THE LA SALLE ANTICLINAL BELT AND ADJACENT STRUCTURES IN EAST-CENTRAL ILLINOIS

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ABSTRACT.—Structural development of the LaSalle Anticlinal Belt and some adjacent structures from the time of deposition of Colchester (No. 2) Coal (middle Pennsylvanian time) to the present within a five county area in east-central Illinois has been interpreted from an isopach map of the Carbondale Formation and a sequence of stratigraphic and structural cross sections.

The Colchester (No. 2) Coal, which is assumed to have been originally deposited over an essentially level surface, is now 1000 feet higher on some parts of the LaSalle Anticlinal Belt than it is in the basin part of the area. About four-fifths of the structural movement that has occurred since deposition of No. 2 Coal is believed to have taken place near the end of, or after, Pennsylvanian time.

Present structure of the Kimmswick "Trenton" Limestone (Ordovician) in the area shows that the structural movement following deposition of No. 2 Coal constitutes less than half the total movement that has occurred during the entire structural history of the LaSalle Anticlinal Belt.

The LaSalle Anticlinal Belt, one of the major structural features of Illinois, extends south-southeastward from north of LaSalle County to northeast Wabash County and from there a short distance into southwest Indiana. Its existence and general location within the several counties it traverses have long been known, and it frequently has been the subject of geologic investigation. Studies have shown it to be a complex structure that along different parts of its trend may consist of (1) a series of en echelon folds, (2) a simple asymmetrical anticline, or (3) a monocline.

Because of a cover of glacial drift and scant subsurface information along the major part of its strike, much of the detail of structure and history of development of the anticline still remains obscure. Opportunities to observe the structure in outcrop generally are limited to the vicinity of LaSalle, near its northern terminus, where the crest has been breached by the Illinois River and some of its tributaries. There Ordovician and Pennsylvanian rocks are well exposed in several places. Smaller outcrops are found in other localities, but they usually are too small to reveal much of the structure. As a consequence of this limited exposure, opportunities for detailed investigation are largely dependent upon subsurface data and methods.

The considerable amount of data from petroleum prospecting along the anticlinal belt in east-central Illinois and the existence of relatively strong folding in parts of this area make it ideal for subsurface investigation of present-day structure and structural growth.

This report is an outgrowth of more comprehensive studies of subsurface Pennsylvanian geology and

