SOME ASPECTS OF THE PALEONTOLOGY, STRATIGRAPHY, AND SEDIMENTATION OF THE CORRY SANDSTONE OF NORTHWESTERN PENNSYLVANIA

A dissertation submitted to the

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DOCTOR OF PHILOSOPHY

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by

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I hereby recommend that the thesis prepared under my supervision by Daniel B. Sass

entitled Some Aspects of the Paleontology, Stratigraphy, and Sedimentation of the Corry Sandstone of Northwestern Pennsylvania

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

Approved by:

Kenneth E. Caster

[illegible]

Form 668—G.S. and T.C.—500—5-45

DEDICATION

This work is dedicated to the memory of the writer's late father, Julius Sass, whose respect for truth was passed on to a grateful son.

ACKNOWLEDGMENTS

All of the work was performed while the writer was a student and Curator of the Museum at the University of Cincinnati. The faculty and staff of the Department of Geology not only granted permission for the use of departmental facilities but also gave freely of their time and experience to lighten the problems which frequently accompany a study of this kind. Dr. K. E. Caster was particularly helpful in accompanying the writer in the field, granting access to his personal library, field notes and collections, and volunteering information from his own experience in northwestern Pennsylvania.

In the course of the field investigation and the preparation of the manuscript it was necessary to seek financial assistance to defray a portion of the expenses involved. Such aid was acquired in the form of grants from the American Association of Petroleum Geologists Research Fund and the Fenneman Fund of the University of Cincinnati.

Dr. William S. Lytle of the Pennsylvania Geological Survey granted access to both published and unpublished maps and bulletins of the Survey. Drs. J. F. Pepper and Wallace de Witt, Jr., of the United States Geological Survey, sent copies of their publications and information from their field notes. Dr. F. D. Holland, Jr., of the University of North Dakota, supplied copies of diagrams and photographs from his dissertation. Mr. William H. Heers, Librarian of the United States Geological Survey, sent rare foreign periodicals. All of these individuals and the organizations they represent, have thus contributed to the completion of this work.

At times when the type specimens of certain species were necessary for the accurate identification of material at hand, their receipt was expedited by the personal attention of Dr. K. V. W. Palmer, Director of the Paleontological Research Institution, and Dr. D. W. Fisher, State Paleontologist of the New York Geological Survey.

Permission to reproduce a road map of the State of Pennsylvania was graciously accorded by Mr. Richard E. Scully of the General Drafting Co., Inc., Covent Station, New Jersey.

Fellow students at the University of Cincinnati were helpful in many ways. Mr. Orville D. Naegele accompanied the writer in the field during the summer of 1958. Mr. John L. Carter and Mr. John K. Pope made helpful suggestions concerning photographic technique. Miss Ruth Brill assisted in the typing of the manuscript.

Elizabeth A. Dalvé draughted many of the text figures used in the manuscript.

To all of these people and many more, a simple but meaningful - thank you!

ABSTRACT

A thorough study of the fauna of the Corry sandstone of northwestern Pennsylvania is herein initiated. Species of four genera, two of the Porifera and two of the Brachiopoda, are described. Some hitherto unrecognized morphological characteristics of the Dictyospongiidae are emphasized.

Four species of the brachiopod genus *Paraphorhynchus* Weller (1905) are described, one of which, *P. casteri* is new. A new criterion of the genus is proposed in the presence of a "posterior adductor process" in the pedicle valve. Characteristics of the genus *Syringothyris* Winchell (1863), s.s., are evaluated; two Corry species are redescribed and compared with similar forms in the underlying Knapp formation. The species *Syringothyris randalli* Simpson is reassigned to the genus *Syringothyris*, s.s., and the genus *Syringopleura* Schuchert (1910), resurrected by Holland (1958), is rejected.

An attempt is made to reconstruct the former continuity of the Corry sandstone throughout its area of surface outcrop in northwestern Pennsylvania. The formation is divided into three members including: (1) a Lower sandstone member; (2) a Middle siltstone; and (3) an Upper sandstone member.

The Lower Mississippian (Kinderhookian) age of the Corry is reaffirmed. A correlation of the Lower Corry member with the upper portion of the Bedford shale of Ohio is suggested.

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INTRODUCTION

Purpose And Scope Of The Investigation

The Corry sandstone has been cited (Dickey, et al., 1943) as one of the most readily recognizable formations in the Oil Region of northwestern Pennsylvania. It is the first markedly non-conformable unit in the Devono-Mississippian terrane of the region. The Corry lies above the Devono-Mississippian facies (Big Bend and Chagrin magnafacies of Caster, 1934, p. 24) without itself being an integral part of the facies pattern expressed by the antecedent record in the Penn-York Embayment.

The present study of the surface expression of the Corry has a threefold objective: (1) to establish the stratigraphic continuity of the Corry in northwestern Pennsylvania; (2) to initiate a study of its fauna and the relationship of this fauna to temporally and spatially adjacent faunas; (3) to further knowledge of the faunal and sedimentary history of the Devono-Mississippian boundary in northwestern Pennsylvania.

Although a fauna has long been recognized, it has never been thoroughly studied. Girty (1912, p. 303) apparently undertook such a study which, but for a list, was never published. Chadwick (1935b, p. 337) documented the fauna from the fragmentary lists of others. Caster (1930, 1934) is the only worker to date to give serious attention to the fauna. However, his study was only incidental to a more ambitious undertaking. Questioned generic and specific identifications have marked a larger part of the faunal studies of the Corry.

The precise nature of the stratigraphy of the Corry has yet to be settled. Throughout much of the published work on the stratigraphy of northwestern Pennsylvania runs the constant theme that all correlations are to be considered tentative until such time as more paleontological data becomes available.

There has been no thorough sedimentological investigation of the Corry sandstone. The recent work of Pepper, *et al.*, (1954), dealing with the Berea sandstone of Ohio, gives little sedimentary data about the Corry - the supposed temporal correlative of the Berea. A more thorough study along sedimentological lines could enable geologists to better understand the paleogeography and dynamics of early Mississippian time in the Oil Region.

The field work on which this report is based was conducted during portions of the summers of 1957 and 1958. The primary purpose of this phase of the investigation was to supplement relevant faunal material in the Museum of the University of Cincinnati with specimens collected *in situ*.

No effort was made to map the Corry in detail. Instead, as many locations as possible were visited, the sections measured and collections of both a lithologic and faunal nature assembled. Opportunities to measure complete sections and delimit faunal zones within the Corry were the exception rather than the rule.

Figures 1-6 of the text are designed to supplement the discussions which follow. The time-rock terminology at the left of Fig. 6 is a compilation from a number of sources which include Caster (1934), Dickey (1941, p. 5), Lytle, et al., (1958, p. 6), and Holland (1958, p. 27). Since there is no general agreement among geologists as to the higher stratigraphic nomenclature for northwestern Pennsylvania, only an arbitrary selection such as this is now feasible.

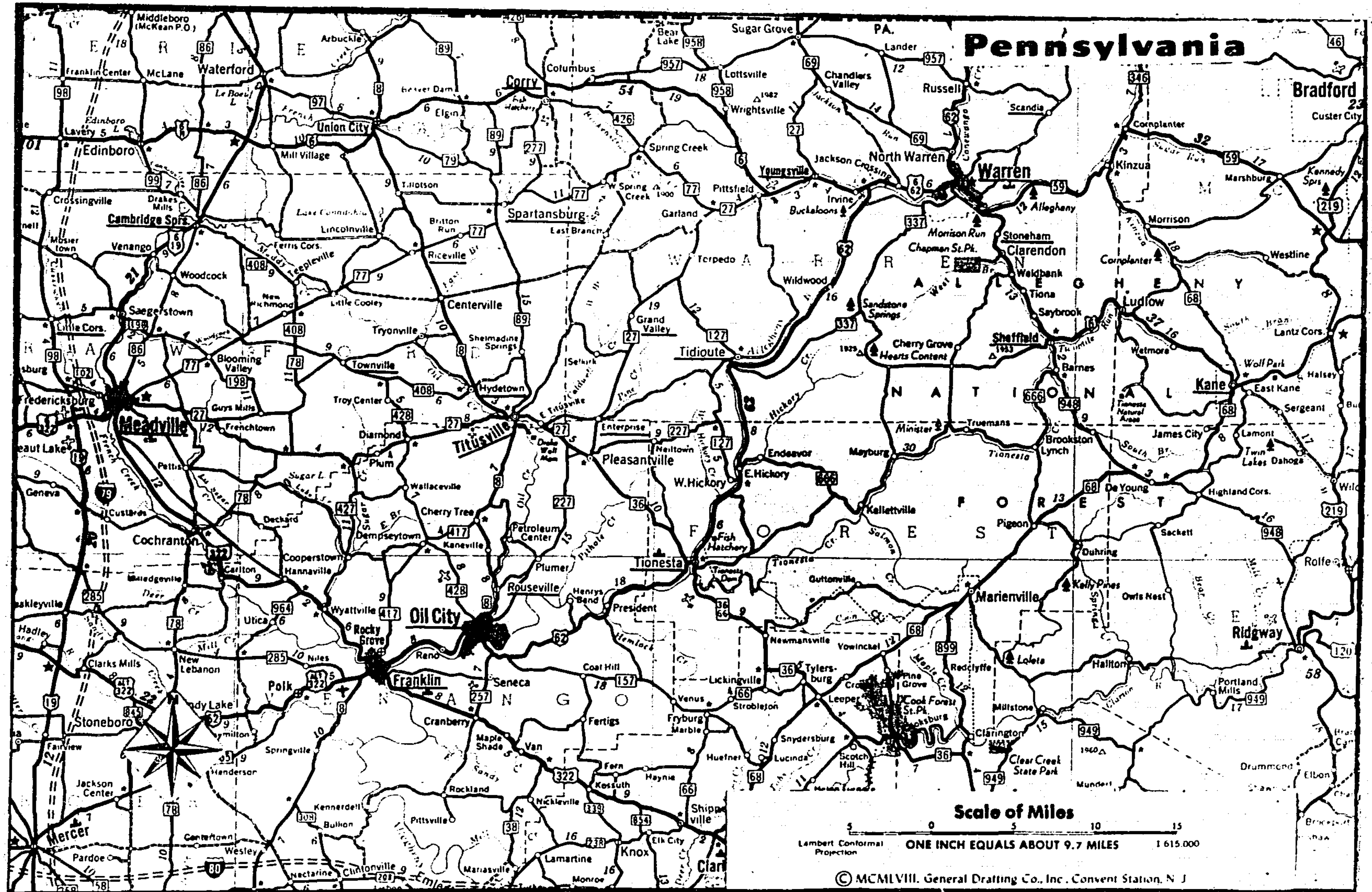
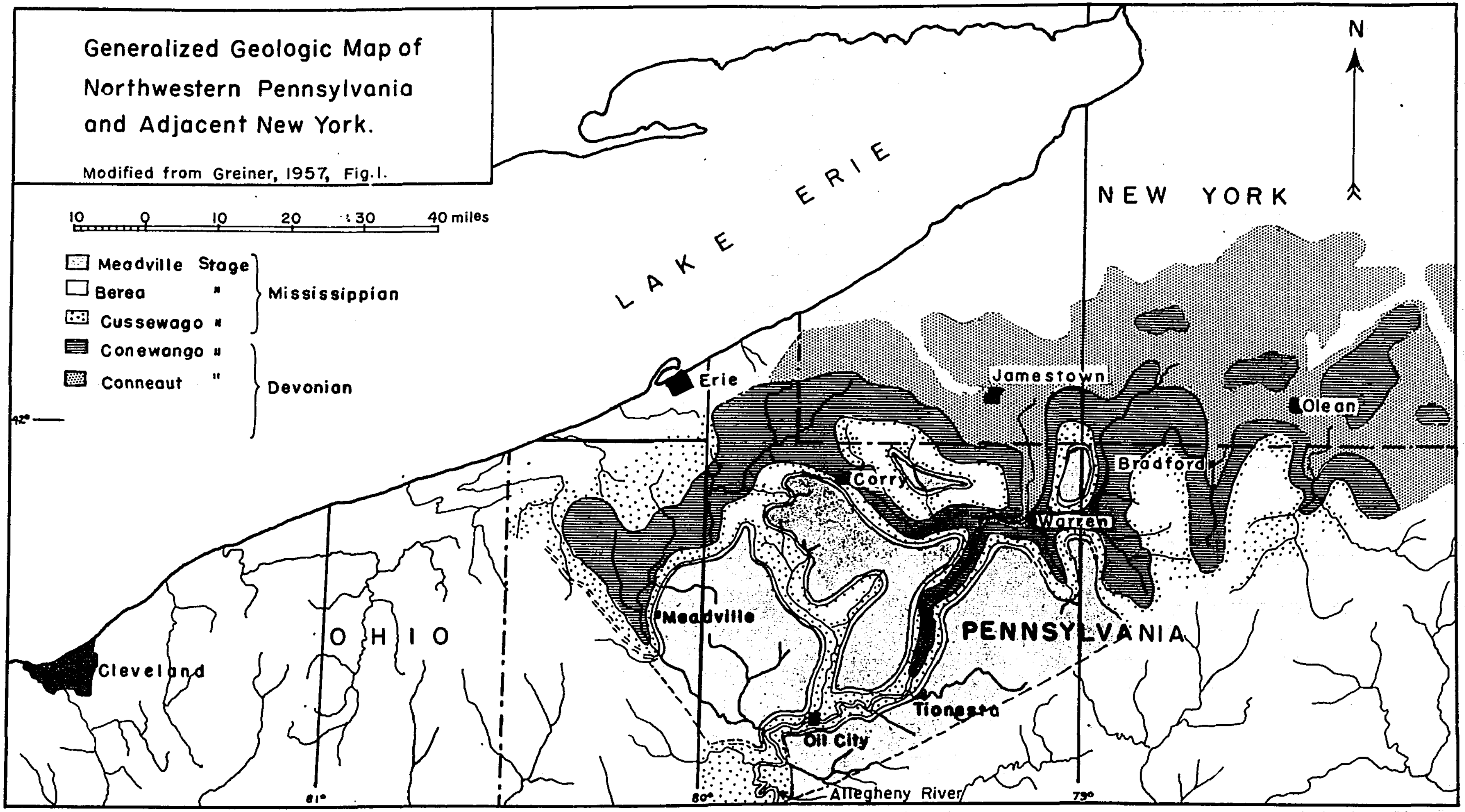


Fig. 1. - General location map of northwestern Pennsylvania showing roads and place names used in the text. (Copyright, General Drafting Co., Inc., Covent Station, N. J.; reproduced by permission.)

FIG. 2


Generalized Geologic Map of Northwestern Pennsylvania and Adjacent New York.
Modified from Greiner, 1957, Fig. 1.
10 0 10 20 30 40 miles
Meadville Stage
Berea
Cussewago
Conewango
Conneaut
Mississippian
Devonian
LAKE ERIE
NEW YORK
N
Erie
Jamestown
Olean
Corry
Bradford
Warren
Meadville
OHIO
PENNSYLVANIA
Cleveland
Tionesta
Oil City
Allegheny River
42°
81°
80°
79°

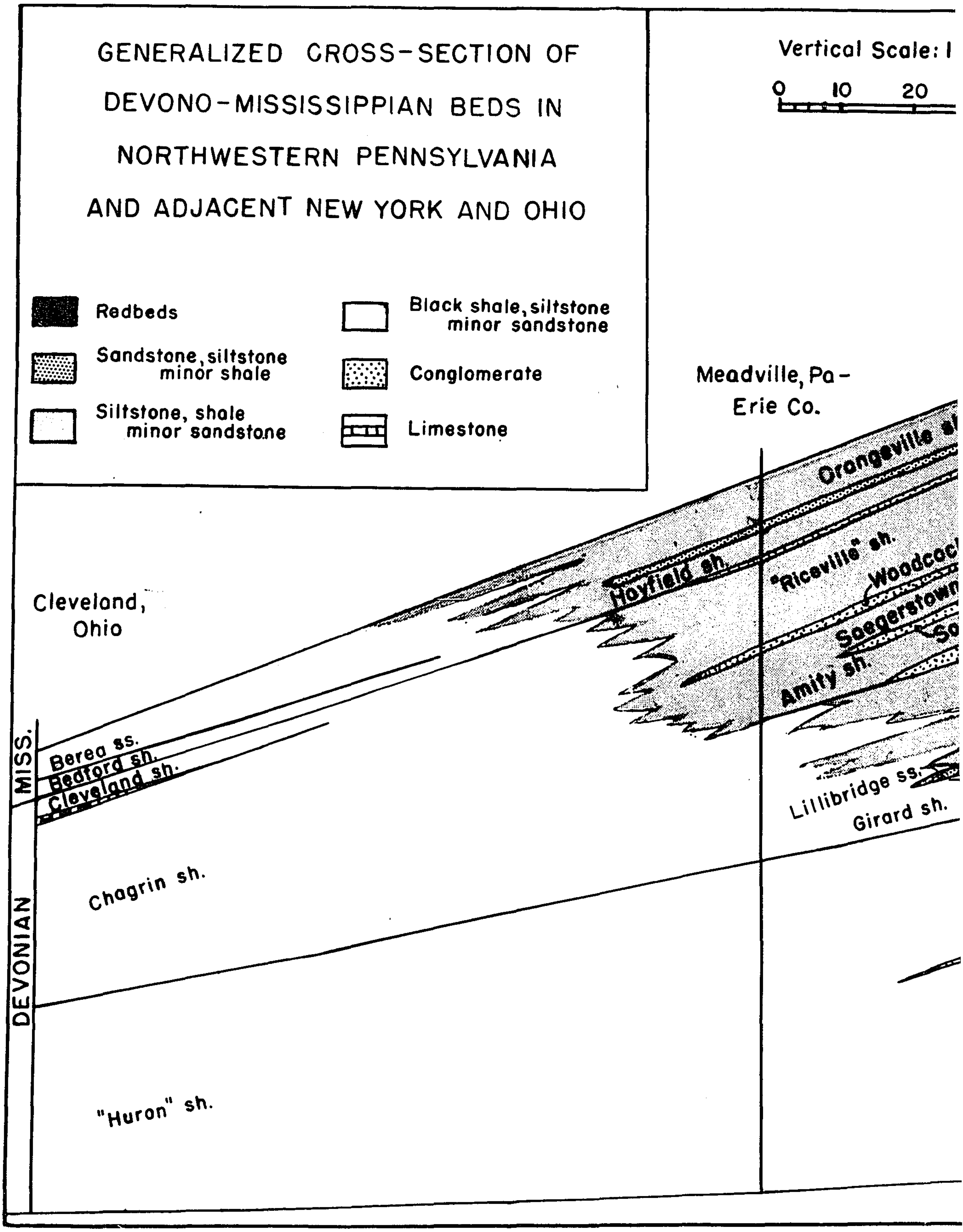
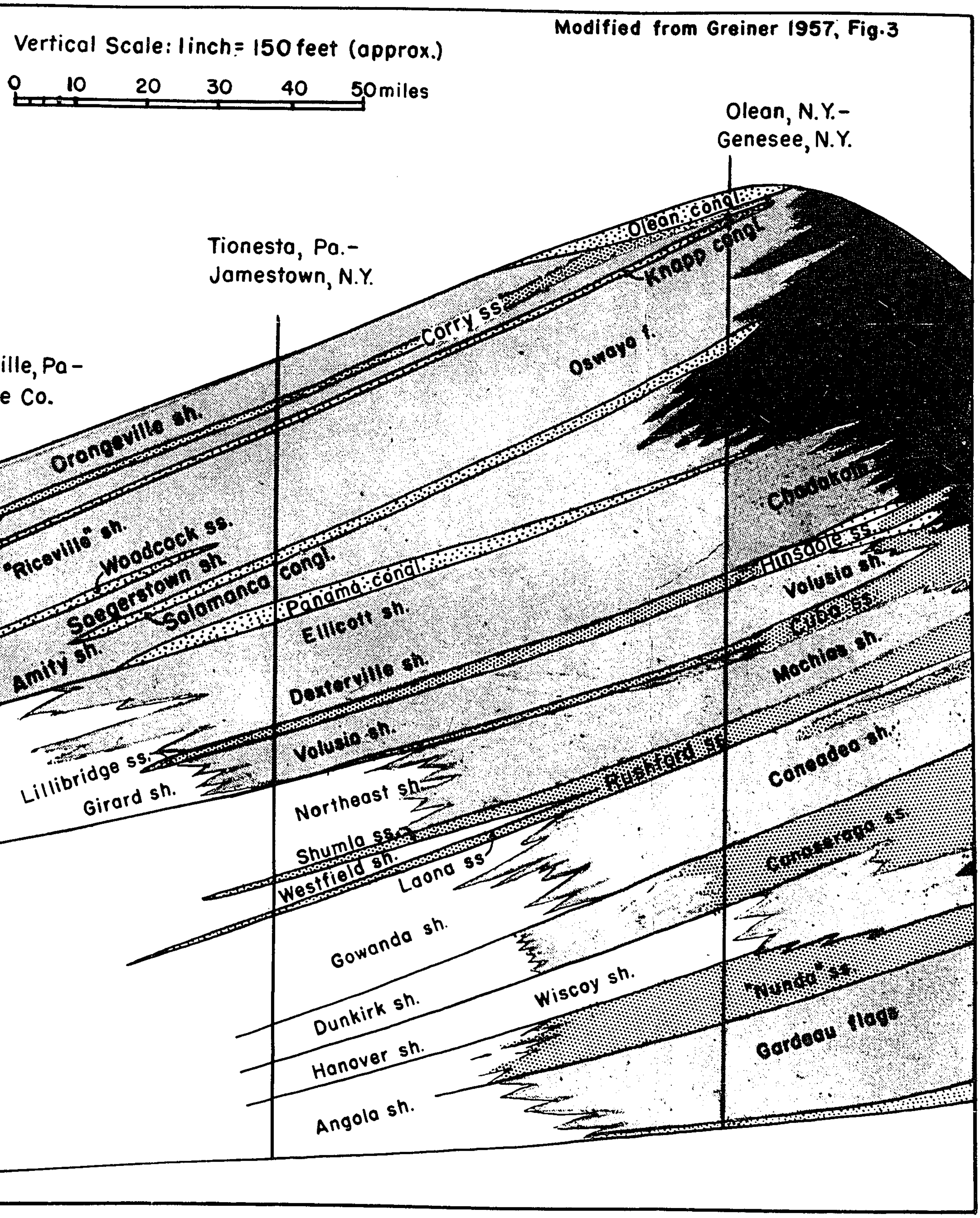

GENERALIZED CROSS-SECTION OF
DEVONO-MISSISSIPPIAN BEDS IN
NORTHWESTERN PENNSYLVANIA
AND ADJACENT NEW YORK AND OHIO
Redbeds
Sandstone, siltstone minor shale
Siltstone, shale minor sandstone
Black shale, siltstone minor sandstone
Conglomerate
Limestone
Vertical Scale:
0
10
20
Meadville, Pa - Erie Co.
Cleveland, Ohio
Hayfield sh.
"Riceville" sh.
Saegerstown
Amity sh.
Lillibridge ss.
Girard sh.
MISS.
Berea ss.
Bedford sh.
Cleveland sh.
DEVONIAN
Chagrin sh.
"Huron" sh.

FIG. 3


Modified from Greiner 1957, Fig.3
Vertical Scale: l inch = 150 feet (approx.)
0 10 20 30 40 50 miles
Olean, N.Y.-
Genesee, N.Y.
Tionesta, Pa.-
Jamestown, N.Y.
ille, Pa-
e Co.
Olean congl.
Knapp congl.
Corry ss.
Oswayo f.
Orangeville sh.
"Riceville" sh.
Woodcock ss.
Saegerstown sh.
Salamanca congl.
Panama congl.
Ellicott sh.
Amity sh.
Chadakoin
Hinsdale ss.
Volusia sh.
Cuba ss.
Machias sh.
Dexterville sh.
Volusia sh.
Lillibridge ss.
Girard sh.
Rushford ss.
Caneadea sh.
Northeast sh.
Shumla ss.
Westfield sh.
Laona ss.
Canaseraga ss.
Gowanda sh.
Dunkirk sh.
Wiscoy sh.
"Nunda" ss.
Hanover sh.
Gardeau flags
Angola sh.

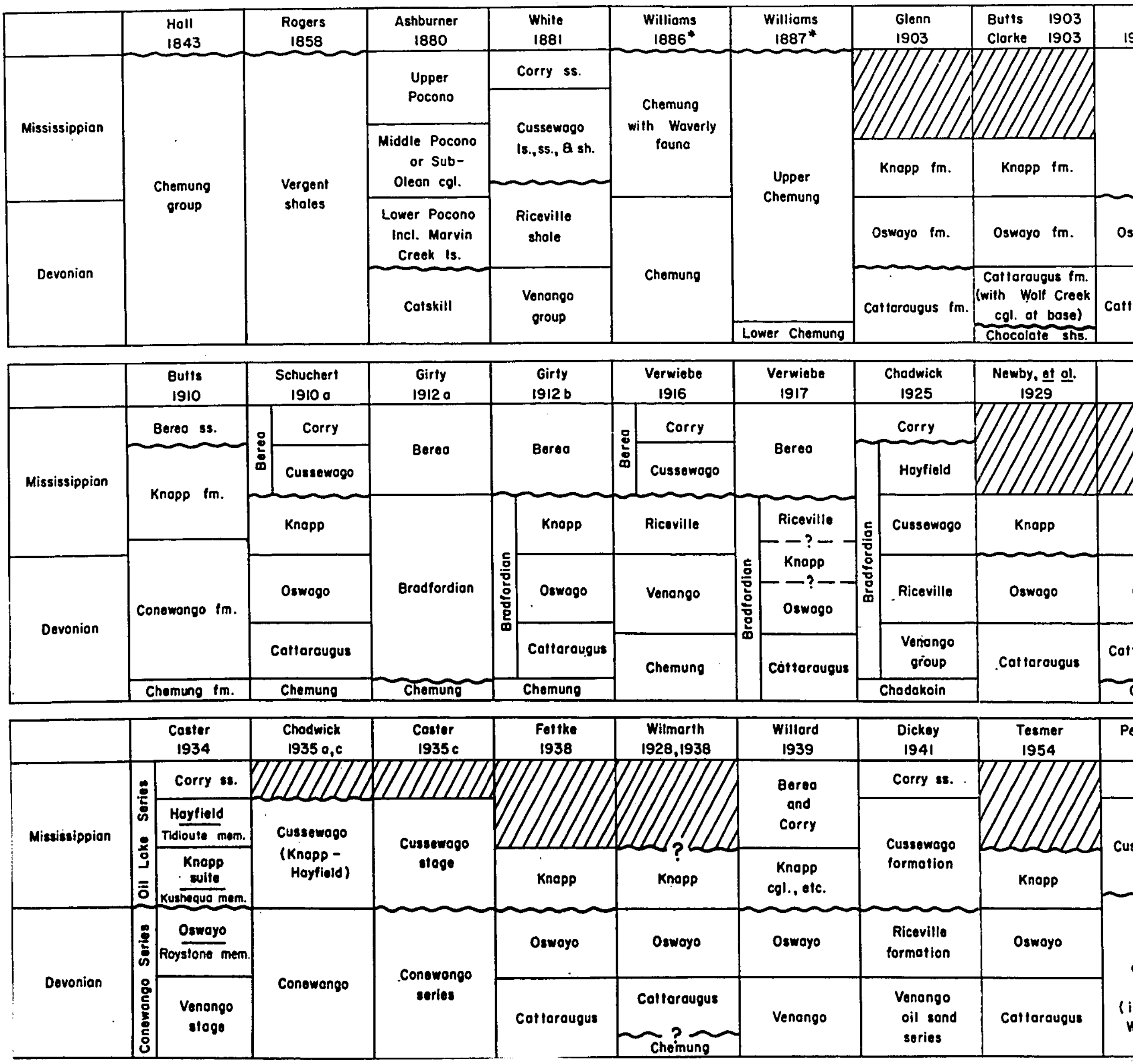


Fig. 4. - Chart showing the various interpretations of the position of the Devono-Mississippian boundary (heavy undulatory line) in southwestern New York and northwestern Pennsylvania. Cross-ruling indicates formation not present in area or not considered by author. The abbreviations and the term "This paper" are those of Holland (1958, p. 7, fig. 5) from whom this chart is reproduced.

*Williams considered the Mississippian absent in the Olean area, but mentioned "Waverly" elements (Syringothyris) in the fauna.

White 1881	Williams 1886*	Williams 1887*	Glenn 1903	Butts 1903 Clarke 1903	Fuller 1903 a,b	Girty 1904	Eastman 1907
Corry ss.	Chemung with Waverly fauna	Upper Chemung			Mauch Chunk	Cussewago	
Cussewago ls.,ss., & sh.			Knapp fm.	Knapp fm.		Knapp	Knapp beds
Riceville shale	Chemung		Oswayo fm.	Oswayo fm.	Oswayo fm.	Oswayo	Oswayo beds
Venango group			Cattaraugus fm.	Cattaraugus fm. (with Wolf Creek cgl. at base)	Cattaraugus fm.	Cattaraugus	Cattaraugus beds including Wolf Creek cgl.
		Lower Chemung		Chocolate shs.		Chemung	Chemung beds

Girty 1912 b	Verwiebe 1916	Verwiebe 1917	Chadwick 1925	Newby, et al. 1929	Curry 1931	Chadwick 1933	Fettke 1933
Berea	Berea: Corry	Berea	Corry			Mississippian (undifferentiated)	
	Berea: Cussewago		Bradfordian: Hayfield				
Bradfordian: Knapp	Riceville	Bradfordian: Riceville —?—	Bradfordian: Cussewago	Knapp	Knapp		Bradford group: Knapp
Bradfordian: Oswago	Venango	Bradfordian: Knapp —?— Oswago	Bradfordian: Riceville	Oswago	Oswago	Riceville sh.	Bradford group: Oswago
Bradfordian: Cattaraugus	Chemung	Bradfordian: Cattaraugus	Bradfordian: Venango group	Cattaraugus	Cattaraugus	Venango	Bradford group: Cattaraugus
Chemung			Chadakoin		Chemung		Chemung

Fettke 1938	Wilmarth 1928,1938	Willard 1939	Dickey 1941	Tesmer 1954	Pepper, et al. 1954	Tesmer 1955	This paper
		Berea and Corry	Corry ss.		Corry ss.		Kinderhookian: Corry ss.
	?		Cussewago formation		Cussewago ss.		Kinderhookian: Tidioute sh.; Knapp fm.; Kushequa
Knapp	Knapp	Knapp cgl., etc.		Knapp		Conewango group: Knapp	
Oswayo	Oswayo	Oswayo	Riceville formation	Oswayo	Riceville shale and older rocks (in sense of White 1881)	Conewango group: Oswayo	Conewangoan: Ricevillean: Oswayo; Roystone mem.
Cattaraugus	Cattaraugus	Venango	Venango oil sand series	Cattaraugus		Conewango group: Cattaraugus	Conewangoan: Venangoan: (undifferentiated)
	? Chemung					Chadakoin	

various interpretations of the
ssippian boundary (heavy
tern New York and northwestern
ndicates formation not pres-
l by author. The abbrevia-
er" are those of Holland
om this chart is reproduced.

sissippian absent in the Olean
' elements (Syringothyris) in

STRATIGRAPHIC MEMBERS OCCURRING I

MISSISSIPPIAN SYSTEM — PA

Waverlyan subsystem

Kinderhookian series

(Crawford sub-series)

Shenango stage

(Shenango monothem)

- Hempfield shale member* .... *Sh*
- Shenango sandstone member (Johnsonburg sandstone*) .... "S

Meadville stage

(Meadville monothem)

- Custards shale member* .... *Up*
- Conneaut limestone member* .... *Up*
- Harvest Home shale member* .... *Lo*
- (Byham limestone member*) .... *Mi*
- Sharpsville sandstone member } Sharpsville .... "S
- West Mead limestone member* } formational .... *Lo*
- Shaws sandstone member* } suite .... *Sh*
- Orangeville shale member (stage?) .... "C

Oil Lake series

Berea stage

- Corry sandstone member *3rd*

Cussewago stage

(Cussewago monothem)

- Hayfield shale "formation" .... *Cu*
- (Little's Corner limestone member*) .... *Cu*
- Tidioute shale member*
- Cobham conglomerate member* } Knapp .... *Up*
- East Kane shale member* } formational .... *Kn*
- Wetmore conglomerate member* } suite .... *Lo*
- Kushequa shale member* .... *Ki*
- (Marvin Creek limestone zone) .... *Mo*

DEVONIAN SYSTEM

Conewango series

Riceville stage

(Riceville monothem)

- Oswayo shale member .... "I
- Roystone coquinite member* .... *Mi*

Venango stage

(Venango monothem)

- Woodcock sandstone member .... *Fi*
- (Hosmer Run conglomerate)
- (Tuna-Kilbuck conglomerate lens)
- Saegerstown shale member
- Pope Hollow conglomerate } Salamanca
- North Warren shale member* } formational
- Bimber Run conglomerate member* } suite
- Amity shale
- (Dutchman's conglomerate lens*)
- Panama conglomerate member .... *Th*

Chautauquan series .... "

Chadakoin stage

(Chadakoin monothem)

- (Tanners Hill red band)
- Ellicott shale member* .... "
- Dexterville shale member*
- Lillibridge sandstone member* .... *Qu*

Girard stage

- Girard shale
- Cuba sandstone

*Note: Members marked with an asterisk (*) are designated by geographic

Fig. 5. - Composite stratigraphic section in southwestern New York and northwestern Pennsylvania. (Reproduced from Caster, 1934, chart facing p. 63.)

Stratigraphic Members Occurring in Northwestern Pennsylvania

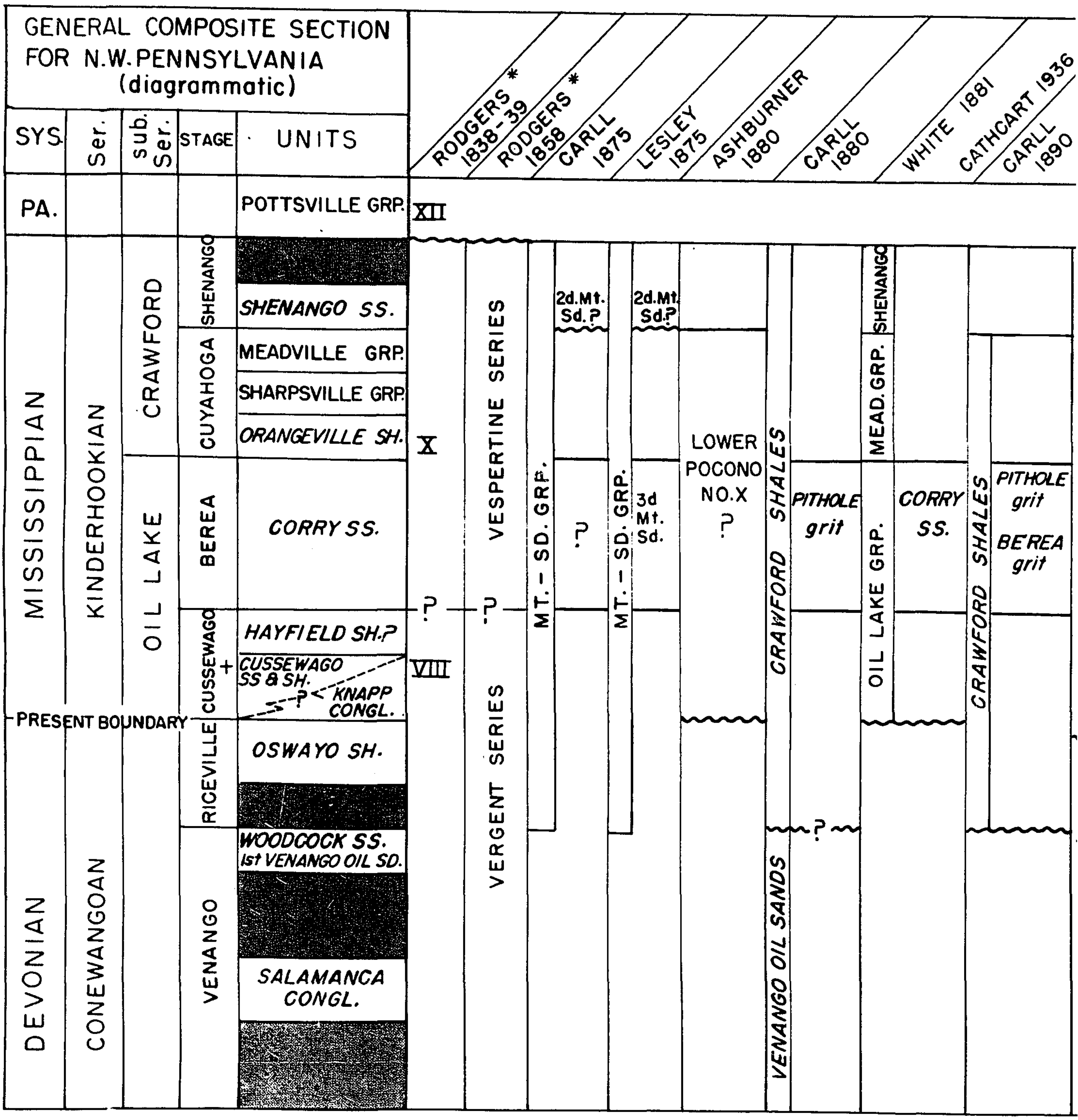
Partial Synonymy

)		
:m)		
member*	*Shenango shale*	
one member (Johnsonburg sandstone*)	*"Sub-Olean conglomerate"; 2nd Mountain sand.*	
em)		
ıember*	*Upper Meadville shale*	*Original Meadville group*
›ne member*	*Upper Meadville limestone*	
hale member*	*Lower Meadville shale*	
ıe member*)	*Middle Meadville limestone*	
tone member — Sharpsville formational suite	*"Sub-Olean conglomerate"*	*Original Sharpsville formation*
stone member* — Sharpsville formational suite	*Lower Meadville limestone*	
member* — Sharpsville formational suite	*Sharpsville sandstone*	
: member (stage?)	*"Cuyahoga" of Pennsylvania*	
member	*3rd Mountain sand; Pit Hole Grit*	
ıem)		
'formation"	*Cussewago shale*	
limestone member*)	*Cussewago limestone, Hayfield limestone*	
ıember*		
erate member* — Knapp formational suite	*Upper Knapp conglomerate; Cussewago sandstone*	
member* — Knapp formational suite	*Knapp shale (middle)*	
ıerate member* — Knapp formational suite	*Lower Knapp conglomerate*	
member*	*Knapp shale*	
.imestone zone)	*Marvin Creek limestone ("Meadville limestone")*	
m)		
›mber	*"Red Bedford" of the Oil Region*	
ite member*	*Mistaken for the Marvin Creek limestone by some geologists*	
m)		
tone member	*First Venango oil sand*	
nglomerate)		
onglomerate lens)		
e member		
glomerate — Salamanca formational suite	*"A"*	
ıale member* — Salamanca formational suite	*Second Venango oil sand*	
glomerate member* — Salamanca formational suite	*"B"*	
ıglomerate lens*)		
erate member	*Third Venango oil sand*	
	"Upper Chemung"	
.em)		
·d band)		
ıember*	*"Pink Rock"*	
member*		
ıtone member*	*Quarry sandstone*	

with an asterisk (*) are designated by geographic name for the first time in this report.

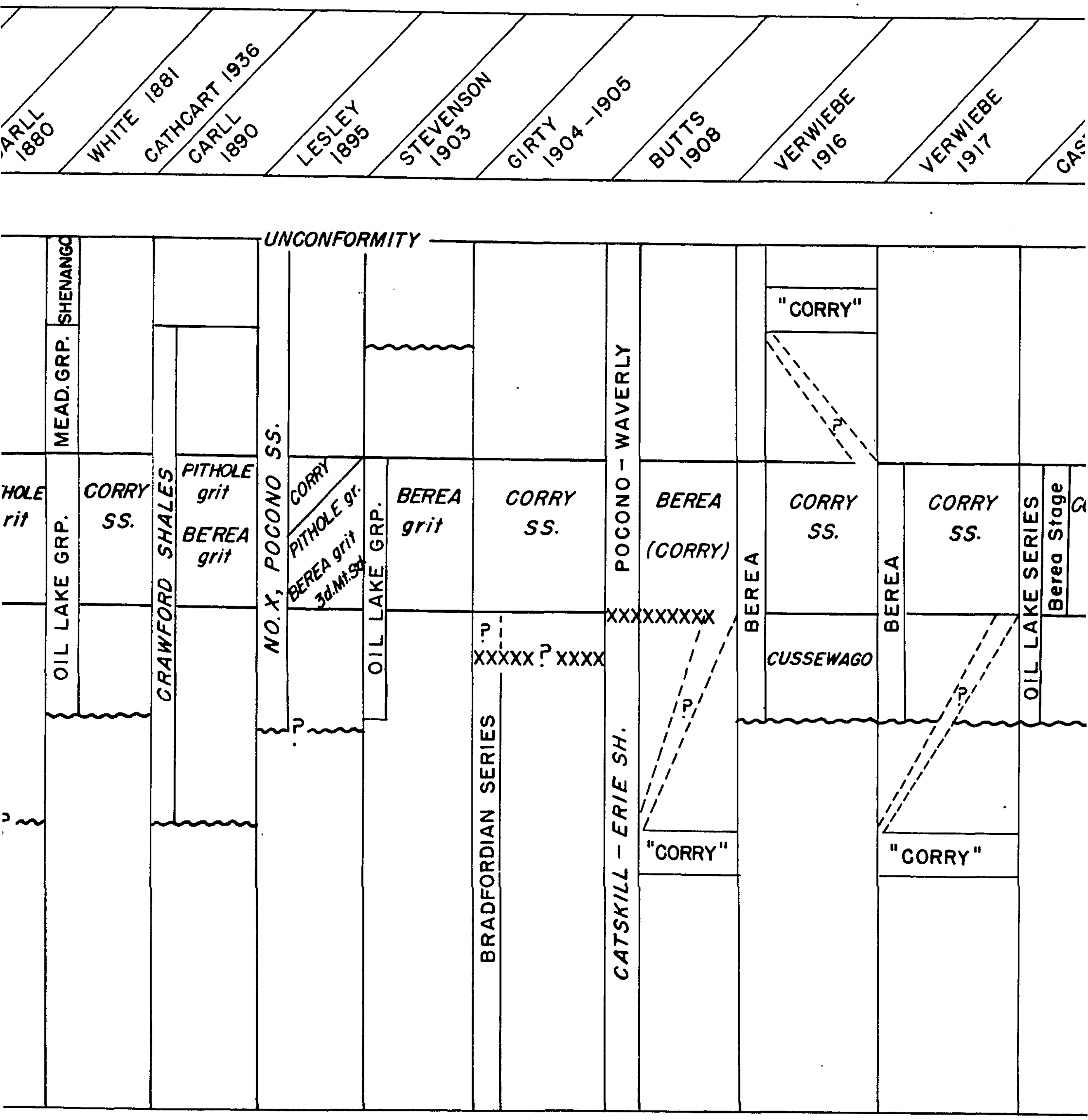
: section in southwestern
.vania. (Reproduced from
.)

A HISTORY OF THI



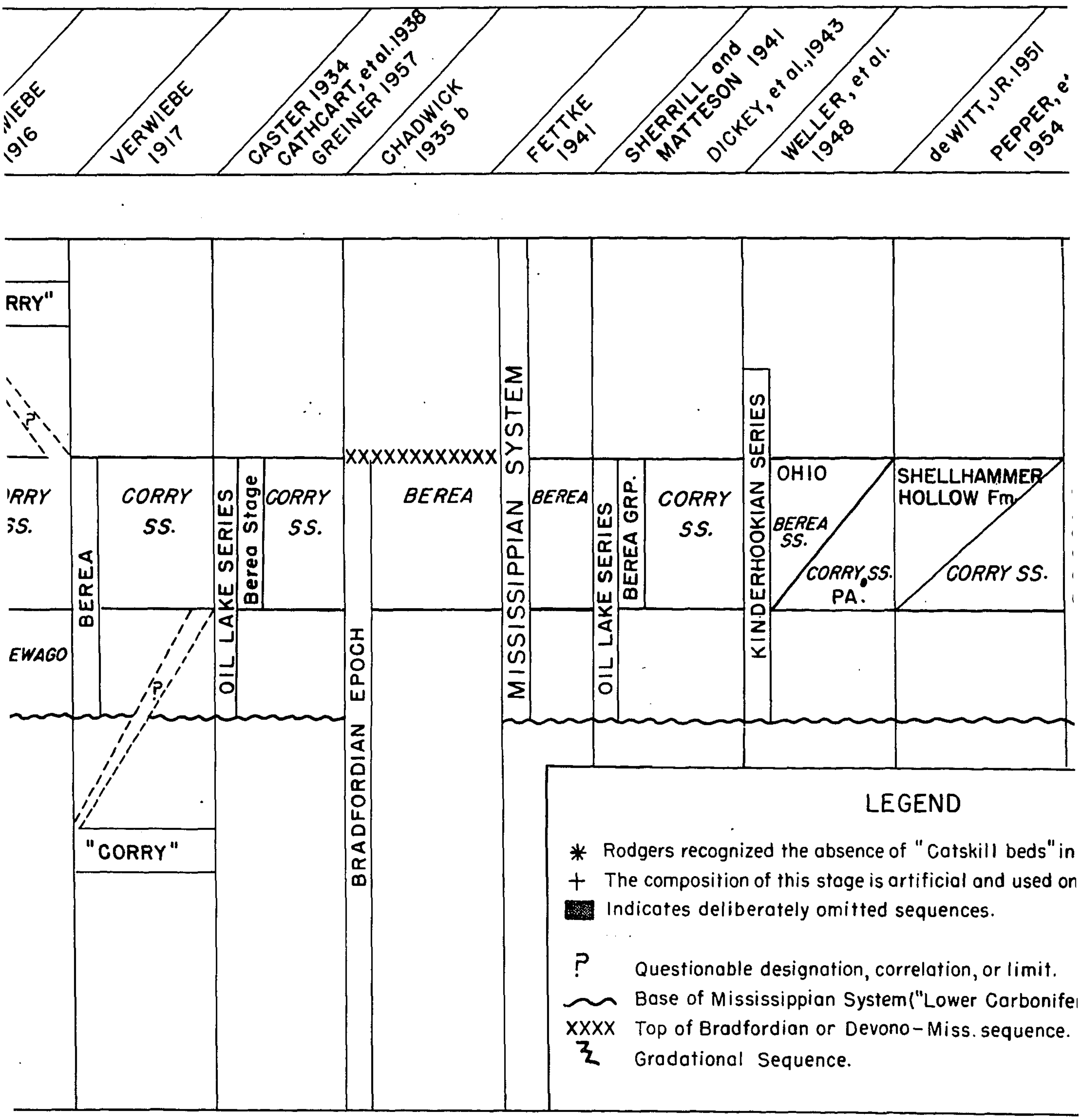
HISTORY OF THE NOMENCLATURE AND STRATIGRAPHIC POSITIO

(In Northwestern Pennsylvania)



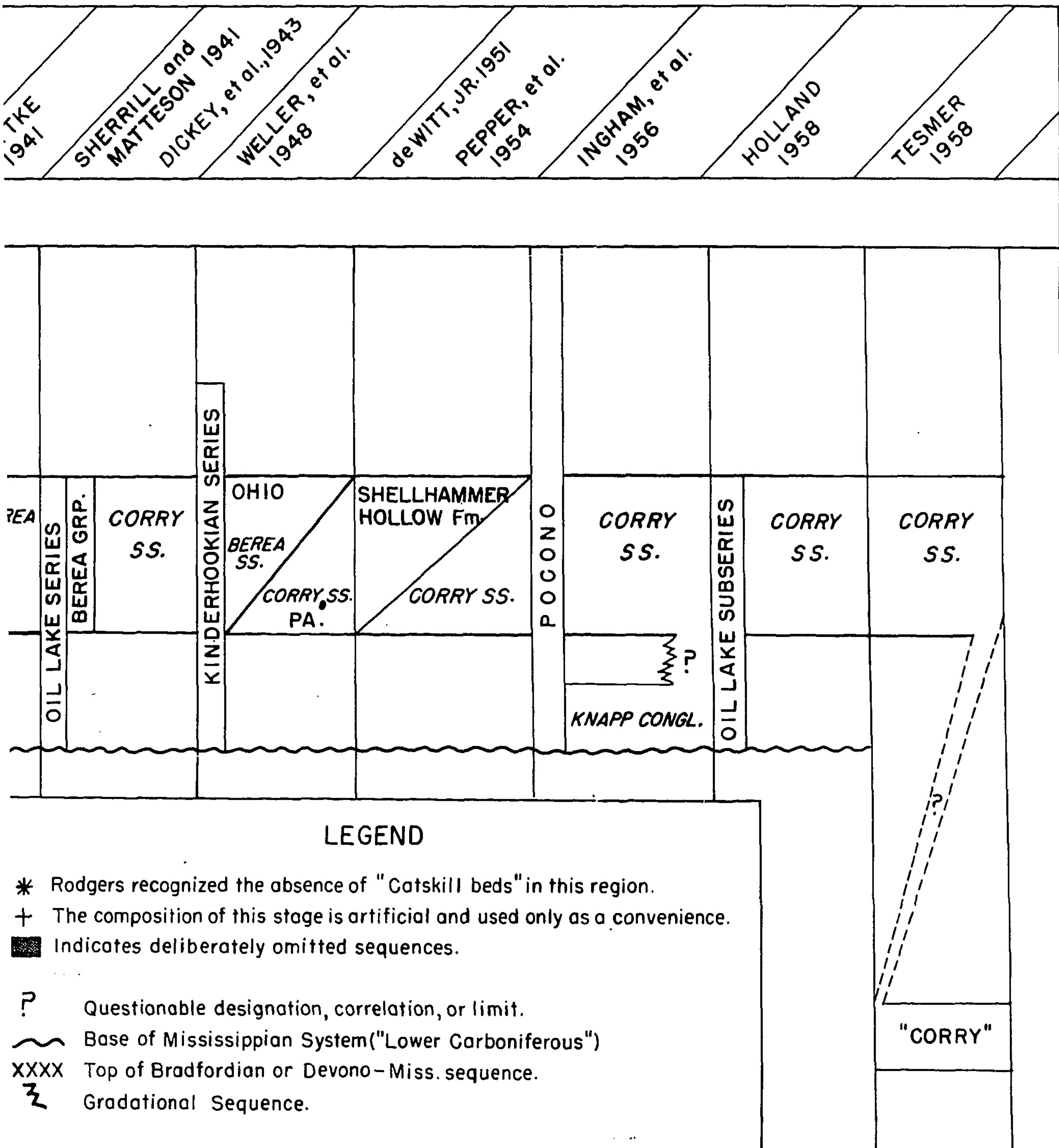
RAPHIC POSITION OF THE CORRY SANDSTONE

ʼennsylvania)



Y SANDSTONE

FIG.6



PREVIOUS WORK

The Corry sandstone of northwestern Pennsylvania is an integral part of the vast Devono-Mississippian sedimentary complex called by Barrell (1913, p. 470) the "Coastal Plain or Catskill Delta." The present study is confined to the Corry sandstone itself, except for paleontologic or stratigraphic excursions into other units as the prime objective seems to require. For further information on the history of the Catskill delta, Barrell (1913, 1914), Chadwick (1933), Caster (1934), and Greiner (1957) should be consulted. The accumulation of these Penn-York (Caster, 1935b) sediments was initiated by orogenic pulsations beginning in either early or late Lower-Middle Devonian time - the Schickshockian orogeny of Kay (1942) or Acadian "revolution" of Schuchert and Dunbar (1933). The rocks resulting from this combination of circumstances very early received the attention of American geologists.

Summary of Previous Work

<u>Evolution of the stratigraphic name "Corry."</u> - In the earlier reports on the geology of Pennsylvania there is little to indicate that the Corry sandstone was recognized as a distinct stratigraphic unit. The First Pennsylvania Geological Survey (1836-1841), under the

directorship of H. D. Rodgers, was primarily concerned with expanding the resources of the growing coal industry. Exploratory emphasis was directed toward the eastern and northeastern portions of Pennsylvania.

Rodgers' attempt to translate his stratigraphic units from eastern Pennsylvania across the state to the Ohio border was tempered by his suspicion that lithologic changes might occur. Hence his reluctance to give formational designations to his stratigraphic units, as expressed (1838, p. 20):

> For the present I have studiously abstained from framing a nomenclature for the several formations of the extensive system of rocks here enumerated, preferring (until I become entirely familiar with the many modifications, which they undergo in their course through the Appalachian region,) to designate them as well by their numerical position, counting from the bottom of the group, as by distinctive features in the rocks, and a reference to their geographical situation.

Rodgers (1838) presented a hasty sketch of the general geology of Erie and part of Crawford Counties in northwestern Pennsylvania. In ascending order, he described the stratigraphic sequence as consisting of nos. VIII, X, and XII of his total of thirteen formations projected from his "Lower Secondary Formations of Pennsylvania" east of the Susquehanna River. A year later the sequence remained essentially the same (see Rodgers, 1839, p. 109).

In his final report for the "First Survey" Rodgers (1858, p. vi) apparently decided to name his formations. He applied the term "Paleozoic" to the system previously called "Lower Secondary" but rejected the existing formational terminology of the British and New York State Surveys as being, respectively, not applicable and too local. Rodgers (1858, p. 104-109) also gave "series" designations to units formerly called "Formations." (Both classifications encompassed thick sequences of strata which have been long-since subdivided.) Each "series" name, of which there were fifteen, corresponded to a different period of the day, e. g. Primal (Dawn) through Seral (Nightfall). In the vicinity of Warren, Pennsylvania Rodgers (1858, p. 144) recorded the presence of the "Vespertine series" overlying the "Vergent series" (the Chemung and Portage of New York State).

Northwestern Pennsylvania received little further attention until the advent of the Second Pennsylvania Geological Survey (1874-1895). In Report I for Venango County, Carll (1875, p. 12) referred to a series of non-productive sandstones and conglomerates as the "Barren Oil-measures of Venango; or the Mountain-sand Group" - terms adopted from the usage of drillers. These beds were defined as lying between the "Great Conglomerate" and the "Oil-Sand Group." In a diagram opposite p. 34 (op. cit.) Carll illustrated the relative position of the three

"Mountain-sands." The lowermost, although not discussed in the text, approximates the position of the Corry sandstone as the sequence is interpreted today.

Carll (1875, p. 13) planned to restrict the usage of the terms to Venango County, not wishing to apply them to the whole Oil Region of western Pennsylvania. His superior, J. P. Lesley, (then State Geologist) apparently overruled Carll and not only applied the terms outside of Venango County but also attempted to trace the three "Mountain-sands" across the state line into Ohio and correlate them with the Berea grit. He (Lesley, 1875, p. 60) remarked that the third "Mountain-sand" had no Ohio equivalent.

