3-D Geologic Mapping for Hydrogeologic Applications

Alan E. Kehew
Michigan Geological Survey

Formation of the MGS

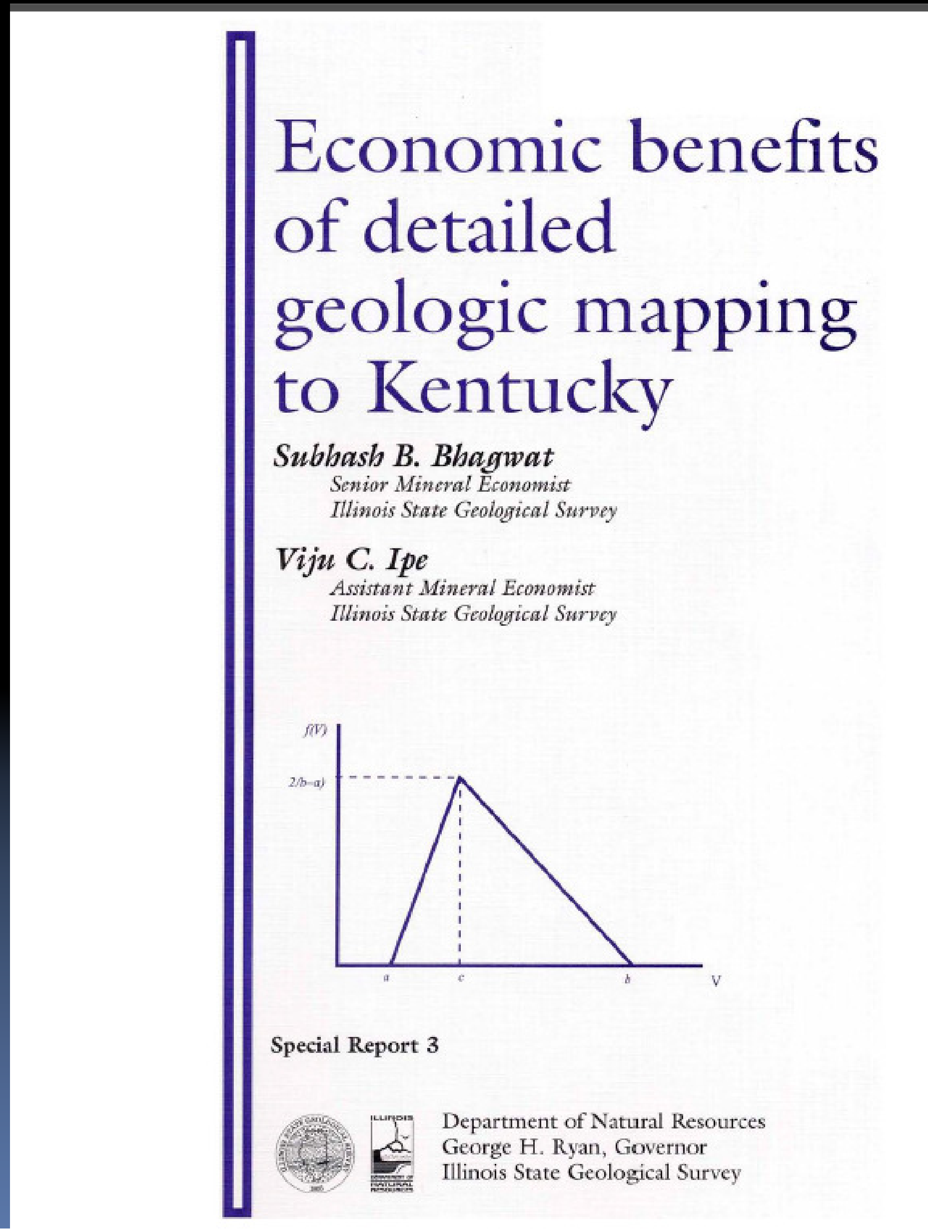
- Transfer of Survey from MDEQ; Oct, 2011
  - No base funding/personnel included in transfer
  - Assume responsibility for geologic mapping and investigation of geologic resources of the state.
  - No regulatory authority
- Progress since transfer
  - Development of strategic plan
  - Formation of advisory council
  - Development of web site
  - Receipt of 4 mapping grants
  - Major components of Survey
    - Surficial/mapping section
    - Subsurface/MGRRE section (Michigan Geological Repository for Research and Education; 400,000 ft of core plus many other resources from Michigan Basin; research in petroleum geology, carbon sequestration, etc.

WHY DO GEOLOGIC MAPPING?

- Production of detailed geologic maps for use in attracting economic development, locating sand and gravel resources, delineation and protection of aquifers, and other applications.
- The entire state of Kentucky was mapped. An economic study some years later found a 30:1 benefit :cost ratio.
- Components of mapping
  - Field work-examination of all surface exposures of sediment
  - Drilling; contract drilling to investigate subsurface materials
  - GIS: production of maps using GIS (Geographic Information Systems Maps)
  - Shift to new generation of 3-D maps and models
  - Use of geophysics or other technologies

Economic Value of Geologic Mapping

All of Kentucky was mapped some years ago. This is an analysis of value of that work.



Economic benefits of detailed geologic mapping to Kentucky

Subhash B. Bhagwat
Senior Mineral Economist
Illinois State Geological Survey

Viju C. Ipe
Assistant Mineral Economist
Illinois State Geological Survey

Special Report 3

Department of Natural Resources
George H. Ryan, Governor
Illinois State Geological Survey

Map value

The aggregate value of GQ maps in this study was based on only a fraction of actual sales data. On the basis of the user response, the study computed the average minimum and maximum expected values of a quadrangle map to be $27,776 and $43,527. We calculated the aggregated value of GQ maps sold over a fraction of the study years to be at least $2.25 billion at the minimum and $3.53 billion at the maximum in 1999 dollars. The cost of the geologic mapping program in Kentucky was about $90 million in 1999 dollars. The value of the geologic maps to the users was at least 25 to 38 times higher than the cost of the mapping program. When cost estimates for the mapping program were inflated by 1% per year above inflation, the value of the maps outweighed costs by a minimum margin of 17:1 and a maximum of 28:1. Even when mapping costs were inflated by 2% per year above the rate of inflation, the value remained comfortably higher than costs, at a minimum ratio of 12:1 and a maximum of 18.5:1.

Cost of maps: $90 million
Value to users: $2.25-3.53 billion
Ratio: 25-38:1

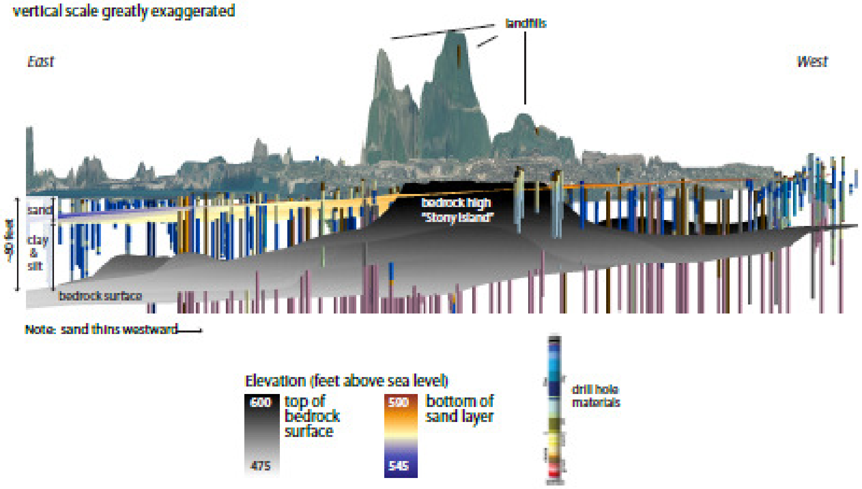
What data and maps are neighboring states developing to assess their groundwater resources?

- States like Illinois are spending hundreds of thousands of dollars to collect near surface data using modeling software to create 3-D subsurface models for a new generation of users.

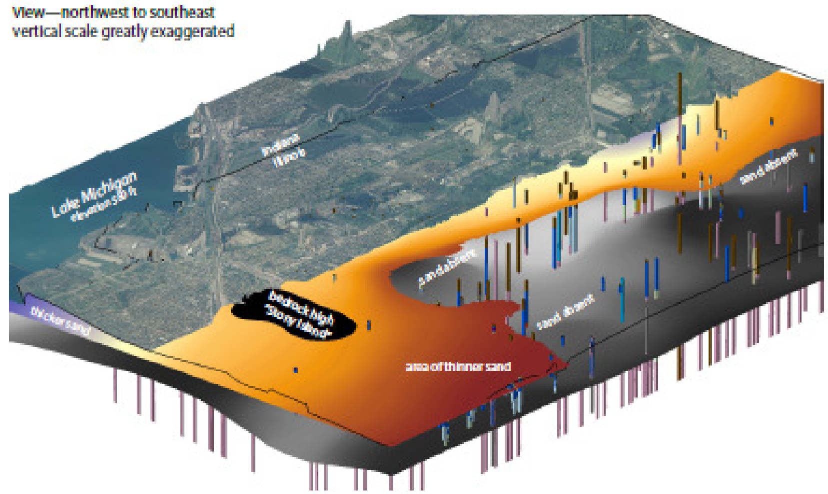
Subsurface Geology of the Lake Calumet area, Illinois—in 3D: a first step in addressing development issues

Great Lakes
GEOLOGIC MAPPING COALITION

View—north to south
vertical scale greatly exaggerated



View—northwest to southeast
vertical scale greatly exaggerated

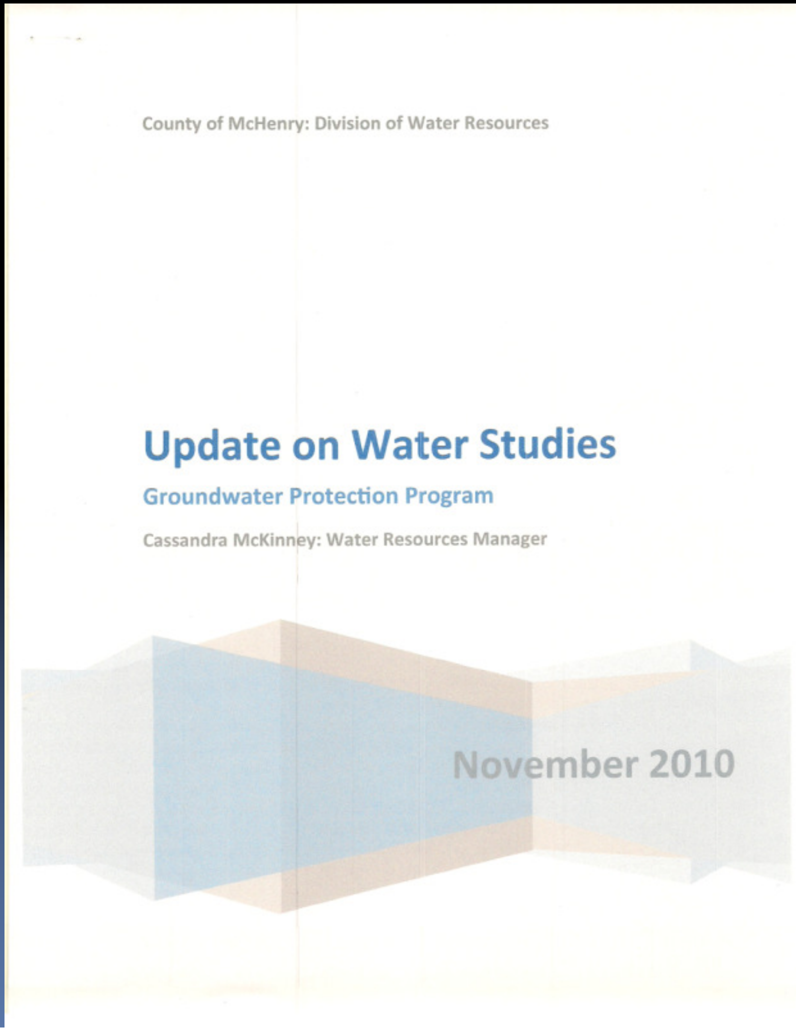


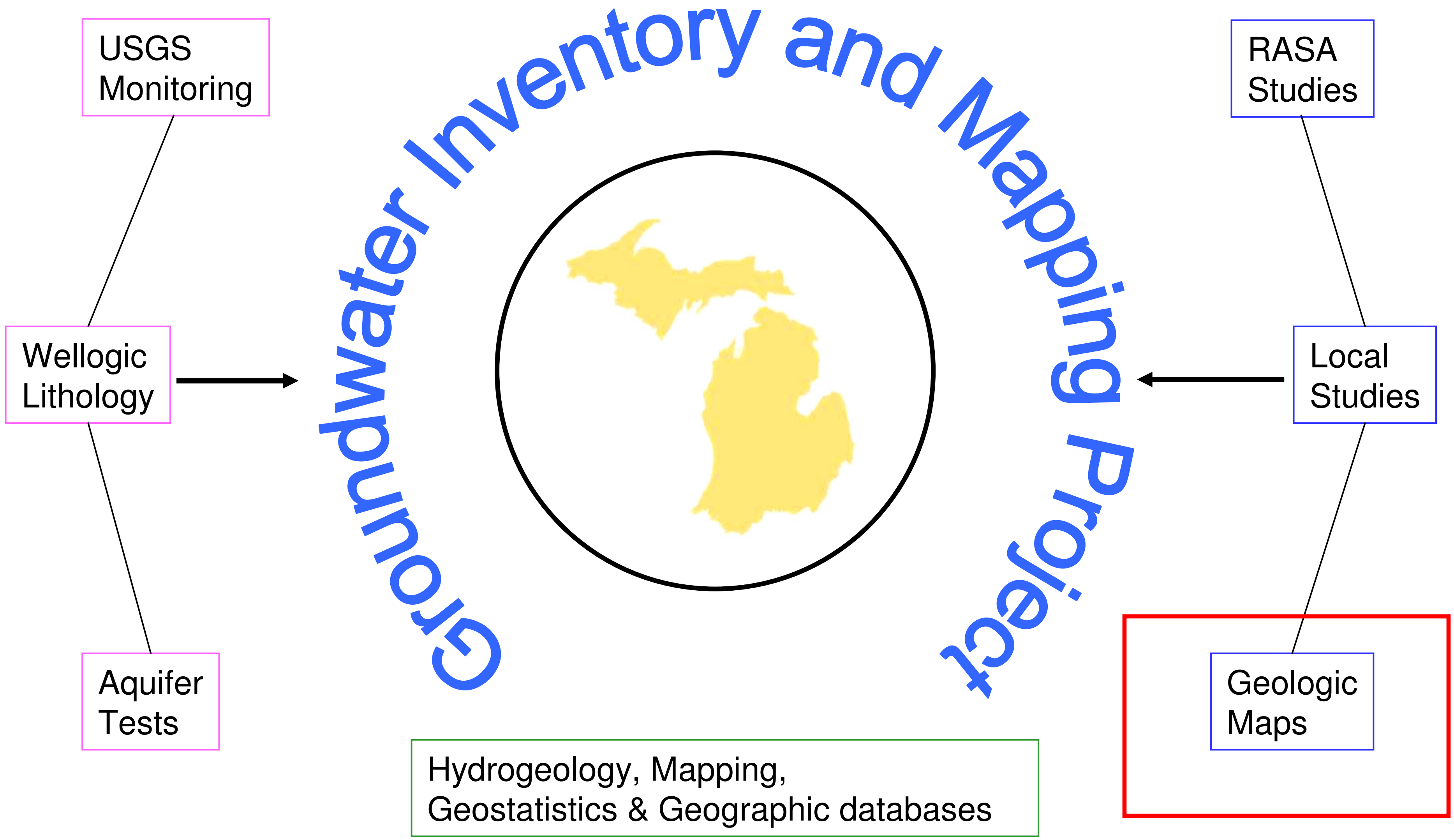
ILLINOIS STATE GEOLOGICAL SURVEY
PRAIRIE RESEARCH INSTITUTE

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

3-D mapping for aquifer delineation

- McHenry Co. Illinois (NW of Chicago) has determined that by 2050, their groundwater withdrawals will be unsustainable.
- They have contracted with the Illinois State Geological Survey to develop 3-D maps of their aquifers.





