QUANTITATIVE CHARACTERIZATION OF MOLDIC AND VUGGY PORE SPACE IN KARST AQUIFERS USING IMAGE AND GEOSPATIAL ANALYSIS

Geo^{3}T^2 Technical Conference

Cary, NC

BACKGROUND

Alexander Culpepper (GIT)

Raleigh, NC Environmental

B.S. Geology

UNC-Charlotte 2009

M.S. Geology

East Carolina University 2012

Dr. Alex K. Manda

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- **Introduction**
- **Methods of analysis**
  - Study Sites
  - Downhole tools
  - Data Acquisition
  - Image Processing and spatial analysis
- **Results and Discussion**
  - Distributions of pore area, perimeter, and shape index
  - Influence of scale of observation
  - 2D porosity analyses
- **Summary and Conclusions**

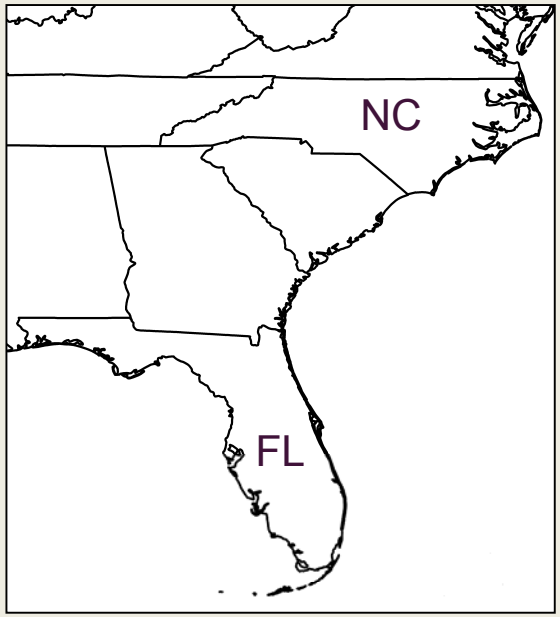
OVERVIEW

THESIS TITLE

- **Quantitative Comparison of 2D Porosity and Pore Geometry**
- **Between the Upper Castle Hayne, Aquifer, North Carolina, and the Biscayne Aquifer, Florida**
- **Using Image and Geospatial Analysis**

INTRODUCTION

- **Castle Hayne aquifer;**
  - Eastern, NC
- **Biscayne aquifer;**
  - Southeastern, FL

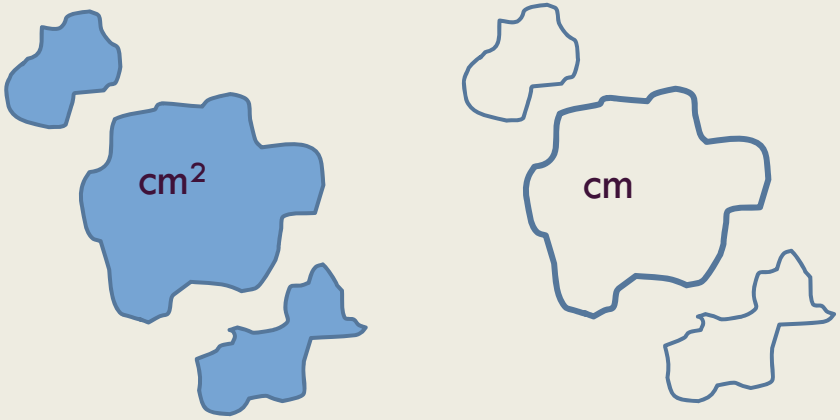


- **Complex internal structure**
- **Development of dissolution features**
- **Significantly influences the hydraulic properties**

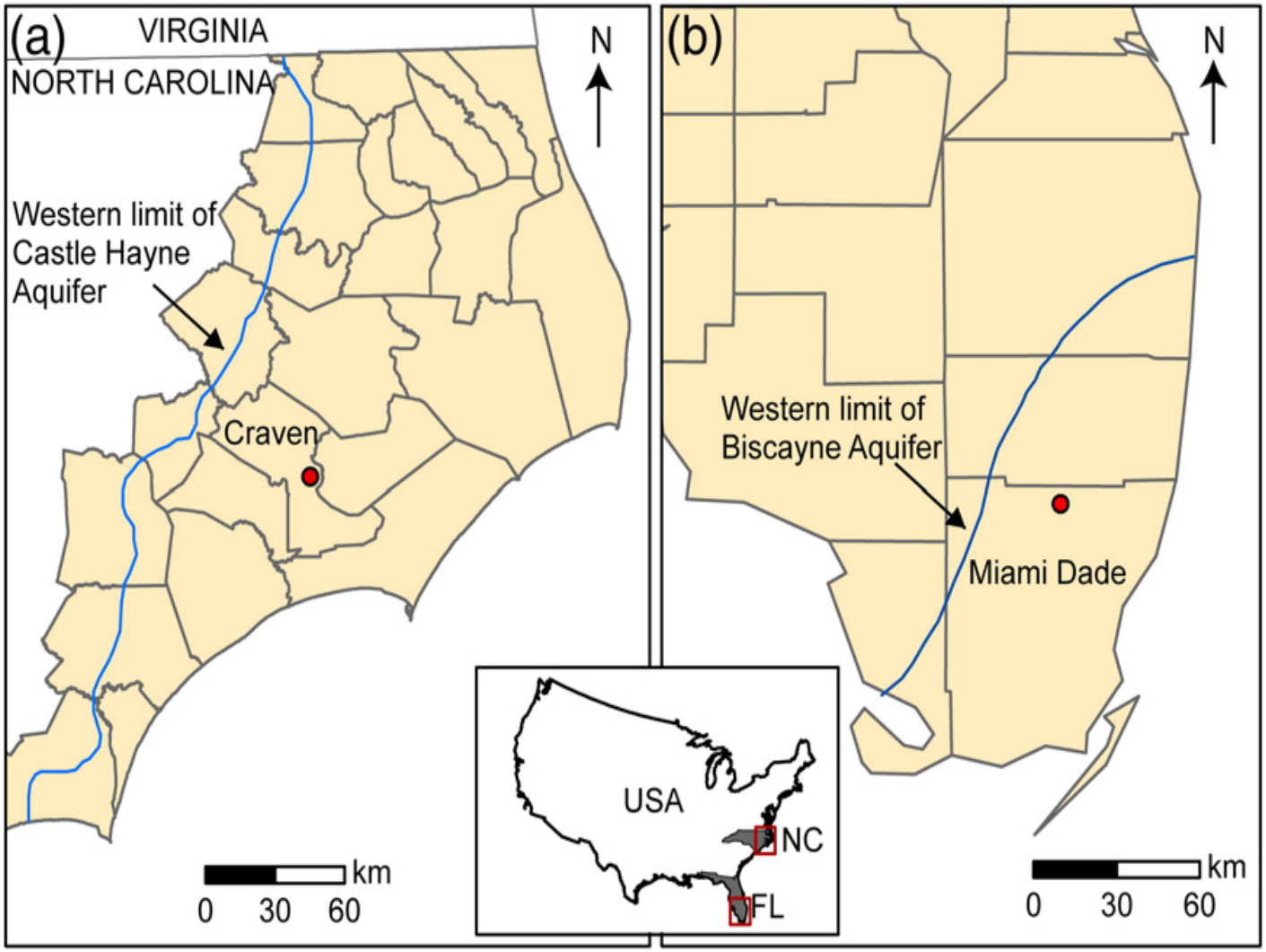
INTRODUCTION CONT.

- **Evaluating and comparing these aquifer systems using the often more difficult to obtain data**

- **Pore Attributes:**
  - Pore area
  - Pore perimeter
  - Pore complexity
  - Spatial distribution of porosity



- **Critical in advancing the quantitative understanding of these highly productive systems**



STUDY SITES

Castle Hayne

Biscayne

- **Spring Garden Member of the Castle Hayne Limestone formation**
- **Lower part of the Miami Limestone and the upper part of the Fort Thompson Formations**

