella carbonaria																		
Cancrinella boonensis																		
Meekella striatocostata																R		
Streptorhynchus affine																		
Wellerella osagensis																		
Derbyia crassa																		
Derbyia bennetti																		
Derbyia sp.																		
Hystriculina wabashensis																		
Echinaria semipunctata																		
Echinaria sp.																		
Echinoconchus sp.																		
Antiquatonia crassicostata																R		
Antiquatonia sp.																		
Reticulatia americana																		
Reticulatia sp.																		
Pulchratia cf. P. symmetrica																		
Pulchratia sp.																		
Dictyoclostus sp.																		
Juresania nebrascensis																		
Juresania sp.																		
Linoproductus sp.																C		
L. cf. L. prattenianus																		
L. cf. L. platyumbonus																R		
productid indeterminate																		
Chonetinella flemingi																		
Lissochonetes plattsmouthensis																		
Orbiculoidea sp.																		

Table 6 (cont'd.)

	HR-n	30-34-15	75-SB	28-34-14	COON CRK	34-26-16	27-26-16-1	27-26-16-2	27-26-16	26-26-16-1	26-26-16-2	12-26-16	9-27-16-1	9-27-16-2	QWW	PQ's	BS	KTPK
ECHINODERMS:																		
pelmatozoan debris	A	R	R									R				C		
Ulocrinus sp.																		
Parulocrinus sp.																		
Erisocrinus typus																		
Erisocrinus sp.																		
Parerisocrinus sp.																		
Delocrinus sp.																		
Endelocrinus sp.																		
Perimestocrinus sp.																		
Graffhamicrinus sp.																		
Cibolocrinus conicus																		
Apographiocrinus typicalis																		
Exoriocrinus sp.																		
Exocrinus sp.																		
Exaeteocrinus sp.																		
Euonychocrinus dubius																		
Paramphicrinus poundi																		
Paragassizocrinus sp.																		
Laudonocrinus sp.																		
Parethelocrinus sp.																		
Contocrinus sp.																		
Elibatocrinus sp.																		
Isoallagecrinus sp.																		
Stellarocrinus sp.																		
cf. Aesiocrinus sp.																		
Anobasocrinus sp.																		
Plaxocrinus sp.																		
cymbiocrinid indeterminate																		
cromeocrinid indeterminate																		
pirassocrinid indeterminate																		
?Sciadiocrinus sp.																		
?Schistocrinus sp.																		
?Archaeocidaris sp.																		
GASTROPODS:																		
Glabrocingulum sp.																		
G. (Glabrocingulum) wannense																		
G. (G.) grayvillense																		
G. (Ananias) welleri																		
Euphemites vittatus																		
Pharkidonotus percarinatus																R		
Pharkidonotus tricarinatus																		

Table 6 (cont'd.)

	HR-n	30-34-15	75-SB	28-34-14	COON CRK	34-26-16	27-26-16-1	27-26-16-2	27-26-16	26-26-16-1	26-26-16-2	12-26-16	9-27-16-1	9-27-16-2	QWW	PQ's	BS	KTPK
Cymatospira montfortianus																		
Retispira tenuilineata																		
Bellerophon graphicus																		
bellerophontid indeterminate		R														C		
Worthenia tabulata																		
Hypselentoma perhumerosa																		
Phymatopleura nodosa																		
Ianthinopsis cf. I. brevis																		
I. cf. I. primigenia																		
I. cf. I. paludinaeformis																		
Ianthinopsis sp.																		
Meekospira choctawensis																		
Meekospira sp.																		
Naticopsis scintilla																		
Naticopsis meeki																		
cf. Murchisonia																		
murchisoniid indeterminate																		
Straparollus (Amphiscapha) reedsi																C		
S. (Amphiscapha) catilloides																R		
Trepospira sp.																R		
T. (Trepospira) discoidalis																		
Euconospira turbiniformis																		
Pseudozygopleura sp.																		
Gosseletina cf. G. spironema																		
Gosseletina sp.																		
?Goniasma sp.																		
Trachydomia newelli																		
Trachydomia sayrei																		
platycerid indeterminate																		
steinkern indeterminate																		
Lepetopsis peregrina																		
BIVALVES:																		
Septimyalina cf. S. burmai																		
Septimyalina sp.																R		
Myalina (Myalina) sp.																R		
M. (Orthomyalina) slocomi																		
myalinid indeterminate	R															R		
Wilkingia sp.																		
Edmondia sp.																		
Phestia bellistriata																		
Paleoneilo taffiana	R	R																
Nuculopsis ventricosus			R															

Table 6 (cont'd.)

	HR-n	30-34-15	75-SB	28-34-14	COON CRK	34-26-16	27-26-16-1	27-26-16-2	27-26-16	26-26-16-1	26-26-16-2	12-26-16	9-27-16-1	9-27-16-2	QWW	PQ's	BS	KTPK
nuculanid indeterminate																		
Paleyoldia glabra																		
Astartella sp.																		
Cypricardella sp.																		
Pseudomonotis sp.																		
Aviculopecten gradicosta																		
Aviculopecten cf. A. occidentalis																		
Aviculopecten sp.																		
Acanthopecten cf. A. meeki																		
Acanthopecten sp.																		
?Limipecten sp.																		
pectinid indeterminate																		
Parallelodon kansasense	R																	
Parallelodon sp.																		
bivalves indeterminate																		
CEPHALOPODS:																		
nautiloids indeterminate																		
Pseudorthoceras knoxense																		
Metacoceras cornutum																		
Brachycycloceras curtum																		
Mooreoceras normale																		
Tainoceras sp.																		
Liroceras sp.																		
Eoasianites hyattianum																		
"Bisatoceras" ?genus novum																		
Prothallassoceras kingorum																		
Neoaganides sp.																		
Marathonites sp.																		
ammonoid indeterminate																		
BRYOZOANS:																		
Fenestella sp.																		
Fenestrellina sp.																		
fenestellid debris	R	R																
ramose cryptostome																		
massive cryptostome																		
ramose trepostome																		
globular trepostome																		
encrusting trepostome																		
ramose cyclostome																		
ramose ? ctenostome																		
Meekoporella dehiscens																		
?Polypora sp.																		

Table 6 (cont'd.)

	HR-n	30-34-15	75-SB	28-34-14	COON CRK	34-26-16	27-26-16-1	27-26-16-2	27-26-16	26-26-16-1	26-26-16-2	12-26-16	9-27-16-1	9-27-16-2	QMW	PQ's	BS	KTPK
?Rhombopora sp.																		
?Cyclotrypa sp.																		
COELENTERATES:																		
Sutherlandia sp.																		
Michelinia sp.																R		
Syringopora multattenuata																		
auloporid indeterminate																R		
Caninia torquia												A						
Lophamplexus sp.																		
Stereostylus sp.																		
Lophophyllidium sp.																		
Geyerophyllum cf. G. cylindricum																		
Geyerophyllum sp.																		
Dibunophyllum valeriae																		
Dibunophyllum sp.																		
Neokoninckophyllum heckeli																		
Neokoninckophyllum sp.																		
coral indeterminate	R																	
PORIFERA:																		
Girtyocoelia beedei																		
Girtyocoelia sp.																		
Maeandrostia kansasensis																		
Maeandrostia sp.																		
Heliospongia ramosa																		
ROSTROCONCHS:																		
Pseudoconocardium lanterna																		
CONULARIDS:																		
Conularia crustula																		
Mesoconularia sp.																		
TRILOBITES:																		
Ditomopyge scitula																		
Ditomopyge sp.																		
Ameura missouriensis																		
Paladin sp. ? novum																		
SCAPHOPODS:																		
Plagioglypta annulistriata																		
Dentalium (Paleodentalium) kansasense																		
VERTEBRATES:																		
Petalodus destructor																		
Orodus sp.																		
PHYLLOID ALGAE:																		

Table 7--Distribution of biotic elements in the Tyro oolite and the 3rd and 4th oolitic zones.

TAXON / LOCALITY	TYRO OOLITE:	TyQ	TyQ-u	HR	SP	FCC	HWJ	CSBH	3RD OOLITIC HORIZ.	HR	NW-NW-34-34-14	NEC-34-34-14	SWC-23-34-14	NEC-14-34-14	SEC-1-34-14	SW-NE-NE-35-33-14	4TH OOLITIC HORIZ.	CP	NWC-17-35-14	NW-NE-SE-12-35-14	ESL-6-35-14	NWC-30-34-15	NWC-20-34-14	NWC-12-34-14	SW-NE-NE-35-33-14
BRACHIOPODS:																									
Composita subtilita			C							C	A								R	R	A	R	A		R
Phricodothyris perplexa		R	R																	R	C				R
Punctospirifer kentuckyensis			C								R										A		R		R
Neospirifer dunbari		R	R															R							
Hustedia "mormoni"		R	R							R	R								R		A	R	C	R	R
Enteletes pugnoides																									
Schizophoria "texana"																									
Crurithyris planoconvexa			A																						
Dielasma bovidens																				R	R		R		R
Rhipidomella carbonaria		R	R																						
Cancrinella boonensis		R	R																						
Meekella striatocostata																									
Streptorhynchus affine																					R				
Wellerella osagensis																									
Derbyia crassa		R	C								R										C				
Derbyia bennetti																					R				
Derbyia sp.										R									R		A				
Hystriculina wabashensis		R																							
Echinaria semipunctata										C															
Echinaria sp.		R																							
Echinoconchus sp.																									
Antiquatonia crassicostata																									
Antiquatonia sp.																									
Reticulatia americana																									
Reticulatia sp.																									
Pulchratia cf. P. symmetrica			R																						
Pulchratia sp.											R														
Dictyoclostus sp.			R																				R		
Juresania nebrascensis																									R
Juresania sp.			R																						
Linoproductus sp.			R							R															
L. cf. L. prattenianus																									
L. cf. L. platyumbonus																									
productid indeterminate		R								R								R					R		R
Chonetinella flemingi		R																							
Lissochonetes plattsmouthensis																									
Orbiculoidea sp.																									

Table 7 (cont'd.)

	TYRO OOLITE	TYO	TYO-u	HR	SP	FCC	HWJ	CSBH	3RD HORIZ.	HR	34-34-14	34-34-14	23-34-14	14-34-14	1-34-14	35-33-14	4TH HORIZ.	CP	17-35-14	12-35-14	6-35-14	30-34-15	20-34-14	12-34-14	35-33-14
ECHINODERMS:																									
pelmatozoan debris		R	C							R	A							C	R	R	R	C	R	R	R
Ulocrinus sp.																									
Parulocrinus sp.																									
Erisocrinus typus			R																						
Erisocrinus sp.																									
Parerisocrinus sp.																									
Delocrinus sp.		R																			R				
Endelocrinus sp.			R																						
Perimestocrinus sp.																									
Graffhamicrinus sp.																									
Cibolocrinus conicus			R																						
Apographiocrinus typicalis		R	R																						
Exoriocrinus sp.																									
Exocrinus sp.																									
Exaeteocrinus sp.			R																						
Euonychocrinus dubius																									
Paramphicrinus poundi																									
Paragassizocrinus sp.			R																						
Laudonocrinus sp.																									
Parethelocrinus sp.																									
Contocrinus sp.																									
Elibatocrinus sp.																									
Isoallagecrinus sp.																									
Stellarocrinus sp.																									
cf. Aesiocrinus sp.																									
Anobasocrinus sp.																									
Plaxocrinus sp.																									
cymbiocrinid indeterminate																									
cromeocrinid indeterminate																									
pirassocrinid indeterminate			R																						
?Sciadiocrinus sp.																									
?Schistocrinus sp.																									
?Archaeocidaris sp.																									
GASTROPODS:																									
Glabrocingulum sp.																									R
G. (Glabrocingulum) wannense			R																						
G. (G.) grayvillense			C																						
G. (Ananias) welleri																									
Euphemites vittatus			C																						
Pharkidonotus percarinatus			R																						
Pharkidonotus tricarinatus																									

Table 7 (cont'd.)

	TYRO OOLITE	TyQ	TyQ-u	HR	SP	FCC	HWJ	CSBH	3RD HORIZ.	HR	34-34-14	34-34-14	23-34-14	14-34-14	1-34-14	35-33-14	4TH HORIZ.	CP	17-35-14	12-35-14	6-35-14	30-34-15	20-34-14	12-34-14	35-33-14
Cymatospira montfortianus																									
Retispira tenuilineata																									
Bellerophon graphicus																		R							
bellerophontid indeterminate											R														
Worthenia tabulata			R																						
Hypselentoma perhumerosa																		A							
Phymatopleura nodosa			R																						
Ianthinopsis cf. I. brevis																									
I. cf. I. primigenia			R																						
I. cf. I. paludinaeformis			R																						
Ianthinopsis sp.																									
Meekospira choctawensis			C																						
Meekospira sp.										R															
Naticopsis scintilla																									
Naticopsis meeki																		C							
cf. Murchisonia																									
murchisoniid indeterminate																		C							
Straparollus (Amphiscapha) reedsi																									
S. (Amphiscapha) catilloides			R							R										R					
Trepospira sp.																									
T. (Trepospira) discoidalis			R							R															
Euconospira turbiniformis																									
Pseudozygopleura sp.			R																						
Gosseletina cf. G. spironema																									
Gosseletina sp.																									
?Goniasma sp.																		R							
Trachydomia newelli																									
Trachydomia sayrei																									
platycerid indeterminate																									
steinkern indeterminate			R							R										R	R				
Lepetopsis peregrina																									
BIVALVES:																									
Septimyalina cf. S. burmai																									
Septimyalina sp.																					R				
Myalina (Myalina) sp.			R																						
M. (Orthomyalina) slocomi																									
myalinid indeterminate										R									R		R	R			
Wilkingia sp.			R																						
Edmondia sp.																									
Phestia bellistriata																									
Paleoneilo taftiana																									
Nuculopsis ventricosus																									

Table 7 (cont'd.)

	TYRO OOLITE	TyQ	TyQ-u	HR	SP	FCC	HWJ	CSBH	3RD HORIZ.	HR	34-34-14	34-34-14	23-34-14	14-34-14	1-34-14	35-33-14	4TH HORIZ.	CP	17-35-14	12-35-14	6-35-14	30-34-15	20-34-14	12-34-14	35-33-14
nuculanid indeterminate																									
Paleyoldia glabra																									
Astartella sp.																									
Cypricardella sp.																									
Pseudomonotis sp.																									
Aviculopecten gradicosta																									
Aviculopecten cf. A. occidentalis			C																						
Aviculopecten sp.		R								C															
Acanthopecten cf. A. meeki																					R				
Acanthopecten sp.																									
?Limipecten sp.																									
pectinid indeterminate		R																							
Parallelodon kansasense																									
Parallelodon sp.																									
bivalves indeterminate																									
CEPHALOPODS:																									
nautiloids indeterminate										R													R		
Pseudorthoceras knoxense																									
Metacoceras cornutum																									
Brachycycloceras curtum																									
Mooreoceras normale																									
Tainoceras sp.																									
Liroceras sp.																									
Eoasianites hyattianum			R																						
"Bisatoceras" ?genus novum			R																						
Prothallassoceras kingorum			R																						
Neoaganides sp.																									
Marathonites sp.			R																						
ammonoid indeterminate																									
BRYOZOANS:																									
Fenestella sp.																					R				
Fenestrellina sp.																					R				
fenestellid debris		R									R								R						R
ramose cryptostome																									
massive cryptostome																									
ramose trepostome																									
globular trepostome																									
encrusting trepostome																					R				
ramose cyclostome																									
ramose ? ctenostome																									
Meekoporella dehiscens																									
?Polypora sp.			R																						

Table 7 (cont'd.)

	TYRO OOLITE	TyQ	TyQ-u	HR	SP	FCC	HWJ	CSBH	3RD HORIZ.	HR	34-34-14	34-34-14	23-34-14	14-34-14	1-34-14	35-33-14	4TH HORIZ.	CP	17-35-14	12-35-14	6-35-14	30-34-15	20-34-14	12-34-14	35-33-14
?Rhombopora sp.																									
?Cyclotrypa sp.																									
COELENTERATES:																									
Sutherlandia sp.																									
Michelinia sp.																									
Syringopora multattenuata																									
auloporid indeterminate																									
Caninia torquia																									
Lophamplexus sp.																									
Stereostylus sp.																									
Lophophyllidium sp.																									
Geyerophyllum cf. G. cylindricum																									
Geyerophyllum sp.																									
Dibunophyllum valeriae																									
Dibunophyllum sp.																									
Neokoninckophyllum heckeli																									
Neokoninckophyllum sp.																									
coral indeterminate																					R				
PORIFERA:																									
Girtyocoelia beedei			C																						
Girtyocoelia sp.																									
Maeandrostia kansasensis			R																						
Maeandrostia sp.																									
Heliospongia ramosa																									
ROSTROCONCHS:																									
Pseudoconocardium lanterna																									
CONULARIDS:																									
Conularia crustula																									
Mesoconularia sp.										R															
TRILOBITES:																									
Ditomopyge scitula																									
Ditomopyge sp.																									
Ameura missouriensis																									
Paladin sp. ? novum																									
SCAPHOPODS:																									
Plagioglypta annulistriata																									
Dentalium (Paleodentalium) kansasense			C																						
VERTEBRATES:																									
Petalodus destructor																									
Orodus sp.																									
PHYLLOID ALGAE:																									

Table 8--Distribution of biotic elements in the South Bend Limestone Member.

TAXON \ LOCALITY	RM	SCWL-4-34-14	SW-NW-SE-27-33-14	NEC-34-32-14	SE-SW-SE-28-32-14	H160Q-nw$_1$	H160Q-nwh	H160Q-off md_t	ECR-1	ECR-2	SWC-22-30-15	FNW	WL-NWC-35-26-16	NL-NE-NE-33-26-16	NW-NW-SW-33-26-16	NE-NE-SE-33-26-16	CSL-SE-27-26-16	CSL-12-26-16	QWW-1	QWW-2	PQ's-h	BS-1	BS-2	KTPK-1	KTPK-2
BRACHIOPODS:																									
Composita subtilita	R			C		R		A	R	R	A	C		R	C	C		A	C	A	A	C	C		C
Phricodothyris perplexa								C		R		R			R			R			R	C	C		
Punctospirifer kentuckyensis				R	R			C			C								R		A	C	C		C
Neospirifer dunbari	R			R				C						A								R	R		
Hustedia "mormoni"				R				C			C			R											
Enteletes pugnoides																									
Schizophoria "texana"																									
Crurithyris planoconvexa								R																	
Dielasma bovidens								R	R						R				C		R				
Rhipidomella carbonaria				A				C												R					C
Cancrinella boonensis									R						R					R	R				
Meekella striatocostata						R	C	R	R		R	C		R	C					C		R	R		R
Streptorhynchus affine								R																	
Wellerella osagensis								C																	
Derbyia crassa								R				A			A				C		C	C	R		
Derbyia bennetti								R			A	R			R										
Derbyia sp.						R			C											C					C
Hystriculina wabashensis				R				A														C	C		
Echinaria semipunctata								R																	
Echinaria sp.																									
Echinoconchus sp.																									
Antiquatonia crassicostata																									
Antiquatonia sp.																									
Reticulatia americana																									
Reticulatia sp.		R						R																	
Pulchratia cf. P. symmetrica																									
Pulchratia sp.																									
Dictyoclostus sp.																									
Juresania nebrascensis								R													R				
Juresania sp.																									
Linoproductus sp.							R	R												R		R	R		
L. cf. L. prattenianus								R																	
L. cf. L. platyumbonus								R																	
productid indeterminate				R																					
Chonetinella flemingi				R				C													A		C		A
Lissochonetes plattsmouthensis																									
Orbiculoidea sp.								R																	

Table 8 (cont'd.)

	RM	4-34-14	27-33-14	34-32-14	28-32-14	H160Q-nw$_1$	H160Q-nw$_h$	H160Q-om$_t$	ECR-1	ECR-2	22-30-15	FNW	35-26-16	NL-33-26-16	NW-33-26-16	NE-33-26-16	27-26-16	12-26-16	QWW-1	QWW-2	PQ's-h	BS-1	BS-2	KTPK-1	KTPK-2
ECHINODERMS:																									
pelmatozoan debris	R			C		R		A	R		R	R	R	C		A		C	R	A	C	C	C		C
Ulocrinus sp.								R																	
Parulocrinus sp.								R																	
Erisocrinus typus					R			C																	
Erisocrinus sp.																									
Parerisocrinus sp.																									
Delocrinus sp.								R																	
Endelocrinus sp.								R																	
Perimestocrinus sp.																									
Graffhamicrinus sp.																									
Cibolocrinus conicus																									
Apographiocrinus typicalis								R																	
Exoriocrinus sp.								R																	
Exocrinus sp.								R																	
Exaeteocrinus sp.																									
Euonychocrinus dubius																									
Paramphicrinus poundi								R																	
Paragassizocrinus sp.																									
Laudonocrinus sp.								R																	
Parethelocrinus sp.								R																	
Contocrinus sp.								R																	
Elibatocrinus sp.								R																	
Isoallagecrinus sp.								R																	
Stellarocrinus sp.																									
cf. Aesiocrinus sp.																									
Anobasocrinus sp.																									
Plaxocrinus sp.																									
cymbiocrinid indeterminate																									
cromeocrinid indeterminate																									
pirassocrinid indeterminate				R												R				R					
?Sciadiocrinus sp.																R									
?Schistocrinus sp.								R																	
?Archaeocidaris sp.								R																	
GASTROPODS:																									
Glabrocingulum sp.																									
G. (Glabrocingulum) wannense																									
G. (G.) grayvillense																				R					
G. (Ananias) welleri																									
Euphemites vittatus												R													
Pharkidonotus percarinatus																									
Pharkidonotus tricarinatus																									

Table 8 (cont'd.)

	RM	4-34-14	27-33-14	34-32-14	28-32-14	H160Q-nw_l	H160Q-nw_h	H160Q-om_t	ECR-1	ECR-2	22-30-15	FNW	35-26-16	NL-33-26-16	NW-33-26-16	NE-33-26-16	27-26-16	12-26-16	QWW-1	QWW-2	PQ's-h	BS-1	BS-2	KTPK-1	KTPK-2
Cymatospira montfortianus																									
Retispira tenuilineata																									
Bellerophon graphicus																									
bellerophontid indeterminate																		R	R		R	R			
Worthenia tabulata																									
Hypselentoma perhumerosa																									
Phymatopleura nodosa																									
Ianthinopsis cf. I. brevis																									
I. cf. I. primigenia																									
I. cf. I. paludinaeformis																									
Ianthinopsis sp.																									
Meekospira choctawensis																									
Meekospira sp.																									
Naticopsis scintilla							R																		
Naticopsis meeki																									
cf. Murchisonia																									
murchisoniid indeterminate																									
Straparollus (Amphiscapha) reedsi																									
S. (Amphiscapha) catilloides																					R				
Trepospira sp.																									
T. (Trepospira) discoidalis																									
Euconospira turbiniformis								R							C										
Pseudozygopleura sp.																									
Gosseletina cf. G. spironema																									
Gosseletina sp.																									
?Goniasma sp.																									
Trachydomia newelli																									
Trachydomia sayrei																									
platycerid indeterminate																									
steinkern indeterminate											R														
Lepetopsis peregrina																									
BIVALVES:																									
Septimyalina cf. S. burmai																									
Septimyalina sp.	R				R			R			R	C		R	R			R	C						
Myalina (Myalina) sp.																									
M. (Orthomyalina) slocomi																									
myalinid indeterminate					R															R					
Wilkingia sp.											R														
Edmondia sp.															R				R						
Phestia bellistriata																									
Paleoneilo taffiana								R																	
Nuculopsis ventricosus																									

Table 8 (cont'd.)

	RM	4-34-14	27-33-14	34-32-14	28-32-14	H160Q-nw1	H160Q-nwh	H160Q-omt	ECR-1	ECR-2	22-30-15	FNW	35-26-16	NL-33-26-15	NW-33-26-15	NE-33-26-15	27-26-16	12-26-16	QWW-1	QWW-2	PQ's-h	BS-1	BS-2	KTPK-1	KTPK-2
nuculanid indeterminate																R									
Paleyoldia glabra					R									R											
Astartella sp.																									
Cypricardella sp.																									
Pseudomonotis sp.															R										
Aviculopecten gradicosta															R										
Aviculopecten cf. A. occidentalis																			R						
Aviculopecten sp.					R						R	R						R	R						
Acanthopecten cf. A. meeki																									
Acanthopecten sp.																									
?Limipecten sp.																									
pectinid indeterminate																									
Parallelodon kansasense														R											
Parallelodon sp.																									
bivalves indeterminate																									
CEPHALOPODS:																									
nautiloids indeterminate																									
Pseudorthoceras knoxense																									
Metacoceras cornutum															R										
Brachycycloceras curtum																									
Mooreoceras normale																									
Tainoceras sp.								R																	
Liroceras sp.																									
Eoasianites hyattianum				R																					
"Bisatoceras" ?genus novum																									
Prothallassoceras kingorum																									
Neoaganides sp.																									
Marathonites sp.																									
ammonoid indeterminate																									
BRYOZOANS:																									
Fenestella sp.																	R								
Fenestrellina sp.																									
fenestellid debris								C						R	C		R		C	R					C
ramose cryptostome																									
massive cryptostome																									
ramose trepostome				C																					
globular trepostome								R																	
encrusting trepostome				C				R																	
ramose cyclostome																									
ramose ? ctenostome								R																	
Meekoporella dehiscens																									
?Polypora sp.																									

Table 8 (cont'd.)

