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REPORT OF INVESTIGATIONS 185

STRATIGRAPHIC AND SEDIMENTOLOGIC ASPECTS OF THE LEMONT DRIFT OF NORTHEASTERN ILLINOIS

BY

LELAND HORBERG and PAUL EDWIN POTTER

AUG. 26th 1818

PRINTED BY AUTHORITY OF THE STATE OF ILLINOIS

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STRATIGRAPHIC AND SEDIMENTOLOGIC ASPECTS OF THE LEMONT DRIFT OF NORTHEASTERN ILLINOIS

BY

LELAND HORBERG* and PAUL EDWIN POTTER

ABSTRACT

The Lemont drift occurs southwest of Chicago. Field and laboratory studies have provided additional information as to its age and source and contributed to knowledge of its environment of deposition.

Two fraction analyses of the Lemont till show that dolomite is dominant in size ranges from 0.5 mm. to at least 256 mm., chert has a restricted size range, crystallines are in negligible abundance, and the clay fraction is composed of illite and quartz. This evidence supports a hypothesis of local derivation for most of the Lemont drift larger than 0.5 mm.

The Lemont till is clearly differentiated from the Valparaiso till by its low clay content. As shown by Scheffé's form of the analysis of variance, roundness of 16 to 32 mm. dolomite is similar, however. Dolomite roundness in both tills is significantly less than that of associated outwash and esker gravel.

Crystalline pebble counts indicate that the Lemont and Valparaiso tills had similar patterns of drift dispersion from a common source region in the Canadian Shield. Differences in texture and shale-pebble content, however, most probably resulted from differences in depositional environment and changes in the local source area caused by covering of pre-Cary drift.

Truncated remnants of a buried soil show a maximum depth of leaching of 78 inches which indicates a probable Sangamon age. Although morphologic soil zonation is pronounced, clay-mineral contrasts between parent material and B horizon are minor.

Favored by retreat down the backslope of the Niagara cuesta and possibly by an ameliorating late Illinoian climate, conditions for ponding and slackwater deposition were provided, and the Lemont complex of water-laid drift with minor amounts of till was deposited.

INTRODUCTION

The Lemont drift of the Chicago region has long been of interest because of uncertainties as to its age and origin. It is one of the oldest known drifts in the region, underlying the surficial drift of Cary age, and is the only drift that is thoroughly oxidized and has remnants of a buried soil profile at its top. Discussion of age has centered on whether the drift is Tazewell or Illinoian. Problems of origin arise from differences in sedimentary properties of the Lemont and Cary drifts: the Lemont includes a complex of silty till and water-laid silt, gravel, and sand, whereas the Cary drifts are composed dominantly of clayey till; the Lemont contains very few Devonian shale pebbles from the basin of Lake Michigan, whereas they are abundant in the Cary tills.

The Lemont was named by Bretz (1939, p. 53) from exposures in abandoned quarries in Niagaran dolomite west of Lemont (locality 13, fig. 1). Possible equivalent deposits, which extend southward along the DesPlaines Valley for about 12 miles into the Joliet region, have been described by Goldthwait (1909, p. 42), Fisher (1925, p. 79-87), and Horberg and Emery (1943).

Acknowledgments

The technical assistance and advice of many members of the Illinois Geological Survey staff is gratefully acknowledged. We are particularly indebted to Arthur Bevan, M. M. Leighton, and H. B. Willman for their careful editing and helpful suggestions.

Colin R. Blyth, Department of Mathematics, University of Illinois, called our attention to and provided essential help in application of Scheffé's analysis of variance method.

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*University of Chicago.

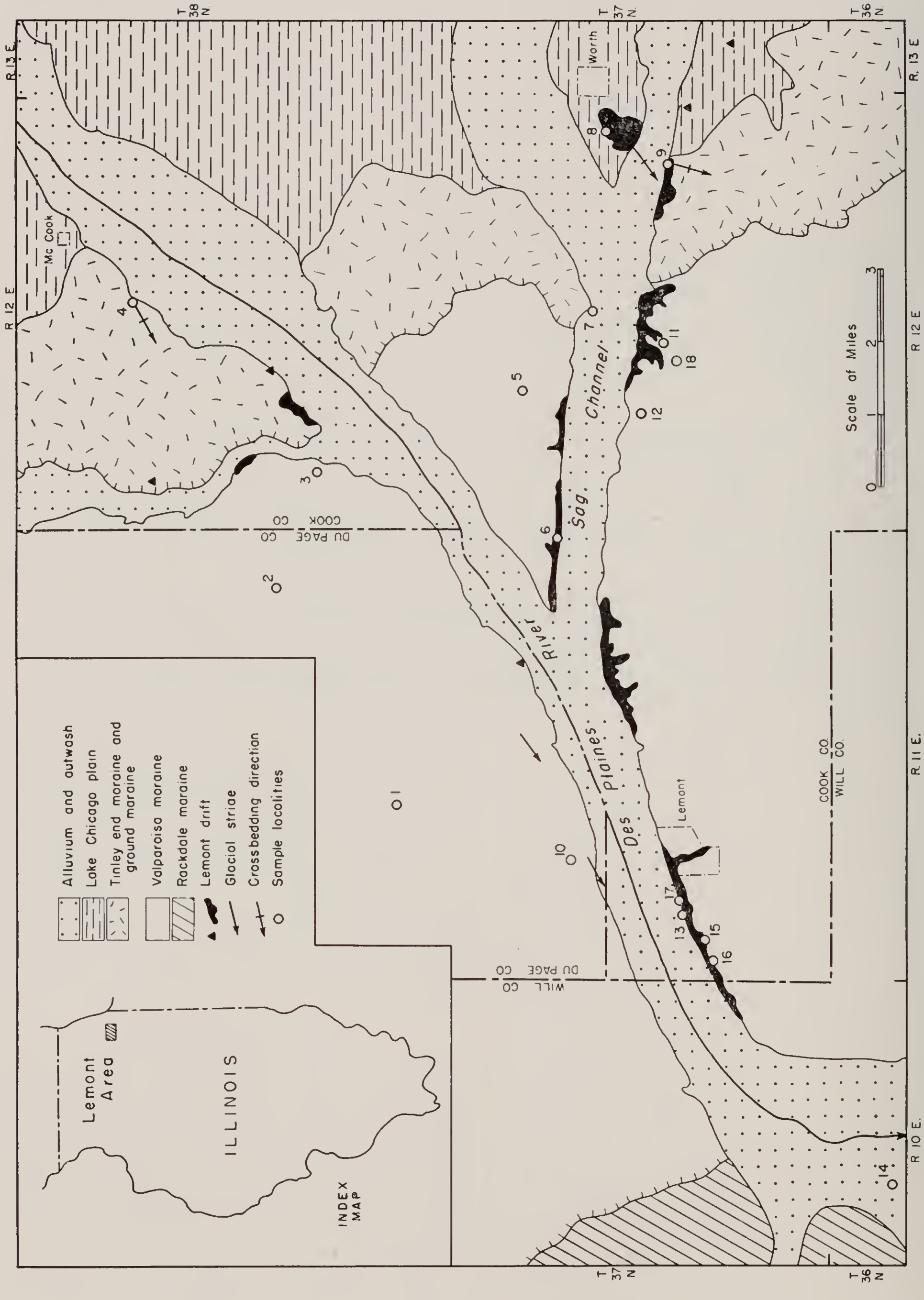

FIG. 1.—Index map showing distribution of Lemont drift and sample locations (see appendix 2).

