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SOIL TONGUES AND THEIR CONFUSION WITH CERTAIN INDICATORS OF PERIGLACIAL CLIMATE

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ABSTRACT. Homogeneous soil-like materials in wedge-shaped, tapering bodies have been reported in unconsolidated deposits in temperate climates. By analogy with structures found in areas underlain by permanently frozen ground they are thought to bear evidence of periglacial climatic conditions.

Certain solution structures (soil tongues) may be confused with frost crack and fossil ice wedge fillings. Soil tongues originate through differential solution operative with soil formation upon calcareous, coarse-grained surficial deposits. Because soil tongues form in humid temperate climates where periglacial conditions may once have been active, their correct interpretation is important.

INTRODUCTION

Wedge-shaped structures extending downward into unconsolidated deposits have been reported by several investigators from surficial accumulations in temperate climates. These are thought to reflect the more rigorous climatic conditions of a periglacial environment (Cailleux, 1943; Denny, 1936; Fearnsides, 1940; Horberg, 1949, 1951; Paterson, 1940; Wolfe, 1953). By analogy with forms now found in areas underlain by permanently frozen ground these features have been ascribed to filling of "ice wedges" and "frost cracks." Their presence has been used to reconstruct the varying climatic conditions of the immediate geologic past.

This paper describes solution structures which may be confused with fossil ice wedge and frost crack fillings. Pedologists refer to them as "soil tongues." The fact that these may form in temperate climates where periglacial conditions might once have been active gives their correct interpretation added significance.

HISTORY OF INVESTIGATION

The structures which have prompted this report were first examined in the field during the summer of 1949 by Dr. Sheldon Judson and Mr. Joseph Roberts, both of the Department of Geology, University of Wisconsin. This preliminary investigation concluded that the features were frost-crack fillings developed under periglacial climatic conditions.

In May 1950 they were included as a stop in the first annual field conference of the midwestern "Friends of the Pleistocene."[1] The fact that these structures were initially interpreted as frost features gives added warning to the importance of their proper identification.

[1] The "Friends of the Pleistocene," an informal organization composed of those interested in various aspects of the Pleistocene, was founded in 1933 by Professors Richard Foster Flint, George White, and J. Walter Goldthwait. The first meeting was held in the New Hampshire coastal area. Since then (with the exception of the World War II years) an annual field meting has been held at various spots in the northeastern states. In 1950 Professor Sheldon Judson led in Wisconsin the first field meeting of a midwestern group of the "Friends." In 1952 a Rocky Mountain section of the "Friends" was organized at the Salt Lake City sectional meeting of the Geological Society of America. The first field meeting of this group was led by Mr. Gerald Richmond in Rocky Mountain National Park.

When the writer undertook a detailed study of these features in the fall of 1952, they were still thought to be relics from a past periglacial climate in south-central Wisconsin. Excavation during that fall and the fall of 1953, as well as a survey of the literature, correspondence with other workers, and examination of similar features in Ohio, demonstrates that they are not fossil ice wedges or frost-crack fillings but owe their genesis largely to differential solution.

NATURE OF SOIL TONGUES

General Statement

Solution by waters percolating downward from the surface through soluble earth materials may produce a variety of effects most of which are familiar to geologists. Of less familiarity to them are differential solution effects which are evident along the base of many soil profiles. These solutions and variations in parent material produce the irregularities visible in subsoil-parent material boundaries. Thus, vertical, lobe-like subsoil extensions appear to penetrate downward into the parent material. These extensions are referred to as soil tongues by pedologists (Brown and Thorp, 1942, p. 14-15), but reference to them in most of the soils literature is meager. Goldthwait (1952) uses the term soil pendant. Though soil tongue is not entirely satisfactory as a name for the solution structures discussed, the writer feels that acceptance of the term by soil scientists warrants its use in this paper.

Usually soil tongues are but a few inches in vertical dimension and mark the slightly irregular base of the B horizon as it develops downward into parent material. They are best developed in the B_3 subhorizon of the pedalfer soils forming in calcareous, sandy gravel deposits.

The soil tongues here described are large in size, reaching 5 to 6 feet in depth. Because they may be confused with structures of different genesis, their recognition by the geologist interested in surficial deposits is important.

Soil tongues were studied in detail in an exposure in south-central Wisconsin, and similar features have been examined in Ohio. Still other tongues have been reported to the writer by investigators working in Indiana.

South-central Wisconsin

General setting.—The soil tongues most thoroughly investigated in the course of this study were located in a gravel pit excavated in deposits of Cary age in the NE¼NW¼ sec. 13, T. 11 N., R. 8 E. (Dekorra Township), west-central Columbia County. It is 13 miles south of Portage, Wisconsin, on County Highway "V" and 2½ miles south of Dekorra (fig. 1).[2]

The gravel pit, formerly operated by the Poynette Cement Block and Products Company, is now owned by the Madison Brick Company, Route 3, Madison, Wisconsin.