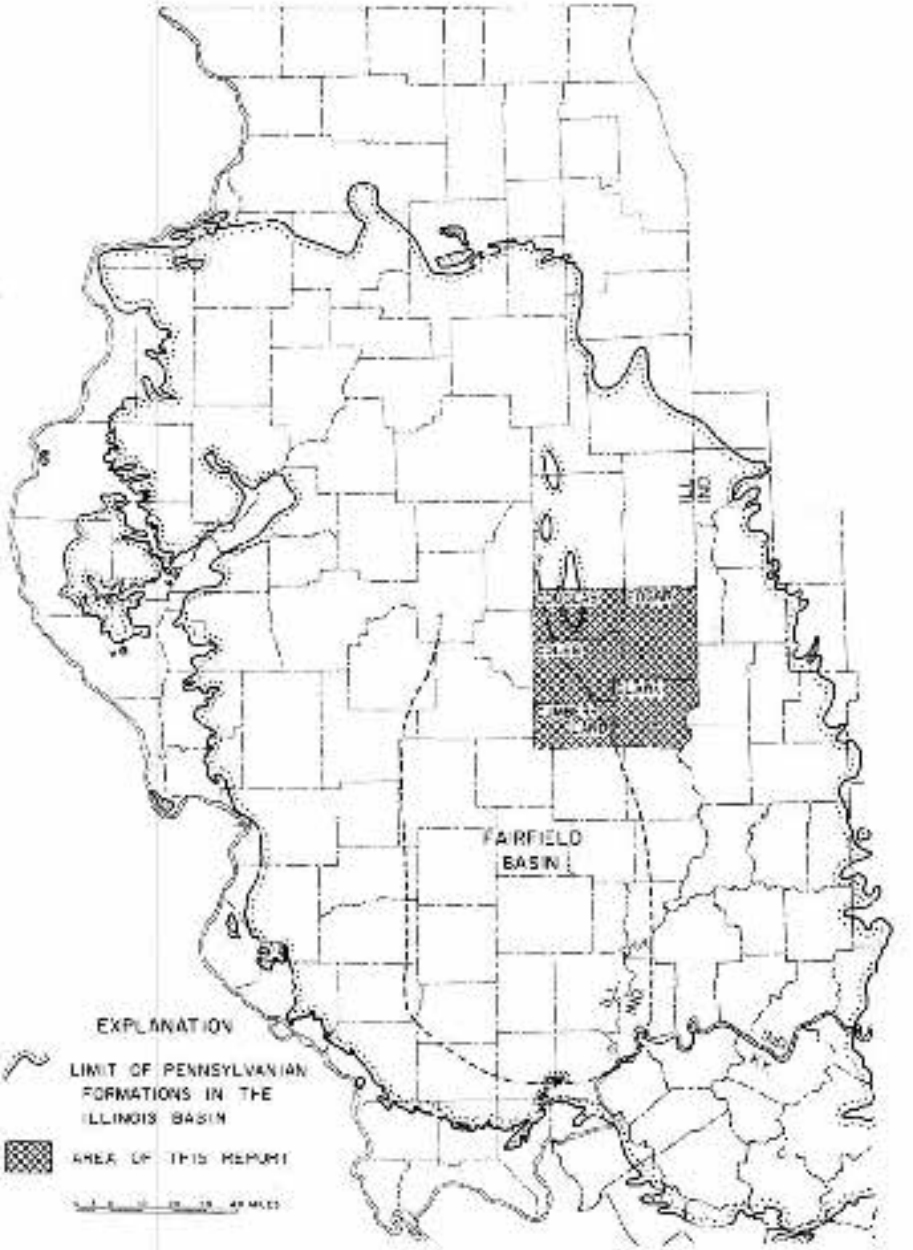

FIGURE 1. Index map showing the location of the report area relative to the Pennsylvanian boundary in the Illinois Basin and relative to the Fairfield Basin.

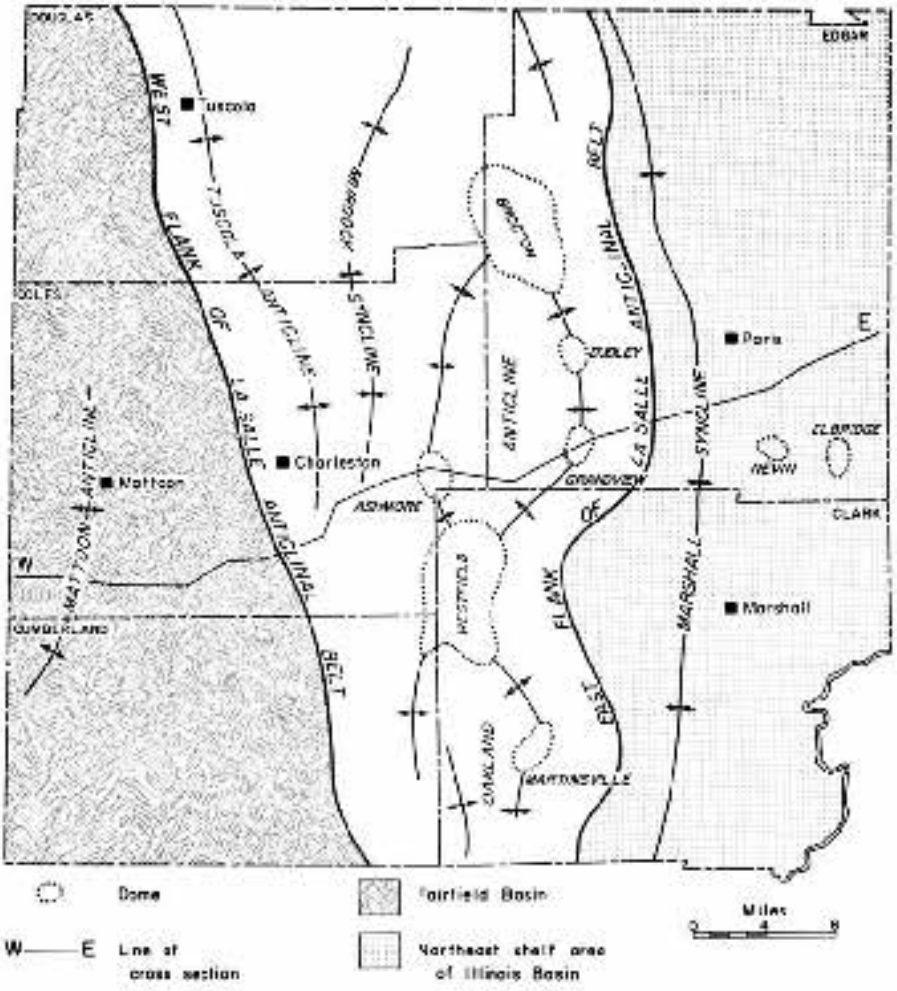

FIGURE 2. Index map of report area showing position of major structural features.

coal resources of several counties in east-central Illinois (Clegg, 1959, 1965). As the studies were concerned mainly with strata of approximately the upper half of the Pennsylvanian System, only that part of the structural development of the LaSalle Anticlinal Belt that took place after deposition of Colchester (No. 2) Coal is considered in the present report. Earlier movement involving lower Pennsylvanian and pre-Pennsylvanian strata has been reported in many publications.

