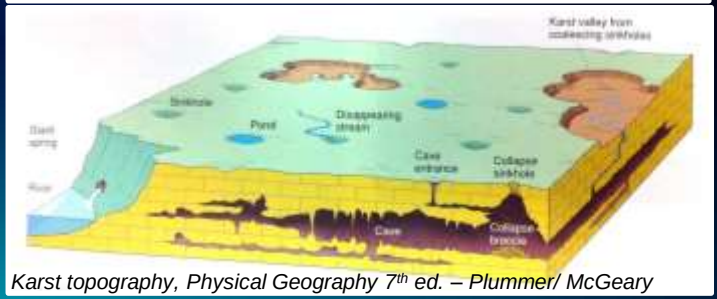
Testing Karst Hazard Predictions in Qatar

James Duggan — University of Leeds, United Kingdom
Jeremy Jameson — ExxonMobil Research Qatar
Rob Ross — Qatar Petroleum
Christian Strohmenger — ExxonMobil Research Qatar

Presentation Outline

- Research Objectives and Methods
- Definition of Types of karst in Qatar
- Geological History of Qatar, Karst models
- Database and Analytical Methods
- Data Manipulation and Analysis
- Results of Data Analysis - Comparison
- Field Observations- Types of Karsts
- Conclusions

Al Musfur (Central Qatar), Cave entrance



Karst topography, Physical Geography 7th ed. – Plummer/ McGeary

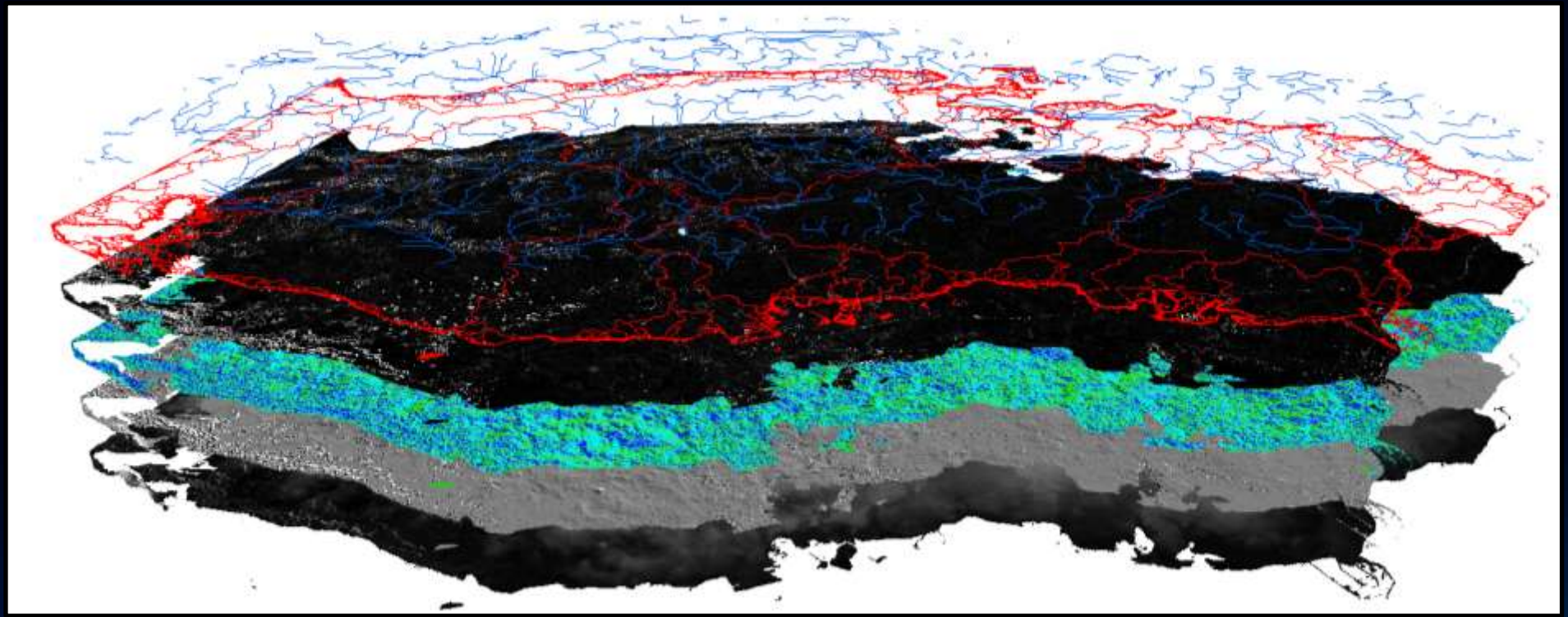
MSc. GIS Deliverable

- **Co-operative Through:**
  - University of Leeds, School of geography UK
  - ExxonMobil Research Qatar

(Expected Delivery: April 2014**)**

- **Dissertation Title:** Karst Hazard Prediction - Testing Predictions against Data
- **Advisors:** Dr. Duncan Quincey, Dr. Andrew Evans and Dr. Jeremy Jameson

- **Area of Interest:** State of Qatar



Research Objective

- Models for the origin(s) and distribution of karst in Qatar
- Terrain analysis to extract surface features
    1. Evaluation of surface weathering patterns
    2. Comparison to know karsts and Rus gypsum distribution
- **TODAY:** Obtain feedback from audience

Comment - This is a progress report on MSc. GIS work

Please contact me @:

JMSDuggan@gmail.com

Karst- *Definitions and Origins*

Practical Definition

- Any dissolution or collapse feature that creates a geotechnical hazard

2007 West Bay construction site. Shows entrance to a cave filled with red sand

Formal Definition

- Derived from a Slavic term standing for stony ground
- Landscape developed in limestone characterized by sinkholes, caves, bedrock collapse

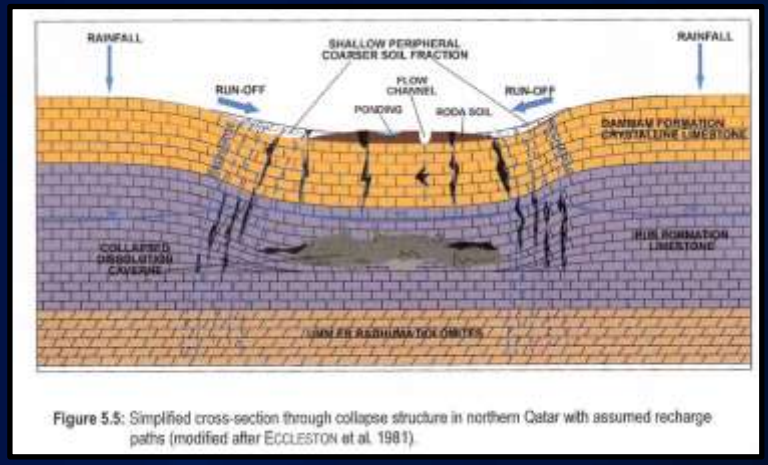
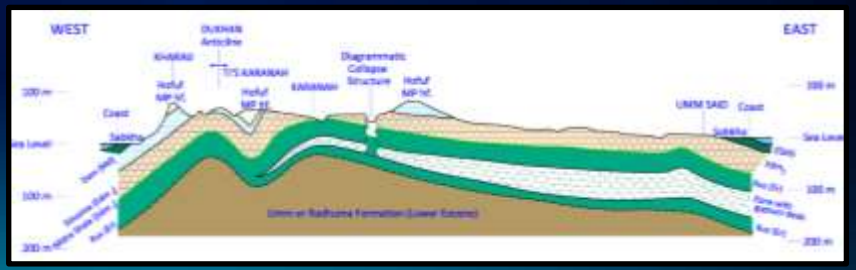


Figure 5.5: Simplified cross-section through collapse structure in northern Qatar with assumed recharge paths (modified after ECCLESTON et al. 1981)

