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Surficial Materials in the Conterminous United States

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INTRODUCTION

The Earth's bedrock is overlain in many places by a loosely compacted and mostly unconsolidated blanket of sediments in which soils commonly are developed. These sediments generally were eroded from underlying rock, and then were transported and deposited. In places, they exceed 1000 ft (330 m) in thickness. Where the sediment blanket is absent, bedrock is either exposed or has been weathered to produce a residual soil. This map shows the sediments and the weathered, residual material; for ease of discussion, these are referred to here as "surficial materials." Certain areas on this map include a significant number of rock outcrops, which cannot be shown at the scale of the map; this is noted in the "Description of Map Units" section.

Most daily human activities occur on or near the Earth's surface. Homeowners, communities, and governments can make improved decisions about hazard, resource, and environmental issues, when they understand the nature of surficial materials and how they vary from place to place. For example, are the surficial materials upon which a home is built stable enough to resist subsidence or lateral movement during an earthquake? Do these materials support a ground water resource adequate for new homes? Can they adequately filter contaminants and protect buried aquifers both in underlying sediments and in bedrock? Are they suitable for development of a new wetland? Where can we find materials suitable for aggregate?

The USGS National Cooperative Geologic Mapping Program (NCGMP) works with the State geological surveys to identify priority areas for mapping of surficial materials (for example, in areas of complex and poorly understood deposits of various sediment types, where metropolitan areas are experiencing rapid growth). To help establish these priorities, a modern, synoptic overview of the geology is needed. This map represents an overview of our current knowledge of the composition and distribution of surficial materials in the conterminous United States*. The best available map has been a highly generalized depiction at 1:7,500,000-scale (about 120 miles to the inch), prepared for the USGS National Atlas (Hunt, 1979; 1986).

This map is compiled at a slightly more detailed scale (about 80 miles to the inch) than Hunt (1979; 1986). We used digital methods, which enabled us to rapidly incorporate the variety of source maps available to us. State-scale geologic maps from the western United States were brought directly into this map, without expending the time needed to resolve interpretive differences among them. Therefore, abrupt changes in surficial materials are indicated along many State boundaries. This of course is an artifact of our compilation technique, and a limitation on its utility. However, this approach supports the basic premise of the map -- to provide an overview of surficial materials, and to identify areas where additional work may be needed in order to resolve scientific issues that can, in turn, lead to improved mapping.

* The map covers only the conterminous U.S. because similar geologic information in digital form was not readily available for Alaska and Hawaii.

ACKNOWLEDGMENTS

This map was funded by the USGS National Cooperative Geologic Mapping Program. Geologic maps and digital files that were used to create this map are listed in the "References and Compilation Sources" section. David R. Soller (for the eastern States) and Marith C. Reheis (for the western States) compiled and generalized the map units from the source materials. Darren VanSistine (for the western States) and David R. Soller (for the eastern States) performed the digital processing of map data. Nancy R. Stamm and David R. Soller prepared the final, printed product. The compilers thank Russell W. Graymer and Van S. Williams (USGS) for their critical reviews of this map.

GENERAL DISTRIBUTION OF SURFICIAL MATERIAL TYPES

Surficial materials can be classified according to their age, texture, composition, and environment of deposition or formation. The environment of deposition is particularly helpful in understanding differences among these materials. For example, the texture, internal structure, and thickness of materials transported and deposited by glaciers are markedly different from residual materials developed in place, in bedrock. A highly generalized graphical depiction of the sediment texture and depositional environment of map units is shown in Figure 1.

The map shows broad, regional differences in the nature of materials at land surface. To help identify different units on the map, small index maps showing the general distribution of each unit are provided; this technique was adapted from: Miles, C., compiler, 2003, Geologic shaded-relief map of Pennsylvania: Pennsylvania Bureau of Topographic and Geologic Survey Map 67, scale 1:500,000. In the Atlantic and Gulf coastal zones, clayey to sandy materials have been deposited in beach, lagoonal, nearshore, and related environments. Inland, broad areas especially in the southern, central, and western parts of the Nation are covered by thin residual materials weathered from the underlying bedrock, and "mass-movement" (landslide and hillside creep) sediments mostly derived from residual materials that have been slightly transported downslope and redeposited. In many places, the residual and mass-movement materials are patchy or absent and bedrock is exposed, especially on hillslopes. For large areas of the midwest, these and other materials are blanketed by windblown sediments, especially on the uplands. Coarse- to fine-grained alluvial and lake sediments are commonly found in major river valleys throughout the Nation, in low-lying areas of glacial-age lakes (e.g., surrounding the Great Salt Lake, Utah), and in internally drained valleys in the Great