Geographic and Geologic Setting

The area studied includes five counties of east-central Illinois—Cumberland, Coles, Douglas, Edgar, and Clark (Fig. 1).

Figure 2 shows the general posi-

tions and trends of fold axes. Approximately the west third of the study area is in the Fairfield Basin, which is the deeper part of the Illinois Basin. Immediately to the east is the structurally higher LaSalle Anticlinal Belt. The Marshall Syncline borders the LaSalle Anticlinal Belt on the east in Clark and Edgar Counties. Each of these three major structural divisions of the area is characterized by subsidiary anticlines, synclines, domes, and basins.

The Fairfield Basin occupies a considerable part of south-central Illinois. The largest subsidiary structure of that part of the Fairfield Basin included within the report area is the Mattoon Anticline (Fig. 2), which strikes generally north-south along the west side of northern Cumberland and southern Coles Counties. A few smaller anticlines also are present, especially in northern Coles County and in Douglas County, but for the sake of clarity they have not been shown in Figure 2. The Fairfield Basin is structurally the lowest part of the report area.

The LaSalle Anticlinal Belt occupies almost half the report area, with its west flank forming a structural divide at the edge of the Fairfield Basin in Cumberland, Coles, and Douglas Counties. It is a complex structure consisting of subsidiary anticlines and synclines and has a gentle southward plunge.

The structurally highest segment of the LaSalle Anticlinal Belt within the report area is the Tuscola Anticline, an asymmetrical, southward-plunging fold extending into the report area from the northwest part of Douglas County southeast to the vicinity of Charleston in Coles County. Throughout its length its steeper west flank coincides with the west flank of the LaSalle Anticlinal Belt. South of Charleston the LaSalle Anticlinal Belt becomes generally monoclinal, with strata dipping less steeply westward into the Fairfield Basin.

The small, gently southward-plunging Murdock Syncline lies adjacent to the east side of the Tuscola Anticline in Douglas County and northern Coles County. Limited data preclude accurate definition of the north and south ends of the Murdock Syncline. It probably loses its identity in Champaign County a few miles north of Douglas County. There is some indication that towards its south end the syncline is less prominently developed and that it may swing towards the southwest around the south end of the Tuscola Anticline to form a low cross fold in the west flank of the LaSalle Anticlinal Belt a few miles south of Charleston.

The most complex subsidiary structure of the LaSalle Anticlinal Belt in the report area is the Oakland Anticline. It is a composite structure consisting of several domes, anticlines, synclines, and poorly defined basins. Most prominent of these are the Brocton Dome in western Edgar County and the Westfield Dome in northwestern Clark County. The Oakland Anticline is an asymmetrical fold with its steeper east limb being common to the west flank of the Marshall Syncline.

The Marshall Syncline also is asymmetrical, with a comparatively steep west flank. It plunges gently southward and strikes north-south through Clark County and the south-

ern half of Edgar County, then swings slightly northwestward around the east side of the Brocton Dome. It appears to extend north of the report area at least as far as Iroquois County. South of Clark County it becomes broader and more gently dipping on both flanks, and ultimately loses its identity against what appears to be a low and irregular east-west cross fold of the LaSalle Anticlinal Belt in south-central Crawford County. The Elbridge Dome and the Nevins Dome on the east synclinal flank in southeastern Edgar County were formed by the draping of rock strata over deeply buried structures generally considered to be Silurian reefs.

Materials and Methods

Almost all of the data used in this study were obtained from records of petroleum test drilling. The most dependable and most extensively used of these were electric logs.

