The Lovers Leap section and related observations of multiple and cross-cutting glacial drifts in the Great Bend area, Indiana

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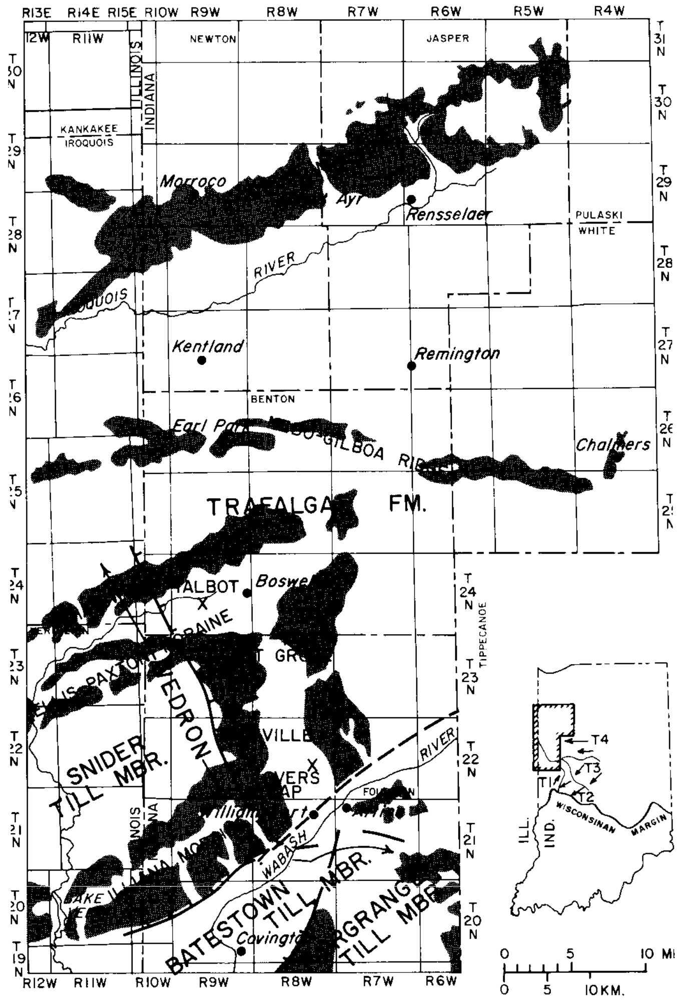


Figure 1. Map of a part of northwestern Indiana and adjacent Illinois showing glacial moraines, stratigraphic-unit boundaries, postulated directions (arrows in index map) of Trafalgar ice movement (Huron-Erie Lobe), and locations of four sites mentioned in the text. Unit boundaries indicated by hachured lines and, where buried, by dashed line. Numbers associated with arrows in index map refer to the numbered Trafalgar tills shown in Figure 4. For details of locations of the four sites, see Figure 2. Partly from Bleuer and others (1983).

LOCATION AND SIGNIFICANCE

The glacial geology of the area north of the Great Bend of the Wabash River in west-central Indiana (Fig. 1) illustrates important early developed principles regarding multiple continental glaciation, the movements of adjoining ice lobes, and the interrelated deposits. Perhaps the first documentation of a lithologically definable till stratigraphy that is basic to interpretation of glacial movement and sedimentation throughout much of the Midwest was made in the Great Bend area. A half century after the first documentation was made, the till stratigraphy here would emerge as the regionally mappable sequence. Further, it would illustrate cross-cutting relationships of morainal ridges and the interbedding of multiple-source deposits. Here, therefore, is a clear demonstration of how deposits first classified on the basis of surface morphology relate to those that are classifiable on a mappable, till-stratigraphy basis.