Ashburner (1880, p. 43), working in McKean County, Pennsylvania, in a diagram showing a refinement of the Carboniferous system, divided the Lower Carboniferous into a lower, middle, and upper Pocono sandstone and equated them to "Formation X" and the "Vespertine series" of Rodgers (1838, 1858). The term "Pocono" was attributed by Ashburner (1880, p. 41) to J. P. Lesley, the State Geologist.

J. F. Carll, in a report on Warren and adjacent counties, decided to put an end to the ambiguity of the "Mountain-sand" designation for that portion of the geological column which Ashburner had just refined elsewhere. In proposing a new terminology he compounded the duplication which Rodgers had tried so unsuccessfully to avoid. Carll (1880, p. 81-82) declared:

> The designations First, Second and Third Mountain sands, used provisionally in 1874, answered very well for the purposes of that local report; but, to adhere to the use of these ordinal numbers still, ..., would only perpetuate confusion in our geological nomenclature. Other rocks than those thus numbered in early oil well borings have been found intruding into the series; and to these additional rocks fixed geographical names have been assigned in districts outside of and adjoining the oil regions proper. I propose therefore to adopt in this report such geographical names, and to drop the use of the terms First, Second and Third Oil sands as no longer available....
>
> The Third mountain sand will receive in this report a new name, the Pithole grit.
>
> This rock was first recognized as a persistant sandstone in the Pithole oil wells,..., and making conspicuous outcrops along the Allegheny river on the south and along Oil Creek on the west.
>
> The term grit sufficiently designates it as a sandstone; but what is more important, will serve to associate it in the reader's mind with the Berea grit of Ohio, which seems to have been a cotemporaneous formation; although the two rocks have not been traced across country towards each other to a common place of actual meeting.

In addition, Carll (1880, p. 82 and pl. XI) designated as the "Crawford shale" a portion of the sequence of strata which he (Carll, 1875) had called the "Mountain-sand Group."

In 1881 I. C. White published his report on the geology of Erie and Crawford Counties and proposed a considerable number of changes in the geological nomenclature of the area. Within his newly created "Oil Lake Group" White (1881, p. 230) named, correlated, and designated the type section for the Corry sandstone in the following terms:

> About one mile south from Corry are two extensive quarries in the summit of the hill just west from the Methodist church; one east from the Corry road owned by Mr. Colegrove, the other west from it and owned by Mr. Heath. Eight feet of the rock is found on the summit, and it has probably suffered from erosion, as the upper half is so badly shattered that it cannot be used except for riprap...; the lower half comes in layers 2" or 3" up to 12" thick. The whole bed has a yellowish or buffish white tinge, is quite hard and tolerably fine-grained. From this locality I have named it the _Corry Sandstone_, and it is identical with the _3rd Mt. Sand_ of Mr. Carll. Few fossils occur in it, but in the lower portion were seen species of _Allorisma_, and _Orthis_ and a broad-winged _Spirifer_.

Despite White's formal designation, the name "Corry" was not readily accepted. Many contemporaneous authors preferred the older terminology. From the series of changes which followed, it would almost appear as though White had labored in vain. His correlation of the Corry with the Berea of Ohio (White, 1881, p. 94), supporting the earlier contention of Carll (1880), did not go unchallenged even as it was proposed. Lesley (1881, p. xiii), in the introduction to White's report, said, "...[White's correlation] is only probable in his opinion and has not been completely demonstrated."

Stratigraphic continuity in northwestern Pennsylvania. - Early attempts to trace the Corry within Pennsylvania were beset with uncertainty despite White's lucid descriptions. Carll (1883, p. 341) observed, "The Pithole grit is not massive; nor is its horizon always constant, or clearly defined." Lesley (1885, p. cii) expressed somewhat the same opinion; using the terms "Third Mountain-Sand" and "Pithole grit" he remarked that the formation could not be traced from Tidioute to Warren.

Carll (1890, pl. 4) employed the terms "Berea" and "Pithole grit" interchangeably - still including the formation within his somewhat modified sequence, designated earlier, the "Crawford shales." His references to the Corry at a number of localities established the following generalizations:

1. At Tidioute, the "Pithole grit" appeared to be a sandy horizon - not a massive sandstone.
2. Throughout the highlands of Venango County the "Berea grit" appeared to be a persistent and ideal key horizon.
3. The "Berea grit" appeared to thin out and disappear eastwards in Forest and Clarion Counties, Pennsylvania.
4. The top and base were not clearly defined.
5. The base frequently contained irregular lentils of limestone.

Lesley (1895, p. 1629) was determined to use the term "Pocono" (subtended by the "No. X" of Rodgers) to delimit the strata of the "first, oldest or lowest subdivision of the great Carboniferous System." In what was apparently an effort to clarify the nomenclatorial maze, he objected strongly to the use of the Ohio term "Waverly", declaring (p. 1779):

> The Waverly formation of southern Ohio occupies the same general horizon as the sub-conglomerate formations of western Pennsylvania; and that is all that can be said of it. Its use has produced confusion and hence has been kept out of Pennsylvania reports.

While condemning dual nomenclature in one instance, Lesley encouraged it in others. He apparently recognized the Corry's synonymies since he used them when referring to its horizon in the Venango area; but for the area of northwestern Pennsylvania he (Lesley, 1895, p. 1785) declared:

> ...such names as Shenango shales and conglomerate, sub-Olean, Meadville, Cussewago, Corry, will always be confined to the special districts in which they were first applied;.... In a word, the geological nomenclature of Erie, Crawford, Warren and Stateline counties to the south and east of them, must remain isolated and peculiar,....

Lesley's decision appears to have encouraged the use of archaic nomenclature rather than hastening its demise. The stratigraphic interval occupied by the Corry was not effected, except for the overlapping terminology; the situation remained static until the turn of the century.

The first of several radical changes in the classification of the Corry was suggested by Stevenson in 1903.

He left the formation in the Oil Lake Group of White (1881); but, relying on the Ohio paleontology of Herrick (1891), placed the entire group of Pennsylvania formations in the Upper Devonian.

Girty (1904) created the "Bradfordian Series" for the New York formations below the Olean (Pottsville) conglomerate, stating (p. 24) that:

> The position of this series is quite apart from the determination of its age as Devonian or Carboniferous, a question reserved for further study.

He traced the Corry from the type section into the region of Warren, Pennsylvania, recognizing its occurrence immediately above the "sub-Olean conglomerate" (Knapp, in this instance). Girty repeated this observation in 1905 and proceeded to defeat his own good work by (1905, p. 6) equating the Berea grit of Ohio (supposedly of Mississippian age) with the Corry and Cussewago sandstones of White (1881) and then (1905, p. 7) contending that the "Bradfordian" (including the Cussewago) had "its true relations with the Devonian."

In Butts' 1906-1908 report for the Pennsylvania Topographic and Geologic Survey the Berea (Corry) sandstone was depicted, in several instances, (1908, p. 129 and 191) to be the basal member of the Mississippian Pocono-Waverly sequence. He cited the Berea-Corry correlation of Girty (1904) and recognized the occurrence of the Corry below the Olean (Pottsville) conglomerate in the

Warren, Pennsylvania area. However, Butts (1908, p. 192) actually only traced the Berea (Corry) to the vicinity of Tionesta, Pennsylvania where it purportedly dipped beneath the surface (see text fig. 7) and (op. cit., p. 195) correlated with the Venango-first sand. In 1910 Butts, then working in the Warren quadrangle, designated the Corry as "Berea" and reported the formation to be present as a "feather edge" immediately overlying the Knapp formation in that area. He stated that the "Berea" could not be found in place but its characteristic fauna made it readily recognizable in the float. The Berea (Corry) was classified as basal Mississippian while the underlying Knapp was placed in the "Devono-Carboniferous" category. Butts did not here mention his previous correlation of the Corry with the Venango-first sand.

Verwiebe (1916) discounted Butts' (1908) correlation of the Corry with the Venango-first sand and (p. 55) declared:

> In tracing the Knapp formation to the south, it strikes one immediately as not improbable that the Knapp is the northern representative of the Venango 1st Oil sand.

This paved the way for his suggestion that in the Warren quadrangle the "Berea" was absent because of erosion. He (Verwiebe, 1916, p. 47) contended that the Corry, in the Allegheny River section, was represented by a sandstone 160' higher than its usually designated position and

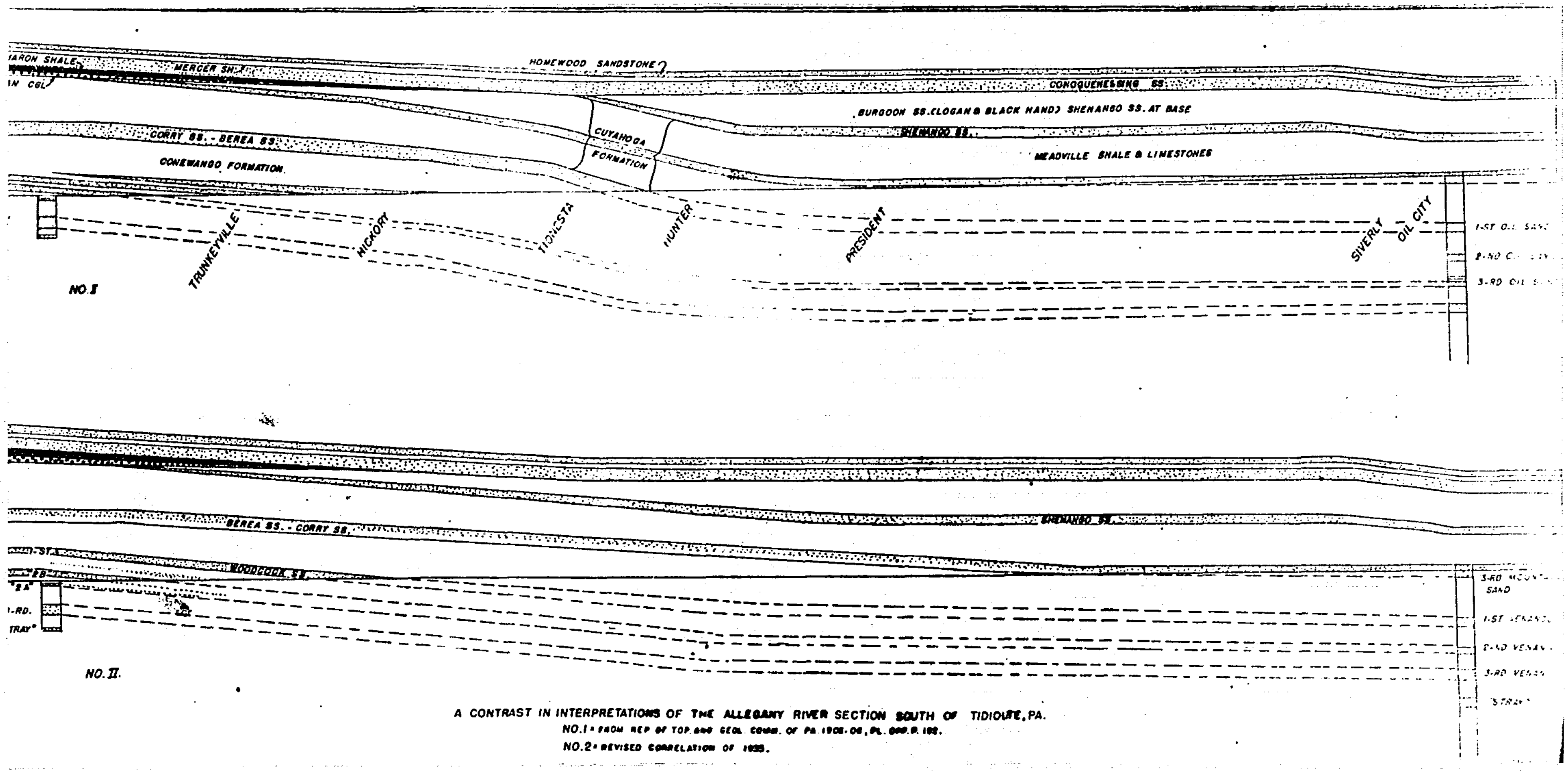


Fig. 7. - Comparative interpretation of the structure along the Allegheny River from Tidioute to Oil City, Pennsylvania. (Reproduced from Caster, 1934, chart facing p. 167.)

characterized at its base by a limestone layer which Caster (1943, p. 171) has identified as the Conneaut (Upper Meadville) limestone. Caster's work made possible the identification of Verwiebe's "Corry" as the Shenango sandstone.

In 1917 Verwiebe visited White's fossiliferous sections of the Corry sandstone at Cobham's Hill and along the road to Enterprise in the Warren area. He decided (1917, p. 306) that these sections represented the First Venango oil sand rather than the Corry - a correlation which he had denied to Butts (1908).

In the years between 1917 and 1934 a number of authors referred to the Corry without altering its stratigraphic position as defined by White. However, changes were made with respect to the superformational classification of it and the adjacent beds and the position of theDevono-Mississippian boundary. (See text fig. 4)

In 1934 Caster, as part of a study of the general stratigraphy of northwestern Pennsylvania, made the most comprehensive evaluation of the Corry to date. Some of Caster's formational and superformational designations have since been altered but his work appears to be sound and has been used as a starting point for more recent stratigraphic work. His designation of the Devono-

Mississippian boundary (see text fig. 5) has been strengthened by the recent faunal analysis of Holland (1958).

Among the contributions of Caster was the recognition of the importance of the Corry and the subjacent beds to a fuller understanding of the stratigraphy of northwestern Pennsylvania. Within his then newly created Oil Lake series (the former Oil Lake group of White, 1881) Caster (1934, p. 52) erected a new category to include the Corry, stating:

> The "Berea stage" is at present designed to account for the Corry sandstone at the top of the Oil Lake series. There is reasonable certainty that this formation is the eastward continuation of the upper Berea sandstone of Ohio. The Corry belongs in the Oil Lake series faunally, and lithically, rather than the Crawford series. It cannot justifiably be included in the Cussewago stage. Wherefore a separate stage is created for it.

In 1935 Caster (p. 912) disposed of the "Bradfordian" of Girty (1904) citing both a "minor disconformity" and faunal differences between the basal Mississippian, Oil Lake series, and the Upper Devonian, Conewango series. The same year Chadwick, who had previously agreed with most of Caster's conclusions, reversed himself and questioned the correlation of the "Corry" at Stoney Lonesome (Warren quadrangle) with that of Pithole Creek (Oil City quadrangle) on both a faunal and a stratigraphic basis. Chadwick (1935b, p. 338) concluded:

> In short, until and unless further collecting and further stratigraphic tracing prove that these Cussewago beds (Kushequa, Knapp, Hayfield and probably the so called "Berea") are not really the latest and highest Devonian, it will be best to adhere to the original definition and scope of the Bradfordian epoch of Dr. Girty....
>
> The faunal groups now recognized are...(6) the Conewango, which with probably the overlying (7?) Cussewago (including perhaps also the false "Berea" of Pennsylvania) constitute the closing epoch (Bradfordian) of the Upper Devonian.

The Bradfordian was therefore revived, if only briefly, and the Corry sandstone placed in the Devonian.

The boundary and correlational disputes outlined above must have been disheartening to Cathcart (1936) who decided that the stratigraphic subdivisions of White (1881) were "as satisfactory as any." In 1938 Cathcart, et al., reporting on the Tidioute quadrangle of Pennsylvania, tentatively accepted the Devono-Mississippian boundary of Caster (1934) and set the pattern for much of the more recent deliberation concerning the place of the Corry in the stratigraphic sequence of northwestern Pennsylvania. However, there was still little uniformity in the superformational designations and the terms "Corry" and "Berea" were used interchangeably.

Fettke (1941) accepted Caster's boundary but preferred to use the term "Berea" instead of "Corry" for the Pennsylvania stratum. Sherrill and Matteson (1941, p. 16) accepted most of Caster's designations but preferred "Berea group" to "Berea stage" and used "Corry" in preference to "Berea." Dickey, et al., (1943) followed Sherrill and Matteson in their terminology.

In 1946 three separate investigations by Rittenhouse, Demarest, and de Witt, Jr. indicated that an absolute equivalency between the terms "Corry" and "Berea" might be inaccurate. This distinction is reflected in Chart No. 5 of Weller, et al., (1948).

In 1951 de Witt, Jr. crystallized his earlier ideas and demonstrated (pl. 2) that in central Crawford County the Corry graded laterally into a siltstone sequence called (p. 1362) the Shellhammer Hollow formation. This conclusion was well documented and expanded in 1954 in the paper of Pepper, de Witt, Jr., and Demarest. These authors (1954, p. 34) concluded:

> The Corry sandstone of eastern Crawford County and Venango County, which has been confused with the Berea in some places, cannot be distinguished from the Berea by its elevations alone; for the top of the Corry and the top of the Berea probably do not differ by more than 10 feet stratigraphically. Nevertheless, the Corry is not an eastern siltstone phase of the Berea,....

The Corry-Berea union was dissolved and the westernmost limit of the Corry established.

In 1956 Ingham, et al., suggested that the Corry might be traceable slightly eastward beyond the line established by Caster (1934, p. 123), "...from Big Bend southwestward between Tionesta and Marionville, Pennsylvania." The section described at Brookston (Ingham, *et al*., 1956, p. 14), visited during this investigation, would appear to justify that expansion.

The work of Greiner (1957), concerned largely with paleontological problems, and mainly related to the Devonian sequence, adds little to the immediate discussion. His usage of stratigraphic units exemplifies the cyclical nature of nomenclature in that Greiner accepts the terminology of Caster (1934) as Cathcart (1936) accepted that of White (1881).

Despite the gradual convergence of ideas pertaining to the Corry, the formation has not undergone its last change of status. In a recent publication Tesmer (1958) places the Corry in the Cattaraugus formation (Devonian) and equates it to the Pope Hollow conglomerate, the upper member of Caster's Salamanca "formational suite." In a personal communication Dr. Tesmer has explained that the Corry and Pope Hollow "appear to occupy the same horizon but may not be temporal equivalents." The idea is an interesting one but contradicts all previous correlations and leaves the position of the Devono-Mississippian boundary unsettled. It is possible that Tesmer may have fallen victim to the "trap" which Caster (1934, p. 115) cautioned against when he said:

> In its wide-spread development in an east-west direction the Cobham conglomerate [= Corry] is similar to the Pope Hollow and Panama conglomerates of the underlying Venango formation.

Correlation with the Berea sandstone of Ohio. - Until very recently, the traditional correlative of the Corry, as already indicated above, was the Berea sandstone of Ohio. This relationship had been postulated, almost without exception, on the basis of the relative stratigraphic position of the two formations in their respective areas. Complications have arisen because of: (1) the failure of various workers to agree on the nature of the Devono-Mississippian sequence in northeastern Ohio and northwestern Pennsylvania; (2) disagreement as to the nature of the Berea and Corry sandstones themselves; (3) a lack of sufficient paleontological evidence; and (4) the scarcity of good outcrops in critical areas. Only the salient points of the proposed correlations are covered here as an introduction to the complex stratigraphy of the Pennsylvania-Ohio border. Figs. 8, 9, and 10 are included in the text as an adjunct to the discussion which follows.

Some of the difficulties which accompany the inferred Corry-Berea relationship antedate the actual association of the two formations. The failure of two prominent geologists to agree on the nature of the Berea grit of Newberry (1870) very early set the stage for much of the problem which arose.

M. C. Read (1873, p. 508), in describing the geology of Trumbull County, Ohio, casually inferred, under the heading of "Bedford Shale", that the Berea was a tripartite formation consisting of two sandstones and a medial shale. He had not previously, in the text or illustrations (e. g., 1873, p. 506), made such an assertion. J. P. Lesley believed the "Berea" to be a tripartite formation in Pennsylvania but declared (1875, p. 60), "The Berea grit is a single formation in Ohio." The dichotomy which was to plague stratigraphers was thus established.

In 1880 Carll (p. 82) suggested that his newly designated "Pithole grit" (Corry) was deposited contemporaneously with the Berea grit of Ohio. He did not, at the time, comment on the nature of this relationship other than to say that it was readily demonstrable. The following year I. C. White (1881, p. 91-94) definitely stated that the Corry sandstone continued into Ohio as the Berea grit (see text fig. 8); the remainder of his Oil Lake group he correlated with the Bedford shale underlying the Berea. White therefore accepted Lesley's postulated single-unit Berea in Ohio. Subsequently, a number of geologists followed White's lead in accepting a direct Berea-Corry correlation. The work of Cushing (1888, p. 215), Carll (1890, p. 93), and Orton (1893) reflect this usage.

Girty (1905, p. 6), in accordance with an earlier suggestion of Stevenson (1903), declared, "The Berea grit

I. C. WHITE 1881

OHIO	PENNSYLVANIA
Berea grit	Corry sandstone
Bedford shale	Cussewago {limestone, shale, sandstone}
Cleveland shale	

H. P. CUSHING 1887

OHIO	PENNSYLVANIA
Berea grit	Corry sandstone
Bedford shale	Cussewago shale
	Cussewago sandstone

C. S. PROSSER 1912

OHIO	PENNSYLVANIA
Berea sandstone	Corry sandstone Cussewago {shale, sandstone}
Bedford shale	

G. H. CHADWICK 1925

OHIO	PENNSYLVANIA
Berea sandstone	Corry sandstone
Bedford shale	
Cleveland shale	
	Hayfield shale
	Cussewago sandstone

K. E. CASTER 1934

OHIO	PENNSYLVANIA	OHIO (ALTERNATE HYPOTHESIS)	PENNSYLVANIA (ALTERNATE HYPOTHESIS)
Upper Berea sandstone	Corry sandstone	Berea sandstone	Corry sandstone
Berea shale	Hayfield shale	Bedford shale	Hayfield shale
Basal Berea sandstone	Cussewago sandstone		Cussewago sandstone
Bedford shale	Kushequa shale		

THIS PAPER

OHIO	PENNSYLVANIA (Crawford County) Western	Central	Eastern
Berea sandstone	Berea sandstone	Shellhammer Hollow formation	Corry sandstone
Bedford shale	Bedford shale		
Cussewago sandstone (Murrysville sand in subsurface)	Cussewago sandstone (Murrysville sand in subsurface)		
Cleveland member of the Ohio shale			

Fig. 8. - Proposed correlations of the Devono-Missisippian formations in northeastern Ohio and northwestern Pennsylvania. The expression "this paper" refers to the work of Pepper, et al., (1954, p. 38, fig. 24) from whom this chart is taken.

of Ohio is White's Cussewago sandstone, together probably with the Cussewago flags and Corry sandstone." Such a correlation would infer that the Berea was a tripartite formation (in the sense of Read, 1873) and that the Corry would be related, because of its stratigraphic position, to the uppermost Berea. Schuchert (1910, p. 548), Prosser (1912, p. 351, 394, 396), and Verwiebe (1916, p. 43, 44, 46) subscribe to a correlation of this nature.

Chadwick (1923 and 1925) considered the Corry and Berea to be direct correlatives but differed from previous workers concerning the nature of the beds subjacent to the two formations. He (Chadwick, 1925, p. 436) correlated the Knapp formation of Glenn (1903) with the Cussewago sandstone of White (1881) and renamed White's Cussewago shale and limestone (see text fig. 5) the Hayfield shale and limestone. In addition, he postulated the presence of a great transgressive disconformity extending from the base of the Cleveland shale of Ohio to the base of the Corry sandstone in Erie County, Pennsylvania. Such a disconformity would have the effect of splitting White's Oil Lake group, making the Corry Mississippian in age and the subjacent beds "Bradfordian" and unrelated to the Bedford shale which underlies the Berea.

Caster (1934) did not accept Chadwick's stratigraphy in its entirety and proposed two alternate Corry-

Berea relationships based on the premise of a threefold Berea formation in Ohio (<u>see</u> text fig. 8). The first choice, which Caster favored, would correlate the Corry sandstone, Hayfield shale, and Cussewago sandstone of Pennsylvania with, respectively, the upper Berea sandstone, medial Berea shale and basal Berea sandstone. The Bedford shale of Ohio would, in this scheme, correlate with the Kushaqua shale, the basal member of Caster's newly erected Cussewago "Monothem." The second alternative would equate only the Corry with the basal Berea sandstone, and the Hayfield shale (underlying the Corry) with the Bedford shale of Ohio which Caster (1934, p. 164) recognized as disconformable with the overlying Berea sandstone. Caster, like Chadwick, designated the Knapp formation of Warren County as the equivalent of the Cussewago sandstone of Crawford and Erie Counties.

The various correlations outlined above do not represent all of the possible relationships between the Berea and Corry sandstones, as subsequent workers were prompt to point out. Cathcart, *et al.*, (1938, p. 3) described the Corry itself as a tripartite formation consisting of two sandstones and a medial shale; the basal sandstone was judged to be the equivalent of the upper Knapp formation. All three Corry units were correlated with the three-part Berea of Ohio but no details of the relationship were given in this 1938 report on the

Tidioute quadrangle. Dickey's (1941, p. 5) publication on the Titusville quadrangle affirmed Cathcart's three-part Corry but equated it to the upper Berea rather than the entire formation.

The search for additional petroleum reserves during the Second World War stimulated a series of oil and gas investigations conducted in the area of Pennsylvania covered in this study. From these investigations a series of papers and reports emerged which altered many of the concepts of the stratigraphy of northwestern Pennsylvania as well as the relationship between the Berea and Corry sandstones. Among the published reports from which the more recent opinions crystallized were those of Rittenhouse (1946), Demarest (1946) and de Witt, Jr., (1946 and 1951). The essence of these reports is contained in the United States Geological Survey Professional Paper 259 by Pepper, de Witt, Jr., and Demarest (1954).

Pepper, _et al_., (1954, p. 39) asserted that the Berea sandstone is a single, not tripartite, formation in Ohio. Evidence was presented to prove that the Corry, Cussewago, and Berea formations are three separate entities - each representing an independent lobe of a vast deltaic complex which developed during Lower Mississippian time (_see_ text fig. 9). Rather than being direct correlatives, the authors believe that the Corry and Berea sandstones are temporal equivalents which, in the area

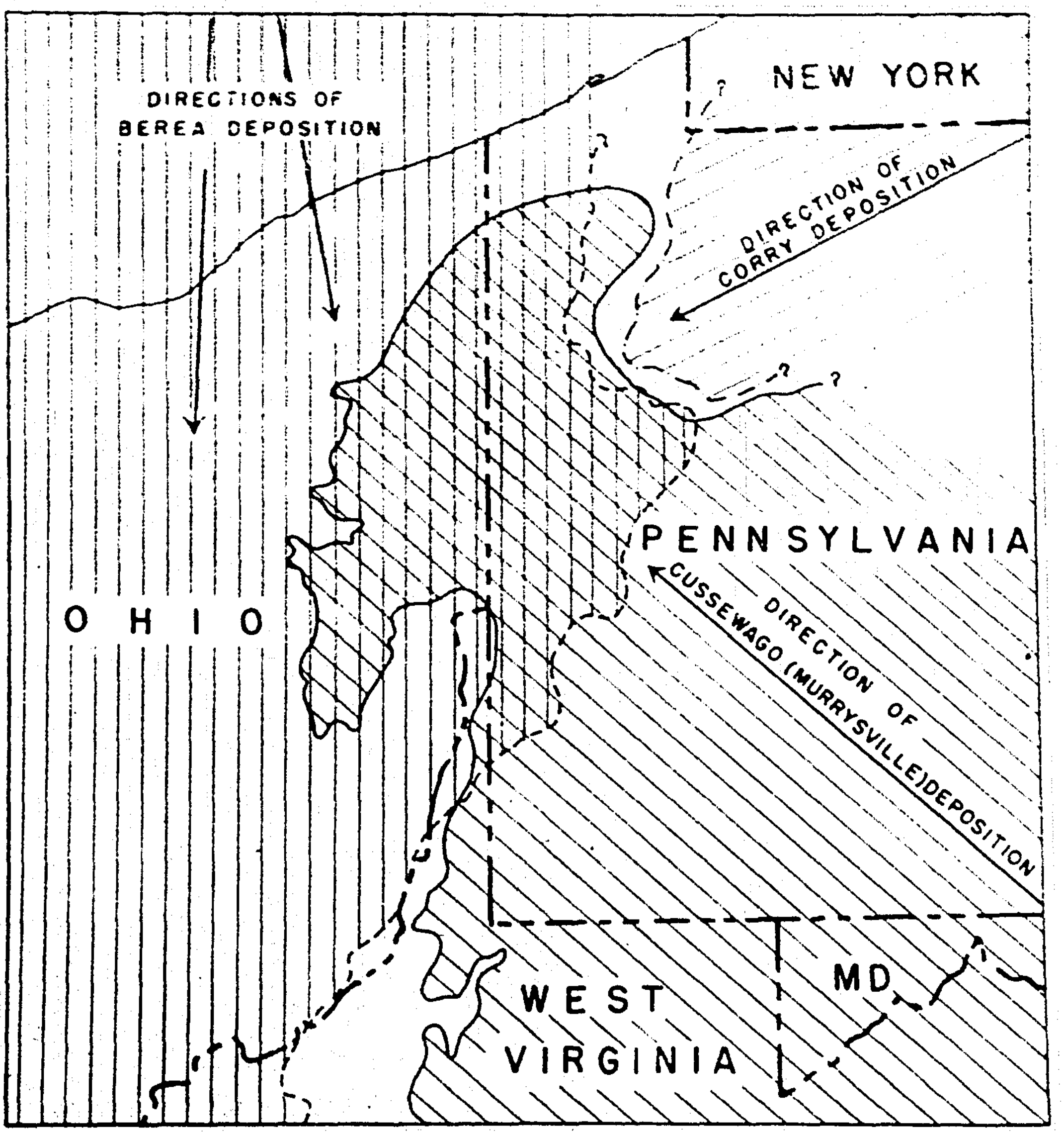
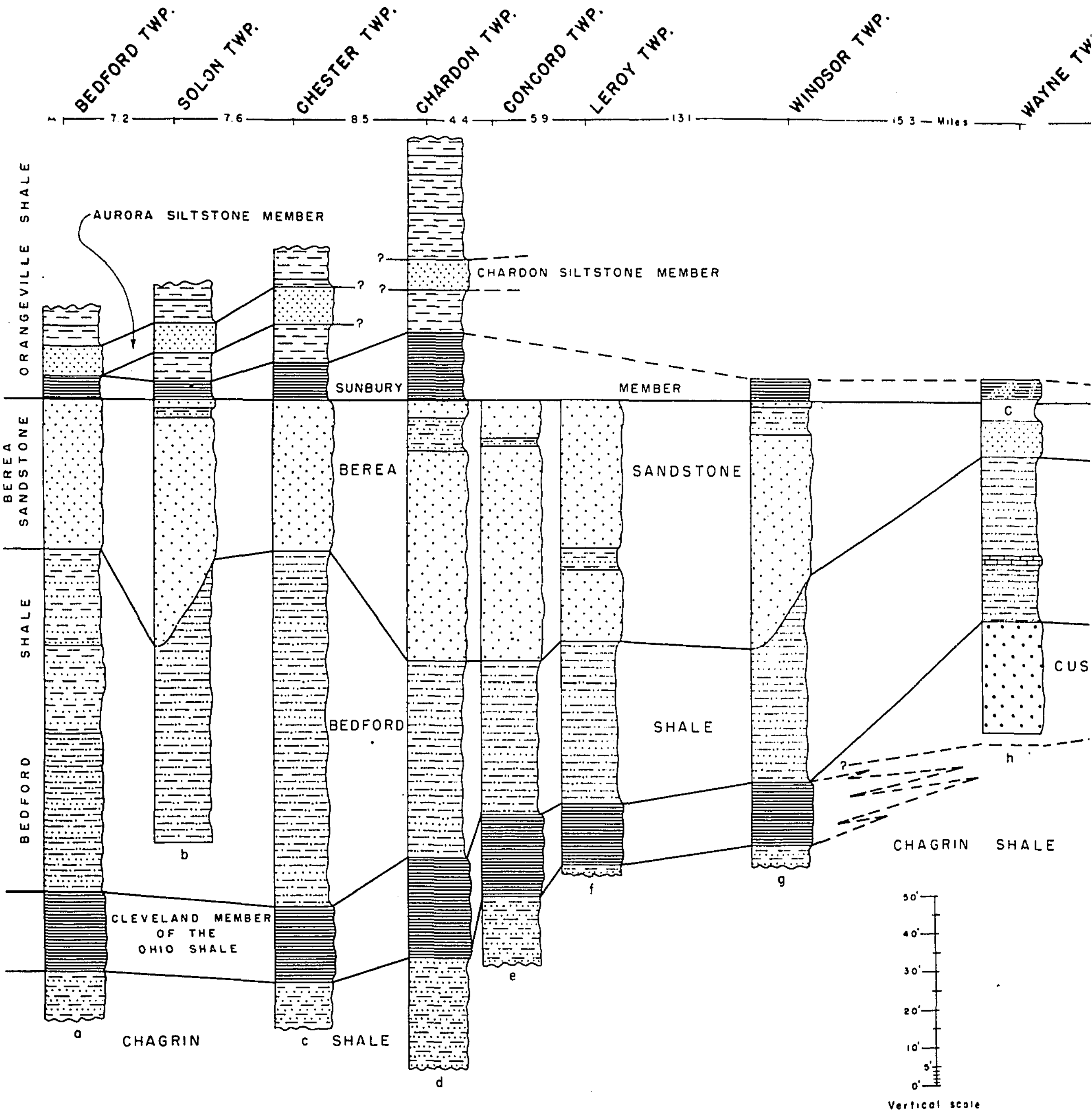


Fig. 9. - Proposed relation and direction of deposition of the Berea, Cussewago, and Corry sandstones in northwestern Pennsylvania and northeastern Ohio. (Reproduced from Pepper, et al., 1954, p. 40, fig. 25.)

between Meadville and Riceville, Pennsylvania, lose their identity in a common siltstone facies called by de Witt, Jr., (1951, p. 1362) the Shellhammer Hollow formation (see text fig. 8).

Pepper, et al., (1954, p. 21) rejected the Knapp-Cussewago sandstone correlation of Chadwick and Caster and (p. 25) equated White's (1881) Cussewago shale (the Hayfield of Chadwick) with the Bedford shale of Ohio. Their interesting correlation for northeastern Ohio and a portion of northwestern Pennsylvania is exemplified by text figure 10 and will receive further attention in this study.



STRATIGRAPHIC SECTIONS BETWEEN BEDFORD T(OHIO, AND SPARTA TOWNSHIP, CRAWFORD (

(MODIFIED FROM DE WITT, 19

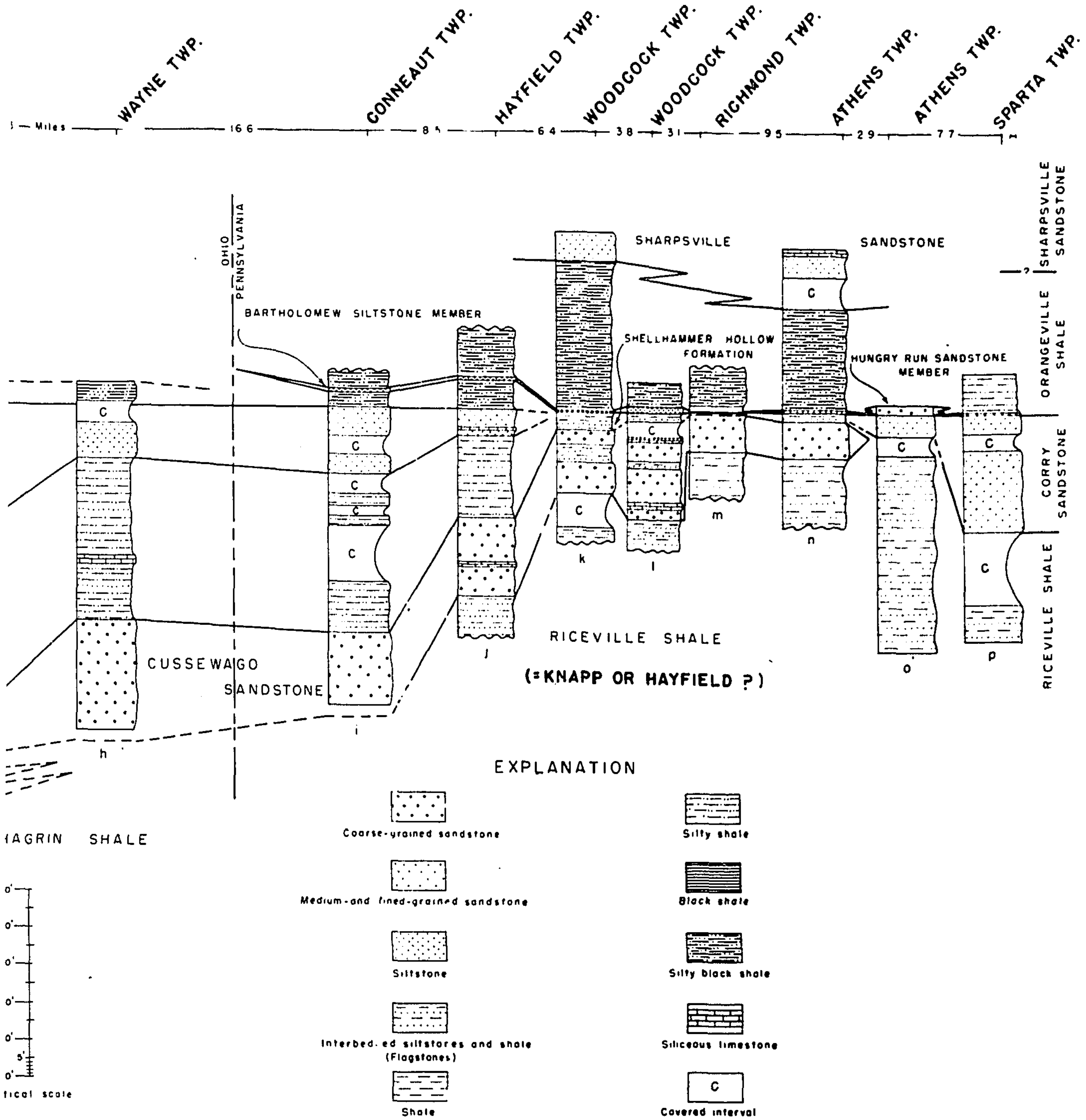


Fig. 10

ETWEEN BEDFORD TOWNSHIP, CUYAHOGA COUNTY,
WNSHIP, CRAWFORD COUNTY, PENNSYLVANIA.

D FROM DE WITT, 1951. PL.2)

STRATIGRAPHY AND SEDIMENTATION

In conformity with previously stated objectives, the comments which follow are based upon general observations in the field and an evaluation of existing literature pertinent to the Corry sandstone. Text figure 11, based upon these sources (see also Table 1 and Appendix A), represents the writer's present views of the spatial relationships of the Corry and the adjacent formations. With the ultimate completion of the paleontological study and the devotion of more specific efforts in the field of sedimentation, it is anticipated that some modification of the present interpretation may be necessary.

The precise relationship between the Corry sandstone and the adjacent formations is, at present, inadequately known. A portion of the difficulty can be attributed to the general absence of extensive outcrops in northwestern Pennsylvania and the erratic distribution of those which do exist. Then too, except for the work of Caster (1930/1934) and Holland (1958) in the eastern portions of the area under consideration (see text fig. 12), the faunas of the underlying formations have not been thoroughly studied. The litho-facies changes which occur in the subjacent beds contribute further difficulties.

With few exceptions our knowledge of the beds above and below the Corry stems from uncoordinated individual

LOCATION OF

AUTHORS										
SASS	CASTER	PEPPER	deWITT	CATHCART	OTHERS					
(1959)	(1934)	(1954)	(1946)	(1936)		W	Y	C	UC	CS
9										
10										
11										
14						X				
15							X			
16							X			
17										
19					INGHAM, et. al. (1956:14)					
20										
	19						X			
	29					X				
	31					X				
	68	118	107							
	102							X		
	103	104	93	130	WHITE (1881:230)			X		
	112						X			
	116					X				
	123					X				
	129	114	103							
	140			433						
	203			1565						
	214			1298	VERWIEBE (1917:306)					
		59		258	PROSSER (1912:401)					
		65								
		73								
		87	78	819						
		90	81	493						
		94	84		WHITE (1881:192)				X	
		95							X	
		96	85	482					X	
		97	86					X		
		98	87						X	
		102	91	139				X		
		103	92	377				X		
		105	94	387				X		
		106	95	379				X		
		110	99	961						
		111	100	963a	WHITE (1881:186)					
		113	102	1000						
		117	106							
		119	108							
	108	**121**	110							
				38						
				56						
				259	PROSSER (1912 : 399)					
				398			X			
				432			X			
				486					X	
				588						
				767					X	
				910						
				963						
				979				X		
				1005						
				1061						
	203			**1565**						
					DICKEY (unpublished)					

* THE OUTCROP DESIGNATIONS USED FOR THIS REPORT ARE INDICATED BY THE BOLD-FACED NUMERALS.

SYM

W - Warren Quadrangle.
Y - Youngsville.
C - Corry Quadrangle.
UC - Union City Quadrangle.
CS - Cambridge Springs Quadra

OF OUTCROPS

TABLE I

QUADRANGLES												LOCATION					
												LATITUDE N			LONGITUDE W		
UC	CS	K	Sh	Td	Ti	To	M	L	Tn	OC	F	0	/	//	0	/	//
									X			41	29	44	79	27	48
										X		41	29	18	79	35	44
							X					41	37	30	80	09	00
												41	49	08	79	08	05
												41	55	27	79	23	33
												41	49	27	79	19	12
						X						41	40	49	79	48	02
		X										41	36	46	78	58	24
				X								41	32	51	79	15	54
												41	49	31	79	18	06
												41	51	36	79	04	09
												41	48	42	79	04	06
										X		41	28	30	79	41	30
												41	54	45	79	38	57
												41	54	15	79	38	00
												41	48	51	79	16	06
												41	48	10	79	12	26
												41	50	06	79	05	54
					X							41	33	50	79	39	40
				X								41	40	28	79	25	48
					X							41	43	06	79	32	15
					X							41	37	53	79	34	12
								X				41	43	30	80	15	05
							X					41	36	25	80	10	10
							X					41	41	00	80	08	30
						X						41	43	00	79	53	00
						X						41	43	30	79	47	15
X												41	46	20	79	48	30
X												41	46	18	79	48	30
X												41	46	40	79	47	15
												41	47	50	79	43	50
X												41	47	25	79	54	40
												41	53	00	79	41	00
												41	52	40	79	39	45
												41	52	10	79	37	30
												41	49	00	79	40	25
					X							41	40	30	79	42	55
					X							41	40	15	79	40	45
					X							41	38	10	79	40	25
										X		41	29	00	79	41	30
										X		41	27	30	79	41	20
										X		41	26	00	79	42	45
				X								41	40	58	79	20	33
				X								41	40	36	79	24	12
							X					41	42	24	80	14	26
												41	48	12	79	28	27
												41	47	39	79	23	05
X												41	47	56	79	56	00
					X							41	37	48	79	36	20
X												41	50	43	79	56	21
				X								41	43	32	79	26	32
					X							41	39	48	79	41	56
												41	48	36	79	33	30
						X						41	41	32	79	49	00
						X						41	41	30	79	58	24
					X							41	43	06	79	32	15
									X			41	29	05	79	27	48

SYMBOLS AND QUADRANGLE DESIGNATIONS FOR PENNSYLVANIA

ngle.

gle.

ıdrangle.

ˈings Quadrangle.

K – Kane Quadrangle.

Sh – Sheffield Quadrangle.

Td – Tidioute Quadrangle.

Ti – Titusville Quadrangle.

To – Townville Quadrangle.

M – Meadville Quadrangle.

L – Linesville Quadrangle.

Tn – Tionesta Quadrangle.

OC – Oil City Quadrangle.

F – Franklin Quadrangle.

studies of quadrangle-sized or county areas. These studies cover the better part of a century and only a resumé of their conclusions is herein presented. Table 2, which follows, summarizes the designations accorded to the formations above and below the Corry sandstone by various authors.

The Formations Below

White (1881, p. 94-95), discussing his Oil Lake Group of Erie and Crawford Counties, stated:

> These [Cussewago shales] separate the Corry sandstone above from the Cussewago sandstone below, and hold (near the top) the Cussewago limestone;...
> In some places the interval between the Corry sandstone and the Cussewago sandstone is filled, not with shales (with the limestone,) but with sandy flags (without the limestone;)...

These generalizations were modified or enlarged upon by subsequent writers. Cushing (1888, p. 215), among others, correlated White's Cussewago shale with the Bedford shale of Ohio. [White did not make this correlation himself but noted that the Bedford shale belonged in the interval represented by the Cussewago shale.]

Chadwick, discussing the stratigraphic relationships of the Chagrin formation of Ohio, declared (1925, p. 457), "Following down the Allegheny River in Pennsylvania, the Knapp is overlain by the Corry (Berea), a shale wedging in between,..." He further correlated the

TABLE 2. - The formations above and below the Corry sandstone as designated by various authors.

Area	Source	Fm. Below	Fm. Above
Warren Quad.	Butts, 1910, fig. 5, pg. 38.	Knapp fm.	Cuyahoga fm. (= Orangeville sh.)
Warren Quad.	Caster, 1934, p. 116.	Hayfield sh.	Orangeville sh.
E. Erie and Crawford Co.	White, 1881, p. 66, fig. 7.	Cussewago ss.	Orangeville sh.
E. Carwford & Venango Co.	Demarest, 1946, (Prelim. Map & Text)	Cussewago ss. (= Murrysville sd.)	?
W. Crawford & Venango Co.	de Witt, 1946, (Prelim. Map & Text)	Bedford sh. (= Hayfield sh.)	Orangeville sh.
E. Crawford Co. [Corry & Union City Quads.]	de Witt, 1951, p. 1362.	Riceville sh. [= Knapp?]	Orangeville sh.
Kane Quad.	Ingham, <u>et al</u>., 1956, p. 14.	U.? Knapp ss. & congl.	"shale"
Sheffield Quad.	Ingham, <u>et al</u>., 1956, pl. 7.	Knapp ss. & congl.	Shenango & Cuyahoga ss. & sh.
Tidioute Quad.	Cathcart, <u>et al</u>., 1938, & Caster, 1934, p. 119.	Hayfield sh. & white ss.	Orangeville sh.
Titusville Quad.	Dickey, 1941, p. 5-6.	Cussewago fm.	Cuyahoga fm.
Tionesta Quad.	Dickey, 1941, [unpublished]	Cussewago sh. & ss.	Cuyahoga sh. & sdy. sh.

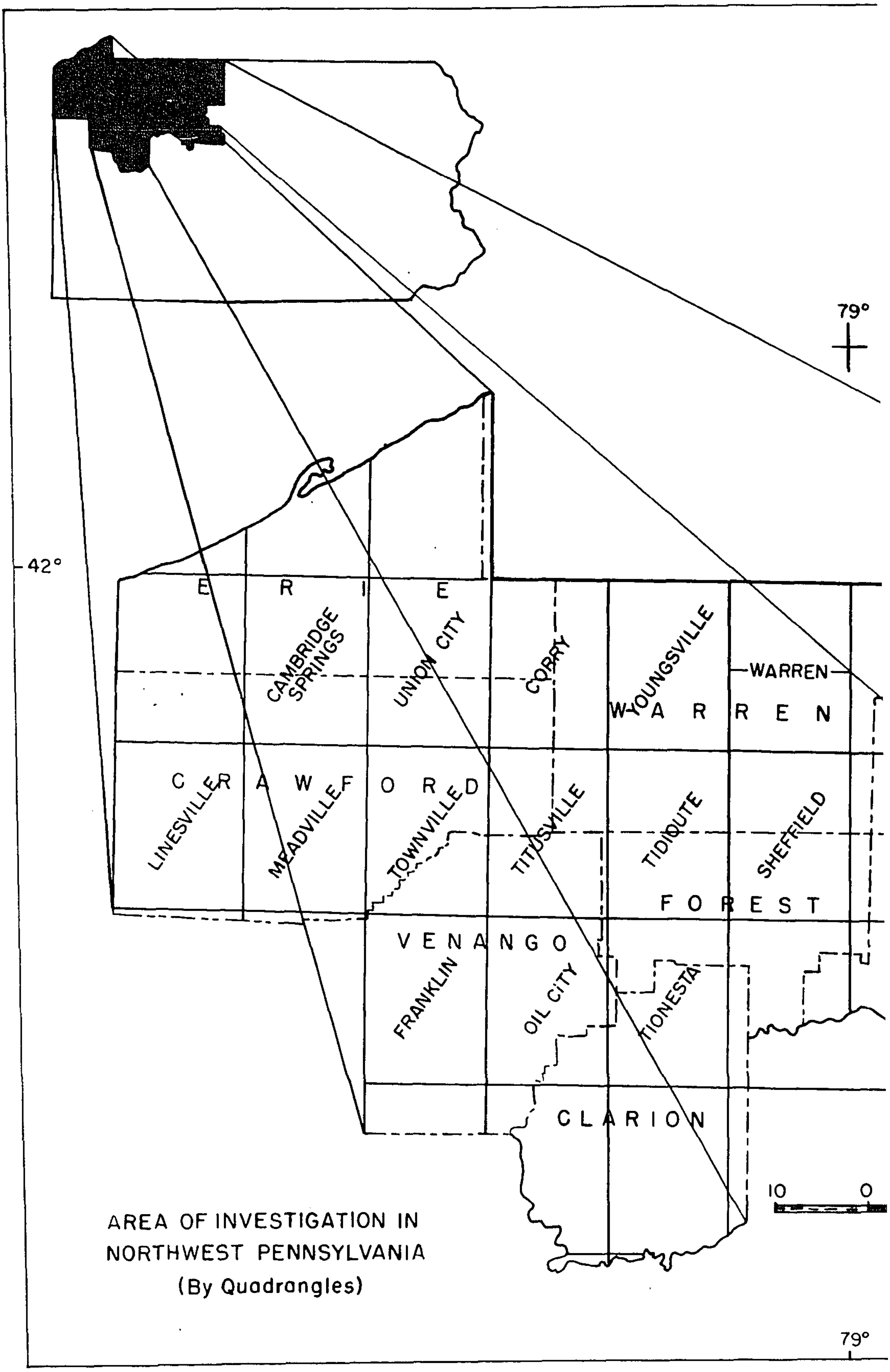
TABLE 2. - Continued

Area	Source	Fm. Below	Fm. Above
Oil City Quad.	Dickey, *et al.*, 1943, p. 20.	Cussewago ss. & sh.	Cuyahoga sh. & ss.
Franklin Quad.	Sherrill & Matteson, 1941, p. 16.	Cussewago sh.	Cuyahoga sh.

Cussewago sandstone of White (1881) with the Knapp beds of Glenn (1903) and postulated an unconformity between the Knapp and the Corry to account for the thinning of the Cussewago shale and the discontinuity he assumed to separate it from the Bedford shale of Ohio. He (Chadwick, 1925, p. 463) summarized his case as follows:

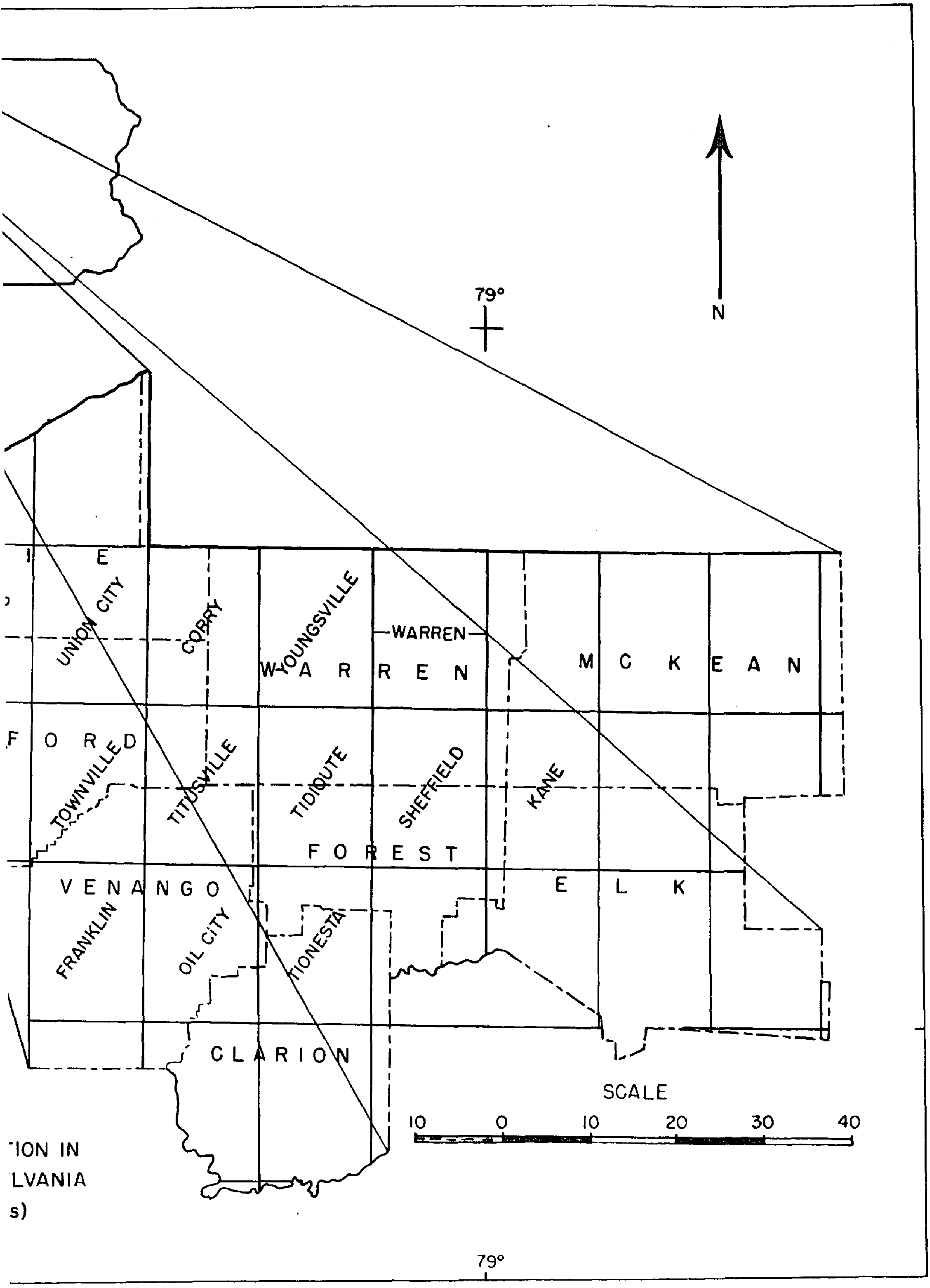
> This unconformity I believe to be the same as that found at the top of the Chagrin in Ohio; so that, just as the Millers and Woodcock sandstones are let into the series in passing east from Cleveland to the Grand River, so in turn the Cussewago sand is inserted in crossing the Grand River valley, to be followed by an increasing thickness of true (non-Bedford) Cussewago shale, which for distinction we will rename the (Hayfield shale) and limestone.
>
> In this view the shale between the Cussewago sandstone and the Corry (Berea) is at first all Bedford, but the plane of unconformity rises eastward, beveling out the Bedford, as already the Cleveland, and gradually substituting the Hayfield shale in the sections. Some undulations in the plane will account for the erratic behavior of the thin Cussewago (Hayfield) limestone beneath this plane. The shale above the Knapp at Warren probably is Hayfield.

