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Devonian of the North-Central Region, United States

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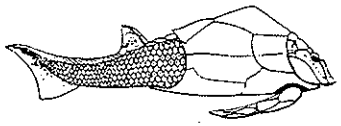


DEVONIAN OF

THE NORTH-CENTRAL REGION, UNITED STATES

CHARLES COLLINSON

ABSTRACT

Devonian rocks of the north-central region occur in an irregular southeast-northwest band extending from the western slope of the Cincinnati arch in Indiana to the eastern slope of the Cambridge arch in central Nebraska. Northward they are bounded by the Sioux arch-Canadian Shield-Wisconsin arch complex. On the south they are limited by the Ozark uplift, the Pascola arch and the Nashville dome.

The eastern third of the area is dominated by the Illinois basin in which there are more than 1700 feet of marine Devonian sediments representing a virtually complete record correlated to the Devonian standards of New York and western Europe by means of conodonts and brachiopods. In the western part of the area, deposition occurred in a broad, shallow basin centred in central and southwestern Iowa. More than 700 feet of sediments accumulated mainly during middle and late Devonian time with probable Lower Devonian rocks confined to the deep part.

A broad arch involving the Lincoln fold of northeastern Missouri and the Sangamon arch of Illinois formed a divide over which no Lower and few Middle Devonian rocks were deposited but which was blanketed by argillaceous sediments in late Devonian time.

Lithologically, the Lower Devonian is dominated by siliceous carbonates. The Middle consists mainly of sandy fossiliferous limestone but also includes nonfossiliferous lithographic limestone, gypsum, and sandstone. The Upper Devonian consists of widespread black and grey shales with prominent limestone facies in Iowa.

INTRODUCTION

This Regional paper is composed of two papers on the main basins of the north-central region of the United States — the Illinois basin and the central Iowa basin. The Michigan basin has not been included.

There has been a 23-year lapse since publication of the last regional summary of the Devonian of north-central United States (Illinois Geol. Survey Bull. 68). This record of subsequent progress describes the individual units, their geographic setting, stratigraphic relationships, faunal aspects and geologic age so that a regional picture of depositional patterns, sources of sediments, palaeogeography and correlation emerges.

Much unpublished material is included — more than 2500 well records and 300 geophysical logs were examined — and all diagrams and maps are new. Seven authors and five geological surveys contributed data, but the material does not necessarily represent the official view of any of the participating organizations.

We are indebted to many people. At Iowa City, H. Garland Hershey, State Geologist, provided personal councel and two helpful contributors, Mary C. Parker and Don I. Koch. Joseph Straka provided data concerning the English River Siltstone. In Bloomington, State Geologist John Pat-

ton, T. A. Dawson, R. H. Shaver, and R. W. Orr were very helpful. As is obvious, we drew heavily on Orr's unpublished manuscripts. Thicknesses shown for Kansas were provided by Paul L. Hilpman, Kansas Geological Survey.

In Urbana, State Geologist John C. Frye encouraged the study and H. B. Willman critically read the final manuscript. Wayne Meents, William G. North, and Alan James gave invaluable help in evaluating and assembling data. Dick Eddy, Charles Bolian, Susan Cordon, Bob White, and Herbert Baker provided excellent technical assistance.

REGIONAL SETTING

Of two basins dominating the north-central United States during the Devonian, only one, the Illinois basin, was significant in the post-Devonian development of the region. The other, a broad ill-defined shallow structure was centred in central Iowa and covered eastern Nebraska, most of Iowa, southern Minnesota, northern Missouri and northwestern Illinois. Although this basin was a prominent feature during the Devonian, when it received more than 700 feet of sediment (Fig. 2), it does not correspond with earlier or later structural features of the region (Fig. 1). It did not develop until near the end of the Early Devonian and barely lasted through the period.

During the Silurian, deposition in the western part of our area was centred in the North Kansas basin in Nebraska, near the present Nemaha uplift. The Devonian seas occupied a quite different area, so that in much of the Iowa

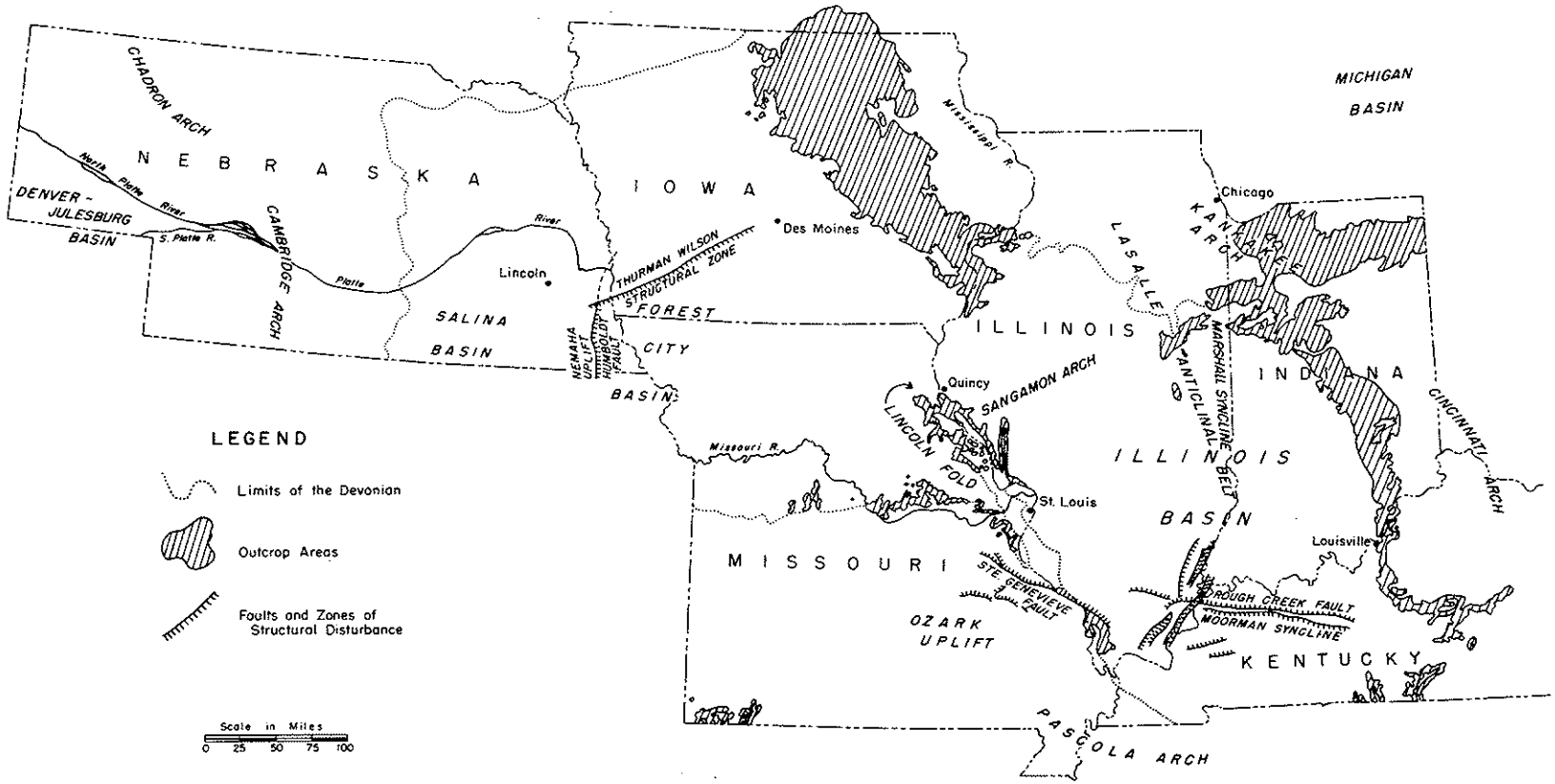


Fig. 1. Distribution of Devonian outcrops and important structural features in north-central United States.

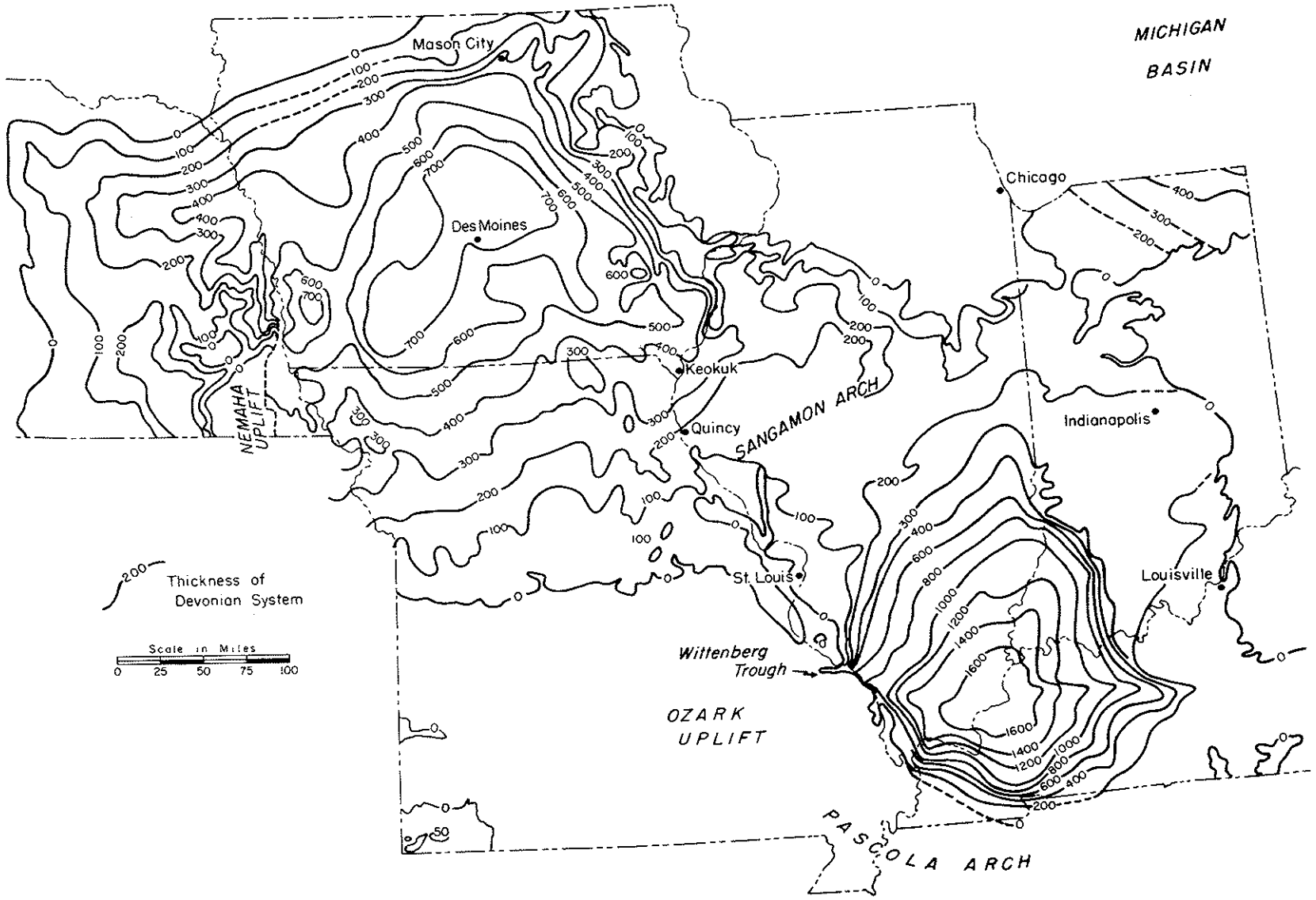


Fig. 2. Thickness of the Devonian System in north-central United States.

basin, the Devonian lies on Ordovician rather than Silurian rocks (Fig. 8). The Chautauqua, Ozark and Sangamon arches provided the southern margin of this basin and the Sioux-Wisconsin arch completed its northern margin. Although limited on the west by the Cambridge arch, the basin must have been connected northwestward with the Cordilleran and Arctic seas as well as eastward with the Michigan basin.

The Illinois basin (Fig. 2) began much earlier and has continued as an entity. More than 1700 feet of Devonian strata rest upon the Silurian. The Ozarks provided a stable western margin throughout the Devonian. Southwestward the basin is sharply truncated by the post-Palaeozoic Pascola arch, but it originally communicated to the Ouachita region. The Nashville-Cincinnati, Kankakee and Sangamon arches were low, shifting, frequently inundated sills separating the Illinois basin from the Appalachian, Michigan, and Iowa basins. Within the Illinois basin, the Moorman syncline was a deep east-west trough flanked on the north by a positive belt which later fractured to become the Rough Creek fault zone. A western counterpart, the narrow Wittenberg trough (Fig. 1, 9 and 10), extends northwestward from Union County, Illinois, into Ste. Genevieve County, Missouri. It also contains an abnormally thick Devonian section.

GEOLOGIC HISTORY

At the beginning of the Devonian, about nine-tenths of the north-central region was emergent and remained so until the middle of the period. The Ozark uplift, the Chadron-Cambridge arch areas, the Sioux uplift, the Sangamon, Kankakee and Cincinnati arches and great expanses of their flanks were exposed. Only in the deepest part of the Illinois basin did deposition continue from latest Silurian to earliest Devonian. Early Devonian sediments in the basin were mainly siliceous and argillaceous carbonates, giving rise to the Bailey, Grassy Knob and Clear Creek Formations. The Backbone Limestone and the unnamed limestone member at the top of the Bailey are relatively pure carbonate units that consist of fossil debris swept into the basin from the shallow margins. These pure carbonate wedges did not reach the deepest part of the basin where siliceous sediments were continuously deposited.

In central Iowa, sedimentation began in a v
area in late Early Devonian time (Fig. 9) with
of the La Porte City Chert. The sea that o
basin in Early Devonian time probably connect
Michigan basin to the northeast. From such s
nings, the areas of deposition expanded thro
period with brief episodes of partial or complete
of the seas. One such retreat followed deposi
Clear Creek Chert and resulted in bevelling o
edges of that and earlier Devonian formation
continued in the exposed positive areas during th
vonian, and many hundreds of feet of Silurian a
cian sediments were removed. On the eroded
sures and cavities up to 70 feet deep later be
with Middle Devonian sediments.

At the beginning of the Middle Devonian, a n
gression was initiated by local deposition of the D
Sandstone. Following immediately, the crinoi
ates of the Grand Tower and Jeffersonville accu
southeastern Missouri, southern Illinois and we
tucky where very little terrigenous sediment r
shore parts of the basin and marine fossils shov
of transport. To the north these normal marine
grade shoreward into hypersaline sandy dolomit
and upper Grand Tower) precipitated on exte
tidal flats flanking the Sangamon, Kankakee and
arches.

During much of Middle Devonian time, the San
Kankakee arches were low-lying partial barriers
highly saline waters in the inter-connected basin
gan and central Iowa from the normal marine wa
Illinois basin. The evaporite-bearing carbonates
carbonates of the Wapsipinicon and Detroit Ri
tions (Fig. 11) were deposited north of the barr
then on there appears to have been an intermitte
tion from Iowa and eastern Nebraska across th
the Cordilleran and Arctic seas.

Midway in the Middle Devonian Epoch, tector
canic activity in the Appalachians was renewed.
effect in midwestern seas was the spreading of
of ash, the Tioga Bentonite, from a volcanic
northern Virginia into Indiana, Illinois and pos

Following minor withdrawal of the sea, sand eroded from the Wisconsin and Ozark highlands was deposited as the Beauvais Sandstone. Thereafter, a small amount of clay from the rising Appalachian highlands crossed the Appalachian trough and the Findlay-Cincinnati-Nashville arch into the Midwest. This clay was incorporated as a minor constituent in the younger Middle Devonian carbonates, which are therefore darker, finer grained and less commonly dolomitized than the earlier Middle Devonian units (Jeffersonville, Grand Tower and Wapsipinicon). Coral, stromatoporoid and algal mounds and biostromes grew in the shallow Cedar Valley seas in eastern and north-central Iowa and northwestern Illinois isolating high salinity waters in Iowa and northern Missouri where gypsum continued to be precipitated. Hoing Sandstone was deposited over much of the area as the initial deposit of the advancing Middle Devonian sea.

The end of the Middle Devonian saw a great increase in the orogenic activity to the east and construction of the westward facing Catskill delta. Sediments during late Middle Devonian time became increasingly clastic with deposition of the Blocher Shale in the eastern part of the Illinois basin. The muds did not reach the region northwest of the Sangamon arch until late Devonian time. There was local uplift in many areas accompanied by bevelling of Middle Devonian units and deposition of thin discontinuous sandstones. In northwestern Illinois there was virtually no break in deposition between Cedar Valley and the earliest mud facies (Sweetland Creek). When the muds from the uplifted areas to the east reached midwestern United States, they buried many of the older structural features. The Sangamon arch was covered. The Illinois and Iowa basins continued to sink and each collected more than 300 feet of shale.

The widespread Late Devonian sea was commonly choked with marine vegetation giving rise to black carbonaceous shale that extends from the Appalachian region westward to Kansas and southwestward to Texas. In Iowa and northwestern Illinois the shales are lighter in color and the Shell Rock, Aplington, Louisiana and some beds in the Lime Creek were deposited in areas where carbonate-fixing organisms flourished. The youngest Devonian clastic units (Saverton and equivalents) thicken northward and indicate a source in that direction.

The end of the Devonian in north-central United States is marked by no significant geologic event. In the west and north some uplift occurred, but conditions in general continued as they had been in the Late Devonian.

SYSTEMS AND SERIES BOUNDARIES

Silurian-Devonian Boundary

Recognition of the base of the Devonian presents few problems over much of the north-central area. Except where Lower Devonian deposits are present (Fig. 9), Middle and Upper Devonian rocks overlie a pronounced unconformity on Silurian and Ordovician rocks (Fig. 8). Where Lower Devonian rocks are present, however, the boundary is very difficult to recognize. The base of the Bailey, where the boundary is generally placed, is not only poorly exposed and relatively unfossiliferous but grades into the unnamed shale member at the top of the underlying Moccasin Springs Formation. Recent fossil discoveries (see *Bailey* under *Stratigraphic Units*) suggest that the lower part of the Bailey may be youngest Silurian. It seems assured that the Silurian and Devonian rocks are entirely transitional in this region.

Devonian-Mississippian Boundary

The Devonian-Mississippian boundary is one of complete transition over most of the north-central area (Collinson, 1961). Except in western Illinois and northeastern Missouri, where the Louisiana or "Glen Park" of Illinois are present, the boundary occurs within the New Albany Shale and in Indiana even within the Clegg Creek Member. It is difficult to recognize except palaeontologically and in only a few areas can Mississippian and Devonian be differentiated by geophysical means.

