Screenings
from the Soil Research Lab

IOWA ENGINEERING EXPERIMENT STATION
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An Unhurried Look at the Pleistocene:

OPERATION DEEPEST FREEZE

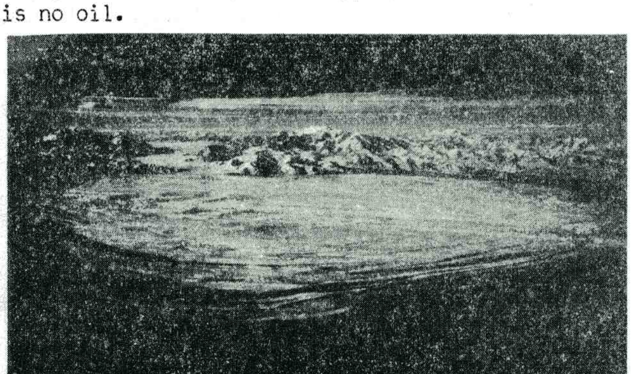
One day Great Uncle Aurignacian, 300 generations removed, was sitting in his cave swapping shaggy mammoth stories with the boys when the talk turned to that universal topic, weather.

"Bastardly cold lately," exclaimed one of the older cavemen, who often recounted stories of seeing and stepping on a vast hill of ice that reached to the moon. He singled out a young idealist and said, "John Foster, why don't you wander north, build a fire, and melt all that ice?

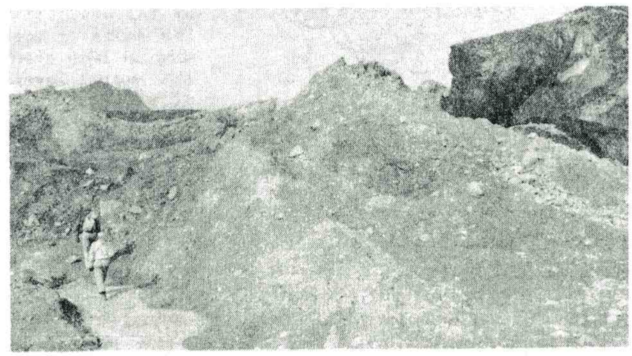
Unfortunately when John Foster got to the glacier his wood was wet, and the ice age was thus prolonged several thousand years. Science is a long history of failures.

Of Time and Temperature

Pleistocene means the ice age, or a time when glaciers repeatedly slathered ice over as much as 30 percent of the earth's land surface. The actual time involved in the Pleistocene is the merest wart off Father Time, probably less than a ten-thousandth of his entire configuration since the earth began. Even during this geologically short period of time, variously guesstimated at 300,000 to a million years, most of our modern landscape was formed. The time is so short that a hard-rock geologist thinks Pleistocene is a dirty word. He's just disappointed because there is no oil.



Malaspina at night. This glacier on the south coast of Alaska shows how ice can spread out if it gets a chance. During the Pleistocene similar spreading occurred over much of Europe and North America.



Melting glacial ice (upper right) leaves plentiful heaps of pulverized rock debris, or glacial drift. Unstratified drift shown in the photo is called glacial till. Original color usually gray, but very slight weathering changes the color to tan or brown.

Glaciation gave the earth a new face, in some places severely smoothed and sculptured, in other places coated with pulverized, mixed rock debris commonly called glacial till. Till is a very important soil material. Side effects of glaciation are even more spectacular because once known they are obvious, but ordinarily they go unsuspected. These will be discussed a bit later.

During the Pleistocene, modern man evolved and eventually succeeded in getting the under hand. Apparently his arrival so kindled the fires of hell that practically all the ice melted. Remnants of continental glaciation are in Greenland and Antarctica.

Recent?

The time since the last retreat of the glaciers is formally or informally called the Recent. Because the disappearance was not very sudden and the departure time varies from place to place, the term Recent is losing out. It's probably more accurate to assume we still live in the Pleistocene.

The Pleistocene and Recent epochs together make up the Quaternary period. The Quaternary and its predecessor, the Tertiary, together make up a large time unit, the Cenozoic era, or time of the mammals. Now you know where you are. The previous major time span, or Mesozoic era, belonged to the dinosaurs. In view of this it's interesting to contemplate what will come next.

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Maximum North American extent of Pleistocene glaciation. Dashed line shows central U. S. extent of the Wisconsin. Shaded area is glacial Lake Agassiz, formed by ice damming during retreat of the Wisconsin. Sediments in ice-marginal lakes often show annual layers or varves, which are analogous to tree rings and are a useful aid in chronology.