In 1934 Caster (see text fig. 5) re-classified the Devono-Mississippian sequence of northwestern Pennsylvania. On paleontological grounds he (Caster, 1934, p. 155-165) related the Bedford shale of Ohio to his "Knapp formational suite"; more specifically, to its basal member, the then newly-designated Kushequa shale. Caster also designated Chadwick's Hayfield shale and limestone as the Hayfield monothem stating (1934, p. 116):



AREA OF INVESTIGATION IN
NORTHWEST PENNSYLVANIA
(By Quadrangles)

FIG. 12


79°
N
E
UNION CITY
CORRY
YOUNGSVILLE
WARREN
W A R R E N
M C K E A N
F O R D
TOWNVILLE
TITUSVILLE
TIDIOUTE
SHEFFIELD
KANE
F O R E S T
V E N A N G O
E L K
FRANKLIN
OIL CITY
TIONESTA
C L A R I O N
SCALE
10 0 10 20 30 40
'ION IN
LVANIA
s)
79°

The monothem is really composed of two parts, seemingly of member rank. The upper is the Hayfield *sensu stricto*, which includes the Hayfield limestone (here called *Littles Corner limestone*), and a lower member which enters toward the east and south which is only meagerly developed in the type Hayfield area. This lower member is being termed the *Tidioute* shale member.

Caster traced the Hayfield monothem from the Warren to the Meadville area and with reference to the Corry sandstone (*op. cit.*, p. 116) declared:

At Glade, Warren County, on the Allegheny River, the Corry sandstone has been mapped as immediately overlying the Knapp upper congomerate (Cobham). This is not actually the case, for about from 10 to 15 feet of Hayfield shale (Tidioute) intervene.

On page 119 of the same report Caster said:

The contact of the Hayfield shale with the overlying Corry sandstone is most interesting for everywhere it appears to be gradational. In the Upper two or three feet of the Hayfield, especially on the Allegheny River and on Oil Creek, there is an alteration of olivaceous shale and white sandstone layers which grade vertically into the base of the Corry sandstone. However, the Corry fauna does not occur in the gradational zone or below.

At times Caster appears to have equated the Cobham conglomerate and the Cussewago sandstone, both of which were assumed to underlie his Hayfield monothem. A frequently overlooked portion of Caster's work involves the correlation of the Bedford shale of Ohio which he (Caster, 1934, p. 165) postulated might possibly be represented by the Hayfield shale rather than the Kushequa in northwestern Pennsylvania.

De Witt (1951), studying the Berea sandstone in Ohio and Pennsylvania, concluded that the Cussewago sandstone and the "Riceville shale", which he depicts as underlying the Corry in Erie and Crawford Counties of Pennsylvania (see text fig. 10), were separate lithologic units. Curious as to his usage of the term "Riceville" the writer corresponded with de Witt who (1958, Personal communication) indicated that the term was employed in the sense of the original definition of I. C. White (1881, p. 97-98) with the possibility that the designation "Knapp" might be applicable. Caster's separation (1934, p. 95) of the upper portion of the original Riceville as Knapp would indicate that the latter usage might be appropriate.

Pepper, et al., (1954) expanded de Witt's work of 1951. They denied the extent of Caster's Tidioute shale from Tidioute to Meadville to the Allegheny River stating (1954, p. 52):

> The writers conclude that White's Cussewago shale is synonymous with the Bedford shale and that, because the name Bedford has priority, the names Cussewago shale and Hayfield shale are invalid and may be dropped from the literature. Also, the names Cussewago limestone, Hayfield limestone, or Littles Corner limestone cannot be applied to definite rock units and may also be dropped from the literature.

Thus, contrary to the long standing dictum of Lesley (1895, p. 1779), Ohio stratigraphic terminology was once again introduced into the stratigraphic nomenclature of northwestern Pennsylvania. The work of Pepper, et al., while adequate for the section in Ohio and the Berea sandstone, leaves many questions unanswered as to the formation or formations which underlie the Corry; particularly with respect to their correlation. Greiner (1957) chose to interpret Caster freely and designated the strata underlying the Corry from Warren to Meadville, Pennsylvania simply as the Hayfield shale. The present writer feels that such oversimplifications are not acceptable. Rather than add to the uncertainty of the situation, the writer has chosen to cite the opinions of many investigators on text figure 11 in the hope that sound field and paleontological practice will ultimately solve the problem of the formations subjacent to the Corry sandstone.

The Formation Above

Regardless of the stage designation, the formation generally construed as overlying the Corry sandstone is the Orangeville shale of White (1880). Other than its constancy as a dark, fissile, olive shale its most outstanding characteristic, for the purposes of this report, is the presence of the Bartholomew siltstone member near the base, which de Witt (1951, p. 1368) considered, along with the Cussewago sandstone, "...the key to working out the stratigraphy of the lower Mississippian rocks in that area [northwestern Pennsylvania]."

The Corry Sandstone

Many generalizations have been written concerning various aspects of Corry stratigraphy. The theory of Caster (1934) and others that the Corry might be a tripartite formation is one with which the present writer is in complete accord. As such, it forms the framework of the discussion which follows as well as the basis for the construction of text figure 11. The descriptive terms used with reference to lithologic properties are mainly those of size and texture rather than chemical composition.

The basal member: - Caster's observations on the nature of the lower contact of the Corry appear to be well taken, for the unit herein designated as the Lower Corry sandstone appears to be universally gradational with the formation below.

The Lower Corry has a minimum thickness of a few inches at locations 14-S (Warren quadrangle) and 19-S (Kane quadrangle). It gradually increases in thickness southwesterly and attains a maximum thickness of ten to twelve feet in the Tionesta (location 9-S) and Oil City (location 121-P) quadrangles. North and northwest of this trend the Lower Corry appears to thin gradually and is last recognized in the vicinity of Riceville (location 94-P) in the Union City quadrangle. From Riceville to Meadville and beyond, the Corry is apparently lost by grading into the Shellhammer Hollow formation of de Witt (1951). (See text fig. 10.)

Lithologically the Lower Corry has frequently been described as a grayish-white to buff, pure grit or sandstone with more or less constant charcteristics throughout. However, this constancy is frequently interrupted (e.g. the massive nature of the lower member is not continuous throughout the entire area of outcrop). At outcrops 110-P (Titusville quadrangle) and 94-P (Union City quadrangle) the lower member is irregularly bedded in increments of twelve to eighteen inches rather than massive. (See Appendix A, text fig. A18.) The lower contact of this member has several peculiarities worthy of note.

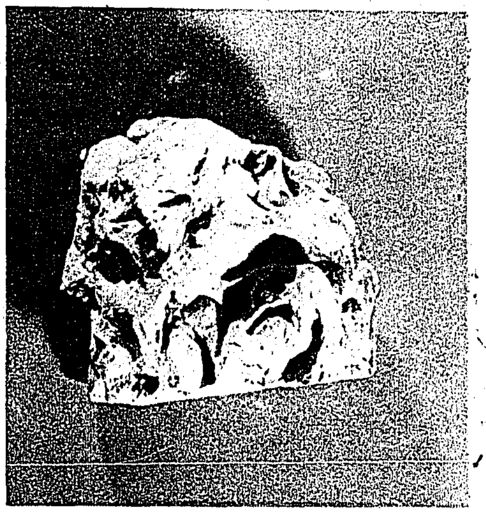
At many outcrops (see Appendix A, text figs. A8, A16) the base has either calcareous concretions at its contact with the formation below or irregularly disposed lenticular intervals which have high concentration of calcium carbonate. The concretions are non-fossiliferous and composed mainly of crystalline calcite. Upon preliminary microscopic examination the lenticular intervals proved to contain re-crystallized portions of still-recognizable shell material.

The concentration of the shell material as a constituent of the sample as a whole proved to approach 25% of the total weight when removed by treatment with hydrochloric acid. (See text fig. 13.) The resulting voids, which are actually artificially induced molds, when filled with latex, produced casts such as those made from the natural molds. This similarity suggests that the natural molds found in such profusion at many Lower Corry outcrops are the product of the removal of carbonate shell material by natural processes (e.g. solution by groundwater).

That calcite concretions may have formed from calcium carbonate derived from such an internal source is proposed by Waldschmidt. He (1941, p. 1865) suggests that diagenetic factors such as the application of increased pressure plus the decomposition of organic material resulting in the formation of carbonic acid, ammonium carbonate and other solvents would result in the solution and redeposition of organic carbonates such as shell material. Pettijohn (1957, p. 297) makes the same suggestion.

It thus appears that the carbonate concretions and the concentrations of shell material, inferred from the predominance of the molds in the Corry sandstone, have a direct relationship. The necessity of postulating an

A.



B.

Fig. 13 - Sample from the base of the Lower Corry sandstone collected at location 103-C (Corry quadrangle); the type section of the Corry. The photographs show the surface of the same sample (A) before and (B) after emersion in hydrochloric acid. Note the artificial molds created by the removal of the carbonate shell material.

outside source to account for the concretions in the Lower Corry is therefore avoided. Unfortunately, the concretions cannot be used to demark the base of the Corry for they occur in similar positions in other sandstones in northwestern Pennsylvania (e.g. the Cussewago sandstone at location 11-S).

Angular fragments of shale or siltstone are frequently found surrounded by the sand grains of the basal portion of the Lower Corry. Some appear remarkably fresh upon exposure and resemble the lithology of the strata immediately below the Corry. Twenhofel (1950, p. 301) attributes similar accumulations to the destruction of mud-crack polygons by the vigorous action of water.

At the eastern limit of Lower Corry exposures, in the Kane, Warren, and Youngsville quadrangles, the contact with the Knapp and other beds cannot be distinctly placed and, in fact, appears to be gradational. In these quadrangles the Corry, like the Knapp, contains rounded pebbles of milky quartz measuring up to 3 cm. in length and 2 cm. in width. In addition, at locality 19-S (Kane quadrangle) fragments of carbonized organic material were found along with the molds of brachiopods and other marine organisms.

Lithologically, aside from the features described above, the Lower Corry appears to represent an accumulation of detrital material, predominantly quartz, with very few varietal minerals. The grains of quartz are in general angular to sub-angular, lenticular to equidimensional, and, as determined by a few preliminary measurements, vary in average diameter from 0.072 mm at Sill Run (Warren quadrangle) to 0.070 mm at location 9-S (Tionesta quadrangle). Grains of a single specimen taken at the type section (location 103-C) in the Corry quadrangle have an average diameter of 0.057 mm. From these few measurements it appears that the average diameter of the quartz grains in the Lower Corry falls at the lowermost boundary of sand-sized particles as qualified by Wentworth (1922) and as such the member can be called a very fine grained sandstone.

More precisely, this lower member can qualify as a very fine grained orthoquartzite in the sense of Pettijohn (1957, p. 295-300) since it: (1) has at least 90% quartz; (2) contains "characteristic" molds and casts of fossils; (3) is well sorted; (4) has well rounded quartz pebbles at the base of the bed; and (5) has a great areal extent in proportion to its thickness.

<u>The middle member</u>. - The Lower Corry grades upward, almost imperceptibly, into a lithologic interval herein designated as the <u>Middle Corry siltstone member</u>. This unit is best developed in the Tionesta and Oil City Quadrangles where it attains a maximum thickness of ten

feet. To the north and northeast of these quadrangles it is only sporadically developed. Its absence may be due to non-deposition or pre-Pennsylvanian erosion but positive evidence for either possibility is lacking. To the northwest, like the lower member it is not recognizable west of Riceville in the Union City Quadrangle.

The sequence is usually gray to greenish-gray in color on fresh exposure and contains appreciable quantities of small mica crystals oriented parallel to the bedding planes. While occasional thin sequences of shale may be present, in the main the member tends to be flaggy with certain more durable layers weathered in relief. (See Appendix A, text fig. A19.) It is this sequence that White (1881, p. 92) at the type section (location 103-C) characterized as being "shattered" and unfit for construction purposes.

The Middle siltstone has generally been considered to be unfossiliferous; in a broad sense this is apparently so. However, the writer has in his possession two small faunal collections from this member, one from locality 103-C (Corry quadrangle) and the other from locality 121-P (Oil City quadrangle). The former contains spiriferoid brachiopods and the latter productids. Other faunal assemblages may be located in the course of future collecting.

The upper member. - Like the sequence below it, the Middle Corry siltstone grades into the third and uppermost member herein assigned to the Corry - the Upper sandstone member. This unit is the least persistent of the three, particularly in the northern portion of the outcrop area where it is totally absent. The Upper sandstone finds its optimum development in the Tionesta, Oil City, and Titusville quadrangles where it attains a maximum thickness of ten feet. North, east, and west of these quadrangles it thins rapidly or is missing. The Upper Corry is lithologically similar to the Lower sandstone member. As far as is known at the present this unit has not yielded a fauna. Where developed, it grades into the sequence most generally agreed to overlie it - the Orangeville shale.

The lithologic units described above were deposited in a setting which has been called the Penn-York Embayment by Caster (1935b) or Corry Bay (Pepper, et al., 1954). As reconstructed by Pepper, et al., (1954, pls. 13A-13I), the Bay existed as a coastal indentation of the Devono-Mississippian epicontinental sea. It was bordered to the north and west by the fluctuating Red Bedford delta and on the southwest by the Cussewago-Murraysville delta.

The western or seaward entrance to Corry Bay is depicted as having been closed or restricted by sand bars during Early Bedford and Berea times. Such a history would have created conditions which were alternately restrictive and non-restrictive with respect to the free flowage of marine currents and must have affected both the deposition of sediments and the life of the marine organisms in the embayment.

STRATIGRAPHIC PALEONTOLOGY

Composition Of The Fauna

Caster (1934, p. 123-124) records more than 56 separate genera of invertebrates, based upon his own collections from the Corry sandstone, and states (footnote, p. 123), "This list does not include all the forms known to exist in the Corry..." The writer's collection is somewhat less voluminous than Caster's list would indicate it might be, but a complete faunal accounting would be premature at this time. In the writer's collection, as in Caster's, the majority of the species represent the phylum Brachiopoda. The Gastropoda and Pelecypoda (as yet unstudied) form the next-most important groups with the former more conspicuous by virtue of its representation by a greater number of individuals. The Porifera are a minor faunal element but an important one. The remainder of the writer's collection consists of a single conularid, a mold of a shark (?) spine, tracks and trails, and numerous problematical markings.

Of the Porifera, species of the following genera have been recognized by the writer:

1. Clathrospongia
2. Ectenodictya Hall (1884)
3. [?] Phragmodictya Hall (1882)

Genera of the Brachiopoda recognized thus far are:

1. <u>Paraphorhynchus</u> Weller (1905)
2. <u>Syringothyris</u> Winchell (1863)
3. [?] <u>Septosyringothyris</u> Vandercammen (1955)
4. <u>Cyrtospirifer</u> Nalivkin (<u>in</u> Fredericks, 1926)
5. <u>Camarotoechia</u> Hall and Clarke (1893)
6. <u>Rhipidomella</u> Oehlert (1890)
7. <u>Schuchertella</u> Girty (1904)
8. <u>Chonetes</u> de Koninck (1842)
9. <u>Lingula</u> Bruguière (1797)

The Gastropoda appear to be represented, in part, by the following genera:

1. <u>Platycerus</u> Conrad (1840)
2. <u>Euomphalus</u> Sowerby (1814)

Only the Porifera and species of the brachiopod genera <u>Paraphorhynchus</u>, <u>Syringothyris</u>, and [?] <u>Septosyringothyris</u> (in part) have been thoroughly investigated thus far and will constitute the basis for the discussion which follows. Their areal distribution is documented on Tables 3 and 4. (<u>See</u> also text fig. 11.) Other genera are mentioned in the text to supplement the discussion but their specific identification is not to be construed as final.

Table 3. - List of the faunal elements herein described and the localities from which they were collected. Localities arranged from easternmost (right) to westernmost (left). (*See* also fig. 11, Appendix A.)

Species	Locations												
	767 CT	90 P	113 P	103 C	214 C	1565 CT	910 CT	140 C	112 C	116 C	14 S	123 C	19 S
Clathrospongia abacus Hall, 1884				x									
Ectenodictya carlli (Hall and Clarke) 1898										x			
Paraphorhynchus mediale (Simpson), 1889	x			x	x	x	x	x	x	x	x	x	
P. striatum (Simpson), 1889	x			x	x	x	x	x	x	x	x	x	x
P. girtyi Caster, 1930												x	
P. Casteri, n. sp.										x			
Syringothyris angulata Simpson, 1890		x	x							x			
S. randalli Simpson, 1890								x		x		x	x

TABLE 4. - Elements of the Corry fauna; arranged by quadrangle.

Quadrangle	Locality		
Kane	19-S		
Paraphorhynchus striatum (Simpson), 1889	x		
Syringothyris angulata Simpson, 1890	x		
Warren	123-C	14-S	116-C
Ectenodictya carlli (Hall and Clarke), 1898			x
Paraphorhynchus mediale (Simpson), 1889	x	x	x
Paraphorhynchus striatum (Simpson), 1889	x	x	x
Paraphorhynchus girtyi Caster, 1930	x		
Paraphorhynchus casteri n.sp.			x
Syringothyris angulata Simpson, 1890			x
Syringothyris randalli Simpson, 1890	x		x
Youngsville	112-C		
Paraphorhynchus mediale (Simpson), 1889	x		
Paraphorhynchus striatum (Simpson), 1889	x		

TABLE 4. - Continued

Quadrangle	Locality	
Tidioute	140-C	910-CT
Paraphorhynchus mediale (Simpson), 1889	x	x
Paraphorhynchus striatum (Simpson), 1889	x	x
Syringothyris randalli Simpson, 1890	x	

Quadrangle	Locality
Corry	103-C
Clathrospongia abacus Hall, 1884	x
Paraphorhynchus mediale (Simpson), 1889	x
Paraphorhynchus striatum (Simpson), 1889	x

Quadrangle	Locality		
Titusville	1565-CT	214-C	113-P
Paraphorhynchus mediale (Simpson), 1889	x	x	
Paraphorhynchus striatum (Simpson), 1889	x	x	
Syringothyris angulata Simpson, 1890			x

TABLE 4. - Continued

Quadrangle	Locality
Union City	767-CT
Paraphorhynchus mediale (Simpson), 1889	x
Paraphorhynchus striatum (Simpson), 1889	x
Townville	90-P
Syringothyris angulata	x

Distribution Of The Fauna

The base of the Lower member of the Corry appears to represent the habitat of what was a thriving diversified invertebrate community. The distribution of the fauna within the member is sporatic and appears to have both areal and vertical limitations. Good faunal assemblages seem to be limited to the lower four feet of the member, with the most prolific accumulations within a foot of the lower contact.

Porifera: - The sponges are few in number and rather widely dispersed; single specimens of each of three genera having been recorded from the Warren (location 116-C), Corry (103-C), and Oil City (location 68-C) quadrangles. Only specimens from the first two locations have been positively identified. As will be shown, it is the paucity of numbers and morphological features rather than locality which contribute to the importance of the sponges in the Corry sandstone.

Brachiopoda: - Four species of the genus *Paraphorhynchus* Weller (1905) and two of *Syringothyris* Winchell (1863) are discussed in detail in the section on systematic paleontology. Two of the four paraphorhynchoid species, *P. mediale* (Simpson) and *P. striatum* (Simpson), appear to have the same areal distribution, but the former was apparently the more prolific. *P. girtyi* Caster and *P. casteri* n.sp. are not only severely limited in numbers, with only a total of four specimens of the two species recorded thus far, but also appear to have been limited to the eastern portion of the area under investigation.

The syringothyroids exibit an equally interesting distribution. The ranges of the species of *Syringothyris*, *sensu stricto*, overlap, but the species themselves exibit differences other than morphological ones. Specimens of *S. randalli* Simpson far outnumber those of *S. angulata* Simpson, of which only four are in the writer's possession. *S. randalli* appears to be confined to the eastern portion of the area of investigation, while *S. angulata* is represented at both its eastern and western extremities.

Numerous specimens of syringothyroids, herein tentatively referred to the genus *Septosyringothyris* Vandercammen (1955), for reasons discussed under systematic paleontology, occur along with both *S. angulata* Simpson and *S. randalli* Simpson. It is quite possible that these syringothyroids, with a syrinx supported by a median septum, will prove to be of great stratigraphic value for correlative purposes.

Gastropoda: - The gastropods have yet to be studied by the writer. However, certain significant distribution patterns emerged when the locations of the specimens of this faunal element were being recorded. From the writer's observations certain genera seem to have flourished in limited areas. Species of the genus Platyceras Conrad (1840) appear to be the dominant representatives of the Gastropoda at locality 116-C (Warren quadrangle), while the genus Euomphalus Sowerby (1814) is superior in numbers at locality 140-C (Tidioute quadrangle). This differentiation may have ecological significance.

Ecological Implications

Porifera: - De Laubenfels (1936, p. 54) ends his discussion of factors involved in studying the paleoecology of sponges with the statement, "It appears that in the past Porifera occurred in much the same environments as at present, and led similar lives." Disregarding, for the moment, that both Hutton's dogma and our concept of environmental critera have been altered by modern oceanographic research, a few of de Laubenfels' predications may be helpful in understanding the interrelationships between the sponges and their environment during Corry time. Some of the criteria of de Laubenfels (1936, p. 44-54) and the relationships observed by the writer and other workers compare as follows:

De Laubenfels (1936, p. 44):

> ...wherever fossil sponges occur there was probably a large island or continent within a few hundred kilometers.

It is the opinion of Caster (1934/1939) and others that the "Catskill Delta" was slowly building westward from a land mass to the east of the area under study, during Devono-Mississippian time.

De Laubenfels (1936, p. 46):

> ...the finer the particles in question, the fewer are the sponges that occur [the inhalent openings become clogged].

The grains of the constituent minerals of the Lower Corry, in which the sponges occur, have previously been cited as approaching silt size. This could account for the small number of sponges found in the Lower member. The subsequent changes to the finer, true silts of the Middle member might be responsible for their absence in the Middle and Upper members of the Corry.

De Laubenfels (1936, p. 49):

> ...one may...state with considerable confidence that the occurrence of fossil hexactinellid sponges [which concern us here] indicates that their horizon had been characterized by darkness [and concomitantly great depth].

The above statement is subject to a variance of opinion since some sponges exibit remarkable adaptive capabilities. De Laubenfels (*op. cit.*, p. 48) cites the case of *Acarnus erithacus* (Demospongiae) which normally occurs in zones of good illumination but which has been reported from depths of 700 meters off of the California coast. Clarke (1920, p. 36) cites the migration of the Dictyosponges, "...into the shallow and cool waters of the Chemung...", where he presumed they evolved further and subsequently migrated again into deeper waters during the Mississippian. Caster (1939, p. 18, text fig. 7) has effectively shown that the "glass sponges" not only could, but did thrive in near-shore environments. (See text fig. 14 below.)

In addition, certain sponges of the Corry were apparently capable of inducing morphological variation to cope with a changing environment. Such appears to be the case with Ectenodictya carlli Hall which was discovered to have developed, in addition to double rows of strands in the horizontal component of the primary reticulum, a series of diagonal strands in the constricted area below the mesial bulge. (See pl. 1, fig. 3.) Such devices are construed by the writer as structural in nature, designed to support the distal portion of the cup, expanding to minimize the suffocating effects of the encroaching fine sediment; or possibly as bracing to combat the effects of strong currents. In essence, the sponges could have been: (1) limited in number by the nature of the sediment; (2) capable of morphological variation, within limits, to cope with environmental change; (3) inhabitants of relatively "shallow water"; (4) unable to cope with the silts-

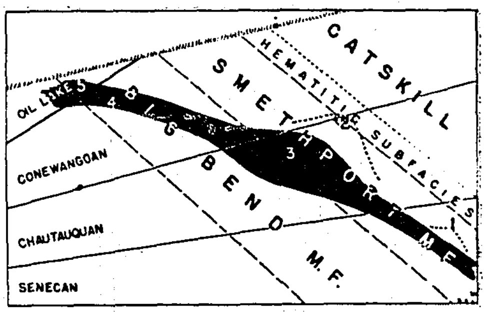


Fig. 14. - Highly generalized facieological distribution chart of the Upper Devonian and Lower Mississippian siliceous sponges in the Penn-York Embayment, with special reference to forms discussed in this paper. The large sigmoidal lens shows the major environmental distribution; the dotted line indicates the general limits of the aberrant forms herein described in relation to the axis. To be sure, there were since very ancient times siliceous sponges in considerably more seaward facies than here shown, but during the time here indicated they appear to have been very scarce in the Embayment; at least they are not well known. 1, Occurrence of *Ithacadictya cornelli* Caster in the near-shore subfacies of the Smethport magnafacies. 2, The unusual environment of *Corticospongia bradfordensis* in the marine hematitic subfacies of the Catskill magnafacies. 3, Zone of maximum development of the Dictyospongiidae in the Embayment. 4, The uppermost Devonian occurrences of dictyosponges in the Warren County area of Pennsylvania. 5, Western Pennsylvania and eastern Ohio occurrences of siliceous sponges in the "Waverlyan," including *Titusvillia drakei*, *Calathospongia tidioutensis* and *C. carceralis*. Facieology from Caster, 1934, 1938. (Reproduced in its entirety from Caster, 1939, fig. 7.)

after Lower Corry time and eliminated from the remainder of the sequence by extinction or migration.

Brachiopoda: - Greiner (1957, p. 40-43), citing Cooper (1937) and others, lists the following morphological traits of brachiopods as possible representative adjustments to specific environmental conditions:

1. Heavy shells; suggest habitat as near-shore or sublittoral zone (characterized by coarse sandstones or conglomerates).
2. Median fold; facilitates ingress and egress of water currents that aerate the mantle and bring in food.
3. Plication; increases shell strength under arduous conditions.
4. Strong muscles; indicate a habitat characterized by strong wave and current action.

The species of Paraphorhynchus Weller (1905) all share in common: (1) well developed folds and sulci; (2) costellated plicae on the entire surface of both (?) valves; (3) evidence of relatively large pedicles, via a sizeable foramen in the pedicle valves; (4) large diductor muscle scars; and (5) the development of additional muscles of closure (the "posterior adductor process"). The development of such features can be interpreted as an attempt to compensate for the inability of weak dentition and fragile tissue to cope with arduous living conditions. If such is the case, it should be possible to discern the relative severity of such conditions, areally, by examining the distribution and characteristics of individual brachiopod species. (See Table 3 and test fig. 11.)

Paraphorhynchus mediale (Simpson) and P. striatum (Simpson) are widely dispersed sympatric species and exibit only a modest development of surface ornamentation (see pls. 4, 5). P. girtyi Caster and P. casteri n. sp. appear to be ecotypic and restricted to the easternmost area of outcrop (Warren quadrangle). They are characterized by the development of coarse plicae and carinae and crenulate diductor muscle scars in the pedicle valve. The heavy ornamentation and musclature must indicate an environment closer to the shore line and more violent than that occupied by species to the west. This relationship appears to be substantiated by similar phenomena in other genera.

Syringothyris angulata Simpson, while represented by a few specimens, is a widely dispersed form. Syringothyris randalli, represented by many individuals, is confined to the easternmost areas of outcrop (see Table 3); it has two sets of striae on the diductor muscle scar of the pedicle valve as opposed to the single set borne by S. angulata. Further, S. randalli has heavy deposits of secondary callist material in the delthyrium, rostral and lateral cavities, as though an attempt were made to achieve stability in a turbulent sea.

All these adjustments by brachiopod species, apparently confined to the easternmost area of outcrop, indicate that this area was probably within the zone of wave-base activity, frequently disrupted by storms, tides and strong currents; perhaps at the junction of the littoral and neritic zones.

Gastropoda: - While the easternmost area of outcrop may represent a tumultuous marine environment it seems to have been one which offered all the ingredients necessary for the propagation of vast populations. Location 116-C (Sill Run, Warren quadrangle) appears to have been a most favored location, reminiscent of a modern reef. With few exceptions, almost all of the genera and species (brachiopods in particular) in the writer's collection are represented here.

At this locality the genus Platyceras Conrad (1840) is the dominant representative of the Gastropoda. This association of brachiopods and gastropods was at first perplexing. However, the subsequent discovery of what appears to be a boring in a brachiopod mold made by a gastropod radula suggests that this relationship is not coincidental. It appears that the platycerids were carniverous, perhaps preying on certain species of Brachiopoda.

The Corry may offer a unique opportunity for the study of the relationships between the organisms themselves as well as between the organisms and their environment.

Possible Origins Of The Fauna

Girty (1905, p. 6) stated, "The supposed equivalent of the Berea grit in northwestern Pennsylvania contains a fauna which is without question of a Mississippian type,...;" the source and nature of the fauna were not discussed. Weller (1905) differentiated a northern from a southern Kinderhookian fauna in the mid-continent region stating (op. cit., p. 634):

> During earlier Kinderhookian time these two faunas were restricted, one to the more northern, the other to the more southern region, and the two provinces were separated by some barrier, doubtless a land barrier. Near the close of the Kinderhookian epoch, the barrier separating the two provinces was removed, and the fauna from the south migrated into the northern province... With the removal of the barrier, however, the northern fauna did not make any headway into the southern province.

It is interesting to note that both of Weller's faunas contain species of the brachiopod genera herein described (e.g. *Paraphorhynchus transversum* Weller and *Syringothyris extensus* Hall).

Schuchert (1910, p. 223-224) postulated a dual origin for the syringothyroids as follows:

> Syringothyris therefore originated in the Cordilleran sea during the later Devonian [?] and not in the Atlantic province as the writer heretofore held, but it was not a conspicuous member of any fauna until Mississippian time. The genus is then present in most of the formations from the early Kinderhook to the Keokuk, and it persists even into the Spergen of the Meramecian series. At no time, however, was there more than one species in a fauna and all these are very much alike [?].
>
> Another phylum [?] originated in the Atlantic realm of the Appalachian province in Spirifer randalli [= Syringothyris randalli Simpson], which also has a well developed syrinx, but differs from Syringothyris of the Mississippian sea in having a strongly plicated fold and sinus. This stock must be separated generically from those of the Mississippian sea because of its different phyletic derivation,...

Girty (1911) effectively refuted Schuchert's thesis of a separate derivation for syringothyroids with a plicate fold and sulcus but did not comment specifically on the Cordilleran origin of the mid-continent representatives of the group.

Williams (1943) suggests that the fauna of the Louisiana limestone of Missouri (which he considers to be Kinderhookian in age) resembles that of the Hamilton (Middle Devonian) of the eastern United States rather than the Upper Devonian faunas of the mid-continent region. To substantiate this contention he lists a number of Hamilton brachiopod genera which duplicate those previously listed above as Corry forms (e.g. Rhipidomella, Schuchertella, and Camarotoechia). Citing the fauna of the Cleveland and Bedford shales of Ohio as indicative of a migratory path from the east, Williams (1943, p. 49) remarked that, "...the presence of the rare genus Paraphorhynchus in the Berea (Corry) sandstone of Pennsylvania suggest either that there was communication between the Louisiana area and these areas [Ohio, Indiana, and Illinois] as late as in early Waverly time or that the faunas were derived from a common source."

The opinions above are too diverse to warrant further comment in the course of a localized study such as that undertaken here. However, in the course of the preparation necessary for the descriptive text on systematic paleontology certain faunal distribution patterns emerged which may be significant for future work concerning the Corry. At present there appear to be three distinct faunal elements within the Lower Corry, each exibiting a slightly different origin and/or evolutionary history.

The Dictyospongiidae represent a slowly evolving group, apparently indigenous to the Appalachian province, which reached its climax during the Upper Devonian; some species appear to have become extinct during Lower Corry time. Clarke (1920, p. 36-37) has traced their evolution from the Silurian through the Mississippian and attributes their ultimate westward migration during the latter period to (*op. cit.*, p. 36),"...an incursion of fresh waters which flooded the Devonian province with gravel from eastern lands."

Caster (1939) has recorded the facieological preferences of a number of species of the dictyosponges and depicted their migratory shifts with respect to the westward migration of magnafacies boundaries (<u>see</u> text fig. 14). Unfortunately the distribution and identification of the dictyosponges in the Mississippian strata west of Pennsylvania is not well recorded.

The Brachiopoda studied thus far appear to be divisible into two elements - one foreign and the other native to the Penn-York Embayment. The paraphorhynchoids represent the exotic element; they have not been reported in the Embayment either above or below the Lower Corry sandstone. Their total absence in the Knapp and sudden appearance in the Lower Corry would appear to discount the possibility that the genus is diphyletic.

Species of the genus <u>Paraphorhynchus</u> Weller (1905) are reported in North America, in addition to those of the Penn-York Embayment, only from Lower Mississippian (Kinderhookian) strata of Illinois, Iowa, and Missouri. Some of the formations involved (<u>e</u>.<u>g</u>. the Louisiana limestone of Missouri) had formerly been placed in the Upper Devonian but subsequent workers have established their age as Lower Mississippian. Consequently, *Paraphorhynchus* has become an excellent index fossil of the Lower Mississippian where reported in North America.

Outside of North America this distinction does not hold. Nalivkin (1937) and Simorin (1956) have described species of the genus from the Famennian (Upper Devonian) as well as the Lower Mississippian beds of Kazakhstan and the Karagandin Basin of south-central Asia (*see* text fig. 22). Although such far-flung occurrences are admittedly tenuous it appears that the paraphorhynchoids originated in south-central Asia and subsequently migrated into North America.

The syringothyroids appear to represent an element derived from antecedent spiriferoid stock in the Penn-York Embayment. They are reported by Holland (1958) from the Lower Mississippian Knapp but not from the underlying Upper Devonian Oswayo formation. Their initial appearance in the Lower Mississippian formations of North America marks the group as excellent guide fossils of Lower Mississippian time.

The reported initial occurrence of species of the genus *Syringothyris* in Upper Tournaisian beds of Australia by Maxwell (1954, p. 41) and in the Middle Tournaisian formations of the Karagandin Basin by Simorin (1956, Table 2) may lend credence to the North American origin and subsequent migration of the genus as supposed by Termier and Termier (1949).

Maxwell (1954, p. 7, Map 1) has shown supposed late Paleozoic faunal migration routes effecting the northern hemisphere and Australia. By coincidence, these routes could mark the migratory path of the paraphorhynchoids into North America during Devono-Mississippian time and the exit routes of the syringothyroids from North America during Mississippian time. Maxwell's map is reproduced below.

Age And Correlation

The Mississippian (Kinderhookian) age of the Corry sandstone has been reiterated many times since White first named the formation in 1881. The faunal elements studied herein do but affirm this assignment. It is the relationship of the Corry with beds of equivalent age to the west of Pennsylvania, not its age, which remains problematical.

Correlations to date have depended largely on lithology or stratigraphic position since the intended correlative, the Berea sandstone of Ohio, is markedly unfossiliferous. Rather than argue the merits of the relationships already suggested the writer prefers to hold the question of absolute correlation in abeyance and discuss instead the possible avenues of investigation.

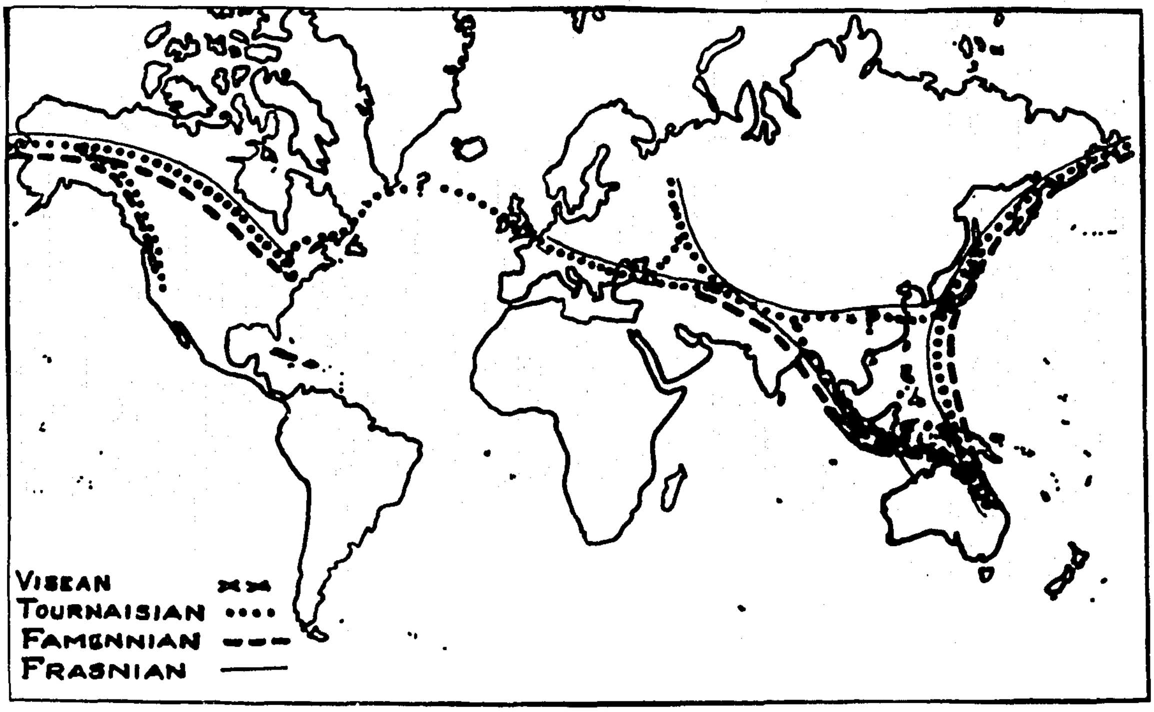


Fig. 15. - Faunal migration routes of the late Paleozoic. (Reproduced from Maxwell, 1954, p. 7, Map 1.)

Correlation A: - This would involve a direct Berea-Corry relationship of variations between a single or tripartite Berea sandstone with a single or tripartite Corry. The relationships would, of necessity, be based on lithology and stratigraphic position. Such correlations have been discussed previously (see text fig. 8).

Correlation B: - In 1951 de Witt suggested that the Bedford shale of Ohio and the Corry sandstone of northwestern Pennsylvania merged into a siltstone sequence called the Shellhammer Hollow formation in the vicinity of Meadville, Pennsylvania. (See text fig. 10.) A shallow strait was presumed to exist in the Meadville area during much of Corry time.

In discussing the paleogeography of late Bedford time Pepper, et al., (1954, p. 104) state, "In the eastern part of Corry Bay the lowest beds of the Corry sandstone were being deposited. In the subsequent chronology of Berea paleogeography the strait at the entrance to Corry Bay (op cit., pls. 13E-13H) is shown as being closed during early Berea time and open during middle and late Berea time. Such a series of events suggests that the Lower fossiliferous member of the Corry could correlate with a portion of the Bedford shale. The Middle siltstone member would relate to the slight interruption between Bedford-Berea deposition, the closure of the strait during early Berea time, or both.

The Upper Corry sandstone member and the Berea proper would then be temporal equivalents with the strait between the epicontinental sea and Corry Bay being open. In this way the paleogeographic interpretations of Pepper, et al., (1954) and the extant lithologic units might correspond, in that median siltstone of the Corry could relate to the gradual closure of the strait and the restriction of the waters in Corry Bay. The Upper and Lower Corry sandstones would represent times when the strait was open and Corry Bay swept by marine currents of the epicontinental sea to the west.

These relationships are admittedly arbitrary and must be substantiated by other means if their validity is to be ascertained. Further exploration of the problem must involve the biologic factors. This particular facet of the problem has always presented difficulties because of the relatively unfossiliferous nature of the Berea sandstone. In addition to plant fragments, de Witt (1958, personal communication) reports an assemblage of small pelecypods in the upper five feet of the Berea at Kinsman, Ohio. This distribution is what might be expected if the statement of Pepper, et al., (1954, p. 1) that, "The Berea sandstone was deposited above the Bedford shale, at first subaerially as a delta and later as a marine pavement that formed as the sea inundated this delta," is to be accepted. Briefly, the circumstances of its deposition do not warrent any expectation of finding a large marine fauna in the Berea sandstone.

Caster (1943, p. 161-162) has, from various sources, listed the components of the Bedford fauna which he (Caster) believes to consist of a minor Hamilton (Middle Devonian) element and a major Mississippian element. The Mississippian aspect of the Bedford fauna, he believes, had a common heritage with the fauna of the Knapp. Caster (1934, p. 163) concluded:

> The Bedford Syringothyris "carteri" is very closely related to the forms occurring in the Knapp monothem, and quite indistinguishable from species occurring in the Corry sandstone. The Bedford forms seem clearly to be of the Mississippian type, and more specifically, of lower Kinderhookian age.

The study of the Lower Corry fauna initiated herein does not as yet provide a sufficient basis for definitive correlation. The Porifera, known to exist in the Bedford, are not adequately described for comparison with those of the Corry. Paraphorhynchoids are as yet unreported from the Bedford. The syringothyroids described herein compare favorably with those of the Knapp and will perhaps prove to be equally comparable with those of the Bedford, as Caster has intimated. Other faunal elements of the Bedford and Corry must be studied and compared. This faunal comparison must be effected by the study of accurately zoned topotype material. It should be noted that the Bedford has a faunal zone not only at its base but also near its upper limit according to de Witt (1958, personal communication) who noted the zone in the vicinity of Kinsman, Ohio.

If the Lower Corry and comparable Bedford faunas are found to be intimately related the following theories would appear to supplement each other:

1. William's (1943) suggestion that the fauna of the Louisiana limestone of Missouri and the Corry sandstone of Pennsylvania either stemmed from a common source or were related by way of migratory routes represented by the Cleveland and Bedford shales of Ohio.
2. De Witt's (1951) proposed coalesence of the Bedford and the Corry into the Shellhammer Hollow formation.
3. The paleogeographic interpretations of Pepper, *et al.*, (1954) and their proposed simultaneous deposition of the Lower Corry and the Upper Bedford.
4. The similarity between Bedford and Lower Corry syringothyroids noted by Caster (1934) and his supposition that the Bedford represents a westerly subneritic zone of the Penn-York Embayment.

Correlation C: - There are in the Lower Corry and the Knapp syringothyroids with a syrinx supported by a median septum; Holland (1958) has referred the Knapp forms to the genus _Syringopleura_ Schuchert (1910). The writer has rejected the assignment of the septate syringothyroids to this genus for reasons discussed herein under systematic paleontology. Regardless of the difference of opinion on the genus to which the species belong, the specimens from the Knapp and Corry compare favorably.

Schuchert (1890, p. 11) erected the species _Syringothyris herricki_ for specimens, described previously as _Syringothyris cuspidatus_ by Herrick in 1888, which exibit a syrinx supported by a median septum. Hyde (1953, p. 277) suggested that the median septum in this species is a variable feature and not particularly diagnostic. All of the specimens described by the authors cited above appear to have come from the Byer sandstone member of the Logan formation which lies some 250 feet above the Berea. If the septate forms in the Byer should be found equivalent to those in the Knapp and Corry, it might be argued that the three formations were related - particularly if other faunal elements were also found to correspond. The Corry would thus correlate with beds younger than the Berea.

Of the three possible alternate correlations, the second (B), appears to be the most promising. It must be emphasized that the final proof of any proposed correlation of the Corry sandstone will lie in careful studies of the paleontology and sedimentology of the formations involved.

SUMMARY AND CONCLUSIONS

During the Lower Mississippian (Kinderhookian) epoch a portion of what is now northwestern Pennsylvania was apparently occupied by an embayment of the epicontinental sea which lay to the west. According to Pepper, et al., (1954) this "Corry Bay" was bordered to the northwest by the Bedford-Berea delta and to the southwest by the Cussewago-Murrysville delta. At its westernmost extremity the embayment was intermittently cut-off from the sea beyond by the closure of an unnamed strait.

The sediments in the embayment subjacent to the Corry sandstone (Knapp, et seq.) reflect the westward encroachment of the magnafacies boundaries defined by Caster (1934) and re-affirmed by Holland (1958). For reasons not well understood, the Corry sediments do not reflect similar lateral facieological changes except at the extreme margins of the area of outcrop.

The gradational nature of the contact of the basal Corry sandstone with the subjacent beds suggests that there was little, if any, interruption between the deposition of the sediments of underlying formations and those of the Corry. Pepper, et al., (1954) proposed a northeastern source for the Corry sediments (see text fig. 9). The quartz grains of the basal Corry approach, but do not attain, particle sizes which are termed "silt." The small sized grains may indicate a remote primary source of sediment or an adjacent secondary source reflecting more than one cycle of sedimentation.

The fauna is confined largely to the Lower member of the Corry and appears to contain elements of at least three distinct origins.

The "glass sponges" represent a group which, according to Clarke (1920), had its origins in the early Paleozoic of the Appalachian province. Their limited representation in the Corry sandstone is probably due to unfavorable environmental factors. That some species did manage to adjust themselves is evidenced by the increased structural supports of the outer reticulum of *Ectenodictya carlli* Hall. The record of the westward (?) migration of the surviving forms is not well documented, but species of the genus *Ectenodictya* Hall have been reported from the Keokuk beds at Crawfordsville, Indiana.

The Brachiopoda are divisible into two distinct groups, one foreign and the other native to the Corry embayment. The paraphorhynchoids appear to have originated during the Famennian in south-central Asia and subsequently migrated to the eastern North American continent during Lower Kinderhookian time by way of the mid-continent area.

Two species, _Paraphorhynchus_ _mediale_ (Simpson) and _P._ _striatum_ (Simpson), are equitably distributed within the Lower Corry wherever a distinct fauna can be recognized. Contrarily, _Paraphorhynchus_ _girtyi_ Caster and _P._ _casteri_ n. sp. are found only in the eastern area of outcrop. Their coarse plicae, strong concentric carinae and rugose muscle scars are interpreted as adjustments to a tumultuous existence in a near-shore environment. Since species of the genus are not reported from the Knapp and did not survive Lower Corry time they are considered good indices of the Corry. Whether the extinction of the genus was due to its inability to compete with others occupying the same ecological niche or some other cause is not apparent.

The syringothyroids represent the element indigenous to the embayment, for the Corry and Knapp species studied thus far are identical. The group is believed to have originated from Middle Devonian spiriferoids but their migratory history and evolution prior to Mississippian time is not well documented.

The species of *Syringothyris* Winchell, s.s., are irregularly distributed in the Lower Corry. *Syringothyris randalli* Simpson is more prolific but appears to be restricted to the eastern area of outcrop. Several species of as-yet-unnamed septate syringothyroids coexist with both *S. angulata* and *S. randalli*.

The restriction of the more rugose brachiopod species to the eastern area of outcrop and the concomitant inclusion of rounded pebbles in the same sequence is interpreted as indicative of near-shore conditions. This environment appears to have been suited for the establishment of large populations for it is in this area (Warren quadrangle and vicinity) that the largest faunal assemblages are found. The concentration of particular gastropod species in this well populated area is considered to represent an association which existed in life.

The Lower Corry sandstone grades into the silts of the Middle Corry member. The change in the nature of the sediment may be associated with the gradual closure of the western strait postulated by Pepper, *et al.*, (1954); other explanations for this change are also possible. Whatever the mechanism, with the change, the fauna of the Lower Corry either perished (paraphorhynchoids) or gradually migrated (syringothyroids) as the silts gradually accrued. A few productids and cyrtospirifers apparently survived in the new environment.

The Middle Corry siltstone grades into the sandstone of the Upper Corry member which has yet to yield a fauna. The Upper member, in turn, grades into the overlying Orangeville shale. The record of the Upper and Middle Corry members in the eastern area of outcrop has been obliterated by pre-Pennsylvania or post-Paleozoic erosion.

It is suggested that the Lower Corry member may correlate, in part, with the upper portion of the Bedford shale of Ohio rather than with the Berea sandstone as has previously been supposed. Such a correlation appears to integrate the hitherto unrelated theories of other workers who have dealt with the formations in question. Only a careful systematic and stratigraphic study of the Corry and Bedford faunas will invalidate or support this suggestion.

SYSTEMATIC PALEONTOLOGY

Source and nature of collection: - The fauna here described was in part collected by the writer in northwestern Pennsylvania during the summers of 1957 and 1958. The remainder of the specimens were donated by Dr. K. E. Caster to the University of Cincinnati Museum.

With few exceptions, the specimens studied were natural internal and external molds presumably caused by the solution of the original or subsequently recrystallized carbonate shell material; all are from the Corry sandstone unless otherwise indicated.

Preparation of specimens: - It was determined that the nature of the finer morphological features of the fossils could be most readily discerned through the preparation of artificial casts. The casts were made from black, liquid, water soluble, pre-vulcanized, latex emulsion; commercially obtainable as "Permaweld" from the Polymer Chemical Company, Cincinnati 12, Ohio.

After some experimentation, the latex casts were successfully made in the following manner: The surface of the specimen was first dampened with a liquid detergent (Kodak photo-Flo) to serve as a wetting agent and facilitate the removal of the finished cast from the mold. Two initial coats of very thin latex were applied to the surface of the dampened mold with a fine brush. After each application of the initial coats the latex, while still wet, was blown with compressed air. (This technique eliminated air bubbles and forced the latex into the deeper recesses of the mold.) Subsequent coats of increased viscosity were applied by brush, in 24 hour increments, until a total thickness of approximately 1/8 to 1/4 inch was achieved.

In some instances it was necessary to give the cast additional support. For the internal features of Brachiopods (e.g., syrinx or dental support plates) the depression in the mold was filled, in part, with thin slivers of balsa wood moistened in liquid latex. The "filler" was installed subsequent to the first two thin coats and prior to the application of the more viscous layers. The outside of the cast was occasionally reinforced by the application of latex-saturated medicinal cotton or gauze along with the final coat.

Prior to microscopic study or photographic reproduction both casts and molds were coated with a patina of sublimated ammonium chloride to further emphasize the details of the morphology.

Paleontologic plates: - All plates illustrating described or identified species were prepared in the conventional manner (i.e., illuminated from the upper left side, etc). The photographs are approximately natural size unless otherwise indicated.

<u>Locations</u>: - The collecting site for each individual specimen used to describe or identify a species is designated by a numbering system defined in Tables 1 and A-1. In addition, the sites are plotted, along with other pertinent information, on a series of United States Geological Survey topographic maps reproduced (approximately x ¼) in Appendix A.

<u>Types</u>: - The types for each species described or identified herein are accessioned and stored with the collections of the University of Cincinnati Museum, Dept. of Geology, Cincinnati 21, Ohio. All accession numbers of the above named repository are preceded by the designation - UCM. Types, stored elsewhere, are so designated whenever practical.

<u>Taxonomy</u>: - All taxonomic decisions are made in accordance with the International Rules of Zoological Nomenclature - as emended and modified by the Fourteenth International Congress of Zoology at Copenhagen, Denmark in August, 1953. The term Règles will designate the above named authority when, for the purposes of this paper, reference is necessary for the clarification or explanation of a particular point of taxonomy.

Phylum Porifera

Recent publications and textbooks reflect the general disagreement among diverse authors with respect to the classification of both fossil and living Porifera. The lack of solidarity is particularly noticable in the higher taxa where a division exists not only among paleontologists but also between paleontologists and neontologists. Despite the objections of King (1943) and others, the classification employed herein for the higher taxa is that of de Laubenfels (1955) which is well documented in a previous publication (<u>see</u> de Laubenfels, 1936).

Most of de Laubenfels' proposed changes, particularly with respect to the "glass sponges", appear to be in accord with the International Code of Zoological Nomenclature and are long-overdue applications of the Law of Priority. Further, de Laubenfels' subdivisions of the fossil Hyalospongia into orders which approximate those of living forms is a commendable effort to resolve the differences between paleontologist and neontologist.

The general accord of the present writer with the classification proposed by de Laubenfels (1955) extends to, but does not include, the subfamilial rank. The subdivision of the family Dictyospongiidae into subfamilies based upon the presence or absence of the prismatic form appears to be too artificial. Clarke (1918, p. 180) emphasized the gradational nature of external form in the "glass sponges." Citing the external structural features of *Hydnoceras walcotti* he (Clarke, *loc. cit.*) demonstrated the existence of all four basic structural patterns (obcone, prism, node, and ring) in a single individual. Until the nature of the relationships between the "glass sponges" is better understood it seems prudent to employ the subfamilial designations of Hall and Clarke (1898) for the purposes of this report.

Phylum PORIFERA Grant, 1872

Class HYALOSPONGEA Vosmaer, 1886

[nom. correct. de Laubenfels, 1955 (ex Hyalospongiae Vosmaer, 1886)] [= Hexactinellida Sollas, 1887]

Order LYSSAKIDA Zittel, 1877

[nom. correct. de Laubenfels, 1955 (ex Lyssakina Zittel, 1877)]

Family DICTYOSPONGIIDAE Hall, 1882

[nom. transl. de Laubenfels, 1955 (ex Dictyospongidae Zittel - Eastman, 1913, ex Dictyospongiae Hall, 1882)]

Subfamily DICTYOSPONGIINAE Hall and Clarke, 1898

Genus Clathrospongia Hall, 1884

1863 Dictyophyton Hall, James [pars], New York State Cab. Nat. Hist., 16th Ann. Rept., p. 87; p. 90, pl. 3, fig. 4 [non p. 90, pl. 5, fig. 3 (Thysanodictya)].

1883 Clathrospongia Hall, J. [nomen nudum], [title only], American Assoc. Adv. Sci., Proceedings (1882), vol. 31, p. 419.

1884 Dictyophyton (Clathrospongia) Hall, J. New York State Mus. Nat. Hist., 35th Ann. Rept., p. 466; p. 474, pl. (18) 19, figs. 2-4.

1890 Dictyophyton, Hall, J., New York State Geologist, 9th Ann. Rept., p. 57-88.

1898 Clathrospongia, Hall, J. and Clarke, J. M., New York State Mus., Mem. 2, p. 121-122.

1955 [non] Clathrospongia Hall, J. and Clarke, J. M. Laubenfels, M. W. de, Treatise on Invertebrate Paleontology, edited by Moore, R. C., pt. E (Archaeocyatha and Porifera), p. E 74.

TYPE SPECIES (by original monotypic designation): Dictyophyton (Clathrospongia) abacus Hall, James, New York State Mus. Nat. Hist., 35th Ann. Rept., p. 478, pl. (18) 19, figs. 2-4, 1884. Waverly group (Mississippian) at Warren, Pennsylvania (i. e. Knapp or Corry formation in modern terminology). (Beds of the Waverly group do not occur within the city limits of Warren but their remnants are found to the south and east of Warren; see Appendix A, pl. A-1.)