GLACIAL GEOLOGY

General

The area of study is situated in southwestern Cook County and includes adjoining parts of DuPage and Will counties. The area may be divided into (1) the DesPlaines and Sag valleys, which were outlet channels of glacial Lake Chicago; (2) the north-south trending belt of Cary moraines with the Valparaiso moraine system on the west and the Tinley end moraine and ground moraine on the east; and (3) the lake plain of Lake Chicago (fig. 1). Most of the area is covered with deposits of Cary age, but about a dozen exposures of Lemont drift and some outcrops of the underlying Silurian Niagaran dolomite occur along the DesPlaines and Sag valleys.

Glacial striae on the Niagaran dolomite below Valparaiso and Tinley drift indicate that the Cary ice sheet moved in a southwesterly direction across the area (fig. 1). Striae below Lemont drift 2 miles northeast of Lemont (fig. 1) trend S 55° W and record a similar direction of movement for the Lemont ice (Bretz, 1955, p. 68).

Lemont Drift

The Lemont drift is differentiated from overlying Cary drifts on the basis of its yellowish-brown color (caused by oxidation), the silty character of the till and associated water-laid deposits, and its low content of Devonian shale pebbles. It includes both massive and rudely bedded ("water-laid") types of stony tills, slackwater and lacustrine silts, outwash sand and gravel with openwork gravel layers, deltaic gravel with foreset beds and cobbles and boulders that indicate deposition close to the ice front, and at one locality, laminated lacustrine clay.

The complex facies relations are best shown in the gravel pit west of Worth (locality 8, fig. 1). As shown in figure 2, the sediments here include, from oldest to youngest: a lower till, a relatively thick sequence of bedded silt with sandy layers that in places show current ripples and cut-and-fill structures, a discontinuous wedge of lacustrine clay, and an upper unit of till with associated deltaic gravel. At the type locality near Lemont (locality 13, fig. 1) the deposit contains more till, as indicated in the section below.

	Thickness (feet)	*Depth (feet)*
Wisconsin (Cary)—Valparaiso		
Till, clayey, gray, calcareous except for upper 2 feet	4	4
Illinoian—Lemont drift		
Silt, sandy, bedded, yellow brown, calcareous, irregular contact with overlying till	4	8
Gravel, sandy, silty, yellow brown, calcareous, in places indurated with calcareous cement	2	10
Silt, sandy, bedded, yellow brown, calcareous	2	12
Till, silty, yellow brown and gray, rudely bedded, calcareous . .	2	14
Till, silty, massive, yellow brown with irregular masses of unoxidized light gray till, calcareous, more stony than the Valparaiso	18	32
Silt, as above, base not exposed .	4	36

In contrast to both of the above exposures, the Lemont at the Dolese-Shepard

Fig. 2.—Diagram showing facies relations of Lemont drift in gravel pit at Worth, Ill. (locality 8). Wt, Tinley till; Wv, Valparaiso till; S, Sangamon soil on Lemont drift; Lt, Lemont till; Lg, Lemont gravel; Lc, Lemont clay; Ls, Lemont silt with some sand. Vertical interval about 30 feet; horizontal distance about 800 feet.

quarry near McCook (locality 4, fig. 1) is composed mainly of gravel, as shown by the section below.

	Thickness (feet)	*Depth (feet)*
Wisconsin (Cary)—Tinley till		
Till, very clayey, yellow gray to gray, calcareous	15	15
Illinoian—Lemont gravel with weathered zone		
Gravel, coarse, average about 2 inches, yellow brown, oxidized, noncalcareous, many dolomite pebbles soft and rotten, limonite stains, discontinuous; horizon 3 of weathering profile . . .	4.5	19.5
Gravel, as above, coarser in places with cobbles up to 8 inches, largely dolomite, rounded till pebbles with granule armor common, brown, oxidized, calcareous; horizon 4 of weathering profile . .	8	27.5
Gravel, sandy, average about 0.5 inches, poorly sorted, cut-and-fill structures, openwork gravel with manganese-coated pebbles present in places, prominent foresets with average dip direction about S 5° W, oxidized, yellow brown, calcareous; horizon 4	4	31.5
Gravel, clayey, composed of over 50 percent armored till pebbles, unoxidized, gray, sharp contact with oxidized gravel above and below, calcareous	2.5	34
Gravel, composed largely of dolomite slab-stones 0.5 to 1 foot, poorly sorted, imbrication shows current moving S 40° W, yellow brown, calcareous	2	36
Gravel, sandy, average about 0.5 inches, poorly sorted, foreset and horizontal beds, yellow brown, calcareous	5	41
Silurian Niagaran dolomite		

The Lemont is not well exposed at the remaining localities shown in figure 1. It is composed in most places of bedded silt with thin gravel seams and associated gravel layers that locally are indurated; in a few places the silt is massive and loess-like.

Buried Soil on Lemont Drift

Remnants of a truncated soil profile on Lemont drift are exposed at localities 4, 8, and 9 (fig. 1). The most nearly complete section was observed in the gravel pit near Worth (locality 8) where remnants were noted at five places in the pit (fig. 2). A section exposed in 1954 in the northeastern corner of the pit is given below.

Horizon	Description	Color (Munsel)	pH	Thickness (inches)	Depth (inches)
	Recent soil on Tinley till:				
A	Loam, silty, noncalcareous, gray humus .			6	6
B_1	Loam, clayey, noncalcareous, dense. . .			9	15
B_2	Till, noncalcareous, joints with colloid fillings			9	24
C	Till, clayey, calcareous, brownish gray . .		8.0	14	38
	Buried soil on Lemont sand and gravel:				
2	Gumbo gravel, dense, gravelly, rare weathered dolomites in lower part, largely fine gravel particles in a clayey matrix, noncalcareous, dark reddish brown to dark yellowish brown	5 YR 3/4 to 10 YR 4/4	7.0–7.8	30	30
3_a	Gravel, clayey, silty, dolomite residuals, noncalcareous, more pebbly than above, Mn stain in lower 10 inches, dark yellowish brown to yellowish brown	10 YR 4/4 to 10 YR 5/4	6.5–7.8	25	55
3_b	Gravel, coarse, silty clay matrix, rotten dolomites, matrix noncalcareous but some pebbles react with acid, yellowish red ("ferretto zone")	5 YR 5/8	7.5–7.8	23	78
4	Silt, clayey, bedded, calcareous with poorly developed veinlets and lime disseminations in upper 3 inches, gray with brown mottlings		8.0	8	86

At other places in the gravel pit, remnants of the soil are marked by shallower leached horizons and horizons of reddish-brown iron-oxide concentrations.

