Improved Geohazard Analysis for Drilling Favorability Maps

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Overview

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Introduction to Geohazards & Favorability Mapping

Section 2

Common Practices for Favorability Mapping

Section 3

New Quantitative Approach

Section 4

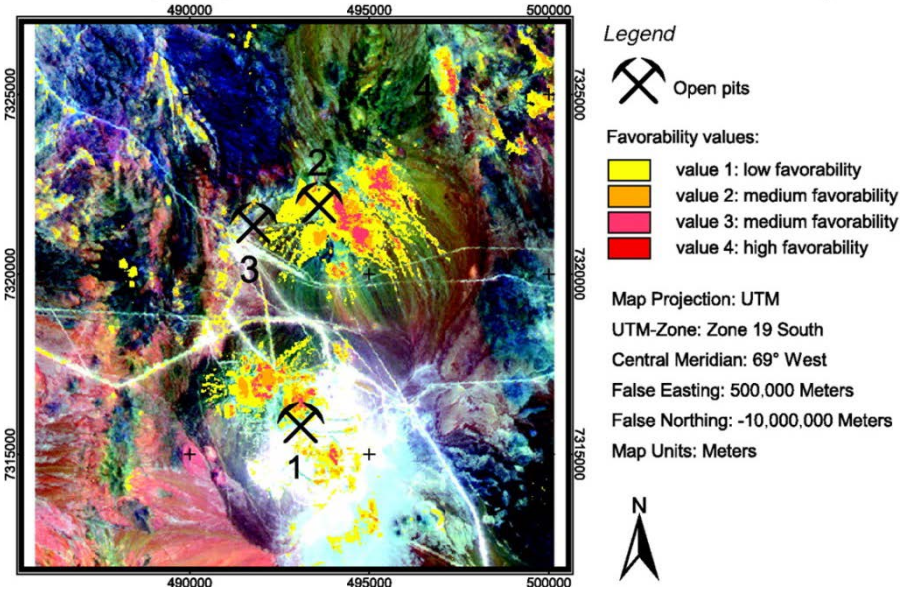
Conclusions, Q&A

Section 1

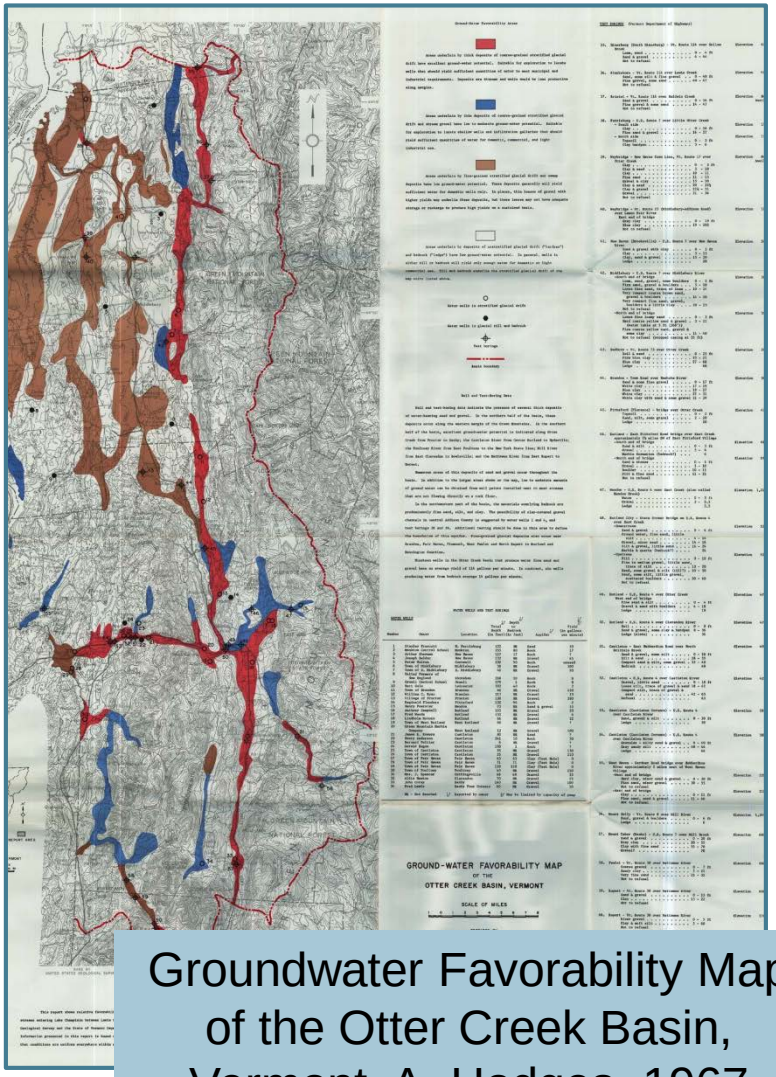
Introduction to Geohazards & Favorability Mapping

History of Favorability Mapping

- Historically used to indicate likelihood of discovering oil and gas, metallic minerals, and groundwater



Favorability Map of Altered Rocks at La Escondia Mining District, Ott et al., 2006