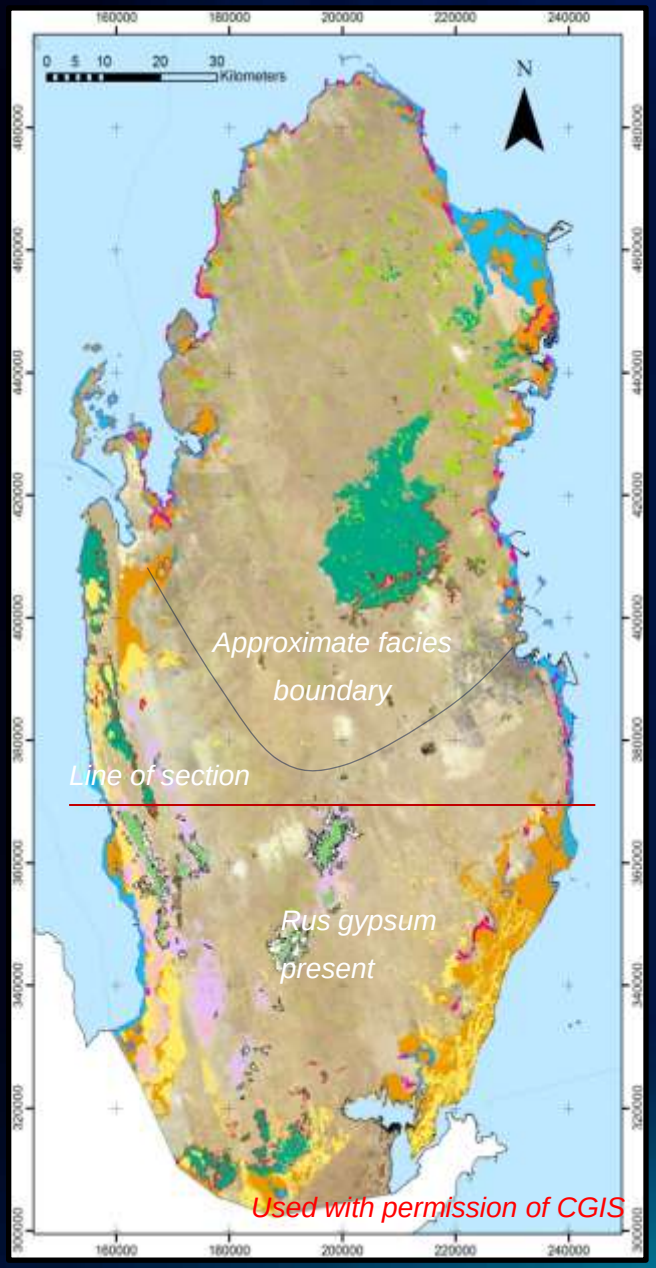
Civil Engineering Impacts

- Foundation risk- limited load bearing capacity
- Conduit for water

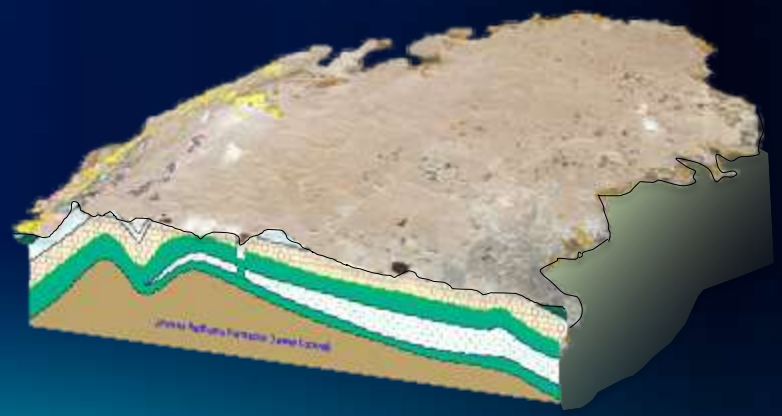


East, West cross section of Qatar. Shows Rus Gypsum layer dissolved in places form Karst

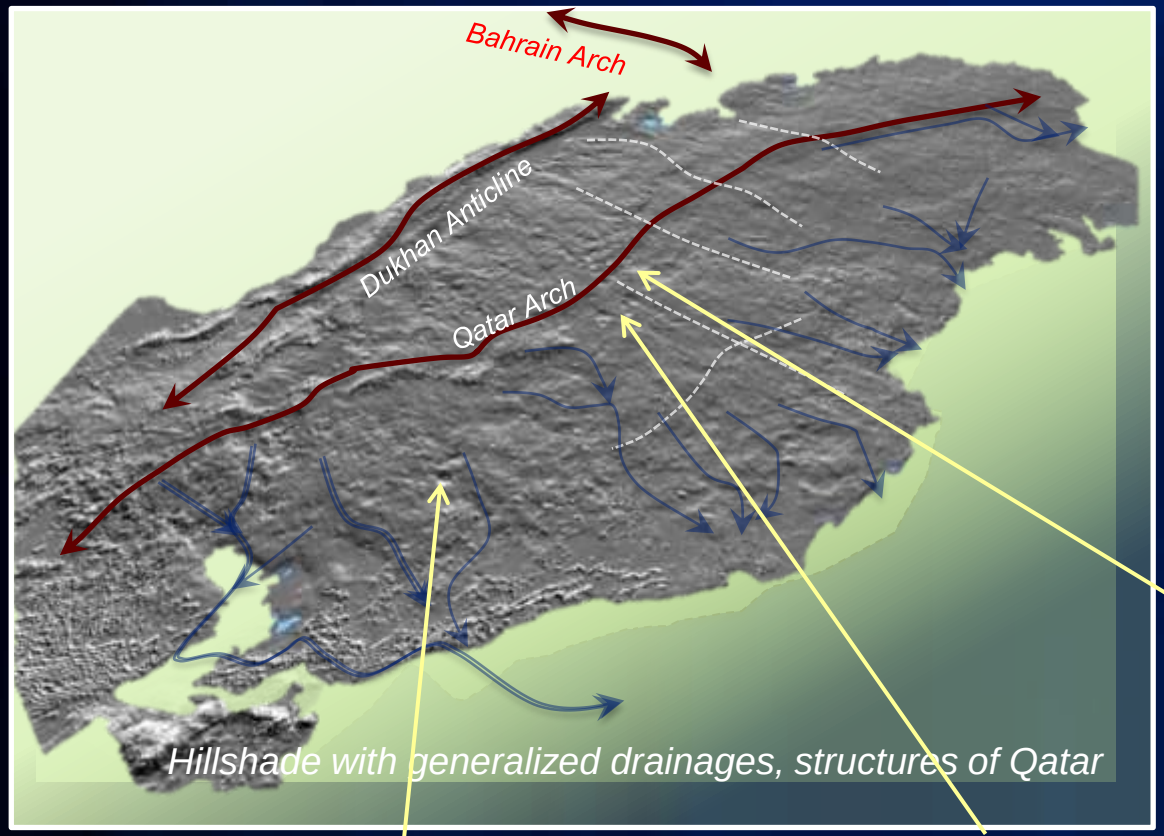
Qatar Geological Setting- *Overview*



- 80 % of land surface of Qatar is Eocene Damman formation (limestone and dolomite)
- The Eocene has been subaerially exposed for much of its 30 million year old history
- Southern Qatar is marked by a soluble layer of gypsum in the lower Eocene Rus Formation
- Dissolution of Rus gypsum at depth is one mechanism of surface collapse and karst formation



Qatar Geological Setting- *Overview of geomorphology*



Hillshade with generalized drainages, structures of Qatar

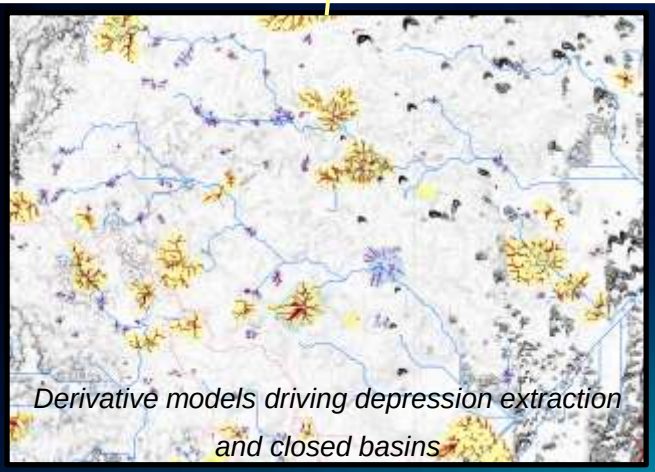
Pleistocene Drainages (Wadis)

Structural Features

Lineaments

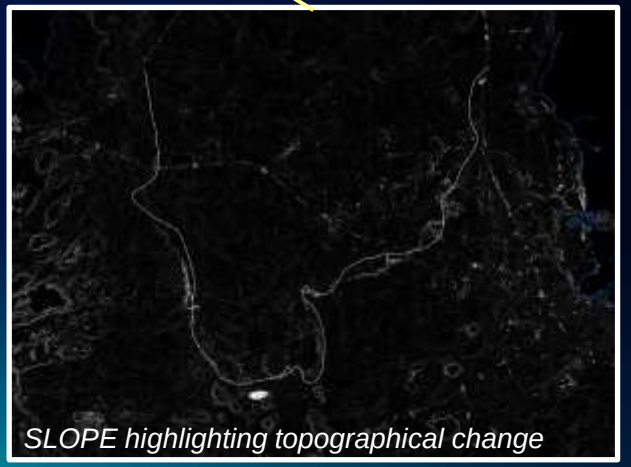
The climate during ~ 40% of the last million years has been humid, promoting the formation of:

- Drainages (Karst flow paths)
- Karst depressions (Closed basins)


Derivative models driving depression extraction and closed basins


Hillshade and contours (1M)

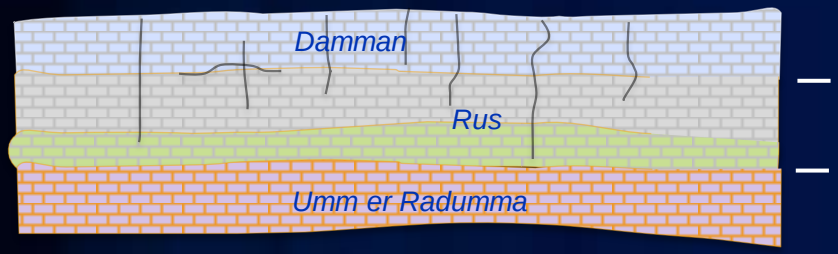

Depression area example


SLOPE highlighting topographical change

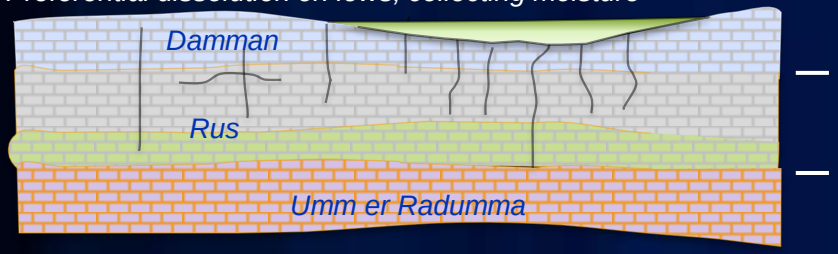
Qatar Karst Models

Surface Dissolution

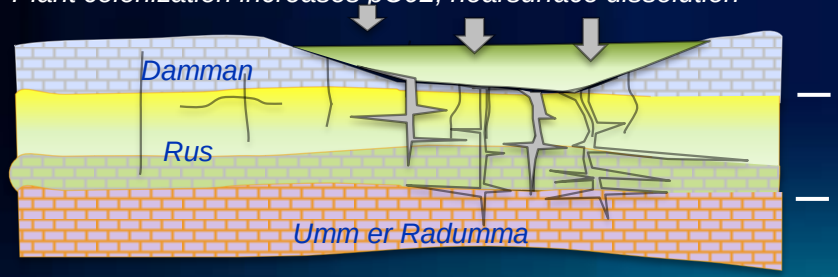
Surface weathering of fractured, Eocene limestone