At locality 9, in a borrow pit near the junction of State highways 7 and 83, the buried soil occurs on sandy stratified Lemont silt below thin Cary gravel. It consists of a reddish-brown leached zone two feet thick (horizon 3) underlain by four feet of yellowish-brown calcareous silt (horizon 4).

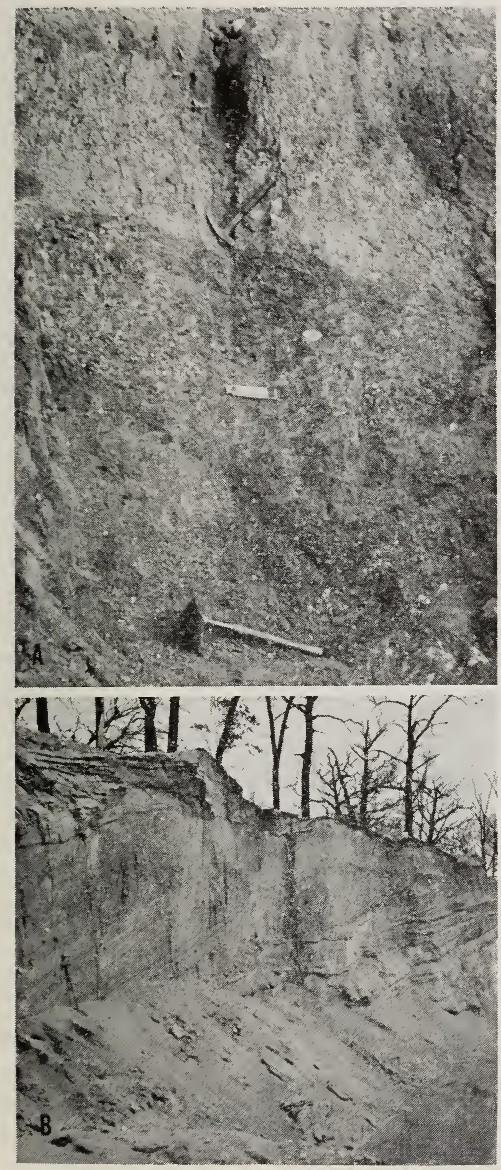

Plate 1.—Buried soil and Lemont drift. A. Buried soil on Lemont gravel below Tinley till, gravel pit, Worth, Ill. (locality 8, fig. 1). Base of Tinley and top of horizon 2 is at hammer; base of horizon 2 is at rule; upper part of "ferretto zone," horizon 3b is at shovel. B. Deltaic gravels and overlying silts. Soil profile (A) is approximately 75 feet beyond right edge of picture.

The paleosol at locality 4, the Dolese-Shepard quarry near McCook, is described above in the geologic section for that locality. It is distinguished by a limonite-stained leached horizon 54-inches thick on Lemont gravel (horizon 3) and is overlain by 15 feet of calcareous unoxidized Tinley (Cary) till.

Three samples of the 2-micron fraction from horizons 2, 3, and 4 of the buried soil at locality 8 were analyzed by H. D. Glass of the Illinois State Geological Survey. All consist of an illite of muscovite crystallization with fairly good crystallinity and a considerable amount of quartz. The amount of quartz increases downward in the profile. At Lemont (locality 13) another sample of the 2-micron fraction from oxidized but otherwise unweathered till also contained an illite-quartz association. Thus except for the decrease in quartz, little or no mineralogic change accompanied profile development. According to Jackson and Sherman (1953, p. 262), the decrease in 2-micron quartz is the first expression of the intermediate stages of soil weathering. The uniformity of illite in horizons 2, 3, and 4 confirms the observations of Grim (1942, p. 259) and Jackson and Sherman (1953, p. 263) that the illite present in many soils is usually inherited from parent material.

Wisconsin (Cary) Deposits

Deposits of Cary age in the area include the Valparaiso and Tinley drifts and deposits related to glacial Lake Chicago.

The Valparaiso morainic system in the area is composed of at least three north-south trending end moraines, crowded together without intervening ground moraines and, in places, superposed. Most of the drift consists of light-gray to yellow-gray clayey till with pebbles and boulders dominantly of dolomite. The average depth of leaching of the till is about 3 feet.

The Tinley drift is differentiated from the Valparaiso primarily on the basis of morphology and areal relations (Bretz, 1939, p. 50). In a few places, such as in the Worth pit, the two tills occur together stratigraphically; here they are differentiated by an unconformity with basal gravel and the greater abundance of Devonian shale pebbles in the Tinley.

Deposits related to glacial Lake Chicago include discontinuous lacustrine clays and silts in beach gravels on the lake plain and glacial-river gravels along the DesPlaines and Sag outlet valleys.

SEDIMENTOLOGY

Compared with other sediments, few data are available for glacial deposits, especially for tills. Contributions to the sedimentology of glacial deposits have been made by Udden (1914), Krumbein (1933), Lundqvist (1935), Wentworth (1936), Davis (1951), Swineford and Frye (1951), Holmes (1941 and 1952), Shepps (1953), Dreimanis and Reavely (1953), Murray (1953), and others. In this study, objectives of sedimentological investigation were: 1) to contribute to the general sedimentology of glacial deposits, and 2) to clarify the origin of the Lemont drift through integration of sedimentologic and field evidence. We believed that the best way to achieve the second objective was by comparing the Lemont drift with the overlying clayey Valparaiso till.

Fraction Analyses

Preliminary to such comparison, however, two fraction analyses (size versus mineralogy) were made of the Lemont till. As early demonstrated by Trowbridge and Shepard (1932), mineralogical composition is size dependent. Subsequent examples of this dependence in the clay, silt, sand, and gravel fractions have been provided by Correns (1938), Cogen (1935, p. 3-5), Grim (1950, p. 13-21), Van Andel (1950, p. 18-21), Potter (1955, p. 7-8), White (1955, personal communication), and others. A fraction analysis for glacial till has been made by Davis (1951). The dependence of mineralogic composition on size for the Lemont till is clearly shown in figures 3 and 4.

Figure 3 was obtained by sizing two samples of till (localities 8 and 13) and counting 100 to 200 particles per size grade. In figure 3 mineralogic abundance is expressed in number percent; composition of each size grade totals 100 percent. Figure 4 shows the same data expressed as weight percent of the entire sample.

