

ADVANCED CHARACTERIZATION OF FRACTURED RESERVOIRS IN CARBONATE ROCKS: THE MICHIGAN BASIN



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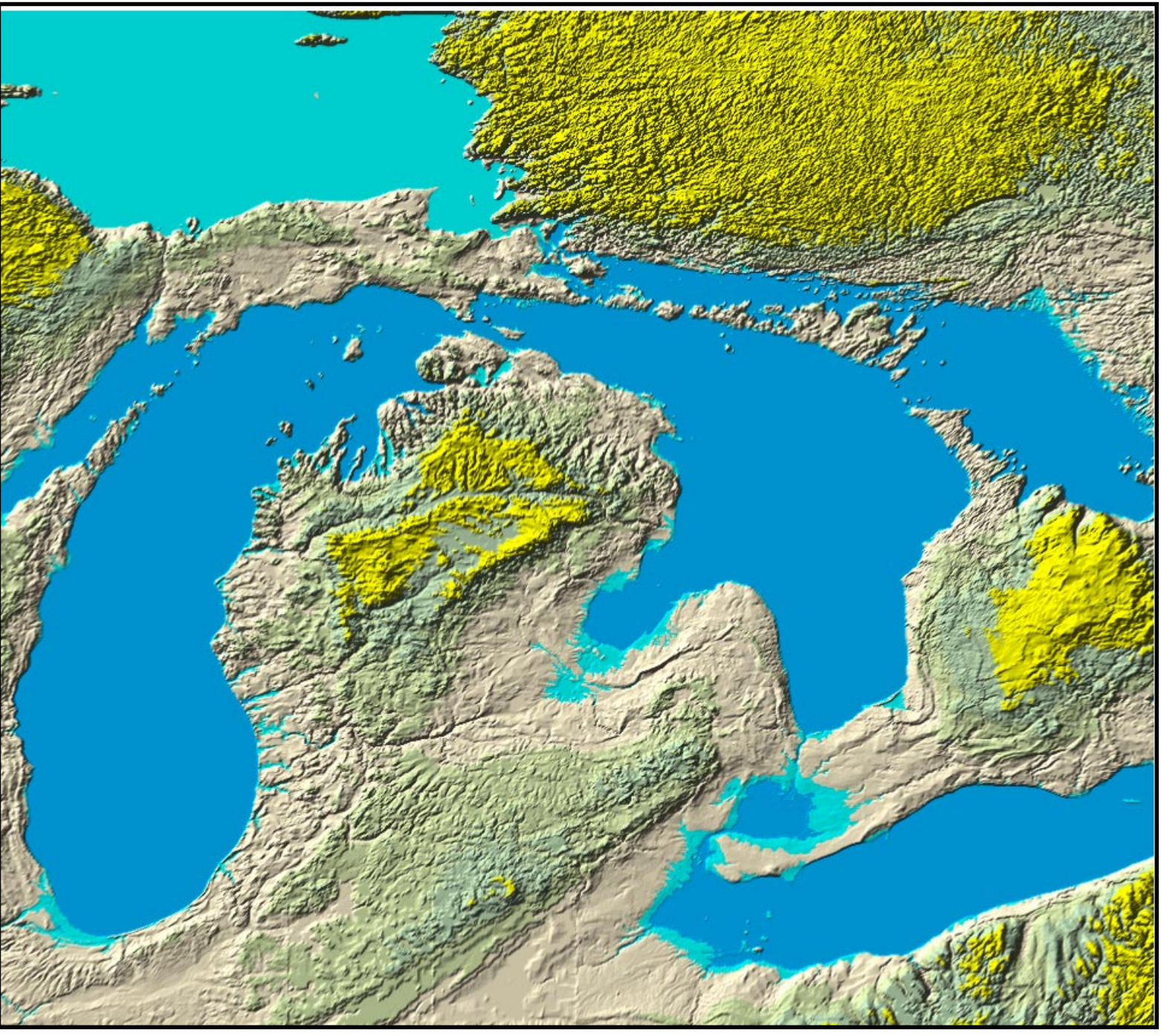
Project Team

- **J. Wood, S. Chittick, C. Asiala - Michigan Technological University**
- **W. Harrison - Western Michigan University**
- **P. Halder, DOE, Tulsa, OK.**

Project Objectives

- **Compilation of geologic & engineering data for Michigan Basin**
- **Characterization of Fractures in Michigan Basin & Michigan Reservoirs**
- **Quantifying Fracture Patterns at a Variety of Scales**
- **Developing a Basin Model for Fracture Development**

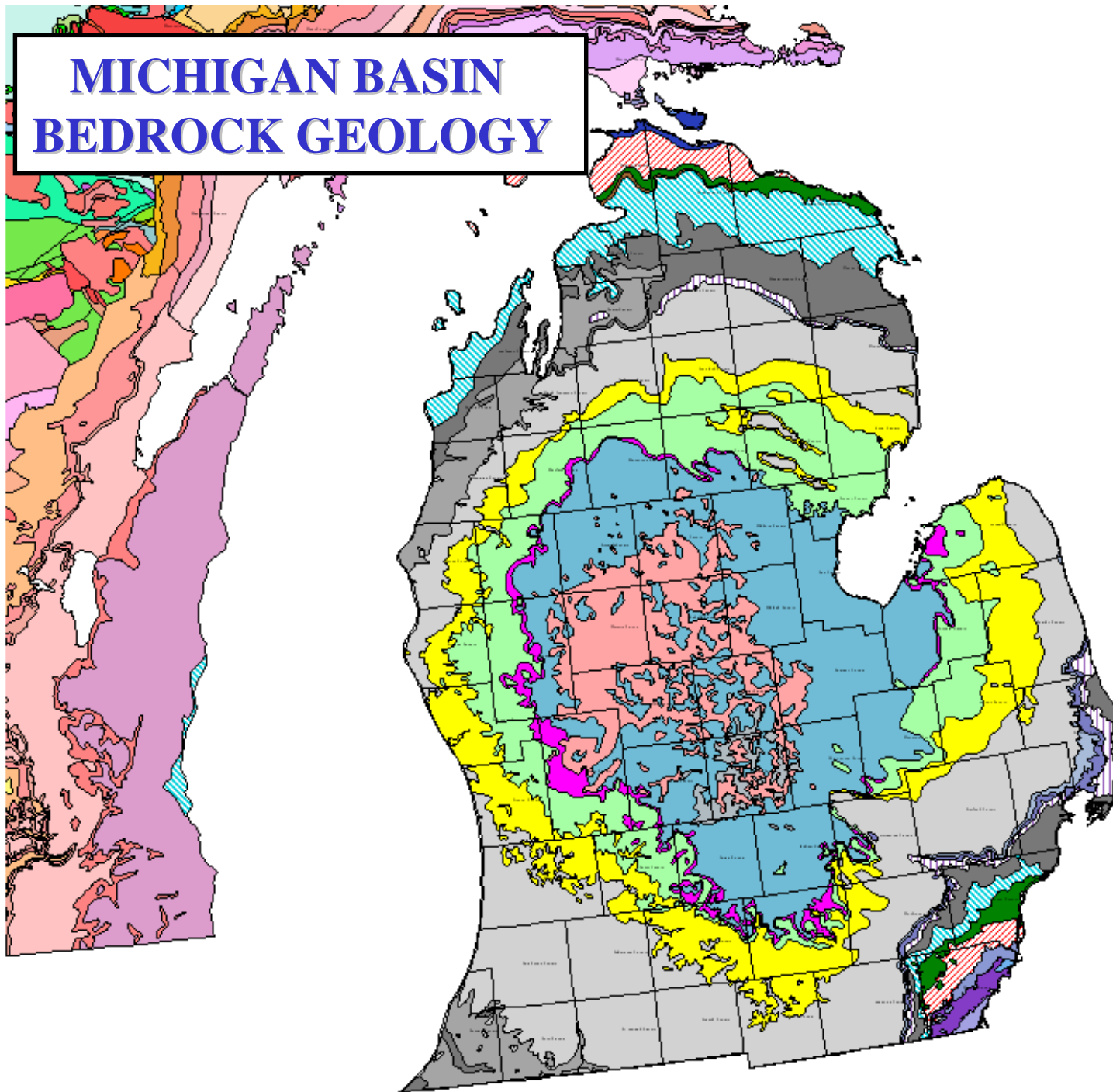
MICHIGAN BASIN DEM



Project Description

- A university–industry consortium will develop a model for fractured carbonate reservoirs using the Michigan Basin as a prototype. The project will combine traditional historical data with 2D and 3D (?) seismic data as well as data from modern logging tools in a novel way to produce a new methodology for characterizing fractured reservoirs in carbonate rocks. GIS-based software will be used to display and manipulate the data and to image it on a variety of scales, ranging from basin-scale to well-scale.

MICHIGAN BASIN BEDROCK GEOLOGY



Project Deliverables

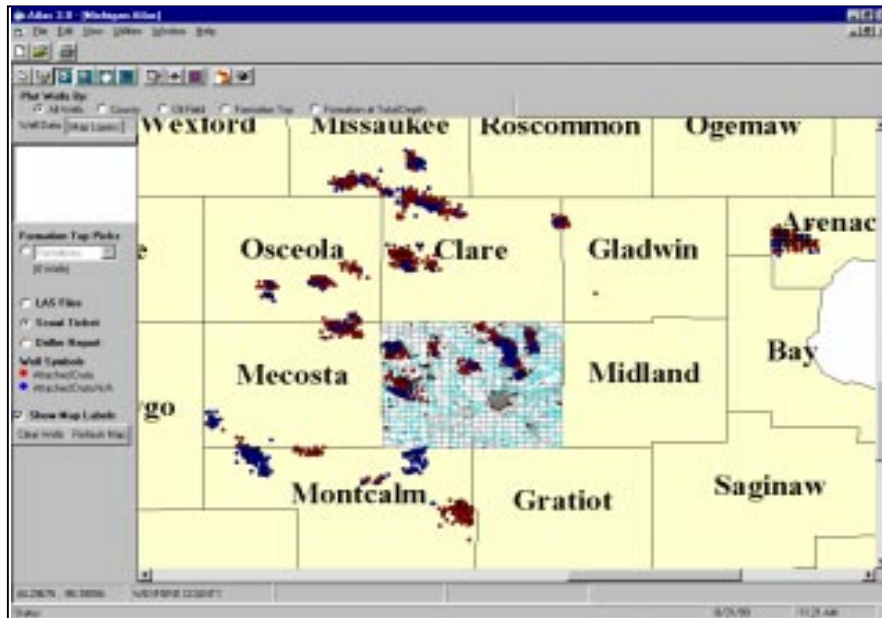
- A library of formation tops picks (300,000+)
- digitized well locations (latitude & longitude; 50,000+)
- scanned images of well header records
- digitized and interpreted logs of key wells
- hydrocarbon logs,
- engineering data, and
- an electronic “Atlas” of project data

Status of Project Deliverables

- formation tops picks: ~ 30% (95,000 out of 300,000+)
- digitized well locations: 90+ % (latitude & longitude; 50,000+)
- scanned images of Scout Tickets: 99%
- digitized/interpreted logs of key wells (pending)
- hydrocarbon logs (acquired, to be processed)
- engineering data, (pending)
- electronic “Atlas” of project data: complete

Atlas 3.0

A GIS Tool for Technology Transfer



Atlas maps Oil and Gas Wells by County, Oil Field, Formation at Total Depth, and Formation Top Picks. The user can:

- Edit individual wells in the database
- Display & select formation top picks
- Display raster images like Scout Tickets
- Export formation top picks
- Plot towns, roads, streams, lakes, etc.

Well	Formation Code	Formation Name	Measured Depth
02230	205PILL	Laramie Member	1121
02230	201GLDN	Caladenia Limestone	1280
02230	201DGR	Yorkway	2264
02230	20109F	Steele	2281
02230	2100494	Union Table	2281

Edit Screen

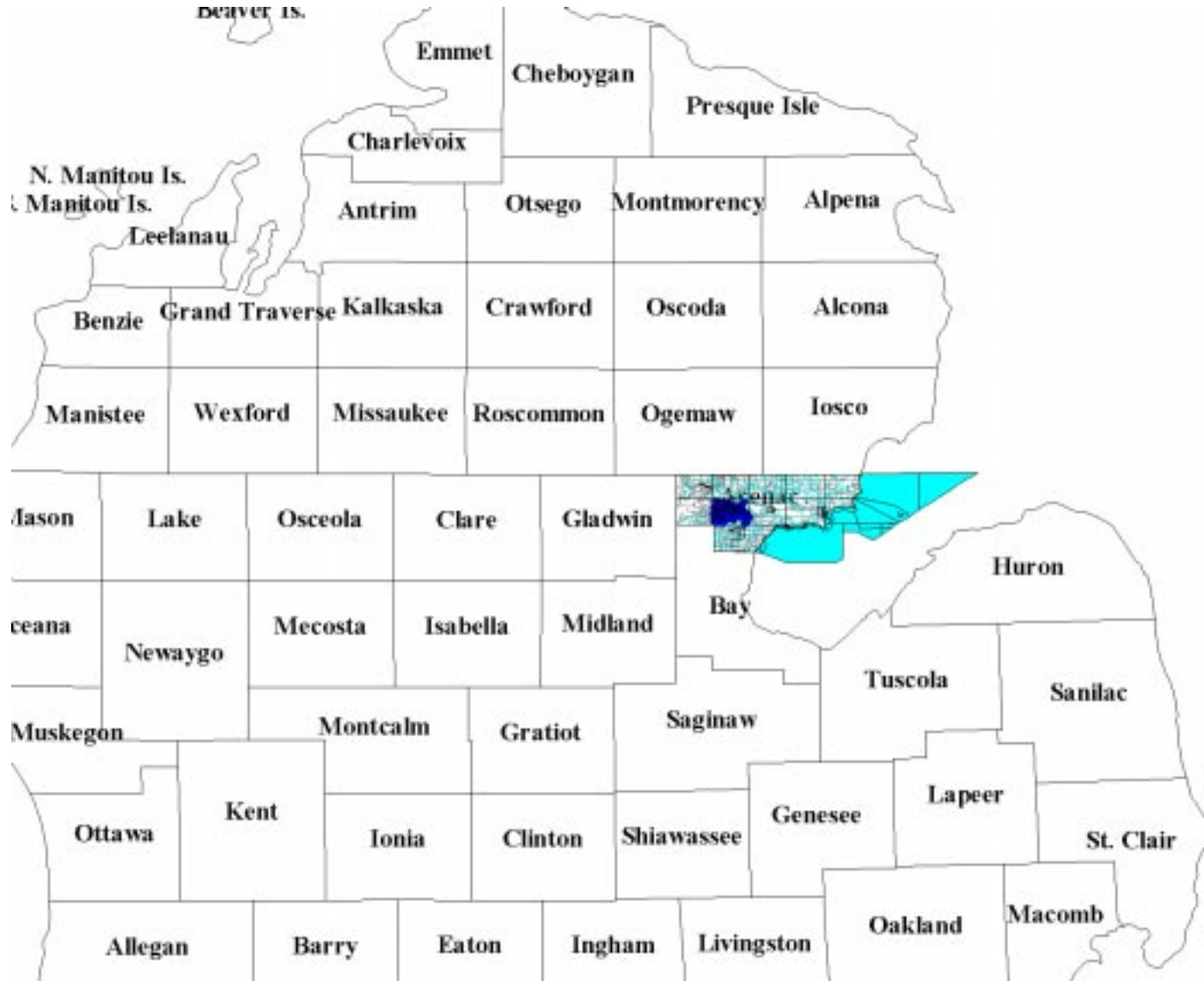
Edit the Header information and the Tops data for the wells plotted on the map. Wells and Formation Tops can be added, updated, and deleted.