The pit is a few hundred feet south and east of the confluence of the Wisconsin River and a small unnamed creek. The valley is now partially

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[2] Since completion of this work, two additional soil tongue exposures have been found in a gravel pit and in a county highway road cut in the NW¼SW¼ sec. 34, T. 11 N., R. 8 E. (Columbia County, Wisconsin).

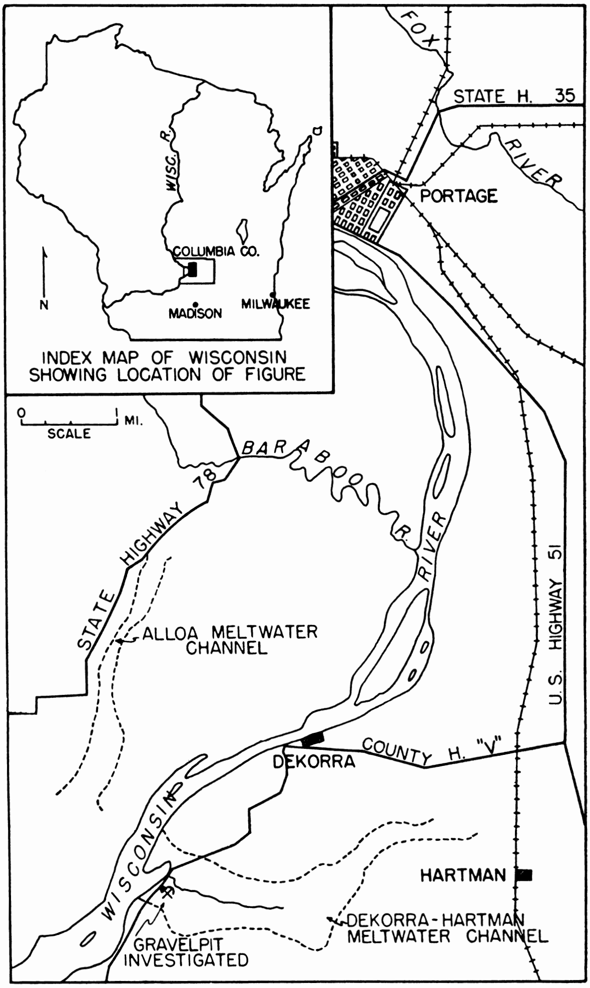


Fig. 1. West-central Columbia County, Wisconsin (after Thwaites, 1943, fig. 15).

drowned by waters impounded behind the Prairie du Sac Dam, 14 miles south on the Wisconsin River. Back water level is maintained at a mean elevation of 774 feet above sea level. Before damming, the river level was 22 feet below average pit elevation.

The glacial geology of the area is included in a *Map Showing the Surficial Deposits of Southeastern Wisconsin* (Alden, 1918, pl. 3), and briefly discussed by Bretz (1950). Thwaites (1943, fig. 15) partially remapped the area for his report on the glacial geology of northeastern Wisconsin. A modification of Thwaites' map is reproduced as figure 1.

A reconstruction of the Cary substage glacial history of the immediate area shows that a glacial meltwater channel between Hartman and Dekorra was active early during the excavation of a preglacial valley at the site of the present Wisconsin River (fig. 1). Because of rapid downcutting by the Wisconsin River, this channel was short-lived. The outwash material brought down and deposited in it is exposed in the gravel pit discussed in this paper.

Since accumulation of the outwash, wind activity has been locally important. The finer material was picked up from younger beds and redeposited.

Pit description.—Four main elements were present in the gravel pit opening. They were: (1) a sandy gravel outwash high in limestone and dolomite; (2) a dune sand cover; (3) a silt loam "pan" between the dune sand and the outwash; (4) soil tongues extending downward into the outwash below the "pan" (fig. 2-A).