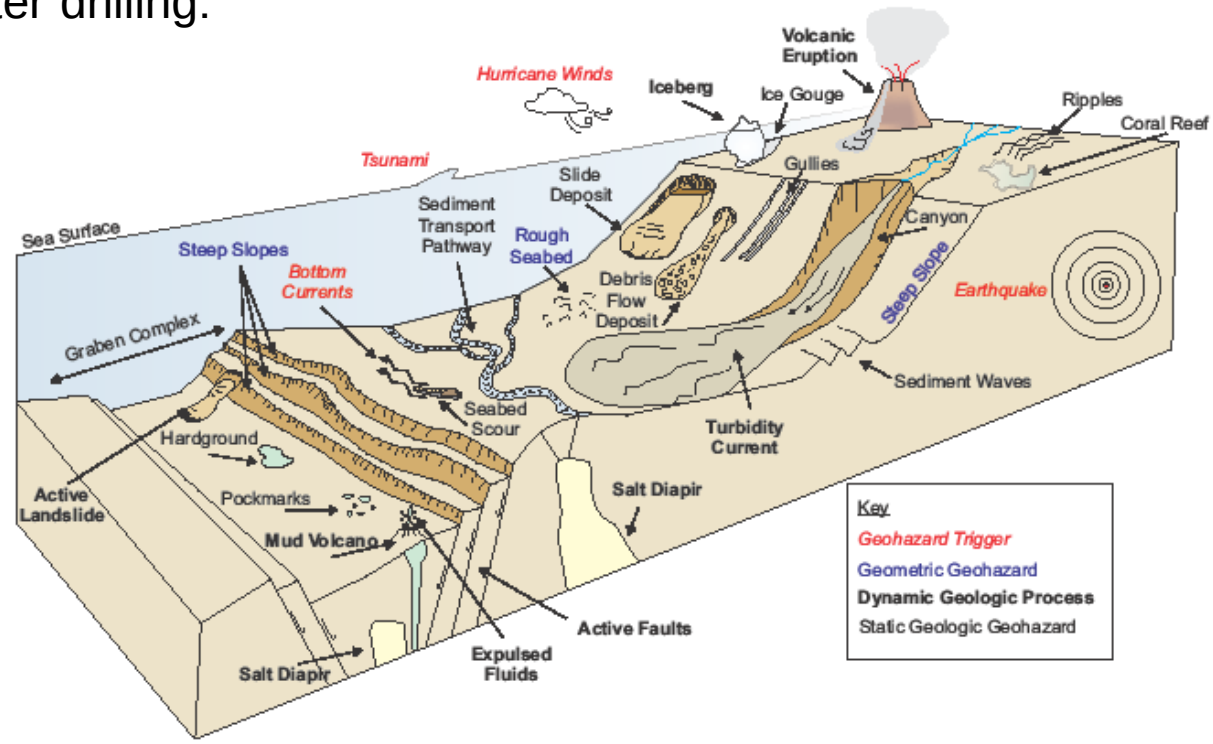
Groundwater Favorability Map of the Otter Creek Basin, Vermont, A. Hodges, 1967

Geohazards

"A geological state that may lead to widespread damage or risk"

Most common in deepwater drilling:

- Shallow gas
- Faults
- Expulsion
- Steep slopes
- High pressured sands

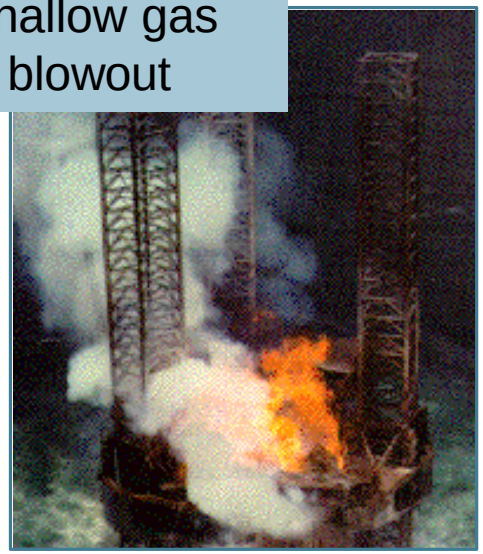


From: ABS Pipeline Route Determination Guidance Notes (in prep)

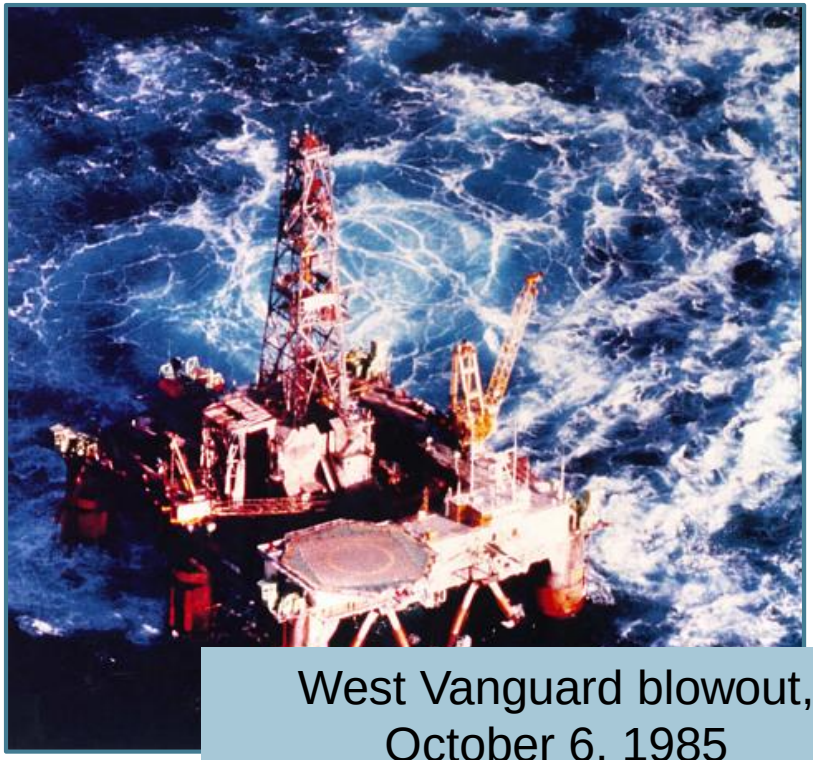
Favorability Mapping for Geohazards

- Drilling costs >$1 million/day
- Delays caused by unanticipated hazards = $$$$ (compounded by current oil prices)
- Drilling (or pipeline) favorability maps used to identify and avoid geohazards

Shallow gas blowout



http://www.jwco.com/technical-litterature/p07.htm



West Vanguard blowout, October 6, 1985

http://www.canadian-wellsite.com/images/Photo%20Gallery/BFM/West_Vanguard_Blowout.jpg