Form	Form - To	Bottom	Top	Form - To	Bottom
DRP					
Dr. La.					
SPR #	120-1300	-4.22	Den	3055m	-7.7.1
Mar. RR	13.0	4.22	DR		
Co. La.	1442-1475		Rel		
Co. RR			Rel		
Am			Mig		
DR-Ind			Cal		
Am	1475	2734	Chn		
FP	3000	2734	Trans		

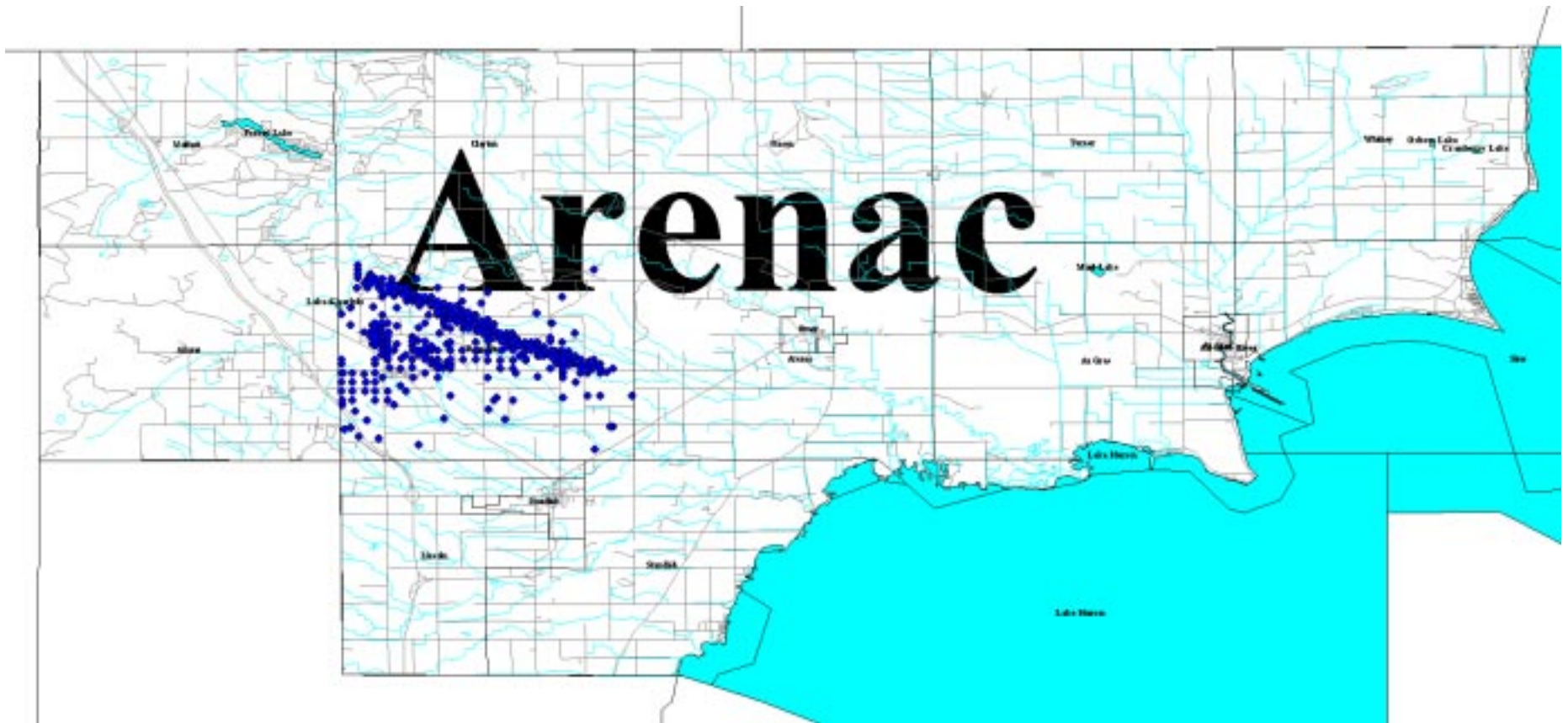
Scout Tickets

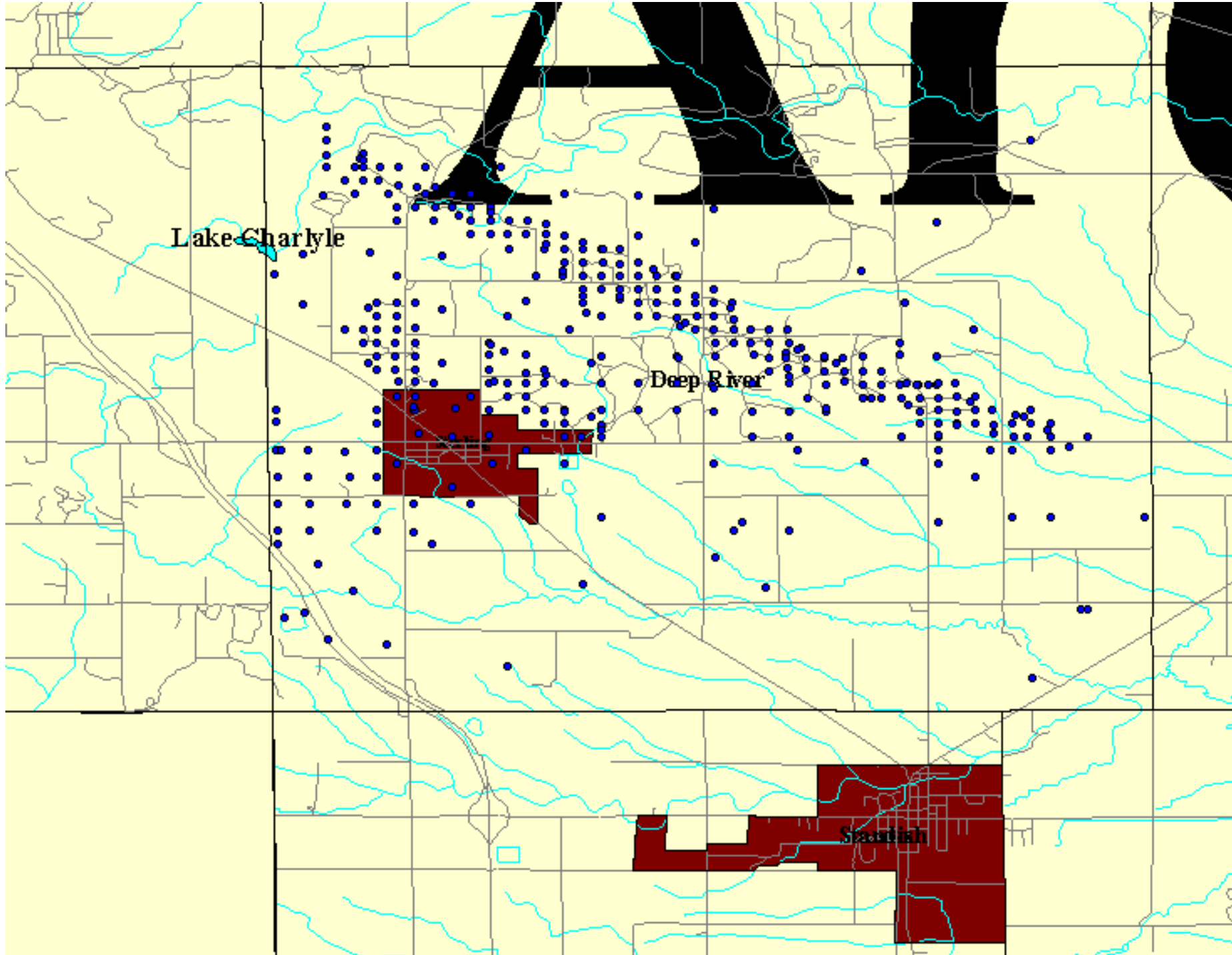
Atlas can display Scout Tickets for the current well. Clicking on the Next and Previous buttons will display notes and additional pages. The image can be zoomed and the Scout Ticket can remain open.

ARENAC COUNTY, MI

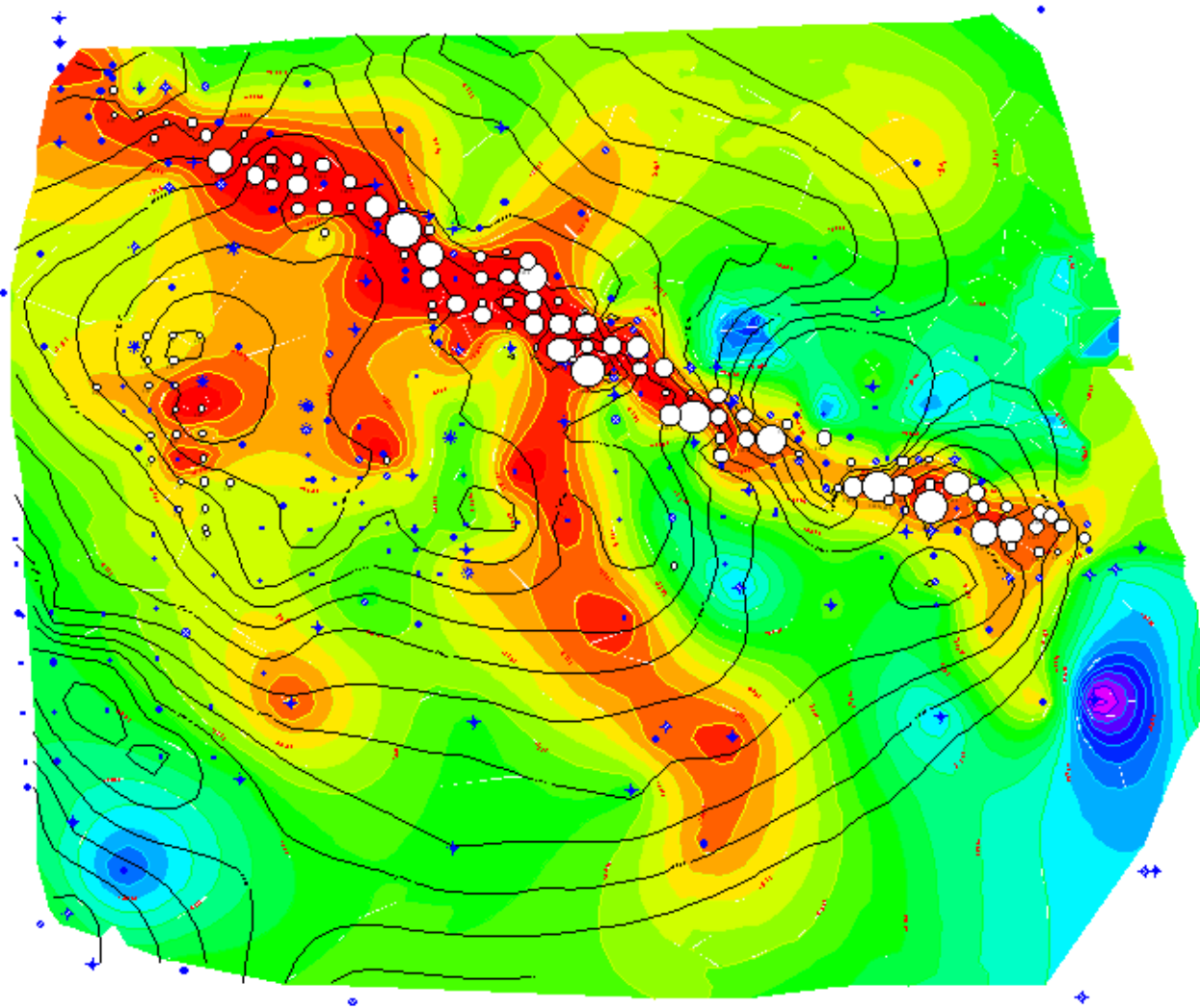


DEEP RIVER FIELD





DEEP RIVER FIELD

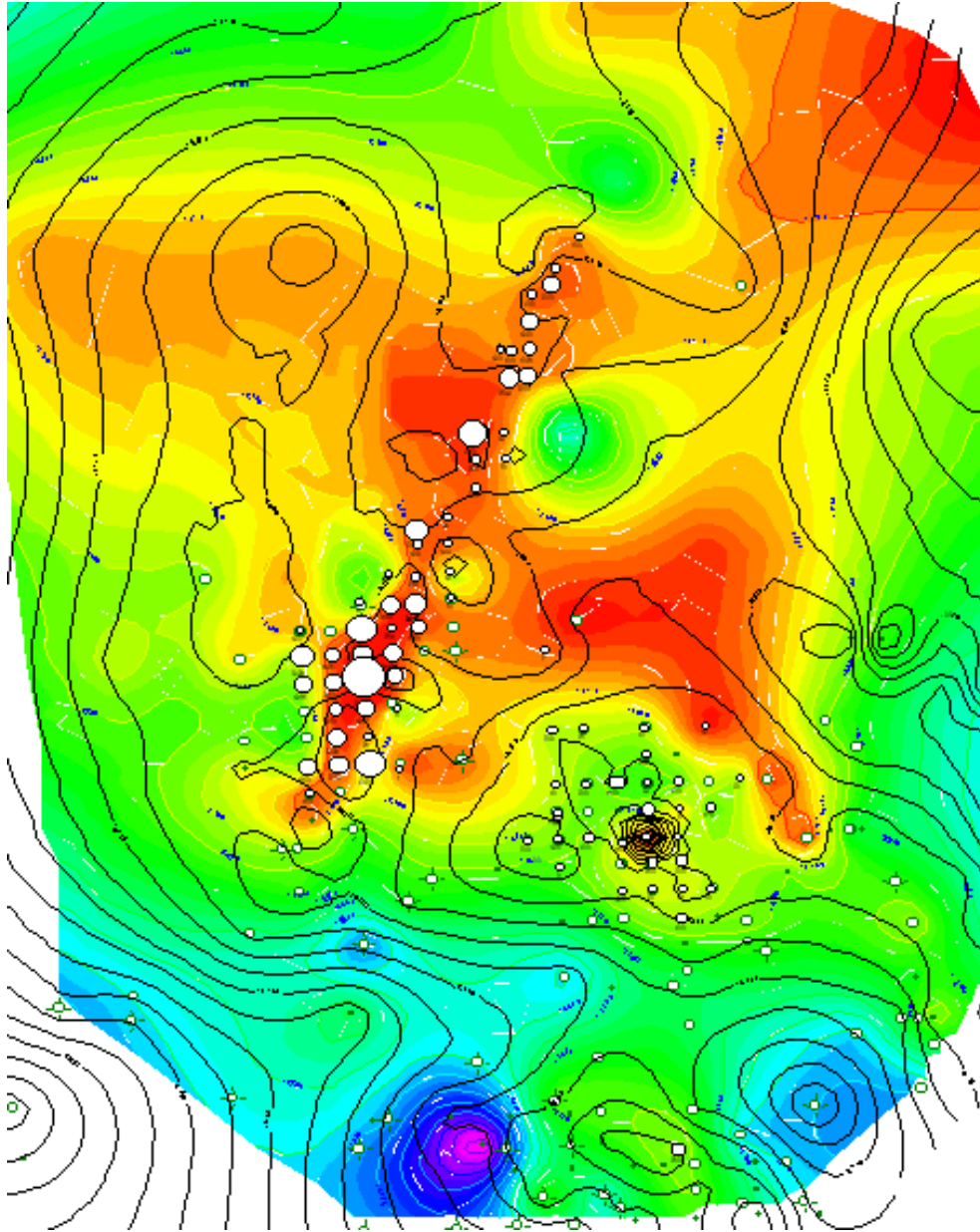


A good example of a dolomite “chimneys” in N. Arenac County cutting across structure in a NW - SE direction.

These types of fields are typical of carbonate reservoirs in the Michigan Basin and are good producers but are difficult to locate.

Initial production values reflect total HC production and follow porosity.

N. ADAMS FIELD

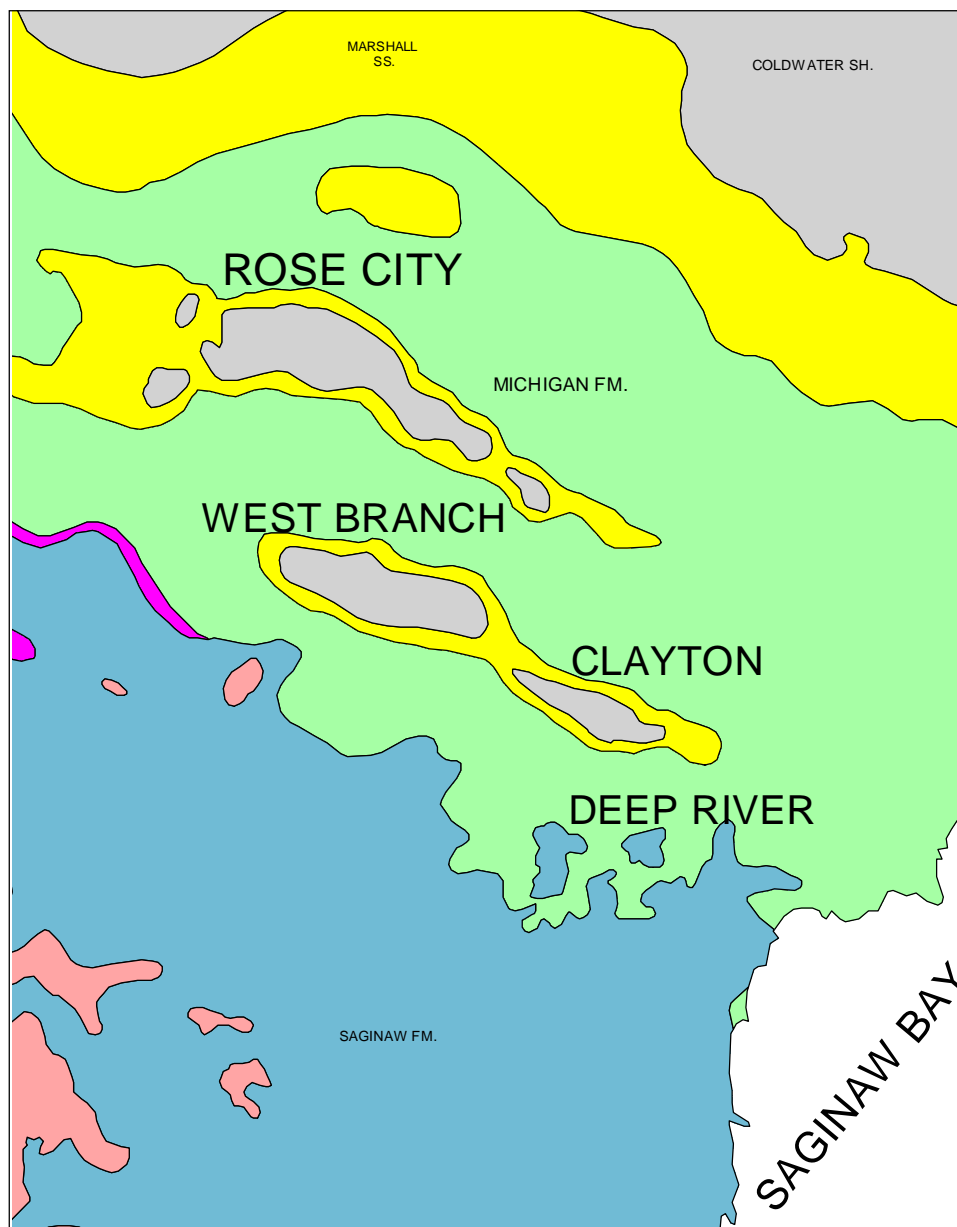


Another good example of a dolomite “chimneys” in N. Arenac County but cutting across structure in a NE - SW direction.