Four vantage points in the Great Bend area are particularly focal for illustration of the basic concepts that are addressed here. Foremost is the Lovers Leap section (also known historically as the Stone Creek section), which is exposed on the northwest side of Big Pine Creek, a Wabash River tributary, 4 mi (6.4 km) north of Williamsport, Warren County, Indiana, NW¼NW¼NW¼Sec.23,T.22N.,R.8W., Williamsport 7½-minute Quadrangle (Fig. 2D). Here well exposed are three superimposed tills and other drift materials that a pioneer of continental-glaciation theories, Thomas Chrowder Chamberlain, used to demonstrate his beliefs. In fact, our Figure 3 is taken from Chamberlin's contribution to James Geike's (1894) *The Great Ice Age* and was used as Geike's frontispiece. (See the further history and significance of this site and of Chamberlin's work in Bleuer, 1975.)

Although the Lovers Leap section is on private property, access may be readily obtained by responsible educational and professional groups or individuals by asking permission in advance from the owner, Mr. Deane Braymeyer of Attica, Indiana.

A single exposure such as that at Lovers Leap cannot stand alone as demonstration of the complex, modern interpretation of glacial stratigraphy of the Great Bend area. The locations of three supplementary instructive sites, therefore, are shown in Figures 1 and 2A, B, C, and D and described in the following pages (Talbot, Locust Grove, and Judyville).

The first supplementary site having a key role in our theme is at Judyville, about 5 mi (8 km) west-northwest of Lovers Leap and 2.5 mi (4 km) west of the intersection of U.S. 41 and Indiana 63, Warren County, Indiana, NW¼NE¼NW¼Sec.13, T.22N.,R.9W., West Lebanon 7½-minute Quadrangle (Fig. 2C). The vantage points here are along public roads of free access. The second supplementary site, also of free public-road access, is at Locust Grove about 6 mi (9.6 km) north-northwest of Judyville and 3.8 mi (6 km) west of U.S. 41, center of N-S line between sees. 15 and 16, T.23N.,R.9W., Tab 7½-minute Quadrangle (Fig. 2B). These two sites provide views of morainal ridges left by ice of both northern and eastern sources. Here one may appraise topographic form together with the facts from augering programs and formulate for himself, even though in the footsteps of both