	RM	4-34-14	27-33-14	34-32-14	28-32-14	H160Q-nw1	H160Q-nwh	H160Q-omt	ECR-1	ECR-2	22-30-15	FNW	35-26-16	NL-33-26-15	NW-33-26-15	NE-33-26-15	27-26-16	12-26-16	QWW-1	QWW-2	PQ's-h	BS-1	BS-2	KTPK-1	KTPK-2
?Rhombopora sp.								R																	
?Cyclotrypa sp.																									
COELENTERATES:																									
Sutherlandia sp.								R																	
Michelinia sp.																									
Syringopora multattenuata																									
auloporid indeterminate																									
Caninia torquia																									
Lophamplexus sp.																									
Stereostylus sp.																									
Lophophyllidium sp.																									R
Geyerophyllum cf. G. cylindricum																									
Geyerophyllum sp.																									
Dibunophyllum valeriae																									
Dibunophyllum sp.																									
Neokoninckophyllum heckeli																									
Neokoninckophyllum sp.																									
coral indeterminate																									
PORIFERA:																									
Girtyocoelia beedei	C																								
Girtyocoelia sp.																									
Maeandrostia kansasensis																									
Maeandrostia sp.																									
Heliospongia ramosa																									
ROSTROCONCHS:																									
Pseudoconocardium lanterna																									
CONULARIDS:																									
Conularia crustula																									
Mesoconularia sp.				R																					
TRILOBITES:																									
Ditomopyge scitula								R																	
Ditomopyge sp.															R										
Ameura missouriensis																									
Paladin sp. ? novum																									
SCAPHOPODS:																									
Plagioglypta annulistriata																									
Dentalium (Paleodentalium) kansasense																									
VERTEBRATES:																									
Petalodus destructor								R																	
Orodus sp.								R																	
PHYLLOID ALGAE:						R	C	C		C							A			A					R

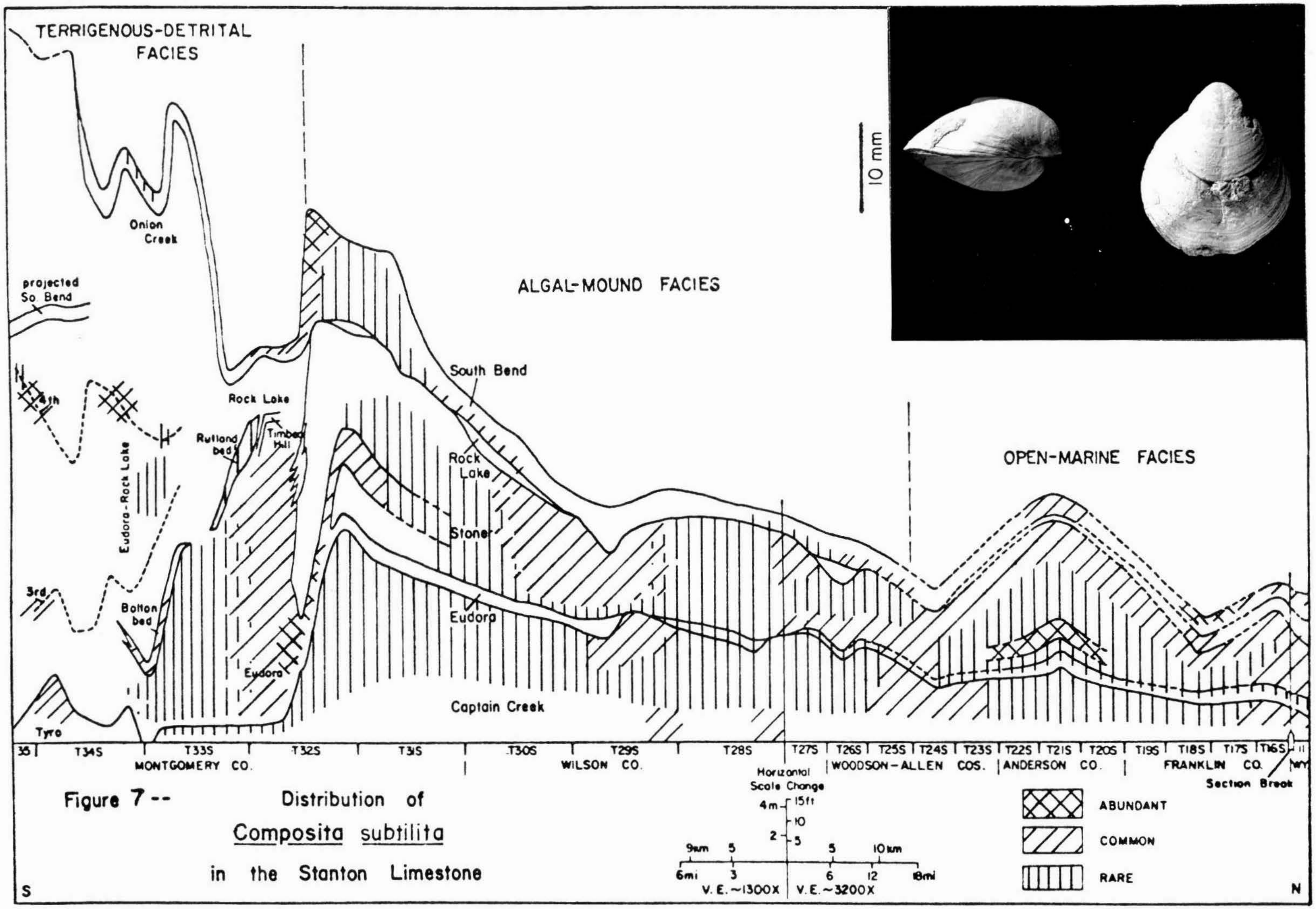

Figure 7 -- Distribution of Composita subtilita in the Stanton Limestone

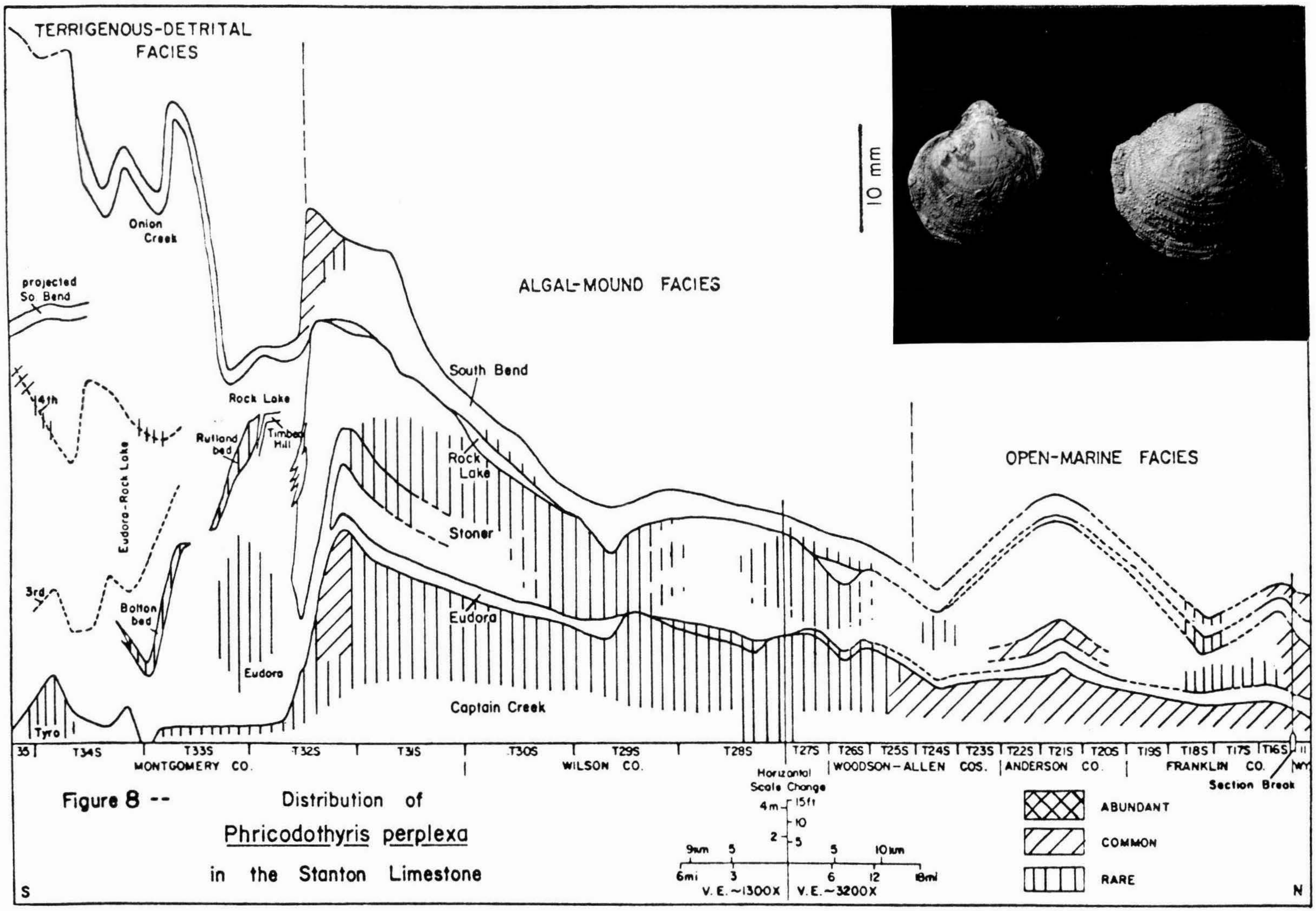

Figure 8 -- Distribution of Phricodothyris perplexa in the Stanton Limestone

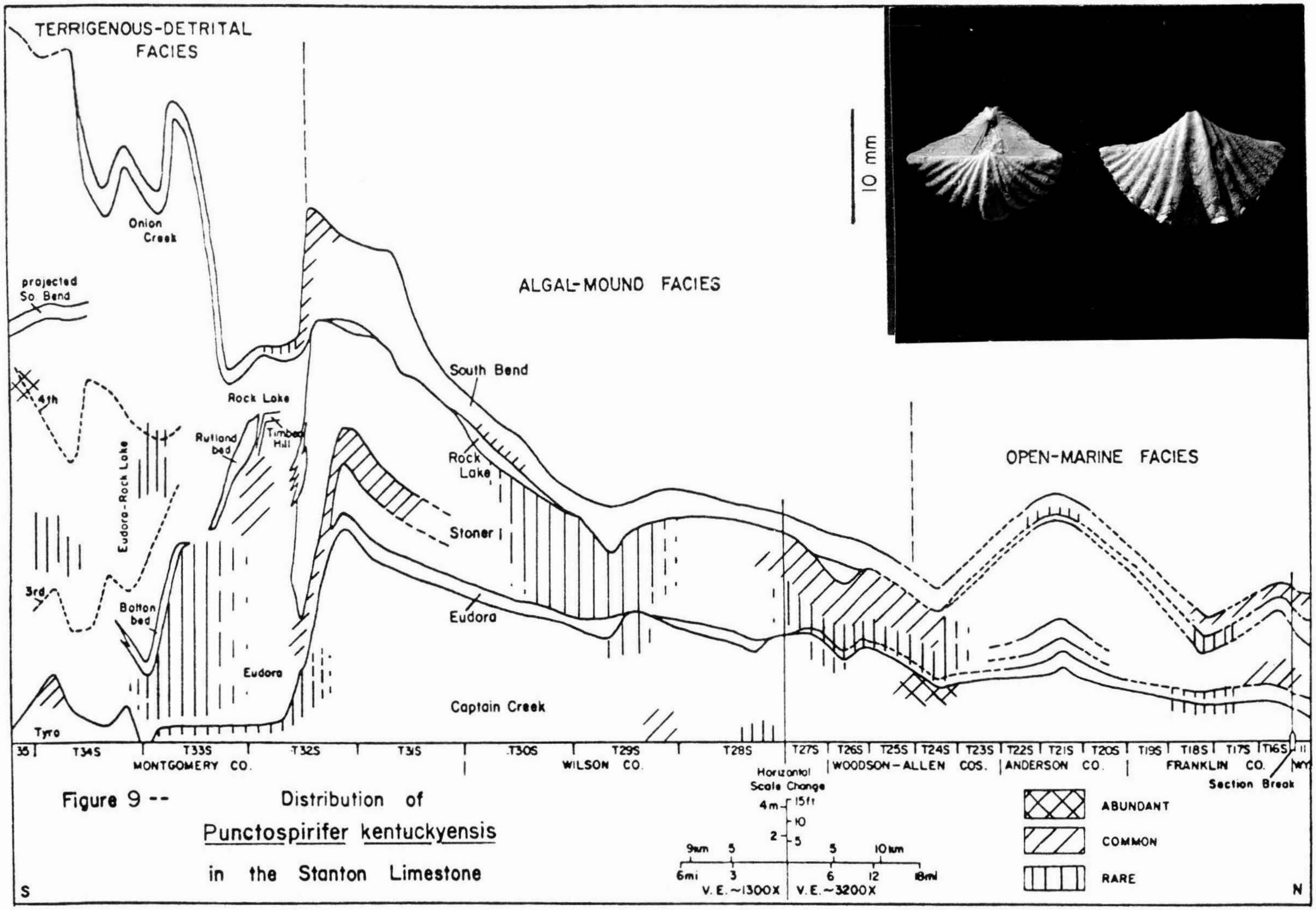

Figure 9 -- Distribution of Punctospirifer kentuckyensis in the Stanton Limestone

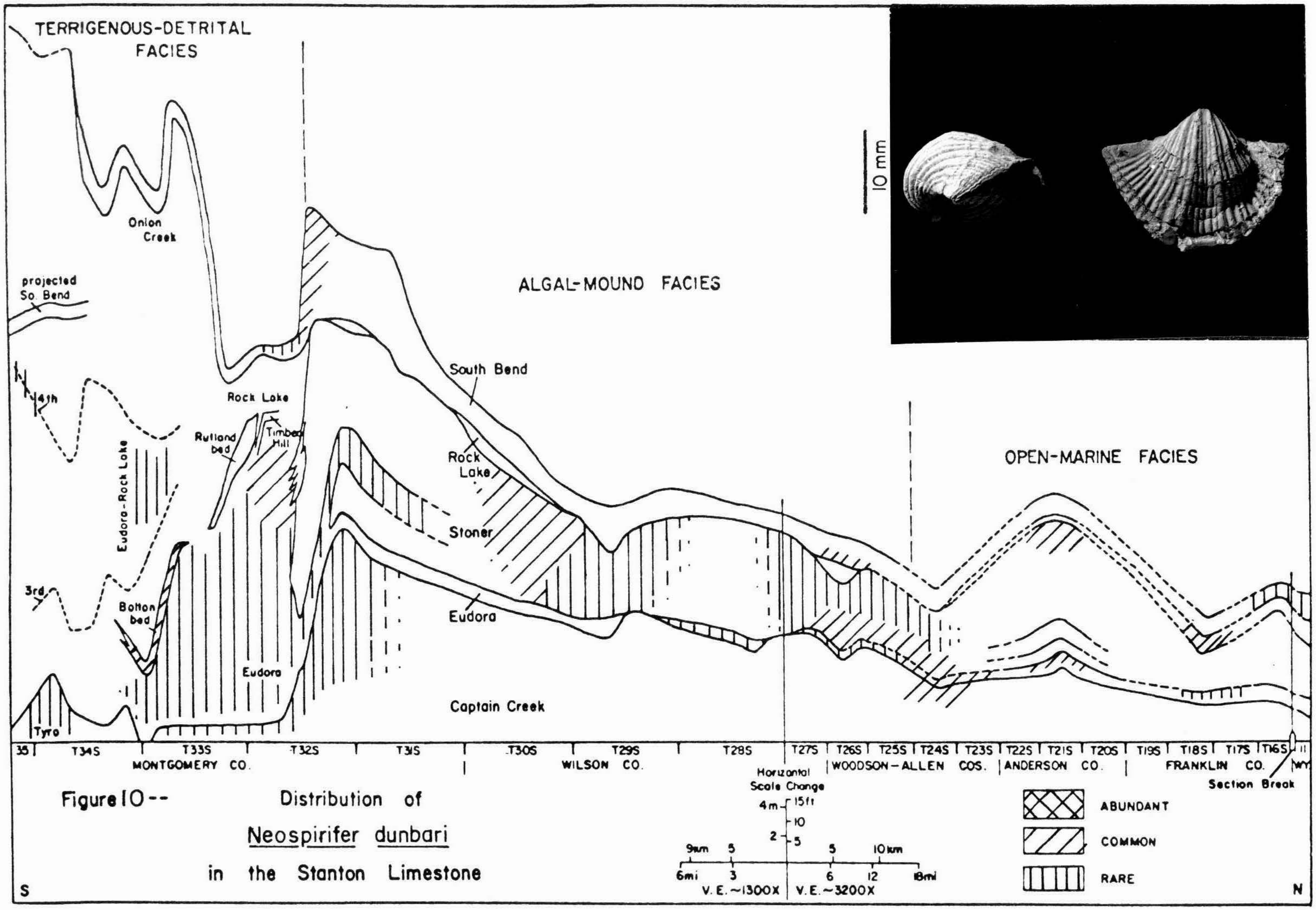

Figure 10 -- Distribution of <u>Neospirifer dunbari</u> in the Stanton Limestone

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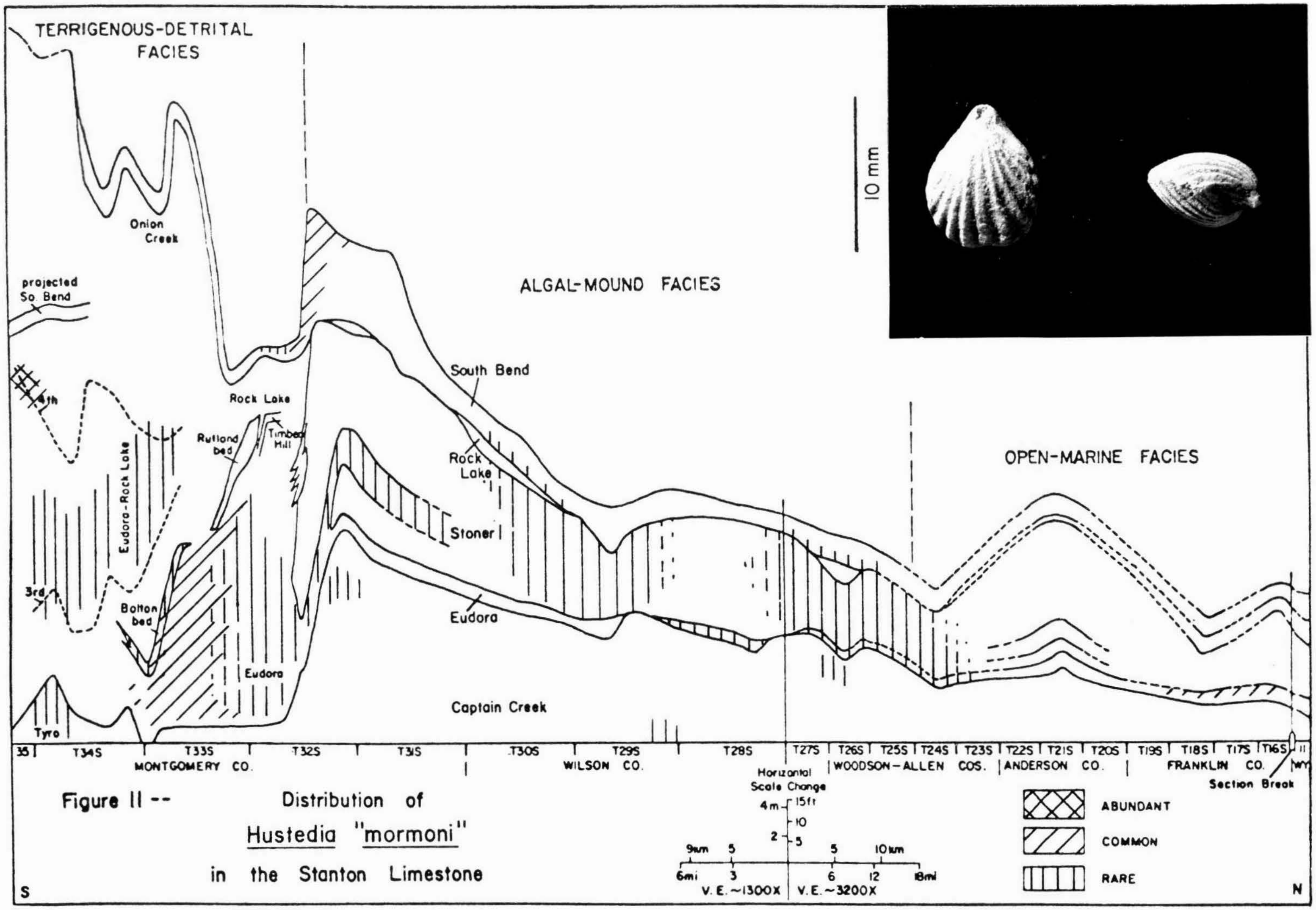