Preferential dissolution on lows, collecting moisture



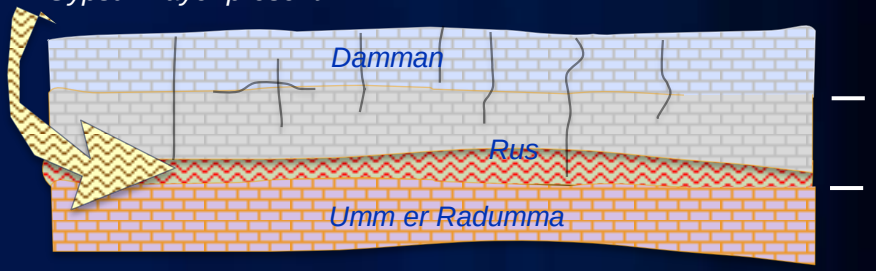
Plant colonization increases pC02, nearsurface dissolution



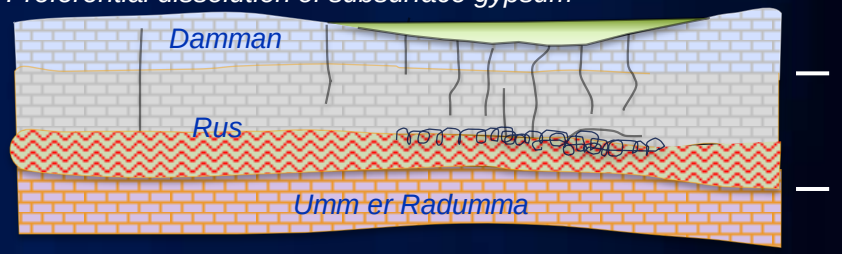
NORTH

SubSurface Dissolution

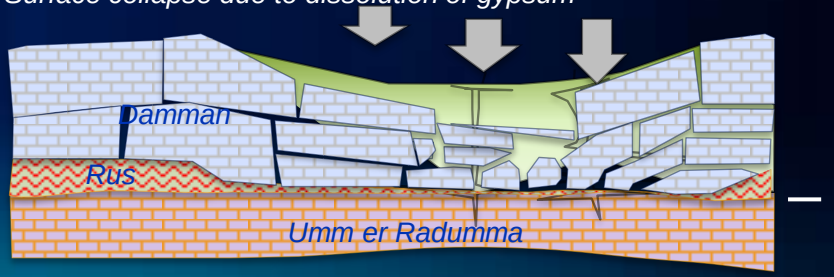
Gypsum layer present



Preferential dissolution of subsurface gypsum



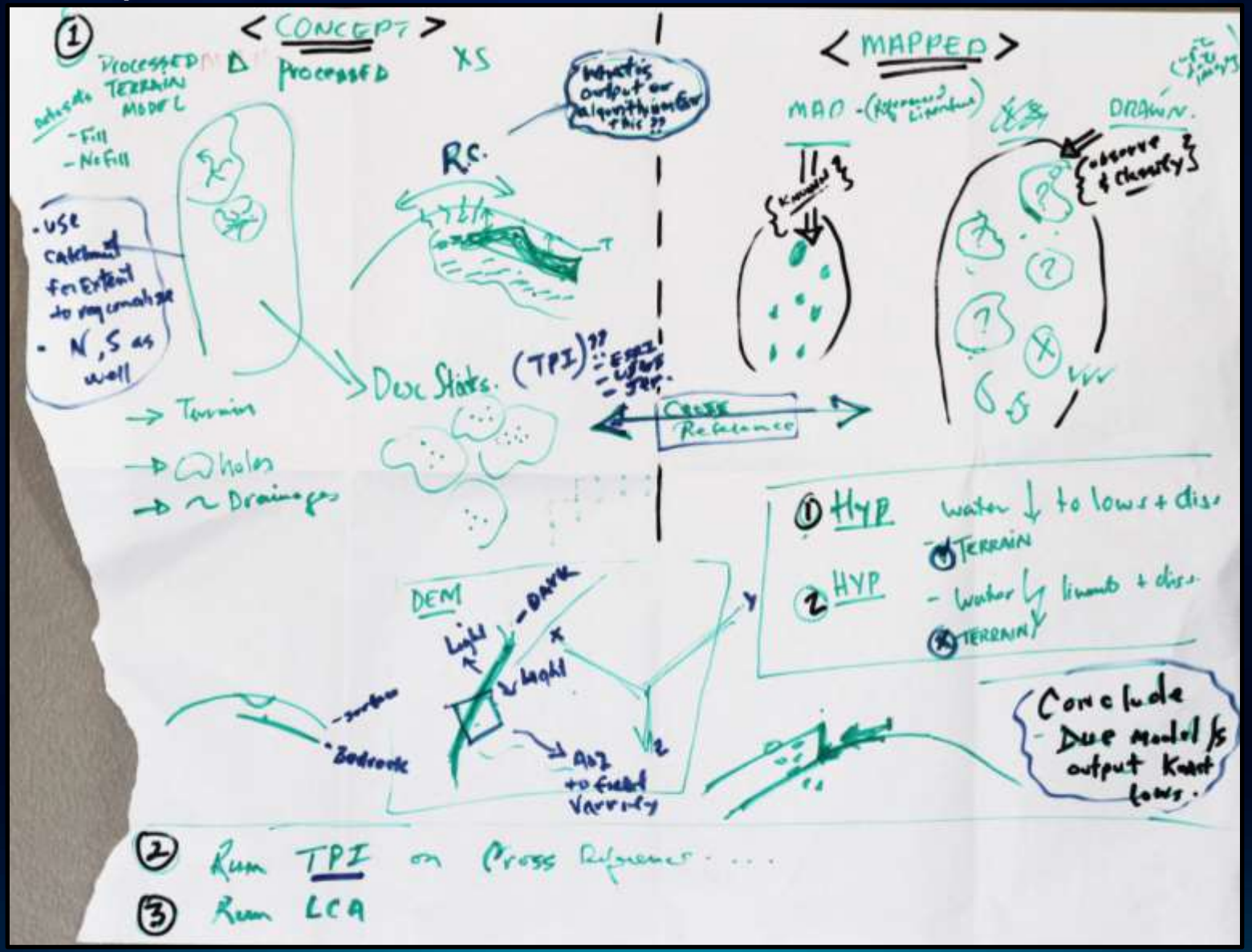
Surface collapse due to dissolution of gypsum



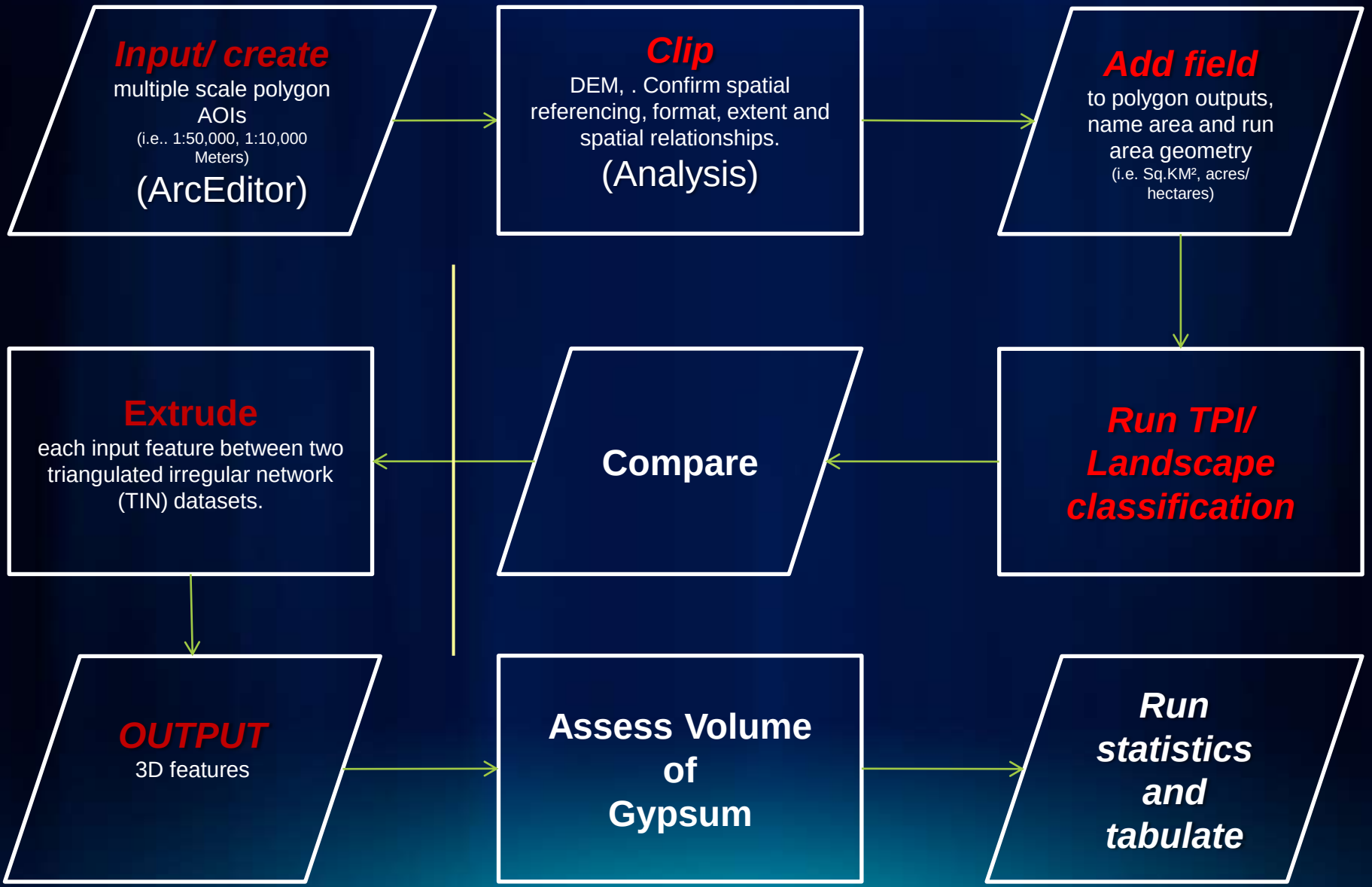
SOUTH

Project Planning

Rich picture



Data Flow/ Pipeline for Analysis



Database and dataset models

Input Datasets

Dataset	Owner	Coverage	Description	Research Project Use	Data Access (crutial, not cructial)	License Agreement
Topographical Elevation Dataset	ExxonMobil	Peninsula of Qatar	DEM, DTM, DSM (10M cell size)	Surface elevation and geomorhology modeling	crucial	Purchased - Use for company purposes.
WorldView-2 Elevation Dataset	ExxonMobil	Penisula of Qatar	DEM,Bathymetry	Surface elevation and geomorhology modeling	Best dataset (upgrade)	Possible future dataset upgrade
Aerial Ortho-imagery	ExxonMobil	Coast of Qatar	true colour composite (1M cell size)	True colour viewing, spectral reflectance/ signature discerning classification of landscape for geology purposes	not crucial	Purchased - Use for company purposes.
Spot 5 imagery	ExxonMobil	Peninsula of Qatar	Multi-spectral satellite imagery (2.5M cell size)	True colour viewing, spectral reflectance/ signature discerning classification of landscape for geology purposes	not crucial	Purchased - Use for company purposes. Education is highlighted
Geology	ExxonMobil	Peninsula of Qatar	Shape file/ feature class	Peninsula wide representation for the State of Qatar's geology	not crucial	Purchased - Use for company purposes
Soils	ExxonMobil	Peninsula of Qatar	Shape file/ feature class	Peninsula wide representation for the State of Qatar's soils	not crucial	Purchased - Use for company purposes