The following relationships are indicated for figures 3 and 4:

1. dominance of dolomite especially in the range 0.5 mm. to more than 256 mm.
2. rapid decrease in dolomite in the smaller sand grades (<0.5 mm.).
3. chert largely restricted to the range 0.5 mm. to 64 mm.
4. crystallines in negligible abundance.
5. a clay fraction composed of illite and finely ground quartz.

A hypothesis of local derivation for much of the Lemont till best explains the above relationships. The scarcity of durable crystalline rocks of Canadian Shield derivation shows that most of the Lemont drift larger than 0.5 mm. was derived from Paleozoic sediments. That this Paleozoic source was essentially local (perhaps 80 percent derived from distances less than 20 miles) is indicated by the abundance and lithologic similarity of the dolomite pebbles and cobbles in the till to the immediately underlying Niagaran bedrock. The size range of chert pebbles further substantiates this conclusion. The bedrock of the Chicago region contains chert nodules and layers rarely more than 50 to 75 mm. thick. The observed upper size limit of chert pebbles in the Lemont till, 64 mm., corresponds well to the thickness of the cherts in the bedrock.

For the sand fraction less than 0.5 mm., the progressive and rapid decrease in carbonates is best explained by a combination of local derivation and decreased resistance to abrasion. Glacial erosion of a carbonate bedrock incorporates boulders, cobbles, and

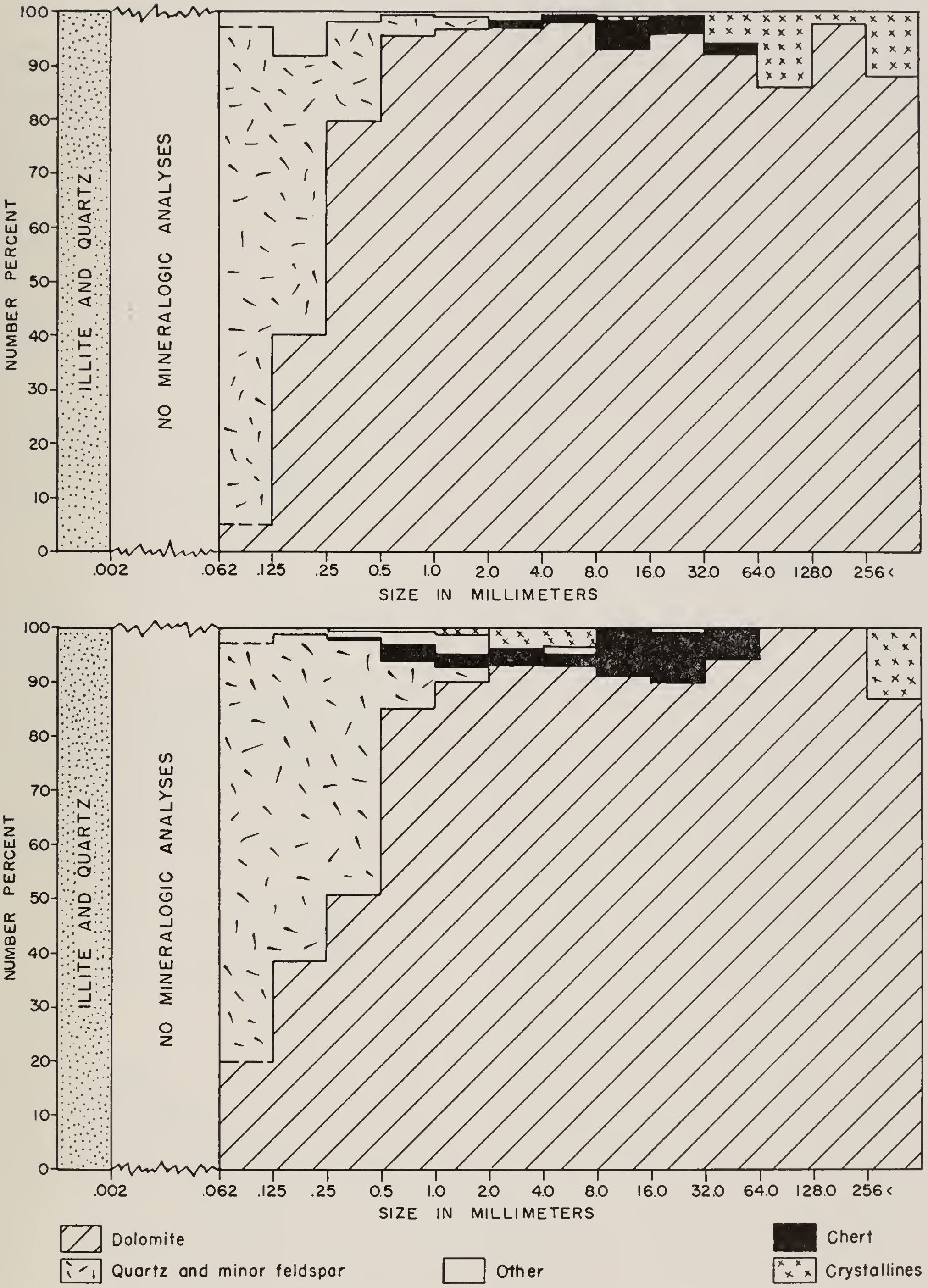

Fig. 3.—Fraction analyses, in number percent, of two samples of Lemont till; locality 8 (above) and 13 (below). Compare with figure 4.

possibly pebble-sized carbonates in the till, but carbonate granules or sands are incorporated in negligible amounts. Only by glacial abrasion of larger fragments could appreciable amounts of finer carbonates be obtained. Thus the rapid decrease of carbonates in the smaller sand grades suggests a short history of transportation.