Glaciation in Stages

Careful study of glacial deposits shows that the ice made more advances than a college boy on a first date. Between advances the terrain was allowed to warm up and weather a while. The soil profile resulting from each of these weathering intervals is aptly termed a paleosol, literally meaning ancient soil. Paleosols are often buried and preserved under later glacial deposits and thus serve to separate the older from the younger. A good roadcut in the right place may show one or more paleosols.

At this point we must modestly admit that Iowa is world-famous for its paleosols. In fact, much of the fundamental work on the Pleistocene was done in Iowa and adjacent states suchas Illinoise. The succession of glacial and interglacial stages were first recognized and named here, and is taken as a reference point for other areas.

Glacial stages are named for states where the deposits are fairly well exposed. The Nebraskan and Kansan ice sheets pushed across Iowa into Nebraska and Kansas, and incidentally far enough south into Missouri for people to say you-all and whistle Dixie. Actually the Nebraskan is so covered up and eroded that nobody knows exactly where it goes.

Farther east a later glaciation, the Illinoian, covered most of Illinois, Indiana and Ohio, and even took a nip at Kentucky.

Between Glacial Stages

The time between two successive glaciations is called an interglacial stage, and is a period of warmth and weathering. Interglacial stages are named after important places like Afton and Yarmouth, Iowa, and Sangamon County, Illinois.

SUBDIVISION OF THE PLEISTOCENE

Note that a geological column is read from the bottom up; oldest formations are put at the bottom to correspond to the sequence seen in exposed sections.

Stages in North America		European Equivalents	
Glacial	Interglacial	Glacial	Interglacia
	Recent		
Wisconsin		Würm	
	Sangamon		R/W
Illinoian		Riss	
	Yarmouth		M/R
Kansan		Mindel	
	Aftonian		G/M
Nebraskan		Günz	
			D/G
?		Donau	

Like modern surface soils, the character of a paleosol depends on such things as climate, slope, and time for weathering. And some paleosols really have a lot of character. For example, our most famous paleosol is a highly weathered, gray, blocky clay called gumbotil. The best way to remember about gumbotil is to try to drive over it after a rain. It contains over 50% clay, nearly all of it our sticky friend montmorillonite. Need we say more? We will.

In better drained, eroded areas the gumbotil passes into a thinner, red-brown clayey soil designated by the old-time geologists as ferreto. Recent detailed work by R. V. Ruhe relates properties of a paleosol to age of the surface on which it has developed. That is, erosion can cut a fresh surface in very old stuff, with the result that there is less time for the eroded surface to develop a paleosol. For example, a Kansan till surface weathering throughout the Yarmouth, Illinoian and Sangamon will have a very good gumbotil. But if erosion were active in, say, the late Sangamon, the late Sangamon erosion surface will be weathered much less.

Light-colored Wisconsin loess over darker colored Kansan till. To the left of the man is a thin paleosol, or darker, weathered zone in the surface of the Kansan till. On a flat, uneroded area this will become gumbotil.

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THE WISCONSIN GLACIAL STAGE

Fortunately for man and beast, whether she be wife or mother-in-law, the glaciers came back, smoothed over the rough spots and spread a nice new layer of till. This Wisconsin age till has magnificent corn-growing qualities far excelling the sticky sterility or blocky hardness of a paleosol.

But what of areas not covered by Wisconsin till? Never fear, for God also gave us loess, a widespread silt layer excellent for corn, beans and alfalfa. In fact, where would we be without it? Probably raising tobacco and closing schools like some solid citizens farther south. Pride can be a very stubborn refuge if you don't have anything else.

Draft from the Drift

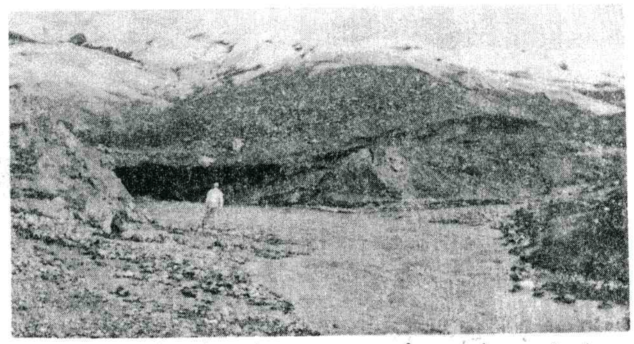
Glacial till is a wild mixture of clay, silt, sand, gravel and boulders deposited directly from melting ice. Some is believed deposited under the ice sheet where melting is caused by pressure; some is deposited at the ice sheet margins.

