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SUBDIVISIONS AND CORRELATIONS
 OF THE
 TULLY FORMATION (UPPER DEVONIAN)
 IN NEW YORK STATE AND PENNSYLVANIA
 ON THE BASIS OF
 A STATISTICAL AND STRATIGRAPHICAL ANALYSIS
 OF SELECTED CONODONTS

by

Ulrich Mayr

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ABSTRACT

A fourfold subdivision and a correlation of the calcareous parts of the Tully Formation in New York and Pennsylvania are based on the ratios of the abundance of the conodonts Polygnathus linguiformis, P. varca, P. ? iuvenis and Icriodus. The statistical distribution of the four taxa is independent of the local lithology, but follows stratigraphical units.

The studied conodont faunal succession of the Tully Formation includes a conodont zone not yet described from Europe. This new zone is thought to be younger than the base of the Assise de Fromelennes (?Upper Devonian, France) and is furthermore correlated with the lowest part of the to 1 α zone (Upper Devonian, Germany).

The conodonts of the Tully Formation are considered to be similar to those of the lower Geneseo Shale, the Alto Formation (Illinois), and the Cedar Valley Limestone (Minnesota).

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EUROPE		NORTH - AMERICA		
Series	Ammonoid zones	Series	Stage	Ammonoid zones
Frasnian (part) Aspidian (part)	Manticoceras cordatum to 1 (β)γ	Senecan (part)	Finger Lakes	Probeloceras lutheri — ? —
	Pharciceras lunulicosta to 1α			Manticoceras simulator — ? — Ponticeras perlatum
Cluettian (part)	Manticoceras terebratum	Erian (part)	Tag- hantic	Pharciceras zplexum
			Trough- noga	Tornoceras sp.

FIG. 1 STRATIGRAPHICAL TERMS FOR THE DEVONIAN
CURRENTLY IN USE IN NORTH - AMERICA

(after Rickard 1964)

A) INTRODUCTION

The classic section of Devonian strata in New York* has become a type for the system in North America. It is nevertheless, not free from controversy and its correlation with the European system poses some problems. Among the problems frequently discussed is the position of the Middle/Upper Devonian boundary.

In 1942 Cooper established the Taghanic Stage in the uppermost Middle Devonian to include the Tully Limestone and clastics, the Geneseo Shale, and several other formations in midwestern U.S.A. Its main constituent, the Tully Formation is characterized by a fauna of Hamilton and Ithaca aspect together with several particular forms which are, according to Cooper and J.S. Williams (1935), Receptaculites sp., Leptaena "rhomboidalis", Scutellum tullium, and Hypothyridina venustula. The argument, however, is not finished and evidence for an Upper Devonian age of the Tully Formation is also present (House, 1962).

Conodonts are proving of use in Europe in assessing the age of many problematic formations, whether or not a macrofauna be present. In the Mississippian and Devonian of North America they are also proving their worth.

* In this study New York State is referred to as New York.

The present study concerns the application of conodont studies to the Tully Limestone, with several aims:

1. Clarification of the biostratigraphic relations of the Tully Formation in New York and Pennsylvania.
2. Comparison of the Tully conodont fauna with equivalent North American faunas.
3. Establishment of the age of the Tully Formation in terms of the European conodont section.

During the fieldwork (falls of 1963 and 1964) two areas in New York between Canandaigua Lake and Tully, and in Pennsylvania between Blair County and Lycoming County were sampled (see appendix). Also some reference material was collected from the Givetian type section (i.e. Assise de Fromelennes) in fall of 1965. Ordinary methods such as the treatment with acetic acid and the use of a magnetic separator were applied to free the conodonts from the limestone.

This study was carried out under supervision of Dr. D. L. Dineley and his guidance and interest, as well as that of the rest of the staff of the Department of Geology, are gratefully acknowledged. I am deeply indebted to Dr. J. E. Graham (Carleton University, Ottawa) without whose help the statistical part would not have been prepared. Thanks are furthermore extended to

Dr. A. Beugnies (Faculte Polytechnique de Mons), who showed me the type section of the Assise de Fromelennes (France). Dr. J. W. Huddle (United States Geological Survey) and Dr. L. V. Rickard (New York State Geological Survey) have given a great amount of paleontological and stratigraphical advice. Also, discussions with Mr. P. Bär (University of Giessen, Germany) were very valuable. Financial support for the writer was provided by the Geological Survey of Canada and the Department of Geology, University of Ottawa.

B) OUTLINE OF MIDDLE/UPPER DEVONIAN STRATIGRAPHY IN EUROPE

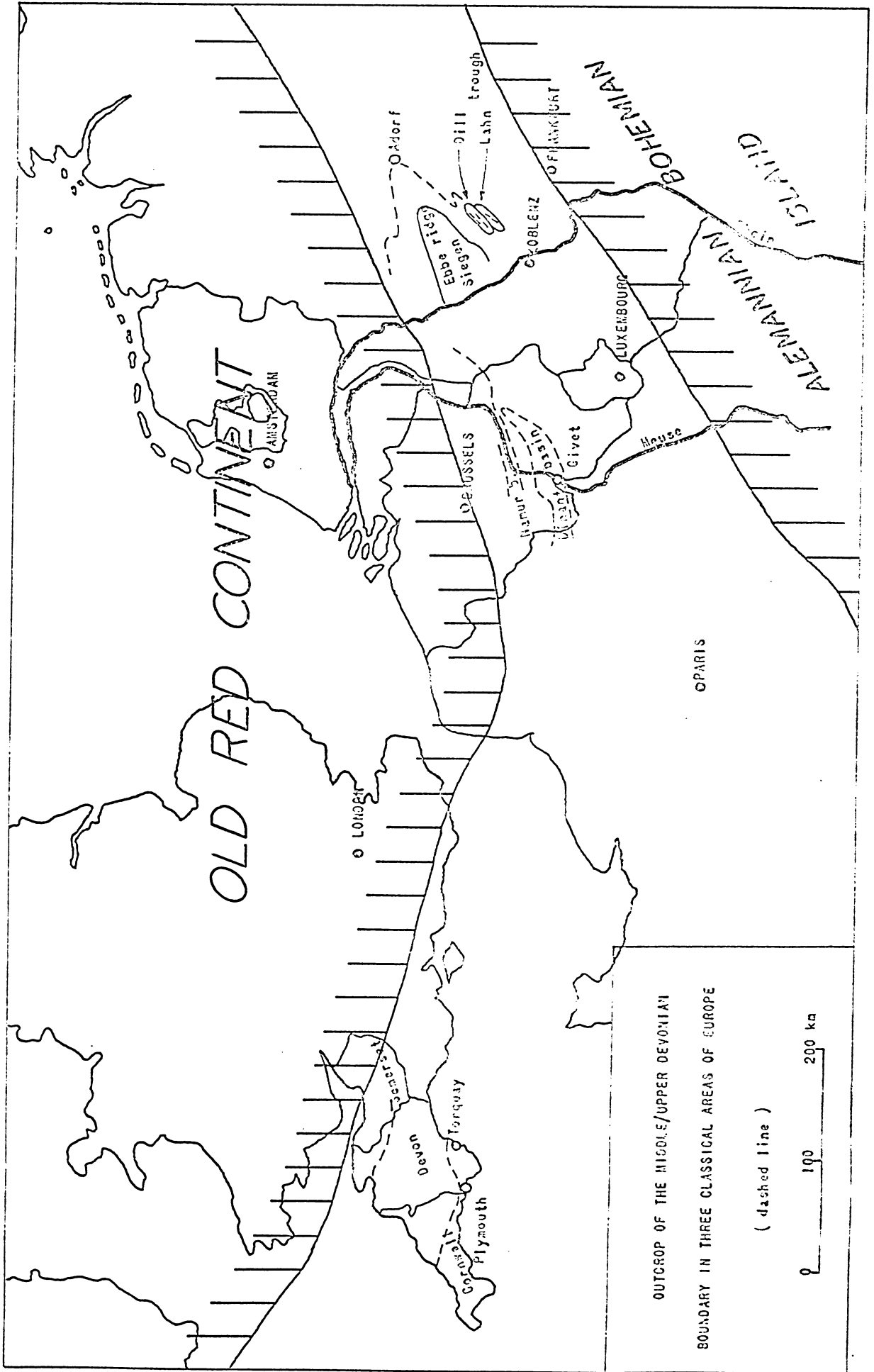
PALEOGEOGRAPHY OF THE GIVETIAN AND FRASNIAN

Based on many detailed stratigraphical and paleontological investigations, the geography of Europe during Devonian times is fairly well known and in fig. 4 the correlation of three very important areas is shown.

At the end of the Middle Devonian and the beginning of the Upper Devonian the geography of central Europe was controlled by two continental features - in the north (eastern Ireland, central England, and Scandinavia) the Old Red Continent, and in the south (southern Germany and northern France) the Alemannian - Bohemian Island. This southern island separated the Variscan geosyncline from the marine regions of the Mediterranean and North Africa.

The topography in the Variscan geosyncline was by no means uniform. In the Rhenish part the geosyncline was differentiated into several elongated troughs and longitudinal ridges which acted as shoals. The largest of these ridges was the Siegen - ridge (see fig. 2) with troughs towards the south (Lahn and Dill). Farther west in Belgium the conditions were more uniform. There a relatively shallow trough with less complex features was

FIG. 2



OUTCROP OF THE MIDDLE/UPPER DEVONIAN

BOUNDARY IN THREE CLASSICAL AREAS OF EUROPE

(dashed line)

0 100 200 km

situated (W. Schmidt, 1951). In south west England a bottom morphology with ridges and troughs has similarly been assumed (Hendriks, 1959; but see Dineley, 1966 for qualification).

The variations of the sediments in the Variscan geosyncline correspond to the differences in the bottom morphology. The upper Givetian rocks of the Rhenish Schiefergebirge consist of the reef limestones fringing the different ridges (Jux, 1960), interfingering with the shales and siltstones of the troughs and the tuffs and flows of strong submarine eruptions (Kegel, 1934). Nonreefous limestones are rare and often occur as lenses in the shales. The lithologies of the Upper Devonian are as varied, but cephalopod limestones are dominant over the reef limestones, which continue from the Middle Devonian. On the top of the Middle Devonian tuffs an iron ore zone is sometimes found (see figs. 3 and 4).

In the western trough in Belgium the variation in lithology is not as extreme as described above. The Givetian consists of limestone with variable amounts of argillaceous material. It thins towards the north and shows sandy layers in the Namur basin. The Upper Devonian is shaly and also loses thickness in a northerly direction (Kegel, 1948; W. Schmidt, 1951; Gignoux, 1960).

In south west England the situation is similar to the one in Germany. Limestones, clastics, and volcanics are interbedded vertically and laterally (Dineley, 1961).

The described picture is of course very generalized and many unsolved stratigraphical problems exist in all three regions. Against this background of a very varied geosyncline the three classical areas of the European Devonian, south west England, the Meuse valley, and the Adorf region have to be discussed.

POSITION OF THE MIDDLE/UPPER DEVONIAN BOUNDARY

South west England

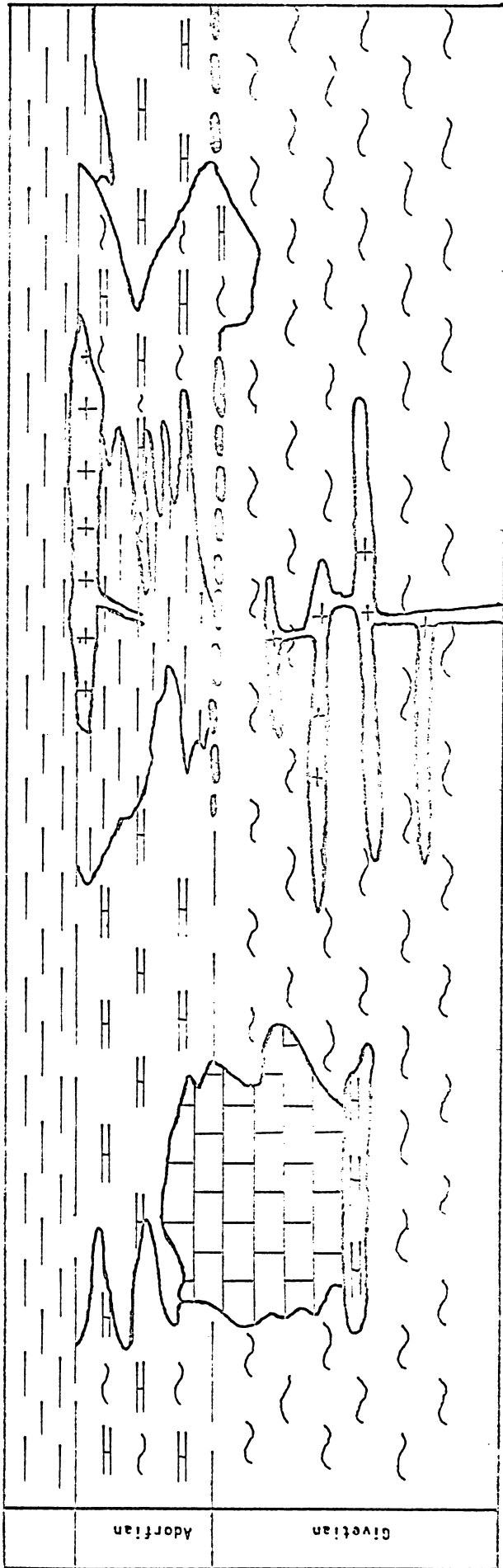
In south west England the Devonian rocks outcrop in two belts, one in north Devon and west Somerset and the second in Cornwall and south Devon (see fig. 2), separated by the Carboniferous rocks of central Devon. In these belts Murchison and Sedgwick recognized a rock series different from both the Silurian and Carboniferous and in 1839 introduced the term Devonian. But in south west England the type area of the Devonian is located rather unfortunately because the exposure is bad and facies changes are abrupt. Moreover, the rocks are tectonically deformed and have undergone metamorphism so that fossils

are either destroyed or distorted. The Middle/Upper Devonian boundary lies in the top beds of the Torquay and Plymouth Limestones, which are succeeded by shales and slates. The boundary is shown by the local ranges of Maenioceras terebratum, Manticoceras cordatum, Hypothyridina cuboides, Stringocephalus burtini, and others (see fig. 4; Dineley, 1961; House & Selwood, 1964).

Meuse valley

In the Ardennes the Meuse valley cuts across the Dinant and Namur basins (see fig. 2), through rocks ranging in age from Cambrian to Carboniferous. The Givetian type section is situated on the southern rim of the Dinant basin at the escarpment below Fort Charlemont and Trois Fontaines just south of the town of Givet (see fig. 10). Here Gosselet and Maillieux clarified and defined the upper part of the Middle Devonian in a series of investigations beginning in 1860. Because of the almost entire lack of cephalopods, they base their stratigraphy on brachiopods and corals (Stringocephalus burtini, Spirifer mediotexus, Spirifer undiferus, Hexagonaria quadrigemina; Lecompte & Waterlot in Waterlot, 1957).

The position of the Middle/Upper Devonian boundary is controversial. It involves the placing of



- shale [Symbol: horizontal dashes]
- bedded limest. [Symbol: horizontal dashes with vertical ticks]
- tuff [Symbol: wavy lines]
- iron ore [Symbol: horizontal dashes with vertical ticks]
- interbedded tuff and limestone [Symbol: wavy lines with horizontal dashes]
- diabase [Symbol: vertical lines]
- massive limestone [Symbol: horizontal dashes]

FIG. 3 EXAMPLE OF FACIES RELATIONSHIPS IN THE RHENISH SCHIEFERGEBIRGE (after Pauly 1958)

the Assise de Fromelennes, a formation which consists, at its type section near Givet, of about 130 m of shale, stromatoporoidal and algal limestone, and contains a fauna of both Givetian and Frasnian affinities. The most important index fossils are Stringocephalus burtini, Spirifer verneuili, and Spirifer tenticulum (see fig. 4). In 1942 Maillieux published a faunal study from over 30 localities of the Fromelennes Formation, mainly in southern Belgium, and concluded that the character of the fauna was dominantly Frasnian. The opposite point of view was held by Moureau (1932) and Bonte and Ricour (1948), who denied the evidence for an Upper Devonian correlation. For lithological and practical reasons as well as because of the occurrence of Stringocephalus burtini, they regarded the Fromelennes Formation as Givetian and placed the Middle/Upper Devonian boundary in the zone of Spirifer orbelianus. However, in accordance with the ruling of the Conseil Geologique de Belgique, it is general in Belgium to consider the Fromelennes Formation as Frasnian and to take the appearance of Spirifer tenticulum as a marker of the beginning of the Upper Devonian.

Rhenish Schiefergebirge (Adorf)

In the Rhenish Schiefergebirge the main outcrop of the Middle/Upper Devonian contact lies along an arch which surrounds the eastern edge of the Ebbe and Siegerland anticlines. Until about 1913 the distinction of Middle Devonian from Upper Devonian was done there by lithological rather than by paleontological means. For details of the earlier subdivisions see Murchison (1859). Holzapfel (1895) and Denckmann (1903) were among those who pointed out the importance of paleontology to distinguish the successions of the different facies.

In 1913 Wedekind, relying on this earlier work, published his study of the cephalopod zonation of the Adorf Stage at the easternmost extension of the Siegerland anticline. The type locality is in a deserted ore mine on the Martenberg near the village of Adorf (for details see Holzapfel, 1895; Paeckelmann, 1928, 1936; Ziegler, 1958). According to Wedekind, the Upper Devonian starts here with the appearance of Pharciceras lunulicosta. He and others (Wedekind, 1917; H. Schmidt, 1926; Matern, 1929) extended and revised the local cephalopod stratigraphy in the following years into the orthochronology of the marine Devonian.

	PLYMOUTH	TORQUAY	BELGIUM FRANCE	ADOLF
Upper Dev. (part)	Warren Point Beds 3	Saltern Cove Beds 7	Assise de Frasne 13	to 1 (β) γ 15
		Babbacombe Slates 8	Assise de Fromelles II 12	to 1 α 14
Middle Dev. (part)	Plymouth Limestone 1	Torquay 4, 5, 6	Gid 10	Grenzlagerzone
		Limestone	Gic 9	Volcanios

1. Stringocephalus burtini
2. Hypothyridina cuboides
3. Manticoceras sp.
4. Bedekindella britonense
5. Stringocephalus burtini
6. Maenicoeras terebratum
7. Probeloceras forcipiferum
8. Manticoceras sp.
9. Spirifer mediotextus
10. Hexagonaria quadrigemina
11. Spirifer tenticulus
12. Stringocephalus burtini
13. Spirifer orbelianus
14. Pharioeras lunulicosta
15. Manticoceras cordatum

FIG. 4
 CURRENT VIEWS ON MIDDLE/UPPER DEVONIAN CORRELATION
 OF THE CLASSICAL EUROPEAN SECTIONS
 (mainly after Brinkmann 1959 and House & Selwood 1964)

The situation for Europe and North America was reviewed by House (1962) and it is generally agreed that the extinction of Maenioceras terebratum and some other genera and the appearance of Pharciceras lunulicosta mark the beginning of the Upper Devonian.

In addition to cephalopod chronology, more or less successful parachronological schemes based on corals and ostracods have been established. For reference see Walter (1928), Wedekind (1937), Middleton (1959), Rabien (1954).

A peculiarity of the Middle/Upper Devonian boundary in many areas of the eastern part of the Rhenish Schiefergebirge is the presence of an iron ore zone, reaching from the uppermost Middle Devonian locally into the middle Adorfian (Grenzlagerzone in German terminology, Lippert, 1951). This is significant, because the lithology of these rocks does not permit treatment for obtaining conodonts, see page 90

CONODONT RESEARCH IN THE CLASSICAL AREAS

For about 15 years use has been made of the stratigraphical value of conodonts (Beckmann, 1953) and they are recognized as valuable index fossils in hitherto barren sections. The work of Bischoff, Sannemann, and

Ziegler, who established parachronologies in various parts of the Paleozoic in Germany, advanced the application of conodont studies on a world-wide basis.

However, little conodont research has been done in the three previously mentioned areas of the Middle and Upper Devonian. From south west England, Dineley and Rhodes (1956) reported the occurrence of Devonian and Carboniferous conodonts. Their second paper (Rhodes & Dineley, 1957) is more explicit and they discuss what seems to be a Middle Devonian fauna containing Polygnathus linguiformis and P. varca. Unfortunately the stratigraphic position of the section (a borehole) cannot be directly defined and the sequence might even be inverted. Apparently more conodont studies are underway, but nothing of significance has been published yet (Matthews, 1962; see also House & Selwood, 1964, p. 53).

Equally unsatisfactory is present knowledge of the Belgian - French type area. The reasons may lie partly in the paucity of occurrence of these fossils in the limestones of this region. A very generalized study was published in 1960 by Serre and Lys. Detailed research is just starting (Bouckaert & Ziegler, 1965).

The most intensive work on Middle and Upper Devonian conodonts has been done in the Rhenish Schiefergebirge.

