PROJECT FINAL REPORT

Scanning Electron Micrographs of Mississippian Age Conodonts From Southwestern Virginia, West Virginia, and Kentucky

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Submitted to Faculty Research Committee
by
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Abstract of Research

Conodonts, an extinct group of microfossils generally less than one millimeter in size, are considered to be the hard parts of an animal having uncertain biological affinities. However, conodonts have great utility in the petroleum industry for the recognition of potential oil- and gas-bearing strata in the subsurface. The age and recognition of these potential oil-and gas-bearing beds is dependent on accurate identification and comparison of conodont faunas with those from different geographic regions. The purpose of this research was to obtain high quality professionally acceptable scanning electron micrographs of Mississippian age conodont faunas.

The writer has recovered several thousand conodont specimens from rocks Mississippian in age in West Virginia, Virginia and Kentucky and these are on file at Morehead State University. Approximately 70 of these identified specimens were selected and individually mounted on 10 centimeter stubs using a solution of Elmer's glue as a mounting medium. Each stub contained approximately 4 conodont specimens. These stubs were then transported to the scanning electron microscopy laboratory at the Museum of Natural History, Washington, D.C. At the laboratory each specimen was carbon and gold coated to permit the highest resolution possible for maximum specimen detail in order to produce high quality micrographs for publication.

Approximately five SEM sessions of 4 hours each were held between the period of March 15 - June 50, 1978. A Cambridge S4-10 scanning electron microscope was used to photograph each specimen in oral, aboral, and lateral view to enhance specimen detail. Two hundred ten polaroid micrographs and negatives were obtained with magnifications ranging from 60x to 350x. The quality of the negatives was excellent and these are now being prepared to produce photographic plates to accompany two manuscripts to be submitted for publication to the Journal of Paleontology. The preparation and photographing of these plates is being done by the writer with equipment available at Morehead State University.

Enclosed are xerox copies of the program and abstract of paper, pertaining in part to this research, that was presented at the North-Central section of the Geological Society of America meeting in April, 1977 at Southern Illinois University. In addition, a copy of one of the manuscripts to be submitted to the Journal of Paleontology is enclosed. This manuscript will contain at least 5 photographic plates presently in preparation from negatives obtained in this research project. A second manuscript will be forthcoming and will include 10 photographic plates of Mississippian-age conodonts from Virginia, West Virginia and Kentucky. A photographic plate of significant Mississippian conodonts found in rocks of the Morehead area will be published, as a result of this research study, in the field trip guidebook for the Kentucky region now in preparation in conjunction with the Ninth International Congress of Carboniferous Stratigraphy and Geology to be held in the United States in May, 1979. Conodont faunas of Middle and Upper Mississippian ages have been previously studied in many areas but no report has been published which illustrates with high quality scanning electron micrographs conodonts of this age from the Southern Appalachians.

Final Statement

Budgeted Expenditures

1. Salaries and Wages (technician)				
a. 4/13/78	Susanne Braden 8 hrs @ $12/hr		$96.00	
5/16/67	Susanne Braden 8 hrs @ $12/hr		96.00	
5/22/78	Susanne Braden 4 hrs @ $12/hr		48.00	$240.00
2. Travel				
a. 4/20/78	Smithsonian Institute, Washington, D.C. (3 days)			
		Train Fare	$44.50	
		Food and lodging	60.00	$104.50
b. 5/18/78	(3 days)	Train Fare (one way)	$30.50	
		Food and lodging	60.00	$90.50
c. 6/18/78	(4 days)	Train Fare	$46.00	
			80.00	$126.00
		Total		*$321.00
3. Supplies				
a. 3/23/78	Natural Learning Systems - Polaroid Film, Type 52 - 10 boxes		$142.50	
b. 5/2/78	Natural Learning Systems - Polaroid Film, Type 52 - 6 boxes		85.50	$228.00
		Total Expenditures		$789.00

*$6.00 was transferred from supply money to defray over-expenditure on travel.

The uppermost Wolfcampian Sweetognathus whitei-Neogondolella bisselli Assemblage Zone corresponds to the lower fifty feet of the Skinner Ranch at its type section. Associated is an undescribed Sweetognathus related genus. The present study indicates this assemblage to be absent from the deeper water facies at Dugout Mountain in the western Glass Mountains. The overlying lower Leonardian Neostreptognathus pequopensis Assemblage Zone is found throughout a narrow interval of the Skinner Ranch Formation in the Glass Mountains, above which conodonts of the Neostreptognathodus sulcoplicatus-N. prayi Assemblage Zone occur to the top of the formation. Neogondolella idahoensis and Neogondolella n. sp. are associated with both Leonardian assemblages.

ENVIRONMENTAL INTERPRETATION OF CONODONT DISTRIBUTION IN THE DENMAR FORMATION (EARLY CHESTERIAN) IN THE HURRICANE RIDGE SYNCLINE OF SOUTHWESTERN VIRGINIA AND WEST VIRGINIA

CHAPLIN, J. R., Geoscience Department, Morehead State University, Morehead, Kentucky 40351

Lithic units comprising the Denmar Formation have yielded conodonts of the Gnathodus bilineatus - Cavusgnathus charactus Zone (Early Chesterian). Lithologic sequences within the Denmar Formation consist of repetitive shallow-water carbonate and clastic units comprised primarily of siltstones and shales, lime mudstones, skeletal lime mudstones, skeletal wackestones and skeletal packstones. All of these lithic units contain progressively increasing amounts of detrital material from the southwest to the northeast.

Interpretation of depositional environments indicates minor off-lapping or shoaling environments associated with a regional Mississippian transgression were responsible for the repetitive nature of the sequences. The sequences display the complete transition from tidal flat, restricted subtidal, to open marine shelf deposits.

Conodont distribution patterns (chiefly form taxonomy) in the Denmar Formation reflect the following: 1) progressively lower abundance and diversity from southwest (purer carbonate facies) to northeast (more detrital facies), 2) overall low abundance and diversity in siltstones, shales, and lime mudstones, 3) low to moderate abundance and diversity in skeletal lime mudstones and packstones and 4) maximum abundance and diversity in thick, continuous sequences of skeletal wackestones. The differences in the distribution patterns and relative conodont abundances are considered to be the result of environmental influences, primarily higher detrital sedimentation rate to the northeast, rather than the result of evolutionary influences.

MATHEMATICAL MODEL STUDY OF THE UPPER MISSISSIPPI RIVER BASIN

CHEN, Yung Hai, and SIMONS, Daryl B., Department of Civil Engineering, Engineering Research Center, Colorado State University, Fort Collins, Colorado 80523

The Upper Mississippi River is part of the main riverine artery of the United States. Its exploitation both commercially and recreationally is an important aspect of the national economy. The reach of river has been modified with locks, dams, dikes and bank revetment to provide a 9-foot navigation channel. The creation of navigation pools converted a portion of the floodplain from wooded islands and dry marshes into excellent marsh and aquatic habitats. After more than 30 years of operation some of the marsh and aquatic habitat is disappearing from the riverine environment mainly due to sediment

2. *Richard Waugh,* Alan Zick*: Structural Geology of the Southern Part of the Paron Quadrangle, Arkansas 1340
3. *George W. Viele*: A Plate Tectonic Model, Ouachita Folded Belt 1400
4. *L. W. Younker,* J. L. Younker*: Regional Metamorphism: The Source of the Heat 1420
5. *D. F. Palmer,* R. A. Heimlich, R. J. Kolb*: Petrofabric Analysis of the Newfound Gap Dunite, Haywood and Buncombe Counties, North Carolina . . 1440

   Coffee Break 1500

6. *Ron Pisarik,* John Petershagen, Kurt Wilke, L.V.A. Sendlein*: Magnetic Studies of the Manson Disturbed Area 1520
7. *L. D. McGinnis,* G. M. Carlsen, C. P. Ervin*: Precision Gravity Leveling Study in the Mississippi Embayment 1540
8. *R. D. Cole,* J. L. Sexton*: Rhythmic Variations in Oil Shale Stratification: Green River Formation, Piceance Creek Basin, Colorado 1600
9. *J. L. Sexton,* R. D. Cole*: Maximum Entropy Spectral Analysis of Varved Oil Shale, Green River Formation, Colorado 1620

SYMPOSIUM: CARBONIFEROUS CONODONTS (PANDER SOCIETY)

SIU-C Student Center, Ballroom B, 1320 hours

Willi Ziegler and Thomas L. Thompson, Presiding

1. *H. Richard Lane*: The Burlington Shelf and Its Conodont Faunas . . . 1320
2. *Robert C. Burton*: Conodonts from Reef Banks of Mississippian Age in the Sacramento Mountains, New Mexico 1340
3. *Charles A. Sandberg,* Raymond C. Gutschick*: Deep-Water Osagean Conodont Faunas from a Starved Basin in Utah 1400
4. *J. R. Chaplin*: Environmental Interpretation of Conodont Distribution in the Denmar Formation (Early Chesterian) in the Hurricane Ridge Syncline of Southwestern Virginia and West Virginia 1420
5. *Glen K. Merrill*: Restudy of Conodonts from the Barnett Formation (Carboniferous, Central Texas) 1440
6. *Sonny Baxter*: The Occurrence of *Taphrognathus* and *Cavusgnathus* in the Mississippian of Western Canada 1500