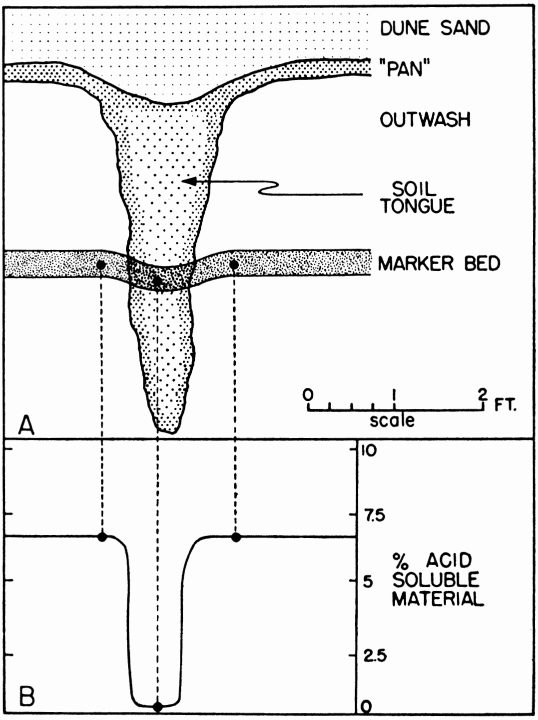
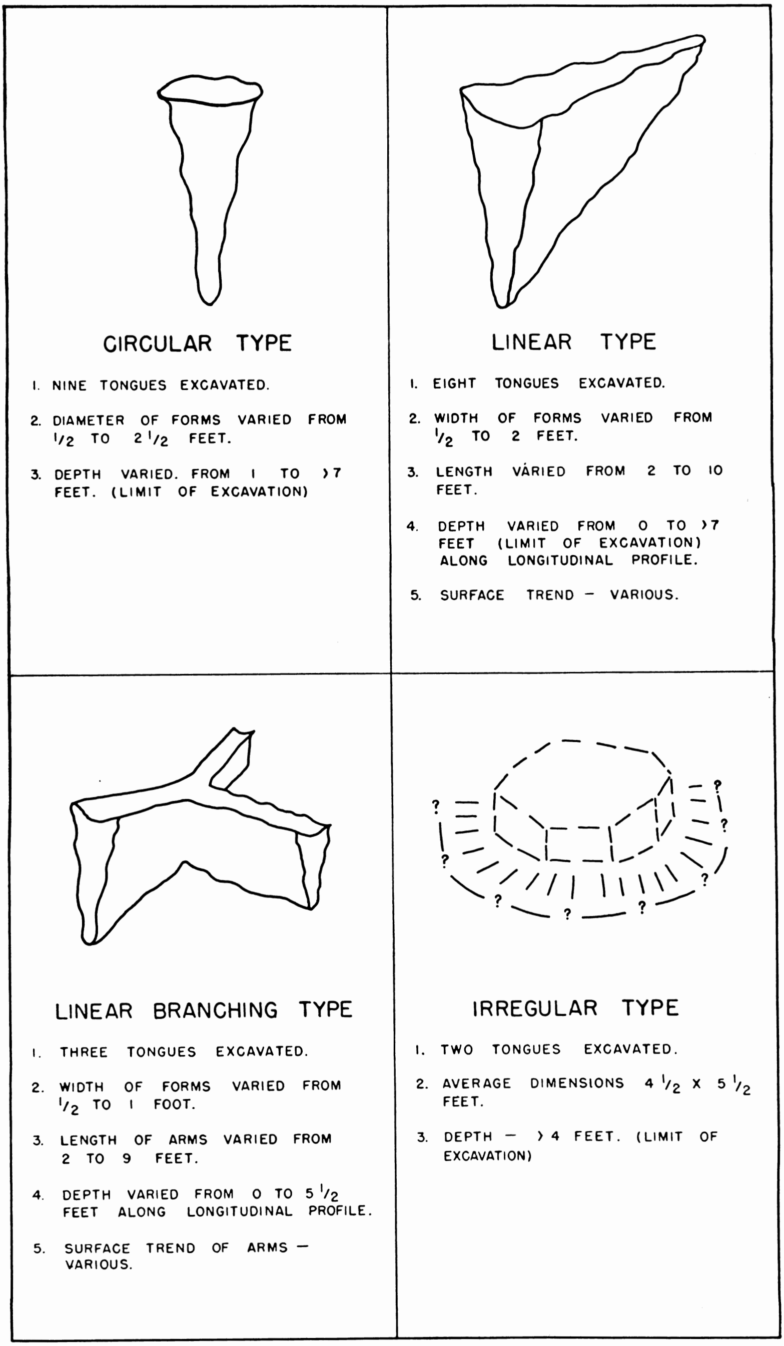


Fig. 2. A, Cross-section of soil tongue. B, Curve of percent loss of acid soluble material from unaltered outwash to soil tongue.

(1) *Outwash.* The discontinuous beds of sand and gravel outwash were exposed in the working face of the pit. In general, the outwash varied in grain size from pebbly sand and sand in the north near the small creek to a pebbly gravel and sandy gravel toward the southern limit of the exposure, over a distance of 60 feet. Although most of the outwash in the pit was composed of gravel with poorly defined bedding contacts, well-delineated white quartz sand layers occasionally occurred in the sequence. These well-bedded layers provided excellent marker beds, and their importance in the interpretation of soil tongue formation is referred to below. The quartz sand layers increased in number and thickness toward the creek.