Datasets used thus far,

CGIS 2010 terrain dataset (masspoints, breaklines)

CGIS 2008 Ortho photos

SPOT5 2010 satellite images

** Note: In a world where accurate and precise rendering of data outputs is important.. Good data in means good data out.*

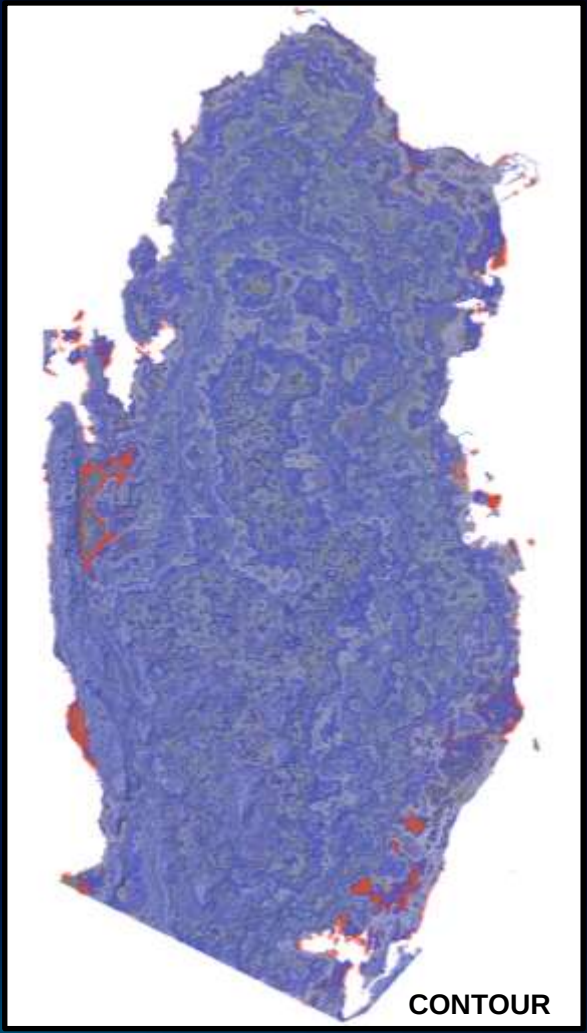
Aerial photography
Oblique aerial photography shot at less then 1:500

Rendered model in Arc Globe
Data input:
2010, Digital Elevation Model produced from DTM (10X10M cell)
2010, Spot 5 imagery (2.5X2.5M cell)

Analysis

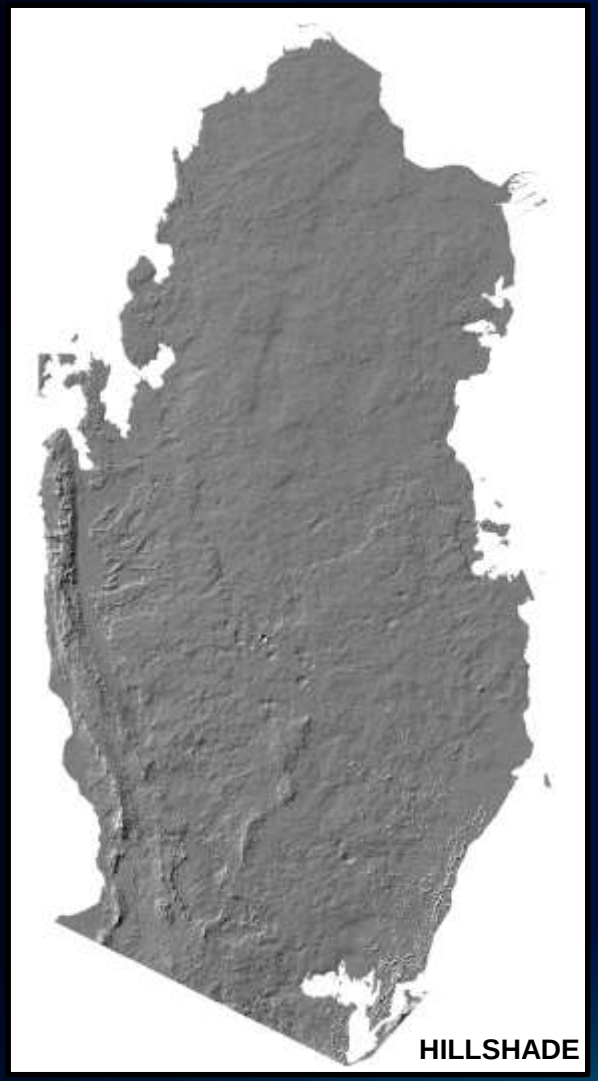
Models

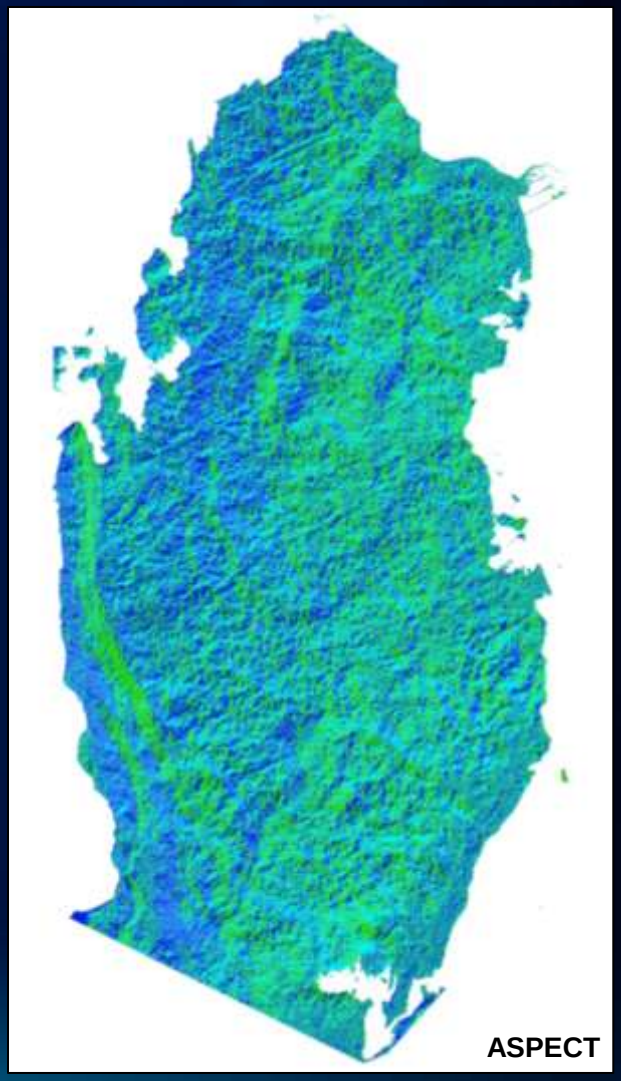
1. A) Create Terrain, DEM dataset, contours (1M)