Figure 11 -- Distribution of Hustedia "mormoni" in the Stanton Limestone

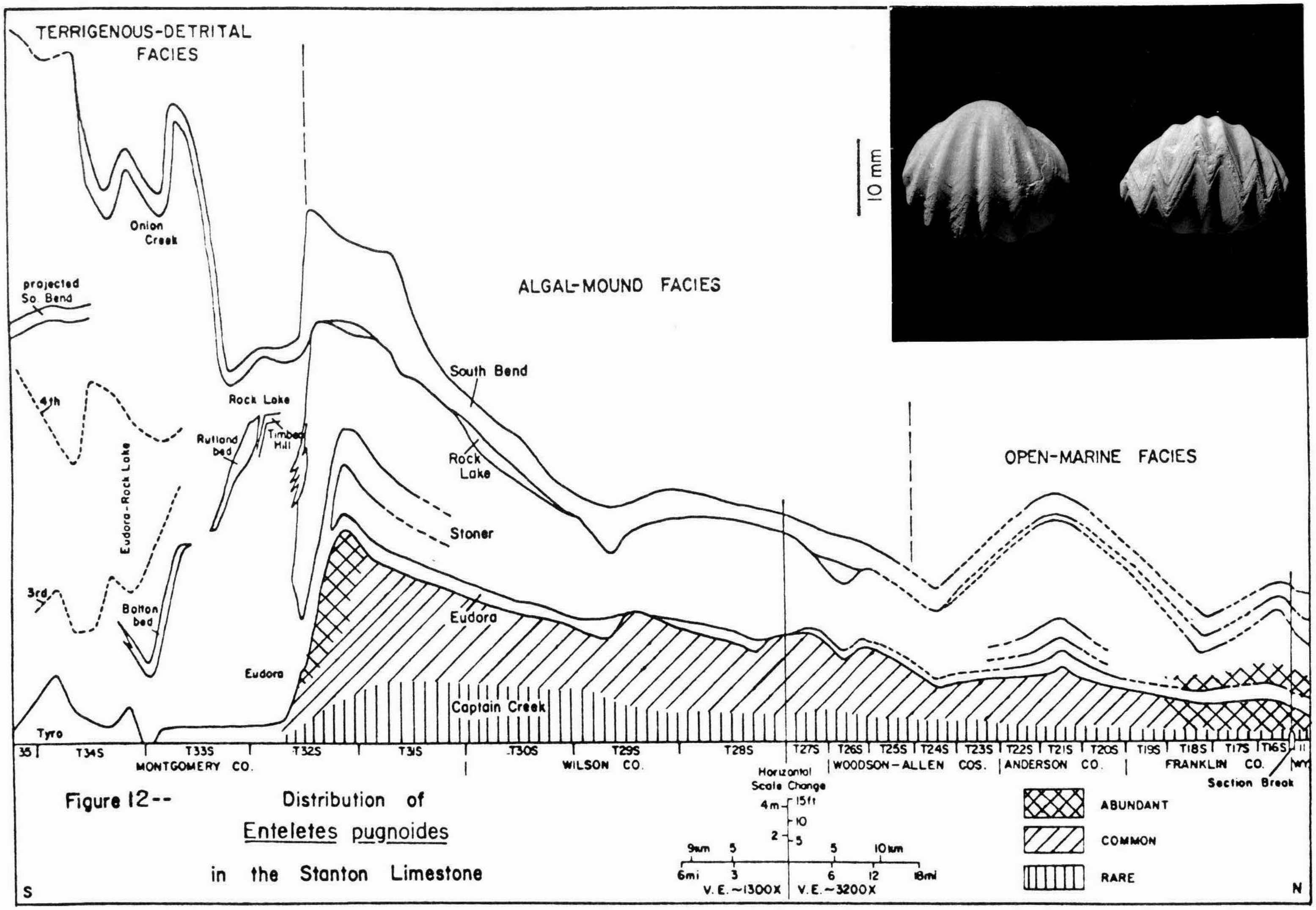

Figure 12-- Distribution of Enteletes pugnoides in the Stanton Limestone

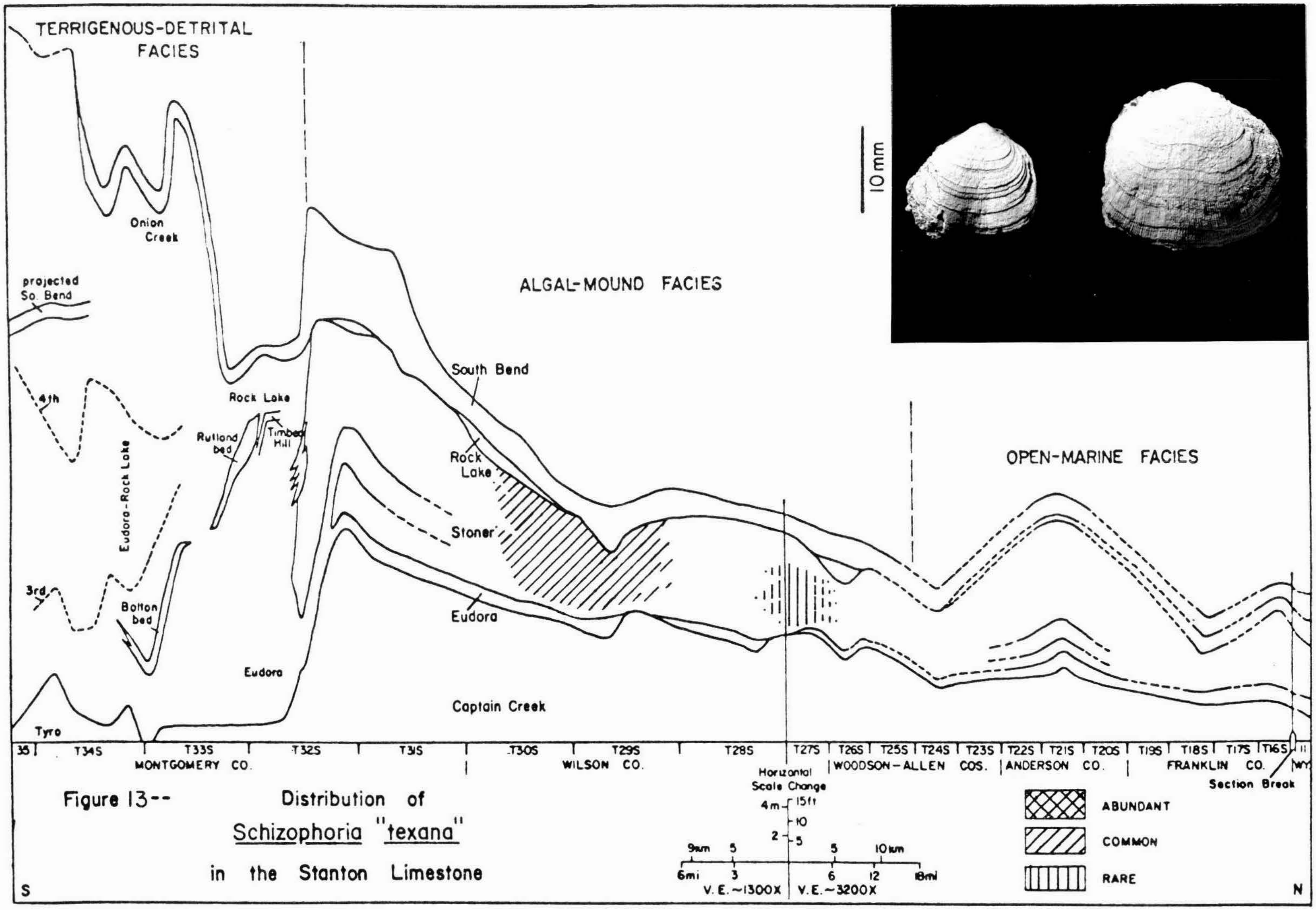

Figure 13-- Distribution of Schizophoria "texana" in the Stanton Limestone

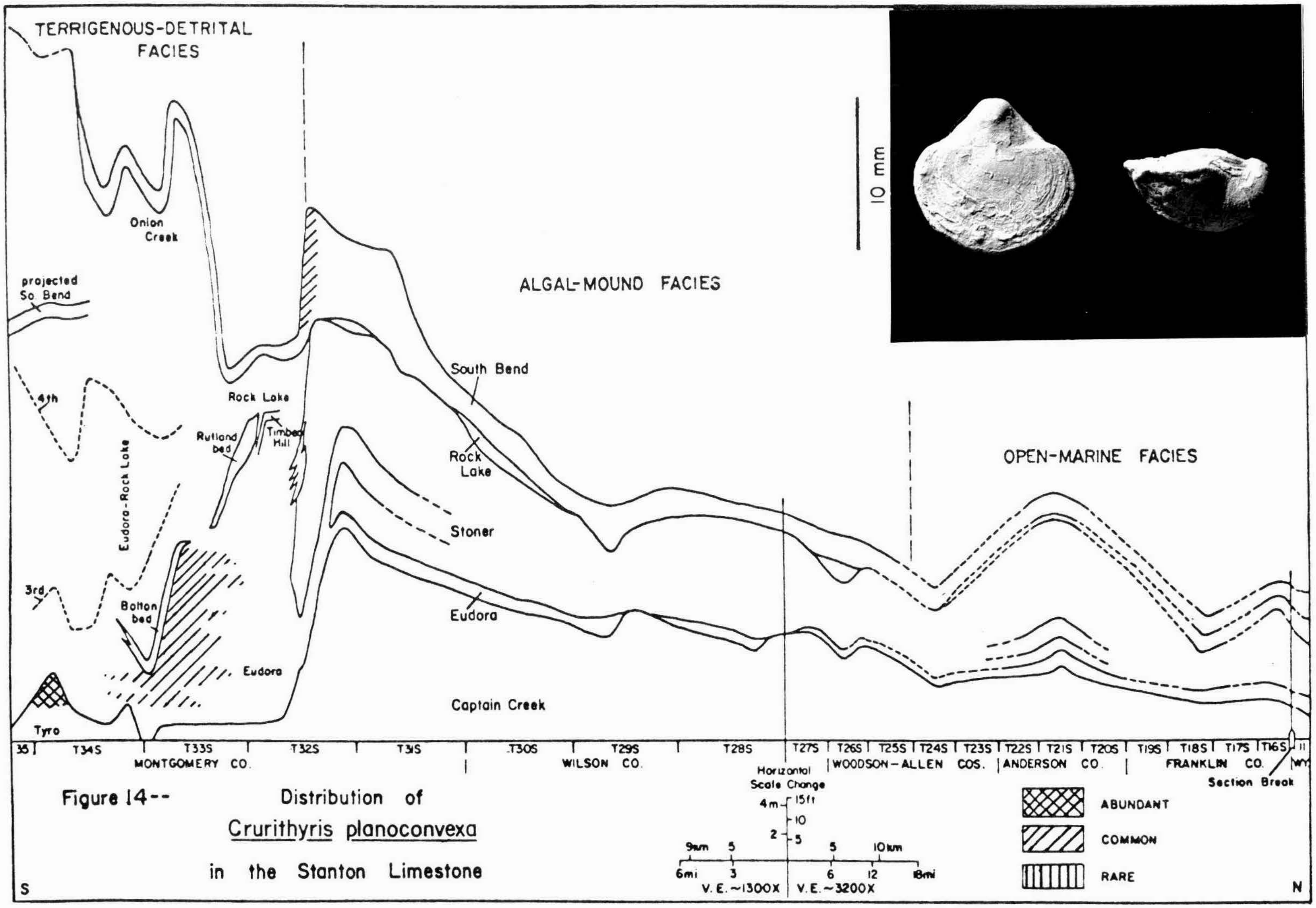

Figure 14-- Distribution of Crurithyris planoconvexa in the Stanton Limestone

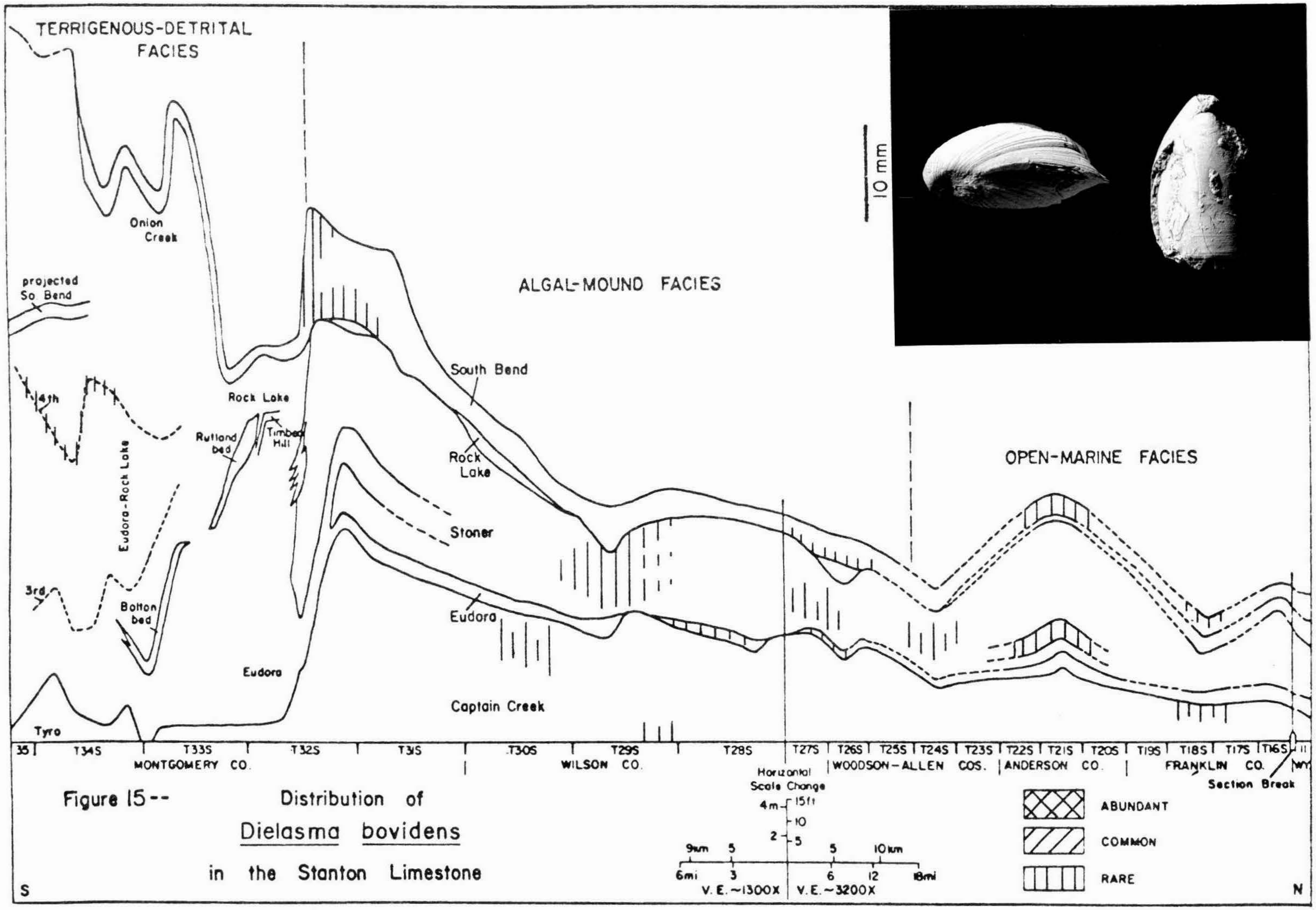

Figure 15 -- Distribution of <u>Dielasma</u> <u>bovidens</u> in the Stanton Limestone

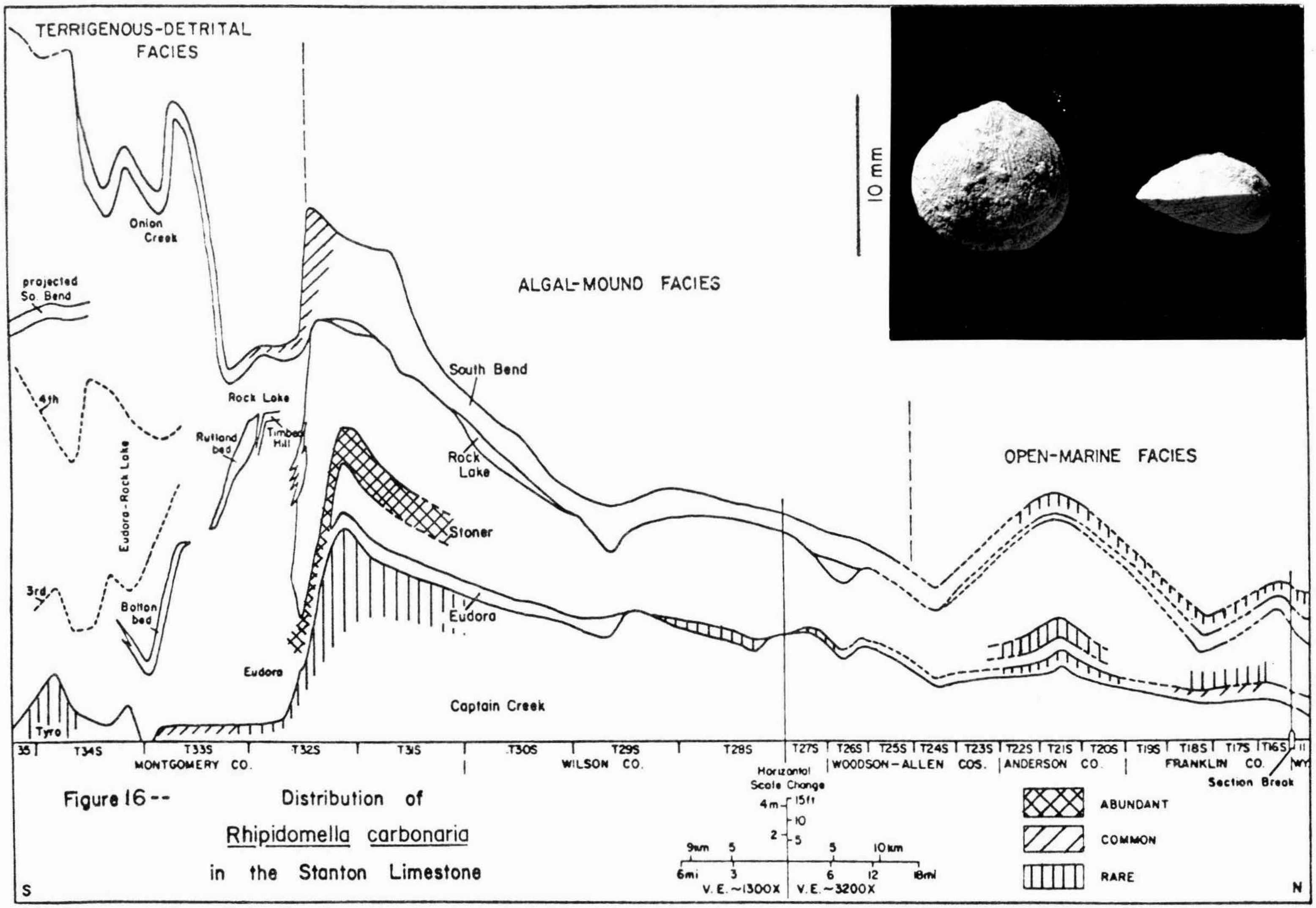

Figure 16 -- Distribution of <u>Rhipidomella carbonaria</u> in the Stanton Limestone