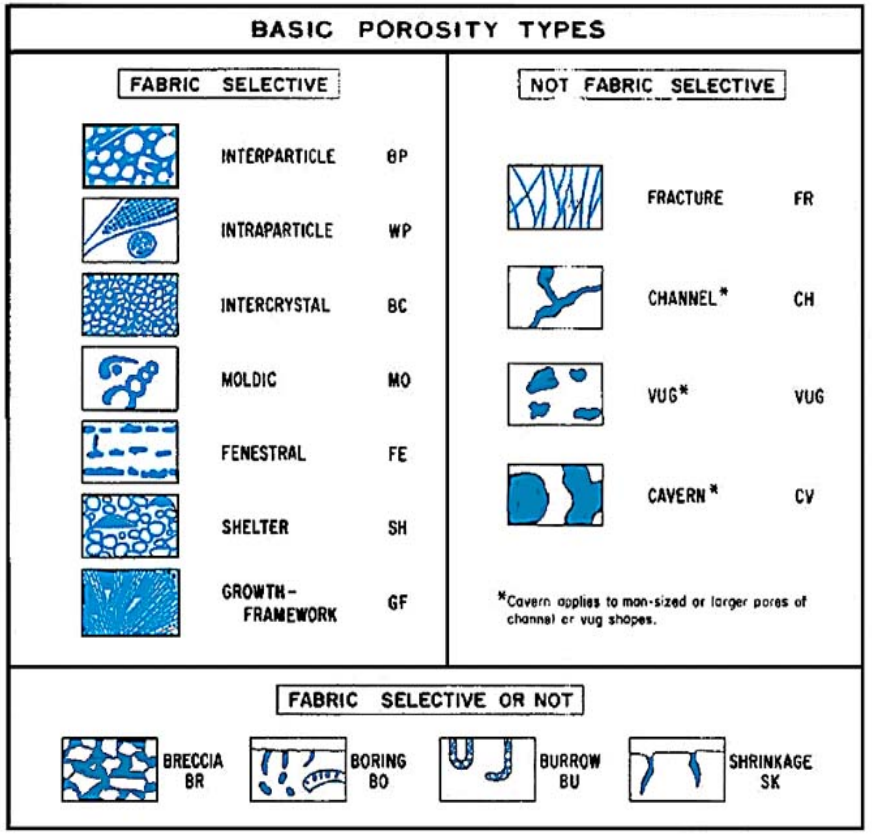
STUDY SITES PORE TYPES

Castle Hayne

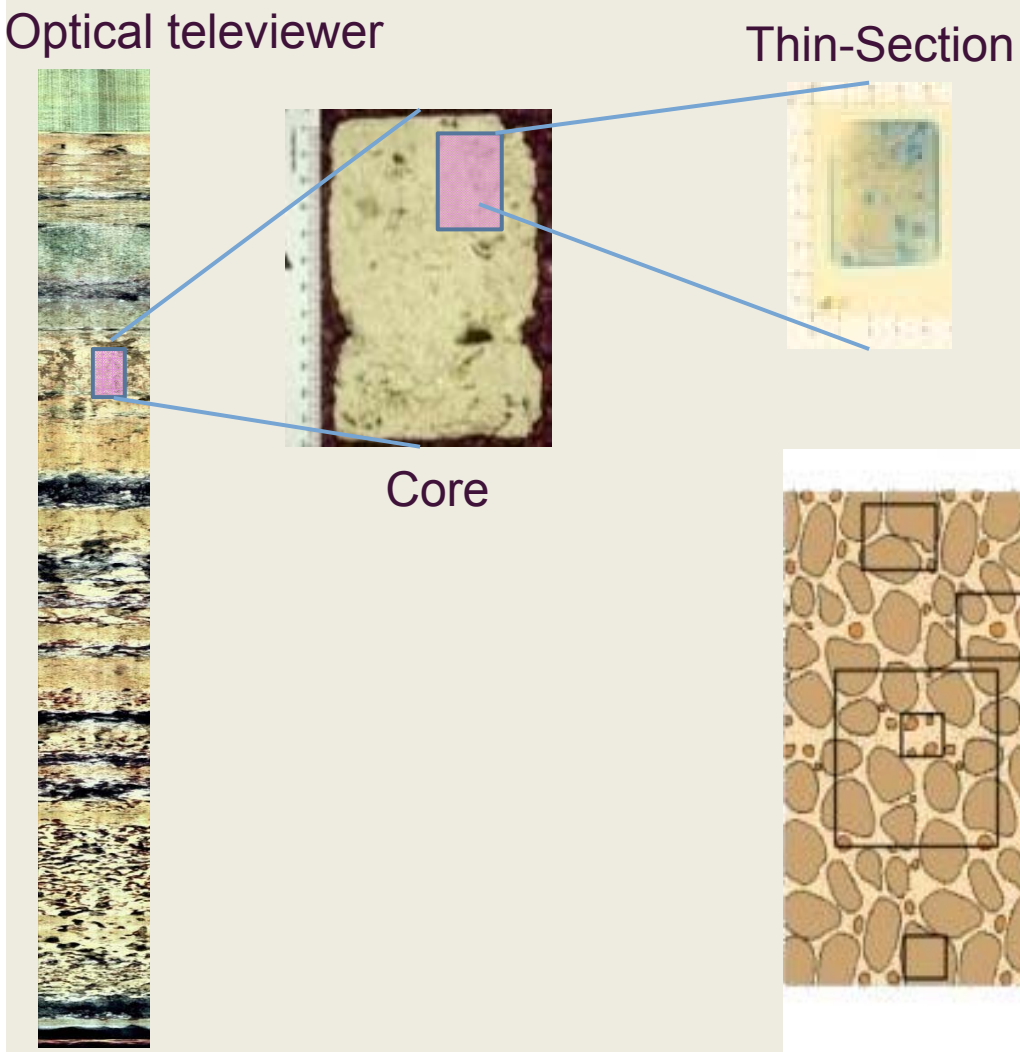
- **Primarily controlled by selective leaching of aragonite shells**

Biscayne

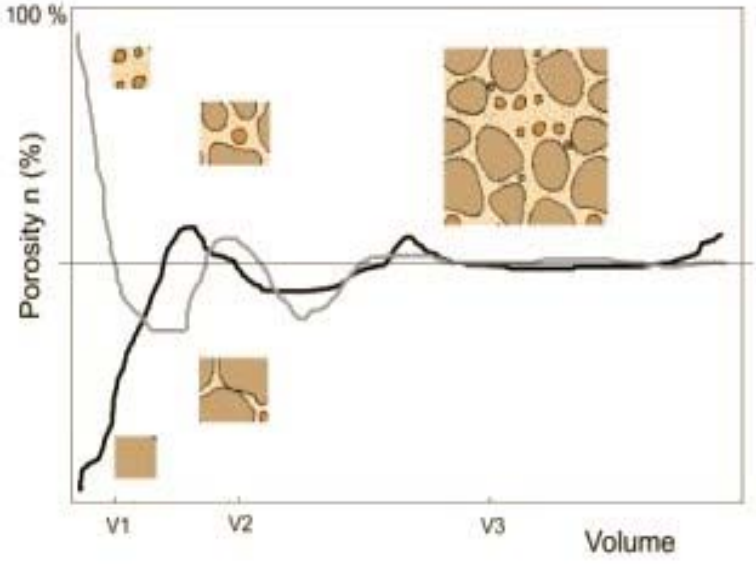
- **Highly permeable rock mass is riddled with secondary solution cavities**