CIRCULAR TYPE

1. NINE TONGUES EXCAVATED.
2. DIAMETER OF FORMS VARIED FROM 1/2 TO 2 1/2 FEET.
3. DEPTH VARIED. FROM 1 TO > 7 FEET. (LIMIT OF EXCAVATION)

LINEAR TYPE

1. EIGHT TONGUES EXCAVATED.
2. WIDTH OF FORMS VARIED FROM 1/2 TO 2 FEET.
3. LENGTH VARIED FROM 2 TO 10 FEET.
4. DEPTH VARIED FROM 0 TO > 7 FEET (LIMIT OF EXCAVATION) ALONG LONGITUDINAL PROFILE.
5. SURFACE TREND – VARIOUS.

LINEAR BRANCHING TYPE

1. THREE TONGUES EXCAVATED.
2. WIDTH OF FORMS VARIED FROM 1/2 TO 1 FOOT.
3. LENGTH OF ARMS VARIED FROM 2 TO 9 FEET.
4. DEPTH VARIED FROM 0 TO 5 1/2 FEET ALONG LONGITUDINAL PROFILE.
5. SURFACE TREND OF ARMS – VARIOUS.

IRREGULAR TYPE

1. TWO TONGUES EXCAVATED.
2. AVERAGE DIMENSIONS 4 1/2 X 5 1/2 FEET.
3. DEPTH – > 4 FEET. (LIMIT OF EXCAVATION)

Fig. 3. Type, trend, and dimensions of tongue structures.

(2) *Dune sand.* This deposit irregularly overlies the pit area, ranging in thickness from 3 to 6 feet.

(3) *Silt loam "pan."* This horizon is sharply delineated from the underlying outwash and overlying dune sand by its reddish-brown color and difference in composition. Pebbles present in this "pan" consisted mainly of chert fragments and some highly decomposed limestone and dolomite pebbles in a silt loam matrix. The thickness of this horizon varied from 3 to 4 inches.

(4) *Soil tongues.* These striking soil bodies were identical in texture and composition to the "pan" between the dune sand and the outwash. The shape of these soil tongues varied from tapering pipe to wedge-shaped and are described in more detail below.

Detailed description of soil tongues.—A three dimensional examination of the gravel pit was undertaken to obtain a clear picture of the various shapes, sizes, and trends of soil tongue forms. Vertical cuts were made by shovel at ½- to 1-foot intervals back into the face of the pit. These progressive slices were photographed and their nature recorded as to character of material, as well as width, length, and depth of soil tongues. On this basis, three general shapes were delineated (fig. 3).

(1) Some of the soil tongues excavated had little horizontal continuity and were apparently *circular* in ground plan, resembling conical or tapering pipes. The average diameter was between 1 and 2 feet.

(2) Most of the large scale forms were found to be definitely *linear* in ground plan—wedge-shaped in three dimensions. The average surface exposed was about 2 by 8 feet (pl. 1-A). A modification of this wedge-shaped soil tongue was termed the branching form.

(3) An *irregular* type is illustrated in figure 3. The ground plan of the two tongues excavated was somewhat obscure, but average dimensions were about 4 by 6 feet. Both soil bodies were homogeneous, showing no clearly discernible marker beds passing through them and continuing into the enclosing outwash.

In cross-section a generalized soil tongue would consist of a tapering reddish-brown silt loam body extending downward into the outwash for at

TABLE 1

Comparison Pebble Counts of Selected Tongues and Adjacent Outwash (20-30 mm. size fraction)

Pebble type	% Totals Outwash	 Tongues
Carbonates (limestone and dolomite)	65.9	10.4
Chert	7.2	29.2
Quartzite	4.0	8.0
Sandstone, Shale	5.7	11.6
Felsite	2.8	3.6
Silicic coarse-grained crystalline	4.4	11.6
Basalt	3.6	3.2
Mafic coarse-grained crystalline	4.4	16.1
Others	2.0	5.9
Totals	100.0	99.6
84.2% carbonate loss in tongues		

TABLE 2

The Relative Amounts of Acid Soluble Material in Marker Beds Between Soil Tongues and Adjacent Outwash (0.125-1.0 mm. size fraction)

	No. samples	% Acid-soluble	Range	% Soluble material lost
In outwash	6	6.8	4.7-7.9	
In soil tongues	6	0.3	0.1-0.4	95.7

least 4 feet (fig. 2-A and pl. 1-B). Pebbles in the silt loam mass included chert fragments, highly disintegrated limestone and dolomite pebbles, silicic and mafic crystalline pebbles, and shale and sandstone fragments. Table 1 compares the pebble composition of five averaged soil tongues and the outwash adjacent to each. Using the outwash composition as a base, comparison shows a marked decrease of limestone and dolomite pebbles in the tongues.