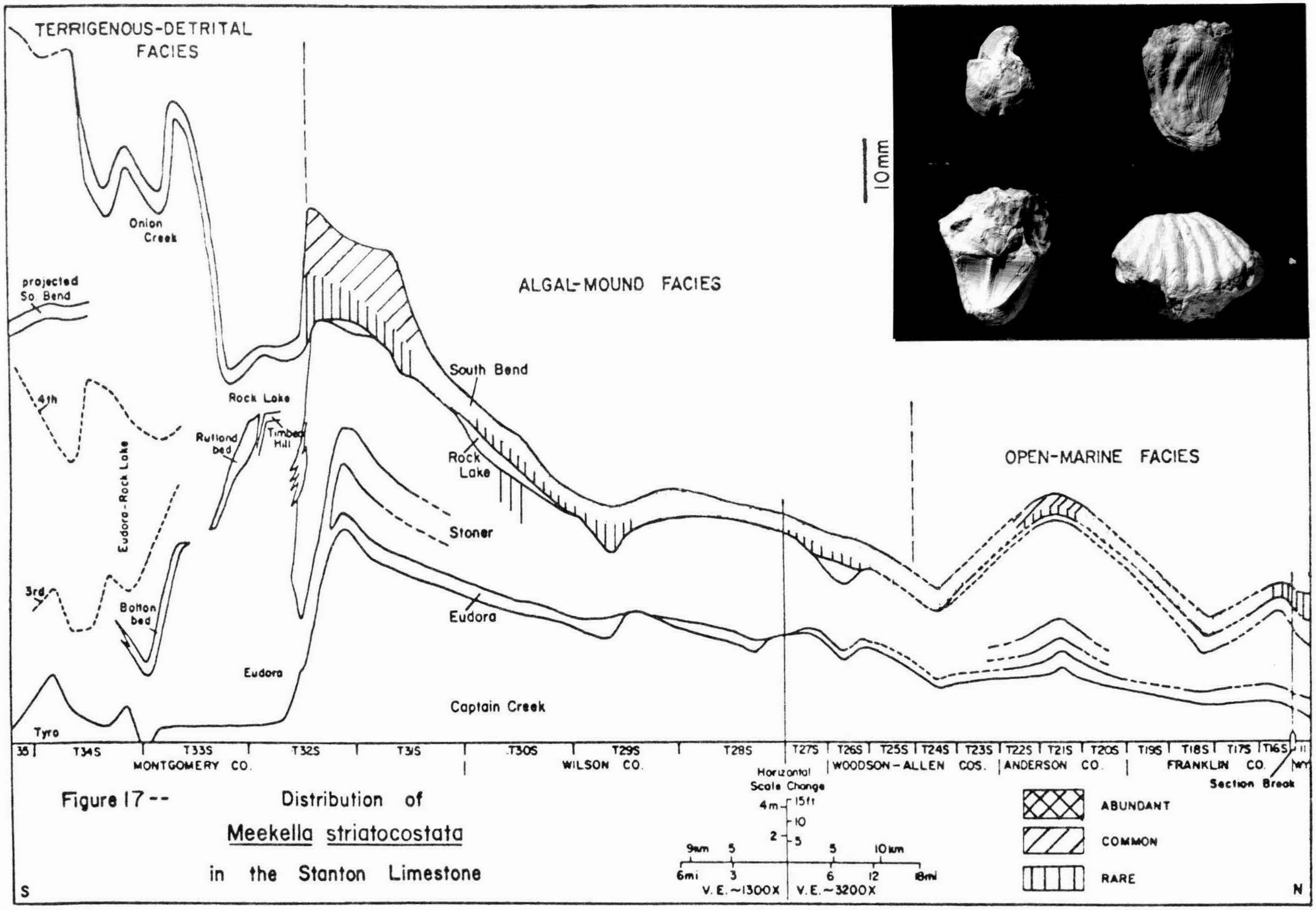

Figure 17 -- Distribution of Meekella striatocostata in the Stanton Limestone

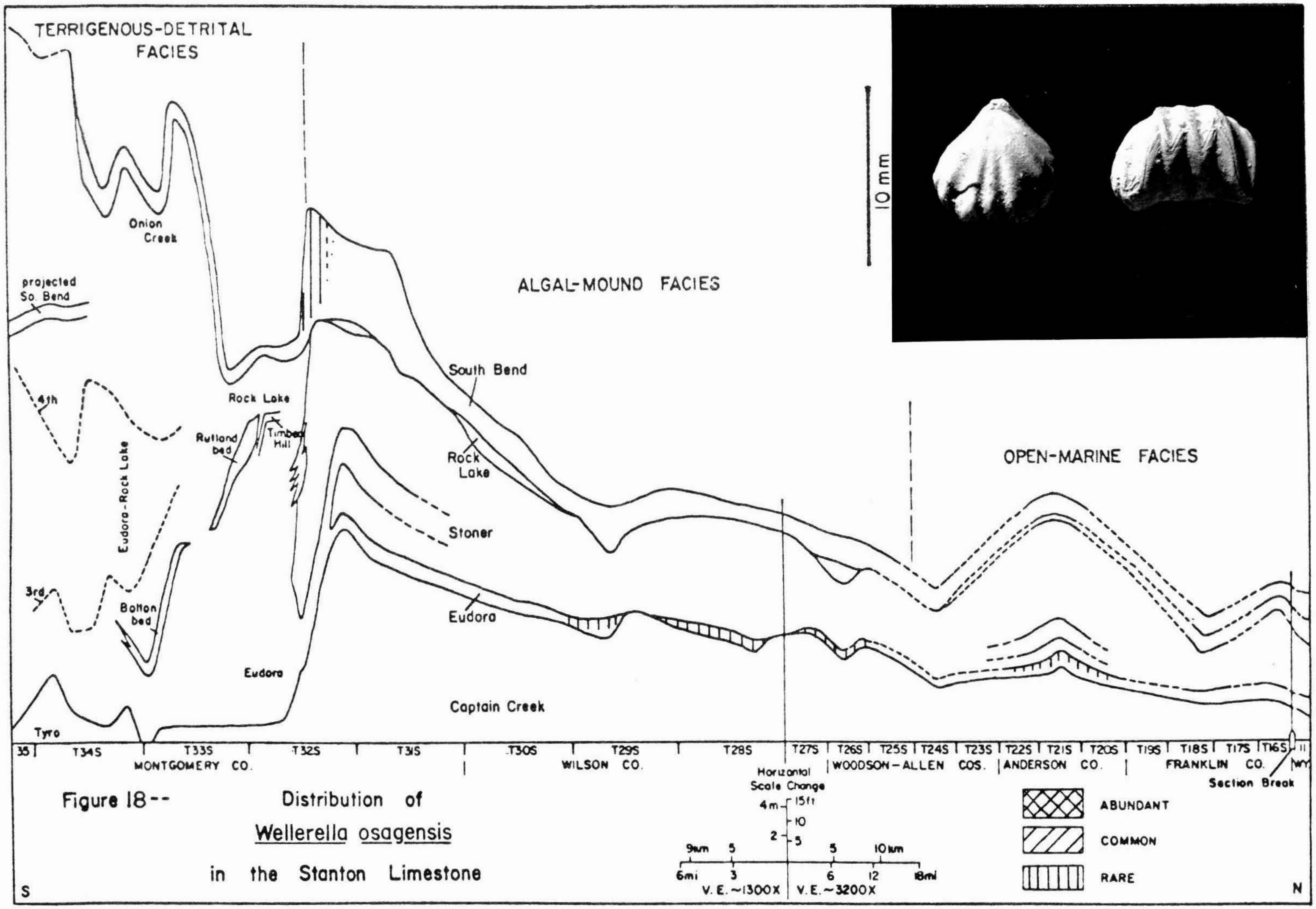

Figure 18-- Distribution of <u>Wellerella osagensis</u> in the Stanton Limestone

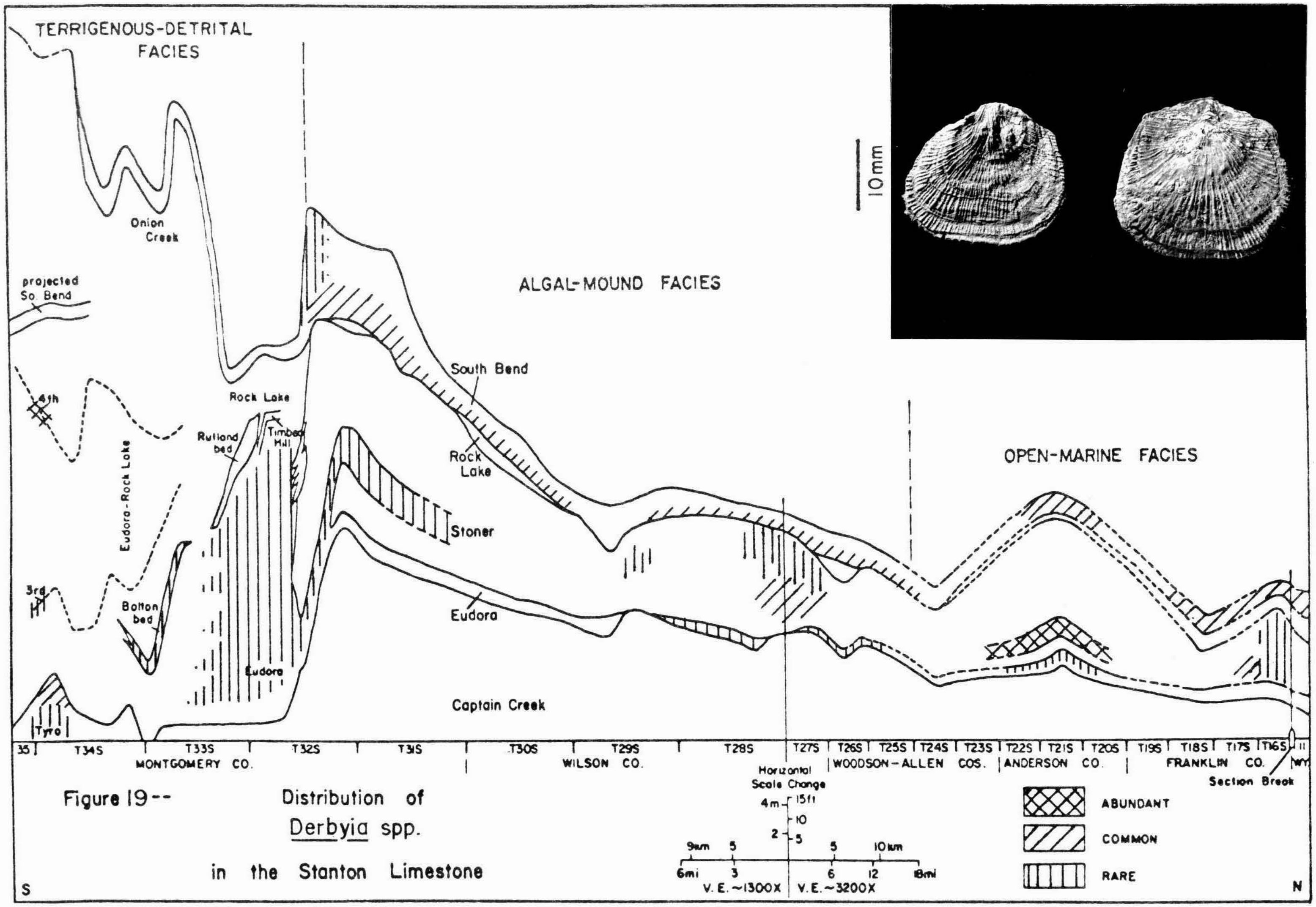

Figure 19-- Distribution of Derbyia spp. in the Stanton Limestone

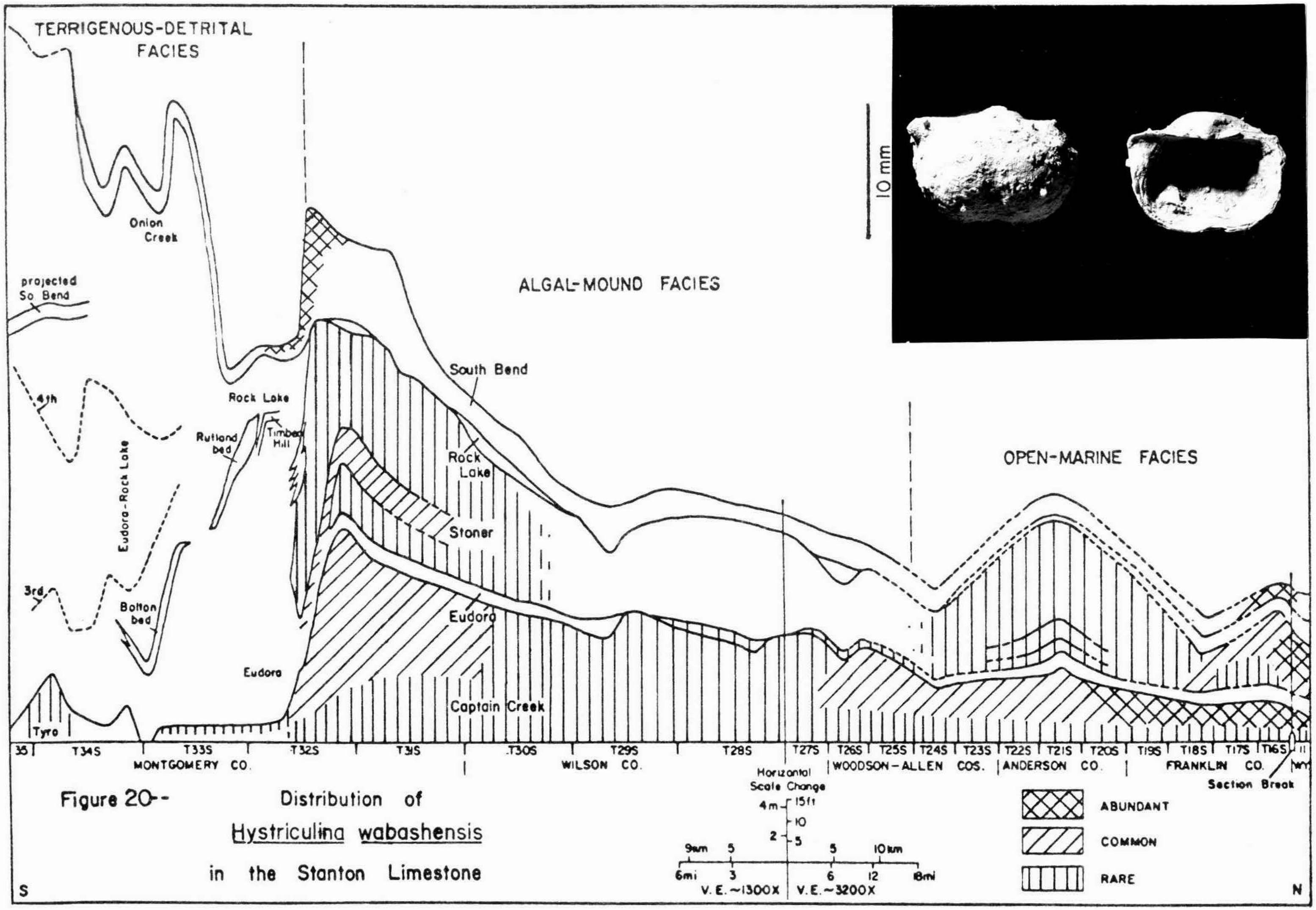

Figure 20-- Distribution of Hystriculina wabashensis in the Stanton Limestone

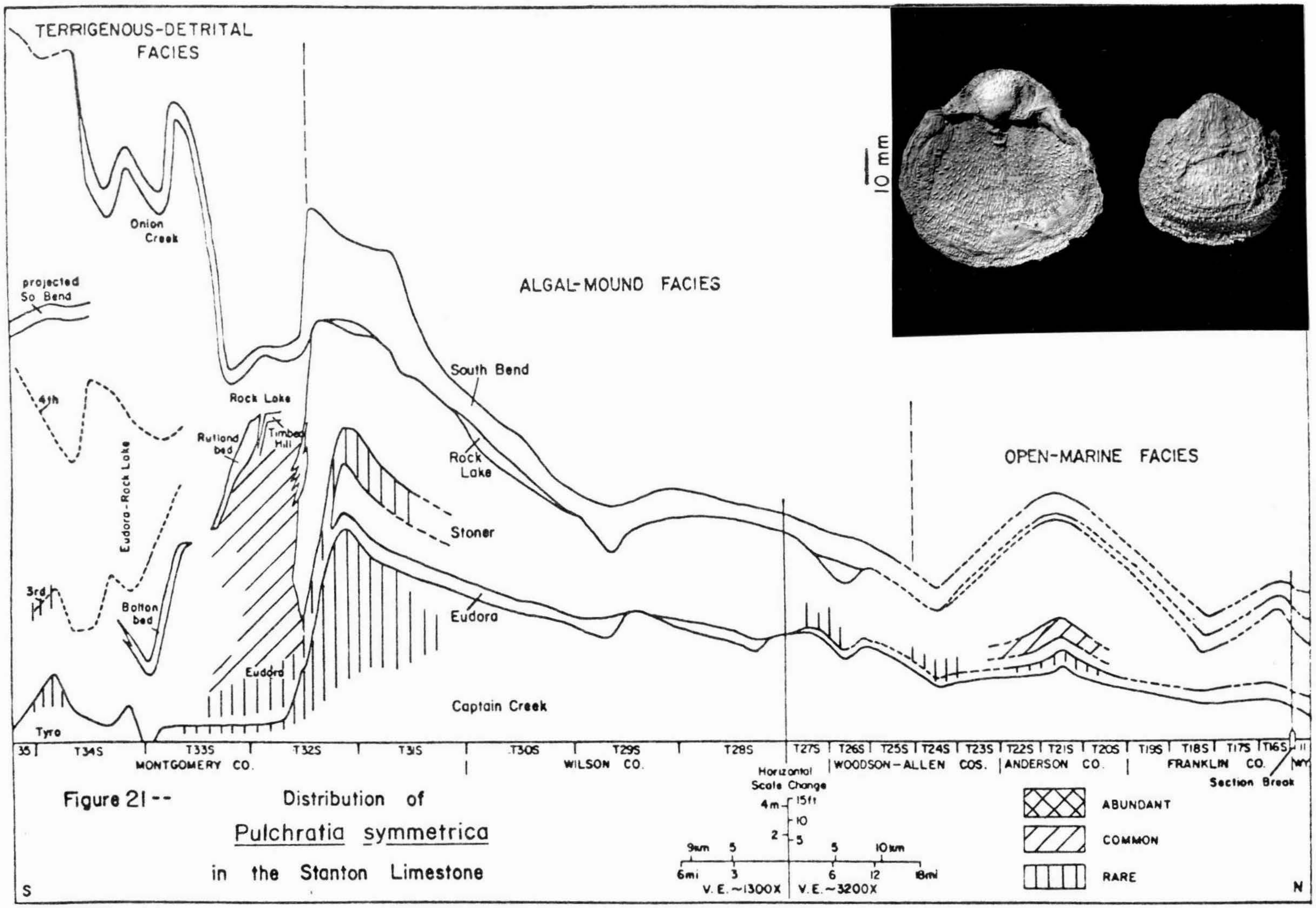

Figure 21 -- Distribution of Pulchratia symmetrica in the Stanton Limestone

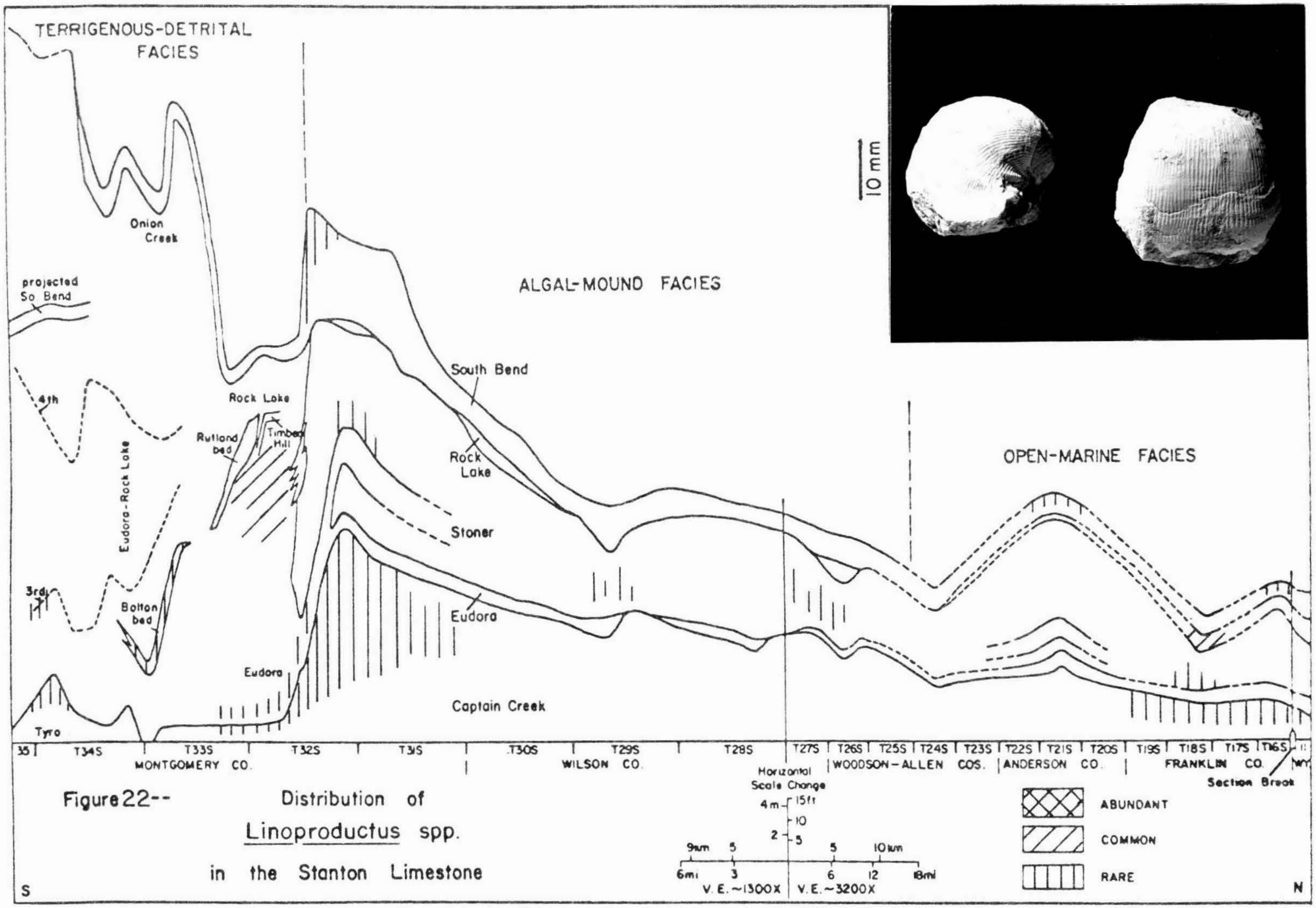

Figure 22-- Distribution of Linoproductus spp. in the Stanton Limestone

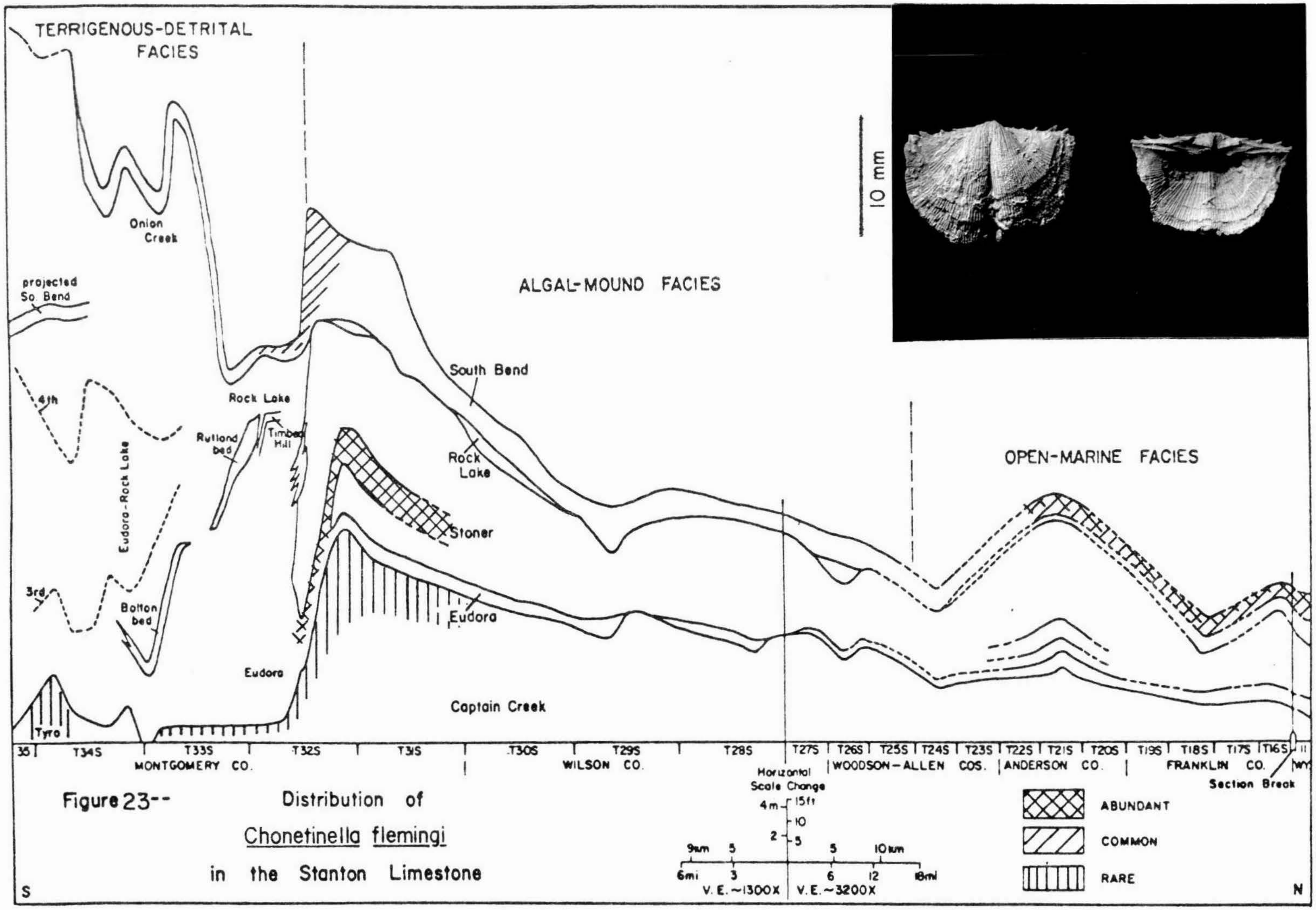

Figure 23-- Distribution of Chonetinella flemingi in the Stanton Limestone

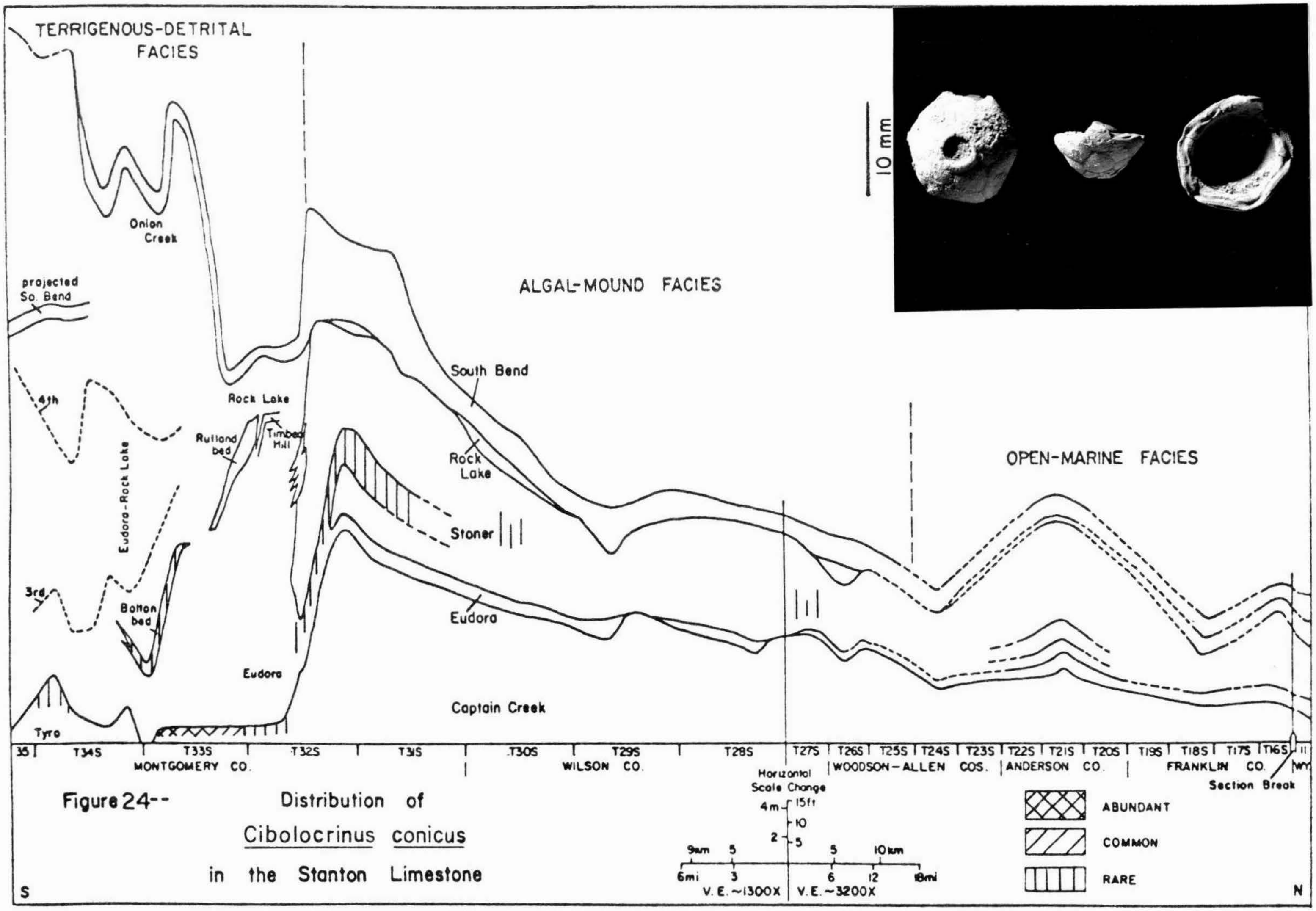

Figure 24-- Distribution of Cibolocrinus conicus in the Stanton Limestone

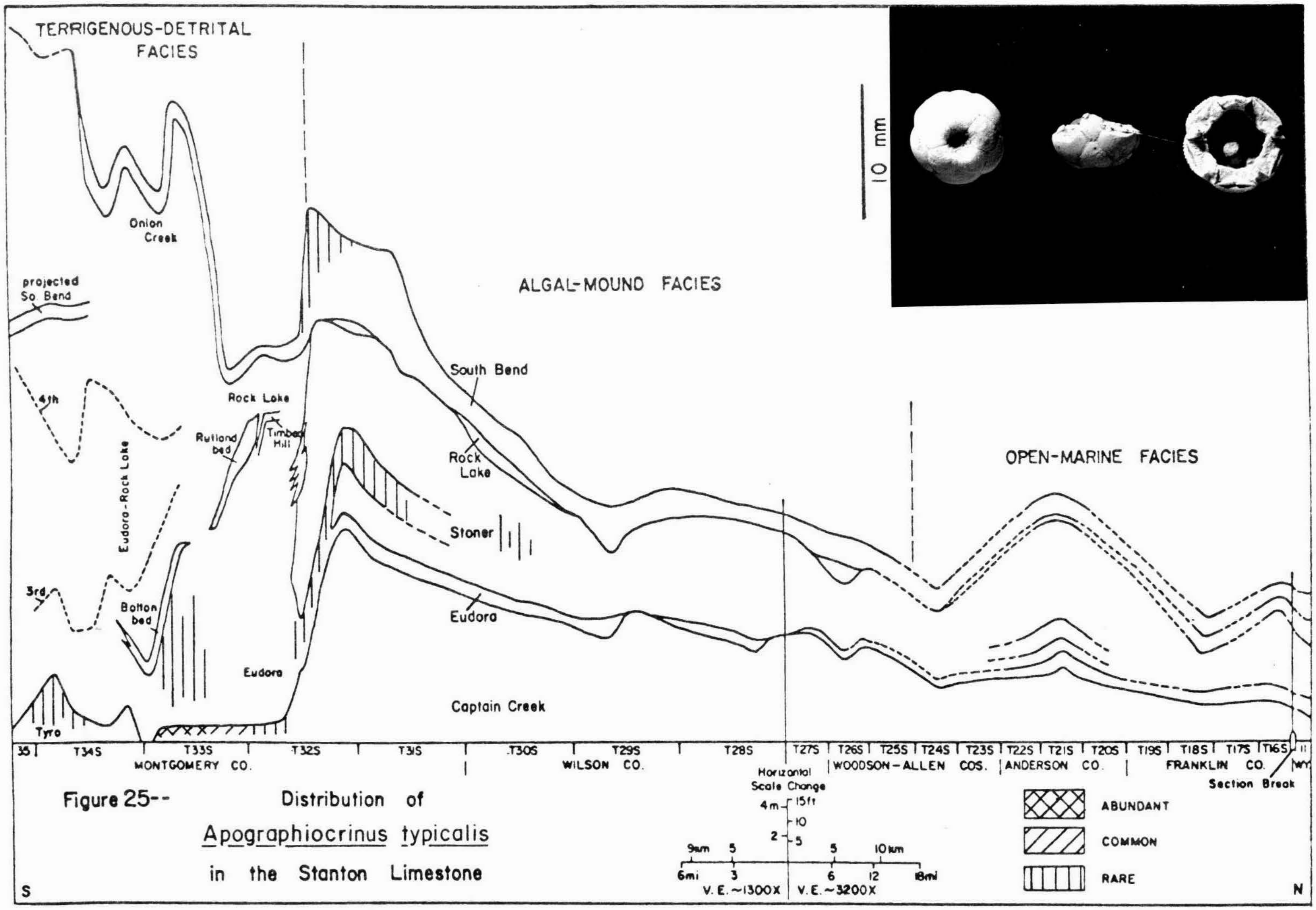

Figure 25-- Distribution of Apographiocrinus typicalis in the Stanton Limestone

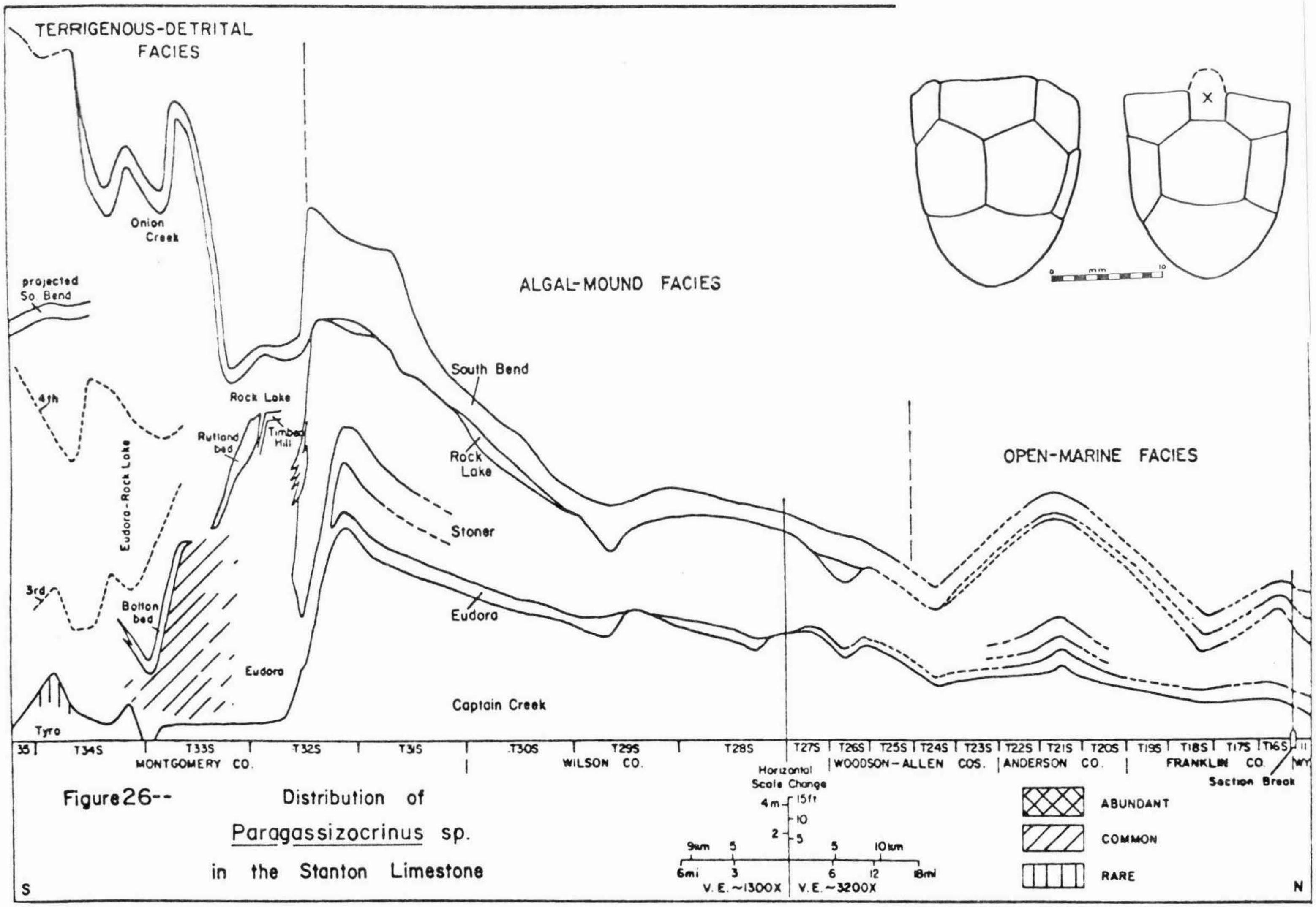

Figure 26-- Distribution of <u>Paragassizocrinus</u> sp. in the Stanton Limestone