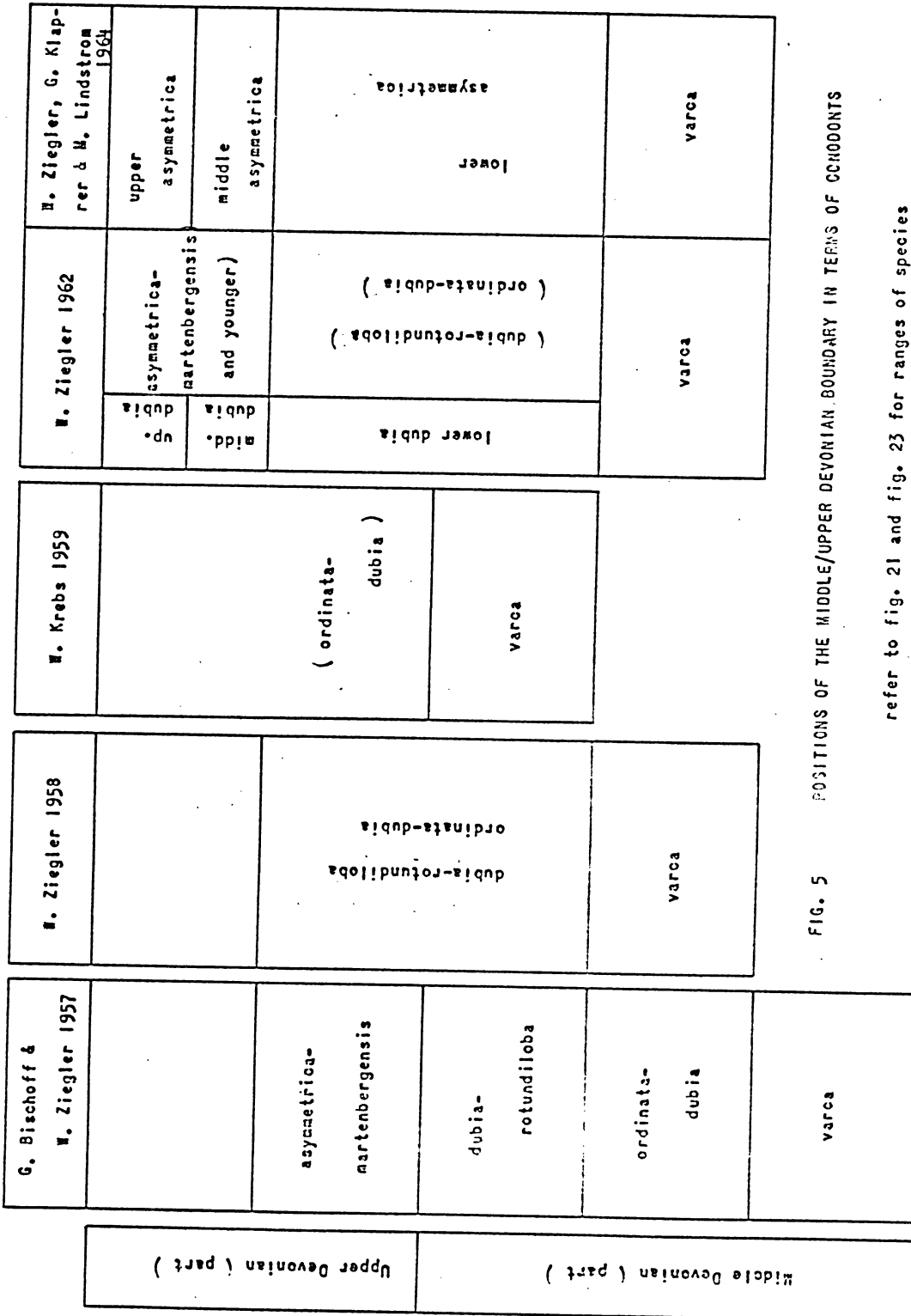


FIG. 5 POSITIONS OF THE MIDDLE/UPPER DEVONIAN BOUNDARY IN TERMS OF CCRHOONTS

refer to fig. 21 and fig. 23 for ranges of species

The first comprehensive study was from Bischoff and Ziegler in 1957, who set up a parachronology for the Eifelian and Givetian stages. They placed the Middle/Upper Devonian boundary between the dubia - rotundiloba and asymmetrica - martenbergensis sub-zones and defined it with the extinction of Polygnathus linguiformis and P. webbi and the appearance of Palmatolepis martenbergensis (see fig. 5).

One year later Ziegler (1958) published a revision of the zonation in the upper Givetian and described conodont material from the section at Adorf. Accordingly the Middle/Upper Devonian boundary does not lie between the dubia - rotundiloba and asymmetrica - martenbergensis sub-zones, but somewhere within the dubia - rotundiloba and ordinata - dubia zones, because the stratigraphic position of the beds between the first Pharciceras and the last Maenioceras, which contain those two conodont sub-zones, is not known. No diagnostic macrofossils have been found in these beds.

The application of Bischoff and Ziegler's parachronology in the iron mines of the Lahn and Dill area did not confirm their assumed position of the Middle/Upper Devonian boundary either. Upper Devonian goniatites were found below the ordinata - dubia and dubia - rotundiloba sub-zones (Dengler, 1959). Because of this and supported by his own studies of the Upper Devonian stratigraphy of

the mines in the south west part of the Dill trough, Krebs (1959) lowered the Middle/Upper Devonian boundary in respect of conodonts between the varca and ordinata - dubia sub-zones.

No comment on this position of the Middle/Upper Devonian boundary was made by Ziegler (1962) who, following a further suggestion of Krebs in the aforementioned study, revised his own earlier work stratigraphically and in terminology. His new dubia zone comprises the former ordinata - dubia, dubia - rotundiloba, and asymmetrica - martenbergensis sub-zones (For details see figure 5). In 1964 the name of P. dubia was changed to P. asymmetrica (Ziegler, Klapper & Lindstrom).



OUTCROP OF THE TULLY FORMATION
 (mainly after Cooper & J.S. Williams 1935,
 and Willard 1937)

FIG. 6

⊗ isolated occurrences

C) OUTLINE OF THE STRATIGRAPHY OF THE TULLY FORMATION

AREAL EXTENT

The Tully Formation crops out in New York as a narrow belt of limestone from Canandaigua Lake eastward to Chenango valley (fig. 6). Further east the calcareous rocks change facies laterally into clastics and east of Otsego Lake are replaced by the Gilboa shales and sandstones. In Pennsylvania the Tully Limestone is exposed from Bedford County along the Bald Eagle Valley to Lycoming Co. and clastic members crop out in Carbon Co. and Monroe Co. In West Virginia and Maryland, the outcrops of the Tully Limestone form a southward extension of those in Pennsylvania and lie along the Alleghenny front near Keyser.

Besides the surface exposure, the Tully Limestone is known from numerous oil and gas wells in New York, Pennsylvania, and West Virginia and provides a good marker horizon.

In the past the stratigraphic position of the Tully Formation has been shifted back and forth between the Middle and the Upper Devonian because of the lack of definitive fossils (see fig. 7).

Upper Devonian	S. G. Williams 1887	H. S. Williams 1890	G. A. Cooper & J. S. Williams 1935	J. W. Wells 1940	G. A. Cooper 1942	M. R. House 1962
		Hypothyridina ouboides	?			Pharciceras asplexum
Middle Devonian	Hamilton affinities of fauna			Sphaerospongia	Taghantic Stage	

FIG. 7 STRATIGRAPHICAL POSITION OF THE TULLY FORMATION AS ASSIGNED BY VARIOUS AUTHORS

PREVIOUS WORK

The first description of the Tully Limestone in New York came from Vanuxem in 1838. He mentioned it as a limestone, 12 ft - 16 ft (3.60 m - 4.80 m) thick, stretching from beyond Seneca Lake to almost DeRuyter, but he mentioned no fossils. In 1842 in his final report on the survey of the Third Geological District of New York he gave more details. He realized the full extent of the limestones from Canandaigua Lake to Chenango valley and mentioned the fauna. Hypothyridina venustula (Atrypa cuboides in Van.) and Orthis tullia (O. tulliensis in Van.) were in his opinion the most abundant and distinct species (p. 164). At the same time, Conrad (1841) made a correlation of the Aymestry Limestone of the Welsh Borderland with the Tully Limestone. The first Tully Limestone from Pennsylvania was reported in 1883 (White).

After the discoveries of the first surveys, a second period of more detailed investigations started about 1890 and ended with the 1 : 62500 scale geological mapping of Clarke and Luther in New York in the early years of the twentieth century (Clarke, 1904; Clarke & Luther, 1905; Luther, 1909). During this period S. G. Williams (1887) extended the faunal list of the Tully Limestone to 120 species and discussed their local distribution. He

emphasized the similarity with the underlying Hamilton fauna (see fig. 7). In 1890 H. S. Williams published a study of the principles of world-wide correlation and showed a thorough appreciation of the Tully fauna known to him. He considered it as twofold, because the main portion has Hamilton characteristics whereas some other species have European affinities. He correlated the Tully with the cuboides zone (Upper Devonian) of Germany on the presence of Hypothyrdinia and Scutellum which have no antecedents in the North American Devonian. This view was generally followed until about 1930.

A third period of detailed stratigraphical and paleontological investigation of the Tully Formation in New York and Pennsylvania falls into the years between 1930 and 1940. In his papers on the Hamilton Group Cooper (1930, 1934) discussed the lower boundary of the Tully and pointed out the disconformable contact with the underlying shale. Trainer (1932), making the first detailed lithological study of the limestones, rejected Grabau's (1917) theory of a detrital origin, but did not give any consideration to the fauna. Knowledge of the areal extent increased; Fettke (1933) reported Tully Limestone from wells near the New York and Pennsylvania border between Warren Co. (Pa.) and Bradford Co. (Pa.), Cooper and J. S. Williams (1935) traced the Tully fauna far into eastern New York almost to

the Schoharie valley (fig. 6). In Pennsylvania the early reports of White (1883) had been doubted (H. S. Williams & Kindle, 1905), but the findings of Butts (1918) and Willard (1934, 1937) confirmed the existence of the Tully Limestone.

Ideas about the Frasnian age of the Tully were challenged by Chadwick (1935), who pointed out the absolute dominance of the Hamilton faunal elements. Likewise in the geological map of Bellefonte Quadrangle (Pa.), Butts and Moore (1936) placed their Tully outcrops on the upper part of the Hamilton Group. Cooper and J. S. Williams (1935) published what was then the most extensive survey of the Tully Formation and were able to distinguish 5 members on lithological and paleontological evidence (see fig. 8). They did not follow H. S. Williams's (1890) view of an Upper Devonian age because of the lack of other important species of the cuboides zone besides Hypothyridina and Scutellum. They declared themselves incompetent to give any final answer at that stage. Two years later Willard (1937) presented a similar comprehensive survey of the Tully Formation in Pennsylvania. He distinguished two lithological facies which may or may not correspond with some of the members of Cooper and J. S. Williams (1935) in New York. The fauna, except for two new brachiopod and pelecypod species, is not as varied as the New York fauna.

In 1940 J. W. Wells presented new evidence for a Givetian age of the Tully and later (1942) Cooper evaluated the work of H. S. Williams (1890) more critically than before, (Cooper & T. S. Williams, 1935). Accordingly H. S. Williams did not know the full extent of the Tully fauna. Because of the appearance of many forms of the European cuboides zone in apparently higher strata (Chemung), Cooper placed the Tully finally in the Middle Devonian and defined the Taghanic Stage for rocks containing Hypothyridina venustula or to be correlated with such.

During 1949 Stevenson and Skinner in Pennsylvania reported clastic members farther east which they thought might be correlated with the clastic members of the Tully Formation in New York.

The problem of the biostratigraphical position of the Tully Formation was again taken up by House (1962). On the evidence of Pharciceras amplexum he tentatively determined a lower Frasnian position for the Tully Limestone. This procedure was followed by Rickard (1964), who maintained an Upper Devonian age for the Taghanic Stage but omitted the Geneseo Shale partly, formerly included by Cooper (1942).

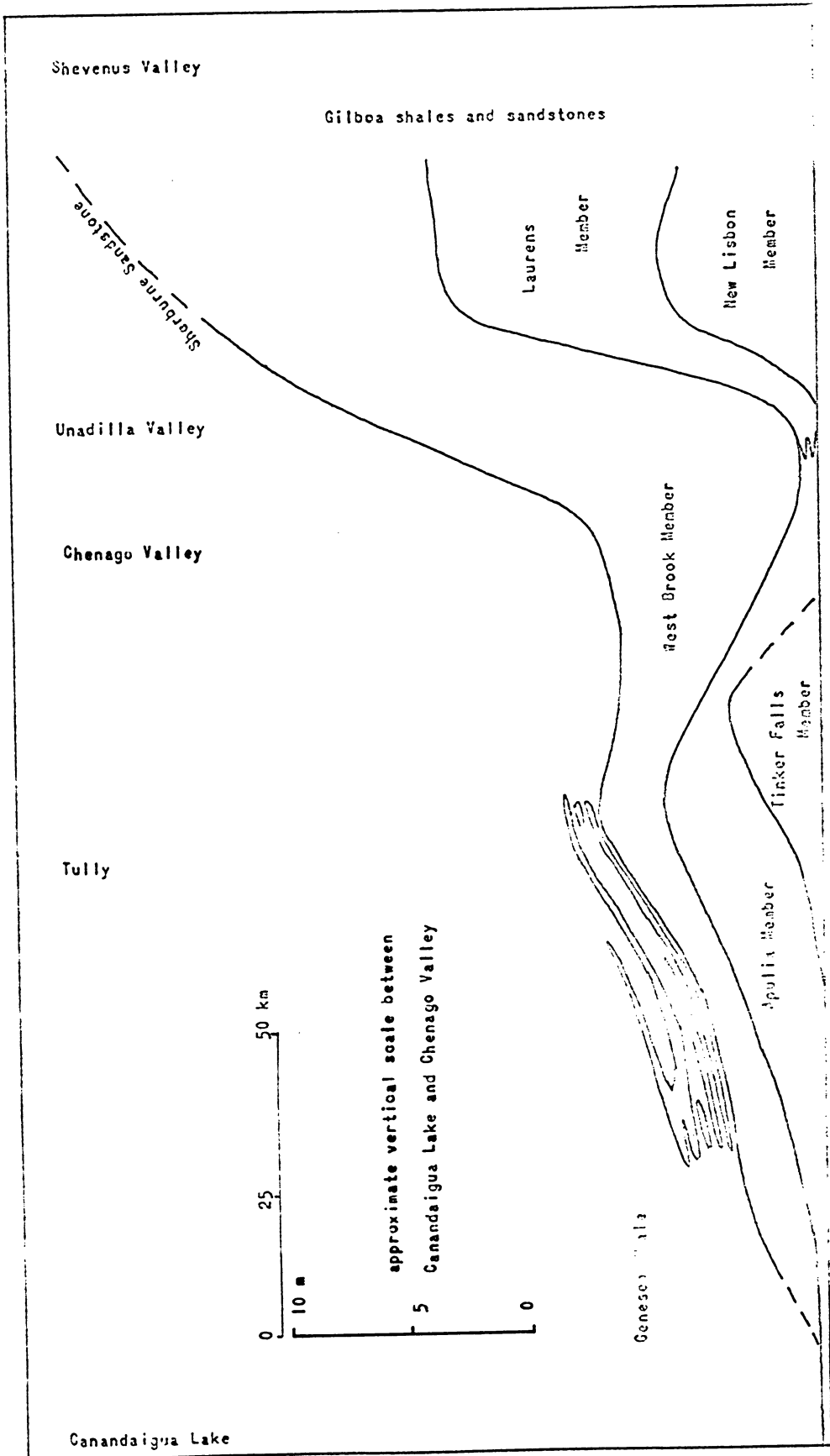
Small occurrences of limestone, recorded from the Harrel Shale in West Virginia, have been assigned to the Tully, but apparently no fossils have been discovered yet (Dennison & Naegele, 1963).

STRATIGRAPHY OF THE TULLY FORMATION

"One of the most carefully studied examples of facies changes in the North American record is that in the Middle and Upper Devonian rocks of New York State and adjacent Pennsylvania. Now that these changes are understood, we know that they record the gradual growth of a great delta, called the Catskill Delta, fed by several streams from rising mountains to the east and south east".

Thus Dunbar and Rodgers (1961) introduce an example of facies change and sum up the paleogeographical situation in Devonian times for New York. This great change from east to west, from red non-marine sandstones through siltstones to dark shale and limestones is clearly manifested in the Tully Formation.

Johnson and Friedmann (1966) reconstructed the environments of deposition and found indications of flood-plain and swamp deposits in the east which interfinger westwards with lagoonal and littoral marine sediments. The latter grade into shallow water marine sediments which become more and more calcareous. Both Rich (1951) and Cooper (1959) favored a shallow, quiet water environment



DETERMINATION OF THE TULLY FORMATION AFTER COOPER & WILLIAMS 1935

FIG. 8

below wavebase for the Middle Devonian sediments in New York.

New York

A detailed account of the stratigraphy of the Tully Formation which included a subdivision into several members was given by Cooper and J. S. Williams in 1935. The distinction of these members is based on lithological and paleontological characters (presence or absence of characteristic genera), but is actually difficult to apply in the field (see fig. 8).

The lowest (Tinker Falls) member consists at its type section of interbedded shales and argillaceous limestones and contains Chonetes aurora and its characteristic fossil. It extends from Owasco Lake to DeRuyter, a distance of 40 km (see fig. 6).

The Apulia Member consists of thick bedded limestone in the western part, of shale with calcareous lenses east of Chenango valley. Hypothyridina venustula is the characteristic fossil. Schizophoria tulliensis, Chonetes aurora and Leptostrophia tulliensis become rare west of the type section. This member has a wide areal extent and reaches 160 km from Canandaigua Lake to Unadilla valley.

Strata above the beds abounding in Hypothyridina

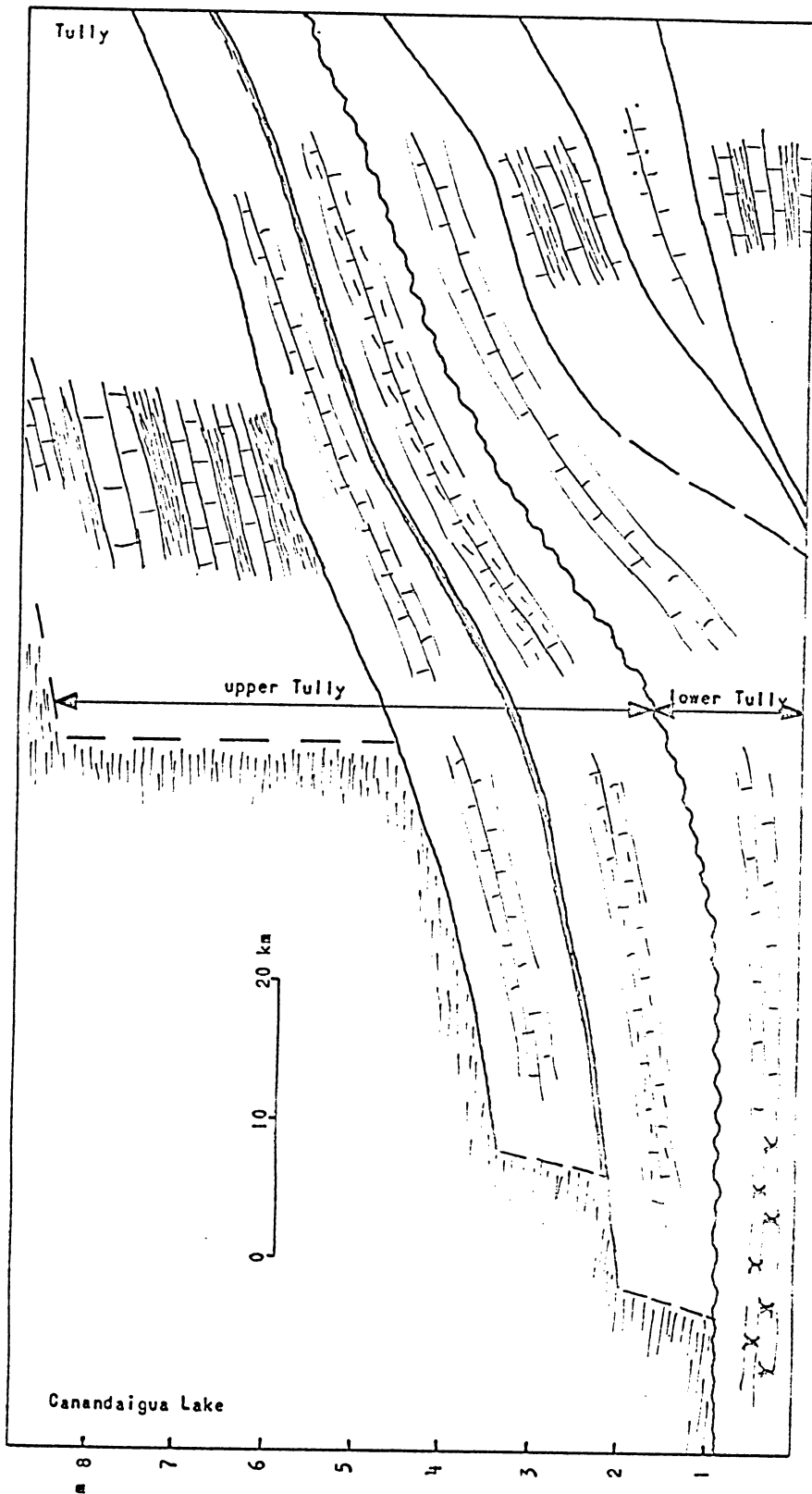


FIG. 9
SUBDIVISIONS OF THE TULLY FORMATION BETWEEN CANANDAIGUA LAKE AND TULLY AFTER HECKEL 1965
showing some of the members. Simplified from a preliminary sketch provided by L. V. Rickard.
Lithologies are indicated by standard symbols, see fig. 13.

were assigned to the West Brook Member. It extends from Seneca Lake to Unadilla valley (140 km). The lower part of this member has Elytha fimbriata as characteristic fossil, the upper beds are famous for the abundance of corals.