USGS science for a changing world
125 years of science for America

State of Michigan DEQ Department of Environmental Quality

Michigan State University

RS&GIS Michigan State University

(a) Location and water yielding capabilities of aquifers in the state

- Limitations
  - We lack a large-scale, 3-D geologic framework to derive the hydrogeology of the glacial deposits that cover most of the state (Glacial Landsystems map provides a small-scale 1:500K, 2-D framework).

- Water well records in the Wellogic database have varying degrees of detail and quality, but do provide our best third-dimension view of the drift.

  - Public water supply aquifer tests tend to be available for wells that have sufficient yield for a municipal supply. Hence, this dataset is biased against wells with low - moderate yields (i.e. typical residential wells).

The glacial geology of Michigan is very complicated due to the interaction of 3 different glacial lobes during the last glaciation.

Data sources for geologic mapping

Exposure in gravel pit

Rotasonic drilling

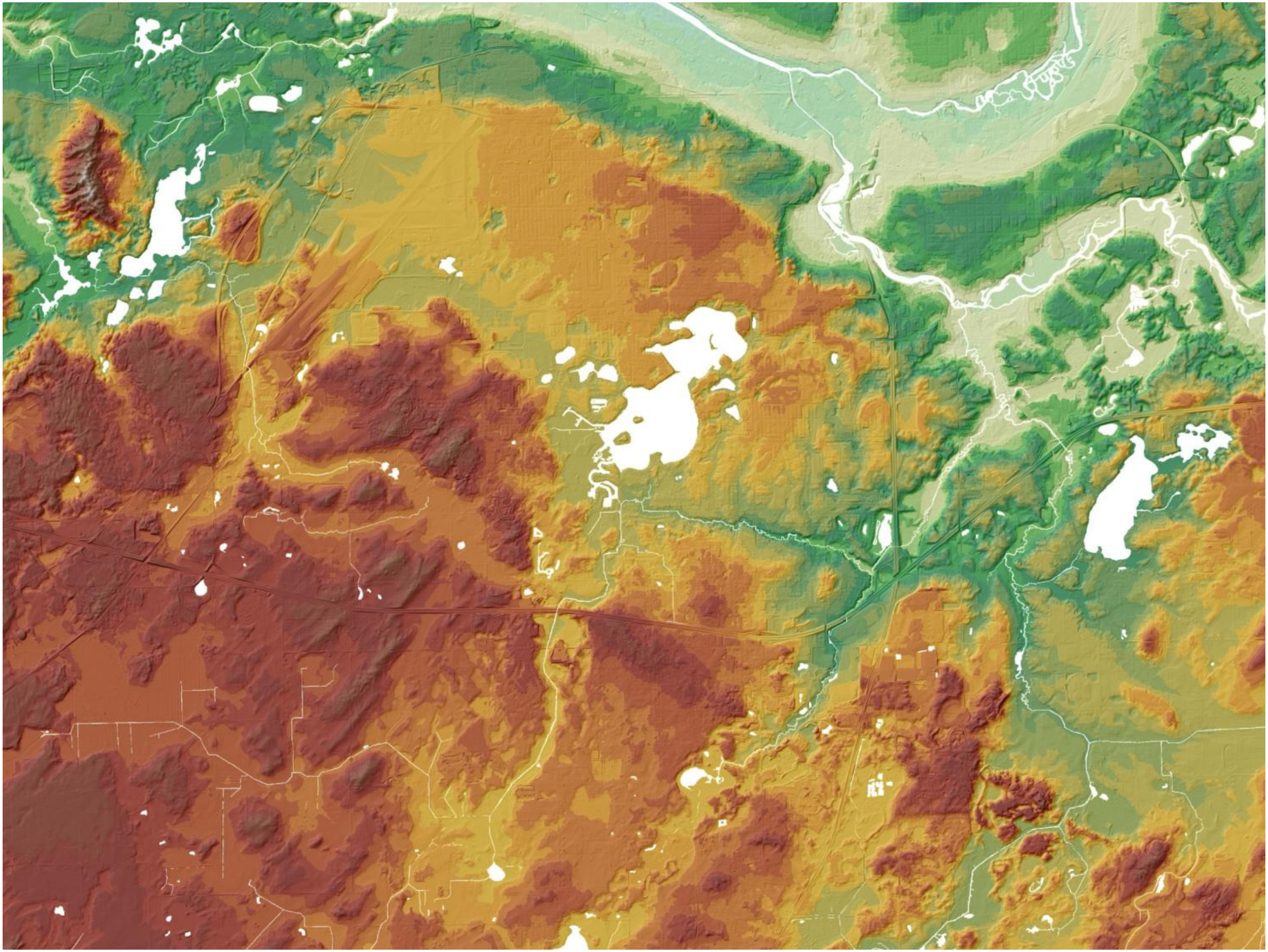
Bagging and transfer to core boxes

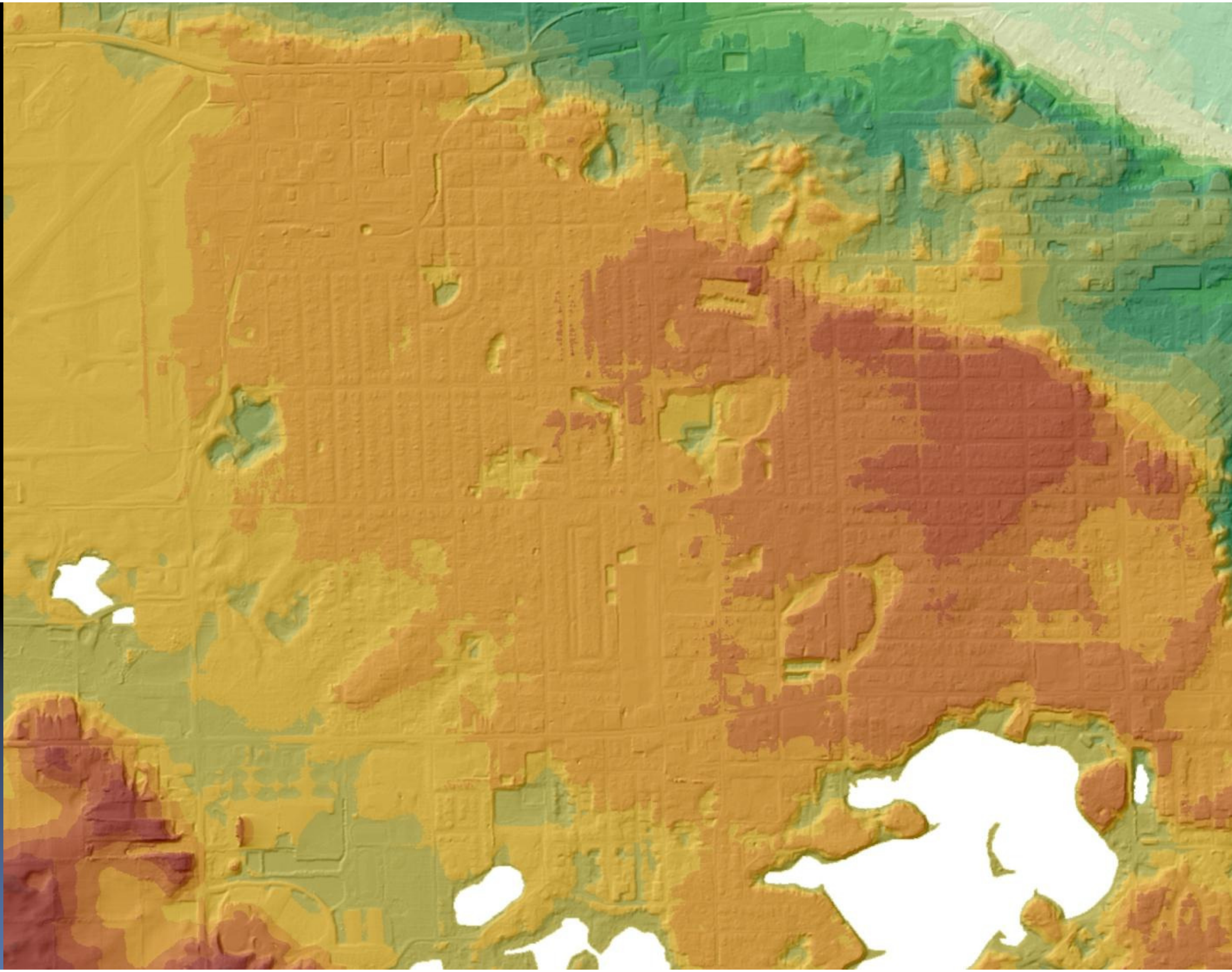
Sediment cores are analyzed and then archived at WMU core repository


Till : Mixture of clay, silt, sand, gravel,
cobbles and boulders.

Other techniques used by MGS

- LiDAR (Light Detection and Ranging)
  - Airborne laser images—very high resolution
  - Very useful for mapping when available
- Geophysical techniques
  - Resistivity
  - EM
  - Seismic refraction
  - Ground penetrating radar
  - Gamma Ray logs
- Remote sensing/GIS
- Subsurface data
  - Water well logs
  - Drilling samples from MGRRE
  - Environmental and engineering borings





Remote Sensing

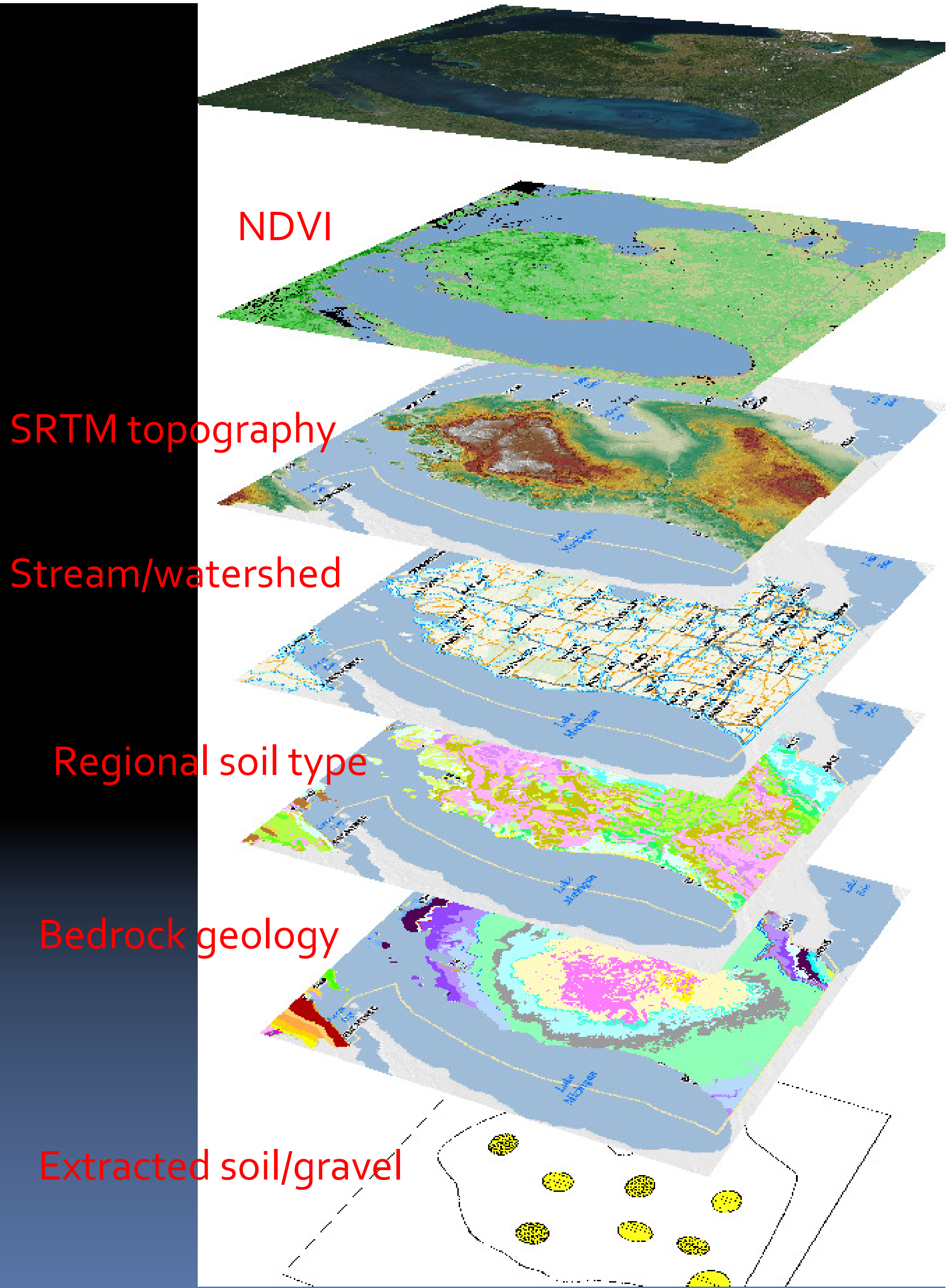
We can take advantage of the fact that glacial deposits often have physical, spatial, and textural attributes that can be explored for mapping these units on regional scales.

