UNIVERSITY OF MINNESOTA
MINNESOTA GEOLOGICAL SURVEY
D.L. Southwick, Director

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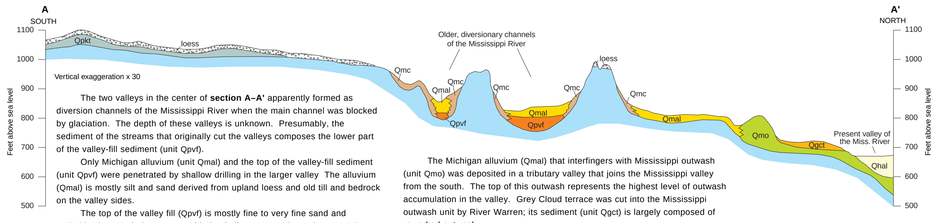
COUNTY ATLAS SERIES
ATLAS C-12, PART A
Plate 4—Quaternary Stratigraphy



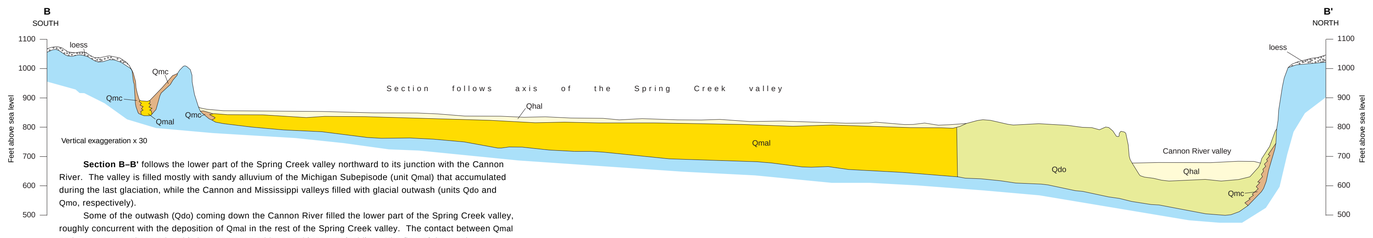
The two valleys in the center of **section A–A'** apparently formed as diversion channels of the Mississippi River when the main channel was blocked by glaciation. The depth of these valleys is unknown. Presumably, the sediment of the streams that originally cut the valleys composes the lower part of the valley-fill sediment (unit Qpvf).

Only Michigan alluvium (unit Qmal) and the top of the valley-fill sediment (unit Qpvf) were penetrated by shallow drilling in the larger valley The alluvium (Qmal) is mostly silt and sand derived from upland loess and old till and bedrock on the valley sides.

The top of the valley fill (Qpvf) is mostly fine to very fine sand and probably slopewash, but strong oxidation indicates pre-Wisconsin age. A layer of sand and gravel (too thin to show) between Michigan alluvium (Qmal) and valley-fill sediment (Qpvf) is apparently spillover outwash from the Mississippi valley at its highest level.

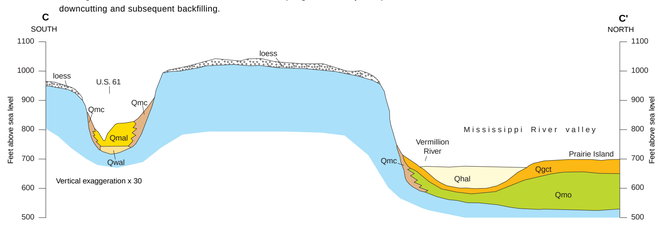
The Michigan alluvium (Qmal) that interfingers with Mississippi outwash (unit Qmo) was deposited in a tributary valley that joins the Mississippi valley from the south. The top of this outwash represents the highest level of outwash accumulation in the valley. Grey Cloud terrace was cut into the Mississippi outwash unit by River Warren; its sediment (unit Qgct) is largely composed of reworked outwash.

Modern alluvium (unit Qhal) in the Mississippi valley is very thick. The valley is slowly refilling with sediment, after having been overdeepened by drainage from Lake Agassiz.