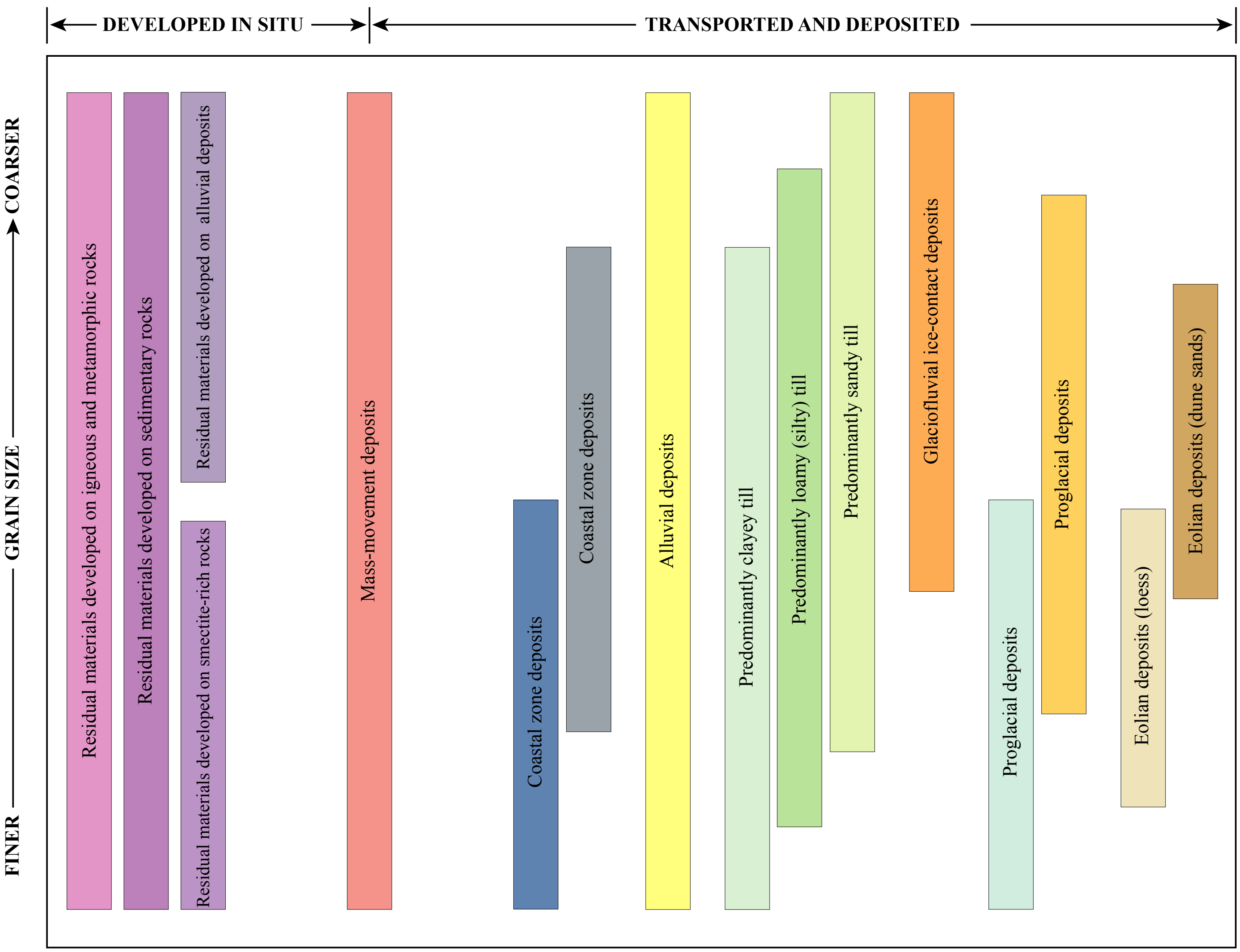

Figure 1. The general texture and transport history for various depositional environments in our classification of map units. The figure is intended only to acquaint the reader with the general characteristics, similarities, and differences among the map units, and should not be used as a definitive guide to a map unit's characteristics. To simplify the presentation, not all map units are shown here.