These attributes could be extracted from various remote sensing products:

Topographic Expression	(LIDAR/SRTM)
Spatial association with stream networks	(LIDAR/SRTM)
Water capacity expressed in vegetation intensity	(NDVI)
Texture/ roughness	(Radar)
Soil Moisture	(AMSR-E)

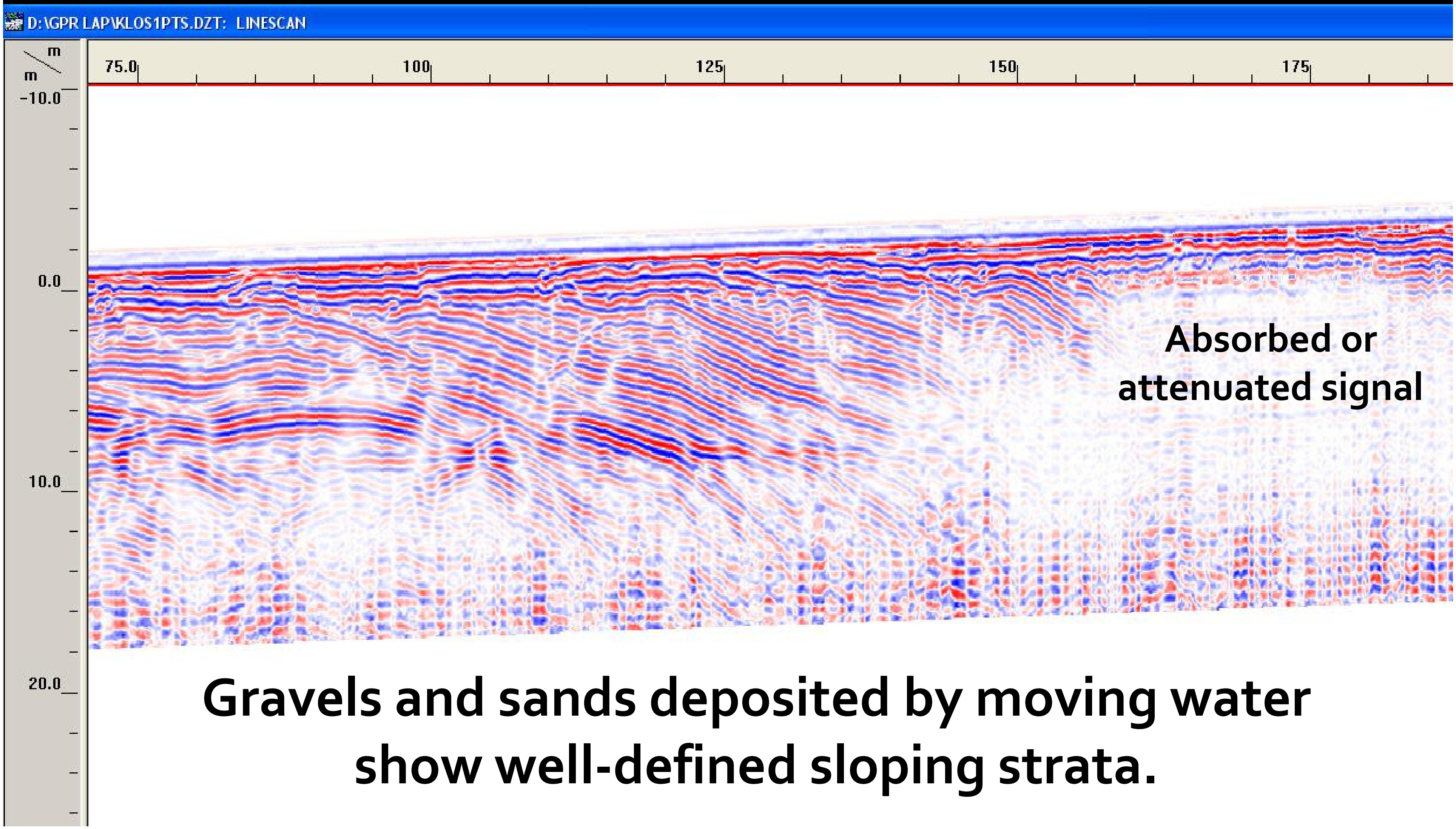
GIS Platform

The use of GIS technologies facilitates spatial correlations of observations extracted from co-registered remote sensing & other relevant data sets & hence the identification of these deposits



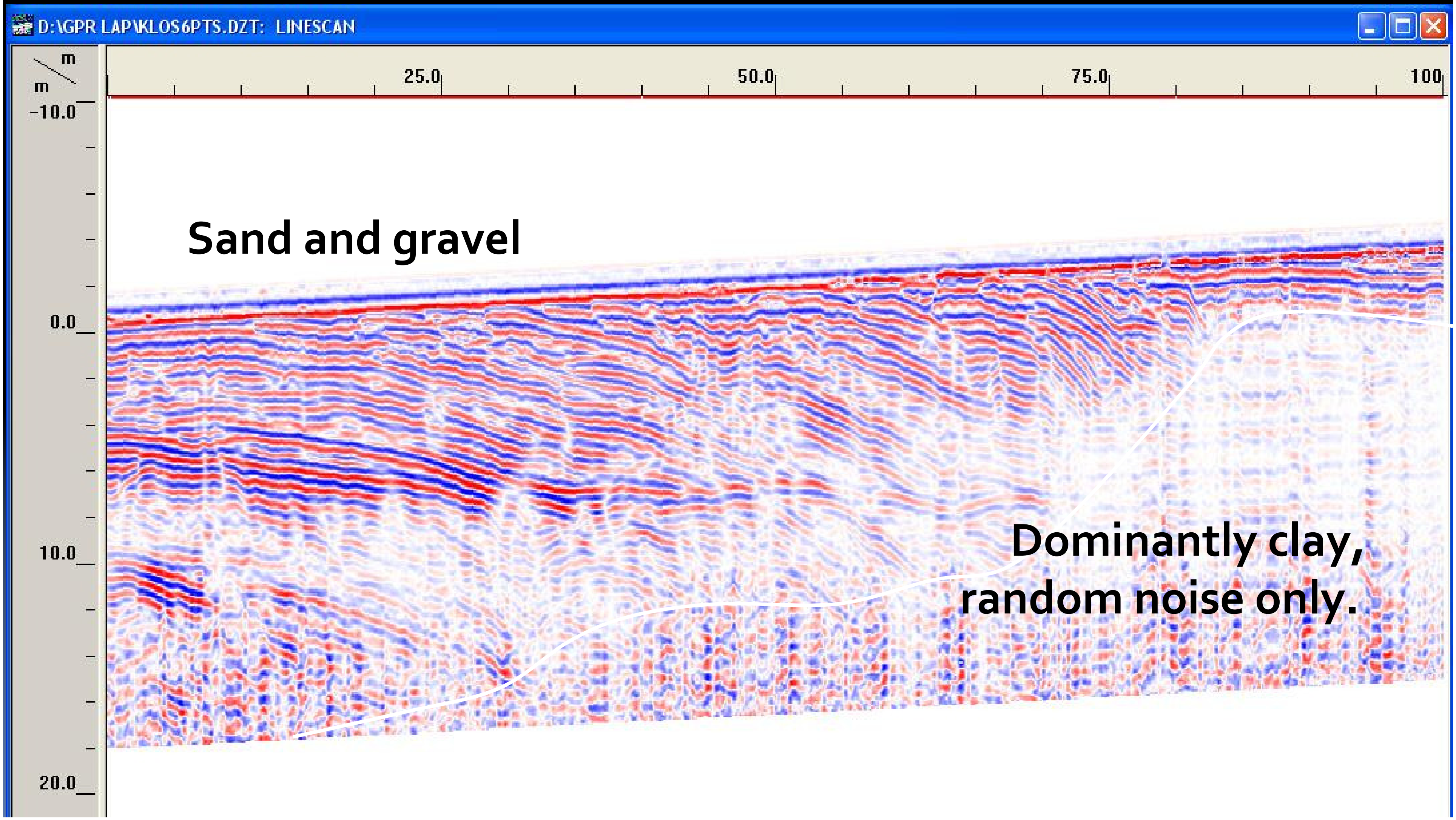
Ground Penetrating Radar

A GPR slice along smooth floor of pit. Record is about 350 ft long by 40 ft deep



Gravels and sands deposited by moving water show well-defined sloping strata.

High clay content absorbs the radio pulse, leaving only background noise.



Geologic mapping programs through the National Cooperative Geologic Mapping Program

National Cooperative Geologic Mapping Program

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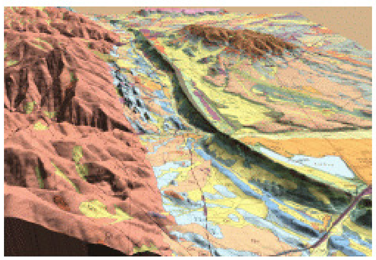

Geologic map draped over a Digital Elevation Model (DEM) image in an oblique view of Morrison, Colorado. Courtesy of the Colorado Geological Survey.

The **National Cooperative Geologic Mapping Program** (NCGMP) provides accurate geologic maps and three-dimensional framework models that help to sustain and improve the quality of life and economic vitality of the Nation and to mitigate natural hazards.

The NCGMP is the primary source of funds for the production of geologic maps in the United States.

The NCGMP represents over a decade of successful cooperation among Federal (FEDMAP), State (STATEMAP), and university (EDMAP) partners to deliver digital geologic maps to customers. Each of these three components has a unique role, yet all work cooperatively to select and map high-priority areas for new geologic maps.

Geologic mapping data from all of North America is presented via the National Geologic Map Database and a common set of geologic map standards is being developed by the NCGMP in cooperation with the North American Geologic Map Data Model Steering Committee.

Quick Links

- **Geologic Map Database**
- **FEDMAP**
- **STATEMAP**
- **EDMAP**
- **Geologic Mapping Teams:** Western | Central | Eastern

What You Will Find on This Site

About the Program — How the Program began, how it is funded and evaluated, its major components and products.

About Geologic Maps and Mapping — How geologic maps are made, what they are used for, and their importance in the history of the USGS.

STATEMAP

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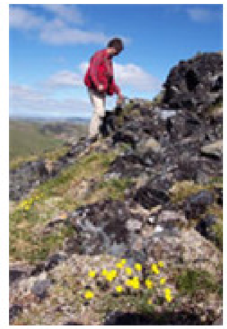
STATEMAP -- State Geologic Survey Mapping Component

STATEMAP receives funds through an annual competitive grant process. Every Federal dollar awarded to a State Geological Survey is matched by a State dollar.

The primary objective of the STATEMAP component of the NCGMP is to establish the geologic framework of areas that are vital to the welfare of individual States. Each State Geologist determines the State's mapping priorities in consultation with a State Mapping Advisory Committee. These priorities are based on State requirements for geologic map information in areas of multiple-issue need or compelling single-issue need and in areas where mapping is required to solve critical Earth science problems.

Each STATEMAP project focuses on a specific area or issue. Although the individual projects last for only one year, they frequently build upon the results of previous years' mapping activities. Employees of the State Geological Surveys conduct the geologic mapping and frequently work closely with EDMAP students and their professors, as well as with FEDMAP geologists who may be mapping within the State.



Alaska Division of Geological and Geophysical Surveys Geologist David Szumigala examines the Casadepaga Schist at the "Glaucophane Volcano," Solomon Quadrangle, Seward Peninsula. Photo by Melanie Werdon, ADGGS.

Search

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Geologic Mapping Teams: Western | Central | Eastern

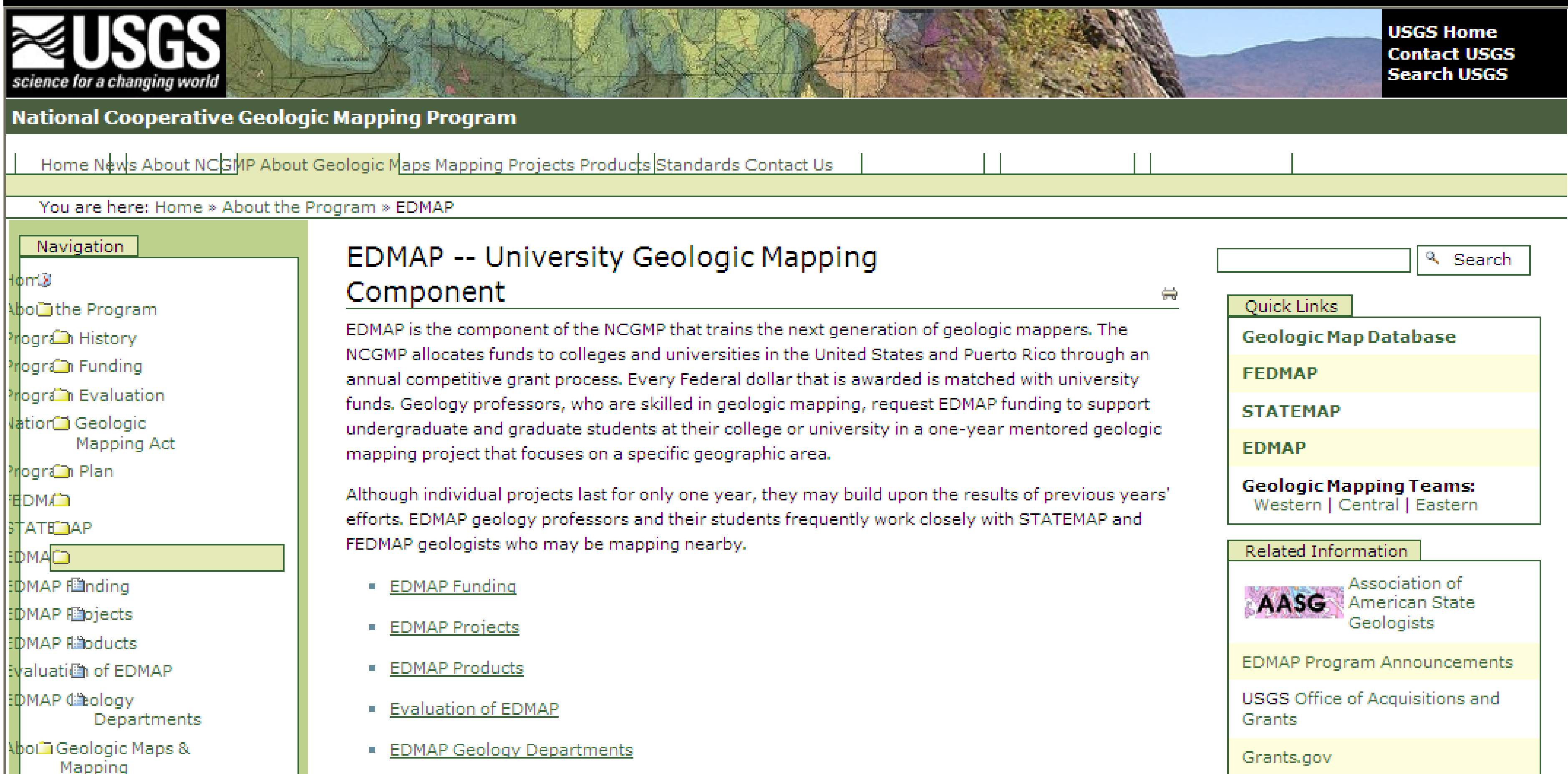
Related Information

AASG Association of American State Geologists
STATEMAP Program Announcements
USGS Office of Acquisitions and Grants
Grants.gov

STATEMAP

- This program is a <u>1:1 federal/state match</u>.
- Salaries and other in-kind contributions can be used as a match.
- Every survey that applies receives some funding, depending on the request and the quality of the proposal. The deliverables are 7 1/2 minute quadrangles.
- A new proposal must be written every year. In 2009, the awards ranged from $0 for states that did not apply, such as Michigan, to $226,000.
- Must have a mapping advisory council to set priorities
- This year, we have received our first STATEMAP grant (transferred from MDEQ) and our second grant for FY 2012-2013.

