U.S. Department of the Interior
U.S. Geological Survey

Scientific Investigations Map 3392
Sheet 2 of 2

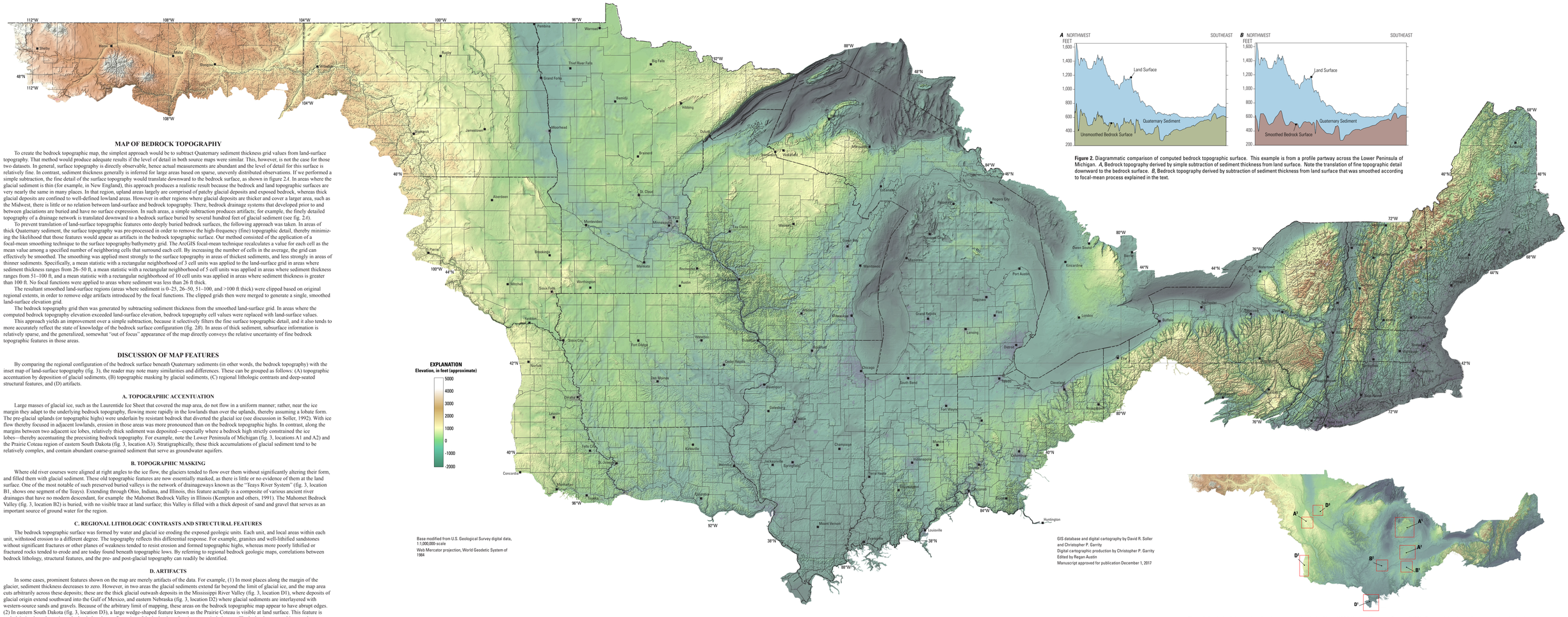

Figure 2. Diagrammatic comparison of computed bedrock topographic surface. This example is from a profile partway across the Lower Peninsula of Michigan. *A*, Bedrock topography derived by simple subtraction of sediment thickness from land surface. Note the translation of fine topographic detail downward to the bedrock surface. *B*, Bedrock topography derived by subtraction of sediment thickness from land surface that was smoothed according to focal-mean process explained in the text.

Figure 3. Shaded relief map of land surface topography, derived from USGS National Elevation Dataset (NED). By examining the land surface and the bedrock topographic maps, along with the drift thickness map, areas underlain by relatively thick and thin deposits of unconsolidated, Quaternary sediment can be compared and contrasted. The selected locations (for example, A1, D2) highlight areas of particular interest (see "Discussion of Map Features").