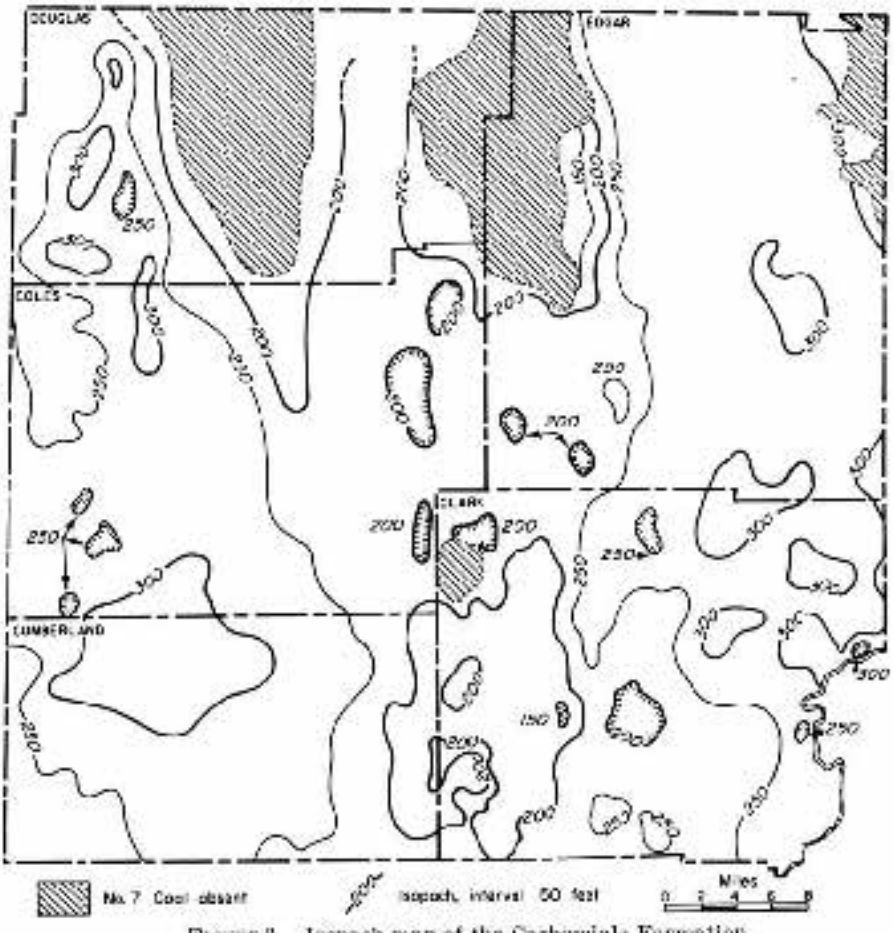

FIGURE 3. Isopach map of the Carbondale Formation.

The data were used to construct an isopach map (Fig. 3) and a progressively developed cross section extending east-west across the central part of the report area (Fig. 4). The map and cross section, in conjunction with structure contour maps of three Pennsylvanian coals (Clegg,