Ah, but when ice melts it makes water! Sub-glacial melt water happens to be very muddy. Washed material left by this water is called stratified drift. It comes in two varieties: outwash, which is washed out from the glacier and occupies river valleys, and ice-contact features, which are as the name implies. Ice-contact features usually exist as hills or ridges, meaning the water that left them must have been confined by ice.

According to popular theory, (Screenings, Vol. 1, No. 4), the silt that makes up loess blew from glacial outwash rivers like the Missouri. Most loess is believed deposited during Wisconsin time, since it buries all the old till plain paleosols but is thin or absent on areas of Wisconsin till.

In some places an older, probably Illinoian, loess has been identified; this underlies the

In cold climates, soils are bothered by permafrost phenomena such as ice wedges. An ice wedge cut through this loess paleosol, then melted so the void filled in with later loess. Gentleman on the left is Alaskan geologist Troy Péwé.



An outwash-bearing stream emerges from under a glacier. Note the extreme dirtiness of the basal ice.

Wisconsin loess and is separated from it by a paleosol. It is called the Loveland loess after another important place, Loveland, Iowa.

EUROPE AND OTHER PLACES

Glaciers in different parts of the world kept the same time schedule, so that when America was plastered Europe and Asia were too. Studies in the Alps show four major glaciations which may correlate to the four stages in this country. Later studies show there may be a fifth, earlier stage of limited extent.

Alpine glacial stages are called the Donau, Günz, Mindel, Riss, and Würm. Interglacial stages are denoted G/M for Günz-Mindel, M/R for Mindel-Riss, etc., a system which blesses the memory. The Würm shows several similarities to our own Wisconsin, including the deposition of loess. Two divisions of the Würm are recognized, and detailed studies of the loess have shown evidence for at least four substages.

Substaging the Wisconsin

In history, religion and politics the most recent events are known in the most detail. The Wisconsin glacial stage is therefore divided into a set of substages, on the basis of evidences that the ice front did not retreat evenly, but retreated part way and then re-advanced. At latest count there were six sub-stages, some solidly established, some in doubt. The Wisconsin loess reflects some of these breaks with weakly developed paleosols, indicating pauses in deposition.

Substages of the Wisconsin:

Glacial	Interglacial
Valders	
	Two Creeks?
Mankato	

Cary	
	Brady
Tazewell	

Iowan	

Farmdale?	

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This North Dakota kame consists of stratified sands and gravels once confined by glacial ice. The surrounding plain is glacial till.

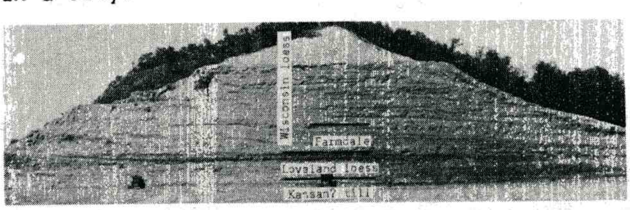
Coming of Man

The Pleistocene is also the age of man, unless he gets foolish. While fossils are rare and the record is very spotty, the evidence is all in favor of man branching off from his hairy cousins long before the Pleistocene even started.

The oldest human fossils are a long way from the nearest glaciers, making positive dating difficult. Probably a good guess is that the real ancestral low-brows, the Java man and Peking man (Pithecanthropus and Sinanthropus their formal names) lived in Asia during the G/M interglacial stage, probably corresponding to our own Aftonian.

Neanderthal man is much better known, about 100 individuals having been found in Europe, Africa, and Siberia. Neanderthal was still rather short and sluggish, more reminiscent of types seen among one's in-laws than those occupying one's own side of the family. Neanderthal apparently had high regard for his fellow man, although dog meat was more to his liking as it was less stringy and made better gravy. Neanderthal would not have understood the modern theory that killing for territory is so much more noble than killing for meat.

Because of his lack of human awareness, Neanderthal man gave way to Cro-Magnon man, who was essentially modern. The only major difference is that Cro-Magnon lived in a cave. This distinction will be rather fine to those who live in a city.



Re-exposed type section of the Loveland loess near Loveland, Iowa. From the bottom the probable ages are Kansan, Illinoian (Loveland loess) with Sangamon paleosol (dark band), Farmdale (loess and weak paleosol), and indifferentiated Wisconsin.

Man in the New World

Man came to the American Eden rather late, and through a natural process of doing what he wanted to do he became an Indian. The Eskimos did similarly, although they came later. The probable route was via the Bering Strait.

Entry of man apparently caused widespread extinction of edible land mammals, including camels, horses, giant bison, giant beaver, mammoths and mastodon. Most of these animals lived in the Americas until the retreat of the last glaciation, 10,000 to 5,000 years ago. Man was here at least 10,000 years ago.