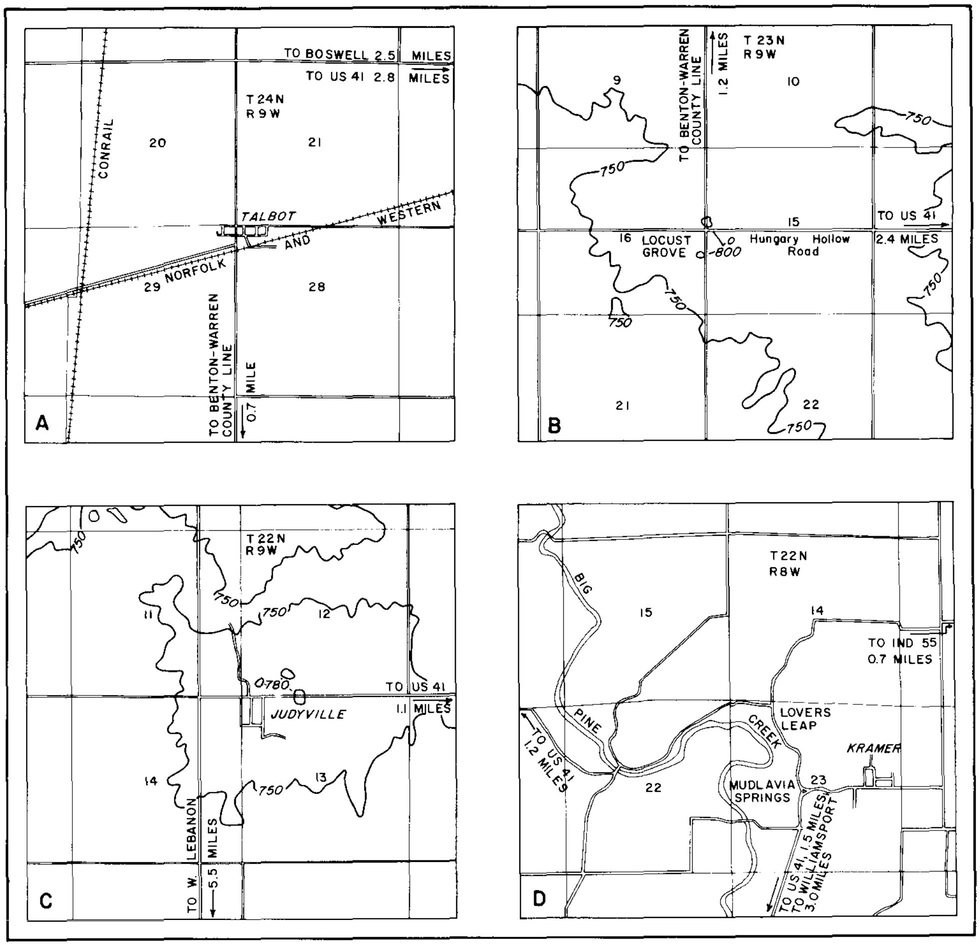


Figure 2. Four maps showing locations of and access to vantage points for field demonstration of glacial geology in the Great Bend area. A, Talbot area; B, Locust Grove area; C, Judyville area; and D, Lovers Leap area. See same locations at a smaller scale in Figure 1. Areas between 750- and 800-ft (225- and 340-m) contours in map B and between 750- and 780-ft (225- and 234-m) contours in map C define the highest parts of the moraine defining the distal Trafalgar margin shown in Figure 1. Bases for the four maps are from U.S. Geological Survey 7½-minute Quadrangle maps, in order from A to D: Boswell and Tab; Tab; West Lebanon, Tab, and Williamsport; and Williamsport.

the pioneers and modern glacial stratigraphers, the answers to questions that have been posed on the cross-cutting nature and continuity of multiple drifts.

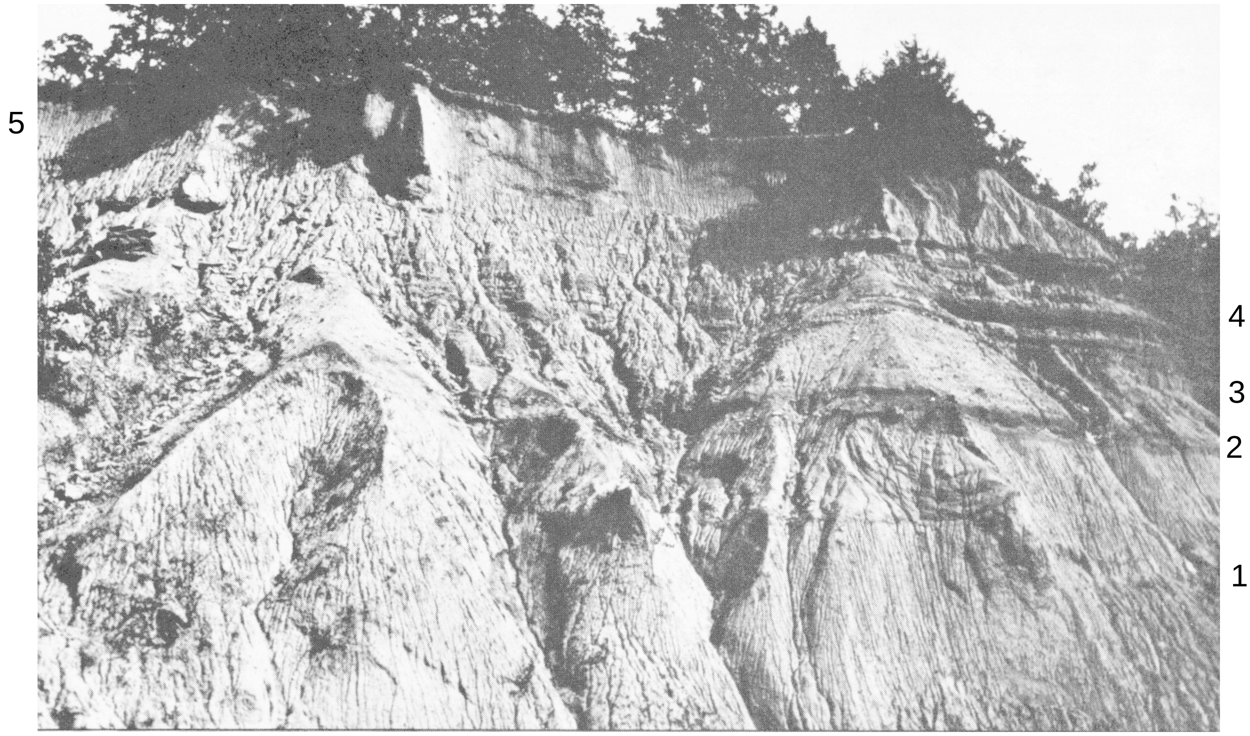
A third supplementary site is in the impressive boulder field (glacial erratics) immediately north of the Chatsworth Moraine (Fig. 1) and along the county road immediately south of Talbot, Benton County, Indiana (section line between secs. 28 and 29, T.24N.,R.9W., Baswell 7½-minute Quadrangle (Fig. 2A). Here the erratics are associated with disintegration till, and not only were they mapped by Frank Leverett (as recorded by Leverett and Taylor, 1915, pl. 6), but they also served as Chamberlin's (1883) type examples for his concept of englacial drift.