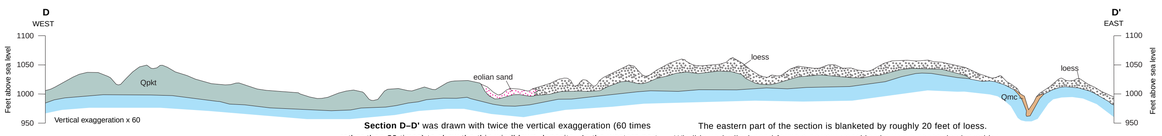
Section B–B' follows the lower part of the Spring Creek valley northward to its junction with the Cannon River. The valley is filled mostly with sandy alluvium of the Michigan Subepisode (unit Qmal) that accumulated during the last glaciation, while the Cannon and Mississippi valleys filled with glacial outwash (units Qdo and Qmo, respectively).

Some of the outwash (Qdo) coming down the Cannon River filled the lower part of the Spring Creek valley, roughly concurrent with the deposition of Qmal in the rest of the Spring Creek valley. The contact between Qmal and Qdo was not observed and is here represented by an arbitrary vertical line. The flow of the creek was impeded as the valley filled, and it spilled over into a diversion channel to find a new course to the Mississippi. Lacking a stream connection to the Cannon River, the Spring Creek valley escaped the River Warren downcutting and subsequent backfilling.



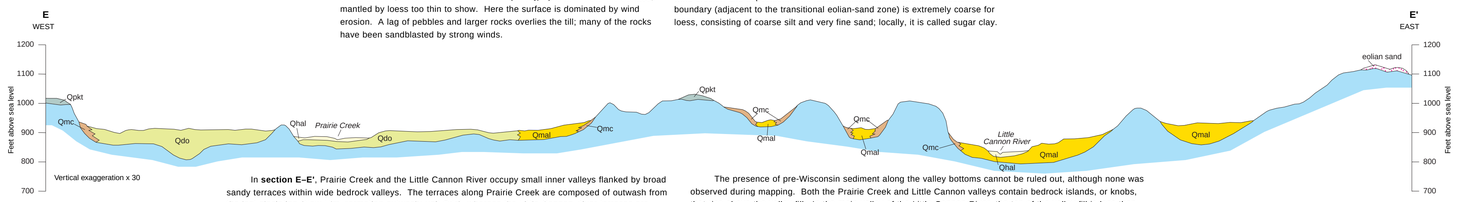
The Michigan alluvium (unit Qmal) at the base of the small valley near the south end of **section C–C'** consists mostly of silt, fine sand, and silty clay. It was deposited in thin flat beds under quiet water as the Cannon River filled with outwash. This slackwater silt is underlain by oxidized, leached sand (unit Qwal), interpreted as pre-Michigan alluvium. Pebbles in the sand are mostly chert, with a few erratics derived from old tills.

The uplands are composed of bedrock that is mantled with loess. The bedrock surface was once covered by till, and thin patches of till may remain, but none were observed near the line of section. However, erratic cobbles and pebbles of Superior provenance are present on top of the bedrock in places, under the loess. The Mississippi River valley is deep and is filled chiefly with outwash (unit Qmo) from the last glaciation; the upper part of the outwash was removed and reworked by River Warren. Prairie Island is a gravel bar that formed in this giant stream.



Section D–D' was drawn with twice the vertical exaggeration (60 times rather than 30 times) to show the thin windblown deposits. In the western part of the section, till of the Pierce Formation (unit Qpkt) is at or near the surface, mantled by loess too thin to show. Here the surface is dominated by wind erosion. A lag of pebbles and larger rocks overlies the till; many of the rocks have been sandblasted by strong winds.

The eastern part of the section is blanketed by roughly 20 feet of loess. Windblown (eolian) sand forms a narrow transition between zones dominated by wind erosion and deposition. The loess within a mile or two of its western boundary (adjacent to the transitional eolian-sand zone) is extremely coarse for loess, consisting of coarse silt and very fine sand; locally, it is called sugar clay.

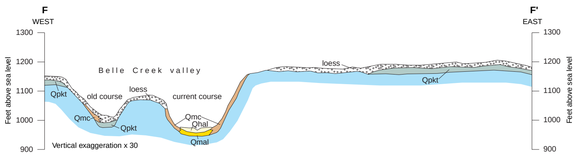


In **section E–E'**, Prairie Creek and the Little Cannon River occupy small inner valleys flanked by broad sandy terraces within wide bedrock valleys. The terraces along Prairie Creek are composed of outwash from the last glaciation (New Ulm Formation outwash; unit Qdo), whereas the Little Cannon River terraces are composed of locally derived sand deposited during the last glaciation (unit Qmal). In both places, the material that makes up the terraces also underlies the relatively thin alluvium (unit Qhal).