EDMAP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About Geologic Maps & Mapping
EDMAP -- University Geologic Mapping Component
EDMAP is the component of the NCGMP that trains the next generation of geologic mappers. The NCGMP allocates funds to colleges and universities in the United States and Puerto Rico through an annual competitive grant process. Every Federal dollar that is awarded is matched with university funds. Geology professors, who are skilled in geologic mapping, request EDMAP funding to support undergraduate and graduate students at their college or university in a one-year mentored geologic mapping project that focuses on a specific geographic area.
Although individual projects last for only one year, they may build upon the results of previous years' efforts. EDMAP geology professors and their students frequently work closely with STATEMAP and FEDMAP geologists who may be mapping nearby.
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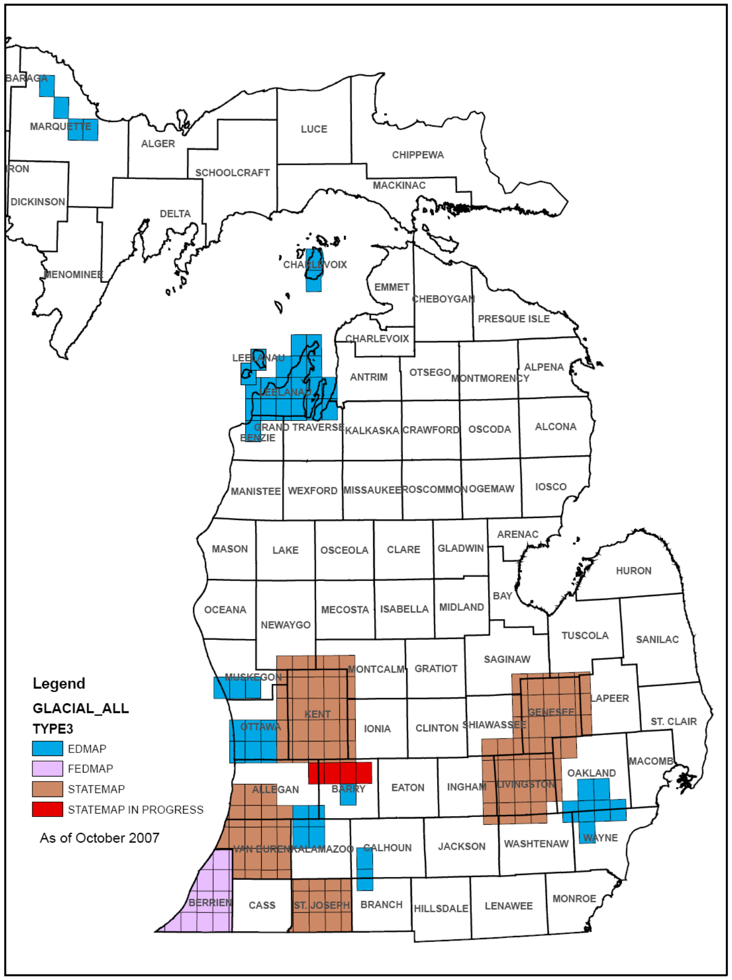
http://igs.indiana.edu/GreatLakesGeology/index.html

Great Lakes Geologic Mapping Coalition

- Current appropriation: $750,000
- Also a 1:1 match. Recently other states have provided the match for Michigan.
- Representatives from all states meet with Members of Congress every year in DC
- Annual goal is $4.5 million

Status of mapping projects in Michigan



USGS NATIONAL MAPPING ACT PROJECTS

Michigan Geological Survey: Calhoun County, 2012-2013

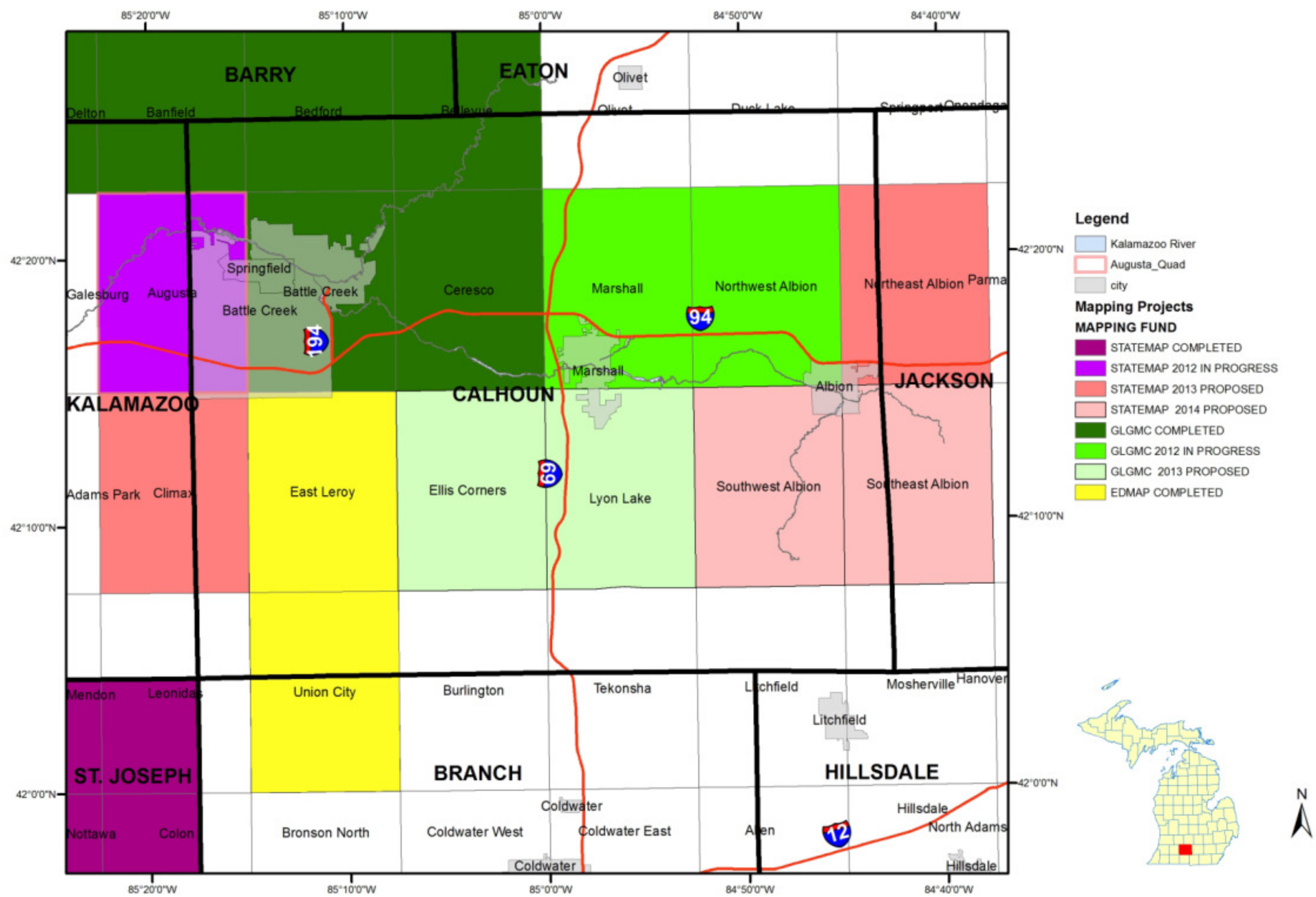
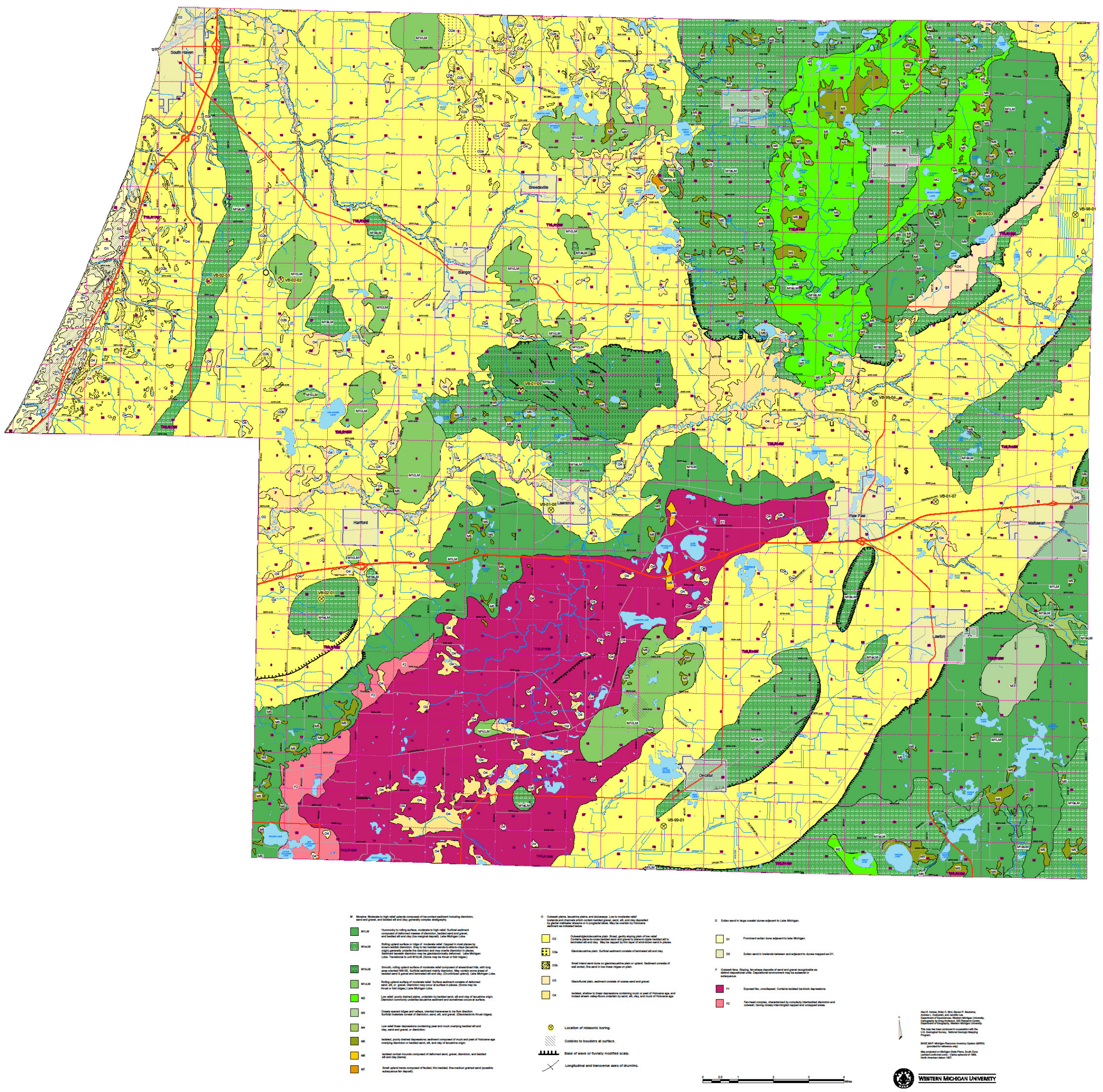


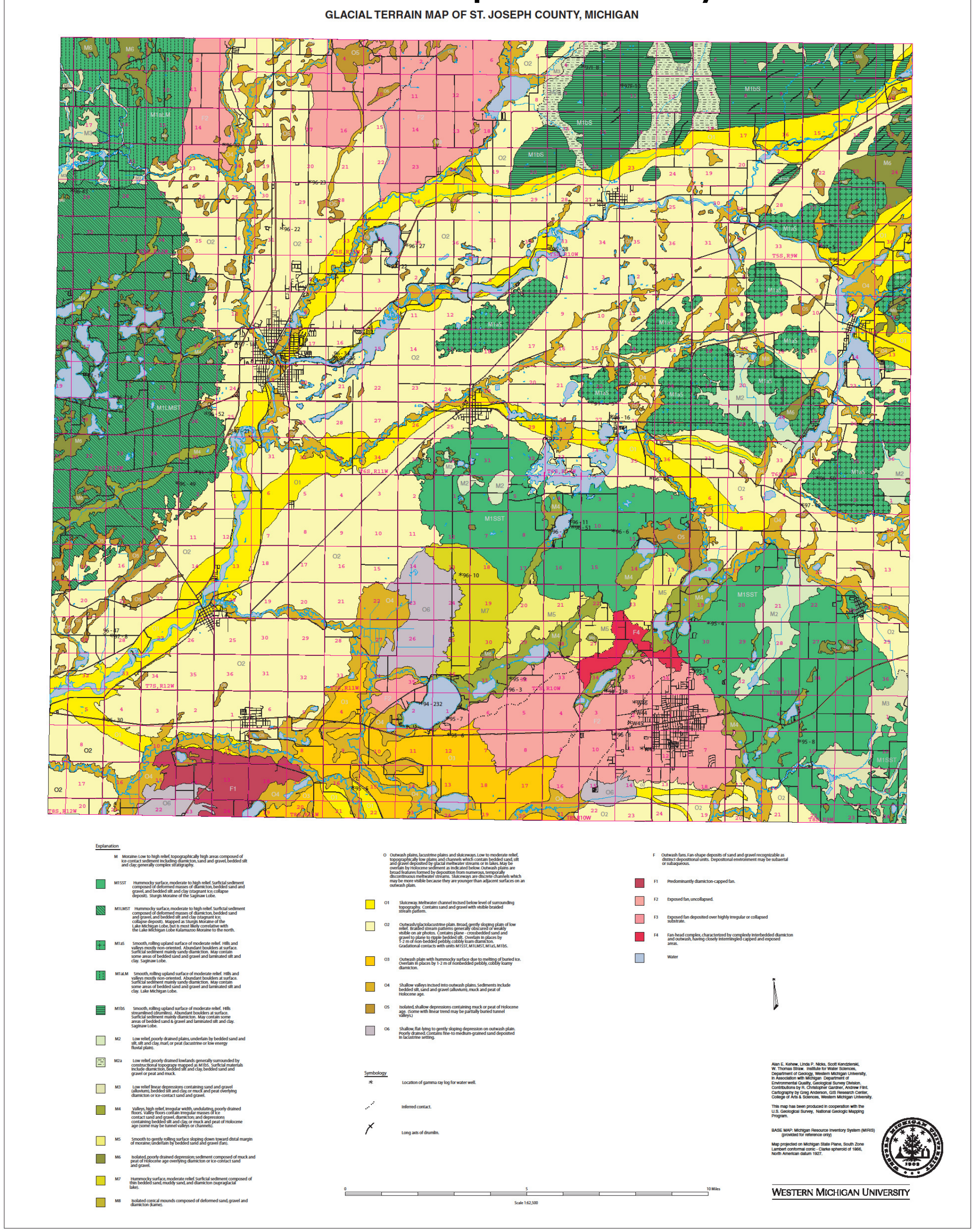
Figure 1 CALHOUN COUNTY AREA, MICHIGAN QUAD INDEX MAP
Proposed East Leroy, Ellis Corners, Lyons Lake, FY2013