The multiple purpose of this chapter is now evident. To summarize, highlights of the glacial geology of the Great Bend area are to be advanced as especially pertinent to the understanding not only of an important facet of Indiana geology, but also of the materials and means of continental glaciation in general. At the same time, a recurrent history-of-geology element in our theme is to pay tribute to one of America's great pioneering geologists, Thomas Chrowder Chamberlain (1843-1928), whose higher educational and professional experiences began at Beloit College in Wisconsin and, after many scientific travels and contributions, ended at the University of Chicago. (See Fenton and Fenton, 1956, p. 302-317.)

GENERAL INFORMATION

Lovers Leap Section

Although the section at Lovers Leap on Big Pine Creek (Figs. 1, 2D, and 3) played an important role in Chamberlin's concept of imbricate drift sheets, it was long denied later at-



SECTION OF STONE CREEK, NEAR WILLIAMSPORT, INDIANA:

TO ILLUSTRATE THE IMBRICATION OF THE DRIFT-SERIES. (Seep. 736).

1. Reddish Till. 2. Old ferruginous gravel. 3. Blue Till. 4. Gravel, fresher than 'old ferruginous gravel' (2). 5. Gray Till. The Tills differ not only in colour but in constituents.

Figure *3*. Photograph (recomposed) showing section at Lovers Leap on Big Pine Creek that was used as the frontispiece of James Geikie's The *Great Ice Age* (1894, 3d cd.). This is T. C. Chamberlin's photograph (labeled as the Stone Creek section), which is numbered 16 in the U.S. Geological Survey Library in Denver, Colorado (I. P. Schultz, written communication, 1973).

tention to its focal role because it was lost under the designation Stone Creek section. As Bleuer's (1975) study showed, no creek by that name ever existed in that area, but comparisons of the early description and photograph (Fig. 3) with the present-day exposure removed all doubt that this section is the one that beautifully supported the principles espoused by Chamberlain in his publications of 1883, 1888, and 1894. This exposure along the northeast bluff of the creek (detailed location given above) is more than 150 ft (45 m) wide, its lowest part being exposed at the far southeast end. It is described in modern stratigraphic terms as follows:

Trafalgar Formation

1. Till, loam; well-developed gray-brown podzolic soil in upper 2-3 ft (0.6-0.9 m); some loess admixture within upper profile, leached in upper 3-3.5 ft (0.9-1.0 m), variably along exposure; rootlets penetrate vertical joints as much as 10 ft (3.0 m); oxidized yellowish-brown (10YR 6/4 to 5/4) to 6 ft (1.8 m), grading to 10YR 5/2 below 10 ft (3 m); variable oxidation depth along exposure about 8-12 ft (2.4-3.6 m) deep; calcareous; coarse fissility developed on outer surface; massive inside; hard and dry till stands as bold vertical cliff, thickest at east end; base of till is undulatory and has 4-5 ft (1.2- 1.5 m) of relief; although uniform in most places, one spur exposes stratified till, sand, and pea gravel in lower 5 ft (1.5 m) and in places the basal few inches are cemented with carbonate; basal 9-10 in (22.5-25 cm) oxidized; unit ranges between 12 and 20 ft (3.6 and 6.0 m) in thickness . . . . 0.0-17.0 ft (0.0-5.1 m)

Wedron Formation, 85 ft (25 m) exposed

Unnamed at member rank

2. Gravel, medium to coarse; interbedded sand; scattered carbonate-cemented masses, the upper 5-10 in (13-25 cm) being entirely cemented; thin, highly oxidized gravel at base where immediately above till; unit ranges between 15 and 20 ft (4.5 to 6 m) in thickness. . ..17.0-40.0 ft (5.1 -12.1 m)

Snider Till Member

3. Till, clay loam to silty clay loam, grayish-brown (10YR 5/2), calcareous; massive to coarsely angular, blocky jointing very sticky; abundant shale pebbles; oxidized in upper 3-6 in (7.5-15 cm); marked N-S orientation of elongate pebbles (see Bleuer, 1974, Figure 4); unit ranges between O and 11 ft (3.3 m) in thickness. . . .40.0-51.0 ft (12.1 -15.5 m)

4. Sand, medium-to coarse-grained, poorly exposed; becomes

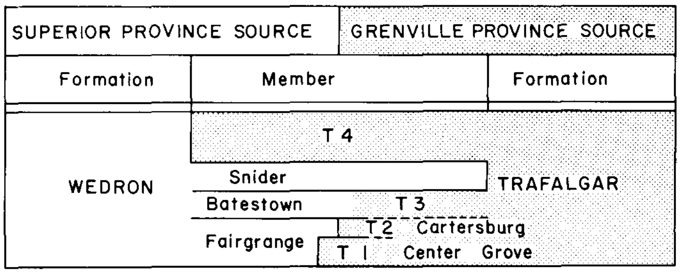


Figure 4. Diagram showing classification of Wisconsinan deposits of the lake Michigan Lobe (source in the Superior Province) and Huron-Erie Lobe (East White Sublobe; source in the Grenville Province). Symbols T1 through T4 represent successively deposited eastern-source tills representing directions of ice movements shown by arrows in the index map of Figure 1.