MAP OF BEDROCK TOPOGRAPHY

To create the bedrock topographic map, the simplest approach would be to subtract Quaternary sediment thickness grid values from land-surface topography. That method would produce adequate results if the level of detail in both source maps were similar. This, however, is not the case for those two datasets. In general, surface topography is directly observable, hence actual measurements are abundant and the level of detail for this surface is relatively fine. In contrast, sediment thickness generally is inferred for large areas based on sparse, unevenly distributed observations. If we performed a simple subtraction, the fine detail of the surface topography would translate downward to the bedrock surface, as shown in figure 2*A*. In areas where the glacial sediment is thin (for example, in New England), this approach produces a realistic result because the bedrock and land topographic surfaces are very nearly the same in many places. In that region, upland areas largely are comprised of patchy glacial deposits and exposed bedrock, whereas thick glacial deposits are confined to well-defined lowland areas. However in other regions where glacial deposits are thicker and cover a larger area, such as the Midwest, there is little or no relation between land-surface and bedrock topography. There, bedrock drainage systems that developed prior to and between glaciations are buried and have no surface expression. In such areas, a simple subtraction produces artifacts; for example, the finely detailed topography of a drainage network is translated downward to a bedrock surface buried by several hundred feet of glacial sediment (see fig. 2*A*).

To prevent translation of land-surface topographic features onto deeply buried bedrock surfaces, the following approach was taken. In areas of thick Quaternary sediment, the surface topography was pre-processed in order to remove the high-frequency (fine) topographic detail, thereby minimizing the likelihood that those features would appear as artifacts in the bedrock topographic surface. Our method consisted of the application of a focal-mean smoothing technique to the surface topography/bathymetry grid. The ArcGIS focal-mean technique recalculates a value for each cell as the mean value among a specified number of neighboring cells that surround each cell. By increasing the number of cells in the average, the grid can effectively be smoothed. The smoothing was applied most strongly to the surface topography in areas of thickest sediments, and less strongly in areas of thinner sediments. Specifically, a mean statistic with a rectangular neighborhood of 3 cell units was applied to the land-surface grid in areas where sediment thickness ranges from 26–50 ft, a mean statistic with a rectangular neighborhood of 5 cell units was applied in areas where sediment thickness ranges from 51–100 ft, and a mean statistic with a rectangular neighborhood of 10 cell units was applied in areas where sediment thickness is greater than 100 ft. No focal functions were applied to areas where sediment was less than 26 ft thick.

The resultant smoothed land-surface regions (areas where sediment is 0–25, 26–50, 51–100, and >100 ft thick) were clipped based on original regional extents, in order to remove edge artifacts introduced by the focal functions. The clipped grids then were merged to generate a single, smoothed land-surface elevation grid.

The bedrock topography grid then was generated by subtracting sediment thickness from the smoothed land-surface grid. In areas where the computed bedrock topography elevation exceeded land-surface elevation, bedrock topography cell values were replaced with land-surface values.

This approach yields an improvement over a simple subtraction, because it selectively filters the fine surface topographic detail, and it also tends to more accurately reflect the state of knowledge of the bedrock surface configuration (fig. 2*B*). In areas of thick sediment, subsurface information is relatively sparse, and the generalized, somewhat "out of focus" appearance of the map directly conveys the relative uncertainty of fine bedrock topographic features in those areas.

DISCUSSION OF MAP FEATURES

By comparing the regional configuration of the bedrock surface beneath Quaternary sediments (in other words, the bedrock topography) with the inset map of land-surface topography (fig. 3), the reader may note many similarities and differences. These can be grouped as follows: (A) topographic accentuation by deposition of glacial sediments, (B) topographic masking by glacial sediments, (C) regional lithologic contrasts and deep-seated structural features, and (D) artifacts.