   Coffee Break 1520

7. *Marcel Weyant*: Carboniferous Conodont-Zonation in Northwestern Sahara 1540
8. *Robert T. Liner,* Walter L. Manger, Doy L. Zachry*: Mississippian-Pennsylvanian Boundary, Northeastern Llano Region, Central Texas . . . 1600
9. *Walter L. Manger,* Paul Brenckle, H. Richard Lane, W. Bruce Saunders*: Biostratigraphy of the Mississippian-Pennsylvanian Boundary, Southern Midcontinent and Southwestern United States 1620
10. *Robert C. Grayson, Jr.*: Correlation of Late Morrowan and Early Atokan (Early Pennsylvanian) Conodont Faunas from the Frontal Ouachita Mountains and the Ardmore Basin (Oklahoma) 1640

*Speaker

Environmental Interpretation of Conodont Distribution in the Denmar Formation (Early Chesterian) in the Hurricane Ridge Syncline of Southwestern Virginia and West Virginia

James R. Chaplin

Morehead State University, Morehead, Kentucky 40351

ABSTRACT -- Repetitive shallow-water carbonate and clastic units comprising the Denmar Formation have yielded conodonts of the *Gnathodus bilineatus*-*Cavusgnathus charactus* Zone (Early Chesterian). Conodont distribution patterns and relative conodont abundances are considered to be the result of environmental influences, primarily higher detrital sedimentation to the northeast, rather than the result of evolutionary influences. The biostratigraphic value of these conodont taxa and other conodont taxa from horizons of similar age are discussed.

INTRODUCTION

The Southern Appalachians contain some of the thickest and most varied sections of Mississippian rocks in North America but the numerous problems associated with these rocks have been long neglected. Refinement in rock-stratigraphic subdivision together with more closely spaced and more detailed lithic correlations are urgently needed. So-called rock-stratigraphic units of the Mississippian of the Southern Appalachians have been based largely upon the persistence of certain lithologies whose lower and upper limits were regarded as reliable time boundaries. Rock-stratigraphic units should be distinguished and delimited on the basis of lithologic characteristics and not be faunally defined. Age should play no part in differentiating or determining the boundaries of any rock-stratigraphic unit.

Another problem in Southern Appalachian Mississippian stratigraphy is the lack of understanding of the lateral relationships between lithic units not only along strike but also in adjacent belts. Work on lithofacies and environmental interpretations has been largely lacking.

Abundant faunas and floras in the Mississippian of the Appalachians have received surprisingly little detailed and systematic study. In order to identify formations earlier stratigraphers found it necessary to place heavy reliance upon a few so-called "guide fossils" which had been found to be useful guides in the thinner sections of the type Mississippi Valley section. The Mississippian section of the Southern Appalachians is a thicker more complete depositional record compared with the thinner, less complete, though better known type section of the Mississippi Valley. One can expect to find similar faunas of the type region occurring through much greater stratigraphic thicknesses in the Southern Appalachians. Additional problems have resulted from reliance on the occurrence of megafossils whose stratigraphic ranges were not precisely known even in the type Mississippi Valley region.

Another problem in Southern Appalachian Mississippian stratigraphy is the misconception by many workers that widespread persistence of certain lithofacies is evidence of contemporaneous deposition. Previous workers have failed to realize or adequately demonstrate, due to limited faunal data, that a single lithologic unit may be diachronous throughout all or a part of its outcrop belt if the environment of deposition shifted with the passage of time. Similarly the belief that identical or closely similar faunal assemblages in deposits at widely separated localities prove the contemporaneous age of the rocks should be carefully weighed against the thesis that a faunal assemblage favored by a given set of environmental conditions may have remained relatively unchanged throughout a considerable time span and might now be found as a fossil assemblage co-extensive with the given lithologic, time-transgressive unit. Application of such a paleoecological or facies-fauna concept is needed to help solve some of the biostratigraphic problems which have arisen from previous studies of Southern Appalachian Mississippian stratigraphy.

To help resolve some of the problems of Mississippian biostratigraphy in the Southern Appalachians, the writer has described and illustrated biostratigraphically significant conodonts from the Denmar Formation within the Hurricane Ridge syncline located in the southern portion of the Appalachian miogeosyncline. Conodont faunas of Middle and Upper Mississippian ages have been previously studied in many areas but no report has been published which illustrates conodonts of this age from the Southern Appalachians.

LOCATION - GEOLOGIC SETTING

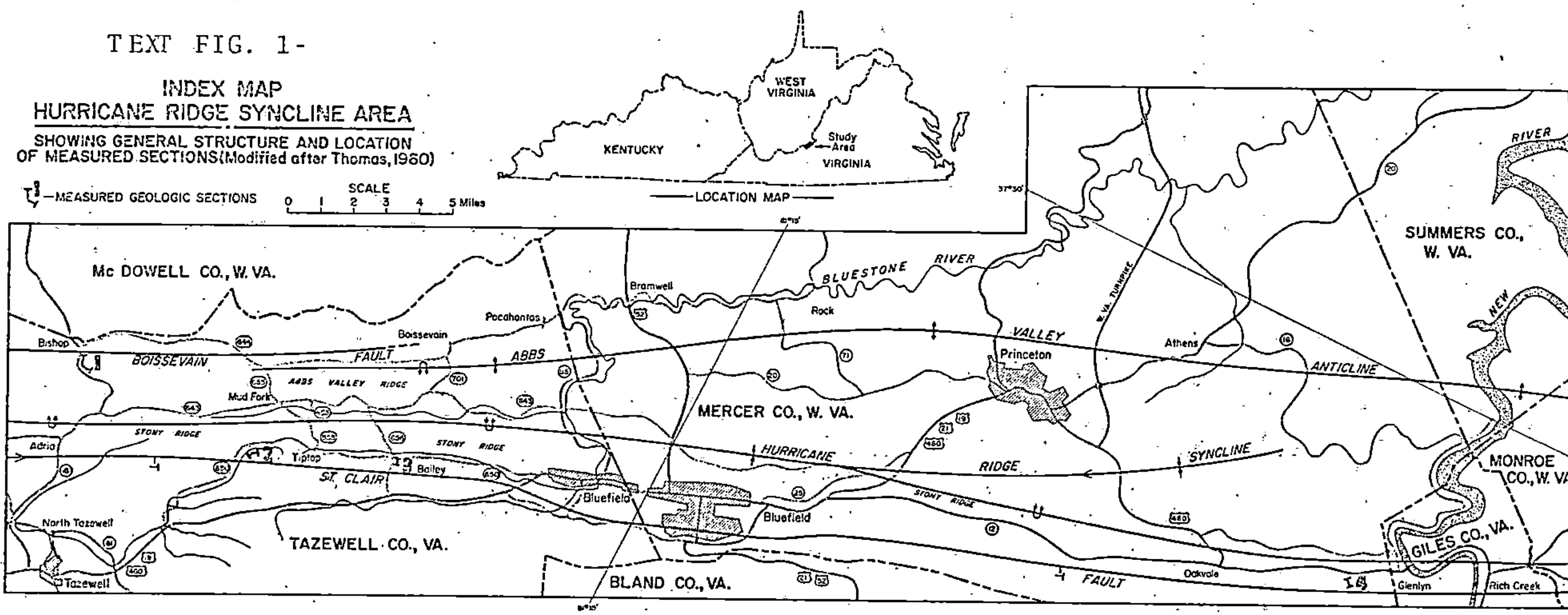
The Hurricane Ridge syncline is an elongate overturned structure parallel and adjacent to the northwestern structural front of the folded and thrust faulted Appalachians in southern West Virginia and adjacent Virginia (Text-fig. 1). The measured stratigraphic sections from which the conodonts were described and illustrated in this study occur along a strike distance of 40 miles and include: (1) Bishop-Stony Ridge section on the normal northwest limb of the Hurricane Ridge syncline, within the 7.5-minute North Tazewell, Virginia Quadrangle; (2) Tiptop section on the overturned southeast flank of the syncline, within 7.5-minute Tiptop, Virginia Quadrangle; (3) Willowton section on the overturned southeast flank of the syncline within the 7.5-minute Oakvale, West Virginia Quadrangle (Text-fig. 1). The general locations of the sampled localities are shown in Text-fig. 1.

The Hurricane Ridge syncline is developed along the western side of the folded Appalachians in Tazewell County, Virginia and extends northeastward across adjacent parts of West Virginia and back into Virginia in the northwest salient of Giles County along New River (Price, 1931, Cooper, 1944, Thomas, 1966)(Text-fig. 1).

The axis of the Hurricane Ridge syncline strikes northeast and can be traced approximately 80 miles from Tazwell County, Virginia, to Monroe County, West Virginia

TEXT FIG. 1-

INDEX MAP
HURRICANE RIDGE SYNCLINE AREA
SHOWING GENERAL STRUCTURE AND LOCATION OF MEASURED SECTIONS (Modified after Thomas, 1960)



(Reger, 1926, p. 146). The syncline is doubly plunging; its maximum depression extends along strike about 20 miles from south of Princeton, West Virginia, southwestward into Tazewell County, Virginia. The fold is tight at the southwest and is progressively more open toward the northeast.

The southeast flank of the Hurricane Ridge syncline is overturned and overridden by the St. Clair thrust fault which parallels the synclinal axis as far northeast as southern Monroe County, West Virginia (Text-fig. 1). In Tazewell County, Virginia the dip of this limb is as steep as 50 degrees overturned to the southeast. In Monroe County, West Virginia, where the axis of the syncline is farther west of the St. Clair thrust fault, the beds on the southeast flank resume a normal northwest dip.