The following remarks on the genus Clathrospongia are taken from Hall and Clarke (1898, p. 121-122):

> REMARKS: This term [Clathrospongia] was introduced without definition and was intended to cover, in a subgeneric sense, the species Dictyophyton abacus, Hall, which represents a strong development of the erect reticulating surface lamellae such as also occur in the genus Thysanodictya. Unlike the species of the latter genus, however, the form of the cup is regularly obconical, and it appears to terminate below in an acute point. There is still some uncertainty in regard to this character, but nevertheless the differences in the form of the cups, and the characters of their earlier

growth are evident. It has been found necessary in consideration of a number of different species where imperfect preservation has precluded definite knowledge of the basal structure, to refer to this genus some forms which, when better known, may prove to belong in some other association. Indeed, in the type-species only are the generic features clearly defined, and hence the group must for the time being serve in a measure as a convenient receptacle for certain imperfectly known forms.

Clathrospongia abacus Hall, 1884

Plate 1, figures 1-2; text figure 16.

1883 Clathrospongia abacus Hall, James [nomen nudum], [title only], American Assoc. Adv. Sci., Proceedings (1882), vol. 31, p. 419.

1884 Dictyophyton (Clathrospongia) abacus Hall, J., New York State Mus. Nat. Hist., 35th Ann. Rept., p. 474, pl. (18) 19, figs. 2-4.

1898 Clathrospongia abacus, Hall, J. and Clarke, J. M., New York State Mus., Mem. 2, p. 153, pl. 49, figs. 5-8.

1930 Clathrospongia abacus, Caster, K. E., Bull. American Paleontology, vol. 15 (No. 58), p. 238, pl. 73, figs. 1-3.

1934 Clathrospongia abacus, Laubenfels, M. W. de, Treatise on Invertebrate Paleontology, edited by Moore, R. C., pt. E (Archaeocyatha and Porifera), p. E 74, fig. 56,2.

SPECIMENS: The information which follows is based upon a single natural mold of the interior and a latex cast derived therefrom.

DESCRIPTION: The sponge is medium sized and turbinate in shape. From an acute (?) base, expansion to the aperture was probably rapid but weathering has destroyed those portions of the cup necessary for detailed description. The nature of the megaloscleres is nowhere apparent and is presumed to have been modifications of triaxons characteristically assigned to this group. Dermal spicules and microscleres could not be distinguished.

The prominent longitudinal and transverse spicular strands of the primary reticulum intersect normally at regular intervals and form quadrules which consistantly approximate 9 mm. in length and width. The bands themselves, in life, were extended outwardly into free horizontal and vertical projections giving the exterior a fenestrate appearance. According to Hall and Clarke (1898, p. 153) the fenestrations are subdivided into smaller areoles by subordinate reticulating bands but the weathered surface of the specimen under discussion does not show this characteristic.

Fortuitous preservation (see pl. 1, fig. 2) reveals the existance of a thicker mesoglea than has heretofore been ascribed to this species; the flattened, silt filled, region approximate 3 mm. in thickness. Superimposed upon the interior of this region is the impression of a reasonably well ordered paragastric reticulum with primary quadrules approximating 8 mm. in lenth and 5 mm. in width. The primary quadrules are subdivided into meres of the second order. Whether or not the subdivisions of the paragastric reticulum are directly responsible for the subdivisions of the primary reticulum reported by Hall and Clarke (1898) could not be determined.

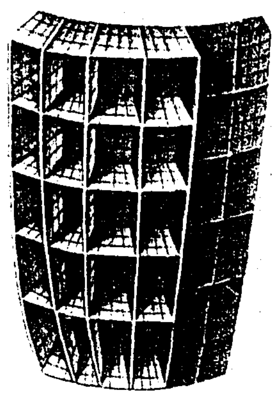


Fig. 16. - Clathrospongia abacus Hall, 1884. Sketch showing the primary reticulum and its supposed subdivisions. (Reproduced from Hall and Clarke, 1898, pl. 49, fig. 7.)

DIMENSIONS: The length of the mold approximates 85 mm.; diameter of cup, at upper extremity, 47 mm.; diameter at base 18 mm.

FIGURED SPECIMENS AND LOCALITIES:

UCM No.	Type	Locality
34548	Hypotype	103-C

OCCURRENCE: Collected by K. E. Caster from the basal Corry sandstone at location 103-C. This is the type section for the Corry sandstone.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: The fenestrate primary reticulum and the turbinate shape constitute the outstanding characteristics of the genus Clathrospongia Hall. The acute base and lack of a basal diaphragm permit differentiation from its generic homeomorph Thysanodictya Hall and Clarke. Species of the genus Clathrospongia Hall are apparently distinguished by the size of the cup and the nature of the reticulum. The specimen under discussion compares favorably with C. abacus Hall and is therefore assigned to that species.

Clathrospongia abacus Hall is readily distinguishable from the obscure Hamilton form C. hamiltonensis (Hall) which has irregularly developed primary quadrules measuring 12 mm. on a side (at the median portion of the cup) and distinct nodules at the intersection of the primary bands.

Of the Chemung species C. fenestrata (Hall) is subcylindrical, larger (138 mm. in length), and nodular at the intersection of the primary bands of the reticulum. C. vascellum (Hall) is much larger (260 mm. in length) and has primary quadrules measuring 26 X 30 mm. C. tomaculum (Hall) is subcylindrical and longer than C. abacus Hall (135 mm.), the vertical fasicles of the primary reticulum are more strongly developed than the horizontal, and the primary quadrules measure 17 X 15 mm. C. irregularis (Hall), like C. abacus Hall has primary quadrules measuring 9 mm. on each side but exibits nodular development at the intersection of the primary reticular bands. C. desmia Hall and Clarke has rectangular quadrules with the horizontal bands of the primary reticulum twice as far apart as the vertical bands.

The Waverly species C. caprondonta Hall and Clarke is much longer than C. abacus Hall (185 mm. in length) with large primary quadrules measuring 13 mm. in width and 19 mm. in length.

REMARKS: Species of the genus Clathrospongia Hall have been reported from the Middle Devonian Hamilton group and the Upper Devonian Chemung group of New York as well as from the Lower Mississippian (Kinderhookian) series of Pennsylvania. The genus itself has never been adequately defined. Hall and Clarke (1898, p. 122), as seen above, considered it "a convenient receptacle for certain imperfectly known forms." Examination of the illustrations in Hall and Clarke (1898) appear to bear out this contention. The vicissitudes of preservation are such that the matter of the presence or absence of a basal disc, which differentiates Clathrospongia Hall from Thysanodictya Hall and Clarke, seems to be somewhat nebulous. A re-examination of the two genera appears to be in order.

Subfamily CALATHOSPONGIINAE Hall and Clarke, 1898

Genus Ectenodictya Hall, 1884

1863 Dictyophyton Hall, James [pars], New York State Cab. Nat. Hist., 16th Ann. Rept., p. 87, pl. 4, fig. 6; pl. 5, fig. 1; pl. 5A, fig. 1 [non pl. 4, figs. 1-3 (Thamnodictya)].

1883 Phragmodictya ? Hall, J. [nomen nudum], [title only], American Assoc. Adv. Sci., Proceedings (1882), vol. 31, p. 419.

1884 Dictyophyton, Hall, J. [pars], New York State Mus. Nat. Hist., 35th Ann. Rept., p. 466, pl. (17) 18, fig. 9 [non pl. (18) 19, fig. 5 (Tylodictya)].

1884 *Ectenodictya* Hall, J. [*pars*], *op. cit.*, pl. (18) 19, fig. 1 [*non* pl. (19) 20, fig. 1 (*Phragmodictya*); fig. 10 (*Thysanodictya*)].

1888 [*non*] *Dictyophyton*, Hinde, G. J., British Fossil Sponges, Palaeontological Soc., Mon., vol. 1, pt. 2, p. 126-127, pl. 2, fig. 4.

1898 *Calathospongia* Hall, J. and Clarke, J. M., New York State Mus., Mem. 2, p. 155-156.

1898 (?) *Ectenodictya*, Hall, J. and Clarke, J. M., *op. cit.*, p. 164, pl. 54, figs. 3-4.

1913 *Calathospongia*, Zittel, K. A., Textbook of Palaeontology, vol. 1, edited by Eastman, C. R., MacMillan and Co., London, p. 61.

1939 *Calathospongia*, Caster, K. E., Jour. Paleontology, vol. 13, p. 10-12.

1955 *Ectenodictya*, Laubenfels, M. W. de, Treatise on Invertebrate Paleontology, edited by Moore, R. C., pt. E (Archaeocyatha and Porifera), p. E 73.

TYPE SPECIES (by subsequent monotypic designation; Hall, J. and Clarke, J. M., 1898, p. 164): *Ectenodictya implexa* Hall, J., New York State Mus. Nat. Hist., 35th Ann. Rept., p. 475, pl. (18) 19, fig. 1, 1884. Waverly group (Mississippian) at Warren and Oil City, Pennsylvania.

The following description of the genus Ectenodictya is taken from Hall (1884, p. 466):

> DIAGNOSIS: Discoid, globose, ovoid or irregularly expanding or explanate forms, consisting of a reticulate frond or envelope.
> Several species referred to this genus are broadly spreading forms which are flattened, discoid or subovoid in form, sometimes apparently conforming to the sea-bottom and variously infolded or plicated. The reticulation is irregular, presenting radiating and concentric striae which are frequently interrupted and altered in their direction.

REMARKS: Hall (1884) assigned four species to his genus Ectenodictya (E. implexa, E. expansa, E. burlingtonensis, and E. eccentrica) but failed to designate a type species. Much of the material, by Hall's own admission, was fragmentary.

Hall and Clarke (1898, p. 164), upon re-examination of the original specimens and comparison with newly acquired material, reassigned all but one species of the genus Ectenodictya Hall (E. implexa) to other genera. The validity of the genus Ectenodictya itself was questioned by the co-authors who suggested (1898, p. 158, 165) that the fragments assigned earlier by Hall to E. implexa were probably fragments of Calathospongia redfieldi (Hall) or C. carlli Hall and Clarke. Such a decision would incorrectly render Ectenodictya Hall a junior subjective synonym of the genus Calathospongia Hall and Clarke, erected by Hall and Clarke (1898,

p. 155). The single species E. implexa Hall was maintained (op. cit., p. 306) as a dubious species.

De Laubenfels (1955, p. E 73) referred Calathospongia Hall and Clarke to synonomy under Ectenodictya Hall. It is not known whether the type species (C. redfieldi and E. implexa) of the two genera were examined before this decision was made.

Ectenodictya carlli (Hall and Clarke), 1898, emend.
Plate 1, figure 3. text figure 17.
Plate 2, figure 1.
Plate 3, figures 1-3.

1898 Calathospongia carlli Hall, James, and Clarke, J. M., New York State Mus., Mem. 2, p. 158; p. 159, fig. 21, pl. 52, figs. 4-7.

1955 Ectenodictya carlli (Hall and Clarke). Laubenfels, M. W. de, Treatise on Invertebrate Paleontology, edited by Moore, R. C., pt. E (Archaeocyatha and Porifera), p. E 73.

SPECIMENS: The information which follows is based upon a single natural cast of the exterior and a latex mold derived therefrom.

DESCRIPTION: The specimen is flattened and imperfectly preserved. In life the cup was apparently medium sized and funnel-shaped with the upper half longitudinally fluted. The base, which is incomplete, appears to have been flat. The maximum diameter appears to have been that of the aperture.

Approximately one-third of the distance from the base, the cup developed a bulge which carries the linear flutings of the distal section. The cup expands rapidly beyond the bulge until what is presumed to be the aperture is attained. The aperture was probably fluted in life.

There is no evidence of nodes (unless the single bulge is so construed) or prismatic faces. The surface is smooth with a well developed reticular pattern lacking all indication of the nature of the dermal spicules. The primary reticulum is composed of strongly developed transverse bands and thin vertical bands which are only sporadically preserved. The strands of the reticulum were presumably formed by bundles of modified triaxial megloscleres but this fact cannot be verified because of the coarseness of the preservation.

Photographic enlargment of a portion of the primary reticulum (see pl. 1, fig. 3) reveals some interesting details of composition and distribution. The predominance of the transverse bands is due to their duplicate nature. The paired transverse bands are regularly spaced only near the aperture where the distance between them is about 3.5 mm. Toward the base the distance gradually diminishes and reaches a minimum of 1.3 mm. at the lowest measurable portion of the specimen.

In the concave constricted areas approaching the bulge and adjacent to the convex longitudinal fluting (partially destroyed) the primary reticular net appears to grow more complex by the addition of extra strands, irregularly but generally diagonally disposed with respect to the quadrules. The adventitous strands appear to have served as structural cross-bracing of the constricted and fluted portions of the cup. They are not unlike the diagonal fasicles seen in the skeletons of the extant genus Euplectella Owen (1841).

The dimensions of the primary quadrules themselves are difficult to ascertain - principally because of the apparently diffuse and weakly developed longitudinal strands. The quadrules vary in size dependant upon their relative position in the reticulum. Adjacent to the aperture they are approximately 4 mm square, at the bulge 3 mm, and near the base 2 mm. The primary quadrules are themselves subdivided into meres of at least the fourth order. Whether this subdivision is created by the impression of a well-order inner reticulum or actual subsidiary fasicles of the primary net could not be determined.

Microscleres, presumably present in life, could not be found in the specimen under discussion. The spicular bands of the reticulum were probably somewhat fused in the living organism into a dictyine-like skeleton as in *Euplectella*. The regular nature of the fluting suggests that this shape was the normal one and not an accident of preservation as has been frequently suggested with respect to this and other Paleozoic hexactinellids.

DIMENSIONS: The illustration shown on pl. 2, fig. 1, is x 0.85 natural size. Height of the somewhat-incomplete hypotype about 166 mm; diameter of the base, 72.7 mm; diameter of aperture, restored, 125 mm.

TYPES: Lectotype [herein designated]: *Calathospongia carlli* Hall and Clarke, 1898, New York State Museum-Paleontology No. 58 (= New York State Mus., Mem. 2, pl. 52, figs. 4-5). Collected by J. F. Carll on the flats of Oil Creek near Pleasantville, Venango County, Pennsylvania. [?] Paratype: New York State Museum-Paleontology No. 59 (= New York State Mus., Mem. 2, pl. 52, fig. 6).

FIGURED SPECIMENS AND LOCALITIES:

UCM No.	Type	Locality
34549	Hypotype	116-C
	Lectotype	Pleasantville, Pa.
	[?] Paratype	Pleasantville, Pa.

OCCURRENCE: Collected by K. E. Caster from the basal Corry sandstone at location 116-C.

DISCUSSION: The genus Ectenodictya Hall [= Calathospongia Hall and Clarke] is apparently indigenous to the Mississippian since all of the described species have been assigned to rocks of that age. The type species, E. implexa Hall, was inadequately described from fragmentary material and, if extant, its repository is unknown. There are however some elements of the original description of the genus and species by Hall (1884, p. 466, 475) which merit special attention. These described features include: (1) the irregular nature of the reticulum and the interruption of the concentric striae with accompanying alteration of direction; (2) the presence of protuberances, "not sufficiently elevated to be termed nodes." To the above Hall and Clarke (1898, p. 165) added (3), "the characteristic predominance of the horizontal spicular bands."

Hall and Clarke (1898) frequently referred to the irregularities on the surface of a number of species assigned to the genus as distortions due to crowding or compression. Yet, these irregularities appear to constitute a major characteristic of the genus Ectenodictya Hall, the species of which are differentiated on the degree of irregularity of the cup and the nature of the reticulum. Caster (1939, p. 11) has suggested that there are two form tendencies in the genus Ectenodictya Hall [= Calathospongia Hall and Clarke], namely:

> ...(1) those that have the characteristic form of the genotype C. redfieldi, with constricted basal attachment, expanded broadly nodose basal zone, constricted lower neck and broad mesial bulge followed by an upper constricted neck and expanded aperature; and (2) essentailly all of the other species attributed to the form genus in which the hourglass shape apparently prevails, i. e., those species with a broadly expanded basal attachment, constricted mesial part and broadly expanded aperture of about the same diameter as the base.

The specimen at hand is presumed to fall into the second category. It appears to have its closest affinities with Ectenodictya carlli (Hall and Clarke) [= Calathospongia carlli Hall and Clarke].

There is no single illustration given by Hall and Clarke (1898) which corresponds exactly to the specimen under discussion. Fig. 21, p. 159 (op. cit.) exibits a remarkable resemblance to the gross shape, fluting, basal constriction, and reticulation of the specimen under discussion. Neither the original description (op. cit., p. 158) nor the figures used for illustration delineate the double rows of the horizontal strands of the primary reticulum or the diagonal strands so prominent in the specimen studies. These features have apparently been overlooked.

The Hall and Clarke specimens (New York State Museum-Paleontology Nos. 58 and 59) are both labelled "types." The two specimens prove to have less in common than one would be lead to expect. No. 58 falls into Caster's second form category and has the characteristic

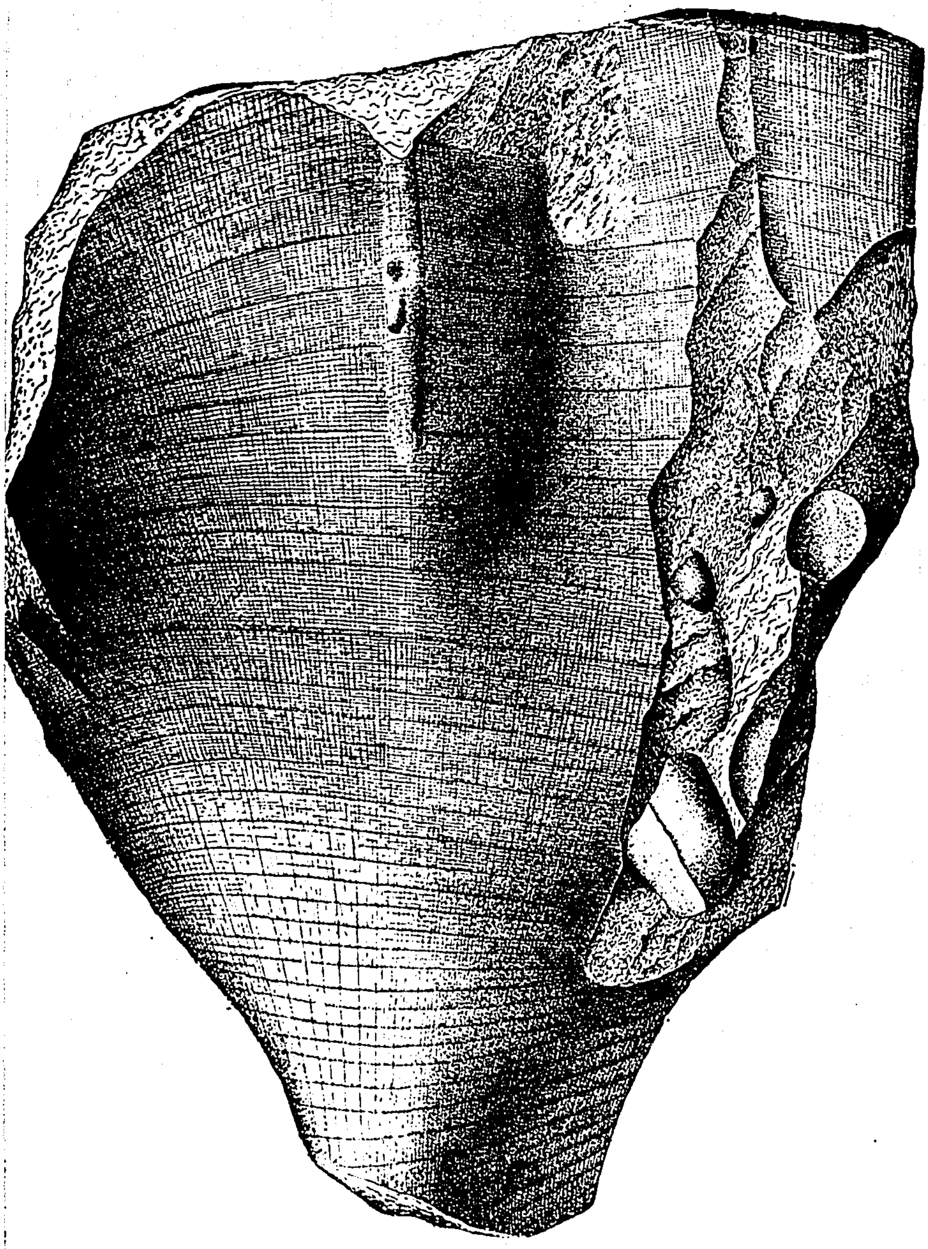


Fig. 17. - Calathospongia carlli Hall and Clarke. No scale was given with the original illustration. (Reproduced from Hall and Clarke, 1898, p. 159, text fig. 21.)

accentuated horizontal reticular bands which Hall and Clarke (1898, p. 156) attribute to the form genus Ectenodictya redfieldi (Hall) [= Calathospongia redfieldi (Hall)] as well as the diagonal strands described above. No. 59 recalls Caster's first category but shows no size differentiation between the horizontal and vertical reticular bands of the primary reticulum and lacks the diagonal strands. It is much smaller than either the specimen under discussion or No. 58. Details of comparative measurements are given in Table 5 below.

Location	UCM No. 34549	NYSM No. 58	NYSM No. 59
Length	166.0 mm	148.0 mm	86.2 mm
Width at base	72.7 mm	54.3 mm	37.6 mm
Width at top	125.0 mm	150.0 mm	53.8 mm
Width between horizontal reticular bands	3.5 mm	3.5 mm	2.0 mm

Table 5. - Comparative measurements of several specimens of the species Ectenodictya carlli (Hall and Clarke).

The specimen under discussion compares favorably with No. 58 and its identification as Ectenodictya carlli (Hall and Clarke) seems justified. Further, since a holotype has apparently never been designated for the species, NYSM No. 58 is so designated as the lectotype. NYSM No. 59 is provisionally named a paratype although further investigation will probably necessitate a change in its specific designation.

At first glance a portion of the specimen figured herein (see pl. 2, fig. 1) appears to resemble E. redfieldi (Hall) but further examination proves this relationship to be an illusion. E. carlli (Hall and Clarke) differs from E. redfieldi in that it is somewhat broader, lacks the distinct bulge and accompanying sharp constrictions, has primary quadrules which vary in size, is distinctly fluted, and does not exibit the development of prismatic faces. It lacks the prismatic form, large primary quadrules (10 x 12 mm), and nodular intersections of the reticular bands of E. tiffanyi (Hall and Clarke). E. carceralis (Hall and Clarke) has too strongly developed vertical strands of the primary reticulum, a prismatic shape, and too large-sized quadrules (8 x 10 mm) for a favorable comparison with E. carlli. E. sacculus (Hall) has weaker horizontal reticular strands than E. carlli and is itself a highly questionable species. E. tidioutensis (Caster) has larger primary quadrules (11 x 8 mm), a bulge similar to that of E. redfieldi, and exibits a stronger development of the vertical fasicles. E. amphorina (Hall and Clarke) and E. magnifica (Hall and Clarke) are both Keokuk species. The former differs from E. carlli by exibiting prominent vertical spicular strands while the latter has primary quadrules which are far too large (24 x 24 mm) for favorable comparison.

REMARKS: The question of the examination of the type specimens by de Laubenfels was posed previously. If this has been done and the genera *Ectenodictya* Hall and *Calathospongia* Hall and Clarke are one-and-the-same, it appears that the revival of the generic name *Ectenodictya* constitutes a burdensome nomenclatorial change. Despite its admitted priority the name has not been used since 1898, its type species poorly described, and the type specimen presumed to be lost. *Calathospongia*, to the contrary, has been employed by recent authors (*i. e.*, Caster, 1939) and has the added advantage of having well documented and available types.

<u>General observations on the "glass sponges."</u> - The description of two specimens can hardly be construed as adequate for generalizations concerning an entire family. Yet, certain descrepancies have been noted in the writer's brief encounter with the Dictyospongiidae. It appears that many of the generic designations of Hall and Clarke (1898) were hastily conceived and based on fragmentary material. A re-working of the entire family would certainly be in order.

In such a project some care should be taken to explore the details of the reticulum more thoroughly. As indicated in the discussion above, reticular bands frequently described as "prominent" may actually consist of two or more bundles of fasicles. Further, it is rarely clear as to the exact meaning of the terms "secondary reticulation" or "subdivisions of the primary reticulum." It is entirely possible, although the walls of the fossil "glass sponges" are generally construed as having been thin, that distinctions can be made between the inner and outer reticula. Further, the so-called "subdivisions of the primary reticulum, may be due to the impressions of well organized and fortudinously placed spicules of the inner reticulum. This appears to be the case in the brief study made here.

Phylum Brachiopoda

One has but to read the abbreviated history of the Brachiopoda in Muir-Wood (1955) to appreciate the existing uncertainty of its position in the world of invertebrates. Within the phylum the higher taxonomic categories of the earlier workers are, in the light of modern research, gradually being altered. At the moment, more questions are being asked than answered.

The preliminary classification outlined by Muir-Wood (1955) adequately reflects the present incomplete status of our knowledge with respect to the Brachiopoda. Until the promised revision of the phylum in the Treatise on Invertebrate Paleontology is available, Muir-Wood's classification will provide an interim opportunity for reconsideration; it is the classification used here.

Phylum BRACHIOPODA Dumeril, 1806

Class ARTICULATA Huxley, 1869

Suborder RHYNCHONELLOIDEA Moore, 1952

emend. Muir-Wood, 1955

Superfamily RHYNCHONELLACEA Schuchert, 1896

Family CAMAROTOECHIIDAE Schuchert and LeVene, 1929

Subfamily CAMAROTOECHIINAE Schuchert and LeVene, 1929

Genus Paraphorhynchus Weller, 1905

1855 [non] Rhynconella Shumard, B. F., Missouri Geol. Surv., Ann. Rept. 1-2, pt. 2, p. 204, pl. C, figs. 5a-c [(Shumardella) fide Branson, E. B., 1938, p. 50].

1868 [?] Rhynchonella Meek, F. B. and Worthen, A. H., Geol. Surv. Illinois, vol. 3, p. 450-452, pl. 14, figs. 7a-d [fide Weller, Stuart, 1914, p. 189].

1877 [non] Rhynchonella, Gosselet, Jules, Ann. Soc. Géol. Nord., t. 4, p. 314, pl. 3, fig. 4; pl. 4, fig. 5 [(Camarotoechia) fide Sartenaer, Paul, 1958, p. 2].

1883 Rhynchonella, Carll, J. F., 2d Pennsylvania Geol. Surv., Rept. I4, p. 305 [footnote].

1887 [<u>non</u>] <u>Rhynchonella</u>, Gosselet, Jules, Ann. Soc. Géol., Nord., t. 14, p. 218-221, pl. 3, figs. 14-18 [(<u>Camarotoechia</u>)].

1889 <u>Rhynchonella</u>, Simpson, G. B. [<u>pars</u>], in Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 892-893, 900-901 [<u>sc</u>. <u>R</u>. <u>striata</u> Simpson and <u>R</u>. <u>medialis</u> Simpson, 1889].

1889 <u>Rhynchonella</u>, Rowley, R. R., American Geologist, vol. 3, p. 116.

1890 <u>Rhynchonella</u>, Simpson, G. B. [<u>pars</u>], American Phil. Soc., Trans., vol. 16, p. 444-445, text figs. 9-10 [<u>non</u> p. 443, text fig. 8 (<u>Stenoscisma</u>)].

1894 [<u>non</u>] <u>Rhynchonella</u>, Keyes, C. R., Missouri Geol. Surv., vol. 5, p. 100, pl. 41, fig. 11 [(<u>Shumardella</u>) <u>fide</u> Weller, Stuart, 1914, p. 222].

1894 [?] <u>Rhynchonella</u> (<u>Pugnax</u>) Hall, James and Clarke, J. M. [<u>pars</u>], New York Geol. Surv., Nat. Hist. of New York, Palaeont., vol. 8, pt. 2, p. 204 [footnote], pl. 60, figs. 33-34 [<u>non</u> pl. 60, figs. 23-26 (<u>Pugnoides</u>)].

1900 <u>Pugnax</u>, Weller, Stuart, Iowa Geol. Surv., Ann. Rept., vol. 10, p. 76.

1900 <u>Pugnax</u>, Weller, Stuart, Acad. Sci. St. Louis, Trans., vol. 10, p. 72, pl. 2, figs. 16-17.

1901 _Pugnax_, Weller, Stuart, Acad. Sci. St. Louis, Trans., vol. 11, p. 154-156, pl. 13, figs. 14-16.

1905 _Paraphorhynchus_ Weller, Stuart, Acad. Sci. St. Louis, Trans., vol. 15, p. 260-261, pl. 1, figs. 1-15, text figs. 1-7.

1910 [_non_] _Paraphorhynchus_, Greger, D. K., American Jour. Sci., 4th ser., vol. 29 [p. 73, figs. 1-6 (_Rhynchotreta_); p. 74, figs. 9-10 (_Rhynchotreta_): _fide_ Weller, Stuart, 1914, p. 208, 211].

1914 _Paryphorhynchus_ Weller, Stuart [_nom. correct_.], Illinois Geol. Surv., Mon. 1, pt. 1, p. 187, text fig. 8; pt. 2, pl. 26, figs. 10-28.

1925 _Paryphorhynchus_, Van Tuyl, F. M., Iowa Geol. Surv., Repts. and Papers, vol. 30, p. 56, pl. 3, figs. 9-10.

1925 _Paraphorhynchus_, Branson, E. B. and Williams, J. S., Geol. Soc. America, Bull., vol. 36, p. 217.

1928 _Paraphorhynchus_, Moore, R. C., Missouri Bur. Geol. and Mines, vol. 21, 2d ser., p. 21, 27, 49, 53, 59, 63, 98.

1929 _Paraphorhynchus_, Schuchert, Charles and LeVene, C. M., Fossilium Catalogus, edited by Pompeckj, J. F., I. Animalia, pt. 42, p. 93.

1930 Paraphorhynchus, Caster, K. E., Bull. American Paleontology, vol. 15 (No. 58), p. 163, pl. 30, figs. 13-22; pl. 32, fig. 18.

1931 Paraphorhynchus, Laudon, L. R., Iowa Geol. Surv., Repts. and Papers, vol. 35, p. 362, 363, 364, 368-369, 392.

1934 Paraphorhynchus, Caster, K. E., Bull. American Paleontology, vol. 21 (No. 71), p. 123.

1937 Paryphorhynchus, Nalivkin, D. V., Central Geol. and Prospecting Inst., Trans., Fasc. 99, p. 78-82 (Russian), p. 134-162 (English), pls. 11-13.

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TYPE SPECIES (by subsequent designation; Schuchert, Charles, and LeVene, C. M., 1929, p. 93): Paraphorhynchus elongatum Weller, 1905, St. Louis Acad. Sci., Trans., vol. 15 (No. 4), p. 261-262, pl. 1, figs. 1-5. Kinderhook limestone (Mississippian) on the South Fabius River in the southeastern corner of Knox County, Missouri.

The original description of the genus Paraphorhynchus by Weller (1905, p. 260-261) reads as follows:

> DIAGNOSIS: Shell rostrate, or rather large size, coarsely plicate with usually simple plications which extend nearly to the beak, with a deep sinus in the pedicle valve and an elevated fold in the brachial valve of the mature shell. Surface of both valves marked by very fine longitudinal striae [costellae] which increase by bifurcation and intercalation. In the interior of the pedicle valve there is a pair of vertical dental lamellae which support the teeth and extend forward into the cavity of the valve and between which there is a narrow

> muscular scar. In the brachial valve a strong median septum supports posteriorly a hinge-plate with a cruralium-like cavity, anteriorly each lateral division of the hinge-plate is produced into the cavity of the shell as a crural process, and the median septum also continues forward towards the front of the shell beyond the cruralium-like hinge-plate. Cardinal process wanting. Shell structure fibrous, not punctate.
>
> The members of this genus differ exteriorly from *Pugnax* [Hall and Clarke, 1893] with which they have usually been placed, in the longitudinally striated shell surface, and in the more strongly plicated shell with the plications extending nearly to the beak. Internally the characters of the shell resemble *Camarotoechia* [Hall and Clarke, 1893] rather than *Pugnax*, the strong median septum of the brachial valve with its cruralium-like hinge-plate being absent in the typical forms of *Pugnax*.

Branson (1938, p. 167) included the following observations in his discussion of the genus *Paraphorhynchus* Weller, 1905, based on species from the Bushberg sandstone of Missouri.

> The genus was in process of rapid evolution and every feature of the shell excepting the striae displays numerous differences. The number of plications in the sinus ranges from three to seven. The number of plications on each lateral slope varies from four, two short and almost obsolete, to five long and well defined; from broad and low to sharp crested and high. The beak comes to an almost needle-like point which projects backward in the plane of the valve in some while in others it keeps almost the curve of the rest of the shell and is blunt. The posterior lateral margins range from an angle of 47 degrees from the median line to 90 degrees, from straight to strongly concave. The fold and sinus range greatly in width and height.
>
> The Chouteau specimens [*loc. cit.*, p. 47] vary greatly but the variations depend mainly on age.

REMARKS:

Synonomy: - Some authors (e.g. Williams, 1943, p. 83) regard the assignment of certain Missouri brachiopods to the genus Rhynchonella Fisher de Waldheim (1809) by Meek and Worthen (1868) as the earliest acceptable synonym of the genus Paraphorhynchus Weller (1905). Meek and Worthen (loc. cit.) disclosed that the previous usage of the generic designation for the species Rhynchonella missouriensis by Shumard (1855, p. 204, pl. C, figs. 5a-c), actually represented two different species - not various stages of growth as Shumard himself presumed.

Although favorably impressed with the comparison between Shumard's smaller specimen (op. cit., fig. 5a) and the English species Rhynchonella pugnus (Martin), Meek and Worthen were hesitant to place the two in synonomy. They were somewhat confused by Davidson's personal assurance that R. pugnus was striated when they could not find the striae on the specimens he had sent them. They (Meek and Worthen, 1868, p. 452) stated:

> Should future comparisons of more extensive collections, however, bring to light good distinctions between the smaller, obscurely plicated and non-striated shell represented by Dr. Shumard's figure 5a, and R. pugnus, (Martin) (sp.), we would propose to restrict the name Missouriensis to that type, and to distinguish the larger, strongly plicated and distinctly striated shell we have figured, under the name R. striato-costata.

It is to be noted that the specific designations put forth in the quotation above were merely suggestions - not direct proposals.

In 1894 Hall and Clarke (p. 202) proposed the subgenus *Pugnax* for species of American rhynchonellids characterized by a trihedral shape and believed to be related to the type species *Rhynchonella loxia* Fisher de Waldheim. Included in the group were the striated species tentatively suggested by Meek and Worthen (1868). In a footnote Hall and Clarke (1894, p. 204) stated:

> The American Carboniferous shells representing the specific type of *R. pugnus*, namely, *R. striatocostata* Meek and Worthen, *R. missouriensis* Shumard, bear a fine radiate-lineate ornamentation, and what might be interpreted as a similar character is apparent in many of Davidson's [1863] figures of the Carboniferous species (Carboniferous Brachiopoda, pl. 22), though this feature is not mentioned in his descriptions.

(Examination of the plate cited above failed to reveal to the present writer the striae which Hall and Clarke presumed to be present.)

The professional stature of Hall and Clarke was such that for many years their assignment of the species of Shumard and Meek and Worthen to the subgenus *Pugnax* was accepted without question. Subsequent authors accorded the subgenus full generic status (*see* synonomy above). This usage, particularly in synonomy with the genus *Paraphorhynchus* Weller (1905), was probably in error since the genus Pugnax Hall and Clarke lacks a distinct median septum in the brachial valve and is a rarity in American faunas.

In 1914 Weller (p. 222) placed the species Rhynconella [sic] missouriensis Shumard (1855) in synonomy with his newly created species Shumardella missouriensis (Shumard). Shumard's controversial Figures 5a-c, discussed above, were cited as examples of the new species. In the same publication Weller (1914, p. 224) erred by again citing Shumard's Figure 5a as representative of the species Shumardella obsolens (Hall). The duplication was not immediately detected for it remained uncorrected in Schuchert and LeVene (1929, p. 113). Branson (1938, p. 50-51) appears to have rectified the discrepancy by assigning only Shumard's Figures 5b-c to the species Shumardella missouriensis (Shumard) Weller (1914).

With the assignment of Shumard's Figures 5a-c to the genus Shumardella Weller (1910), the decision of some authors to relate the same specimens to the genus Paraphorhynchus Weller (1905) via the genera Rhynchonella Fisher de Waldheim (1809) and Pugnax Hall and Clarke (1894) appears to be somewhat questionable; as the synonomy of Williams (1943, p. 83) suggests.

Until 1937 the genus Paraphorhynchus Weller (1905) was presumed to be limited to specific outcrops of Lower

Mississippian strata in the continental United States. In that year Nalivkin (1937, p. 78-82) described nine species of the genus from the Upper Devonian Fammenian sequence of Kazakhstan, S. S. R. Two of these species, P. triaequalis (Gosselet) and P. gonthieri (Gosselet), were considered to be synonymous with species from the Fammenian of the Ardenne region of France and Belgium which Gosselet (1877/1887) had previously assigned to the genus Rhynchonella. Simorin (1956) recognized five of Nalivkin's species, including the two cited above, also in the Fammenian sequence of the Karagandin basin, U. S. S. R.

Examination of the original descriptions and illustrations of Gosselet failed to reveal any justification for the synonomy proposed by Nalivkin and repeated by Simorin. Gosselet (1877, p. 314, pl. 3, fig. 4; pl. 4, fig. 5) neither describes or illustrates any characteristics which would lead one to believe that Rhynchonella triaequalis Gosselet and Paryphorhynchus triaequalis (Gosselet) Nalivkin are comparable. The same can be said for the inferred relationship between Rhynchonella gonthieri (Gosselet) Nalivkin (see Gosselet, 1887, p. 218-221, pl. 3, figs. 14-18).

The writer's conclusions with respect to the species cited above have been substantiated by the studies of

Mallieux (1933) and Sartenar (1958). These authors place many of Gosselet's species assigned to the genus *Rhynchonella* in synonomy with species they assigned to the genus *Camarotoechia* Hall and Clarke. Sartenar (1958, p. 12-16) is particularly emphatic in noting that Gosselet himself used the species *triaequalis* interchangeably between *Camarotoechia* and *Rhynchonella*. Sartenar's 1958 study resulted in the erection of several new subspecies (*e.g.* *Camarotoechia nux praenux* Sartenar) with which all or portions of Gosselet's species *Rhynchonella triaequalis* were declared to be synonymous.

While the weight of the evidence may, at present, deny the occurrence of the genus *Paraphorhynchus* in the Upper Devonian Fammenian sequence of France and Belgium, there can be little doubt as to its identification in strata of comparable age in Kazakhstan and the Karagandin basin. In conformance with the criteria presently regarded as valid for the recognition of the genus *Paraphorhynchus* Weller (1905), the identification of the asiatic species by Nalivkin (1937) and Simorin (1956) is acceptable to the writer. Thus, the genus not only occurs outside of the United States but also in strata older (Upper Devonian) than had previously been supposed.

Orthography: - Between 1905 and 1914 Weller, without explanation, changed the spelling of the genus from *Paraphorhynchus* (1905) to *Paryphorhynchus* (1914).

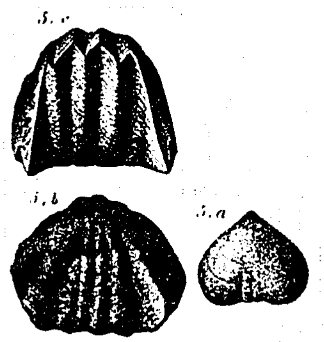

Fig. 18. - The original illustrations of Rhynchonella missouriensis Shumard. (Reproduced from Shumard, B. F., 1855, pl. C, figs. 5a-c.

Williams (1943, p. 83) investigated the change and states:

> G. H. Girty states that he imperfectly remembers that Weller wrote him that he made the change because he had discovered an error in transliteration. The changing of the spelling of generic names on that basis has been upheld in opinion 36 of the International Commission of Zoological Nomenclature. However, as para is a common combining form and pary is not, it seems best to return to the original spelling.

Nalivkin (1937), Cooper (1944), and Simorin (1956) prefer the usage of the prefix pary. Caster (1930), Branson (1938), and Williams (1943) exploy the prefix para. The latter usage is preferred in this paper.

Generic distinctions: - Weller (1905, p. 259) originally established the genus Paraphorhynchus for Rhynchonelloid shells of large size, with simple coarse plications, having the external surface covered with fine radiating "striae" [= costellae]. The internal structures were presumed to resemble those of the genus Camarotoechia Hall and Clarke (1893). These characteristics, Weller believed, were deserving of the generic rank which he accorded them. Such external distinctions are difficult to establish in all but perfectly preserved specimens. Variations in shape concomitant with age, as described by Branson (1938) and cited above, could add to the difficulty of positive identification.

Weller (1905/1914) thought that the rostral portions of both valves of *Paraphorhynchus* were homeomorphic (in internal characteristics) with those of other rhynchonellid genera. In gross aspect he was perhaps correct (*see* text figures 19-21). However, as will be shown, the genus *Paraphorhynchus* does possess distinct internal morphological features which permit its positive identification to the exclusion of similar appearing genera.

Species of the genus *Camarotoechia* Hall and Clarke (1893), which frequently occur in the same stratigraphic sequence, are most likely to be confused with *Paraphorhynchus* in the absence of well preserved interiors and exteriors. Hall and Clarke (1894, p. 190) cite crenulations on the dental sockets as a distinguishing internal characteristic of *Camarotoechia*. Holland (1958, p. 171) notes the presence of corresponding serrations on the surface of the teeth of some species of *Camarotoechia*, in addition to those on the dental sockets.

Weller (1914, p. 175), without reference to the crenulations on the teeth and sockets, distinguishes *Camarotoechia* from *Paraphorhynchus* and other rhynchonellids as follows:

> The essential generic characters of *Camarotoechia* are found in a combination of the internal and external features of the shell. The median septum of the brachial valve supporting the v-shaped crural cavity [= septalium] and the divided hinge-plate are identical in all essential

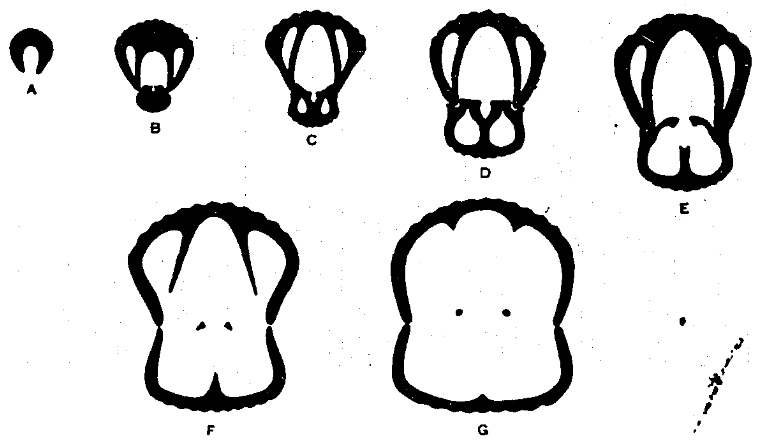

Fig. 19. - Cross-sections of the rostral portion of the shell of Paraphorhynchus elongatum Weller, 1905 (x 2½); the brachial valve is lowermost. (Reproduced from Weller, Stuart, 1914, p. 187, fig. 8.)

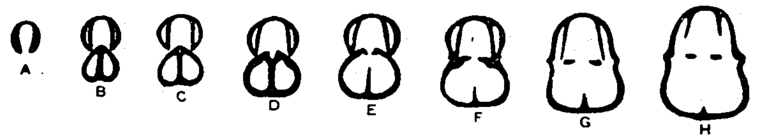

Fig. 20. - Cross-sections of the rostral portion of the shell of Camarotechia chouteauensis Weller, 1910 (x 2½); the pedicle valve is uppermost. (Reproduced from Weller, Stuart, 1914, p. 176, fig. 5.)

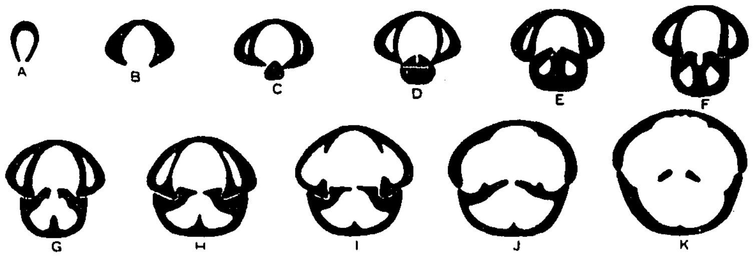

Fig. 21. - Cross-sections of the rostral portion of the shell of Pugnoides ottumwa (White) Weller, 1910 (x 2½); the brachial valve is lowermost. (Reproduced from Weller, Stuart, 1914, p. 193, fig. 9.)

> respects with the rostral characters of _Wilsonia_, _Liorhynchus_, _Paryphorhynchus_ and _Pugnoides_, the five genera being differentiated one from another by constant external characters. In _Wilsonia_ the shell is subcubical in form with plications flattened anteriorly and longitudinally grooved, especially in the fold and sinus. _Liorhynchus_ is a larger shell with the plications usually nearly obsolete upon the lateral slopes of the valves. _Paryphorhynchus_ also is a much larger shell with the entire external surface of the valves marked by fine radiating striae in addition to the plications, and _Pugnoides_ has plications becoming obsolete towards the beak.

Table 6 which follows documents the distinguishing characteristics of _Paraphorhynchus_ and other similar appearing, impunctate, rhynchonellids, as currently recognized.

Generic characteristics: - The inverted syrinx-like structure on the floor of the pedicle valve has been previously noted by Weller (1905, p. 260) and Caster (1930, p. 166). Neither author emphasized the importance of the structure as a distinguishing feature of the genus. Its presence in the pedicle valves of all four known species in the Corry sandstone, below, is considered to be significant.

Proof of the existence of such a structure in the mid-continent species and those described in Russia cannot be offered at this time. The descriptions of Branson (1938), Nalivkin (1937), Williams (1943), and Simorin (1956) are chiefly concerned with external characteristics. A single illustration of Branson's (1938,

TABLE 6. - Distinguishing characteristics of the genus *Paraphorhynchus* and other plicated rhynchonellid brachiopods [according to Weller (1914) and Roger (1952)].

Genus	Characteristics & Range
Camarotoechia Hall and Clarke (1893).	Contour triangular; angular plicae reaching the dentate frontal margin; dorsal median septum, divided posteriorly to form a septalium the branches of which support a divided hinge-plate; brachial fold and pedicle sinus. Range - Silurian to Lower Permian.
Paraphorhynchus Weller (1905)	Internal characters similar to *Camarotoechia*; mesial fold and sinus well developed; both valves with rounded broad plicae; surface of valves marked by fine, radiating striae. Range - Upper Devonian to Lower Mississippian.
Leiorhynchus Hall (1860)	Internal characters as in *Camarotoechia*; mesial fold and sinus well developed; plicae obsolete on lateral slopes of valves and well developed on fold and sinus. Range - Upper Silurian to Permian.
Pugnoides Weller (1910)	Internal characters as in *Camarotoechia*; rounded or subangular plicae which are obsolete in the posterior portion of the shell. Range - Upper Devonian to Mississippian.
Allorhynchus Weller (1910)	Externally like *Camarotoechia*; brachial valve with divided hinge-plate but no median septum and no septalium. Range - Lower Carboniferous.
Pugnax Hall and Clarke (1893)	Mesial fold and sinus well developed; strong anterior plicae becoming obsolete posteriorally; brachial valve with unsupported divided hinge-plate, no median septum or cardinal process. Range - Devonian to Permian.

TABLE 6. - Continued

Genus	Characteristics & Range
Rhynchotetra Weller (1910)	Median septum in each valve; spondylium in the pedicle valve; septalium lacking in the brachial valve; surface with fine radiating striae as in Paraphorhynchus. Range - Mississippian to Permian.
Shumardella Weller (1910)	Mesial fold and sinus well developed anteriorly; anterior margin of the sinus linguloid; plicae may be obsolete, strongest development on the fold and sinus; brachial valve with a strong median septum forming a septalium which is short in an antero-posterior direction and entirely closed on the cardinal side; exterior may be marked by coarse radiate striae. Range - Mississippian.

pl. 17, fig. 1) for Paraphorhynchus transversum Weller suggests that such a supposed muscle attachment may be present in species other than those described here.

As previously discussed, Holland (1958) has coined a tern, adductor process, for a similar structure attached to the delthyrial plate in some cyrtospiriferids. Holland's terminology is herein adopted but modified by the usage of quotation marks to signify that the "adductor process" in paraphorhynchoids lacks attachment to a delthyrial plate.

The "adductor process" thus becomes an important generic characteristic of Paraphorhynchus Weller (1905) which distinguishes the genus from all others assigned to the Camarotoechiidae. It is particularly useful in differentiating Paraphorhynchus from Camarotoechia Hall and Clarke (1893), which Weller (1914, p. 187) declared to be replicas of each other internally.

Internal morphology and preservation: - From the almost complete absence of the brachial valve and the presence of the "adductor process" the writer has reached some tentative conclusions which are admittedly speculative.

Unlike Camarotoechia, for which both valves are usually found and which had strong dentition supplemented by crenulations on both teeth and sockets, the teeth and sockets of Paraphorhynchus probably served as fulcral points for opening and closing the shell rather than as structures for keeping the valves together. The "adductor process" could have evolved to supplement the other muscular attachments in containing the valves as well as manipulating them.

In life the pedicle valve was apparently partially buried in the sea bottom with its stability augmented by a sizeable pedicle. (See Appendix A, text fig. A9.) Upon death the soft parts, presumed to have been delicate, must have disintegrated rapidly permitting the removal of the brachial valve by the action of currents. The disintegration of the soft parts combined with the partial burial of the shell allowed rapid filling of the pedicle valve with sediment. That some sediment entered *via* the pedicle foramen is substantiated by the merging of the enclosing matrix and the material filling the valve (see pl. 6, fig. 1).

The subsequent activity of groundwater in the porous sandstone matrix of the Corry is presumed to have removed the carbonate material of the original shell, leaving only the molds of the interior and occasionally the exterior of the pedicle valve. The missing brachial valves could have been carried shoreward and abraded by wave action; their subsequent representation could be in the numerous indistinguishable cavities which occur in eroded fragments of the basal Corry sandstone.

Ecology: - From the representation of the genus studied here and the distribution of species studied elsewhere in North America (see text fig. 22) certain generalizations with respect to the ecological preference of the genus Paraphorhynchus Weller (1905), can be made.

Williams (1943, p. 83) reports a single internal mold of a specimen of P. striatocostatum (Meek and Worthen) Weller from, "the yellow-brown calcareous mudstone of the [base] of the Louisiana limestone," at Clarksville, Missouri. Weller (1914, p. 189) believed the species P. transversum Weller to be, "...restricted in its distribution to some of the fine yellow sandstone formations in the Kinderhook at Burlington, Iowa; Washington County, Iowa; and Kinderhook, Illinois." Branson (1938, p. 46-47) records 335 specimens of P. elongatum Weller and a few of P. crenulatum Branson from the Chouteau limestone near Columbia, Missouri; at other localities the same horizon was apparently barren. From the Bushberg sandstone, between the Louisiana and Chouteau limestones, of Montgomery County, Missouri, Branson also reports numerous specimens of P. striatocostatum (Meek and Worthen) Weller, P. transversum Weller and P. bushbergense Branson.

Within the limits of the areal distribution of the genus in northwestern Pennsylvania (see Table 3) similar observations were made by the writer. The largest concentrations of individuals of a species are found in the basal Corry sandstone coincidental with the presence of carbonate lentils or heavy concentrations of carbonate cement (see text fig. 13). Fewer individuals are found in conglomeritic phases or where calcium carbonate is not in evidence in the matrix of the sandstone. The genus has yet to be reported from the medial micaceous siltstone or the upper sandstone members of the Corry.

From the above, the organisms appear to have preferred bottoms characterized by carbonate deposition, been tolerant of sandy or silty environments (providing enough carbonate was locally available) and abhorred pure silts and clays.

Distribution: - Nalivkin (1937) recorded eight definite species of the genus (see Table 7) from northeastern Kazakhstan; seven of these are restricted to the Upper Devonian (Fammenian) Meister and Sulcifer beds. The eighth species, a single specimen of *P. striatocostatum* (Meek and Worthen) Weller, is assigned to the Lower Carboniferous (Tournaisian) Kassin beds which are considered to be Kinderhookian in age. Simorin (1956) describes four of Nalivkin's species from the Karagandin basin; P. triaequalis (Gosselet) Nalivkin, P. gonthieri (Gosselet) Nalivkin, P. zobeida Nalivkin, and P. fatima Nalivkin, all from beds of Upper Devonian age equivalent to the Meister and Sulcifer beds.

The lowermost representation of the genus in the mid-continent region is the above mentioned presence of the species P. striatocostatum (Meek and Worthen) Weller, in the basal Louisiana limestone of Missouri. Branson (1938, p. 5) referred the formation to the Devonian but Weller, et al. (1948), assigned it as the uppermost member of the Kinderhookian Fabius group considered to be Devono-Mississippian in age. The genus is not included in Holland's (1958) study of the brachiopods of the Knapp formation of northwestern Pennsylvania which he (Holland) regards as Lower Mississippian in age. As far as the writer can determine the genus makes its initial appearance in the area of northwestern Pennsylvania in the basal Corry sandstone.

Pending further study, the present distribution indicates the possibility that the genus originated in south-central Asia in the Upper Devonian and subsequently reached North America via routes discussed in the preceding sections. If this presumption is to be ultimately substantiated paraphorhynchoids must be found in the Devono-Mississippian sequences of the western United States and Canada.

<u>Evolutionary trends</u>: - Without detailed study of the types, only general statements concerning the evolution of the genus appear to be in order.

The genus could have evolved from either camarotoechoid or leiorhynchoid stock; the internal and external characteristics of the two groups are similar enough to elicit such comparisons. Details of the distribution known at present, indicate that initial evolutionary changes took place in Asia but the possibility of the independent homeomorphic development of geographically isolated groups cannot be overlooked.

Once established in a particular environment, each group apparently evolved rapidly as Branson (1938, p. 167) has indicated. In the species described above some specific modes of change are indicated. <u>P</u>. <u>girtyi</u> Caster and <u>P</u>. <u>casteri</u> n. sp., appear to have been near-shore species. As such, living in an environment subject to wave and current action, they exibit a more rugose external appearance and concomitant changes in the nature of the diductor muscle attachment. The variations in the total number of plicae on each valve (<u>e</u>.<u>g</u>. <u>P</u>. <u>striatum</u>, 11-16) may indicate attempts to adjust the water vascular system to changing conditions of sedimentation as suggested for certain spiriferoids by Termier and Termier (1949).

Regardless of the accuracy of the suppositions above, species of the genus were apparently unable to cope with their changing environment and neither in northwestern Pennsylvania or elsewhere survived the end of the Lower Mississippian (Kinderhookian) epoch.