In contrast, the remainder of the sand, quartz, and minor feldspar had a more dis-

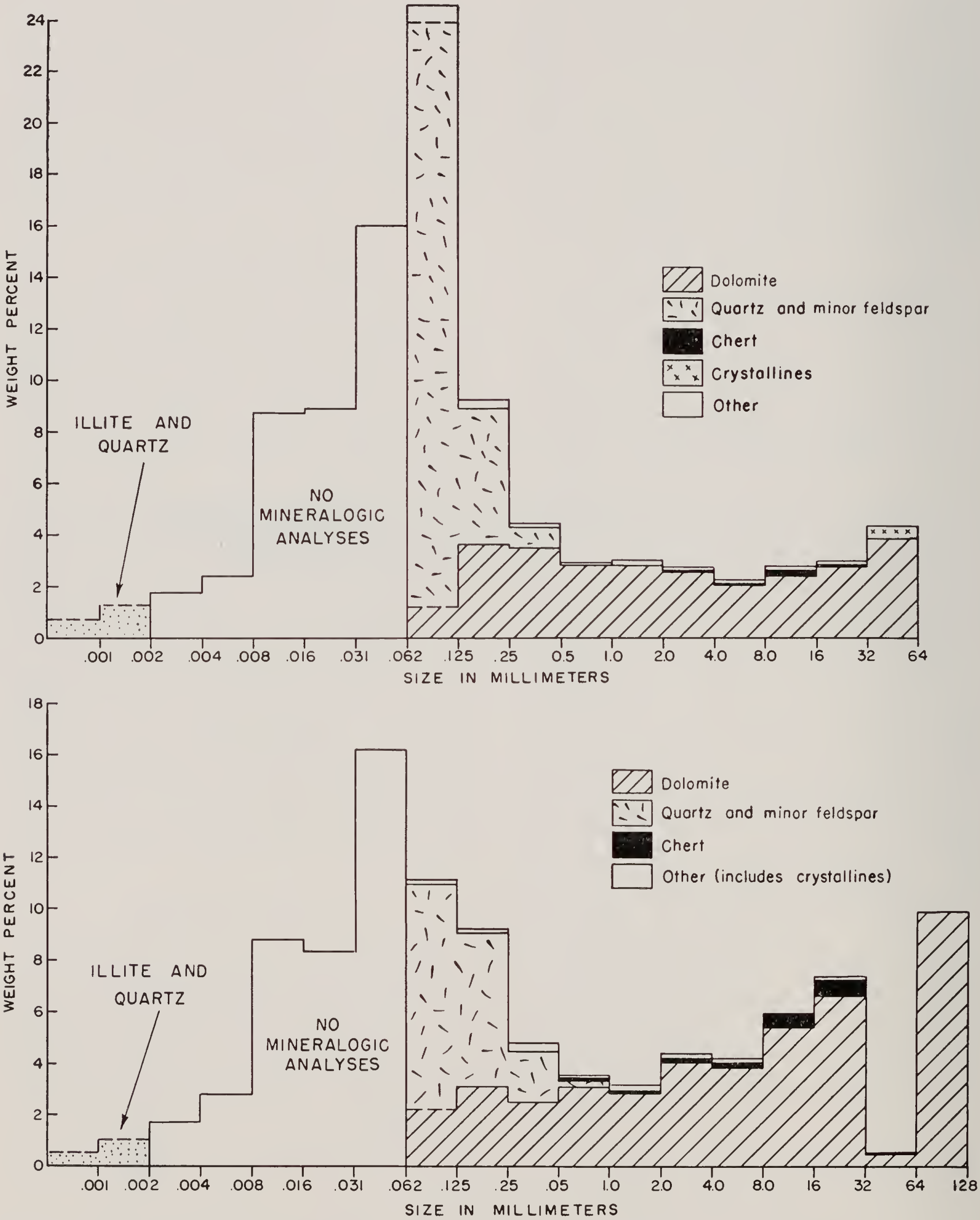

Fig. 4.—Fraction analyses, in weight percent, of two samples of Lemont till; locality 8 (above) and 13 (below). Compare with figure 3.

tant source. The small amount of feldspar—estimated as less than five percent—suggests an ultimate origin of much of the sand from Cambrian and Ordovician sandstones to the north. Illite in the clay fraction probably implies derivation from Devonian shales in the basin of Lake Michigan. The abundance of quartz in the clay fraction is best interpreted as an inheritance from the abrasion of the quartz of the sand fraction.

Hence, the source of Lemont clastics 0.5 mm. and larger was overwhelmingly local, whereas the sands less than 0.5 mm. had a more distant source (as probably did the silt and clay fractions). Evidence of this basal till provides strong support for a general hypothesis of "local loading," especially for particles larger than 0.5 mm.

TEXTURE

Eight Valparaiso till size-analyses (Krumbein, 1933, p. 388) from the area adjacent to the Lemont exposures were compared with the two size analyses of Lemont till. As shown in figure 5, the Valparaiso analyses are distinct from those of the Lemont. Whereas the Valparaiso analyses have approximately 40 percent clay, those of the Lemont have less than four percent. Lemont till deposition took place in an environment that prevented deposition of most of the clay fraction. In Lemont till deposition, there is implied a greater role for meltwater. What effect did more abundant meltwater have on abrasion of the larger clastic components?

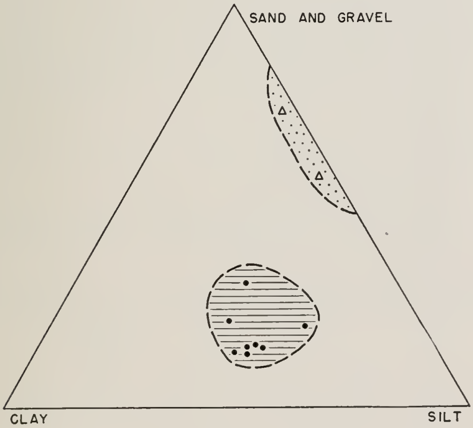

FIG. 5.—Triangle diagram showing textural contrast between Lemont till (stippled) and overlying Valparaiso till (shaded). Valparaiso analyses from Krumbein (1933, p. 388).

TABLE 1.—COMPARATIVE DOLOMITE ROUNDNESS (16 to 32 mm.)

VALPARAISO TILL		LEMONT TILL		OUTWASH AND ESKER GRAVEL	
Locality	Roundness	Locality	Roundness	Locality	Roundness
3	0.37	13	0.34	7	0.45
1	0.26	17	0.38	8	0.53
5	0.34	15	0.35	14	0.51
2	0.34	16	0.39	12	0.52
8	0.36	8	0.40	9	0.40
11	0.30	6	0.29	8	0.53
10	0.30				
Average	0.33		0.36		0.49

Comparison of the roundness of 16-to-32 mm. dolomite pebbles collected from Lemont till, Valparaiso till, and outwash and esker gravels provides one index. Samples of 40 pebbles were collected at 19 localities and roundness estimated with the Krumbein chart (1941, p. 68-70). Table 1 shows the results of this sampling.

The significance of the mean values 0.32, 0.36, and 0.49 was tested with a form of the analysis of variance (Scheffé, 1953). A brief explanation and examples of the calculations are given in Appendix 1.

Geologically, two hypotheses are of interest:

1. Are the means of dolomite roundness in the Valparaiso and Lemont tills equal $(H_1: \mu_1 = \mu_2)$?

2. If so, is their average value significantly different from that of outwash and esker gravel $\left(H_2: \frac{\mu_1 + \mu_2}{2} = \mu_3\right)$?