East of Unadilla valley two sandstone members have been recognized, the New Lisbon Member with Leiorhynchus, which underlies the Laurens Member. The latter is the equivalent to the Apulia and contains Hypothyridina.

The latest stratigraphical scheme for the Tully Formation between Canandaigua Lake and Unadilla valley was proposed by Heckel (1965). On the basis of a disconformity he divides the Tully Formation into a lower and an upper part. Both of these divisions consist of several members, some of which are single beds only. The validity of these subdivisions has been proven independently in the field (Rickard, oral communication) and sections examined during the course of sampling for the present study were afterwards easily correlated with Heckel's subdivisions (see fig. 9).

The sections exposed at Borodino near Skaneateles Lake are not easy to fit into the stratigraphical system. Here massive limestone bodies, occurring in the upper part of the Tully Formation contain a mixed Apulia and Westbrook fauna and cannot be traced beyond this single locality.

The base of the Tully Formation is marked by a distinct disconformity (Cooper & J. S. Williams, 1935). However opinions on the situation at the top of the Tully Formation vary. The gradual change in lithologies and the interlayering of limestone and shale between Owasco Lake and Tully indicate a transition between the Tully Formation and the Geneseo Shale. However, this transition cannot be postulated on lithological evidence west of Owasco Lake, where the change between the lithologies is very abrupt. Also, the sudden disappearance of the Tully macrofauna at the base of the Geneseo Shale implies a disconformable contact (Cooper & J. S. Williams, 1935; Grossman, 1944).

Pennsylvania

In the limestones of the Tully Formation in Pennsylvania, individual members cannot be distinguished. However, it is possible (Willard, 1937) to separate two facies, different in both their lithologies and faunas. A massive facies in the south west of Pennsylvania (Bedford, Blair, and southern Centre Co.) is composed of thickly bedded limestone (see fig. 2), but the thickness of exposed sections rarely exceeds 1 m. The most important species of the fauna are Chonetes aurora, Emanuella pennsylvanica, Echinocoelia ambocoelioides, Hypothyridina venustula.

The second facies is confined to the central part of Pennsylvania (Lycoming Co.), with more than 70m of thin, dark limestone beds interbedded with calcareous shale. The fauna includes corals (Lopholasma), Elytha fimbriata and some species of Spirifer. In eastern Lycoming Co. the Tully Formation thins very suddenly and wedges out, but an isolated outcrop is known in Northumberland Co. to the south.

The separation of the two facies is not sharp. At the section near Curtin (north Centre Co., see fig. 25) the shaly northern facies is interlayered with massive beds of the southern facies. The increase in thickness from south to north is also gradual. Willard (1937) assumed that the massive southern limestones are to be correlated with the upper part of the northern platy, shaly facies, taking the transition between the Tully Limestone and the overlying Burkett Shale as a guide horizon. Tentatively he correlated the whole of the Tully Limestone in Pennsylvania with the Apulia Member of New York.

Eight localities of the clastic members of the Tully Formation have been discovered near Lehighton (Carbon Co.; Stevenson & Skinner, 1949). On faunal evidence the rocks can be divided into three members which were tentatively correlated with the Laurens, New Lisbon, and Westbrook Members respectively of New York.

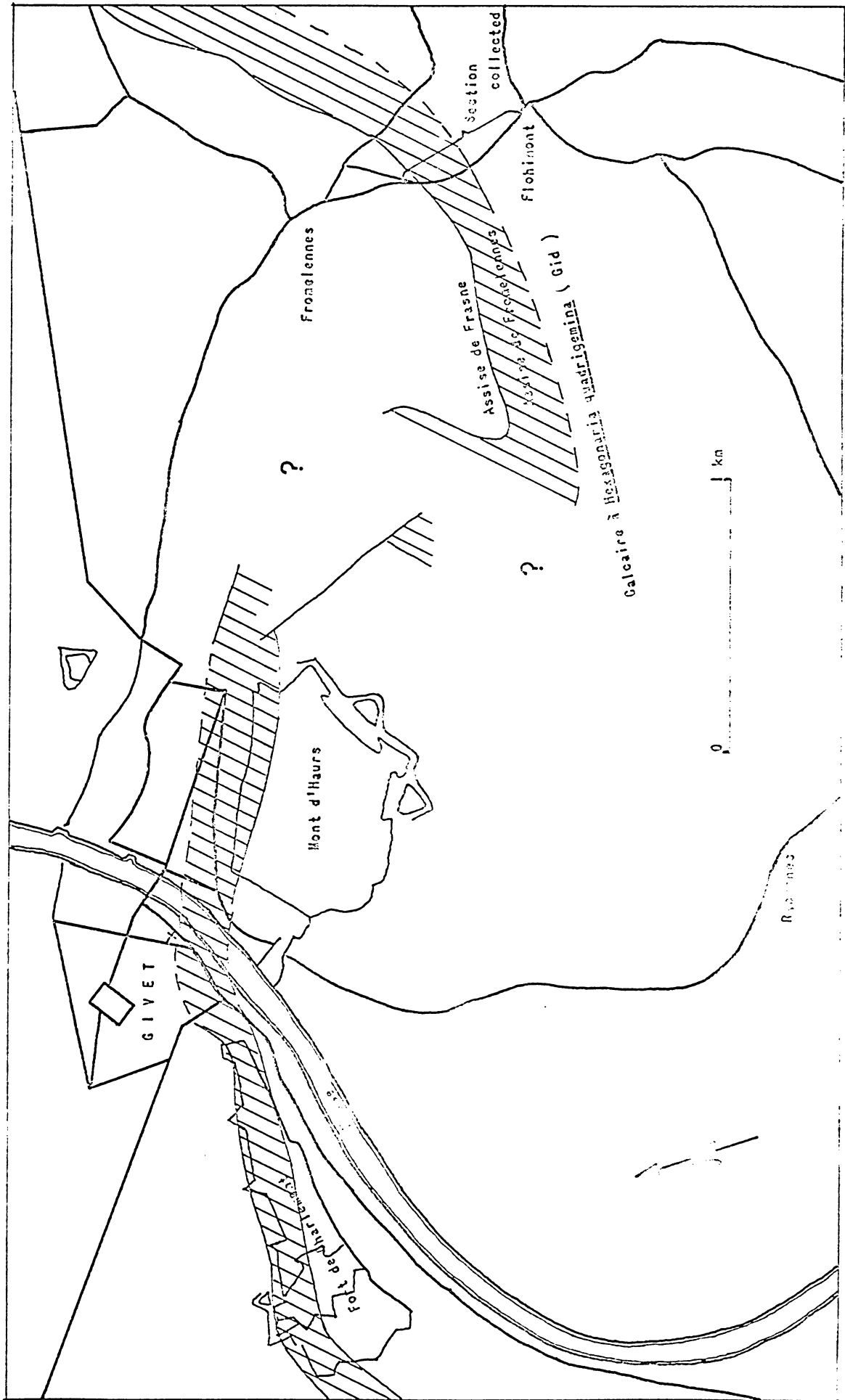
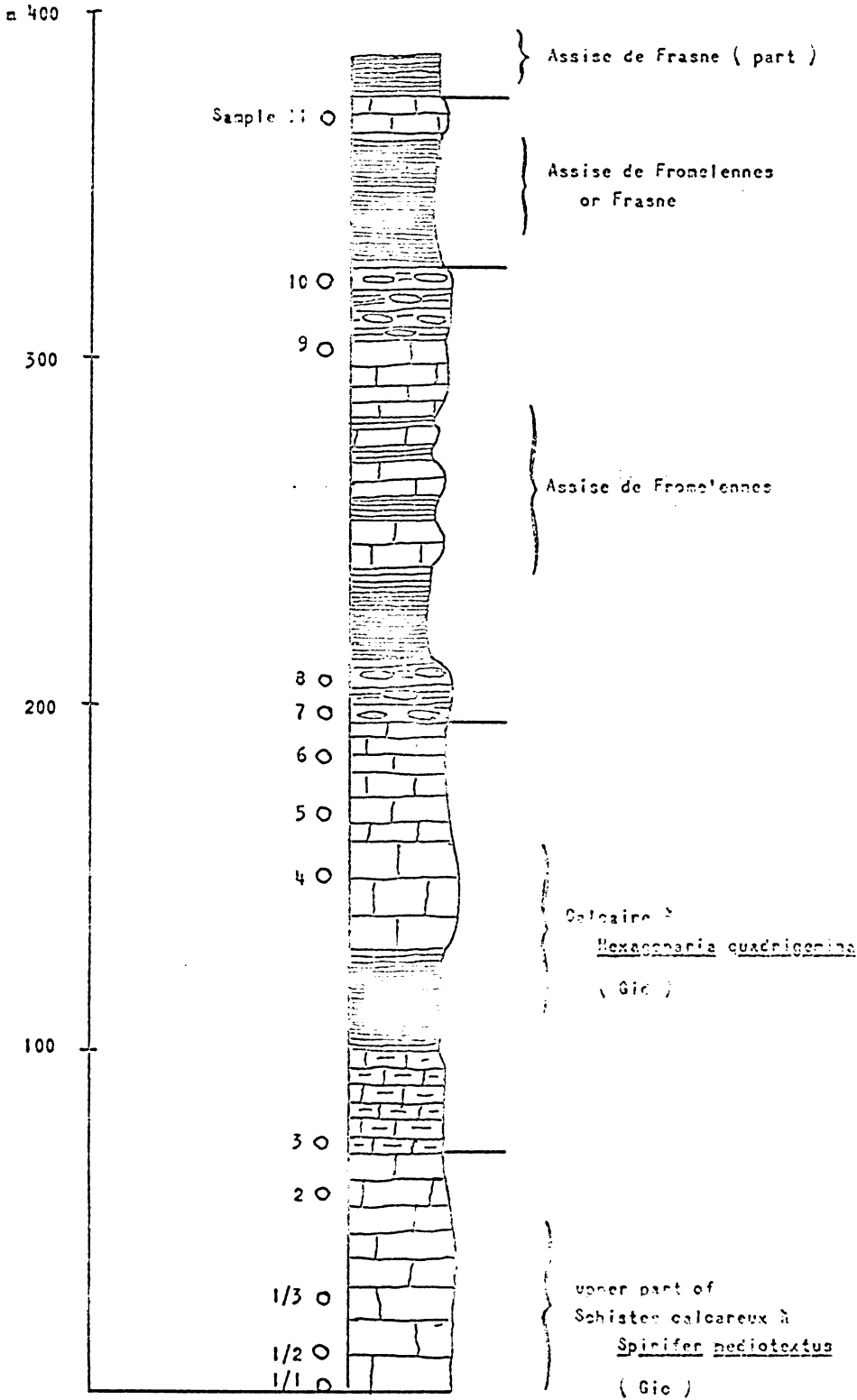


FIG. 10

SECTION OF THE FROMELLES REGION AT GIVET

(after Bonte & Ricour 1948 and Carte geologique de Franco, sheet Givet)



STRATIGRAPHY, simplified

(See also figs 15)

FIG. 11

D) SECTIONS AND FAUNAL LISTS

For this study the following genera with proven stratigraphic value are considered:

Bryantodus (selected species)

Icriodus

Ozarkodina (selected species)

Polygnathus

Spathognathodus

Genera of the long-ranging bar-type conodonts such as Hindeodella, Ligonodina, Lonchodina, etc. have been proven not valuable for stratigraphical purposes.

GIVET

In France about 370 m of the Fromelennes Formation and the immediately underlying part of the Upper Givetian along the road between Flohimont and Fromelennes have been sampled for the present study (fig. 10). Thirteen samples of 7 lb average weight were collected in distances varying according to lithology and outcrop conditions between 4 m and 75 m. Only three samples, one from the Gic, (see fig. 4) and two from the lower Fromelennes Formation yielded conodonts. The reason for the paucity of these faunas is probably the very rapid sedimentation in the Belgian part

of the Variscan geosyncline (see Bouckaert & Ziegler 1965).
For details of sample locations and lithologies see fig. 11.

SAMPLE 1/1

Weight: 9 lb; horizon: Gic
Lithology: Calcarenite, medium-dark-grey, with zones of
coarse calcite crystals
Identified: Bryantodus sp.
Icriodus cymbiformis
Ozarkodina sp.
Polygnathus linguiformis
Spathognathodus bipennatus
Total number of specimens: 81
Material studied: 17

SAMPLE 7

Weight: 5 lb; horizon: Base of Fromelennes Formation
Lithology: Calcisiltite, light-grey, with single small
calcite crystals, fossiliferous
Polygnathus pennata
Icriodus sp.
Total number of specimens: 8
Material studied: 3

SAMPLE 8

Weight: 6.5 lb; horizon: lower Fromelennes Formation

Lithology: Calcisiltite, medium-yellow-grey, slightly argillaceous, fossiliferous

Icriodus cymbiformis

I. nodosus

I. sp.

Polygnathus pennata

P. varca

Total number of specimens: 26

Material studied: 7

Preservation: The preservation of the specimens is very good. The amount of broken conodonts is small and encrustations by sand grains or secondary minerals are rare.

NEW YORK

In New York 23 sections over an east-west distance of about 100 km and a north-south extension of 40 km were examined and sampled. The distances of the individual sections vary between 3 km and 20 km. The spacing between the single samples in the sections in the western half is generally 1 m and is extended to 1.50 m in the eastern half of the area visited, because of the greater thickness of the sections. The average number of samples per section

Fig. 12



Assise de
Fromelennes

Calcaire à
Hexagonaria
quadrigemina

CONTACT OF THE GIVETIAN LIMESTONES AND THE FROMELENNES
FORMATION

(figured section about 3m x 6m)

is 6. The weight of the samples varies between less than 1 lb in one instance and 8 lb as maximum. 6 lb is about the average sample weight.

As examples for the faunal contents of individual samples three sections at the east shore of Canandaigua Lake, near Ovid, and south of Otisco Lake were selected. For details of lithologies and sample spacings see figure 13.

Section 1

SAMPLE 1

Weight: 6 lb

Lithology: Calcilutite, dark-grey, with small rusty stained grains (pyrite), fossiliferous

Identified: Bryantodus stratfordensis

Icriodus cymbiformis

Ozarkodina congesta

O. elegans

Polygnathus beckmanni? (fragment)

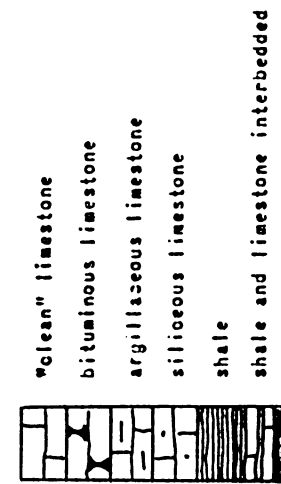
P. linguiformis

P. varca

P. xyla

Total number of specimens: 370

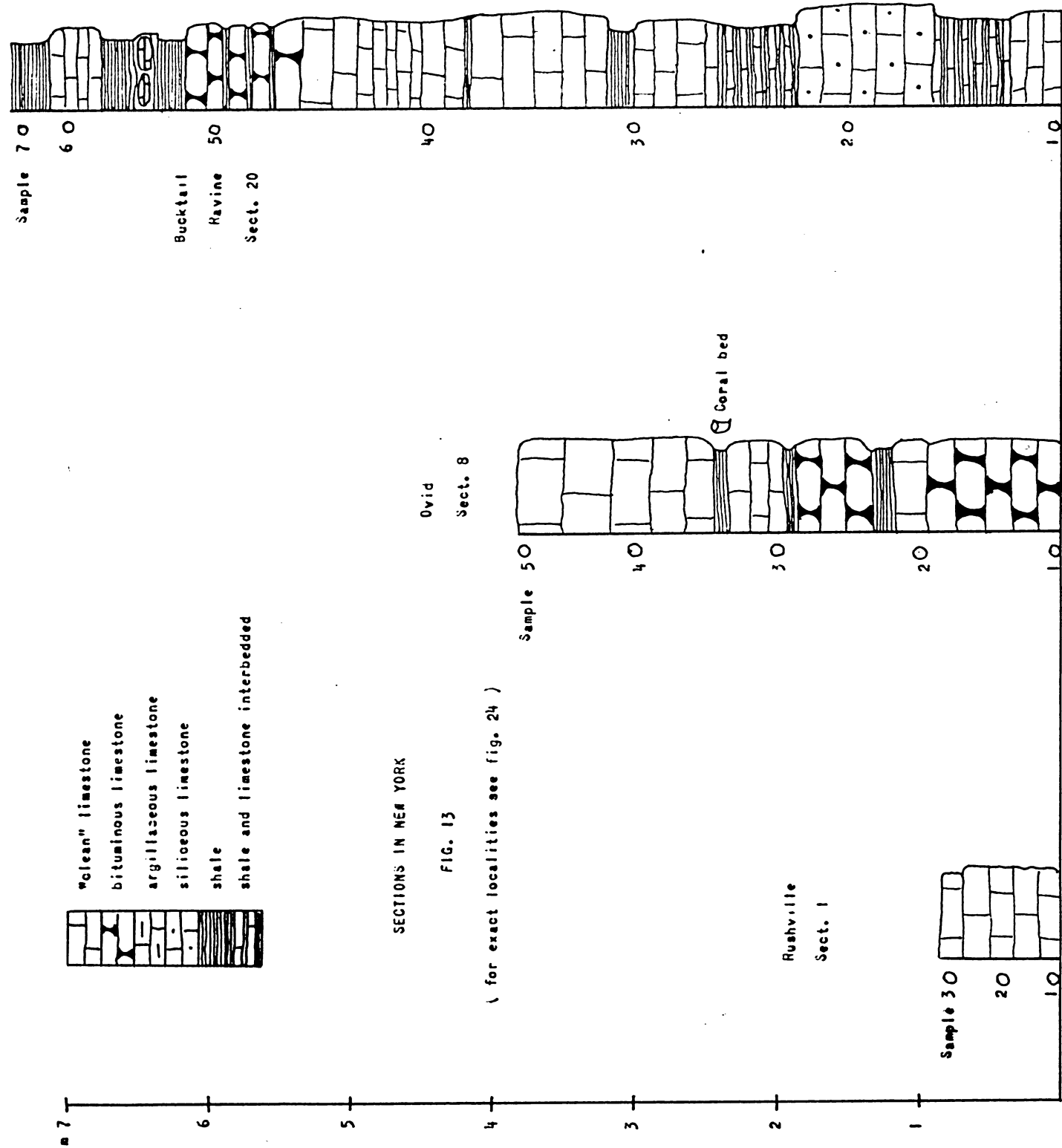
Material studied: 88



SECTIONS IN NEW YORK

FIG. 13

(for exact localities see fig. 24)



SAMPLE 2

Lithology: Calcilutite, dark-grey, bituminous

Weight: 5 lb

Identified: Icriodus cymbiformis
Ozarkodina congesta
Polygnathus linguiformis
P. varca

Total number of specimens: 59

Material studied: 17

SAMPLE 3

Weight: 5 lb

Lithology: Calcilutite, medium-grey, single calcite
 crystals, fossiliferous

Identified: Bryantodus stratfordensis
Icriodus curvatus
I. nodosus
Ozarkodina congesta
Polygnathus caelata
P. cristata
P. decorosa
P. linguiformis
P. varca
P. n. sp. a

Total number of specimens: 292

Material studied: 52

Section 8

SAMPLE 1

Weight: 5 lb

Lithology: Calcilutite, dark-grey, bituminous, slightly argillaceous, fossiliferous

Identified: Icriodus nodosus

Ozarkodina sp.

Polygnathus beckmanni? (fragment)

P. cristata

P. decorosa

P. linguiformis

P. varca

Total number of specimens: 744

Material studied: 38

SAMPLE 2

Weight: 3.5 lb

Lithology: Calcilutite, dark-grey, bituminous, with small weathered pyrite grains, interbedded with thin shale bands, fossiliferous

Identified: Bryantodus sp.
 Icriodus latericrescens
 I. nodosus
 Ozarkodina congesta
 O. lata
 Polygnathus linguiformis
 P. decorosa
 P. pennata
 P. varca

Total number of specimens: 90

Material studied: 20

SAMPLE 3

Weight: 6 lb

Lithology: Calcilutite, dark-grey, bituminous, fossiliferous,
 macrofossils partly pyritized

Identified: Byrantodus sp.
 Icriodus nodosus
 Polygnathus linguiformis

Total number of specimens: 270

Material studied: 22

SAMPLE 4

Weight: 5 lb

Lithology: Calcilutite, dark-grey, small patches with

abundant calcite crystals, bituminous,
fossiliferous

Identified: Icriodus latericrescens

I. nodosus

Ozarkodina congesta

O. elegans

O. sp.

Polygnathus? iuvenis *

P. linguiformis

Total number of specimens: 134

Material studied: 21

SAMPLE 5

Weight: 7 lb

Lithology: Same as above, argillaceous

Identified: Icriodus latericrescens

I. nodosus

Ozarkodina sp.