Species differentiation: - No single author concerned with the genus *Paraphorhynchus* Weller (1905) has enumerated the principles of specific differentiation. The most commonly used criteria appear to be:

1. Relative size as defined by;
   a. Maximum length of the valves measured as both straight line distance and distance along the curvature of the valve.
   b. Maximum width and its position relative to the mid-point of the line of maximum length.
   c. Ratio of length to width (= shell index).
2. Origin of the sulcus of the pedicle valve with respect to the umbo.
3. External ornamentation, including;
   a. Total number of plicae on each valve.
   b. Number and disposition of plicae on fold, sinus, and lateral margins.
   c. Number of costellae (striae, *auct*.) per mm.
   d. Presence or absence and position of concentric rugosities or growth lines.
4. Internal characteristics;
   a. Generally not well preserved but where present are discussed in terms of the

> disposition of the pallial sinuses, muscle scars, and ovarian markings.

Table 7 which follows is, in effect, a catalogue of measurements taken from the more lucid descriptions of each of the known species of the genus Paraphorhynchus Weller (1905). Measurements of the pedicle valve are emphasized since, with one exception, only this valve is known for the species found in the Corry sandstone. Illustrations of the mid-continent American species are to be found on Plate 7 of this report.

The information for the Russian species is somewhat limited by the nature of the original descriptions of Nalivkin (1937) and subsequent re-descriptions of Simorin (1956). In many of Nalivkin's descriptions actual linear measurements are omitted. Since the photographic plates carry no mention of scale it was impossible to estimate size from the photographs.

Distribution: - The world-wide distribution of the genus is shown on text figure 22.

TABLE 7. - Characteristics of the pedicle valve of typical specimens of known species of the genus Paraphorhynchus Weller (1905). (All linear measurements are given in mm.)

Species	Length	Width	L/W	Origin of Sulcus	Plicae in Sulcus	Tot. Plicae
P. elongatum Weller	37.0	28.8	1.3	At mid-valve	4-5	10-14
P. striato-costatum (Meek and Worthen)	25.0	26.0	0.96	At umbo	3-5	9-12
P. transversum Weller	25.0	31.0	0.81	At umbo	4	12
P. striatum (Simpson)	35.0	35.0	1.0	At umbo	5	11-16
P. mediale (Simpson)	25.0	30.0	0.83	At umbo	11	20
P. crenulatum Branson	23.0	25.0	0.92	Anterior of mid-valve	5-7	9-13
P. bushbergense Branson	18.0	32.0	0.56	Anterior of mid-valve	4-6	10-14
P. girtyi Caster	26.0	29.0	0.89	Anterior of mid-valve	4	10-12
P. triaequalis [?] (Gosselet)	15.5	16.5	0.94	At umbo	2-3	10-11
P. gonthieri [?] (Gosselet)	13.0	14.0	0.93	At umbo	4-5	12-13
P. fatima	10.0	14.0	0.72	At mid-valve	2-5	10-15
P. zobieda Nalivkin	12.0	13.5	0.89	At umbo	1	9
P. zuleika Nalivkin					2-4	8-16
P. badura Nalivkin					3-4	9-12
P. čelak Nalivkin					3-6	10-20

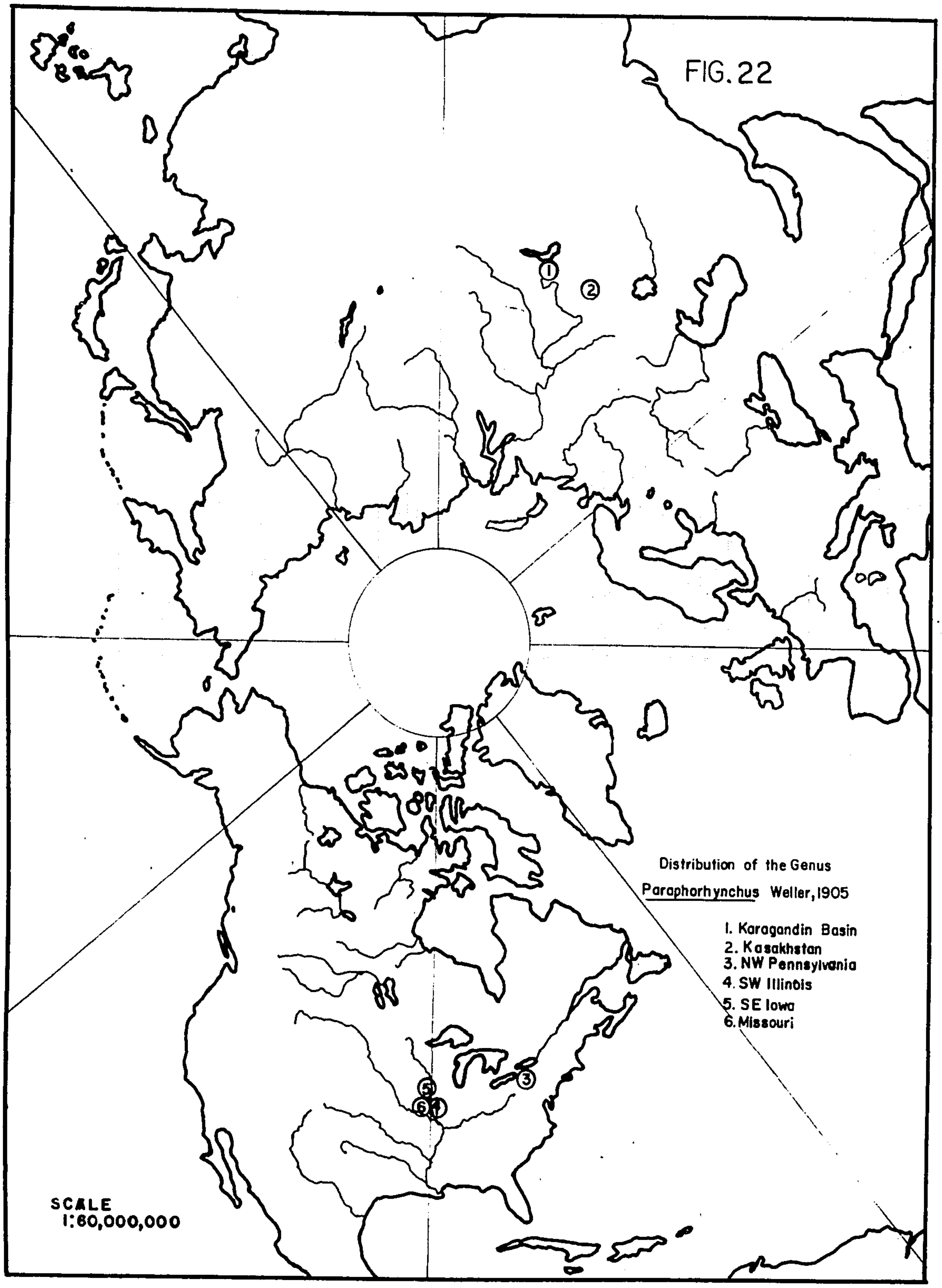
FIG. 22
Distribution of the Genus
Paraphorhynchus Weller, 1905
1. Karagandin Basin
2. Kasakhstan
3. NW Pennsylvania
4. SW Illinois
5. SE Iowa
6. Missouri
SCALE
1:60,000,000

Paraphorhynchus mediale (Simpson), 1889 emend.

Plate 4, figures 1-10.

Plate 6, figures 1-2.

1883 Rhynchonella missouriensis Meek and Worthen, Carll, J. F., 2d Pennsylvania Geol. Surv., Rept. I4, p. 305 [fide Lesley, J. P., 1889, p. 893].

1889 Rhynchonella medialis Simpson, G. B. [nomen nudum], [title only], 2d Pennsylvania Geol. Surv., Rept. O3, p. 257.

1889 Rhynchonella medialis Simpson, G. B., in Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 892-893.

1890 Rhynchonella medialis, Simpson, G. B., American Phil. Soc., Trans., vol. 16, p. 444, text-fig. 9.

1892 Rhynchonella medialis, Lesley, J. P., 2d Pennsylvania Geol. Surv., Final Rept., vol. 2, 1494.

1897 Rhynchonella medialis, Schuchert, Charles, United States Geol. Surv., Bull. 87, p. 360.

1898 Rhynchonella medialis, Weller, Stuart, United States Geol. Surv., Bull. 153, p. 534.

1905 Paraphorhynchus medialis (Simpson). Weller, Stuart, Acad. Sci. St. Louis, Trans., vol. 16, p. 259.

1930 Paraphorhynchus medialis (Simpson). Caster, K. E., Bull. American Paleontology, vol. 15 (No. 58), p. 163-164, pl. 32, fig. 18; pl. 30, figs. 14, 21.

1934 Paraphorhynchus mediale (Simpson). Caster, K. E., Bull. American Paleontology, vol. 21 (No. 71), p. 124.

SPECIMENS: The description below is based upon eleven natural molds of the interior and two molds of the exterior of the pedicle valve only. The brachial valve is, as yet, unknown. The molds of the exteriors were discovered only after the examination of hundreds of samples collected in the field; they appear to be a rarity. Latex casts of the better specimens were of great value in accentuating morphological details which might have otherwise gone unobserved. All measurements are of necessity "straight line" distances since the molds do not readily lend themselves to measurements along curved planes.

DESCRIPTION:

Exterior: - The pedicle valve is rostrate and of medium size in comparison with other elements of the brachiopod fauna (e.g. Chonetes vs. Cyrtospirifer). The maximum width of the valve is always greater than the length and achieves its greatest dimension anterior of the mid-point of the distance from the beak to the anterior commissure. The shell index (L/W) has an arithmetic mean of 0.82 for the eleven specimens studied.

The valve is generally convex in profile with the greatest convexity near the umbo. In planar view the valve is generally sub-triangular. The beak ridges are straight and at the apex of the valve join in an angle which varies from 100° to 120°. The lateral margins are rounded and do not appear to have been extended anteriorly into the marked lingual extension characteristic of other species of the genus (*e.g.*, *P. elongatum* Weller).

The beak is suberect and perforated by a sizeable mesothyrid foramen which, in one specimen, measures 2 mm in diameter. The umbo is slightly flattened; its entire central portion is occupied by the sulcus which begins at the edge of the foramen. From the umbo the sulcus widens rapidly and occupies at least half of the width of the commissure upon attainment of the anterior portion of the shell. The sulcus is consistently shallow for its entire length.

The surface of the valve is marked by approximately twenty rounded plicae, from nine to eleven of which occupy the sulcus. The plicae vary in width according to position. The two bounding the sulcus are the largest - measuring 1 mm in width at the base; the plicae on the lateral margins measure approximately 0.75 mm and those in the sulcus 0.5 mm. Four of the plicae in the sulcus originate posterior to the umbo, the remainder are intercalated between the others just anterior of the umbo; all are distinct for the entire length of the sulcus. The plicae on the lateral slopes also originate at the foramen but have a tendency to become obsolete anteriorly.

The entire surface of the valve is covered with fine radiating costellae (striae, auct.) five of which occupy the space of 1 mm. In addition, angular, elevated, concentric carinae (probably representing growth stages) mark the surface of the valve; they are best developed at the lateral margins of the shell and cross the plicae in the sulcus without loss of definition. The carinae originate at the beak and exibit a mixoperipheral habit which results in a constriction of the beak.

Interior: - The palintrope is small and interrupted medially by a large, open, triangular, delthyrium the posterior end of which is enlarged by the foramen. Deltidial plates appear to be absent. The sides of the delthyrium are lined by stout, slightly convergent, complete, dental lamellae which form umbonal cavities between themselves and the postero-lateral sides of the umbo. The nature of the dentition could not be determined.

The dental lamellae do not extend beyond the hinge line but elevated, ridge-like, callosities, which appear to originate at their bases, are joined anteriorly of the mid-point of the valve producing a lenticular ridge which surrounds the diductor muscle scar. The diductor scar is deeply incised in the floor of the valve and has a short sulcus at its anterior end which marks the pedicle attachment of the anterior adductor muscle.

Lying between the dental lamellae on the floor of the diductor muscle scar, extending from the rear of the umbo and not quite attaining the anterior limit of the diductor scar, is a sulcate ridge which Caster (1930, p. 166) considered to represent the pedicle attachment for the posterior adductor muscles. (*See* pl. 6, figs. 1-2.) The ridge can best be described as resembling an inverted, flattened, syrinx with the seam of the tube depressed to form a sulcus. An analogous structure has recently been described by Holland (1958) from the pedicle valve of the subspecies *Cyrtospirifer horridus strigosus* Holland; he (Holland, 1958, p. 398) termed the structure an *adductor process*. However, the adductor process is buttressed against a delthyrial plate - a structure which does not exist in the genus *Paraphorhynchus* Weller (1905).

Ovarian markings are prominent on and adjacent to the elevated ridge surrounding the diductor muscle scar. The vascular sinuses are quite distinct with one main trunk on either side of the umbo. Each trunk bifurcates anterior to the base of the dental lamellae; if further divisions of the main trunks are effected, the details are not sufficiently clear in the specimens at hand. However, repeated branching does take place with the branches extending toward the lateral margins in what Caster (1930, p. 164) has termed as a "pectinate manner."

DIMENSIONS: Given for figured specimens only. All measurements were taken at their maxima as straight line distances.

Characteristic	UCM 34554	UCM 34555
Length	24.2 mm	22.3 mm
Width	33.9 mm	27.5 mm
Shell index (L/W)	0.72	0.81
Apical angle	120°	116°
Plicae in sulcus	9	11
Width between bases of dent. lamellae	5.0 mm	6.0 mm

TYPES: Holotype [by monotypic designation]: Rhynchonella medialis Simpson, 1889, Pennsylvania Geol. Surv. No. 9509 (= 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 892, fig. viii-x [?]) deposited at Philadelphia

Acad. Nat. Sci. Collected by F. A. Randall from "the Waverly group [Corry] at Warren, Pennsylvania." [Probably either from east of Warren or the hills south of Warren, since no known Corry occurs actually at Warren, since no known Corry occurs actually at Warren, Pennsylvania.]

FIGURED SPECIMENS AND LOCALITIES:

UCM No.	Type	Locality
34554	Hypotype	112-C
34555	Hypotype	116-C

OCCURRENCE: Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 103-C, 112-C, 116-C, 123-C, 140-C, 214-C, 767-CT, 910-CT, 1565-CT, and 14-S.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: General size, shape, costellation of the surface, and the presence of the "adductor process" mark the figured specimens and others in the writer's collection as paraphorhynchoids. The total number of plicae (20), the number of plicae in the sulcus (9-11), the general configuration of the diductor muscle scar, the character of the vascular system, and general dimensions agree sufficiently with previously described specimens to permit the assignment of the specimens in question to the species _Paraphorhynchus mediale_ (Simpson).

With reference to all described American species of the genus, _Paraphorhynchus mediale_ (Simpson) appears to have dimensions which compare most favorably with _P. transversum_ Weller, but the latter species has only four plicae in the sulcus of a total complement of twelve. _P. girtyi_ Caster, despite its favorable shell index (0.89), is a more rugose form with four angular plicae in a sulcus which originates at mid-valve rather than at the foramen. _P. striatum_ (Simpson) is generally equidimentional and has only five plicae in the sulcus. The remaining American species differ significantly in one or more external features (_see_ Table 7 and pl. 7). All of the Russian species appear to be smaller; none have as many plicae in the sulcus.

Until more detailed descriptions of the internal features of other species are presented the uniqueness of _Paraphorhynchus mediale_ (Simpson) will lie in the great number of plicae (9-11) in the sulcus of the pedicle valve. Since this is in keeping with the form criteria originally established by Weller (1905) it appears to suffice for the present.

REMARKS: In the synonomy given above, the reader may have noted the assignment of the date 1889 as the initial date of publication for the species *Paraphorhynchus mediale* (Simpson). Several dates have been used in the literature including, 1888, 1889, and 1890; only 1889 is correct. Simpson originally presented his paper before the American Philosophical Society on December 21, 1888. The paper was not published until 1890 in the Trans. American Phil. Soc., n.s., vol. 16, p. 435-460. On page 440 of the aforementioned volume of the journal, Simpson described and figured his new species *Rhynchonella medialis*. The preceding year (1889) Lesley described and figured *Rhychonella medialis* Simpson, on pages 892-893 of P4 of the Second Geological Survey of Pennsylvania. The description and illustration of Lesley are precise duplicates of Simpson's published report of 1890. Since the work is obviously that of Simpson he, not Lesley, is credited with the initial publication of the species *Paraphorhynchus mediale* (Simpson) as of 1889.

Paraphorhynchus striatum (Simpson), 1889 emend.

Plate 5, figures 1-5.

Plate 6, figure 3.

1883 Rhynchonella missouriensis Meek and Worthen, Carll, J. F., 2d Pennsylvania Geol. Surv., Rept. I4, p. 305 [fide Lesley, J. P., 1889, p. 893].

1889 Rhynchonella striata Simpson, G. B. [nomen nudum], [title only], 2d Pennsylvania Geol. Surv., Rept. O3, p. 257.

1889 Rhynchonella striata Simpson, G. B., in Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 900-901.

1890 Rhynchonella striata, Simpson, G. B., American Phil. Soc., Trans., vol. 16, p. 444-445, text fig. 10.

1892 Rhynchonella striata, Lesley, J. P., 2d Pennsylvania Geol. Surv., Final Rept., vol. 2, p. 1494.

1895 Rhynchonella striata, Lesley, J. P., et al., 2d Pennsylvania Geol. Surv., Final Rept., vol. 3, pt. 1, p. 1688, pl. 125.

1897 Rhynchonella (?) striata, Schuchert, Charles, United States Geol. Surv., Bull. 87, p. 364.

1898 Rhynchonella striata, Weller, Stuart, United States Geol. Surv., Bull. 153, p. 535.

1905 Paraphorhynchus striata (Simpson) Weller, Stuart, Acad. Sci. St. Louis, Trans., vol. 16, p. 259.

1930 Paraphorhynchus striata (Simpson). Caster, K. E., Bull. American Paleo., vol. 15 (No. 58), p. 166, pl. 30, figs. 16, 20.

1934 Paraphorhynchus striatum (Simpson). Caster, K. E., Bull. American Paleo., vol. 21 (No. 71), p. 124.

SPECIMENS: The following description is based upon a collection of twenty natural molds of the interior, a portion of a single mold of the exterior, and latex casts made from the molds. All specimens are of the pedicle valve; the brachial valve is, as yet, unknown. The limitations of measurable dimensions are the same as those which apply to the preceding species P. mediale (Simpson).

DESCRIPTION:

Exterior: - The valve is rostrate, broadly triangular and of medium size (in accordance with the standard previously set). The greatest width of the shell is anterior of the mid-point of the valve and is usually greater than the length. The difference between the two dimensions can vary from 11 mm to less than 0.1 mm. The shell index (L/W) has an arithmetic mean of 0.76 for the twenty specimens studied.

In profile the valve is convex posteriorly, flattening toward the anterior as the sulcus deepens; the lateral margins retain their convexity. In planar view many specimens are broadly triangular. The beak ridges are generally straight and join at the apex in an angle which varies from 100° to 130°. Anterior of the cardinal extremities, the lateral margins are gently rounded. The beak is suberect and somewhat pointed; the foramen is submesothyrid. The sulcus originates at the umbo widening and deepening gradually as the anterior margin is attained; details of its conformation cannot be further ascertained from the material at hand. Five to six rounded plicae, which originate at the umbo, occupy the sulcus for its entire length. Three plicae are found on each side of the sulcus the largest of which defines the sulcus proper. The extreme lateral sides of the valve are smooth. Fine radiating costellae (striae, auct.) originate at the beak and cover the entire surface of the shell. Indistinct, concentric growth lines are also present.

Interior: - The palintrope is small with rounded postero-lateral margins. The delthyrium is triangular and open; there is no evidence of closure by deltidial plates. The deltidium is demarked ventrally by a pair of slightly convergent dental lamellae which are joined to the floor of the valve just anterior of the hinge-line, producing a central rostral cavity and two narrow lateral umbonal cavities. Details of the dentition are not apparent.

Between the dental lamellae, extending anteriorly for approximately one-half the length of the valve, an oblong depression marks the site of attachment of the diductor muscles. The scar is bounded by a ridge which originates at the base of the dental lamellae. The anterior portion of the diductor scar is breached by an elongate depression which probably marks the pedicle attachment of the anterior adductor muscles. Posterior to the aforementioned depression, occupying the median portion of the floor of the diductor muscle scar, is an elongate process similar to that described in the pedicle valve of P. mediale (Simpson). It lies between the dental lamellae and appears to have attained the posterior wall of the umbo where additional support was provided by the deposition of adventitous shell material. (See pl. 6, fig. 3.) As in the case of P. mediale (Simpson), the resemblance of this process to an inverted syrinx is striking; Hölland's term "adductor process", as modified, appears to describe it adequately. As suggested, it probably represents the pedicle attachment for the posterior adductor muscles.

Distinct ovarian markings occupy the lateral slopes of the umbo. Dendritic pallial markings are observed at the lateral margins of the shell but details of their origin are obscure.

DIMENSIONS: Given for figured specimens only. All linear measurements were taken at their maxima as straight line distances. (The accidental destruction of a portion of UCM 34557 prohibits the citation of exact measurements.)

Characteristic	UCM 34556	UCM 34557	UCM 34558
Length	20.8 mm	?	25.5 mm
Width	21.1 mm	?	30.5 mm
Shell index (L/W)	0.98	?	0.86
Apical angle	120°	110°	120°
Plicae in sulcus	5	5	5
Width between bases of dent. lamellae	4.0 mm	5.5 mm	6.0 mm

TYPES: Syntypes: Rhynchonella striata Simpson, 1889, Pennsylvania Geol. Surv., Nos. 9,506, 9,507, 9,508 (= 2d Pennsylvania Geol. Surv., Rept. P4, vol. 2, p. 900-901, fig. x). Collected by F. A. Randall from the Waverly group [Corry] in the vicinity of Warren, Pennsylvania.

FIGURED SPECIMENS AND LOCALITIES:

UCM No.	Type	Locality
34556	Hypotype	116-C
34557	Hypotype	116-C
34558	Hypotype	123-C

OCCURRENCE: The specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 103-C, 112-C, 116-C, 123-C, 140-C, 214-C, 767-CT, 910-CT, 1565-CT, 14-S, and 19-S.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: The costellate exterior, general shape, size, and the presence of the "adductor process" permit assignment of these specimens to the genus *Paraphorhynchus* Weller (1905). The number of plicae in the sulcus (5-6), general dimensions, and characteristics of the muscle scars compare favorably with the species *P. striatum* (Simpson) as described by Caster (1930, p. 166).

P. striatum (Simpson) has fewer plicae in the sulcus than does *P. mediale* (Simpson); 5-6 *vs* 9-11. It differs from *P. girtyi* Caster by the possession of rounded rather than angular plicae, being less rugose, the conformation of the pedicle attachment of the diductor muscle scar, and in having the sulcus originate at the umbo. Of the mid-continent species *P. striatum* (Simpson) appears to have its closest affinities with *P. striatocostatum* (Meek and Worthen) or *P. transversum* Weller both of which display variations of the exterior ornamentation and measurement that warrant favorable comparison. (*See* Table 7.) Unfortunately, the details of the muscular impressions of these forms have not been adequately described. Branson (1938, p. 202, pl. 17, fig. 1) does illustrate a pedicle valve of *P. transversum* Weller which suggests that this species also possesses an "adductor process." (*See* also pl. 7, fig. 12, this report.)

P. elongatum Weller, unlike *P. striatum* (Simpson), is always longer than wide. *P. bushbergense* Branson and *P. crenulatum* Branson, in addition to other distinguishing characteristics, differ from *P. striatum* (Simpson) in that their sulci originate anterior of the mid-portion of the valve. The Russian species described by Nalivkin and Simorin (*see* Table 7) are all smaller forms; the characteristics of the muscle scars of these species is unknown.

REMARKS: As in the case of *P. mediale* (Simpson), the first published account of *P. striatum* (Simpson) appeared in Report P4 of the Second Geological Survey of Pennsylvania on pages 900-901. The description is a precise duplicate of the published version of Simpson's original address which did not appear until 1890 on pages 444-445 of the Transactions of the American Philosophical Society, n.s., vol. 16. The date of original publication is therefore credited to Simpson as of 1889.

Paraphorhynchus girtyi Caster, 1930

Plate 5, figures 6-10, 12.

Plate 6, figure 4.

1930 _Paraphorhynchus girtyi_ Caster, K. E., Bull. American Paleontology, vol. 15 (No. 58), p. 165, pl. 30, figs. 15, 17-19, 22.

1934 _Paraphorhynchus girtyi_, Caster, K. E., Bull. American Paleontology, vol. 21 (No. 71), p. 124.

SPECIMENS: The descriptive material below is based upon two specimens: (1) the holotype, a natural internal mold of both valves, (2) a single internal mold of the pedicle valve which compares favorably with the holotype. The exterior of the species is, as yet, unknown. Latex casts were made of both specimens.

DESCRIPTION:

General appearance: - The shell is rostrate, medium to large, and subquadrate to subtriangular in outline. The form in profile is biconvex with the brachial valve the smaller and more gibbous than the pedicle valve. The cardinal margin is subterabratulid; the anterior commissure uniplicate. As inferred from the molds, the external appearance is presumed to be rugose with heavy plicae and concentric ribbing marked by radiating costellae (striae, <u>auct</u>.).

<u>Interior</u> - <u>pedicle</u> <u>valve</u>: - The beak is erect, the valve moderately convex. The greatest convexity occurs at the umbo anterior of which the central portion of the valve flattens to accomodate the sulcus while the lateral slopes retain their convexity to the shell margins. The maximum width occurs anterior of the mid-point and always exceeds the length. The postero-lateral margins are straight and form an angle of 100° at the apex.

The sulcus originates anterior of the umbo and is relatively shallow for its entire length. From its inception it widens rapidly and occupies one half of the width of the anterior commissure. Four angular plicae are present in the sulcus for its entire length. The lateral margins each have three to four plicae, the largest of which delimits the lateral extent of the sulcus. The posterior and extreme lateral expressions of the plicae are not distinctly preserved.

The palintrope is small with rounded lateral margins; its mesial portion is occupied by a large triangular delthyrium which has a small submesothyrid foramen at its apex. The sides of delthyrium appear to be moderately restricted by a pair of descrete deltidial plates the details of which are indistinct. Narrow, complete, dental lamellae demark the delthyrium ventrally; the junction of their bases with the pedicle valve does not exceed the margin of the hinge-line and effects the formation of two narrow umbonal cavities between their sides and the lateral extremities of the umbo. Details of the dentition are not apparent.

An elevated ridge, originating at the bases of the lamellae and extending anteriorly for one-third of the total length of the valve, surrounds a deeply incised subtrapezoidal diductor muscle scar. Irregular, concentric varices mark the anterior portion of the muscle scar recording, perhaps, stages in the development of the muscles. In the middle of the diductor scar, extending from the posterior portion of the umbo to a position just anterior of the hinge-line, lies a syrinx-like "adductor process"; presumed to be the attachment for the posterior adductor muscles.

Ovarian markings are nowhere apparent. The dendritic development of the vascular system is well shown on the lateral portions of the valve but the origin of the system cannot be discerned.

Interior - brachial valve: - The brachial valve is smaller and more inflated than the pedicle valve. The fold originates anterior of the umbo and is distinctive only at the anterior margin of the shell. The surface of the fold has five angular plicae which are deeply marked on the mold of the interior under study. The plicae apparently originate at the umbo and gradually widen as the anterior margin is reached. The lateral portions of the valve each have three well developed plicae which, like those of the fold originate at the umbo. Observations of the umbonal portions of the valve indicate that the surface was covered with radial costellae. The mold (see pl. 5, fig. 8) has heavy concentric carinae which give the valve a rugose appearance. At the anterior end, the junction of the carinae and the plicae form a series of cheveron-like patterns on the fold.

The beak is recurved ventrally, and protrudes into the delthyrium of the pedicle valve. A well developed median septum extends from the beak to the center of the valve. The posterior portion of the septum is split and joined to the inner margins of a divided hinge-plate forming a triangular cavity (= septalium). (See pl. 5, fig. 9; pl. 6, fig. 4.) The hinge-plates lie between the dental sockets and the crural bases but the detail of their structure is obscure in the material at hand.

DIMENSIONS: For figured specimens only.

Characteristic	Repository Number	
(Pedicle Valve)	UCM 34560	Paleo. Res. Inst. 5154
Length	27.0 mm	23.0 mm
Width	30.0 mm	27.0 mm
Shell index (L/W)	0.9	0.86
Apical angle	90°	100°
Plicae in sulcus	4	4
Width between dental lamellae	6.0 mm	6.0 mm
(Brachial Valve)		
Length		21.0 mm
Width		28.0 mm
Shell index (L/W)		0.75
Plicae on fold		5
Length of median septum		13.0 mm

TYPES: Holotype: *Paraphorhynchus girtyi* Caster, 1930, Paleontological Research Institute No. 5154 (= Bull. American Paleontology, vol. 15 (No. 58), p. 165, pl. 30, figs. 15, 17-19, 22). Collected by K. E. Caster from the Corry sandstone at Cobham, Pennsylvania.

FIGURED SPECIMENS AND LOCALITIES:

Repository No.	Type	Locality
PRI 5154	Holotype (Mold)	123-C
UCM 34559 (= PRI 5154)	Plastoholotype (Cast)	123-C
UCM 34560	Hypotype	123-C

OCCURRENCE: The specimens studied were collected by K. E. Caster and the writer from the basal Corry sandstone at locality 123-C.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: The septalium, divided hinge-plate, brachial median septum, general size and shape of No. 5154 attest to its camarotoechid affinities. The inferred costellation of the mold and the presence of the "adductor process" in the pedicle valve permit its assignment to the genus Paraphorhynchus Weller (1905). The single pedicle valve (No. 34560) compares favorably with the pedicle valve of No. 5154 in the nature of its subtrapezoidal diductor scar, the presence of an "adductor process", the number of plicae in the sulcus (4), and its comparable shell index. No. 34560 is therefore assigned to the species Paraphorhynchus girtyi Caster (1930).

Paraphorhynchus girtyi Caster differs from *P. mediale* (Simpson) and *P. striatum* (Simpson) by virtue of its excessive rugosity, lesser number of plicae in the sulcus (4), origin of the sulcus at mid-valve, and subtrapezoidal diductor muscle scar. *P. elongatum* Weller, sometimes has four plicae in the sulcus but has a greater length than width. *P. transversum* Weller also has four sulcal plicae but its sulcus, unlike that of *P. girtyi*, originates at the umbo; it is also a less rugose form. *P. crenulatum* Branson is also a rugose form but its rugosity is confined to the postero-lateral margins and it has five to seven plicae in the sulcus.

The Russian species all appear to be smaller forms. In general, both exteriors and interiors are inadequately described. (*See* Table 7.)

REMARKS: The presence of the "adductor process" (described also for the two preceding species) and the unique form of the diductor muscle scar emphasize the importance of internal morphology in the study of brachiopods. The subtrapezoidal muscle scar which, in part, separates *P. girtyi* Caster from all other species of the genus may exist in the mid-continent or Russian species but thus far has not been documented.

<u>Paraphorhynchus</u> <u>casteri</u>, n. sp.

Plate 5, figures 11, 13-14.

Plate 6, figure 5.

SPECIMENS: The description which follows is based upon the molds of the interior of the pedicle valve of two separate individuals. A latex cast made from a deep mold of the holotype contained, on the reverse side, a portion of the exterior of the valve; thus permitting a descriptive reconstruction of the exterior. Only the holotype is figured.

DESCRIPTION:

<u>Exterior</u>: - The valve is large, broadly triangular, and rostrate. The maximum width occurs anterior of the mid-point of the valve and is greater than the length. The two dimensions differ from 5 mm to 8 mm in the specimens studied. In profile the valve is convex with the greatest convexity occuring at the antero-lateral margins. The beak ridges are straight, converging at the apex at angles which vary from 90° to 100°. From the cardinal margin the lateral extremeties are gently curved and form a sub-erect lingual extension at the anterior commissure.

The beak is erect; the foramen mesothyrid. The sulcus originates at the umbo and is already broad and shallow at its inception. It remains relatively shallow but widens perceptibly as the anterior margin is approached and occupies one-half the linear distance across the anterior commissure. Six to eight large, sharply angular plicae, which originate at the umbo, occupy the sulcus for its entire length, increasing in width toward the anterior of the sulcus. The lateral margins each possess three large, angular, plicae which originate anterior of the umbo. The largest and innermost of the three define the margin of the sulcus. The extreme lateral and postero-lateral margins appear to be non-plicate.

Fine radiating costellae (striae, auct.), which originate at the beak (see pl. 5, fig. 11), cover the shell surface. Coarse, concentric, carinae appear at the anterior margin of the shell and disrupt the plicae when crossing the sulcus.

Interior; - The palintrope is small with rounded lateral margins. The delthyrium is triangular with a broad base; it appears to be partially closed by discrete deltidial plates. Details of the structure are lacking. The teeth are supported by weak, thin, dental lamellae which also form small umbonal cavities along the lateral margins of the umbo. The lamellae are recessive and do not reach the hinge-line of the shell.

A modestly elevated ridge, originating at the base of the dental lamellae, surrounds a weakly impressed ovoid diductor muscle scar, the anterior portion of which does not attain one-quarter of the total shell length. At the posterior end of the diductor scar a weak "adductor process" is present but its structure is obscured by the deeply incised plicae in the sulcus. Details of the reproductive and vascular systems are obscure.

DIMENSIONS: All linear measurements are straight line distances.

Characteristic	UCM 34561	UCM 34562
Length	35.0 mm	33.0 mm
Width	43.0 mm	37.0 mm
Shell index (L/W)	0.81	0.89
Apical angle	100^{o}	90^{o}
Plicae in sulcus	6	8
Width between bases of dental lamellae	4.0 mm	5.0 mm

TYPES: Holotype: Paraphorhynchus casteri n. sp., 1959, UCM No. 34561 (= herein pl. 5, figs. 11, 13-14; pl. 6, fig. 5). Paratype: UCM No. 34562 (not figured). Collected by the writer from the basal Corry sandstone at Sill Run, two and one-half miles southwest of Warren, Pennsylvania.

FIGURED SPECIMENS AND LOCALITIES:

UCM No.	Type	Locality
34561	Holotype	116-C

OCCURRENCE: The specimens studied were collected by the writer from the basal Corry sandstone at locality 116-C.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: The general shape, surface costellation and "adductor process" compare favorably with similar features of the paraphorhynchoids described above. *P. casteri* differs from all previously described species by virtue of its excessive rugosity, number of plicae in the sulcus (6-8), and weakly developed, oval, diductor muscle scar. Its closest affinities are probably with *P. girtyi* Caster which is also a rugose form but the latter species is smaller, has a subtrapozoidal diductor muscle scar, only four plicae in the sulcus which originates anterior to the mid-point of the valve. (*See* Table 7 for further comparisons.)

REMARKS: The species is named for K. E. Caster in recognition of his paleontological studies in northwestern Pennsylvania.

Suborder SPIRIFEROIDEA Allen, 1940

emend. Muir-Wood, 1955

Superfamily PUNCTOSPIRACEA Cooper, 1944

Family SPIRIFERINIDAE Davidson, 1884

Subfamily SYRINGOTHYRINAE Schuchert and LeVene, 1929

Genus Syringothyris Winchell, 1863

1857 Spirifer Hall, James [pars], New York State Cab. Nat. Hist., 10th Ann. Rept., Appendix C, p. 170 [sc. S. carteri Hall, 1857].

1863 Syringothyris Winchell, Alexander, Philadelphia Acad. Nat. Sci., Proc., vol. 15, p. 6-8.

1867 Syringothyris, Davidson, Thomas, Geol. Mag., vol. 4, p. 311-313, pl. 14, figs. 1-11.

1867 Syringothyris, Meek, F. B., Geol. Mag., vol. 4, p. 315-316.

1867 Syringothyris, Carpenter, W. B., Ann. and Mag. Nat. Hist., vol. 20, 3d ser., p. 68-73, figs. 1-3.

1871 Syringothyris, Winchell, Alexander, Philadelphia Acad. Sci., Procl., vol. 11, p. 69, f. n.

1871 Syringothyris, Winchell, Alexander, Philadelphia Acad. Sci., Procl., vol. 11, p. 252-253.

1888 Syringothyris, Herrick, C. L., Denison Univ. Sci. Lab., Bull., vol. 3, pt. 1, p. 41-42, pl. 1, fig. 7; pl. 2, fig. 17; pl. 5, figs. 4-7.

1890 Syringothyris, Schuchert, Charles, New York State Geologist, 9th Ann. Rept., p. 28-37.

1894 Syringothyris, Hall, James and Clarke, J. M., New York State Geologist, 13th Ann. Rept., p. 760, pl. 30, figs. 1-11.

1894 Syringothyris, Hall, James and Clarke, J. M., New York Geol. Surv., Nat. Hist. of New York, Palaeont., vol. 8, pt. 2, p. 47-51, pl. 25, figs. 33-35; pl. 26, figs. 6-12; pl. 27, figs. 1-18.

1911 Syringothyris, Girty, G. H., Jour. Geology, vol. 19 (No. 6), p. 548-554.

1914 Syringothyris, Weller, Stuart, Illinois Geol. Surv., Mon. 1, pt. 1, p. 384-386; pt. 2, pl. 68, figs. 1-15; pl. 69, figs. 1-9; pl. 70, figs. 1-15; pl. 71, figs. 1-7; pl. 72, figs. 1-23; pl. 73, figs. 8-10.

1920 Syringothyris, North, F. J., Geol. Soc. London, Quart. Jour., vol. 76, p. 162-190, pls. 11, 12.

1930 Syringothyris, Caster, K. E., Bull. American Paleontology, vol. 15 (No. 58), p. 32-35, pl. 26, figs. 2-5; pl. 27, figs. 1-8; pl. 28, figs. 1-12; pl. 29, figs. 1-10.

1937 Syringothyris, Nalivkin, D. V., Central Geol. and Prospecting Inst., Trans., Fasc. 99, p. 109-110 (Russian), pl. 33, figs. 1-2.

1938 Syringothyris, Branson, E. B., Univ. Missouri Studies, vol. 13 (No. 3), p. 67-68, 174, pl. 6, figs. 5-7; pl. 8, figs. 6-11; pl. 19, figs. 3, 4 6.

1943 Syringothyris, Williams, J. S., United States Geol. Surv., Prof. Paper 203, p. 86-88, pl. 8, figs. 51-58.

1949 Syringothyris, Termier, Henri and Termier, Geneviève, Serv. Geol. Maroc, Notes and Mem., No. 74, p. 103-104, text fig. 10.

1953 Syringothyris, Hyde, J. E., Ohio Geol. Surv., Bull. 51, (edited by Marple, M. F.), p. 263-280, pls. 27-35.

1955 Syringothyris, Glenister, B. F., Royal Soc. Western Australia, Jour., vol. 39, p. 70-71, pl. 7, fig. 15; pl. 8, fig. 9; text fig. 7.

1956 Syringothyris, Simorin, A. M., Akad. Nauk Kazakhstan, S.S.R., (edited by Bykov, M. S.), Inst. Geol. Nauk, Alma-Ata, p. 203-206 (Russian), pl. 18, figs. 5-11.

1957 Syringothyris, Amos, A. J., Jour. Paleont., vol. 31, p. 103-104, pl. 18, figs. 1-7; text figs. 2, 3.

1958 Syringothyris, Holland, F. D., Jr., Thesis, Doctor of Philosophy, Univ. of Cincinnati [in press, Pal. Res. Inst., 1959], p. 275-294, pl. 13; pl. 14, figs. 1-11; pl. 15, figs. 8-9.

TYPE SPECIES (by subsequent designation; International Commission on Zoological Nomenclature, Opinion 100, 1928): Syringothyris typa Winchell, 1863, Philadelphia Acad. Nat. Sci., Proceedings, vol. 15, p. 6-7. [Not illustrated; first illustrations, loaned by Winchell, appear in Davidson, Thomas, 1867, pl. 14, figs. 1-5] Burlington limestone, Mississippian; Burlington, Iowa.

The often cited, but seldom quoted, original description of the genus Syringothyris by Winchell (1863, p. 6-8) reads, in part, as follows:

> DIAGNOSIS: Shell with an elongated hinge-line. Ventral valve with a mesial sinus, a very broad area, and a narrow triangular fissure closed toward the apex by an external, convex pseudo-deltidium, beneath which, and diverging from it, is another transverse plate connecting the vertical dental lamellae, arched above, and beneath giving off a couple of median parallel lamellae, which are incurved so as to nearly join their inferior edges - thus forming a slit-bearing tube, which projects beyond the limits of the plate, from which it originates into the interior of the shell. A low median ridge extends from the beak to the anterior part of the valve. Dorsal valve depressed, without area, with a distinct mesial fold. Shell structure fibrous.
>
> ...The shell substance is impunctate in all conditions and under high powers.

REMARKS:

Synonomy: - Only monographic treatment would accord the genus Syringothyris Winchell (1863) the consideration that is its due. Such a study is beyond the scope of this paper. The immediate objective is to accurately describe the species of Syringothyris, sensu stricto, in the Corry sandstone and compare them with those recently documented from the Knapp by Holland (1958).

The entries above, which record only a portion of the available literature on this genus, were deliberately selected to: (1) denote the work of authors whose studies on Syringothyris will receive further consideration in the text which follows and, (2) demonstrate the world-wide distribution of this genus. With the exception of the work of Hall (1857), all synonomous references prior to Winchell's designation of the genus Syringothyris in 1863, which are largely of historic interest, have been omitted. For accounts of references prior to 1863 the reader is referred to North (1920), Muir-Wood (1951), and Holland (1958).

Winchell's original description of Syringothyris, is admittedly inadequate by modern standards. His failure to familiarize himself with the published work of others and to designate a type species for his genus set in motion a controversy which was not settled until 1928 when the International Commission on Zoological Nomenclature (Opinion 100) suspended the rules and declared the type species of Syringothyris Winchell to be Syringothyris typa Winchell (1863). (See Holland, 1958, p. 278-280.)

Generic distinctions: - Weller (1914, p. 385) summarized the essential generic features of Syringothyris Winchell (1863) as: (1) a punctate shell structure [contrary to Winchell's opinion], except in the perideltidial region of the interarea; (2) the absence of plicae on the fold and sulcus; (3) the development of a syrinx attached to the "delthyrial plate" and presumed (herein) to be unsupported by a median septum; (4) the textile-like ornamentation of the external surface; and (5) the high cardinal area (= interarea). He (Weller, loc. cit.) remarked, "...the distinguishing characters are confined to the pedicle valve, indeed, from the brachial valves alone not even the species can be successfully identified."

Criterion number one, above, had become a cause célèbre much earlier when Winchell (1863, p. 7) said categorically that, "The shell substance [of Syringothyris] is impunctate...," and thus initiated a dispute which at times attained the magnitude of a personal vendetta. The issue of the presence or absence of punctae in the shell of _Syringothyris_, reached a heated climax in a series of sharp literary excanges between King, Carpenter, Meek, and Davidson in 1867. Some unanimity in the affirmative appeared to have been attained in 1867 when Carpenter (the sole dissenter other than Winchell), who had earlier denied the presence of punctae, upon re-examination of shell material sent by Winchell, declared (1867, p. 70) that _S. typa_ Winchell (1863) had "perforations" 1/3000 of an inch in diameter set 1/3000 of an inch from each other. Hall and Clarke (1894, p. 47), North (1920, p. 221), and Amos (1957, p. 103) have since concluded that the presence of punctae constitutes an essential characteristic of the genus; as did Vandercammen (1955, p. 391, _fide_ Holland, 1958, p. 281).

The issue, however, is not a simple one, despite the assurances of the authors cited above. Williams, describing _Syringothyris hannibalensis_ (Swallow), decalred (1943, p. 87), "Punctate shell structure was not seen on any of the specimens examined,..." Glenister, describing a new species of _Syringothyris_, _S. spissus_, declared flatly (1955, p. 70), "The shells are impunctate." He (Glenister) refuted the argument that punctae could have been destroyed by silicification in citing the presence of punctae in other genera from the same horizon and stated (_op. cit._, p. 71),

> It is difficult to believe that a complex structure such as a syrinx could appear simultaneously in two fundamentally different spiriferoid groups (puncatate and impunctate). The fact that both punctate and impunctate syrinx-bearing forms do appear simultaneously shows clearly the inadequacy of a classification which accepts the presence or absence of punctae as of primary taxonomic importance. As indicated earlier in this paper, the author is of the opinion that the presence or absence of punctae in the spiriferids is of secondary importance. For this reason it is proposed that the species under discussion [*Syringothyris spissus* Glenister] be assigned to *Syringothyris* and that this genus be expanded to include impunctate forms.

Glenister assigns the genus *Syringothyris* Winchell (1863) to the superfamily Spiriferacea rather than the informally proposed Punctospiracea as Cooper (1944) and Muir-Wood (1955, p. 92) have done. Glenister's removal of the genus from the superfamily Punctospiracea was anticipated by Roger (1952, p. 110) who likewise assigned *Syringothyris* to the superfamily Spiriferacea. Holland (1958, p. 283-284) cites William's (1956, p. 284) rejection of Cooper's Punctospiracea and "...willingly adopted," the rejection. Thus he (Holland) apparently accepts Glenister's contention that the genus *Syringothyris* Winchell (1863) can be either punctate or impunctate. The writer tends to agree with Holland, but working only with molds and latex casts, is unable to pursue the matter further. For reasons stated above, the genus is, for the present, left in the superfamily Punctospiracea.

Weller's criterion number two, above, had been anticipated much earlier by Winchell. He (Winchell, 1863, p. 8), speaking of *Syringothyris halli*, declared that the mesial fold and sinus, were "destitute of ribs [plicae]." Hall and Clarke, aware of Simpson's description "of the plicae on the fold and sulcus of *Syringothyris randalli* Simpson (1890), declared (1894, p. 47) that the fold and sulcus of *Syringothyris* were "*generally* non-plicate."

Schuchert (1910) apparently sided with Winchell and, removing those species of *Syringothyris* with supposedly plicate folds and sulcae from the genus, (*op. cit.*, p. 222) erected the genus *Syringopleura* Schuchert, designating *Syringothyris randalli* Simpson as the type species. The following year Girty (1911, p. 548-553), who examined Simpson's types at the Philadelphia Academy of Science, rejected Schuchert's new genus *Syringopleura* on the grounds that: (1) the plicae were highly imaginative in Simpson's original drawings (1890, p. 441, text fig. 6); and (2) Simpson had confused the valves of *Syringothyris randalli* with those of *Spirifera disjuncta* Hall [= *Cyrtospirifer* sp. Nalivkin, *in* Fredricks,1926], which do have plicate folds and sulci. Yet Girty (1911, p. 549) did mention "obscure radial markings" in the sulcus of *S. randalli* Simpson.

Weller (1914, p. 384), despite his denial of the existence of plicae on the fold and sulcus, cited above, apparently contradicted himself somewhat when he described *Syringothyris* as having "...the fold and sinus well developed and *usually* non-plicate." North (1920, p. 170), Caster (1930, p. 174), Branson (1938, p. 67), and Stainbrook (1943, p. 432) all consider the genus *Syringothyris* Winchell (1863) to be devoid of plicae on the fold and sulcus. More recently Glenister (1955, p. 70), speaking of the pedicle valve of *S. spissus* Glenister, observed:

> A deep, uniformly-rounded sinus is present in the pedicle valve, extending from the beak anteriorly. The sinus is smooth,...

Holland (1958, p. 289), sums up the situation as follows:

> The writer has not seen specimens of syringothyroids from the Penn-York Embayment in which the sulcus is strongly or completely plicate. Moreover the fold does not seem to reflect even weak ribs to compliment those which may creep into the sulcus. Hence, while there are forms of syringothyroids with plicae developed in the sulcus; it is safe to say that these can be distinguished externally from associated spiriferoids by possession of a smooth fold and a smooth or weakly plicate sulcus.

Through the courtesy of K. E. Caster the writer was able to obtain photographs of Simpson's types of *Syringothyris randalli* and *S. angulata*. Examination of these illustrations and rubber casts and molds of the writer's own specimens indicate that Holland's observations are correct (*see* pl. 8, figs. 1, 6; pl. 9, fig. 1). In certain respects it even appears that the fold of the brachial valve of S. angulata Simpson may have been faintly costellate. For the remainder of this section of the present work the writer accepts the view that the sulcus and possibly the fold of syringothyroids may be faintly plicate or costellate.

Weller's criterion number three, the presence of the syrinx, received universal recognition even prior to Winchell's formal proposal of the genus Syringothyris. However, its manner of growth, form, and function are still uncertain.

Winchell (1863, p. 7-8) considered the syrinx and the "transverse plate" to which it was attached to be modifications of a "false inner deltidium." He did not speculate as to its use. Schuchert (1890, p. 29) recorded the presence of a split tube and a median supporting septum for the species Syringothyris herricki Schuchert.

Hall and Clarke (1894, p. 49) proposed that the syrinx may have served to enclose a functionless pedicle rather than serve as the base of attachment for the pedicle muscles as suggested previously by King (1868, p. 18). North (1920, p. 168-170) sagaciously noted that the form of the syrinx was related to the growth-stage of the individual and that its earlier formed portion was frequently masked by the deposition of adventitious shell-material. Hyde (1953, p. 264) suggested that the presence of a median septum or the partial development of the syrinx represented respectively phylogerontic and phyloneantic stages of growth. He (Hyde, 1953, p. 265) remarked further, that the syrinx remained constant, within limits, for a particular species and that it probably served as an attachment for the adductor muscles rather than the pedicle.

Holland (1958, p. 276) describes the origin of the syrinx as follows:

> On the interior of the pedicle valve a transverse subdelthyrial plate [= transverse plate = delthyrial plate = syringal plate, *auct*.] extends forward from the apex for one-third to two-thirds of the length of the delthyrium. Two processes of the underside of the subdelthyrial plate form the syrinx which may be slit longitudinally on its underside, may be a complete tube, or may be a solid spine-like process.

With such a diversity both of opinion and form it is not surprising that the nature and function of the syrinx have remained enigmatic. The writer's study has revealed that while the syrinx, *s.l.*, is significant generically, it is equally important as a specific trait.

The presence of the remaining generic features, the textile-like external ornamentation and the high cardinal area, have always received universal acceptance; it is their function which has been questioned.

The "twilled-cloth" external appearance of *Syringothyris* is distinctive, but the purpose of such ornamentation is unknown. The "twilled-cloth" texture is created by elongate pustules arranged in a chevron-shaped pattern on the crest of each plica. Holland (1958, p. 287) sums up current speculation as to the function of this ornament in the following manner:

> It seems possible to the writer that the spinules of Syringothyris [Winchell, 1863] and Syringopleura [Schuchert, 1910] represent the position of setae on the edge of the mantle unless the suggestion of Vandercammen (1955) that the spinules represent the termina of puncta proves universally correct.

As for the interarea (= cardinal area, auct.), it too displays characteristics of uncertain origin and function. Weller observed, in Syringothyris, the tripartite nature of the interarea and stated (1914, p. 384):

> The pedicle valve subsemipyramidal in form, the high cardinal area either flat, concave or convex, differentiated into three regions, a central including the delthyrium, and two lateral,...; the central region is distinctly marked by vertical striae, while the lateral regions are marked only by horizontal lines of growth;...

This differention of the interarea was subsequently noted in other taxa. Dunbar and Condra reported a similar phenomenon in the Orthotetinae and called the vertically striated region (1932, p. 67, text fig. 1) the perideltidial area. After duly reporting that the shell lamellae passed unbroken from the perideltidial area to the lateral regions they (Dunbar and Condra, 1932, p. 68) concluded, "The reason for this specialization of the cardinal area is an enigma." Holland (1958, p. 284-286) came to the same conclusion.

From the preceding discussion it appears that the distinctive features of the genus *Syringothyris* Winchell (1863), *s.s.*, should be:

1. Shell structure punctate or impunctate; except in the perideltidial region which is never punctate. (No one has thus far, noted whether punctate forms are endopunctate or exopunctate.)
2. The fold and sulcus *may* display faint plicae, particularly along their lateral margins. This distinction is apparently more common in the sulcus.
3. An unsupported syrinx developed from a transverse subdelthyrial plate, modifications of which take place concomitant with increasing age and the correlated disposition of adventitious shell material.
4. Textile-like ornamentation of the lateral plicae on both valves.
5. High interarea with a vertically-striated perideltidial region.

The presence of only part of these features, or modifications thereof have correctly or incorrectly been the bases for the erection of a number of genera. (See Table 8.)

TABLE 8. - Status of proposed syringothyroid genera. (Modified from Holland, 1958, p. 294, Table 10.)

Genus	Distinguishing Features
Syringothyris Winchell (1863)	Large, high area, textile-like exterior, punctate and impunctate, syrinx unsupported.
Syringopleura Schuchert (1910)	Punctate and impunctate, dental pl. short and thick, syrinx supported [?].
Pseudosyringothyris Fredericks (1916)	Subdelthyrial plate with roller-like callosity with longitudinal furrow.
Prosyringothyris Fredericks (1916)	Bilobed extensions of the subdelthyrial plate lacks ½ to 1/3 of a circle of meeting on the underside.
Plicatosyrinx Minato	Impunctate, plicate fold and sulcus, no (?) dental plates or median septum.
Pseudosyrinx Weller (1914)	Punctate and impunctate, without syrinx or subdelthyrial plate.
Asyrinxia Campbell (1957)	Punctate, "textile" surface, high area, alate, 4-6 weak costae in sulcus, perideltidium, no transverse plate or sulcus.
Eosyringothyris Stainbrook (1943)	Impunctate, high area, perideltidium, pustulose exterior, small subdelthyrial plate ends in a short sharp spine.
Septosyringothyris Vandercammen (1955)	Punctate, dental plates short and thick, long syrinx supported by a median septum.
Syringospira Kindle (1904)	Impunctate, high area, granulose surface, fold and sulcus costate, frill on area, blister-like plates in the posterior of pedicle valve, short dental plates, transverse plate without syrinx or delthyrial tube, stegidium.

Generic relationships: - With the exception of the syrinx, many of the internal morphological features of the pedicle valve of *Syringothyris* Winchell, *sensu stricto*, are shared by *Cyrtospirifer* Nalivkin (*in* Fredricks, 1926). Comparison of Greiner's Plate 7, figures 16-19 (*Cyrtospirifer nucalis* Greiner) with the writer's Plate 9, figures, 8-11 (*Syringothyris randalli* Simpson) demonstrates that the two species share in common:

1. Callists, originating on the dental lamellae which seal the delthyrium, in varying degrees, from below.
2. Thick, stout, divergent dental lamellae encircling the muscle field.
3. High cardinal areas (= interarea).
4. Well defined sulci.
5. *Transverse subdelthyrial plates* [*fide* Holland, 1958, p. 456 whose usage of the term is herein adopted].
6. Flanges at the lateral margins of the delthyrium.
7. Posterior adductor muscle attachments which Greiner (1957, p. 30) calls, "a spear-like apical boss or callus of secondary growth." [Holland (1958) calls this process the *posterior adductor process*; his terminology is herein adopted, but modified by quotation marks to differentiate

between its attachment to the subdelthyrial plate in cyrtospiriferids as opposed to such a union in *Syringothyris*].