The hypotheses were tested at the five percent level. The difference between dolomite roundness in the two tills (H_1) is not significant (table 2). The thirteen samples from Valparaiso and Lemont tills can be considered to have been obtained from the same population. Hence they were combined, tested against dolomite roundness in outwash and esker gravel (H_2), and found to be significantly different. What geologic hypothesis best accords with this evidence?

Plumley (1949, p. 558-559) found that, depending on stream gradient, 16-to-32 mm. limestone gravel reaches a roundness of 0.49 in as little as 3 to 6 miles. This contrasts sharply with glacial transport which only produces angular to subangular (0.34) dolomite pebbles. Whereas the presence of blunted and faceted pebbles in till indicates abrasional impact, this impact is not only less frequent in tills, but involves particles capable of little rotation. Hence progressive abrasion could not lead to well-rounded fragments. Lack of rotation is also the probable reason for the greater role of crushing in glacial transport. Thus, because both impact and rotation in response to impact are less than in stream-bed deposits, glacial transport produces blunted, faceted, angular to subangular fragments. The similarity of dolomite roundness in Lemont and Valparaiso tills indicates, in spite of pronounced differences in clay matrix, that this process was essentially identical for both tills. It suggests that the greater abundance of silt in Lemont till is more probably the result of incorporation of pro-Lemont silts than removal of clay-size particles during deposition.

CRYSTALLINE AND SHALE PEBBLES

The areal relations of the Valparaiso morainic system (Bretz, 1939, p. 46) clearly indicate a regional pattern of drift dispersion and a restricted source region in the Canadian Shield. Because the Lemont is known at only a few exposures over a limited area, a comparable morphologic approach to its pattern of drift dispersion and source region in the Canadian Shield is not possible. We have an indirect method for estimating this pattern, however, by comparing the pre-Cambrian rock types (commonly referred to as crystallines) in the Lemont with those in the Valparaiso till, with its known pattern of drift dispersion. Similar pebble suites for the Lemont and Valparaiso would indicate a common crystalline source region in the shield and would lend support to a hypothesis of a common pattern of drift dispersion.

Crystalline pebbles were collected from three exposures of Valparaiso till (localities 1, 10, and 18) and from four exposures of Lemont till and gravel (localities 8, 13, 15, and 16). Because crystallines are much less abundant in the Lemont than in the Valparaiso, it was necessary to select a rather wide size range (8 to 32 mm.) and to sample Lemont outwash as well as till.

A total of 1295 pebbles was collected and classified into five groups: phaneritic acid igneous, phaneritic basic igneous, diabase, metamorphic, and volcanic. As shown in table 3, the homogeneity of the Valparaiso and Lemont crystallines was tested by forming a contingency table (Mood, 1950, p. 273-281). The lack of significance at the five percent level indicates that there are less than five chances out of 100 that the two samples were not derived from the same population.

This indicates that, with respect to these variables of classification, the Lemont and

TABLE 2.—TESTS OF TWO CONTRASTS

Hypotheses	$\hat{\theta}$	$\hat{\sigma}^2_{\hat{\theta}}$	Confidence region
$H_1 : \mu_1 = \mu_2$	−0.034	0.0006592	$-0.103 \leqslant \theta \leqslant 0.035$
$H_2 : \frac{\mu_1 + \mu_2}{2} = \mu_3$	−0.149	0.0005198	$-0.172 \leqslant \theta \leqslant -0.126$

Table 3.—Homogeneity of Valparaiso and Lemont Crystalline Pebbles

	Phaneritic acid igneous	Phaneritic basic igneous	Diabase	Metamorphic	Volcanic	Totals
Valparaiso till . .	302 (38.0%)	83 (10.5%)	365 (46.0%)	31 (3.9%)	13 (1.6%)	794
Lemont till. . . .	194 (38.7%)	65 (12.9%)	217 (43.3%)	20 (4.0%)	5 (1.0%)	501
Totals	496	148	582	51	18	1295

$\chi^2 = 3.36$; $\chi^2_{0.05} = 9.49$ for 4 degrees of freedom.

Valparaiso ice sheets crossed the same area of the shield. This crystalline homogeneity harmonizes with the local southwesterly direction of sediment transport for both the Lemont (crossbedding and striae) and the Valparaiso (striae and moraine configuration). It suggests a regional pattern of Lemont drift dispersion, from the shield by way of the Michigan Basin, that in major outline was similar to that of the Valparaiso drift.

The Devonian shale-pebble content of the Lemont and Valparaiso tills contrasts sharply, however. As shown in figures 3 and 4, the Lemont till has negligible amounts of shale pebbles. Considering only that portion of Valparaiso till in and north of the area of Lemont exposures, Krumbein (1933, p. 394, samples 1 to 7) estimated its content of Devonian shale and silt pebbles to be approximately 16 percent. What factors could be responsible for this contrast, when crossbedding, striae, and crystalline pebble counts indicate similar local and distant patterns of drift dispersion?

Evidence of a widespread cover of Tazewell and Lemont drift below the surficial Cary drift is supported by surface and subsurface data. Within the area under consideration, the Lemont drift is essentially continuous along the DesPlaines and Sag valleys (fig. 1) and probably is present under Cary drift throughout most of the upland area. Tazewell drift also is exposed below Cary drift about five miles southeast of the area in a clay pit in the northern part of Blue Island (NE¼ NW¼ sec. 25, T. 37 N., R. 13 E., Cook Co., Ill.), as described in the section below.

	Thickness (feet)	*Depth (feet)*
Wisconsin		
Cary		
Till, gray, and lake clays . .	18	18
Late Tazewell		
Till, gray, compact, jointed .	6	24
Tazewell (Bloomington?)		
Till, reddish brown	2	26
Tazewell (Shelbyville?)		
Till, hard, compact, gray . .	10	36

The widespread extent of Tazewell drift is indicated by hundreds of borings which show that hard, compact tills occur below Cary drift and cover the Niagaran bedrock throughout a large part of the Chicago region (Otto, 1942). This cover of protective drift would have minimized incorporation of the underlying Niagaran dolomite into the Valparaiso till; conversely, absence of such a cover favored the Lemont's high dolomite content.

As shown by Holmes (1952, p. 1003), gravel derived from a shale-rich till may have very few shale pebbles. Hence it would be expected that even though the ice had access to the same Devonian shale bedrock as the Valparaiso ice, the water-laid facies of the Lemont would have very few shale pebbles. Because dolomite roundness is similar in the two tills, it seems more likely that the Lemont till's greater silt content resulted from overriding of pro-Lemont silts rather than from removal of clay-size particles during deposition. This implication suggests that the significant factor in both Lemont's higher silt and lower shale-pebble content was the overriding and incorporation of proglacial deposits. In the formation of the proglacial deposits, abrasion of shale fragments was rapid relative to increase in dolomite roundness.