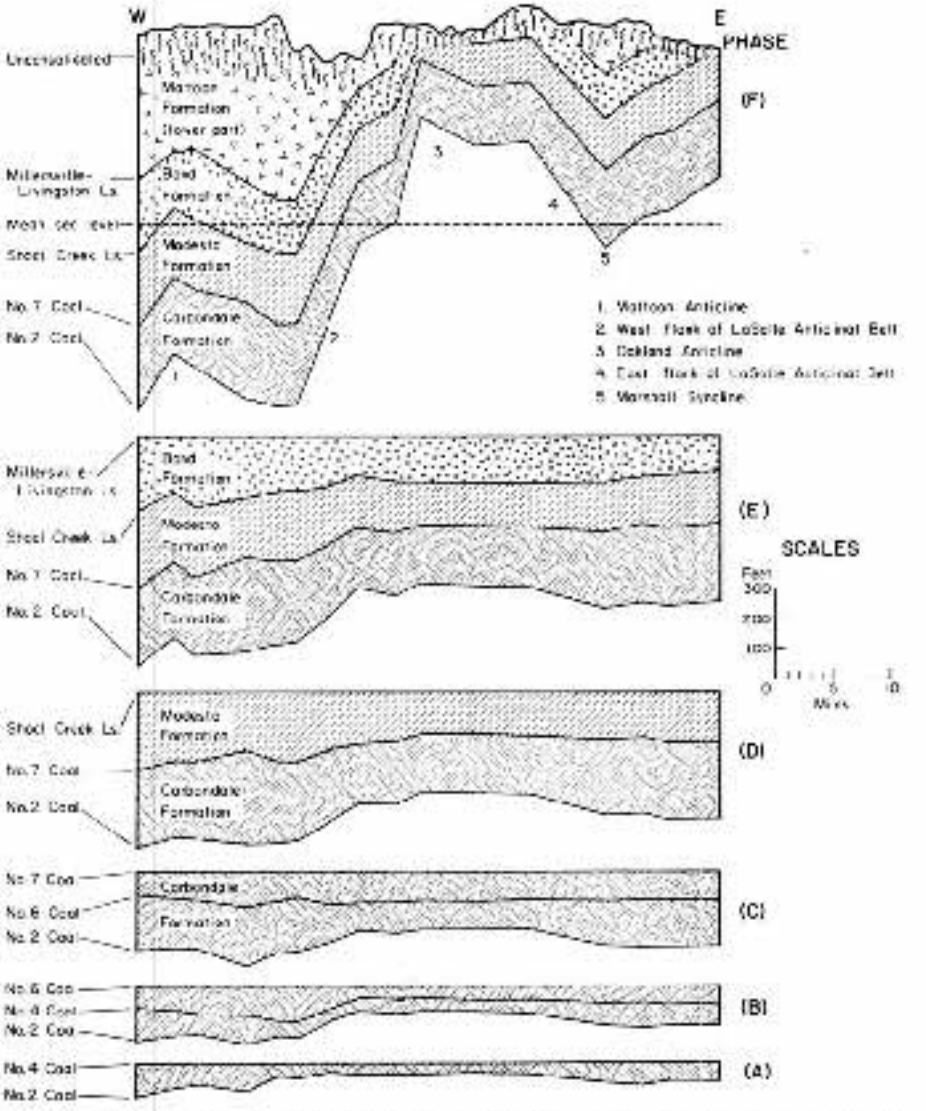

FIGURE 4. Stratigraphic and structural cross sections showing progressive development and present structure of the LaSalle Anticlinal Belt and adjacent structures in central Coles and Edgar Counties. The line of cross section is shown on Figure 2 (W-E).

1960, 1965), provide a basis for studying structural development. Hence the report is based almost entirely upon subsurface geologic materials and methods.

The lines of isopach maps connect points of equal vertical distance between two reference surfaces and thereby show any variation in thickness of the intervening strata. They also permit interpretation of the structure of the lower reference surface as it was at the time the upper was formed, thereby revealing the extent and nature of any structural movement that may have taken place within the time interval between the formation of the two surfaces. For instance, the structure of Colchester (No. 2) Coal as it was at the time Danville (No. 7) Coal was deposited can be interpreted from the isopach map (Fig. 3). The detail with which structural movement can be shown is determined by the quantity and quality of subsurface data used and the contour interval selected for mapping.

Use of isopach maps for structural interpretation necessitates, of course, the assumption that the strata involved were deposited originally over essentially flat and horizontal surfaces. Such an assumption generally is considered to be valid where Pennsylvanian limestones and coals in Illinois are concerned.

To interpret tectonic movement from isopach maps and stratigraphic cross sections the possible role played by differential compaction of sediments must be considered. The draping of Pennsylvanian strata over Silurian reefs in southeastern Edgar County is the result of differential compaction of thicker sediments in areas adjacent to the reefs. Probably some of the smaller domes of the Oakland Anticline also are due, in part at least, to differential compaction over and around sandstone bodies. In general, however, tectonic movement appears to have been the controlling factor that determined major locations and trends of the structural features in this area, with differential compaction serving only to increase the degree of structural dip.

Stratigraphic cross sections offer a somewhat more limited means of studying structural development in that they normally display conditions in one direction only, that is, along the line of the cross section. However, when supported by isopach and structure maps of the area traversed, their reliability as indicators of conditions for some distance on either side of their line of traverse is considerably enhanced. The same reasoning applies to the use of structural cross sections. As is true of isopach maps, the originally level deposition of the reference strata must be assumed and the possible role of differential compaction of sediments considered.

Inasmuch as they are supported by detailed structural maps of several coals (Clegg, 1959, 1965), the isopach map and cross section prepared for this report are considered to provide a reasonably reliable picture that may, in general, be applied to the area as a whole.

Interpretation

The Carbondale Formation includes all strata between the top of Danville (No. 7) Coal and the base of Colchester (No. 2) Coal. Al-

though the isopach interval is 50 feet (Fig. 3), the positions of all the major structural features except the Marshall Syncline can be identified on the isopach map. The Fairfield Basin is the area generally west of the 250-foot contour that extends from north-northwest to south-southeast through Douglas, Coles, and Cumberland Counties. Maximum thickness of the Carbondale Formation in this part of the Fairfield Basin is slightly more than 300 feet. The presence of relatively smaller positive structures within the Fairfield Basin, i.e., the Mattoon Anticline and other small folds north of it, is suggested by the hachured 250-foot contours. Stratigraphic thinning over these structures indicates that movement took place there during the time interval between deposition of No. 2 Coal and No. 7 Coal.