The northwest flank of the Hurricane Ridge syncline is formed by the Abbs Valley anticline. The common limb dips steeply southeastward. The northwest flank of the Abbs Valley anticline is nearly vertical at the Tazewell County-Mercer County boundary. Farther southwest, the crest of the anticline is obscured by the high-angle, reverse Richlands-Boissevain fault (Text-fig. 1).

The Hurricane Ridge syncline and Abbs Valley anticline define the northwestern structural front of the folded and thrust-faulted Appalachians in southernmost West Virginia and adjacent Virginia. Beds to the northwest are all nearly flat lying.

STRATIGRAPHY

Stratigraphic nomenclature for the Mississippian System in the Southern Appalachians is almost wholly inadequate as a framework for understanding the complex vertical and lateral variations in the stratigraphic succession. The following conclusions represent an attempt to summarize some of the perplexing problems in the stratigraphic nomenclature for the Mississippian System in the Southern Appalachians:

(1) Formational names were employed in the Appalachians from type localities in the Mississippi Valley region;

(2) Some type localities in the Mississippi Valley were not clearly defined;

(3) Rock sequences in the Mississippian type area are complex with numerous vertical and lateral facies changes;

(4) The better known sections in the Mississippian type region consist of thinner and more incomplete rock sequences;

(5) Several of the formational names in the type area have been used with meanings other than their original usage;

(6) Formations in the Appalachians were defined on the basis of paleontologic data and not lithologic criteria;

(7) Similar lithologies have been considered time-equivalent by workers in both the Appalachians and type Mississippi Valley region with almost total disregard for facies relationships;

(8) Fossils which were abundant and believed to have great biostratigraphic utility in the type area for identifying formations are not always found in strata of the Appalachians. Many of these fossils are possibly strongly facies controlled;

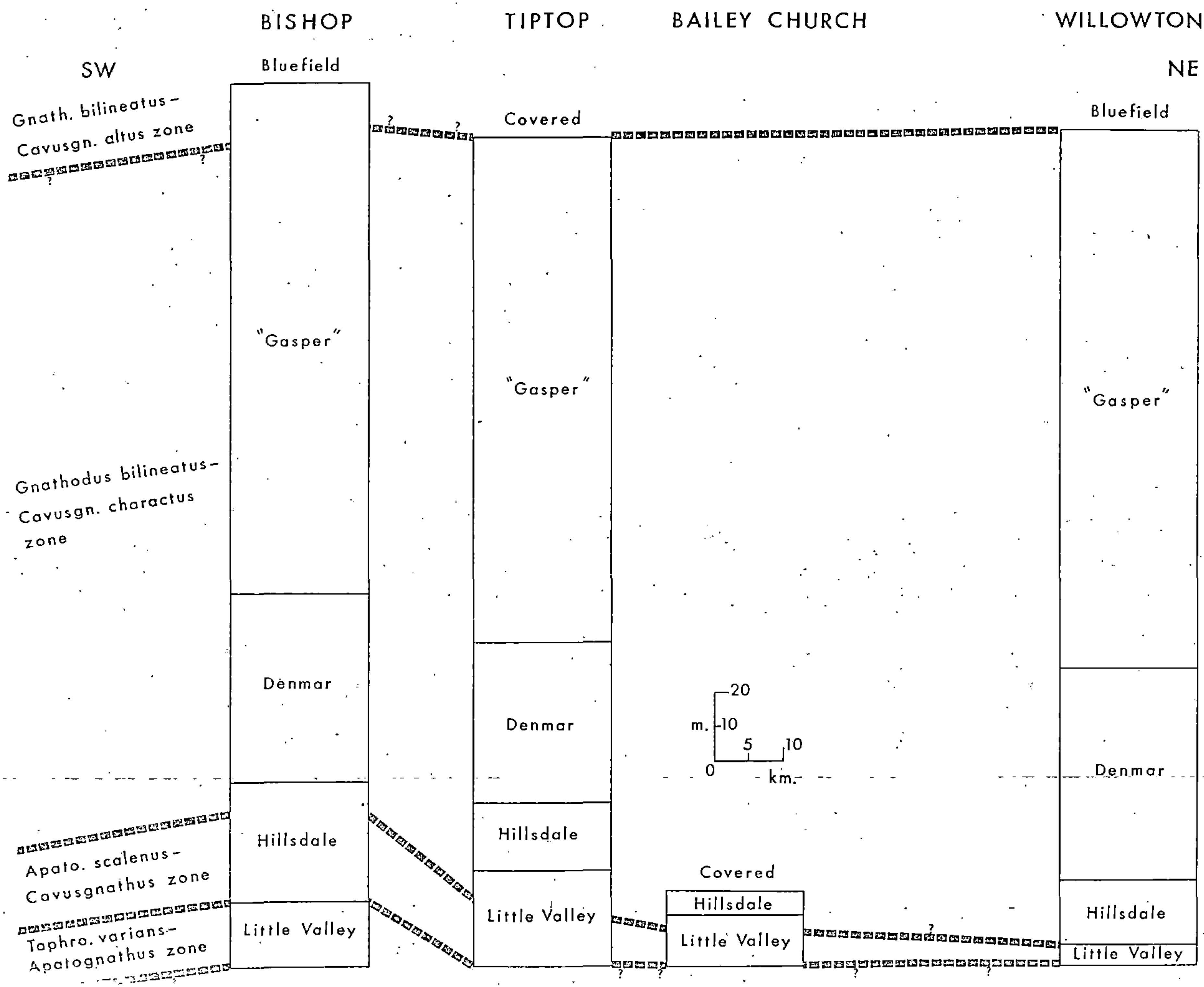
(9) Field identifications of the so-called "guide" fossils by earlier workers, particularly at the species level, may have been incorrect;

(10) The biostratigraphic ranges of several of the diagnostic fossils employed earlier have been extended in both areas.

Text-fig. 2 shows the general stratigraphic succession of Late Mississippian units within the Hurricane Ridge syncline, the stratigraphic position of the Denmar Formation with respect to underlying and overlying lithic units, and the Late Mississippian conodont zones as recognized in this study.

The Denmar was named by Wells (1950) for a sequence of gray, slightly cherty, calcarenite and calcilutite beds on the eastern slope of Droop Mountain along County Road No. 30, near the town of Denmar, Pocahontas County, West Virginia. The type section is located approximately 65 miles northeast of the study area. At the type section the Denmar Formation is 65 meters thick. Wells (1950) distinguished the Denmar

TEXT FIG. 2- LATE MISSISSIPPIAN CONODONT ZONES OF THE HURRICANE RIDGE SYNCLINE



from the Hillsdale Formation below by its less chert, lighter color, and more sandy material. Butts (1940) extended the usage of the name, Ste. Genevieve, from the type Mississippi Valley region into the Hurricane Ridge syncline for the limestone sequence referred to in this paper as the Denmar Formation. Blanchard (1974) in an unpublished doctoral dissertation combined the Denmar and overlying "Gasper" Formation into one lithologic sequence that he referred to informally as the "Gasper-Denmar" Formation of the Greenbrier Group in the writer's study area.

Three complete and well exposed sections of the Denmar formation were studied. The rocks range in thickness from 55 meters in the Bishop section in the southwest located on the normal northwestern limb of the structure to 47 meters at the Tiptop section, and 61 meters at Willowton in the northeast on the overturned southeastern limb.

The lower contact of the Denmar Formation is placed at the first occurrence of massive bluish-gray to yellowish-gray, slightly calcareous terrigenous siltstones and shales that overlie dark-gray, medium- to thick-bedded, chert-bearing skeletal wackestones of the Hillsdale Formation. This lower contact is well exposed at Bishop, Tiptop, and at Willowton.

The upper contact of the Denmar Formation is placed at the top of light-gray to yellowish-gray, medium- to thick-bedded, ooid-bryozoan-echinoderm packstone units which underlie yellowish-gray to bluish-gray calcareous, locally plant bearing terrigenous siltstones and shales of the "Gasper" Formation. Many of the shale intercalations are mottled pale red-purple. At Bishop, there is a 1.5 meter covered interval above the packstones and just below the first exposure of terrigenous siltstones and shales of the "Gasper" Formation.

Age and Correlation - Conodonts in the Denmar Formation are characteristic of the Gnathodus bilineatus - Cavusgnathus charactus Zone (Collinson, Scott, and Rexroad, 1962). This broad and generalized zone was named from the Ste. Geneieve-Cypress interval of the late Valmeyeran and early Chesterian in the Illinois Basin. Collinson and other (1961) correlated this zone with the Cu IIIα Goniatites Zone of western Europe. In the Mississippi Valley region this zone is bounded at the bottom by the youngest occurrences of Apatognathus and Spathognathodus scitulus. The upper limit is marked by the oldest occurrences of Lonchodina furnishi, L. paraclarki, Roundya barnettana and Cavusgnathus altus. In this study the base of this zone is recognized by the youngest occurrences of Apatognathus porcatus, A. scalenus, Hibbardella abnormis, Ozarkodina laevipostica and Spathognathodus scitulus and by the first appearances of Gnathodus bilineatus, G. commutatus G. homopunctatus, G. nodosus, Hibbardella fragilis H. ortha, Hindeodus alatoides, H. imperfectus, Neoprioniodus camurus, N. singularis, Ozardodina curvata, Spathognathodus cambelli and S. cristulus (Plates 1-5). The basal lithic boundary of the Denmar Formation does not parallel the Gnathodus bilineatus - Cavusgnathus charactus zonal boundary as the basal zonal boundary occurs in the upper Hillsdale at Bishop, in the upper Little Valley at Tiptop and at the base of the Hillsdale in the Willowton section (Text-fig. 2). The upper limit of the Gnathodus bilineatus - Cavusgnathus charactus Zone in the study area is somewhat tenuous due to a lack of diagnostic conodont taxa but appears to correlate approximately with the top of the overlying "Gasper" Formation (Text-fug. 2).