Section 2

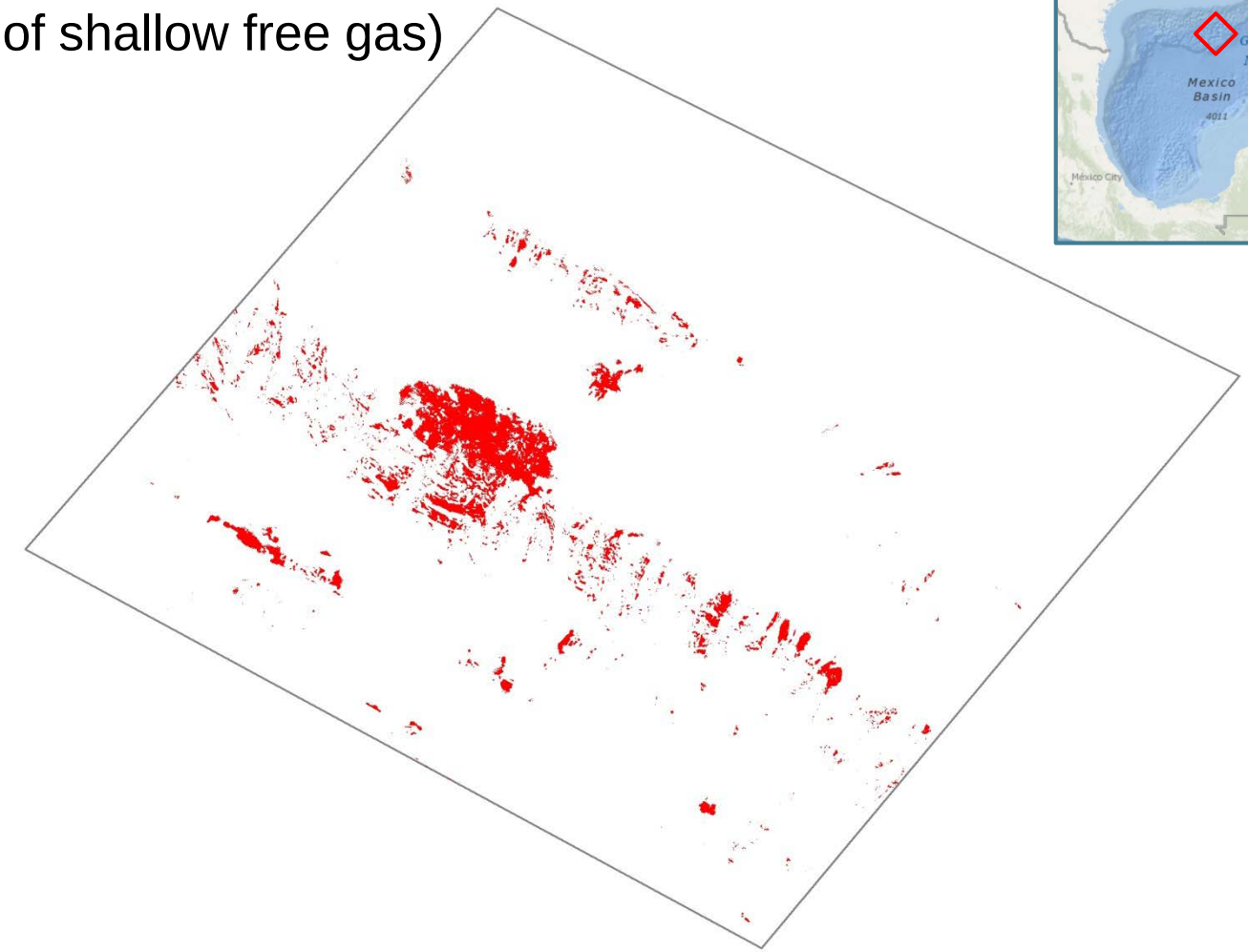
Common Approaches to Favorability Mapping

Map Production

- Prior to map creation, hazards are identified through interpretation of:
  - 3D/2D Seismic
  - Multibeam Bathymetry
  - Backscatter
  - Side Scan Sonar
  - Sub-bottom Profiler
- Shapefiles created showing spatial extent of each hazard
- Shapefiles are then combined or “stacked” on top of one another in GIS creating a map that shows the total presence of geohazards in the pipeline or drilling site

Example Geohazard Data – Map View

High Amplitude Anomalies
(indicative of shallow free gas)