The LaSalle Anticlinal Belt, which occupies a roughly triangular area in the central part of the report area, also is readily recognizable. Here stratigraphic thickness between No. 2 and No. 7 Coals is less than 250 feet, with a minimum of slightly less than 150 feet. The positions of the Tuscola Anticline, the Murdock Syncline, and the composite Oakland Anticline, all structural elements of the LaSalle Anticlinal Belt, also are identifiable. Lesser positive structures of the Oakland Anticline are indicated by 200-foot hachured contours. As suggested previously, differential compaction of sediments around sandstone bodies within and below the Carbondale Formation may be in part responsible for minor variation in thickness of the Carbondale strata in at least some of these small areas.

Although Carbondale strata thicken east of the Oakland Anticline, there is no tendency towards general thinning east of the present position of the axis of the Marshall Syncline in Clark and Edgar Counties. The implication is that development of the east flank of the Marshall Syncline in Illinois had not begun before deposition of the Danville (No. 7) Coal was completed.

Absence of No. 7 Coal from four localities in the area (Fig. 3) is a result of post-Pennsylvanian erosion. It is significant that the Carbondale Formation is relatively thinner approaching those barren localities on the LaSalle Anticlinal Belt, indicating that during deposition of Carbondale strata the elevation of No. 2 Coal over these localized areas increased relative to that in the surrounding areas. There was no thinning of the Carbondale Formation approaching the barren area in northeast Edgar County, however, because development of the east flank of the Marshall Syncline had not begun by the time No. 7 Coal was deposited.

Depth and elevation data from sixteen electric logs were used in preparing a progressively developed stratigraphic cross section and a structural cross section from west to east across the central part of the report area (Fig. 4). The line traversed by the section is indicated in Figure 2. This line crosses the LaSalle Anticlinal Belt near the south ends of both the Tuscola Anticline and the Murdock Syncline where they are considerably less pronounced than they are farther north. Structural growth can best be followed in Figure 4 by beginning at

the bottom and progressing upward.

Phase A shows that by the time Summum (No. 4) Coal had been deposited Colchester (No. 2) Coal had already been slightly folded. Movement is reflected in the upfolding of No. 2 Coal over the Mattoon Anticline, downfolding across the Fairfield Basin, and upfolding over the general area of the LaSalle Anticlinal Belt. The crest of the Mattoon Anticline at this time was east of its present position (shown in the structural cross section, phase F) and the deepest part of the Fairfield Basin was west of its present position. There was very little difference in elevation across the entire Anticlinal Belt at that time, whereas at the present time the Oakland Anticline is considerably higher than that part of the anticlinal belt to the west. East of the Oakland Anticline the dip was gently eastward and there was no indication of an east flank to the Marshall Syncline. The very slight variation in stratigraphic thickness just east of the present location of the axis of the Marshall Syncline probably is a function of differential compaction of sediments. Minor thickness variations of this sort are present in all the succeeding phases, but as they do not occur repeatedly in the same place and do not persist for a long period of time, they probably result from differential settling rather than tectonic movement.

Phase B was constructed with the top of Herrin (No. 6) Coal as the horizontal datum and shows the structural movement that had taken place after deposition of No. 4 Coal. That there seems to have been no additional development of the Mattoon Anticline is indicated by lack of a fold at that point in No. 4 Coal. The No. 2 Coal, however, still retained essentially the same structure here that it had when No. 4 Coal was deposited.

The westward dip of No. 4 Coal on the west flank of the LaSalle Anticlinal Belt indicates continued structural movement there. This movement is also reflected in No. 2 Coal which by this time dipped somewhat more steeply than it did when No. 4 Coal was deposited.

Minor downfolding of both No. 4 and No. 2 Coals on the west side of the LaSalle Anticlinal Belt may indicate the position of the south end of the Murdock Syncline. If so, it was somewhat east of its presumed present position. However, as previously explained, the location of the south end of the Murdock Syncline is not well known.

Only minor additional folding had taken place along the west side of the Marshall Syncline after deposition of No. 4 Coal, as evidenced by the very slight eastward dip of that coal. This very slight dip could be attributed to differential compaction rather than to tectonic movement. The No. 2 Coal still retained essentially the same structural attitude that it had when No. 4 Coal was deposited. The east flank of the Marshall Syncline had not begun to develop when No. 6 Coal was deposited.

