Toward a Goal of a “Super” Three-dimensional Geologic Map

Where have we been?
Where are we going?

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Cross-sections

Basic Depiction of Three Dimensionality
1984 - Hand drafted

Boone-Winnebago Counties, IL

2004 - Computer generated

Middle Illinois River Valley
1999 - Multiple cross-sections from a 3D model
Advantages/Uses

• Most conventional of all 3D methods and widely used pre-and post-computer

• Visualize slice of the Earth

• Point-to-point check on data

Disadvantages

• Restricted to one line of data

• Not “true” 3D
Stack-unit Maps

Early 1900s - 1990s
Early 1900s – European “stack-unit” Maps

Striped pattern = thin layer of one unit over another

Dutch: 1925 Rotterdam 50K
Early 1980s

Basic Pre-computer "3D" Maps

Stack-unit map concept of upper 6.1m
Stack-unit Map to 6.1m

- **py** colluvium
- **zu-wia** geosol/Argyle till
- **win** Nimtz till
- **(g-o)** discont Glasford sg

Portion of Boone/Winnebago Counties, IL
### Quaternary Deposits

<table>
<thead>
<tr>
<th>Code</th>
<th>Code</th>
<th>Quaternary Deposits</th>
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</thead>
<tbody>
<tr>
<td>A</td>
<td>a</td>
<td>Cahokia Alluvium</td>
</tr>
<tr>
<td>B</td>
<td>b</td>
<td>Richland Loess</td>
</tr>
<tr>
<td>C</td>
<td>c</td>
<td>Peoria Loess/Roxana Silt</td>
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<tr>
<td>D</td>
<td>d</td>
<td>Parkland Sand</td>
</tr>
<tr>
<td>E</td>
<td>e</td>
<td>Grayslake Peat</td>
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<tr>
<td>F</td>
<td>f</td>
<td>Equality Fm. silty lake seds</td>
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<tr>
<td>G</td>
<td>g</td>
<td>Equality Fm. s. lake seds</td>
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<tr>
<td>Y</td>
<td>y</td>
<td>Peyton Colluvium</td>
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<tr>
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<td>h</td>
<td>Henry Fm. s&amp;g</td>
</tr>
<tr>
<td>I</td>
<td>i</td>
<td>Wedron Fm. sandy dms</td>
</tr>
<tr>
<td>J</td>
<td>j</td>
<td>Wedron Fm. lm/sandy dm</td>
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<tr>
<td>K</td>
<td>k</td>
<td>S &amp; g within Wedron Fm.</td>
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<tr>
<td></td>
<td>z</td>
<td>between 6-15m of surface</td>
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<tr>
<td>L</td>
<td>l</td>
<td>Winnebago Fm. sandy dm</td>
</tr>
<tr>
<td>M</td>
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<td>S &amp; g within Winn. Fm.</td>
</tr>
<tr>
<td>N</td>
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<td>Teneriffe Silt</td>
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<tr>
<td>O</td>
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<td>Pearl Fm. s&amp;g</td>
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<tr>
<td>P</td>
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<td>Glasford Fm. si/clayey dms</td>
</tr>
<tr>
<td>Q</td>
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<td>Glasford Fm. lm/sandy dms</td>
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<td>R</td>
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<td>S&amp;g within Glasford Fm.</td>
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<td>between 6-15m of surface</td>
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<td>U</td>
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<td>Wolf Creek Fm. dms</td>
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<tr>
<td>V</td>
<td>v</td>
<td>Mounds Gravel</td>
</tr>
<tr>
<td>W</td>
<td>w</td>
<td>Cretaceous silts/sands</td>
</tr>
<tr>
<td>X</td>
<td></td>
<td>Surface mines/made land</td>
</tr>
</tbody>
</table>

**Bold Uppercase = materials >6m thick**

**Lowercase = materials <6m thick**

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**Mid 1980s**

**Pre-computer - Increasing Depths to 15m to Better Accommodate Needs**

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Pre-I: Late-90s

Pre-glac: Glacial
Use of Parentheses –

- Parentheses around lowercase letter indicates its discontinuity.

- Parentheses around lowercase lowest unit indicates its presence at or just below 15m.

- Parentheses around BOLD lowest unit indicates its presence at or just below 15m.

- Parentheses around BOLD letter indicates that material is not consistently >6m thick, but is always present.

- Parentheses around numeral indicates that bedrock sfc may be above 15m but it generally lies below 15m.