There is little doubt that the top of the Louisiana and its correlatives represent the European Devonian-Carboniferous boundary (Scott and Collinson, 1961; also see *Louisiana Limestone* under *Stratigraphic Units*). Although the sys-

tem differentiation in Europe is based on the cephalopod genera *Wocklumeria* and *Gattendorfia,* the conodont faunas carrying the earliest forms of *Gnathodus* (Scott and Collinson, 1961; Ziegler, 1962) are the most practical means for identifying the boundary in north-central United States.

Over much of Iowa, the Maple Mill and English River Formations are lithologically similar as well as relatively unfossiliferous and the Devonian-Mississippian contact can only be approximated. On the flanks of the Ozark uplift, the Glen Park-Bushberg complex represents a zone of gradation between the Devonian and Mississippian and also contains much reworked fossil material from older units. Thus the systemic boundary can be recognized only as lying within this complex. In Nebraska the systemic boundary is projected from the top of the Maple Mill in western Iowa.

Lower Devonian-Middle Devonian Series Boundary

Klapper and Ziegler (1967) state that North American conodont faunas which contain *Icriodus latericrescens huddlei* and no other representatives of the species are correlative with Lower Devonian (Emsian) faunas from western Germany. Orr (in press) has reported such faunas from the Backbone, Little Saline and Clear Creek formations.

Klapper and Ziegler have also reported the combination of *Icriodus latericrescens huddlei* and *I. latericrescens* n. ssp. in the Schoharie Formation of New York, and Orr has reported the same fauna in the uppermost part of the Clear Creek Formation in Illinois. Inasmuch as the Schoharie has been referred to the Emsian by Oliver (1963) on the basis of its brachiopod and trilobite fauna, we place the Lower-Middle Devonian boundary, *i.e.* the Emsian-Eifelian boundary, above the Clear Creek.

House (1962) reported *Foordites* cf. *F. buttsi* in the Nedrow Member of the Onondaga, indicating that the Emsian-Eifelian boundary lies below the Nedrow. Oliver (1963, p. 15) referred the Edgecliff, Nedrow and Moorehouse Members of the Onondaga to the Eifelian on the basis of their coral faunas. Orr (in press) and Klapper and Ziegler (1967) report *Icriodus latericrescens* n. ssp. from the Edgecliff, and Orr has also reported it from the Dutch Creek Member of the Grand Tower Formation in Illinois. No counterpart of this fauna is known from Europe, so there is no direct evidence for correlation. However, the Schoharie is Lower Devonian, the Nedrow is Middle Devonian and the corals tend to indicate a Middle Devonian age for the Edgecliff, which leads us to place the Lower-Middle Devonian boundary, *i.e.* Emsian-Eifelian boundary, at the base of the Edgecliff and correlate it to the base of the Dutch Creek Member of the Grand Tower.

Middle Devonian-Upper Devonian Series Boundary

There is general agreement that the Middle Devonian-Upper Devonian (Givetian-Frasnian) boundary in Europe belongs above the range of the cephalopod *Maenioceras terebratum* and below that of *Pharciceras lunulicosta,* but there is a thin zone in which neither occurs. Conodonts occur throughout the section, however, and have become the practical basis for recognizing the boundary.

Ziegler (1966) made a detailed study of conodonts in the vicinity of the boundary. *Polygnathus cristata, P. ordinata, Schmidtognathus wittekindti* and *S. pietzneri* are found immediately above the upper limit of *Maenioceras terebratum. Polygnathus asymmetrica* and *P. transitans* first occur near the middle of the unassigned zone. The first occurrence of *Ancyrodella rotundiloba* is with *Pharciceras lunulicosta.* Most of these species occur in the north-central United States. *Polygnathus cristata* is known from the upper part of the Alto Formation in Illinois (Orr, in press) correlating that part of the formation to the lower part of the unassigned zone. The lower part of the formation is undoubtedly Middle Devonian. *Polygnathus cristata, P. ordinata, P. transitans* and *Ancyrodella rotundiloba* all occur in the Blocher Member of the New Albany in Indiana. The boundary thus lies within the Blocher. *Polygnathus asymmetrica* occurs in the lower part of the Snyder Creek Shale of Missouri, which suggests that the Snyder Creek is entirely Upper Devonian. The abundance of *Ancyrodella rotundiloba* in the uppermost Cedar Valley of Illinois indicates that the Middle Devonian-Upper Devonian boundary lies within the upper Cedar Valley in some places.

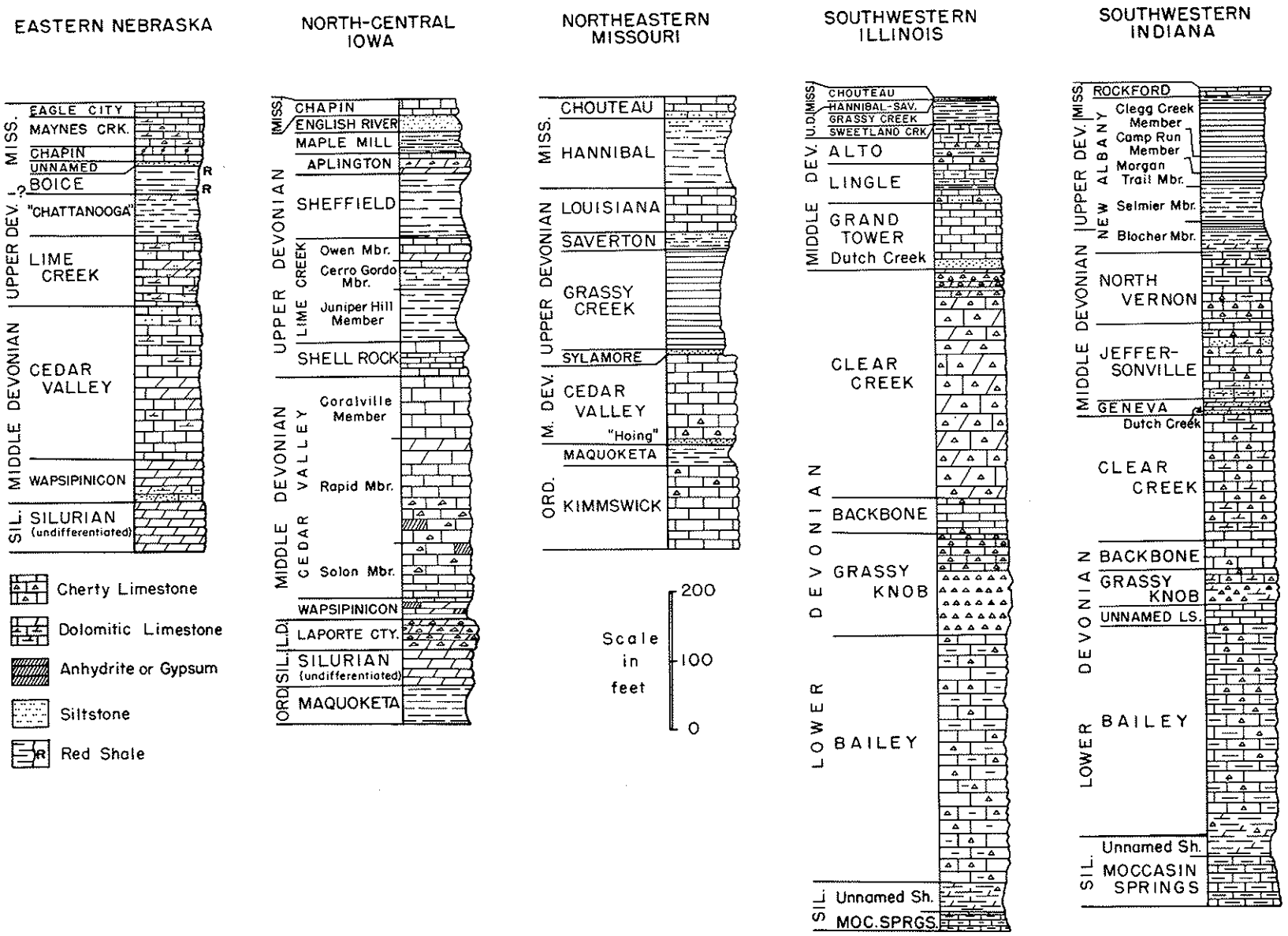


Fig. 3. Generalized stratigraphic sections for Devonian rocks in north-central United States.

ILLINOIS BASIN

CHARLES COLLINSON, LEROY E. BECKER, GERARD W. JAMES, JOHN W. KOENIG and DAVID H. SWANN

STRATIGRAPHIC UNITS

LOWER DEVONIAN

Bailey Limestone

The Bailey Limestone (Ulrich, 1904), oldest and most extensive of the Lower Devonian formations, has been described in Illinois by Weller (1944), in Missouri by Croneis (1944) and in subsurface in Illinois by North (1965). The formation crops out extensively in southwestern Illinois and southeastern Missouri, especially in fault blocks of the Ste. Genevieve fault system (Fig. 1). Croneis (1944) recognized three lithologic subdivisions in Missouri: (1) a lower unit consisting of 125 feet of thin- to medium-bedded grey and buff limestone interbedded with calcareous shale and chert, (2) a middle 75-foot unit of medium- to thick-bedded grey and buff limestone containing grey chert nodules and (3) an upper 100-foot unit of light grey to buff thick-bedded chert. This latter unit was differentiated as a formation, the Grassy Knob Chert, by Savage (1925), and is so accepted by the present authors

As restricted by removal of the Grassy Knob, the Bailey nowhere exceeds 500 feet in thickness; it ranges between 200 and 350 feet in the central part of the Illinois basin. In the western half of the basin, its thickness is locally variable because of deposition over Silurian reefs and biohermal ridges, many of which protrude through the entire Lower Devonian (Fig. 9). The Bailey is generally a brownish grey silty, cherty dolomitic limestone, but in the reef area it is a less cherty, greenish argillaceous dolomite.

Tansey (1924) listed 49 macro-species mainly from the upper part of the formation in Missouri. The fauna is largely silicified. Its commonest species are *Leptaena rhomboidalis, Dalmanites* sp. (pygidia) and several species of rhynchonellid brachiopods. *Scyphocrinus elegans* is found low in the formation. The latter is a European index for the zone in which *Monograptus transgrediens* and *Spathognathodus eosteinhornensis* also occur and probably indicates a latest Silurian age.

Conodonts are known from the Bailey in a core from White County, Illinois (Fig. 7, well 7), and include the simple forms *Belodus, Acodina* and *Paltodus*. Collinson has identified *Icriodus woschmidti,* index for the lowermost Devonian, in the uppermost part of the Bailey in the core and *Spathognathodus eosteinhornensis* in the upper shale member of the Moccasin Springs below it. The latter species is an index for uppermost Silurian rocks throughout Europe. In view of these occurrences it seems likely that at least lowermost Bailey is Silurian in age and that the Silurian-Devonian section is entirely gradational with no unconformity separating the two systems in the deeper parts of the Illinois basin.

Unnamed Limestone Member of the Bailey Limestone

Over most of the central and western parts of the Illinois basin a grey to white, pure non-cherty limestone 10 to 40 feet thick occurs at the top of the Bailey. Because the unit is distinctive and identifiable over a large area, we have indicated it on our cross sections and stratigraphic columns (Figs. 3 and 7). Swann believes it may be a northward extension of the Flat Gap Limestone of Tennessee. In Washington County, Illinois, where it is especially well developed, it has been referred to by the oil field term "Beaucoup."

The unit is well exposed in Quarry Hill near Ozora, Ste. Genevieve County, Missouri, where it consists of 5 to 10 feet of heavily bedded grey-white encrinital limestone (Croneis, 1944).

Grassy Knob Chert

The Grassy Knob is a light grey to buff, thick-bedded chert unit that was originally included in the Bailey by Ulrich (1904), but was differentiated by Savage (1925) who considered it to be Oriskany in age. Although included as a member of the Bailey in recent years (Koenig, 1961; North, 1965), the Grassy Knob is sufficiently distinctive and widespread to stand separately as a formation. At the type locality in Jackson County, southwestern Illinois, it is about 225 feet thick. It has been best described by Weller (1939) who stated that it cannot be recognized where the Backbone is not identifiable.

The Grassy Knob is approximately 200 feet thick in the Wittenberg trough and over much of the Illinois basin. In southernmost Illinois it reaches 300 feet and in Kentucky is more than 200. In the central parts of the basin the Grassy Knob appears to lie conformably on the Bailey and to be overlain conformably by the Backbone. Around the edges of the basin, however, the pre-Dutch Creek unconformity bevels the formation and it is overlain by the Dutch Creek, Grand Tower, Jeffersonville, Lingle and New Albany. In southeastern Illinois and southwestern Indiana, an upper very cherty limestone member can be differentiated, the remaining heavily bedded chert being referred to as the lower member.

Fossils are very rare in the Grassy Knob. Orr (1964, personal communication) has found the conodont genera *Acodina, Belodus* and *Paltodus* but no stratigraphically diagnostic forms. *Icriodus latericrescens huddlei,* an index of Lower Devonian rocks, occurs closely above and below the unit.

Little Saline Formation - Backbone Limestone

Little Saline was formally proposed by Weller and St. Clair (1928) after casual references in reports by Dake and Savage. Savage (1920) used Little Saline in the same report in which he introduced "Back-bone" for Helderberg rocks at Devil's Backbone in southwestern Illinois. Little Saline was named from Ozora Quarries on Little Saline Creek in the Wittenberg trough area. Although essentially equivalents, Little Saline is used in Missouri whereas Backbone is used in Illinois, Indiana and Kentucky.

The Little Saline-Backbone is underlain by the Grassy Knob Chert and is overlain by the Clear Creek Formation. All appear conformable. The unit is a slightly cherty, light pinkish grey to white, crinoidal limestone. It has a relatively high log resistivity compared to the low resistivity of the Bailey and Clear Creek (Fig. 4), but in some areas it is difficult to recognize electrically. The formation crops out in southwestern Illinois and southeastern Missouri and has been described by Weller (1944) and Croneis (1944). North (1965) mapped the subsurface extent of the Backbone in Illinois and showed it as a broad band 25 to 60 miles wide which follows the contours of the outer slopes

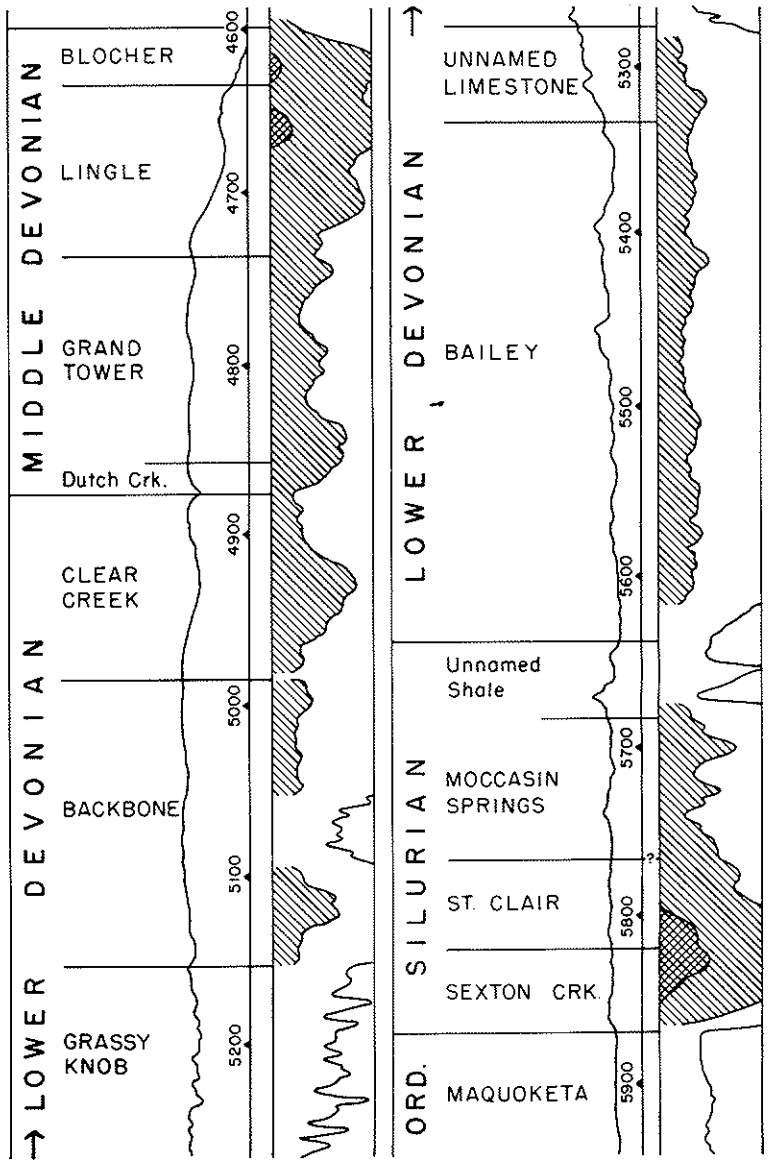


Fig. 4. Geophysical log of Continental Oil Company, Well #1-D, Cooper Estate, SW, SW, SW, Sec. 13, T 3 S, R 14 W, Gibson County, southwestern Indiana.