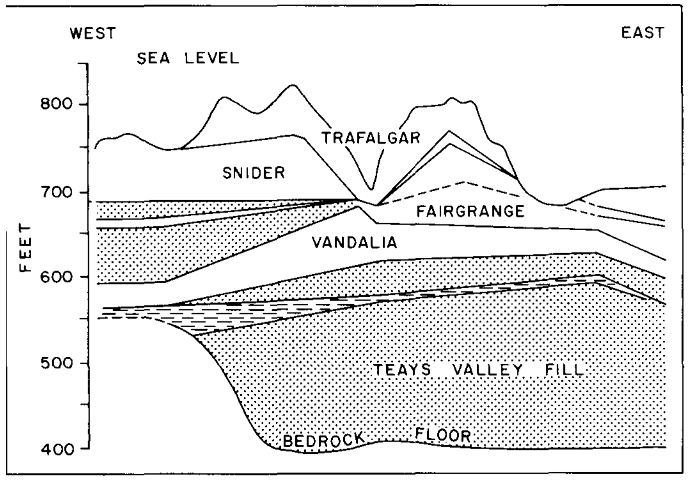


Figure 5. West-to-east cross section extending about 24 mi (38.4 km) along the crest of the Ellis-Paxton Moraine from the Illinois state line and extending off the moraine to the eastern Warren County line in Indiana (Fig. 1.) Section shows eastern-source till (Trafalgar Fro.) overlapping buried moraine forms made up of the Snider and Fairgrange Till Members of northern source (Wedron Fro.). The Vandalia Till Member (Glasford Fro.) is the youngest Illinoian till shown. The Teays Valley crosses line of section obliquely from west-northwest to east-southeast. Patterned units consist of stratified sediments.

more gravelly to southeast and merges with upper gravel; basal 3-4 ft (0.9- 1.2 m) at southeast end is heavily iron stained, yellowish-brown to olive-brown (1OYR to 5YR 4/8); calcareous throughout unit is 2 to 3 ft (0.6 to 0.9 m) thick at east end and 35 to 40 ft (10.6 to 12.1 m) thick at west end. . . .51.0-62.0 ft (15.5-18.8 m)

Fairgrange Till Member

5. Till, loam; scattered slightly more clayey masses in upper 5 ft (1.5 m); generally pinkish or lavender cast in moist and dry exposures, respectively top 10 in (25 cm) heavily streaked and oxidized by groundwater; intense brown (7.5YR [to 5YR] 5/6); medium to coarse angular, blocky jointing; few joint coats of 5YR 3/4; below is grayer (5YR 5/1); abundant joints oxidized as much as half an inch on either side and having heavy dark oxide coats; calcareous; base is stream level. . . .62.0- 102.0 ft (18.8-31 m)

Although this section is so situated in west-central Indiana that the Batestown Till Member (Wedron Formation) shown in Figs. 1 and 4 is absent, the Big Pine Creek exposure is an excellent example showing that eastern-source till (upper tongue of the Trafalgar Formation) overlaps northern-source tills (Snider and Fairgrange Till Members, Wedron Formation). The latter tills are defined from the nearby Danville, Illinois, area (Johnson and others, 1972). This sequence of an upper brown to gray loam till, a middle clayey till, and a lower pinkish to brown loam till is basic to all of west-central Indiana. Snider till can be recognized by drillers owing to its texture and shale content, and it effects a distinctive signature on gamma-ray logs (Fig. 6). It is, therefore, a key unit for distinguishing the Trafalgar-Wedron relationships, that is, the relationships between tills of eastern and northern sources.

In detailed analyses in sedimentation laboratories, these tills may be further distinguished. A large amount of garnet in relationship to epidote identifies the Trafalgar till as emanating from its eastern source, the Grenville Province, noted in Figure 4, just as the underlying Snider and Fairgrange till mineralogy reveals their northern source as the Superior Province. In addition, high bulk-magnetic susceptibility parallels high garnet epidote ratios in the eastern-source tills.

These stratigraphic relations became fully clear in the late 1970s and early 1980s, and they appear to have settled some standing problems. For example, does the Crawfordsville Moraine (named in Montgomery County, Indiana) extend north of the Wabash River and there continue north to Benton County (the ridge on which Judyville and Locust Grove are shown in Fig. 1) as proposed and mapped by Wayne (1965)? And does this Trafalgar morainal material correlate with the 20,000-year-old Cartersburg Till Member of the Trafalgar Formation at the Cartersburg type locality in Hendricks County, Indiana, there forming the uppermost member of the Trafalgar? If both answers are yes, the entire sequence of central Illinois tills of the Wisconsinan Stage would have been deposited in a span of time of less than 1,000 years. This would have required an uncommonly high rate of advance by Wedron ice, faster than the already known high rate of Trafalgar advance. Unraveling the complexly interfingered eastern and northern till sequence shown in Figures 4 and 6 for west-central Indiana, however, has obviated the unlikely circumstance posed above. The Trafalgar till northwest of the Great Bend of the Wabash must be considered as a younger till than any type Trafalgar till, and the Cartersburg till must be assigned an age approximately that of the Fairgrange. The exposure at Lovers Leap was instrumental in solving this enigma and others, as were intense programs of study by Illinois and Indiana glacial geologists of depositional morphology, of sedimentological parameters, and of sequences investigated through subsurface methods.