Van Buren County

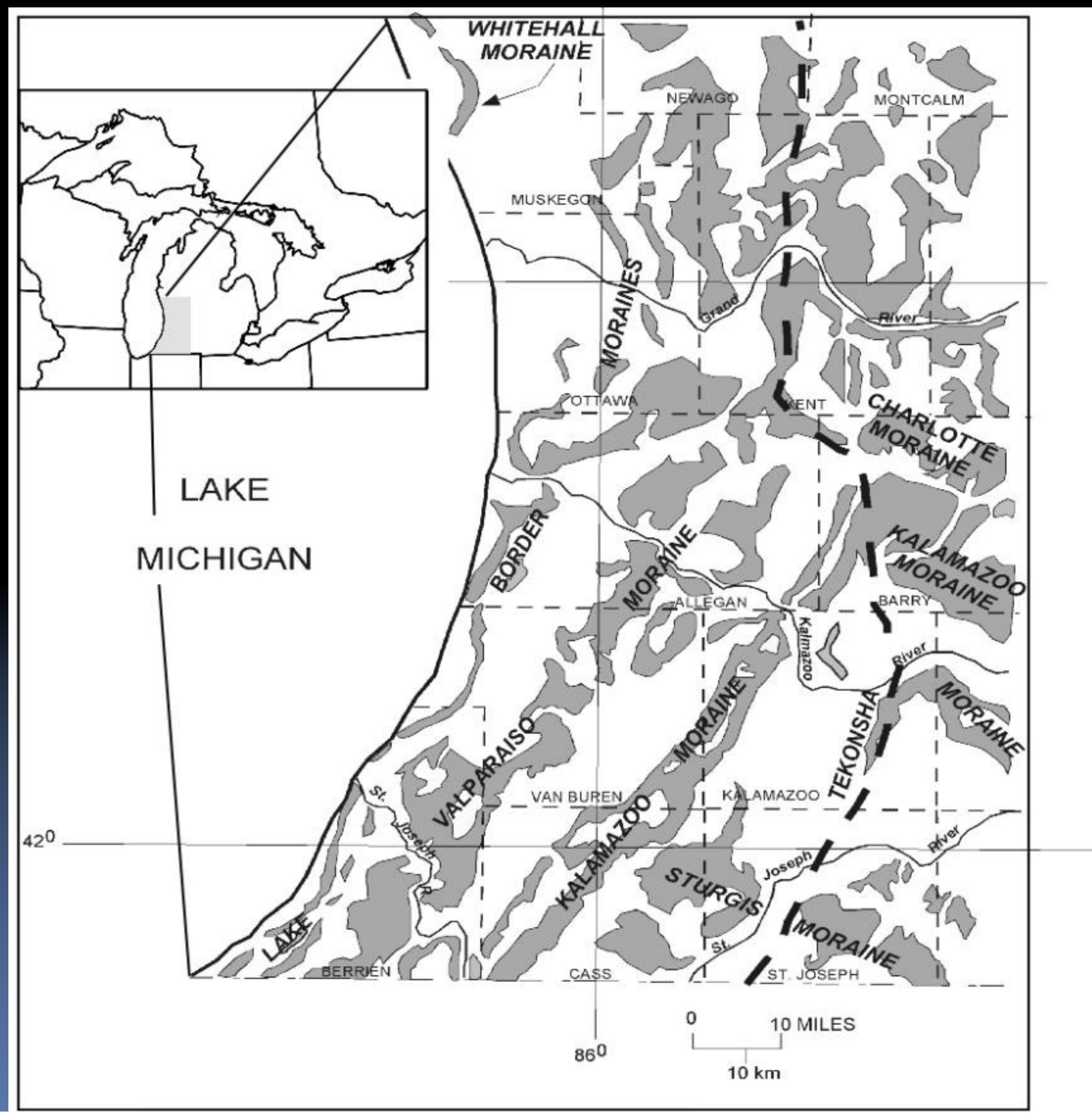
GLACIAL TERRAIN MAP OF VAN BUREN COUNTY MICHIGAN

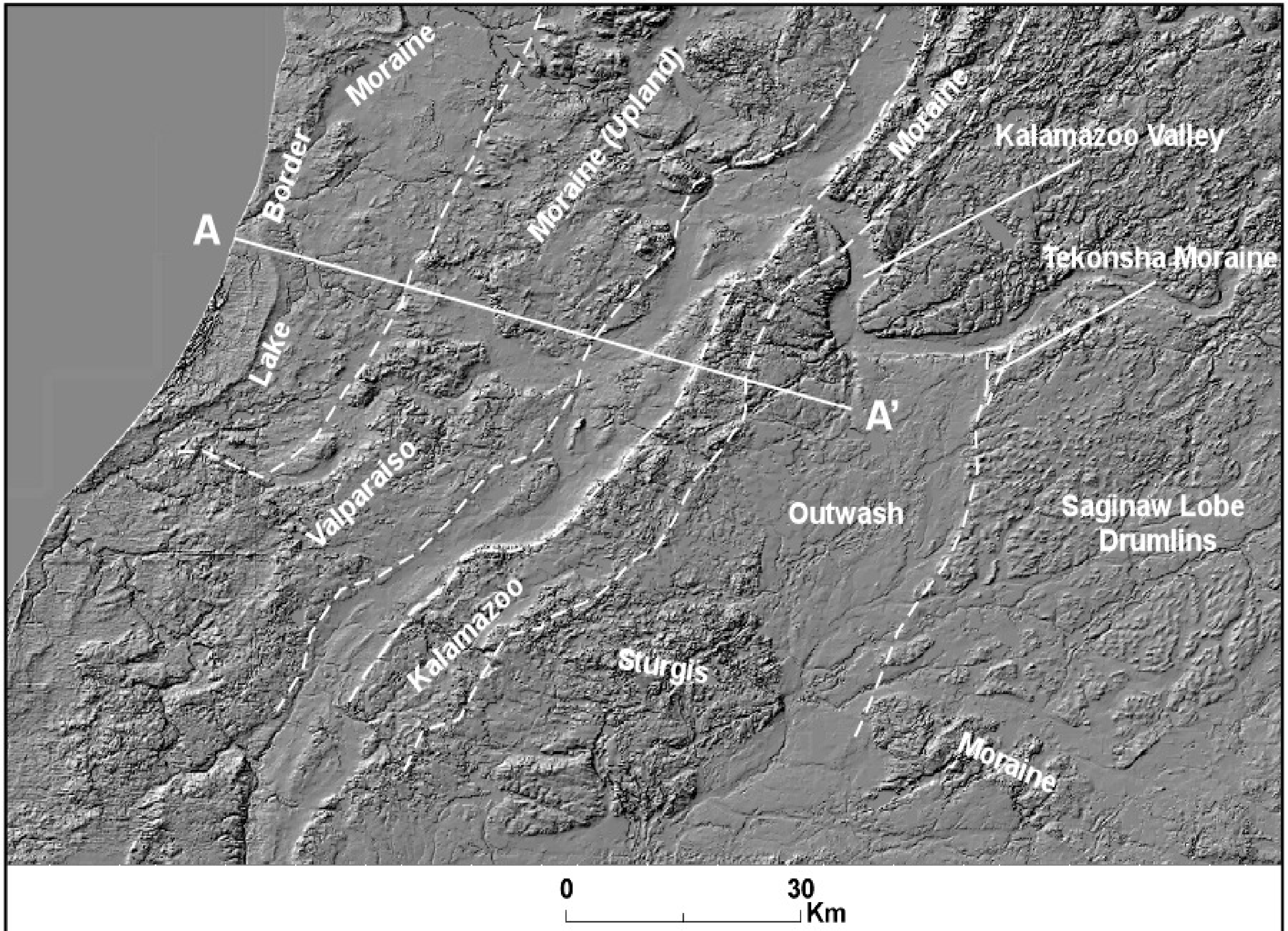


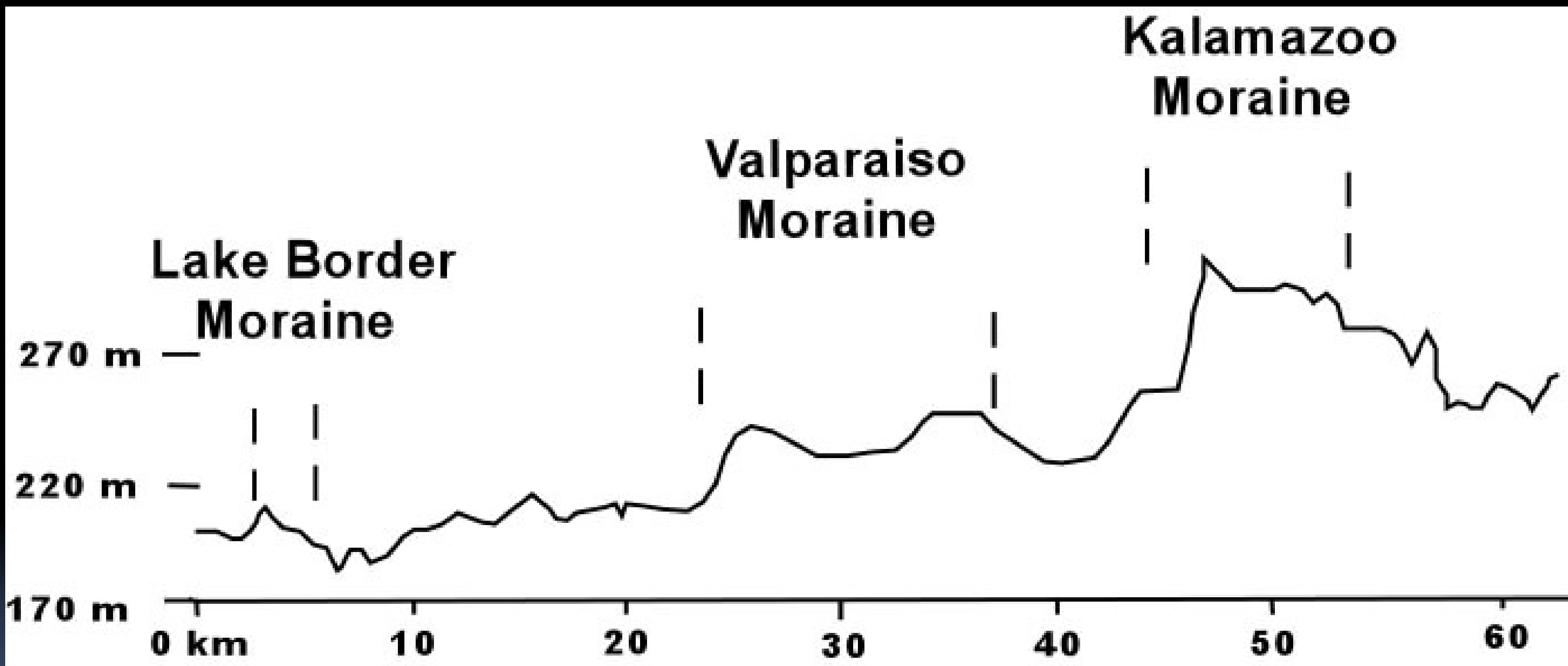
St. Joseph County

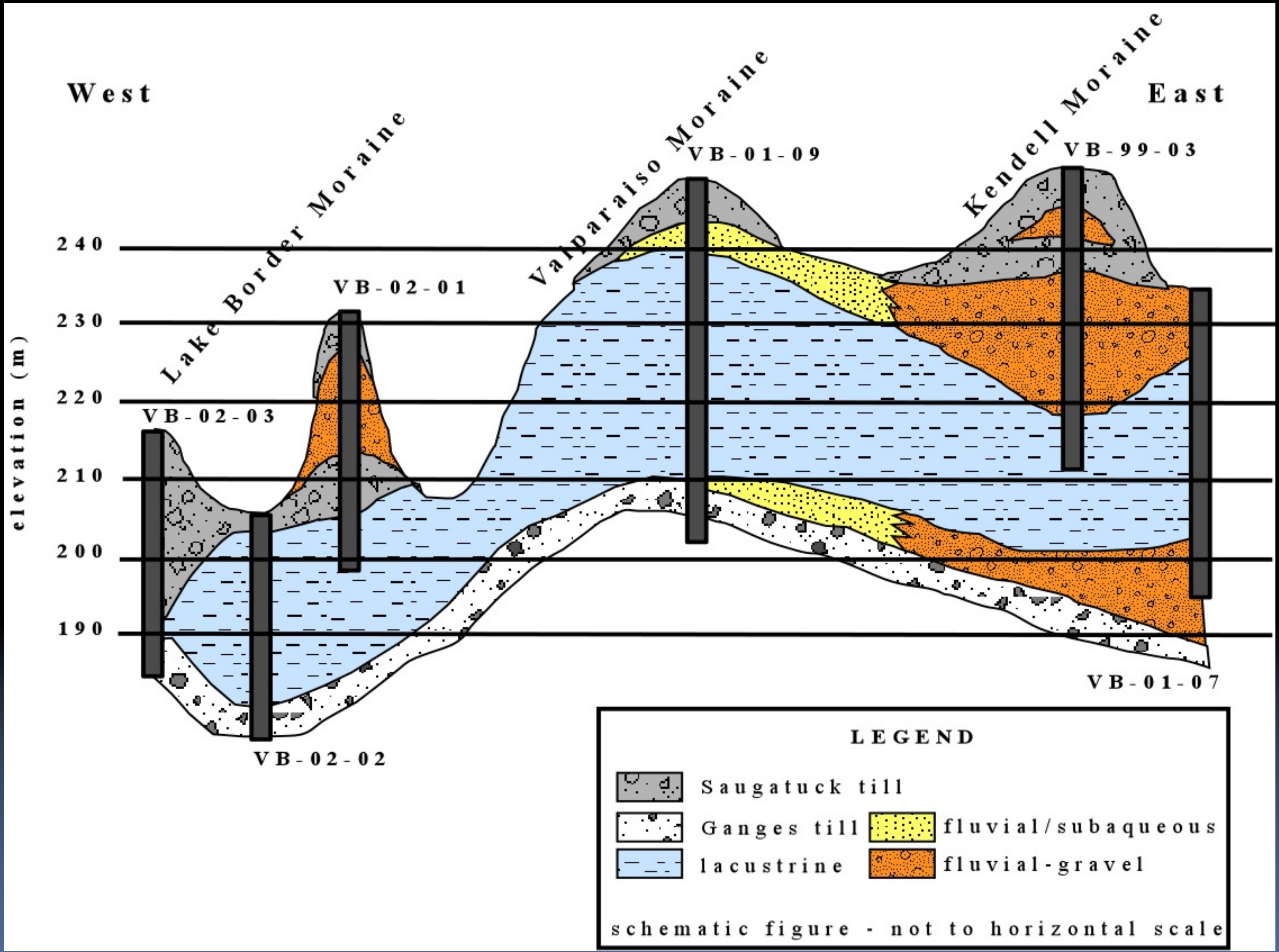


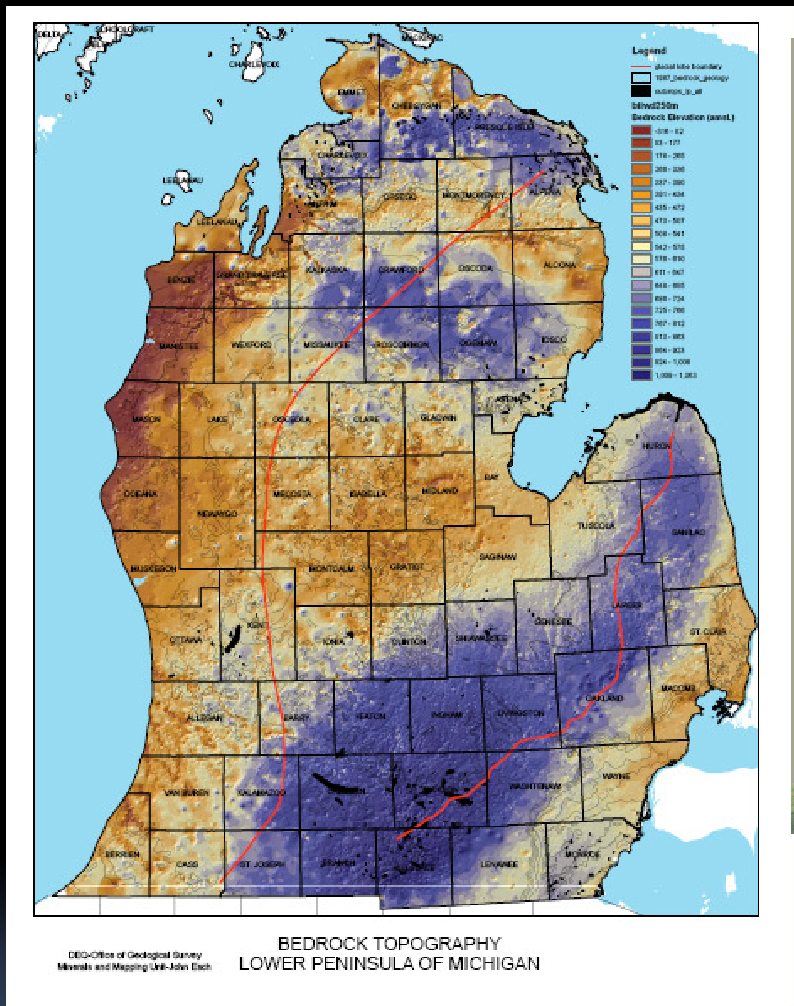
Stratigraphic architecture of the Lake Michigan Lobe