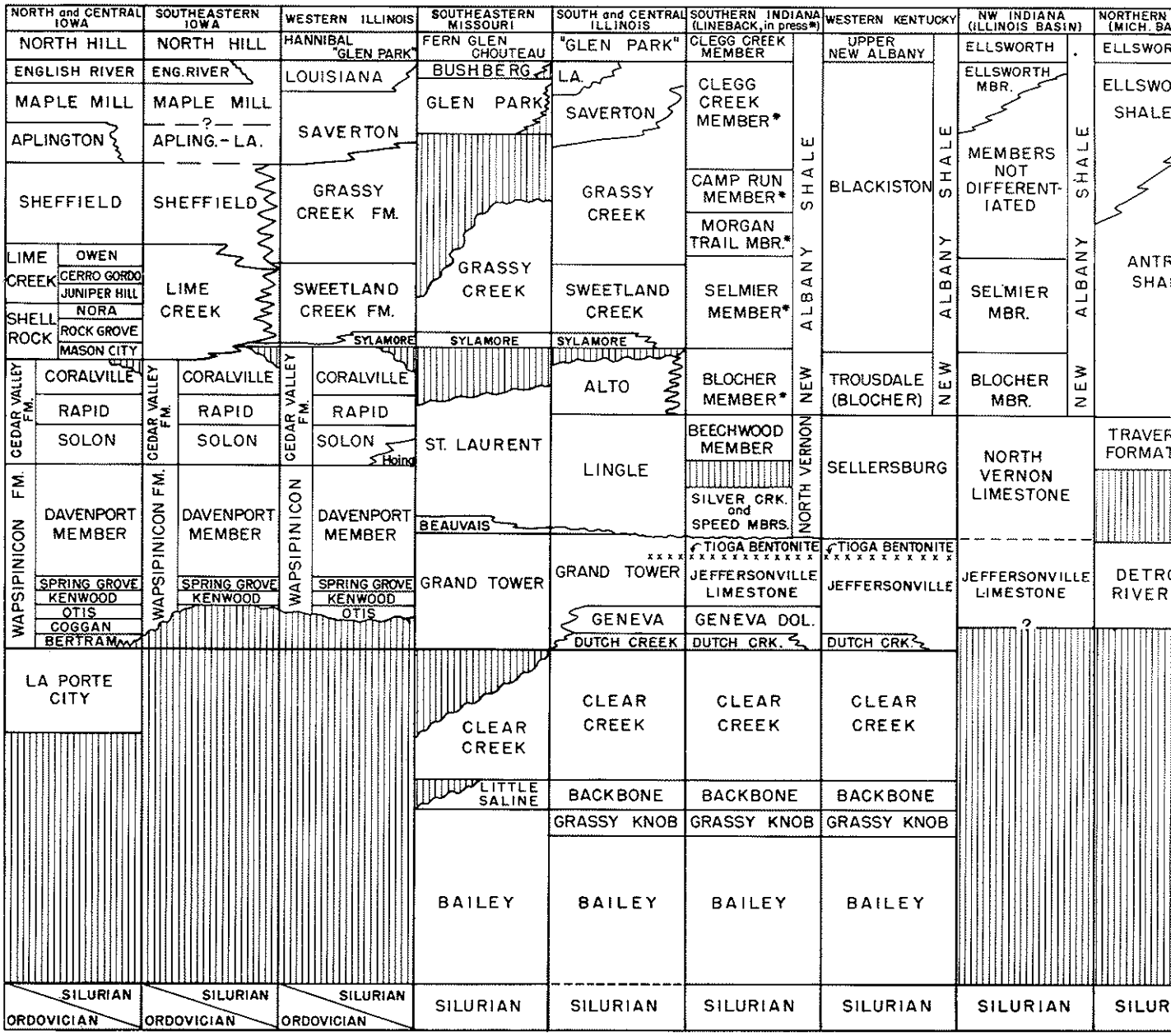
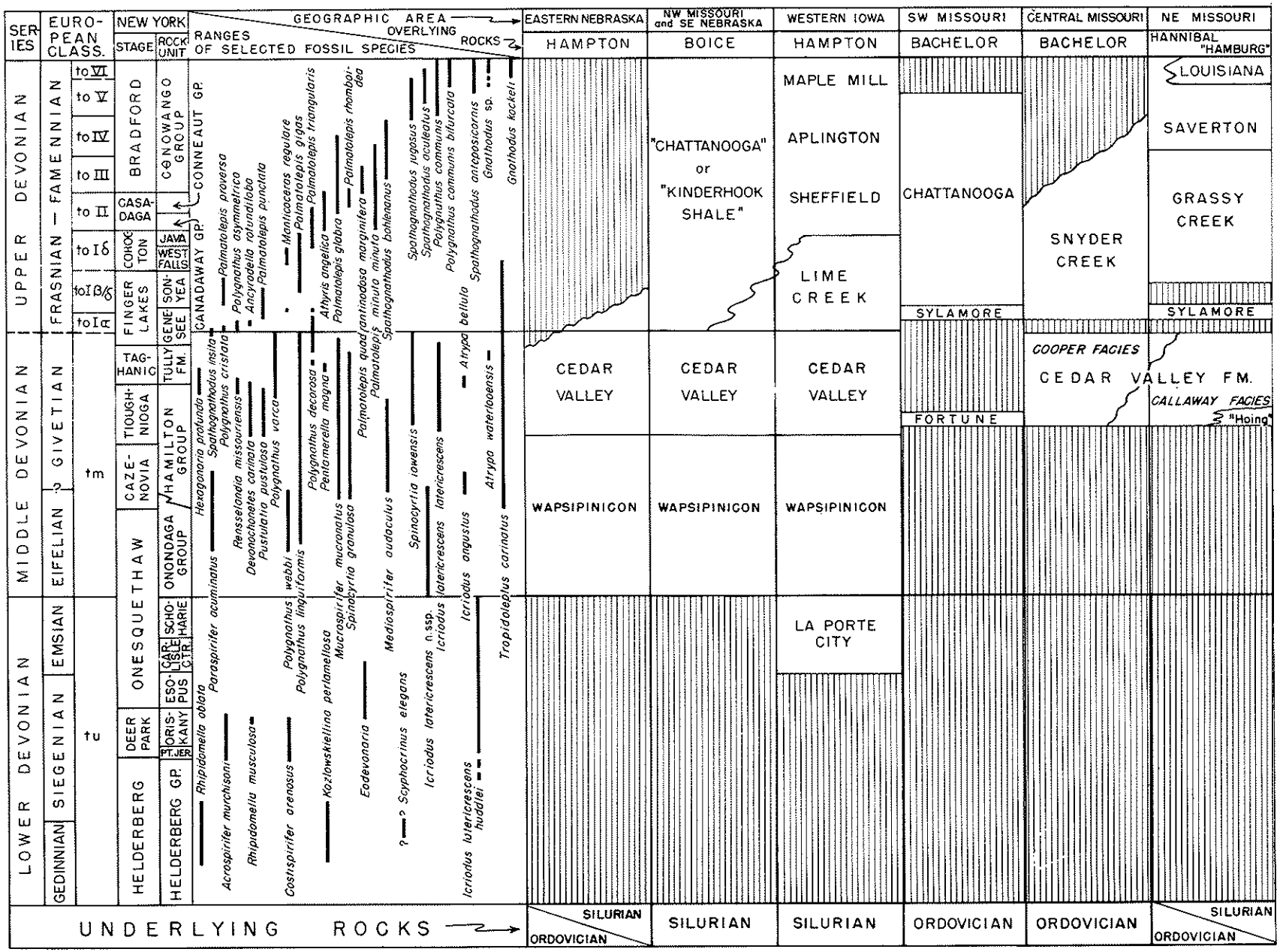


Fig. 5. Correlation chart of Devonian formations in north-central United States showing correlations to New York and western Europe and ranges of selected



Indiana associated with the New Albany Shale are redefined, or newly introduced by Lineback (in preparation). The Detroit River and Traverse have been extended into northern Indiana from Michigan by Schneider and Keller (in preparation).

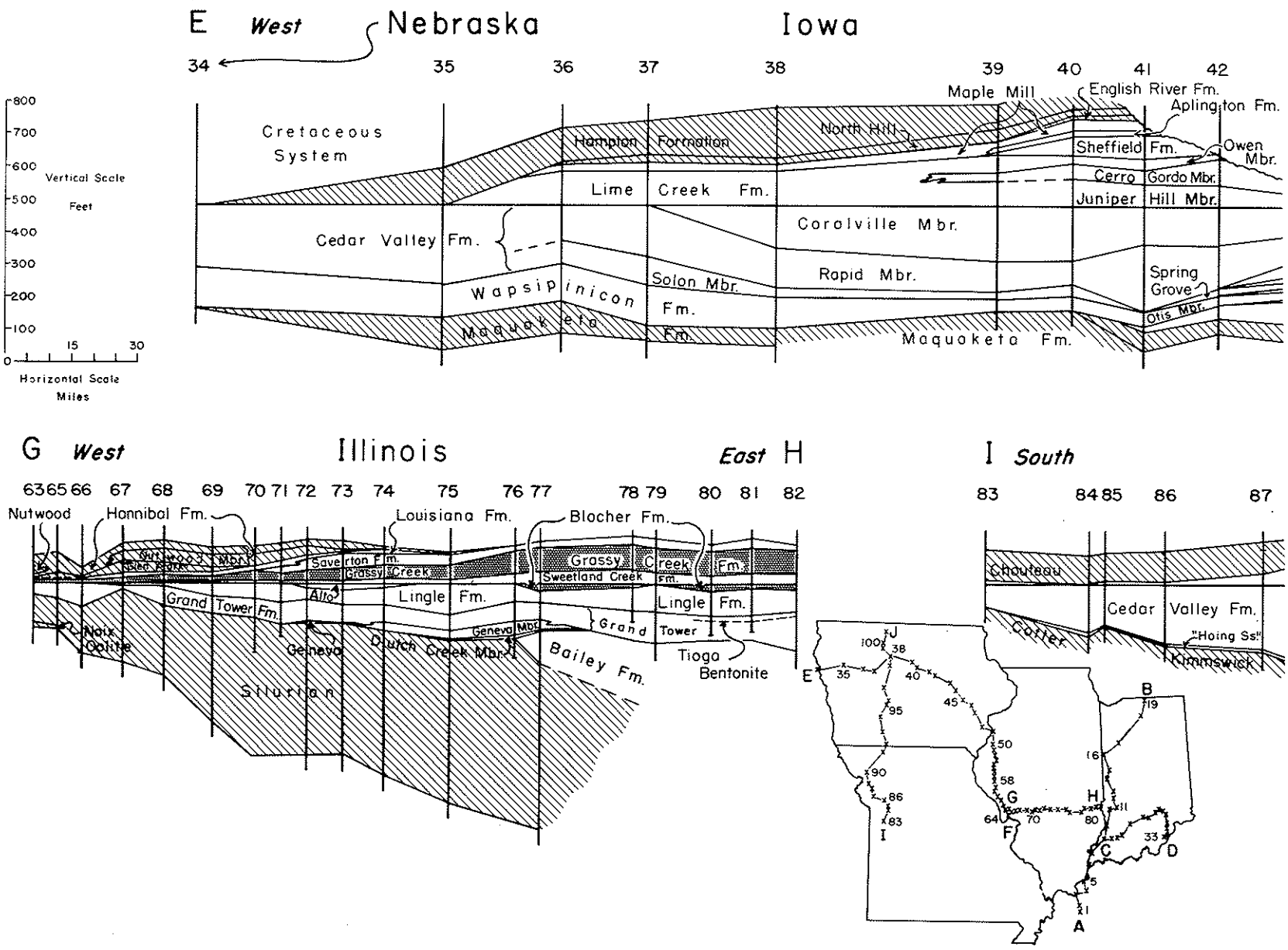
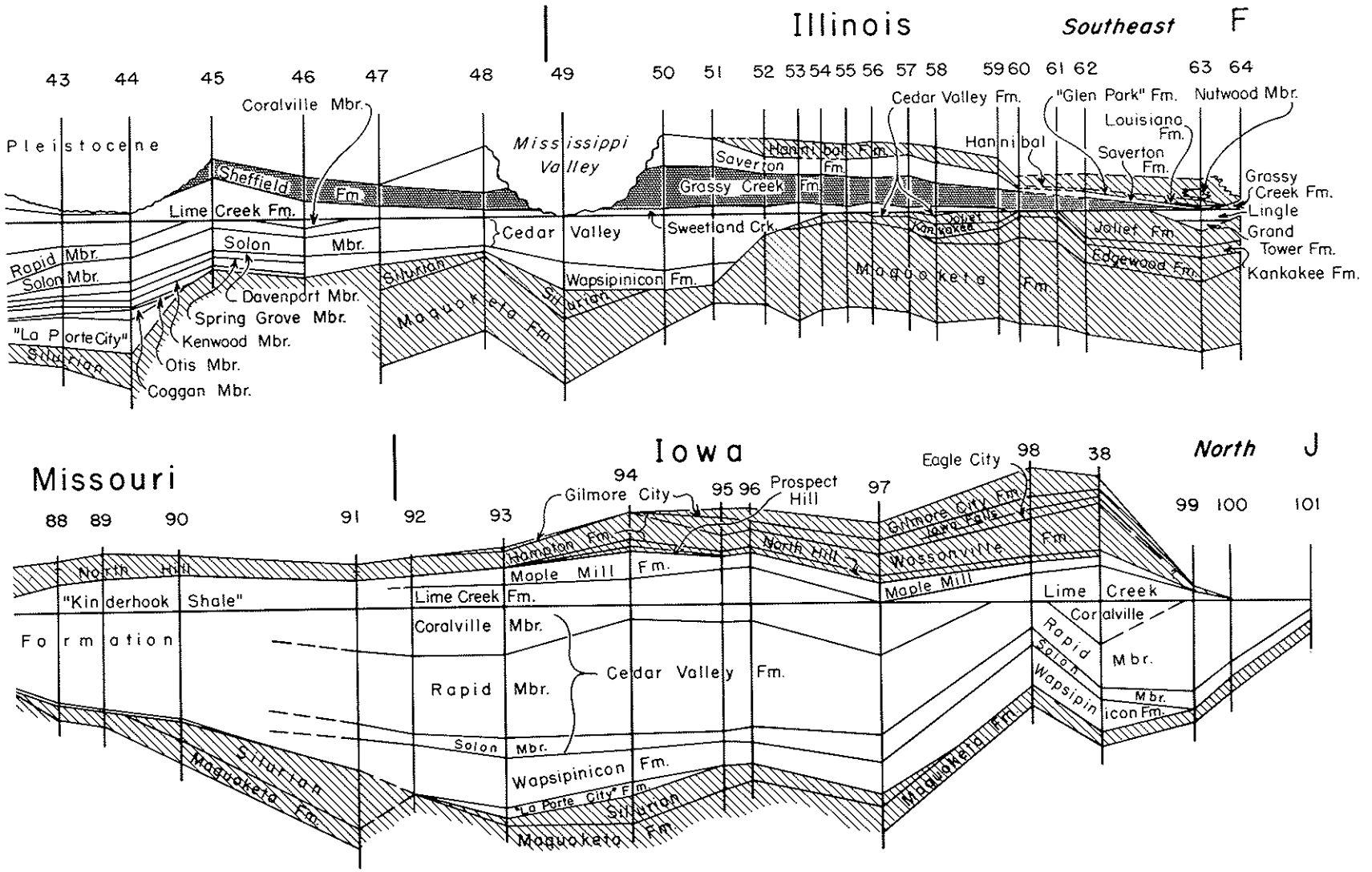


Fig. 6. Cross sections through the Devonian of Iowa, Missouri and Illinois. Diagonal



shading indicates non-Devonian rocks. Dark shading, as in the Grassy Creek Formation, indicates black shale.

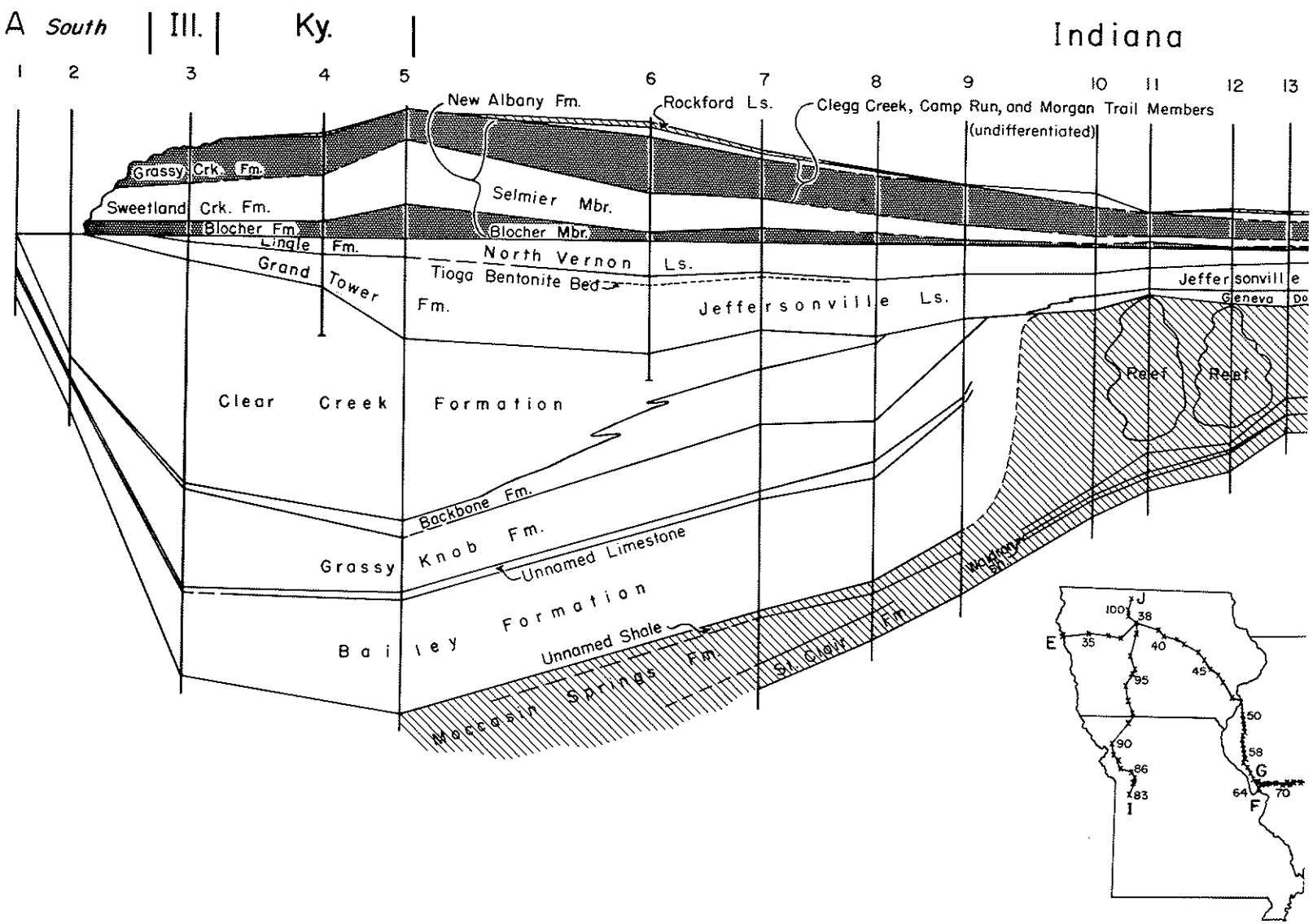
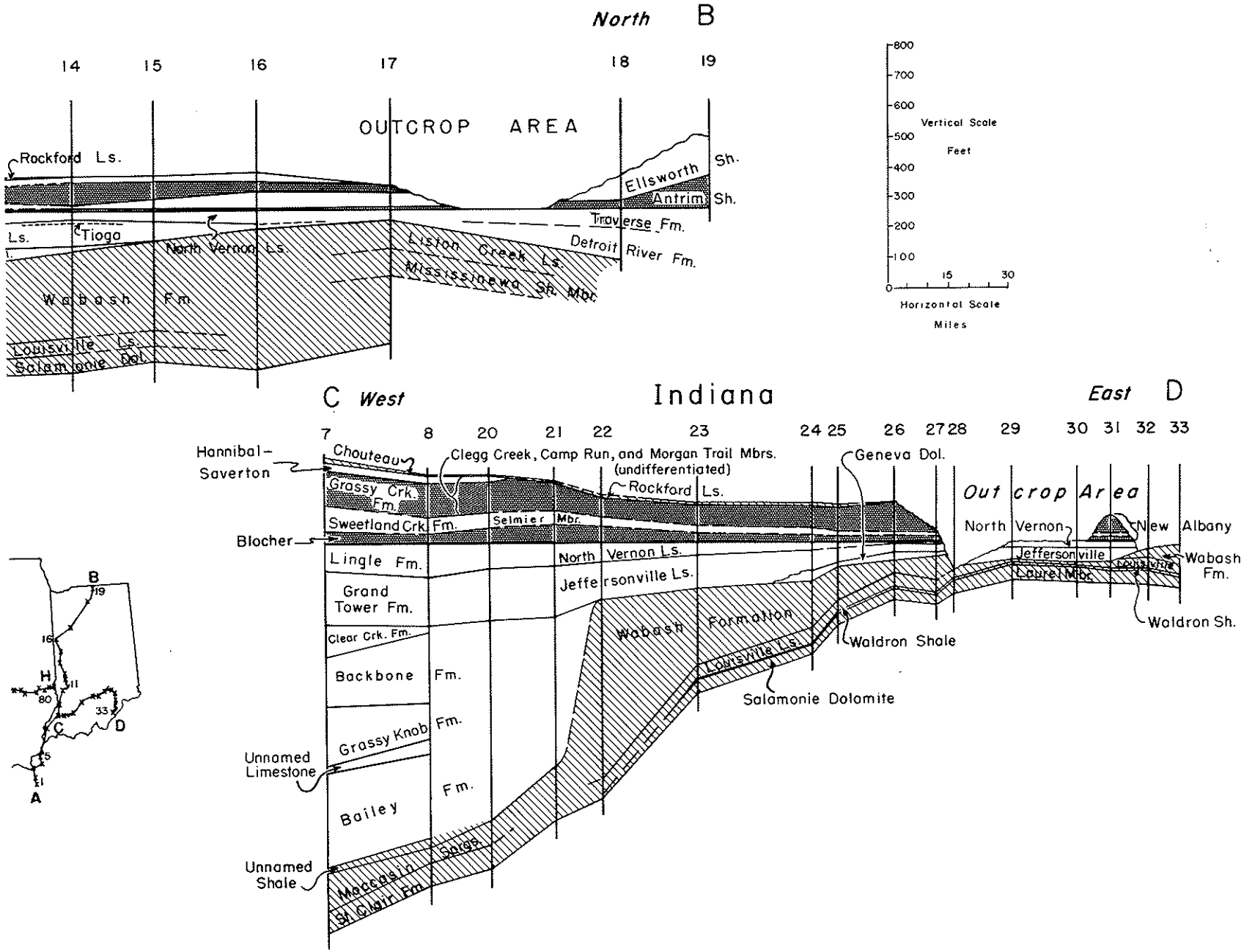