In the Midwestern United States, this zone is widespread in the Illinois Basin as well as in the Pella Beds of south-central Iowa (Rexroad and Furnish, 1964). Thompson and Goebel (1969) have also described this zone from the subsurface of Kansas. Clark and others (1969) indicated that the Gnathodus bilineatus - Cavusgnathus charactus Zone is widespread in Utah and Nevada where it is found in the Great Blue Limestone and Chainman Shale. Rice and Langenheim (1974) described this zone in the Battleship Wash Formation, in Clark County, Nevada. Rhodes, Austin, and Druce (1969) correlated this zone with their Mestognathus beckmanni - Gnathodus bilineatus and Gnathodus mononodosus zones and to the uppermost part of their Apatognathus scalenus - Cavusgnathus Zone in the British Avonian. In the revised British Avonian conodont zonation by Austin (1973) the Gnathodus bilineatus - Cavusgnathus-charactus Zone of the type Mississippi Valley region is correlated with the British Mestognathus beckmanni - Gnathodus bilineatus and Gnathodus bilineatus and Gnathodus mononodosus zones.

Lithofacies -- To determine major lithofacies and environments of deposition the following were noted:

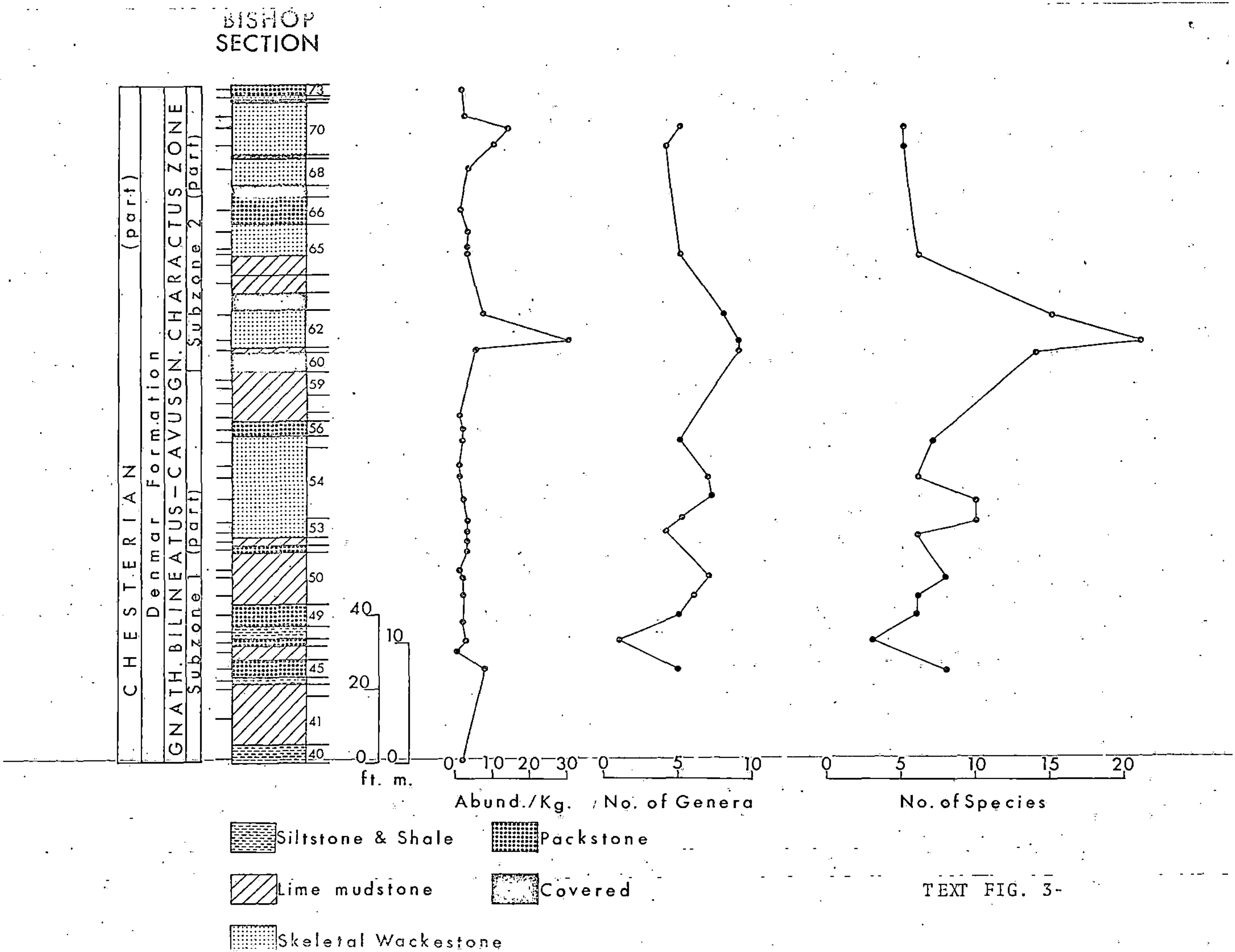
(1) Every major vertical change in lithology was noted and sampled:

(2) The distribution, types, and orientation of macrofossils were noted in the field;

(3) Sedimentary structures were noted in the field

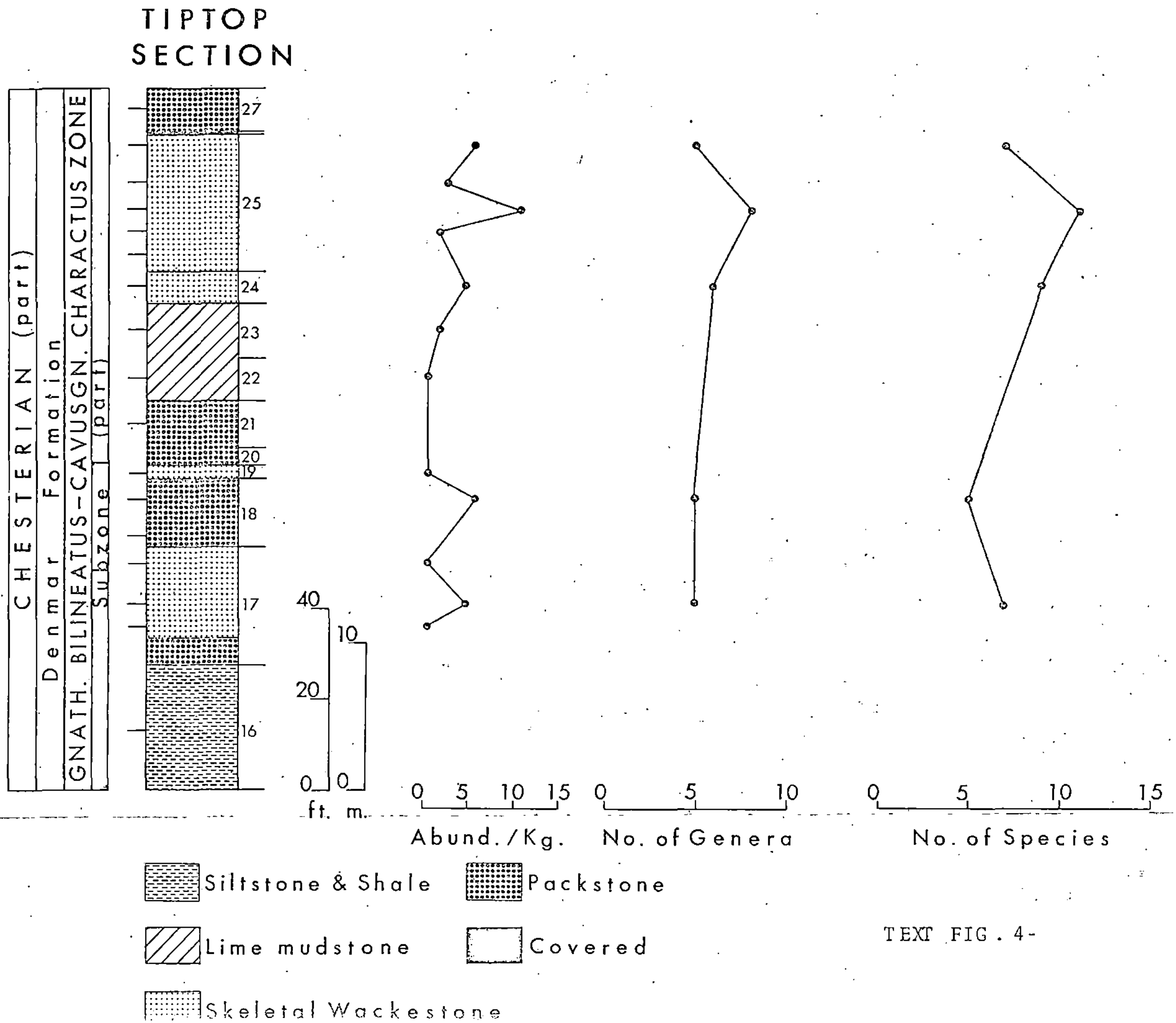
(4) Sixty-five thin sections were examined for textural properties

Four major lithofacies were identified. These consist of siltstones and shales, lime mudstones, skeletal wackestones, and packstones. Dunham's (1962) textural classification was used to classify the carbonates. Thin sections of carbonates in the Tiptop and Willowton sections located on the overturned southeastern limb show minor deformation of ooids, grain-to grain pressure solution, and stylolites. However, the sedimentary fabric has not been altered appreciably. (Text figs. 3-5) illustrate these four lithofacies and their distribution throughout the Denmar at all localities. In these text figures the dashes along the left side of the stratigraphic column indicate conodont sampled intervals, the unit numbers are shown along the right side of the column and the curves show the conodont abundance per kilogram of sample, the number of form-genera, and the number of form-species in samples containing 10 or more specimens respectively at each locality.