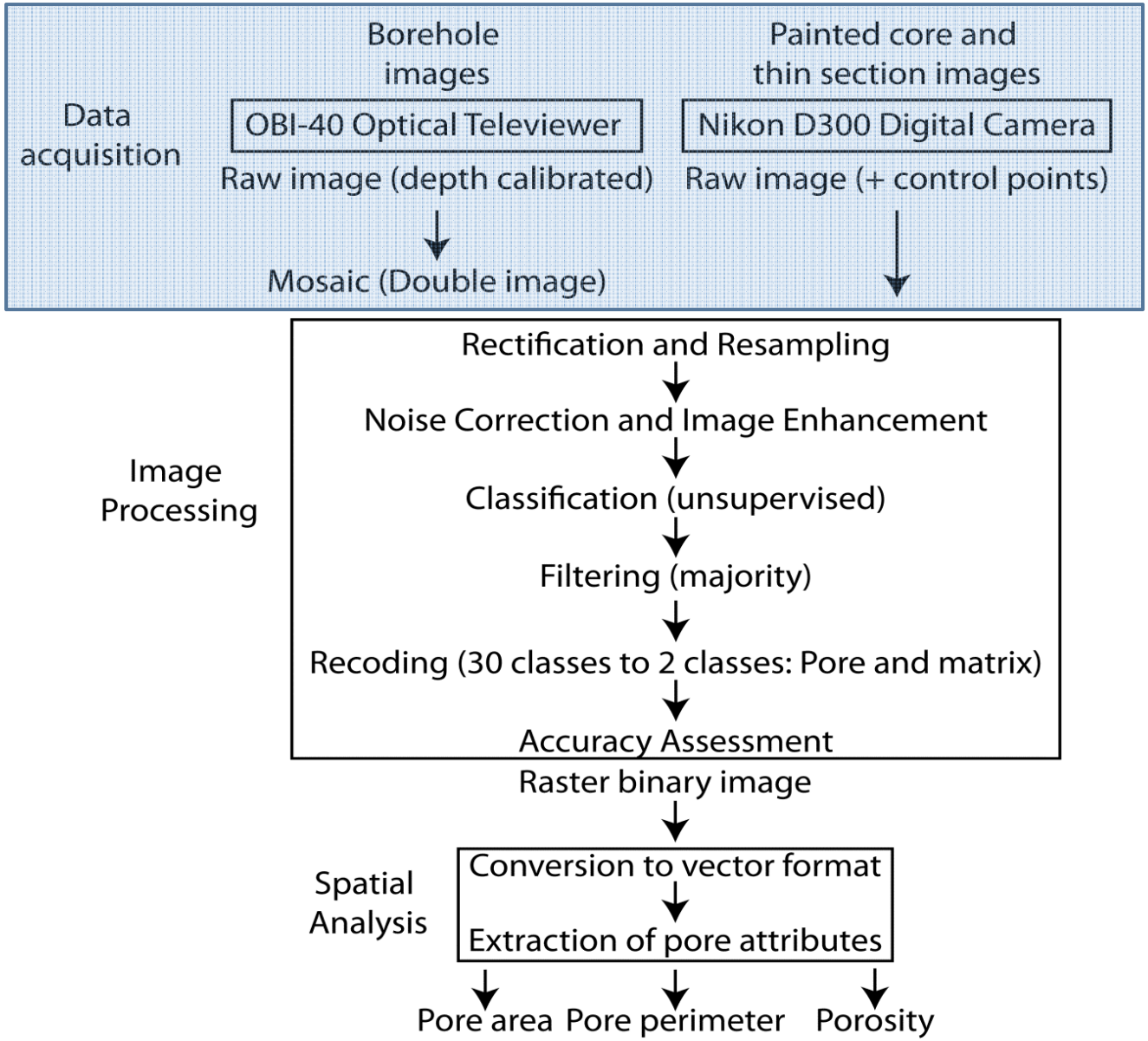
SCALE OF OBSERVATION



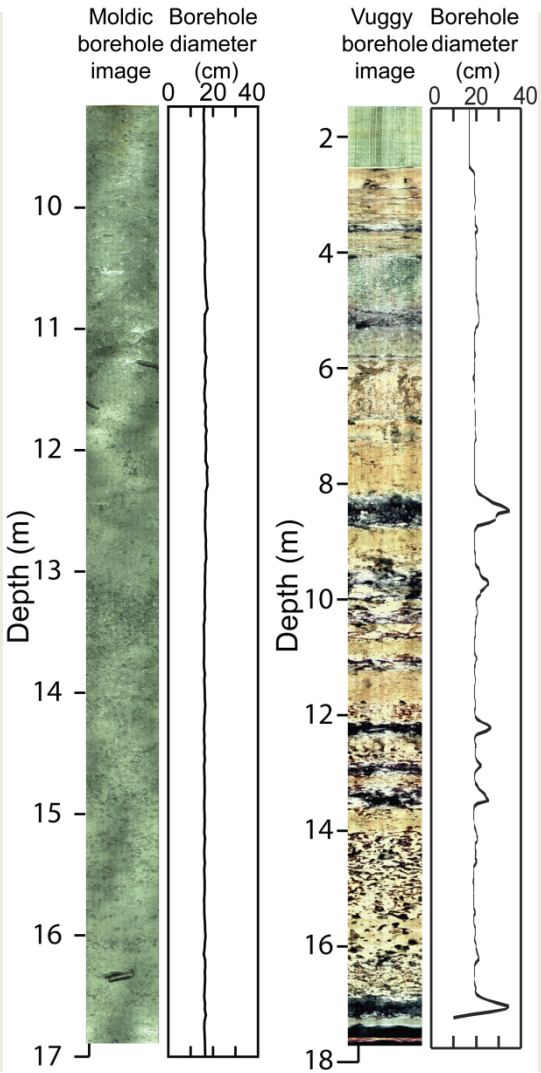
Scale of observation is critical in the study of karst formations

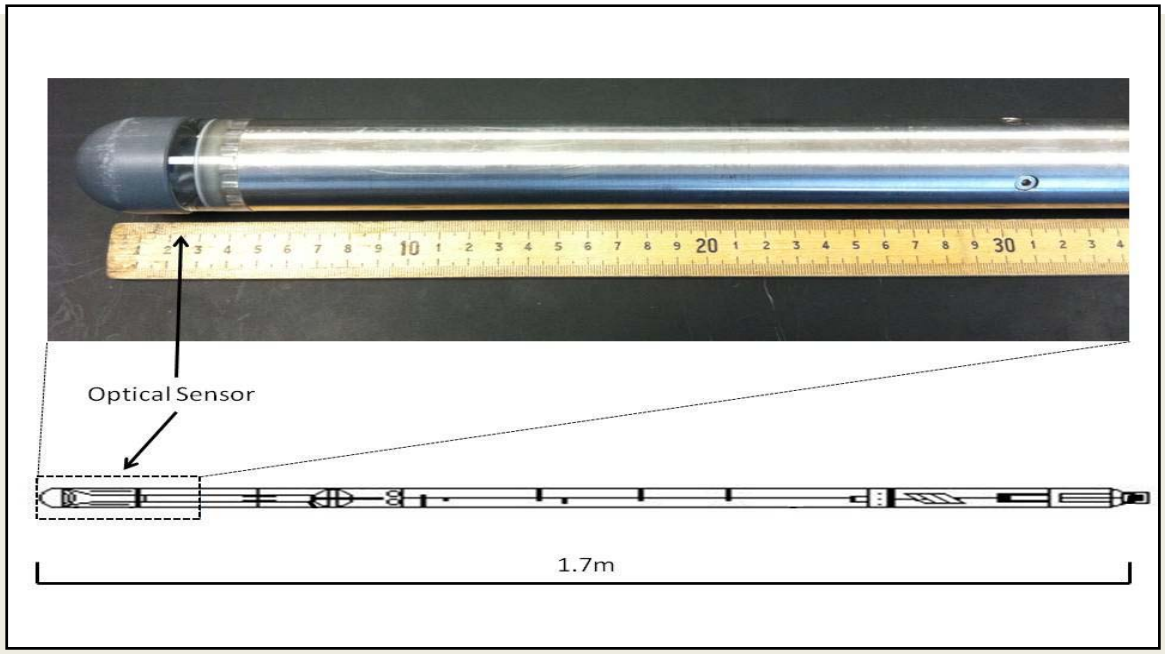


OVERVIEW OF PROCEDURES



DOWNHOLE TOOLS





- **OBI-40 slimhole optical televiewer manufactured by Advanced Logic Technology (ALT)**
- **Continuous and orientated 360° images**

DATA ACQUISITION

ECU Logging Trailer

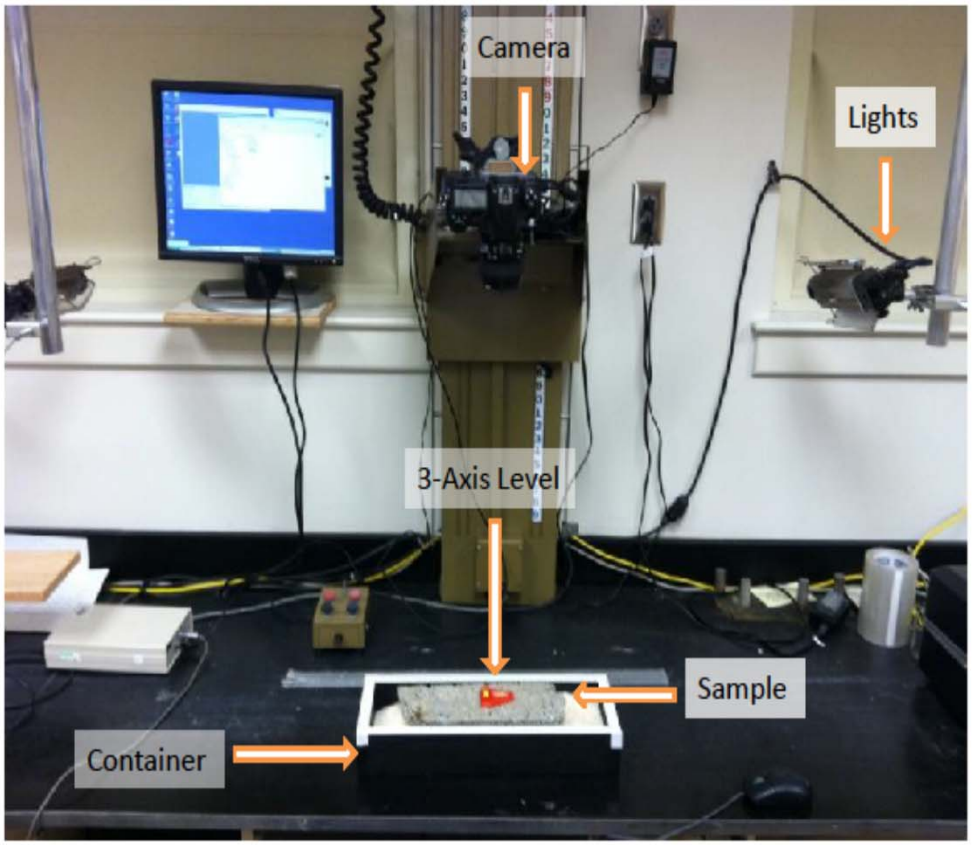
Portable PC
-MS Log windows interface program

Mount Sopris Instruments

MSI/ ALT MATRIX
Acquisition Console

4MX A-100Winch
500m single-conductor Wireline (0.125')

DATA ACQUISITION CONT.