- Parentheses indicate bedrock not continuously between 6-15m, but may be within 6m of sfc over a portion of the map area.
Mid 1990s  Increasing Depths to 30.5m to Better Accommodate Needs

Unit >50’ (15.2m) thick
Unit usually >50’ thick
Unit < 20’ (6.1m) thick
Stack-unit Map to 30.5m

Portion of Woodstock Quadrangle, IL

Stack-unit labeling scheme

Portion of legend

Unit thickness (ft)

<table>
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<tr>
<th>20</th>
<th>20–50</th>
<th>&gt;50</th>
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<tr>
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<tr>
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Material Description

- **g**: Accretion gley: poorly drained, possibly laminated, fine depressions
- **c**: Cahokia Alluvium: stream deposits—a mixture of sand, with some sand
- **p**: Grayslake Peat: peat and muck with possible interbeds
- **e**: Equality Formation, Carmi Member: bedded fine grains
- **d**: Equality Formation, Dolton Member: mainly sand with b
- **b**: Henry Formation, Batavia Member: sand and gravel of unit deposited mostly along the fronts of moraines
- **w**: Henry Formation, Wasco Member: ice-contact sand and kames
- **h**: Haeger diamicton: sandy loam to loam diamicton that a
- **u**: Haeger diamicton, sand and gravel facies: surface or n
- **a**: Wedron Formation: undifferentiated diamicton

Outwash deposits, 20 to 120 feet thick, from ice adv
several diamicton units, but mostly the Haeger...
Advantages/Uses
• Distribution of materials in their order of occurrence up to 30.5m shown in map polygons
• Known succession of materials is depicted for land-use decision making in specific areas
• Legend can accommodate complexity

Disadvantages
• Very difficult to visualize regional patterns
• Legend can be difficult to decipher
• Only goes to maximum depth of 30.5m
• Not “true” 3D
Early 1990s  Computer–based color-coding of stack-unit mapping to 15m
Map Legend

Utilizes color shades, and line/dot patterns of different colors representing material groups

133 unique stack-unit combinations
Advantages/Uses

- Distribution of materials shown in order of occurrence in upper 15m
- Can visualize regional geologic trends and understand local geologic relationships
- Allows portrayal of detailed local information within context of broad regional trends
- Provides basis for mapping aquifer sensitivity and mineral resources

Disadvantages

- Only goes to a 15m depth and not “true” 3D
- Legend difficult to construct
- Showing additional complexity and/or mapping to >depths restricted by # of available colors and patterns and producing a meaningful map

NOTE – map has 133 successions within 785 polygons. Procedure was unsuccessful when applied to statewide stack-unit map having >800 successions within >5200 polygons
“True” 3D Mapping and Modeling

Early 1990s - present
East-central Illinois – Mahomet Bedrock Valley project

Isopachous maps

Structure-contour maps
Perspective of the topography of land surface showing cross-sectional geology

Mahomet Valley  East-central IL
Cross sections

Elevation slices

Fence diagram

Chair slice

Mahomet Valley  East-central IL
3-D blocks of Quaternary over bedrock materials

Villa Grove Quadrangle
East-central Illinois
Sand & gravel in Wisconsin + Illinois Episode deposits

Villa Grove Quadrangle
East-central Illinois
Solids Model

Kane County, Illinois
“Floating” Units
Batestown Member outwash

Zone color key
15 surficial unit
14 equality
13 wadsworth
12 wadsworth_outwash
11 haegar
10 beaver
9 yorkville
8 yorkville_outwash
7 batestown
6 batestown_outwash
5 tiskilwa
4 ashmore
3 glastord
2 bedrock
1 model_bottom

Primary: kane0624.faces

Kane County, Illinois
Gridding and contouring tops, bottoms, and thicknesses help evaluate regional trends and identify errors and anomalies.
Create sophisticated surfaces

Bedrock surface of Middle Illinois River valley
Solids
Lithostratigraphic Model showing data

Antioch Quadrangle
NE Illinois
Pull-apart Model

Wauconda Quadrangle, NE Illinois
Advantages/Uses

- Many options for showing surfaces, depths, and thicknesses
- Many options for public to visualize/understand the geology and to inspire them
- Many options for geologists to visualize and better define the geology and its history
- Combines geologic interpretation with very rigorous use of raw data and statistics
- Excellent analytical tool
- GIS helps verify preliminary stratigraphic picks/identifies points of questionable quality
- Many options to create derivative maps
- Many options for on-demand release of publications
- Maps/databases are updatable & publically available
- Requires geologists to address their data and science, in new ways, with new perspectives
Disadvantages