Fig. 7. Cross sections through the Devonian of Indiana, Kentucky and Illinois.



Diagonal shading indicates non-Devonian rocks. Dark shading, as in the New Albany, indicates black shale.

of the basin rather closely, extending from the Wittenberg trough through southern Illinois and southwestern Indiana.

The Backbone is thin or unrecognizable in the deep parts of the Illinois basin inasmuch as it represents fossil debris swept in from the shallow margins to the north and northeast. Around the margin, it reaches a maximum of more than 200 feet but further upslope is sharply truncated by the unconformity at the base of the Dutch Creek. In the

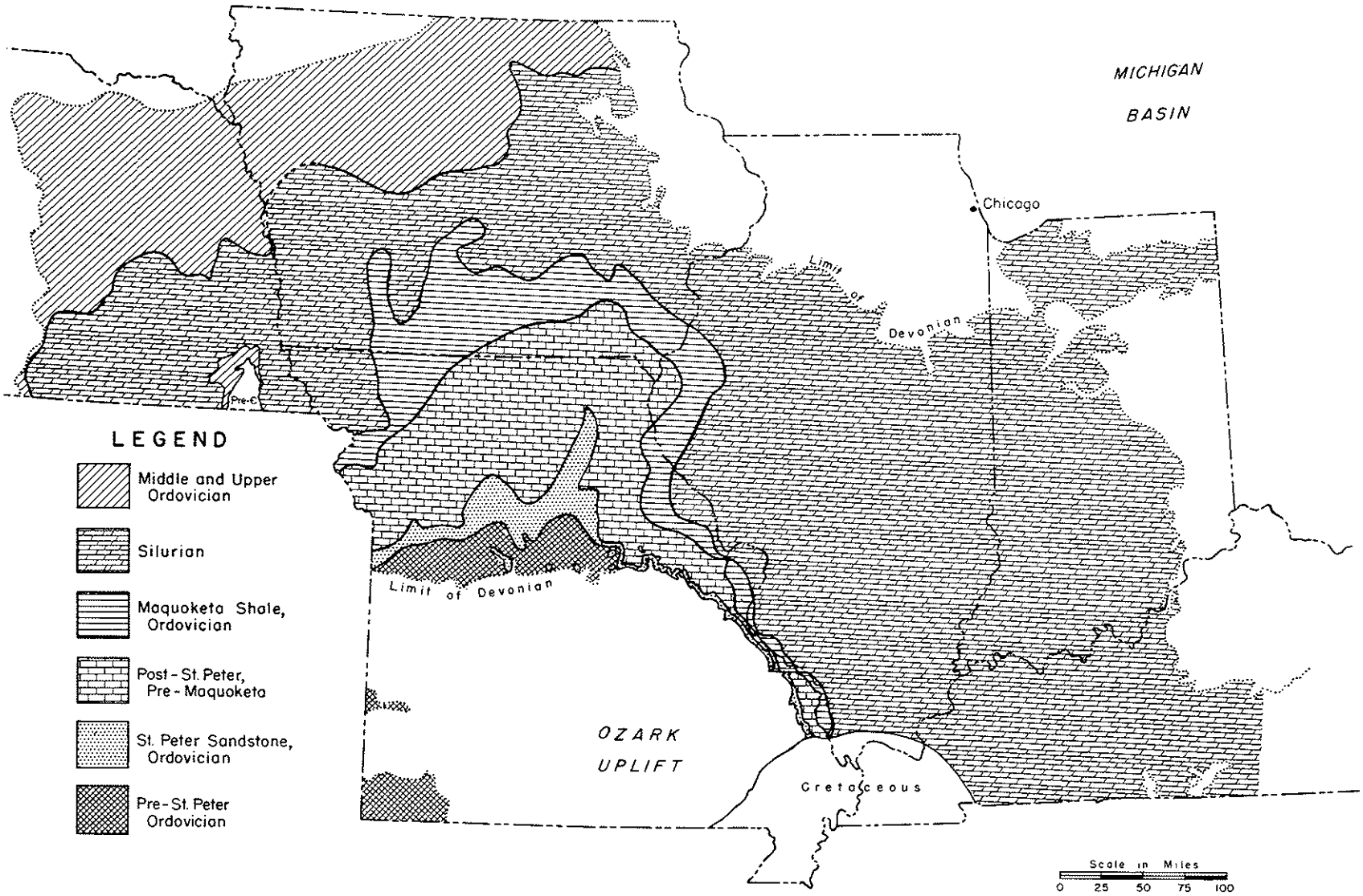


Fig. 8. Generalized pre-Devonian geology.

outcrops in the Wittenberg trough the formation is approximately 100 feet thick.

The formation has a large macrofauna, largely of brachiopods. The chief species (Weller and St. Clair, 1928) are *Acrospirifer murchisoni, Costispirifer arenosus* and *"Rensselaeria ovoides."* Most show correlation with the Oriskany of New York and indicate a Deerparkian (Siegenian) age. Corals are sparse, gastropods and trilobites are common

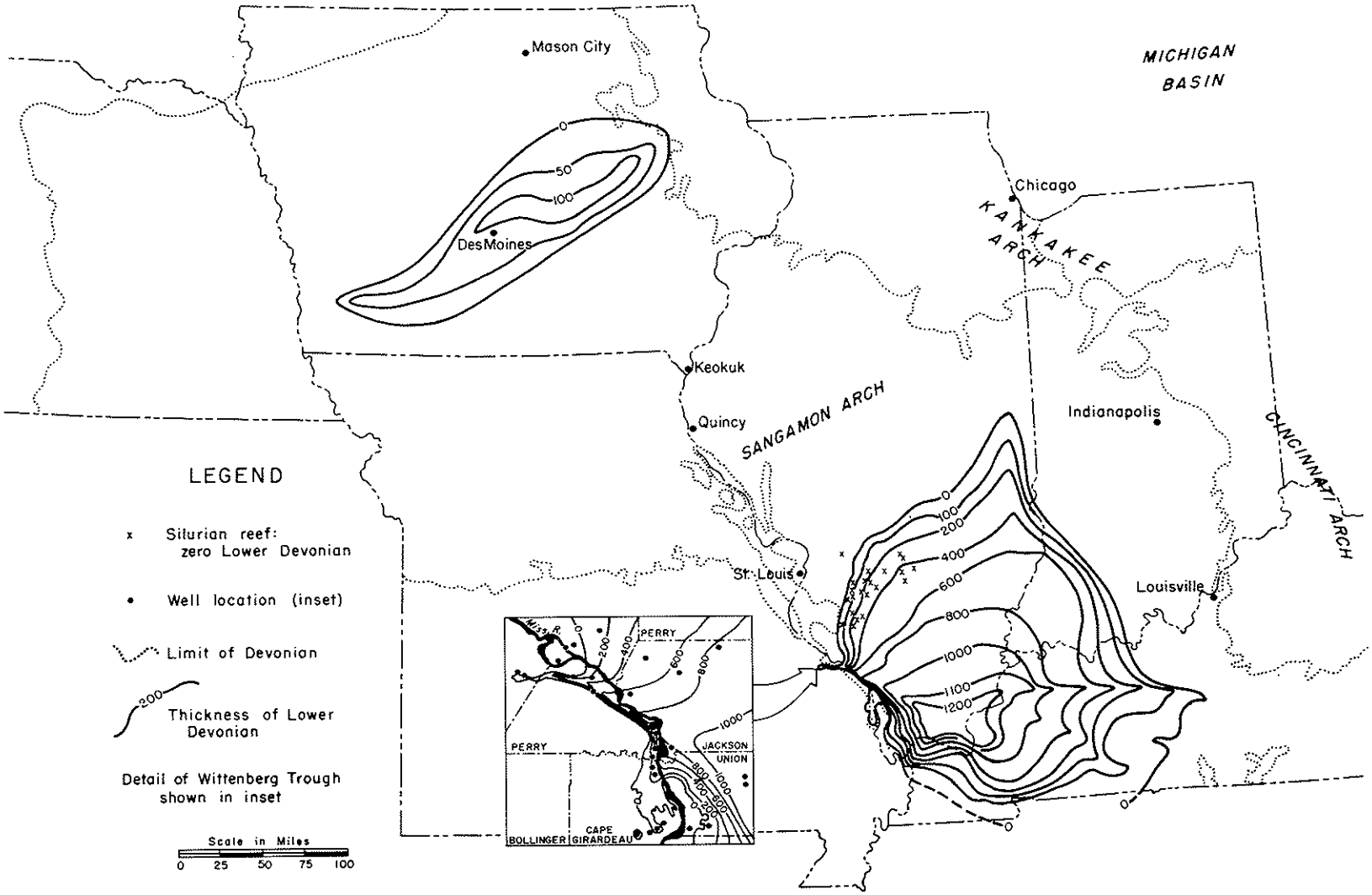


Fig. 9. Thickness of the Lower Devonian showing locations of Silurian reefs that project through the Lower Devonian.

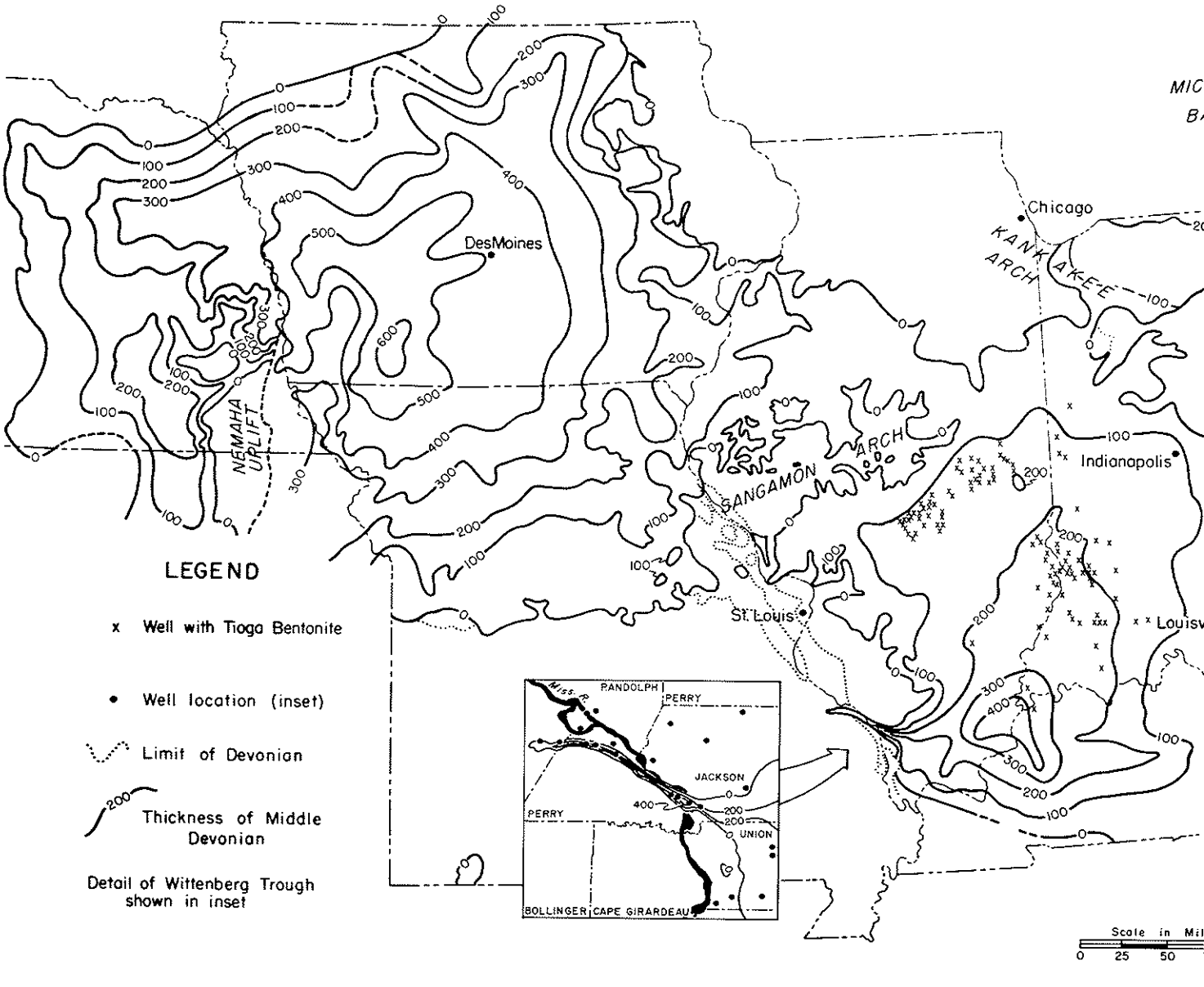


Fig. 10. Thickness of the Middle Devonian showing locations of wells containing the Tioga Bentonite Bed.

and bryozoa, especially the genus *Lichenalia,* are very abundant in the upper half of the formation. Conodonts are relatively common. Orr (in press) has reported a fauna dominated by the genera *Acodina, Belodus* and *Paltodus* but also including the index subspecies *Icriodus latericrescens huddlei,* indicative of late Early Devonian (Emsian-early Onesquethawan) age.

Clear Creek Chert

Worthen (1866) named the Clear Creek Chert for rocks cropping out along Clear Creek in Union County, southwestern Illinois, where it consists of white to buff thin-bedded chert with minor light grey limestone. As originally described, the formation included all the Lower Devonian and some Silurian rocks. Subsequently, the Bailey, Grassy Knob and Backbone were separated from the Clear Creek. In Missouri, the Clear Creek occurs in the Wittenberg trough area where it is about 300 feet thick. In the deep southeastern part of the Illinois basin, it attains a thickness of more than 600 feet.

Over most of its extent the Clear Creek is overlain by the Grand Tower-Jeffersonville or the Dutch Creek and Geneva, but in part of southwestern Illinois it is overlain by Lingle or even New Albany Shale. The formation is everywhere underlain by the Backbone or the Grassy Knob with which it is essentially conformable.

The macrofauna of the Clear Creek is large and varied but is preserved only as moulds. The most typical fossil is the chonetid brachiopod *Eodevonaria melonicus.* Orr has reported *Icriodus latericrescens huddlei, Paltodus, Acodina* and *Belodus* in a conodont fauna distributed throughout the formation. Klapper and Ziegler (1967) consider the fauna to be Emsian in age and probably a correlative of the early Onesquethawan of New York. Orr (personal communication, 1964) has found *Icriodus latericrescens bilatericrescens* in the subsurface Clear Creek of southeastern Illinois. The subspecies is considered indicative of late Emsian age (Ziegler, 1965).

MIDDLE DEVONIAN

Dutch Creek Sandstone

Sand occurs irregularly throughout the Grand Tower Limestone in the Illinois Basin, but most accumulations of more than a few inches are at the base of the formation and are referred to as the Dutch Creek Sandstone Member. The sandstone is local (Fig. 11), and in a few places the basal Grand Tower Limestone is not sandy. Meents and Swann (1965) have summarized the Dutch Creek occurrence and characteristics in Illinois. The unit was named by Savage (1920) from outcrops in southwestern Illinois, where it averages 15 feet in thickness. In southernmost Illinois several wells have encountered 10 to 15 feet of bedded sandstone, but the average subsurface thickness is less than 5 feet. The sand is well rounded, and is cemented by carbonate. The color ranges from nearly white to iron-stain brown; in many places the sandstone is cross-bedded. Where the Grand Tower is mainly limestone, the Dutch Creek can be distinguished on logs and mapped separately (Fig. 11). Where the Geneva is present, however, the sandstone is difficult to identify in the porous dolomite. Nevertheless, sample studies show that beneath the Geneva in north-central Illinois the Dutch Creek, though sporadic, is present over much of the Geneva area in Illinois and western Indiana (Fig. 11). The presence of the Dutch Creek in any significant concentrations in eastern Indiana is doubtful.