This field produced over 5 million bbls oil to date and is still producing from a few stripper wells.

Note deep “sink” holes in lower center in top porosity.

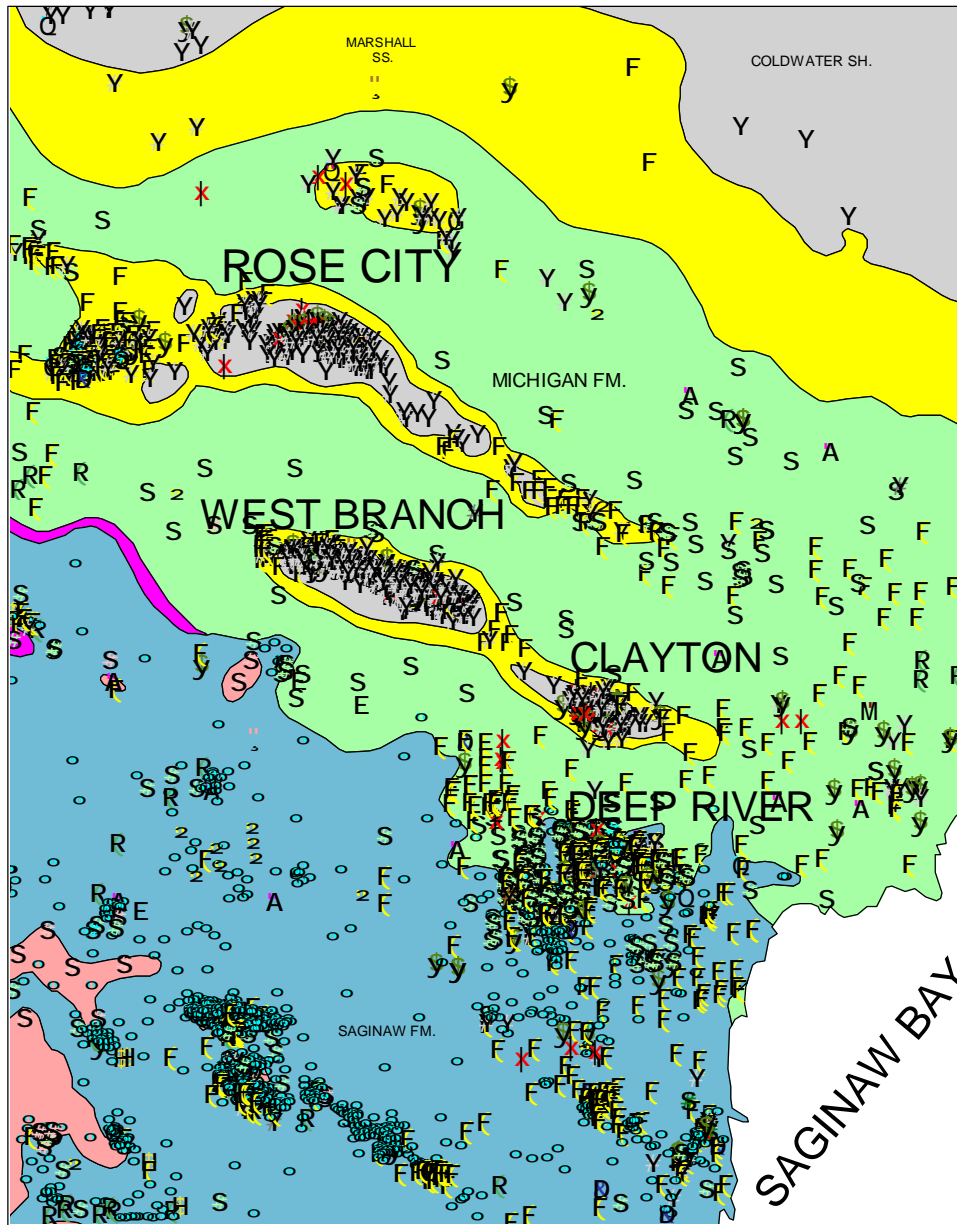
Color - “top porosity”
lines - Top Dundee Fm.
Open circles - Initial Production



**DIGITAL GEOLOGIC MAP
DEEP RIVER FIELD
ARENAC COUNTY, MI**

DEEP RIVER, MI.

Source: USGS



DIGITAL GEOLOGIC MAP
DEEP RIVER FIELD
ARENAC COUNTY, MI

With sub-glacial formations
from project database

DEEP RIVER, MI.

Applications

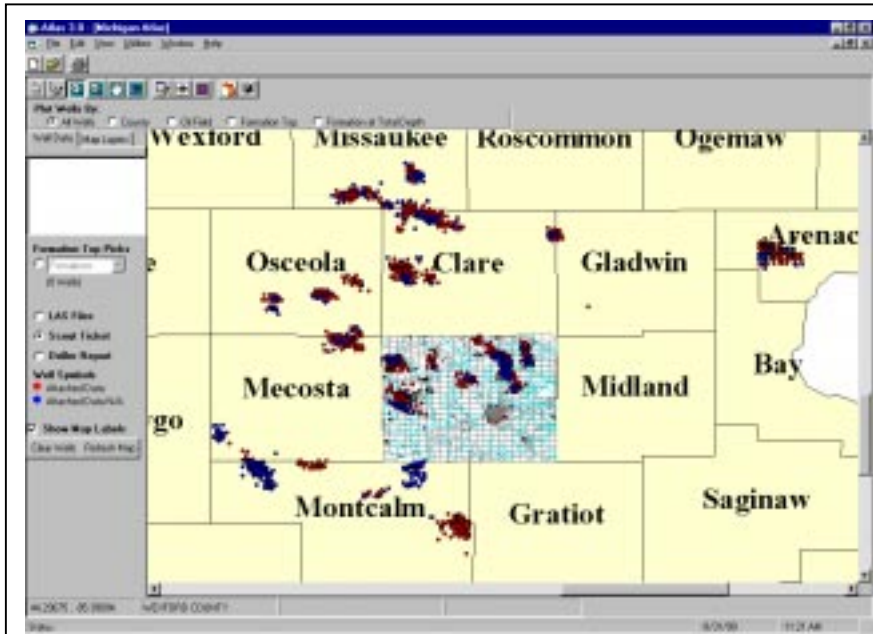
- Main application to industry is ATLAS GIS-based software program
- Code developed and program + data delivered
- 2 CD ROMs - 1 ATLAS program with TIGER support data, 2 with project data (field locations, tops, production & engineering data, raster images of scout tickets & driller's reports)

Part I.

ATLAS Screenshots

**Selected examples of use of ATLAS
program with project database.**

Atlas 3.0 Subsurface Visualization Lab



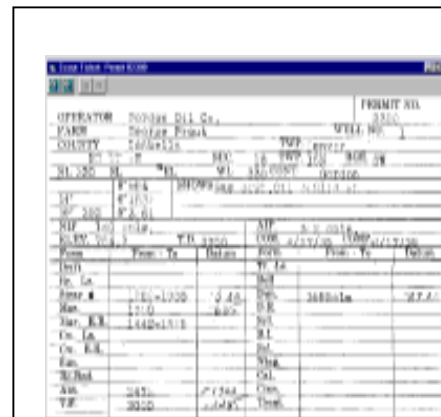
Atlas maps Oil and Gas Wells by County, Oil Field, Formation at Total Depth, and Formation Top Pick. When a subset of wells from the database is plotted, the user can:

- Edit individual wells in the database
- Show which of the plotted wells have a selected Formation Top Pick
- Display Document Images like Scout Tickets
- Export Formation Top Picks for 3D plotting



Edit Screen

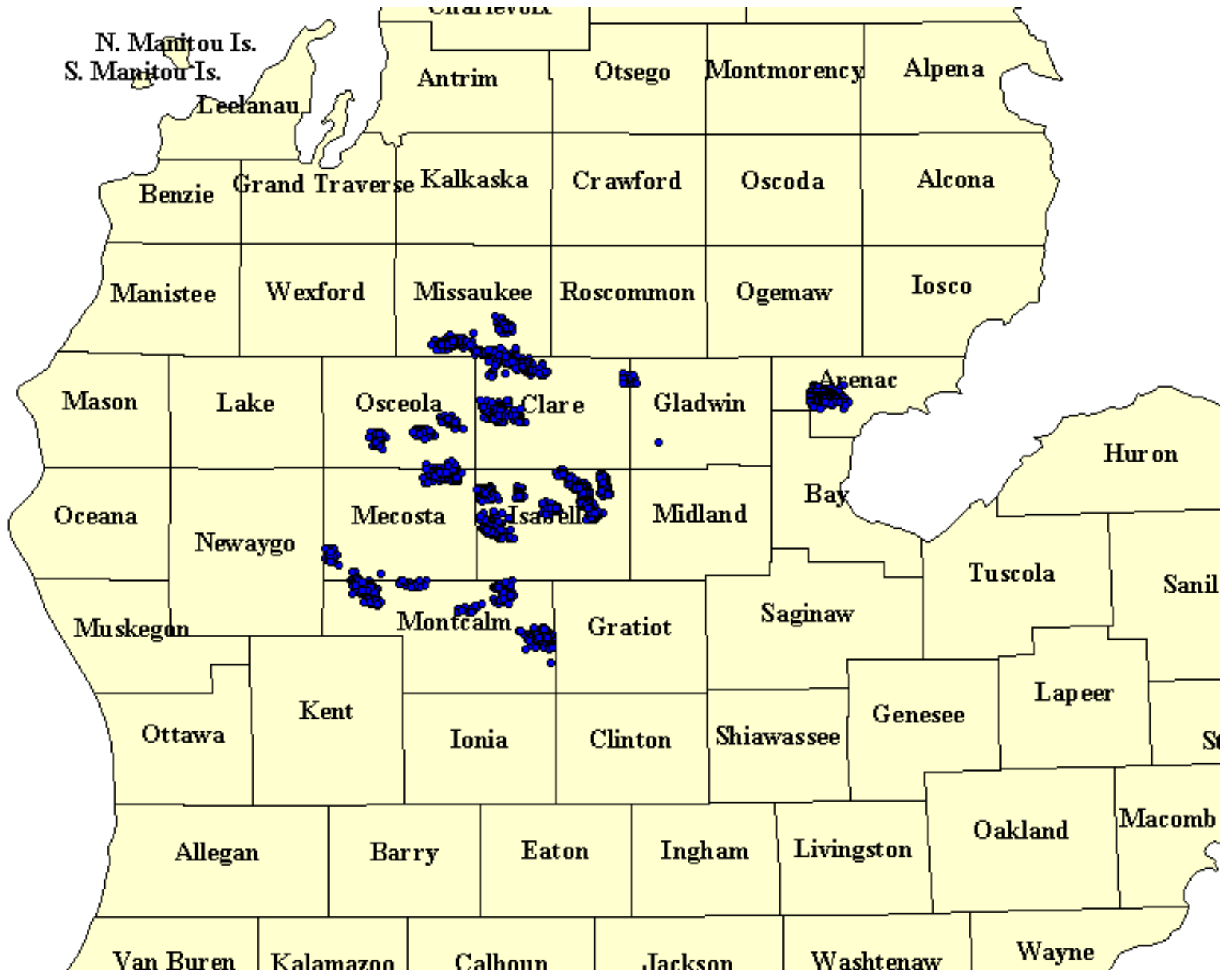
Edit the Header information and the Tops data for the wells plotted on the map. Wells and Formation Tops can be added, updated, and deleted.

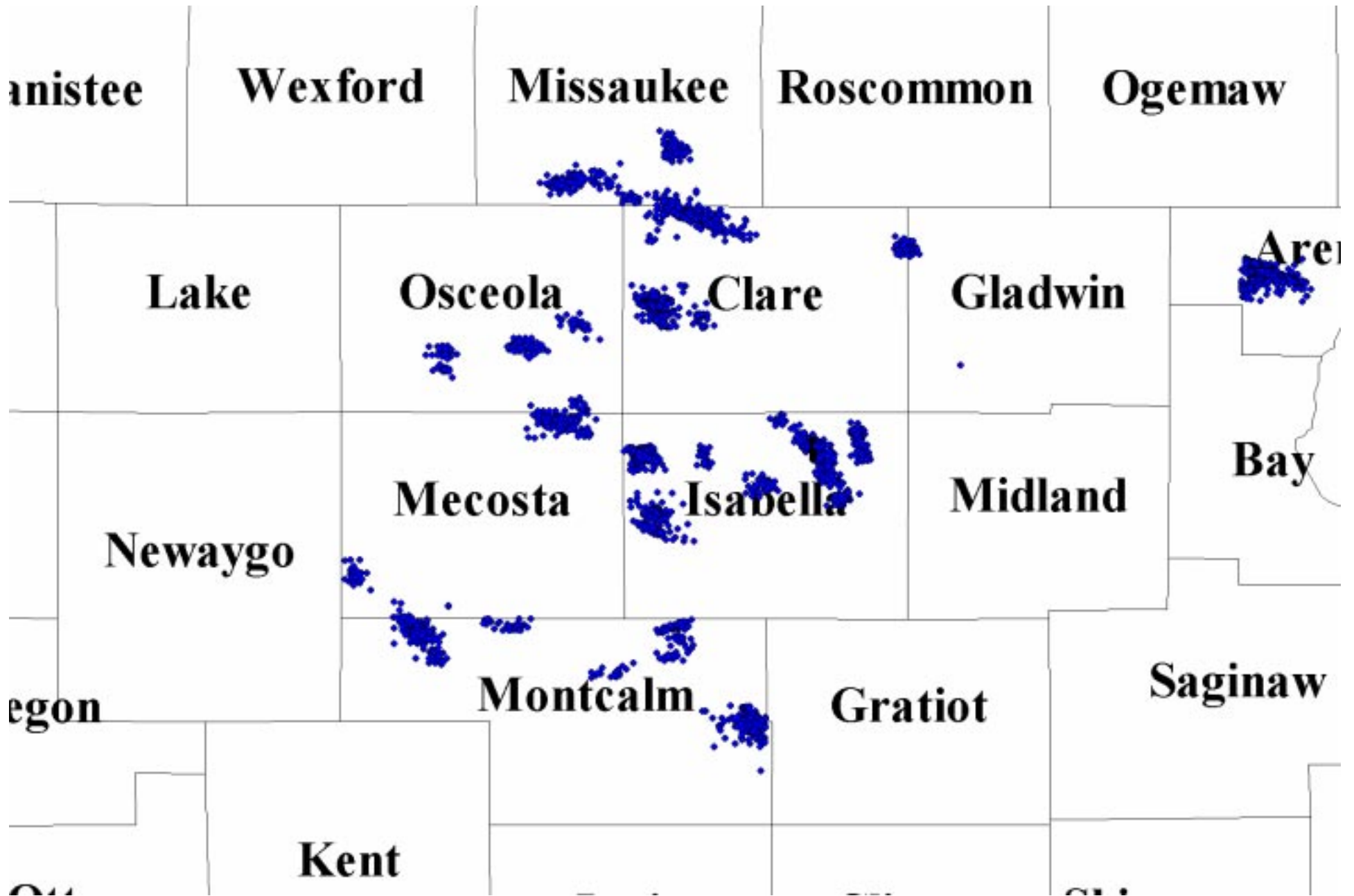


Scout Tickets

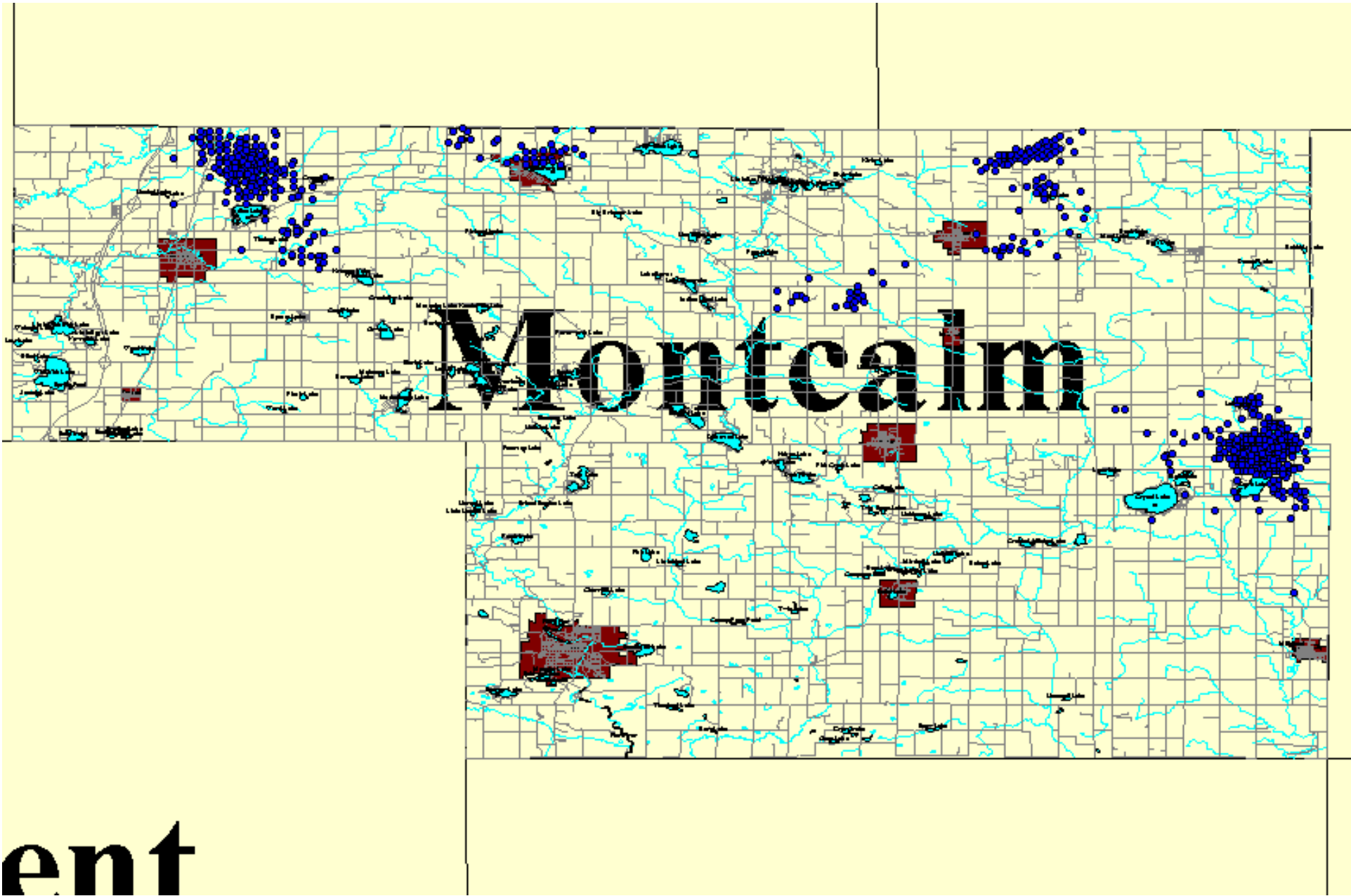
When the Scout Ticket button is clicked on the Edit Screen, the Scout Ticket for the current well is displayed. These are scanned images of the original Scout Tickets. Clicking on the Next and Previous buttons will display notes written on the back of the Scout Ticket and any additional pages. The image can be zoomed in or out and the Scout Ticket can remain open while entering data on the Edit Screen.