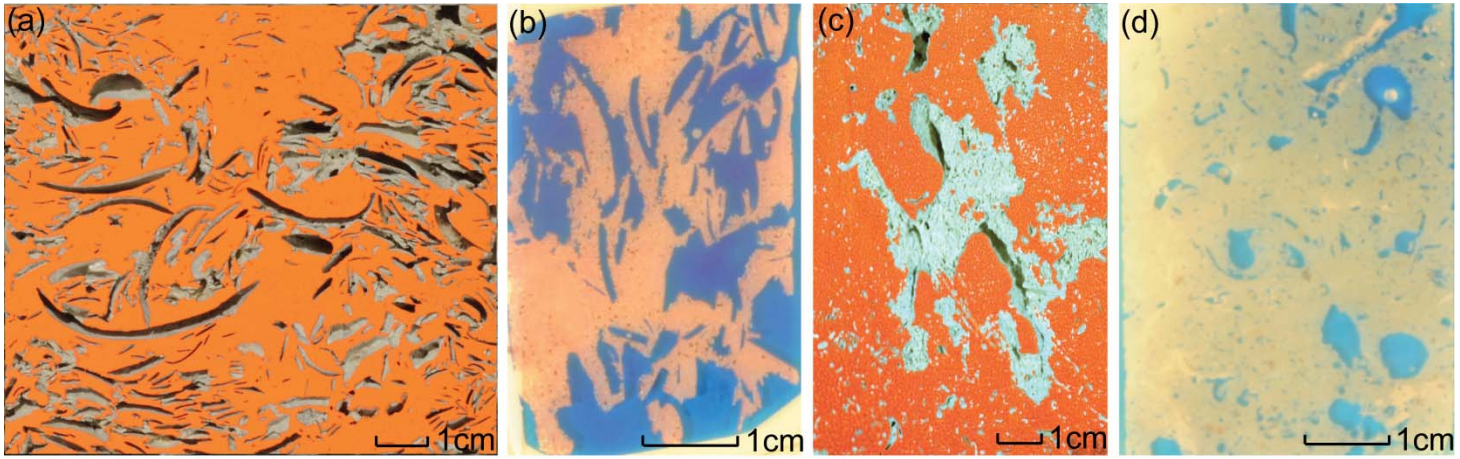
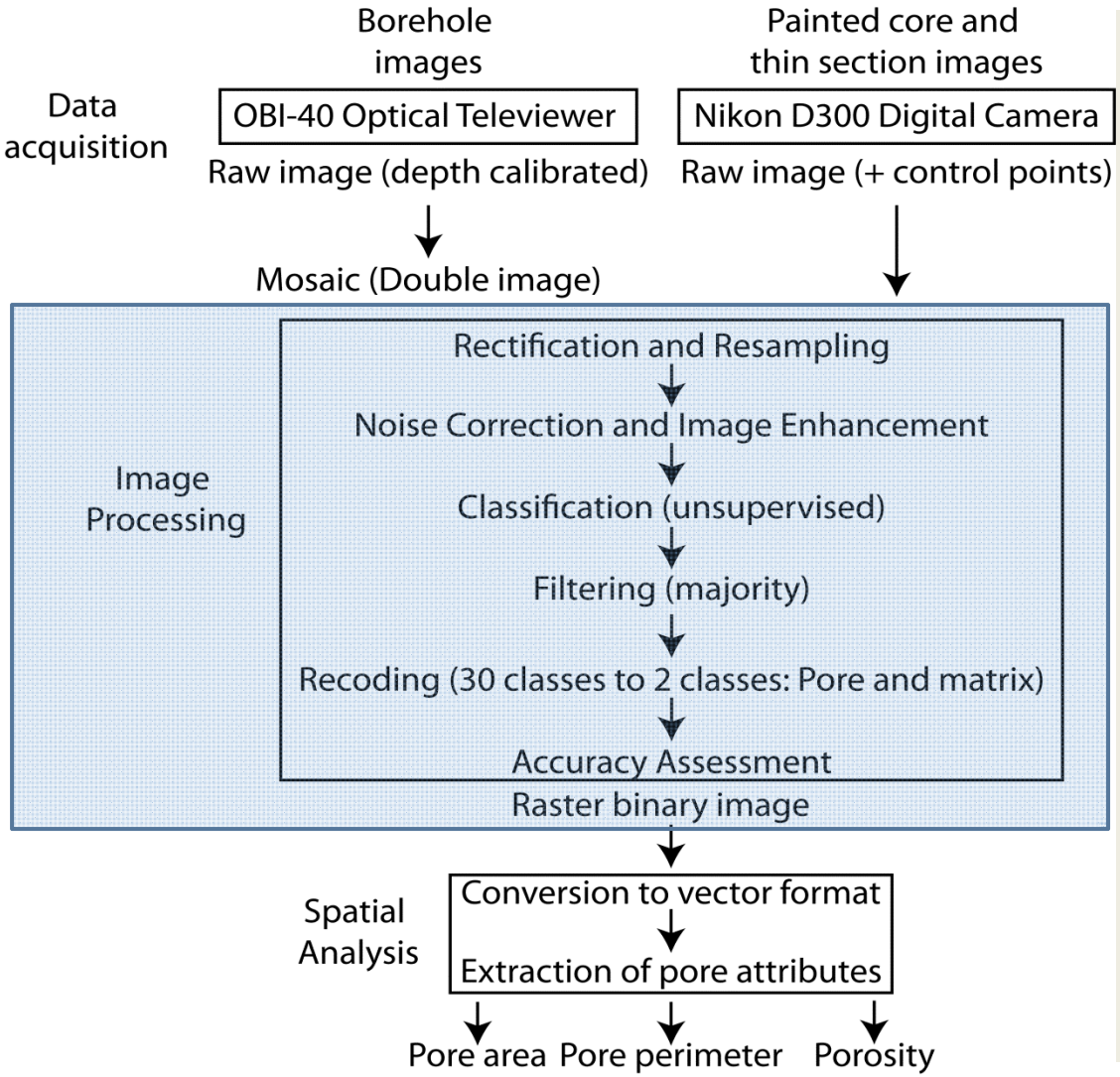
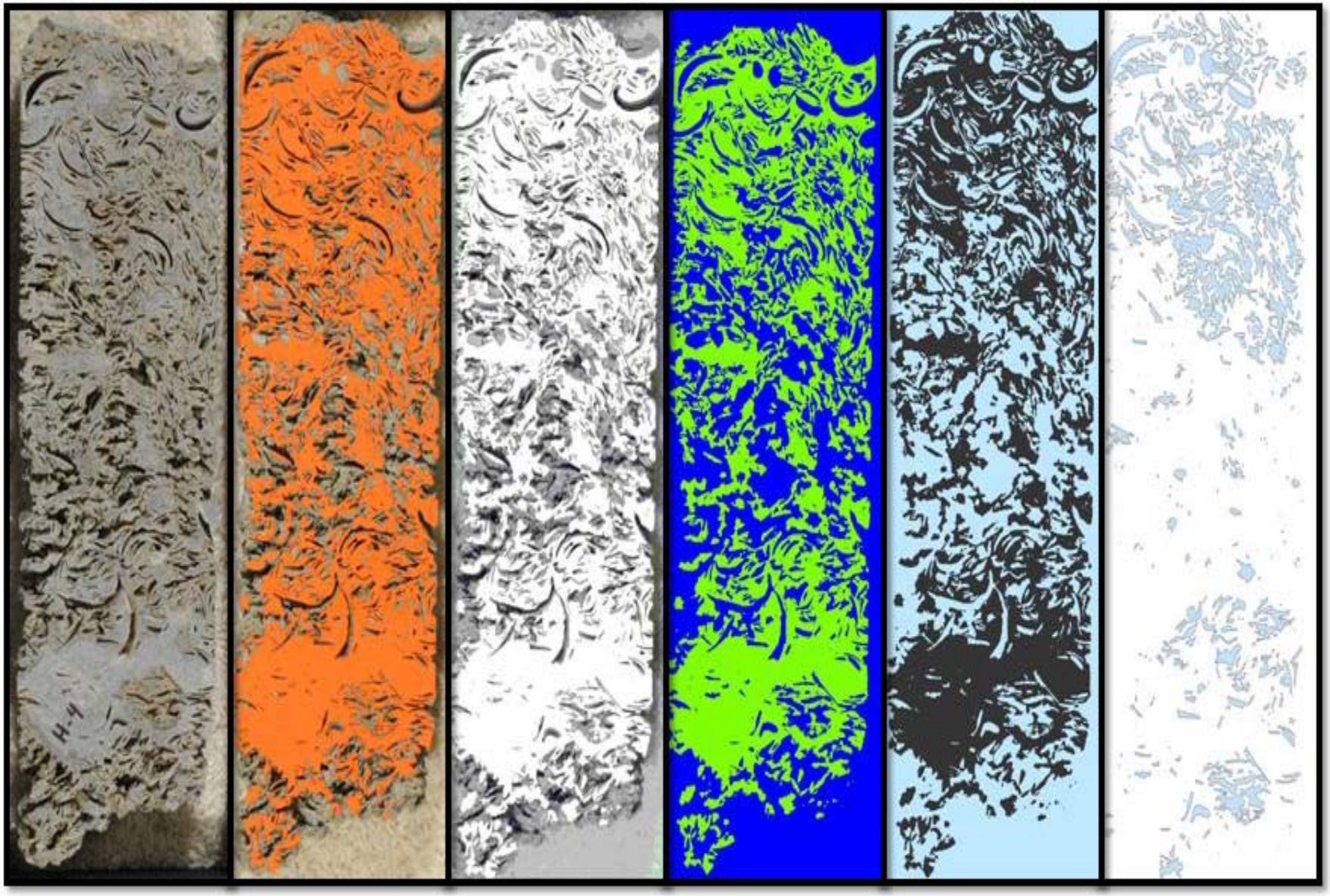