Polygnathus? iuvenis

P. n. sp. b

Total number of specimens: 446

Material studied: 34

* See page 103 for explanation of this name.

Section 20

SAMPLE 1

Weight: 5 lb

Lithology: Fine calcisiltite, medium-grey, argillaceous,
fossiliferous

Identified: Bryantodus sp.

Icriodus symmetricus

Ozarkodina sp.

Polygnathus linguiformis

Total number of specimens: 82

Material studied: 9

SAMPLE 2

Weight: 6 lb

Lithology: Calcisiltite, medium-grey, argillaceous,
very hard

Identified: Icriodus nodosus

Polygnathus linguiformis

P. varca

Total number of specimens: 19

Material studied: 3

SAMPLE 3

Weight: 6 lb

Lithology: Calcilutite, medium-grey, with small weathered pyrite nodules, bituminous, fossiliferous

Identified: Bryantodus sp.

Icriodus nodosus

I. symmetricus

Ozarkodina sp.

Polygnathus linguiformis

P. varca

Spathognathodus planus

Total number of specimens: 67

Material studied: 13

SAMPLE 4

Weight: 8 lb

Lithology: Calcilutite, fine calcisiltite, dark-grey, with shale partings, fossiliferous

Identified: Icriodus nodosus

I. symmetricus

Ozarkodina lata

O. sp.

Polygnathus linguiformis

P. varcaP. sp.Total number of specimens: 360Material studied: 24

SAMPLE 5

Weight: 5 lbLithology: Calcilutite, light-grey, small pyrite grains,
single small calcite crystals, shale laminae,
fossiliferousIdentified: Icriodus curvatusI. cymbiformisI. latericrescensI. nodosusPolygnathus? juvenisP. linguiformisTotal number of specimens: 180Material studied: 13

SAMPLE 6

Weight: 6 lbLithology: Fine calcisiltite, medium-grey, argillaceousIdentified: Bryantodus sp.Icriodus cymbiformis

I. nodosus

Ozarkodina sp.

Polygnathus decorosa

P.? iuvenis

P. varca

Total number of specimens: 29

Material studied: 7

SAMPLE 7

Weight: 3 lb

Lithology: black shale (Geneseo)

Identified: Polygnathus pennata? (fragment)

Total number of specimens: 2

Several samples from the immediatly overlying Geneseo Shale and the interbedded limestones were taken.

Fauna from 4 shale samples:

Identified: Bryantodus sp.

Icriodus nodosus

Ozarkodina sp.

Polygnathus decorosa

P.? iuvenis

P. linguiformis

P. varca

P. pennata? (fragment)

The weights of the shale samples varied between 2.5 lb and 4 lb; in one case 64 specimens were found (but see also sample 7, section 20).

Fauna from 7 samples, limestones interbedded with shale:

Identified: Bryantodus sp.
 Icriodus curvatus
 I. cymbiformis
 I. nodosus
 I. symmetricus
 Ozarkodina sp.
 Polygnathus caelata
 P. cristata
 P. cf. dengleri
 P. ectypa
 P. decorosa
 P.? iuvenis
 P. pennata
 P. varca
 P. xyla

Sample weights vary between 3 lb and 6 lb. The highest number of specimens per sample is 160.

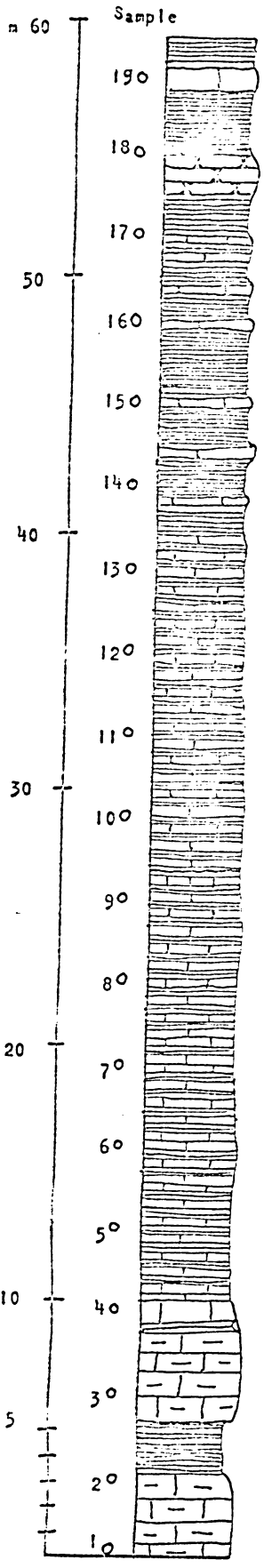
Preservation: The preservation of the specimens is adequate, although most of the more fragile specimens are broken.

Many Polygnathus are without a blade and almost all specimens

of Bryantodus and Ozarkodina are broken. This was probably caused partly by the use of a magnetic separator for the separation of the conodonts from the heavy mineral fraction. Eroded conodonts occur locally and most notably are larger specimens of Polygnathus linguiformis which have lost either the transverse ornamentation of the posterior part or the entire posterior tip. Also, specimens of Icriodus which are almost unrecognizable are found. Bleaching was detected in one sample only. Conodonts from the limestones interbedded with shale at the upper part of the Tully Formation show a high amount of encrustation by secondary minerals.

PENNSYLVANIA

In Pennsylvania 6 sections of the Tully Formation along the Bald Eagle Valley were examined and sampled over a distance of 150 km; 67 km was the greatest distance between two sections. The very high amount of non-calcareous material makes these limestones not very suitable for conodont studies, but it was possible to process some of the material and to obtain faunas from both of the different facies (see fig. 14).

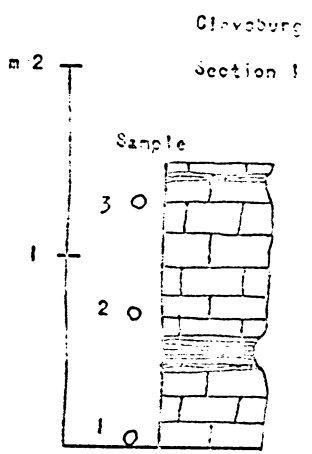


Section 6, Lockport

FIG. 14 SECTIONS IN PENNSYLVANIA

(for exact localities see fig. 25)

lithological legend on fig. 12



Cleveburg
Section 1

Section 1

SAMPLE 1

Weight: 5.8 lb
Lithology: Calcisiltite, dark-grey, argillaceous,
 fossiliferous
Identified: Bryantodus sp.
Ozarkodina sp.
Polygnathus decorosa
P. varca
P. linguiformis
Total number of specimens: 64
Material studied: 11

SAMPLE 3

Weight: 5.3 lb
Lithology: Calcisiltite, medium-grey, argillaceous,
 grading into shaly interbedded laminae,
 fossiliferous
Identified: Icriodus cymbiformis
I. latericrescens
Ozarkodina congesta
Polygnathus beckmanni
P. decorosa
P.? iuvenis

P. linguiformis

P. pennata

P. varca

P. xyla

Total number of specimens: 232

Material studied: 44

Section 6

SAMPLE 18

Weight: 5.8 lb

Lithology: Calcisiltite, shaly, light-grey, bituminous

Identified: Bryantodus sp.

Icriodus nodosus

Ozarkodina sp.

Polygnathus beckmanni

P. linguiformis

P. varca

Total number of specimens: 29

Material studied: 10

SAMPLE 19

Weight: 5.3 lb

Lithology: Calcisiltite, medium-grey, argillaceous

Identified: Icriodus latericrescens

I. nodosus

I. symmetricus

Ozarkodina sp.

Polygnathus? iuvenis

Total number of specimens: 59

Material studied: 8

The lower samples of this section, 1-17, either showed no fauna at all, or single specimens of Polygnathus linguiformis and P. varca only.

Preservation: The specimens from Pennsylvania are in good state. However a high number of encrusted specimens is observed.

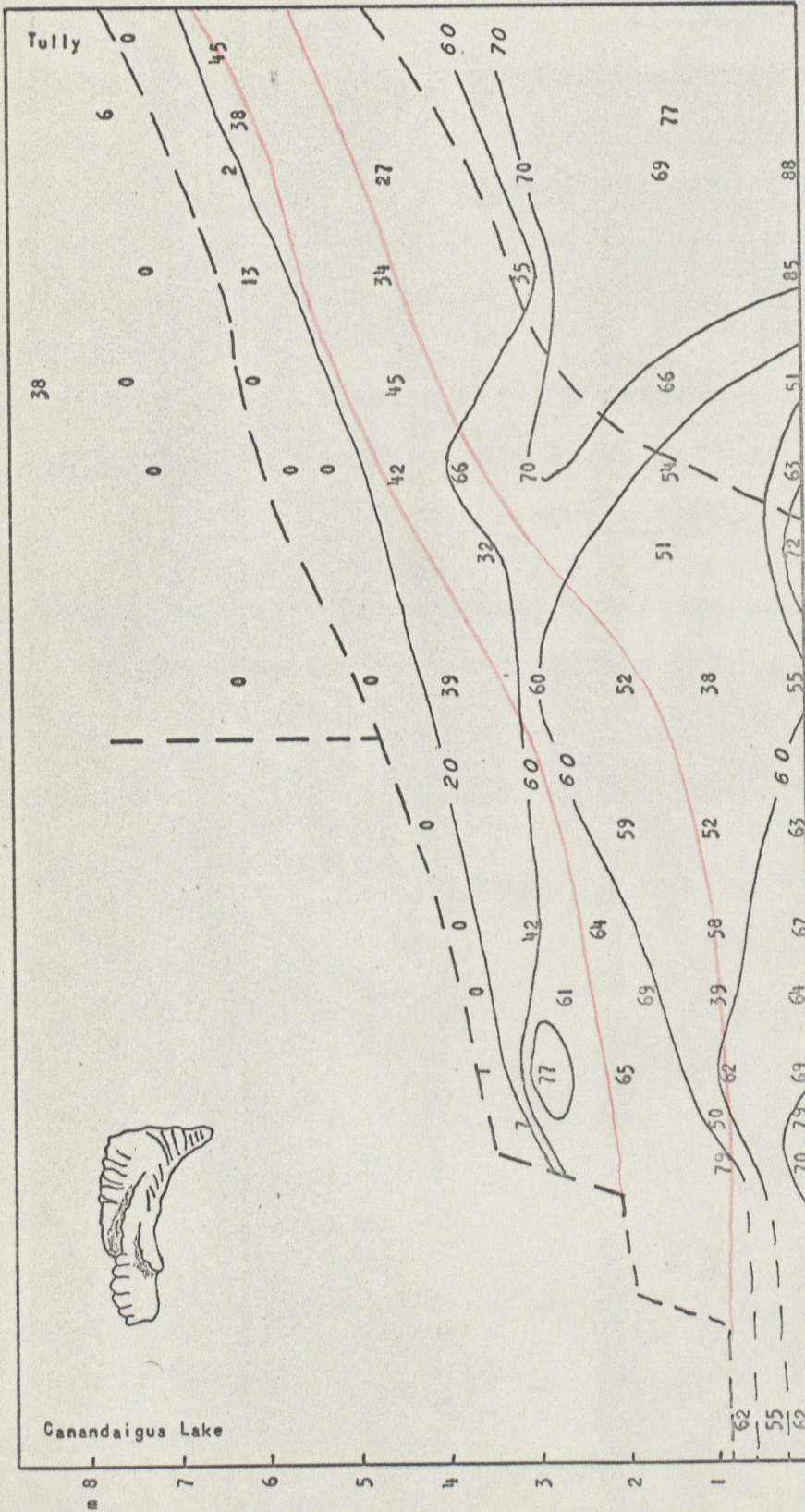
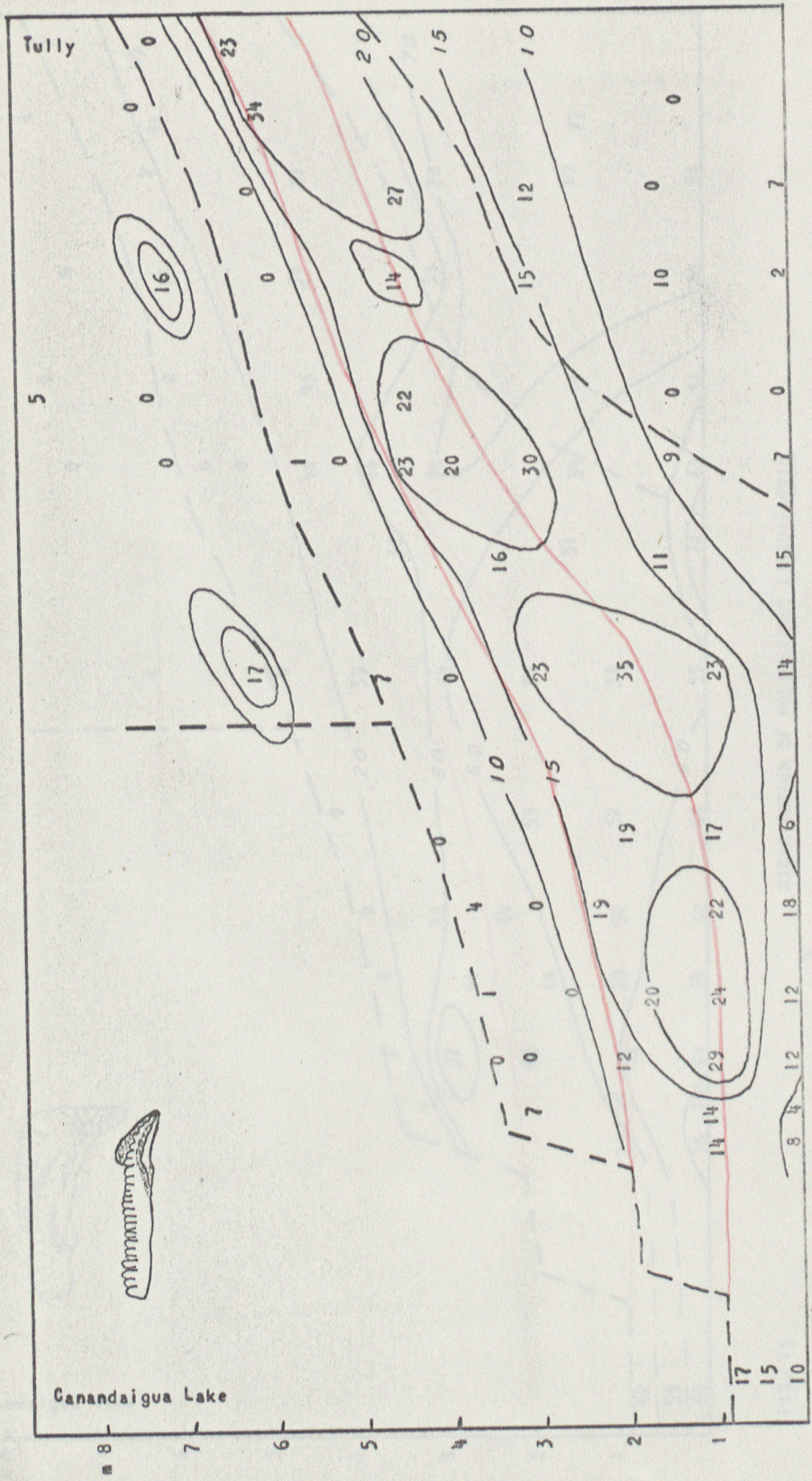


FIG. 15

DISTRIBUTION OF *POLYGNATHUS LINGUIFORMIS*

The contour lines are lines of equal χ^2 (i.e. *P. linguiformis* + *P. varca* + *P. ? juvenis* + *Ieriodus* = 100%).
 The two non vertical dashed lines indicate the area of statistical treatment (see fig. 19), the red lines trace units from fig. 9. The contour lines are approximate and indicate trends only.



DISTRIBUTION OF POLYNATHUS VARCA (see fig. 15 for explanation)

FIG. 16

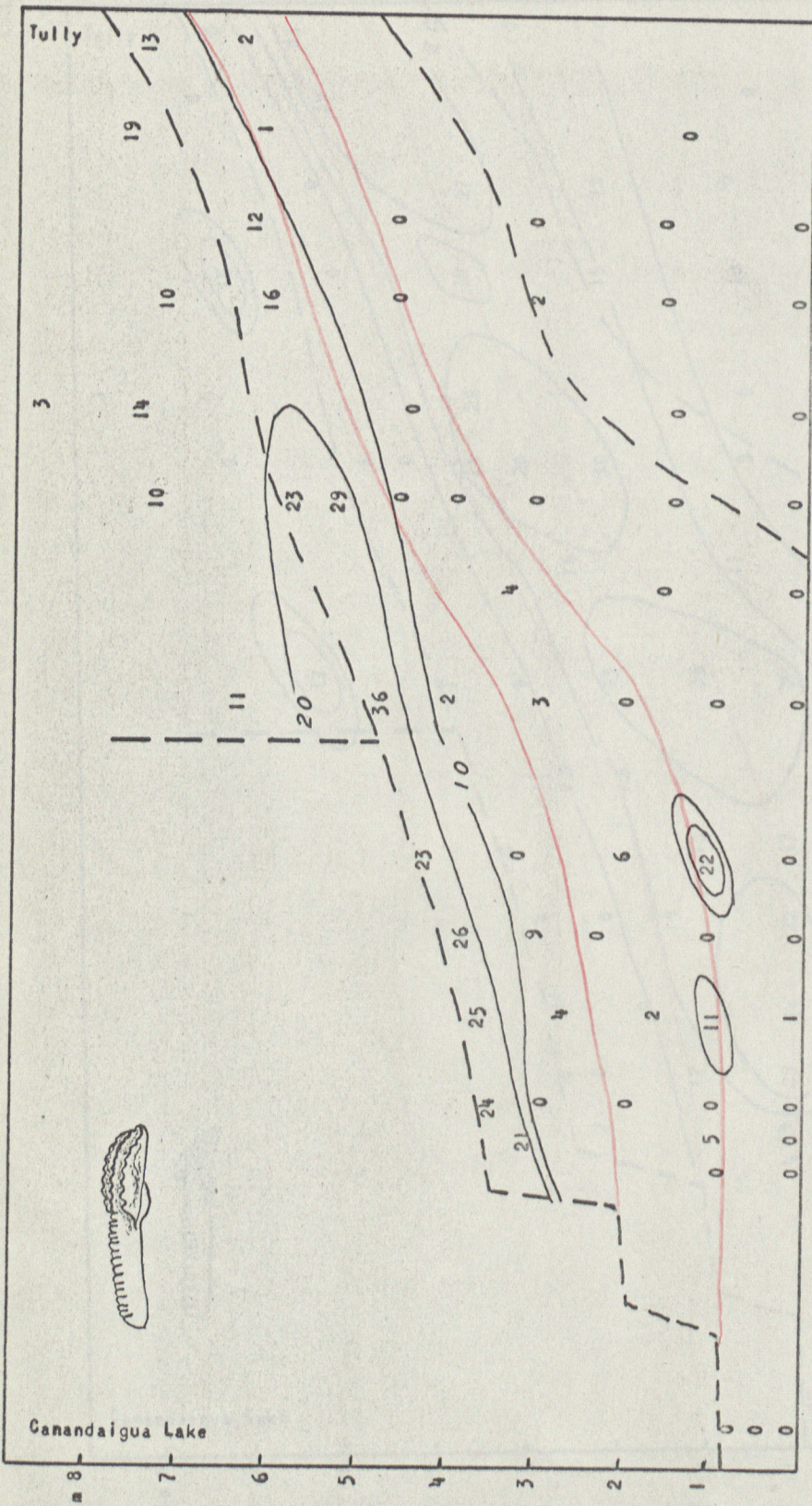
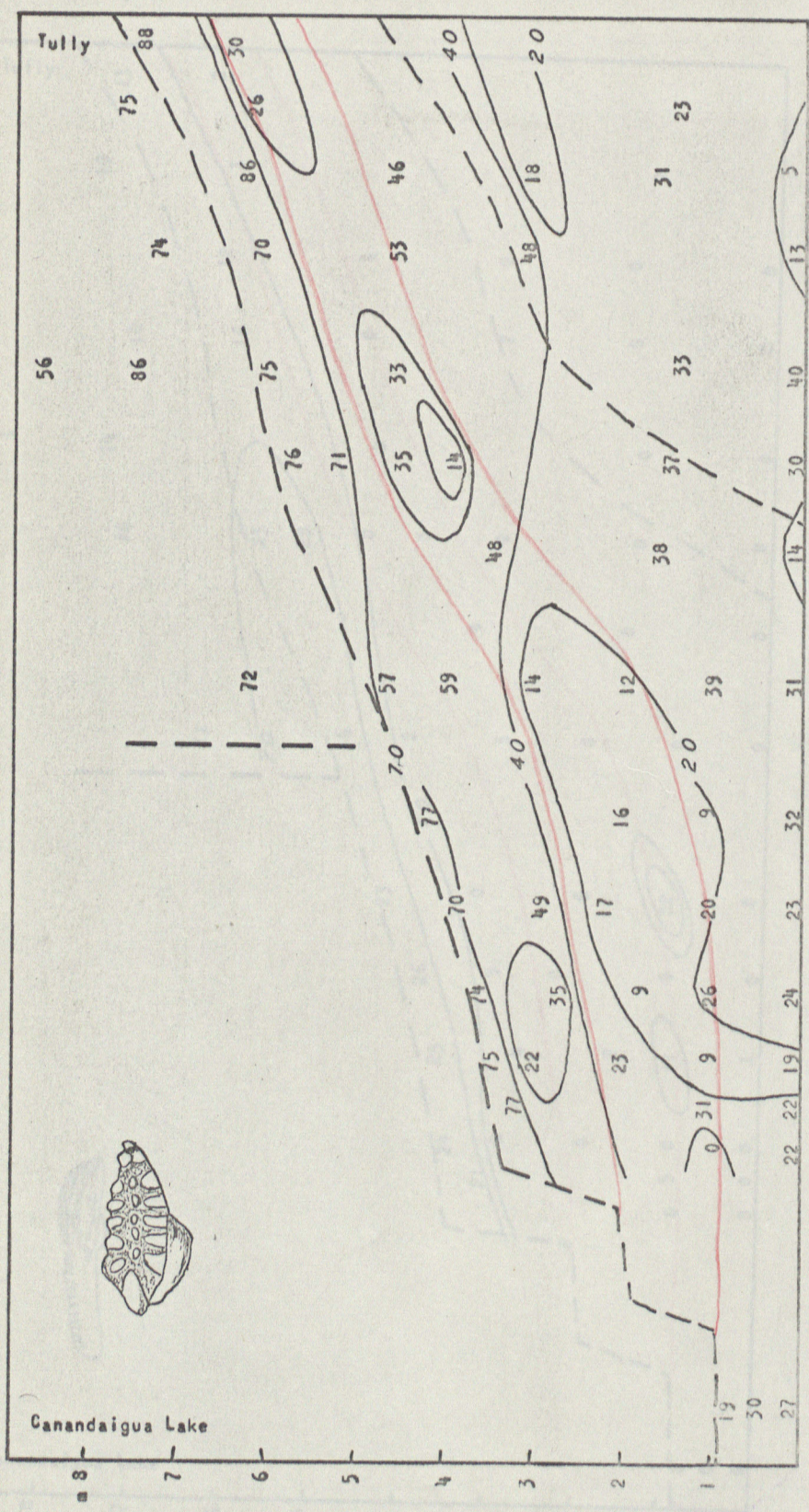


FIG. 17 DISTRIBUTION OF POLYGNATHUS? JUVENIS (see fig. 15 for explanation)



DISTRIBUTION OF *ICRIODUS* (see fig. 15 for explanation)

FIG. 13

E) INTERPRETATION OF THE FAUNAS

DISCRIMINANT ANALYSIS

The main constituents of the fauna are Polygnathus linguiformis, P. varca, P.? iuvenis, Icriodus and bar-type conodonts. These five groups constitute an average of about 70% of the complete assemblages (bar-types alone 20%). For a subdivision of the Tully Formation the variations in the relative abundance of P. linguiformis, P. varca, P.? iuvenis, and Icriodus appeared to be the most significant features.