Two types of scanned documents stored as multi-page TIF files can be accessed from Atlas. When a project is opened, the document description and the directory path to the images are entered into the Project Information Screen.

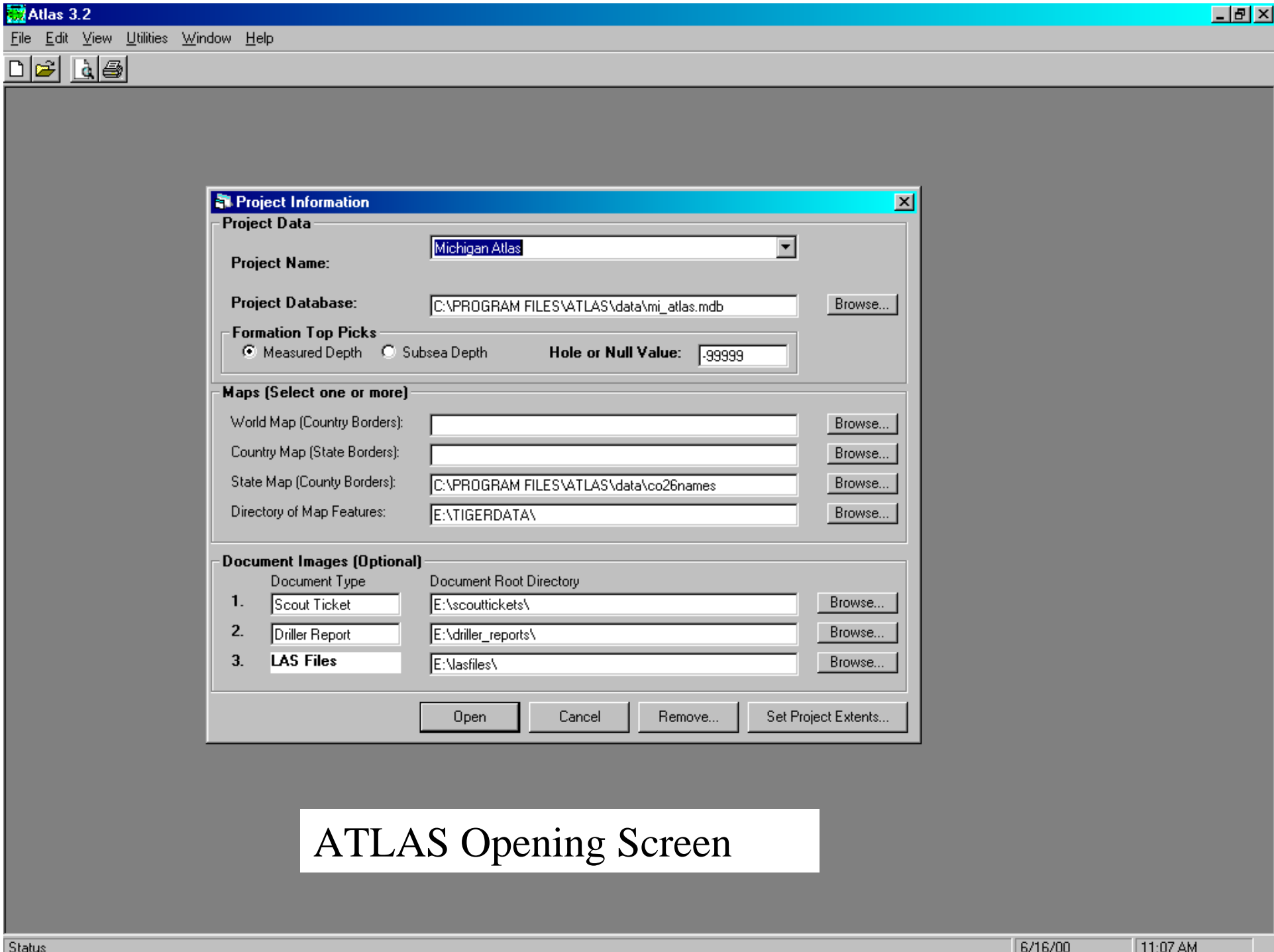




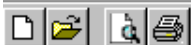
Atlas clipboard



ent



ATLAS Opening Screen



Plot Wells By:
 All Wells County Oil Field

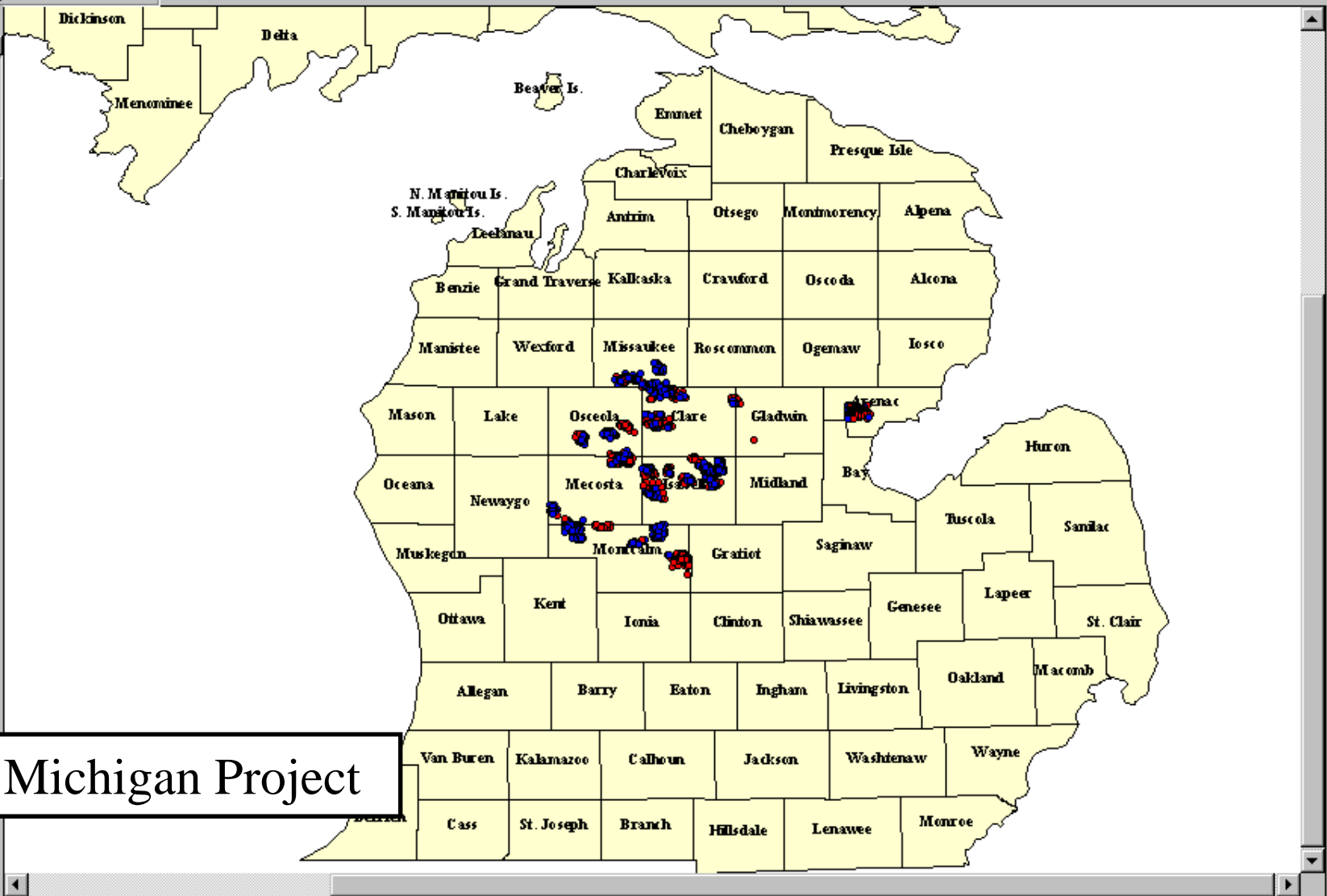
Well Data | Map Features



- Formation Tops
 - Formations
 - (0 Wells)
- Well Status/Type
 - Status
 - Type
- LAS Files
- Scout Ticket
- Driller Report

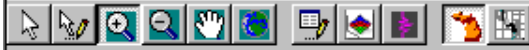
Well Symbols
● Attached Data
● Attached Data N/A

Show Map Labels
Clear Wells Refresh Map



ATLAS Michigan Project

ATLAS Edit Screen



Plot Wells By:
 All Wells County Oil Field

Well Data | Map Features



Formation Tops
 Formations: [Dropdown]
 (0 Wells)

Well Status/Type
 Status [Dropdown]
 Type [Dropdown]

LAS Files
 Scout Ticket
 Driller Report

Well Symbols
● Attached Data
● Attached Data N/A

Show Map Labels
 Clear Wells | Refresh Map

All Wells in Michigan Atlas

Permit*: 00128BD Lat*/Long*: 43.77086 -84.69301

Oil Field*: WISE Well Status Codes: BDW ACT 1

Operator: SUMMIT PETROLEUM CORPORATION FORM * Required Entry

Well Name: NORTH WISE UNIT 3

KB*: 775 Subsea TD: -2975 IP-Before: 0

Total Depth: 1415 Formation at TD: MCGN1 IP-After: 0

County Code/Name*: 37 ISABELLA IP-Water: [Empty]

SECT/TWN/RNG: 20 16N 3W Top of Porosity: [Empty]

Quarters: NE NW NE No. Formation Tops: 2

Footage Calls: 200 FNL 1090 FWL Issue Date: 5/31/60

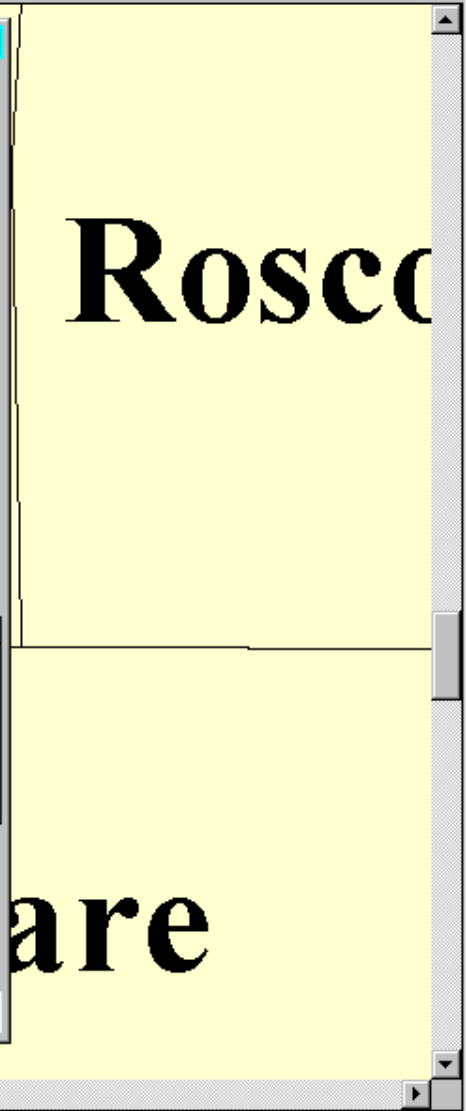
Comment: [Empty] Drill Start Date: 12/16/89

Drill Compl Date: 12/26/89

Selected Wells	Permit	FormationCode	FormationName	Measured Depth
00128BD	00128BD	302TRVRL	Traverse Limestone	2996
00129BD	00128BD	302DNDE	Dundee	3643
00651				
00806				
00823				
00849				
00850				

Click a Formation to Update the Current Formation Tops Record

Record: 1 of 3117



All Wells in Michigan Atlas

Permit*: 00128BD Lat*/Long*: 43.77086 -84.69301

Oil Field*: WISE Well Status Codes: BDW ACT 1

Operator: SUMMIT PETROLEUM CORPORATION FORM * Required Entry

Well Name: NORTH WISE UNIT 3

KB*: 775 Subsea TD: -2975 IP-Before: 0

Total Depth: 1415 Formation at TD: MCGN1 IP-After: 0

County Code/Name*: 37 ISABELLA IP-Water:

SECT/TWN/RNG: 20 16N 3W Top of Porosity:

Quarters: NE NW NE No. Formation Tops: 2

Footage Calls: 200 FNL 1090 FWL Issue Date: 5/31/60

Comment: Drill Start Date: 12/16/89

Drill Compl Date: 12/26/89

Selected Wells		Formation Tops			
Permit	FormationCode	FormationName	Measured Depth		
00128BD	302TRVRL	Traverse Limestone	2996		
00128BD	302DNDE	Dundee	3643		

Click a Formation to Update the Current Formation Tops Record

Record: 1 of 3117

ATLAS Edit Screen



ATLAS Map Features

Plot Wells By:

All Wells County Oil Field

Well Data | Map Features

- GLADWIN
- ISABELLA
- MECOSTA
- MISSAUKEE
- MONTCALM**
- OSCEOLA

Formation Tops

Formations

(0 Wells)