Basin of the western U.S. In the northeast and north-central United States, glacial ice caused the accumulation of extensive and thick deposits (in places exceeding 1000 ft) of till and associated glacial lake and stream sediments; these materials support a rich agricultural and industrial infrastructure.

METHODOLOGY

The compilation of this map began with an inventory of available source maps. We used maps that met the following criteria: were statewide or larger in area; showed surficial materials at land surface (or could be interpreted to derive such information); and were Geographic Information System (GIS) files in ArcInfo format. For the conterminous U.S. east of 102 degrees West Longitude, we used a 1:2,500,000-scale recompilation (Fullerton and others, written commun.) of the "Quaternary Geologic Atlas of the United States" series (U.S. Geological Survey, Map I-1420, scale 1:1,000,000). That recompilation contained more than 150 different types of surficial materials. For the conterminous U.S. west of 102 degrees West Longitude, we used published statewide geologic maps, which mostly were at 1:500,000-scale. Those maps emphasized the bedrock geology, although they also showed some of the major unconsolidated units such as alluvium in major river valleys and large deposits of lake sediment. Significant interpretation therefore was required in order to identify the appropriate residual surficial material developed in each mapped bedrock unit.

The disparity in information content among source maps argued for a broad classification with few units. We began with a simple classification based on that of the British Geological Survey (McMillan and Powell, 1999). For the eastern source map (Fullerton and others, written commun.), each of the 150 map unit descriptions were interpreted and manually parsed into various attribute fields in a spreadsheet. Attributes included: unit name, dominant sediment texture, geologic age, environment of deposition, and thickness. After using these attributes to classify the map units, the map was displayed and evaluated and, iteratively, a revised classification emerged that adequately displayed and highlighted the broad variations in surficial materials. This classification emphasizes sediment texture and depositional environment.

Parsing into sediment texture and depositional environment fields was especially challenging because the map unit descriptions were in many cases quite lengthy and complex, and contained information about several different surficial material types. For example, in southwestern North Dakota a unit on a source map is named "Loamy disintegration residuum, sheetwash alluvium, and colluvium on sandstone, siltstone, mudstone, claystone, shale, and lignite" -- this map unit contains three different major types of surficial material and a variety of bedrock lithologies that provide sources for the surficial material. We classified the unit as "Mostly residual materials developed in bedrock, with lesser sheetwash alluvial sediments".

For each source map in the western part of the Nation, unconsolidated units were assigned to the appropriate category in our classification, and bedrock units were assigned to the surficial materials category most appropriate to their rock composition; for example, a sedimentary rock unit predominantly comprised of limestone was assigned to the category "Residual materials developed in limestone and other carbonate rocks".

These source maps then were appended into a single digital map file of the western States, and additional source information for lake and eolian deposits was added (see "General References" under Part 3 of "References and Compilation Sources" section).

We combined the eastern and western GIS map files into a single Postscript file and, using Adobe Illustrator, produced this map without an accompanying GIS database. However, at some future time a GIS database may be prepared.

Sediment thickness estimates were derived from various sources. For the glaciated area and adjacent alluvial valleys mostly in the eastern part of the map, thickness contours from Soller and Packard (1998) were generalized. Elsewhere in the east, sediment thicknesses were derived from the source map unit descriptions. In the west, sediment thicknesses were obtained from source maps and also by generalizing to map units the known thicknesses of local areas. Sediment thickness is shown by stippled patterns and variations in color intensity.

CAVEATS

This map is a highly generalized depiction of surficial materials for the conterminous United States. It is intended solely as an overview of existing knowledge, as an educational tool, and as a guide to support discussions on where additional geologic mapping might be needed. Because of its generalized unit descriptions, regional scale, and incomplete integration across the map area (as discussed below), this map is not intended for decisionmaking at the local, site-specific level.

Many of the processes that create surficial materials (especially those involving wind or mass movement of materials) tend to vary over small distances, and so the delineation of map areas large enough to be visible at the scale of this map (1 inch on the map equals about 80 miles on the ground) is highly problematic. To improve map legibility and comprehension, a classification system was required that assigned the many complex units on source maps into units much more broadly and simply defined.