Dating

Fortunately for figuring out the Pleistocene, a radioactivity method may be used to date plant or animal remains. Unfortunately the method only reaches back 30,000 years, or to about the beginning of the Wisconsin.

Cosmic rays bombarding nitrogen atoms in the air cause a slight conversion to radioactive carbon, C^{14}, which has a half-life of 5,570 years. Living plants and animals contain a certain percentage of this carbon. When an organism dies, it no longer replenishes its carbon, and radioactivity slowly peters out.

Results of the method are widespread verifications and complications. The Farmdale, or earliest substage of the Wisconsin, is dated at about 24,500 years ago. Several samples of wood from the Iowan, supposedly later, have come out radioactively dead, or older than 30,000 years, and the dates have given some people to doubt radiocarbon dating. Tazewell loess was probably deposited 17,000 to 15,000 years ago. The Cary glacial maximum, which in Iowa reached to the city of Des Moines, was 14,000 years ago, and the Mankato started its advance about 11,400 years ago. Final retreat of the Valders ice and drainage of Lake Agassiz was perhaps 5,000 years ago, and the shores of Lake Agassiz were hunted by early man.

Early man is easily recognized from his close-set eyes, heavy brow ridges, and receding chin and forehead. This living specimen of Homo cornea distendus (Milkweed) was discovered during a recent outing of the Greater Louisiana Lowland Bird-Watchers' Society. Apparently it had roamed around unnoticed for years.

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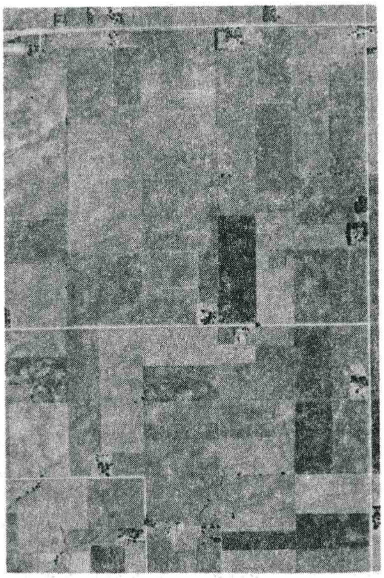

An aerial view of central Iowa shows the mottled, swell-and-swale pattern typical of a young, poorly drained till plain. Slight lineation of the knolls is believed to mark former outlines of the final retreating front edge of the glacier.

WARPED CRUST AND CHANGES IN SEA LEVEL

An interesting side effect, or more accurately, bottom effect, of glaciation was to push the earth's crust down under the tremendous weight of the ice. Former lake and sea shores near glaciated areas are now tilted, whereas once they were level. In fact, the Hudson Bay region in North America and the Baltic Sea region in Europe are still recovering at rates which are measurable. The northern Baltic is rising at almost 3 feet per 100 years, and eventually may become an enclosed lake basin. There the total maximum depression during glaciation was at least 700 feet and perhaps twice that. Hudson Bay has come up 500 feet or more during the past 5000 years.

Surveyors reference their altitudes to sea level, which has about as much stability as a yo-yo. For example, glaciation locked up a lot of water in cold storage, lowering sea level 300 to 400 feet. At the other extreme, during maximum warm periods it was probably 90 feet higher than at present, a fact which if repeated would be a major inconvenience to places like New York and Atlantic City.

As glaciers accumulated and sea level went down, so did the rivers,slicing out deep trenches. When the glaciers melted and sea level came back up, the trenches filled with alluvium, often supplied by outwash from the melting glaciers. This happened so often that in the lower Mississippi Valley the history is recorded in four river terraces, preserved by a simultaneous uplift of the land. The four terraces should correlate to four interglacial stages. Radiocarbon dates show the youngest terrace (the Prairie) is older than 30,000 years, or older than early Wisconsin.

AND WHY DO WE HAVE GLACIERS?

Glaciations have been blamed on everything from sunspots to dust storms to the attitude of the American female. However, now it's believed that cold temperatures are not so vital as having everything just right for the accumulation of snow. For example, in Alaska the major glaciers all prefer the warm, clammy climate of the South, rather than the cold, dry crispiness of the North. Heavy snowfall south of the mountains is related to evaporation from the nearby warm and salty Japan Current.

The Ewing-Donn Theory to explain glaciers was developed from studies of mud cores from the Caribbean. Micro-fossils plus a radiocarbon date showed that there was a sudden ocean warming 11,000 years ago, with virtually no other change in temperature for the last 90,000 years.