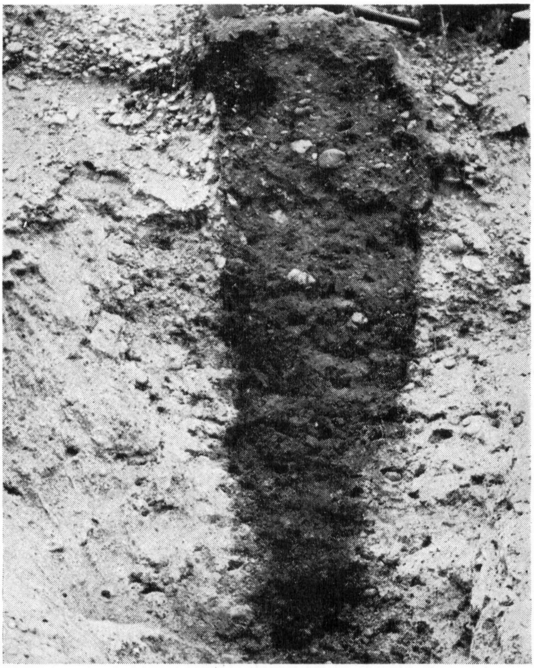
The margins of the soil tongues excavated usually tapered down to the blunt base of the structure, but in some forms the lowermost margins flared out considerably, making it appear to have a bulbous base. Occasionally the zone of contact between outwash gravel and soil tongues showed distinct marginal accumulation of iron oxide. The coloration was a deeper reddish-brown hue than that of the inner portion of the soil tongue. Toward the upper end of the tongues, the margins veered gradually from the vertical, flaring out and merging into the "pan" horizon. (Removal of dune sand in the exploitation of the gravel pit often destroyed this upper flaring end.)

Of great interest in a number of the tongues was the fact that beds of quartz sand in the outwash on either side of the structures continued unbroken through the tongues (pl. 2). Although horizontal continuity was maintained, the beds were bowed downward within the soil tongue. The fact that the marker beds were unbroken from the outwash through some tongues demonstrates that the tongues were formed by alteration of outwash material in situ and not by filling of a crevasse from above. Samples from selected marker beds were treated by acid leaching methods outlined by Richards et al., (1947, p. 93, method 8b). These demonstrated a distinct difference (in terms of acid-soluble material) between samples taken within the soil tongue portion of the individual beds and their continuation into the unaltered outwash (fig. 2). Treatment of samples from the outwash beds showed that they were composed of 4.7-7.9 percent material soluble in 0.5N hydrochloric acid. The same beds in the soil tongues contained only 0.1-0.4 percent of acid soluble material, showing a loss of 94.1-97.8 percent of the carbonate material from outwash to soil tongue (table 2). These observations point to the fact that solution has been very active in formation of soil tongues.

This conclusion is also substantiated by the pebble counts. Limestone and dolomite pebbles composed 65.9 percent of the outwash but only 10.4 percent of the average tongue sample. Thus, 84.2 percent of the carbonate material was lost between the two, with a relative gain in the other pebble types. Anomalous increases in some categories (notably silicic and mafic crystallines) result from the breakup of large pebbles. Because of this, fragments from the same pebble may have been counted more than once.

PLATE 1

A. Ground plan view of linear soil tongue. The tongue is 1½ feet wide and 8 feet long with a shovel standing on its surface. It is outlined by the shallow excavated trench (gravel pit south of Dekorra, Wisconsin).



B. Cross-section view of an homogeneous soil tongue. Note the absence of marker beds in the enclosing outwash (gravel pit south of Dekorra, Wisconsin).

Additional evidence of the importance of solution is reflected in the reduction of grain size in the tongue material. The cumulative grain size curves shown on figure 4 indicate the magnitude of this reduction by comparing the mechanical analyses of gravel beds in the outwash, where fresh, and in the tongues, where partially decomposed. The median diameter of outwash samples was 0.51 mm. and of soil tongue material, 0.38 mm. Computation of the coefficients of sorting showed a value of 1.92 for the selected outwash beds and 1.67 for the same beds in the soil tongues. Standard mechanical analysis techniques were employed following Twenhofel and Tyler (1941) and Krumbein (1932, 1935).