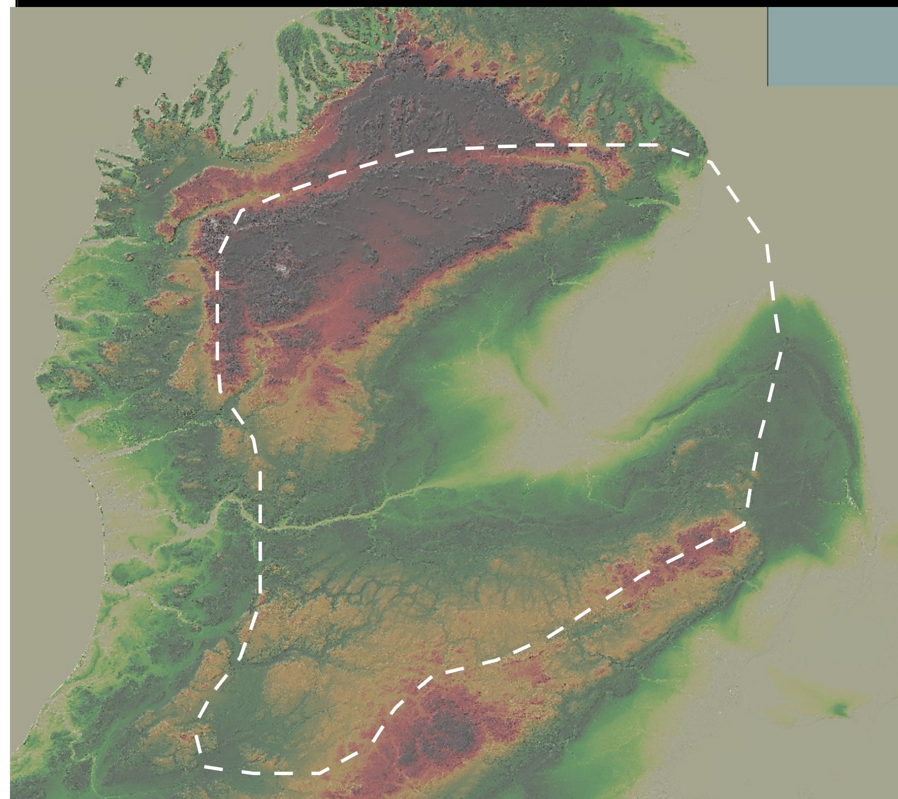

Moraine
Border
Lake
Valparaiso
Moraine (Upland)
Moraine
Kalamazoo Valley
Tekonsha Moraine
A
A'
Outwash
Saginaw Lobe
Drumlins
Kalamazoo
Sturgis
Moraine
0
30
Km


Kalamazoo
Moraine
Valparaiso
Moraine
Lake Border
Moraine
270 m
220 m
170 m
0 km
10
20
30
40
50
60


West
East
Lake Border Moraine
Valparaiso Moraine
Kendell Moraine
VB-02-03
VB-02-01
VB-02-02
VB-01-09
VB-99-03
VB-01-07
elevation (m)
240
230
220
210
200
190
LEGEND
Saugatuck till
Ganges till
lacustrine
fluvial/subaqueous
fluvial-gravel
schematic figure - not to horizontal scale

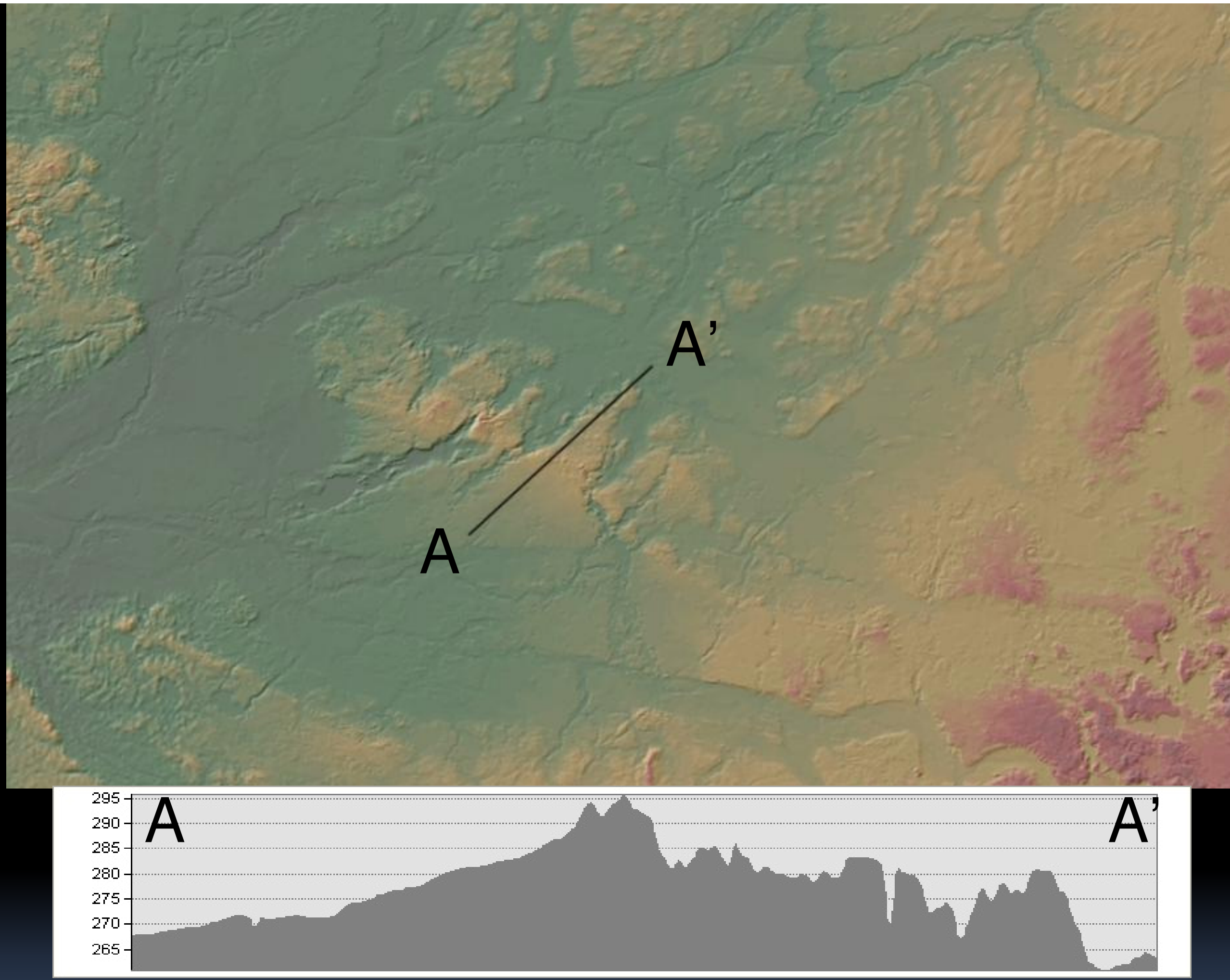


John Esch-MDEQ, OOGM



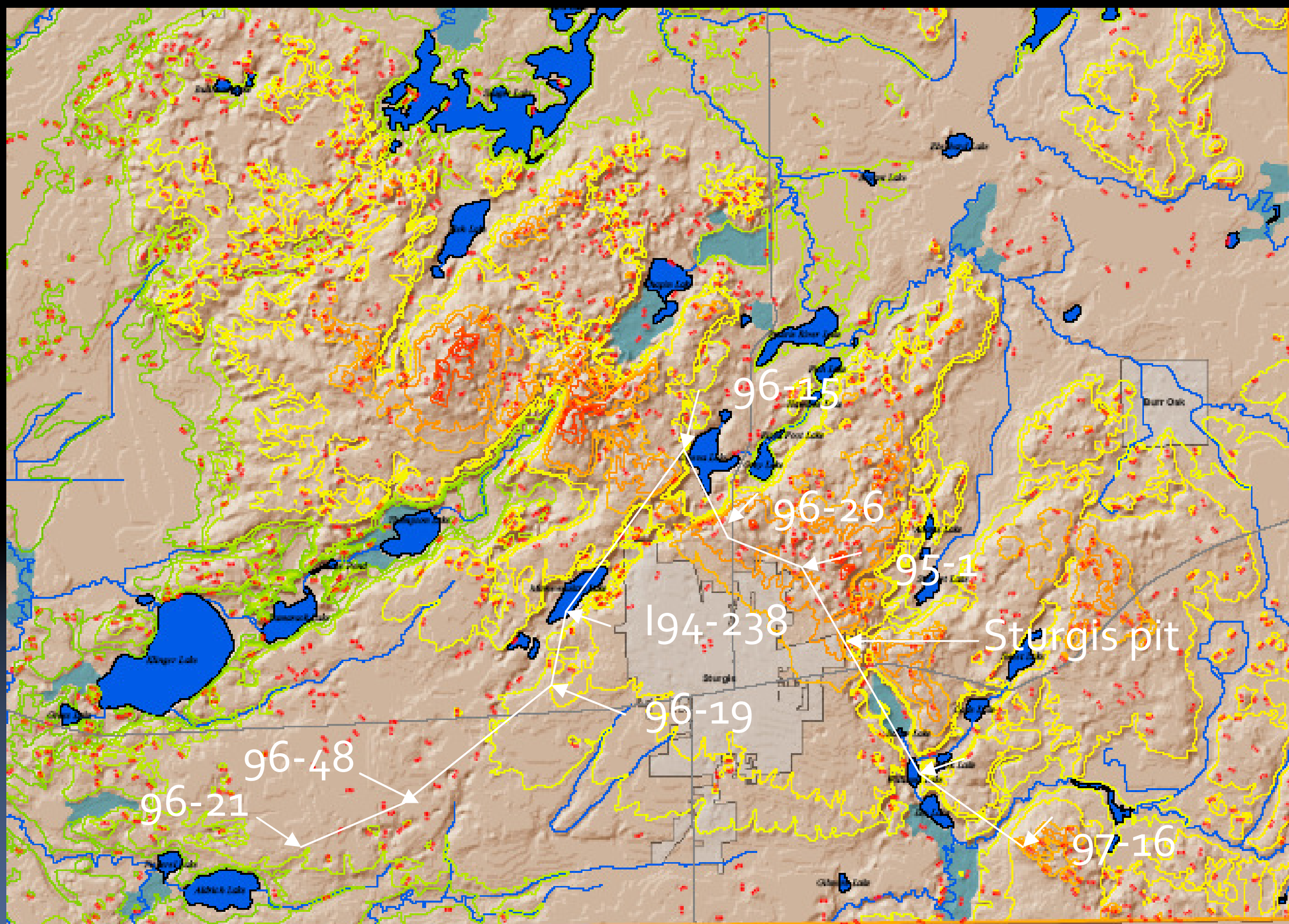
Saginaw Lobe

The bedrock toppography of southern Michigan includes a large NE-SW trending ridge that controlled the eastward and westward expansion of the Lake Michigan and Huron-Erie lobes, respectively.

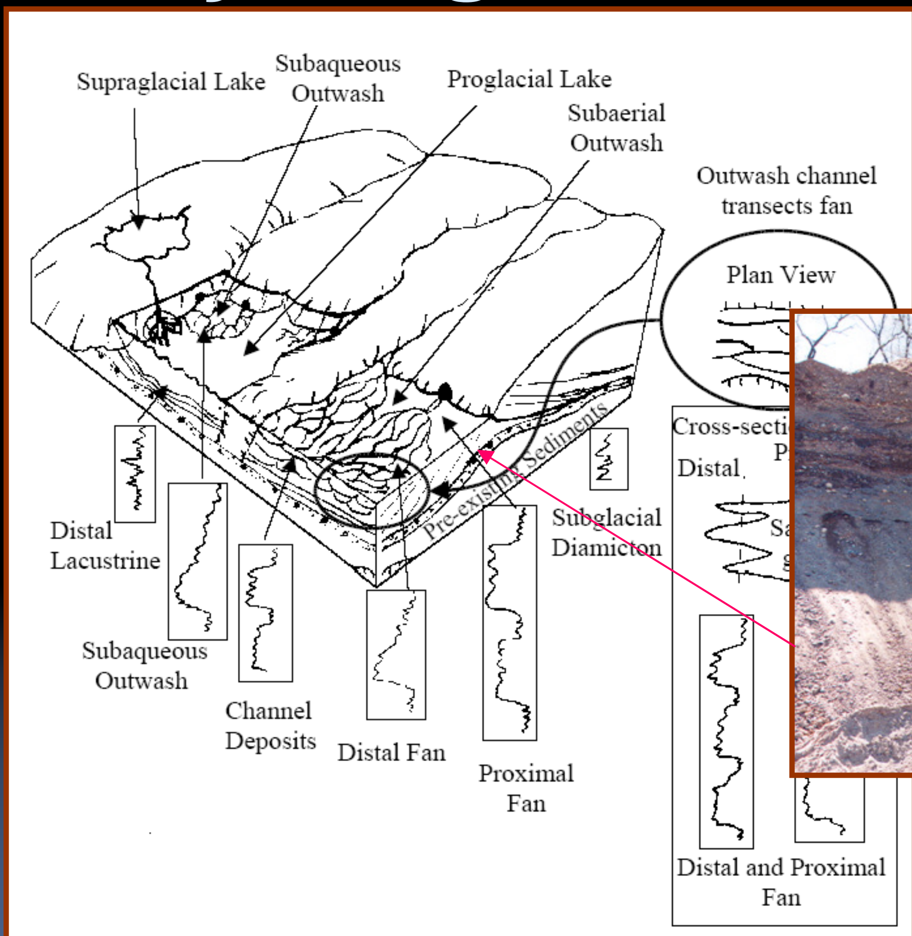


. The Sturgis Moraine. The Sturgis Moraine marks the extent of a major advance of the Saginaw Lobe. The moraine forms a distinct topographic ridge with extensive outwash fans on its distal slopes. In addition, the moraine is cut by tunnel channels that extend beyond the moraine, indicating that the channels were cut prior to the re-advance and were filled with stagnant ice and debris at the time of the re-advance.