Thus greater accessibility of Niagaran bedrock, depositional conditions leading to a greater proportion of water-laid facies, and incorporated proglacial deposits in Lemont drift are believed to be the prime factors responsible for the lower shale content of the Lemont.

AGE OF THE LEMONT DRIFT

The most nearly complete soil profile remnant—at locality 8 (Worth gravel pit), which shows 30 inches of gumbo gravel (horizon 2) and a total depth of leaching of 78 inches—indicates a long period of soil development preceding Cary glaciation. The depth of leaching exceeds the average depth of leaching of about 54 inches on surficial Tazewell drift in Indiana (Thornbury, 1940) and the average depth of about 66 inches on surficial Iowan drift in Iowa (Kay, 1931). Unless special conditions leading to uncommonly deep leaching are assumed for the Worth profile, a pre-Iowan age is indicated.

The paleosol evidence for a long Lemont-Valparaiso nonglacial interval is supported by clear-cut geomorphic evidence of erosion of large valleys in the Lemont drift prior to Valparaiso glaciation (Bretz, 1939, p. 31, 52-53). In the larger eastern tributary valleys of the DesPlaines between Lemont and Joliet to the south and along the DesPlaines Valley above Lemont, the Valparaiso drift with its constructional land forms descends into the valleys, and in places low morainic knobs and kame terraces occur in the valley bottoms. Hence these larger valleys were inherited from erosional topography on the Lemont and were only modified and partially filled during deposition of the Valparaiso drift.

There are three alternatives for the age of the Lemont-Valparaiso interval: 1) Cary-Tazewell interstadial, 2) Iowan-Farmdale interstadial, or 3) Sangamon interglacial. There is essentially no stratigraphic evidence to support the additional possibilities of significant weathering and erosion during the Tazewell-Iowan interstadial, or a hypothetical pre-Farmdale Wisconsin interstadial. Correlation with the Cary-Tazewell interstadial is refuted by the depth of leaching on the Tazewell and Iowan drifts cited above. Evidence for correlation with the Iowan-Farmdale interstadial is also weak, for although the Farmdale loess below calcareous Iowan loess is oxidized and noncalcareous to depths of as much as 6 or 7 feet in Illinois, it is probable that most of the weathering occurred during slow deposition of the loess (Horberg, 1953, p. 35). In addition, no occurrences of a buried horizon 2 at the top of the Farmdale are known. It is concluded, therefore, that the buried soil is most logically interpreted as a truncated Sangamon soil and that the Lemont drift is Illinoian in age.

ORIGIN OF THE LEMONT DRIFT

Regional relations and the dominance of water-laid facies in the Lemont suggest that, as the ice withdrew behind the crest of the Niagara cuesta in late Illinoian time, conditions of ponding and slackwater deposition prevailed. In this environment a complex of slackwater and lacustrine silt and sand, lacustrine clay, deltaic gravel, outwash sand and gravel, ice-margin gravel, rudely bedded ("water-laid") till, and minor "massive" till was deposited. Lemont till represents a readvance of late Illinoian ice up the backslope of the Niagara cuesta. With fluctuations of the ice front, large quantities of water-laid drift were incorporated in the till.

The bedrock topography of the region (Horberg, 1950, pl. 1, p. 44) supports this interpretation. Abundant subsurface data show that the crest of the buried Niagara cuesta extends north and south through Lemont. In preglacial time this escarpment formed a major divide between a large valley system to the west, which drained southward into the ancient Mississippi, and a series of consequent valleys on the backslope of the cuesta, which drained eastward into a broad subsequent lowland in the basin of Lake Michigan. A buried "through valley," which breaches the divide east of Joliet, appears to have been filled and blocked with Lemont drift. The present DesPlaines Valley, which cuts through the divide at Lemont, was not eroded until after the deposition of the Lemont drift.

As shown by the dominance of Niagaran dolomite in the two fraction analyses, Lemont ice had direct access to the underlying bedrock. Although sub-Lemont drift has been reported in the preglacial Hadley Valley south of Lemont (Bretz, 1955, p. 57) and other scattered pre-Lemont drifts are known from the subsurface in the Chicago region (George Otto, personal communication), their combined areal extent is insignificant.

Favored by direct access to bedrock, local glacial erosion accounts for most of the Lemont till larger than 0.5 mm. Subglacial abrasion of the carbonates produced faceted and striated fragments with roundnesses comparable to those of the clayey Valparaiso till.

Crystalline pebbles, striae, and crossbedding indicate distant and local patterns of drift dispersion similar to those of the Cary drifts. Shale-pebble content of the Lemont is notably less, however. Greater accessibility to Niagara bedrock and predominance of water-laid facies during Lemont glaciation are believed responsible for this contrast. A possible late Illinoian ameliorating climate, as well as retreat down the backslope of the Niagara cuesta, favored dominance of water-laid deposits.

Subsequent Sangamon weathering leached Lemont drift in excess of 78 inches and produced appreciable morphologic soil zonation. In at least one exposure, little clay-mineral change accompanied profile development.

Areal relations indicate that free drainage across the Niagara bedrock divide was established during the post-Lemont pre-Cary interval, probably during the advance of the Tazewell ice. Subsequent free drainage, perhaps combined with a colder glacial regimen, provided an environment during Tazewell and Cary time in which normal clayey tills with subordinate water-laid facies were deposited.

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APPENDIX 1

A TEST OF ALL CONTRASTS IN ANALYSIS OF VARIANCE

Application of the single factor form (Mood, 1950, p. 323–326; Krumbein and Miller, 1954, p. 513–514) of the analysis of variance to the data of table 1 suffers from the following limitation: if the F test rejects the $H: \mu_1 = \mu_2 = \mu_3$, what further inferences concerning the population means are valid? Repeated application of the analysis of variance obscures the level of significance, i.e., although a level of significance α may be used throughout all the tests, the actual risk involved will be greater than α. Scheffé (1953) has developed a method for resolving this common problem. The following brief outline presents Scheffé's method in simplified form and illustrates its use.

The Method

The assumptions of Scheffé's method are those of the analysis of variance: the observations are from normally distributed populations with homogeneous variance. The μ_i can only be fixed means, i.e., Model I (Eisenhart, 1947). Our presentation further simplifies Scheffé's method by making the additional assumption that all the μ_i are independent.

A contrast of the population means, μ_i, is defined as the linear function.

$$\theta = \sum_{1}^{k} c_i \mu_i \tag{1}$$

where the k known constants c_i satisfy the condition that their sum is equal to zero,

$$\sum_{1}^{k} c_i = 0 \tag{2}$$

For any contrast its estimate is

$$\hat{\theta} = \sum_{1}^{k} c_i \bar{x}_i \tag{3}$$

and the variance of this estimate is

$$\hat{\sigma}^2_{\hat{\theta}} = \sum_{1}^{k} \frac{c_i^2 \sigma^2}{n_i} \tag{4}$$

which is estimated by

$$\hat{\sigma}^2_{\hat{\theta}} = \sum_{1}^{k} \frac{c_i^2 s^2}{n_i} \tag{5}$$

where s^2 is the within-group variance* and the n_i are the sample sizes of each group.