Well Status/Type

Status

Type

LAS Files

Scout Ticket

Driller Report

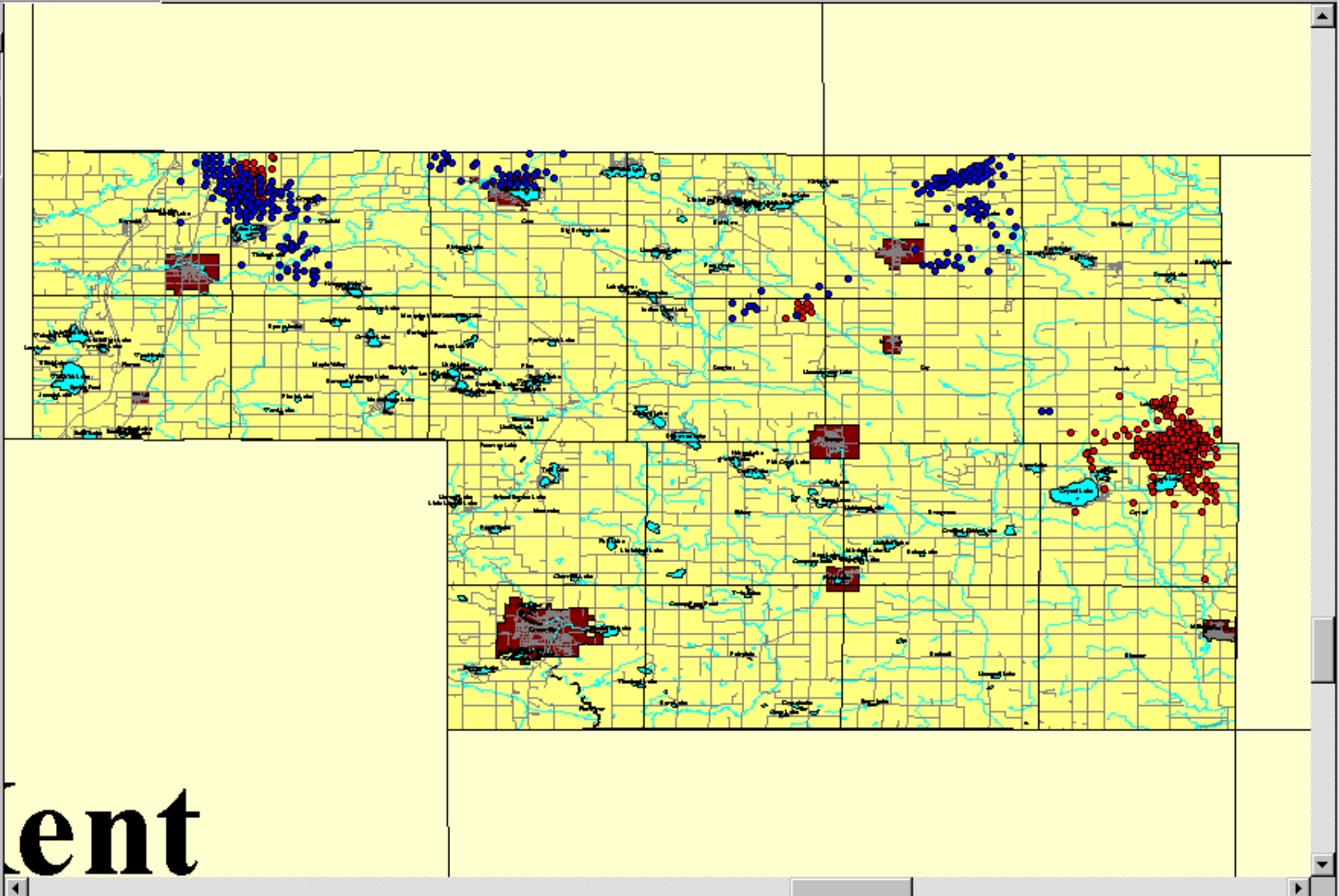
Well Symbols

● Attached Data

● Attached Data N/A

Show Map Labels

Clear Wells Refresh Map



ent

43.43514 , -85.07739

MONTCALM COUNTY



ATLAS Map Features

Plot Wells By:
 All Wells County Oil Field

Well Data | Map Features

- GLADWIN
- ISABELLA
- MECOSTA
- MISSAUKEE
- MONTCALM**
- OSCEOLA

Formation Tops

Formations

(0 Wells)

Well Status/Type

Status

Type

LAS Files

Scout Ticket

Driller Report

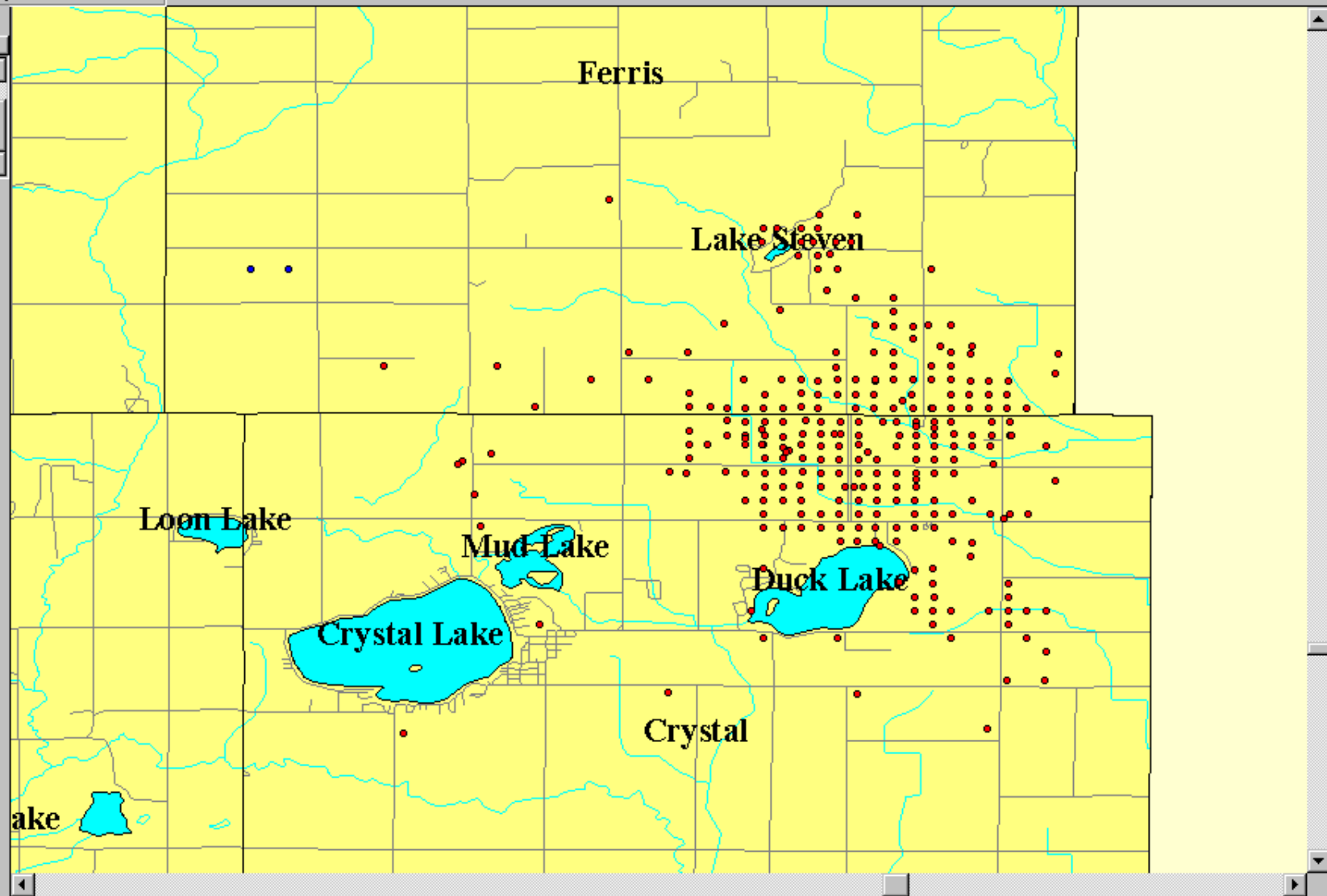
Well Symbols

● Attached Data

● Attached Data N/A

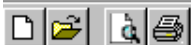
Show Map Labels

Clear Wells Refresh Map



43.34555 , -84.91463

MONTCALM COUNTY



Plot Wells By:

All Wells County Oil Field

Well Data | Map Features

- GLADWIN
- ISABELLA
- MECOSTA
- MISSAUKEE
- MONTCALM**
- OSCEOLA

Formation Tops

Formations

(0 Wells)

Well Status/Type

Status

Type

LAS Files

Scout Ticket

Driller Report

Well Symbols

● Attached Data

● Attached Data N/A

Show Map Labels

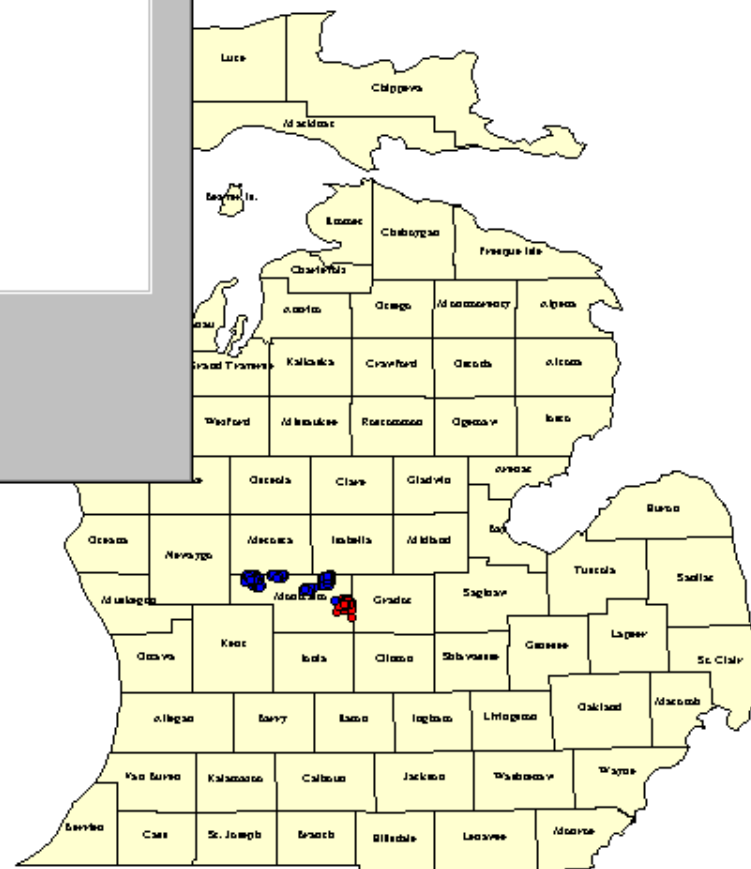
Clear Wells | Refresh Map

ATLAS Formation Top Exporter

Export Data From MONTCALM COUNTY

Select Formation(s) for Exporting

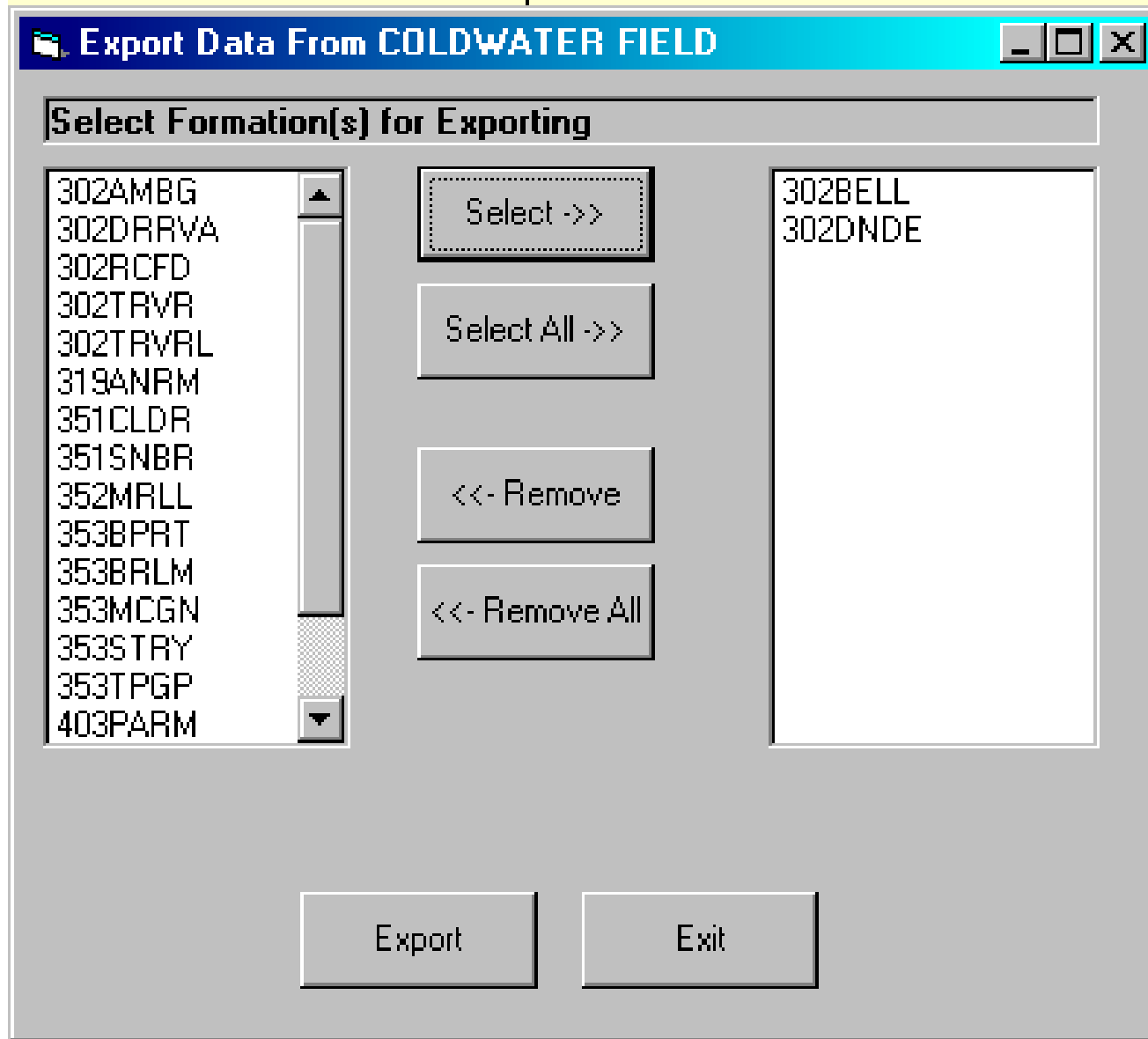
302ALPN	<input type="button" value="Select ->"/> <input type="button" value="Select All ->"/> <input type="button" value="Remove ->"/> <input type="button" value="Remove All ->"/>	302DNDE
302AMBG		
302BBLC		
302BELL		
302DRRV		
302DRRVA		
302DRRVS		
302DRVS		
302MSAD		
302RCFD		
302RDCT		
302RDCTA		
302RDCTD		
302SQBY		
302SYLN		



43.34555 , -84.91463

MONTCALM COUNTY

ATLAS Formation Top Exporter



Part II.