In some cases, units on source maps could not be readily assigned to our classification. As an example, a geologic unit found mostly in the southeastern U.S. is a residual material that developed mostly in metamorphosed sedimentary rocks and, to a lesser extent, in sedimentary rocks. Rather than define a new map unit, we decided to classify it as "Residual materials developed in sedimentary rocks" to distinguish it from "Residual materials formed in igneous and metamorphic rocks". As another example, the source map for New York and New Jersey classified a unit as "Ice-contact deposits and glacial lake deposits -- A complex of ice-contact sand and gravel and glacial lake sediments." This unit could not readily be assigned in our classification to either a coarse- or a fine-grained unit. Therefore, we decided to assign it to a genetically-related unit, glacial till, whose texture ranges from coarse to fine. This decision certainly is imperfect, and illustrates the difficulties in reinterpreting source map information.

A further challenge is presented where map units from different source maps abut. When compiling a map from numerous published sources, many instances occur where, especially along the edges of adjoining source maps, the materials are described and mapped in different ways. Normally, these inconsistencies can be resolved by additional field mapping or through discussions with the geologists who created the source maps, and this is an especially effective approach when mapping at a relatively detailed scale. Lacking such avenues for resolution, units shown on adjacent source maps could not always be reconciled. Therefore, this map shows numerous instances where different map units meet along straight lines, commonly at state or latitude boundaries. For example, in North Dakota, a map unit extends westward where it seems to correspond to a unit from the adjacent source map. However, on that adjacent map, the surficial materials were not shown; there, it must be assumed that the bedrock is exposed and has been weathered to produce residual materials. The residual materials that are inferred from that map are classified differently than the materials described on the map to the east, hence there appears to be a sharp discontinuity in surficial materials. Because this map is an overview, essentially a "snapshot" of current knowledge that can be represented at a national scale, these inconsistencies are retained to indicate what is actually known about the materials, and to indicate where additional mapping may be beneficial.

Regarding the thickness of these surficial materials, scant information at a regional or national scale is available, except within the glaciated area. In most places, this is not a significant problem because these materials generally fall within our lower thickness category (<100 ft). However, for large expanses of alluvial and lacustrine materials (for example, in the Mississippi River Valley, the Platte River Valley, and in internally drained valleys of the western United States), thicknesses may exceed 100 ft, even where not so indicated on the map.

In most places, especially in areas not covered by glacially-deposited sediment, the uppermost material generally constitutes most (and in places, all) of the total thickness of sediment overlying bedrock. However, where sediment is shown exceeding 100 feet in thickness, the surficial material mapped at land surface does not necessarily extend downward to bedrock. In many places the uppermost material may be only a few feet thick, but the total thickness of sediment overlying bedrock is much greater. This is especially common in the glaciated area where the peat or loess shown on the map is only a thin veneer that overlies a complex package of other surficial materials which, in places, exceeds 1000 ft in thickness. Please refer to the "Description of Map Units" section for further information.

SUMMARY

A detailed understanding of the Earth's blanket of sediment and weathered bedrock is critical to our society, because nearly all human activities occur on or within these materials. This level of understanding is now being gained through detailed mapping by the State geological surveys and the USGS. In support of that work, this map provides a rapid, preliminary regional compilation; it does not offer information useful for local decisions, but instead serves to illustrate for educational and planning purposes the general nature and distribution of the Nation's surficial materials at land surface. Perhaps most significantly, the map is intended to highlight regional differences in the mapping of these materials. The compilers hope the map will thereby serve a useful purpose, by helping to guide further mapping efforts.

GEOLOGIC TIME SCALE

PERIOD	EPOCH	AGE	
QUATERNARY	Holocene		
	Pleistocene	late	Wisconsinan
			Sangamonian
		middle	Illinoian
			Yarmouthian
		early	pre-Illinoian
TERTIARY (part)	Pliocene	late	
		early	

Time scale modified from:

a) Hansel, A.K., and Johnson, W.H., 1996, Wedron and Mason Groups: Lithostratigraphic reclassification of deposits of the Wisconsin Episode, Lake Michigan Lobe Area: Illinois State Geological Survey Bulletin 104, 116p.;

b) Sibrava, V., Bowen, D.Q., and Richmond, G.M., editors, 1986, Quaternary glaciations in the northern hemisphere: Report of the International Geological Correlation Programme, Project 24: Pergamon Press, New York, 514 p.; and

c) Remane, J., compiler, 2000, International Stratigraphic Chart: International Union of Geological Sciences, <http://www.stratigraphy.org/>.