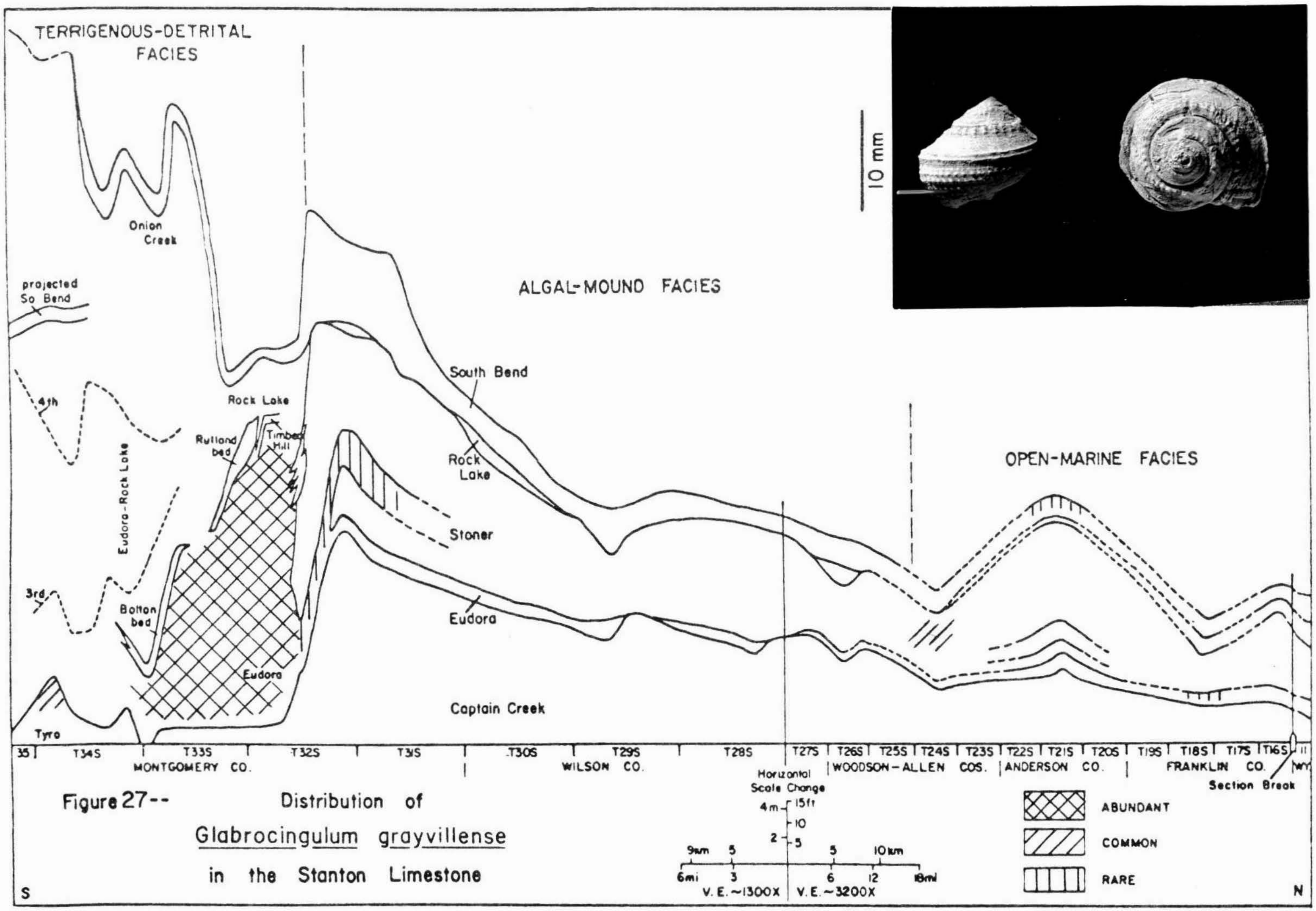

Figure 27-- Distribution of Glabrocingulum grayvillense in the Stanton Limestone

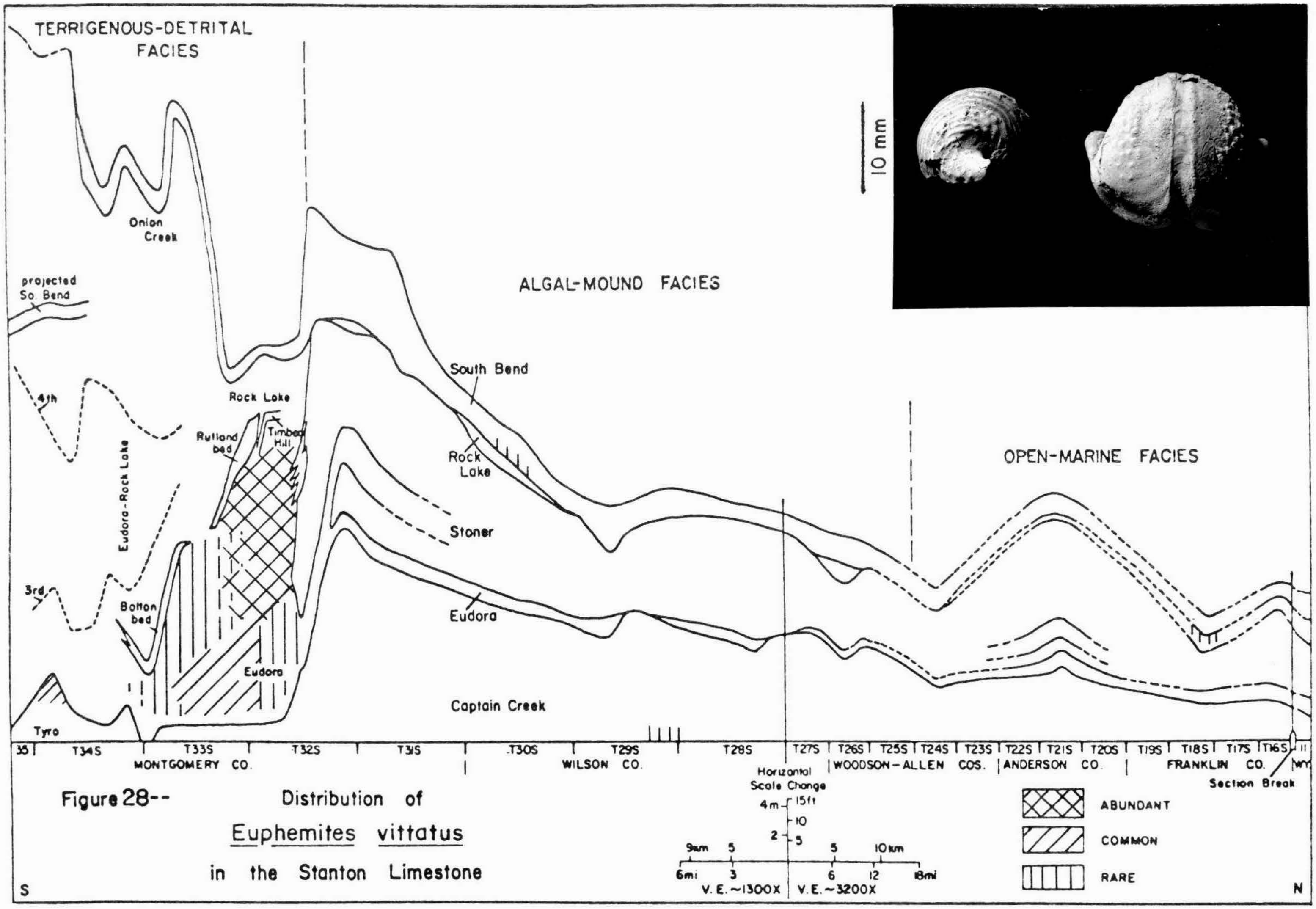

Figure 28-- Distribution of Euphemites vittatus in the Stanton Limestone

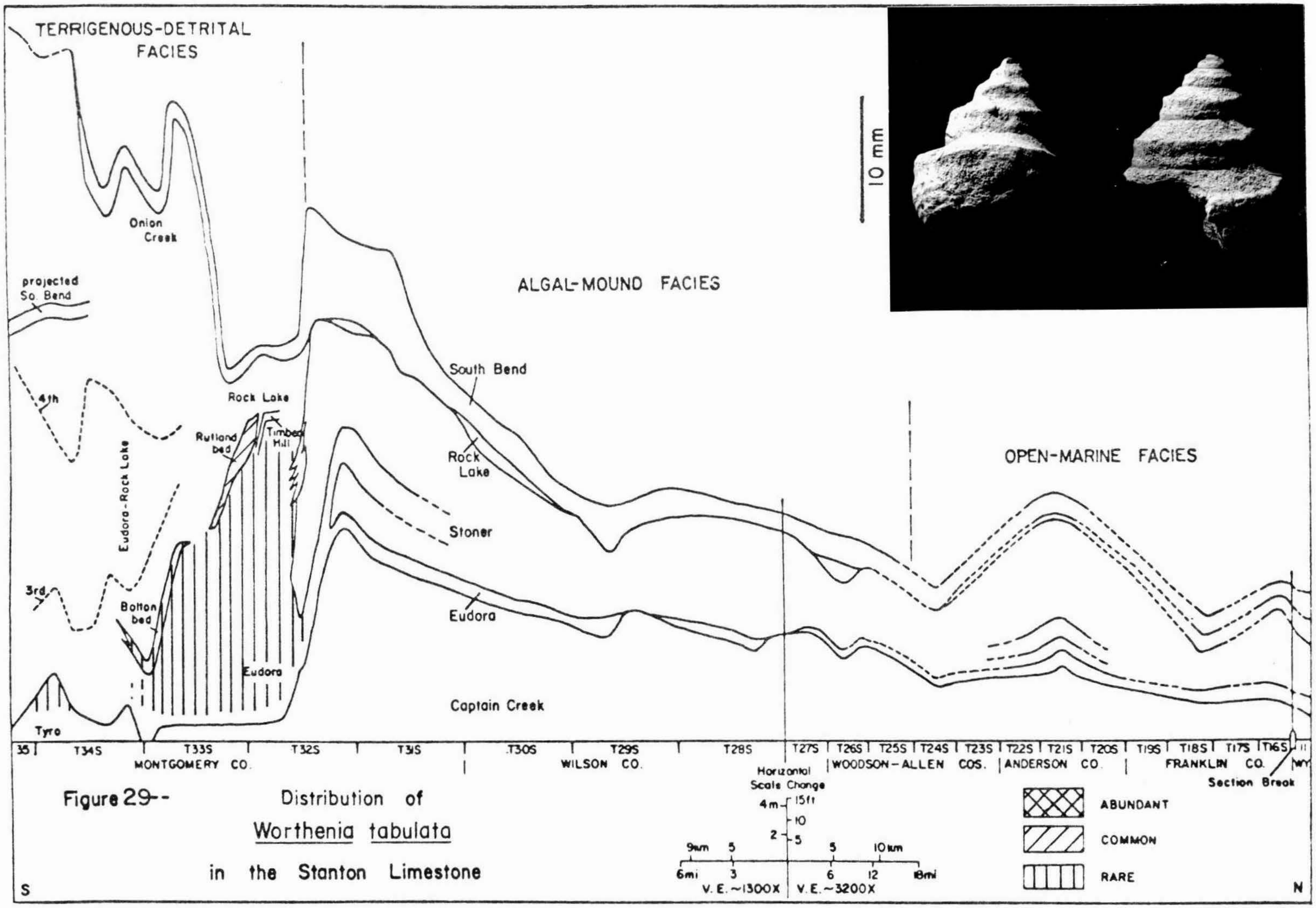

Figure 29-- Distribution of Worthenia tabulata in the Stanton Limestone

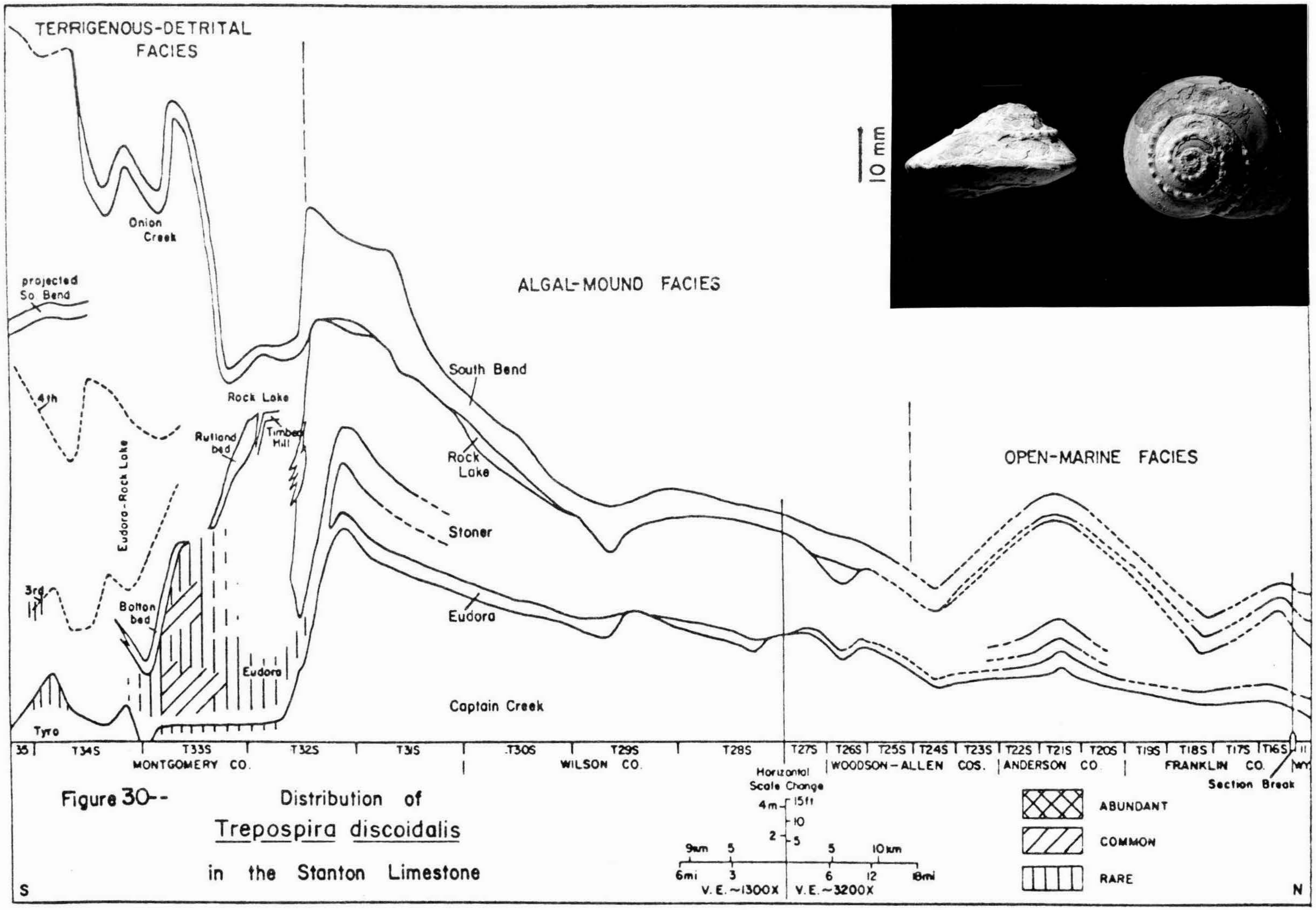

Figure 30-- Distribution of Treposipira discoidalis in the Stanton Limestone

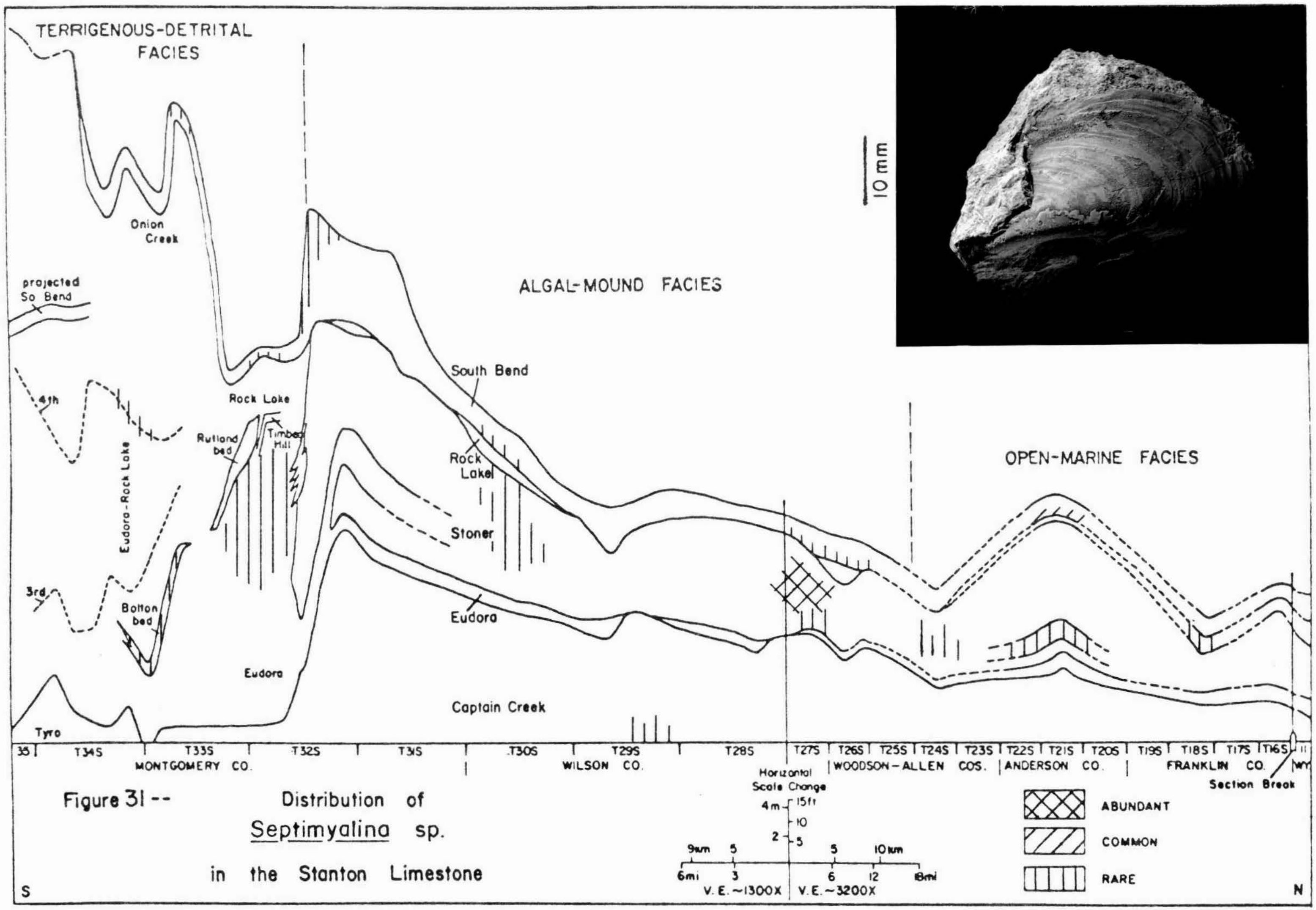

Figure 31 -- Distribution of Septimyalina sp. in the Stanton Limestone

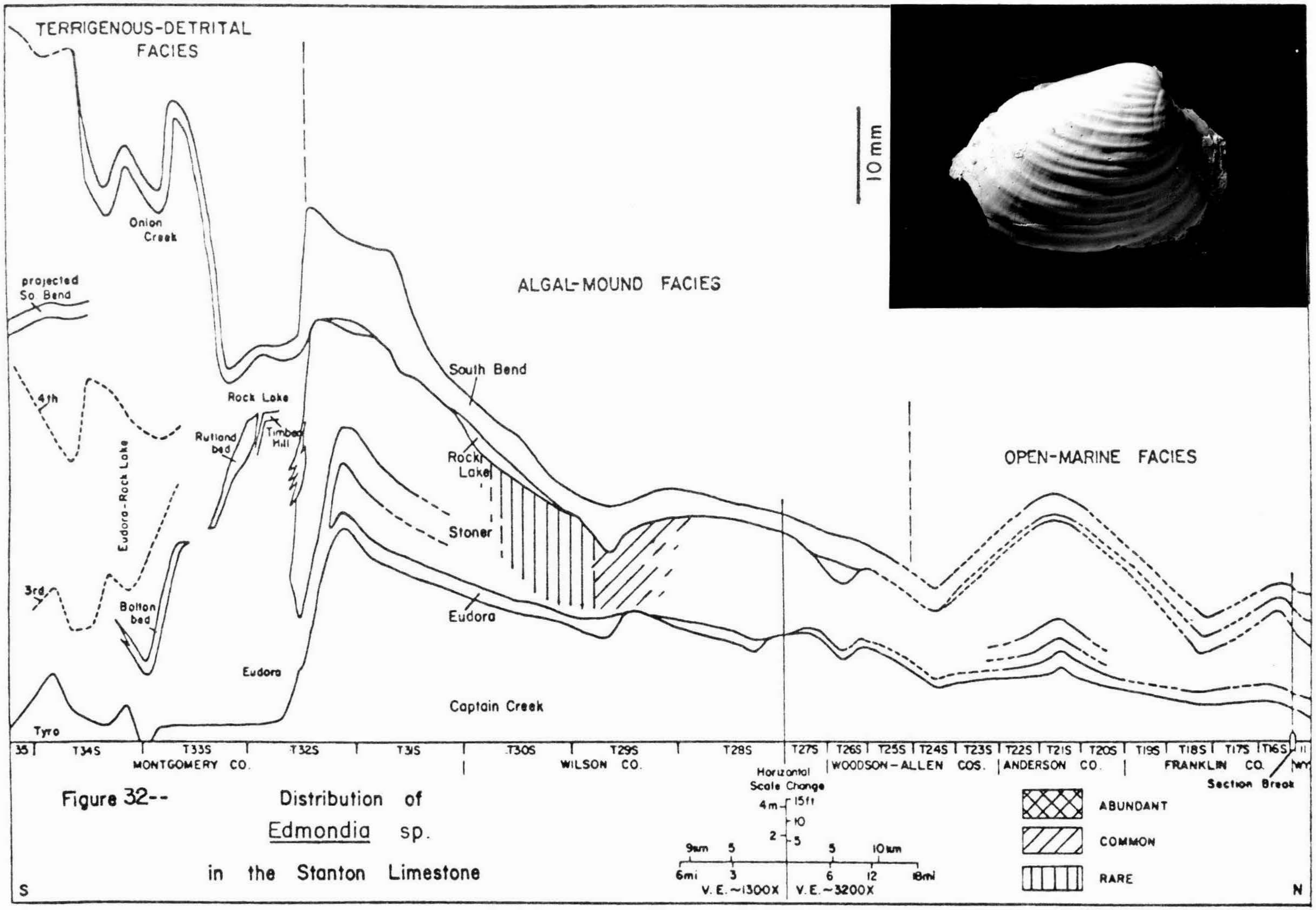

Figure 32-- Distribution of Edmondia sp. in the Stanton Limestone

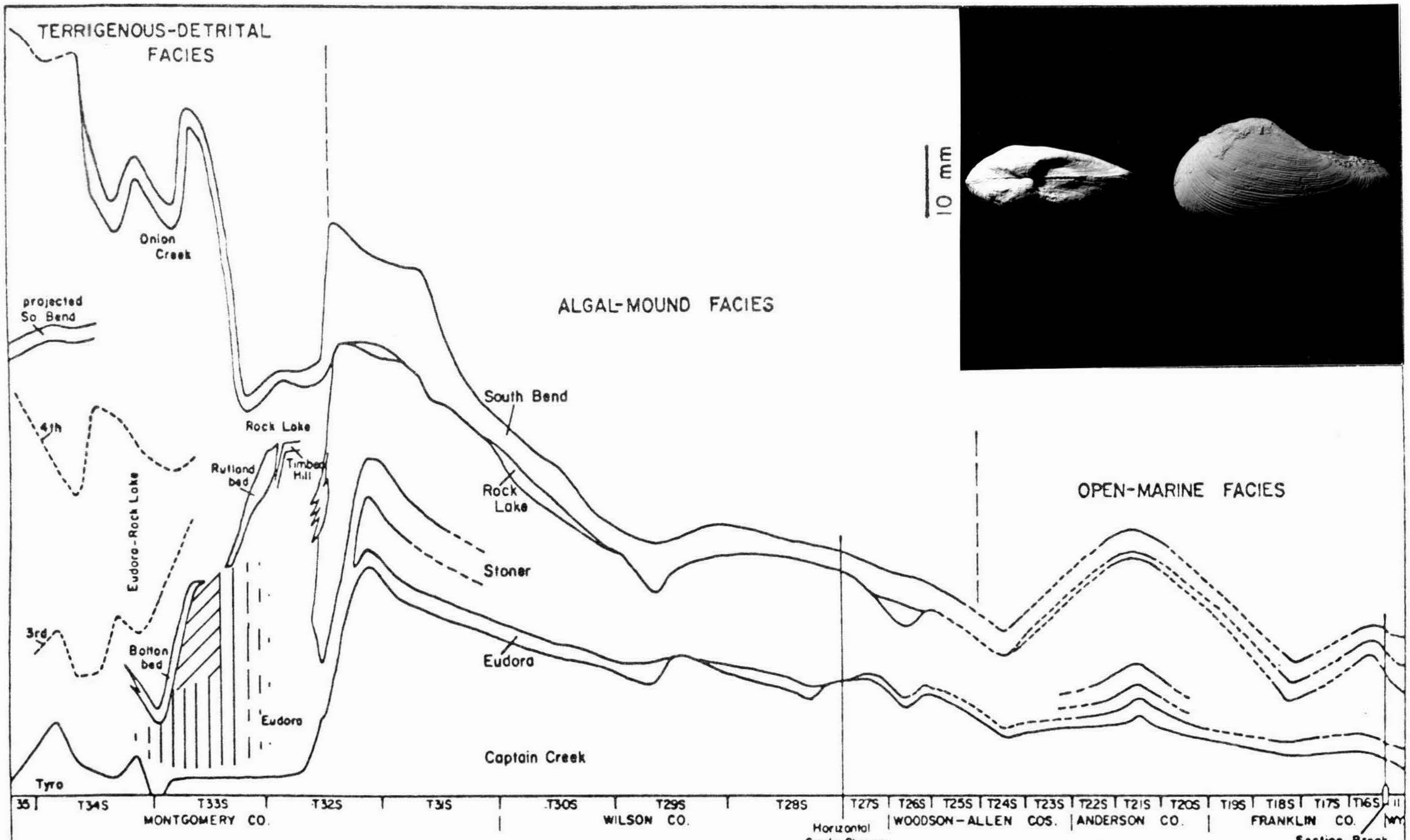

Figure 33-- Distribution of Phestia bellistriata in the Stanton Limestone

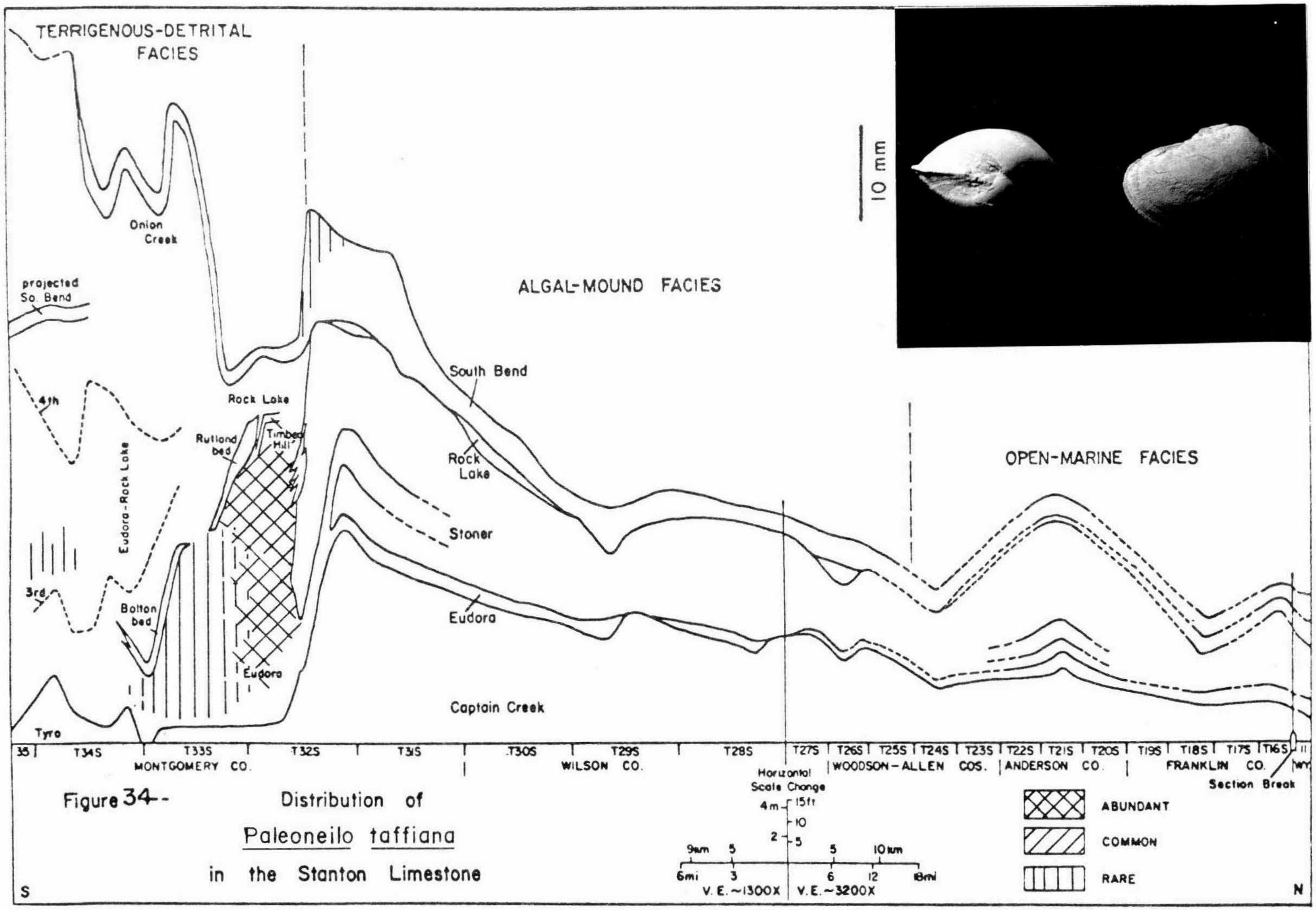

Figure 34-- Distribution of Paleoneilo taffiana in the Stanton Limestone

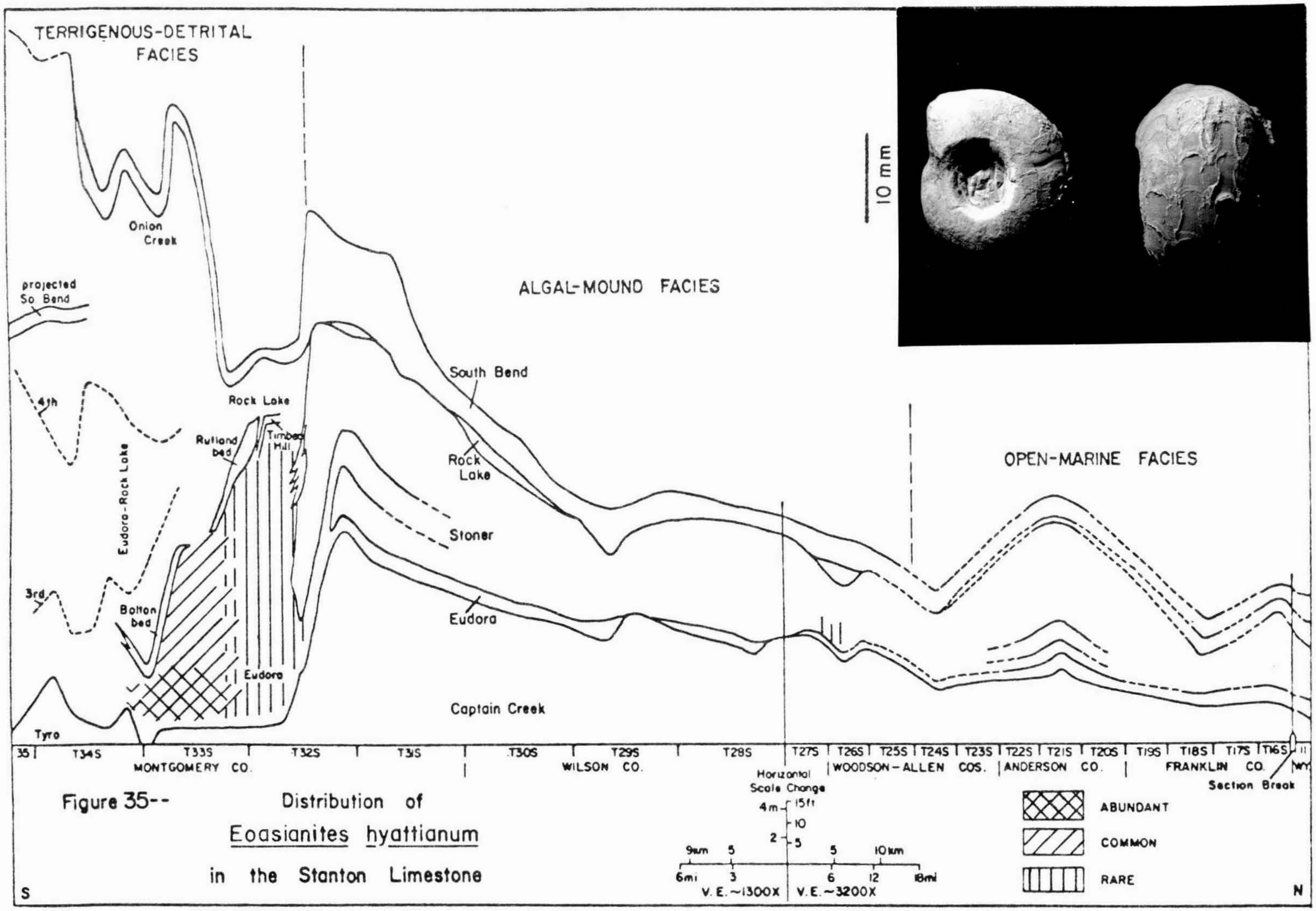

Figure 35-- Distribution of Eoasianites hyattianum in the Stanton Limestone

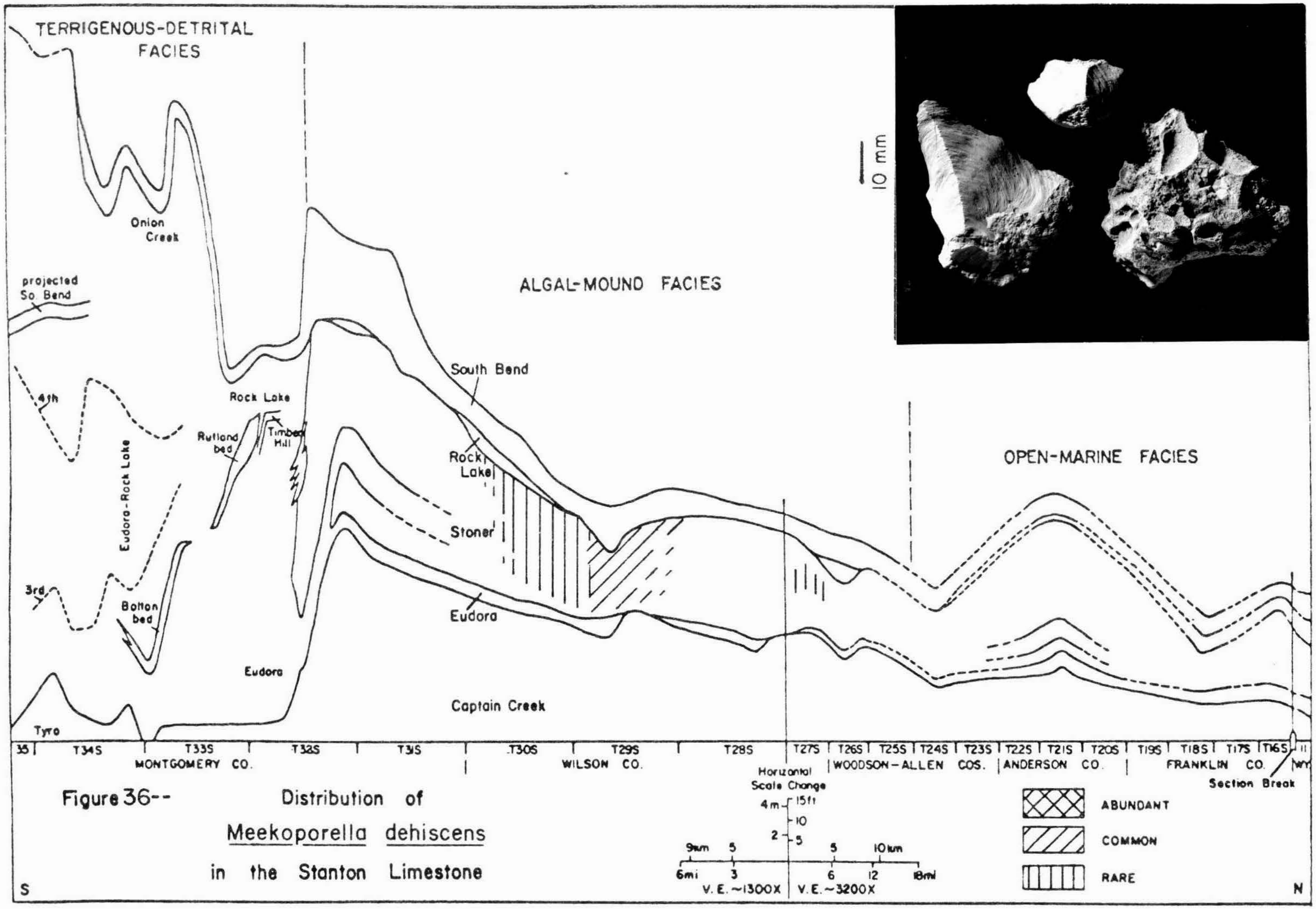

Figure 36-- Distribution of Meekoporella dehiscens in the Stanton Limestone

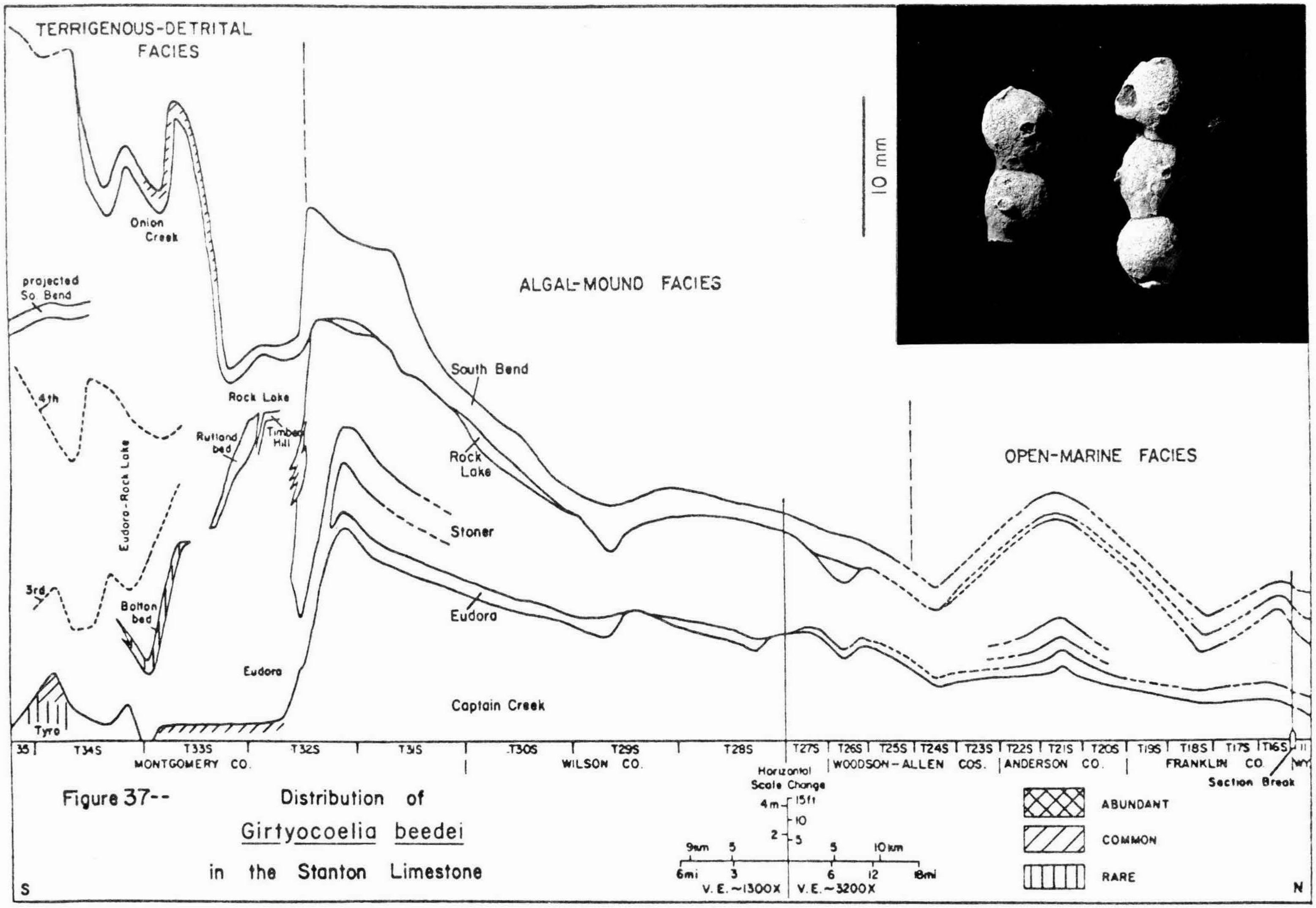

Figure 37-- Distribution of Girtyocoelia beedei in the Stanton Limestone

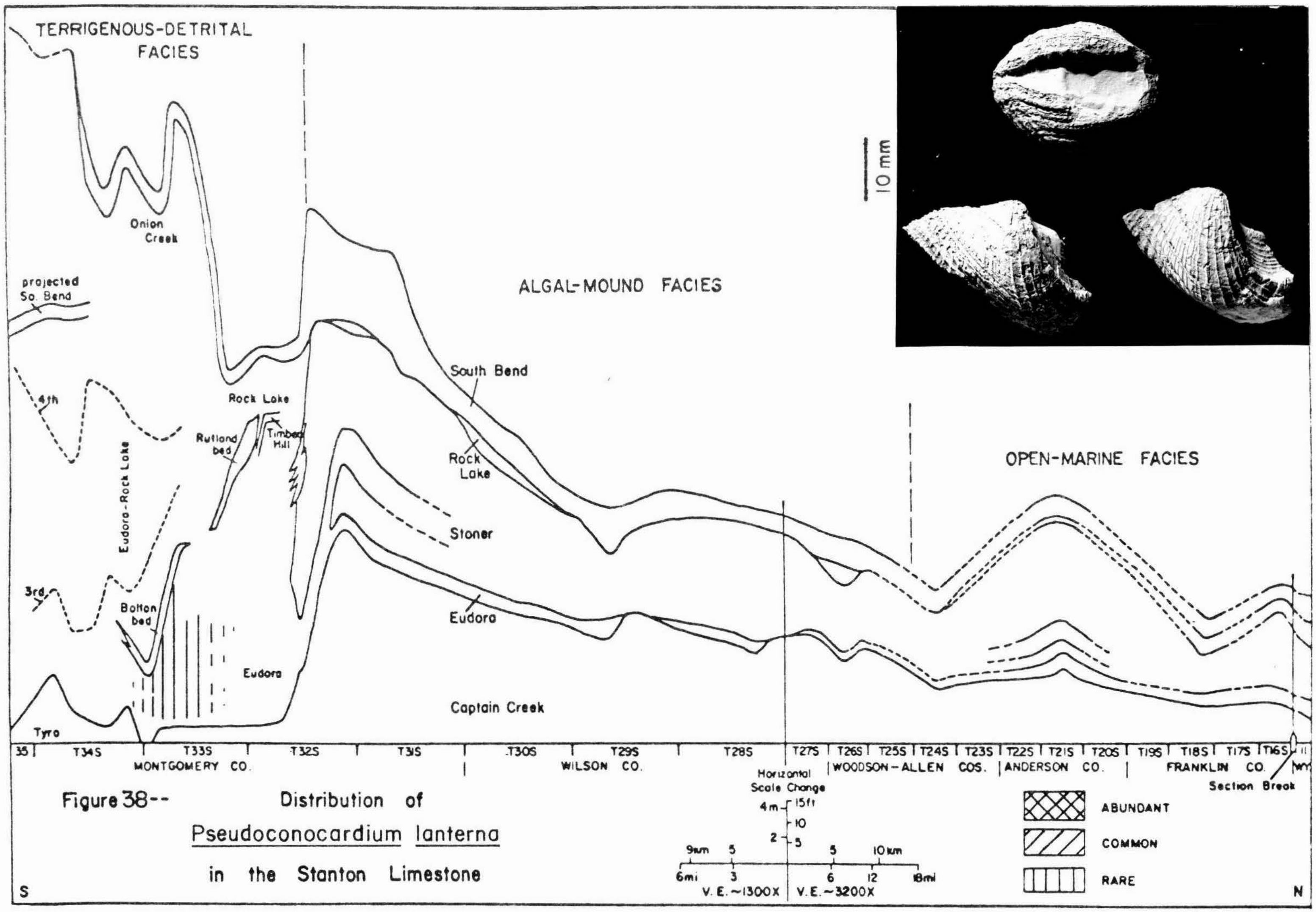

Figure 38-- Distribution of <u>Pseudoconocardium lanterna</u> in the Stanton Limestone

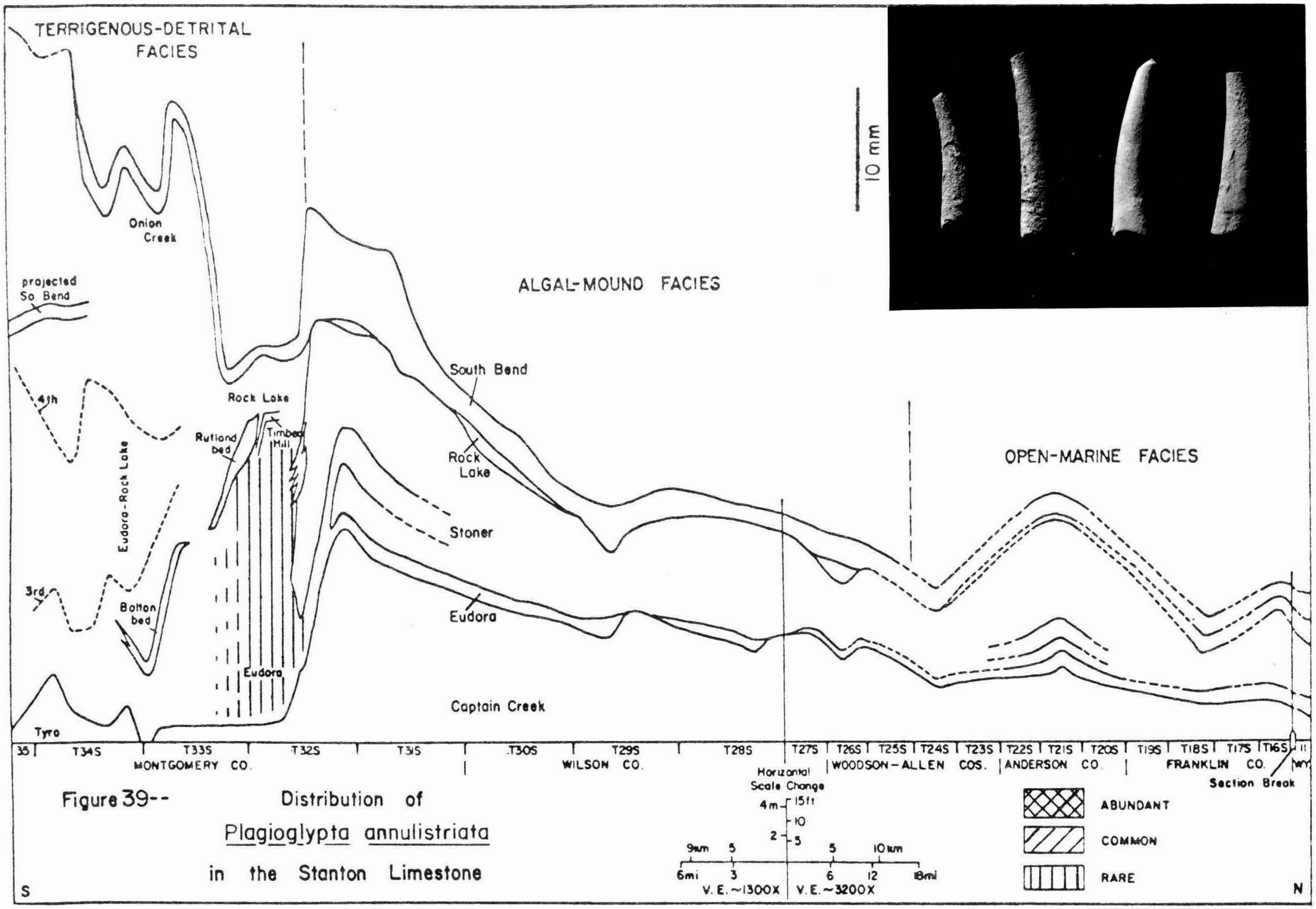

Figure 39-- Distribution of *Plagioglypta annulistriata* in the Stanton Limestone

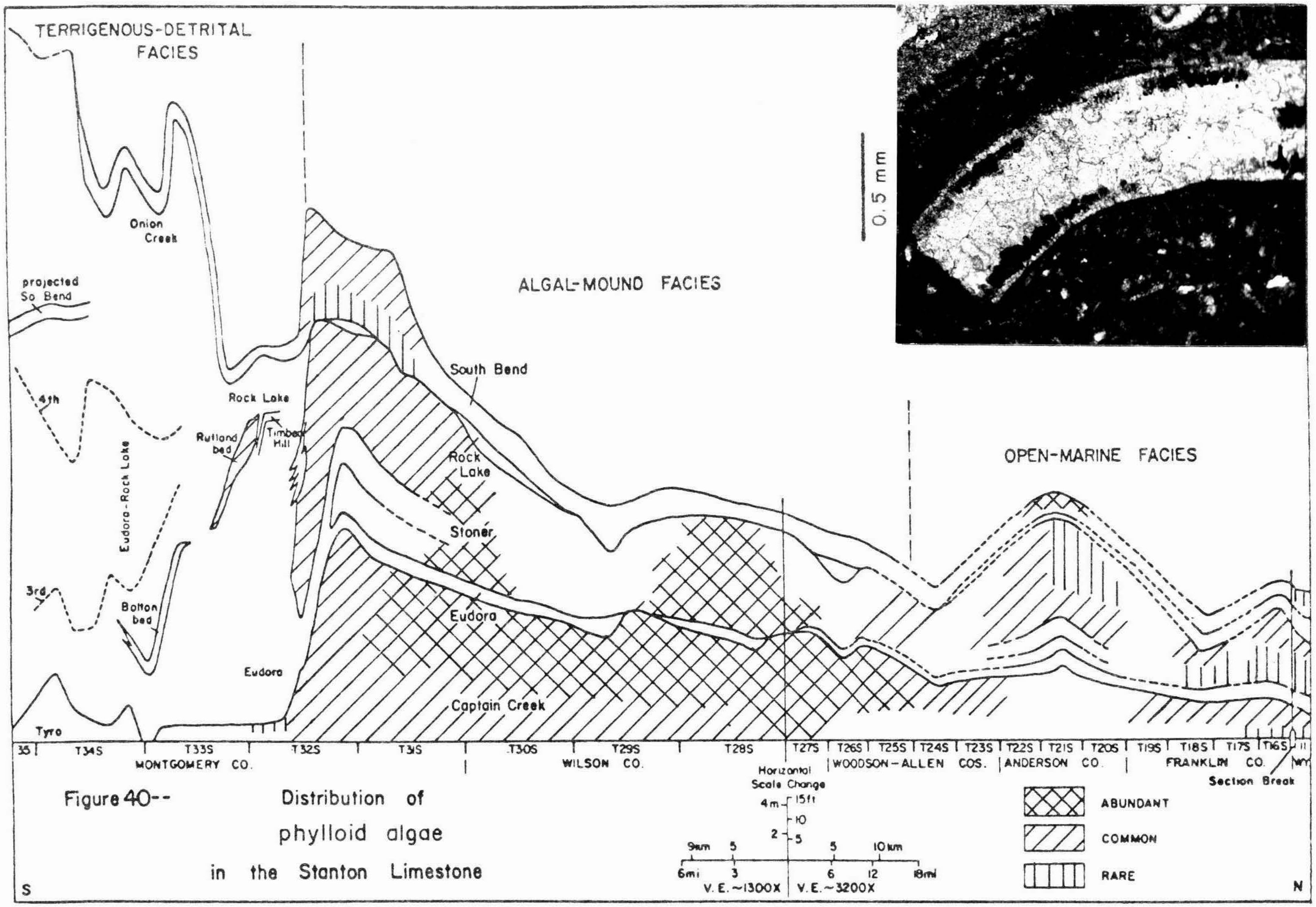

Figure 40-- Distribution of phylloid algae in the Stanton Limestone

APPENDIX C

LOCALITY REGISTER

APPENDIX C

LOCALITY REGISTER

Throughout the text and appendices, localities are indicated by a convenient code that is either a lettered abbreviation for a geographic reference (e. g. KTPK--Kansas Turnpike) or a shortened form of standard township and range notation (NWC 18 32 15--Northwest Corner, section 18). Accompanying some locality designations are additional number or letter codes that note specific stratigraphic collecting intervals or sample horizons. Letter codes "l", "m" or "h" following a locality designation are general references for "low", "middle" or "high" stratigraphic positions within a given unit, and codes "b" or "t" refer to "basal" or "top" portions of a member or bed. When a number code is used after a locality designation, successively higher numbers correspond to successively higher stratigraphic levels in the member or bed.

Localities in this appendix are arranged geographically from north to south, and within each major facies belt, in order of increasing township, section and range numbers. Vertical bars on Figure 41 illustrate stratigraphic and geographic relationships between localities, and are either closed (I) or open (⋮) to respectively indicate exact or approximate stratigraphic intervals for each locality.