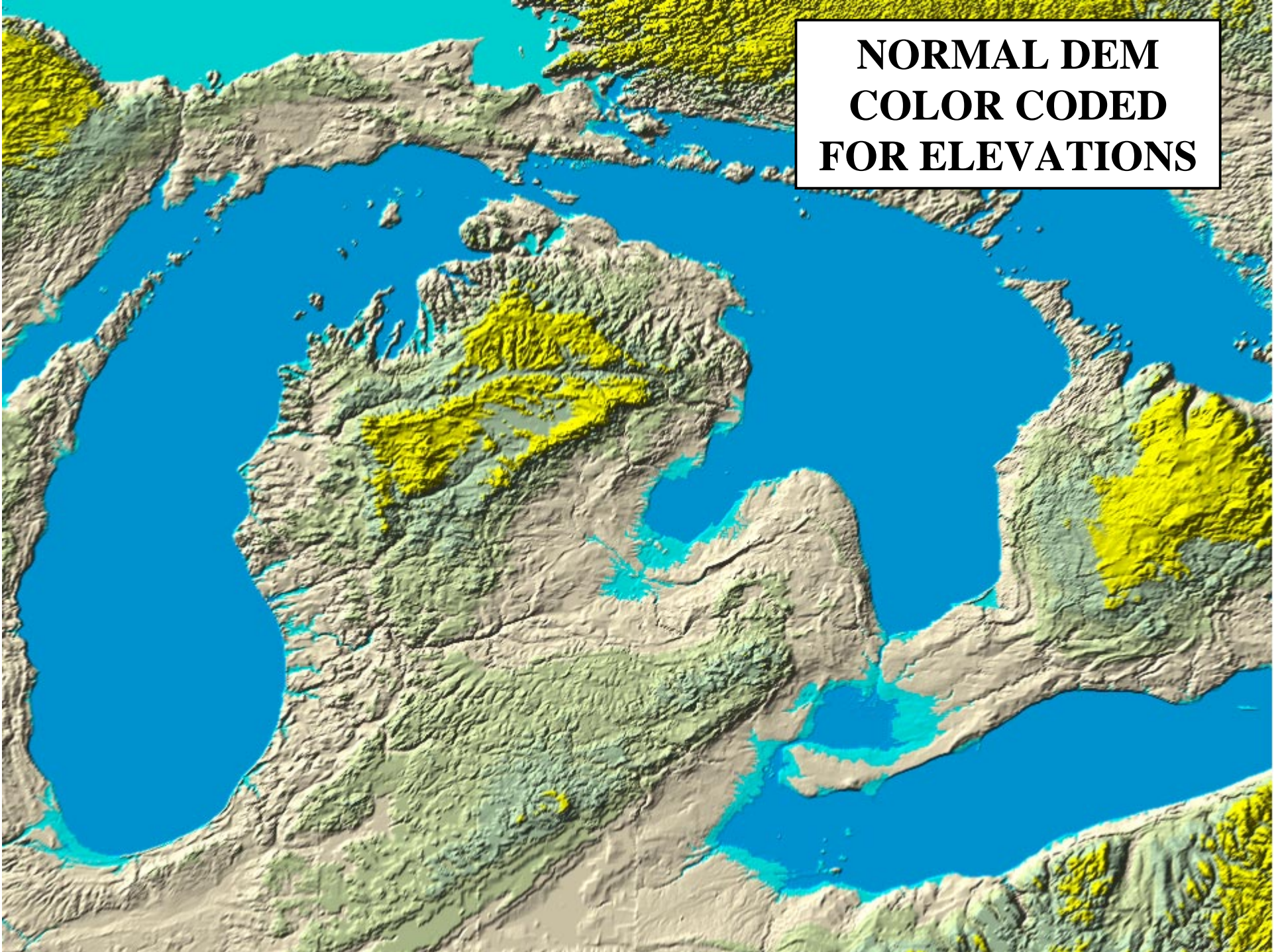
DEM Data & Analysis

**Progress report on use of digital
elevation models (DEMs) in project.**

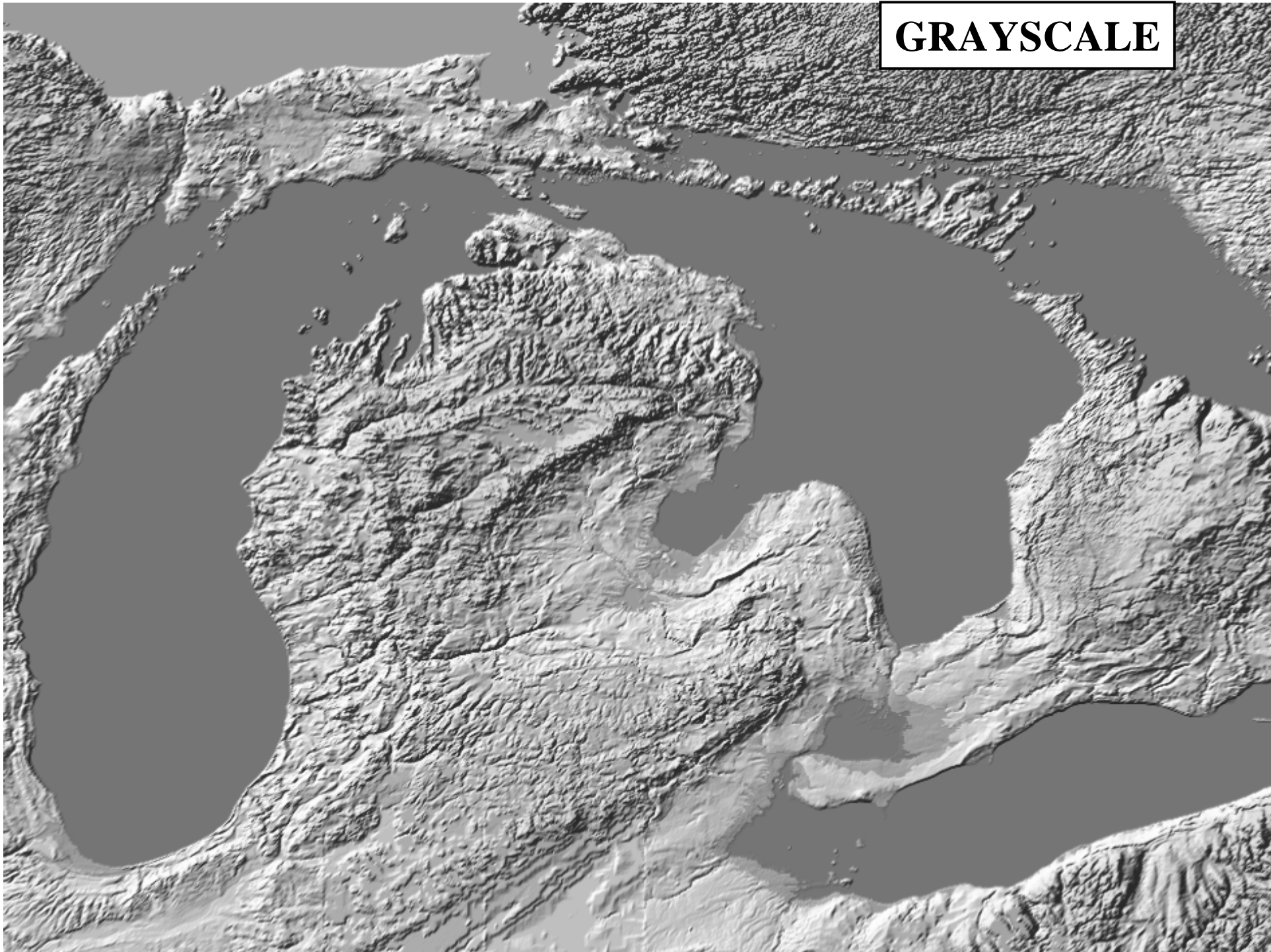
DEMs (digital elevation models) are regularly spaced grids of elevation data. The USGS supplies DEM files for most of the U. S. at scales of 7.5 minutes and 250,000 (~1 degree x 1 degree). 1 km x 1 km data is also available commercially. The advantage of using DEM data in this project is that often elevations reflect underlying geological features, such as faults or lithology.

In this study we are collecting and processing DEM data for the entire Michigan Basin, at 7.5 and 250,000 scales. Typically the data have to be decompressed, checked for elevation units and mosaiced together. Once this is done, the resulting images can be analyzed in various ways. We have applied a number of standard filters to the 1 km x 1 km Michigan data to extract lineations. Typical results are shown in the following slides.

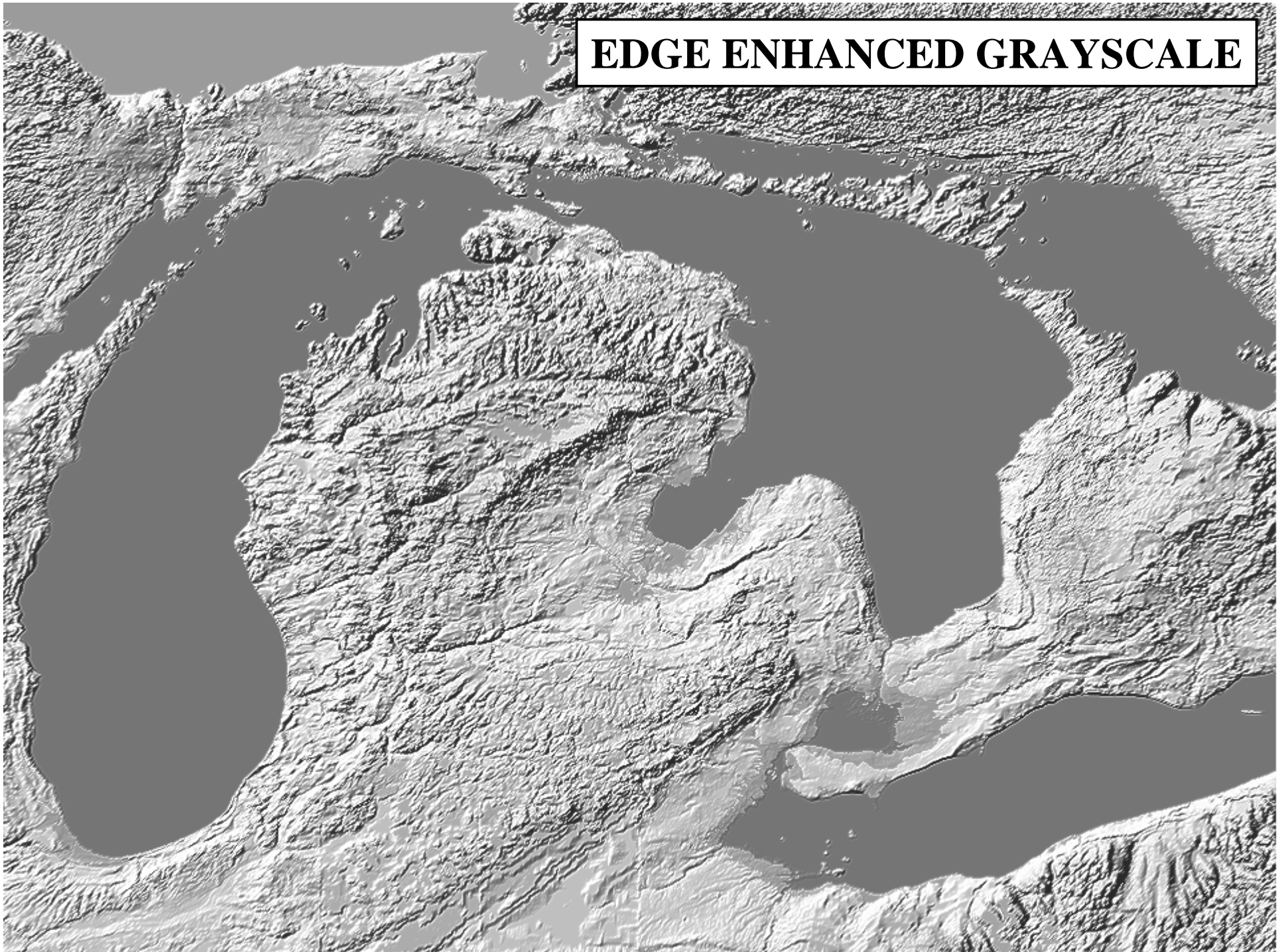
**NORMAL DEM
COLOR CODED
FOR ELEVATIONS**



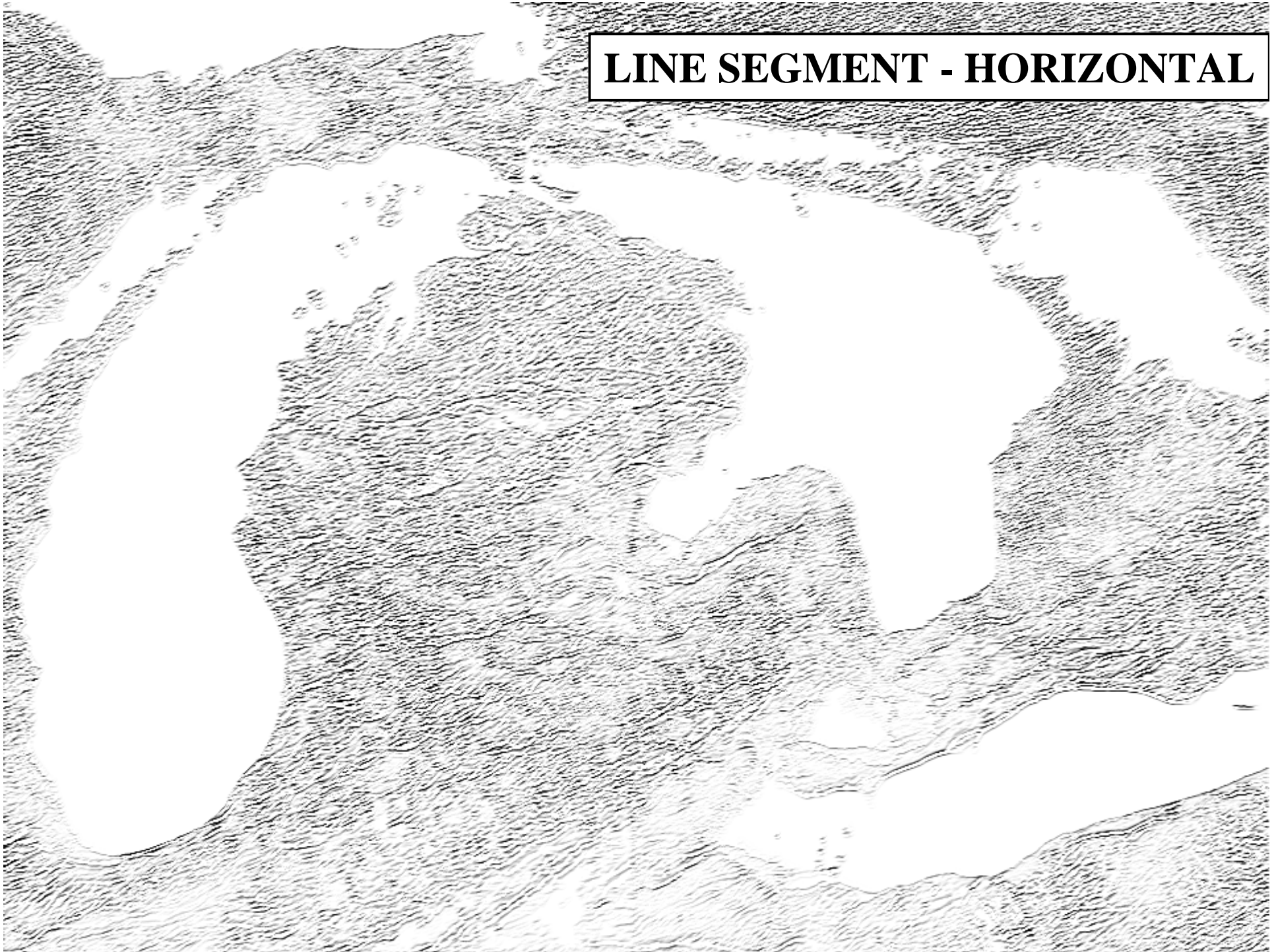
GRAYSCALE

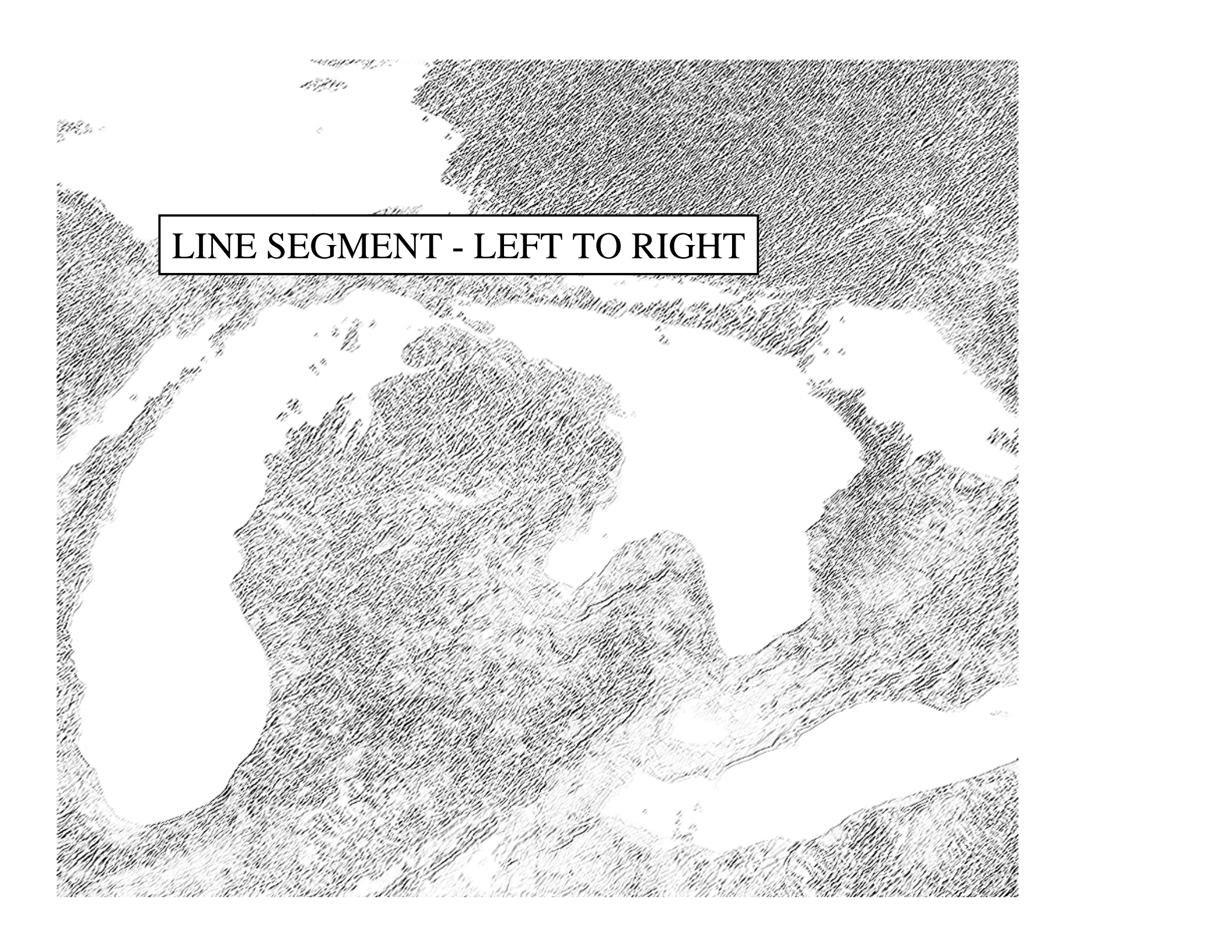


EDGE ENHANCED GRAYSCALE



LINE SEGMENT - HORIZONTAL



The image shows a grayscale, textured surface, possibly a topographical map or a scan of a rough material. The texture is composed of many fine, overlapping lines and curves, creating a complex, organic pattern. A central rectangular box with a black border contains the text "LINE SEGMENT - LEFT TO RIGHT" in a bold, serif font. The text is centered horizontally and vertically within the box. The background is a mix of light and dark gray tones, with the darker areas appearing more densely textured.

LINE SEGMENT - LEFT TO RIGHT

A grayscale topographic map of a mountainous region, likely the Himalayas, showing contour lines and peaks. A central text box contains the text "LINE SEGMENT - RIGHT TO LEFT".