A. TOPOGRAPHIC ACCENTUATION

Large masses of glacial ice, such as the Laurentide Ice Sheet that covered the map area, do not flow in a uniform manner; rather, near the ice margin they adapt to the underlying bedrock topography, flowing more rapidly in the lowlands than over the uplands, thereby assuming a lobate form. The pre-glacial uplands (or topographic highs) were underlain by resistant bedrock that diverted the glacial ice (see discussion in Soller, 1992). With ice flow thereby focused in adjacent lowlands, erosion in those areas was more pronounced than on the bedrock topographic highs. In contrast, along the margins between two adjacent ice lobes, relatively thick sediment was deposited—especially where a bedrock high strictly constrained the ice lobes—thereby accentuating the preexisting bedrock topography. For example, note the Lower Peninsula of Michigan (fig. 3, locations A1 and A2) and the Prairie Coteau region of eastern South Dakota (fig. 3, location A3). Stratigraphically, these thick accumulations of glacial sediment tend to be relatively complex, and contain abundant coarse-grained sediment that serve as groundwater aquifers.

B. TOPOGRAPHIC MASKING

Where old river courses were aligned at right angles to the ice flow, the glaciers tended to flow over them without significantly altering their form, and filled them with glacial sediment. These old topographic features are now essentially masked, as there is little or no evidence of them at the land surface. One of the most notable of such preserved buried valleys is the network of drainageways known as the "Teays River System" (fig. 3, location B1, shows one segment of the Teays). Extending through Ohio, Indiana, and Illinois, this feature actually is a composite of various ancient river drainages that have no modern descendant, for example the Mahomet Bedrock Valley in Illinois (Kempton and others, 1991). The Mahomet Bedrock Valley (fig. 3, location B2) is buried, with no visible trace at land surface; this Valley is filled with a thick deposit of sand and gravel that serves as an important source of ground water for the region.

C. REGIONAL LITHOLOGIC CONTRASTS AND STRUCTURAL FEATURES

The bedrock topographic surface was formed by water and glacial ice eroding the exposed geologic units. Each unit, and local areas within each unit, withstood erosion to a different degree. The topography reflects this differential response. For example, granites and well-lithified sandstones without significant fractures or other planes of weakness tended to resist erosion and formed topographic highs, whereas more poorly lithified or fractured rocks tended to erode and are today found beneath topographic lows. By referring to regional bedrock geologic maps, correlations between bedrock lithology, structural features, and the pre- and post-glacial topography can readily be identified.

D. ARTIFACTS

In some cases, prominent features shown on the map are merely artifacts of the data. For example, (1) In most places along the margin of the glacier, sediment thickness decreases to zero. However, in two areas the glacial sediments extend far beyond the limit of glacial ice, and the map area cuts arbitrarily across these deposits; these are the thick glacial outwash deposits in the Mississippi River Valley (fig. 3, location D1), where deposits of glacial origin extend southward into the Gulf of Mexico, and eastern Nebraska (fig. 3, location D2) where glacial sediments are interlayered with western-source sands and gravels. Because of the arbitrary limit of mapping, these areas on the bedrock topographic map appear to have abrupt edges. (2) In eastern South Dakota (fig. 3, location D3), a large wedge-shaped feature known as the Prairie Coteau is visible at land surface. This feature is underlain in places by resistant bedrock, but the configuration of the bedrock surface is not precisely known. The bedrock topographic map shows sharp, well-defined eastern and western edges to this feature, similar in nature to its surface expression. Although it is possible that the land-surface and bedrock topography are quite similar, it is more plausibly an artifact produced by slightly inaccurate placement of sediment thickness contour lines (which are highly interpretive) on the source map, relative to abrupt changes in landscape elevation (which is directly measurable, and not interpretive). Because this map was derived strictly by computation, and did not benefit from geologic interpretation, artifacts such as this are unavoidable, especially in areas of thick Quaternary sediment. It also is likely that the pitted nature of the bedrock surface on Michigan's Lower Peninsula (fig. 3, location A1) is an artifact caused by incomplete smoothing of the land-surface elevation data.

Map of Bedrock Topography

Quaternary Sediment Thickness and Bedrock Topography of the Glaciated United States East of the Rocky Mountains

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