Analysis cont'd

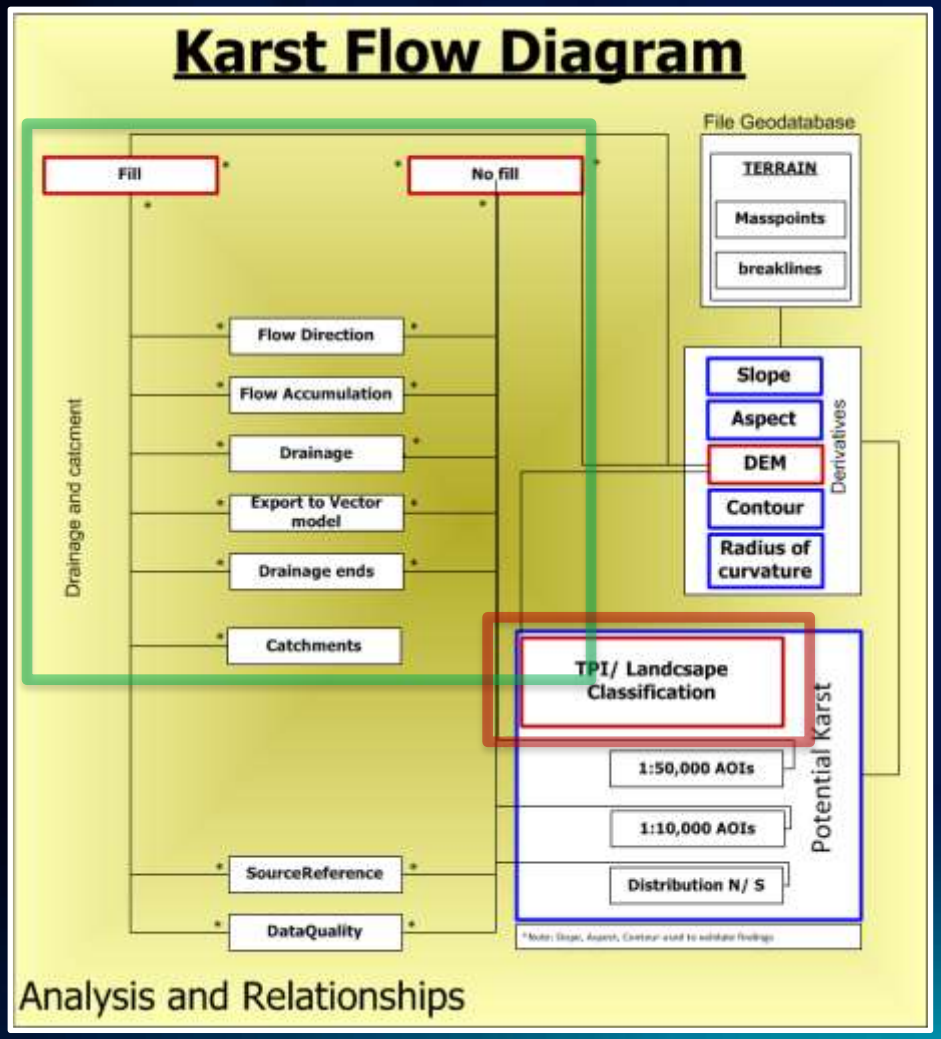
1. B) Create Derivative outputs

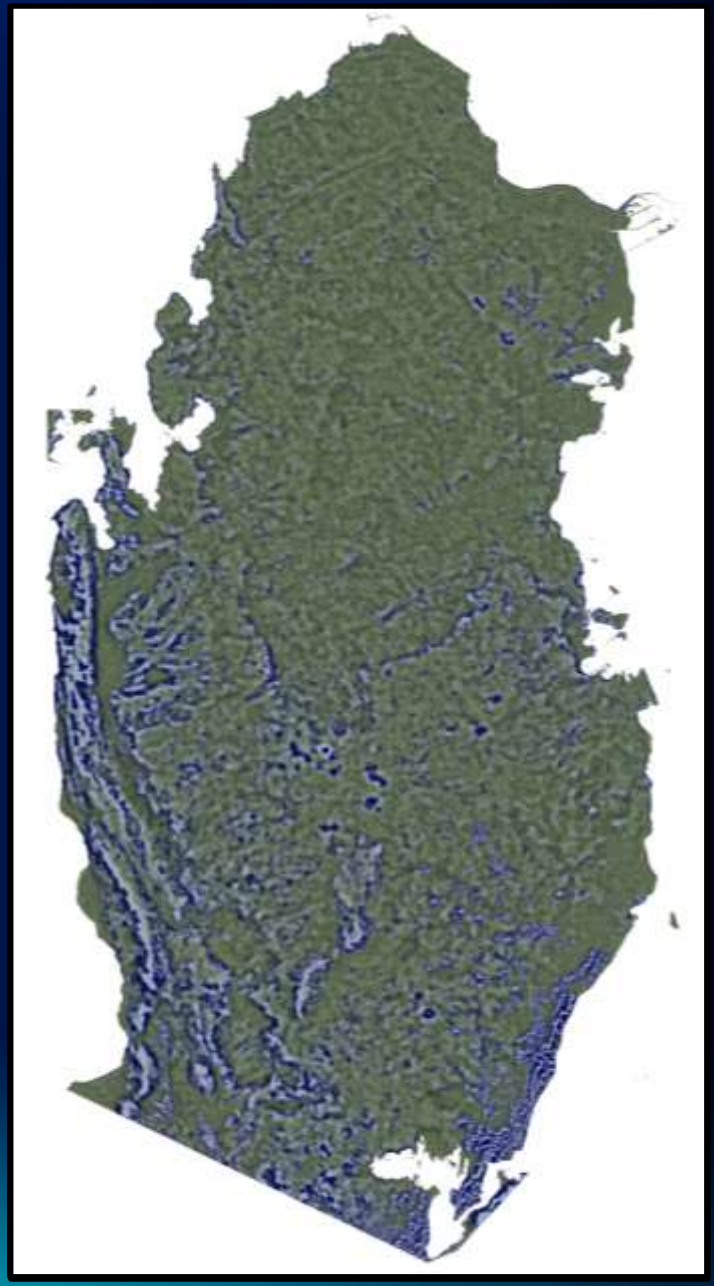




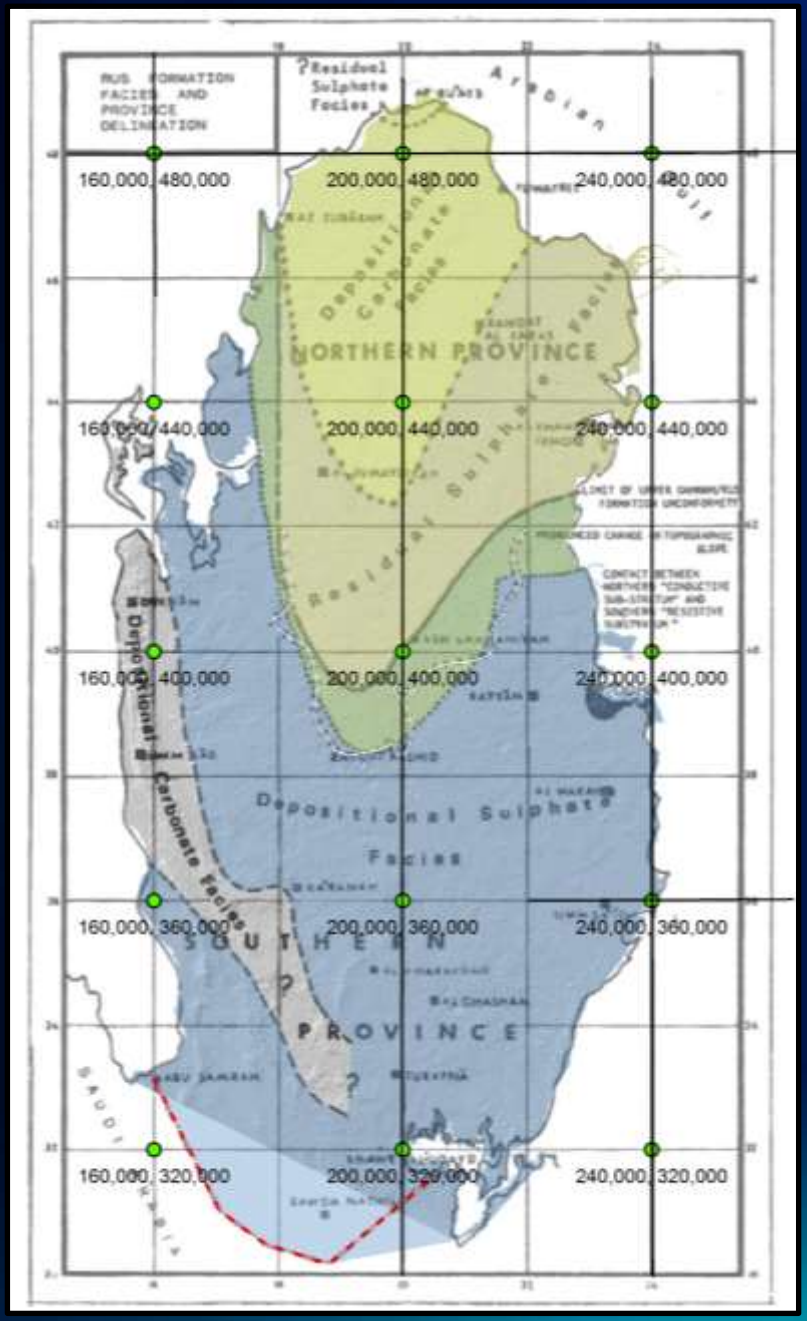
Analysis cont'd

2. Create surface drainage datasets
   I. With fill
   II. With no fill



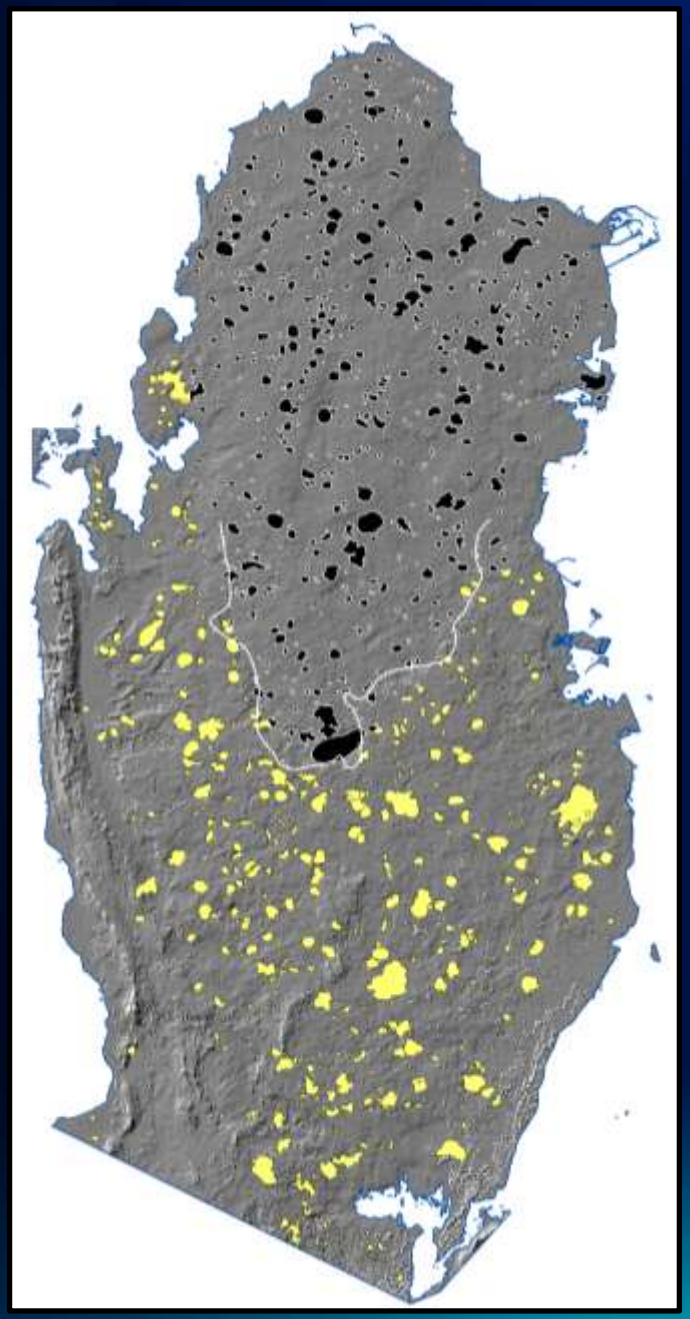


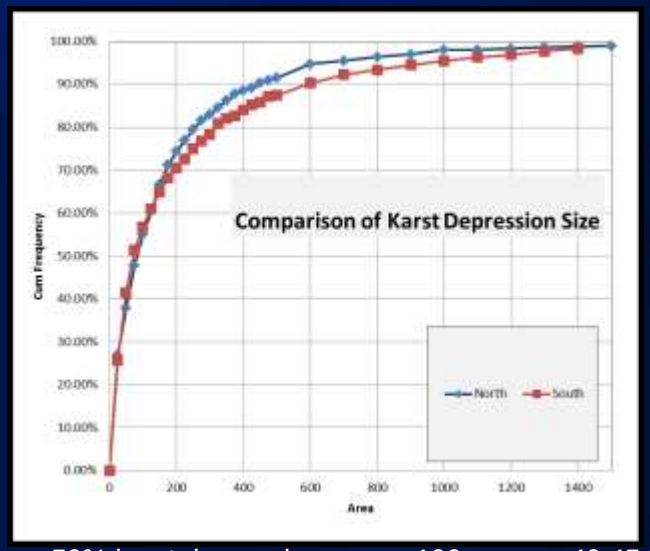
North and South Karst- *Comparison*



- Map (to left) highlights the aerial separation of Qatar into two ground water provinces North, South.
- Hydraulically separated by intervening less permeable materials (USGS, 1985).
- More Carbonate (Limestone) - North
- More Evaporates (Gypsum) - South