LINE SEGMENT - RIGHT TO LEFT

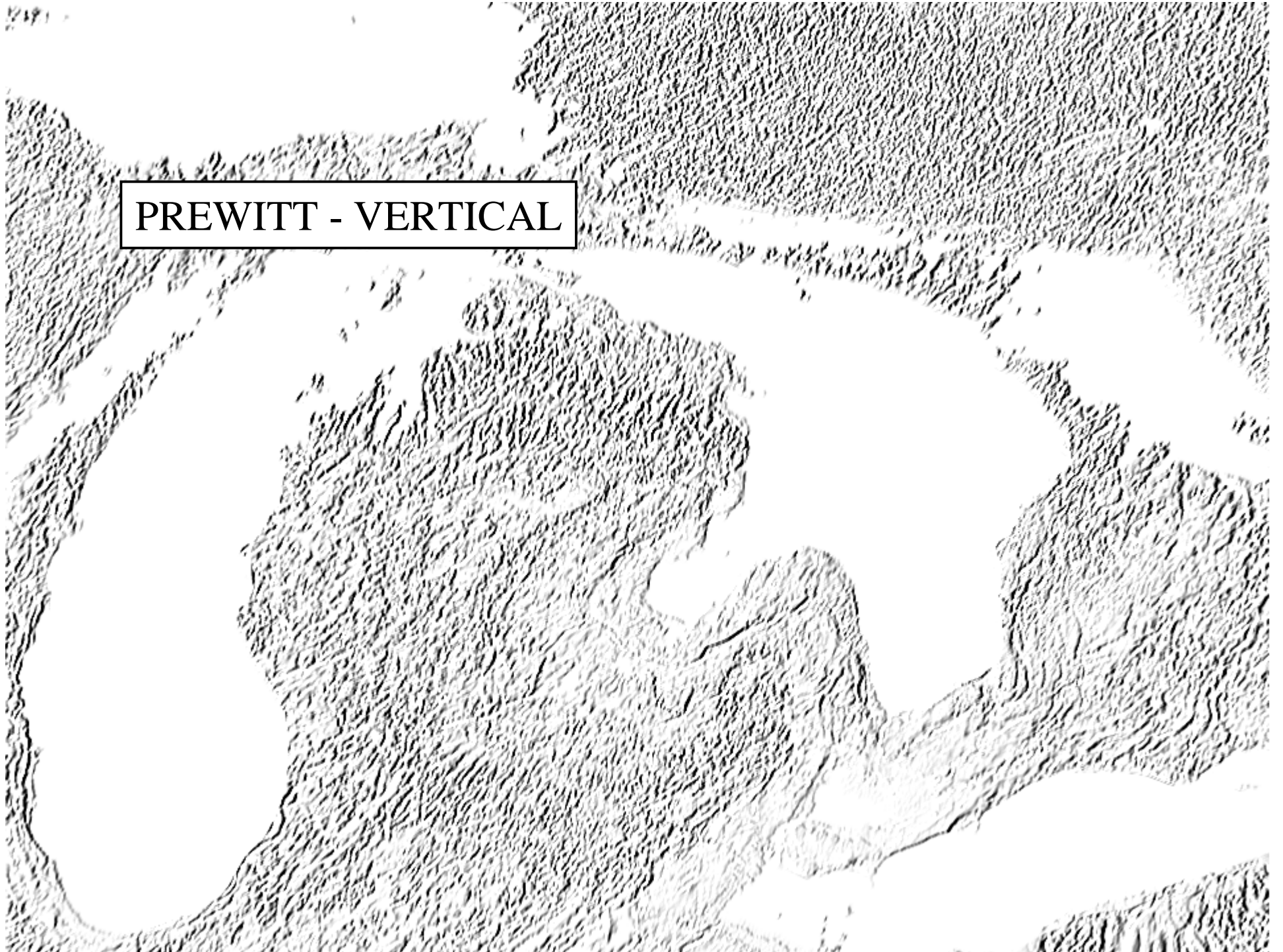
The image shows a grayscale, textured surface, possibly a scan of a physical object. The texture is composed of many small, irregular, light-colored spots and lines against a darker background. A white rectangular box is superimposed on the image, containing the text "LINE SEGMENT - VERTICAL" in a bold, black, serif font. The box is positioned in the upper-left quadrant of the image.

LINE SEGMENT - VERTICAL

PREWITT - HORIZONTAL



PREWITT - VERTICAL



A grayscale topographic map of the world, showing landmasses and ocean basins with shaded relief. A black rectangular box with a white border is centered horizontally across the upper portion of the map, containing the text "SHIFT DIFFERENCE - DIAGONAL".

SHIFT DIFFERENCE - DIAGONAL

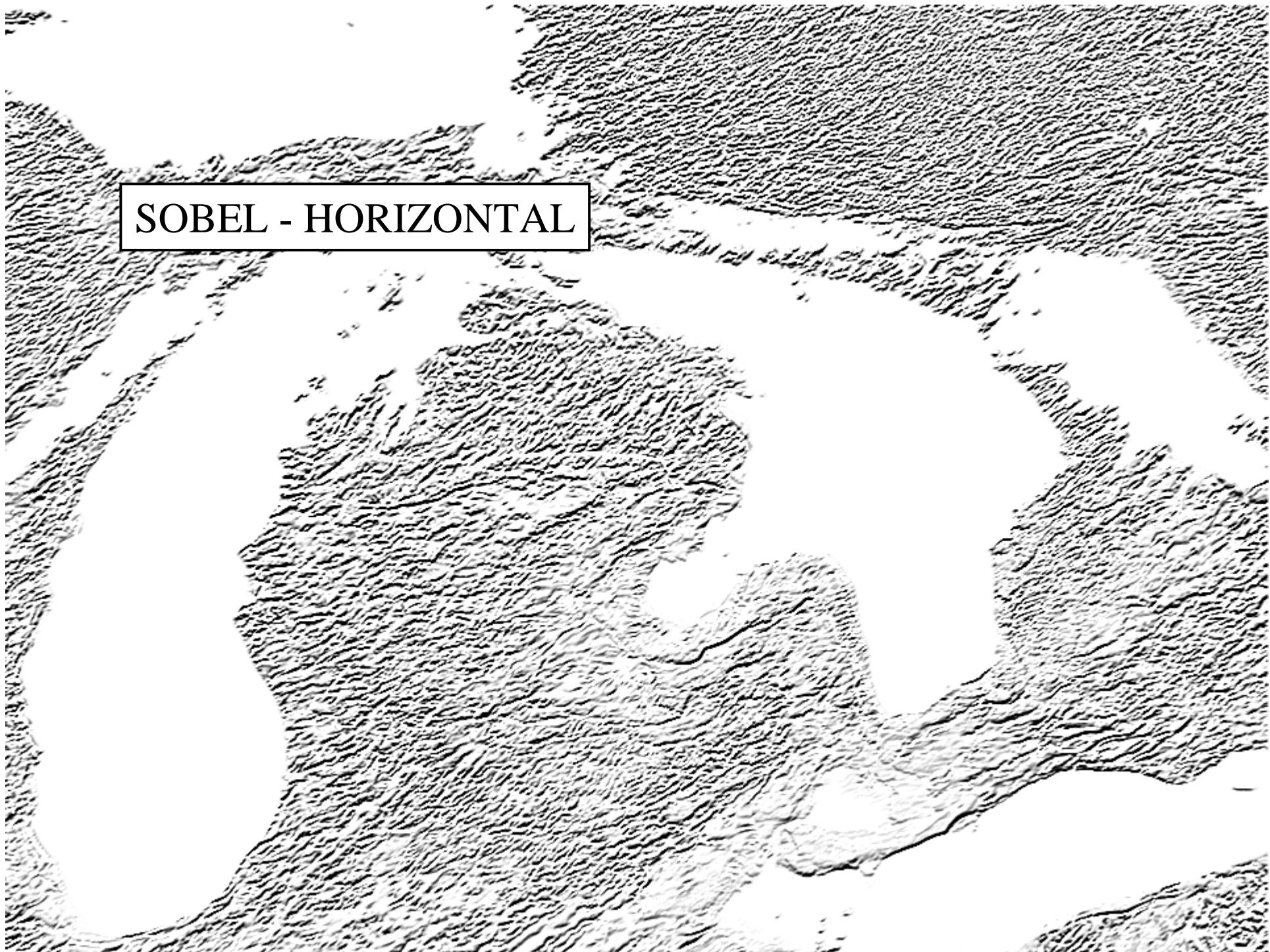
A topographic map of the world, rendered in grayscale, showing the Earth's surface with contour lines representing elevation. The map is centered on the Atlantic Ocean, with North America on the left and South America on the right. A prominent feature is a large, irregularly shaped area in the center of the Atlantic Ocean, which is shaded in a lighter tone than the surrounding landmasses, indicating a significant horizontal shift difference. A black rectangular box is superimposed over the top portion of the map, containing the text "SHIFT DIFFERENCE - HORIZONTAL" in white, bold, uppercase letters.

SHIFT DIFFERENCE - HORIZONTAL

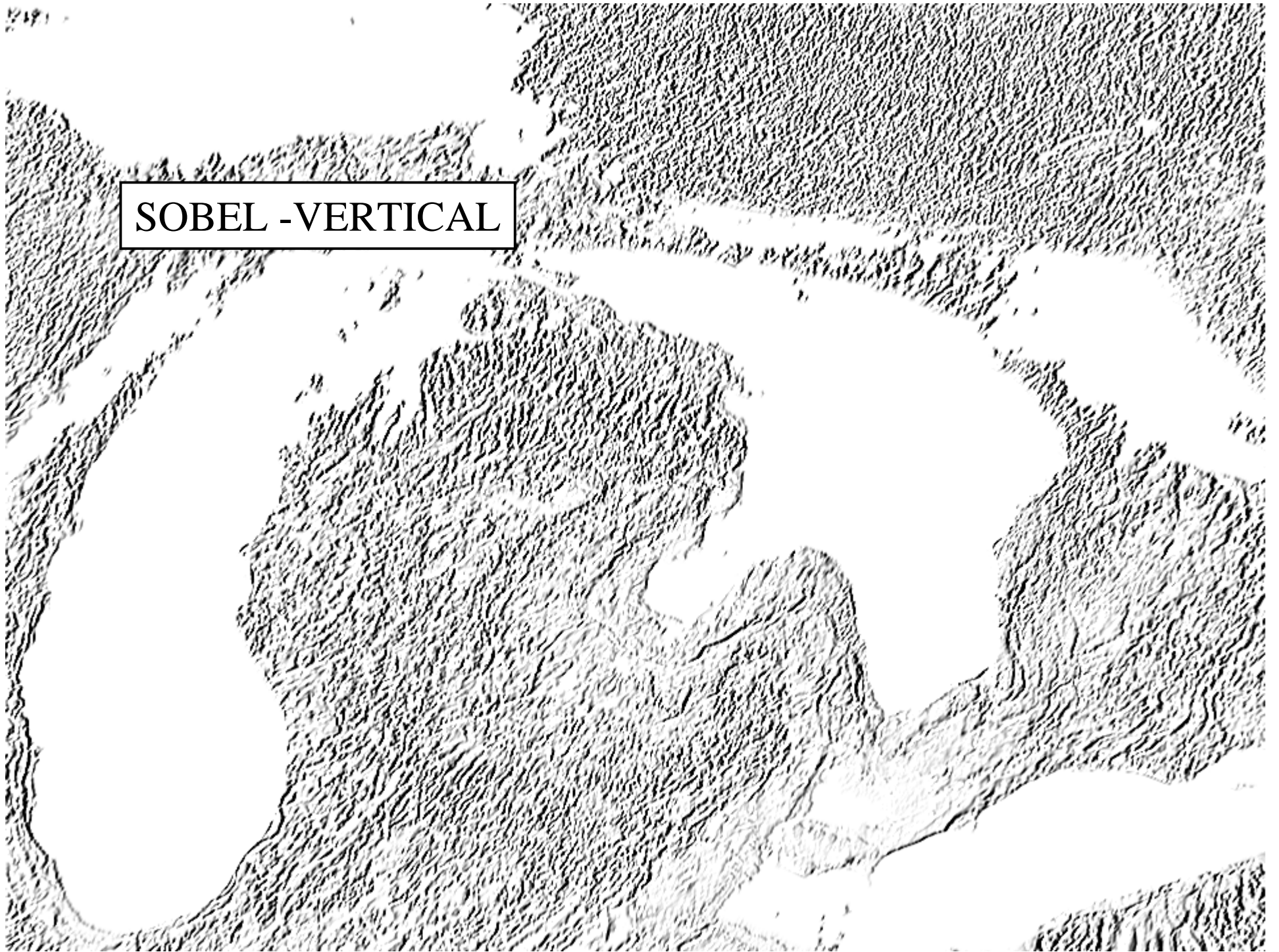
A grayscale topographic map of the Pacific region, showing the Americas, the Pacific Ocean, and the Indian Ocean. A white rectangular box with a black border is centered in the upper left quadrant, containing the text "SHIFT DIFFERENCE - VERTICAL".

SHIFT DIFFERENCE - VERTICAL

SOBEL - HORIZONTAL

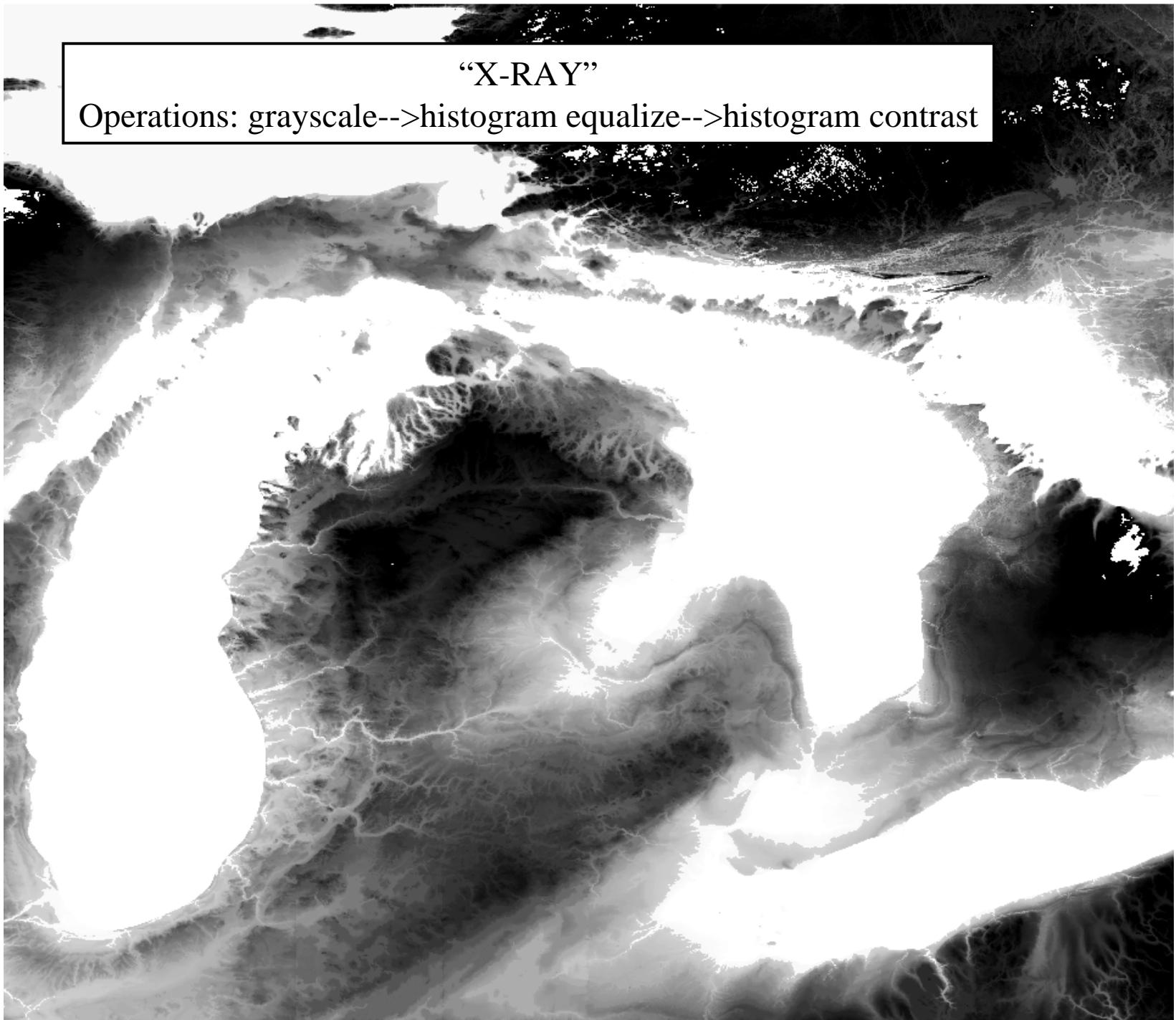


SOBEL - VERTICAL

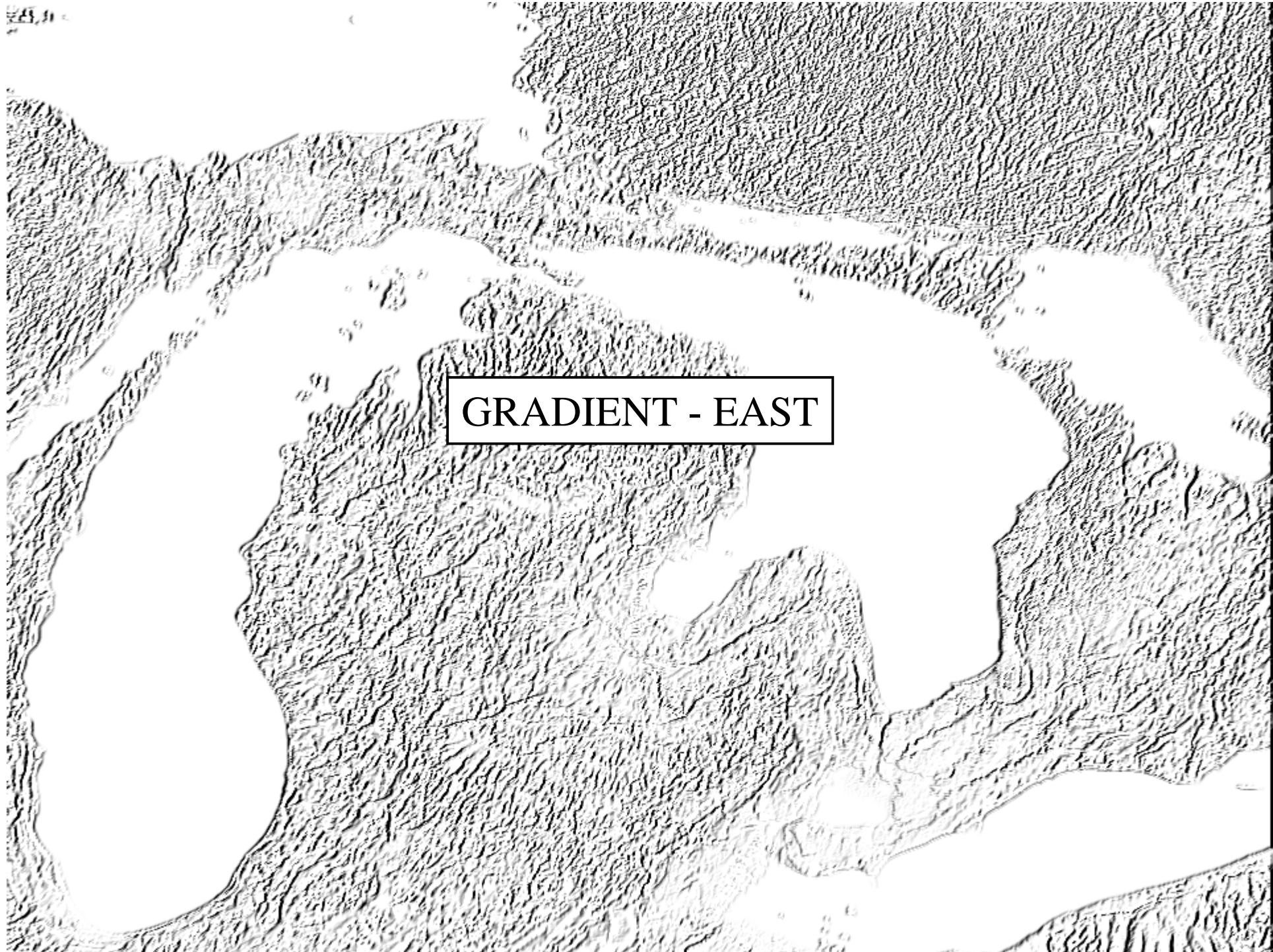


“X-RAY”