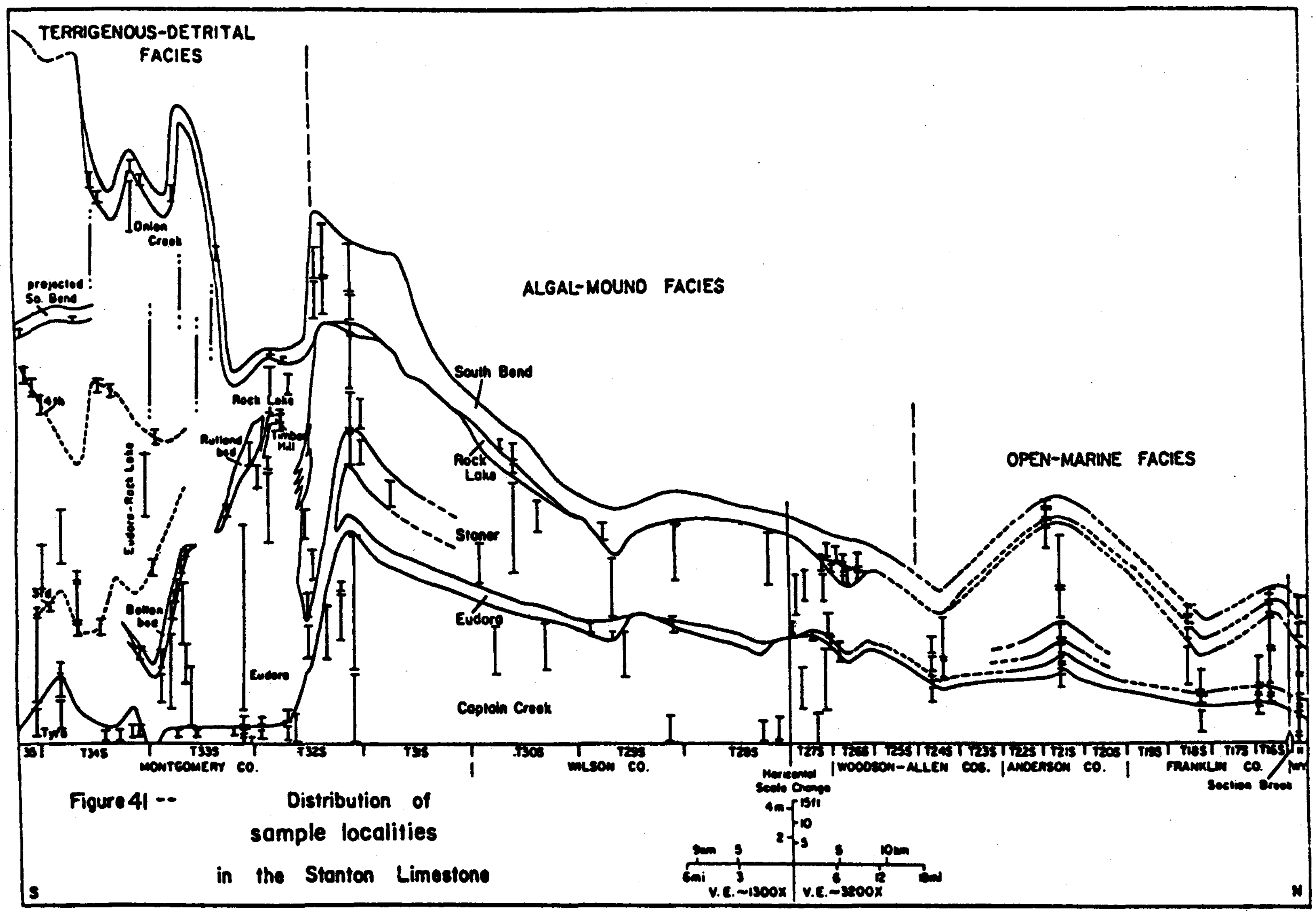

Figure 41 -- Distribution of sample localities in the Stanton Limestone

Localities

Open-Marine Facies Belt

KTPK--Kansas Turnpike

Section 18, T11S, R23E; road cut on north and south side of Kansas Turnpike, approximately 1.2 miles west of the Bonner Springs interchange; members: Captain Creek, Eudora, Stoner, Rock Lake, South Bend.

BS--Bullard School

NW¼, NW¼, NW¼, sec. 22, T16S, R20E; abandoned quarry and small streamcut ESE of old school building site; members: Eudora, Stoner, Rock Lake, South Bend.

EGS--Emory Green School

NE¼, SE¼, SE¼, sec. 27, T16S, R20E; small partially water-filled quarry and drainage gully WNW of former school site; members: upper Captain Creek, Eudora, lower Stoner.

NP--North of Princeton

SW¼, SW¼, SE¼, sec. 12, T18S, R19E; small roadcut and streamcut along north and south sides of paved county road NE of Princeton, Kansas; members: middle and upper Captain Creek, Eudora, lower and middle Stoner.

PQ's--Princeton Quarries

Inactive quarries on east and west sides of section line road south of Princeton, Kansas; east quarry--SW¼, SW¼, NW¼, sec. 24, T18S, R19E; west quarry--SE¼, SE¼, NE¼, sec. 23, T18S, R19E; members: upper Stoner, Rock Lake, South Bend.

MI--Mount Ida

NW¼, SE¼, NE¼, sec. 17, T21S, R19E; large streamcut in west bank of Cedar Creek, north and south of the Missouri-Pacific railroad tressle, approximately 1.5 miles (2.5 km) east of the settlement of Mount Ida, Kansas; members: uppermost Captain Creek, Eudora, lower and middle Stoner.

QWW--Quarry West of Welda

NE¼, NE¼, SE¼, sec. 32, T21S, R19E; active road aggregate quarry west of the settlement of Welda, Kansas; members: uppermost Stoner, Rock Lake, South Bend.

CBQ--Carl Beaty Quarry

SW¼, NW¼, NW¼, sec. 19, T24S, R18E; small inactive quarry owned by Mr. Carl Beaty; member: lower and middle Stoner.

1QSP--First Quarry South Piqua

SW¼, NW¼, SW¼, sec. 34, T24S, R17E; northernmost of two inactive, partially water-filled quarries south of the town of Piqua, Kansas; members: uppermost Captain Creek, Eudora, lower and middle Stoner.

Algal-Mound Facies Belt

CSL 12 26 16--Center of south line, section 12

SE¼, SE¼, SWP, sec. 12, T26S, R16E; roadditch on north and south sides of section line road; members: upper Rock Lake, lower South Bend.

SE SE 26 26 16

SE¼, SE¼, SE¼, sec 26, T26S, R16E; small streamcut in pasture, north of abandoned farm buildings; member: Rock Lake.

CSL 27 26 16--Center of south line, section 27

SW¼, SW¼, SE¼, sec. 27, T26S, R16E; small streamcut east of private driveway along north side of East Buffalo Creek; member: Rock Lake.

CSL SE 27 26 16--Center of south line of southeast quarter

SW¼, SW¼, SE¼, sec. 27, T26S R16E; roadditch along north side of section line road; member: lower South Bend.