Sturgis Area Cross Section Location

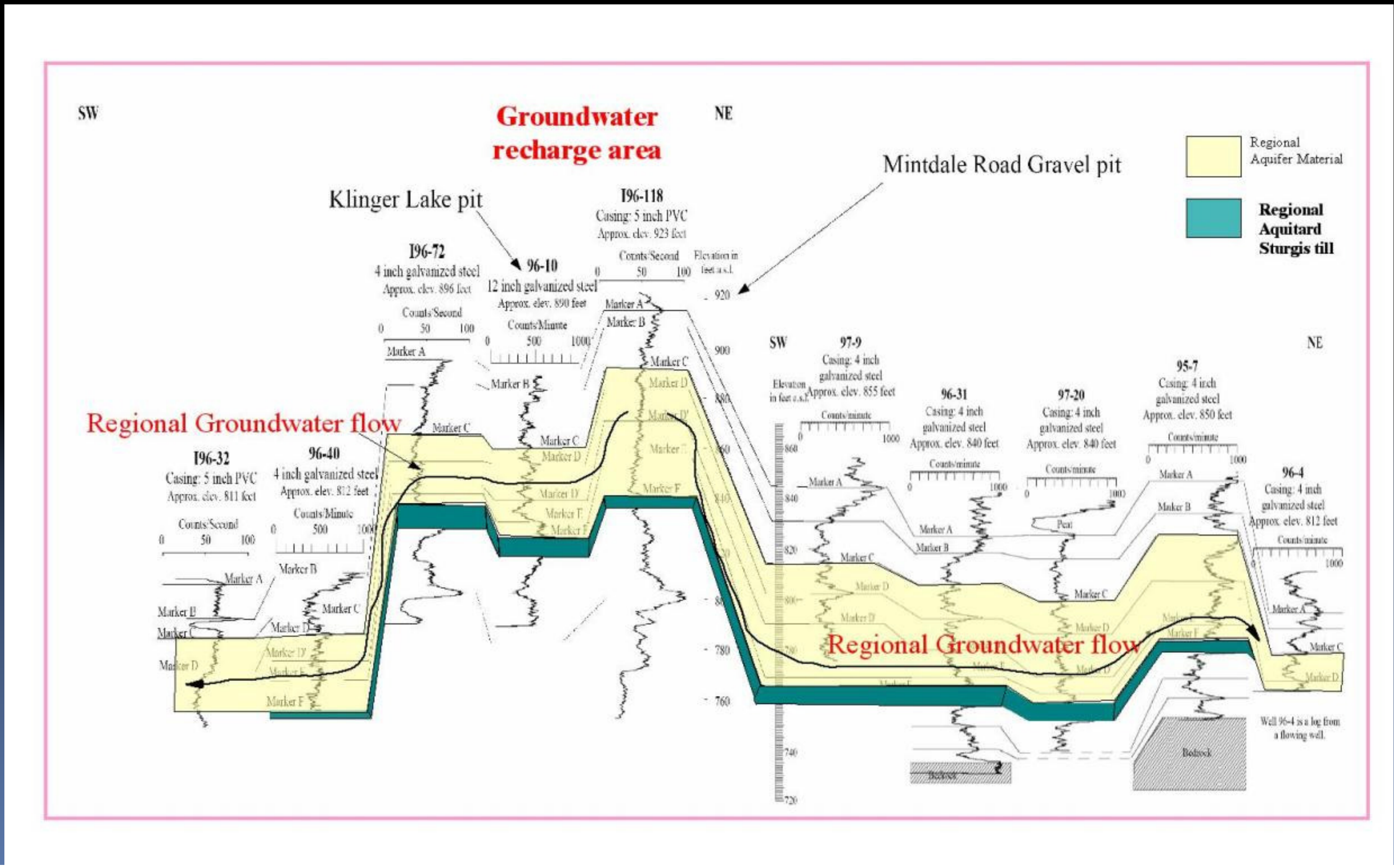


Schematic Diagram of Gamma Ray Logs in St. Joseph



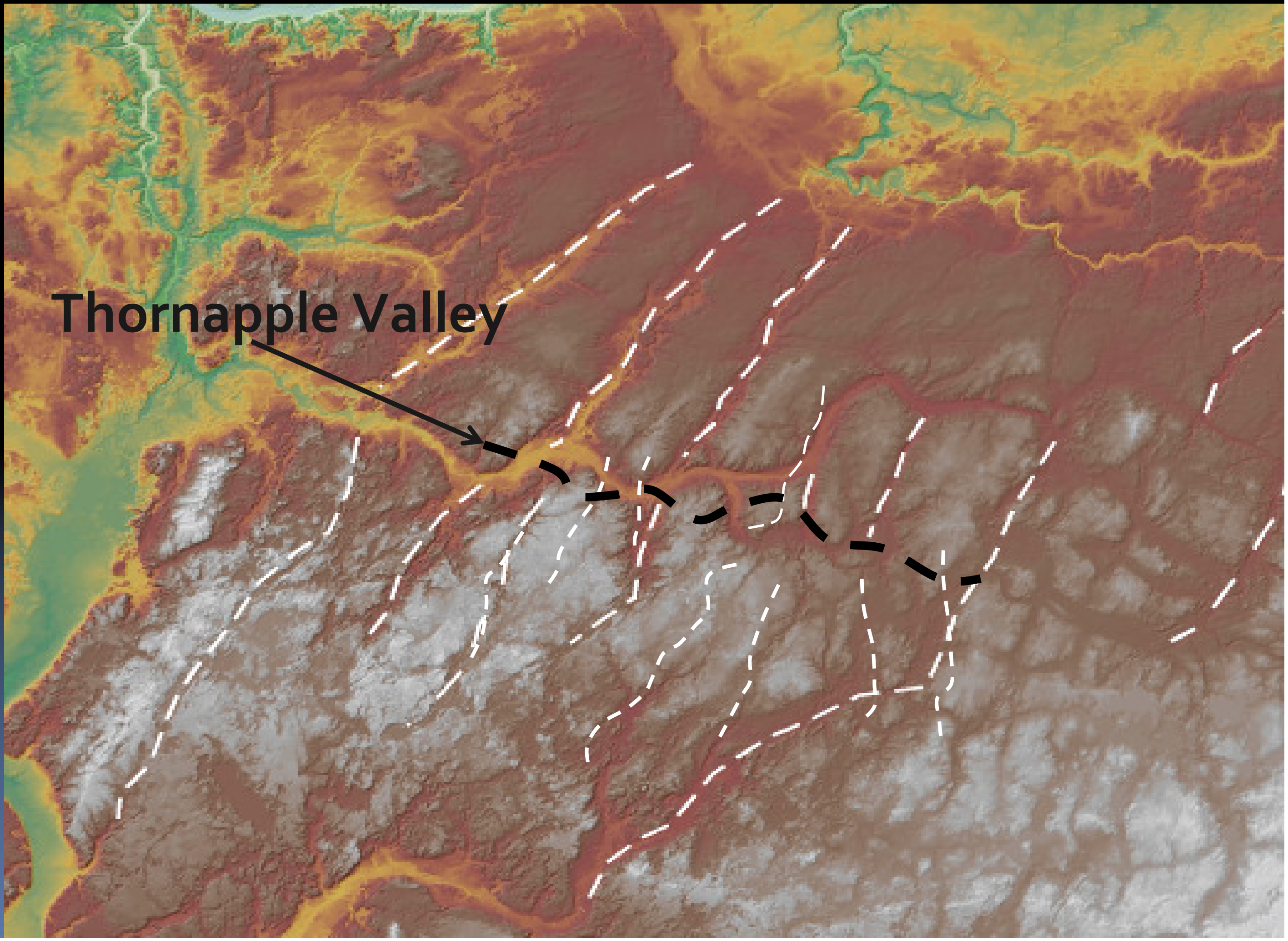
Sturgis Pit

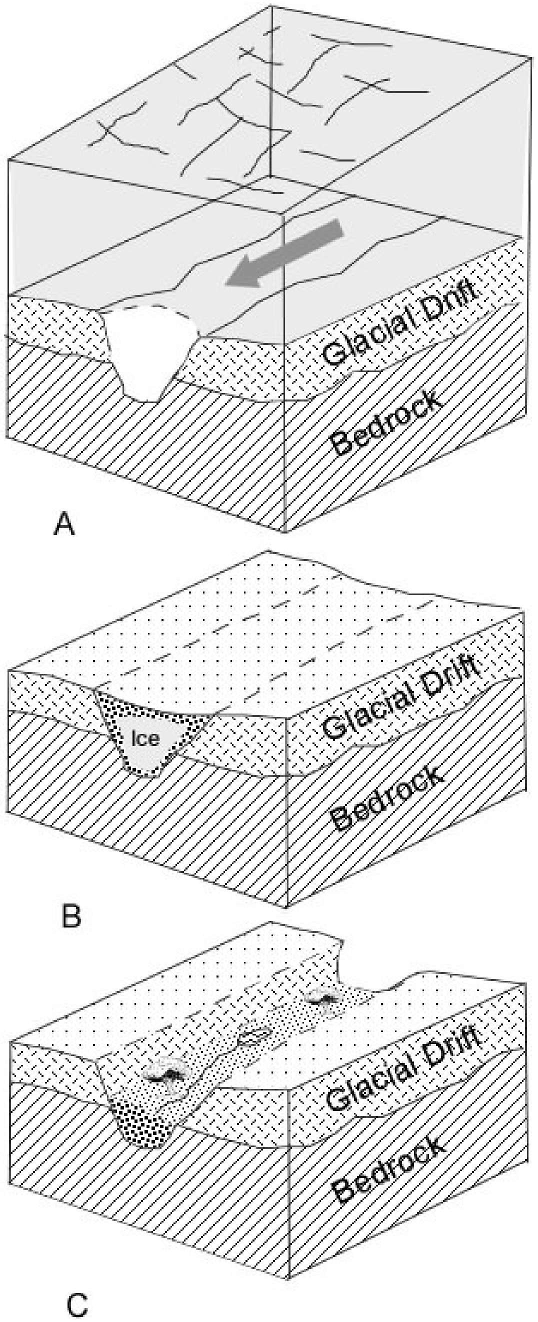
The Sturgis moraine is a regional groundwater recharge area



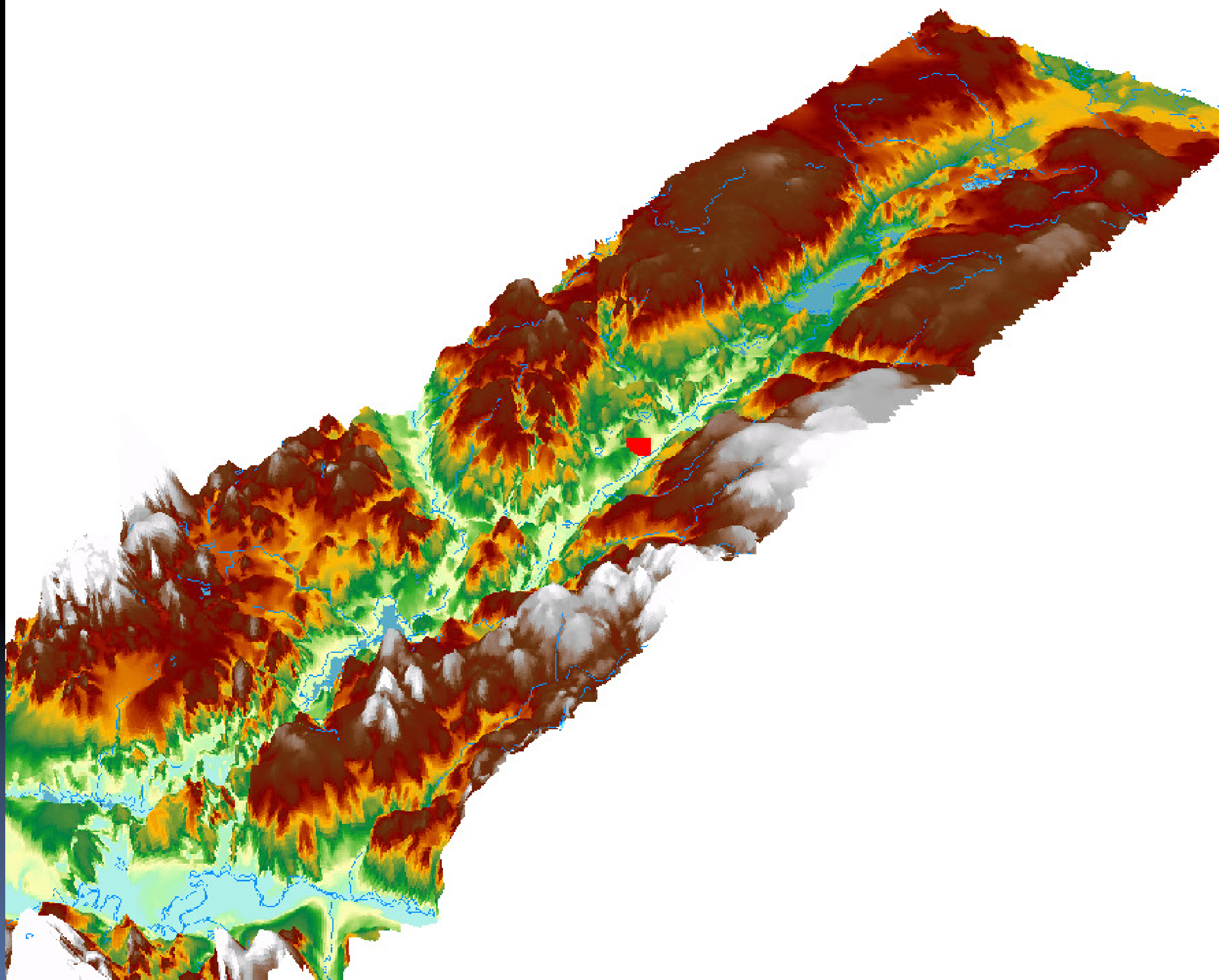
Tunnel valleys in western central part of Saginaw lobe

Tunnel valleys have different morphology north and south of the Thornapple Valley