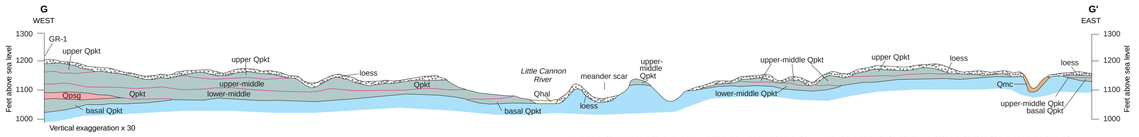
On the east side of the Prairie Creek valley, unit Qmal interfingers with outwash (Qdo). This part of the valley is actually a tributary valley. Its surface is higher than the outwash surface (Qdo) in the main valley, and its sediment is derived from valley walls and nearby uplands.

The presence of pre-Wisconsin sediment along the valley bottoms cannot be ruled out, although none was observed during mapping. Both the Prairie Creek and Little Cannon valleys contain bedrock islands, or knobs, that rise above the valley fill. In the main valley of the Little Cannon River, the top of the valley fill is less than 900 feet but rises above 920 feet east of the bedrock island, which may have protected the fill to the east from downcutting when the main stream changed from depositional to erosional.

Farther east, sandy soils (too thin to map) extend upslope to about 1000 feet, much higher than the valley fill. This is interpreted as a layer of windblown sand derived from the valley fill. There is even a patch of eolian sand on top of the bedrock hill on the east side of the cross section, above 1100 feet.



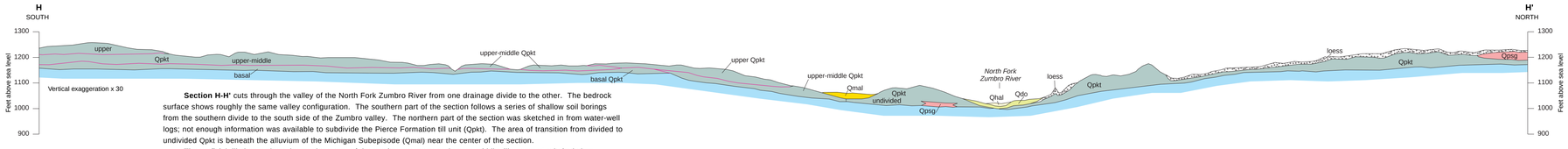
Section F–F' runs through an isolated bedrock hill in the Belle Creek valley. The modern course of the creek swings east around the hill. Between the hill and the west side of the valley is a short stretch of abandoned valley. Under the loess is a remnant of till (unit Qpkt), similar to the till that mantles the bedrock uplands. The till in the present valley was eroded, and the major streams have cut through it into bedrock. However, the abandoned segment has suffered only local slopewash erosion since the main stream was diverted. It is not known whether the till layer was deposited after the river changed course, or whether glaciation actually caused the diversion. An alternative explanation is that this till is a mudflow deposit, derived from the till on the uplands. In this case, the drainage diversion could be younger than the last glaciation to cover this area



Section G-G' shows till stratigraphy of the Pierce Formation (unit Qpkt) in an area that has relatively good subsurface information (a deep borehole [GR-1] forms the west end of the cross section). Drift is thickest here. Eastward to the Little Cannon River, the bedrock surface slopes up as the land surface slopes down. East of the Little Cannon, the section crosses an old meander scar. Farther east, till mantles the surface of the bedrock, but the rock is fairly high, and the till never gets very thick.