Syringothyris Winchell (1863) can be differentiated from *Cyrtospirifer* Nalivkin (*in* Fredericks, 1926, as follows:

1. *Syringothyris*, *s.s.*, has a syrinx in the pedicle valve while *Cyrtospirifer* does not.
2. The fold and sulcus of *Cyrtospirifer* are plicate; those of *Syringothyris* only faintly plicate - if at all.
3. The exterior of *Syringothyris* is characterized by plicae which exibit a "twilled-cloth" texture and do not bifurcate or intercalate; those of *Cyrtospirifer* have spinose micro-ornament and do bifurcate and intercalate.
4. *Cyrtospirifer* has greater total number of plicae on each valve than does *Syringothyris*.

It is the similarities between syringothyroids and other spiriferoids that have prompted a number of writers to postulate the derivation of *Syringothyris* from spiriferoid (*sensu lato*) stock. Hall and Clarke (1894, p. 48) declared, "..., it is quite safe to assume that this peculiar group of forms [*Syringothyris*] is an outcome from normal development with variation along that

[Spirifer plenus Hall] spiriferoid line." North (1920, p. 187) re-emphasized this inferred relationship stating:

> In the Devonian rocks of North America there seems to be clear evidence of the evolution of the syrinx. American palaeontologists have described a number of species of Spirifer in which the fold and sinus are non-plicate, and in which a well-developed apical callosity and transverse plate are seen: as, for example, Sp. granulosus Conrad and Sp. asper Hall, both from the Hamilton group (Middle Devonian).

Termier and Termier (1949, p. 103) are somewhat more specific, stating [in translation]:

> One places Syringothyris in a special family because of the existence of the syrinx... Perhaps, as Girty thought, according to North (1913), this group had its origin in North America through Syringospira [Kindle, 1909] of the Upper Famennien (Conewango). This imperforate form [Syringospira] reminds one of Cyrtospirifer but it has lost the ribs of the fold; its brachial valve has the same characteristics as Syringothyris and further a transverse plate (sub-delthyrial) which bears a median fold which is the forerunner of the syrinx.

Internal morphology and preservation: - In the Corry sandstone conjunct brachial and pedicle valves of the species of Syringothyris are seldom found. Apparently this condition does not pertain to all instances of the occurrence of the genus in the Penn-York Embayment, for Holland (1958) has reported locations in the Knapp where complete specimens were collected.

Unlike Paraphorhynchus Weller (1905), the brachial valves of which are seldom in evidence, numerous molds of the brachial exterior of Syringothyris are found in the

Corry in close proximity to molds of the pedicle valves. Attempts to match pairs of valves were unsuccessful. Since there is no way at present of differentiating between the brachial valves of various Corry species, descriptions of complete specimens has not been attempted herein except in the nature of quotations.

The association of separated brachial and pedicle valves of Syringothyris, in contrast to the wide dispersal of the two valves of Paraphorhynchus for example, is probably attributable to their larger size and weight and similar hydrodynamic quality, hence they were but little moved by currents. As in the case of paraphorhynchoids, it appears that the dentition of Syringothyris was weak; the teeth and sockets serving as fulcral points rather than instruments of closure. The universal presence of the heavily-striated and deeply incised muscle scars may indicate that these structures, rather than the ineffectual teeth and sockets, were instrumental in keeping the valves together as well as opening and closing them. Whether or not the syrinx played a part in these activities remains a mystery.

The origin of the molds themselves was probably the same as that of the paraphorhynchoids - discussed above.

Ecology: - From accounts of the occurrence of Syringothyris in various areas, in addition to that under discussion, certain generalizations relevant to the environmental preference of the genus can be made. Species of *Syringothyris* have been found in almost all of the ordinary sedimentary lithic types:

1. Conglomerate:

   a. Cobham conglomerate (L. Miss.), northwestern Pennsylvania. (Holland, 1958, p. 302: *S. angulata* Simpson.)

2. Coquinoid:

   a. Marvin Creek coquinoid zone of the Knapp (l. Miss.), northwestern Pennsylvania. (Holland, 1958, p. 301: *S. angulata* Simpson.)

3. Sandstone:

   a. Bushberg sandstone (L. Miss.), Missouri. (Branson, 1938, p. 174: *S. bushbergensis* Weller.)

   b. Sistema del Imperial (L. Carb.), Mendoza, Argentina. (Amos, 1957, p. 104: *S. feruglioi* Amos.)

4. Shale:

   a. Salverton shale (L. Miss. ?), northeastern Missouri. (Williams, 1943, p. 87: *S. hannibalensis* (Swallow).)

   b. Bedford shale (L. Miss.), Ohio. (Hyde, 1953, p. 268: *S. bedfordensis* Hyde.)

5. Limestone:

   a. Moogooree limestone (Devono-Miss.), western Australia. (Glenister, 1955, p. 71: *S. spissus* Glenister.)

It would thus appear that species of *Syringothyris* were capable of adapting themselves to a variety of bottom conditions.

The fauna of the Corry sandstone (Syringothyris included), with a few exceptions, appears largely in the basal member. Close examination of bulk lithologic specimens reveals that some species of Syringothyris are represented by individuals of all but the youngest growth stages. Furthermore, gastropods are frequently found in the same faunule in great numbers and various growth stages, particularly at localities 116-C and 1565-CT (see Appendix A, text fig. A9). Greiner (1958, p. 58) has also noted a similar association at lower levels in the Embayment. That this gastropod-brachiopod association may have existed in life is indicated by the occurrence of a conical depression in the mold of the diductor muscle scar of a specimen of S. randalli Simpson (see pl. 9, fig. 7) which is reminiscent of the radula drilling done by recent marine Gastropoda.

Finally, the occurrences of S. randalli Simpson within the basal Corry appear to be limited to the eastern half of the area of investigation (see Table 3 and text fig. 11). This may reflect near shore conditions or even inter-co-tidal association, for the basal Corry member becomes evanescent eastward.

Distribution: - From all accounts the genus _Syringothyris_ Winchell (1863), _s.s._, exhibits a world-wide post-Devonian distribution. Its first appearance appears to be a reliable criterion of Lower Mississippian (Tournaisian) age.

North (1920, p. 221) said of the genus:

> It was initiated in Middle Devonian times, and reached its acme early in the Carboniferous Period. Our knowledge of the pre-Carboniferous history of the genus is, up to the present, derived entirely from its North American representatives.

More recently Termier and Termier (1949, p. 110) commented [in translation]:

> It is clear that several genera originated in North America and subsequently migrated from this source (_Mucrospirifer_ and _Syringothyris_ among others).

The remarks above are interpreted as indicating that the authors regard the ancestral stock of _Syringothyris_, not _Syringothyris_, _s.s._, itself, to have evolved in pre-Mississippian times. There are no unquestioned occurrences of _Syringothyris_ in beds of pre-Mississippian age. Holland (1958, p. 77-78) has cautioned:

> ...nearly universally _Syringothyris_ appears at the base of the Carboniferous sequence. Certainly it is a far more characteristic Mississippian than Devonian genus, and reports of the genus, _sensu stricto_, in Devonian strata, are to be looked upon with doubt.

Glenister (1955, p. 47) discouts occurrences of the genus from the Permian of India, Spitzbergen and Australia which are reported by Maxwell (1954, p. 41-42).

Evolutionary trends: - The syrinx, which characterizes the genus, is a useful tool for specific differentiation. Although North (1920, p. 206) said in commenting on Syringothyris, "The two structures, a median septum and a syrinx-bearing transverse plate, could not coexist in the same shell, since they would mutually interfere one with the other," the fact remains that in the Corry sandstone syringothyrids with and without a median septum supporting the syrinx do occur side-by-side. Whether one form evolved from the other is difficult to determine because of our lack of knowledge of the function of the syrinx. The possibility exists that the syringothyroids as a group may be diphyletic, with coeval and coetaneous septate and nonseptate forms evolving from different stocks.

There are, in addition to modifications of the syrinx, two other factors which may have evolutionary significance. These apparently related factors are: (1) the modification of the dental lamellae, and (2) the deposition of callist shell material in the posterior of the pedicle valve.

Through the medium of secondary deposition on and around the dental lamellae, they become thick and stout. Additional callists from the lamellae, more or less restrict the delthyrial opening and augment and change the shape of the subdelthyrial plate and its syrinx.

In like manner, perhaps for better balance, callist deposits fuse portions of the syrinx and the "posterior adductor process." The posterior wall of the lateral cavities bear callists which could also have been deposited as "ballast" in forms with an ineffectual pedicle and no apparent substitute mode of attachment.

Specific distinctions: - If the features enumerated above characterize the genus, how then, are species of Syringothyris Winchell to be distinguished from one another? Weller (1914, p. 385-386) discussed this problem as follows:

> The essential specific characters are found in the pedicle valve and consist in the proportional height of the cardinal area, its degree of curvature, whether flat, concave, or convex, and especially in the size of the angle between the flatter portions of the area and the plane of the valve, this angle varying among different species from 25 to 110 degrees or more, but being fairly constant among different individuals of the same species. Another set of characters which seem to be of prime importance in specific differentiation are the characters of the delthyrial plate [= syringal plate = subdelthyrial plate = transverse plate, auct.] and the syrinx. In all those species where a sufficient number of individuals have been observed showing these characters, they seem to be constant within reasonably narrow limits of variation, and they have been assumed to be of good specific value in other forms in which they have been observed sometimes in but a single individual; the different characteristics of this plate are shown in its transverse contour externally, whether flat, concave or longitudinally keeled, and in the length and width of the free extension of the syrinx.

No other writer has attempted such a summary, although others have incorporated its essence in their own descriptions of syringothyroid species. While these factors are important, there are others, occasionally touched upon in the literature, which may prove to be of great value in making specific determinations: (1) the disposition of secondarily deposited shell material in and around the posterior portion of the pedicle valve; (2) the nature of the closure of the delthyrium; (3) the development of the dental lamellae throughout progressive stages of growth; and (4) the nature of the "ovarian markings."

North (1920) remarked that the amount of callist material in the apical portion of the pedicle valve of syringothyroids increased in proportion to the age of the individual. Hyde (1953) demonstrated that "testaceous deposits" could and did mask various features of the internal morphology of Syringothyris. Neither author pursued the matter any further. It has been found that callist or "testaceous" material is deposited in a manner indigenous to a particular species and may be employed in specific taxonomy.

The closure of the delthyrium and the nature of the dental lamellae appear to have a direct relationship. The delthyrium is commonly described as being restricted by the growth of a structure variously called the "pseudodeltidium", stegidium, or xenidium. Whatever the terminology used, the structure usually occurs on the dorsal side of the delthyrium. The writer's observations have revealed that partial closure of the delthyrium is also effected on the ventral side by the development of callist material related, as is the subdelthyrial plate and the syrinx, to the dental lamellae. (See pl. 8, figs. 3-4; pl. 9, figs. 8-10.) Like other "testaceous" material, this ventral delthyrial plug appears to have value in specific determinations. Greiner (1957, p.20) noted a similar structure in the cyrtospiriferids but referred to it simply as a "secondary growth." (See Greiner, 1957, pl. 7, figs. 16, 17, 19.)

"Ovarian markings" also appear to have patterns of value in making specific determinations. (Compare pl. 8, fig. 4 and pl. 9, fig. 9.)

Syringothyris angulata Simpson, 1890 emend.

Plate 8, figures 1-8.

1889 *Syringothyris angulata* Simpson, G. B. [*nomen nudum*], [title only], 2d Pennsylvania Geol. Surv., Rept. O3, p. 258.

1890 *Syringothyris angulatus* Simpson, Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 3, p. 1150, figs. numbered 1-3.

1890 *Syringothyris angulata* Simpson, G. B., American Phil. Soc., Trans., vol. 16, p. 440, fig. 5 [figs. numbered 1-3].

1890 *Syringothyris angulata*, Schuchert, Charles, New York State Geologist, 9th Ann. Rept., p. 32.

1894 *Syringothyris angulata*, Hall, James and Clarke, J. M., Nat. Hist. New York, Paleont., vol. 8, pt. 2, p. 50, pl. 27, figs. 14-15.

1898 *Syringothyris angulatus*, Weller, Stuart, United States Geol. Surv., Bull. 153, p. 619.

1930 *Syringothyris angulata*, Caster, K. E. [*pars*], Bull. American Paleo., vol. 15 (No. 58), p. 32-35, pl. 26, figs. 2, 4-5; pl. 27, figs. 1-3; pl. 28, fig. 9; pl. 29, figs. 1-8 [*non* pl. 27, figs. 4, 6-7; pl. 28, figs. 1-8, 10-12; pl. 29, figs. 9-10 (*Syringothyris randalli* Simpson)].

1958 Syringothyris angulata, Holland, F. D. Jr. [pars], Thesis, Doctor of Philosophy, Univ. of Cincinnati [in press, Pal. Res. Inst., 1959], p. 295-303, pl. 13, figs. 1-5, 10-15; pl. 14, figs. 1-2 [non pl. 13, figs. 6-9 (Syringothyris randalli Simpson)].

1958 Syringothyris warrenensis [?] Holland, F. D., Jr., Thesis, Doctor of Philosophy, Univ. of Cincinnati [in press, Pal. Res. Inst., 1959], p. 303-307, pl. 14, figs. 3-10.

SPECIMENS: The information which follows is based mainly upon six natural molds of the interior of the pedicle valve and the latex casts derived therefrom. Descriptive reconstructions of the exterior of the brachial and pedicle valves are based upon illustrations of Simpson's types. Examination of hundreds of rock specimens failed to disclose a single example of S. angulata Simpson with the two valves attached. Separate brachial valves could not be identified as to specific affiliation. As mentioned above, Weller (1914, p. 385) denies the importance of the brachial valve in the identification of species and describes the interior simply as "essentially as in Spirifer." Measurements are given only for the interarea since the extremities of the molds are frequently masked by the enclosing matrix.

DESCRIPTION:

General appearance: - The shell is generally medium to large sized and spiriferoid in shape. The form in profile is biconvex. The interarea of the pedicle valve is large and that of the brachial valve insignificant. In planar view the cardinal margin is megathyrid; the anterior commissure uniplicate. The lateral margins of both valves possess radial plicae which exibit a "twilled-cloth" texture. The fold and sulcus may possess faint plicae, particularly at their lateral extremities.

The brachial exterior: - (See pl. 8, fig. 6.) The cardinal margin is straight and equal to the greatest width of the shell. The greatest convexity occurs along the median line of the valve and is accentuated at the umbo. The fold appears to originate at or posterior to the umbo and increases in both breadth and height anteriorally. From the mold (pl. 8, fig. 6) the crown of the sulcus appears to bear faint radiating costellae. The lateral slopes of the valve each bear 18-20 radiating subangular plicae which originate at the beak and neither bifurcate or intercalate. The plicae appear to be narrower and less distinct toward the posterior margin.

The surface of the valve bears irregularly disposed concentric carinae which are faint near the posterior margin of the shell and deeply incised at the anterior margin. It is assumed that the exterior exibited the "twilled-cloth" appearance.

<u>The brachial interior</u>: - For this description the writer is indebted to Holland (1958, p. 299) who says:

> The cardinalia are strong and spiriferoid. Wide sockets, which narrow posteriorally, are excavated in the strong, pendant socket plates and bounded by high heavy inner socket ridges. The cardinal process is a low vertically striate area nearly flush against the posterior wall of the valve. Below this is commonly developed a low, broad, nearly vertical median ridge or buttress at the posterior of the valve. Lateral branches of this ridge may connect with the socket plates or these plates may hang free. In some specimens this vertical posterior buttress is produced anteriorly as a short low median septum. Interior markings obscure. Details of the spiralia not known.

<u>The pedicle exterior</u>: - The valve has a high inter-area which may be orthocline to apsacline and slightly recurved at its apex. The greatest width of the shell is at the cardinal margin which is coincident with the hinge line.

In profile the valve is generally convex, flattening somewhat anteriorally; the lateral margins retain their convexity. The beak ridges are gently curved and join at the apex at an angle which approximates 120°. Anterior of the cardinal extremities, the lateral margins are gently rounded.

The sulcus apparently originates at or near the umbo and gradually widens anteriorally but always remains shallow and somewhat indistinct. Although generally considered to be non-plicate, impressions on the molds of the interior show a few faint plicae at the lateral and anterior margins of the sulcus. (See pl. 8, figs. 1, 8.) The plicae on the lateral slopes of the valve are indistinct in the specimens at hand but apparently are similar in conformation and distribution to those of the brachial valve.

Pedicle interior: - The interarea is large and gently concave; it is interrupted mesially by a large triangular delthyrium the length of which is greater than its maximum width. There is no indication, on either mold or latex cast, of a perideltidial area. The lateral margins of the delthyrium are marked by elongate narrow flanges for their entire length. From the apex to approximately 2/3 of its length the delthyrium is covered by what appears to be a single convex plate, the edges of which are welded to the bordering flanges. This is probably the "pseudodeltidium" of various authors but neither mold nor cast exibit sufficient detail for further comment here. The "deltidial plate" frequently shows on molds of the interior as a narrow horizontal slit just below the mold of the upper surface of the delthyrium. The posterior portion of the deltyrium appears to have been plugged with callist deposits.

The lateral margins of the delthyrium are delimited ventrally by stout, complete, divergent dental plates which, in joining the floor of the valve, divide the posterior margin of the pedicle valve into a central rostral cavity and two lateral cavities. The bases of the dental lamellae extend beyond the hinge line as a pair of elevated sinuous ridges which join near the anterior margin of the shell forming an oval-shaped arena which surrounds the muscle scars. (See pl. 8, figs. 3-4.)

A pair of striated diductor muscle scars occupy most of the floor of the oval-shaped arena and exibit a curious serration at their lateral extremities. A long, thin, bilobed anterior adductor scar occupies the central-anterior portion of the muscle scar area. Its postero-central region has a thick, bilobed, "posterior adductor process" the median sulcus of which displays elongate striae. The "posterior adductor process" appears as an elongate "wrinkly" area in the midst of the triangularly shaped mold of the posterior wall of the rostral cavity; it never attains the summit of the mold. (See pl. 8, figs. 1, 2, 5, 7, 8.)

A number of structures, critical for syringothyroid identification, are derived from the upper extremities of the dental lamellae. At the juncture of the dental lamellae and the lateral margins of the delthyrium, callist deposits develop which grow inward and partially restrict the delthyrial opening from below (<u>see</u> pl. 8, fig. 3, 4). These deposits are genetically related to the dental lamellae, fused to the edges of the delthyrium but are not conjunct, and appear to have value in making specific determinations, as indicated previously.

Slightly below the cardinal margin an inverted "shoehorn-like" process (= <u>subdelthyrial plate</u>) is suspended between the dental lamellae. It is dorsally convex or flattened dorso-ventrally, and projects slightly anterior of the cardinal margin and the dental lamellae. If it is formed by conjunct lateral plates the suture is not apparent on mold or cast. On the underside of the projected area two processes, originating at its lateral margins, curl inward and form an open tube or syrinx. The open portion of the syrinx bears elongate striae; there is no evidence of a median septum contributing to its support.

On the underside of the interarea, in the lateral cavities, the latex casts show elevated, elongate regions adjacent to the delthyrium. Upon examination of the molds they proved to be elongate "tear-drop" impressions, more deeply incised than the casts would indicate. They may represent callists in the living organism.

Scattered ovarian markings are also faintly represented in the posterior extremities of the lateral cavities.

Due to the nature of preservation of the material at hand the nature of the dentition, vascular system, and the presence or absence of punctae could not be determined.

DIMENSIONS: Given for only those figured specimens in possession of the writer and taken largely from latex casts.

Characteristic	UCM 34563	UCM 34564
Apical angle	120°	120°
Delthyrial angle	40°	40°
Height of delthyrium	16 mm	14 mm
Width of delthyrium	7 mm	7.5 mm
Length of cardinal margin	39.5 mm	37.5 mm

TYPE: Lectotype [by subsequent designation, Holland, 1958, p. 299]: Syringothyris angulata Simpson, 1890, Academy of Natural Sciences of Philadelphia. No. 3535 (= American Phil. Soc., Trans., n.s., vol. 16, p. 440, fig. 5, specimen number 3). Collected by F. A. Randall from the Pocono (Waverly) formation X. at Warren, Pennsylvania. [Probably from the Kushequa shale, fide Holland, 1958, p. 299.]

FIGURED SPECIMENS AND LOCALITIES:

Repository No.	Type	Locality
UCM		
34563	Hypotype	116-C
34564	Hypotype	116-C
Phil. Acad. Sci.		
9535	Lectotype	Warren, Pa.
9533	Paratype	Warren, Pa.
9538	Paratype	Warren, Pa.

OCCURRENCE: Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 116-C, 113-P, and 90-P.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: The presence of an unsupported syrinx, the faintly plicate fold and sulcus, the "twilled-cloth" appearance of plicae which neither bifurcate or intercalate, and the high cardinal area all mark the specimens on hand as species of the genus *Syringothyris* Winchell (1863), *sensu stricto*. General shape, character and position of the impression of the "posterior adductor process" on the mold of the posterior wall of the rostral cavity (*cf*. figs. 1-2, pl. 8 and figs. 5, 8, pl. 8), and the mold of the subdelthyrial plate and syrinx, permit assignment of these specimens to the species *Syringothyris* angulata Simpson. The presence of the dorsally convex "shoehorn-like" subdelthyrial plate and its subtended syrinx mark this species as unique among American syringothyroids. The question of its supposed synonymous relationship with S. randalli Simpson will be considered in the discussion of that species.

Holland (1958, p. 303) has erected a new species which he calls Syringothyris warrenensis, placing in synonomy with it S. randalli Simpson, Hall and Clarke, S. typa Winchell, and S. herricki Schuchert. His (Holland, 1958, p. 303-305) description of the species includes such characteristics as:

1. A strong covering (xenidium) of the delthyrium for 2/3 to 3/4 of its length.
2. Strong dental lamellae sufficiently thickened to restrict or close the delthyrium ventrally.
3. A heavy transverse plate with a "roof-shaped syrinx."

This species supposedly differs from S. angulata Simpson but the relationship is not clear to the writer. Examination of Holland's Plate 14, figures 3-10, fails to reveal any significant differences between Syringothyris warrenensis Holland and S. angulata Simpson (see herein, pl. 8, figs. 1-8). Because of the similarity in both description and illustration Syringothyris warrenensis Holland is herein rejected and declared to be a junior subjective synonym of *Syringothyris angulata* Simpson.

REMARKS: The exact date of publication of *S. angulata* Simpson is difficult to establish. The species, originally presented orally in 1888, appears in 1890 in two different publications as noted in the specific synonomy above. Lesley (2d Pennsylvania Geol. Surv., Rept. P 4, p. 1150) not only uses Simpson's wording in his description but also, without explanation, changed the spelling of the specific name from *angulata* to *angulatus*. Since Simpson was no doubt responsible for the original description he is awarded authorship of *S. angulata* as of 1890.

Syringothyris randalli Simpson, 1890 emend.

Plate 9, figures 1-11.

1889 *Syringothyris randalli* Simpson, G. B. [*nomen nudum*], [title only], 2d Pennsylvania Geol. Surv., Rept. O3, p. 258.

1890 *Syringothyris randalli* Simpson, G. B., *in* Lesley, J. P., 2d Pennsylvania Geol. Surv., Rept. P4, vol. 3, p. 1150-1152, fig. 6 [illustrations numbered 1-2].

1890 *Syringothyris randalli*, Simpson, G. B., American Phil. Soc., Trans., vol. 16, p. 441-442, fig. 6 [illustrations numbered 1-2].

1890 Syringothyris randalli, Schuchert, Charles, New York State Geologist, 9th Ann. Rept., p. 36.

1894 Syringothyris randalli, Hall, James and Clarke, J. M., New York State Geologist, 13th Ann. Rept., pl. 30, figs. 10-11.

1894 Syringothyris randalli, Hall, James and Clarke, J. M. [pars], New York Geol. Surv., Nat. Hist. New York, Palaeont., vol. 8, pt. 2, p. 50, pl. 27, figs. 13, 16-17 [non pl. 27, figs. 14-15 (Syringothyris angulata].

1898 Syringothyris randalli, Weller, Stuart, United States Geol. Surv., Bull. 153, p. 621.

1910 Syringopleura randalli, Schuchert, Charles, American Jour. Sci., vol. 30, 4th ser., p. 224.

1911 Syringothyris randalli, Girty, G. H., Jour. Geology, vol. 19 (No. 6), p. 548-554.

1920 Syringothyris randalli (Simpson) [?], North, F. J., Geol. Soc. London, Quart. Jour., vol. 76, p. 190.

1934 Syringothyris randalli, Caster, K. E., Bull. American Paleontology, vol. 21 (No. 71), p. 71.

1939 Syringothyris texta (Hall), Willard, Bradford, Pennsylvania Geol. Surv., ser. 4, Bull. G 19, pl. 22, fig. 8.

1953 Syringothyris randalli, Hyde, J. E., Ohio Geol. Surv., Bull. 51 (edited by Marple, M. F.), p. 277-278.

1958 Syringopleura randalli (Simpson), Holland, F. D. Jr., Thesis, Doctor of Philosophy, Univ. of Cincinnati [in press, Pal. Res. Inst., 1959], p. 310, pl. 15, figs. 8-9.

SPECIMENS: The morphological descriptions which follow are based primarily upon five accessioned specimens in the writer's possession. With a single exception (a mold of the exterior of the pedicle valve), all are molds of the interior of the pedicle valve. In addition, dozens of poorly preserved specimens were observed in the course of the preparation of material collected in the field. Comparisons were also made with photographs of Simpson's type, furnished by K. E. Caster.

Although numerous examples of "apparent" syringothyroid brachial valve molds were found, none were joined to an undoubted pedicle valve of Syringothyris randalli Simpson. For this reason, and the fact that Simpson's (1890, p. 441) description of the brachial valve may have been based upon a cyrtospiriferid valve (*fide* Girty, 1911, p. 550), no attempt is made herein to give a descriptive reconstruction of the brachial valve of this species.

Because the matrix surrounding the molds masks the extremities of the valve, measurements are given for the interarea only.

DESCRIPTION:

The pedicle exterior: - The valve has an interarea which is generally apsacline and gently concave. Its greatest width is at the cardinal margin which is coincident with the hinge line.

The profile is convex, both longitudinally and transversely with the maximum convexity centered at the umbo. The beak ridges curve gently and join at the apex of the valve at an angle which approximates 120°. Anterior of the cardinal extremities the lateral margins are gently rounded.

The sulcus originates at the beak, gradually widening and deepening as the anterior margin of the valve is attained. while the single cast of the exterior on hand does not exibit plicae in the sulcus; the photograph of Simpson's holotype does (see pl. 9, fig. 1). The lateral slopes of the valve are each occupied by 15 plicae which originate at the posterior margin of the valve. The plicae tend to be less distinct near the cardinal extremities; all exibit the characteristic "twilled-cloth" texture.

Pedicle interior: - The concave interarea is divided mesially by a large triangular delthyrium, the length of which exceeds its maximum width. The perideltidial area is not apparent on eitner mold or cast. The lateral margins of the delthyrium are sculptured by elongate narrow flanges for their entire length. There is no direct evidence for closure of the delthyrium by deltidial plates of any kind. Occasionally, certain molds suggest the existence of such closure near the apex of the delthyrium but this feature, if existent, defies reproduction by the method of making casts herein employed.

The edges of the delthyrium are sutured to thick, complete, divergent dental plates which in joining the floor of the pedicle valve create a central rostral and two lateral cavities at the posterior extremity of the valve. The bases of the dental lamellae extend anteriorally in a lingual pattern to the mid point of the valve, falling short of complete coalesance (<u>see</u> pl. 9, figs. 10-11). The area so defined encloses the muscle scars.

The central portion of the muscle field is characterized by an elongate "anticlinal ridge" which marks the position of the deep median sulcus. The diductor muscle scars occupy all of the lateral portions of the muscle field and transgress the sides of the median ridge. They (the diductor muscle scars) bear overlapping striae of two kinds: (1) curved, elongate striae parallel to the sides of the muscle field; and (2) striae at the posterior portion of the muscle field, diagonally disposed to its sides, converging towards the center of the elongate ridge - but not attaining it. (<u>See</u> pl. 8, figs. 6-7.) A long bilobed, "posterior adductor process" with a median sinus occupies the postero-central portion of the muscle field at the summit of the elongate ridge demarking the sulcus (<u>see</u> pl. 9, figs. 9-11). At its posterior margin the "adductor process" frequently appears to be thickened by secondary deposition of shell material. Its impression on the mold of the posterior portion of the rostral cavity is extremely deep and all but intersects the mold of the syrinx (<u>see</u> pl. 9, figs. 2, 3, 5-7).

As in the case of <u>S</u>. <u>angulata</u> Simpson, a number of structures appear to be derived from the deposition of callist material at the upper extremities of the dental lamellae. Accretion of such material at the juncture of the dental lamellae and the lateral margins of the delthyrium completely closes the delthyrium from its apex for about 2/3 of the total length, leaving no evidence of a pedicle opening of any kind. Viewed from above the callists have the appearance of conjunct triangular deltidial plates. However, the mold of the dorsal surface of the delthyrium exibits sutures which leave no doubt as to their relationship to the dental lamellae (<u>see</u> pl. 9, fig. 7-9). It is quite possible that these conjunct callists are responsible for the frequent reference to the "pseudo-deltidium" supposedly closing delthyrium.

Below the callists mentioned above, the dental lamellae are connected by a thin transverse subdelthyrial plate which gives no indication of having formed from the fusion of two separate lamellae. The mesial portion of the underside of the subdelthyrial plate gives rise to a pair of processes which curl ventrally while simultaneously extending forward slightly beyond the hinge line and create an elongate tube-like process or syrinx. The two lateral processes are not fused mesially, for the ventral side of the syrinx bears an elongate, striated slit. The syrinx is unsupported for 9/10 of its length (see pl. 9, fig. 9). At its posterior margin the syrinx is thickened by a callist deposit which fuses it to the posterior margin of the "posterior adductor process." In mature individuals the anterior face of the fused callists joining the posterior portions of the syrinx and the "posterior adductor process" is marked by a slender sinus connecting the mesial sinus of the adductor process to the slit on the underside of the syrinx. This connective sinus frequently occupies a slender vertical ridge which faintly resembles a weak median septum. The slender, sinus-bearing ridge however, is not found in individuals at the neanic growth stage. In fact, there is some indication, from a few poorly preserved molds, that the syrinx may form initially even without the support of the subdelthyrial plate. This observation cannot be adequately substantiated at the moment.

In the molds of the interior of specimens on hand, the posterior margins of the lateral cavities are marked by peculiar "tear-drop" depressions which lie with their blunt ends adjacent to the margins of the rostral cavity. These positive representations of the depressions are not readily discernible in casts made from the molds. The depressions appear to be characteristic of this genus for they are represented in the holotype as well as the writer's specimens. (Compare pl. 9, figs. 2-3 with pl. 9, figs. 5-6.) They probably represent the impressions of callist deposits.

The posterior half of the valve, from the underside of the interarea to the anterior edge of the muscle scar, bears markings of two types (see pl. 9, figs. 8-9). The first type is expressed as a series of concentrically disposed pits which have frequently been interpreted as "ovarian markings." The second type appears as a series of *en échelon* grooves not unlike the cuts a housewife would make in the crust of a pie. The writer has no intimation of their origin, but they may represent impressions of the spirialia of the brachial valve. The vascular system, usually preserved in this portion of the shell, is not represented on the writer's specimens.

The preservation of the material at hand prohibits any investigation of the presence or absence of punctae. For the same reason the nature of the dentition is not apparent.

DIMENSIONS: Given for only those figured specimens in possession of the writer and taken mainly from latex casts.

Characteristic	UCM 34565	UCM 34566
Apical angle	120°	120°
Delthyrial angle	40°	40°
Height of delthyrium	15 mm	7 mm
Width of delthyrium	12 mm	6 mm
Length of cardinal margin	46 mm	32 mm

TYPE: Holotype [by monotype]: Syringothyris randalli Simpson, 1890, Academy of Natural Sciences of Philadelphia No. 3532 (= American Phil. Soc. Trans., n.s., vol. 16, p. 441-442, fig. 6, specimens numbered 1, 2). Collected by F. A. Randall from the "Chemung" [= Corry] near Warren and at Union City, Erie County, Pennsylvania.

FIGURED SPECIMENS AND LOCALITIES:

Repository No.	Type	Locality
UCM 34565	Hypotype	116-C
UCM 34566	Hypotype	116-C
Phil. Acad. Sci.		
3532	Hypotype	Warren, Pa.

OCCURRENCE: Specimens studied were collected by the writer and K. E. Caster from the basal Corry sandstone at localities 116-C, 123-C, 140-C, and 19-S.

GEOLOGIC AGE: Lower Mississippian, Kinderhookian.

DISCUSSION: That the specimens described above belong to a species of the genus *Syringothyris* Winchell (1863), *sensu stricto*, is evidenced by the universal presence of unsupported syringes, the faintly plicate sulci, the "textile-cloth" appearance of the exteriors, and the high interareas. The specimens are further assigned to the species *Syringothyris randalli* Simpson because they share with the holotype the possession of prominent "tear-drop" impressions, conformity of general shape in posterior view, and molds of the interior which show almost conjunct impressions of the syringes and the "posterior adductor processes." (*See* pl. 9, figs. 1-7.)

Syringothyris randalli Simpson differs from *Syringothyris angulata* Simpson principally in the characteristics of the interior of the pedicle valve. Briefly summarized these differences are:

1. The delthyrium of S. randalli is closed for 2/3 of its length by conjunct callists which originate on the dental lamellae; callists from the same source restrict, but do not close, the delthyrium of S. angulata.
2. The subdelthyrial plate of S. randalli is flat; that of S. angulata convex or "shoehorn-like."
3. The syrinx of S. randalli is pointed; that of S. angulata flat.
4. The diductor muscle scars of S. randalli bear two sets of striae; those of S. angulata only one discernable set of striae.
5. The expression of the sulcus is much more prominent in the muscle field of S. randalli than that of S. angulata.
6. In the posterior portions of the molds of the rostral cavity, the impressions of the syrinx and the posterior adductor muscles of S. randalli almost intersect; in S. angulata the two are not proximate.

These differences appear to be of sufficient magnitude to warrant separation of the two species. For this reason, the synonymous relationship between Syringothyris randalli Simpson and Syringothyris angulata Simpson postulated by Caster (1930, p. 174) and Holland (1958, p.295) is rejected and the individuality of the two species reestablished.

Schuchert (1910, p. 224) established the genus Syringopleura Schuchert citing Syringothyris randalli Simpson as the type species for the genus. Girty's (1911) rejection of the genus appears to be substantiated by the facts enumerated above. Holland, while accepting Girty's rejection of Syringopleura Schuchert on one account revised the genus on another. He (Holland, 1958, p. 289) says:

> Thus while the writer agrees with Girty (1911) in rejecting Syringopleura Schuchert on the basis it was originally conceived [plicate fold and sulcus], it is accepted herein on the basis of a different character; namely, the possession by the type species, Syringothyris randalli Simpson, of a syrinx set low in the valve and supported from below by a median septum.

From the observations made above, the writer must conclude that Holland has erred. If Holland only observed the molds of his specimens of S. randalli Simpson he must have concluded that the deeply incised impression of the posterior adductor process was the mold of a median septum. If casts were made of his molds, the callist fusing the posterior regions of the posterior adductor process and the syrinx must have been interpreted as a median septum. (Compare Holland's fig. 7, pl. 15 to figs. 5-7, pl. 9 herein.) In the writer's opinion Syringothyris randalli Simpson is, at best, a pseudo-septate form.

Syringopleura Schuchert (1910), as revised by Holland (1958), is therefore rejected since the type, Syringothyris randalli Simpson (1890), does not possess the characteristics assigned to the genus. However, while Holland's designation of a type species may have been unfortunate, his recognition of septate syringothyroid species in the Penn-York Embayment appears to be correct. The writer has in his possession a number of as-yet-unidentified syringothyroid specimens the molds and casts of which exibit a syrinx supported by a true median septum in the pedicle valve. These specimens bear a descriptive resemblance to Syringothyris herricki Schuchert (1910) but the species was not illustrated by Schuchert, although he does refer to drawings of Syringothyris cuspidatus, Herrick (1888, pl. 5, figs. 4-7) which are eminently unsatisfactory. The problem of septate syringothyroids will not be solved until the types of Syringothyris herricki Schuchert and Septosyringothyris Vandercammen (1955) are examined. Such action is anticipated in the near future.

REMARKS: The species Syringothyris randalli Simpson appears in legally acceptable published form simultaneously in Lesley (1890, p. 1150-1152) and Simpson (1890, p. 441-442). It is impossible to determine which reference has priority. However, since Lesley's description is obviously borrowed from Simpson, as was the case with species described above, the authorship of Syringothyris randalli is awarded to Simpson as of 1890.

APPENDIX A

APPENDIX A

Atlas of Outcrops

Outcrop locations are plotted for but twelve of the fifteen quadrangles involved in this study. Undoubted Corry outcrops could not be located in the Cambridge Springs, Sheffield, and Townville Quadrangles.

Contrary to the implications of many publications concerned with the Corry sandstone, it is the base of the formation, not the top, which is most readily distinguished. Hence, where determined, elevations are given for the base. The data was obtained from: (1) estimates in the field using topographic maps; (2) Caster (1934); (3) de Witt, Jr. (1958, personal communication); (4) Cathcart (1936, unpublished maps). Thicknesses were determined directly in the field.

TABLE A1

Explanation Of Symbols Used On Topographic Maps

Symbol	Explanation
●	Outcrop visited only, no collection made.
■	Outcrop measured and collection made.
⬢	Specimens collected to supplement Caster collection.
▲	Outcrop visited and specimens collected.
*1-S	Outcrop designation of Sass (1958).
1-C	Outcrop designation of Caster (1934).
1-P	Outcrop designation of Pepper, et al., (1954).
1-CT	Outcrop designation of Cathcart (1936, unpublished).
*	For synonomy see Table No. 1

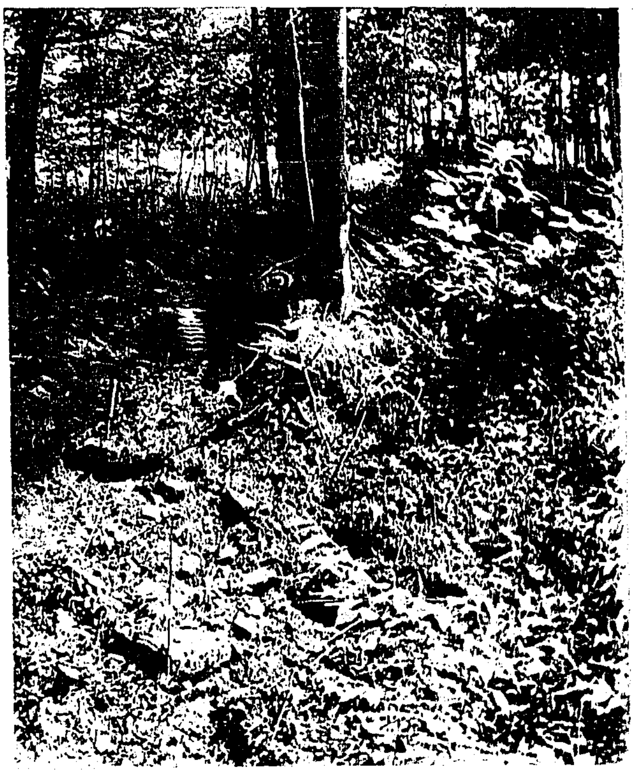

Fig. Al. - Section 14-S; Warren Quadrangle, approximately 1 mi. southwest of Glade on the road to Pleasant School and 100 yds. east of the Mead Township boundary. The hammer rests upon a conglomeritic phase of the Knapp formation. Resting conformably on the Knapp is a 4" - 6" layer of Corry sandstone with the characteristic index fossil Paraphorhynchus striatum (Simpson). This is the only location in the Warren Quadrangle at which the Corry sandstone was found in place. (Approximate elevation of base of Corry - 1700' A. T.; thickness - 4" - 6".)

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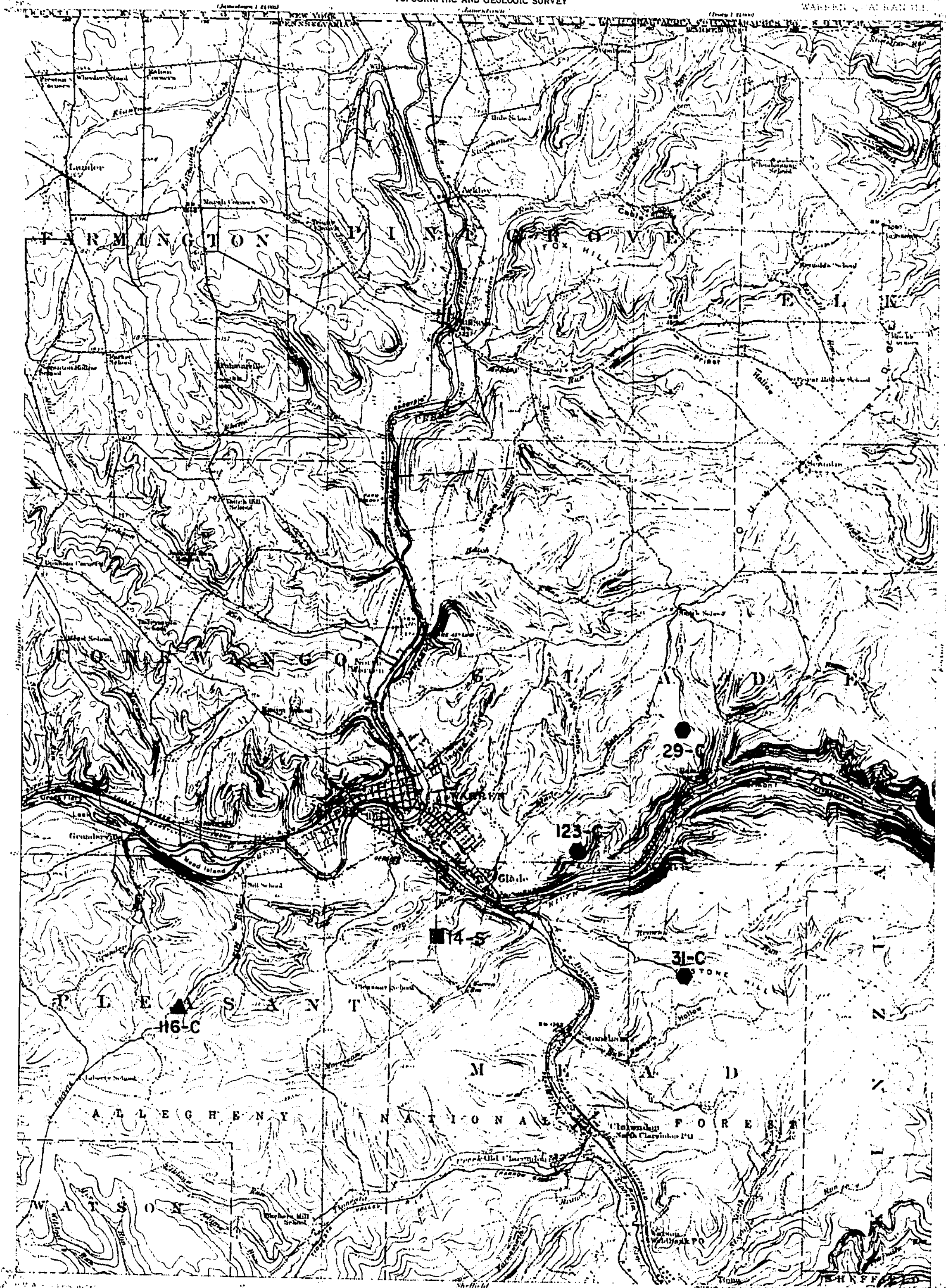
PLATE A-1



SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

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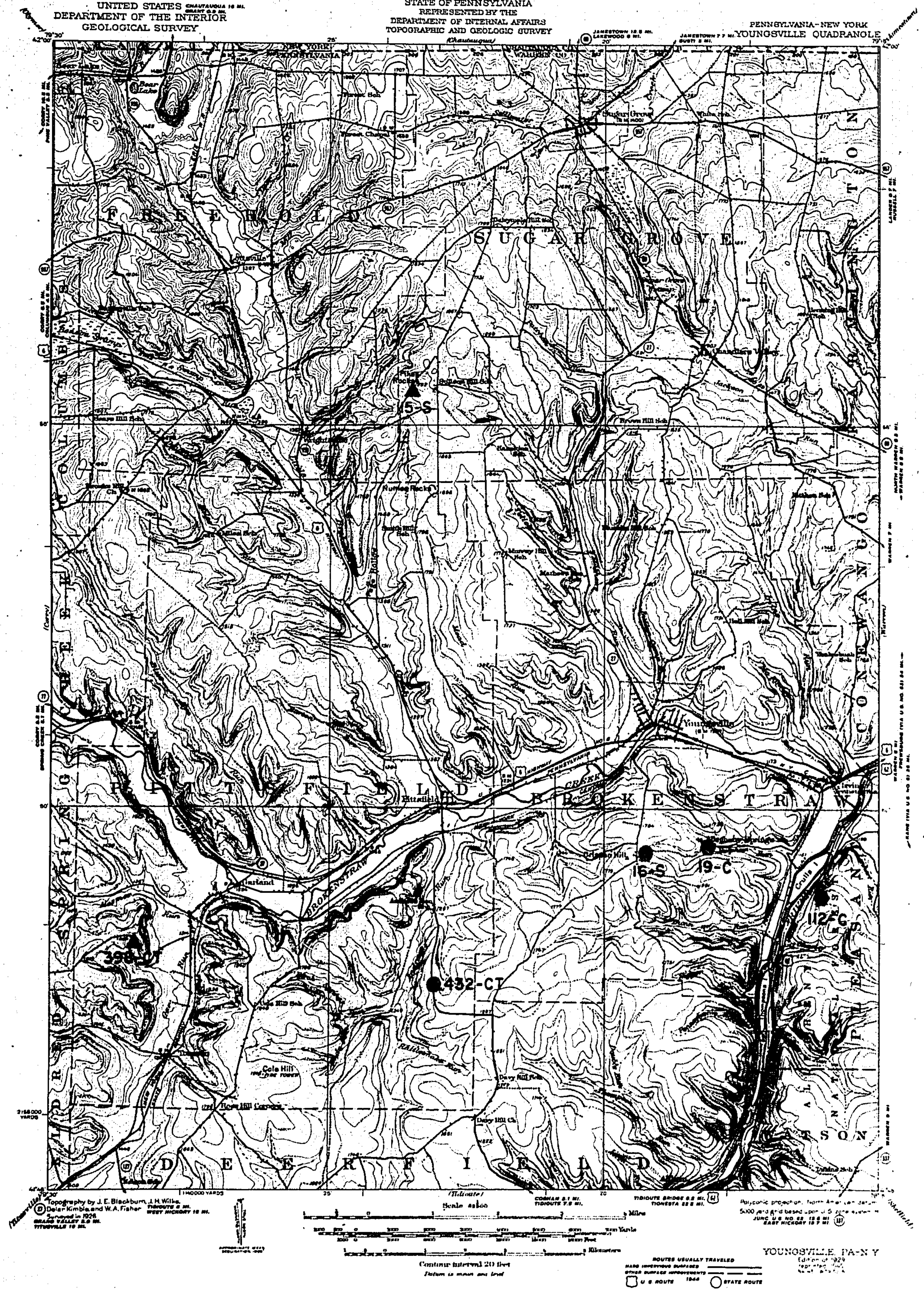
PLATE A-2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STATE OF PENNSYLVANIA
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DEPARTMENT OF INTERNAL AFFAIRS
TOPOGRAPHIC AND GEOLOGIC SURVEY
PENNSYLVANIA-NEW YORK
YOUNGSVILLE QUADRANGLE
NEW YORK
PENNSYLVANIA
FREEHOLD
SUGAR GROVE
Sugar Grove
Chandlers Valley
Pike Rocks
15-S
Nutting Rocks
Youngsville
PITTSFIELD
Pittsfield
BROKENSTRAW
BROKENSTRAW
CREEK
Garland
16-S
19-C
112-C
39-S
432-CT
Cole Hill
Davy Hill Sch.
DEERFIELD
WATSON
Topography by J. E. Blackburn, J. H. Wilke,
Delar Kimble and W. A. Fisher
Surveyed in 1926
Scale 1:62500
Contour interval 20 feet
Datum is mean sea level
YOUNGSVILLE, PA-N Y

Fig. A2. - Section 103-C; Corry Quadrangle, approximately 1.2 mi. south of Corry on the road to Colgrove School. This is all that remains of the type section at Colgrove Quarry which has been filled-in for a housing project. The student is resting on the uppermost ledge of the Lower Corry sandstone which contains, at the base, calcareous lentils and molds of the brachiopod *Paraphorhynchus striatum* (Simpson). The vegetation above conceals the micaeceous-silty phase of the Middle Corry reminiscent of a similar lithology to the south in the vicinity of Oil City. (Approximate elevation of base of Corry - 1760' A. T.; thickness - 9'.)

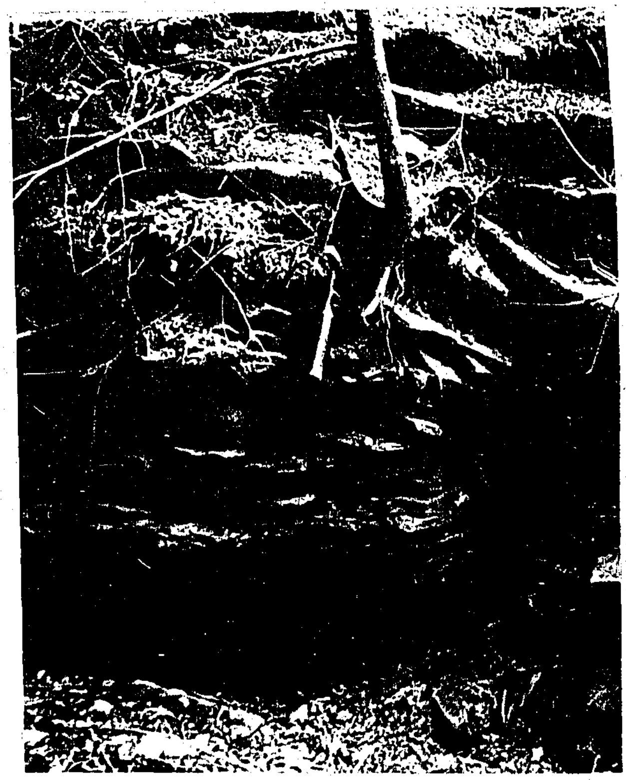


Fig. A3. - Section 106-P; Corry Quadrangle, near the headwaters of a small tributary of Oil Creek, 0.6 mi. southeast of Spartansburg. The thin-bedded sandstone represents the top of the Corry according to Pepper, et al., 1954. The hammer rests upon the overlying Bartholomew siltstone. The section is apparently unfossiliferous. (Approximate elevation of base of Corry - 1566.9' A. T.; thickness - 30'.)