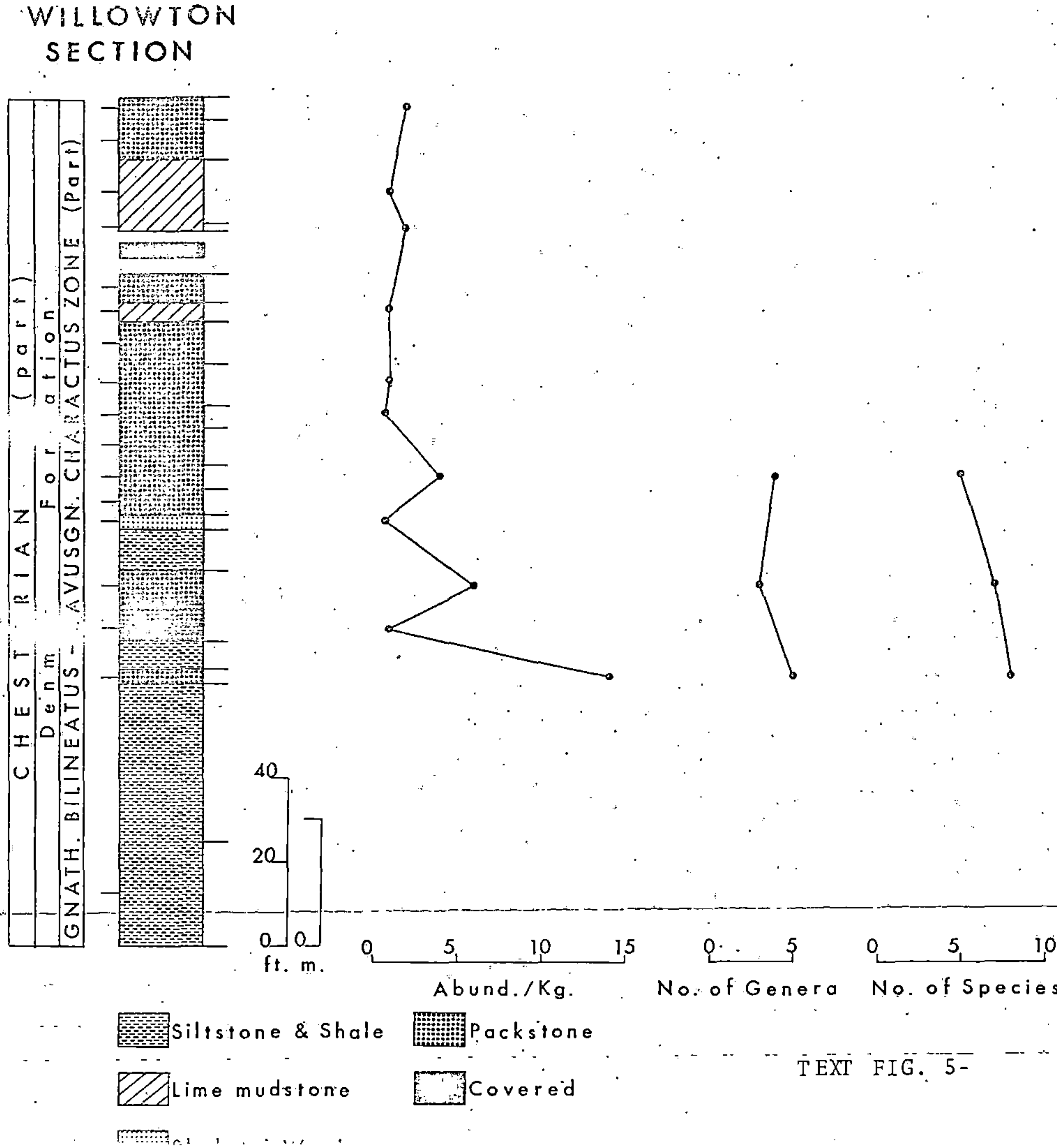
BISHOP SECTION
CHESTERIAN (part)
Denmar Formation
GNATH. BILINEATUS-CAVUSGN. CHARACTUS ZONE
Subzone 2 (part)
Subzone 1 (part)
73
70
68
66
65
62
60
59
56
54
53
50
49
45
41
40
ft. m.
Abund./Kg.
No. of Genera
No. of Species
Siltstone & Shale
Packstone
Lime mudstone
Covered
Skeletal Wackestone

TEXT FIG. 3-



TIPTOP SECTION
CHESTERIAN (part)
Denmar Formation
GNATH. BILINEATUS-CAVUSGN. CHARACTUS ZONE
Subzone (part)
27
25
24
23
22
21
20
19
18
17
16
40
20
0
ft.
10
0
m.
0 5 10 15
Abund./Kg.
0 5 10
No. of Genera
0 5 10 15
No. of Species
Siltstone & Shale
Packstone
Lime mudstone
Covered
Skeletal Wackestone

TEXT FIG. 4-



WILLOWTON
SECTION
CHESTERIAN (part)
Denm For ation
GNATH. BILINEATUS - AVUSGN. CHARACTUS ZONE (Part)
40
20
0
0
ft. m.
0
5
10
15
Abund./Kg.
0
5
No. of Genera
0
5
10
No. of Species
Siltstone & Shale
Packstone
Lime mudstone
Covered

TEXT FIG. 5-

Lime mudstones in the Denmar Formation consist of gray to dark gray, mud-supported sediments composed of abundant lime mud (85-95 percent), sand-size skeletal grains (echinoderm, bryozoan, brachiopod, Foraminifera, and ostracode fragments), and silt and sand-size non-skeletal grains of pellets and lime mud intraclasts. Terrigenous grains of quartz, mica and feldspar occur in some lime mudstones with detrital quartz most common. Paleontologically, this lithofacies contains relatively few micro and macrofossils, with many units often barren. This lithofacies can be subdivided into skeletal and non-skeletal lime mudstones. In most cases when skeletal grains are present they probably reflect local current reworking and sorting or storm wave accumulations rather than aggregations of living populations in-situ. Many skeletal grains, particularly foraminiferan tests and gastropod shells, are often infilled with mud. Scattered non-partitioned tubes of the blue-green alga, Girvanella were observed in some lime mudstone thin sections. Many thin sections of lime mudstones containing bioclasts have a mottled and swirled appearance suggestive of intensive burrowing. Some of the lime mudstones grade vertically into skeletal wackestones in thin section and frequently the interface between these two lithofacies is marked by burrows which tend to be normal to bedding and infilled with either lime mud or abraded bioclasts suggesting the former presence of relatively deep-burrowing, tidal-flat organisms. Non-skeletal grains in this lithofacies consist of pellets and intraclasts. The pellets are structureless, ovoid grains of micrite less than 0.25 mm in size and are usually superficially coated. Although some may be of fecal origin, the angularity and wide size range in poorly sorted lime mudstones suggest many are probably of algal origin. Intraclasts are not very common but when present consist of well rounded fragments, ranging in size from 1 to 20 mm in diameter, of quartz-bearing lime mud. Physical sedimentary structures of the lime mudstone lithofacies observed in outcrop and in thin section consist primarily of horizontal- to cross-laminations and wavy undulatory laminations. This lithofacies is most common in the Bishop section to the southwest (Text-fig. 3).