These variations (i.e. P. linguiformis + P. varca + P.? iuvenis + Icriodus = 100%) are shown on figures 15, 16, 17 and 18, where 16 sections of the Tully Formation in between Canandaigua Lake and Tully, New York, a distance of almost 100 km, were projected into an E - W plane. The contact of the Tully Limestone and the underlying Hamilton Shale was taken as a datum plane and the percentages of specimens (complete and larger fragments with distinct features) were plotted in the approximate positions of the samples as defined by the geographical location of the section and the height above the Tully/Hamilton boundary.

The distribution charts show a distinct and different pattern for each of the four conodont groups.

The values for P. linguiformis (fig. 15) demonstrate a very sharp decrease in the highest samples of the limestone and, below that, a zone of gradual increase between the 20% and 60% lines. However, in the remaining part the values are relatively uniform, varying about 60%.

The distribution of P. varca is characterized by a distinct maximum within the 15% lines (fig. 16).

The distribution of P.? iuvenis is inverse to that of P. linguiformis. P.? iuvenis is restricted almost exclusively to the top of the limestone and the limestones interbedded with shale above (fig. 17).

The array of the percentages of Icriodus indicates that a gradual increase from the lower to upper part of the sections takes place. The maximum lies in the highest parts of the limestone and the limestones interbedded with shale (fig. 18).

To evaluate these four distribution patterns simultaneously a statistical approach (i.e. discriminant analysis) was believed to be most suitable (J. E. Graham, personal communication). For that procedure the samples were grouped arbitrarily into several populations and the discriminant analysis would indicate whether these populations could be distinguished by linear functions which involve the

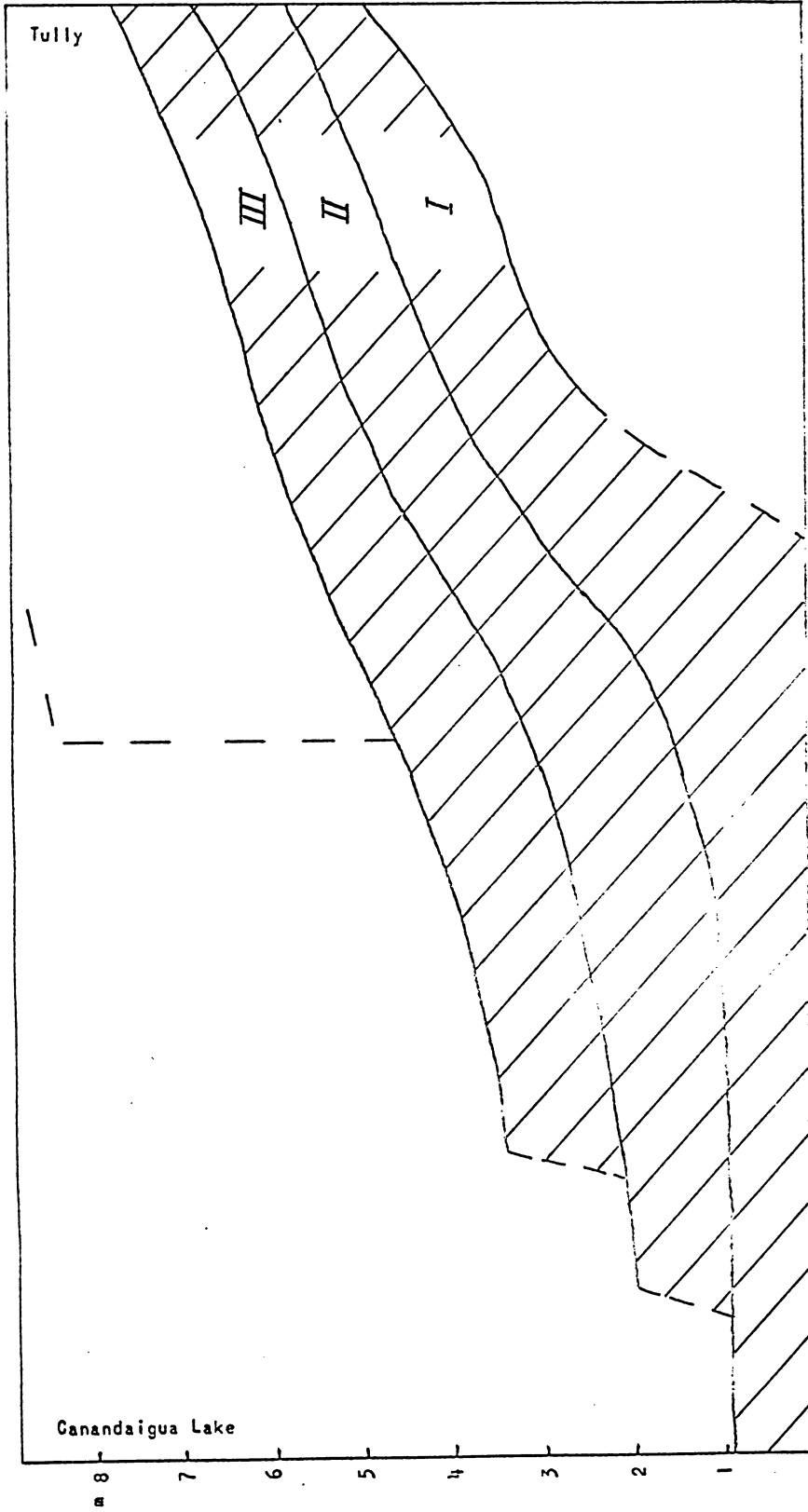


FIG. 19 AREA OF STATISTICAL APPROACH AND SEQUENCE OF LEVELS

I, II, III, are the areas indicated in fig. 9

proportions of the abundance of P. linguiformis, P. varca, P.? iuvenis and Icriodus.

As a guide for the preliminary grouping of 37 samples three members recognized by Heckel (1965), into which the highest number of samples could be placed, were selected and designated as levels I, II and III (see fig. 19).

To simplify the mathematical approach, it was assumed that an observation from an unknown level (i.e. population) arises from one of only two possible populations. Suppose that n_1 and n_2 observations are available from populations 1 and 2 respectively. For each sample observations were made on k characteristics denoted by x_1, x_2, \dots, x_k , (incidence of the occurrence of P. linguiformis, P. varca, P.? iuvenis, and Icriodus). The discrimination problem was then one of determining what linear function of the observations, i.e.,

$$X = a_1x_1 + a_2x_2 + \dots + a_nx_n$$

will be "best" for assessing an unknown individual to one of the two populations. (X is called a "discriminant function".) The mathematical treatment is as follows (J.E. Graham, written communication):

"The basic assumption underlying a rigorous discriminant function analysis is that for each population the $x_j, j = 1, 2, \dots, k$, are

jointly distributed in a multivariate normal distribution with possibly differing means but with common variances and covariances. Departures from these assumptions, provided that they are not severe, will not seriously effect the validity of the analysis.

Let $x_{\ell ij}$ denote the j -th observation on the i -th characteristic from the ℓ -th population. Then

$$\bar{x}_{\ell i} = \frac{\sum_{j=1}^{n_i} x_{\ell ij}}{n_{\ell i}} = \text{mean of the } n_i \text{ observations on the } i\text{-th characteristic in population } \ell, \ell = 1 \text{ or } 2.$$

$$\text{Let } d_i = \bar{x}_{1i} - \bar{x}_{2i}.$$

Now, since

$$X = a_1 x_1 + a_2 x_2 + \dots + a_k x_k,$$

where the a_i are to be determined, it follows that

$$\bar{X}_1 = a_1 \bar{x}_{11} + a_2 \bar{x}_{12} + \dots + a_k \bar{x}_{1k},$$

$$\bar{X}_2 = a_1 \bar{x}_{21} + a_2 \bar{x}_{22} + \dots + a_k \bar{x}_{2k},$$

$$\text{Let } D = \bar{X}_1 - \bar{X}_2 = a_1 (\bar{x}_{11} - \bar{x}_{21}) + a_2$$

$$(\bar{x}_{12} - \bar{x}_{22}) + \dots + a_k (\bar{x}_{1k} - \bar{x}_{2k})$$

$$= \sum_{i=1}^k a_i d_i$$

Now suppose that \bar{X}_1 and \bar{X}_2 are the means of random samples* of sizes n_1 and n_2 from normally distributed populations with means μ_1 and μ_2 and variances σ_1^2 and σ_2^2 . The hypothesis we wish to test is that $\mu_1 = \mu_2$ (i.e. that it is not possible to discriminate between the two populations because the discriminant function has the same expectation in the two populations) against the alternative $\mu_1 \neq \mu_2$ (and therefore that discrimination is possible provided the sample sizes are large enough). By referring to the familiar t-test on the equality of two populations means μ_1 and μ_2 the test statistic

$$t = \frac{\bar{X}_1 - \bar{X}_2}{s_X \sqrt{\frac{1}{n_1} + \frac{1}{n_2}}}$$

is suggested. Here s_X is the estimated standard deviation of the discriminant function;

* Sample in the context of this communication means the complete amount of "geological" samples from one population.

where

$$s_x^2 = \sum_{i=1}^k \sum_{m=1}^k a_i a_m \text{cov}(x_i, x_m)$$

where the covariance of x_i and x_m , i.e. $\text{cov}(x_i, x_m)$ is calculated from the available sample under the assumption of a constant covariance structure from population to population. Thus

$$\begin{aligned} \text{Cov}(x_i, x_m) &= \frac{\sum_{l=1}^2 \sum_{j=1}^{n_l} (x_{l1j} - \bar{x}_{l1})(x_{lmj} - \bar{x}_{lm})}{n_1 + n_2 - 2} \\ &= \frac{S(x_i, x_m)}{n_1 + n_2 - 2} . \end{aligned}$$

If $\mu_1 - \mu_2 \neq 0$, choose the a_1, a_2, \dots, a_k which makes t a maximum. This is equivalent to the maximization of D^2/s_x^2 . This maximization leads directly to the system of linear equations

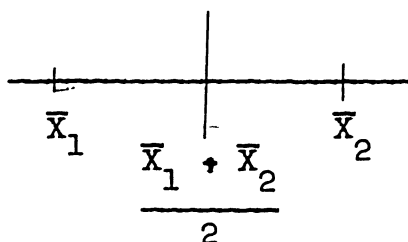
$$\begin{aligned} a_1 S(x_1^2) + a_2 S(x_1 x_2) + \dots + a_k S(x_1 x_k) &= d_1 \\ a_1 S(x_2 x_1) + a_2 S(x_2^2) + \dots + a_k S(x_2 x_k) &= d_2 \\ \vdots \quad \dots \quad \dots \quad \dots \quad \vdots & \\ a_1 S(x_k x_1) + a_2 S(x_k x_2) + \dots + a_k S(x_k^2) &= d_k \end{aligned}$$

which may then be solved using matrix methods

for the unknowns a_1, a_2, \dots, a_k .

Having thus determined numerical values for the a_1 's, the discriminant function can now be specified.

In order to decide which of the two populations a given unit belongs to, the observations on the k characteristics are substituted into the discriminant function in which the a_1 have previously been determined. This gives a single numerical value for X , say X_0 . The sample data employed to establish the discriminant function can also be used to establish \bar{X}_1 for population 1 and \bar{X}_2 for population 2. The value $(\bar{X}_1 + \bar{X}_2)/2$ then divides the real continuum into two regions as shown in the diagram.



If $\bar{X}_1 < \bar{X}_2$, then $X_0 < (\bar{X}_1 + \bar{X}_2) / 2$ assigns the observation of unknown origin to population 1 and conversely if $X_0 > (\bar{X}_1 + \bar{X}_2) / 2$ it is

assigned to population 2.

The ability of X to actually discriminate rests on the true significance of the difference between \bar{X}_1 and \bar{X}_2 . This difference is readily tested using the fact that

$$t = \frac{\bar{X}_1 - \bar{X}_2}{\sqrt{\text{Var}(\bar{X}_1 - \bar{X}_2)}}$$

follows Student's t -distribution with $n_1 + n_2 - 2$ degrees of freedom under the null hypothesis of equality of μ_1 and μ_2 .

In the application of interest, discrimination must be made between three different populations. A sequential procedure was suggested to do this. Discrimination was made between III and I at the first stage (it was felt that these two populations would be the easiest to distinguish). At the second stage discrimination was made between the selected population from stage I and II.

The basic observations in this geological application were counts of the incidence of fossil types. These were transferred into proportions for each sample. A square root transformation

was applied to these proportions to develop a series of approximately normally distributed variables which would satisfy the assumptions critical to a valid discriminant analysis.

The sequential test procedure followed necessitates the development of three discriminant functions to distinguish between the ${}^3C_2 = 3$ possible pairs of populations to be compared.

$$\text{Let } x_1 = \sqrt{\text{proportions of } \underline{P. linguiformis}}$$

$$\text{Let } x_2 = \sqrt{\text{proportions of } \underline{P. varca}}$$

$$\text{Let } x_3 = \sqrt{\text{proportion of } \underline{P.? iuvenis}}$$

$$\text{Let } x_4 = \sqrt{\text{proportion of } \underline{Icriodus}}$$

Using the available sample data the 3 systems of 4 linear equations in 4 unknowns each which must be solved in the process of discriminating between, respectively, (i) III and I, (ii) III and II, (iii) I and II were, employing matrix notation,

$$\begin{pmatrix} 1.041 & -0.114 & -0.453 & -0.504 \\ -0.114 & 0.450 & -0.001 & -0.040 \\ -0.453 & -0.001 & 0.534 & 0.131 \\ -0.504 & -0.040 & 0.131 & 0.429 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} -0.293 \\ -0.157 \\ 0.239 \\ 0.198 \end{pmatrix}$$

$$\begin{pmatrix} 1.094 & 0.024 & -0.439 & -0.558 \\ 0.024 & 0.706 & -0.030 & -0.417 \\ -0.439 & -0.030 & 0.345 & 0.197 \\ -0.558 & -0.417 & 0.197 & 0.775 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} -0.278 \\ -0.352 \\ 0.271 \\ 0.314 \end{pmatrix}$$

$$\begin{pmatrix} 0.349 & -0.052 & 0.042 & -0.294 \\ -0.052 & 0.476 & 0.033 & -0.309 \\ 0.042 & 0.033 & 0.271 & -0.118 \\ -0.294 & -0.309 & -0.118 & 0.736 \end{pmatrix} \begin{pmatrix} a_1 \\ a_2 \\ a_3 \\ a_4 \end{pmatrix} = \begin{pmatrix} 0.015 \\ -0.096 \\ 0.032 \\ 0.116 \end{pmatrix}$$

These three systems of linear equations were solved to yield the desired discriminant functions.

(1) Comparison: III and I

Discriminant function:

$$X = -0.00739x_1 - 0.322x_2 + 0.364x_3 + 0.601x_4.$$

Discrimination rule:

If $X_0 < 0.368$ assign to I

If $X_0 > 0.368$ assign to III

(2) Comparison: III and II

Discriminant function:

$$X = 0.132x_1 - 0.446x_2 + 0.896x_3 + 0.032x_4.$$

Discrimination rule:

If $X_0 < 0.115$ assign to II

If $X_0 > 0.115$ assign to III

(3) Comparison: I and II

Discriminant function:

$$X = 0.281x_1 + 0.020x_2 + 0.207x_3 + 0.310x_4.$$

Discrimination rule:

If $X_0 < 0.368$ assign to II

If $X_0 > 0.368$ assign to I

The significance of the discriminant functions (1), (2) and (3) were tested yielding test values of $t = 6.97$, $t = 6.42$ and $t = 2.87$, all of which are significant at the 95% level. As anticipated, the discrimination between I and II is the most difficult to carry out".

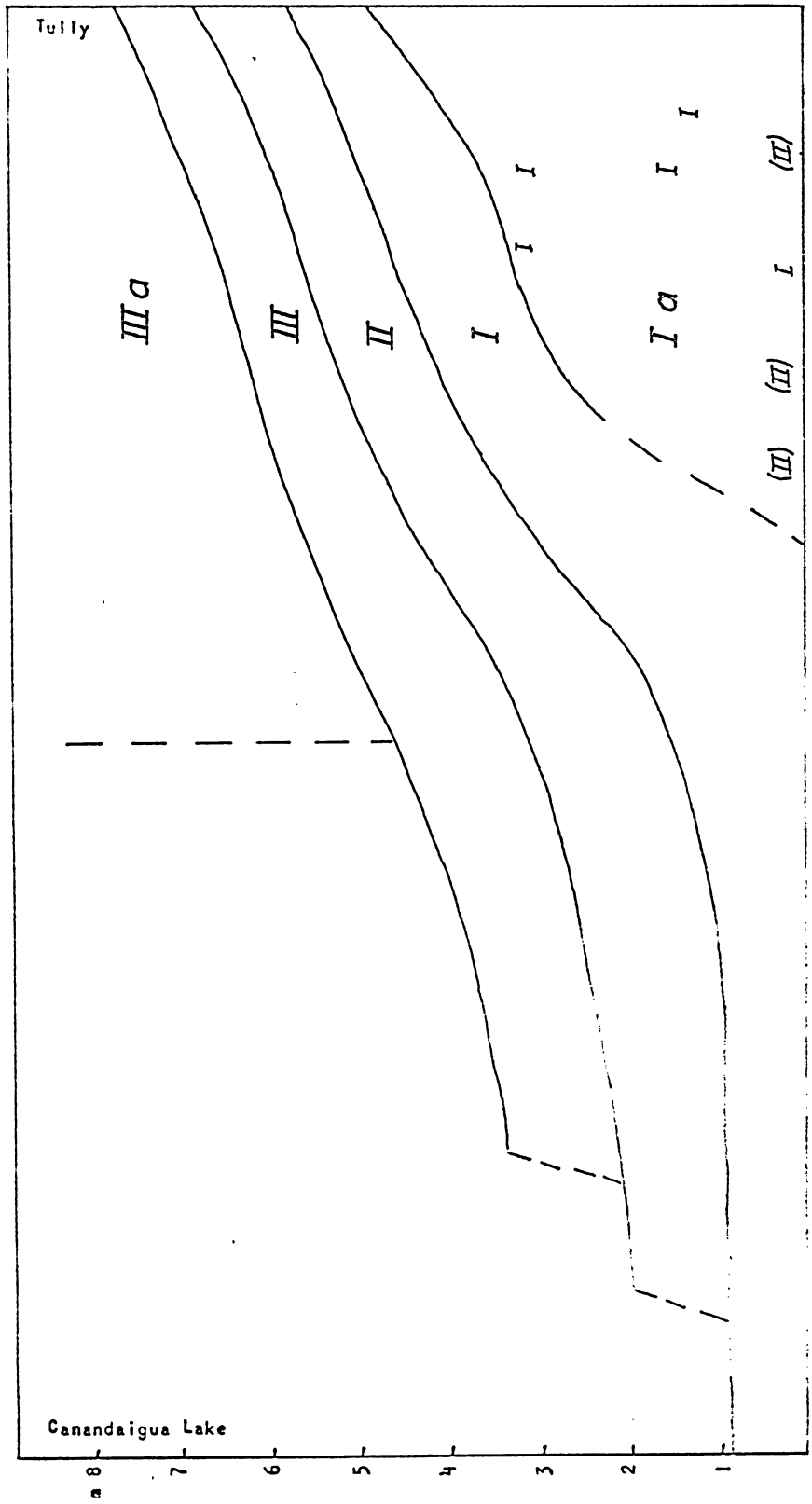


FIG. 20. SUBDIVISIONS OF THE TULLY FORMATION, CANANDAIGUA LAKE AND TULLY.