Briefly, the theory is this: An Arctic Ocean freely connected with the Atlantic should remain open with no permanent accumulation of pack ice as we know it today. A warm and open Arctic Ocean could supply plenty of evaporated water for glaciers.

But as glaciers accumulated, sea level went down so that a submarine ridge known to connect Norway with Greenland served as a water barrier. Isolated from the Atlantic, the Arctic Ocean would again freeze over, and incidentally following isolation the Atlantic should suddenly warm up. No open ocean, no evaporation, no snow, no glaciers. The beauty of the mechanism is that it is cyclic, and could explain the repeated glaciation during the Pleistocene.

What next? Sea level is now up and rising; the Arctic pack ice has thinned 40 percent in the past 15 years. In other words, if you plan to live for a while be careful not to get run over by any glaciers. If the theory and measurements are right it could all get started in the next hundred years.

In northeastern Iowa near the classic "driftless area," loess directly overlies limestone. The dark, clayey layer is the limestone paleosol.

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GLACIAL DEPOSITS IN IOWA

Glacial till

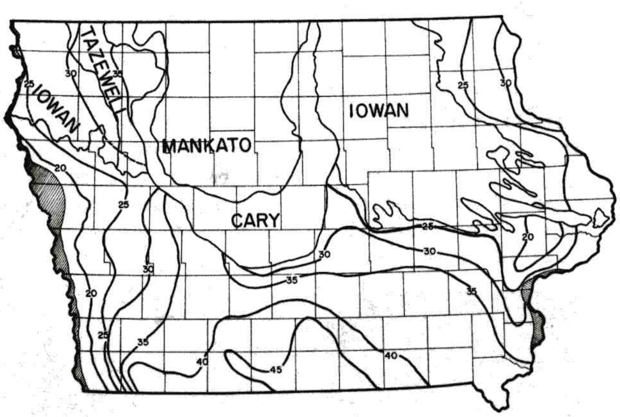
Studies of Kansan and Illinoian tills in Iowa show that an average unweathered sample is about one-third clay, one-third silt, and one-third combined sand and gravel, the gravel fraction usually amounting to less than 4 percent of the total. A statistical sampling scheme shows that the till is not highly variable from place to place. The major clay mineral is montmorillonite. Engineering-wise, the till nearly always classifies as A-7-6.

Gumbotil

Statistical sampling of gumbotil shows that it contains from 55 to 75 percent clay, or enough to give an engineer bad eyesight. Montmorillonite is the major clay mineral. Engineering classification, an extreme A-7-6.

Loess

Loess in Iowa varies from about 10 to 45 percent clay, depending on the locale. The remainder of the loess is nearly all silt, although some loess contains a trace of sand. Fineness, sand and clay content are believed related to the distance from a source. The major clay mineral is montmorillonite. Coarse loess classifies as A-4, fine loess as A-6 or A-7-6.



Map showing Wisconsin drift borders and contoured 5-micron clay contents of C-horizon loess.

An interesting feature of thick, low-clay-content loess deposits is that they absolutely refuse to hold a water table. Percolating water usually seeps down until it encounters a stumbling block such as Loveland loess or gumbotil. Whereas unsaturated loess has sufficient cohesion to stand in vertical faces, saturated loess is but a weak mud. Therefore when roadcuts are cut all the way through the loess, slides may reasonably be expected.

Summary

The soils of Iowa so far studied for engineering uses are rather rich in montmorillonitic clay. Areas not yet investigated are in north-central Iowa, the Iowan and Cary-Mankato drift areas. A major purpose of the field studies is to give an idea of what we are working with and allow an accurate selection of representative samples. The guiding premise is that sampling is the most critical step in setting up a laboratory study---nothing is so worthless as a bad sample. Thus the few samples selected for soil stabilization and mineral content studies are very carefully chosen from hundreds already analyzed for plasticity and particle size.

ACKNOWLEDGEMENTS AND REFERENCES SIGHTED

A standard text is the nicely done Glacial and Pleistocene Geology by R. F. Flint, published in 1957 by Wiley. A comprehensive reference work in two volumes is The Quaternary Era, by J. K. Charlesworth, published in 1957 by Edward Arnold, Ltd., London. Wisconsin glacial problems of the central U. S. are well summarized in an article by M. M. Leighton, Journal of Geology 66:3:288-309, 1958. A summary of Iowa radiocarbon dates is given by Ruhe, Scholtes, and Rubin, Am. Jour. Science 255:10:671-689, 1957. The Ewing-Donn Theory was first presented in Science, June, 1956 and May, 1958, and is somewhat sensationally reported in Harper's (not Harper's Bazaar), September, 1958.

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IN THE NEXT ISSUE: CHLORIDES for dust-free roads.

RLH

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