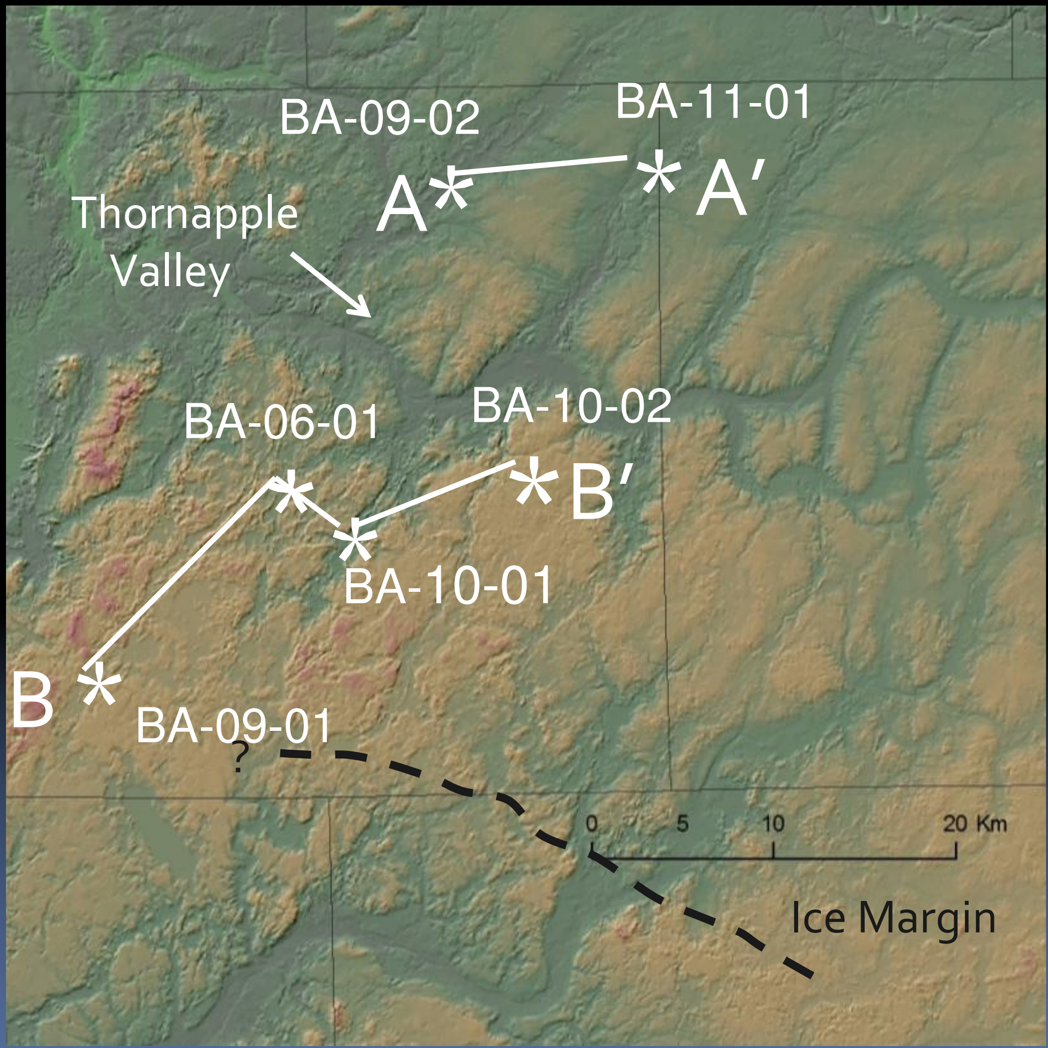


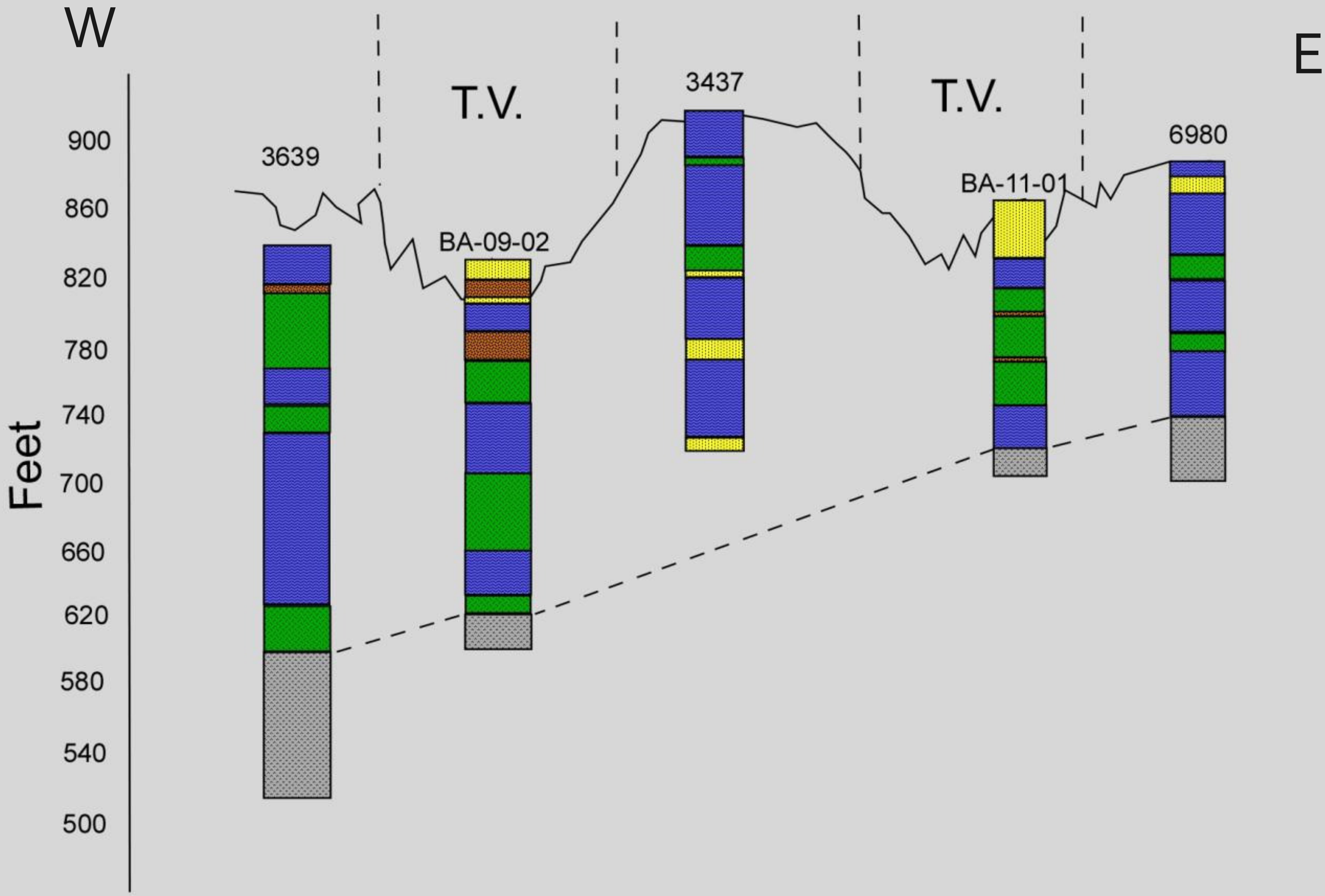


- Tunnel Valleys: deep valleys eroded beneath glaciers now filled with sand and gravel in places
  - How deep was the valley eroded during formation (depth of incision)?
  - What is the nature of the fill above the base of the incised valley?



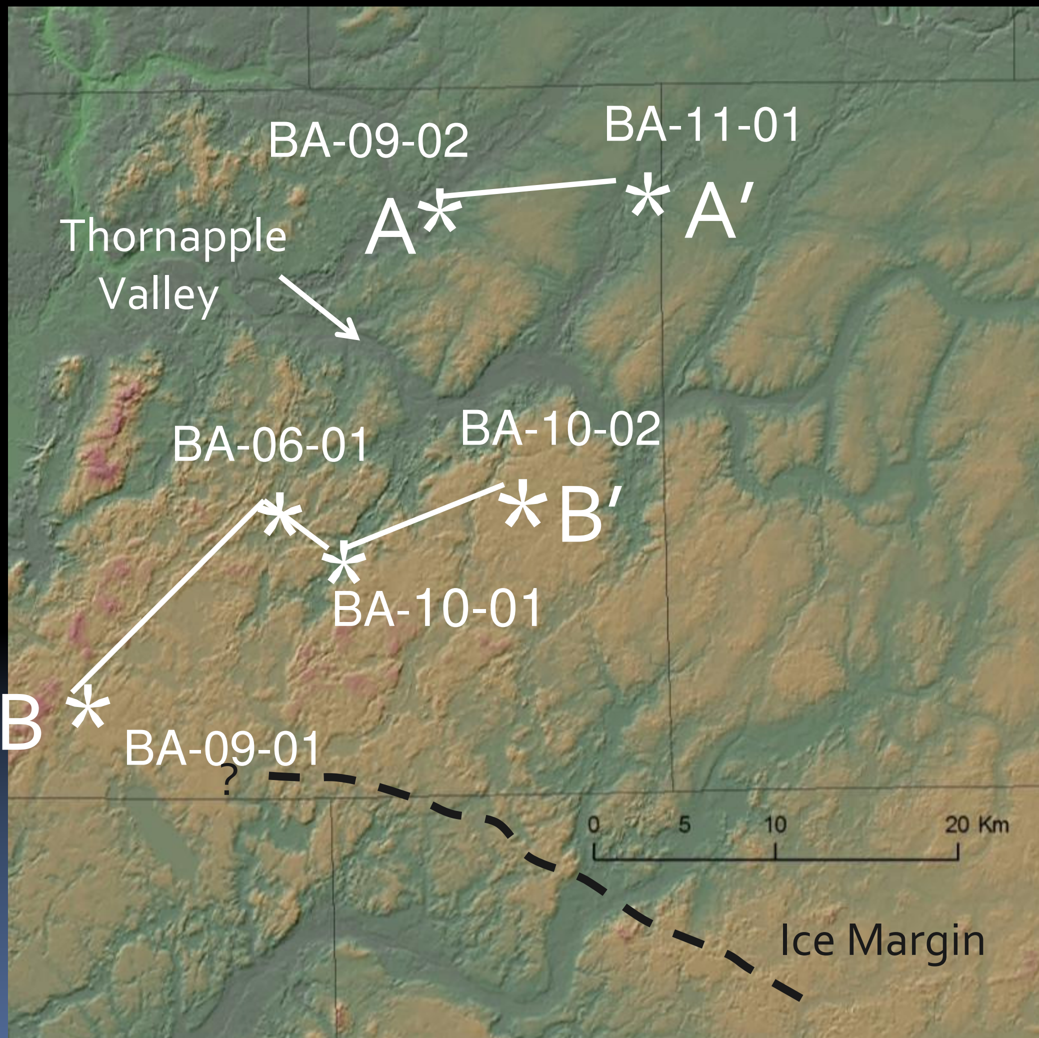
Rotasonic Boring Locations





Very little incision or fill below bottom of topographic valley

Rotasonic Boring Locations



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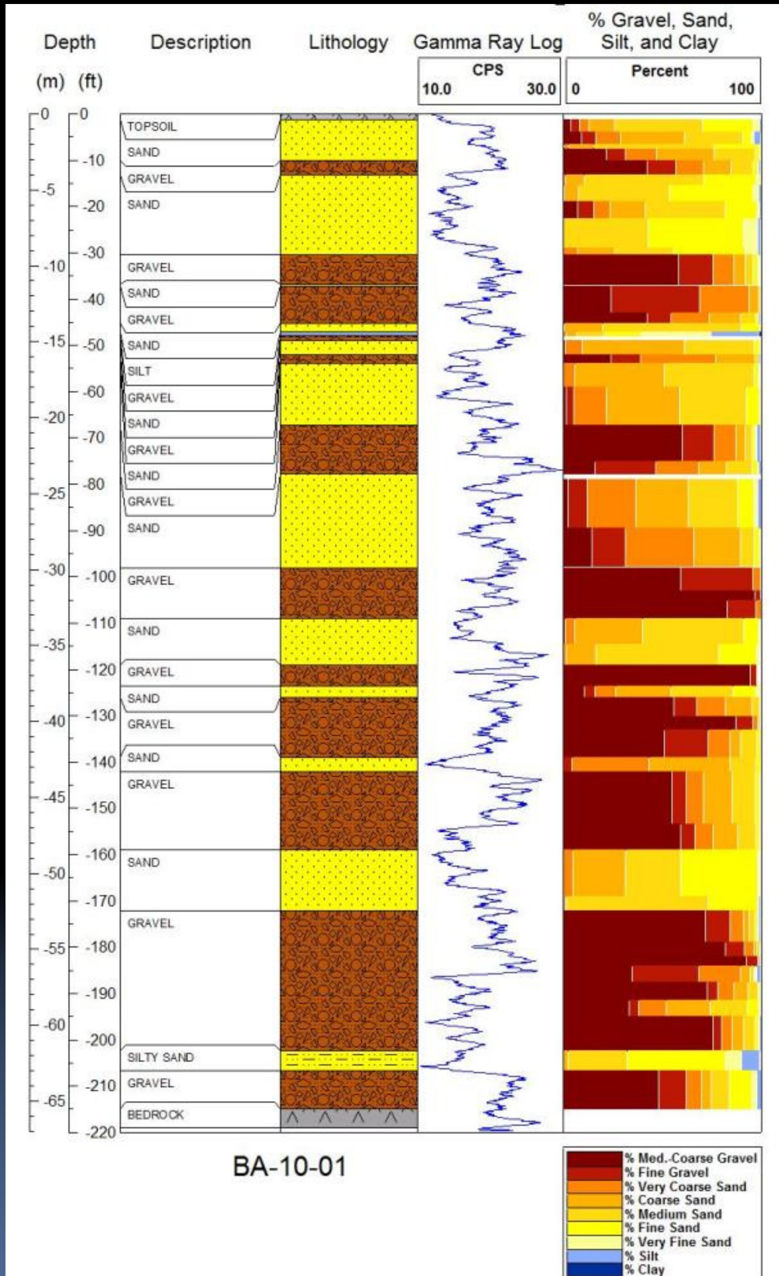
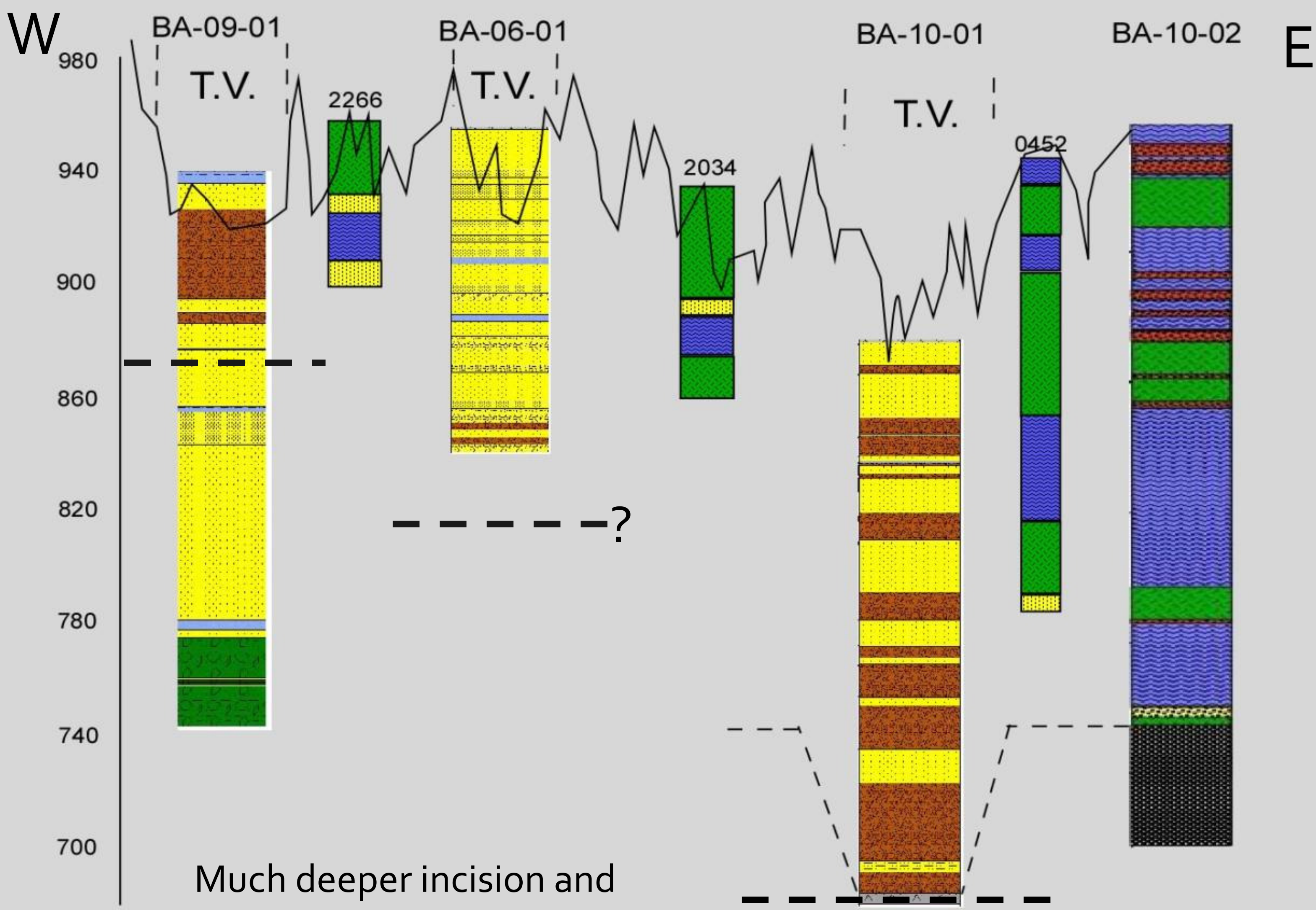


Mostly coarse gravel and sand



Much deeper incision and
thick coarse-grained fills

Thank you for your attention!