Phase C was constructed with the top of Danville (No. 7) Coal as the horizontal datum. This phase includes the same stratigraphic interval as that mapped in Figure 3, the Carbondale Formation, and shows the accumulated structural deformation that had taken place from

the time of formation of No. 2 Coal to that of No. 7 Coal. The No. 6 Coal dipped gently from the west side of the area into the Fairfield Basin and indicated that no further folding of the Mattoon Anticline had taken place since No. 6 Coal was deposited. The position of the anticline was still reflected in No. 2 Coal, however, which retained the folding it had undergone prior to deposition of No. 4 Coal.

The lowest part of the Fairfield Basin in Coles County was still west of its present position and was slightly lower structurally, as indicated by the downfolding of No. 6 Coal and by the additional downfolding of the No. 2 Coal. At the present location of the lowest part of the Fairfield Basin, No. 6 Coal was slightly higher than on either side and showed no evidence of continued folding along the west flank of the LaSalle Anticlinal Belt. The reason for the local structural high of No. 6 Coal is not clear. It may be a function of differential compaction of sediments. The vertical distance between key strata is considerably greater west of the LaSalle Anticlinal Belt, and electric logs indicate that much of the sedimentary material consists of coarse clastics. However, there do not seem to be any locally developed sandstone bodies sufficiently large to account for the amount of difference in elevation shown by No. 6 Coal. The No. 2 Coal still showed the slight downfold that may reflect the south end of the Murdock Syncline, but No. 6 Coal indicated no evidence of further development of this structure. To the east, No. 6 Coal was essentially level, indicating lack of further development of the west flank of the Marshall Syncline. However, the earlier development of this west flank was still reflected by No. 2 Coal, but neither No. 6 nor No. 2 Coal showed any evidence of the beginning of an east synclinal flank in Illinois.

Phase D was constructed with the base of the Shoal Creek Limestone as the horizontal datum. It includes the stratigraphic thickness of two formations—the Carbondale Formation (phase C) and the overlying Modesto Formation, which includes strata between the top of Danville (No. 7) Coal and the base of the Shoal Creek Limestone.

The No. 7 Coal, since its original deposition, had assumed a somewhat anomalous structural attitude west of the LaSalle Anticlinal Belt. As was suggested concerning the structure of the No. 6 Coal in phase C, the structure of No. 7 Coal may be a function of differential compaction. It reflected slight continued development of the Mattoon Anticline but stood structurally higher east of there. It was downwarped at the present position of the lowest part of the Fairfield Basin in the area and showed evidence of further folding of the west flank of the LaSalle Anticlinal Belt. It showed a slight rise at about the present position of the west flank of the Oakland Anticline, which is at the same position as the east flank of the small downfold reflected in No. 2 Coal and thought to be the south end of the Murdock Syncline. From there No. 7 Coal dipped gently eastward with a very slight upfolding, also reflected in the underlying No. 2 Coal, just east of the present axis of the Marshall Syncline. There still

was no indication of the beginning of an east flank of the Marshall Syncline when the Shoal Creek Limestone was deposited.

Phase E (fig. 4) was constructed using the Millersville-Livingston Limestone as the horizontal datum. Three formations, Carbondale, Modesto and Bond, are included, the latter consisting of strata between the base of the Shoal Creek Limestone and the top of the Millersville-Livingston Limestone. The upper limestone is known as Millersville Limestone in the Fairfield Basin and as Livingston Limestone east of the LaSalle Anticlinal Belt and in Indiana (Kosanke et al., 1960).

The Shoal Creek Limestone had, by this time, been folded over the Mattoon Anticline and from there rose gradually eastward, indicating a westward shift of the lowest part of the Fairfield Basin and continued but slight folding of the west part of the LaSalle Anticlinal Belt. It remained essentially level from there to the present position of the axis of the Marshall Syncline and showed slight upfolding of the east limb of this structure. Thus, the first indication of development of the east flank of the Marshall Syncline in Illinois did not occur until about the time the Livingston Limestone was deposited. There was no reflection of the south part of the Murdock Syncline in the structure of the Shoal Creek Limestone, nor had there been any further noticeable development of the Oakland Anticline.

Colchester No. 2 Coal reflected the continued folding of the Mattoon Anticline and the westward shift of the lowest part of the Fairfield Basin. It also showed the continued development of the west flank of the LaSalle Anticlinal Belt. The suspected position of the south end of the Murdock Syncline also was still evident in the structure of No. 2 Coal, as was the incipient east limb of the Marshall Syncline.