IMAGE PROCESSING AND SPATIAL ANALYSIS

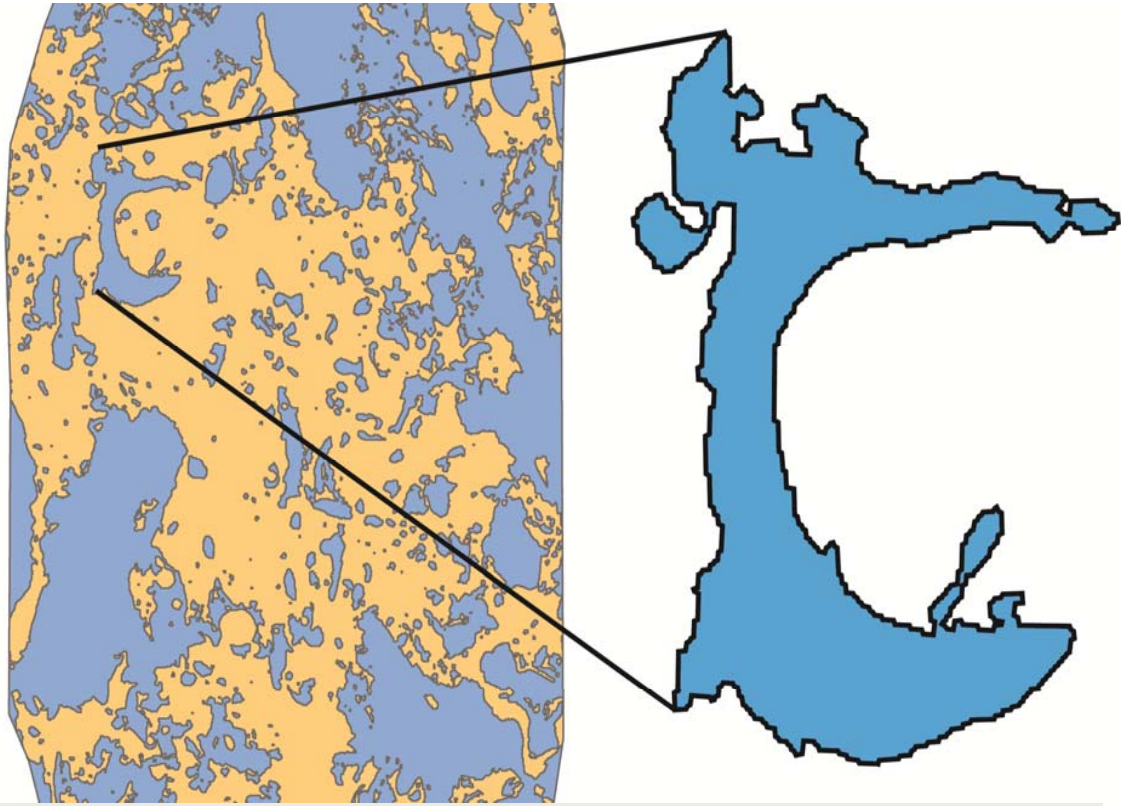


- **Converting images to a GIS ready format**
- **Essential to obtain accurate information for image analysis**

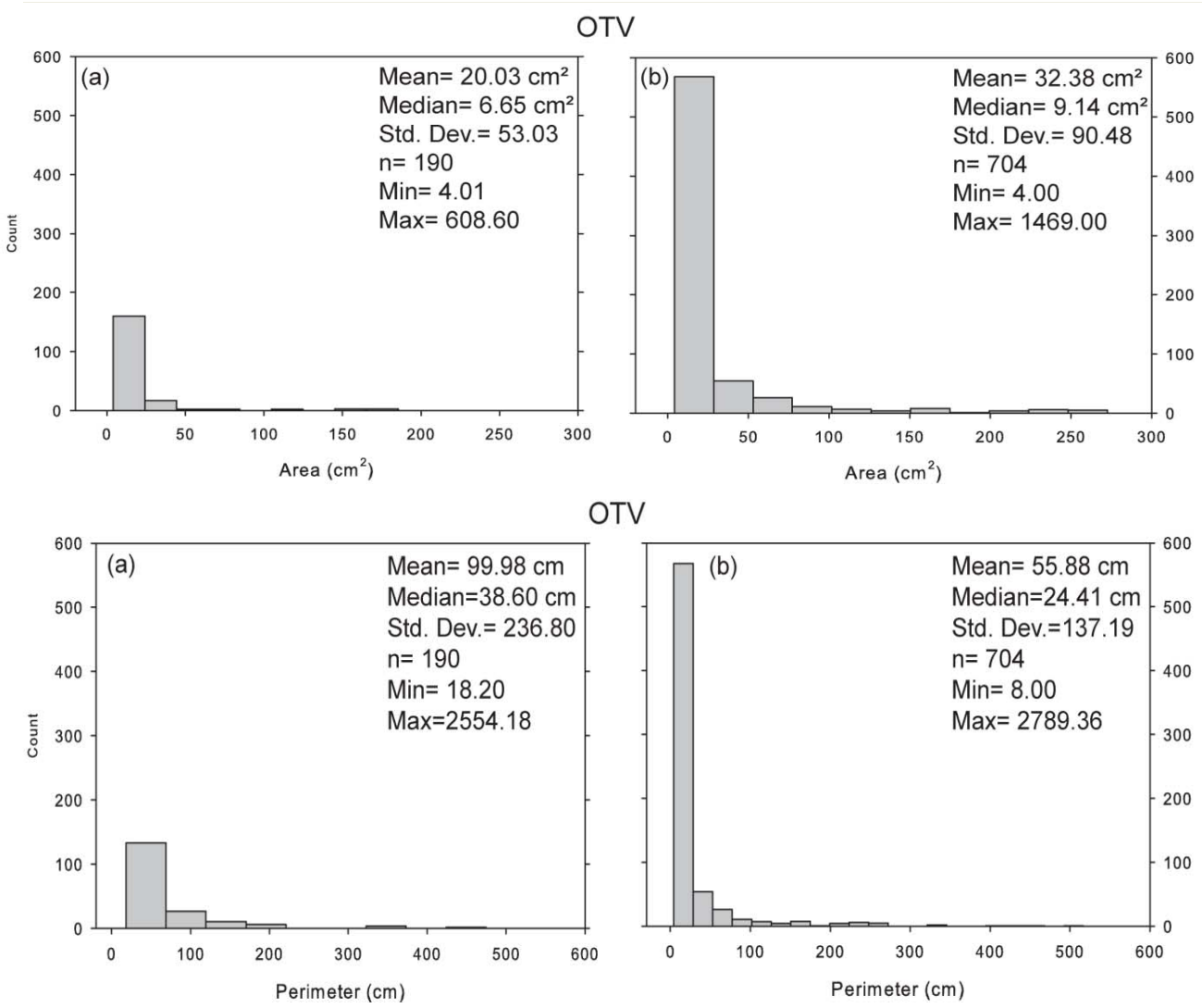


VECTOR ANALYSIS

- In the GIS the binary raster image was converted to vector format.
- Individual features represented as polygons with unique attributes
- The ability to integrate GIS for data extraction