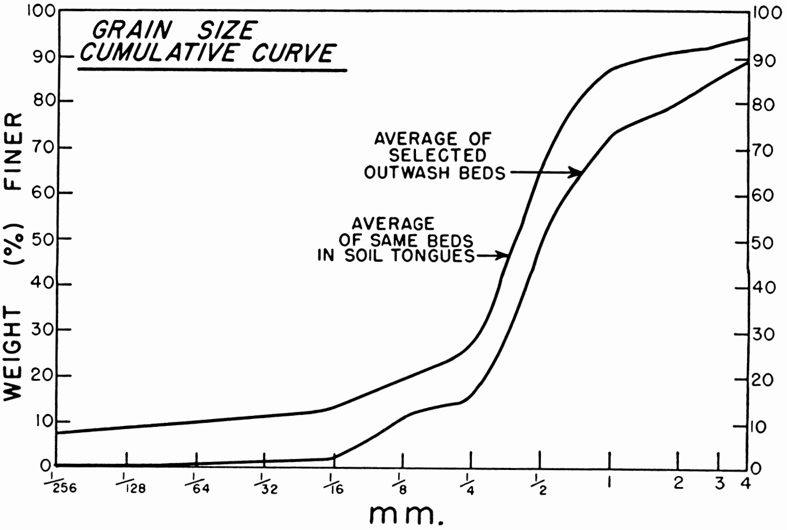


Fig. 4. Grain-size cumulative curves of selected outwash beds and same beds in the soil tongues (0.0039-4.0 mm. size fraction).

Ohio and Indiana

Occurrence of soil tongues reported from Indiana and observed by the writer in Ohio is the result of normal soil profile development upon calcareous glacial and fluvial gravel. They are typically a part of the Fox Series of soils. Brown and Thorp (1942, p. 14-15) describe the Fox silt loam B_3 subhorizon as a

> " . . . dark-brown, gritty and sticky silty clay with a slightly reddish tint and an indistinct blocky structure. Contains many pebbles, more or less disintegrated and, although the reaction is approximately neutral, no limestone fragments remain. This rests abruptly on stratified gravels beneath. The lower boundary of the horizon is very irregular in shape and narrow tongues extend to 4 or 5 feet deep in many places."

Large areas of the Fox Series of soils are found in central Ohio and in Indiana.

In June, 1953 the writer examined several stops visited by the 1952 field conference of the eastern "Friends of the Pleistocene" to compare the soil tongues of central Ohio with those described above in Wisconsin. (Field guide stops #2, 3, 5, and 10; Goldthwait, 1952).

Discounting the lack of a complete soil profile associated with the tongues in the south-central Wisconsin exposure, the Ohio tongues are physically similar: (1) in general cross-section; (2) in exhibiting downbowing of marker beds (if present); and (3) in lack of any obvious break in the continuity of the enclosing bedded material. Difference in the two occurrences should be pointed out: in the Wisconsin exposure, (1) absence of complete soil profile, (2) average depth of development of tongues was greater, and (3) marked areal continuity of many forms. Soil tongues excavated by the writer in Ohio "invariably peter out in any horizontal direction, they being extensive in depth only."[3]

In Indiana, soil tongues have been found and reported by Professor James Thorp of Earlham College and Professor Thomas Bushnell of Purdue University. They describe B_3 subhorizon extensions similar to those in Ohio[4] —a jumbled mass of reddish-brown silt to clay loam, partially decomposed carbonates, and residual pebbles that tapers downward into unweathered glacial and fluvial calcareous deposits. With adequate marker beds, subsidence is shown by downbowing of the bedding. Thus, where marker beds are absent, one cannot assume any vertical break in the indistinctly bedded unconsolidated material enclosing the structures.

Conclusions

1. Soil tongues may reach large size, extending down to depths in excess of 7 feet, and assume at least three general areal patterns: linear, circular, and irregular.
2. In those tongues in which marker beds continue through the tongues, no deep vertical break in the original deposit can be invoked to explain the gross form of these structures. It is then logical to presume that in associated soil tongues with no such markers there has been no original surface break involving the parent material.
3. The loss of carbonate material between soil tongues and outwash strongly suggests solution as the major agency of soil tongue formation through alteration of parent material in situ. They do not represent filling of a crevasse with material from above.
4. Pedologists consider most soil tongues to be extensions of the normal irregularities marking B_3 subhorizons. In addition, they note that best development is found in the Fox Series of soils where amplification of these irregularities is probably taking place in present-day humid temperate regions.