Absolute ages are not provided here, but as a general frame of reference the Pleistocene Epoch occurred between about 1.81 million to about 10,000 years before present.

REFERENCES AND COMPILATION SOURCES

1. General references:

Hunt, C.B., 1986, Surficial deposits of the United States: Van Nostrand Reinhold Company, New York, 189 p.

Hunt, C.B., 1979, Surficial geology of the conterminous United States: U.S. Geological Survey, National Atlas of the United States of America, scale 1:7,500,000.

McMillan, A.A., and Powell, J.H., 1999, BGS Rock Classification Scheme, Volume 4, Classification of artificial (man-made) ground and natural superficial deposits -- applications to geological maps and datasets in the UK: British Geological Survey Research Report, RR 99-04, 65 p.

2. Compilation sources for eastern United States (east of 102 degrees West Longitude):

Fullerton, D.S., Bush, C.A., and Pennell, J.N. (U.S. Geological Survey), written commun., Surficial deposits and materials in the eastern and central United States (east of 102 degrees West Longitude): U.S. Geological Survey unpublished database derived from map series "Quaternary Geologic Atlas of the United States, USGS map I-1420", one ArcInfo file, scale 1:2,500,000. [Printed map derived from this database is available as: Fullerton, D.S., Bush, C.A., and Pennell, J.N., 2003, Map of surficial deposits and materials in the eastern and central United States (east of 102 degrees West Longitude): U.S. Geological Survey Geologic Investigations Series Map I-2789, scale 1:2,500,000.]

Kohfield, K.E., and Muhs, D.R., [n.d.], Mid-continental USA gridded maps of loess thickness: World Data Center-A for Paleoclimatology, Data Contribution Series, NOAA-NGDC Paleoclimatology Program, Boulder, CO.,
<http://www.bgc-jena.mpg.de/bgc_prentice/projects/dirtmap/>.

Mason, J.A., 2001, Transport direction of Peoria Loess in Nebraska and implications for loess sources on the Central Great Plains: Quaternary Research, v. 56, p. 79-86.

Soller, D.R., and Packard, P.H., 1998, Digital representation of a map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: U.S. Geological Survey Digital Data Series, DDS-38, ArcInfo files, scale 1:1,000,000, <http://pubs.usgs.gov/dds/dds38/>.

Swinehart, J.B., and Diffendal, R.F., Jr., 1989, Geology of the pre-dune strata, in A. Bleed and C. Flowerday, eds., An atlas of the Sand Hills: Conservation and Survey Division of the University of Nebraska, Resource Atlas, no. 5, p. 29-42.

3. Compilation sources for western United States (west of 102 degrees West Longitude):

Arizona

Richard, S.M., Reynolds, S.J., Spencer, J.E., and Pearthree, P.A., 2000, Geologic map of Arizona: Arizona Geological Survey Map 35, scale 1:1,000,000. [Used a slightly modified unpublished digital version of this map.]

California

Bedford, D.R. (U.S. Geological Survey), written commun., digital file showing geology of California, digitized from Jennings, C.W., Strand, R.G, and Rogers, T.H. (compilers), 1977, Geologic map of California: California Div. Mines and Geology Map GDM 2, scale 1:750,000. [Some information in this file is found in: Bedford, D.R., Ludington, Steve, Nutt, C.M., Stone, P.A., Miller, D.M., Miller, R.J., Wagner, D.L., and Saucedo, G.J., 2003, Geologic database for digital geology of California, Nevada, and Utah - an application of the North American Data Model: USGS Open-File Report 03-135, 35 p., <http://geopubs.wr.usgs.gov/open-file/of03-135/>.]

Colorado

Green, G.N., 1992, The digital geologic map of Colorado in ArcInfo format: U.S. Geological Survey Open-File Report 92-507, ArcInfo file, <http://pubs.usgs.gov/ of/1992/ofr-92-0507/>. [digitized from Tweto, Ogden, 1979, Geologic map of Colorado: U.S. Geological Survey, scale 1:500,000.]