Skeletal wackestones are a common lithofacies in all sections but are most abundant and thicker in the Bishop section (Text-fig. 3). These limestones occur in medium- to thick-bedded often massive units and are composed of abundant lime mud (50 - 85 percent), skeletal grains, pellets, ooids, superficial ooids and minor intraclasts. Lime mud occurs mainly as matrix but also as infillings of skeletal material such as gastropods, bryozoan zooecia, brachiopod interiors, foraminiferan and ostracode tests. This lithofacies has a higher spar- to micrite ratio than lime mudstones and a higher percentage of skeletal grains (10-70 percent) as compared to lime mudstones (1-10 percent). Many of the skeletal and non-skeletal grains display micritic coatings. Sorting and packing are generally moderate to poor. Paleontologically, this lithofacies contains the highest faunal diversity and highest relative abundance of both micro and macrofossils. Active burrowing is indicated in thin section and in outcrop by uneven contacts between skeletal wackestones and underlying lime mudstones. In outcrop, this lithofacies contains skeletal fossil material of a variety of organisms in-situ (articulated valves of brachiopods, bryozoan fronds, etc.), suggesting aggregations of living populations in-situ or in close proximity to the environment of deposition. Approximately 90 percent of the skeletal grains observed in thin section consist of fenestrate and bifoliate bryozoans, punctate and inpunctate brachiopods, and echinoderm bioclasts. Minor skeletal grains, which may be locally abundant, include calcareous algae, foraminifers and ostracodes. Other taxa including solitary and colonial corals, pelecypods, gastropods, and trilobite fragments are represented. Many of the skeletal grains have micritic coatings suggesting reworking of an original carbonate mud and/or algal borings. Non-skeletal grains in wackestones consist primarily of pellets and ooids with minor amounts of superficial ooids and intraclasts. Ooids occur as spherical to elliptical grains less than 2.0 mm in diameter consisting of two or more coated layers. Ooid nuclei commonly consist of detrital quartz, pellets, Foraminifera, and other bioclasts. Most ooids display concentric coatings but some also exhibit a secondary fibro-radiated structure. There is a noticeable increase in quartz content and micritic mud in the skeletal wackestones in the Denmar to the northeast. In the northeast at Willowton, all skeletal wackestones contain very abundant detrital quartz grains and lime mud. There is also a sharp decrease in relative abundance and faunal diversity of macrofossils and conodonts from the southwest at Bishop toward the northeast at Willowton (Text-figs. 3-5). Vertically, skeletal wackestones are commonly underlain by lime mudstones or terrigenous siltstone and shale units and overlain by packstone units in all sections studied. Laterally equivalent rock types include primarily lime mudstones and terrigenous siltstones and shales.

Packstones are more common and thicker in the Denmar in the Willowton section to the northeast (Text-fig. 5). Packstones are light gray to gray, medium-, thick-bedded to massive, commonly cross-bedded, grain-supported carbonates composed of abundant sand-size and pebble-size skeletal grains together with common sand-size non-skeletal carbonate grains and interstitial lime mud (0-55 percent). Some packstones grade texturally into grainstones according to Dunham's (1962) classification. Spar- to -micrite ratios are appreciably higher in packstones as compared to lime mudstones and skeletal wackestones. Packstones are usually dominated by skeletal grains consisting principally of echinoderm bioclasts and fenestrate bryozoans or non-skeletal grains consisting primarily of ooids and superficial ooids. Many skeletal grains and ooids are covered by thin micrite envelopes. These coatings may have been formed by boring algae in intermittent or medium-energy environments less subject to abrasive wave action. Well-rounded and moderately-to well sorted abraded bioclasts in some packstones suggest carbonate deposition after considerable current reworking. The axial canals of crinoid columnals, zooecia of bryozoans, and internal voids of ostracodes, foraminiferans, and gastropod shells often contain dark lime mud infillings suggesting intraformational reworking of a former lime mudstone environment. Other evidence of wave or current reworking of partially consolidated underlying lime mudstone units consists of lime mud intraclasts and ooid nuclei with lime mud infillings. Burrows are rare in the packstone lithofacies probably due to rapid sedimentation and repeated and thorough reworking of sediments from a variety of contrasting environments. However, some burrow systems were noted in thin section at contacts between ooid packstones and skeletal wackestones. They are oriented both normal and parallel to bedding. Packstones contain an abundant and diverse macrofauna, particularly the bryozoan-echinoderm packstones. However, ooid packstones yield a very sparse macrofauna. Conodonts are abundant but low in taxonomic diversity in some bryozoan-echinoderm packstones but very rare to absent in most ooid packstones. The conodonts in packstones are highly fragmental and restricted mainly to platform types. The relative high abundance of conodonts in some packstones may reflect lag concentrations due to strong reworking from adjacent environments by wave and current action. Vertically, packstones are commonly underlain by skeletal wackestones or fossiliferous siltstones and shales and overlain by lime mudstones or terrigenous siltstones and shales. In the northeast at Willowton, packstones commonly alternate with lime mudstones throughout the Denmar Formation (Text-fig. 5). Laterally, packstones commonly grade into lime mudstones.

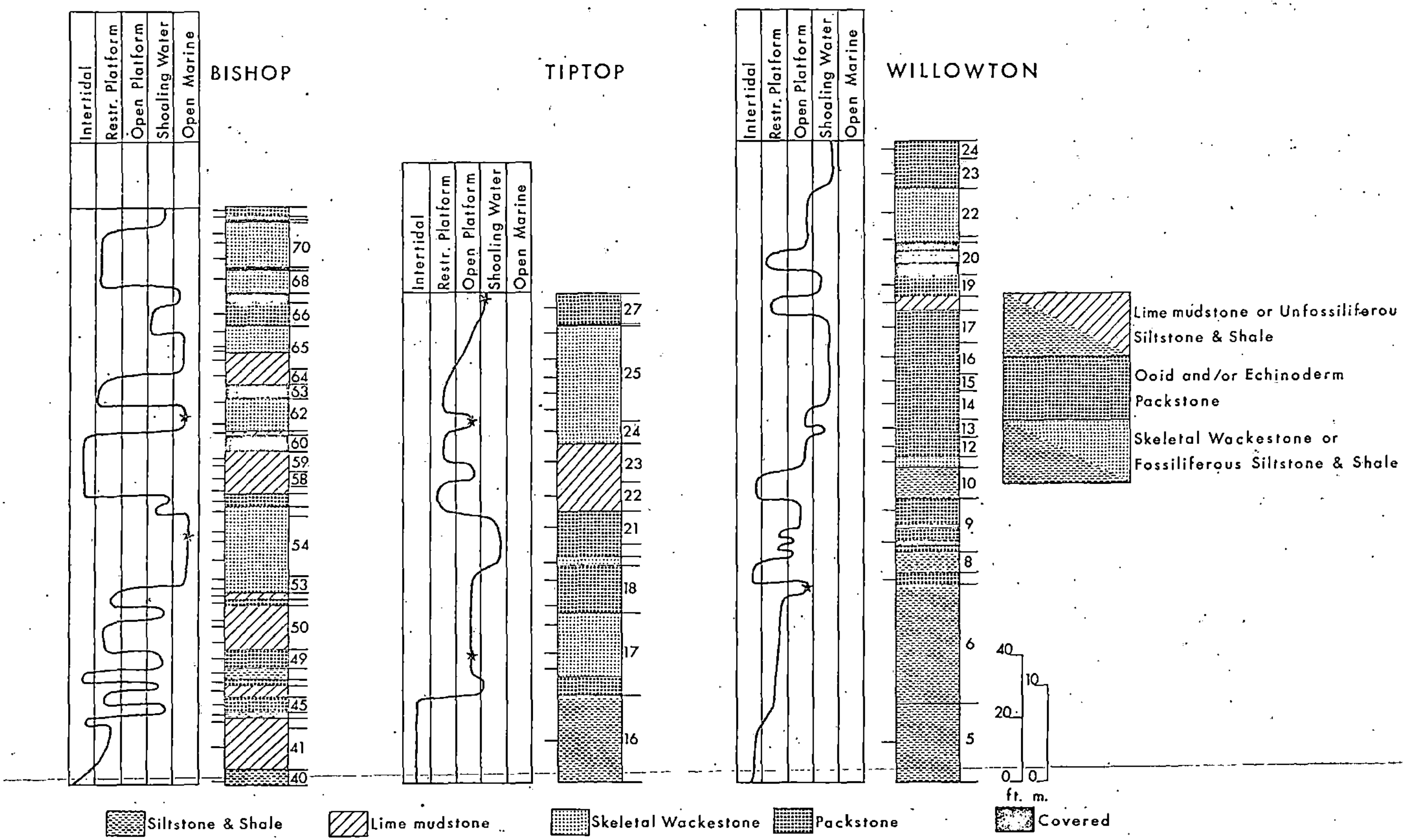
Siltstones and shales occur throughout the Denmar Formation at all localities but are most common in the Denmar Formation at Willowton (Text fig. 5). This lithofacies occurs in medium- to thick-bedded, often massive, units. They are commonly brown tan, reddish-brown, and yellowish-brown in color and composed primarily of subangular to angular, silt- to clay-size quartz, minor amounts of feldspar and randomly oriented mica flakes. The matrix consists of microcrystalline dolomite, or locally microcrystalline calcite. Many of these units are unfossiliferous. Fossiliferous siltstones and shales are calcareous and consist primarily of silt-size skeletal grains including bioclasts of echinoderms, bryozoans, brachiopods, calcareous algae, and ostracodes. Many of the siltstones are laminated and the laminae consist of concentrated silt-size grains of detrital quartz, clay minerals, and muscovite flakes oriented parallel to bedding. These mineral concentrations accentuate the laminated texture and some units often display cross-laminations. Ripple and lenticular bedding occur in some siltstone and shale units. These bedding types have been recognized in modern tidal flat deposits by Reineck (1972) and Reineck and Singh (1973). Paleontologically, this lithofacies contains the most meager micro and macrofauna with many units completely barren. Unfossiliferous siltstones and shales are commonly associated with lime mudstones and frequently overlain by skeletal wackestone and less frequently by packstones whereas, fossiliferous siltstones and shales are commonly associated with skeletal wackestones and overlain by packstones.