ORIGIN OF STRUCTURES

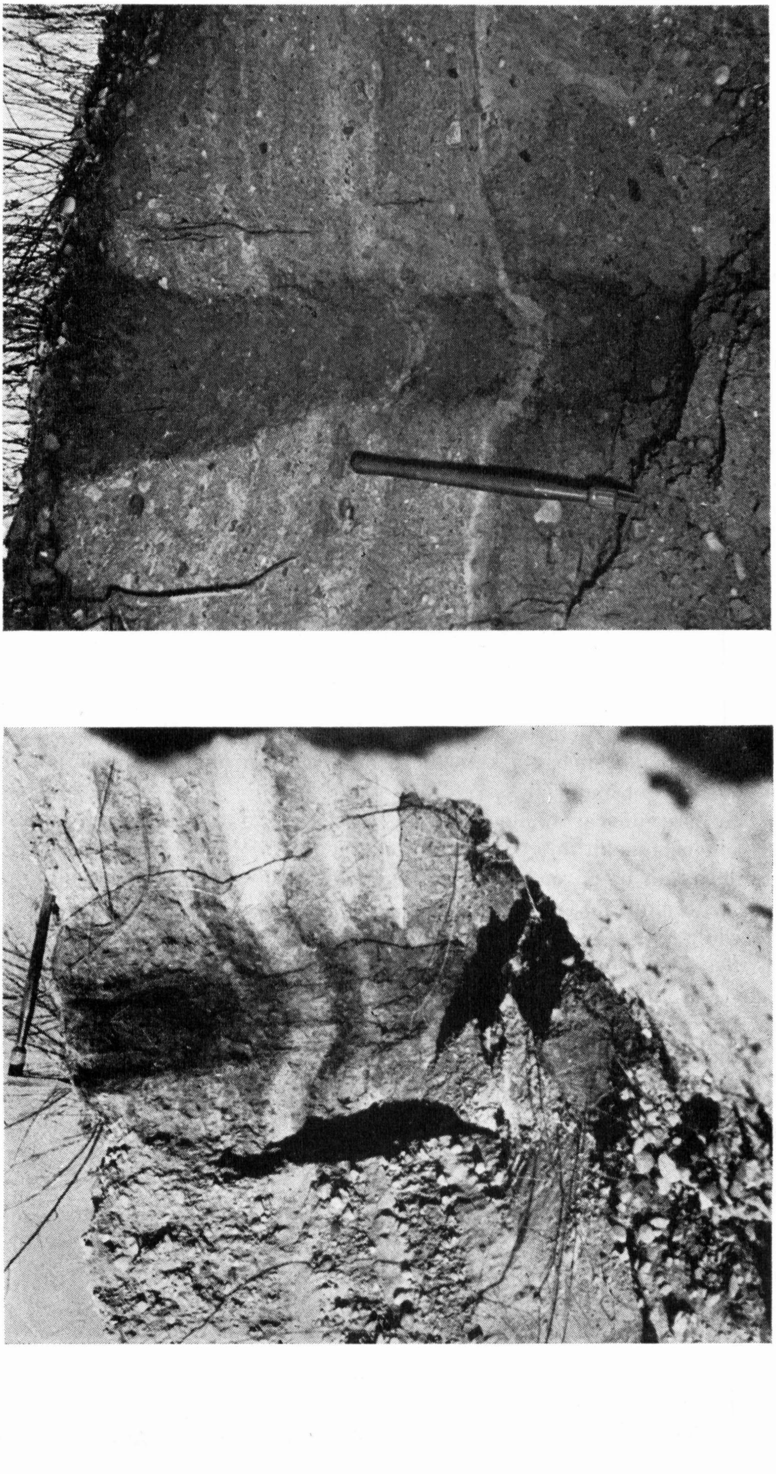
Clearly, frost action could not have produced these conical and wedge-shaped soil tongues. Percolating water bearing organic acids and carbon dioxide is capable of solution and deposition on a scale adequate to explain the vertical and lateral enlargement of these forms.

This process in the Fox Series of soils takes place in calcareous glacial or fluvial gravel parent material where the topography is level to gently rolling and annual precipitation amounts to 25 inches or more. As water percolates

[3] Professor Richard Goldthwait, personal communication, dated February, 1953.

[4] Personal communications, dated January and November, 1953, respectively.

PLATE 2



A

B

Cross-section views of soil tongues. Note the persistence of marker beds through the soil tongues and subsidence of marker beds in the tongues. The length of the shovel is 20 inches (gravel pit south of Dekorra, Wisconsin).

into the parent material, the solution and accumulation processes gradually move deeper as a highly irregular weathering front at the contact between the base of the B horizon and the underlying unleached calcareous gravel. The irregularities in this front are maintained and amplified through differential solution because of a natural channeling of percolating water into them. They are in essence "lows" on the active weathering front.

The areal distribution of these irregularities is thought to depend upon the initial ground surface configuration or upon later conditions that altered it. Proposals that have been considered are. (1) very shallow ice wedges or frost cracks; (2) shallow desiccation cracks; (3) tree roots and fallen logs; (4) faulting; and (5) micro-relief of the original ground surface.