The Dutch Creek sand is largely derived from the Ordovician St. Peter and older sandstones exposed on the east and north flanks of the Ozark uplift (Fig. 8). Much sand also came from positive areas to the north.

A sparse fauna has been reported from the Dutch Creek, but in places it is crowded with moulds and casts of fossils. Prominent among them are moulds of the coral *Pleurodictyum problematicum.* Brachiopods predominate. Among them are *Amphigenia curta, Rhipidomella* cf. *R. penelope* and *Protoleptostrophia perplana.*

Orr (in press) has recorded a sparse conodont fauna in western Illinois and in a core in southeastern Illinois (Fig. 7, well 7). The fauna consists of *Icriodus latericrescens* n. ssp., *I. lateriscrescens huddlei, I. latericrescens bilatericrescens, Paltodus* and *Acodina.* These represent the earliest occurrences of *Icriodus lat.* n. ssp. and the latest occurrence of *I. lat. huddlei.* Klapper and Ziegler (1967) record both subspecies from the Schoharie of New York as well as *I. lat. huddlei* and *I. lat. bilatericrescens* from the Emsian and

possible Siegenian of Europe. Although *Icriodus lat.* n. ssp. is found in isolated occurrences in uppermost Lower Devonian rocks, it is common throughout the Onondaga, the Grand Tower and the Jeffersonville. It is an index for the Middle Devonian.

Geneva Dolomite

The Geneva Dolomite (Fig. 11) extends from its type outcrop in Shelby County, Indiana (Collett, 1882), westward in subsurface across Indiana into central Illinois (Schwalb, 1955). It is a dark colored porous crystalline dolomite and occurs at the surface only in south-central Indiana. At the outcrop it ranges from thin-bedded to massive and contains abundant dark carbonaceous material in bands. In some places the lower part of the Geneva contains enough sand to be differentiated as the Dutch Creek Sandstone.

The Geneva is virtually unfossiliferous in that dolomitization has obliterated all but the outlines of fossil remains. Chitinozoans and scolecodonts are abundant in some samples, but conodonts, common in the other Devonian formations, are entirely absent. The dearth of conodonts is a characteristic commonly associated with abnormal salinity. Considering the distribution of the Geneva high on the basinal slope (Figs. 7 and 11) a very shallow, perhaps abnormally saline environment, seems indicated.

Considerable difference of opinion has existed concerning the relative age of the Geneva and Jeffersonville, the nature of the surface that separates them in the Indiana outcrop belt and the presence or absence of lateral gradation between them. Early writers tended to consider the Geneva as a northerly facies of the Jeffersonville or the Jeffersonville and Sellersburg. Cumings (1922) summarized all earlier views and concluded that the Geneva was probably a distinct formation. Subsequently Dawson (1941) made a detailed study of the relationships and concluded that the Geneva is distinct from and older than the Jeffersonville. Patton and Dawson (1955) and Perkins (1963) arrived at the same conclusion. On the other side, Sutton and Sutton (1937) considered the Geneva a northern facies of the Jeffersonville and Meents and Swann (1965) interpreted the Geneva in Illinois as a facies that grades laterally into the lower part of the Grand Tower.

Because of the lack of fossil evidence and uncertain stratigraphic relationships, the precise age of the Geneva is open to question. In Indiana it is overlain b sonville and in the outcrop areas lies on the Silu Formation. In eastern Illinois it rests on Low rocks.

The Geneva is classified as a formation in as a member of the Grand Tower Limestone i

Pendleton Sandstone

Sandstone of Middle Devonian age occurs and wells along the eastern outcrop belt in I principal exposure is at Pendleton, Madison C 1869). The unit consists of yellowish grey sandstone in massive beds. Its relation to the and Geneva is not clear. Dawson (personal com believes it largely represents a residual conc sand that is abundant in the lower part of the and Grand Tower formations. It may also ir Creek equivalents.

Grand Tower Limestone

The Grand Tower Limestone makes up the l the Middle Devonian carbonate sequence in Illi been described in detail by Meents and Swann formation, named by Keyes (1894) for Gran southwestern Illinois, ranges between 50 and 1 At the type locality, where it is 157 feet thic 35 feet consist mainly of brownish grey, cher phic limestone overlain by the Lingle Lime middle 60 feet of the formation consist of br encrinite, interbedded with tan chert and litho stone. Brachiopods and corals are locally a nautiloids are common. The lower 60 feet cons ferous light grey, medium to coarse cross-bedd limestone which is increasingly sandy down lowermost 12 feet comprise the Dutch Creek Member (Fig. 11).

The Grand Tower extends throughout the and is referred to as the Jeffersonville Limestor and Kentucky. Although the formation is lime southeastern parts of the basin, it is mainly dol northwest where it overlaps the underlying Chert. In this area the lower part of the Gra

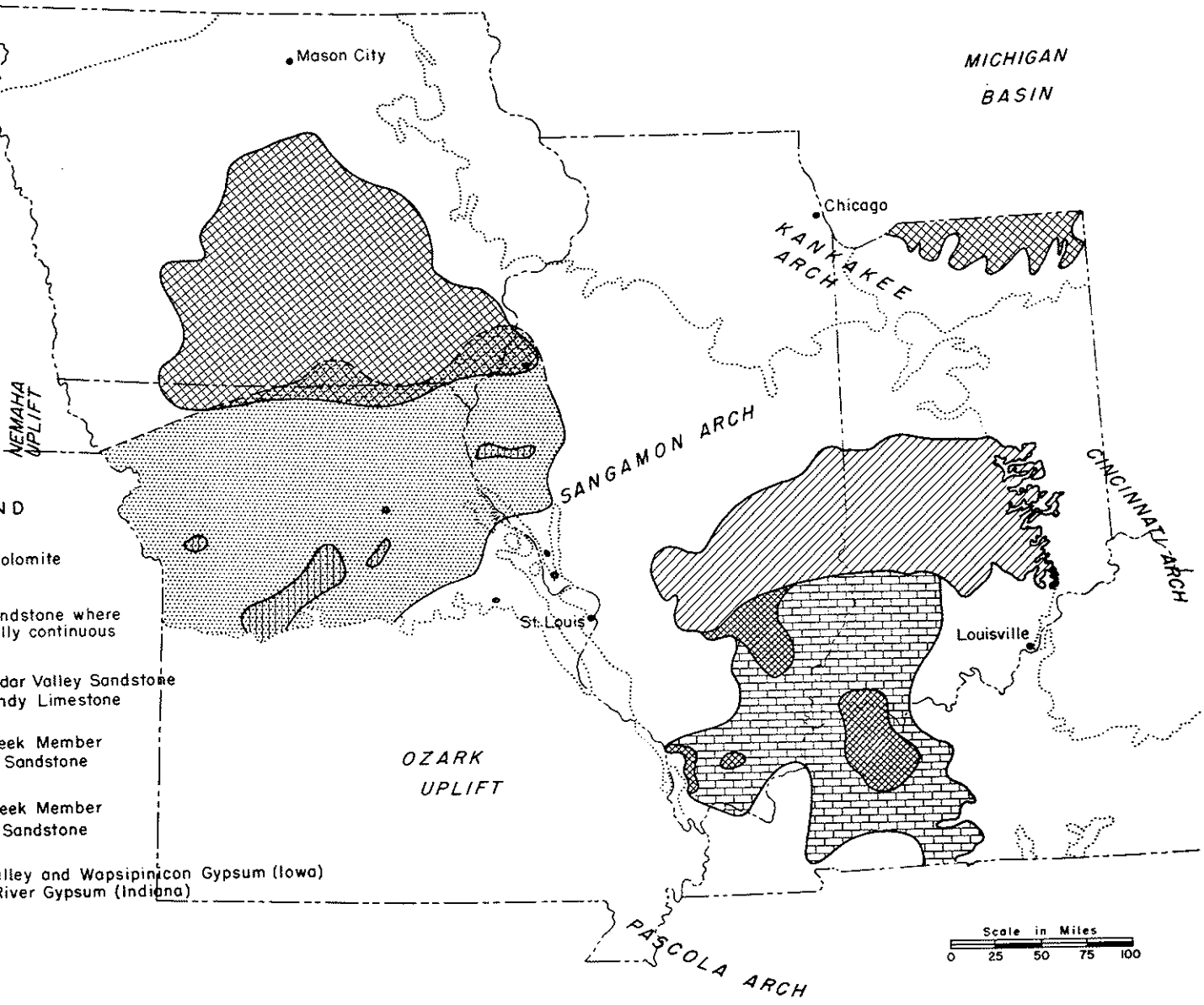


Fig. 11. Map showing distribution of the Geneva Dolomite, certain Middle Devonian sandstones and Middle Devonian evaporites.

represented by dark brown Geneva Dolomite (Fig. 11) over which a somewhat thicker sequence of lighter colored dolomites lies. In the northern and western parts of central Illinois, a virtually unfossiliferous light grey lithographic limestone at the top of the Grand Tower is referred to as the Cooper Member (Meents and Swann, 1957, p. 7). The member grades southeastward into the light-colored dolomite overlying the Geneva.

Around the edges of the Illinois basin, the Grand Tower overlaps Lower Devonian formations and lies directly on Silurian or Ordovician rocks. The Grand Tower in turn is overlapped by the Lingle Limestone.

The macrofauna of the Grand Tower is abundant, and in Missouri is dominated by corals and brachiopods. *Emmonsia emmonsi, Emmonsia hemispherica* and *Favosites turbinatus* are common corals. The abundant brachiopod fauna is nearly identical with that from the New York Onondaga and contains such species as *Amphigenia curta, Paraspirifer acuminatus, "Spirifer" duodenarius, Brevispirifer gregarious, Spirifer grieri, Acrospirifer macrothyris* and *Kozlowskiellina raricostus.* The trilobite, *Odontocephalus aegeria,* is relatively common and is likewise an important element in the Onondaga and Jeffersonville faunas.

Orr (in press) has recorded several stratigraphically important conodont species from the Grand Tower in Missouri and Illinois. *Icriodus latericrescens* n. ssp. ranges from the Dutch Creek into the upper part of the Grand Tower. In Indiana it ranges from Jeffersonville into lower North Vernon and in New York is found in the upper Onondaga and lower Hamilton. Both *Polygnathus linguiformis* and *Icriodus angustus* occur in the upper part of the Grand Tower and Jeffersonville and range upward. The fauna indicates correlation of the Grand Tower with the Onondaga and lower Hamilton (Marcellus) of New York.

Tioga Bentonite Bed

Fettke in 1931 noted the presence of a thick bed of altered volcanic ash in the Appalachian basin and because of its usefulness as a subsurface marker in the Tioga Gas Field, Pennsylvania, named it the Tioga Bentonite (Ebright, Fettke and Ingham, 1949). In 1965, Meents and Swann described its presence in the Illinois basin in the upper parts of the Grand Tower and Jeffersonville Since then it has been identified in more tha wells (Fig. 10). The Tioga is easily identif on sonic logs it can be differentiated even tho than ¼ inch thick. The unit is probably 1 thick in most wells (Fig. 13) and is much distributed than its recorded occurrence indica

The Tioga serves to correlate the upper part Tower and Jeffersonville Formations with the Moorehouse Members of the Onondaga Forma York.

Jeffersonville Limestone

The Jeffersonville Limestone was named (1899) for Jeffersonville, Indiana, where it is in the Falls of the Ohio. It is part of an exten early Middle Devonian carbonates that covers r ern North America. In Indiana and Kentucky tion is referred to as the Jeffersonville; in Illin souri it is the Grand Tower; in Ohio it is th and in New York it is the Onondaga. In Indian tion ranges between 20 and 50 feet in thickn surface it is much thicker, reaching more tha southwestern Indiana and 250 feet in wester Eastward the formation thins internally as wel lapping of beds at the base and truncation at t Dutch Creek Sandstone, which occurs sporad base of the Jeffersonville, is overlapped west of Kentucky outcrop belt, as is the lowest of the resistivity cycles in the Jeffersonville-Grand by Meents and Swann (1965). The post-Tioga formation, equivalent to the Seneca Member a the Onondaga in western New York, is 10 to in the deeper part of the basin but is trunc North Vernon erosion west of the outcrops. T crop section, which ranges from zero to ne thick, represents only the middle two-thirds o tion as it occurs in the subsurface.

The formation, together with its basal sand Dutch Creek, lies unconformably on formati from early Middle Silurian (Laurel Limeston Early Devonian (Clear Creek Chert). Althoug

a thousand feet of section are truncated by the Jeffersonville, its contact with the Middle Silurian limestone in the Louisville region is a textbook example of paraconformity.

In the type area the Jeffersonville consists of grey to bluish grey or bluish brown, dense, crystalline, pure limestone. It is generally thick-bedded but becomes more thinly bedded and slightly shaly in the upper few feet. North of Columbus, Indiana, the Jeffersonville is largely unfossiliferous, light brownish grey, finely laminated dolomite that becomes increasingly sandy northward into central Indiana.

The formation is abundantly fossiliferous. The coral fauna from the Falls of the Ohio is widely known and has been recently monographed by Stumm (1964). The zonation recognized by early workers was formalized by Kindle (1901) into (ascending) the Coral Zone, the *Brevispirifer gregarius* Zone and the *Paraspirifer acuminatus* Zone. Recently, Perkins (1963) has differentiated the upper part of the Coral Zone as his *Amphipora* Zone and the upper part of the *gregarius* Zone as his Fenestrate Bryozoan-brachiopod Zone. The zones are of local facies significance; both *gregarius* and *acuminatus* have more extended ranges than is suggested by their limited vertical occurrence in the Falls region.

The long-held correlation of the Jeffersonville with the middle to upper part of the Onondaga of New York is corroborated by recent study of the conodonts. Orr (in press) records *Icriodus corniger, Polygnathus webbi* and *P. linguiformis. I. corniger,* which occurs no higher than the Eifelian in Wittekindt's (1966) German faunas, ranges up into the Hamilton in New York and suggests a possibility that uppermost Jeffersonville may be a Hamilton correlative. *Paraspirifer acuminatus,* prominent in the upper Jeffersonville, also ranges through the upper part of the Onondaga into the Hamilton. There are divergent views as to the relation of the coral beds of the Jeffersonville to the Geneva Dolomite. Patton and Dawson (1955) and Perkins (1963) believe that the mutual complementary distribution of the two units represents deposition of the coral beds seaward from a pre-existing platform of Geneva Dolomite which became submerged and later covered during Jeffersonville time. Sutton and Sutton (1937), Schwalb (1955) and Meents and Swann (1965) believed that the Geneva is a northern shoreward facies of the coral beds.

North Vernon and Sellersburg Limestone

The limestone above the Jeffersonville and beneath the New Albany Shale in Indiana is called North Vernon (Borden, 1876) but in Kentucky is referred to as Sellersburg (Kindle, 1899). North Vernon, in Jennings County, Indiana, is about 40 miles north of Sellersburg, which lies on the Ohio River in Clark County, Indiana. Three members, Speed (Sutton and Sutton, 1937), Silver Creek (Siebenthal, 1901) and Beechwood (Butts, 1915), all named for localities in Clark County, are recognized in the Indiana outcrop area, but only the Silver Creek and Beechwood extend into Kentucky. The first two members are intertonguing contemporary facies both of which are overlain by the Beechwood. The Speed is a blue-grey shaly crystalline limestone with abundant *Stropheodonta demissa* as well as fenestellid bryozoans. Typical corals are *Hadrophyllum orbignyi* and *Bordenia knappi.* The Silver Creek is a grey, fine grained, argillaceous limestone containing *Platyrachella oweni.* The Beechwood is a dark grey thick-bedded coarsely crinoidal and fossiliferous limestone which contains phosphate pellets. The corals *Odontophyllum, Pleurodictyum* and *Favosites* are common. The North Vernon ranges from 1 to 26 feet in thickness in outcrop but reaches 100 feet in subsurface in southwestern Indiana. The Sellersburg reaches 150 feet in Kentucky.

The unit in general is distinguished from the underlying Jeffersonville by darker color, some argillaceousness, the presence of phosphate pellets, occasional beds with *Tasmanites* and a virtual lack of dolomite which is common in the Jeffersonville in the northern part of the Illinois basin.

The North Vernon fauna is entirely Middle Devonian in aspect. Its correlation to the New York Hamilton was recognized before the unit was named. Orr (in press) reports *Icriodus corniger, Polygnathus webbi, I. latericrescens* and *P. varca,* all of which are consistent with a late Middle Devonian age and correlate to the Hamilton.

Beauvais Formation

At the eastern end of the Wittenberg trough, in Ste. Genevieve County, Missouri, nearly 50 feet of well-rounded, fine to medium, white or iron-stained sandstone form the type section of the Beauvais Sandstone (Dake, 1819; Weller and St. Clair, 1928). The sandstone overlies the Grand

Tower Limestone, and grades upward into the St. Laurent Limestone. Southeastward the sandstone does not occur in the scattered outcrops and wells in the Wittenberg trough nor in the outcrop region of southwestern Illinois. Northeastward in the subsurface of western Illinois, there are scattered sandstone bodies ranging up to 10 feet in thickness at the base of the Lingle Limestone that are classified as a basal member of the Lingle but are equivalent to the Beauvais.

The Beauvais is not especially fossiliferous although *Rensselandia claypolei,* a Hamilton age brachiopod, is fairly common. Orr (in press) has reported *Icriodus angustus* and *Polygnathus linguiformis* from the formation. The former indicates correlation to the Hamilton of New York (Emsian or early Eifelian age).

St. Laurent Formation

Named from steeply dipping outcrops along St. Laurent Creek, Perry County, (Dake, 1918; Weller and St. Clair, 1928) the St. Laurent is confined to a small area within the Wittenberg trough in southeastern Missouri, where it reaches thicknesses of at least 275 feet. It is equivalent to and the direct extension of the Lingle and Alto Formations of Illinois, but the youngest part of the formation, equivalent to the Alto, is probably not exposed. Outcrops are limited to several small, truncated slivers along intersecting fault planes. Because of its location in a zone of structural instability, the lithology of the St. Laurent is highly variable. Generally, it consists of thinly bedded dense grey and blue-grey limestone. In the basal few feet, limestone and chert conglomerate and breccia are interbedded with thin sandy limestones. The middle 150 feet are represented by grey, dense, slightly cherty, argillaceous limestones. Fossils are abundant in the more argillaceous zones. The upper 50 feet are very cherty, sandy, and fossiliferous. The lower contact of the St. Laurent is gradational with Beauvais Sandstone.