NE NE SE 33 26 16

NE¼, NE¼, SE¼, sec. 33, T26S, R16E; poor exposure in stream bed on east and west sides of section line road member: lower South Bend.

NW NW SW 33 26 16

NW¼, NW¼, SW¼, sec. 33, T26S, R16E; bedding plane exposure in roadbed along section line, near small stream crossing; member: South Bend.

NL NE NE 33 26 16--North line of northeast quarter

NE¼, NE¼, NE¼, sec. 33, T26S, R16E; small ledge in east creek bank on north side of section line road at small low-water bridge; member: upper South Bend.

NW NE NW 34 26 16

NW¼, NE¼, NW¼, sec. 34, T26S, R16E; poor exposure in roadditch west of creek bridge on section line road; member: lower Rock Lake.

WL NWC 35 26 16--West line at northwest corner, section 35

NW¼, NW¼, NW¼, sec. 35, T26S, R16E; roadditch on east side of section line road; member: lower South Bend.

EEQ--East of Erickson's Quarry

NE¼, NW¼, sec. 3, T27S, R17E; small, rubbly roadditch exposure on north side of Woodson-Wilson County line road; member: lower Stoner.

EQ--Erickson's Quarry

SW¼, SW¼, sec. 5, T27S, R17E; inoperative quarry on south side of Woodson-Wilson County line road; presently owned by Mr. Gary Nelson, Chanute, Kansas; member: middle and upper Captain Creek (algal-mound lithofacies).

NBRC--North Buffalo Roadcut

SE¼, SE¼, sec 6, T27S, R16E; long roadcut on the east and west sides of U. S. Highway 75, north of town of Buffalo, Kansas; member: upper Stoner (rim lithofacies).

NW NE 9 27 16

SW¼, NW¼, NE¼, sec. 9, T27S, R16E; small, poor exposure in embankment of small stream; in pasture approximately ¼ mile south of section line road; member: Rock Lake.

JCT 75-39--Junction of U. S. Hwy 75 and Kansas Hwy 39

NE¼, SW¼, sec. 17, T27S, R16E; field and roadcut exposures on north side of highway junction; member: middle Captain Creek (algal-mound lithofacies).

WCSLS--Wilson County State Lake Spillway

SE¼, SW¼, sec. 17, T27S, R16E; large cut, east and west sides of state lake drainage channel; member: Captain Creek (algal-mound lithofacies).

NQEB--New Quarry East of Buffalo

NE¼, NE¼, sec. 22, T27S, R16E; large, inoperative, partially water-filled quarry; owned by Mr. Mel Carlson, Chanute, Kansas; members: uppermost Captain Creek, Eudora, lower and middle Stoner (algal-mound lithofacies).

RRSENQEB--Railroad Southeast of NQEB

NW¼, SW¼, sec. 36, T27S, R16E; long railroad cut along north and south sides of Atchison, Topeka and Santa Fe railway; members: upper Captain Creek, Eudora (covered), lower Stoner (algal-mound lithofacies).

NW SW 24 27 15

NW¼, SW¼, sec. 24, T27S, R15E; bedding plane road-ditch exposures along east side of Kansas Highway 39; member: middle Stoner (rim lithofacies).

DQSR--Doyle's Quarry South of Roper

SW¼, SE¼, sec. 35, T27S, R15E; small, inoperative water-filled quarry approximately 100 meters east of Kansas Highway 39; owned by the Doyle family, Roper, Kansas; member: middle Stoner (rim lithofacies).

WSL 6 28 17--West on South Line, section 6

SE¼, SW¼, sec. 6, T28S, R17E; small roadcut near west end of the south section line road; members: Benedict bed, lower Captain Creek (algal-mound lithofacies).

CWL 6 28 17--Center of West Line, section 6

NE¼, SE¼, sec. 1, T28S, R16E; small roadcut on west side of road and outcrop in field approximately 100 meters west of roadcut; members: Benedict bed, lower Captain Creek.

BB--Benedict Bridge

NE¼, NE¼, sec. 16, T28S, R15E; bedding plane exposures along river banks and in bed of Verdigris River (at low-water ford southwest of town of Benedict, Kansas); member: upper Stoner (rim lithofacies), Rock Lake (poorly exposed).

CSL 9 29 15--Center of South Line, section 9

SW¼, SW¼, SE¼, sec. 9, T29S, R15E; roadcut on south side of Kansas Highway 47; member: upper Stoner (algal-mound lithofacies).

CSL 10 29 15--Center of South Line, section 10

SE¼, SE¼, SW¼, sec. 10, T29S, R15E; roadcut on north side of Kansas Highway 47; member: lower Captain Creek (algal-mound lithofacies).

NEC 14 29 15--Northeast Corner, section 14

NE¼, NE¼, NE¼, sec. 14, T29S, R15E; outcrop along hillside on south side of Kansas Highway 47; member: upper Eudora.

ACS-ACN--Altoona Cut South-Altoona Cut North

Long roadcut exposure on north and south sides of Kansas Highway 47 near the center of the north line, sec. 18, T29S, R15E; members: uppermost Captain Creek, Eudora, Stoner (channel lithofacies).

QNWC 23 29 15--Quarry in Northwest Corner, section 23

NW¼, NW¼, NW¼, sec. 23, T29S, R15E; large inoperative partially water-filled quarry; member: middle and upper Captain Creek (algal-mound lithofacies).

QEWW--Quarry East of the Water Works

SE¼, SE¼, sec. 14, T29S, R14E; abandoned quarry operation east of Fredonia town water works; presently being used as a sanitary landfill; member: upper Stoner (channel lithofacies).

FNW--Fredonia Northwest

NE¼, SW¼, NE¼, sec. 24, T29S, R14E; inactive northwest wall of the Fredonia Cement Plant quarry; only remotely accessible due to construction of new crusher; type section of Newell's (1933) "Fredonia facies"; members: middle and upper Stoner, Rock Lake (covered), lower South Bend (channel lithofacies).

QCSL 7 30 15--Quarry near Center of South Line, section 15

SE¼, SW¼, sec. 7, T30S, R15E; inoperative quarry in pasture near south center of section 7, approximately 300 meters north of section line road; owned by Mr. Bill Graff, Neodesha, Kansas; member: middle and upper Captain Creek (algal-mound lithofacies).

CSL 22 30 15--Center of South Line, section 22

SW¼, SE¼, sec. 22, T30S, R15E; long roadcut on north and south sides of Kansas Highway 96, 5.5 km west of Neodesha; members: middle and upper Captain Creek, Eudora (covered), lower Stoner (algal-mound lithofacies).

SWC 22 30 15--Southwest Corner, section 22

SW¼, SW¼, SW¼, sec 22, T30S, R15E; small roadcut at corner of Kansas Highway 96 and north-south section line road; member: lower South Bend.

QSEC 25 30 14--Quarry in Southeast Corner, section 25

SE¼, SE¼, SE¼, sec. 25, T30S, R14E; small, abandoned quarry in pasture, just north of section line road; member: lower Stoner (algal-mound lithofacies).

RC--Racket Creek

SE¼, NE¼, NW¼, sec. 1, T32S, R14E; small roadside outcrop at crest of hill on west side of paved county road; member: lower Stoner shale.

NW NW 1 32 14

NW¼, NW¼, NW¼, sec. 1, T32S, R14E; small exposure along dismantled and abandoned Atchison, Topeka and Santa Fe railroad right of way; member: lower Stoner shale and middle Stoner algal-mound lithofacies.

ECR--Elk City Roadcut

SW¼, NE¼, sec. 7, T32S, R15E; nearly complete Stanton section in long roadcut west of the Elk City Dam; members: Captain Creek, Eudora (covered), Stoner, Rock Lake, South Bend (algal-mound lithofacies).

TMQ--Table Mound Quarry

SE¼, SE¼, sec. 9, T32S, R15E; inoperative quarry on northeast prong of Table Mound, east of the Elk City Dam and reservoir; member: middle and upper Captain Creek (algal-mound lithofacies).

TQ--Tarantula Quarry

SE¼, SE¼, NW¼, sec. 16, T32S, R15E; abandoned and partially water-filled quarry, approximately 500 meters west of paved road on southwest side of Table Mound; member: middle and upper Captain Creek (algal-mound lithofacies).

QSC 16 32 14--Quarry in South-Center, section 16

NE¼, SW¼, SE¼, sec. 16, T32S, R14E; small inoperative quarry at end of unimproved access road, approximately 200-300 meters southeast of farm buildings; member: upper Stoner (algal-mound lithofacies).

H160Q--U. S. Highway 160 Quarry

NE¼, NE¼, SW¼, sec. 17, T32S, R14E; inoperative quarry on west side of Highway 160; quarry exposes transition from algal-mound lithofacies (north wall) to off-mound non-algal carbonate lithofacies (south wall); members; uppermost Stoner, Rock Lake South Bend.

NW NW 18 32 15

NW¼, NW¼, NW¼, sec. 18, T32S, R15E; small stock pond exposure in pasture; accessible from north on unimproved road that junctions with paved county road approximately 200 meters west of Locality ECR; member: lower and middle Stoner (including Stoner shale bed).

NE 23 32 14

NE¼, sec. 23, T32S, R14E; scattered lithologic blocks in poor intermittent exposure throughout pasture northeast of Timber Hill and along the west side of the Elk City reservoir; members: Captain Creek, Eudora (cov.), Stoner.

CCRA--Card Creek Recreation Area

SW¼, NW¼, sec. 23, T32S, R14E; poor, intermittent hillside outcrop on west side of north prong of Timber Hill, immediately south of Card Creek Recreation Area campgrounds along unused access road; members: Catpain Creek, Eudora (covered), Stoner (algal-mound lithofacies).

Terrigenous-Detrital Facies Belt

CWL NW 25 32 14--Center of West Line, Northwest quarter

SW¼, NW¼, NW¼, sec 25, T32S, R14E; roadcut along paved accuss road to Card Creek Recreation area; east side of Timber Hill; members: uppermost Eudora, Timber Hill siltstone, Rock Lake, South Bend.

SE SW SE 28 32 14

SE¼, SW¼, SE¼, sec. 28, T32S, R14E; small roadcut on north and south sides of U. S. Highway 160; members: Onion Creek sandstone, lower South Bend.

Coon Creek

SE¼, SE¼, SE¼, sec. 28, T32S, R14E; outcrop in drainage ravine of Coon Creek, immediately north of U. S. Highway 160; members: Timber Hill siltstone, Rock Lake, Onion Creek sandstone, lower South Bend.

NEC 34 32 14--Northeast Corner, section 34

NE¼, NE¼, NE¼, sec. 34, T32S, R14E; roadcut along north and south side of U. S. Highway 160, approximately 100 meters east of prominent ravine crossing highway, and approximately 2 km west of Card Creek Recreation area turn-off; member: South Bend.

SCEL 35 32 14--South of Center on East Line, section 35

SE¼, NE¼, SE¼, sec. 35, T32S, R14E; small roadditch outcrop along west side of section line road; members: Eudora, Timber Hill siltstone.

WL NWC 36 32 14--West Line in Northwest Corner, section 36

NW¼, NW¼, NW¼, sec. 36, T32S, R14E; exposure on west side of access road to Card Creek Recreation area, south-east side of Timber Hill; roadcut also extends northward along west line in southwest corner, section 25; members: Timber Hill siltstone, Rock Lake, lower South Bend.

Loc. 14a--Locality 14a (of Heckel, 1975a)

SE¼, NE¼, NW¼, sec. 36, T32S, R14E; small, rubbly exposure in roadditch on north side of U. S. Highway 160; member: uppermost Captain Creek.

SBHM-398--Shale Bank at Highway Marker 398

Center of SW¼, NW¼, NW¼, sec. 36, T32S, R14E; large roadcut exposure on north and south sides of U. S. Highway 160, immediately west of Card Creek Recreation area turn-off; members: Upper Eudora (including Stoner equivalent shales), Timber Hill siltstone, Rock Lake, ?lower South Bend (covered at top of roadcut).

SE NW 1 33 14

SE¼, NW¼, sec. 1, T33S, R14E; small streamcut in gully south of section line road; west of Highland Center Cemetery; member: uppermost Captain Creek.

RB_t--Rutland bed type section

NE¼, NE¼, NE¼, sec. 2, T33S, R14E; ledges exposed in small abandoned quarry operation south and southeast of farmhouse on west side of section line road, and on east side of section road in small stock pond; member: Rutland bed.

WM--Walker Mound

NW¼, NE¼, NE¼, sec. 5, T33S, R15E; roadditch exposure on south side of section line road, northeast flank of Walker Mound; exposure begins 20-30 meters east of farmhouse driveway; members: Captain Creek, lower Eudora.

WM-west--Walker Mound west

NE¼, NW¼, NE¼, sec. 5, T33S, R15E; hillside outcrop in gully on west flank of Walker Mound; members: upper Eudora, Timber Hill siltstone.

GP--Gay's Pond

SE¼, NW¼, NE¼, sec. 7, T33S, R15E; small, rubbly exposure around oil field waste pond in Bill Gay's pasture; members: middle Captain Creek (shale), Eudora (cov.).

SW SE SW 7 33 15

SW¼, SE¼, SW¼, sec. 7, T33S, R15E; roadditch and streambed outcrop on north side of section line road; member: upper Captain Creek.

ESL 5 33 14--East on South Line, section 5

SW¼, SE¼, SE¼, sec. 5 T33S, R14E; small, poor roadditch outcrop along north side of section line road; member: lower Captain Creek.

NEC 12 33 14--Northeast Corner, section 12

NE¼, NE¼, NE¼, sec. 12, T33S, R14E; poor outcrop in field at crest of hill, southwest of farmhouse; member: Rutland bed.

WNL 14 33 14--West on North Line, section 14

NE¼, NE¼, NW¼, sec. 14, T33S, R14E; roadditch exposure on north and south sides of section line road; member: upper South Bend.

PHF--Patterson's Hog Farm

NE¼, NE¼, NE¼, sec. 23, T33S, R14E; dredged shale and limestone blocks around stock pond in hog pen approximately 300 meters west of Thurman Patterson's farmhouse; member: middle and upper Captain Creek.

PGS--Patterson's Ground Silo

NE¼, NW¼, NW¼, sec. 24, T33S, R14E; outcrop in walls of old ground silo located approximately 200 meters SSW of Patterson's farmhouse; member: upper Eudora.

NW NW 23 33 14

NW¼, NW¼, sec. 23, T33S, R14E; small outcrop in stream bank, east of bridge crossing section line road; member: Bolton bed.

CSPHF--Creek South of Patterson's Hog Farm

NW¼, NW¼, sec. 24, T33S, R14E; outcrop in streambed and banks of Onion Creek, east side of section line road; member: upper Captain Creek.

SE SW NW 24 33 14

SE¼, SW¼, NW¼, sec. 24, T33S, R14E; outcrop in east facing hillside, approximately 200-300 meters NW of abandoned farm buildings; members: middle and upper Eudora, Bolton bed.

RF and RFG--Rollin's Farm and Rollin's Farm Gate

SE¼, SE¼, SW¼, sec. 24, T33S, R14E; outcrop along driveway and continuing up adjacent hillside; at the east gate of Rollin's farm; members: upper Eudora, Bolton bed, lower Rock Lake.

SEC NW SW 25 33 14--Southeast Corner, NW SW, section 25

SE¼, NW¼, SW¼, sec. 25, T33S, R14E; small outcrop in ditch on south side of Atchison, Topeka and Santa Fe railroad tracks; member: upper Captain Creek.

NWL 25 33 14--North on West Line, section 25

NW¼, NW¼, NW¼, sec. 25, T33S, R14E; dredged blocks brought up in east roadditch along section line road; member: Bolton bed.

RFP--Rollin's Farm Pond

SW¼, NW¼, NW¼, sec. 25, T33S, R14E; dredged shale around small stock pond near west gate of Rollin's farm; member: upper Eudora.

SE SW 25 33 14

SE¼, SE¼, SW¼, sec. 25, T33S, R14E; small roadditch exposure along north side of section line road; member: Bolton bed.

NW SE 27 33 14

SW¼, NW¼, SE¼, sec. 27, T33S, R14E; roadditch exposure along south side of abandoned access road; members: Onion Creek sandstone, lower South Bend.

BH--Brook's Hill

SW¼, SW¼, SW¼, sec. 31, T33S R15E; small hillside outcrop at extreme SW corner of section, west of the Brook's family farmhouse; members: upper Eudora, Bolton bed.

NE NE 35 33 14

SW¼, NE¼, NE¼, sec. 35, T33S, R14E; intermittent limestone horizons cropping out along small, grassy hillside; members: 3rd oolitic and 4th oolitic horizons.

TB--Type Bolton bed

NW¼, NW¼, sec. 36, T33S, R14E; outcrop along south side of Atchison, Topeka and Santa Fe railroad right of way; member: Bolton bed.

SEC 1 34 14--Southeast Corner, section 1

SE¼, SE¼, SE¼, sec. 1, T34S, R14E; small roadditch exposure along west side of section line road; member: 3rd oolitic horizon.

SCWL 4 34 14--South of Center on West Line, section 4

NW¼, NW¼, SW¼, sec. 4, T34S, R14E; roadditch exposure on south side of U. S. Highway 75 at section line road intersection; member: South Bend.

75 SB--U. S. Highway 75 Shale Bank

NE¼, SE¼, sec. 5, T34S, R14E; small outcrop in roadditch and in small embankment on south side of U. S. Highway 75; members: Rock Lake, lower South Bend.

NE SW 6 34 15

NE¼, SW¼, sec. 6, T34S, R15E; small roadditch exposure along north side of section line road in southern half of section 6; member: upper Eudora.

CWL NW 6 34 15--Center of West Line, NW, section 6

NW¼, NW¼, SW¼, sec. 6, T34S, R15E; outcrop in small embankment on east side of paved secondary road, at crest of small southward rise in road; members: upper Eudora, Bolton bed.

CSBH--Creek South of Brook's Hill

NW¼, NW¼ SW¼, sec. 6, T34S, R15E; outcrop in bed of small creek, east side of pave section line road; member: Tyro oolite.

<u>HWJ</u>--Hill West of Jefferson

NE¼, NE¼, NE¼, sec. 7, T34S, R15E; outcrop at crest of larg hill at corner of section line road, due west of settlement of Jefferson, Kansas; member: Tyro oolite.

<u>RM</u>--Round Mound

SE¼, SE¼, SE¼, sec. 8 T34S, R14E; dredged blocks in roadditch along east side of section line road, southeast of Round Mound; member: upper South Bend.

<u>NWC 12 34 14</u>--Northwest Corner, section 12

NW¼, NW¼, NW¼, sec. 12, T34S, R14E; limestone blocks dredged up in excavation of small stock pond; member: 4th oolitic horizon.

<u>NEC 14 34 14</u>--Northeast Corner, section 14

NE¼, NE¼, NE¼, sec. 14, T34S, R14E; dredged bolcks in roadditch on south side of section line road, east of small stock pond; member: 3rd oolitic horizon.

<u>HL</u>--Havana Lake

SE¼, NW¼, SE¼, sec. 18, T34S, R14E; series of outcrop ledges in open pasture north of Havana Lake residential area; member: lower South Bend.

<u>FCC</u>--Fawn Creek Cemetery

NW¼, SE¼, SE¼, sec. 19, T34S, R15E; small outcrop in hillside west of farmhouse, north of Fawn Creek Cemetery; member: Tyro oolite.

<u>NWC 20 34 14</u>--Northwest Corner, section 20

NW¼, NW¼, NW¼, sec. 20, T34S, R14E; small, rubbly ledges outcropping around stock pond and in roadditches at intersection of section line roads; members: 4th oolitic horizon, Rock Lake (covered), lower South Bend.

<u>CWL 23 34 14</u>--Center of West Line, section 23

NW¼, NW¼, SW¼, sec. 23, T34S, R14E; small roadside outcrop along east side of section line road; member: 3rd oolitic horizon.

SWC 23 34 14--Southwest Corner, section 23

SW¼, SW¼, SW¼, sec. 23, T34S, R14E; outcrop in hillside and roadditch at the intersection of section line roads in extreme southwest corner of section; members: 3rd oolitic horizon, Rock Lake.

SWC 24 34 13--Southwest Corner, section 24

SW¼, SW¼, SW¼, sec. 24, T34S, R13; large blocks exposed in streambed and in field, northeast corner of intersection of U. S. Highway 166 and county blacktop; member: lower South Bend.

SCWL 28 34 14--South of Center on West Line, section 28

SW¼, NW¼, SW¼, sec. 28, T34S, R14E; large outcrop of massive sandstone overlying shale along east and west sides of section line road, immediately north of farm driveway; member: Rock Lake.

NWC 30 34 15--Northwest Corner, section 30

NW¼, NW¼, NW¼, sec. 30, T34S, R15E; small, rubbly exposure approcimately 20-30 meters south of section line road along the east side of county blacktop; member: Rock Lake, 4th oolitic horizon.

TyQ and TyQ-u--Tyro Quarry and Tyro Quarry-upper zone

NW¼, SW¼, SE¼, sec. 30, T34S, R15E; large abandoned gravel and aggregate quarry designated by Heckel (1975a) as the type section for the Tyro oolite; richly fossiliferous upper zone of Tyro exposed in extreme northeast part of quarry in bedding planes; members: Tyro oolite, Eudora, Rock Lake.

SP--Stoney Point

SE¼, SE¼, sec. 30 T34S, R15E; prominent outcropping ledge at 950' contour level around NE side of Stoney Point hillside; member: Tyro oolite, Eudora (covered).

NEC 34 34 14--Northeast Corner, section 34

NE¼, NE¼, NE¼, sec. 34, T34S, R14E; small, poor roadditch exposure along west side of section line road; member: 3rd oolitic horizon.

NW NW 34 34 14

NW¼, NW¼, sec. 34, T34S, R14E; outcrop along small, wooded ravine approximately 100 meters ESE of farm buildings; member: 3rd oolitic horizon.

HR and HR-n--Hafer Run and Hafer Run-north

SE¼, SE¼, NE¼, sec. 4, T35S, R14E; streambed and streambank outcrops along short course of Hafer Run; approximately 300-400 meters west of small roadside park on U. S. Highway 166 west of settlement of Tyro, Kansas; members: Tyro oolite, Eudora, 3rd oolitic horizon, Rock Lake.

ESL 6 35 14--East on South Line, section 6

SE¼, SW¼, SE¼, sec. 6, T35S, R14E; small roadditch exposure of bedding plane surfaces on north side of U. S. Highway 166; member: 4th oolitic horizon.

ECNE 7 35 15--East Corner of Northeast Quarter

NE¼, NE¼, NE¼, sec. 7 T35S, R15E; small, rubbly roadditch outcrop along north side of unimproved oil field access road; member: Tyro oolite.

CNW 8 35 15--Center of Northwest Quarter, section 8

NE¼, NW¼, NW¼, sec. 8, T35S, R15E; exposure in roadbed and in adjacent ditches on north and south sides of section line road; members; Tyro oolite, ?Eudora.

NW NE SE 12 35 14

NW¼, NE¼, SE¼, sec. 12, T35S, R14E; small, continuous outcropping roadside ledges along east and west sides of paved county road, at crest of small rise in road; approximately 2 km south of Tyro, Kansas; member: 4th oolitic horizon.

ESL 15 35 14--East on South Line, section 15

SE¼, SE¼, sec. 15, T35S, R14E; dredged blocks brought up in ditches around small gas pipeline gauging station on north side of section line road; member: Tyro oolite.

CP--Carter's Pond

SE¼, NW¼, SE¼, sec. 16, T35S, R14E; large, prominent ledge at approximately the 870' contour level, outcropping in hillside around fishing-stock pond north of Carter's Farm barn; member: 4th oolitic horizon.

NWC 17 35 14--Northwest Corner, section 17

NW¼, NW¼, NW¼, sec. 17, T35S, R14E; bedding plane outcrop in roadbed along abandoned and partially overgrown north-south section line road; member: 4th oolitic horizon.

APPENDIX D

THIN-SECTION PETROGRAPHIC DATA

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THIN-SECTION PETROGRAPHIC DATA

The composition and distribution of Recent marine biotic assemblages is strongly affected by physical aspects of the sedimentary environment. In particular, the character of the substrate influences specific sediment-organism relationships. Sediment stability, fluidity, grain-size, sorting and texture are substrate related features that may govern the development of specific endo- and epibionts (Craig and Jones, 1966). For example, infaunal deposit-feeding taxa usually dominate fine-textured substrates which contain more organic matter, whereas epifaunal suspension-feeding types generally occupy coarser grained substrates, and filter directly from the water column (Purdy, 1964). Additional aspects of the physical environment such as light penetration, temperature, salinity, depth and water oxygenation also affect the presence or absence of specific organisms; algae can only survive within the photic zone, and certain invertebrates can only tolerate salinity variation within normal marine limits.

There is no reason to doubt that fossil organisms were similarly affected by the physical environment. However, many aspects of the ancient environment cannot be directly evaluated due to the nature of the rock record. Inferences about water depth, light penetration, etc., can only be made through interpretation of specific organisms which are sensitive to these physical aspects. Without these indicator organisms, interpretation of specific aspects of the paleoenvironment must remain speculative. Sediment substrates and their related features can however be more generally evaluated with or without fossil organisms. Different lithologies and sedimentary structures reflect distinctive original sediments, and by analogy with modern sediments, it is possible to interpret the nature of ancient substrates. Furthermore, understanding of modern marine organism-substrate associations enables interpretations of the effects ancient substrates may have had on the composition and distribution of fossil assemblages.

Petrographic examination of Stanton lithologies reveals skeletal and non-skeletal constituents indicative of original sediment type. Numerical point-count data on constituent grain types include all major skeletal groups and non-skeletal mud, micrite, interstitial spar, void-fill spar, dolomite, quartz, ooliths and clasts. Limestones are named according to Dunham (1962) and are intended only as descriptive rather than genetic terms. Sandstones are classified according to Pettijohn, Potter and Siever's (1973) modification of Dott (1964). This system is less indicative of original depositional texture than Dunham's (1962) carbonate classification, but is a useful descriptive scheme.

Non-Skeletal Constituents

As detailed petrology is not a primary concern in this study, simplified definitions of non-skeletal constituents are adopted for petrographic description of limestone lithologies. Certain definitions are modified from more rigorous petrologic studies (Bathurst, 1975; Folk, 1965), and are applied to descriptions of Stanton lithologies in an effort to facilitate a better evaluation of original sediment types. Folk (1965, 1959) considers mud to be any non-visibly crystalline carbonate ooze, and defines spar as any mosaic of crystals greater than four microns formed as cement or through meomorphism. This concept of spar necessarily encompasses microspar (5-10 microns) and pseudospar (10-50 microns). Folk (1965) further recognizes neomorphism as the primary agent responsible for conversion of mud to micrite, and eventually micrite to microspar and pseudospar (grain aggradation). He does not refute the possibility of grain diminution, original microspar, or pseudospar, but presents overwhelming evidence in support of a mud→micrite→microspar→pseudospar neomorphic sequence. Carbonate grains less than five microns (in this study) could not be identified as mud or fine allochemical (skeletal or non-skeletal) debris.

As a result of these limitations and in light of discussion brought forth in Folk (1965), the following definitions and interpretations of non-skeletal matrix and cement are adopted. "Mud" is used in the sense of original non-visibly crystalline carbonate sediment. This includes micrite and microspar (up to 10 microns) that are considered in this study to be neomorphic products of original carbonate mud. "Spar" emcompasses all remaining size grades of visibly crystalline carbonate, including pseudospar, although it has not been unequivocally identified in any thin-sections. Furthermore, no primary sedimentological distinction is made between original intergranular spar cement and void-fill cement. Dolomite has been observed as small, equant, secondary rhombs and as ferroan cement in rare instances. Therefore, in examining non-skeletal data, it should be understood that micrite and fine microspar are collectively described as mud, spar includes all non-dolomitic crystalline carbonate greater than 10 microns, and both are believed to represent close approximations of original matrix. All remaining non-skeletal grains such as ooliths, clasts and quartz are recognized without qualification as original sedimentary particles.