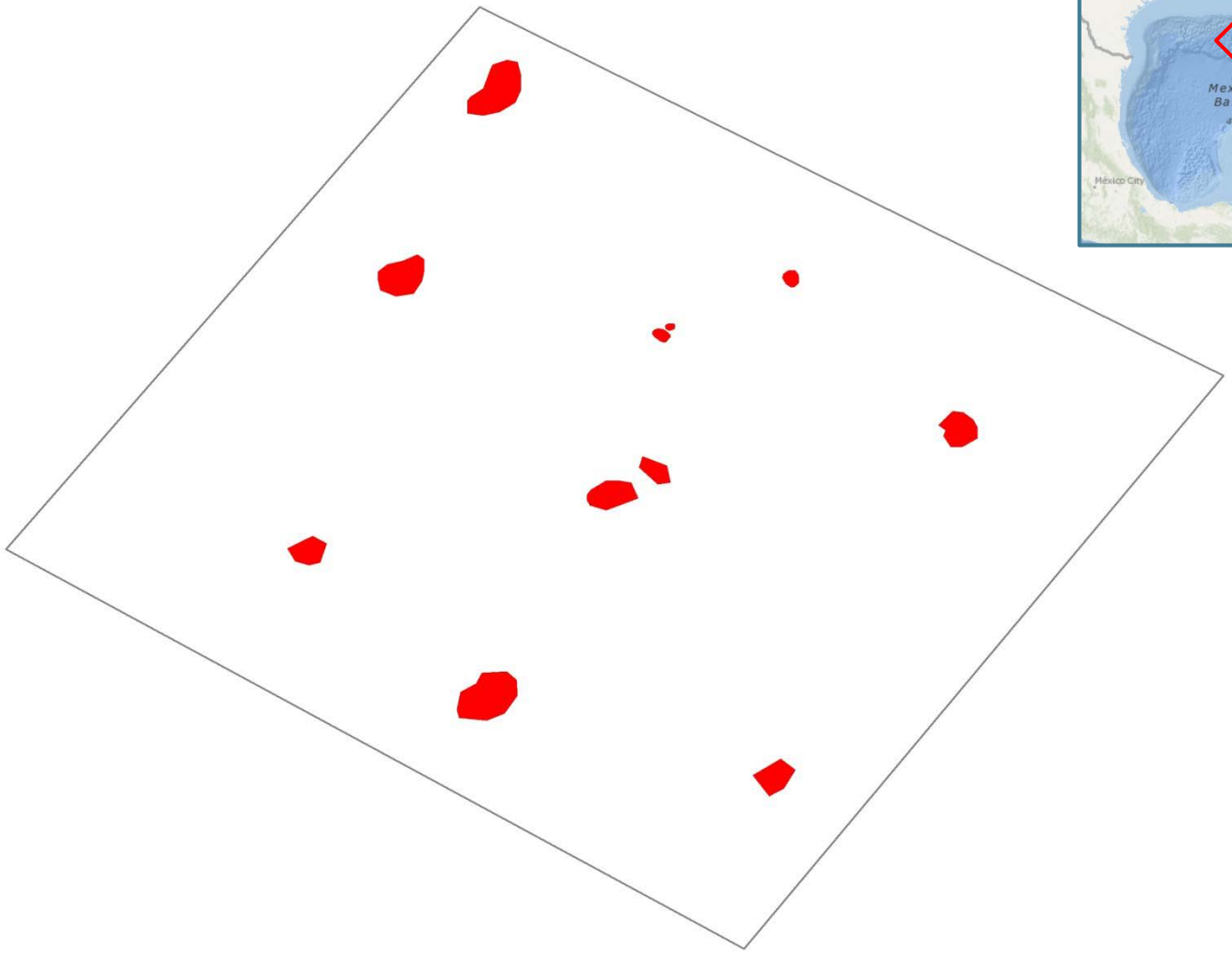


Example Geohazard Data – Map View

Seafloor Failures

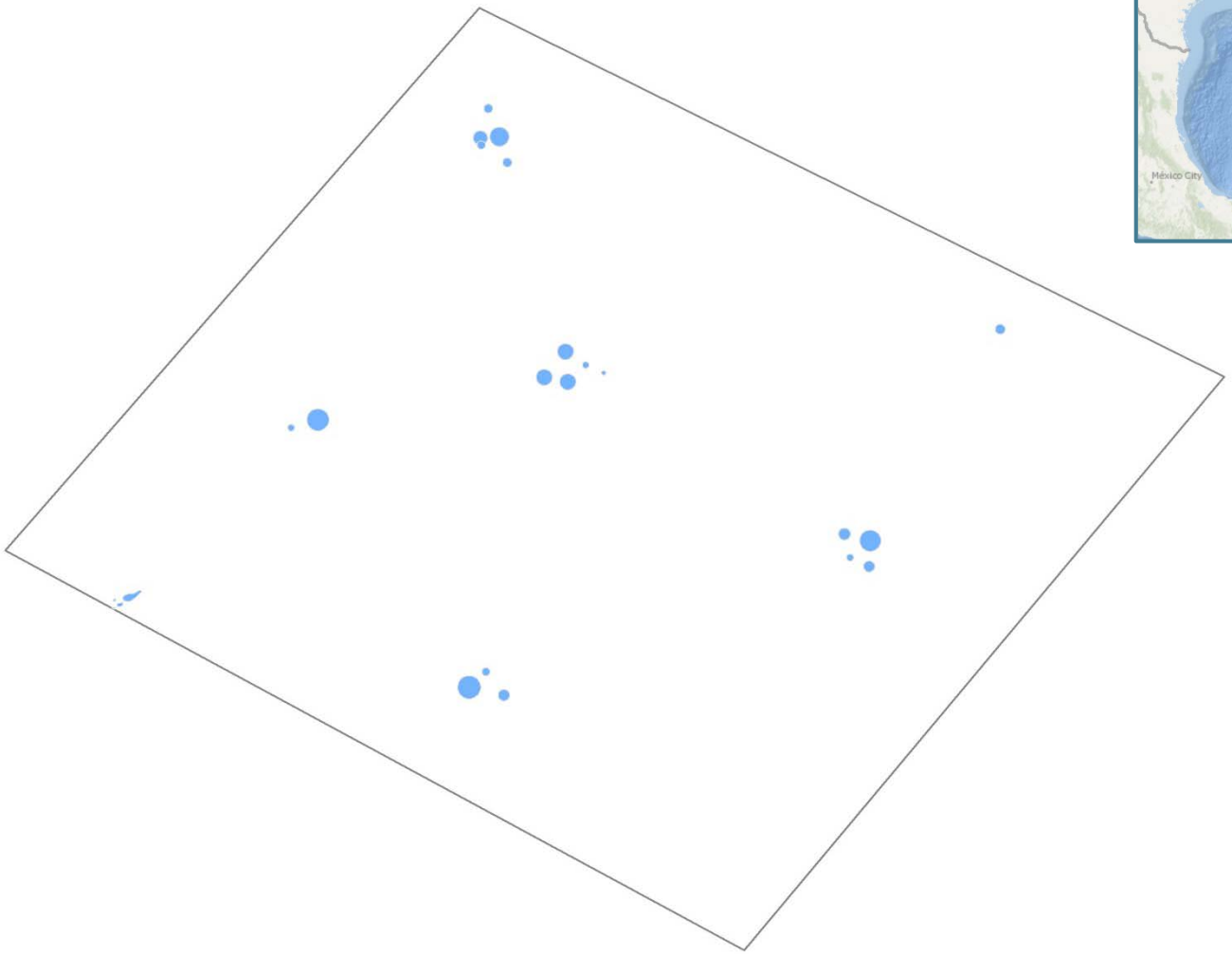
Example Geohazard Data – Map View

Gas Hydrates



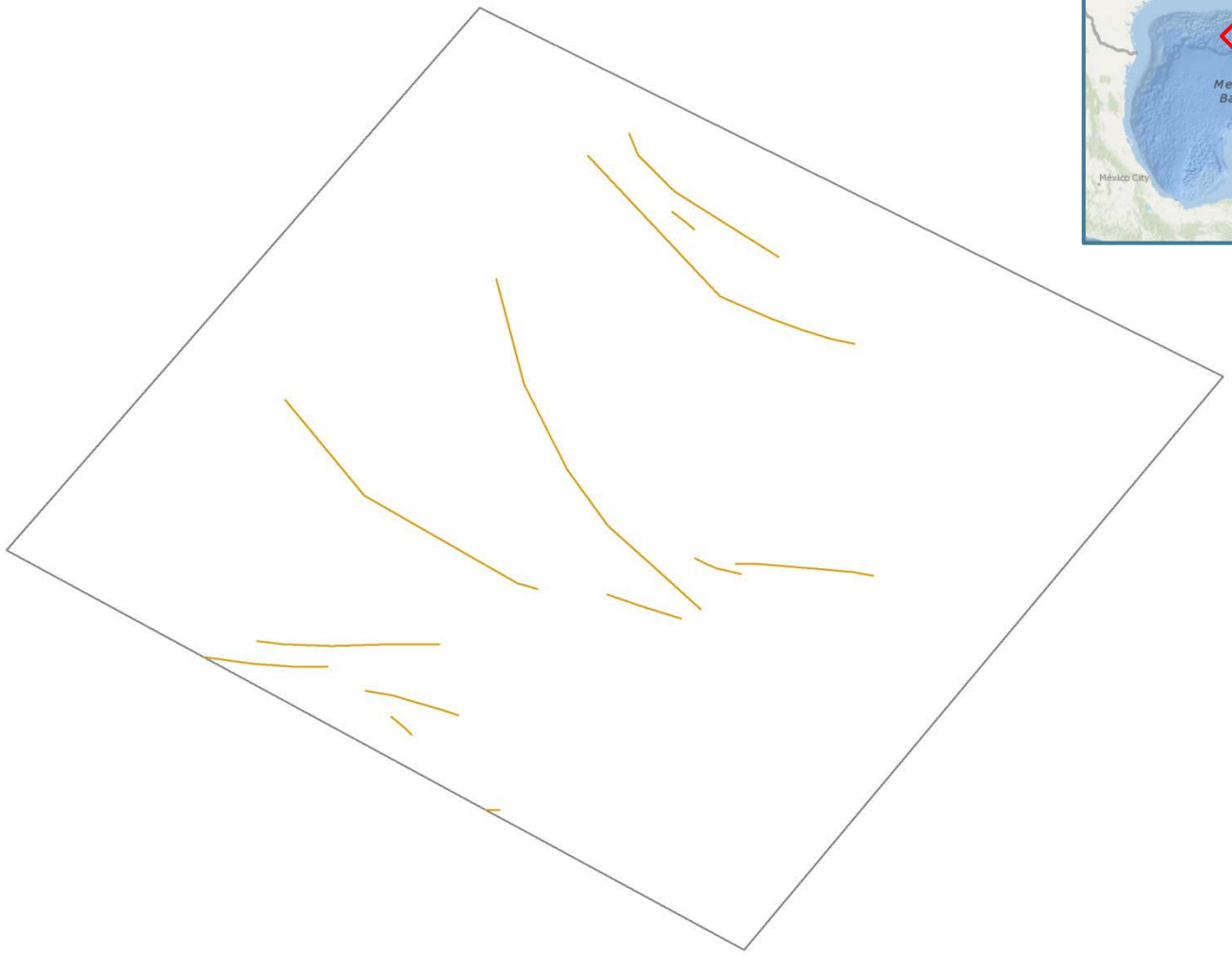
Example Geohazard Data – Map View

Pockmarks or Gas Expulsion Features