The macrofauna includes *Tropidoleptus carinatus, Microcyclus discus, Spirifer fornacula, Athyris vittata* and *Chonetes coronatus* showing equivalence to the Lingle Limestone of Illinois and the Hamilton of New York. Orr (in press) has reported *Icriodus latericrescens latericrescens* and *I. cymbiformis,* indicating the same correlations.

Lingle Limestone

Savage (1920) named the Lingle for limest
out on Lingle Creek in southwestern Illinois.
plied the name Meisenheimer to argillaceous
the limestone, but Weller (1944, p. 96) noted
ceous beds occur throughout the Lingle and
cluded the strata called Meisenheimer with the
now used, the Lingle includes all beds between
the Grand Tower. Orr (1964) illustrated the
and described its conodont fauna. The lower
sists of buff calcareous shale with a few le
grey, fine grained calcarenite. The upper pa
light grey, cherty, coarse crinoidal limestone.
places in southwestern and east-central Illinoi
beds of oolite. In the Illinois basin it is char
a dark fossiliferous limestone with dark shale.
thickens from about 50 feet in the type area
100 feet in the deepest part of the basin. In
termed the North Vernon. The formation e
ward into Kentucky where it is referred to a
burg and into Tennessee where it is called P
called St. Laurent in southeastern Missouri.

The Lingle overlaps the underlying Grand T
the Ozark uplift and the Sangamon arch. Th
slight unconformity between it and the unde
Tower in western Illinois, but conformity prev
remainder of the basin. The Lingle is comm
by the Alto Limestone or its equivalent, the B

The macrofauna of the Lingle is clearly rela
the New York Hamilton Group. The most imp
are *Microcyclus discus, Devonochonetes coron
latia pustulosa, Athyris spiriferoides, Medios
culus, Spinocyrtia granulosa* and *Mucrospirifer*

Orr (in press) has characterized the Lin
fauna as containing mainly *Icriodus latericresc
scens, Polyganthus varca* and *P. linguiform*
and Ziegler (1967) indicate that the firs
ranges from the Skaneateles Member of the H
mation up into the Tully. *P. varca* ranges from
ville Member also into the Tully. Inasmuch as
cristata, which is indicative of post-Tully beds
the Lingle but appears in the overlying Alto, t

is correlated with the upper half of the Hamilton in New York and the North Vernon in Indiana. The fauna correlates with that of the upper part of the Givetian of Germany (Klapper and Ziegler, 1967).

Alto Formation

The Alto Formation (Savage, 1920) was named for dark grey shale and argillaceous limestone cropping out on Clear Creek in Union County, Illinois. The formation is essentially limited to southwestern Illinois. The Alto is thickest in the type area where it reaches approximately 100 feet. Thence eastward it fluctuates between 30 and 70 feet and grades laterally into the Blocher (Fig. 13) in the middle of the state. North-northeastward from the type area the Alto thickens from 30 to 100 feet until it reaches northern Clinton County in southwestern Illinois where it thins out abruptly. In subsurface the Alto is difficult to differentiate from the underlying Lingle.

The macrofauna of the Alto Formation is meagre. The only significant fossils (Savage, 1920) are *Devonochonetes* sp., *"Reticularia" laevis* and *Mucrospirifer mucronatus.* Orr has reported a small conodont fauna from the formation. The important forms are: *Polygnathus cristata, P. decorosa, Icriodus alternatus, I. symmetricus, Polygnathus pennata, P. varca,* and *Palmatolepis* n. sp. The most significant species is *Polygnathus cristata,* the lowest occurrence of which in Germany falls into a zone between uppermost undoubted Middle Devonian (beds with *Maenioceras terebatum*) and lowermost undoubted Upper Devonian (beds with *Pharciceras lunulicosta*). From there the species ranges into the Middle *Polygnathus asymmetrica* Zone of Ziegler (1965). None of the other species in the fauna establish the position of the formation with respect to the series boundary. The present tentative assignment to the Middle Devonian is made because *Polygnathus cristata* is absent from the lower part of the Alto and no undoubted Upper Devonian species have been found.

Blocher Formation

See discussion of New Albany Shale.

UPPER DEVONIAN

New Albany Shale

The New Albany is an interbedded black and grey pyritic shale that is widespread over Indiana (New Albany Shale), Illinois (New Albany Group) and Kentucky and extends westward over much of northern Missouri and southeastern Iowa. It is continuous eastward into the Huron, Ohio, Cleveland, Bedford and Sunbury shales of Ohio, the Antrim and Ellsworth shales of Michigan and the Chattanooga of Tennessee. In western Missouri and southwestern Iowa the same unit is also called Chattanooga. The New Albany and its equivalents include the entire Upper Devonian and early Mississippian of the eastern United States as well as uppermost Middle Devonian in many places. The black shale sequence edges on the Kankakee-Cincinnati arch, on the Wisconsin uplift and the Nemaha uplift in Nebraska. In Indiana the New Albany is considered a formation, but in Illinois it is recognized as a group. The thickness of the Devonian part of the New Albany can be determined by combining thicknesses of Figures 12 and 13.

The name New Albany was proposed by Borden (1874) for rocks previously called *black slate* in Indiana and Kentucky. Cumings (1922) reviewed earlier interpretations and noted the upper portion of the unit had been regarded as Mississippian. Huddle (1934) studied the conodont faunas of the New Albany; he considered the lower 15 feet to be unquestionably Genesee in age and the remainder to be Late Devonian with some possibility that the uppermost beds might be Mississippian. He also recognized lower, middle and upper conodont faunas in the sequence in southeastern Indiana. The lower came from black shales containing thin limestones and concretions making up the lower 15 feet of the unit and capped by a sandstone. This unit corresponds to that described later by Campbell as the Blocher Formation. Its fauna contains such significant species as *Polygnathus linguiformis, P. peracuta, P. foliata,* and *Ancyrodella rotundiloba.* These species indicate that the lower unit of Huddle is mostly Middle Devonian in age but includes beds that are earliest Late Devonian. The middle conodont fauna of Huddle came from the lower part of the upper half of the New Albany which consists of black shale containing thin grey shales, sandstones and limestones. This fauna contains such species as *Polylophodonta concen-*

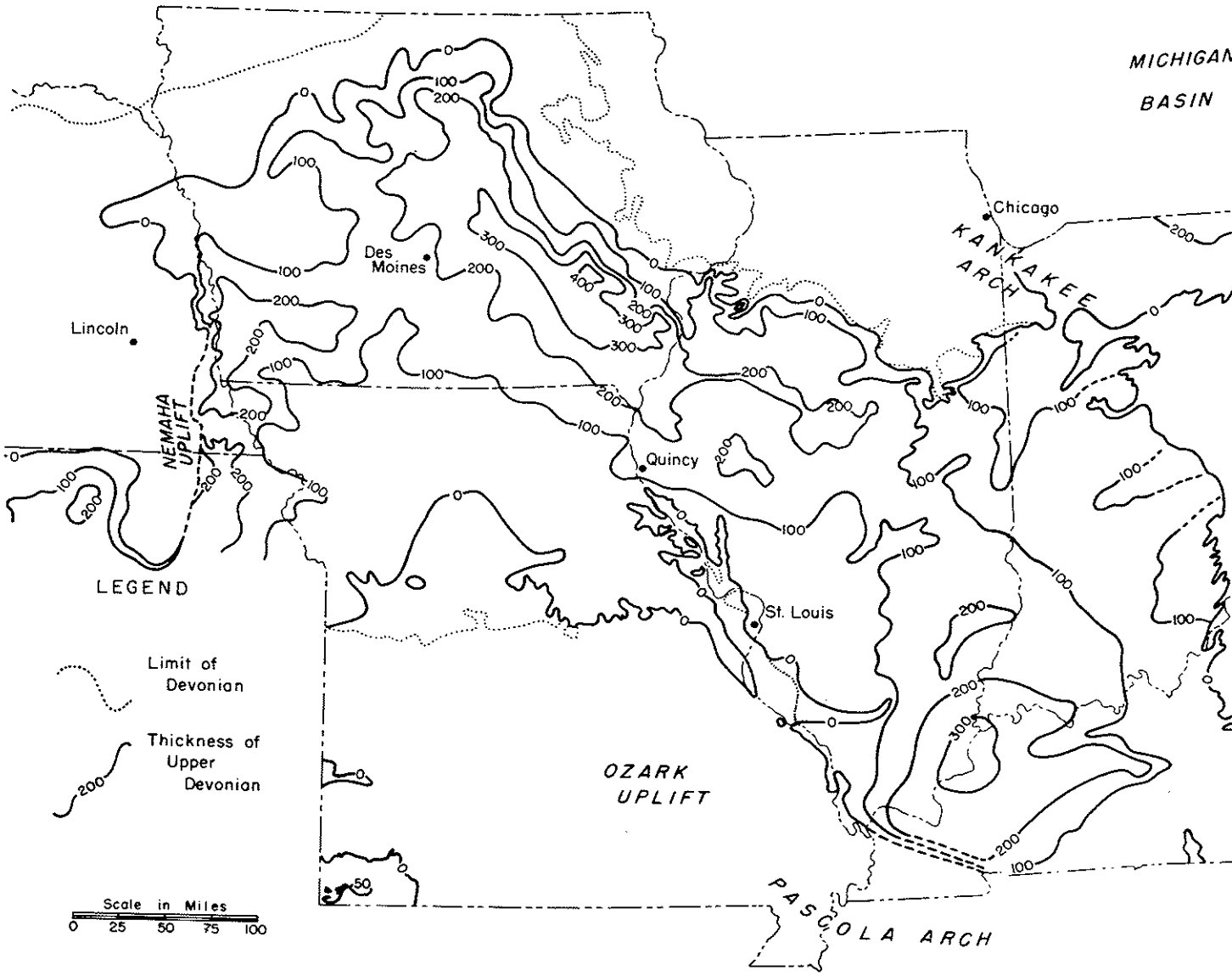


Fig. 12. Thickness map of the Upper Devonian in north-central United States.

trica, Palmatolepis glabra and *Palmatolepis perlobata* all of which indicate a Famennian age. Huddle's upper conodont fauna is of earliest Mississippian age.

Campbell (1946) published a comprehensive treatment of the New Albany in which he named as formations the Blocher (Middle Devonian), Blackiston (Upper Devonian), Sanderson, Underwood, and Henryville (all Mississippian). Most have been subsequently reduced to members but the names are still widely used.

Lineback (in press) recently completed a detailed study of both surface and subsurface stratigraphy of the New Albany and a revision of the nomenclature. He recognizes five members in the southern Indiana outcrop area. The members are in descending order:

Clegg Creek Member. Massively bedded carbon-rich, quartzose, dolomitic, pyritic shale with thin greenish grey shale beds and phosphatic nodules near the top. The Clegg Creek Member includes, as named beds, the units referred to by Campbell (1946) as the Jacobs Chapel, Henryville, Underwood and Falling Run. It also includes Campbell's Sanderson and uppermost Blackiston. The Jacobs Chapel, Henryville and Underwood beds contain a conodont fauna which correlates to that of the Hannibal Shale (Kinderhookian) of western Illinois. The Devonian-Mississippian boundary was placed zero to 4 feet below the Falling Run Bed by Lineback. The Devonian part of the Clegg Creek is equivalent to the Saverton and upper part of the Grassy Creek of Illinois and Missouri.

Camp Run Member. Carbon-rich shale with thin beds of greenish to olive-grey shale. The member is entirely Late Devonian in age and corresponds to part of the Grassy Creek of Illinois and Missouri.

Morgan Trail Member. Carbon-rich shale containing many thin quartzose pyrite beds. Like the Camp Run this member correlates to the lower part of the Grassy Creek Formation.

Selmier Member. Greenish grey dolomitic mudstone. The Selmier is traceable into the early Lower Devonian Sweetland Creek of Illinois.

Blocher Member. Carbon-rich calcareous to dolomitic pyritic shale. It is mainly Middle Devonian in age, although its uppermost part contains earliest Late Devonian conodonts.

We have separately isopached the Blocher Member (Fig. 13) which on our map is a high resistivity unit identified from geophysical logs. It is generally distinguished from the underlying Lingle or North Vernon by its low (positive) self-potential and a characteristic resistivity curve. The Blocher is sharply differentiated by high radioactivity and slower sonic travel time (Fig. 13). The overlying Selmier

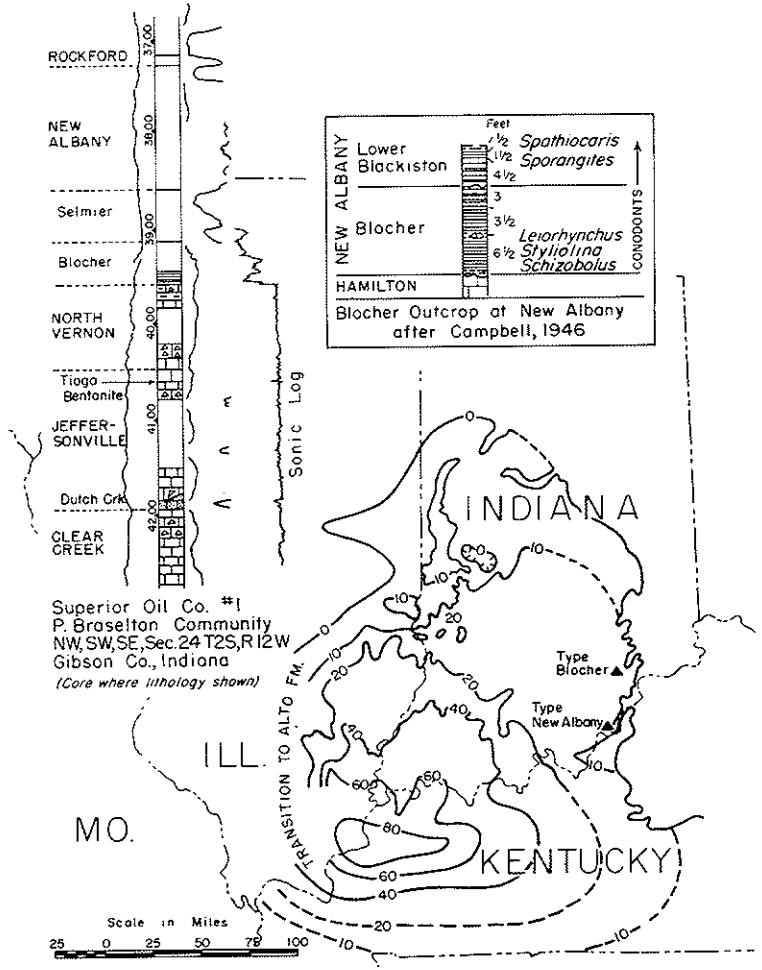


Fig. 13. Thickness of the Blocher Shale, geophysical log of the Middle and Upper Devonian in southwestern Indiana, and the type section of the Blocher after Campbell (1940).

has much lower resistivity. There are difficulties in precisely relating the outcrop and well sample Blocher to the isopached Blocher determined exclusively from logs. Our thicknesses generally are somewhat less than Lineback's.

Lineback kindly provided samples from the Selmier Member. Samples from the base of the member contain: *Palmatolepis subrecta, P. unicornis, Icriodus symmetricus, Ancyrodella curvata* and *A. nodosa* which indicate correlation with Ziegler's (1962) Upper *Palmatolepis gigas* (*to*Iδ) Zone. Our single sample from the upper part of the Selmier contains *Palmatolepis quadrantinodosalobata* which is indicative of the German *toII*. The Selmier is lithologically continuous with the Sweetland Creek of western Illinois. However, the Sweetland Creek is slightly older, ranging from Ziegler's *Ancyrognathus triangularis* (*to*Iγ) to Ziegler's Upper *Palmatolepis gigas* Zone. The apparent difference in age may be attributable to the difference in technique.

Sylamore Sandstone

The Sylamore Sandstone was named by Penrose (1891) from a locality in northwestern Arkansas and the name has been applied to a thin sandstone at or near the base of the Upper Devonian in Missouri and western Illinois. It is rarely more than 5 feet thick and generally is only a few inches. It is a quartz sandstone with rounded grains cemented by pyrite, calcite and dolomite.

The Sylamore contains virtually no fossils other than fish teeth and conodonts which are abundant and well preserved at many localities. The principal species *Palmatolepis proversa, P. triangularis, Ancyrodella curvata, Ancyrognathus triangularis* and *Polygnathus normalis* are indicative of an early Late Devonian age.

As here interpreted the Sylamore is widely but sporadically distributed through southwestern, central and northeastern Missouri and through western and central Illinois (Workman and Gillette, 1956, Figure 5). It extends into western Kentucky and Tennessee, where it is called the Hardin Sandstone, and it may be represented in eastern Illinois and western Indiana by sandy beds in the upper part of the Blocher or the lower part of the Sweetland Creek. It is overlain by the Sweetland Creek, the Grassy Creek or the Snyder Creek and rests on unit age from late Middle Devonian (Cedar Valley cian.

The term Sylamore has been used consistentl for sandstone supposedly pre-Grassy Creek i was erroneously applied to the Bushberg by Mehl (1934, p. 173-175, 180) and others in ce Missouri where the sandstone is directly overla sippian rocks. Branson and Mehl (1934, p. 26 their error when conodonts from their "Sylan to be Kinderhookian in age. Because of this in use and because he was doubtful about corre type section in Arkansas, Mehl (1960, p. 69) p the name be suppressed in Missouri and propose the name *Turpin*. Collinson (1961, p. 102, other hand has written that the status of the t was long ago cleared by Adams and Ulrich (U.S.G.S. Fayetteville Folio when they defined as the basal member of the Chattanooga. In type Sylamore Sandstone section on Sylamor tains typical Late Devonian conodonts (Meh general usage of Sylamore has been very unifo years.

Sweetland Creek Shale

Udden (1899) applied *Sweetland Creek* to greenish grey and black shale overlying the Limestone near Muscatine in southeastern Iov he extended use of the name to western Illinoi man and Gillette in 1956 rejected the name Grassy Creek. Later, Collinson (1961, Figure the presence of a widespread grey shale un Grassy Creek and above the Middle Devoni over much of the Illinois basin. James (196 grey shale in southwestern Illinois to the ty the Sweetland Creek and found that they ha conodont faunas. The unit extends to India correlates with outcrops of the Selmier Me New Albany. In view of these relationships that the Sweetland Creek be restricted to the shales of the type section (Klapper and Furnis ure 2) and the overlying black shale be ref Grassy Creek (Sheffield of Iowa). The Swe (restricted) is only a few inches to a foot th

eastern Missouri and southwestern Illinois. It thickens northward to as much as 50 feet in northwestern Illinois and southeastward to a maximum of 130 feet in southeasternmost Illinois and adjacent Kentucky.