Define the positive constant S from

$$S^2 = (k-1) F_\alpha \tag{6}$$

where F_α is the upper $1-\alpha$ point of the F distribution, with $(k-1, r)$ degrees of freedom, r being the number of degrees of freedom on which s^2 is based. For a given problem, S is constant no matter how many contrasts are tested.

Selecting a level of significance α, the probability is $1-\alpha$ that all the contrasts satisfy

$$\hat{\theta} - S\hat{\sigma}_{\hat{\theta}} \leqslant \theta \leqslant \hat{\theta} + S\hat{\sigma}_{\hat{\theta}} \tag{7}$$

This confidence region is valid no matter how many contrasts suggested by the data are estimated.

For any contrast there are three possibilities:

1. *The confidence interval covers 0.* In this case we decide that the contrast is 0.
2. *The confidence interval lies entirely to the left of 0.* In this case we decide that $\theta < 0$.
3. *The confidence interval lies entirely to the right of 0.* In this case we decide that $\theta > 0$.

Using this rule, our probability of deciding that even one of the many possible zero contrasts is not zero, is at most α.

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*For the data of table 1, s^2 is computed as:

$$s^2 = \frac{\Sigma x_{1i}^2 - n_1\bar{x}_1 + \Sigma x_{2i}^2 - n_2\bar{x}_2 + \Sigma x_{3i}^2 - n_3\bar{x}_3}{n - 3} = \frac{0.0340}{16} = 0.00213$$

APPLICATION OF THE METHOD

Using (6) to compute S, and selecting $\alpha = .05$, we have

$$s^2 = 2\ (3.63) = 7.26$$
$$S = 2.69.$$

To test hypothesis $H_1 : \mu_1 = \mu_2$ form the contrast

$$\theta = c_1\mu_1 + c_2\mu_2$$

where $\sum_{1}^{k} c_i = c_1 + c_2 = 1 + (-1) = 0.$

The estimate of this contrast is

$$\hat{\theta} = c_1\bar{x}_1 + c_2\bar{x}_2 = 0.234 - 0.358 = -\ 0.034$$

and the variance of this estimate is

$$\hat{\sigma}^2_{\hat{\theta}} = \sum_{1}^{k} \frac{c_i^2 s^2}{n_i} = \frac{c_1^2 s^2}{n_1} + \frac{c_2^2 s^2}{n_2} = \frac{1^2 s^2}{7} + \frac{(-1)^2 s^2}{6} = 0.0006592.$$

Forming the confidence region (7) and substituting we have

$$-\ 0.103 \leqslant \theta \leqslant 0.035.$$

Hence θ is estimated as not significantly different at the five percent level and $H_1 : \mu_1 = \mu_2$ is accepted.

Similarly, the estimated contrast for $H_2 : \frac{\mu_1 + \mu_2}{2} = \mu_3$ is

$$\hat{\theta} = c_1\bar{x}_1 + c_2\bar{x}_2 + c_3\bar{x}_3 = \frac{\bar{x}_1}{2} + \frac{\bar{x}_2}{2} + (-1)\,\bar{x}_3$$

where $\sum_{1}^{k} c_i = \tfrac{1}{2} + \tfrac{1}{2} + (-1) = 0$

and its estimated variance is

$$\hat{\sigma}^2_{\hat{\theta}} = \sum_{1}^{k} \frac{c_i^2 s^2}{n_i} = (\tfrac{1}{2})^2 \frac{s^2}{7} + (\tfrac{1}{2})^2 \frac{s^2}{6} + \frac{(-1)^2 s^2}{6} = 0.005198.$$

Forming a confidence region as before gives

$$-\ 0.172 \leqslant \theta \leqslant -\ 0.126$$

which excludes zero; thus this contrast is significant and negative at the five percent level, and H_2 is rejected.

Other geological hypotheses can, of course, be tested: the only condition is that $\sum_{1}^{k} c_i = 0.$

APPENDIX 2

LOCATION OF SAMPLE LOCALITIES SHOWN IN FIGURE 1

1. Valparaiso till: NW¼ NW¼ sec. 4, T. 37 N., R. 11 E., DuPage Co., Ill.
2. Valparaiso till: NW¼ SW¼ sec. 25, T. 38 N., R. 11 E., DuPage Co., Ill.
3. Valparaiso till: NE¼ NE¼ sec. 31, T. 38 N., R. 12 E., Cook Co., Ill.
4. Tinley till and Lemont gravel, west end of Dolese-Shepard quarry: NW¼ SW¼ sec. 15, T. 38 N., R. 12 E., Cook Co., Ill.
5. Valparaiso till: SW¼ SW¼ sec. 9, T. 37 N., R. 12 E., Cook Co., Ill.
6. Lemont silt: SW¼ NE¼ sec. 13, T. 37 N., R. 11 E., Cook Co., Ill.
7. Tinley till and outwash gravel pit: SW corner sec. 15, T. 37 N., R. 13 E., Cook Co., Ill.
8. Tinley till and Lemont drift gravel pit: NE¼ NW¼ sec. 24, T. 37 N., R. 12 E., Cook Co., Ill.
9. Lemont silt, borrow pit: SW¼ SW¼ sec. 24, T. 37 N., R. 12 E., Cook Co., Ill.
10. Valparaiso till: NW¼ SW¼ sec. 17, T. 37 N., R. 11 E., DuPage Co., Ill.
11. Valparaiso till: SW¼ SE¼ sec. 21, T. 37 N., R. 12 E., Cook Co., Ill.
12. Valparaiso esker gravel: SE¼ NW¼ sec. 20, T. 37 N., R. 12 E., Cook Co., Ill.
13. Valparaiso till and Lemont drift: SE¼ NW¼ sec. 3, T. 37 N., R. 11 E., Cook Co., Ill.
14. Valparaiso outwash gravel, gravel pit: SW¼ SW¼ sec. 3, T. 36 N., R. 10 E., Will Co., Ill.
15. Valparaiso and Lemont tills: SE¼ NW¼ sec. 30, T. 37 N., R. 11 E., Cook Co., Ill.
16. Lemont drift: SW¼ NW¼ sec. 30, T. 37 N., R. 11 E., Cook Co., Ill.
17. Valparaiso till and Lemont drift: NW¼ NE¼ sec. 30, T. 37 N., R. 11 E., Cook Co., Ill.
18. Valparaiso till: SW¼ SW¼ NW¼ sec. 28, T. 37 N., R. 12 E., Cook Co., Ill.

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