Operations: grayscale-->histogram equalize-->histogram contrast



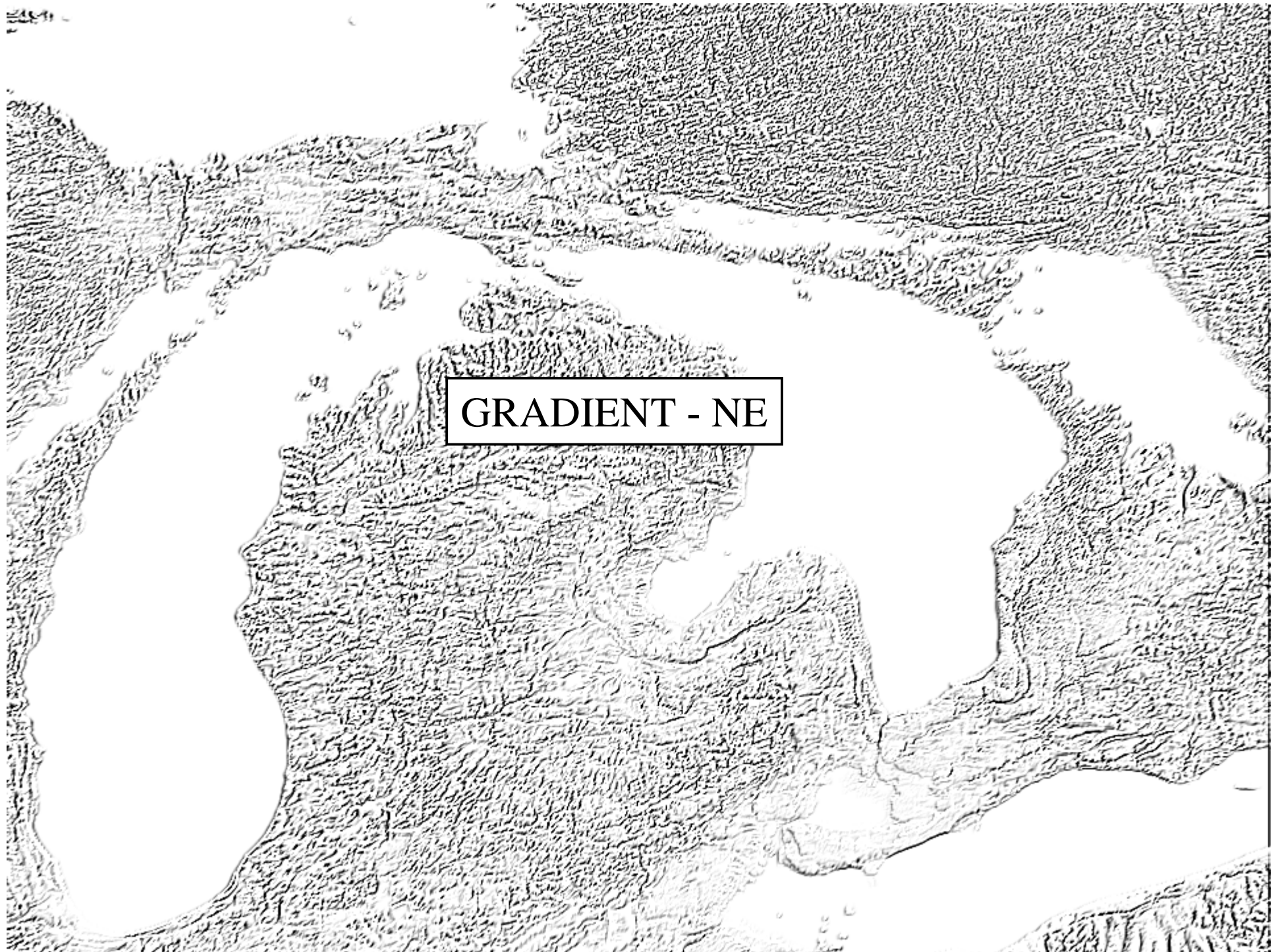
25,0



GRADIENT - EAST

A grayscale topographic map of the United States, oriented with North at the top. The map uses contour lines to represent elevation. A prominent feature is a large, roughly rectangular area in the center of the country that is significantly lower in elevation than the surrounding terrain, representing a major river basin. The text "GRADIENT - NORTH" is centered on the map within a rectangular box.

GRADIENT - NORTH



GRADIENT - NE

A topographic map showing a gradient profile from Northwest to Southeast. The map features a central mountain range with a prominent peak. The terrain is shaded to indicate elevation, with darker areas representing higher elevations and lighter areas representing lower elevations. A rectangular box is drawn across the map, containing the text "GRADIENT - NW".

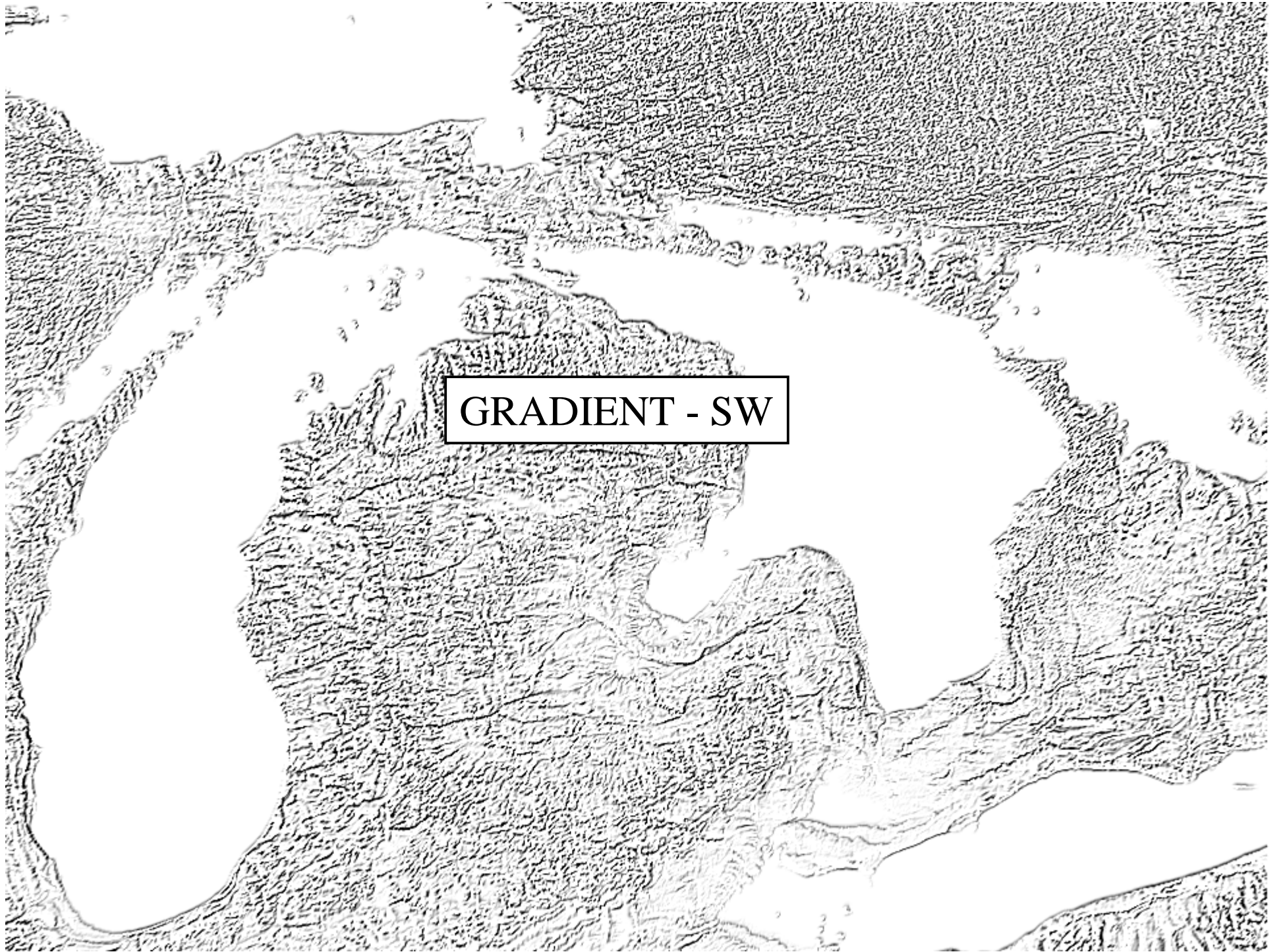
GRADIENT - NW

A grayscale topographic map of the African continent, showing elevation contours and major geographical features like the Nile river basin and the Great Rift Valley. A central text box is overlaid on the map.

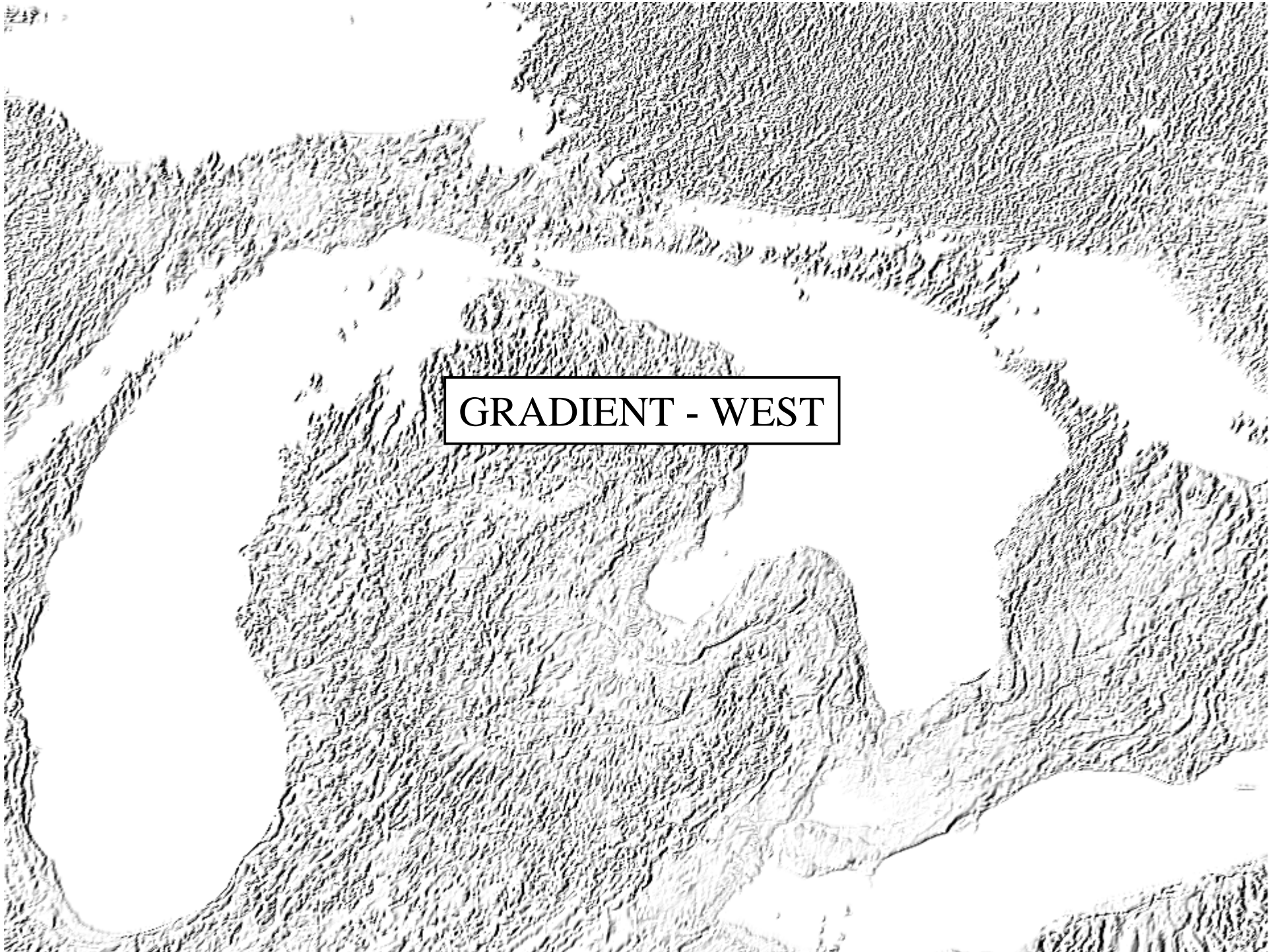
GRADIENT - SOUTH

A topographic map of the Iberian Peninsula, showing the mountainous terrain of Spain and Portugal. The map uses contour lines to represent elevation. A rectangular box is superimposed on the map, containing the text "GRADIENT - SE".

GRADIENT - SE



GRADIENT - SW



GRADIENT - WEST

A grayscale topographic map of the Pacific Ocean region, showing the western coast of North America, the Hawaiian Islands, the Philippines, and the Indonesian archipelago. The map uses contour lines to represent elevation and bathymetry. A central text box is overlaid on the map.

LAPLACIAN - 1

A grayscale topographic map of the Pacific Ocean region, showing the western coast of North America, the Hawaiian Islands, and the western coast of South America. The map uses contour lines to represent elevation and bathymetry. A central text box is overlaid on the map.

LAPLACIAN - 2

The image shows a grayscale, textured surface, likely a rock or mineral specimen, with a complex, irregular shape. The texture is composed of fine, dark, fibrous or crystalline structures. A central text box with a black border contains the text "LAPLACIAN - 3".

LAPLACIAN - 3

A grayscale topographic map of the Mediterranean region, showing the Iberian Peninsula, the Balkans, and the surrounding seas. The terrain is rendered with fine contour lines, indicating elevation changes. A white rectangular box with a black border is centered over the Balkan Peninsula, containing the text "LAPLACIAN - DIAGONAL".

LAPLACIAN - DIAGONAL



LAPLACIAN - HORIZONTAL

A grayscale topographic map of the Pacific region, showing the outlines of North America, South America, and the Pacific Ocean. The map uses shading to represent elevation, with darker areas indicating higher terrain. A central text box with a black border contains the text "LAPLACIAN - VERTICAL".

LAPLACIAN - VERTICAL

BENEFITS & VALUE

- **ATLAS GIS program and associated database offer convenient, rapid access to 100 years of historical data in Michigan Basin in raster format integrated with transfer of that data to a digital format.**
- **Benefits to both industry and researchers**

PROBLEMS

- **Large amount of paper copy (driller's reports) remains to be scanned and integrated into ATLAS.**
- **Quality of DEM files varies from excellent to poor. Poor images (~20% in Michigan) will have to be redone (by USGS or their contractors).**

Summary and Conclusions. I

- DEM data shows that numerous lineations exist at the surface of the Michigan Basin
- Lineations have different origins and must be classified.
- Correlation between surface and subsurface lineations is uncertain, but promising

Summary and Conclusions. II

- **ATLAS GIS program & associated Michigan Basin database ready for distribution.**
- **Program can be linked to other databases for other basins.**
- **Current project will be extended to include portions of Michigan Basin outside Michigan.**
- **Work will continue on developing DEM files for subsurface based on well data.**