BY A. EDGEMONT HAST

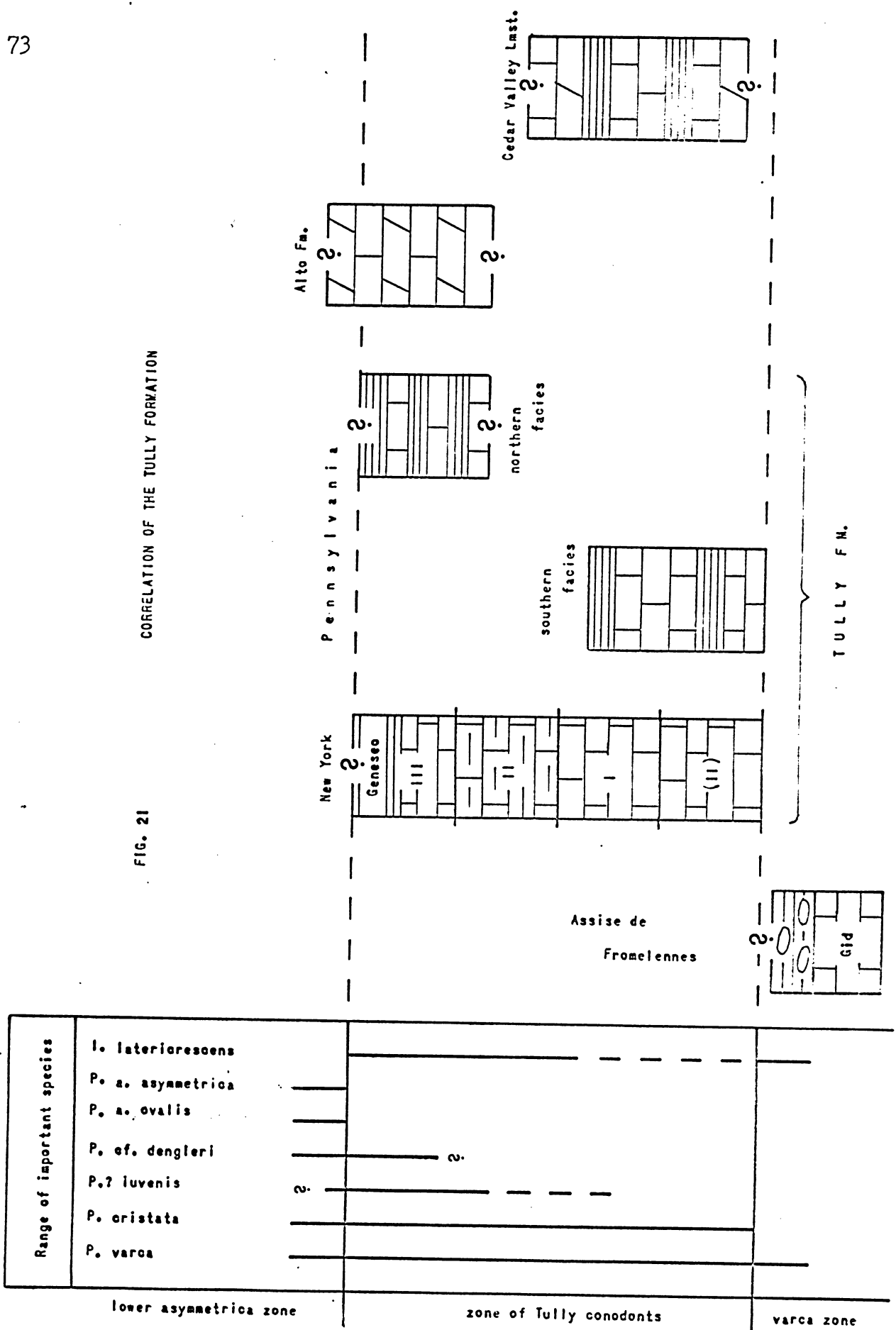
In area Ia the positions of single examples are indicated. See text p. 72. Boundaries of I, II, III coincide with the stratigraphical boundaries from fig. 9.

SUBDIVISIONS WITH THE DISCRIMINANT ANALYSIS

The successive calculation of X_0 for samples not used to establish the three functions gave the following results (fig. 20).

1. Observations from level IIIa (7 samples) are to be included in level III as there is no criterion in the discriminant functions to separate them.
2. Most of the observations from level Ia satisfy the X_0 values for I (5 samples), but at the base an additional unit is indicated (3 samples, see page 78).
3. Four samples (including base and top of the exposed section) from the south west face of the northern quarry near Borodino are similarly to be placed in level I (see page 30).
4. Furthermore, with the aid of the discriminant functions three sections from Pennsylvania were correlated with the levels defined in New York (fig. 21).
 - a) Northern facies: Samples 18 and 19 of the section at Lockport (fig. 14) contained adequate material to calculate the values of X_0 , which referred sample 18 to level II and sample 19 to level III. This distinction again could be made between the two uppermost samples of

FIG. 21
CORRELATION OF THE TULLY FORMATION



section 7 near Jersey Shore (eastern arm of the Susquehanna River, Williamsport qu.).

b) Southern facies: At section 1 near Claysburg (fig. 14) the relationships are not altogether as clear as in the preceding cases. Sample 1 had to be assigned to level II, whereas sample 3 equated to level I. The total number of specimens in sample I (64) appears to be sufficient to give true proportions of the occurrences of P. linguiformis and P. varca. This inversion is very similar to the conditions observed at the base of level Ia in New York and the section at Claysburg is therefore correlated with the lower part of Ia.

VALIDITY OF THE CORRELATION WITH DISCRIMINANT FUNCTIONS

To judge the significance of the aforementioned correlations possible reasons for the varying distributions and possible errors should be assessed.

Influence of Processing

This can be neglected as all samples received identical treatment. The use of the magnetic separator might have caused a higher amount of fractured specimens to be present than in the original limestone, but for the

analysis complete specimens or fragments with distinct features only were counted.

Stratigraphical Influences

This heading includes ecological control on the conodont animal and the subsequent sedimentary fate of the single conodonts. Also the possibility of a time-stratigraphic sequence has to be considered as a cause for the different distributions.

Ecological and Sedimentary Control

Without a detailed study of the composition, textures, and sedimentary structures of the samples and sections no conclusive answer can be given. Some general statements however are possible. As far as the gross lithologies indicate ecological and sedimentary conditions, both levels I and III are clearly independent of them. The samples of level I and Ia come from calcilutites, calcisiltites and occasional calcarenites. The amount of non-calcareous material varies. Samples from the western part of the area studied are more bituminous and may include pyrite. Samples farther east, especially from level Ia contain a higher amount of argillaceous and arenaceous matter. Not

infrequently shaly and nodular beds and shale partings are present; also, the number of macrofossils (brachiopods, crinoids, corals, trilobites) varies from sample to sample.

The differences in lithology are more pronounced in levels III and IIIa. The beds of level III consist in most instances of highly fossiliferous calcilutites (shale laminae are present), but the material of level IIIa is altogether different. Here highly argillaceous and silty limestones which grade into shale are predominant. One of the samples was derived from black shale. No macrofossils were found in these beds. Furthermore, the sections in Pennsylvania in which level III could be traced, carry higher amounts of shale and are much more bituminous than in this level in New York.

In level II the differences in lithology are not very marked. This level is restricted to dominantly shaly limestone, and not very abundant in macrofossils. In Pennsylvania also the limestones are interbedded with shale and contain large amounts of non-calcareous matter. The samples of level II at the base of Ia come from both shaly nodular limestone and relatively pure calcilutite.

Studies of conodont ecology in Ordovician limestones have been undertaken (Barnes, 1964), but the results are hardly applicable in this case. No comparable work on

Devonian conodont faunas has yet been published. Effects of different rates of sedimentation and ecological factors which might have controlled the total abundance of the conodont animals are diminished by the use of ratios instead of absolute values.

Evolutionary Control

Considering this case, the levels are supposed to be products of evolutionary changes rather than caused by different environments. Whether these evolutionary changes (replacement of a P. linguiformis-dominated fauna by a fauna which has Icriodus as main constituent) are of local or more regional importance cannot be said. Orr (1964) found a similar succession in the Lingle Formation. The lower part of the section contained more than 50% P. linguiformis, whereas the uppermost sample yielded almost entirely Icriodus latericrescens. However I. latericrescens is not very abundant in the Tully Formation and in Orr's case an environmental control of the conodont distribution cannot be excluded.

Mathematical limits of the discriminant analysis

The twofold calculation of X_0 does not eliminate observations from possible populations other than those defined by the three functions, and for correlations, successions of observations have to be used. But in the New York area under discussion only those three levels, with the exception of the basal part of level Ia, occur, and in the sections of the northern facies in Pennsylvania two contiguous levels were found in the right succession.

The apparent level II at the base of Ia and the inversion of the levels in the section at Claysburg (leaving aside the possibility that sample 1 does not give true proportions) are to be attributed to this limit of the procedure. But in turn the twofold existence of the same feature indicates a stratigraphical succession instead of a mathematical or sampling inadequacy.

With the three preceeding speculations in mind the following conclusions can be drawn:

1. Because of the variety of lithologies within the single levels, evolutionary rather than environmental changes are more probably the cause of faunal variation at different levels.

2. A local application of the discriminant analysis for correlation appears to be justified.

CORRELATIONS (see fig. 21)

Comparison with Geneseo Conodonts

The Tully fauna is stratigraphically distinct from the conodonts of the overlying Genesee Group as far as is known from the Genundewa Limestone (Bryant, 1921; Ziegler, 1962). In the Genundewa Limestone Polygnathus asymetrica and Ancyrodella rotundiloba, both forms of the lower asymetrica zone appear. But the dividing line between the two faunas must be situated somewhere in the lower part of the Geneseo Shale, as the samples taken from the limestones interbedded with shale at the top of the Tully Formation and from the shale immediately above the last limestone bed show definite Tully characteristics (see p. 72).

Alto and Lingle Formations (Illinois)

The fauna of the type sections of these formations was described by Orr in 1964. Among the stratigraphically more important species in both the Tully and Lingle Formations Icriodus latericrescens and Polygnathus linguiformis are common, whereas in both the Tully and the Alto Formations

P. cristata, P. decorosa, P. pennata are likewise common. Besides those, the Alto Formation contained one specimen of P.? iuvenis, and in the Tully Formation two specimens of Polygnathus were found, which were related to P. n. sp. ORR.

The similarities of the vertical distributions of the above mentioned specimens are outstanding. In the lower Lingle Formation P. linguiformis is dominant, whereas the fauna of the uppermost sample consists almost entirely of Icriodus latericrescens. Polygnathus? iuvenis and P. n. sp. ORR are reported from the Alto Formation.

If the fauna of Orr's sample 5 of the Lingle Formation (Icriodus latericrescens) is seen together with some specimens of the Alto fauna (Polygnathus? iuvenis, P. n. sp. ORR) and contrasted against the remaining underlying linguiformis fauna of the Lingle Formation, these two sections resemble the Icriodus fauna of the upper Tully Formation and the linguiformis fauna of the lower part of the formation. However, this comparison should not be taken too far as other important features of the Tully fauna like the presence of Polygnathus varca and the simultaneous occurrence of P. linguiformis, and P. cristata at the base of the Tully are by no means repeated in the Alto and Lingle Formations. Also Icriodus latericrescens appears together with Polygnathus? iuvenis in the Tully

Formation, whereas it does not extend up into the Alto Formation.

The question of whether or not the Lingle Formation is a correlative of the lower part of the Tully Formation has to be left, but to correlate the Alto Formation with at least the upper part of the Tully Formation on the basis of Polygnathus cristata, P.? iuvenis, P. n. sp. ORR and the absence of P. linguiformis appears to be justified. Orr considered the Alto Formation to be younger, because he did not know of the existence of P. cristata in the Tully Formation.

Cedar Valley Limestone (Minnesota)

A correlation of the fauna from the interlayered clays (Stauffer, 1940) with the Tully conodonts is possible on the basis of Polygnathus linguiformis, P. varca, P. xyla and P.? iuvenis. Although Stauffer did not report P. cristata, this correlation agrees with the ideas of Cooper and Cloud (1938).

Correlation with Europe

The correlation of this fauna with those known from Europe poses some difficulties. The sections in south west

England are not sufficiently understood in respect to conodonts. A visit to the Belgian type section during the course of this study did not provide a satisfactory amount of material, but the presence of Polygnathus varca and P. linguiformis and the absence of definite Upper Devonian species suggest varca zone for at least the base of the Assise de Fromelennes.

In the conodont fauna of the Tully Formation, the abundance of Polygnathus linguiformis and P. varca, and the not uncommon occurrence of P. beckmanni and P. pennata give a Middle Devonian aspect, but P. cristata, P. caelata and P. cf. dengleri are species of the Upper Devonian. Additional components of the fauna are species without great stratigraphic significance (Ozarkodina congesta, O. elegans, O. lata, most species of Icriodus); also contributing to the fauna are species which have not been recorded from Europe such as Polygnathus? iuvenis.

The first step in evaluation of this fauna is to eliminate species with little or no stratigraphic significance (see fig. 23). This covers Bryantodus grandis, B. stratfordensis, all species of Icriodus except I. latericrescens, all Ozarkodina, Polygnathus decorosa, P. linguiformis, P. varca, and P. pennata which all cross the Middle/Upper Devonian boundary. P. xyla is reported from

the Eifelian and the lower Givetian (Bischoff & Ziegler, 1957; Wittekind, 1961) but occurs higher in North America (Stauffer, 1940; Loranger, 1965). Species not recorded from Europe are also excluded. For that reason no exclusive North American species of Bryantodus and Ozarkodina were identified.

This procedure selects as species indicating the varca zone only Polygnathus beckmanni and Icriodus latericrescens. P. beckmanni is the Middle Devonian ancestor of P. caelata and the present material shows a gradational change between the two species. Therefore, in this case they do not have stratigraphical value. Icriodus latericrescens, on the other hand, has yet not been observed in the Upper Devonian and may therefore be used as an argument for the Middle Devonian age of the Tully Formation. As species belonging to the asymmetrica zone in the Tully Formation there are to be considered: Bryantodus aff. alternatus, Polygnathus caelata, P. cristata, P. cf. dengleri, P.? n. sp. BISCHOFF & ZIEGLER. Bryantodus aff. alternatus has little stratigraphical value. Bischoff and Ziegler (1957) reported four specimens only and the present specimen is poorly preserved thus not allowing conclusions to be made. Polygnathus caelata cannot be used for reasons already explained above under P. beckmanni. However, P. cristata and P. dengleri are both guide fossils of the lower asymmetrica zone (Krebs, 1959;

Ziegler, 1962) and do not have any known direct Middle Devonian ancestors. Sufficient numbers of P. cristata occur in the present material to provide data for an Upper Devonian age of the Tully Formation. The specimen of P. cf. dengleri supports this view. Any decisions based on P.? n. sp. BISCHOFF & ZIEGLER should be cautious, because Bischoff and Ziegler (1957) reported three specimens only.

Icriodus latericrescens, Polygnathus cristata and P. cf. dengleri do not indicate any definite stratigraphic position. The Middle Devonian aspect of Icriodus latericrescens does not fit the occurrence of Upper Devonian Polygnathus cristata and P. cf. dengleri. An extension of the range of Icriodus latericrescens into the lower asymmetrica zone does not solve this discrepancy, because of the conspicuous absence of other index fossils of the lower asymmetrica zone, such as Polygnathus asymmetrica ovalis, P. a. asymmetrica, P. normalis, P. ordinata, P. peracuta, P. rugosa, P.? variabilis in the present material. This absence cannot be explained by chance of sampling, because the amount of material is enormous. Extending the range of P. cristata and P. dengleri into the Middle Devonian is a possible solution. However P.? iuvenis, which is of great abundance in the Tully Formation has not been noted from Europe except in a list of synonyms of P. varca (Wittekindt, 1961), but on Wittekindt's pl. 4 only one specimen (fig. 21) seems to have

	PLYMOUTH	TORQUAY	BELGIUM FRANCE	A O O R F
Upper Dev. (part)	Warren Point Beds 3	Saltern Cove Beds	Assise de Frasne 13	to 1 (β) γ 15
	2	Babbacombe Slates 7	Assise de Fromelennes 11	
Middle Dev. (part)	Plymouth Limestone 1	Torquay 4, 5, 6	Gld 10	to 1 α 14 Grenzlagerszone Volcanios
	Limestone	Limestone	Glo 9	

1. Stringocephalus burtini
2. Hypothyridina cubooides
3. Manticoceras sp.
4. Hedekindella brilonense
5. Stringocephalus burtini
6. Maenioceras terebratum
7. Probeloceras forcipiferum
8. Manticoceras sp.
9. Spirifer acdiotextus
10. Hexagonaria quadrigenina
11. Spirifer tentaculum
12. Stringocephalus burtini
13. Spirifer orbelianus
14. Pharioceras lunulicosta
15. Manticoceras cordatum

FIG. 22
CURRENT VIEWS ON MIDDLE/UPPER DEVONIAN CORRELATION
OF THE CLASSICAL EUROPEAN SECTIONS
(mainly after Brinkmann 1959 and House & Selwood 1964)

(same as fig. 4)

Eifelian (part)	Givetian		varoa- zone	to 1 α to 1 (β) γ (part)			
	Oderesh. Kalk	Sparagno- phyllum Kalk		asymmetrica-zone			
				low.	mid.	up.	
				—			Bryantodus aff. alternatus
				—			B. angustus
				—			B. grandis
				—			B. stratfordensis
				—			B. sp. c BISCHOFF & ZIEGLER
							Ioriodus curvatus
							I. cymbiformis
			—				I. latericrescens
							I. nodosus
							Ozarkodina congesta
							O. elegans
							O. lata
							Polygnathus beckmanni
				—			P. caelata
				—			P. oristata
				—			P. decorosa
				—			P. cf. dengleri
				—			P. linguiformis
				—	—	—	P. pennata
				—			P. varoa
				—			P. xyla
				—			P. ? n. sp. BISCHOFF & ZIEGLER
							Spathognathodus planus

FIG. 23 EUROPEAN RANGE OF CONODONT SPECIES RECOGNIZED IN THE TULLY FORMATION

(mainly after Ziegler 1962 and Krebs 1959)

the indicative expanded basal cavity.

These incongruities are easily explained if a fauna missing from the conodont succession recorded from Europe is postulated. This hypothetical fauna can be placed stratigraphically at the boundary between the varca and asymmetrica zones and contains the intermediate fauna of the Tully Formation, characterized by Icriodus latericrescens, Polygnathus cristata, P.? juvenis and the occasional occurrence of P. dengleri together with P. linguiformis and P. varca.

Two reasons for the absence of the Tully fauna in Europe are possible:

a) The conodonts of the Tully Formation represent a biofacies which is particular to North America, and is coeval with either the varca zone or the lower asymmetrica zone.

However, this alleged facies reaches from southern Pennsylvania possibly to Illinois (see p. 80) and thus acquires quite regional aspects. Also the fauna is independent of such a variety of lithologies, ranging from black shale and siltstones to crinoidal limestones and bituminous calcilutites, that this concept appears untenable. Furthermore, many of the Upper Devonian conodont zones of Europe have already been recognized as identical with the

Upper Devonian zonal sequences of North America (Klapper & Furnish, 1962; Ziegler, 1962; Klapper, 1966). In their study of Upper Devonian conodonts from Western Australia, Glenister and Klapper (1966) state:

"Without doubt the ammonoid and conodont zones of the Upper Devonian are geologically homochronous on a worldwide basis".

b) There is a gap in the succession recorded from Europe. In this case the Upper Devonian conodont fauna would not suddenly start at what appears to be the boundary between the varca and asymmetrica zones, but emerge gradually during a short interval before. The presence of this interval between the varca and the asymmetrica zones (defined by the range of Polygnathus cristata and Polygnathus? iuvenis without Polygnathus asymmetrica) would easily explain the simultaneous occurrences of Icriodus latericrescens and Polygnathus cristata. Furthermore, the range of Spathognathodus planus harmonizes with this theory (fig. 23).