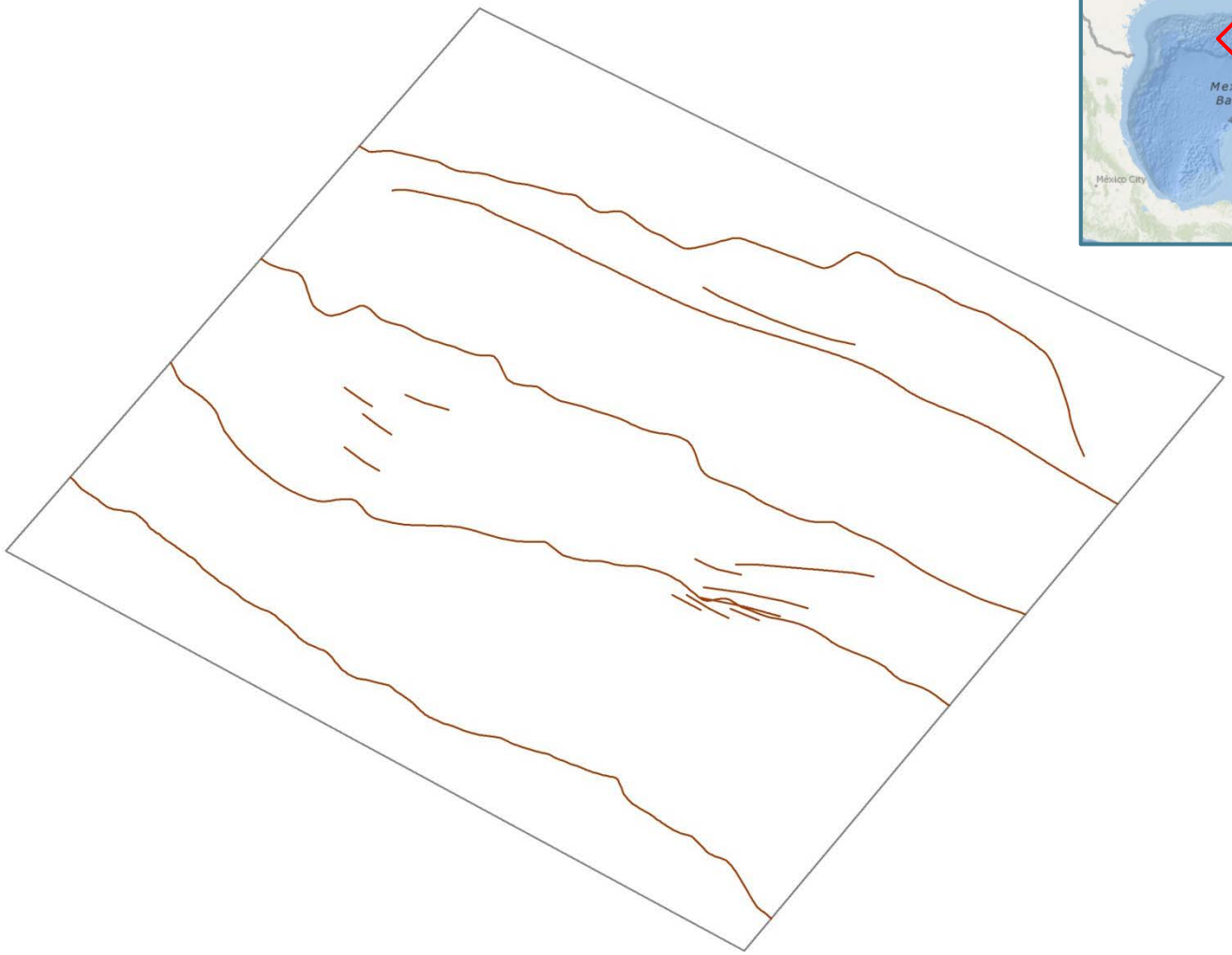
Example Geohazard Data – Map View

Sub-seafloor Faults



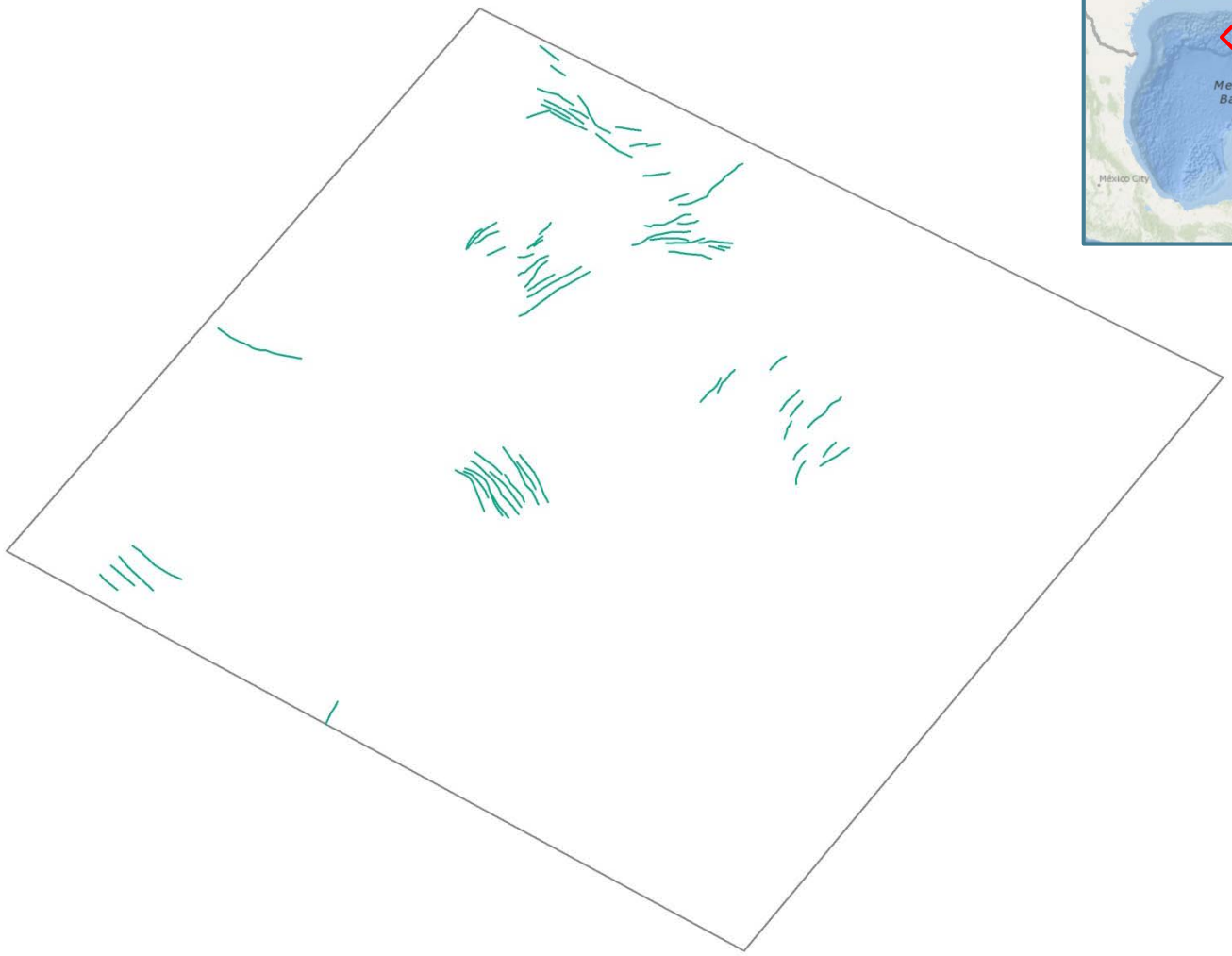
Example Geohazard Data – Map View

Seafloor Faults



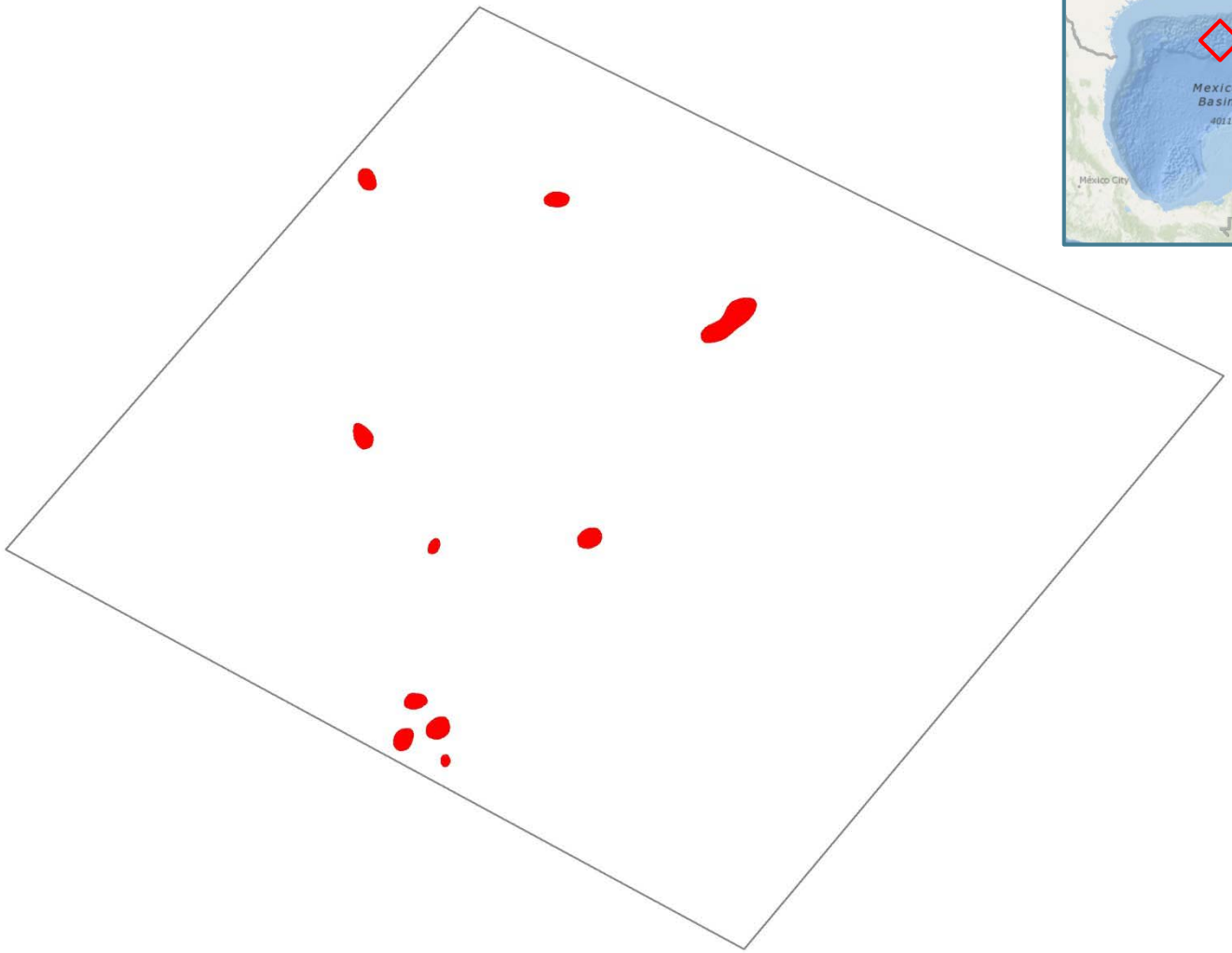
Example Geohazard Data – Map View

Headwall Scarps