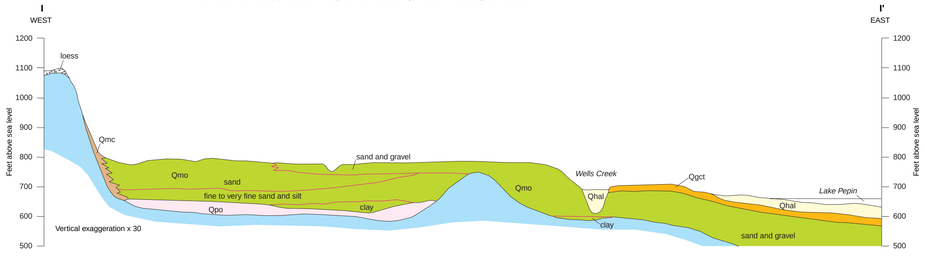
The informally defined till sheets within unit Qpkt form a relatively simple pancakelike stratigraphy, as though the stack of tills were laid down and then dissected by stream erosion. The basal till is restricted to the areas of lowest bedrock elevation on the west side of the section, except for a remnant patch on the east side, at a higher elevation. The remnant is exposed in a quarry, under the upper-middle till. Here the basal till is highly oxidized, indicating a long period of exposure. The lower-middle till is missing, presumably eroded away.

In the center of the section, the stack of tills has been eroded by the Little Cannon River and its tributaries. Paradoxically, the bedrock surface is fairly high here, where the land surface is the lowest. The modern course of the Little Cannon River must have been established over thick drift. The streams did not encounter bedrock until their courses were well established. The upper-middle till, the thickest one, forms the surface over a significant extent of the section. The upper till seems to be present only under the highest elevations; elsewhere it is eroded away. It has apparently been exposed to weathering and erosion for a long time, judging by the thickness and intensity of its oxidized zone. The oxidized zones in the tops of the underlying tills are thinner and less intense.



Section H-H' cuts through the valley of the North Fork Zumbro River from one drainage divide to the other. The bedrock surface shows roughly the same valley configuration. The southern part of the section follows a series of shallow soil borings from the southern divide to the south side of the Zumbro valley. The northern part of the section was sketched in from water-well logs; not enough information was available to subdivide the Pierce Formation till unit (Qpkt). The area of transition from divided to undivided Qpkt is beneath the alluvium of the Michigan Subepisode (Qmal) near the center of the section.

The surficial till sheets along the southern part of the section are upper and upper-middle tills, even at relatively low elevations. This suggests that these tills were draped over an existing valleyside. However, the basal till is in the shallow subsurface at the top of the valley slope. This suggests that the valley did not exist at the time of deposition of the basal till. No lower-middle till was penetrated in any of the soil borings used in creating the section.



Section I-I' shows Mississippi River–valley sediments in a wide part of the valley. In most places along the Mississippi valley south of the Twin Cities, the bulk of the valley fill is coarse sand and gravel, washed out of glaciers farther north. The Mississippi was a braided stream, whose floodplain occupied the whole valley from bluff to bluff. Within the floodplain was a multiplicity of shifting channels, separated by gravel bars.

The western part of this cross section is somewhat protected by the bedrock bluffs to the north, and by a buried bedrock high shown on the section. These barriers kept this area out of the main force of the current during most of the time the valley filled with glacial outwash. As a result, much of the sediment is finer than is typical for Mississippi valley train (unit Qmo).

East of the buried bedrock high, the valley train is mostly sand and gravel. One bed of basal clay may have been deposited behind a low bedrock rise that temporarily protected the area from the mainstream. No older sediments are shown on this side, due to lack of information. In other places along the river, outwash of the last glaciation extends to bedrock, far below the current river level.

Meltwater sediments in the semi-isolated basin west of the central bedrock high form a coarsening-upward sequence of clay and clayey silt; fine to very fine sand and silt; and fine to coarse sand. The sequence is overlain in part by a tongue of sand and gravel that apparently spilled over the bedrock barrier from the main channel. Wood fragments were sieved from cuttings at the base of the valley train west of the bedrock barrier, or from the soil on top of the underlying sediments. A radiocarbon date of 26980 ± 280 years before present indicates that the filling of the Mississippi valley was underway by this time.

The underlying sediments are oxidized and leached; some samples show soil development. They may not represent a single deposit, but they are significantly older than the Michigan Subepisode valley fill. Pebbles of local bedrock are common, but erratic pebbles are also present, indicating that this is not just a bedrock colluvium. Most likely, these sediments are a remnant of older valley fills, elsewhere mostly eroded away but here preserved in a protected location.