Idaho

Johnson, B.R., and Raines, G.L., 1996, Digital representation of the Idaho state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-690, ArcInfo file, <http://wrgis.wr. usgs.gov/open-file/of95-690/>. [digitized from Bond, J.G., and Wood, C.H., 1978, Geologic map of Idaho: Idaho Bureau of Mines and Geology, scale 1:500,000.]

Kansas

Ross, J.A., compiler, Geologic map of Kansas: Kansas Geological Survey Map M-23, ArcInfo file, scale 1:500,000.

Montana

Raines, G.L. and Johnson, B.R., 1996, Digital representation of the Montana state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-691, ArcInfo file, <http://pubs.usgs.gov/of/ 1995/ofr-95-0691/>. [digitized from Ross, C.P., Andrews, D.A., and Witkind, I.J., 1955, Geologic map of Montana: U.S. Geological Survey, scale 1:500,000.]

Soller, D.R., and Packard, P.H., 1998, Digital representation of a map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: U.S. Geological Survey Digital Data Series, DDS-38, ArcInfo files, scale 1:1,000,000, <http://pubs.usgs.gov/dds/dds38/>.

Nebraska

Belohlavy, Francis (Conservation and Survey Division, Univ. of Nebraska - Lincoln), written commun., Digital map of soil parent materials (interpreted as bedrock types, alluvium, etc.) assembled by querying STATSGO data (from USDA Nat. Res. Conserv. Serv.), see <http://www.nrc.state.ne.us/databank/metadata/stgo_doc.html>.

Nevada

Bedford, D.R. (U.S. Geological Survey), written commun., digital file showing geology of Nevada, digitized from Stewart, J.H. and Carlson, J.E., 1978, Geologic map of Nevada: U.S. Geological Survey, scale 1:500,000. [Information about any modifications of the published map are found in: Bedford, D.R., Ludington, Steve, Nutt, C.M., Stone, P.A., Miller, D.M., Miller, R.J., Wagner, D.L., and Saucedo, G.J., 2003, Geologic database for digital geology of California, Nevada, and Utah - an application of the North American Data Model: USGS Open-File Report 03-135, 35p.,<http://geopubs.wr.usgs.gov/open-file/of03-135/>.]

New Mexico

Green, G.N., and Jones, G.E., 1997, The digital geologic map of New Mexico in ArcInfo format: U.S. Geological Survey Open-File Report 97-52, ArcInfo file, <http://pubs.usgs.gov/of/1997/ofr-97-0052/>. [digitized from Anderson, O.J. and Jones, G.E., 1994, Geologic map of New Mexico: New Mexico Bureau of Mines and Mineral Resources, Open-File Report 408 A, B, scale 1:500,000.]

North Dakota

Clayton, Lee, 1980, Geologic map of North Dakota: U.S. Geological Survey Special Map prepared in cooperation with North Dakota Geological Survey, scale 1:500,000. [Used an unpublished, digital version of this map.]

Soller, D.R., and Packard, P.H., 1998, Digital representation of a map showing the thickness and character of Quaternary sediments in the glaciated United States east of the Rocky Mountains: U.S. Geological Survey Digital Data Series, DDS-38, ArcInfo files, scale 1:1,000,000, <http://pubs.usgs.gov/dds/dds38/>.

Oklahoma

Cederstrand, J.R., 1996, Digital geologic map of Cimarron County, Oklahoma: U.S. Geological Survey Open-File Report 96-372, ArcInfo file. [digitized from Sapik, D.B., and Goemaat, R.L., 1973, Reconnaissance of the ground-water resources of Cimarron County, Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-373, scale 1:125,000.]

Cederstrand, J.R., 1996, Digital geologic map of Texas County, Oklahoma: U.S. Geological Survey Open-File Report 96-379, ArcInfo file. [digitized from Wood, P.R., and Hart, D.L., Jr., 1967, Availability of ground water in Texas County, Oklahoma: U.S. Geological Survey Hydrologic Investigations Atlas HA-250, scale 1:125,000.]

Oregon

Walker, G.W. and MacLeod, N.S., 1991, Geologic map of Oregon: USGS, ArcInfo file, scale 1:500,000, <http://geology.wr. usgs.gov/docs/geologic/or/oregon.html>.