PLATE A-3

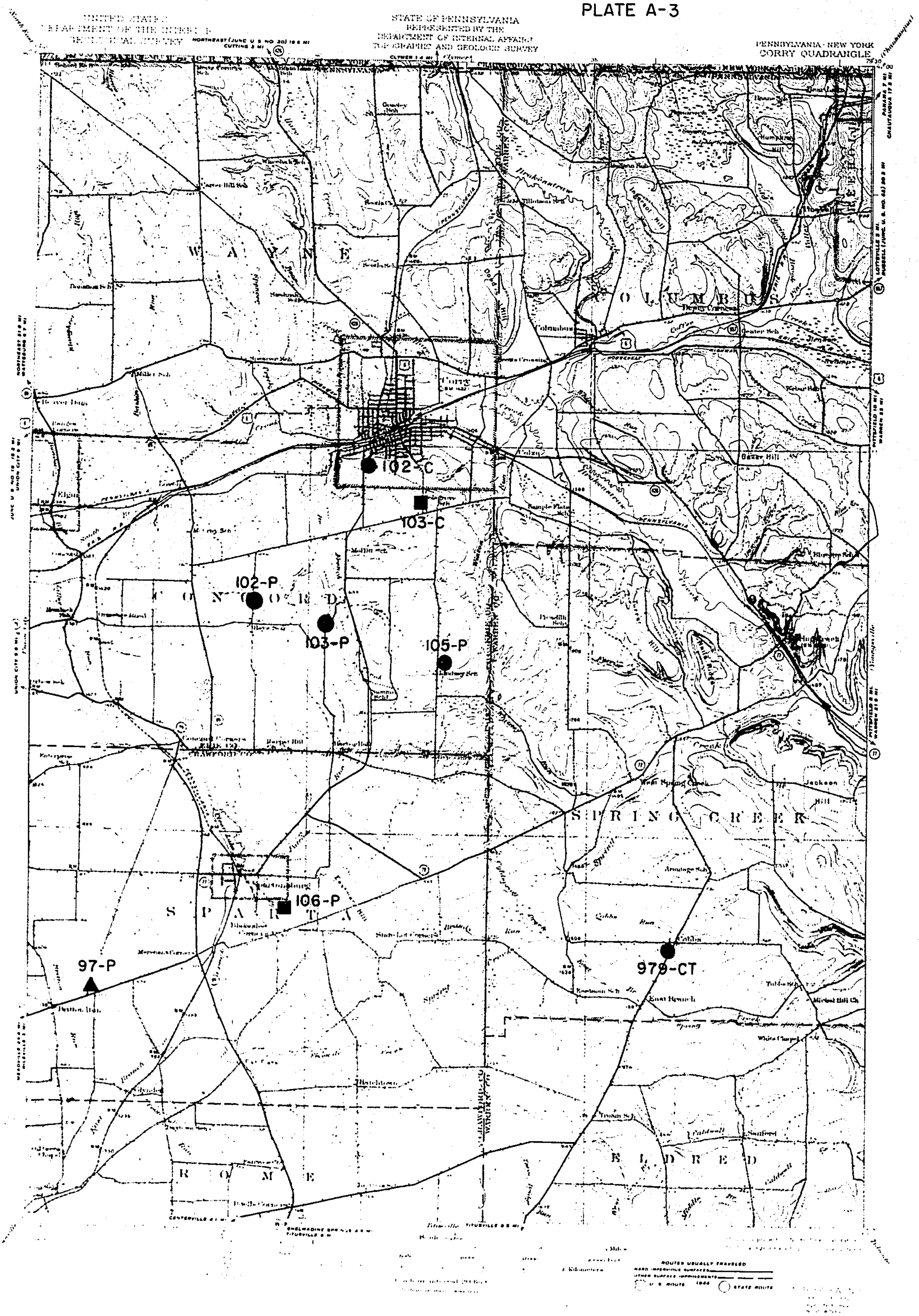
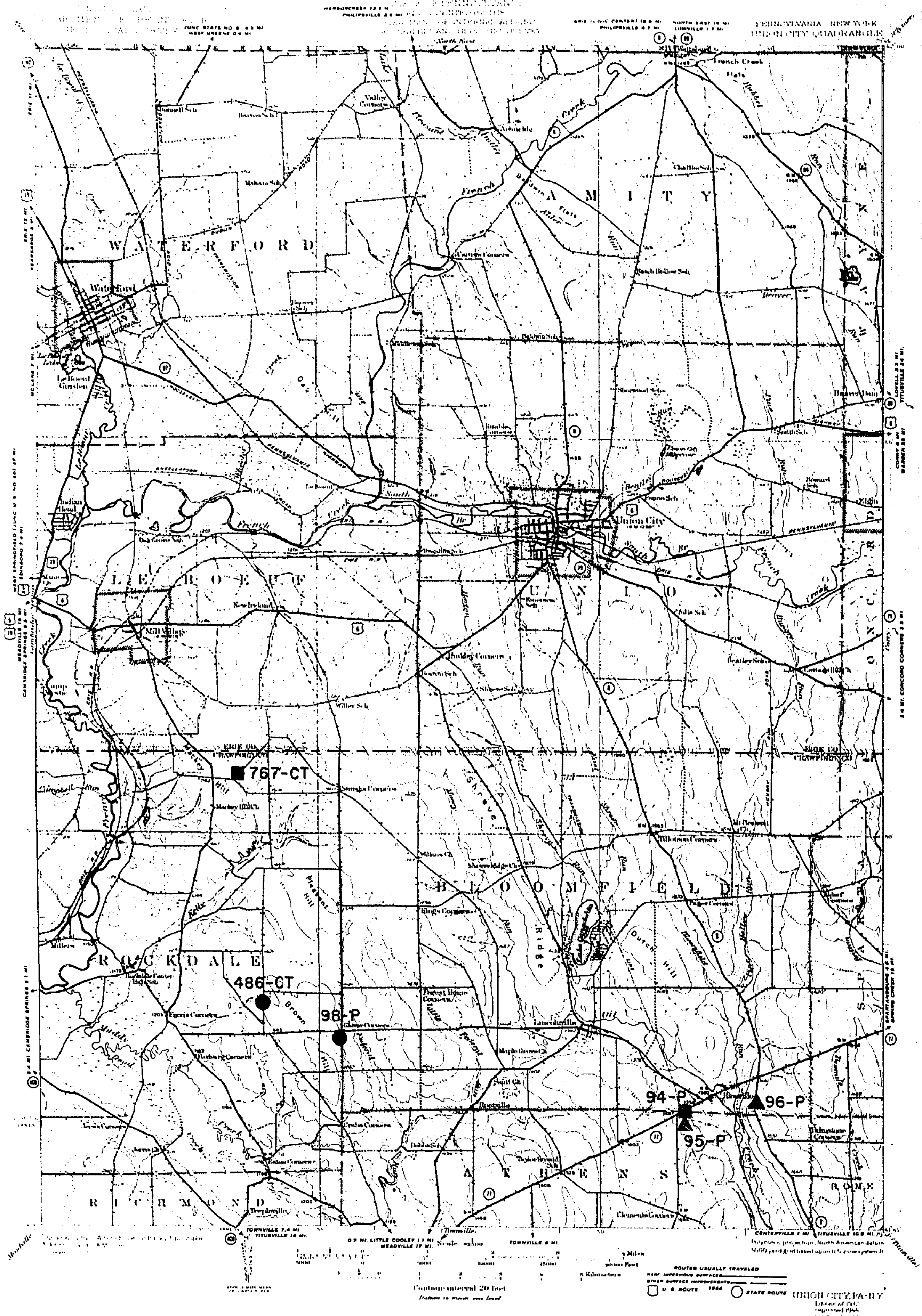

STATE OF PENNSYLVANIA
PENNSYLVANIA-NEW YORK
CORRY QUADRANGLE
102-C
103-C
102-P
103-P
105-P
106-P
97-P
979-CT
W A Y N E
C O L U M B U S
C O N C O R D
S P R I N G C R E E K
S P A R T A
R O M E
E L D R E D

Fig. A4. - Section 94-P; Union City Quadrangle, on the north side of a roadcut along Pennsylvania State Route 77, 0.6 mi. southwest of Riceville. The basal Corry is thin-bedded here and has two fossil zones the uppermost of which is marked by the ruler. (Approximate elevation of base of Corry - 1475' A. T.; thickness - 8'.)

PLATE A-4


767-CT
486-CT
98-P
94-P
95-P
96-P
WATERFORD
AMITY
LE BOEUF
UNION
BLOOMFIELD
ROCKDALE
RICHMOND
ATHENS
ROME
SPARTA
CONCORD
Union City
Waterford
ERIE CO.
CRAWFORD CO.
UNION CITY, PA.-N.Y.

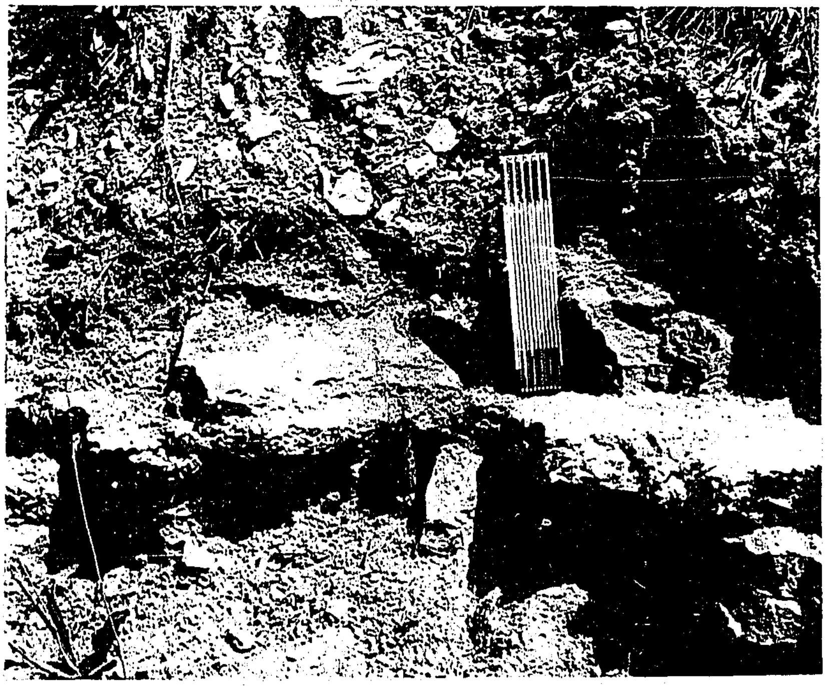
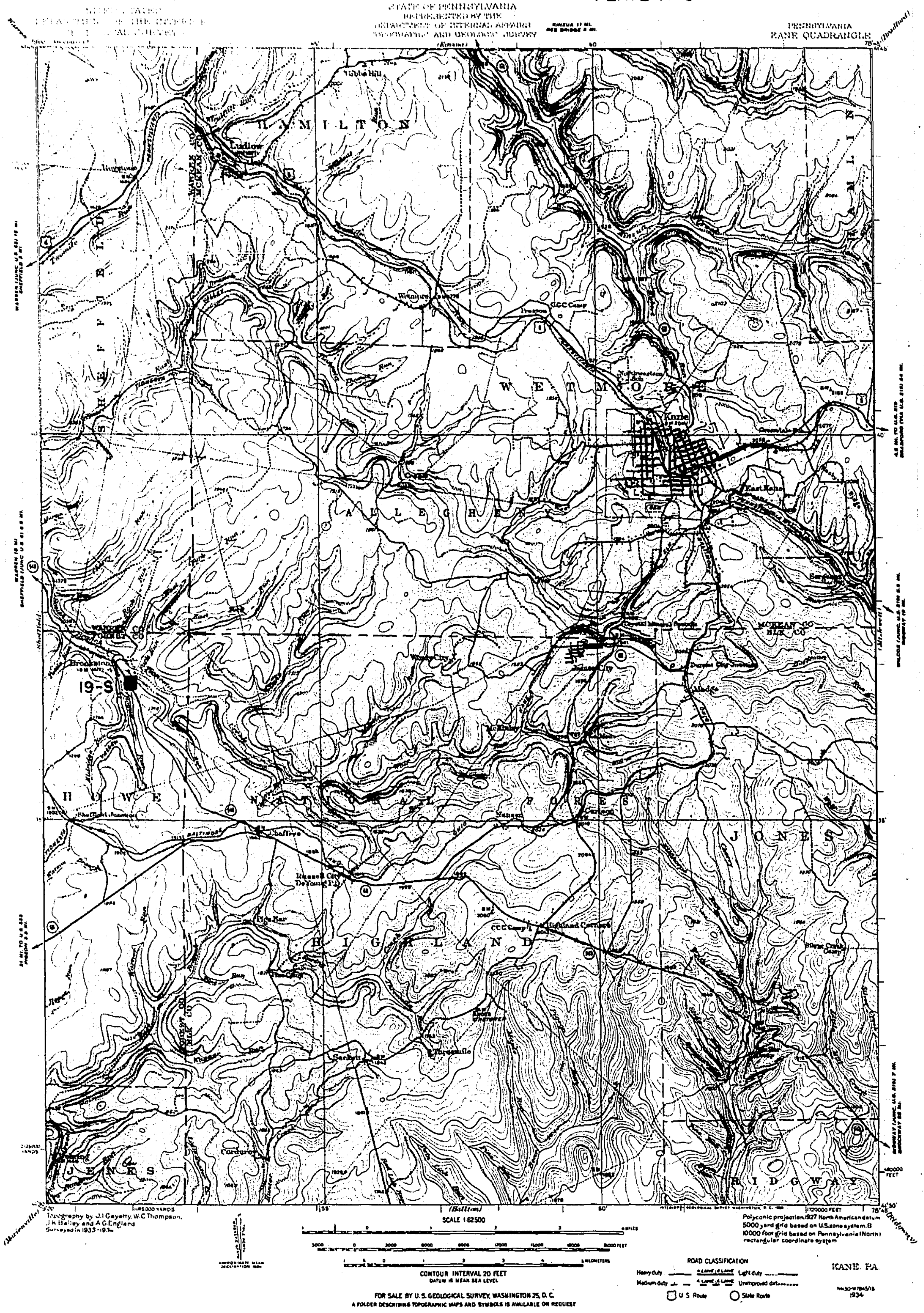


Fig. A5. - Section 19-S; Kane Quadrangle, on the east side of a roadcut along Pennsylvania State Route 948, 0.4 mi. southeast of Brookston. The base of the ruler rests upon a 2" - 3" sandstone bed which lies conformably upon the Knapp. One mold of Paraphorhynchus striatum (Simpson) was found in the thin sandstone band which is presumed to represent the easternmost limit of the Corry. (Approximate elevation of base of Corry - 1560' A. T.; thickness - 2" - 3".)

PLATE A-5


STATE OF PENNSYLVANIA
PENNSYLVANIA
KANE QUADRANGLE
HAMILTON
Ludlow
WETMORE
Kane
East Kane
ALLEGHENY
CCC Camp
19-S
HOWE
NATIONAL FOREST
JONES
HIGHLAND
Highland Corners
RIDGWAY
JENKS
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
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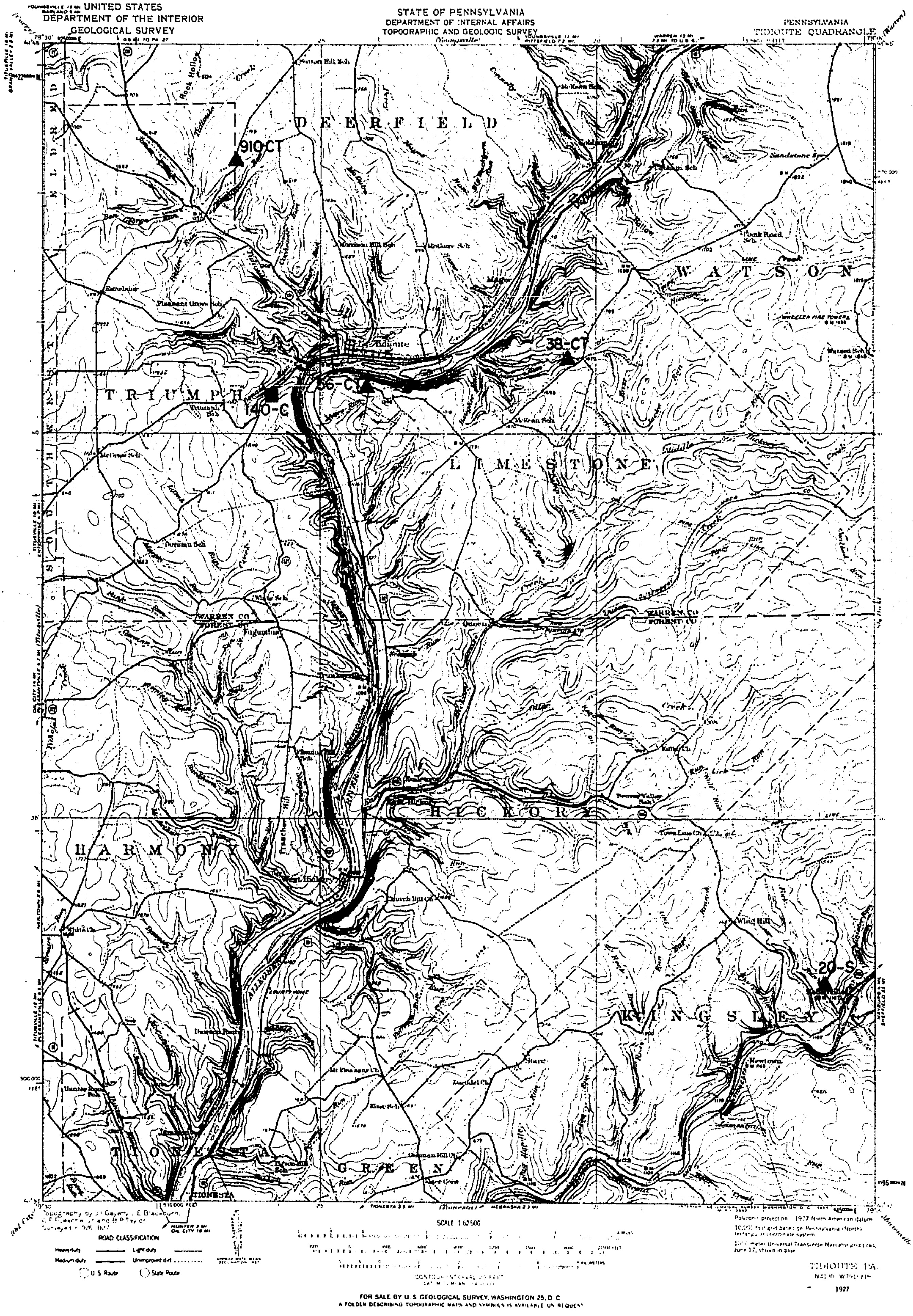
KANE, PA.
1934

Fig. A6. - Section 140-C; Tidioute Quadrangle, along the east side of Pennsylvania State Route 127, 0.4 mi. northeast of Titusville Junction. The hammer is resting on the lowermost ledge of the basal Corry sandstone. Molds of the brachiopod Paraphorhynchus striatum (Simpson) are abundant here. (Approximate elevation of base of Corry - 1478'; thickness - 7'.)

PLATE A-6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TOPOGRAPHIC AND GEOLOGIC SURVEY
PENNSYLVANIA
TIDIOUTE QUADRANGLE
DEERFIELD
910CT
WATSON
38-CT
36-CT
TRIUMPH
140-C
LIMESTONE
WARREN CO
FOREST CO
HICKORY
HARMONY
20-S
KINGSLEY
TIONESTA
GREEN
SCALE 1:62500
ROAD CLASSIFICATION
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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
TIDIOUTE, PA.
1927

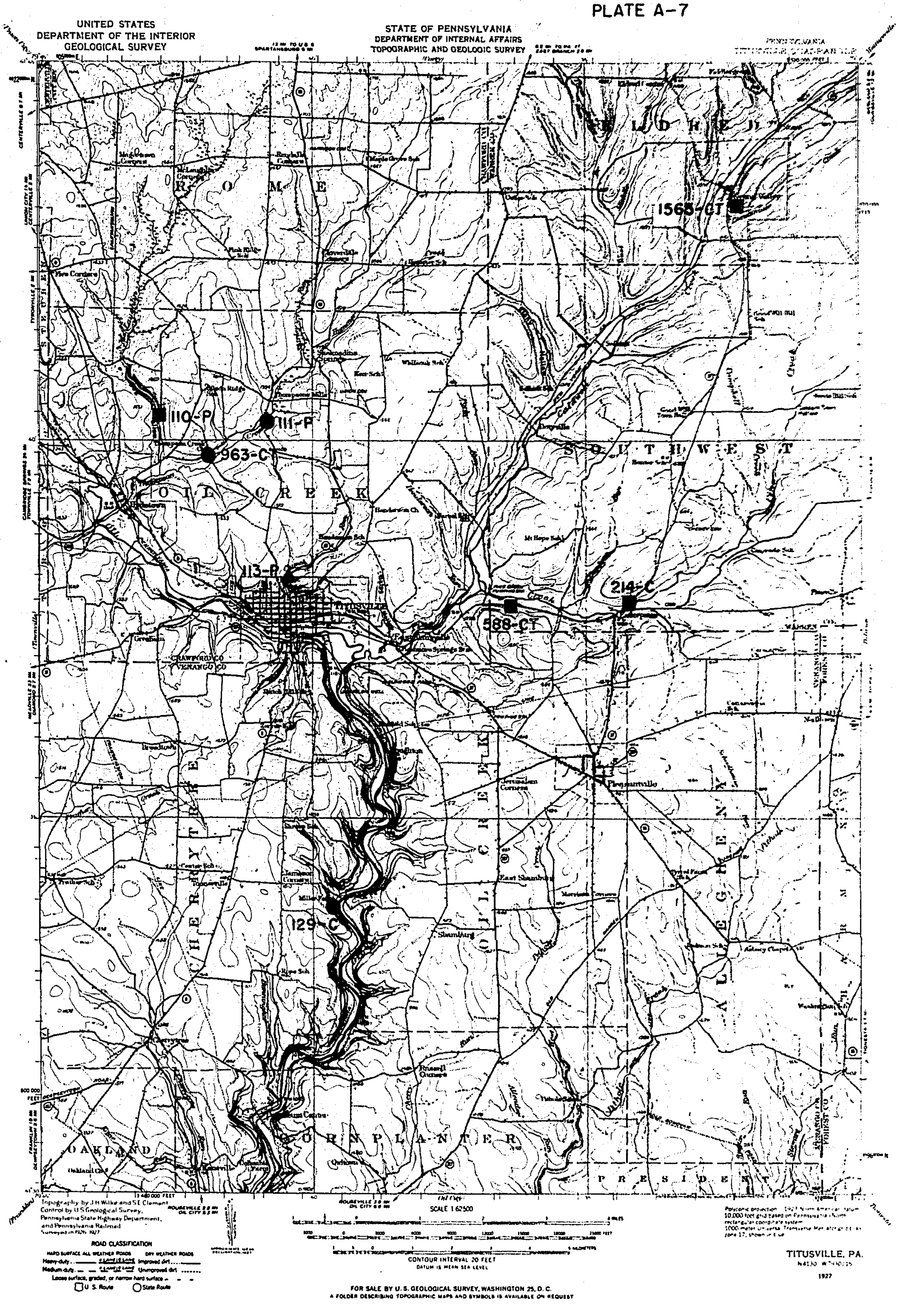
Fig. A7. - Section 1565-CT; Titusville Quadrangle, along the north side of a roadcut 0.1 mi. due east of the junction of Pennsylvania State Route 27 and the first road intersection south of Grand Valley. The hammer rests upon the uppermost faunal zone of the Knapp and the notebook marks the lowest horizon in which the brachiopod Paraphorhynchus striatum (Simpson) was found and which is presumed to be basal Corry. The contact between the two formations appears to be gradational. (Approximate elevation of base of Corry - 1423' A. T.; thickness - 8' - 9'.)

Fig. A8. - Section 1565-CT; Titusville Quadrangle, 20' north of Fig. A7 in a ditch excavated for a water line. The pencil rests upon a massive calcareous lentil in the basal Corry sandstone.

Fig. A9. - Section 1565-CT; Titusville Quadrangle, a photograph of the underside of the calcareous lentil shown in Fig. A8. The pencil points to a large specimen of the brachiopod Paraphorhynchus sp.; other brachiopods and numerous gastropods can also be distinguished. The outcrop is unusual because of the preservation of the calcareous shells of the organisms and its demonstration of the orientation of the shells at the time of burial.

Fig. A10. - Section 110-P; Titusville Quadrangle, along the west bank of McLaughlin Creek at Bog Hollow, 0.7 mi. north of the first north-south road east of Hydetown. The photograph shows the massive basal bed of the Corry sandstone which, in this locality, is neither calcareous nor fossiliferous. (Approximate elevation of base of Corry - 1324' A. T.; thickness - 15'.)

PLATE A-7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TOPOGRAPHIC AND GEOLOGIC SURVEY
ROME
OIL CREEK
SOUTHWEST
CHERRYTREE
ALLEGHENY
CORNPLANTER
OAKLAND
PRESIDENT
1565-CT
110-P
111-P
963-C
113-P
588-CT
214-C
129-C
CRAWFORD CO
VENANGO CO
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
ROAD CLASSIFICATION
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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
TITUSVILLE, PA.
1927

PLATE A-8

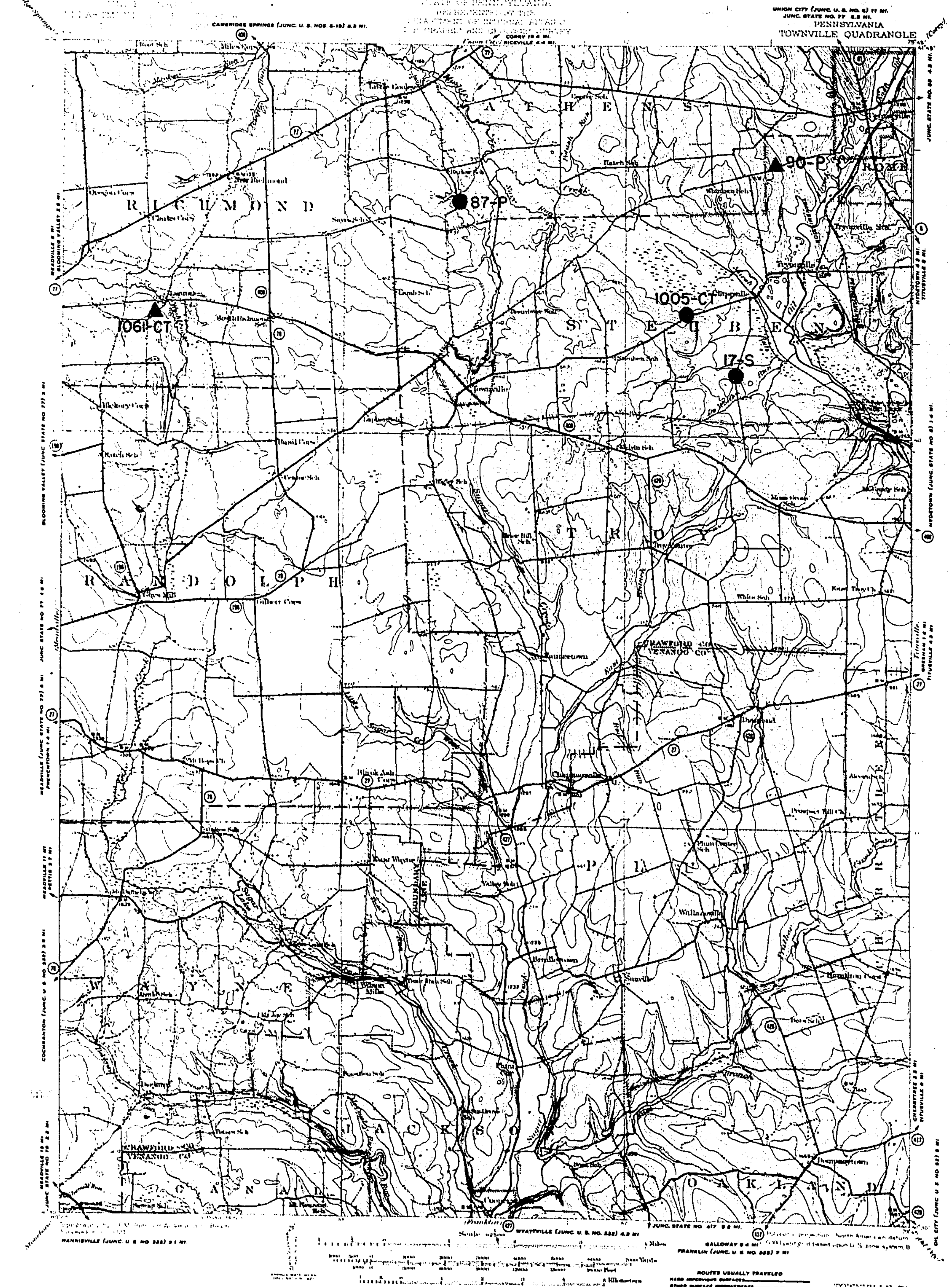

PENNSYLVANIA
TOWNVILLE QUADRANGLE
90-P
87-P
1005-CT
1061-CT
17-S
ROME
R I C H M O N D
A T H E N S
S T E U B E N
T R O Y
R A N D O L P H
J A C K S O N
O A K L A N D
CRAWFORD CO
VENANGO CO
Contour interval 20 feet
Datum is mean sea level
TOWNVILLE, PA.

Fig. 11A. - Section 11-S; Meadville Quadrangle, in a quarry just south of Meadville on the east side of United States Route 322 at the Morgan Street extension. The photograph shows the lower portion of the quarry excavated in the "Cussewago sandstone and shales." The sequence above the ledge consists of shales and a coarse, friable, cross-bedded sandstone. (Approximate elevation of base of Corry - ?; thickness - ?.)

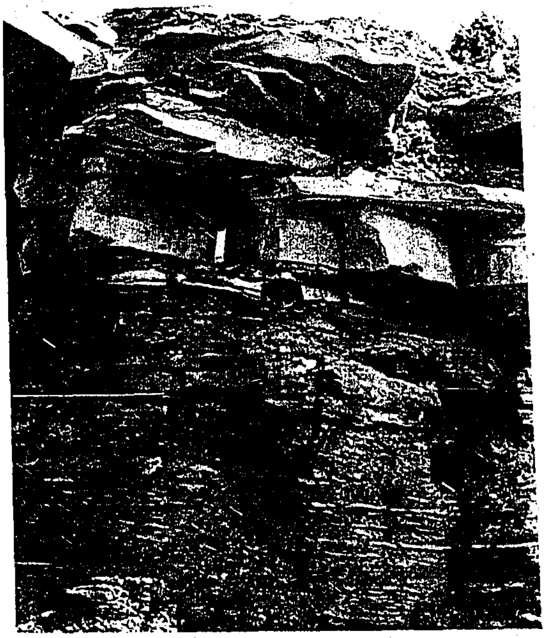
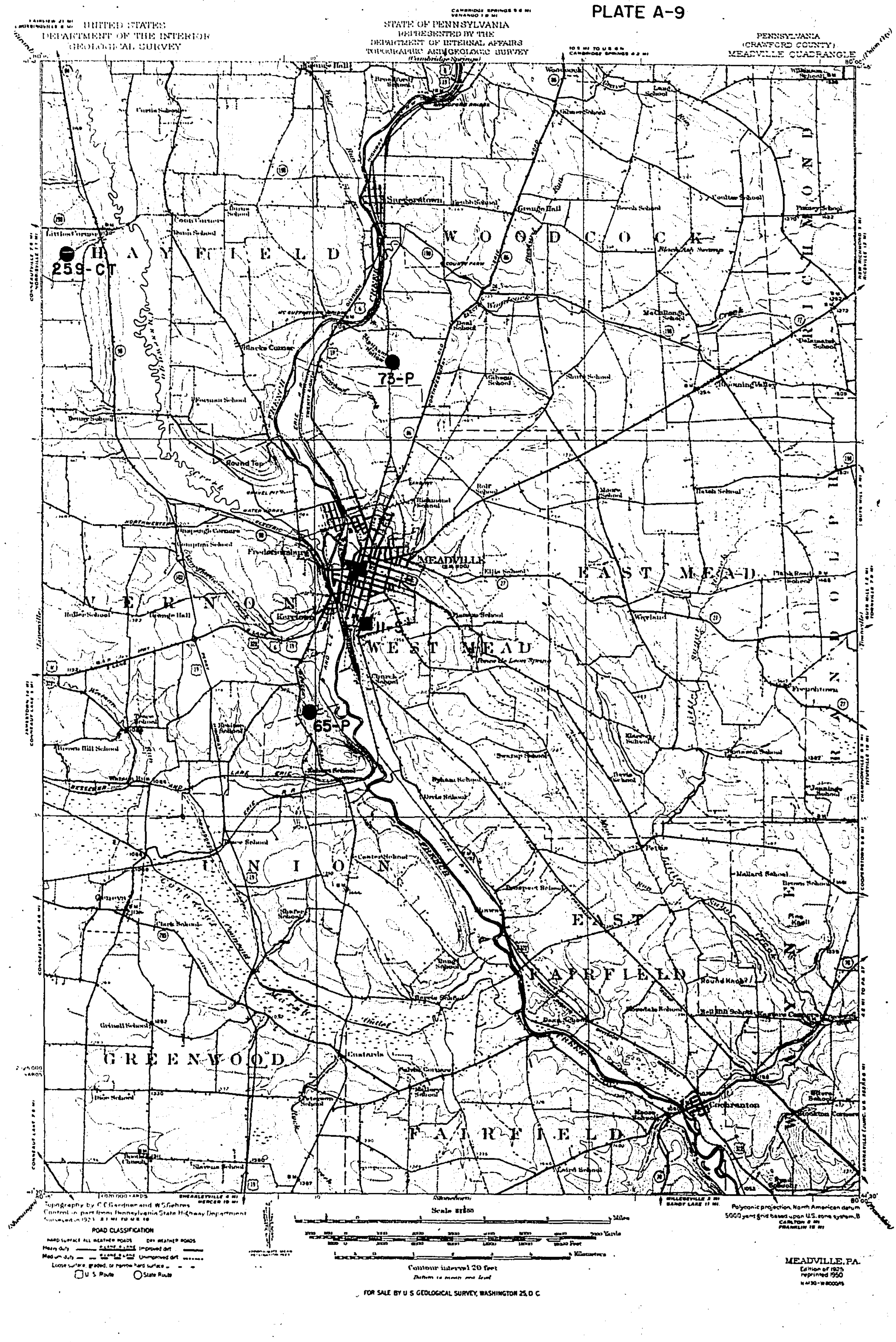


Fig. A12. - Section 11-S; Meadville Quadrangle, close-up of the top of the ledge shown in Fig. A11. The hammer rests upon a sandstone layer with intermittent calcareous lentils and an undescribed productid fauna. The ruler marks a sandstone sequence the base of which contains a network of "worm burrows."

Fig. A13. - Section 11-S; Meadville Quadrangle. The underside of the bed marked by the ruler in Fig. A12, showing the network of "worm burrows."

Fig. A14. - Section 11-S; Meadville Quadrangle. Photograph of the upper portion of the quarry. The student is resting on the 8" - 12" bed of the Bartholomew siltstone. According to Pepper, et al., 1954, a portion of the sequence between the foreground and the Bartholomew siltstone represents the westernmost facies of the Corry sandstone.

PLATE A-9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TOPOGRAPHIC AND GEOLOGIC SURVEY
PENNSYLVANIA
(CRAWFORD COUNTY)
MEADVILLE QUADRANGLE
HAYFIELD
WOODCOCK
VERNON
MEADVILLE
EAST MEAD
WEST MEAD
UNION
EAST FAIRFIELD
GREENWOOD
FAIRFIELD
259-CT
73-P
65-P
H-S
Saegertown
Cochranton
Round Top
Kerrtown
Fredericksburg
Contour interval 20 feet
MEADVILLE, PA.
FOR SALE BY U S GEOLOGICAL SURVEY, WASHINGTON 25, D C

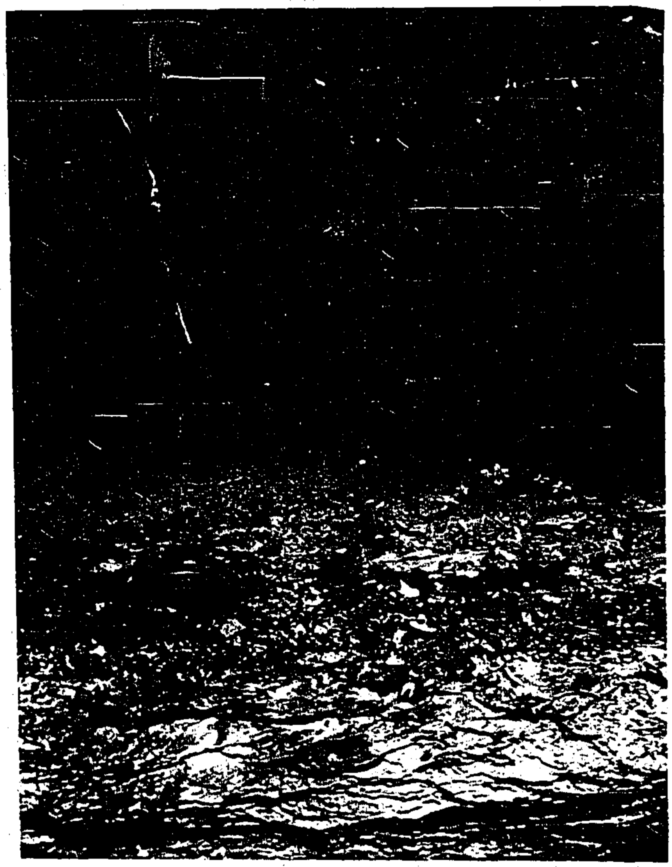

Fig. A15. - Section 59-P; Linesville Quadrangle, 0.8 mi. west of Pennsylvania State Route 98 along the first road to the west - north of Littles Corner and in the stream bed north of the road. The massive ledge at the top of the photograph, which lies 15' below the Bartholomew siltstone, is petroliferous. The undercut sequence below is formed by a friable, cross-beeded sandstone. The combination of the two probably represents the Berea sandstone.

PLATE A-10

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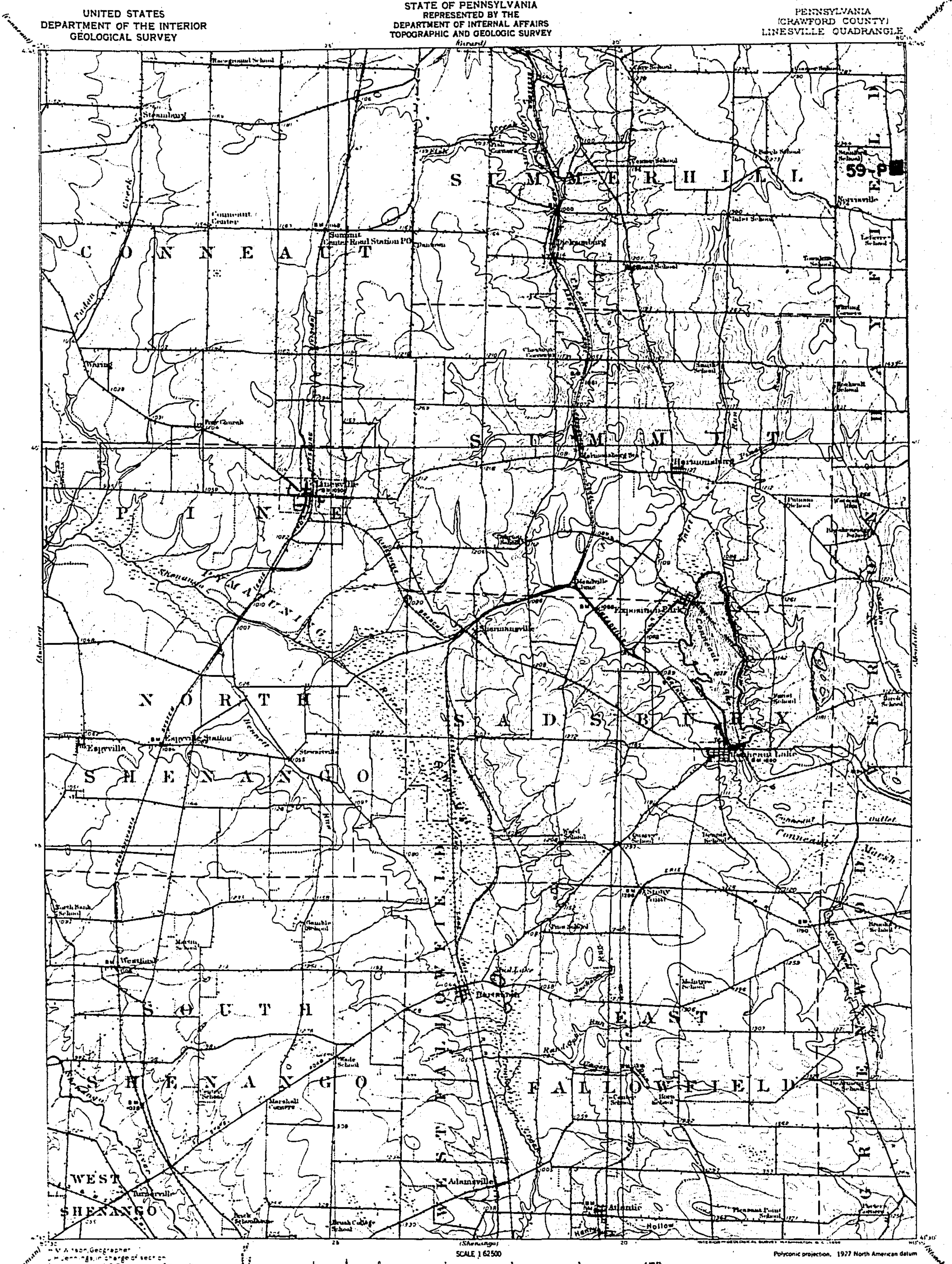
PENNSYLVANIA
(CRAWFORD COUNTY)
LINESVILLE QUADRANGLE



H. M. Wilson, Geographer
J. H. Jennings, in charge of section
Topography by A.C. Roberts and Gilbert Young
Control by C.B. Kendall
Surveyed in 1906

SCALE 1:62500

CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL

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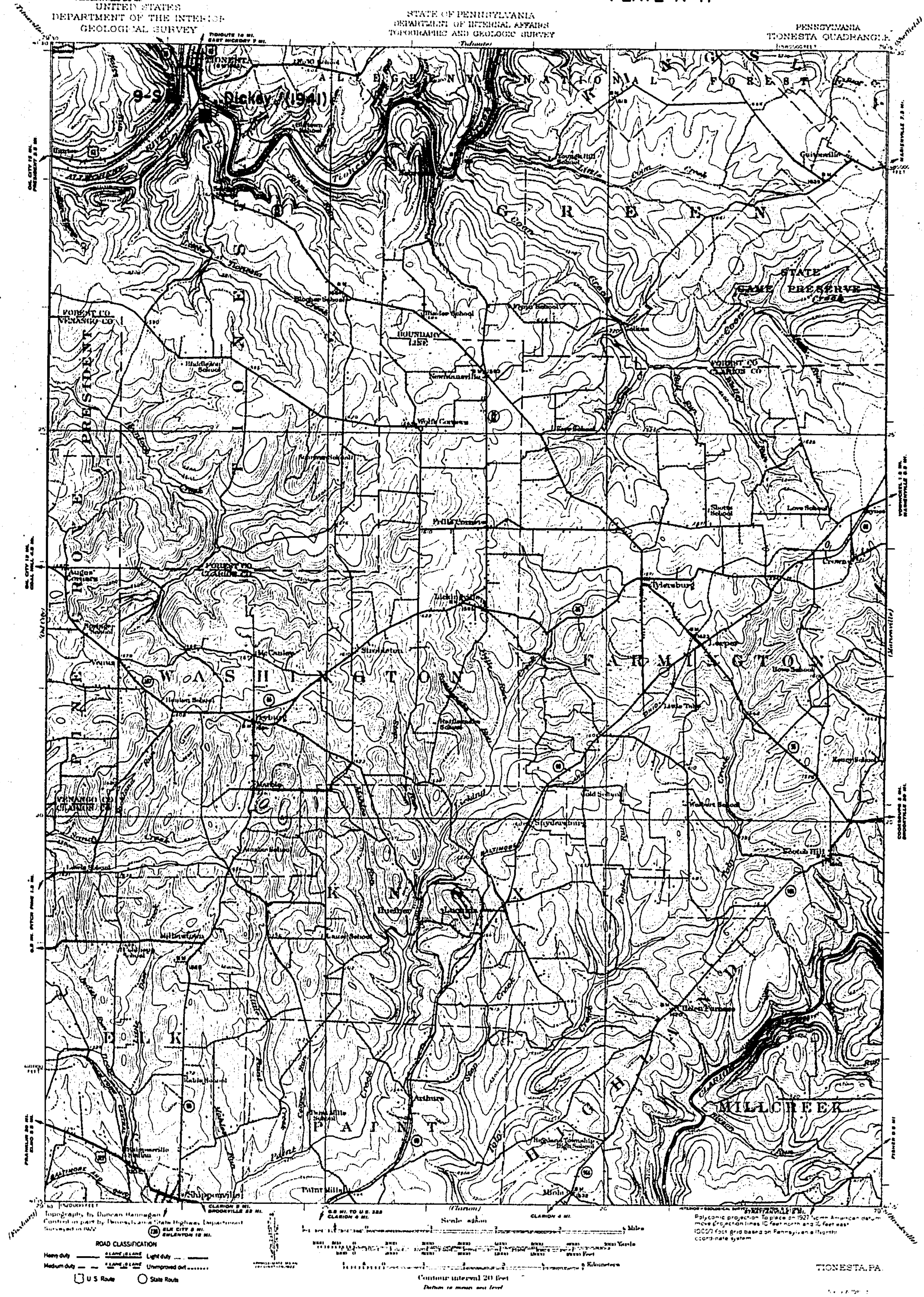
Polyconic projection, 1927 North American datum

LINESVILLE, PA.
N4130—W8015/15
1906

Fig. A16. - Section 9-S; Tionesta Quadrangle, 0.4 mi. south of the intersection of Pennsylvania State Route 36 and United States Route 62 in a roadcut on the west side of the road. The hammer rests at the top of the massive basal Corry sandstone. The spring at the base of the Corry was frequently mentioned in the early reports of the Pennsylvania Geological Survey. Calcareous lentils occur at the base of the Corry but fossils are rare and poorly preserved. (Approximate elevation of base of Corry - 1132' A. T.; thickness - 30'.)

PLATE A-11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STATE OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
TOPOGRAPHIC AND GEOLOGIC SURVEY
PENNSYLVANIA
TIONESTA QUADRANGLE
9-S
Dickey (1941)
ALLEGHENY NATIONAL FOREST
GREEN
STATE GAME PRESERVE
BOUNDARY LINE
PRESIDENT
WASHINGTON
FARMINGTON
KNOX
ELK
PAINT
HIGHLAND
MILLCREEK
Newmansville
Wolfs Corners
Tylersburg
Leeper
Fryburg
Marble
Lucinda
Helen Furnace
Arthurs
Shippenville
Cook Forest
Scale
Contour interval 20 feet
Datum is mean sea level
ROAD CLASSIFICATION
U S Route
State Route
TIONESTA, PA.
1922
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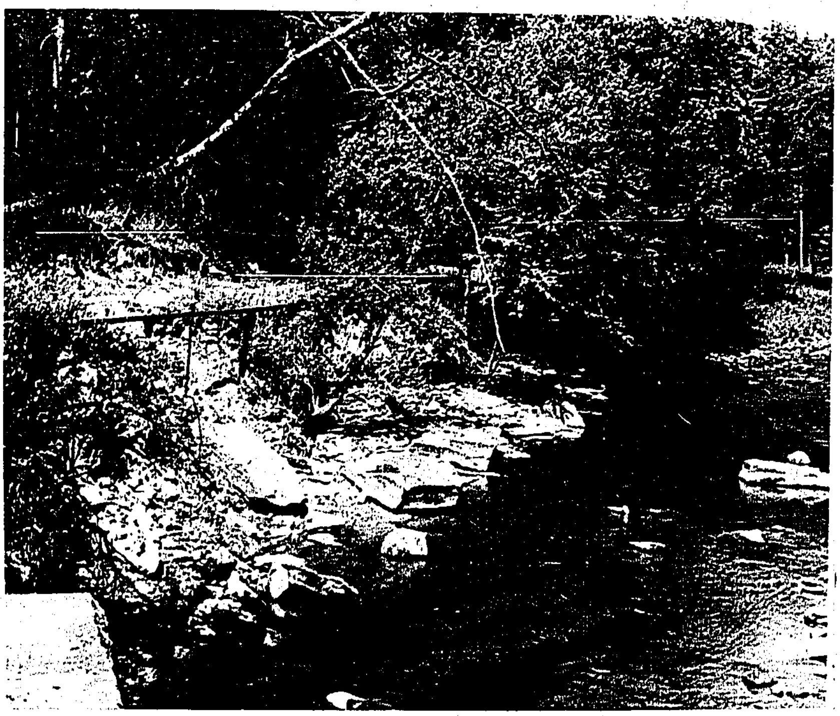


Fig. A17. - Section 10-S; Oil City Quadrangle, just north of the bridge over Pithole Creek. The Corry is found in the bed of the stream.

Fig. A18. - Section 117-P; Oil City Quadrangle, on the east side of Pennsylvania State Route 8, south of the bridge over Oil Creek at Rynd Farm. The hammer rests at the top of the massive basal Corry which is neither calcareous nor abundantly fossiliferous. (Approximate elevation of base of Corry - 1055' A. T.; thickness - 21'.)

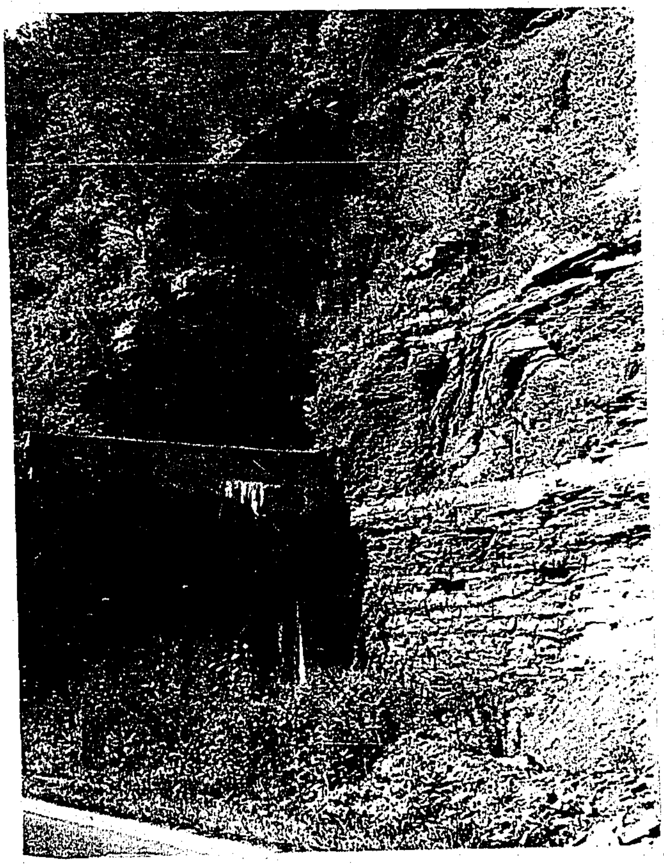
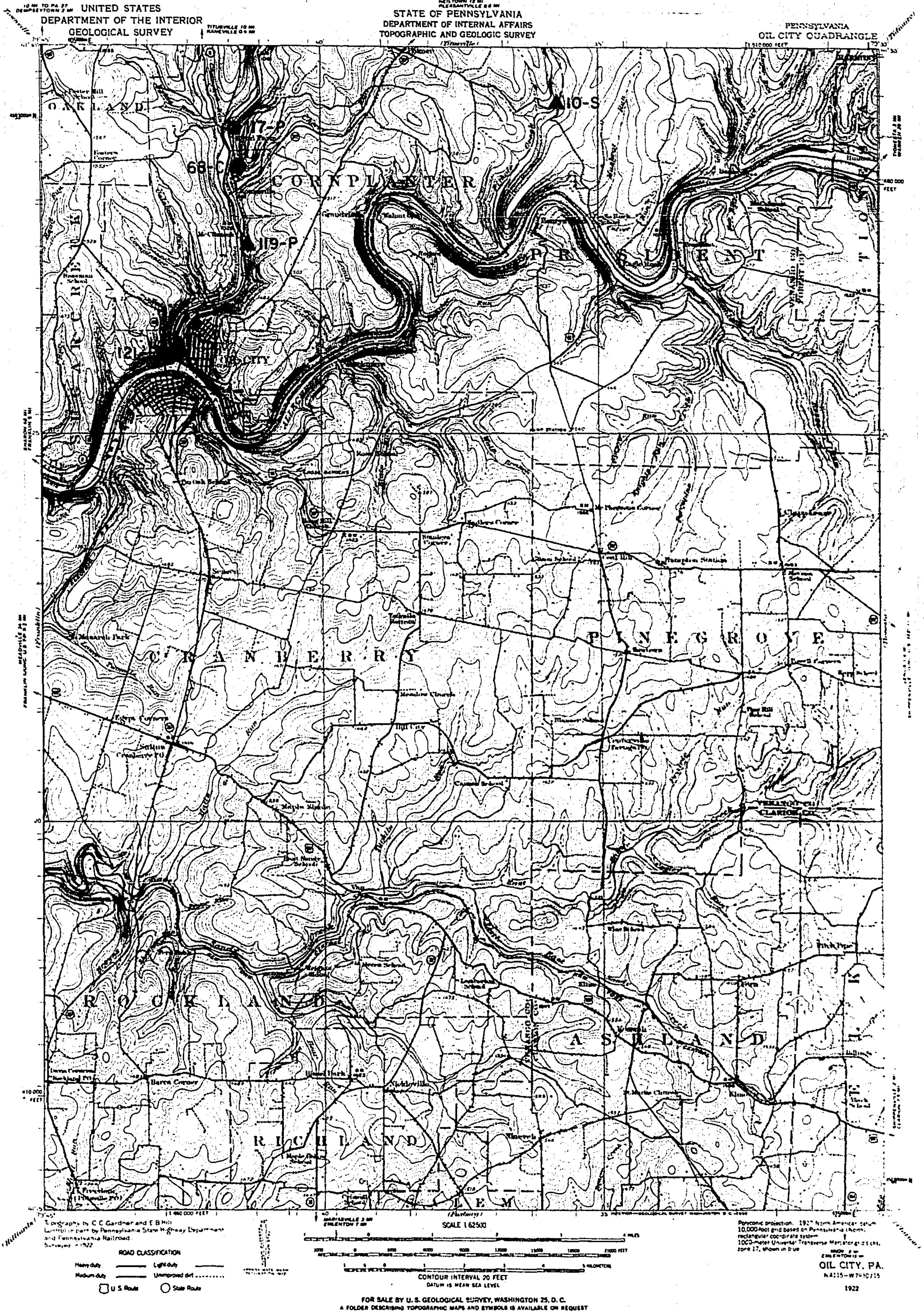


Fig. A19. - Section 121-P; Oil City Quadrangle, at RR tunnel and along Pennsylvania State Route 8 bypass - in Oil City. The section is sparingly fossiliferous. Some productid brachiopods were extracted from the median micaceous-siltstone phase of the Corry near the top of the tunnel. According to Pepper, et al., 1954, the more massive sandstone layers above the tunnel are capped by the Bartholomew siltstone. (Approximate elevation of base of Corry - 987' A. T.; thickness - 30'.)

PLATE A-12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GEOLOGICAL SURVEY
STATE OF PENNSYLVANIA
DEPARTMENT OF INTERNAL AFFAIRS
TOPOGRAPHIC AND GEOLOGIC SURVEY
PENNSYLVANIA
OIL CITY QUADRANGLE
10-S
17-P
68-C
119-P
12
OAKLAND
CORNPLANTER
PRESIDENT
CRANBERRY
PINEGROVE
ROCKLAND
ASHLAND
RICHLAND
SALEM
VENANGO CO.
CLARION CO.
ROAD CLASSIFICATION
SCALE 1:62500
CONTOUR INTERVAL 20 FEET
DATUM IS MEAN SEA LEVEL
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A FOLDER DESCRIBING TOPOGRAPHIC MAPS AND SYMBOLS IS AVAILABLE ON REQUEST
OIL CITY, PA.
1922

REFERENCES

REFERENCES

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PLATES

Explanation of Plate 1

Figure

1 - 2. Clathrospongia abacus Hall, 1884 p. 93

Specimen from the basal Corry sandstone. 1, Mold of the interior showing the natural cast of a remnant of the paragastric reticulum near the aperture, enlarged x 1.1, location 103-C, UCM No. 34548; 2, enlargement of the same, x 1.7, showing detail of the subdivisions of the primary quadrules of the paragastric reticulum.

3. Ectenodictya carlli (Hall and Clarke), 1898 p. 101

3, Enlargement of a portion of a natural cast of the exterior of a specimen collected at location 116-C (see pl. 2, fig. 1). The double rows of the horizontal strands of the primary reticulum and the diagonal strands of the same are well shown, enlarged x 1.4, UCM No. 34549.