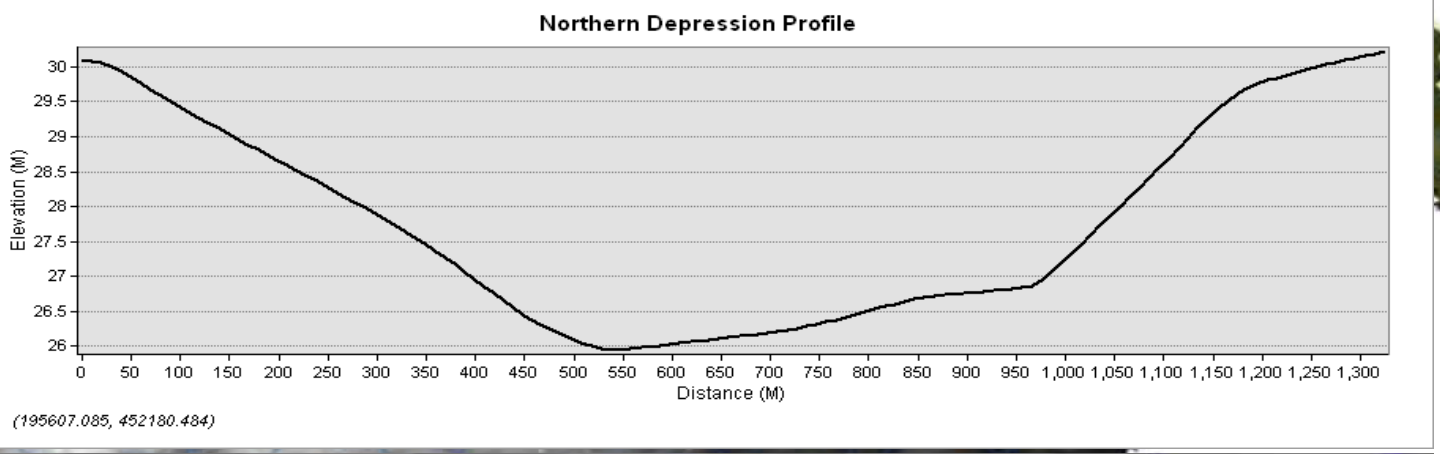
North and South Karst- Results of Analysis

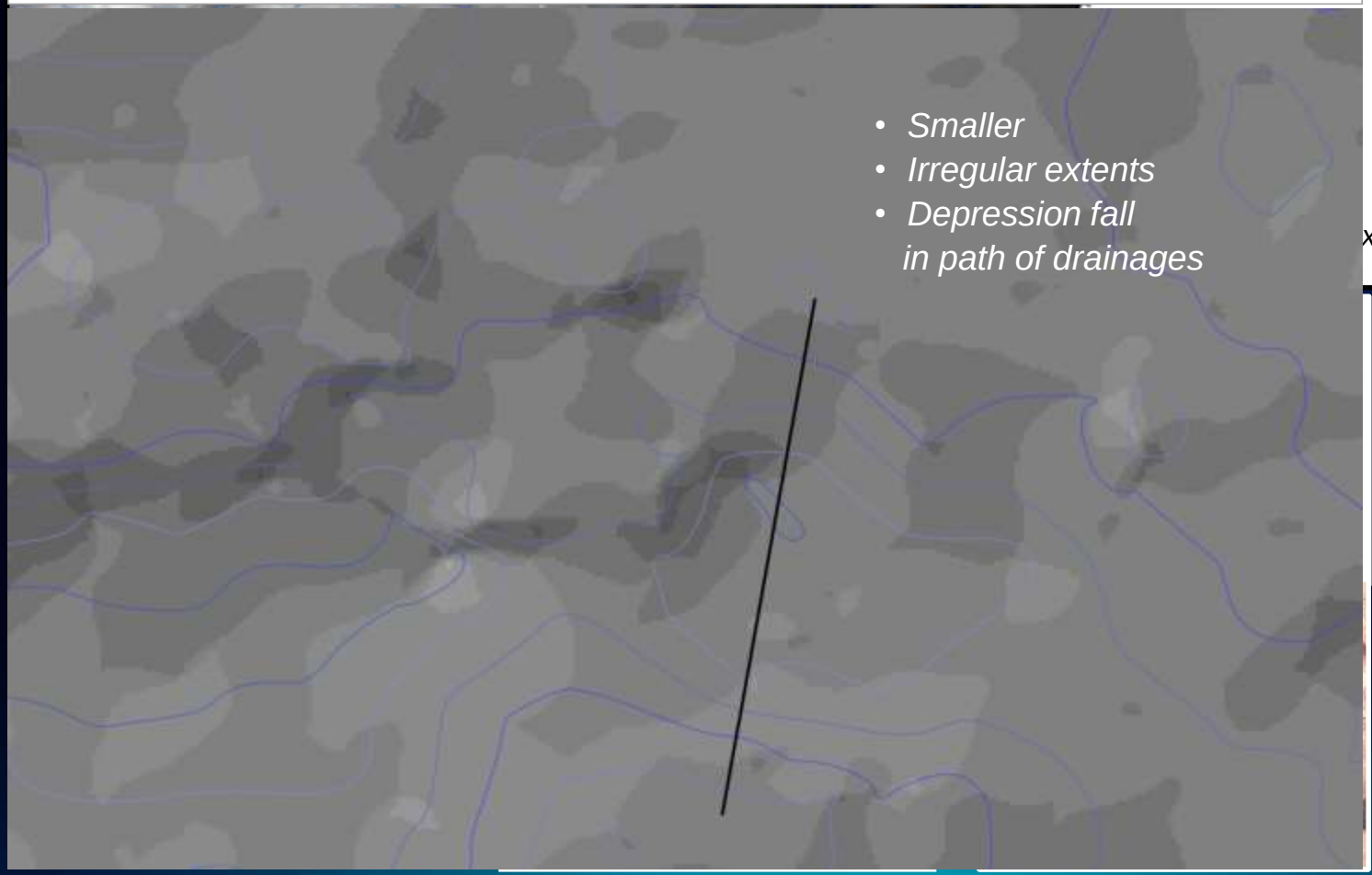




- *50% karst depressions are < 100 acres = 40.45 hectares*
- *N, S : 20 % are > 400 acres = 161.87 hectares*

- *Map of country wide possible Karst features*
- *Map shows two regions north and south separated by Ecclestons limit of gypsum*
- *Same size distribution North and South*


Northern Depression Profile
Elevation (M)
30
29.5
29
28.5
28
27.5
27
26.5
26
0 50 100 150 200 250 300 350 400 450 500 550 600 650 700 750 800 850 900 950 1,000 1,050 1,100 1,150 1,200 1,250 1,300
Distance (M)
(195607.085, 452180.484)