Postglacial alluvium (unit Qhal) under the Mississippi River and Wells Creek is thick, due to the effect of post–River Warren filling. Wells Creek enters the Mississippi valley from the west, flows south of the line of cross section, then loops north through the section. Its alluvium has blocked the lower part of the Frontenac channel, dammed up a shallow lake, and built a small delta into Lake Pepin.

EXPLANATION OF CROSS SECTIONS

- Qhal — **Alluvium.**
- Qgct — **Sand and gravel of Grey Cloud terrace.**
- Qmal — **Alluvium of the Michigan Subepisode.**
- Qwal — **Older alluvium.**
- Qpvf — **Valley-fill sediment.**
- Qmc — **Colluvium.**
- **Loess.**
- **Eolian sand.**
- Qmo — **Mississippi valley train (outwash)**—The unit is divided in section I–I' into the following textural components:
  - sand and gravel
  - sand
  - fine sand and silt
  - clay
- Qpo — **Older Mississippi valley train (outwash).**
- Qdo — **Outwash of the New Ulm Formation.**
- Qpkt — **Till of the Pierce Formation.** The unit is divided in sections G–G' and H–H' into the following till sheets:
  - upper till
  - upper-middle till
  - lower-middle till
  - basal till
- Qpsg — **Glaciofluvial deposits of the Pierce Formation.**
- **Undivided bedrock.**
- **Contact.**
- **Contact between subunits in sections G–G', H–H', and I–I'.**

SCALE 1: 24,000
0 1/2 1 2 MILES
0 .5 1 2 3 KILOMETERS

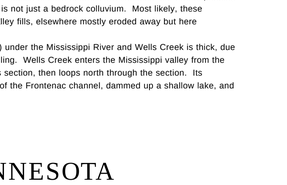


Figure 1. Map of Goodhue County showing selected physical and cultural features and the lines of section. Rotasonic borehole MGS-GR-1 forms the west end of section G–G'.

QUATERNARY STRATIGRAPHY

By

Howard C. Hobbs

1998

INTRODUCTION

This plate is a companion to the surficial geologic map (Plate 3) as it shows Quaternary deposits at depth. The units are described and correlated on Plate 3. The cross sections are enlarged about four times the horizontal scale relative to the map, and thirty times the vertical scale (sixty times for D–D') to show details and thin layers. The cross sections should be regarded as diagrams illustrating significant points, rather than precise geometric relationships. The reader should be able to use this information, along with the thickness of Quaternary sediments (also on Plate 3) to predict, at least in a general way, Quaternary stratigraphy in areas where cross sections were not constructed.

Some aspects of the sections are more precise than others. The land surface (upper line) is based on topographic contours (at the 1:24,000-scale) that cross the line of section. It is the most accurate and detailed line on the sections. However, this surface is misleading in places where the line of section crosses a hillslope obliquely. Here the slope looks more gentle than it would be if the line were drawn straight down the slope. However, the great vertical exaggeration makes all of the hillslopes look steeper than they really are.

The accuracy of the bedrock surface (lowest line) is variable. Where surficial cover is thin, the bedrock surface is approximated by the land surface, and is just as accurate. Elsewhere, the elevation of the bedrock surface is extrapolated from widely separated sources of information like water-well logs, many of which are not on the line of section. For such areas, the line of the bedrock surface represents what the geologist thinks it should be, but the potential margin of error is large.

The uppermost sediment at any given place generally corresponds (given the difference in scale) to the surficial mapping unit on Plate 3. The distribution of buried sediment layers are inferred from scattered subsurface data. The lines chosen for cross sections have a greater than average density of subsurface data, but much extrapolation is still required.

THICKNESS OF QUATERNARY SEDIMENTS AND QUATERNARY STRATIGRAPHY

Most of the thickness of drift (or Quaternary sediments) in Goodhue County is till, except in the valley of the Mississippi River and its tributaries. In general, the till is thickest in the western part of the county (Plate 3). Some of the four tills sheets of the Pierce Formation (unit Qpkt) identified in the western part of the county may not have extended farther east; for example, the lower-middle till of the Pierce was not identified near Wanamingo (section H–H'). An area of thick drift is present north of Zumbrota, in the lee of a major north-south bedrock escarpment. The bedrock surface drops 200 feet from the Galena Group to the Prairie du Chien Group in two to three miles (Plate 2). This area would have been relatively protected from glacial erosion, and may have accumulated thick till, especially in the earlier glaciations.