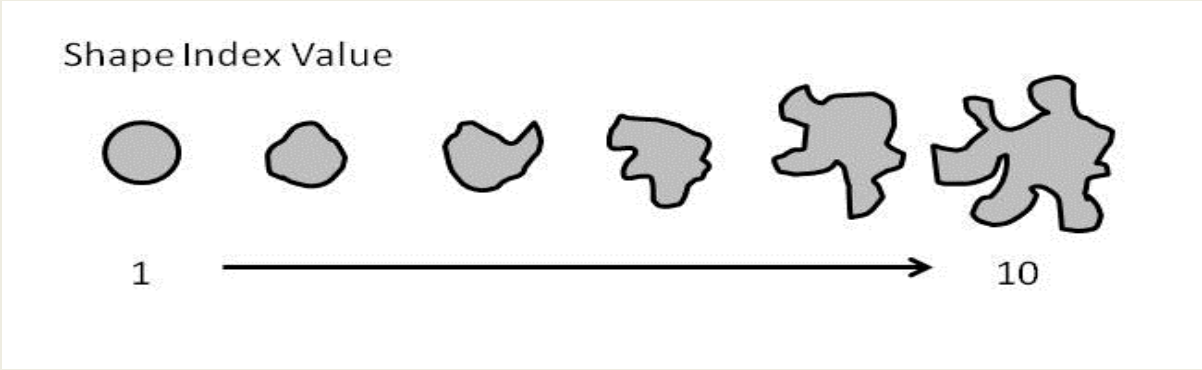
DISTRIBUTIONS OF PORE AREA AND PERIMETER



- **All three-scales observed exponential distribution**
- **Areas have fairly similar results**
- **Perimeters are nearly twice as high in the Castle Hayne**

SHAPE INDEX

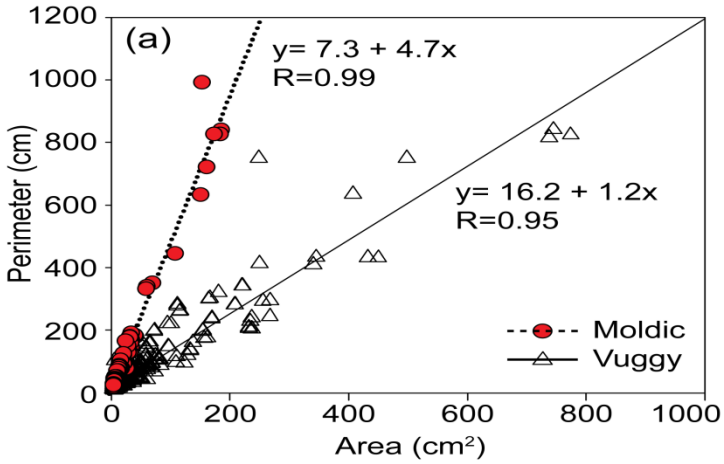
- Used to compute, a shape measure that describes the complex nature of pore shapes
- Range from one to infinity

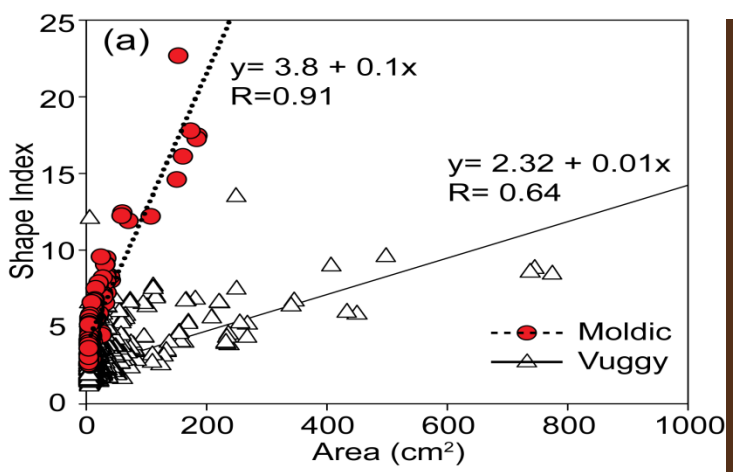


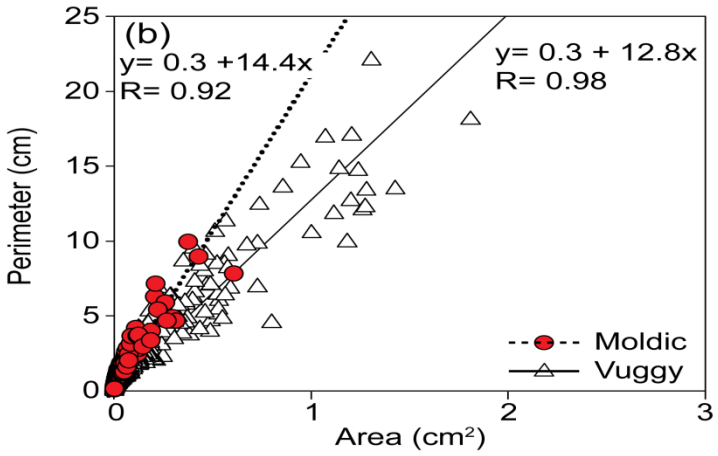
$$\gamma = \frac{P}{2\sqrt{\pi A}}$$

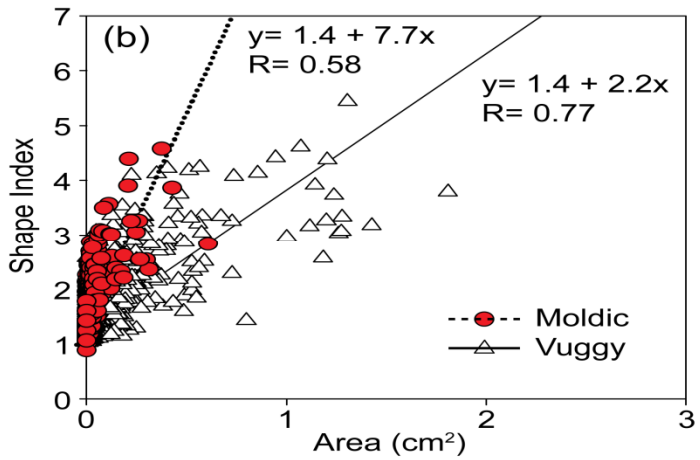
γ= Shape Index
P = Perimeter
A =Area

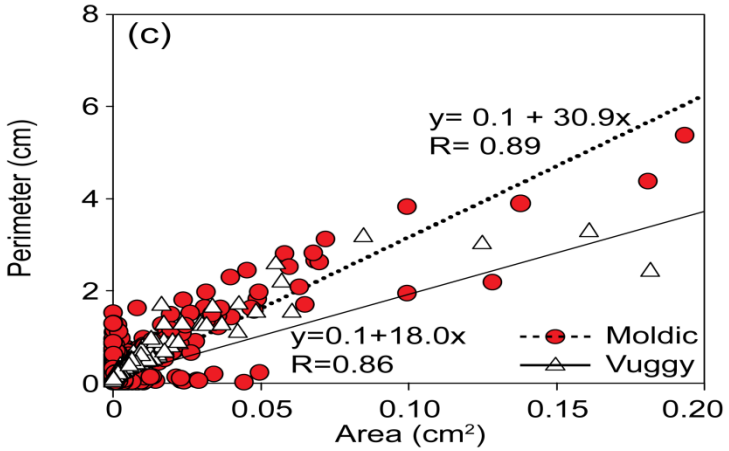
- Shape index is associated with the connectivity of the pores