• Smaller
• Irregular extents
• Depression fall
in path of drainages

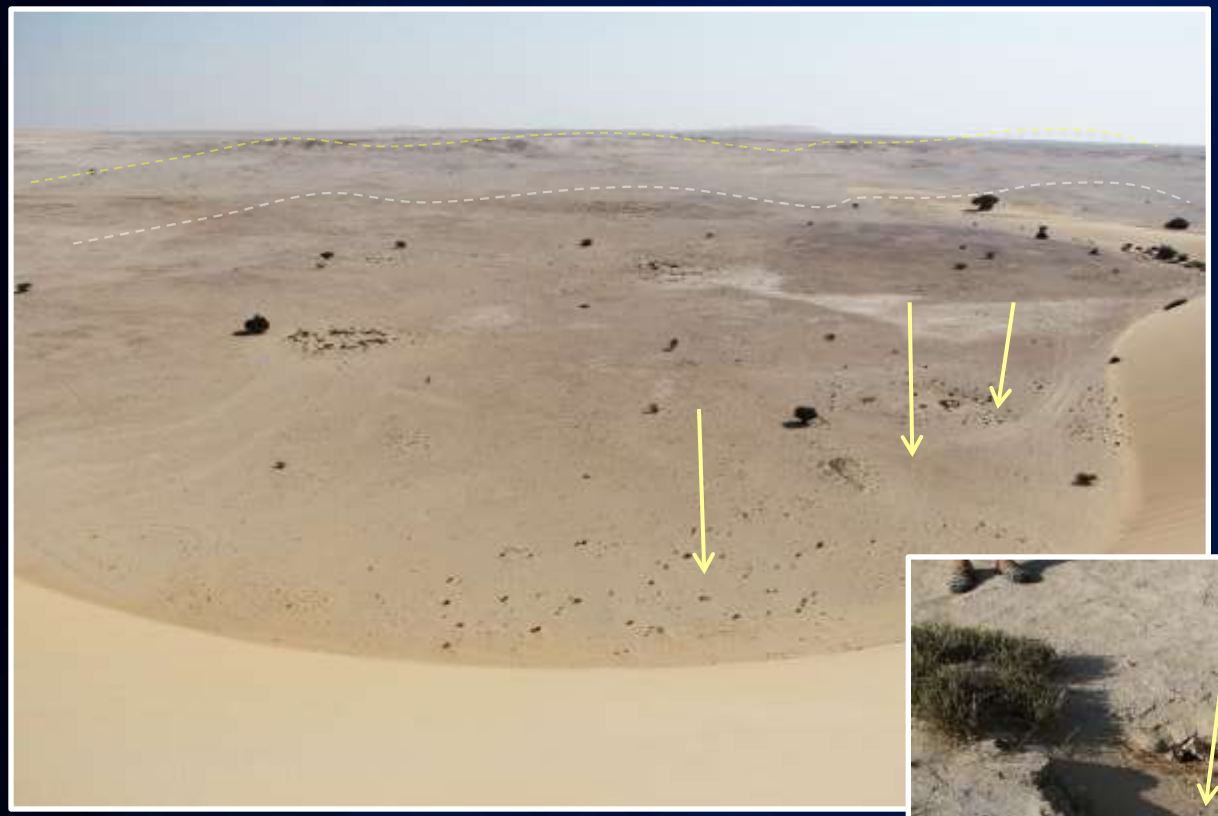
xtent

Northern Karst- *Low Relief Depressions*

Roda Depressions at topographic lows

- No evidence of collapse
- Water stands in lows (i.e. mud polygon evidence)
- Low relief (<5m), gentle slope