Klapper and Furnish (1962) recognized five distinct conodont faunas in the type section of the Sweetland Creek which correspond very closely to Ziegler's *Ancyrognathus triangularis* Zone, Lower *Palmatolepis gigas* Zone, Upper *P. gigas* Zone, Upper *P. gigas* Zone with *P. crepida linguiformis* and Middle *P. triangularis* Zone, ranging from early to middle Late Devonian.

Grassy Creek Shale

Grassy Creek is a brownish black, pyritic, thinly laminated, *Tasmanites*-bearing shale which overlies the Sylamore or the grey shale of the Sweetland Creek and underlies the greenish grey shale of the Saverton. The formation was named from exposures near Louisiana, northeastern Missouri (Keyes, 1898), and originally included the grey shale now known as Saverton as well as the black.

The Grassy Creek is thickest in the northeasternmost corner of Missouri where it reaches more than 170 feet. It thins southward, rides over the Sangamon arch and thins out depositionally on the north and east flanks of the Ozark uplift. Over much of central Illinois the formation ranges between 30 and 60 feet. It has a comparable thickness in Indiana where it is represented by the Morgan Trail, Camp Run and the lower part of the Clegg Creek members of the New Albany (Lineback, in preparation). It thickens to more than 140 feet in the deep part of the Illinois basin in western Kentucky. The formation is not recognized west of north-central Missouri where it grades to an undifferentiated grey shale sequence lumped as "Chattanooga," "Kinderhook Shale" or "Devonian-Mississipian Shale."

Around the Lincoln fold in northeastern Missouri and western Illinois, the Grassy Creek thins and in places is missing depositionally. In Iowa the dark shale facies, which is included in the Sheffield, extends northwestward from the southeast corner of the state as far as Keokuk County in a 70 mile wide 160 foot thick tongue and then grades into the grey shale sequence of the typical Sheffield within a few dozen miles.

The macrofauna of the Grassy Creek is very sparse and its conodont fauna is not well known. Most of the abundant fauna described by Branson and Mehl (1934) as from the Grassy Creek actually came from the overlying Saverton, which they did not differentiate at the time. The abundant fauna of the overlying Saverton and the underlying Sylamore and Sweetland Creek indicate the age of the Grassy Creek to be early Late Devonian and to represent the *toII* and *toIII* elements of the German succession (Collinson, Rexroad and Scott, 1962).

Saverton Shale

The Saverton Shale (Keyes, 1913) named for Saverton Station, Ralls County, Missouri, is a bluish to greenish grey silty shale containing very thin limy or sandy beds. At the type locality it is overlain by Louisiana Limestone and underlain by Grassy Creek Shale. The formation crops out widely in northeastern Missouri and ranges from a wedge edge against the Lincoln fold and Ozark uplift to more than 110 feet in westernmost Illinois. From there eastward the formation ranges from 5 to 100 feet, but in eastern and southern Illinois it is less than 30 feet thick and commonly is so thin that it is lumped with the Hannibal Formation.

In most places the Saverton is overlain by the Mississippian "Glen Park" Formation or by the Hannibal Shale. In northeastern Missouri and western Illinois where the Saverton is overlain by the Louisiana, the Saverton is generally very thin but thickens northeastward as the Louisiana thins and is partially equivalent to the Louisiana (Collinson, 1961).

The Saverton contains few macrofossils except for those recorded by Williams (1943) as coming from the Louisiana Limestone, but which actually come from the yellow-brown argillaceous siltstone at the top of the Saverton. Notable among them are *Spirifer marionensis* and *Orbinaria pyxidata*. Like the macrofossils, the Louisiana conodont faunas listed by Branson (1944) actually came from beds now included in the Saverton. Scott and Collinson (1961) listed from the Louisiana and the uppermost Saverton such important Upper Devonian species as *Palmatolepis minuta, P. glabra, P. gracilis, P. quadrantinodosa marginifera, Gnathodus kockeli* and *Polygnathus communis*. *Palmatolepis minuta,* which occurs in abundance, is known elsewhere in beds no younger than middle Late Devonian (*toIII*). Similarly

P. quadrantinodosa marginifera is not known from beds younger than those of *toIV* designation. *Gnathodus kockeli,* on the other hand, has until recently been considered the conodont index of earliest Carboniferous rocks in Europe. Ziegler (personal communication, 1966) however, has indicated that the species has been found recently in Germany in beds of latest Devonian age (*toVI*) and has reiterated his belief that the Louisiana (and by implication uppermost Saverton) is latest Devonian (*toVI*) in age.

Geophysical logs permit the tracing of the Saverton into Indiana where it is equivalent to part of the Clegg Creek Member of the New Albany Shale. Conodont faunas from the Clegg Creek verify the correlation.

Although it is difficult to trace the Saverton to the Aplington of Iowa in the subsurface, conodont species listed by Anderson (1966) appear to date the Aplington as Late Devonian (probably *toIV* to *toV*) and correlate it in part to the Saverton. Dorheim, using subsurface data, however, correlates the Aplington approximately with the Louisiana.

The Maple Mill of Iowa appears to be at least a partial correlative of the Saverton, inasmuch as its type section contains *Polygnathus communis, Pelekysgnathus inclinata* and *Polygnathus semicostata* (Anderson, 1966). Correlation of the Saverton with the Maple Mill in easternmost Iowa is well established through subsurface tracing. The Iowa Geological Survey classifies the Maple Mill as post-Louisiana in age.

Louisiana Limestone

The Louisiana Limestone (Keyes, 1892) has its type locality near Louisiana, Missouri, where it reaches its maximum thickness of 65 feet. It extends in a narrow lens from central Iowa to central Illinois (Scott and Collinson, 1961). The outcrop area is largely confined to the region where the formation crosses the Mississippi and lower Illinois valleys.

The Louisiana overlies the Saverton conformably and thins reciprocally to it. The formation is overlain by the Mississippian "Glen Park" Formation, or where that is absent, the Hannibal Formation. The Louisiana and "Glen Park" are essentially conformable, but a channeled erosion surface separates them in several places. Lithologically the formation consists of light grey to buff lithographic limestone, with brown dolomite interbeds and thin shale partings. The limestone is very pure and may represent chemical deposition in a shallow sea along the eastern flank of the Lincoln fold.

The Louisiana is well known because of the long controversy concerning its relationship with the lithologically similar McCraney Limestone (Scott and Collinson, 1961). Williams (1943) described the formation and its fauna and concluded that it is Mississippian. The macrofauna is fairly large and is dominated by the small brachiopods *Schuchertella, Chonetes, Ambocoelia* and *Cyrtina.* Microcrinoid calyces are also common as are bryozoans and ostracods. In 1961, Scott and Collinson described the conodont fauna and compared it with German conodont ranges and zones, later published by Ziegler (1962), which are closely related to the standard European cephalopod zones. Scott and Collinson concluded that the Louisiana is of latest Devonian age (*toVI*) and correlates to Ziegler's *costatus* Zone. The age has since been supported by discovery of primitive gnathodids in the German lower Hangenberg Schichten (Winder, 1966).

At present the Iowa Geological Survey correlates the Aplington with the Louisiana (Fig. 5). The microfaunas indicate that the two are not greatly different in age and subsurface control does not permit precise tracing. However, the Louisiana and the uppermost Saverton contain the distinctive and common species *Gnathodus* n. sp., *Gnathodus kockeli* and *Polygnathus communis* (Collinson, Scott and Rexroad, 1962, Chart 3). The Aplington, which has yielded a meagre fauna, contains *Polygnathus communis* but no gnathodids (Anderson, 1966). The Aplington does contain *Icriodus* which has not been reported as indigenous in beds younger than middle late Devonian (*to III*). Ziegler (1962) indicates that gnathodids in Germany are found no lower than the uppermost Devonian (Ziegler's *costatus* Zone). *G.* n. sp. is found only in the Upper *costatus* Zone and is common in the Louisiana. Thus it appears that the Aplington and Louisiana are both Late Devonian in age, but the Louisiana is distinctly (*toVI* versus *toIV-toV* for the Aplington).

CENTRAL IOWA BASIN

CHARLES COLLINSON, MARVIN P. CARLSON, FRED H. DORHEIM and JOHN W. KOENIG

STRATIGRAPHIC UNITS

LOWER DEVONIAN

La Porte City Chert

Lower Devonian rocks have not been previously recognized in Iowa although members of the Iowa Geological Survey have recognized a cherty unit in the subsurface below the Wapsipinicon and above the Silurian. Parker (1967) has proposed the name *La Porte City Chert* for this unit and has designated the La Porte City Well in northeastern Iowa as the type locality. La Porte City is near the northeastern extremity of the La Porte City Chert lens (Fig. 9).

Because no faunas have been recovered from the formation, the possibility exists that the chert represents a development of the Bertram Member of the Wapsipinicon and therefore is Middle Devonian in age. On the other hand, the La Porte City occupies a position in the central Iowa Devonian basin comparable both in stratigraphic position and location to the Clear Creek Chert of the Illinois basin and is nearly identical in lithology. In addition, sandstone comparable to the Hoing is found beneath it in some wells. Thus, in the absence of evidence to the contrary, the La Porte City is correlated to the Clear Creek and is considered Early Devonian in age.

MIDDLE DEVONIAN

Wapsipinicon Formation

The name Wapsipinicon was proposed (Norton, 1875) for beds below the Cedar Valley and above the Silurian on the Wapsipinicon River in east-central Iowa. The formation crops out in a northwesterly belt across eastern Iowa and in subsurface extends westward into Nebraska as well as southeastward into Illinois. In northern Iowa, northern Missouri and western Illinois the formation is overlapped by the Cedar Valley (Fig. 6). Except in the deepest part of the central basin, where it rests on the La Porte City Chert (Fig. 9), the Wapsipinicon lies on Silurian or Ordovician rocks (Fig. 8). The Wapsipinicon is about 100 feet thick in east-central Iowa and thickens westward into the central basin where it reaches more than 200 feet. Southeastward it wedges out against the Sangamon arch and is overlapped by the Cedar Valley. The formation is virtually devoid of fossils, except for some brachiopod moulds. No conodonts have been found, probably because evaporites occur discontinuously throughout the formation. The evaporites occur mainly in central Iowa, northern Missouri and western Illinois (Dorheim, 1967) but are undoubtedly more extensive than shown by Figure 11. Pods and lenses of sand occur at the base of the Wapsipinicon sporadically and increase in frequency outward from the centre of the basin. The sand represents surface deposits and residuum reworked by the advancing Wapsipinicon sea.

The formation includes in ascending order the Bertram, Coggon, Otis, Kenwood, Spring Grove and Davenport Members, all described from localities in Linn County, east-central Iowa.

Bertram Member. This member (Norton, 1895) is a brecciated dolomite or dolomitic limestone. Norton placed it in the Silurian along with the Coggon Member, but questioned assignment. Later, he placed it in the Wapsipinicon as the basal member. Stainbrook (1935) placed the unit in the Otis Member above the Coggon, an interpretation now untenable. Dorheim (1967), with new quarry exposures, established the Bertram's position below the Coggon and above the Silurian; it is restricted to Linn County.

Coggon Member. About 20 feet of massively bedded buff dolomitic limestone with dark chert nodules are assigned to the Coggon Member. The lower few feet are argillaceous and contain brachiopods similar to *Emanuella subumbona*. The member is restricted to the eastern part of Iowa. It contains a thin bentonite that Meents and Swann (1965) regard as the Tioga.

Otis Member. This member (Norton, 1894) is a fine grained to sublithographic light grey to brown limestone with occasional chert seams. The unit is about 20 feet thick in the type area and is apparently confined to eastern Iowa and northwestern Illinois. An *Emanuella*-like brachiopod is found in the member.

Kenwood Member. Named from Cedar Rapids where it is 18 feet thick, the Kenwood Member (Norton, 1894), is generally a soft blue-grey shale with layers of blue-grey limestone. In southeasternmost Iowa, however, it consists of argillaceous, dolomitic limestone with pockets of clay. Economic gypsum deposits occur in southeastern Iowa.

Spring Grove Member. This is a brown laminated dolomite and dolomitic limestone that weathers into thin plates. It crops out extensively in northeastern Iowa. The maximum thickness, 25 feet, occurs in Keokuk County, southeastern Iowa. No fossils have been found.

Davenport Member. In 1894, Norton named two stratigraphic units, the Upper Davenport and the Lower Davenport. Later the fossiliferous Upper Davenport became part of the Cedar Valley and the nonfossiliferous Lower Davenport became the Davenport Member in the Wapsipinicon. The member is a pure, hard, light grey lithographic to brown-grey sublithographic limestone with many limestone breccia beds which are excellent local markers. In the type area near Davenport, the member is more than 40 feet thick. In Keokuk and Washington Counties, where it contains mineable anhydrite and gypsum, the member measures 50 feet.

Cedar Valley Limestone

The name Cedar Valley was formalized by McGee (1891) for "calcareous Devonian sediments stretching from the Minnesota line to Muscatine County in a belt 50 miles in average width." Almost from that beginning, subdivision of the Cedar Valley and its age have been moot questions. Stainbrook (1935, 1944), has been the principal proponent for a Late Devonian age, whereas Cooper (1935, 1944) has summarized views in favor of a Middle Devonian age. Faunal evidence for the Middle Devonian age has become overwhelming in recent years (see p. 966).

The maximum thickness of the Cedar Valley Limestone is more than 500 feet in the deepest part of the basin in southwest Iowa. From there westward the formation extends into Nebraska, where it wedges out against the Cambridge and Sioux arches. Northeastward, it and the older Palaeozoic formations have been removed by erosion. Southeastward the formation wedges onto the Ozark uplift and partially overlaps the Sangamon arch. Thicknesses exceed 200 feet over most of Iowa and 300 feet in the northeastern part. In the northern part of Missouri it is more than 400 feet thick, but in Illinois it is almost everywhere less than 100 feet.

Over most of Iowa the Cedar Valley is overlain by the Upper Devonian Lime Creek and Shell Rock Formations. In western Iowa and eastern Nebraska the Mississippian Hampton lies directly on it and in western Illinois the Sweetland Creek is the overlying unit. In Missouri the Cedar Valley may be overlain by Grassy Creek, Snyder Creek, Bachelor, Hannibal or Chouteau, although in the northernmost part of the state the Lime Creek overlies it. The Cedar Valley generally lies on the Wapsipinicon Formation but overlaps it on the north, east and south to become the oldest Devonian formation. The Cedar Valley consists of the Solon, Rapid and Coralville Members, in ascending order, all named for localities in east-central Iowa (Norton, 1897; Keyes, 1912).

Solon Member. This is a grey, medium to fine grained, dense, fossiliferous limestone. It commonly contains brecciated limestone beds and, in the subsurface, anhydrite. Near the top of the member, *Hexagonaria profunda* biostromes are abundant (the "*profunda* Zone" of Stainbrook (1935) and others). A lower zone is based on the occurrence of *Atrypa independensis.* The Solon is more than 100 feet thick in southeastern Iowa and reaches nearly 200 feet in the central Devonian basin. Elsewhere it is commonly 50 feet thick. Klapper and Ziegler (1967) have listed *Icriodus latericrescens latericrescens, I. nodosus, I. obliquimarginatus, Polygnathus linguiformis, P. decorosa* s.l. and *P. varca.* All indicate correlation with the upper Hamilton Group of New York and a late Middle Devonian age.

Rapid Member. This member is based on a series of limestones about 30 feet thick and containing corals. Rapid has priority over a synonym, Littleton (Stainbrook, 1935). The Rapid is the most widespread of the Cedar Valley members. In central Iowa it is more than 300 feet thick although in outcrop in southeastern Iowa it does not exceed 70. In some places the Rapid is a thick bedded argillaceous limestone characterized by few fossils and a distinctive oblique weathering pattern. The upper part is generally

dolomitic and argillaceous but in southeastern Iowa commonly contains *Hexagonaria* biostromes near the top. In north-central Iowa significant quantities of anhydrite are found in the unit. Brachiopods and corals are abundant throughout the unit in the type area. Stainbrook (1941) proposed three brachiopod zones: (ascending) *Atrypa bellula* Zone; *Pentamerella* Zone; *Atrypa waterlooensis* Zone. The zones are useful in the outcrop belt of eastern Iowa, but have not been distinguished in other areas. Klapper and Ziegler (1967) list the following conodont species from the Rapid: *Icriodus latericrescens latericrescens, I. nodosus, Polygnathus decorosa* s.l., *P. ordinata, Schmidtognathus peracuta* and *S. wittekindti,* indicating a late Middle Devonian age.

Coralville Member. This is the uppermost member. It is truncated by an unconformity and does not occur as widely as the underlying Rapid. It is predominantly grey, fine grained, lithographic limestone which locally contains abundant *Idiostroma* and other stromatoporoids. In southeastern Iowa the basal beds are argillaceous and contain abundant corals. The uppermost beds are commonly dolomitized and are not exposed in the type section. The entire section appears to be present in northwestern Illinois where uppermost beds are Late Devonian in age. From its type area the Coralville thickens into the basin and reaches its maximum of 170 feet in north-central Iowa.

Conodonts collected by Collinson from the Coralville in Iowa and Illinois include *Ancyrodella rotundiloba, Icriodus nodosus, I. symmetricus, I.* cf. *I. cymbiformis, Palmatolepis hassi, Polygnathus foliata, P. ordinata* and *Spathognathodus insita.* The distinctive and short-ranged *Spathognathodus insita,* which is known from the uppermost Cedar Valley at the type section of the Sweetland Creek, is found in the lower part of the Coralville, whereas *Ancyrodella rotundiloba,* a distinctive index for earliest late Devonian rocks (*to1*), is found in the upper part. The Middle Devonian-Upper Devonian boundary almost certainly lies between.

Hoing Sandstone

Sandstone at or near the base of the Cedar Valley Limestone has been called Hoing in western Illinois since oil was discovered on the Hoing farm in Colmar-Plymouth oil field in 1941. Sand freed during the Middle Devonian by weathering of the St. Peter and other Ordovician sandstones was redeposited in the Devonian seas. Although some sand occurs in the earlier Middle Devonian carbonate units, the most uniform distribution is at the base of the Cedar Valley on the north flank of the Ozark uplift (Fig. 1) where the transgressive Cedar Valley overlapped the Wapsipinicon and now lies on older Palaeozoics. Isolated lenses 30 feet thick have been found, but at most localities there is only sandy limestone or dolomite. Sandstone similar to the Hoing occurs in the Lingle Limestone on the southeastern side of the Sangamon arch but is probably an equivalent of the Beauvais Sandstone of Missouri and therefore older than the Hoing. Sand occurs at many levels within the Cedar Valley and Lingle, but concentrations are generally thinner than at the base.