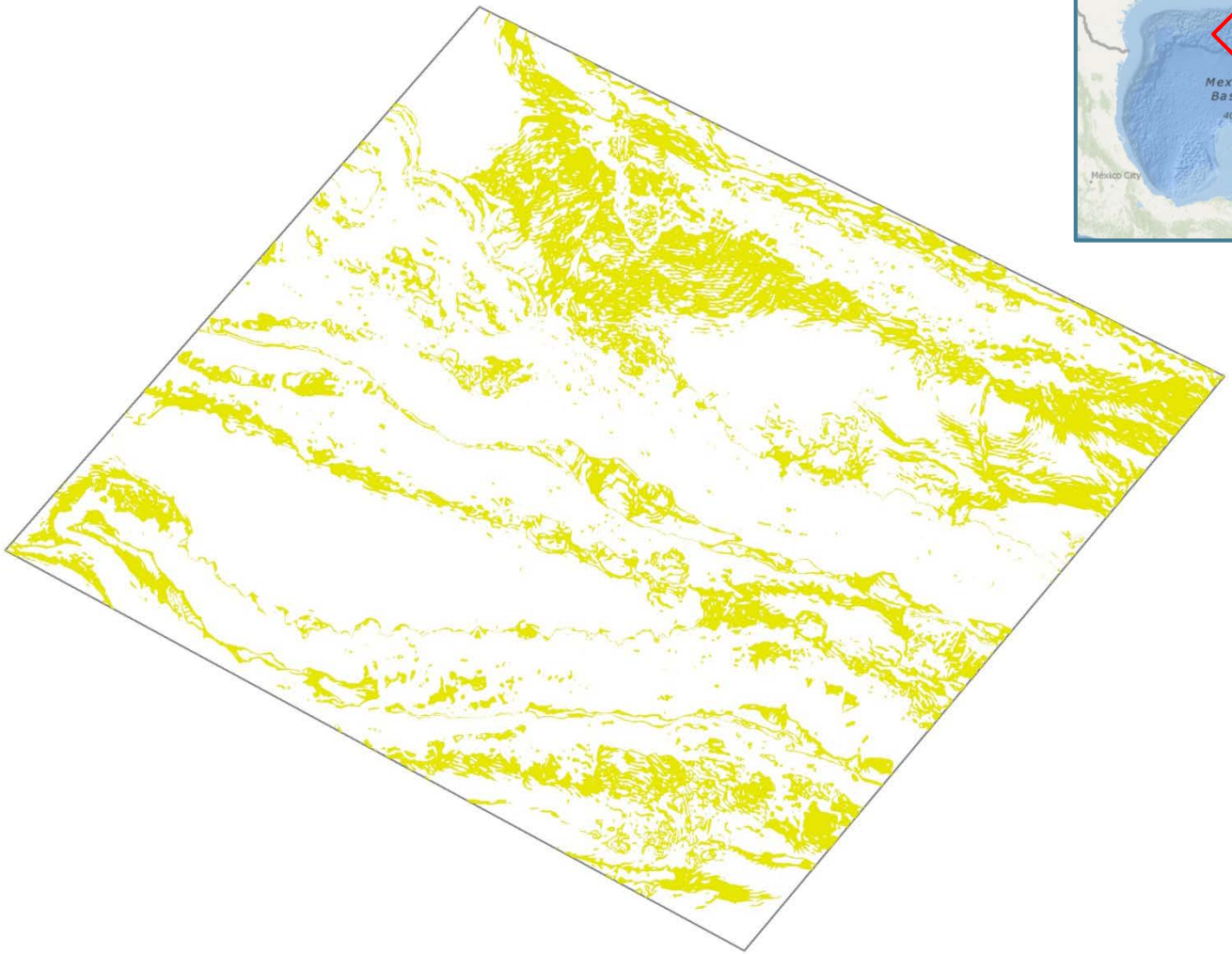
Example Geohazard Data – Map View

Buried Slump Blocks



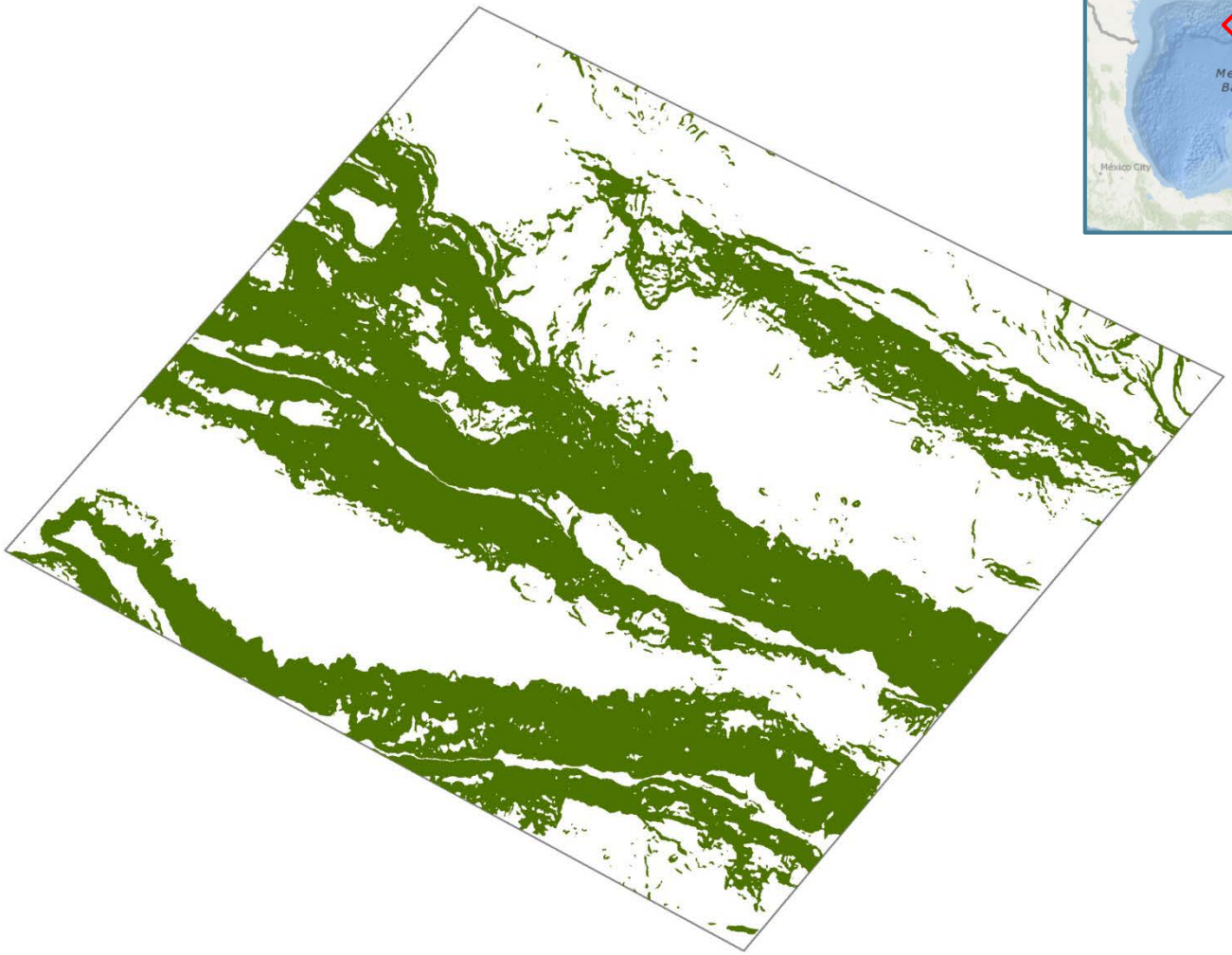
Example Geohazard Data – Map View

Moderate Seafloor Slopes (between 3 and 6°)



Example Geohazard Data – Map View

Steep Seafloor Slopes (greater than 6°)



Favorability Preparation