Further, these studies, having Lovers Leap as one of the focal points, have fully vindicated Chamberlin's (1 888) belief in a "succession of marginal deposits [Wedron Formation] formed by ice movements from the basin of Lake Michigan on the north and [marginal deposits, Trafalgar Formation] from the Erie and Huron basins on the north and northeast" and in a superposition of drifts resulting from the "encroachment of one movement upon the ground of the other."

The highest of the westward-overriding Trafalgar deposits had been mapped by Chamberlain by 1883 as a morainal loop of the so-called Wabash ice lobe (that is, a part of the western Erie, or Maumee, glacier). This morainal loop is the ridge shown at Judyville in Figure 1. The idea of a Wabash ice lobe was also applied northward to account for moraines as far north as the Iroquois Moraine (Fig. 1), and by 1888 the Illinois-Indiana moraines, originating from the Lake Michigan Lobe and truncated along the Trafalgar boundary shown in Figure 1, had been recognized. By 1894, therefore, Chamberlain was able to produce his classic map that first defined an East Wisconsin (now the Wisconsinan) glacial stage.

[n the years following exposition of Chamberlin's views, Leverett (1 899) reiterated and expanded these views, distinguishing the upper, eastern-source tillsheet as a distinct late Wisconsinan event, but later Leverett and Taylor (1915) proposed a lobe-to-lobe continuity of moraines in and out of reentrant morphologies and all across the Midwest. Glacial stratigraphers beginning with Wayne (1963, 1965) and Wayne and others (1966), however, returned at least in part to Chamberlin's interpretation. The cycle is now full circle, as the later studies of Lineback (1979) and Bleuer and others (1983) have returned completely to Chamberlin's positions.

The Ridges at Judyville and Locust Grove

The ridges at Judyville and Locust Grove (Figs. 1, 2B, and 2C) provide multiple vantage points from which one can appreciate the glacial dynamics that have been outlined. The westward view affords a lasting impression of the vast flatlands of the Wisconsinan till plains of Illinois. Here, the black prairie soils, the mollisols, may be all that Gilbert Imlay would recognize today among what he described in 1792 as "chiefly a morass [that].. . produces little else, other than hazel, fallow, a species of dwarf poplar, and a very coarse but luxuriant grass; the latter of which covers mostly the whole surface of the earth . . ." Little could he appreciate that the glacial aftermath and the ingenuity of mankind would combine to transform such a morass into general-purpose farmlands that are among the world's very richest, productive, and expensive.

Locust Grove is just south of the area of superposition of young Trafalgar till in the extended Crawfordsville Moraine of Wayne (1965) (that is, the ridge underlying Judyville) on the Snider till of the Ellis-Paxton Moraine (Cropsey Moraine) of Figure 1. The view here of the junction of tills and moraines of the Huron-Erie Lobe (eastern) and of the Lake Michigan Lobe (northern) tends to suggest that the Ellis-Paxton Moraine and till truncate and rise up over the moraine and till on which Locust