• Very difficult to build models
• Requires highly sophisticated map producers and users
• Requires large amounts of data - quality, integrity, and location must be carefully verified
• Requires considerable software/other support
• Requires a sophisticated data model and database management
• Requires new interfaces (> complex and $) to visualize information
• Requires geologists to address their data and science in new ways with new perspectives (more patience is needed)
• Difficult for geologists to “become one with data”

• Very difficult to know/portray a particular succession of materials at a particular area on the map
How do we combine the complexly detailed stack-unit map with the visually appealing and understandability of a true 3D geologic model?
Super 3-D Map
A reasonable question:

I’ve been looking at your maps – I’m not a geologist, and I have a question about the groundwater beneath a house I just bought.

Based on your maps, I think my well is in the Lower Glasford basal sand. Is it?

Can you tell me the geology at the “control point” near my house (borehole #649)?

-- a homeowner in Cerro Gordo, IL.
Goals for a tool to visualize 3D geology:

- for any map location that the user selects by a mouse-click, *dynamically generate* a log showing all geologic units beneath that point

- keep the tool *simple and intuitive* for anyone to use

- make it accessible through a *web browser*, if possible without plugins
Standards are ESSENTIAL!

DATA MODEL,
NAMING CONVENTIONS,
SCIENCE TERMINOLOGY,
INTERCHANGE FORMAT, ...
SectionIntercept part of the borehole extension
### Borehole Collar

- **Shape**: image
- **PK SysGUID**: `char(36)`
- **Label**: `varchar(255)`
- **DisplayName**: `varchar(255)`
- **TextDescription**: `varchar(4000)`
- **Elevation**: real
- **ElevationUnitsTermGUID**: `char(36)`
- **CartoObjID**: int
- **SymbolSet**: `varchar(255)`
- **PositionUncertainty**: real
- **UTMZone**: `varchar(255)`
- **UTME**: real
- **UTMN**: real
- **OriginTrackingSysGUID**: `char(36)`
- **GroundElevation**: real

### Section Interval

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</tbody>
</table>

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| Bar | 43   | 145 | 40     | 0       | 0             | 0              | 0        |
| Mah | 50   | 185 | 100    | 215     | 0             | 0              | 0        |
From database to “synthetic” borehole

User clicks anywhere on the map.

Database returns all units below that point.

Geologic description and elevation of each unit.

SVG, or…
DESCRIPTION OF UNITS

**Mostly glacial till**—Wedron and Mason Group, of Wisconsin age. In some places overlain by clay, sand and gravel of Holocene age Cahokia Formation

**Mostly glacial till**—upper Glasford Formation, of Illinoian age

**Mostly glacial till**—lower Glasford Formation, of Illinoian age

**Sand and gravel**—lies at base of lower Glasford Formation

**Mostly glacial till**—upper Banner Formation, of pre-Illinoian age

**Sand and gravel**—Mahomet Sand Member of Banner Formation, of pre-Illinoian age
This tool will operate on the NGMDB standard data structure

We invite your ideas and collaboration, on the standards and the tool
Summary

This tool will operate on the NGMDB standard data structure

We invite your ideas and collaboration, on the standards and the tool
Additional views
How do we achieve maximum understandability and still portray needed detail?

Point to a place on the map and the succession “pops” up

The rolling cursor
A reasonable question:

I am not a geologist, but I have a question about ground water at a specific control point from a study you recently published: USGS Geologic Investigations Series Map I-2669; an analysis of Quaternary sediments in East-Central Illinois. I recently purchased a rural home in Piatt County, and I studied your maps before that. I was wondering if you could share the details of your data from control point 649. I am 2 miles SE of this control point.

My property is on IL State Highway 105, 2.6 miles East of Cerro Gordo in Piatt County, at a surface elevation of 700 ft. My well is two years old, 155 ft deep, yielding a steady 20 gal per minute. I surmise from this that lateral transfer is respectable in my layer. I do not have a mineral analysis. I've been told there is some iron in it. It seems likely that my well taps the "Lower Glasford Basal Sand" at a place where the layer is about 10 ft thick. The maps also show a very small region where the layer is about 25 ft thick, located about 2 miles NW of my property. I'm guessing that the data for the thicker spot actually comes from control point 649, but this is conjecture.

-- a homeowner from Cerro Gordo, IL.