DISTINGUISHING TILL UNITS

Till of the Pierce Formation (unit Qpkt) has been subdivided into four separate till sheets in parts of the cross sections. Although descriptive logs from water wells and soil borings can be used to classify a material as till, they do not permit the till to be subdivided. Individual tills can be recognized only in areas where good samples were obtained from excavations and soil borings. All the tills of the Pierce Formation are of Winnipeg provenance (Plate 3) but can be separated by subtle differences in texture and rock type. Four tills were recognized in Rotasonic boring MGS-GR-1 (Fig. 2); they are here named informally by their position in the sequence.

The ***basal till*** contains a high proportion of Paleozoic rock fragments. Roughly half are angular, and appear to be local. This is expected, inasmuch as the bedrock in this region is Paleozoic, and basal tills are typically enriched in the local bedrock. The texture of the basal till is variable. At the Rotasonic boring MGS-GR-1, where it overlies the Decorah Shale, it is rather clayey. In a quarry site at the east end of section G–G', it incorporates an older, oxidized loess at its base and is silty.

The ***lower-middle till*** is low in clay. The proportion of Paleozoic carbonate rock is higher than in the upper-middle and upper tills, but less than in the basal till. Red grains of Superior provenance are sparse to very sparse. Cretaceous grains are more common than in the basal or upper tills, but less than in the upper-middle till.

The ***upper-middle till*** is fairly clayey; it is the richest of all these tills in Cretaceous grains, especially in calcareous shale. It also appears to contain more expandable clay than the other tills, because it develops wetting and drying cracks on exposed surfaces. It has the lowest number of Superior-provenance grains of all the Pierce Formation till sheets.

The ***upper till*** contains the lowest proportion of Paleozoic grains of the four tills, and the highest proportion of Superior-provenance grains.

Gray till of the Illinois Episode has been recognized in a few places in and near Goodhue County, but not along the lines of sections on this plate. Its texture is similar to the older tills of the Pierce Formation. In general, this till is richer in Paleozoic and Cretaceous carbonate grains than most of the older Pierce Formation samples. It is also richer in dark though not red grains.

Minnesota Geological Survey borehole MGS-GR-1; unique no. 250780; elevation, 1197 ± 5 feet
T. 110 N., R. 18 W., sec. 7, CBCBBB

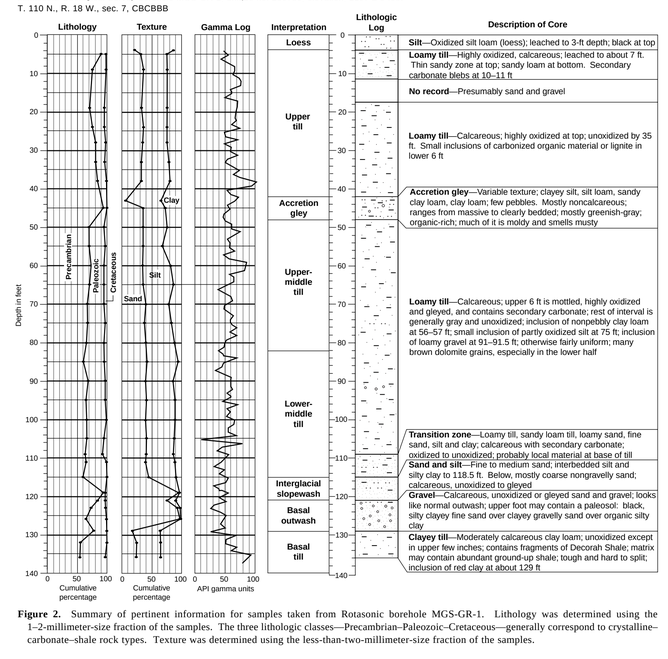


Figure 2. Summary of pertinent information for samples taken from Rotasonic borehole MGS-GR-1. Lithology was determined using the 1–2-millimeter-size fraction of the samples. The three lithologic classes—Precambrian–Paleozoic–Cretaceous—generally correspond to crystalline–carbonate–shale rock types. Texture was determined using the less-than-two-millimeter-size fraction of the samples.