Skeletal Constituents

In all lithofacies, mean skeletal grain size is within the medium to fine sand range (approx. 1.5-2.5ϕ). Preservation of grains is generally good, and in most instances enough microstructural detail remains, such that even badly abraded or fragmented shell material can be easily identified. Some organisms, however, are more susceptible to alteration of original shell material, and occasionally alteration may obscure fine internal structural features. Complete shell alteration obliterates all microstructural detail, leaving only a mosaic of blocky spar calcite. Comprehensive petrographic descriptions and illustrations (Bathurst, 1975; Horowitz and Potter, 1971; Majewske, 1969) have aided identification of all skeletal grain types, including those affected by alteration.

Grain Interpretations

Several problems arise in recognition and interpretation of skeletal and non-skeletal grains. Alteration of particular skeletal grains may be so intense that it is almost impossible to distinguish them from spar cement. Repeated misidentification would necessarily alter true proportions of these constituents in any given sample. Particularly prone to misidentification are fragments of phylloid algae. Internal algal structure is frequently destroyed, leaving only a thin organic rind to recognize a former algal blade. Extreme diagenesis may also destroy external rinds, lending the appearance of an inorganic sparry filling in the rock. However, smoothly curved surfaces bounding these sparry regions and the presence of foraminifers and bryozoans encrusting these curved surfaces may suggest the presence of a former algal blade. Nonetheless, reported proportions of algae and inorganic spar may overlap by 3-4 percent where distinction between former algal blades and inorganic spar has been impossible. Bivalves, gastropods, and other originally aragonitic organisms also alter completely, but distinctive shapes enable fairly easy recognition of these grains.

An additional problem is evaluating the skeletal contribution of different taxonomic groups, and estimating their relative abundance prior to disintegration and/or decomposition. Calcium carbonate is organized in skeletal frameworks according to some basic pattern (Majewske, 1969). The structure of a skeleton and its basic body design are necessarily functions of this organization. Organisms such as green algae with loosely organized bundles of $CaCO_3$ held together by organic material readily disintegrate after death and leave little trace in the sediment. Those with a stronger arrangement of $CaCO_3$ do not disintegrate as rapidly after death and may be preserved in the sediment as whole skeletal material. Body design, also a function of $CaCO_3$

organization, can increase an organism's potential sediment contribution. Single shelled and bivalved organisms can initially contribute only one or two pieces, whereas a segmented or jointed organism such as a crinoid has the potential of contributing a myriad of skeletal pieces.

Any combination of these factors, plus the effects of biological destruction, and abrasion or sorting due to waves and currents, can readily affect the skeletal composition of the sediment. Since point-counts are the only quantitative method for analyzing ancient sediments and are volumetric measures, it is important to realize that numerical data reflects only an organism's ability to contribute mud- or sand-size particles to the sediment, and cannot constitute in any way an undeniable reflection of true biological proportions until more is known about comparative rates of organic production and sedimentation rates in general.

Table 9--Thin-section petrographic data for the Captain Creek Limestone Member.

LOCALITY	Pelmatozoans	Bryozoans	Brachiopods	Algae	Corals	Gastropods	Bivalves	Cephalopods	Trilobites	Ostracodes	Foraminifers	Sponges	Osagia	unidentified	% skeletal	Mud	Micrite	Spar	Void-fill spar	Dolomite	Ooliths	Clasts	Quartz	Total Counts
KTPK-1	10	1	4			4				1	7	9	20	2	18	176	83	8						325
KTPK-h	11	24	7	36						2	2			1	24	40	149	75	4					350
EGS-h	6	3	2	18							2		17	9	15	262	23	18						360
NP-m	3		1								11				4	66	222	47						350
NP-h		2		8						2	1			5	5	212	83	37						350
MY-h	6	1		13											6	136	10	174	10					350
1QSP-m	2	10		8						2	4				7	222	34	53	15					400
1QSP-h	1	15	5	15						3				3	12	271	15	22						350
EQ	4	9	10	18		1	3				2				19	155		45						247
WSL-6-28-17		6		14			3			1	1				10	155		65						245
QCSL-7-30-15	11	12		6		1				6					14	172		42						250
CSL-22-30-15	4	7	1								5				7	166		67						250
WCSLS	2	2		30							12				18	105		99						250
CSL-9-29-15	6	14	5	1		1	1			4	5				15	168		45						250
CCPA			8	88						1	1				27	110	21	25	106					360
ECR-1	19	4		10						1	12			1	13	119	75	104	5					350
ECR-2	7	7	2	1						5	4			1	8	243	20	18	42					350
ECR-3-1	3	6	4	4										2	5	168	32	76	54	1				350
ECR-3-m		3		5							2			3	4	149	25	51	107	5				350
ECR-3-h		4	2	8						1					4	183	86	22	42	2				350
ECR-4-1	4	10	9	12						2	6				12	190	74	31	12					350
ECR-4-m	2	4	20	27						1	3			10	19	186	13	35	43	6				350
ECR-4-h	3		2	12											5	113	111	23	83	3				350
ECR-5-1	2	30	4	45						1	2				24	53		10	203					350
ECR-5-h	1	1	2	9		1				1	11			6	9	199	26	32	61					350
ECR-6-1	4	4	41	6						1	2			1	17	76	80	30	102	1				350
ECR-6-m	3	3	17	15						2	5			11	16	80	5	37	172					350
ECR-6-h	2	10	15	7						2	7			11	15	115	26	135	20					350
ECR-7-1	2	1	1	7							1			4	5	241	18	35	40					350
ECR-7-h	6	4	24	1			3			3	1			6	14	218	23	13	48					350
TO-1		1		16											5	164	37	52	82					350
TO-2		3		16						1	5			3	8	267	14	32	9					350
TO-3	14	2	1	1							10			4	9	143	135	40						350
TO-4	1	3		28							2				9	162	30	18	114					360
TO-5	1	2	50	5						1	5			4	18	161	68	10	69					375
TO-6				40											11	104	41	6	159					350
WM-1	5														1	21		81			241	3		350
WM-h	4	5	3	1						3	3	23	33	6	23	203	42	8	16					350
SE-NW-1-33-14	2	8	1							3				15	8	170	60	71	20					350
FSL-5-33-14															0			87			262	1		350
PHF	4	10	21	5						2	7	34	7	11	30	134	75	50	5					375
SW-SE-SW-7-33-15	4	14	3	4							1	53	14	8	30	207	14	23						350
GP	20	10	4	1						1	10	9	4		17	168	89	34						350
NE-23-32-14	9	6	23	32		2	3			1	8	3	5	7	25	143	55	63						350
SEC-NW-SW-24-33-14	5	4	11	18						3	18	34	12	9	30	218	10	33						375
CSPHF	1	6	14							1	4	48		5	23	180		36	53			2		350
SE-SE-SE-25-33-14	5	5	11	5		2				5	20			17	20	109	80	8					83	350

Table 10--Thin-section petrographic for the Stoner Limestone Member.

LOCALITY	Pelmatozoans	Bryozcans	Brachiopods	Algae	Corals	Gastropods	Bivalves	Cephalopods	Trilobites	Ostracodes	Foraminifers	Sponges	Osagia	unidentified	% skeletal	Mud	Micrite	Spar	Void-fill spar	Dolomite	Ooliths	Clasts	Quartz	Total Counts
KTPK-1	8	11	3	1		1	2		2	2	9			8	13	185	40	53	25					350
KTPK-h	8	5		1	3					5	17			8	13	253	19	30	1					350
BS-1	18	24					2		1	1	11				16	163	89	41						350
BS-m	1	11									3				4	327	2	6						350
BS-h																100								100
EGS-1	5	1		6		5					8				7	185	73	50	17					350
NP-1	2	12	5	13						1	2			3	11	252	28	42						360
NP-m	10	7	6	10					1	2				1	11	168	29	115	1					350
PQ's	3	10	4	3					1		1			1	7	268	3	53	3					350
MI-1	3	10	4	18						1	1				10	203	50	25	58					375
MI-m	10	39	6	17			1		1	1	2			1	21	224	37	32	4					375
OWW-h	6	3	6	18		8			2	4	9			4	17	185	58	47						350
CBO-blw. sh.	1			51						4	5				17	252	3	13	22					350
CBO-1			40	67						2	3				32	230		8						350
CBO-m	32	92	3	10		8	2						31	14	55	17	4	137						350
CBO-h		2	6	22										1	9	159	66	93						350
10SP-1	21	91	15		3	5			1	1	10			1	42	37	14	152						350
10SP-m	1	11	1								7				6	287	44							350
EEO	3	29		21			3			1	6				25	174		13						250
EBPC	17	15	4			9	3			4	4				23	16		152						250
NW-SW-24-27-15	5	23	6	9		10	5			2	11				30	53		109						241
DQSR	42	26	9	1			4			2	6				36	70		87						247
RRSENQEB	6	4		8						2	2				9	141		87						250
BB	98	17	1				2				1				48	22		109						250
CSL-9-29-15	6	14	5	1		1	1			4	5				15	168		45						250
ACS-ACN	26	38					5				11				32	81		88						250
FNW	13	51	2				6			1	5				31	93		80						251
ECR-1	6	5	19	5		1				5	17			14	21	190	10	67	9					350
ECR-2	16	3	17	3			5				11	1		17	21	172	20	70	14					350
ECR-3	15		2	35							6			4	18	136	10	91	51					350
ECR-4	2														1	51	167	40	90					350
ECR-5	2	6	5	33						5	7			13	20	149	26	56	48					350
NW-NW-NW-18-32-14		3	35							3	10				16	181	30	46	17					325
QSC-16-32-14	5		7	28											12	218	16	43	28					345
NE-23-32-14	5	1	11	7						2	2				8	220	27	71	4					350
CCRA	23	5	13						1		5			2	14	140	130	18		2	2		9	350

Table 11--Thin-section petrographic data for the Bolton and Rutland limestone beds.

LOCALITY	Pelmatozoans	Bryozoans	Brachiopods	Algae	Corals	Gastropods	Bivalves	Cephalopods	Trilobites	Ostracodes	Foraminifers	Sponges	Osagia	unidentified	% skeletal	Mud	Micrite	Spar	Void-fill spar	Dolomite	Ooliths	Clasts	Quartz	Total Counts
BOLTON:																								
RFG	72	16	11				7			2	14			7	37	26	3	97			83	12		350
RF	53	6	11							2	12			6	26	33	4	70			144	5	4	350
SE-SW-NW-24-33-14-1-1	75	42	19		7		5				11		11	5	50	53		62			14	9	37	350
SE-SW-NW-24-33-14-1-h	4										2				2			55			217		72	350
SE-SW-NW-24-33-14-2-1	79	38	9		6	21	2				6		9	7	50	13		68			55	16	28	357
SE-SW-NW-24-33-14-2-h	1	2									5				2			62			205	2	3	350
SE-SW-NW-24-33-14-3-1	45	59	23				14				13		3	8	47	37	7	68			29	6	38	350
BH-2	31	1				1					11		47	1	26			102			151	1	4	350
SE-SE-SW-25-33-14-1	29	28	1			4	8			6	4		31	5	33	19	17	55			21	5	117	350
SE-SE-SW-25-33-14-h	98	13	3			9	13				4		52	8	57	32	6	80			12	6	14	350
NW-NW-23-33-14	25	25	17				16							4	25	25	17	43			154	5	19	350
CWL-NW-SW-6-34-15	46	56	10		4		11	13		1	1		23	6	45	14		142			11	3	35	375
RUTLAND:																								
RB_t	18	24	3	53		16	6			1	8			27	45		110	55			30			350
RB_t-2	21	30	6	31	2	3	4				4			12	32	63	95	61	8		10			350
RB_t-4	12	24	5	80		1	3				3			4	38	128	52	38						350
RB_t-west	17	17	8	12		1	10			2	4			9	23	27	122	7			104		10	350
NEC-12-33-14-1	3	9	1	34							1				14	16	50	25			198	10	3	350
NEC-12-33-14-h	2	10	6	76		2	3			1				4	30	7	25	64			115	29	6	350

Table 12--Thin-section petrographic data for the Tyro oolite and the 3rd and 4th oolitic zones.

LOCALITY	Pelmatozoans	Bryozoans	Brachiopods	Algae	Corals	Gastropods	Bivalves	Cephalopods	Trilobites	Ostracodes	Foraminifers	Sponges	Osagia	unidentified	% skeletal	Mud	Micrite	Spar	Void-fill spar	Dolomite	Ooliths	Clasts	Quartz	Total Counts
TYRO:																								
TyO-u	2														1			65			131		3	200
TyO															0			72			278			350
CNW-8-35-15-1															0			103			247			350
ECNE-7-35-15	3	1													1			96			300			400
ESL-15-35-14	2		4							1					2			69			274			350
CSBH	2										2				1			96			250			350
HWJ	26		4											2	9			112			202	4		350
FCC	1	3													1			69			277			350
3RD:																								
NEC-14-34-14	10	1	1				2				1			10	7	2		63			73	2	185	350
CWL-23-34-14	1														0			41			8		296	346
SW-NE-NE-35-33-14			1	2											1			59			3	9	276	350
SEC-1-34-14															0			62					288	350
SWC-23-34-14															0			83			3		264	350
NEC-34-34-14															0		7	132					211	350
4TH:																								
NWC-20-34-14	4	8	2				1						31		13			55			227		22	350
CP	16	7	21				2							2	14			113			6		183	350
NW-NE-NE-12-35-14	9	9	5			2	·1			.2				9	11		3	88			158	2	62	350
SW-NE-NE-35-33-14			1												0			50			291	1	7	350
ESL-6-35-14-west	32	25	40				3			1				1	29		23	38					187	350
NWC-30-34-15	27	13	13				12				1			13	23			112			3		156	350
NWC-12-34-14	2	1	9							1	2				4			109			11	8	217	350
NWC-17-35-14	5	19	3			1	61			1	2			3	27			81			115	16	43	350

Table 13--Thin-section petrographic data for the South Bend Limestone Member.

LOCALITY	Pelmatozoans	Bryozoans	Brachiopods	Algae	Corals	Gastropods	Bivalves	Cephalopods	Trilobites	Ostracodes	Foraminifers	Sponges	Osagia	unidentified	% skeletal	Mud	Micrite	Spar	Void-fill spar	Dolomite	Ooliths	Clasts	Quartz	Total Counts
KTPK-1															0			78					172	250
KTPK-h	8	7	10	1						3	17				15	280	19							350
BS-1		2	1												1	56		51	5		246		14	375
BS-h	8	6	30	2		4				4	7				17	189	81	19						350
PQ's-1	5	10	27				3							2	13	229	30	3					41	350
PQ's-h	20	8	5											1	10	154	66	14	1		69		12	350
OWW-1	5	1									4			1	3			220			102		17	350
OWW-h	9	12	4	17			8		1	5	3		4	1	18	208	14	61	3					350
CSL-12-26-16	7	14	1				3			1	3			7	10			107					207	350
CSL-SE-27-26-16	25	30	6	54		1			2	2				28	42	55		106				33	8	350
NE-NE-SE-33-26-16-1	11													3	4			245					116	375
NW-NW-SW-33-26-16	9	1	1				1			1				2	12	29	1	29	1		33	1	19	128
WL-NWC-35-26-16	10	7	8				1			4			2	1	9	201	58	58						350
ECR-1-1	17		30			3	8				1			2	17		21	129	10				129	350
ECR-1-2	6														2		18	184			75		67	350
ECR-1-3	6	1	27								1				10	161	123	28					3	350
ECR-h-1	41	7	7							3	12			1	20	88	152	29	10					350
ECR-h-2	16	11	2								6			2	11	136	116	33	25	3				350
ECR-h-3	5	4									5				4	209	103	15	9					350
ECR-h-4	13	5	1							3	2			1	7	183	70	71		1				350
ECR-h-5	10	5	2	19							8			6	14	186	38	29	47					350
ECR-h-6	17	3	7				1			1	13			2	13	192	59	40	15					350
H160Q-1	3	1					13								5		1			52		20	260	350
H160Q-2	1									1				2	1	161	152	15					18	350
H160Q-3	3									2				4	3	202	75	21	10	31			4	350
H160Q-4	15	2	1							1	1			1	6	247	23	56		3				350
H160Q-5	6	4	4	10						5	1			1	9	239	32	46	2					350
H160Q-6	8	1	2	6						1	8				7	43	245	30	6					350
H160Q-nw1			1							1	7				3	154	158	17					12	350
H160Q-nw2	7	3		1						2	1			1	4	210	31	94						350
H160Q-nw3	6	1		1							2			1	3	170	131	38						350
H160Q-nw4	25					1					1			2	8	178	60	83						350
H160Q-nw5		23		9						1					9	172	48	47	51					350
H160Q-nw6	14			3						1				3	6	197	31	76	25					350
SWC-22-30-15															0								100	100
CWL-NW-25-32-14-1	4													1	1			240					130	375
CWL-NW-25-32-14-4	27	9		3			13			2	4	28		13	28	223	10	16	2					350
CWL-NW-25-32-14-6	12		7				1							5	7	256	34	8			27			350
WNL-14-33-14	11	12	1	5						1	5	44		6	25	156	81	24	4					350
SW-NW-SE-27-33-14	3														1			145					202	350
NWC-20-34-14	2						1			1				3	2			55			272	16		350
75SB-5-34-14	12	2	2										10		7	86	22	63				10	143	350
HL	21	2	6				7				8			5	14	4		113			124		56	350
SWC-24-34-13															0								100	100
SCWL-4-34-14	18	3	5									5		5	12		34	146				19	65	300

APPENDIX E

SHALE INSOLUBLE RESIDUE DATA

APPENDIX E

SHALE INSOLUBLE RESIDUE DATA

No special analytical emphases have been placed on either fossiliferous or unfossiliferous Eudora and Rock Lake shales, as all samples have been processed identically according to procedure outlined in the methods section (pages 12-15). Insoluble weight percents are used to characterize coarse and fine fractions (greater or less than 2ϕ respectively) of individual shale samples. Weight percent loss after Stoddard's solvent treatment reflects the clay-silt-fine sand proportion in the shale, and percent loss after formic acid treatment provides an estimation of the total carbonate content in a sample. Comparison of greater than 2Φ weight percents for acid- and solvent-insoluble fractions should provide a reasonable estimate of the total carbonate content medium sand-size and greater in each shale. Qualitative binocular observations of plus-2Φ skeletal and non-skeletal constituents supplement percentage data, and further aid characterization of shales. Data for non-black Eudora shales and Rock Lake shales are tabulated separately in this appendix.

Table 14--Insoluble residue data for the Eudora Shale Member.

LOCALITY	Total wt. (grams)	Solvent (grams)	Acid (grams)	10 mesh residue sol./acid	20 mesh residue sol./acid	60 mesh residue sol./acid	Total sol./acid	% > 60 mesh sol./acid
KTPK-1	2790	1395	1395	85.0/910.0	51.2/150.0	69.0/135.4	205.2/1195.4	15.0/86.0
KTPK-h	985	490	495	86.4/240.0	66.0/ 76.2	58.8/ 67.5	211.2/ 383.7	43.0/78.0
BS	795	400	395	-- / --	1.4/ 2.0	-- / 3.2	1.4/ 5.2	.4/ 1.0
EGS	1870	915	955	-- / --	5.2/ 42.1	18.0/ 58.0	23.2/ 100.1	3.0/10.0
NP	2360	1180	1180	28.1/223.0	17.7/ 60.3	48.8/222.7	94.5/ 506.0	8.0/43.0
MI	615	615	--	240.7/---	42.5/ ---	48.6/ ---	331.8/ ---	54.0/ --
1QSP	2050	1025	1025	96.3/ 0.0	76.1/ 0.1	138.4/ 0.4	310.8/ 0.5	30.0/ 0.04
ACS-ACN	2450	1225	1225	395./255.2	170./140.2	163./123.2	729.2/ 518.6	60.0/42.0
PFQ	2430	1215	1215	170./ 0.4	97.8/ 0.6	123./ 3.7	391.3/ 4.7	32.0/ 0.4
CWL-NW-25-32-14	3140	1695	1440	8.9/ 37.6	8.6/ 11.6	22.7/ 51.3	40.2/ 90.6	2.0/ 6.0
SBHM-398-1	2105	1055	1050	2.0/ --	1.3/ --	3.8/ 0.7	7.1/ 0.7	1.9/ 0.1
SBHM-398-2	2160	1080	1080	7.7/ 0.1	1.1/ 0.2	3.4/ 1.2	12.2/ 1.6	1.0/ 0.2
SBHM-398-3	2220	1110	1110	8.6/ 2.2	3.9/ 0.4	10.3/ 1.1	22.8/ 3.7	2.0/ 0.3
SBHM-398-4	2000	1000	1000	21.2/ 0.8	11.2 0.6	13.5/ 1.1	45.9/ 2.5	5.0/ 0.3
BH	4100	2050	2050	16.6/ 0.3	5.7/ --	10.1/ 0.8	32.6/ 1.2	2.0/ 0.06
PGS	2310	1155	1155	51.0/ 4.2	43.1/ 2.9	53.4/ 5.7	147.5/ 12.8	13.0/ 1.0
RF	3860	1930	1930	60.2/ --	9.9/ 0.2	15.9/ 2.1	86.2/ 2.4	4.0/ 0.1
RFP	1130	565	565	7.0/ 1.5	1.7/ 0.5	7.7/ 3.0	16.4/ 4.9	3.0/ 1.0
SCEL-35-32-14	1030	515	515	4.8/ 0.3	9.4/ ---	10.6/ 1.8	24.8/ 2.2	5.0/ 0.4
WM-1	2280	1140	1140	38.9/ 30.5	38.5/ 13.8	34.2/ 10.6	111.6/ 54.9	10.0/ 5.0
WM-2	2150	1075	1075	3.1/ --	---/ 0.1	3.4/ 1.0	6.5/ 1.0	1.0/ 0.09
WM-3	1950	950	950	0.6/ 0.5	---/ ---	1.7/ 0.6	2.3/ 1.1	0.3/ 0.1
WM-4	1360	680	680	1.3/ --	0.9/ --	3.6/ 0.6	5.8/ 0.6	1.0/ 0.08
WM-5	1240	620	620	4.5/ 0.1	1.7/ --	4.8/ 0.6	10.9/ 0.7	2.0/ 0.1
WM-6	1290	645	645	1.5/ 1.2	2.1/ 0.5	5.3/ 0.8	8.9/ 2.5	1.0/ 0.4
NE-SW-6-34-15	1860	930	930	256./348.4	9.1/ 6.7	11.9/ 2.6	276.8/ 357.7	30.0/38.0
SE-SW-NW-24-33-14	2120	1060	1060	18.1/ 53.2	4.1/ 10.5	6.8/ 7.6	28.9/ 71.3	3.0/ 7.0
TMQ	2150	1075	1075	223./ 2.5	81.1/ ---	77.6/ ---	382.2/ 2.5	36.0/ 0.2

Table 15--Insoluble residue data for the Rock Lake Shale Member.

LOCALITY	Total wt. (grams)	Solvent (grams)	Acid (grams)	10 mesh residue sol./acid	20 mesh residue sol./acid	60 mesh residue sol./acid	Total sol./acid	%>60 mesh sol./acid
KTPK	1020	510	510	147./ 89.1	10.8/ 2.5	10.9/ 6.2	168.7/ 97.8	33.0/19.0
BS	2320	1160	1160	18.2/ 1.5	13.1/ 2.4	69.4/ 6.8	100.7/ 10.7	9.0/ 1.0
PQ's	1790	895	895	262./ 0.4	53.7/ ---	84.1/ 0.4	400.5/ 0.8	45.0/ 0.1
QEW	1740	870	870	72.5/ 20.1	33.5/ 24.0	77.6/ 30.7	183.7/ 74.9	21.0/ 9.0
CSL-12-26-16	2960	1480	1480	57.3/ ---	16.4/ 0.8	29.9/ ---	103.7/ 0.8	7.0/ 0.1
NW-NE-9-27-16	1430	715	715	6.4/ 2.2	3.0/ 1.6	3.5/ 2.6	12.9/ 6.4	2.0/ 1.0
ECR-1	2690	1345	1345	44.8/ 4.9	14.1/ 2.9	39.4/ 24.2	98.2/ 32.1	7.0/ 2.0
ECR-h	2510	1255	1255	42.2/ 30.1	7.6/ 3.7	9.8/ 8.4	59.6/ 42.2	5.0/ 3.0
CWL-NW-25-32-14	3380	1690	1690	53.8/ 3.6	2.4/ 0.4	7.9/ ---	64.2/ 4.1	4.0/ 0.2
WL-NWC-36-32-14	2090	1045	1045	0.4/ 4.6	1.1/ 0.8	3.0/ 1.1	4.6/ 6.5	0.4/ 1.0
H160Q	1620	810	810	757./563.9	0.5/ 10.1	---/ 8.9	757.7/582.9	94.0/72.0
RB$_t$	3810	1905	1905	6.4/ 20.6	10.8/ 10.3	19.6/ 15.1	36.8/ 46.1	2.0/ 2.0
NW-NW-23-33-14	2000	1000	1000	---/ 0.4	---/ --	---/ 1.7	--- / 2.1	0.0/ 0.2
RF	1750	875	875	114./ 65.4	13.1/ 2.5	12.1/ 3.3	139.5/ 71.2	16.0/ 8.0
SE-SE-SE-1-33-14	540	270	270	13.5/ 16.5	1.2/ 0.7	1.8/ ---	16.5/ 17.1	6.0/ 6.0
75SB	4290	2145	2145	74.6/ 4.9	9.5/ ---	15.0/ 2.7	99.2/ 7.6	5.0/ 0.4
SWC-23-34-14	2370	1185	1185	83.3/ 26.5	14.8/ 1.4	9.1/ ---	107.3/ 27.8	9.0/ 2.0
NWC-30-34-14	620	310	310	13.2/ 9.6	4.2/ 1.1	3.5/ 2.2	20.9/ 12.9	7.0/ 4.0
EUDORA-ROCK LAKE								
Coon Ck	1980	990	990	1.0/ 0.6	---/ ---	0.7/ 0.9	1.7/ 1.7	0.2/ 0.2
SCWL-28-34-14	2450	1225	1225	156./196.6	6.6/ 7.8	4.8/ 3.0	167.7/207.4	14.0/17.0

Table 16--Insoluble residue data for the Captain Creek and Stoner shale beds.

LOCALITY	Total wt. (grams)	Solvent (grams)	Acid (grams)	10 mesh residue sol./acid	20 mesh residue sol./acid	60 mesh residue sol./acid	Total sol./acid	%>60 mesh sol./acid
CAPTAIN CREEK								
WM	1880	940	940	168./ 0.8	38.5/ ---	62.6/ 0.9	269.2/ 1.8	29.0/ 0.2
STONER								
MI	2000	1000	1000	78.3/ 0.2	31.1/ 0.2	71.1/ 3.5	180.4/ 5.8	18.0/ 1.0
RC	2100	1050	1050	65.1/ 1.3	34.2/ ---	52.3/ 1.4	151.6/ 2.6	14.0/ 0.3
NW-NW-NW-1-32-14	1725	865	860	48.4/ 0.3	33.6/ ---	47.4/ 3.3	129.3/ 3.6	15.0/ 0.4
ECR	4440	2220	2220	39.2/ 1.0	33.8/ ---	63.1/ 4.7	136.2/ 5.7	6.0/ 0.3
NW-NW-NW-18-32-14	3690	1845	1845	50.7/ 0.1	20.3/ ---	37.3/ 2.1	108.4/ 2.3	6.0/ 0.1