Southern Karst- *Higher Relief Depressions*

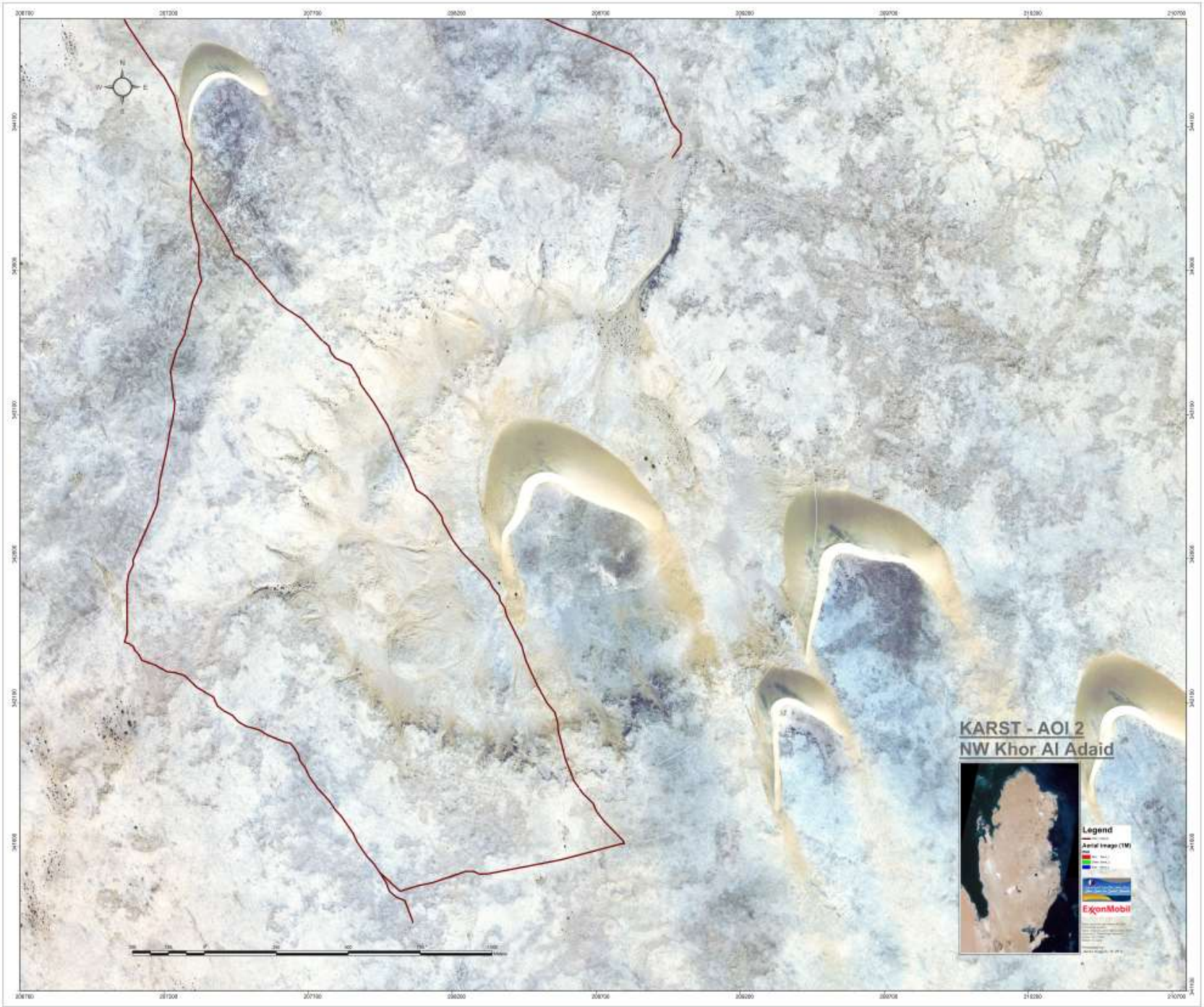


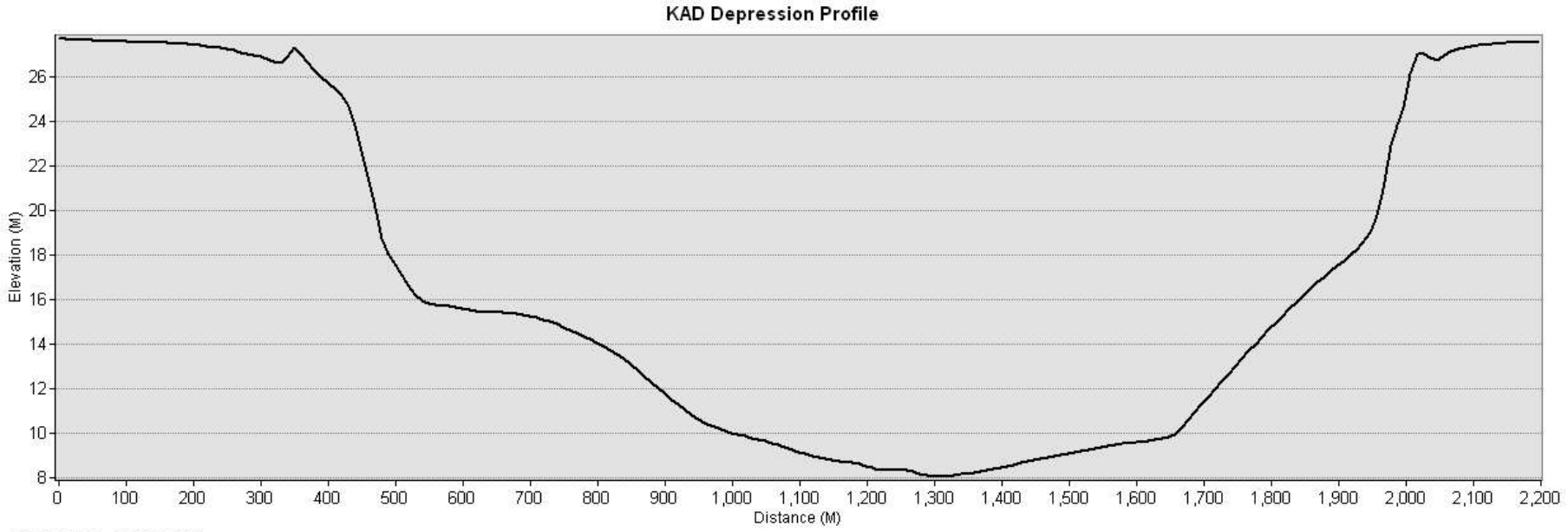
Edge of Depression

Terraced collapse rim

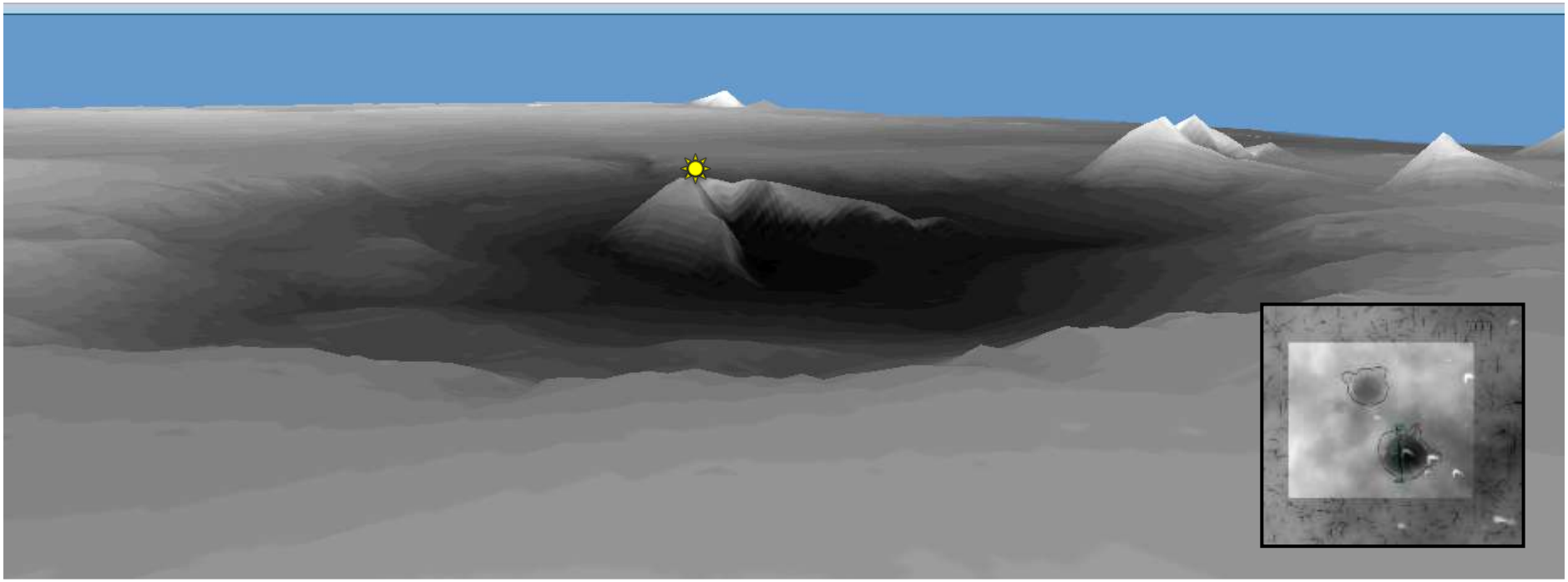
Sinkhole openings

Karst sinkhole mouth


KARST - AOI 2
NW Khor Al Adaid
Legend
Aerial Image (1M)
ExxonMobil

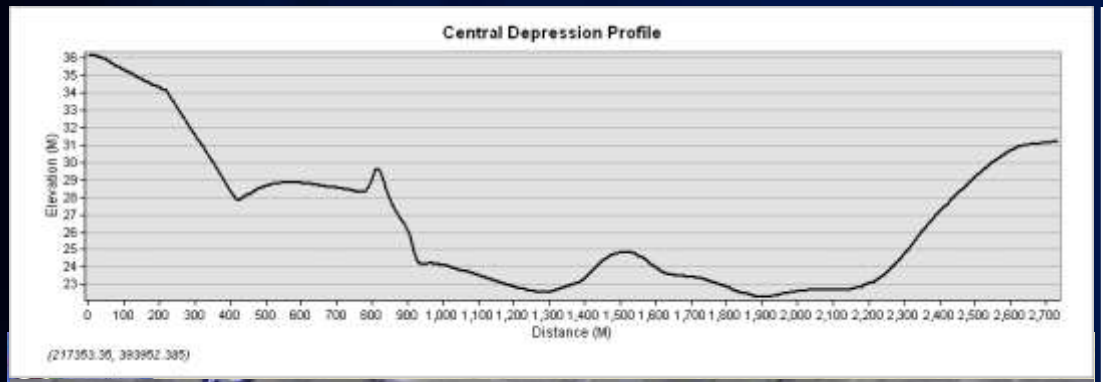


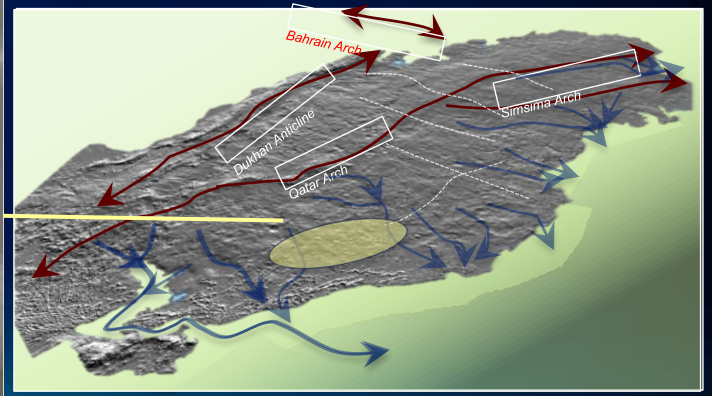
(208641.777, 342809.893)



Known Karst in Qatar- *Collapse features with Caves*

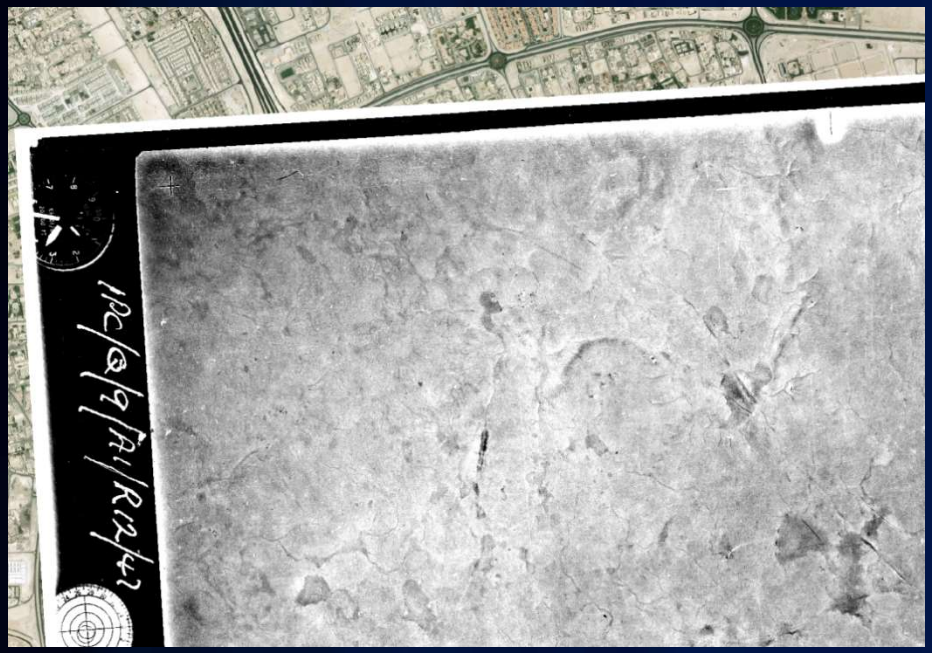
Caves long the Arch Crest





Historical Image Overlay- *Past helping present*

Hazardous karst areas identified using 1947 aerial photos and DEM



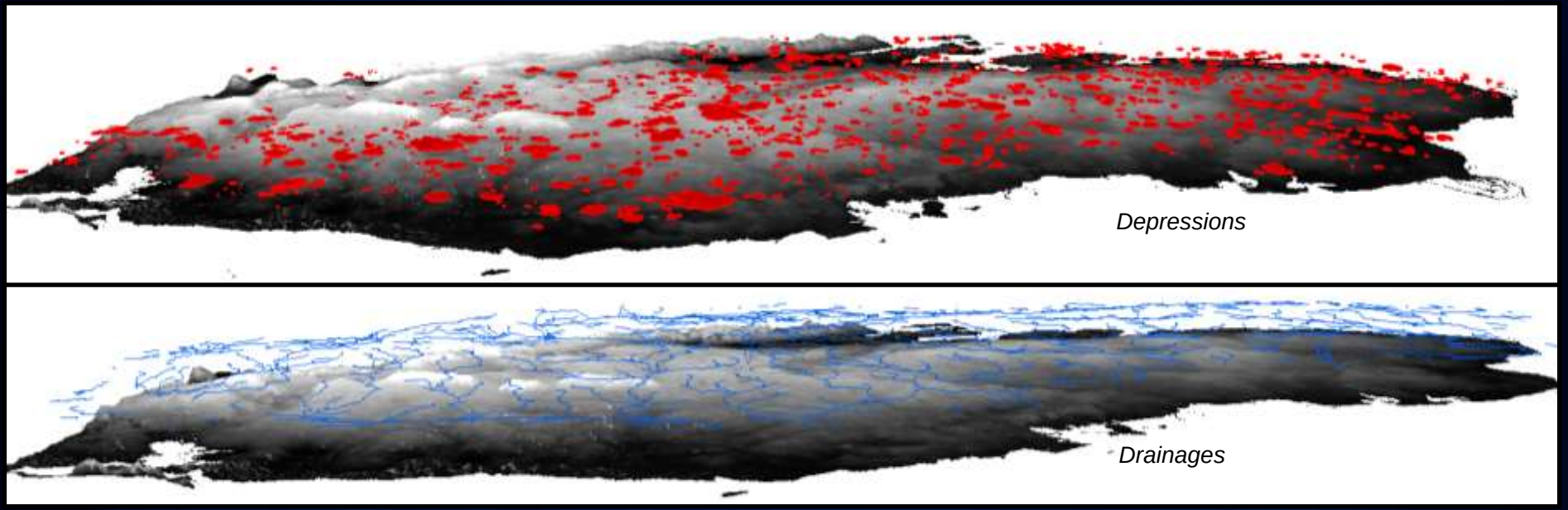
ABOVE: The original input data and the importance of date metadata (‘47’ is 1947). Image shows the 1947 aerial photo and modern satellite imagery before combination through georeferencing.

ABOVE: Georeferencing 1947 image to identifiable terrain on satellite image. Subsequent building development masks some features. The ability to identify features to reference photos is vital. Need to retain older imagery.

Historical Image Overlay- *Past helping present cont'd*

Hazardous karst areas identified using 1947 aerial photos and DEM

Conclusions



- Digital elevation models reveal 2 types of drainage patterns consistent with karst development
    1. Surface collapse with radial drainage patterns
    2. Irregular soil filled surface pits with dendritic drainage patterns

- Large Radial Drainages include known karsts: Al Musfer, Landmark, Superbowl
    1. Show evidence of collapse
    2. Only found where Rus gypsum is present
    3. Southern half of Qatar
- Irregular dendritic surface pits
    1. Coincide with Roda depressions in North Qatar, but found state wide
    2. Show evidence of standing water, surface dissolution
    3. No collapse
- Predictions will need comparison with more field examples and accurate means of measure (i.e. seismic)