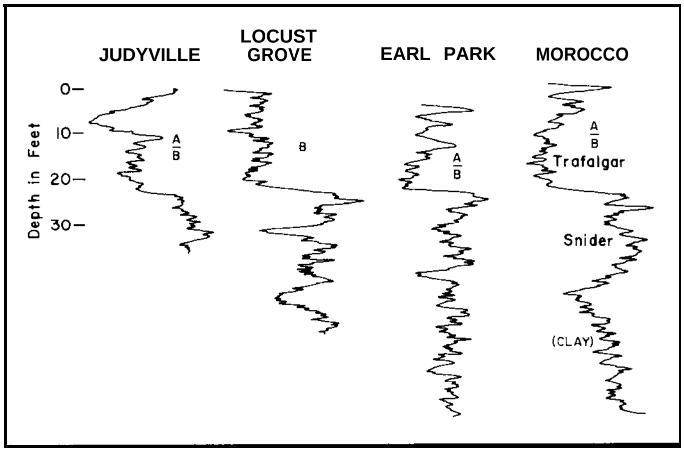


Figure 6. Traces from four gamma-ray logs of shallow holes penetrating Wisconsinan tills north of the Great Bend area, Indiana. Traces show the distinctive Trafalgar and Snider signatures at four locations (shown approximately in Fig. 1) as follows (1, 2), Judyville and Locust Grove in the area of westward pinchout of the Trafalgar till where it rises over the buried till of the Snider member, the Locust Grove log being for a hole north of Locust Grove and above the crest of the buried Ellis-Paxton Moraine; (3), on the Nebo-Gilboa Ridge at Earl Park; and (4), on the Iroquois Moraine at Morocco. Ablation tills, silts, and sands of the Trafalgar Formation (A) lie above basal Trafalgar till (B) and Snider till.

Grove and Judyville are situated (Fig. 1). Indeed, this was the interpretation of Wayne (1965) and Wayne and others (1966), although, southward, they had proposed the reverse situation: overlap of the Bloomington Moraine, extending from Illinois, by the moraine at Judyville and Locust Grove. This latter interpretation was the beginning of denial of Leverett's (Leverett and Taylor, 1915) assertion of morainal continuity through reentrant lobal junctions.

Nevertheless, the recent studies already noted, which are based on drilling programs, show that the Trafalgar and Ellis-Paxton junction is effected by Trafalgar till lying *atop* Snider till and that the same relationship holds northward to the Kankakee River valley. (See these relationships in Figs. 4 and 5.) Therefore, the eastern ends of all the moraines extending eastward from Illinois (Fig. 1) become buried landforms in western Indiana. Studies of aerial photographs support this conclusion, as the Trafalgar boundary is identified on the basis of a diffuse ice-disintegration landscape developed on the O- to 20-ft (O- to 6-m) thick Trafalgar till and associated glacio-fluvial deposits. Here again, modern studies have returned completely to the interpretations of T. C. Chamberlain of so long ago.

The Boulder Fields Near Talbot

The ice-disintegration features mentioned immediately above are shown to particular advantage just inside the Trafalgar margin and immediately north of the Chatsworth Moraine (Figs. 1 and 2A), there consisting of ice-walled lake and large circular disintegration deposits. (See Bleuer, 1974, Figure 4.) Large surficial concentrations of boulders are present in this same area, including the area immediately south of Talbot. Fittingly to our historical context, these concentrations are parts of the great boulder belt of Leverett (Leverett and Taylor, 1915, Plate 6) and of Chamberlin's (1890, 1893) type examples of englacial drift. Here, as noted by Chamberlain, the boulder distribution is associated genetically with looping morainal (ice-lobe) margins; the boulders are entirely superficial or partly buried to completely concealed; many were derived from Laurentian granitic and gneissic rocks as well as from Huronian metamorphic rocks as shown, for example, by certain jasper-quartz and slate conglomcrates (today recognized as the Gowganda Tillite) that had been described in Canada by Sir William Logan; and their angularity and other gross attributes are peculiarly different from the features of boulders found deep within till sheets.

From these and other observations of this suite of erratics, Chamberlain was able to assert forcefully that the boulders were not ice rafted. Also, their gross character showed that they could not have undergone the grinding, abrasive, and otherwise-shaping effects of subglacial transport; they were, indeed, Chamberlain said, englacially and superglacially transported.

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