DEPOSITIONAL ENVIRONMENTS

Sedimentary environments within the strike belt migrated and were not everywhere synchronous as rock boundaries do not parallel zonal, i.e., time boundaries (Text-fig. 2). Tectonism probably contributed to this pattern of environmental diachronism. The abundance and thicknesses of terrigenous sediments in the Denmar to the northeast at Willowton indicates that this area was nearer an eastern-northeastern deltaic source than areas to the southwest. However, minor influxes of terrigenous sediment did occur periodically in the southwest during Denmar time. Five major environments of deposition are inferred within the Denmar Formation (Text-figs. 6,8).

Intertidal (Tidal Flat Facies) - The dominant lithofacies are unfossiliferous siltstones and shales and non-skeletal lime mudstones. Physical sedimentary structures observed in the field and in thin sections of this lithofacies include ripple bedding, flaser bedding, lenticular bedding and scour and fill structures. This environment is best represented at Willowton (Text-fig. 6).

Restricted Platform (Lagoonal) - The dominant lithofacies are thin-bedded wackestones and skeletal lime mudstones with minor packstone beds. Skeletal grains in rocks of this



Denmar Formation — Illustrating Rock Types And Inferred Environments Of Deposition.

TEXT FIG. 6-

environment are dominated by gastropods, ostracodes, algae, Foraminifera, and locally abundant bryozoans and crinoids. Non-skeletal grains consist primarily of pellets and intraclasts representing reworked sediments from the adjacent open platform and shoaling water environments. This environment is best represented at Tiptop (Text-fig. 6).

Open Platform - The dominant lithofacies consist of thin- to -medium bedded bryozoan-echinoderm wackestones and packstones. Skeletal grains consist primarily of bryozoans and echinoderms with minor amounts of gastropods, algae, brachiopods, Foraminifera, and colonial corals. Abundant burrowing was noted in rocks of this environment and chert is also common. This environment is best represented at Tiptop (Text-fig. 6).

Shoaling Water (carbonate banks - echinoderm-bryozoan gardens) - The dominant lithofacies consist of medium- to -thick bedded often cross-bedded echinoderm-bryozoan packstones and ooid packstones some of which grade texturally into grainstones. Skeletal and non-skeletal grains are often rounded and moderately to well sorted. The most common non-skeletal grains are ooids and intraclasts composed of peletal lime mud reworked from the adjacent environments. Pellets, oncolites, and bioclasts with micrite envelopes are more abundant in this environment than in any other environment. This environment is characterized by higher energy, shifting skeletal sand substrates, and possibly flucuating salinities. This environment is best represented to the northeast in the Willowton section (Text-fig. 6)

Open Marine Shelf - The dominant lithofacies in this environment are medium- to -thick bedded echinoderm-bryozoan wackestones and packstones with minor beds of fossiliferous siltstones and shales. Skeletal grains are dominated by bryozoans, echinoderms, and calcareous algae with brachiopods locally common. Intraclasts are the most common non-skeletal grains. This environment is characterized by lower energy, near normal marine salinities, and more stable environmental factors. This environment is best represented to the southwest in the Bishop section (Text-fig. 6)

The most common lithologic sequence in the Denmar is a shoaling upward and regressive offlapping sequence superimposed on a broadly onlapping succession (Text-fig. 6). These shoaling upward sequences are represented at the base by skeletal wackestone or fossiliferous siltstone and shale units representing a deeper, lower energy subtidal, open marine environment with resident communities of brachiopods, echinoderms, and bryozoans. These units commonly overlie lime mudstones of the underlying succession. These units are overlain by ooid and/or echinoderm packstones, some grading into grainstones. These units suggest a shallower, more agitated, higher energy shoaling water environment representing areas where wind-generated waves or possibly tidal currents reworked skeletal and non-skeletal grains and winnowed out lime mud. The top of the shoaling upward sequence is represented by massive or laminated non-skeletal lime mudstones or unfossiliferous siltstones and shales. These units suggest decreasing energy and tidal flat conditions by the increasing silt and clay-size carbonate and/or terrigenous sediment, algal structures, and ripple and lenticular bedding. This shoaling upward sequence is shown by units B-48 - B-50 in the Bishop section (Text-fig. 6) and by units T-19 - T-22 in the Tiptop section (Text-fig. 6). These shoaling upward sequences indicate that carbonate sedimentation rates were often greater than rate of subsidence. During Denmar time marine subtidal conditions persisted in the southwest at Bishop as indicated by the abundant and thick skeletal wackestone units, whereas to the northeast at Willowton thick tidal flat lime mudstones and siltstones and shales indicate prolonged periods of rapid intertidal deposition from a terrigenous source (Text-fig. 6)

CONODONT FAUNA

Continuous sampling of the Denmar Formation has yielded 751 identifiable conodonts (562 from the Bishop section) assigned to 11 form-genera and 21 form-species of the lower part of the Gnathodus bilineatus - Cavusgnathus charactus Zone of Late Valmeyeran and Early Chesterian age (Upper Visean). The overall relative abundance of conodonts from all depositional environments within the Denmar Formation is low with an average yield of 3.4 specimens per kilogram of digested sample. The most abundant form-genera in all depositional environments, in order of decreasing percentages of total fauna, are Cavusgnathus (28%), Gnathodus (24%), Hindeodella (11.2%), Neoprioniodus (10.5%), Ligonodina (9.6%), and Spathognathodus (9.3%). Other form-genera represented include Hibbardella (2.5%), Lambdagnathus (2.0%), Magnilaterella (1.2%), Ozarkodina (.9%) and Hindeodus (.8%). Platform form-genera consisting of Gnathodus, Cavusgnathus, and Spathognathodus comprise 61% of the total conodont fauna.

CONODONT BIOFACIES

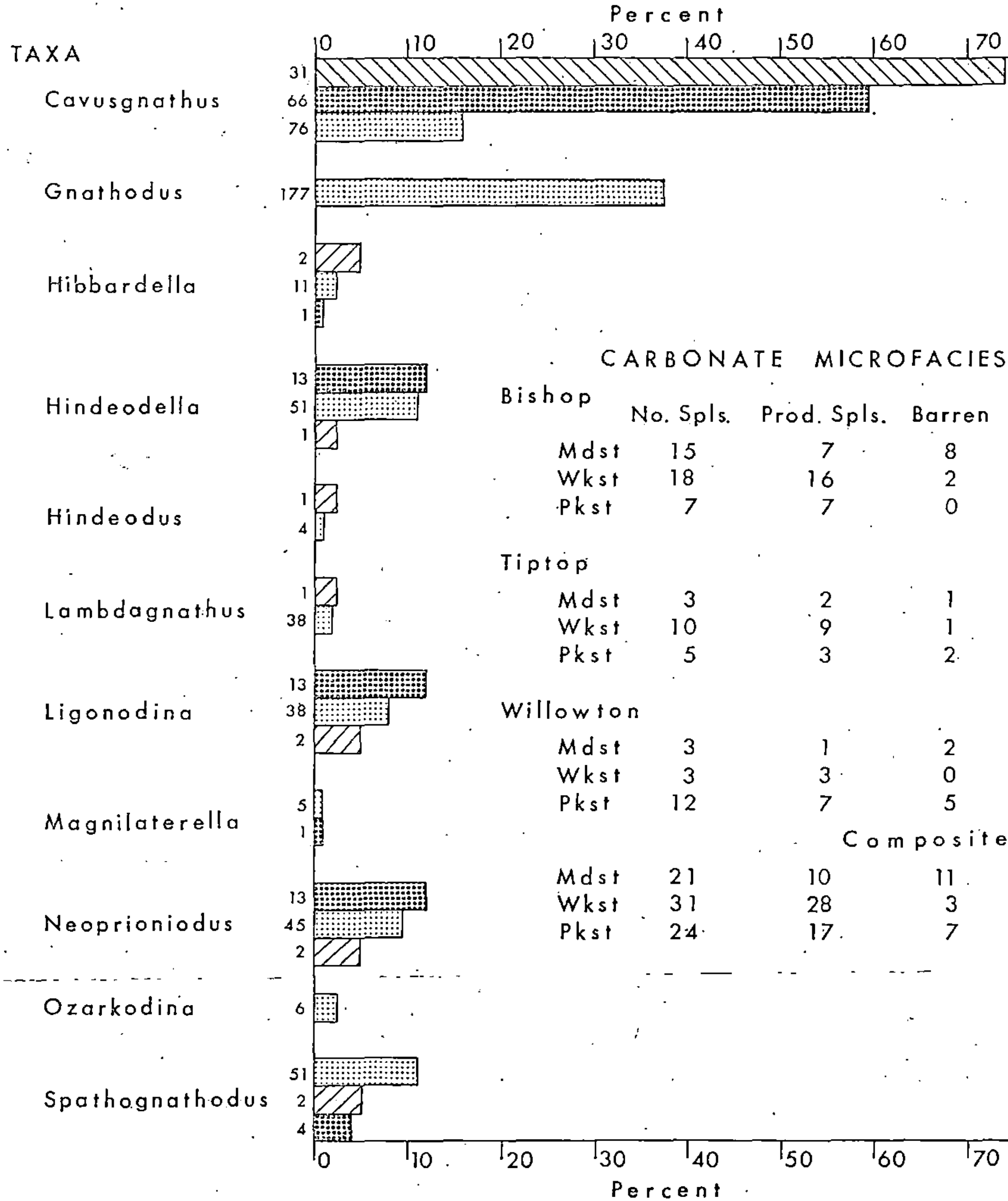
The term "diversity" as used in this paper, refers to the number of conodont form-genera and species recovered from samples yielding 10 or more conodont specimens (Text-figs. 3-5). Diversity does not appear to be affected by sample size in that most species found in large samples were also recovered in small samples.