Callaway, Cooper, Mineola and Ashland Formations

Fraunfelter (1967) has traced the history of these names from the first use of Callaway by Keyes (1894), Cooper by Swallow (1855) and Mineola and Ashland by Branson (1920, 1941) and has proposed the term Cedar City to resolve the difficulty in using Callaway both as a formation and a facies name. Because Cedar City and Cedar Valley are equivalent and similar in character, the name Cedar Valley is extended in this report to Missouri to include those rocks that have been called Callaway, Cooper, Mineola and Ashland. Cooper and Callaway are retained as lithofacies.

Although the Cooper has been considered by many authors as older than the Callaway or Cedar Valley, most of us, along with Fraunfelter, consider it essentially the same age as the Callaway.

The Cooper Limestone member of the Grand Tower, as used in Illinois (Meents and Swann, 1965), is an unfossiliferous light grey lithographic limestone. It overlies and intertongues southward into the upper part of the dolomite which forms the bulk of the Grand Tower in central Illinois and is therefore almost certainly older than the Cooper Facies of Missouri. It is overlain by sandy and phosphatic beds formerly called Cedar Valley (Rubey, 1952) but now placed in the Lingle (Meents and Swann, 1965). There is very little sand at the base of the Illinois Cooper, whereas sand concentrations are common in the overlying beds. Swann's belief that the two (Cooper) units of Grand Tower

and of post-Grand Tower (Cedar Valley) age respectively can be successfully differentiated in Missouri as well as Illinois, is not shared by Koenig, James and Collinson.

State Quarry Limestone

The State Quarry Limestone is restricted to several small areas in Johnson County, central-eastern Iowa. It is a light grey massively bedded limestone composed almost entirely of brachiopod and crinoid fragments with thin layers of chert and fish-tooth conglomerate. The formation attains a maximum thickness of 40 feet. It appears to occur in depressions in the Cedar Valley.

Klapper (personal communication, 1967) has collected a conodont fauna from the type section with abundant *Spathognathodus insita.* Collinson has found the same species in abundance in the Coralville Member of the Cedar Valley in Illinois, occurring below abundant *Ancyrodella rotundiloba,* an undoubted Upper Devonian form. Consequently, the State Quarry Limestone may be interpreted as uppermost Middle Devonian or lowermost Upper Devonian, although it is undoubtedly a facies or at least a correlative of the uppermost Cedar Valley of other areas. The Iowa Geological Survey classifies the State Quarry Limestone as Upper Devonian. Koch (personal communication) correlates the State Quarry limestone with the upper part of the Shell Rock.

Independence Shale

The position and age of the Independence Shale (Calvin, 1878) was for many years the subject of controversy arising from the fact that the formation appears to underlie Cedar Valley yet carries an unequivocal Late Devonian fauna. Stainbrook (1935) interpreted the Independence as lying normally below the Cedar Valley and above the Wapsipinicon. Cooper and others (1942) interpreted it as sink, crevasse and cave fillings and this view is now that of the majority.

Because the Independence is now generally interpreted as cave and sink fillings from the Sweetland Creek, Grassy Creek and Saverton formations we are following the Iowa Geological Survey and suppressing the name. The shale is commonly encountered deep in the Cedar Valley and its relations clearly indicate its displaced position in many exposures.

Fortune Formation

Described by Grohskopf, Clark and Ellison (1943) from Barry County, southwestern Missouri, this formation consists of thin limestone and chert with a basal sandstone. The formation overlies the Ordovician Cotter Formation and is overlain by the Bachelor, Chattanooga or Compton. The unit attains a maximum thickness of only 6 feet and is geographically restricted to an area of less than 100 square miles.

A small conodont fauna, representing *Icriodus alternatus, I. latericrescens latericrescens, I. expensus, Polygnathus decorosa* s.l. and *P.* cf. *ordinata,* is indicative of a late Middle Devonian age and correlates with the upper part of the Lingle Formation of southwestern Illinois.

UPPER DEVONIAN

Shell Rock Formation

Named by Belanski in 1927, the Shell Rock is a variable limestone sequence with a maximum thickness of 70 feet that crops out in a restricted area along the Shell Rock River in north-central Iowa. The unit underlies the type Lime Creek but is laterally equivalent to beds in the lower part of the Lime Creek in southeastern Iowa. These are three members in ascending order: Mason City, Rock Grove and Nora.

Mason City Member. This is a light grey to yellowish brown fine grained to lithographic limestone containing crinoid debris, stromatoporoids, brachiopods, gastropods and corals (Dorheim and Koch, 1966). The unit has a maximum thickness of about 40 feet.

Rock Grove Member. This is mainly light olive-grey fine grained limestone, and more argillaceous and dolomitic than the beds below. It contains significant amounts of dark yellowish brown shale as well as brown to grey dolomitic limestone.

Nora Member. This is mainly a yellowish brown crinoidal shaly and dolomitic limestone distinguished by biostromes of *Actinostroma expansum* and other stromatoporoids. The member is nowhere more than 20 feet thick. Brachiopods and pelecypods are common.

Conodont faunas collected by Anderson and by Collinson are not diagnostic, but both *Ancyrodella gigas* and *A.*

buckeyensis, listed by Anderson (1966) and Thomas (1949), are restricted to earliest Upper Devonian rocks. Because the underlying Coralville Member of the Cedar Valley contains the short-ranged *Spathognathodus insita* (latest Middle Devonian or very earliest Upper Devonian), the entire Shell Rock is placed in the Upper Devonian.

Lime Creek Formation

The Lime Creek (Williams, 1883) was named for Lime Creek near Rockford, north-central Iowa. It lies on the Shell Rock, where that formation is present, and on the Cedar Valley elsewhere. It is overlain by the Sheffield.

The Lime Creek crops out in a 2 to 20 mile wide band from southeastern to north-central Iowa. It is more than 100 feet thick over a large area in central Iowa and locally attains 200 feet. It thins westward. Southward in northern Missouri it is replaced by the Maple Mill Formation. Southeastward in Illinois the formation correlates to the Sweetland Creek.

The formation is divided into (ascending) the Juniper Hill, Cerro Gordo, and Owen Members, differentiated only in north-central Iowa.

Juniper Hill Member. This member (Thomas, 1925) is a blue-grey shale 90 to 100 feet thick. The only common macrofossil species are *Lingula fragilis* and *Iowaspongia annulata.* The unit contains a varied conodont fauna (Anderson, 1966) which is clearly referable to the lower part of the Upper Devonian (late Frasnian) and correlates to the Sweetland Creek of eastern Iowa and Illinois and to the Selmier Member of the New Albany Formation in Indiana. It probably also correlates to the upper part of the Genesee Group in New York.

Cerro Gordo Member. This member (Fenton, 1919) is 30 to 45 feet thick. It is renowned as a source of abundant and well preserved fossils. The localities at the Rockford Brick and Tile Plant and at Bird Hill are especially well known. Three principal zones are recognized in this fossiliferous sequence (Belanski, 1931). All are completely exposed at Rockford in north-central Iowa. The *Douvillina* Zone at the base is blue-grey plastic shale with occasional dark brown shale or nodular limestone beds. The most abundant fauna, which includes compound corals, gastropods and brachiopods, is that of the *Cyrtospirifer whitneyi* Zone. It extends through a sequence of brownish grey calcareous shale interbedded every few feet with nodular argillaceous beds. *Schizophoria iowensis* is abundant at the base. Limestone and calcareous brownish grey shale with abundant brachiopods, horn corals and bryozoans make up the uppermost zone, the *Strophonella hybrida* Zone. The zones are limited to north-central Iowa.

Manticoceras, occurring in the upper part of the Cerro Gordo, is confined to the Frasnian Stage (*toI*) in Europe and verifies the early Late Devonian age of the member, along with the conodont fauna described by Anderson (1967).

Owen Member. Soft buff dolomitic limestone or limy dolomite in which fossils occur mainly as moulds or casts comprise this member (Norton, 1897). Stromotoporoids, although abundant, are dolomitized and difficult to identify. Anderson (1966) found the conodonts *Icriodus cymbiformis, Polygnathus angustidisca* and *P. normalis,* which indicate an early Late Devonian (*toI*) age.

Sheffield Shale

The Sheffield Shale in its type region in north-central Iowa consists of 40 to 90 feet of bluish, greenish and brownish grey shale with thin beds of brown dolomite. It overlies the Lime Creek Formation (Thomas, 1925) although in introducing the name, Fenton (1919) miscorrelated the unit at Sheffield with the lower part of the Lime Creek, later named the Juniper Hill Member. The Sheffield occurs in eastern Iowa and extends westward from the outcrop belt to southeastern Iowa. In southeastern Iowa, where it ranges up to 210 feet, the Sheffield is represented by dark grey to black shales that grade southeastward into the Grassy Creek of Illinois and Missouri. The dark facies extends northwestward as far as central Iowa.

For many years the formation was referred to the Kinderhookian by some authors and to the Devonian by others. The macrofauna of the Sheffield is small, but it includes *Cyrtospirifer disjunctus, Athyris angelica* and *Productella lachrymosa,* which indicate correlation to the Cassadaga of New York. The conodont fauna (Anderson, 1966) includes *Icriodus alternatus, I. iowensis, I. rectus, Palmatolepis triangularis* and *Polygnathus nodocostata,* indicating a mid-Late Devonian (*toI-toII*) age.

Aplington Formation

Stainbrook in 1950 differentiated the upper dolomitic beds of the Sheffield and introduced the name Aplington from a town in northeastern Iowa. In the type area the formation consists of 20 to 40 feet of yellowish brown argillaceous dolomite with seams of chert. A coquina-like limestone is locally present at the base. The formation reaches a maximum of 50 feet to the southwest of the type area but in general thins away from the type area.

Stainbrook (1950) considered the Aplington to be Kinderhookian in age on the basis of its brachiopod fauna. Anderson (1966), however, reports a conodont fauna containing *Icriodus constrictus, I. costatus, I. iowensis, Polygnathus brevilamina, P. communis, P. symmetrica* and *P.* cf. *P. perplexa.* The presence of *Icriodus* leads to the assignment of a Late Devonian age, as it has not been reported from strata younger than the upper part of the Saverton (*toIV-toVI*).

The brachiopod fauna, consisting of moulds of *Camarotoechia, Spirifer, Arctospirifer, Schellwienella, Cleiothyridina* and productids, is transitional to Mississippian faunas.

Some workers consider the Aplington a close correlative of the Louisiana Limestone of northeastern Missouri and western Illinois (see *Louisiana Limestone* under *Stratigraphic Units*).

Maple Mill Shale

The Maple Mill was named (Bain, 1895) for the grey shales exposed at Maple Mill on English River in Washington County, southeastern Iowa. Bain included everything between the Cedar Valley and the English River, but the formation has since been restricted to the upper part of the original unit by differentiation of the Lime Creek, Sheffield and Aplington. The Maple Mill Shale is light grey to greenish grey, silty, and poorly laminated. It is calcareous in places and commonly includes scattered beds of siltstone. *Tasmanites* is common. The formation is 100 feet thick in the type area and more than 200 feet in the southwestern part of Iowa. In the intervening areas it ranges between 20 and 90 feet. The formation extends westward into eastern Nebraska and is continuous with the Saverton in Illinois and Missouri.

The Maple Mill contains a conodont fauna closely related to that of the Saverton (Thomas, 1949; Collinson, 1961; Anderson, 1966) and is of Late Devonian (late Famennian) age.

English River Formation

There is disagreement concerning the age of the English River. The Iowa Geological Survey places it in the Devonian (as it is shown in Figure 5) but the preponderance of evidence indicates that it is Kinderhookian in age.

The formation was named (Bain, 1895) for a locality in Washington County, southeastern Iowa. There it consists of more than 10 feet of coarse grained, buff to white siltstone underlying the McCraney Limestone or, where that is absent, the Prospect Hill Siltstone. A persistent shale separates the latter from the English River where the McCraney is absent (Joseph Straka, personal communication). Exposures of the formation are limited to a relatively small area in southeastern Iowa. In subsurface the unit is also limited to southeastern Iowa and is commonly less than 20 feet thick with a maximum thickness of little more than 30 feet.

The upper two-thirds of the English River in the type area carries a Kinderhookian fauna including the conodonts *Siphonodella duplicata, S. quadruplicata, S. cooperi* and their normal associates plus reworked Devonian specimens. Unfortunately the lower part of the type section does not yield significant faunas.

The best known section assigned to the English River is at Burlington, about 55 miles southeast of the type section. House (1962) and Collinson (1961) have indicated that the strata there referred to as English River are late Devonian in age. House has identified the late Devonian ammonoids *Cymaclymenia* aff. *C. striata* and *Cyrtoclymenia strigata* and Collinson has collected the conodonts *Icriodus, Pelekysgnathus, Polygnathus varinodosa, P. triangularis, Spathognathodus inornata* and *S.* cf. *S. aculeatus.* In view of the differences in age, it seems desirable either to recognize the beds at Burlington as belonging in the Maple Mill (inasmuch as the Maple Mill contains identical though thinner siltstone beds at Burlington and other places) or to distinguish them as a separate unit.

Straka (personal communication) correlates the typical English River with the basal and middle McCraney. He has found the "English River" fauna of Anderson (1966) to be identical with the fauna from the Prospect Hill and considers it a Prospect Hill equivalent.

Snyder Creek Formation

The Snyder Creek was named for exposures in Callaway County, central Missouri (Gallaher, 1900), where the formation overlies the Cedar Valley and underlies the Mississipian Bachelor, Chouteau or Burlington formations. The formation is predominantly greenish grey, calcareous and arenaceous shale with limestone beds near the top and bottom and with thin sandstone beds near the base.

Geographically, the formation is very restricted. In outcrop it occurs only in Callaway and Montgomery Counties where it ranges from 60 feet to less than 10. In the subsurface the formation is rather more widespread.

The upper part of the Snyder Creek is profusely fossiliferous, with the brachiopods *Stropheodonta demissa, Schizophoria striatula* and *Spinocyrtia euryteines;* the coral *Cystiphyllum ellipticum;* the bryozoans *Rhombopora missouriensis* and *Lioclema occidens;* and the pelecypod *Paracyclas rowleyi.* The fauna, as listed by Branson (1944), has Middle as well as Upper Devonian affinities, but the conodont fauna contains the species *Polygnathus asymmetrica* (Ziegler, personal communication, 1963) which is an index for earliest Late Devonian time (*toI*). The ammonoid *Manticoceras regulare,* reported from the formation by Unklesbay (1952), is restricted to rocks of Frasnian age. McAlester (1963) described a relatively large Snyder Creek pelecypod fauna that he referred to the Chemung Stage of New York (Cohocton of our Figure 5). His interpretation as well as ours is that the Snyder Creek is Late Devonian in age.

The Snyder Creek is probably a southern extension of the Lime Creek Formation. To the northeast the formation grades into the Grassy Creek.

Glen Park Limestone

At least two formations from different areas have been called Glen Park. Both range from cross-bedded oolitic limestone and fossil coquina through dense well-bedded limestone to limy siltstone and even shale interbedded with limestone. The type section (Ulrich, 1904) in Goetz Quarry near Glen Park, Jefferson County, Missouri, consists of 5 feet of yellowish grey crinoidal oolitic limestone with phosphate nodules. The macrofauna (Weller and St. Clair, 1928; Branson, 1944) is not clearly indicative of either Devonian or Mississippian age. Collinson has collected conodonts that, in addition to weathered Middle Devonian and Ordovician forms, include *Palmatolepis perlobata, P. rugosa, P. glabra, Polygnathus styriaca* and *Polylophodonta* sp. indicating a Late Devonian (*toII-toV*) age. This unit crops out sporadically along the northeast flank of the Ozark uplift from St. Genevieve County to Warren County, Missouri, and has been noted in the subsurface as far northwest as Audrian County. Its maximum thickness is about 20 feet. It generally overlies Ordovician rocks but toward the northwest lies on Cedar Valley and Snyder Creek. It is overlain by the Bushberg Sandstone and by several overlapping Mississippian units.

A second unit called "Glen Park" or "Hamburg Oolite" is of early Kinderhookian age. It carries a better developed macrofauna and a conodont fauna containing significant numbers of *Gnathodus.* Sometimes known as the "Illinois Glen Park," this Mississippian unit is largely confined to the area east of the Lincoln fold but also occurs in northeastern Missouri.

Bushberg Sandstone

Sand eroded during the Devonian and Mississippian from St. Peter and other Ordovician sandstones formed nearshore deposits circling the Ozarks. The resulting sporadic sandstone concentrations mark the limits of transgression of the seas in which shales and limestones were accumulating. Because of derivation from the same source, deposition under similar conditions and spotty distribution, these sandstones are difficult to distinguish. The term Bushberg (Ulrich, 1904) has been applied to both Devonian and Mississipian units (Fig. 5). The originally described section at the Goetz quarry consists of 10 to 14 feet of yellowish brown, friable, porous, slightly phosphatic quartz sandstone. Unweathered Mississippian conodonts, in addition to broken and weathered Devonian and Ordovician forms, occur in all but the lowermost part. The fauna is a typical early Mississippian (Hannibal) fauna, and the Bushberg in its type region appears to be a near-shore sandstone facies of

the Hannibal Shale. The term has been applied erroneously to Devonian sandstones in other parts of Missouri, and the Missouri Geological Survey officially places the Bushberg in the Devonian. The Bachelor of Mehl (1960) undoubtedly represents part of the Bushberg.

Chattanooga Shale

Upper Devonian rocks (Lime Creek and "Chattanooga") are limited to extreme eastern Nebraska. The Lime Creek argillaceous dolomite and dolomitic limestone reaches a maximum thickness of 125 feet there. The argillaceous content increases to the south until in southeastern Nebraska it can no longer be separated from the overlying "Chattanooga" Shale. Regionally, this facies change is evidenced by the lithologic gradation and the general compensating thicknesses of the Lime Creek and overlying shale. This Upper Devonian shale, the "Chattanooga," is typically green-grey to dark grey with occasional *Tasmanites*. In extreme southeastern Nebraska where this shale reaches its maximum thickness of 230 feet, the upper 5 to 10 feet grade into dolomitic limestone. In this area the presence of occasional basal sand grains and the thinning of the underlying Cedar Valley also suggest a pre-Upper Devonian unconformity.

Unconformably overlying the "Chattanooga" Shale in southeastern Nebraska and adjoining areas is the Boice Shale of early Kinderhook age. Overlying the Boice is a dolomitic siltstone-sandstone bed usually less than 5 feet thick, which overlaps both the Boice and the Devonian subdivisions. The Devonian is overlain by sediments of Pennsylvanian age in local uplifted areas and along portions of its eroded edge.

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