South Dakota

South Dakota Geological Survey, in prep., Geologic map of South Dakota; preliminary version obtained from Nancy Shock, USGS Central Publications Group, Denver, CO.

Texas

Barnes, V.E., editor, 1992, Geologic Map of Texas: Texas Bureau of Economic Geology, scale 1:500,000. [Quaternary units on the map were generalized and then digitized.]

Utah

Bedford, D.R. (USGS), written commun., digital file showing geology of Utah, adapted from Hintze, L.F., Willis, G.C., Laes, D.Y.M., Sprinkel, D.A., and Brown, K.D., 2000, Digital geologic map of Utah: Utah Geological Survey Map 179DM, CDROM. [Information about modifications of the published map are found in: Bedford, D.R., Ludington, Steve, Nutt, C.M., Stone, P.A., Miller, D.M., Miller, R.J., Wagner, D.L., and Saucedo, G.J., 2003, Geologic database for digital geology of California, Nevada, and Utah - an application of the North American Data Model: USGS Open-File Report 03-135, 35 p., <http://geopubs.wr.usgs.gov/open-file/ of03-135/>.]

Washington

Raines, G.L., and Johnson, B.R., 1996, Digital representation of the Washington state geologic map: a contribution to the Interior Columbia River Basin Ecosystem Management Project: U.S. Geological Survey Open-File Report 95-684, ArcInfo file, <http://wrgis.wr.usgs.gov/open-file/of95-684/>. [digitized from Hunting, M.T., Bennett, W.A., Livingston, V.E., Jr., and Moen, W.S., 1961, Geologic map of Washington: Washington Division of Mines and Geology, scale 1:500,000.]

Wyoming

Green, G.N., and Drouillard, P.H., 1994, The digital geologic map of Wyoming in ArcInfo format; U.S. Geological Survey Open-File Report 94-425, ArcInfo file, <http://pubs.usgs.gov/of/1994/ofr-94-0425/>. [digitized from Love, J.D. and Christiansen, A.C., 1985, Geologic map of Wyoming: U.S. Geological Survey, scale 1:500,000.]

General references

Kerwin, M.W. (U.S. Geological Survey), written commun., digital file showing pluvial lakes of the western U.S. Information mostly derived from:

Reheis, Marith, 1999, Extent of Pleistocene lakes in the western Great Basin: U.S. Geological Survey Miscellaneous Field Studies Map MF-2323, <http://pubs.usgs.gov/mf/1999/mf-2323/>.

Mifflin, M.D., and Wheat, M.M., 1979, Pluvial lakes and estimated pluvial climates of Nevada: Nevada Bureau of Mines and Geology Bulletin 94, 57 p., scale 1:1,000,000.

Snyder, C.T., Hardman, G., and Zdenek, F.F., 1964, Pleistocene lakes in the Great Basin: U.S. Geological Survey Miscellaneous Investigations Map I-416, scale 1:1,000,000.

Locke, B. (Montana State University), and Smith, L. (Montana Bureau of Mines and Geology), written commun., digital files from U.S. Forest Service showing the maximum extent of Glacial Lake Missoula.

Muhs, D.R. (U.S. Geological Survey), written commun., digital file showing surficial sands of the western U.S. Information mostly derived from:

Muhs, D.R., and Zarate, Marcelo, 2001, Late Quaternary eolian records of the Americas and their paleoclimatic significance, in V. Markgraf, ed., Interhemispheric Climate Linkages: Academic Press, San Diego, p. 183-216.

Muhs, D.R., and Holliday, V.T., 1995, Evidence of active dune sand on the Great Plains in the 19th century from accounts of early explorers: Quaternary Research, v. 43, p. 198-208.

Thorpe, J., and Smith, H.T.U., 1952, Pleistocene eolian deposits of the United States, Alaska, and parts of Canada: National Research Council Committee for the Study of Eolian Deposits, Geological Society of America, scale 1:2,500,000.

United States Forest Service, [n.d.], Glacial Lake Missoula and the Channelled Scablands: A digital portrait of landforms of the last ice age, Washington, Oregon, northern Idaho, and western Montana: U.S. Department of Agriculture, United States Forest Service, Northern Rockies Region, scale 1:2,000,000.