Overall relative conodont abundance and diversity are maximum in thick skeletal wackestones representative of a more stable, deeper water, open marine subtidal environment in the southwest at Bishop (Text-fig. 3).

All rock types in the Tiptop section contain increasing amounts of detrital terrigenous sediment and lime mud and overall conodont abundance and diversity sharply decreases in the Denmar at Tiptop (Text-fig. 4). However, once again maximum abundance and conodont diversity is found in thick skeletal wackestones characteristic of the open platform marine facies (Text-fig. 4).

In the northeast at Willowton terrigenous sediment is a major constituent of all lithofacies in the Denmar. Conodont abundance and diversity is minimal in the Denmar at Willowton (Text-fig. 5). This is interpreted to be the result of more rapid sedimentation associated with increasing amounts of terrigenous mud and sand derived from an eastern-northeastern detrital source.

Text-fig. 7 shows the major form-genera, the number of specimens in each carbonate microfacies, illustrates the percentages of each form-genera (in terms of total conodont fauna) found in each major carbonate lithofacies and the average yield from each microfacies in the Denmar at all localities. Approximately 502 of the 751 identifiable conodonts were recovered from skeletal wackestone units. Cavusgnathus comprises 74% of the total conodont fauna found in all lime mudstones, 59% of the total conodont fauna found in all packstones, and 16% of the total fauna recovered from all skeletal wackestones. Gnathodus was restricted to the skeletal wackestone lithofacies where it comprises 37% of the total conodont fauna recovered from skeletal wackestones. Hindeodella, Ligonodina, and Neoprioniodus all show relatively similar distribution patterns with regard to all lithofacies. However, they do comprise a slightly higher percentage of the total fauna found in packstones as compared to the other lithofacies. Text-fig. 8 shows a proposed carbonate model for the Denmar Formation with the inferred environments of deposition illustrated with their associated lithofacies. The ecologic preference or relative "dominance" of conodont form-genera within these environments, as summarized from Text-figs. 3-6, is also shown with the width of



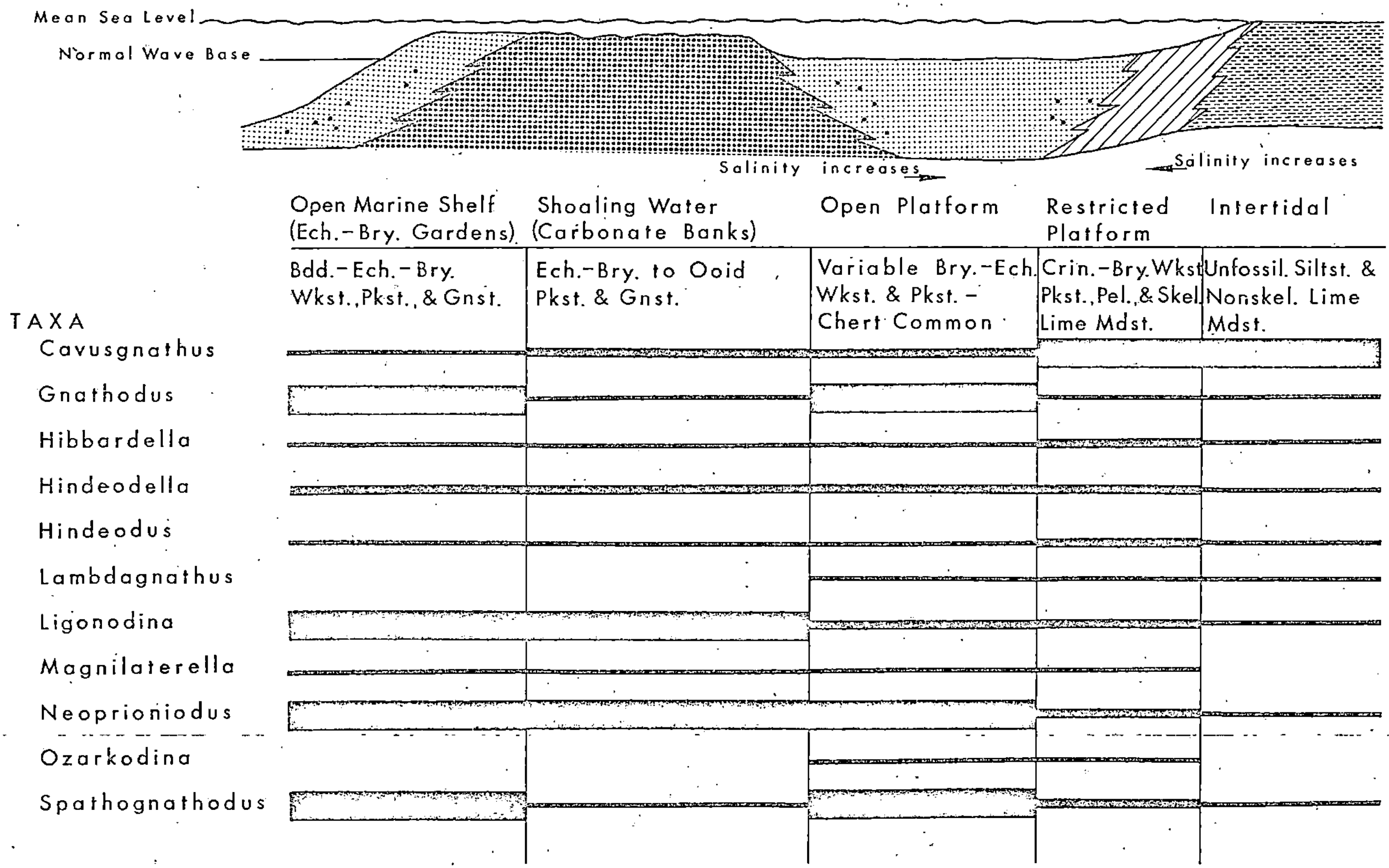
CARBONATE MICROFACIES

	No. Spls.	Prod. Spls.	Barren	Yield/Kg.	Avg. Yield
Bishop					
Mdst	15	7	8	1-3	1.7
Wkst	18	16	2	1-30	5.7
Pkst	7	7	0	1-8	2.9
Tiptop					
Mdst	3	2	1	1-2	1.5
Wkst	10	9	1	1-11	3.9
Pkst	5	3	2	4-6	3.7
Willowton					
Mdst	3	1	2	1	1.0
Wkst	3	3	0	1-2	1.3
Pkst	12	7	5	1-14	4.1
Composite					
Mdst	21	10	11		1.4
Wkst	31	28	3		4.5
Pkst	24	17	7		3.0

TEXT FIG. 7

TEXT FIG. 8-

CARBONATE DEPOSITIONAL MODEL FOR DENMAR FORMATION



the bar indicating relatively higher dominance. The term "dominance" as used in this paper refers to those form-genera that comprise the greatest relative percentages of the total conodont fauna found in each carbonate lithofacies from all depositional environments.

CONCLUSIONS

The study of conodont distribution patterns and carbonate lithofacies in the Denmar Formation reflect the following:

(1) Progressively lower conodont abundance and diversity occurs from southwest (in the carbonate-rich facies) to the northeast (in the more detrital-rich facies). This most likely resulted from a higher influx of terrigenous material and an overall more rapid rate of sedimentation to the northeast;

(2) Overall maximum conodont abundance and diversity occurs in thick, continuous sequences of skeletal wackestones interpreted as representing primarily deeper water, lower energy, more stable open marine conditions with near normal salinity;

(3) Overall minimal conodont abundance and diversity occurs in the more detrital-rich facies composed of siltstones, shales and non-skeletal lime mudstones representative of nearer shore, shallower water, lower energy restricted platform and tidal flat environments. These environments are characterized by less stable ecologic factors such as muddy

substrates, increased water turbidity, and fluctuating salinities ranging from above near normal salinity to well below;

(4) Low to moderate conodont abundance and diversity occur in skeletal lime mudstones of the restricted platform environment and in packstones most characteristic of a higher energy, shoaling water environment;

(5) Relatively high ecological preference is displayed by the form-genus Cavusgnathus for lime mudstone and packstone environments and by the form-genus, Gnathodus for skeletal wackestone environments;

(6) Overall low diversity and high dominance figures of the conodont fauna reflect environmental instability whereas increased environmental stability is reflected by the increased conodont diversities and the decrease in dominance;

(7) Ecological factors which appear to have been most influential on Mississippian conodont abundance and diversity in the study area are variations in amount of detrital sediment influx, environmental stability, substrate, salinity, temperature, turbulence, food, O_2, and light. All of these factors are to some degree depth related, i.e. shallow nearshore environments tend to be less stable, turbulent, sunlit and coarser grained whereas in general, deeper environments tend to be the reverse. However, no single controlling factor can

be selected to explain the distribution and diversity of Early Chesterian conodonts in the Denmar Formation. A variety and probably a combination of environmental factors could have and probably did influence the distribution and diversity of Mississippian conodonts in the Denmar Formation.

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