Phase F, showing the structure as it is at the present time, also shows that the folding that took place following deposition of the Millersville-Livingston Limestone was greater than the total folding that had taken place between the time of deposition of No. 2 Coal and that of the Millersville-Livingston Limestone. The amount of folding that occurred between deposition of No. 2 Coal and the Millersville-Livingston Limestone is noticeably less than that following deposition of the limestone. At the time of formation of the limestone, No. 2 Coal was only 200 feet higher on top of the LaSalle Anticlinal Belt where that structure is traversed by the cross section than it was in the Fairfield Basin. At the present time the elevation difference, measured at the same places, is 1000 feet, indicating that after deposition of the Millersville Limestone the elevation of No. 2 Coal on the LaSalle Anticlinal Belt had increased 800 feet relative to its elevation in the Fairfield Basin.

The Oakland Anticline had its maximum development during the late stages of folding and now stands considerably higher than the rest of the LaSalle Anticlinal Belt in this part of the report area. The two high points of the anticline (fig. 4) are near the tops of the Ashmore and Dudley Domes. The top of the anticline is somewhat lower between these two subsidiary structures.

The Tuscola Anticline, which is too far north to be reflected in the cross section, currently is the structurally highest feature of the LaSalle Anticlinal Belt in the report area. Its structure, based upon contour maps of three coals (Clegg, 1959), indicates that it, too, underwent considerable deformation during the late stages of tectonic development, i.e., after deposition of the Millersville Limestone.

The Murdock Syncline is not depicted in the structural cross section. Whether the slight downfolding shown in the stratigraphic section is actually a reflection of earlier stages in the development of the Murdock Syncline is conjectural. It is possible that the syncline had its inception prior to deposition of the Millersville Limestone and that subsequent folding deepened the structure farther to the north while at the same time the south end was tilted towards the west. The position of the Oakland Anticline adjacent to the south end of the Murdock Syncline is such that tilting and concurrent westward shifting of the syncline's axis could have occurred as the south part of the Oakland Anticline attained its present relative structural elevation.

The above suggestion is offered in support of the previous suggestion that towards its southern end the Murdock Syncline may swing westward around the south end of the Tuscola Anticline. Until more information is available, however, the position of the southern part of the Murdock Syncline remains unknown. It is possible that it never extended farther south than the vicinity of Charleston or that it originally extended farther southward but that the southern extremity was obliterated during the last stages of tectonic activity.

That the present structure of the Marshall Syncline in Illinois developed almost entirely after deposition of the Livingston Limestone is indicated in the structural cross section. Incipient development of the east limb as noted in phase E, had begun when the Livingstone Limestone was deposited, but full development came later. The exact time of the last stages of tectonic activity is not known. In other parts of Illinois, Pennsylvanian strata younger than the Millersville-Livingston Limestone are structurally deformed, suggesting that most of the movement came about near the end of or, more likely, following the close of the Pennsylvanian Period.

Summary and Conclusions

The structural development described includes only a small part of the total tectonic history of the LaSalle Anticlinal Belt and adjacent structures. Formation of the LaSalle Anticlinal Belt originally began at least as early as Ordovician time. It appears to have developed slowly until the end of Mississippian time. Siever (1951) showed that in counties south of the study area a period of strong folding occurred following Mississippian sedimentation. This was followed by a long period of subaerial erosion and peneplanation of the area. He indicated that a second uplift occurred after peneplanation followed by a cycle of erosion that resulted in the incision of deep channels in the peneplain surface. It was upon this incised surface that detritus from the Ap-

palachian geosyncline and some locally derived sediment were deposited. These sediments filled the channels, buried the hills, and ushered in Caseyville deposition. Available records show that the area of this report underwent the same structural and erosional history as did the counties to the south.

By the time of deposition of the first strata of the Carbondale Formation, the erosional irregularities had been deeply buried and No. 2 Coal was laid down over an essentially level surface and hence reflected none of the earlier folding.

The top of the Kimmswick "Trenton" Limestone is 4000 feet below sea level in the Fairfield Basin and about 1,500 feet below sea level on the Ashmore Dome of the Oakland Anticline, a difference of 2500 feet. As No. 2 Coal at the same localities has been shown to have a difference of only 1000 feet in elevation, it is evident that the structural movement that followed deposition of No. 2 Coal constitutes less than half of the total movement that has taken place.

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