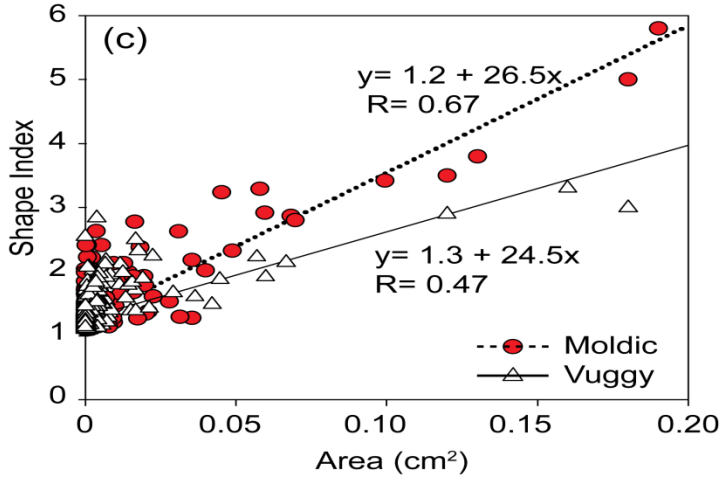








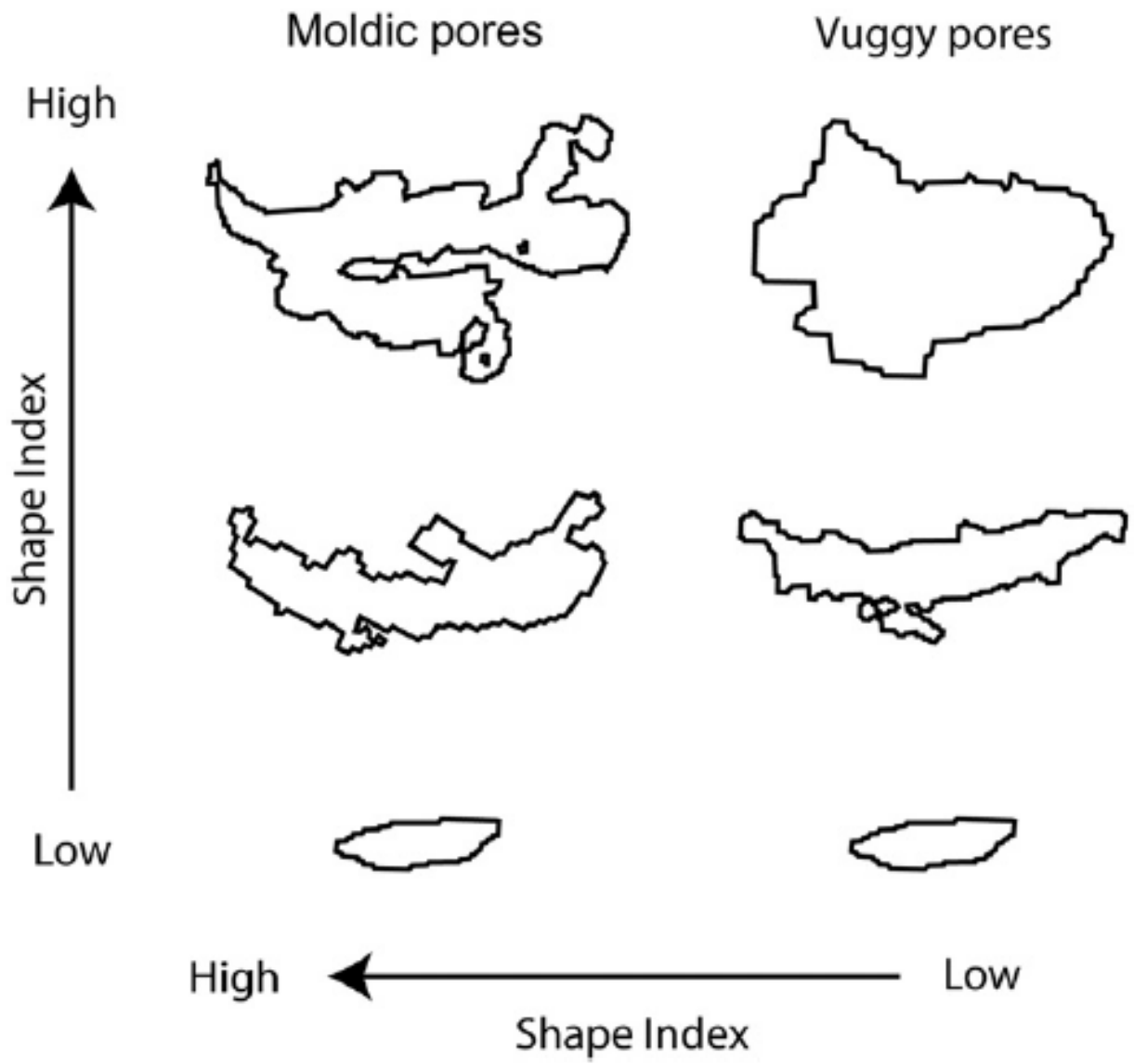




CROSS PLOTS

Area vs. Perimeter

Area vs. Shape Index

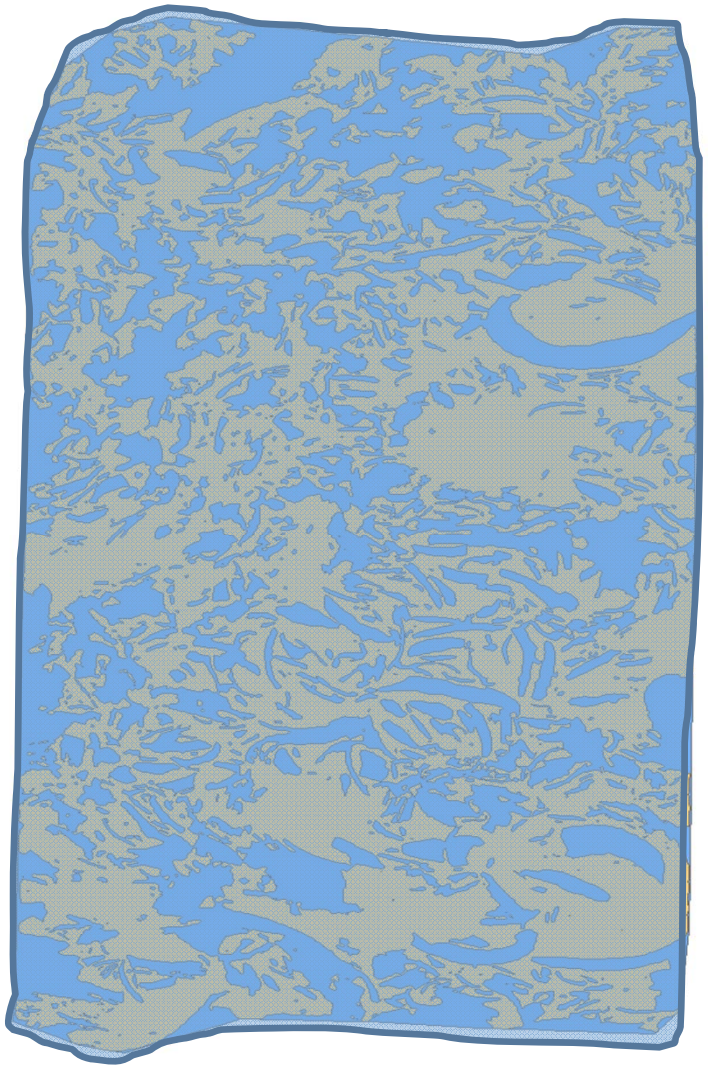


VISUAL OF CROSS PLOT ANALYSIS

Area vs. Perimeter

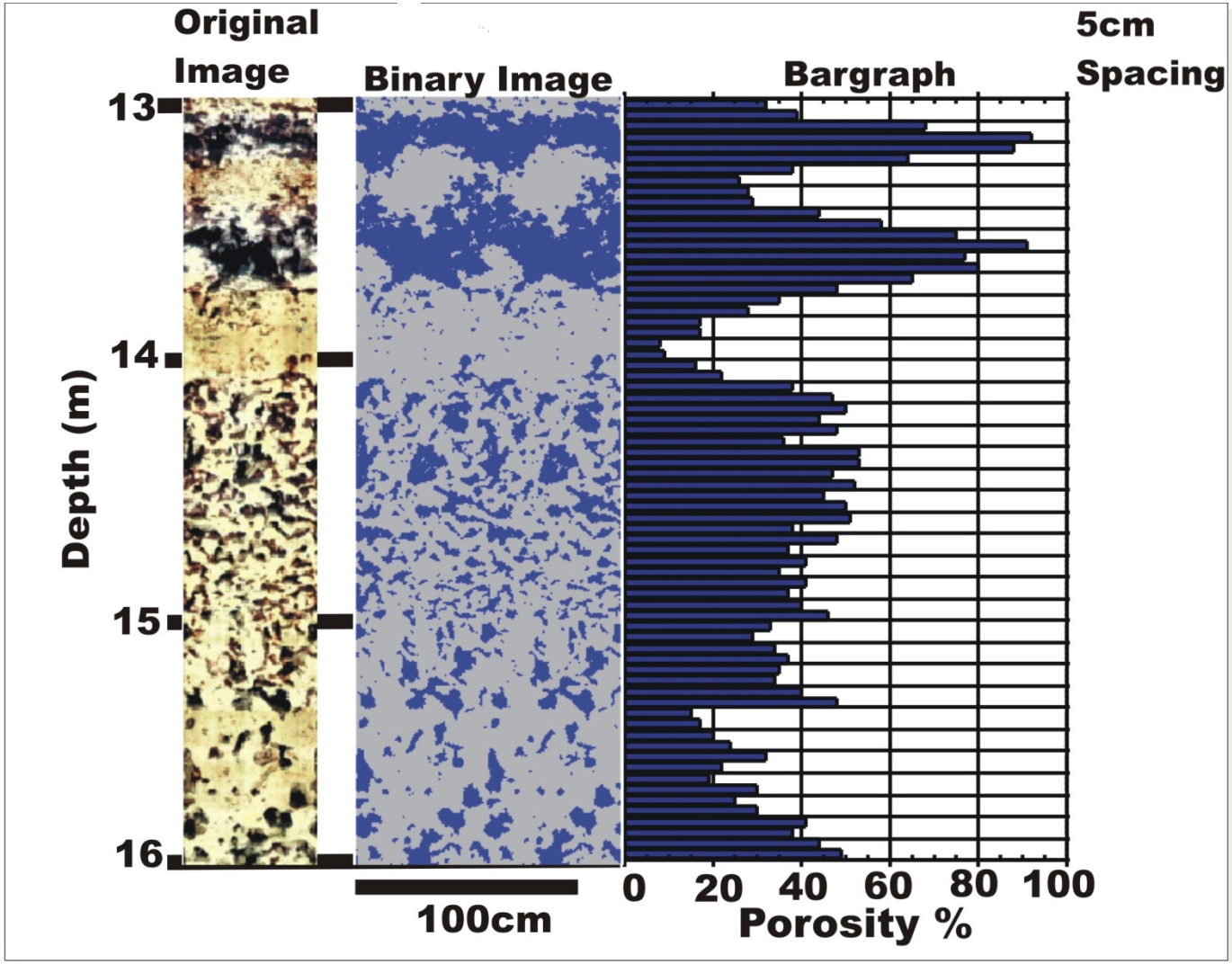
Area vs. Shape Index

2D POROSITY ANALYSIS

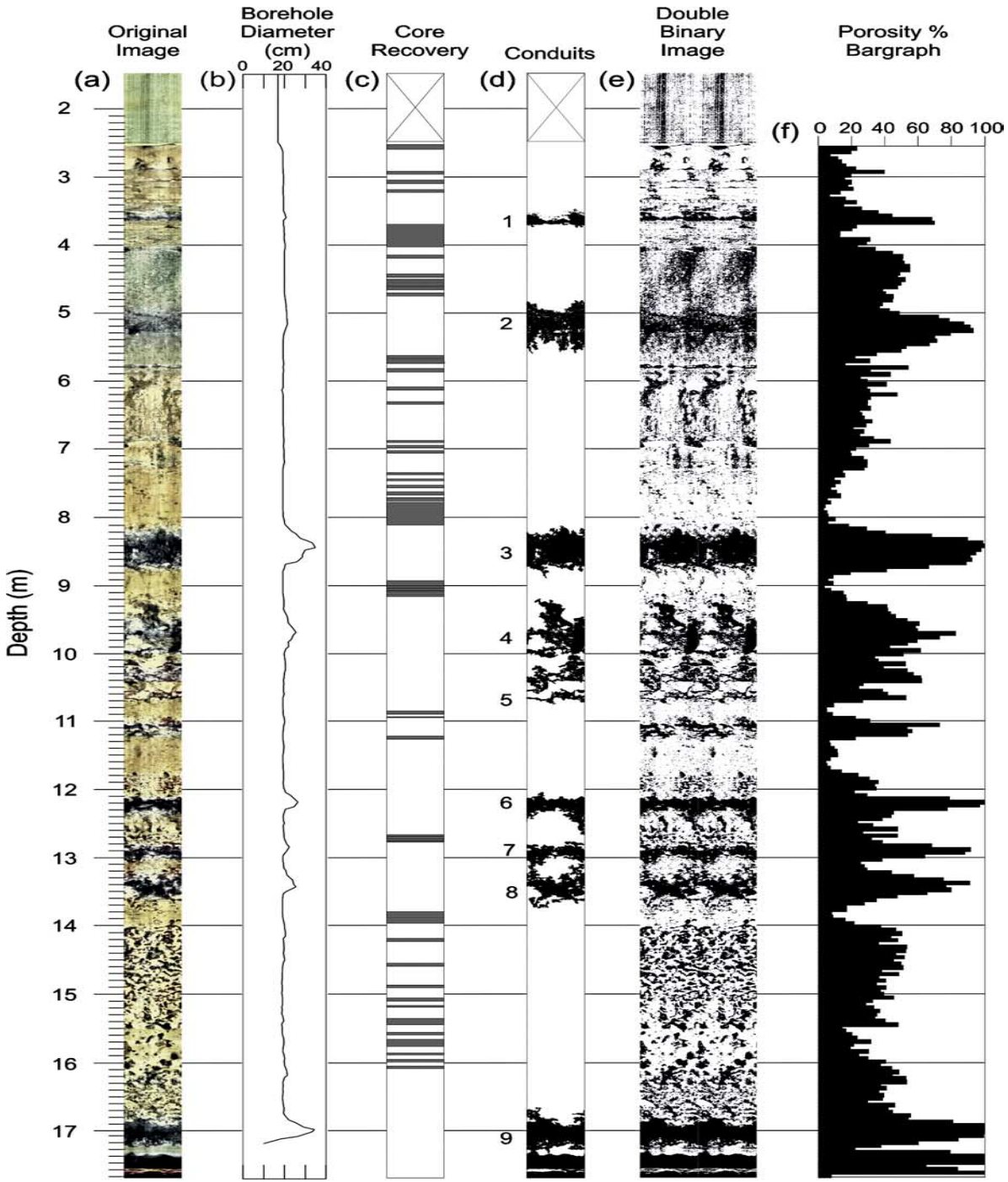


- The percentage of surface area occupied by macropores within a window
- Determine area of macropores within the polygon
- Dividing by the area of the polygon gave a percent area covered by macropores (i.e. the porosity)

GEOSPATIAL POROSITY ANALYSIS



- Conduits
- Porosity
- OTV Scale
- Heterogeneous

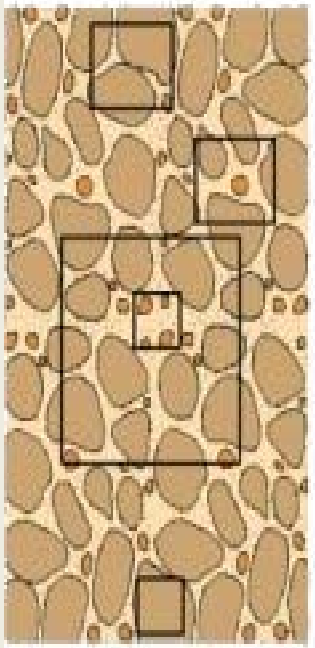


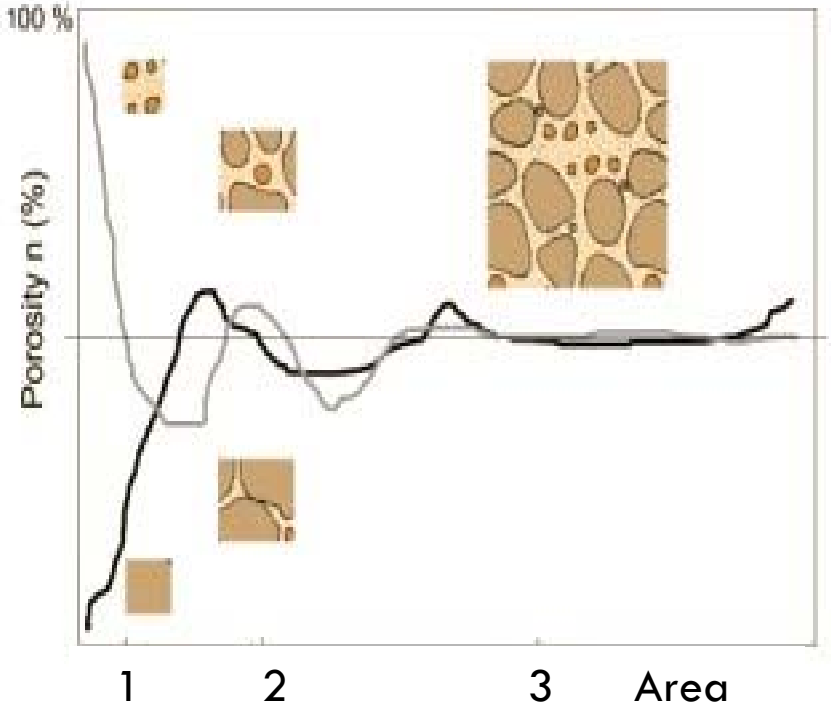
GRAPHIC DISPLAY

FORTY YEARS OF ENGINEERING INTEGRITY

MULTI-SCALE GEOSPATIAL ANALYSIS

- **Heterogeneous character of karst aquifers**
  - **hydraulic properties, including porosity, vary greatly as a function of scale**





- **Implementing a multi-scale, geospatial, analysis provides benefits which compliment other techniques applied to karst formations**

CONCLUSIONS

- **Qualitative to Quantitative Assessment**
  - quantitative measures of pore attributes and structure may be used to compare karst media with different porosity characteristics
- **New Technology**
  - Using digital imaging and GIS spatial-analysis techniques
- **Better understanding of porosity structure**
- **Overcome the unique challenges confronting the evaluation of groundwater flow in karst aquifers.**