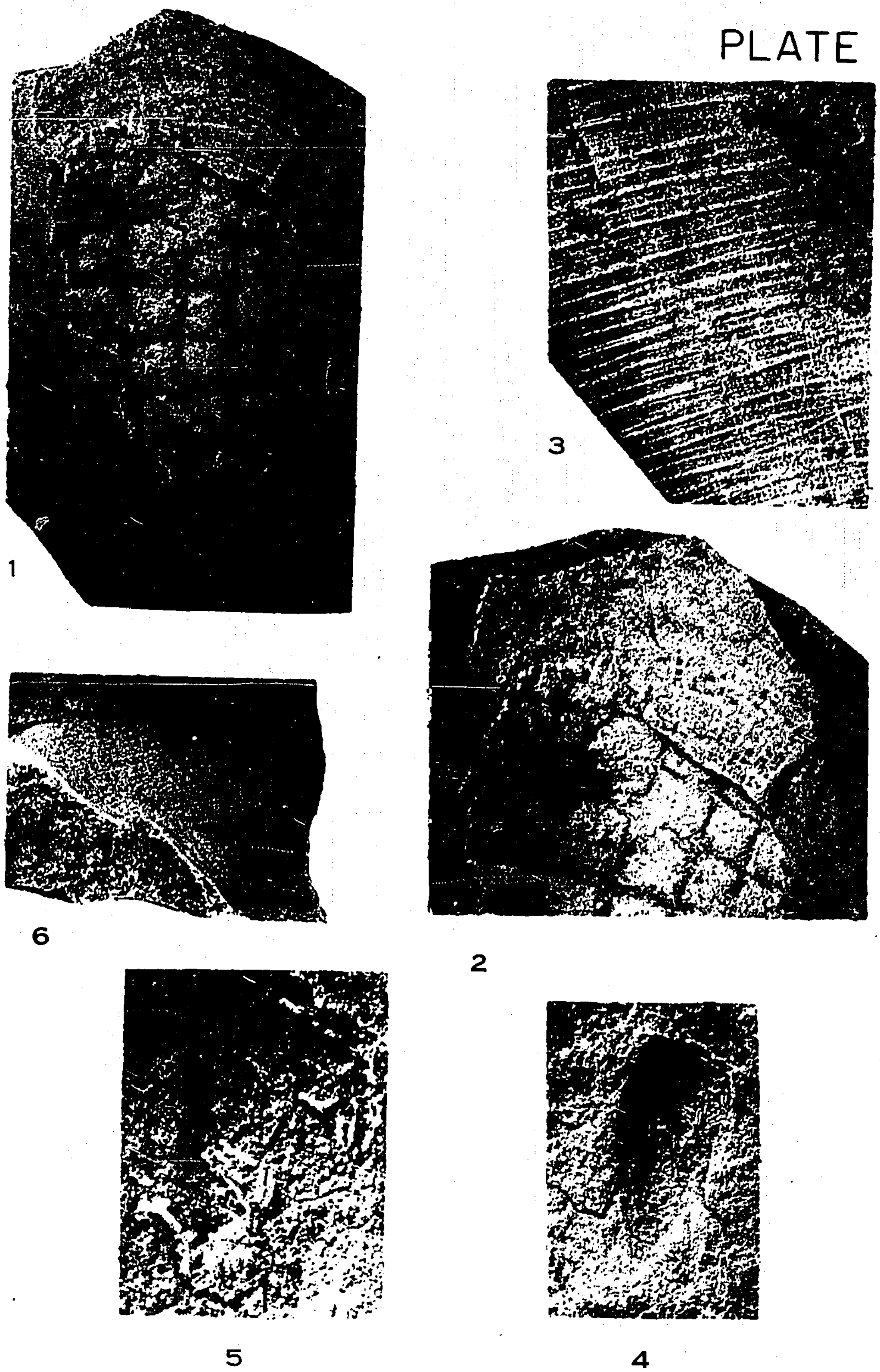
4 - 5. [?] Phragmodictya sp. Hall, 1884

4, Natural mold of an undescribed specimen collected at location 68-C and questionably assigned to the genus Phragmodictya, UCM No. 34551; 5, enlargement of the same, x 3.0, showing bean-shaped diactine microscleres (see Hall and Clarke, 1898, p. 175, fig. 30).

6. ?

Fragment of an undescribed reticulate sponge, UCM No. 34550.

PLATE I



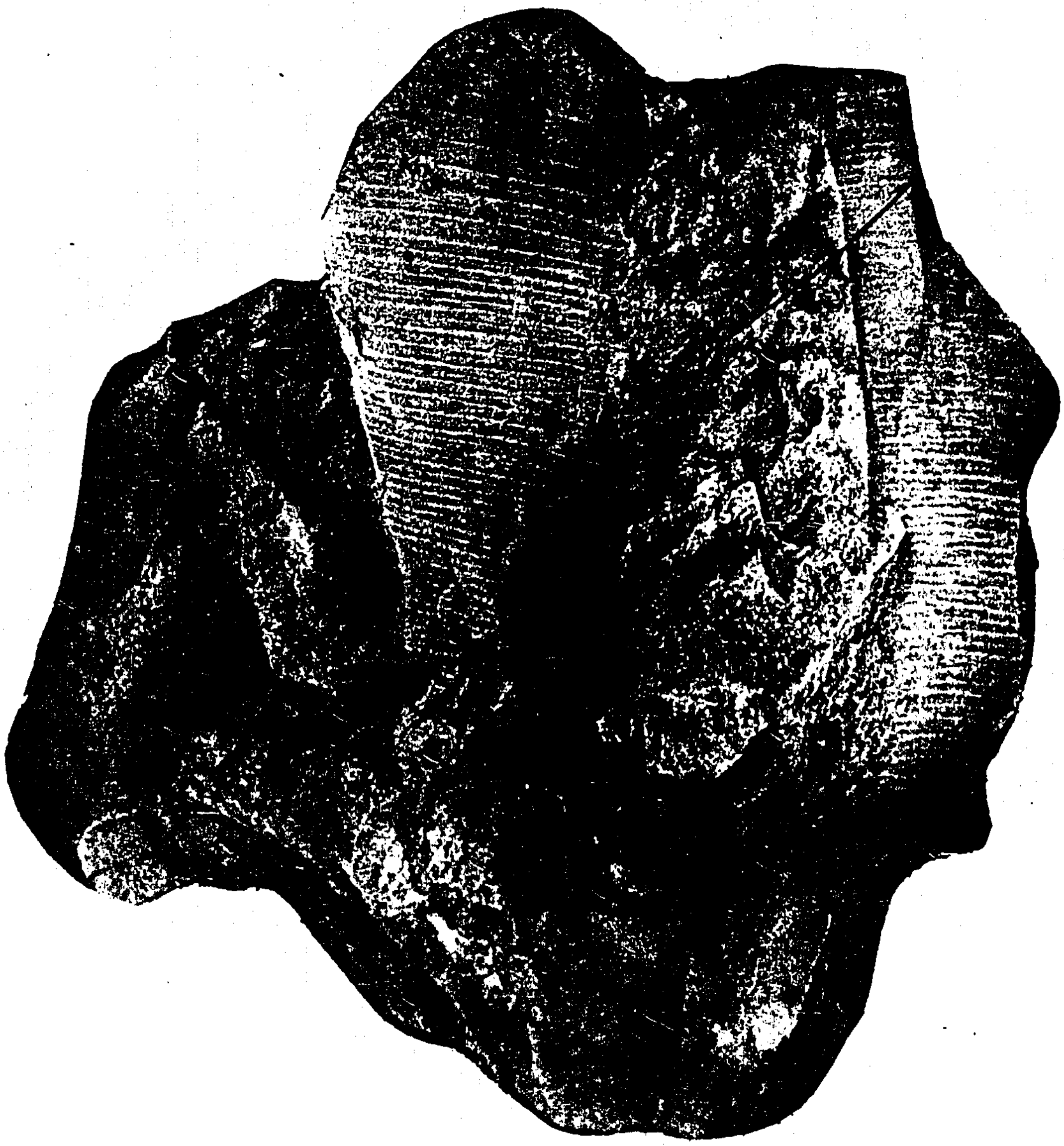
Explanation of Plate 2

Figure

1. <u>Ectenodictya</u> <u>carlli</u> (Hall and Clarke), 1898
p. 101

Specimen from the basal Corry sandstone. Natural cast of the exterior (arrow traverses the broken portion and indicates the area of enlargement shown on pl. 1, fig. 3), x 0.85, location 116-C, UCM No. 34549.

PLATE 2



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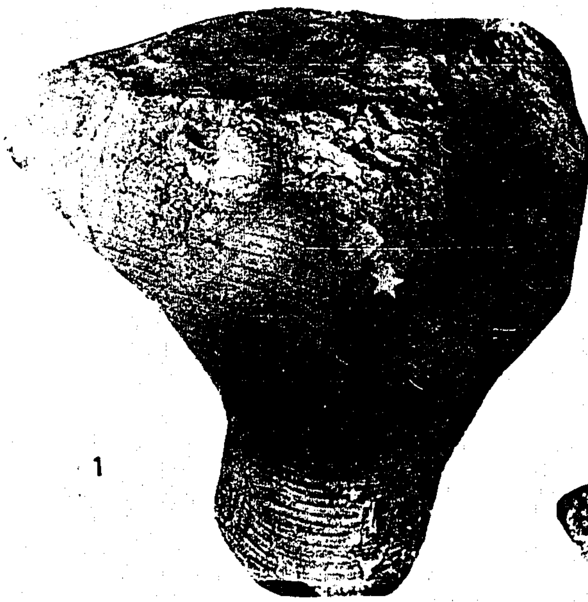
Explanation of Plate 3

Figure

1 - 3. Ectenodictya carlli (Hall and Clarke), 1898 p. 101

Specimens collected by J. F. Carll at Pleasantville, Pa.; on loan to the writer through the courtesy of the New York State Museum. 1, Large specimen showing the characteristic shape, fluting, and mesial bulge, x 0.53, lectotype, New York State Museum-Paleontology No. 58; 2, enlargement of the same showing the double bands of the horizontal components of the primary reticulum as well as the diagonal strands (compare to pl. 1, fig. 3), x 1.55; 3, smaller specimen showing stronger vertical bands and completely lacking double bands or diagonal strands in the horizontal components of the primary reticulu, paratype, New York State Museum-Paleontology No. 59, Both specimens are natural molds of the exterior.

PLATE 3



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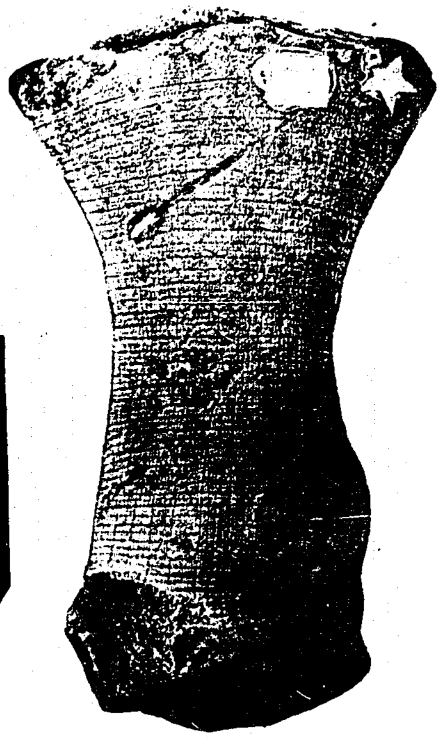

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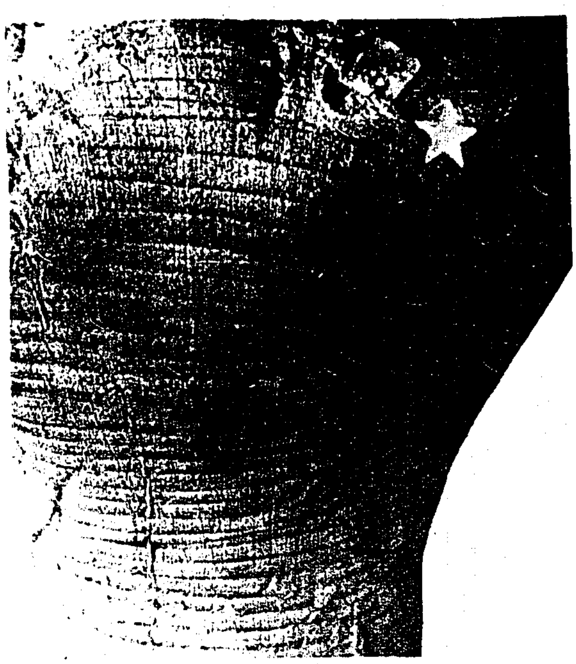

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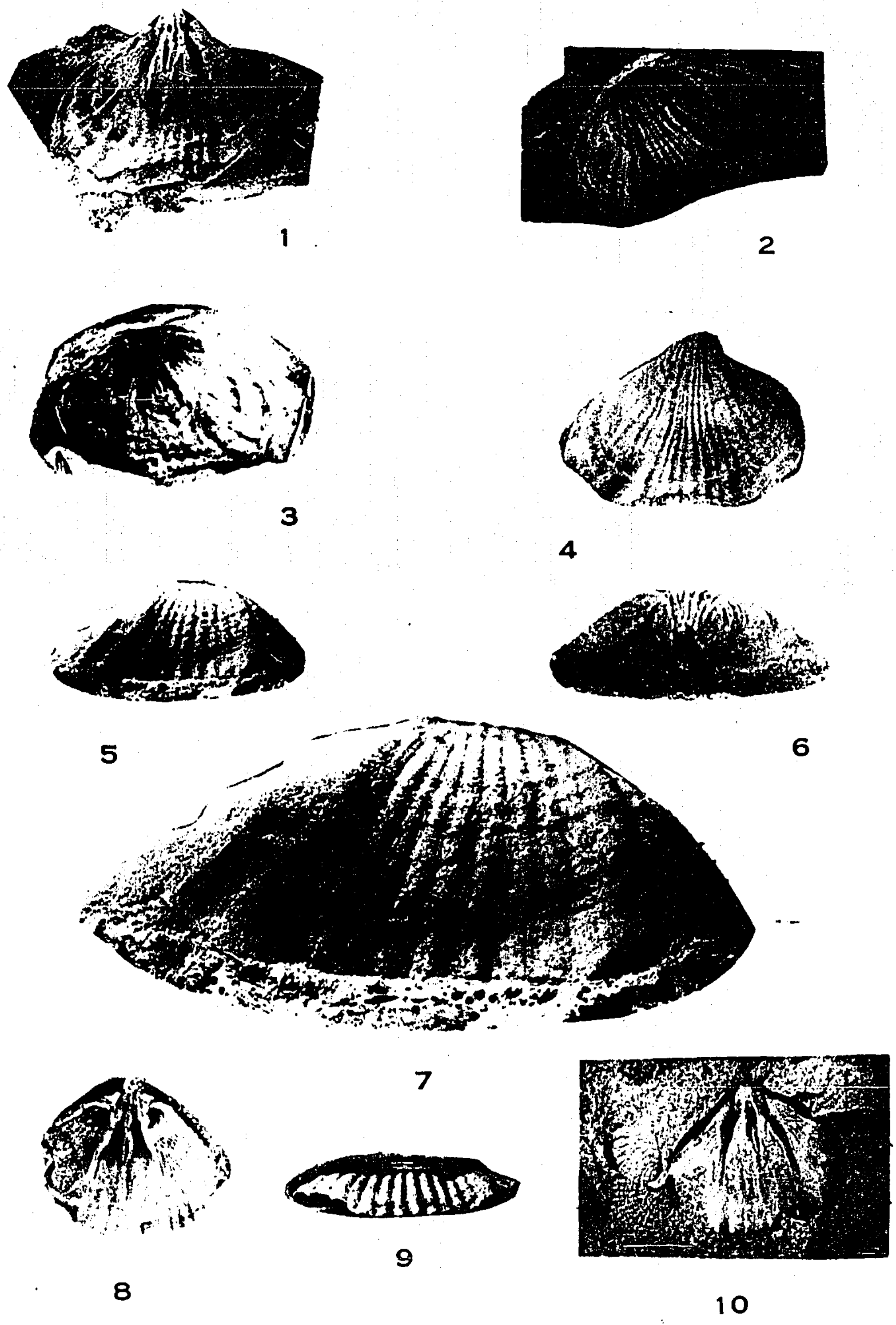
Explanation of Plate 4

Figure

1 - 10. Paraphorhynchus mediale (Simpson), 1889 p. 142

Specimens from the basal Corry sandstone.
1, Natural mold of the interior of the pedicle valve showing the "adductor process", diductor muscle scar, and concentric carinae, locality 112-C, UCM No. 34554; 2, natural mold of the exterior of the pedicle valve showing plicae and concentric carinae, location 112-C, UCM No. 34554; 3, latex cast of fig. 1 showing dental lamellae, diductor muscle scar, "adductor process", umbonal cavities and ovarian markings, UCM No. 34554a; 4, slightly distorted latex cast of fig. 2 showing sulcus and plicae, UCM No. 34554a; 5, view of the anterior of fig. 4 showing plicae in the sulcus; 6, view of the posterior of fig. 4 showing mesothyrid foramen and constriction of the beak; 7, enlargement of fig. 5 showing costellae, x 2.66; 8, latex cast of the interior of the pedicle valve made from fig. 10 and showing dental lamellae, umbonal cavities, "adductor process", and ovarian markings, locality 116-C, UCM No. 34555a; 9, anterior view of latex cast of exterior of pedicle valve showing sulcus and plicae, locality 116-C, UCM No. 34555a; 10, natural mold of the interior of the pedicle valve showing "adductor process", dental lamellae, and ovarian markings, locality 116-C, UCM No. 34555.

PLATE 4



Explanation of Plate 5

Figure

1 - 5. Paraphorhynchus striatum (Simpson), 1889 p. 151

Specimens from the basal Corry sandstone. 1, Natural mold of the interior of the pedicle valve showing the "adductor process", diductor muscle scar and dental lamellae, location 116-C, UCM No. 34556; 2, latex cast of a portion of the exterior of fig. 1 showing plicae in sulcus and on lateral margins of the valve; UCM No. 34556a; 3, latex cast of fig. 1 showing the delthyrium, "adductor process", and teeth, UCM No. 34556a; 4, latex cast of an imperfect specimen showing delthyrium and palintrope, location 116-C, UCM No. 34557a; 5, latex cast of a specimen with a gibbous pedicle valve, location 123-C, UCM No. 34558a.

6 - 10. Paraphorhynchus girtyi Caster, 1930 p. 158

Specimens from the basal Corry sandstone. 6, Natural mold of the interior of both valves of the holotype, inverted to show the erect beak and flattened umbo, location 123-C, PRI No. 5154; 7, view of the mold of the pedicle valve showing the plicae in the sulcus, location 123-C, PRI No. 5154; 8, view of the mold of the brachial valve showing the plicated fold and median septum, location 123-C, PRI No. 5154; 9, latex cast of the posterior portion of PRI No. 5154 showing "adductor process", diductor muscle scar, dental lamellae, and septalium, location 123-C, plastoholotype, UCM No. 34559; 10, natural mold of the interior showing depression for "adductor process", and diductor muscle scar, location 123-C, UCM No. 34560.

11. Paraphorhynchus casteri n. sp. p. 165

Specimen from the basal Corry sandstone. Latex cast of the posterior portion of the exterior of the pedicle valve of the holotype showing the foramen and costellae, location 116-C, UCM No. 34561a.

Figure

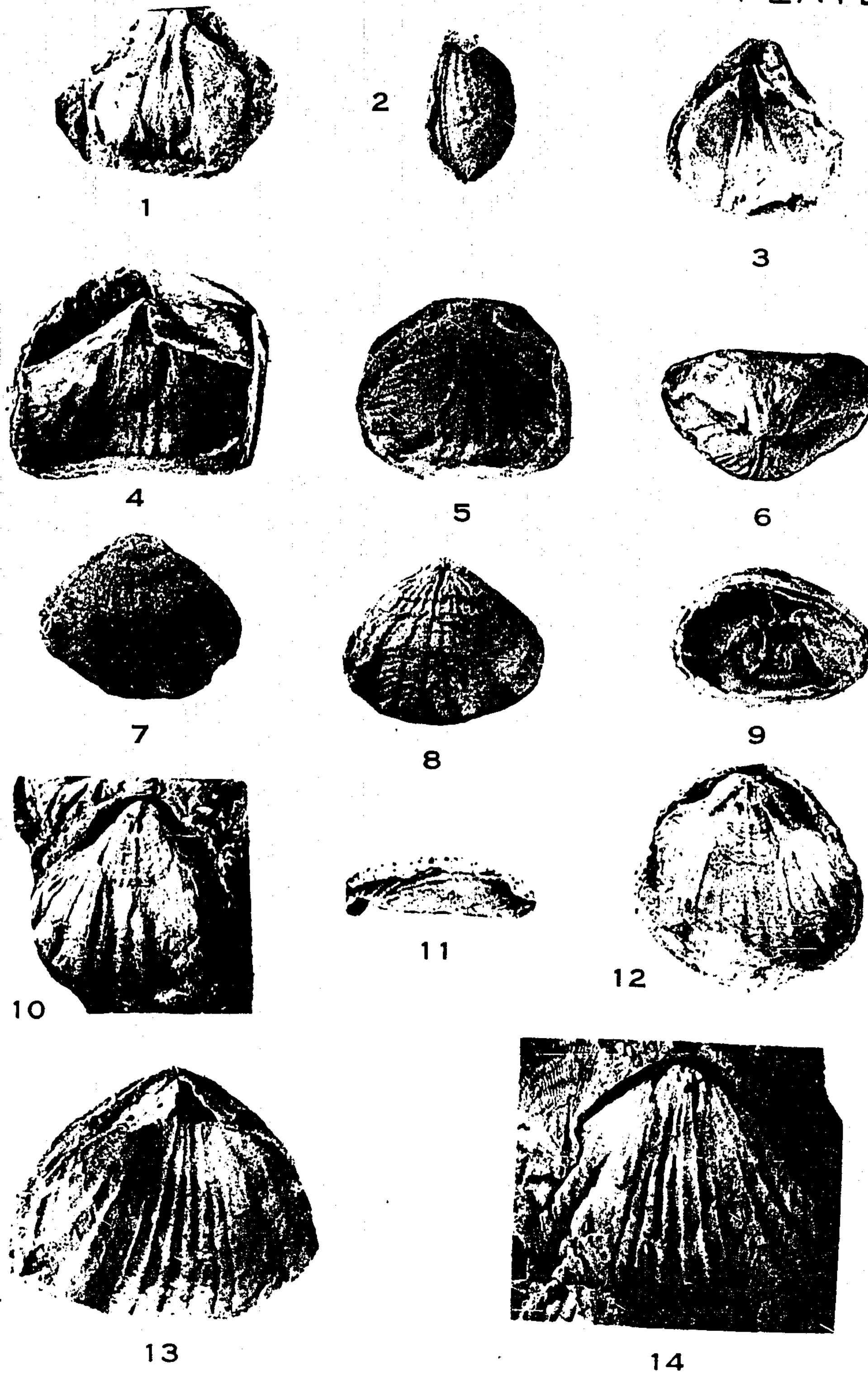
12. _Paraphorhynchus_ _girtyi_ Caster, 1930 p. 158

Latex cast of the interior of fig. 10 showing diductor muscle scar, "adductor process", and deltidial plates, location 123-C, UCM No. 34560a.

13 - 14. _Paraphorhynchus_ _casteri_ n. sp. p. 165

Specimens from the basal Corry sandstone. 13, Latex cast of the interior of the pedicle valve of the holotype showing sulcus and plicae, location 123-C, UCM No. 34561a; 14, natural mold of the interior of the pedicle valve of the holotype showing the plicae in the sulcus and on the lateral slopes (arrow points to the "adductor process"), location 123-C, UCM No. 34561.

PLATE 5



Explanation of Plate 6

Figure

1 - 2. Paraphorhynchus mediale (Simpson), 1889 p. 142

1, Natural mold of the interior of the pedicle valve showing depressions representing the "adductor process", ridge around the diductor muscle scar, dental lamellae, ovarian markings, and vascular sinuses (note the continuation of the mold and the matrix at the beak), enlarged x 2.5, location 116-C, UCM No. 34555; 2, latex cast of the mold in fig. 1 demonstrating the same features and the umbonal cavities, enlarged x 2.5, UCM No. 34555a.

3. Paraphorhynchus striatum (Simpson), 1889 p. 151

Portion of the latex cast of the interior of the pedicle valve showing the dental lamellae, umbonal cavities, "adductor process", and sulcus for insertion of the anterior adductor muscles, enlarged x 2.5, location 123-C, UCM No. 34558a.

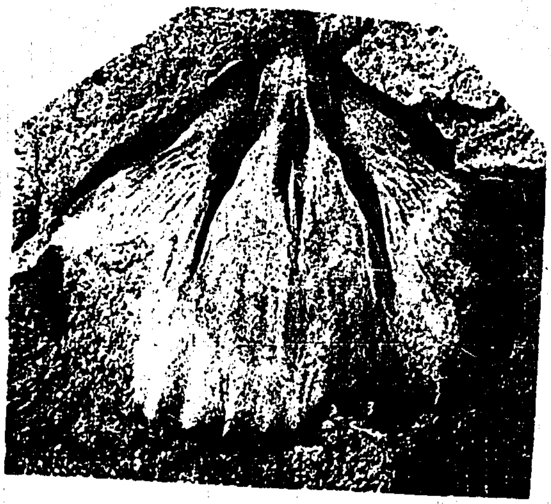
4. Paraphorhynchus girtyi Caster, 1930 p. 158

Latex cast of the posterior extremity of the interiors of both valves of the holotype, showing the median septum, septalium, divided hinge-plate, dental lamellae, "adductor process", and subtrapezoidal adductor muscle scar, enlarged x 2.5, location 123-C, UCM No. 34559.

5. Paraphorhynchus casteri n. sp. p. 165

Natural mold of the interior of the pedicle valve of the holotype showing the plicae in the sulcus, costellation, and "adductor process" (note the arrow which points to the position of the "adductor process"), enlarged x 2.5, location 123-C, UCM No. 34561.

PLATE 6



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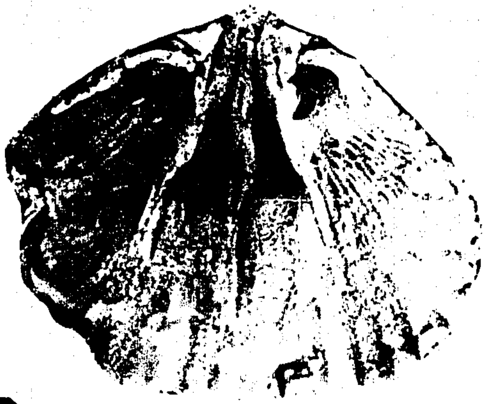

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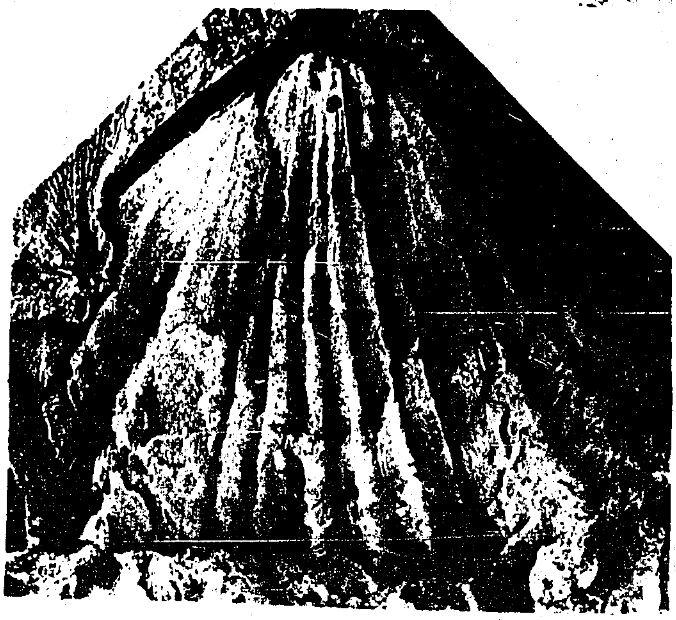

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Explanation of Plate 7

Figure

1 - 3. Paraphorhynchus elongatum Weller, 1905

Specimens from the Chouteau limestone of Missouri. 1-3, Pedicle, profile, and brachial views of a large specimen, Univ. Missouri No. 3743a. (Reproduced from Branson, 1938, pl. 4, figs. 1-3.)

4 - 6. Paraphorhynchus striatocostatum (Meek and Worthen), 1868

Specimens from the Bushberg sandstone of Missouri. 4, Brachial valve [?], Univ. Missouri No. 3889; 5, portion of a shell showing the striae [costellae], Univ. Missouri No. 3889; 6, part of a pedicle valve, Univ. Missouri No. 3889. (Reproduced from Branson, 1938, pl. 17, figs. 18-20.)

7 - 9. Paraphorhynchus crenulatum Branson, 1938

Specimens from the Chouteau limestone of Missouri. 7, Profile view, Univ. Missouri No. 3893 (cotype); 8-9, specimen showing markings and plicae, Univ. Missouri No. 3893. (Reproduced from Branson, 1938, pl. 4, figs. 14-17.)

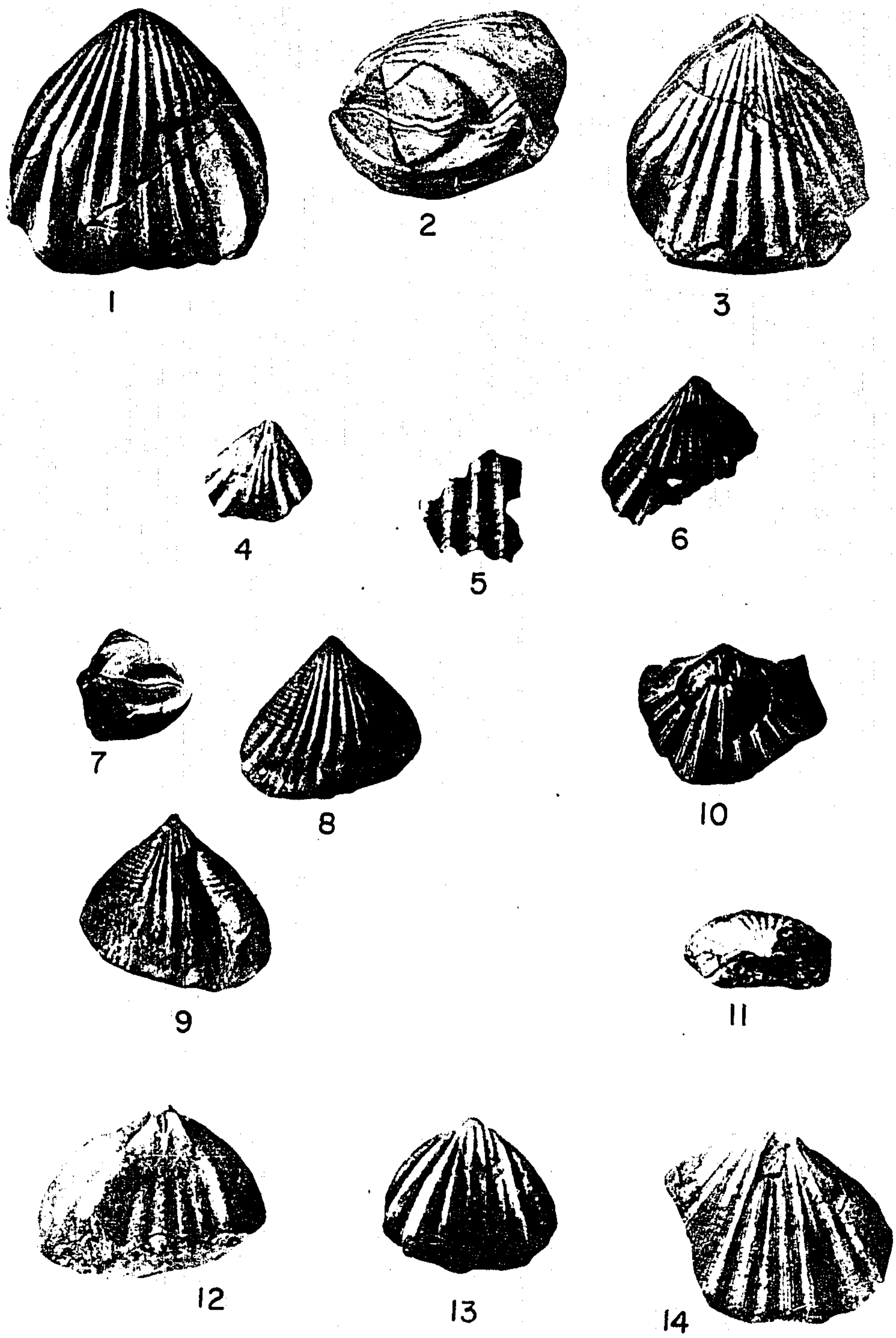
10 - 11. Paraphorhynchus bushbergense Branson, 1938

Specimens from the Bushberg sandstone of Missouri. 10, A large brachial valve, Univ. Missouri No. 3892; 11, posterior view, Univ. Missouri No. 3892. (Reproduced from Branson, 1938, pl. 17, figs. 15-16.)

12 - 14. Paraphorhynchus transversum Weller, 1905

Specimens from the Bushberg sandstone of Missouri. 12-14, Three views of imperfect specimens, Univ. Missouri No. 3888. (Reproduced from Branson, 1938, pl. 17, figs. 1-3.)

PLATE 7



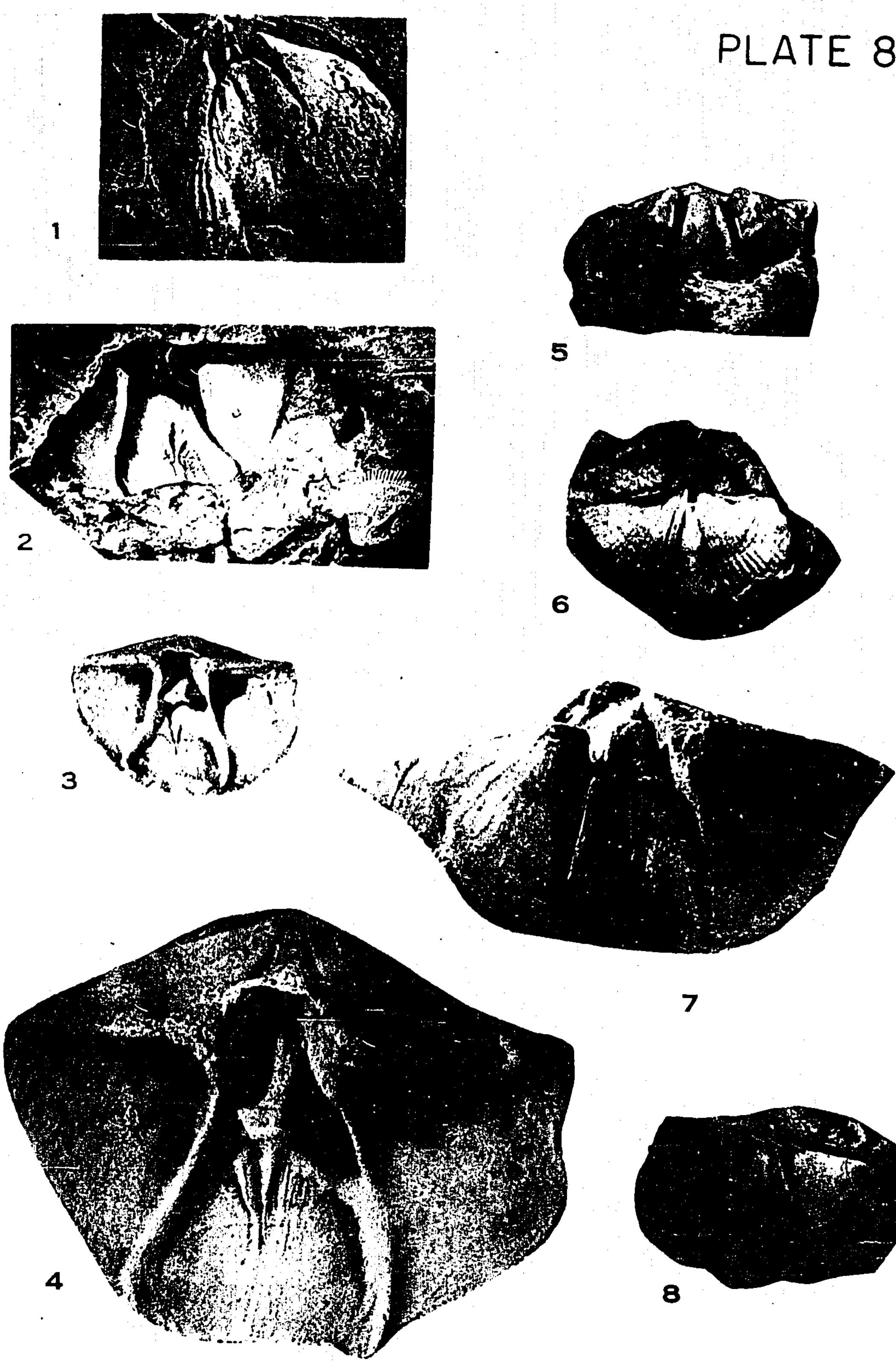
Explanation of Plate 8

Figure

1 - 8. Syringothyris angulata Simpson, 1890 p. 195

Specimens from the basal Corry sandstone.
1, Natural mold of the interior of the pedicle valve showing the "adductor process" and the faint impressions of plicae in the sulcus, locality 116-C, UCM No. 34563; 2, natural mold of the posterior portion of the pedicle valve showing the void representing the subdelthyrial plate and the dental lamellae as well as the impressions of the "adductor process", locality 116-C, UCM No. 34564; 3, latex cast made from the mold in fig. 2 showing the deltidial plate, dental lamellae, "adductor process", and muscle field, UCM No. 34564a; 4, enlargement of fig. 3 showing details of the morphology, x 2.2; 5, posterior view of the mold of the pedicle valve of the lectotype showing the impression of the "adductor process" and the ovarian markings, collected near Warren, Pennsylvania, Phil. Acad. Sci. No. 9535; 6, anterior view of the mold of the exterior of the brachial valve of the lectotype showing the plicae and linear markings on the fold, Phil. Acad. Sci. No. 9535; 7, enlargement of the posterior of the pedicle valve of a paratype, x 2.1, collected at Warren, Pennsylvania, Phil. Acad. Sci., No. 9533; 8, posterior view of a natural mold of a paratype, collected at Warren, Pennsylvania, Phil. Acad. Sci. No. 9538.

PLATE 8



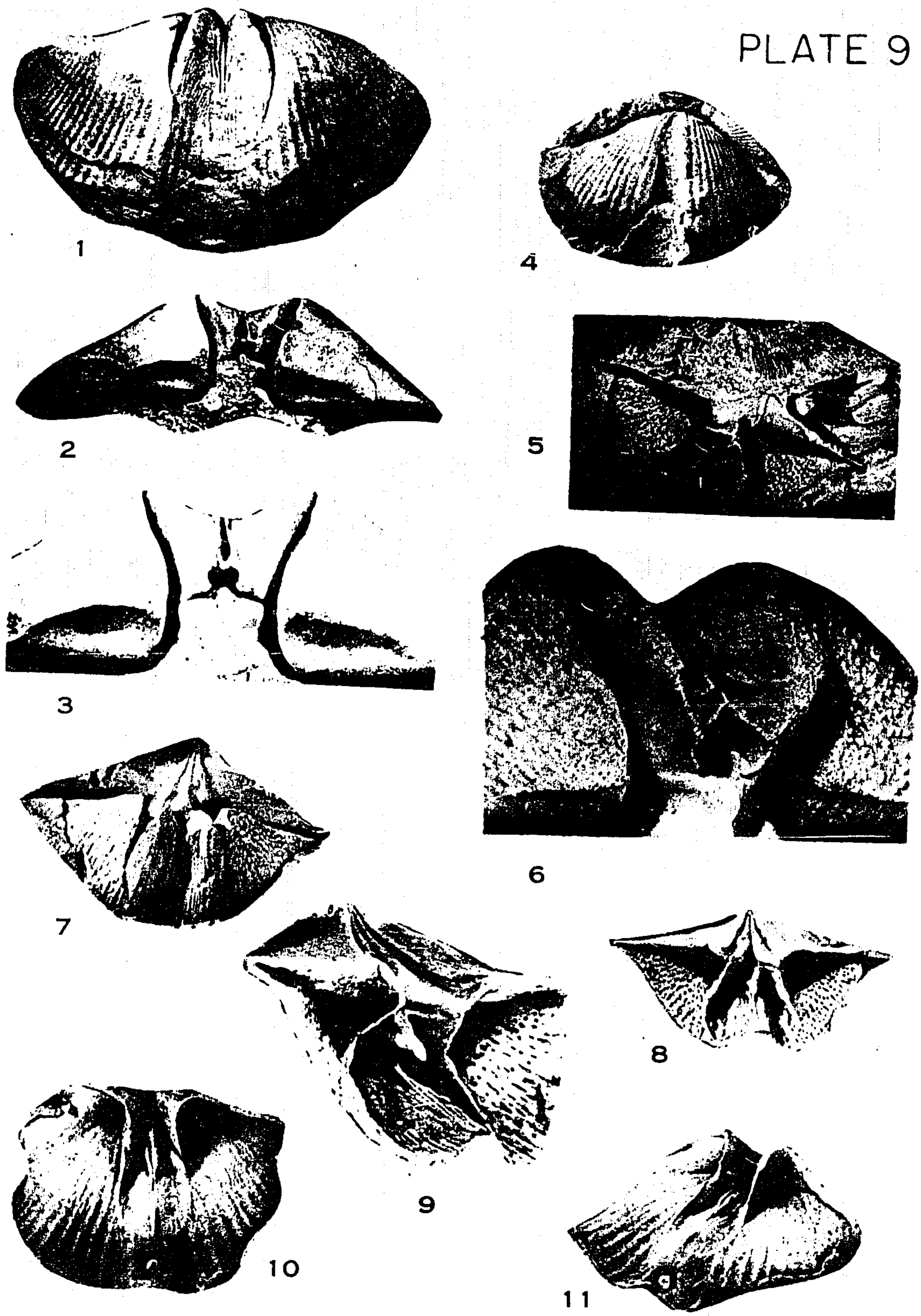
Explanation of Plate 9

Figure

1 - 11. Syringothyris randalli Simpson, 1890 p. 205

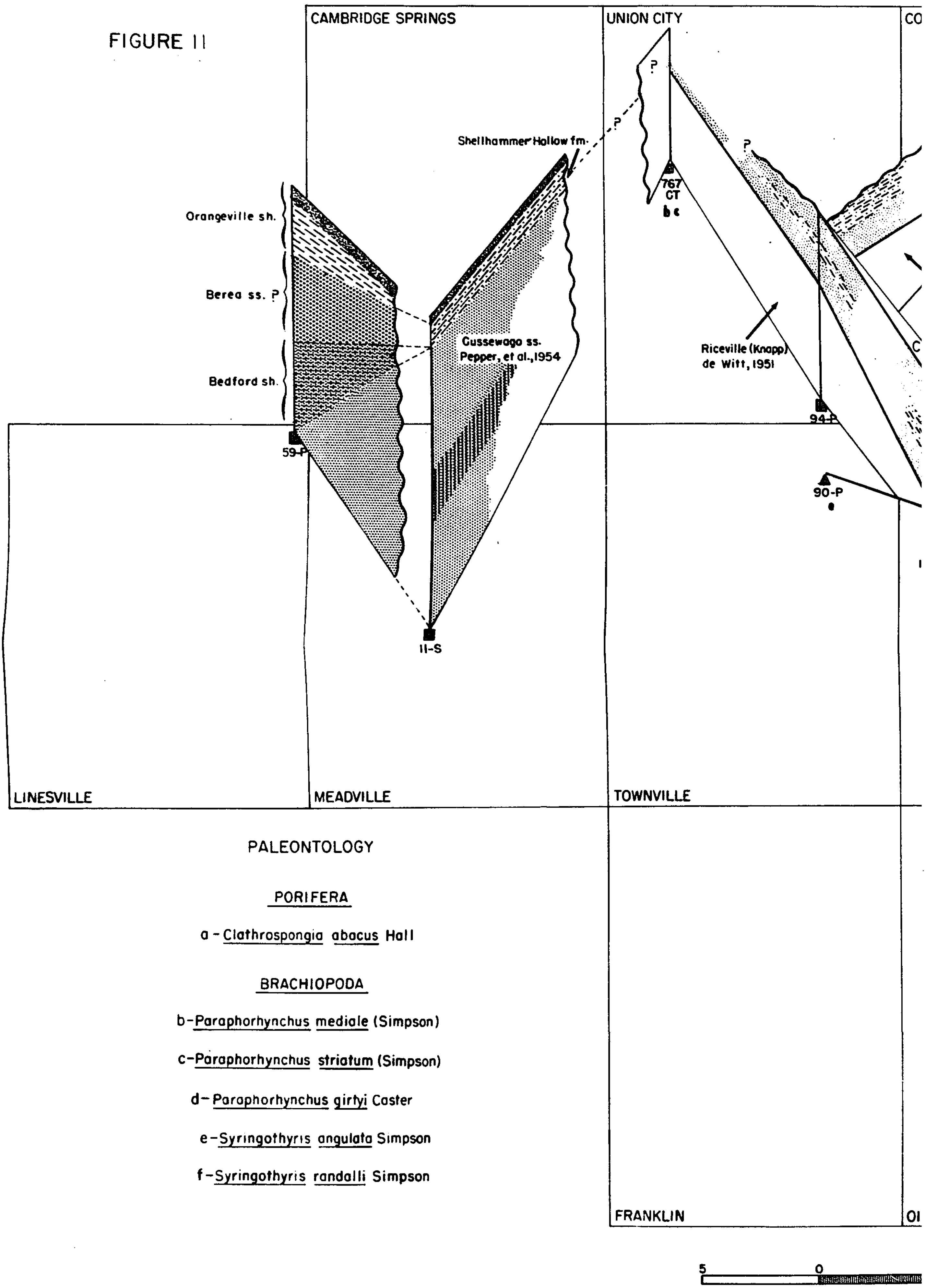
Specimens from the basal Corry sandstone. 1, Anterior view of the natural mold of the interior of the pedicle valve of the holotype showing the plicae in the sulcus, collected from the Corry sandstone near Warren, Pennsylvania, Phil. Acad. Sci. No. 9532; 2, inverted posterior view of the mold in fig. 1 showing the near-coalesence of the impressions of the "adductor process" and the syrinx as well as the "teardrop" impressions; 3, enlargement of fig. 2 showing details of the mold, x 2.0; 4, latex cast of the exterior of the pedicle valve, location 116-C, UCM No. 34565a; 5, posterior view of the natural mold of the pedicle valve showing the impressions of the syrinx, "adductor process", and diductor muscle scars, location 116-C, UCM No. 34565; 6, inverted enlargement of fig. 5 showing the "tear-drop" impression, x 2.7; 7, posterior view of fig. 5, note the circular impression in the mold of the sulcus; 8, latex cast of fig. 5 showing the conjunct lamellar callists constricting the delthyrium, the thickened dental lamellae, the syrinx, and the ovarian markings, UCM No. 34565b; 9, oblique enlargement of fig. 8 showing the unsupported syrinx, x 1.8; 10, anterior view of a cast of the interior of the pedicle valve showing the morphology, enlarged x 2.0, location 116-C, UCM No. 34566a; 11, oblique view of fig. 10 showing the "adductor process" and they syrinx, x 2.0.

PLATE 9



RESTORATION OF THE CONTINUITY OF

FIGURE 11



PALEONTOLOGY

PORIFERA

a - Clathrospongia abacus Hall

BRACHIOPODA

b-Paraphorhynchus mediale (Simpson)

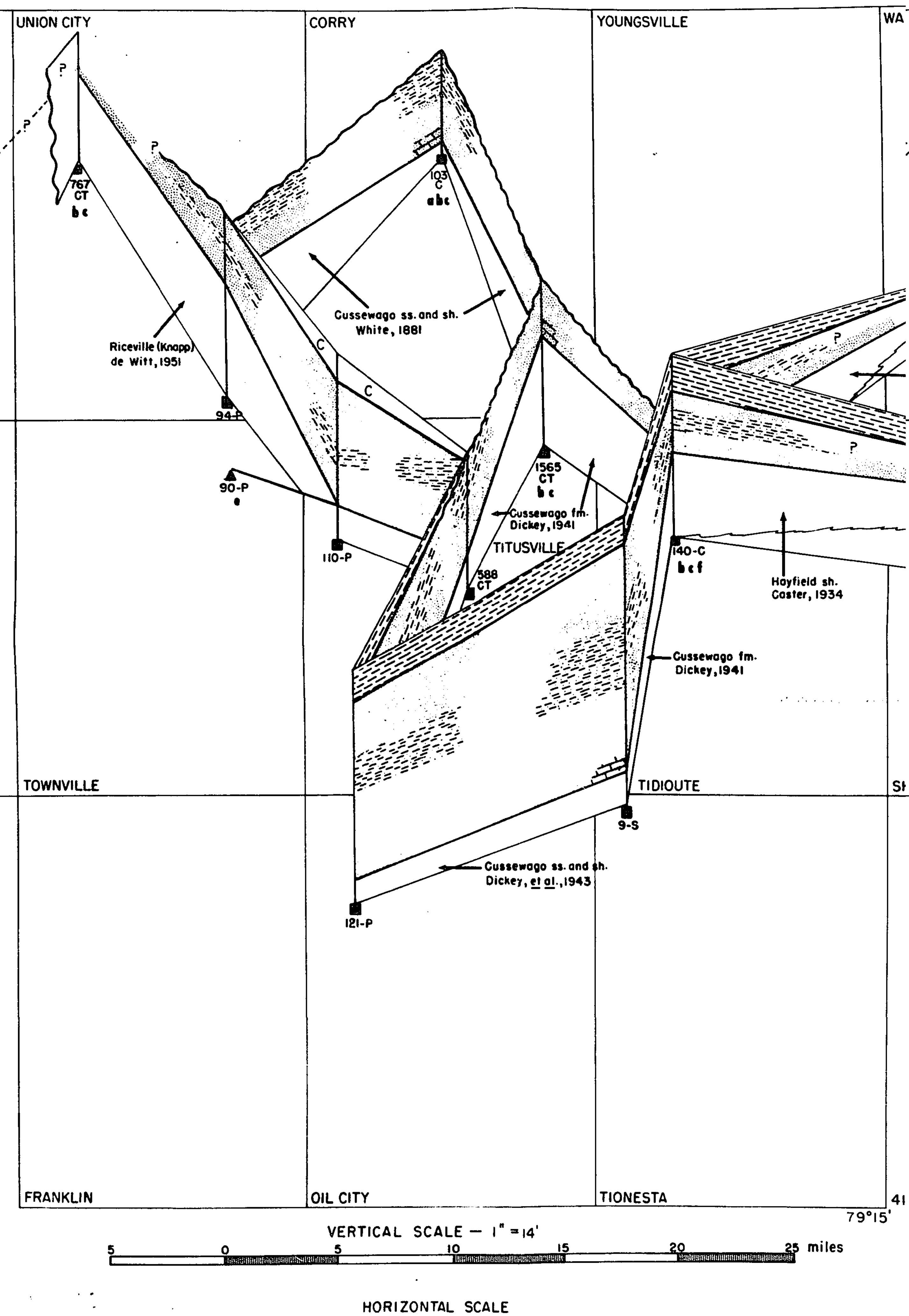
c-Paraphorhynchus striatum (Simpson)

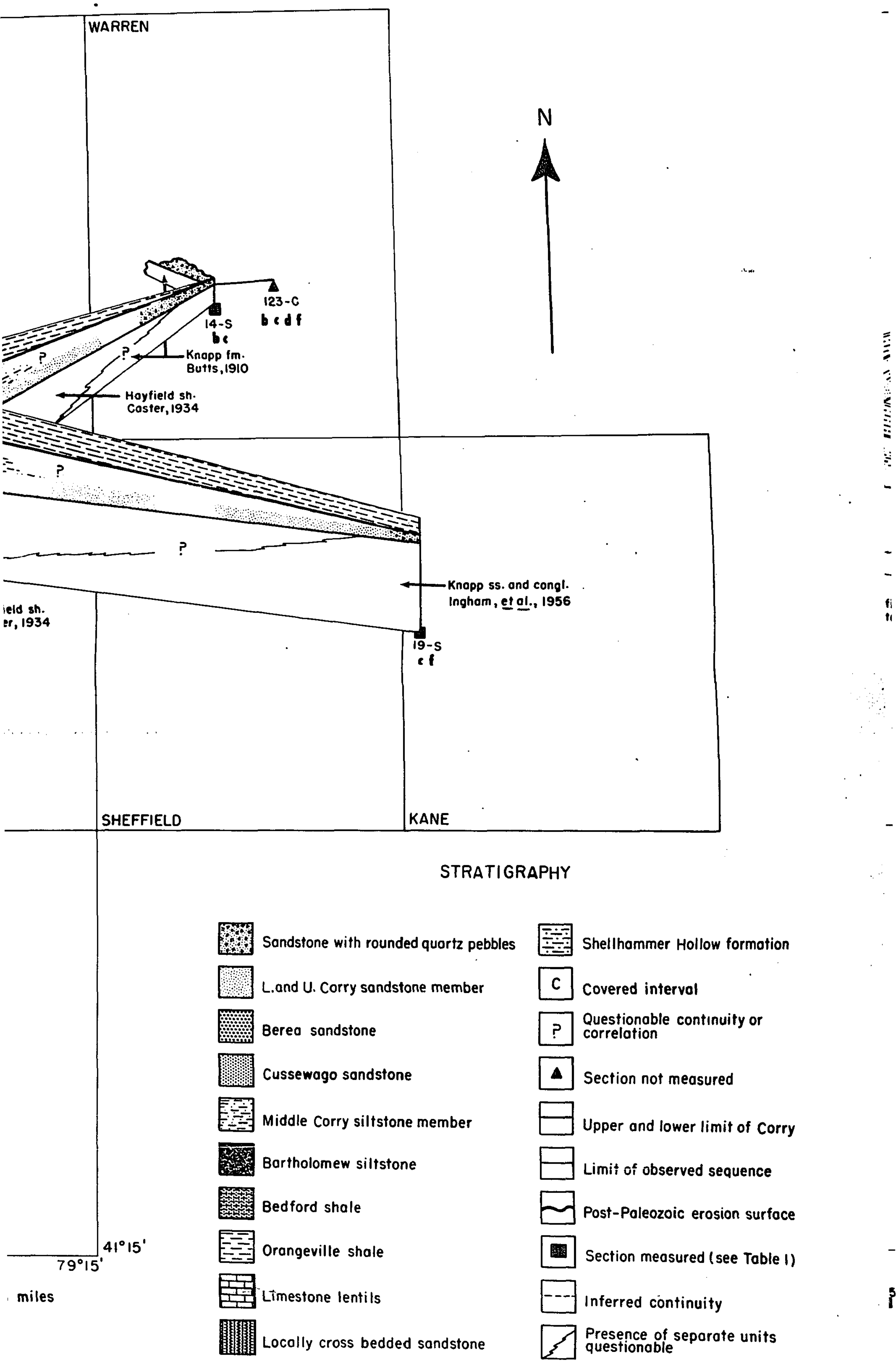
d-Paraphorhynchus girtyi Caster

e-Syringothyris angulata Simpson

f-Syringothyris randalli Simpson

N OF THE CONTINUITY OF THE CORRY SANDSTONE IN NORTHWESTERN PEN




WARREN
N
123-C
b c d f
14-S
b c
Knapp fm.
Butts, 1910
Hayfield sh.
Caster, 1934
Knapp ss. and congl.
Ingham, et al., 1956
ield sh.
er, 1934
19-S
c f
SHEFFIELD
KANE
41°15'
79°15'
miles
STRATIGRAPHY
Sandstone with rounded quartz pebbles
L. and U. Corry sandstone member
Berea sandstone
Cussewago sandstone
Middle Corry siltstone member
Bartholomew siltstone
Bedford shale
Orangeville shale
Limestone lentils
Locally cross bedded sandstone
Shellhammer Hollow formation
Covered interval
Questionable continuity or correlation
Section not measured
Upper and lower limit of Corry
Limit of observed sequence
Post-Paleozoic erosion surface
Section measured (see Table I)
Inferred continuity
Presence of separate units questionable