To find any reason for this absence of the Tully conodont fauna in Europe, it is best to examine the extent of the reported sections containing conodont faunas of the varca and asymmetrica zones. For the varca zone Bischoff and Ziegler list six separate localities of the upper

"Stringocephalus Stage", for the ordinata - dubia sub-zone faunas from four separate localities. None of the samples from wells reported by the same authors is taken lower than the ordinata - dubia sub-zone. The lowest conodont fauna from the Martenberg, near Adorf, is derived from the upper part of the Roteisenstein and already contains Polygnathus asymmetrica ovalis and P. a. asymmetrica (Ziegler, 1958). The faunas listed by Krebs (1959) appear always in positions above the ore beds. Wittekindt's (1961) upper Givetian conodont zonation is in the Discoides Limestone, which does not reach into the Upper Devonian (H. Schmidt, 1958). No uninterrupted section which contains conodonts and definitely crosses the Middle/Upper Devonian boundary, as indicated by cephalopods or other fossils, could be found in the German literature. The reasons for this may lie in the complicated facies relationships of the Middle and Upper Devonian rocks of the studied areas, which are unfavourable for conodont research at the Middle/Upper Devonian boundary.

As already stated (p. 7), two limestone facies are dominant (fig. 3).

a) Facies of the reef limestones: In the massive reef limestones sections exist across the Middle/Upper Devonian boundary, but because of the rare macrofossils and conodonts in this lithology, they do not provide material for study (Kegel, 1934; Beckmann, 1949; Pauly, 1958).

b) Facies of the bedded limestones: The bedded limestones with Upper Devonian cephalopods are confined to regions with Middle Devonian tuffs (Wedekind, 1918; Kegel 1934) and do not reach into the Middle Devonian. However the Middle/Upper Devonian boundary in these regions is often marked by the Grenzlagerzone (see p. 17, fig. 22) from which a macrofauna has been obtained (Matern, 1931; Krebs, 1959) but the ore resists the treatment necessary to free conodonts (Ziegler, 1958).

Because the lowest Upper Devonian conodont faunas have been found in the upper parts of the Grenzlagerzone and immediately above in Germany (Ziegler, 1958; Krebs, 1959), the Tully fauna, which is older than the fauna of the lower asymmetrica - zone (see p. 87), is tentatively correlated with the stratigraphic level of the lower Grenzlagerzone. It seems possible that because of the particular stratigraphy of the Middle/Upper Devonian boundary in the Rhenish Schiefergebirge the German researchers simply missed the equivalents of the Tully conodont fauna within the Grenzlager. Furthermore, this is likely, because no mention of a section with conodonts which crosses the Middle/Upper Devonian boundary is to be found in the literature of the Rhenish Schiefergebirge and also because the Tully fauna is defined by the absence of common guide conodonts rather than by the presence of

particular forms (Polygnathus? iuvenis). Likewise, the concept of an additional conodont zone is supported by a recent publication of Flajs (1966) who reports an uncertain interval between the Middle and Upper Devonian in Austria, which because of the lack of Upper Devonian species, he classifies as Middle Devonian. A study by Ziegler (1966) is said to describe also a new conodont zone between the Middle and Upper Devonian (quoted by Glenister and Klapper, 1966; written communication, Huddle).

The macrofauna of the Grenzlagerzone in the Dill - trough has been studied by Matern (1931). The bulk of the fauna belongs to the tol α and the tol β (γ) zones; in two localities however Maeniocreas terebratum appeared. If the Tully fauna is contained in the stratigraphical interval of the Grenzlagerzone, an Upper Devonian age seems to be more likely than a Middle Devonian age. This question can only be decided finally, when a coeval fauna in the Rhenish Schiefergebirge has been discovered.

Not conflicting with an Upper Devonian age of the Tully is its position above the possible varca zone fauna of the base of the Assise de Fromelennes. If the uppermost varca zone in this formation is already of Upper Devonian age (as argued by Mallieux, 1942), the Tully Formation has to be likewise.

F) CONCLUSIONS

SUMMARY OF RESULTS

The statistical subdivision of the studied part of the Tully Formation in New York offers an independent argument for the validity of at least some of Heckel's (1965) subdivisions. Also the position of the studied section at Borodino in level I confirms this stratigraphical scheme. The existence of a hiatus between the Tully Formation and the overlying shales in New York and Pennsylvania is unlikely. A major break in the conodont fauna does not appear at this contact and the only significant change in the composition of the faunas takes place from level II to III, still within the Tully Limestone. For both New York and Pennsylvania an eastward replacement of the lower parts of the respective overlying shales by the upper part of the Tully Limestone may be assumed. Willard (1939) is of a different opinion for Pennsylvania and considers the thin southern facies to be coeval with the upper part of the thick northern sections.

The correlation of the Tully Limestone with the Cedar Valley Limestone complies with the current views, whereas the correlation with the Alto Formation conflicts with the opinions of both Cooper (1942) and Orr (1964).

The age of the Tully is considered to be lowest Upper Devonian and to be an interval not yet described from Europe. This conclusion is based principally on the study of Krebs (1959), who lists conodont faunas containing Polygnathus cristata and P. dengleri without P. asymmetrica above occurrences of Pharciceras. Palmatolepis transitans also listed in these faunas has not, however, been found in the Tully fauna.

SUGGESTIONS FOR FURTHER WORK

The statistical method applied in this study is sufficient for this special purpose, but can be improved by condensing the three discriminant functions into one single formula, which also rejects observations from populations outside the three levels. Work in this direction is already under way.

Study of the conodont faunas of the limestones scattered in and above the Taghanic Stage on Cooper's (1942) correlation chart will indicate the extent of the Tully conodont zone and the accuracy of former correlations.

A conodont study of the Middle and Upper Devonian type sections in France and Belgium is urgently needed. First attempts (Bouckaert & Ziegler, 1965) disclose already that some of the generally used standards based on macro-fossils might have to be reexamined.

APPENDIX

1 SYSTEMATIC DESCRIPTIONS AND COMMENTS

The material listed under each description is located in the stratigraphically arranged samples. A key to the samples is available in the Geology Department, University of Ottawa.

Genus *Bryantodus* ULRICH & BASSLER 1926

In the present study only species of *Bryantodus* which have been described from Germany are considered.

Bryantodus aff. *alternatus* BISCHOFF & ZIEGLER

pl. 2, fig. 8

1957 *Bryantodus alternatus* n. sp. BISCHOFF & ZIEGLER, p. 45 - 46, pl. 19, fig. 40, 46.

Remarks: An aff. identification appears to be justified, though the specimen shows evidence of corrosion and seems to lack the small intermittent denticles. However Bischoff and Ziegler based their species on 4 specimens only and this specimen might well be within the range of variation.

Material studied: 1 specimen

Distribution: Base of the Tully Limestone, New York

Bryantodus angustus BISCHOFF & ZIEGLER

pl. 2, fig. 12

1957 *Bryantodus angustus* n. sp. BISCHOFF & ZIEGLER, p. 46, pl. 13, fig. 6.

Remarks: Although the anterior bar of the specimen is broken, the important diagnostic feature, the narrow and pointed posterior bar is recognizable. Bischoff and Ziegler report a lower Middle Devonian range in Germany.

Material studied: 1 specimen

Distribution: Base of the Tully Limestone, New York

Bryantodus grandis BISCHOFF & ZIEGLER

pl. 2, fig. 11

1957 Bryantodus grandis n. sp. BISCHOFF & ZIEGLER, p. 48 - 49, pl. 20, fig. 21, 22, 25, 26.

Material studied: 1 specimen

Distribution: Base of the Tully Limestone, New York

Bryantodus stratfordensis STAUFFER

pl. 2, fig. 10

1938 Bryantodus stratfordensis n. sp. STAUFFER, p. 423, pl. 48, fig. 17, pl. 49, fig. 6.

Remarks: Bischoff and Ziegler (1957) report Bryantodus stratfordensis from the lower portion of the Givetian in Germany but the occurrence in the Olentangy Shale assures an age at least as young as upper Middle Devonian (Cooper et al., 1942)

Material studied: 8 specimens

Distribution: Lower part of the Tully Limestone, New York

Bryantodus sp. c. BISCHOFF & ZIEGLER

pl. 2, fig. 9

1957 Bryantodus sp. c. BISCHOFF & ZIEGLER, p. 55, pl. 20, fig. 27.

Remarks: The denticles of the present specimens are less numerous and of flatter cross-sections than those of the specimen figured by Bischoff and Ziegler. However features like the fused anterior denticles, the separate posterior denticles, and the large basal cavity are identical. Also the cross-section of the bar and the aborally directed tip of the anterior branch are very similar.

Material studied: 2 specimens

Distribution: Lower part of the Tully Limestone, New York

Genus Icriodus BRANSON & MEHL 1934Icriodus curvatus BRANSON & MEHL

1938 Icriodus curvatus n. sp. BRANSON & MEHL, p. 162 - 163, pl. 26, fig. 23 - 26.

Material studied: 11 specimens

Distribution: Tully Formation, New York and Pennsylvania

Icriodus cymbiformis BRANSON & MEHL

1938 Icriodus cymbiformis n. sp. BRANSON & MEHL, p. 164, pl. 26, fig. 27 - 29.

Remarks: A specimen of Icriodus is here considered to be Icriodus cymbiformis if the median row of denticles extends

5 or more nodes farther back than the lateral rows and no lateral process is present, regardless of the size of the specimen.

Material studied: 33 specimens

Distribution: Tully Formation, New York and Pennsylvania, Gic, Flohimont (France)

Icriodus latericrescens BRANSON & MEHL

1938 Icriodus latericrescens n. sp. BRANSON & MEHL, p. 164 - 165, pl. 26, fig. 30 - 37.

Remarks: Both subspecies Icriodus latericrescens latericrescens and Icriodus latericrescens bilatericrescens are present.

They are common in the samples of the upper part of the sections, but they never occur in large numbers. They have not been observed in samples from the base of the Tully Formation. Orr (1964) mentioned that specimens of Icriodus latericrescens are morphologically distinct in different stratigraphic levels of the Lower and Middle Devonian, though he did not give any details.

Material studied: 50 specimens

Distribution: See above, Tully Formation, New York and Pennsylvania

Icriodus nodosus (HUDDLE)

1934 Gondolella? nodosa n. sp. HUDDLE, p. 94, pl. 8, fig. 24, 25.

1938 Icriodus nodosus (HUDDLE) BRANSON & MEHL, p. 58, pl. 26, fig. 14 - 17, 22.

Remarks: In many of the specimens the lateral process is broken, so that a distinction from Icriodus symmetricus is difficult.

Material studied: 99 specimens

Distribution: Tully Formation, New York and Pennsylvania, lower Fromelennes Formation, Flohimont (France)

Icriodus symmetricus BRANSON & MEHL

1934 Icriodus symmetricus n. sp. BRANSON & MEHL, p. 226, pl. 12, fig. 1 - 3.

Remarks: see Icriodus nodosus

Material studied: 33 specimens

Distribution: Tully Formation, New York and Pennsylvania.

Genus Ozarkodina BRANSON & MEHL 1934

In the present study only species of Ozarkodina are considered which have been described from Germany.

Ozarkodina congesta STAUFFER

1940 Ozarkodina congesta n. sp. STAUFFER, p. 427, pl. 59, fig. 12.

Remarks: Ozarkodina congesta is reported by Bischoff & Ziegler (1957) from the lower Givetian in Germany. The North American occurrence is considerably higher.

Material studied: 11 specimens

Distribution: Tully Limestone, New York

Ozarkodina elegans (STAUFFER)

Lectotype: Stauffer 1938, pl. 48, fig. 9, for synonymies see Bischoff and Ziegler (1957), p. 76.

Material studied: 12 specimens

Distribution: Tully Limestone, New York

Ozarkodina lata BISCHOFF & ZIEGLER

1957 Ozarkodina lata n. sp. BISCHOFF & ZIEGLER, p. 76 - 77, pl. 20, fig. 9 - 16.

Material studied: 16 specimens

Distribution: Tully Limestone, New York

Genus Polygnathus HINDE 1879

Polygnathus beckmanni BISCHOFF & ZIEGLER

Pl. 1, fig. 1a, b, 2.

1957 Polygnathus beckmanni n. sp. BISCHOFF & ZIEGLER,
pl. 15, p. 86, fig. 25.

Remarks: According to Bischoff & Ziegler (1957) the differences between Polygnathus caelata and Polygnathus beckmanni lie in the curvature of the blade and the carina as well as the widths of the platforms. However, many of the present specimens fit the descriptions of Bischoff and Ziegler for beckmanni and the figures of caelata of Bryant (1921) and the distinction is difficult and arbitrary, especially when the posterior tip is broken. The differences in the present material are gradational.

Material studied: 24 specimens

Distribution: Tully Formation, New York and Pennsylvania

Polygnathus caelata BRYANT

pl. 1, fig. 3

1921 Polygnathus caelatus n. sp. BRYANT, p. 24, pl. 13,
fig. 1 - 13.

Remarks: see Polygnathus beckmanni

Material studied: 1 specimen

Distribution: Tully Limestone, New York

Polygnathus cristata HINDE

Pl. 2, fig. 3, 4, 5a, b

1879 Polygnathus cristatus n. sp. HINDE, p. 366, pl. 17, fig. 11.

Remarks: In some specimens the basal cavities are larger than in those of fig. 10, 13b, 16 on pl. 15, Bischoff & Ziegler, and are similar to the specimens figured by Orr, pl. 3, fig. 5b and 6b

Polygnathus decorosa STAUFFER

1938 Polygnathus decorosus n. sp. STAUFFER, p. 438, pl. 53, fig. 1, 5, 6, 10, 11, 15, 16, 20, 30.

Remarks: see Polygnathus varca

Material studied: 60 specimens

Distribution: Tully Formation, New York and Pennsylvania

Polygnathus cf dengleri BISCHOFF & ZIEGLER

pl. 3, fig. 5a, b

1957 Polygnathus dengleri n. sp. BISCHOFF & ZIEGLER, p. 87 - 88, pl. 15, fig. 14, 15, 17 - 24, pl. 16, fig. 1 - 4.

Remarks: The specimen resembles closely the one figured on pl. 15, fig. 21, though the basal cavity is not as small as the one of fig. 19 on the same plate.

Material studied: 1 specimen

Distribution: Limestone interbedded with shale, top of Tully Formation, New York

Polygnathus ectypa HUDDLE

pl. 2, fig. 2a, b

1939 Polygnathus ectypus n. sp. HUDDLE, p. 17, 103, pl. 8, fig. 38.

Remarks: Polygnathus ectypa is different from Polygnathus cristata because of the longer blade and the platforms with troughs at the anterior ends.

Material studied: 1 specimen

Distribution: Limestone interbedded with shale, top of Tully Formation, New York

Polygnathus? iuvenis STAUFFER

pl. 3, fig. 9a, b, 10a, b, c, pl. 4, fig. 1 - 15

1940 Polygnathus iuvenis n. sp. STAUFFER, p. 429 - 430, pl. 60, fig. 26 - 28, 34, 35, 41.

1964 Polygnathus? sp. ORR, p. 24, pl. 4, fig. 2a - c.

selected as lectotype: fig. 41, pl. 60, Stauffer 1940.

Nomenclature: Stauffer's original name for this species appears as iuvensis, but it is apparent that this title indicates youthful appearance or immaturity rather than

any locality. Its correct latin form should be iuvenis and this spelling is followed throughout the present thesis.

Description: In oral view the conodont is straight or slightly bent posteriorly. In lateral view the posterior part is arched. The shapes of the platforms vary. In some specimens faint flanges only appear, in others full platforms are developed. The platforms are long, narrow, shallow and with denticulated edges. Intermediate forms may only have flanges with few nodes or one platform only is developed. The blade is straight and bears fused denticles, which are slightly inclined posteriorly. Germ denticles may be present. In the area of the platforms, the blade, consisting of discrete nodes, continues to the posterior end. The basal cavity is tear-shaped, very large and extends to the posterior tip.

Remarks: Polygnathus? iuvenis is different from Polygnathus varca through the shape of the basal cavity. The figs. 26 - 28, 34, 35, of plate 60 (Stauffer, 1940) do not show the posterior extension of the basal cavity. Distinction from Spathognathodus is possible when a population containing platform bearing forms as well as smooth forms, is present.

Material studied: 90 specimens

Distribution: Upper Tully Formation, New York and Pennsylvania, see figure 17

Polygnathus linguiformis HINDE

1879 Polygnathus linguiformis n. sp. HINDE, p. 367, pl. 17, fig. 15. For synonymies see Orr, 1964, p. 16, 18.

Material studied: more than 100 specimens

Distribution: Tully Formation, New York and Pennsylvania, more abundant in the lower than in the upper part, see figure 15, Gic, Flohimont (France)

Polygnathus pennata HINDE

pl. 1, fig. 4a, b, 9a, b

1879 Polygnathus pennatus n. sp. HINDE, p. 366, pl. 17, fig. 8.

Material studied: 26 specimens

Distribution: Tully Formation, New York and Pennsylvania; lower Fromelennes Formation, Flohimont (France)

Polygnathus porcilla STAUFFER

pl. 3, fig. 7, 8a, b

1940 Polygnathus porcillus n. sp. STAUFFER, p. 430, pl. 60, fig. 86 - 88.

Remarks: Wittekindt (1961) lists Polygnathus porcilla as synonymous for Polygnathus linguiformis. However, the present material shows, that in juvenile forms of Polygnathus linguiformis, which are of about the same size as Polygnathus porcilla, the inner platform is very

much reduced, whereas in Polygnathus porcilla the platforms are almost symmetrical about the blade. The present specimens are similar to juvenile forms of Polygnathus webbi of Bischoff and Ziegler (1957, pl. 19, fig. 13 - 14), but they do not show the secondary keels on the aboral side, nor have any adult specimens of Polygnathus webbi been found in the present samples.

Material studied: 8 specimens

Distribution: lower Tully Limestone, New York

Polygnathus varca STAUFFER

1940 Polygnathus varcus n. sp. STAUFFER, p. 430, pl. 60, fig. 49, 53, 55.

Remarks: Distinction between small specimens of Polygnathus decorosa and large specimens of Polygnathus varca has been found to be difficult in cases where the blade is broken right at the platforms, as features like the depression of the platforms and the shape of their anterior edges are gradational between the two species. The identification of P. varca for the discriminant analysis is based arbitrarily on the sizes of the preserved platforms.

Material studied: 113 specimens

Distribution: Tully Formation, New York and Pennsylvania, see figure 16, lower Fromelennes Formation, Flohimont (France)

Polygnathus xyla STAUFFER

1940 Polygnathus xylus n. sp. STAUFFER, p. 430 - 431,
pl. 60, fig. 42, 50, 54, 65 - 67, 72 - 74, 78, 79.

Remarks: The smooth and rounded appearance of the platform edges is used as a feature distinguishing Polygnathus xyla.

Material studied: 14 specimens

Distribution: Tully Formation, New York and Pennsylvania

Polygnathus? n. sp. BISCHOFF & ZIEGLER

pl. 2, fig. 1a, b

1957 Polygnathus? n. sp. BISCHOFF & ZIEGLER, p. 102,
pl. 19, fig. 26, 36, 37.

Remarks: The specimens are similar to the one of fig. 26.

Material studied: 2 specimens

Distribution: Base of Tully Limestone, New York

Polygnathus cf. n. sp. ORR

pl. 1, fig. 8a, b, c, 10a, b

1964 Polygnathus n. sp. ORR, p. 22, pl. 3, fig. 1, 3, 9
pl. 4, fig. 1.

Remarks: Because the free blades, which show the extreme anterior increase in length are broken, a cf. identification only seemed justified. Additionally, in the present specimens,

the keel is rather an extension of the rims of the basal cavity than a rounded feature. It is suspected that morphological connections exist between Polygnathus cf. n. sp. ORR and Polygnathus n. sp. b, but this cannot be proved because the material is too scanty.

Material studied: 2 specimens

Distribution: Top of Tully Limestone, New York

Polygnathus n. sp. a

pl. 3, fig. 1 - 4

Description: In oral view the unit is straight or slightly curved; in lateral view slightly S-shaped, with an arch underneath the platforms. The platforms are narrow, non-symmetrical and generally very shallow and smooth. The inner one is $1/2$ to $3/4$ as long as the outer one. One of the platforms usually has a sharp bend at about midlength, so that the anterior part is pointing downward and forward. The platforms do not extend completely to the posterior tip. The blade consists of long, fused, vertically-standing denticles which lose rapidly in height at the platform area and merge into a serrated edge. The length of the free blade is between 1 and 2 times the length of the outer, longer platform. The basal cavity is of medium size and situated at the anterior end of the shorter, inner platform.

Remarks: Gradations to Polygnathus varca exist.

Material studied: 22 specimens

Distribution: Tully Formation, New York and Pennsylvania

Polygnathus n. sp. b

pl. 1, fig. 5 - 7

Description: In oral view the unit is straight or slightly curved, in lateral view the part of the platform behind the basal cavity is straight or bent downward. The platforms are thick, rounded and confluent at the posterior ends, with greatest width at about midway between the posterior and anterior ends. There, the edge of the outer platform is projected in a small hump. The ornamentation consists of a row of round discrete nodes near the lateral margins of the outer and inner platforms. The free blade consists of fused, broad denticles and is about as long as the platforms. In the platform area the blade forms round, more or less separate nodes, which are larger than the ones of the platform ornamentation. On the aboral side is a shallow basal cavity with broad margins which extend into the grooved keel posteriorly. At, or in front of the basal cavity a distinct, narrow ridge extends toward the hump of the outer platform, or the basal cavity itself is expanded in that direction.