(1) Considering shallow ice wedges or frost cracks as altering the surface of the deposit, one must realize that even if cracks are very shallowly developed no discontinuity is present in the outwash bedding stratigraphically below the break. Black (1952, p. 130) points out that Arctic ice wedges begin as minute cracks where the active permafrost layer is split. These are probably the tension cracks of Taber (1943, p. 1521). Permafrost investigation shows the infrequence of ice and frost-cracking in well-drained, coarse-textured materials. The depth of most reported ice wedges is too great to explain the shallow surface alteration allowing differential solution to take place in the situation described.

Frost cracks, which are developed to lesser depths, might entirely be concealed in homogeneous soil tongues and thus account for initiation of solution along vertical zones. This explanation, though, does not explain the conical-shaped structures.

(2) Shallow desiccation cracks might possibly have caused vertical zones of weakness in the ground surface during an arid interval before soil formation started. The coarse texture of these crack fillings and lack of explanation of conical-shaped structures casts doubt on the validity of this proposal.

(3) Tree roots and fallen logs must be discounted because of the complete lack of carbonized material, root fillings, and discontinuity in the bedding.

(4) Faulting could conceivably cause zones more susceptible to solution. If shallow, they could be completely concealed in homogeneous soil tongues where marker beds were absent. At the Wisconsin locality some normal slump faulting within stratigraphic marker beds was examined with respect to a linear soil tongue. The two were found to intersect at an acute angle and were in no way related. Thus, where faulting has been observed, there is no demonstrable genetic relation to the soil tongue. If faults did play a role in tongue formation, the evidence has either been destroyed or was not observed by the writer.

(5) Probably the most plausible explanation for the start of differential leaching in specific zones is the channeling of rain water by initial surface irregularities (micro-relief) into circular, irregular, or linear-shaped depressions.

Thus, the depth to which tongue forms extend depended upon induced irregularities in the active weathering front and the long term climatic environment. The possibility that deep forms are evidence of interglacial soil formation outside the succeeding glacial margin and are continuing to deepen today is being investigated by Goldthwait and Thorp.[5]

GENERAL CONSIDERATIONS

Wedge-shaped structures in unconsolidated deposits have been reported by several investigators in surficial deposits in temperate climates. They conclude that these structures are relics of a past periglacial climatic environment (Cailleux, 1943; Denny, 1936; Fearnsides, 1940; Horberg, 1949, 1951; Paterson, 1940; Wolfe, 1953). Description of some of these structures bears conflicting evidence as to processes involved and climatic conditions surrounding their formation. Zeuner (1945, p. 12) cautions that in general "Features suggestive of these phenomena, however, require a very careful scrutiny before they are interpreted climatically, since there are many structures which resemble them but are not caused by the effects of frost."

Specific warnings as to misinterpretation of shrinkage or desiccation crack fillings with physically similar frost crack and fossil ice wedge fillings have been offered by Hörner (1950, p. 237), Smith (1949, p. 1498-1499), Black (1952, p. 124, 132, and fig. 2), and Troll (1944, p. 549).

The study reported in this paper shows that additional forms, namely soil tongues formed by differential solution of unconsolidated, calcareous deposits, bear a striking resemblance to fossil ice wedge and frost crack fillings. The fact that these form in temperate climates where periglacial conditions may have been active adds a further warning to the problem of their correct interpretation.

A superficial study of these wedge-shaped structures may easily overlook (1) the nature and composition of the material contained, (2) the relationship of enclosing beds to the forms, and (3) the lack of any vertical break in the bedding. Among those that do cause a vertical break in the earth materials involved are ice wedges and frost cracks, and desiccation cracks.

Ice wedges and frost cracks.—The criteria for differentiation of these forms, and the circumstances surrounding their formation are not completely understood (Black, 1952, p. 131 and figs. 3 and 6). Regardless of this, it should be pointed out that soil tongues and fillings of frost cracks and fossil ice wedges may be easily confused because of ground plan and cross-sectional similarities. This raises the question as to whether or not some of the features reported in the literature as ancient frost cracks and fossil ice wedge fillings may not actually be solution structures. Unfortunately, the data included in many of the descriptions is insufficient to decide this point one way or the other. Misidentification would be easy: (1) where no associated frost action features were apparent; (2) where found in medium to coarse-grained carbonate gravel; and (3) where marker beds in the enclosing unconsolidated material were lacking.

[5] Personal communications, dated February and January, 1953, respectively.

Desiccation cracks.—In cross-section, the rock debris filling some desiccation cracks could be confused with the linear type of soil tongues or fossil frost forms if the conditions of formation were not completely understood.

ACKNOWLEDGMENTS

Permission to examine, excavate, and collect samples in the Wisconsin gravel pit was given by the owner, Mr. R. L. Peterson, and by the former owner, Mr. G. Knutsen.

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