Remarks: See Polygnathus cf. n. sp. ORR

Material studied: 8 specimens

Distribution: Top of the Tully Limestone, New York

Polygnathus sp.

pl. 3, fig. 6a, b

Description: The unit is straight in oral view; in lateral view the posterior part is arched and bent downward. The shallow platforms are pointed at the posterior ends, and the anterior edges are bent strongly downward, and merge into the free blade at the aboral edge. The edge of the inner platform is bent up and bears very faint nodes. In the centre of the outer platform a big node is situated, around which the middle part of the platform edge arches in a semi-circle. The edge of the extension bears two radial ribs. The free blade has at least the same length as the platforms. The denticles are round, fused and inclined posteriorly. In the area of the platforms the blade extends as a row of fused nodes to the posterior tip. The basal cavity is shallow and very large. The margins merge into the lowest parts of the anterior edges of the platforms. A keel extends to the posterior end and a groove along the aboral edge of the free blade.

Material studied: 1 specimen

Distribution: Upper Tully Formation, New York

Genus Spathognathodus BRANSON & MEHL 1941

Spathognathodus bipennatus BISCHOFF & ZIEGLER

pl. 3, fig. 6a, b

1957 Spathognathodus bipennatus BISCHOFF & ZIEGLER, p. 115 -
116, pl. 21, fig. 31, a, b, c.

Remarks: The present specimens are about half as wide as
shown in Bischoff and Ziegler's figure. However, they have
the characteristic groove on the oral edge.

Material studied: 3 specimens

Distribution: Gic, Flohimont, (France)

Spathognathodus planus BISCHOFF & ZIEGLER

pl. 3, fig. 7

1957 Spathognathodus planus n. sp. BISCHOFF & ZIEGLER, p. 117,
pl. 19, fig. 34, 35.

Material studied: 4 specimens

Distribution: Tully Limestone, New York

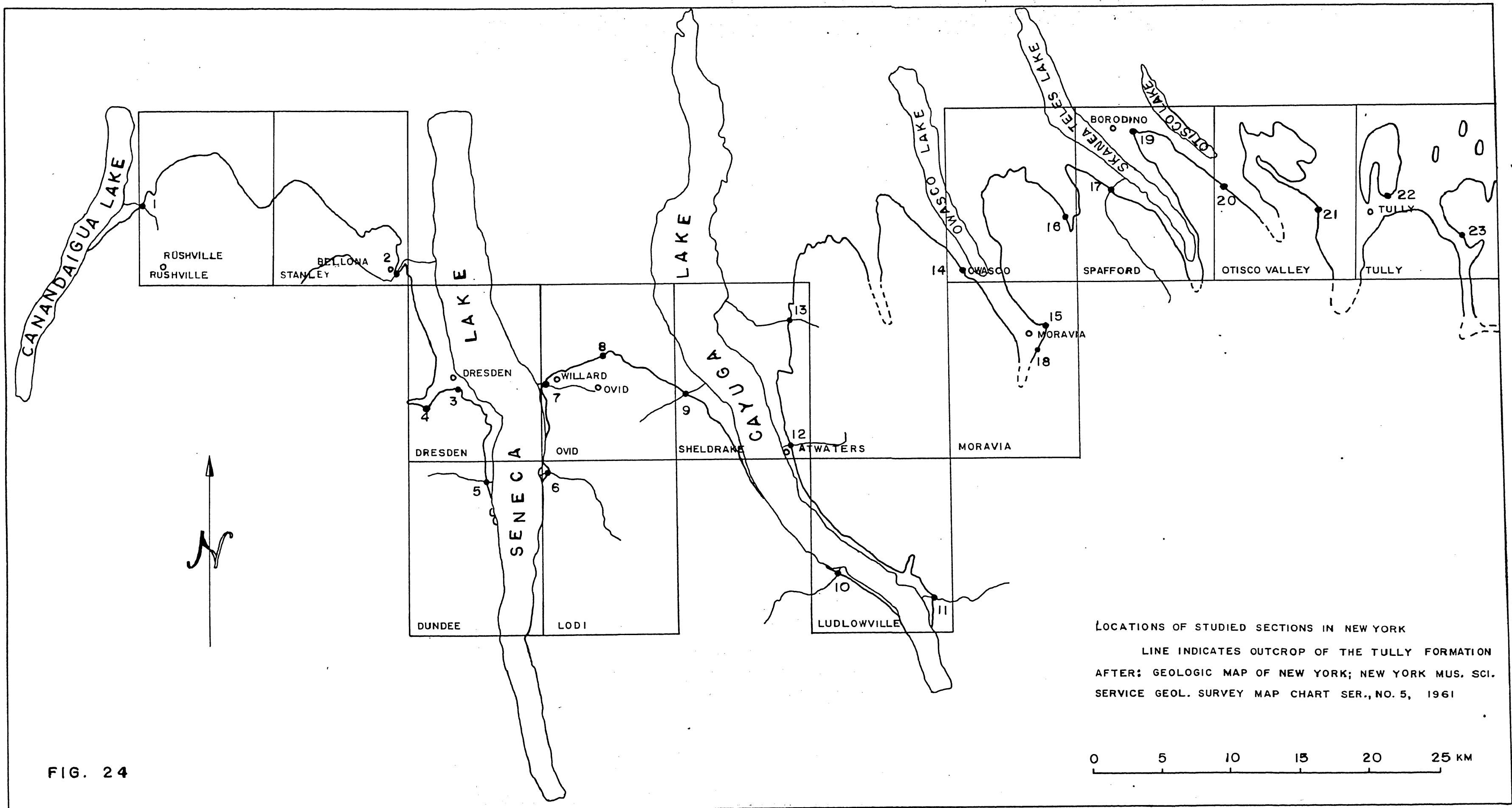


FIG. 24

LOCATIONS OF STUDIED SECTIONS IN NEW YORK
 LINE INDICATES OUTCROP OF THE TULLY FORMATION
 AFTER: GEOLOGIC MAP OF NEW YORK; NEW YORK MUS. SCI.
 SERVICE GEOL. SURVEY MAP CHART SER., NO. 5, 1961

2. LOCATIONS OF SECTIONS

Localities of sections in New York (Quadrangle names refer to 7.5 minute series, fig. 24)

1. Intersection creek and main road, 4.7 km NW of Rushville, Rushville qu.
2. Kashong Creek, Bellona, Stanley qu.
3. Quarry 1 km SE of Dresden, Dresden qu.
4. Gorge 400 m E of Cascade Mills, Keuka Lake Outlet, Dresden qu.
5. Ross Point Creek, Dundee qu.
6. Creek 500 m S of Lodi Point, Lodi qu.
7. Simpson Creek, bridge at Willard State Hospital, Ovid qu.
8. Quarry 2.7 km NE of Ovid, Ovid qu.
9. State Route 89 bridge across Groves Creek, Sheldrake qu.
10. Taughannock Creek, Ludlowville qu.
11. Gulf Creek, 900 m E of Portland Point, Ludlowville qu.
12. 450 m up creek at Atwaters, Sheldrake qu.
13. Beard Gully, 150 m E of road between Black Rock and Chapel Corners, Sheldrake qu.
14. Creek at Edgewater, near intersection of Sherwood Road and Mathers Road, Owasco qu.

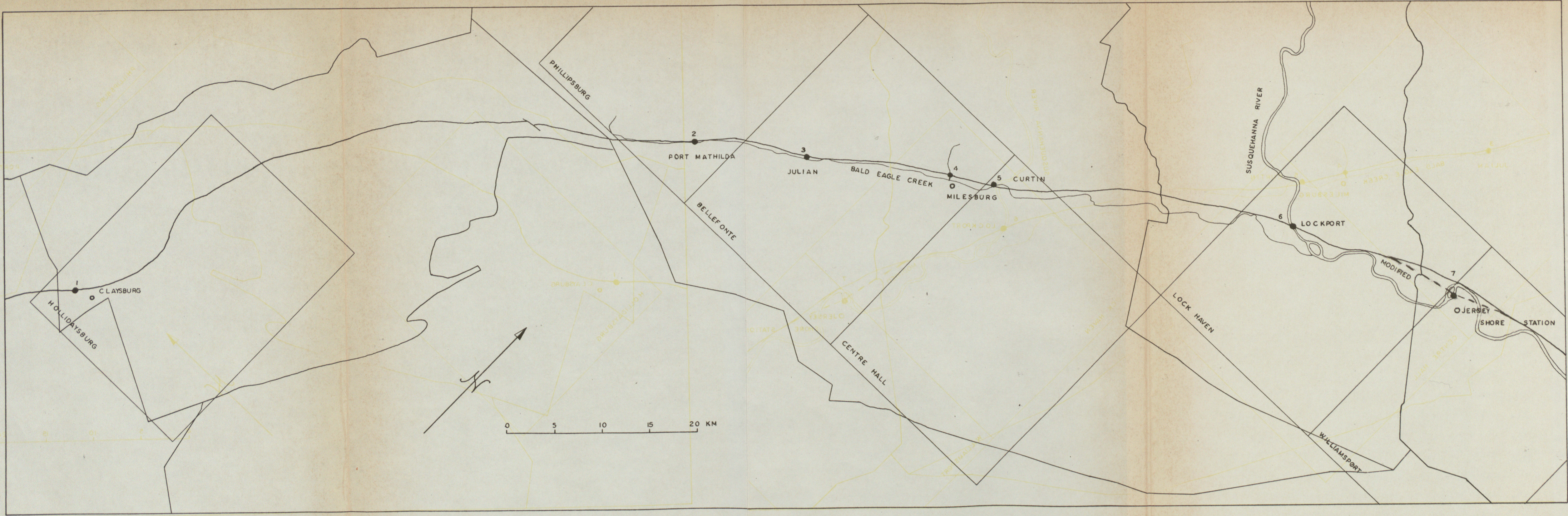


FIG. 25

OUTCROP OF THE MIDDLE UPPER DEVONIAN BOUNDARY (HEAVY LINE) MODIFIED
 AND LOCALITIES OF STUDIED SECTIONS
 TULLY LIMESTONE NOT CONTINUOUS
 AFTER GEOLOGIC MAP OF PENNSYLVANIA, TOPOGRAPHIC AND GEOLOGIC SURVEY, 1960

15. Decker Creek, 500 m above Montville Falls, Moravia qu.
16. Quarry at Cream Hollow Road, 600 m W of State Route 38, Owasco qu.
17. Carpenter Falls, Swamp Creek, Spafford qu.
18. Fillmore Glen, 600 m E of State Route 38, Moravia qu.
19. Northern quarry, near State Route 41, 1.9 km SE of Borodino, Spafford qu.
20. Bucktail Ravine, 600 m SW of Moon Hill Road, Otisco Valley qu.
21. Creek W of Gatehouse Pond, Otisco Valley qu.
22. Ravine 1.7 km NE of Tully, Tully qu.
23. Tinker Falls, 5.2 km S of Apulia, Tully qu.

Localities of sections in Pennsylvania (Quadrangle names refer to 15 minute quadrangles, fig. 25)

1. Ditch of road W of U. S. Route 220, 2 km SW of Claysburg, Hollidaysburg qu.
2. Road cut at Port Mathilda, Phillipsburg qu.
3. Road cut at Julian, Bellefonte qu.
4. Moose Run, 1 km NW of Milesburg, Bellefonte qu.
5. Road cut 500 m NE of Curtin, Centre Hall qu.
6. Lockport, Lock Haven qu.
7. Underneath bridge across E arm of Susquehanna River, 1.6 km NW of Jersey Shore Station, Williamsport qu.

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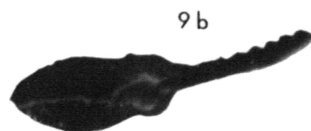
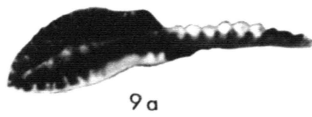
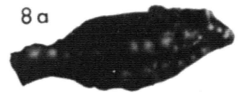
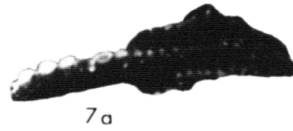
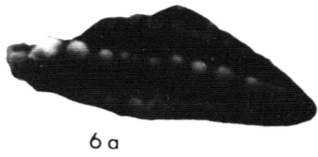
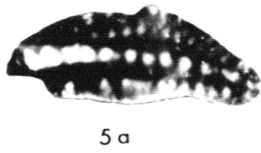
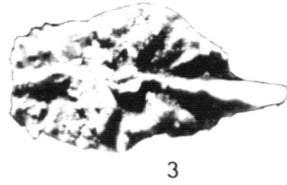
PLATES I - IV

Remark: If not otherwise noted, magnification of the specimens is about 40X. All the specimens were coated with NH_4Cl and photographed on 35 mm film. Some of the outlines are retouched. Numbers in brackets are the personal reference numbers of the author, with the symbol in front of / indicating the locality in New York. The collection will ultimately be repositied with the Geological Survey of Canada.

PLATE I

PAGE

- Fig. 1, 2: Polygnathus beckmanni BISCHOFF & ZIEGLER 101
1, (11 / 1, 2) magnification 30X,
a) aboral view, b) oral view
2, (5 / 3, 2) magnification 30X, oral view
- Fig. 3: Polygnathus caelata BRYANT 101
(15 / 2, 13) oral view
- Fig. 4, 9: Polygnathus pennata HINDE 105
4, (7 / 2, 13) specimen with pathologically
shaped posterior end a) oral view
b) aboral view
9, (10 / 1, 3) a) oral view
b) aboral view
- Fig. 5 - 7: Polygnathus n. sp. b 109
5, (10 / 6, 13) a) oral view b) aboral
view c) lateral view
6, (8 / 5, 51) a) oral view b) aboral
view
7, (15 / 6, 3) basal cavity shows
similarities to Polygnathus n. sp. ORR
a) oral view b) aboral view



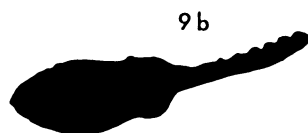
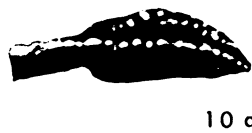
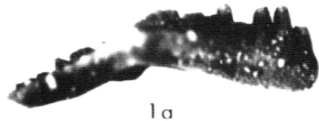


PLATE II

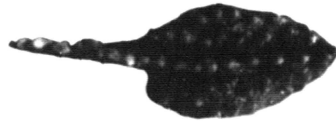
PAGE

- Fig. 1: Polygnathus? n. sp. BISCHOFF & ZIEGLER 107
 (11 / 1, 39) magnification 30X,
 a) oral view b) aboral view
- Fig. 2: Polygnathus ectypa HUDDLE 103
 (17 / 6, 1) a) oral view
 b) aboral view
- Fig. 3 - 5: Polygnathus cristata HINDE 102
 3, (10 / 1, 52) oral view
 4, (3 / 1, 1) oral view
 5, (1 / 2, 2) a) oral view b) aboral view
- Fig. 6: Spathognathodus bipennatus BISCHOFF & 111
 ZIEGLER
 Gic. Flohimont, France: a) oral view
 b) lateral view
- Fig. 7: Spathognathodus planus BISCHOFF & ZIEGLER 111
 (14 / 1, 7)
- aff.
- Fig. 8: Bryantodus alternatus BISCHOFF & ZIEGLER 95
 (5 / 1, 54) magnification 30X,

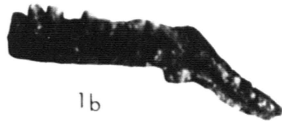
	PAGE
Fig. 9: <u>Bryantodus</u> sp. c BISCHOFF & ZIEGLER (9 / 3, 4) magnification 30X	97
Fig. 10: <u>Bryantodus stratfordensis</u> STAUFFER (3 / 1, 16)	96
Fig. 11: <u>Bryantodus grandis</u> BISCHOFF & ZIEGLER (12 / 1, 31) magnification 30X	96
Fig. 12: <u>Bryantodus angustus</u> BISCHOFF & ZIEGLER (11 / 1, 44) magnification 30X, anterior bar broken	95



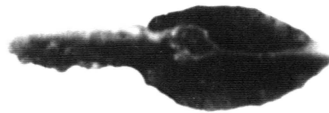
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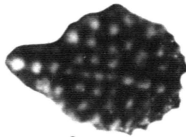
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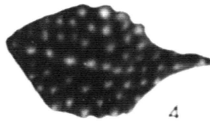
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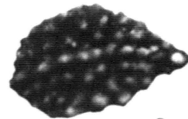
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5a



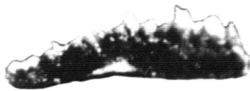
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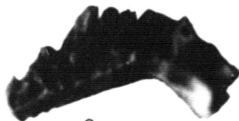
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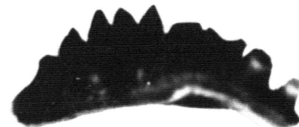
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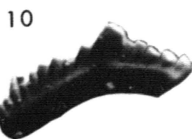
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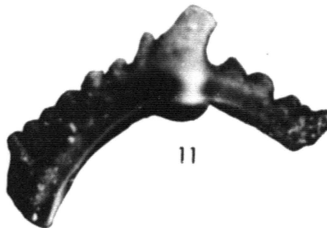
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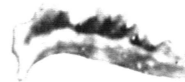
9



10



11



12

- Fig. 1 - 4: Polygnathus n. sp a 108
- 1, (11 / 3, 16) magnification 30
gradation to Polygnathus varca
a) oral view b and c) lateral view
b) showing sharp bend in longer platform
- 2, (5 / 3, 26) a) oral view
b) lateral view showing sharp bend in
longer platform, also pathological?
denticle at anterior end of platform
- 3, (8 / 3, 6) a) oral view b) lateral view
with sharply bent platform
- 4, (18 / 1, 9) a) oral view b) aboral view
- Fig. 5: Polygnathus cf. dengleri BISCHOFF & ZIEGLER 102
(10 / 8, 3) a) oral view
b) aboral view
- Fig. 6: Polygnathus sp. 110
(20 / 7, 5) a) oral view
b) aboral view
- Fig. 7, 8: Polygnathus porcilla STAUFFER 105
7, (5 / 2, 14) oral view
8, (6 / 1, 28) a) oral view b) aboral view

Fig. 9, 10: Polygnathus? iuvenis STAUFFER

9, (6 / 5, 1) a) lateral view

b) aboral view

10, (9 / 3, 5) magnification 30X

a) oral view b) lateral view

c) aboral view



1a



1b



1c



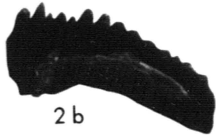
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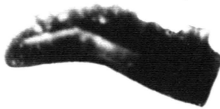
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4a



2b



3b



4b



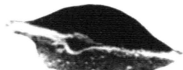
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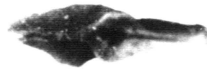
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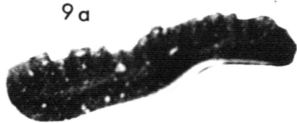
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6b



8a



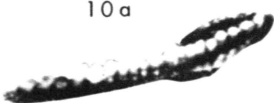
9a



9b



8b



10a



10b



10c

Fig. 1 - 15: Polygnathus? juvenis STAUFFER

103

This plate shows the gradual decrease in platform size from normal Polygnathus types to forms which are identical with Spathognathodus.

- 1, (10 / 6, 28) oral view
- 2, (10 / 6, 6) oral view
 - b) aboral view with parts of basis
- 3, (10 / 6, 7) oral view, sandgrain stuck to free blade
- 4, (4 / 4, 41) oral view
- 5, (9 / 5, 39) narrow platform
 - a) oral view b) lateral view
- 6, (3 / 5, 25) oral view
- 7, (6 / 5, 5) oral view
- 8, (4 / 4, 5) platform without ornamentation, oral view
- 9, (12 / 5, 2) oral view
- 10, (3 / 5, 16)
 - a) oral view
 - b) lateral view c) aboral view

In specimens 9 and 10 the platform consists of a flange with ornamentation

- 11, (10 / 6, 18) oral view, platform as
smooth flange only
- 12, (9 / 5, 16) only one flange with single
denticle a) oral view b) lateral view
- 13, (10 / 4, 8) oral view, platform almost
entirely disappeared
- 14, (18 / 2, 4) platform indicated by very
faint lateral ridge, anterior part
of blade broken during photography
a) oral view b) lateral view
- 15, (6 / 5, 1) same specimen as fig. 9,
pl. 3, lateral view.



1



6



11



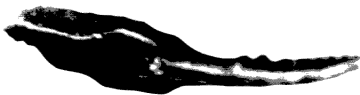
2 a



7



12 a



2 b



8



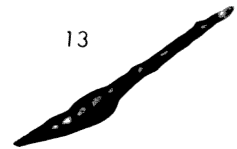
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9



13



4



10 a



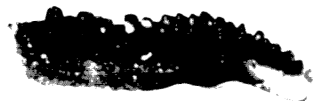
14 a



5 a



10 b



14 b



5 b



10 c



15