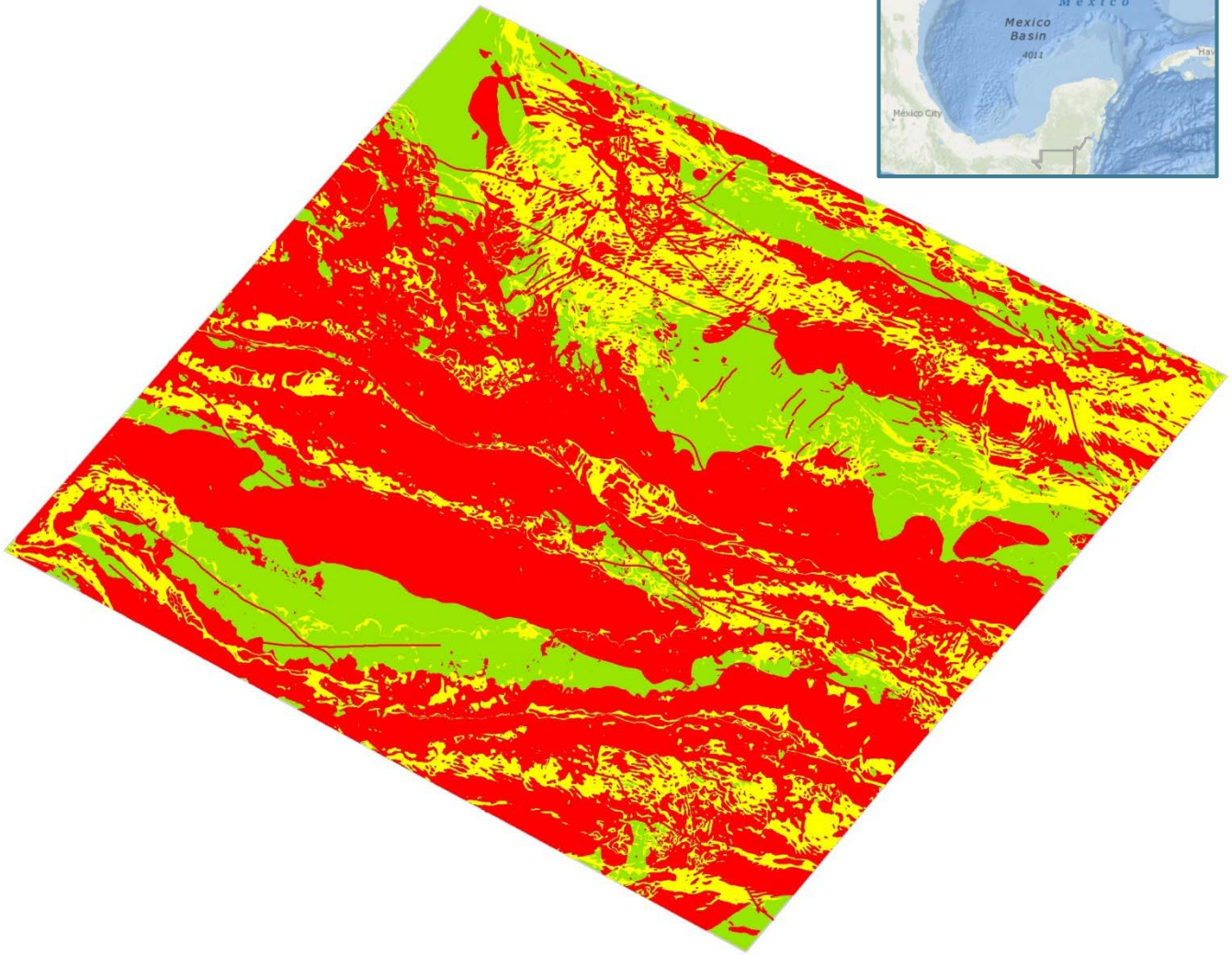
- Dan et al. (2014) detailed a rule-based system for favorability mapping and classified areas as:
  - Yellow – most favorable (gentle slopes, no hazards)
  - Orange – proceed with caution (moderate slopes)
  - Red – least favorable (steep slopes, gas, MTDs, etc.)
- In our experience, most drilling favorability maps produced today are based on similar rule-based procedures
- Typical “Stoplight” red-yellow-green color scheme

Underlying Problem

Some conditions effectively prohibit exploration or production activities (shallow gas) but other areas where less extreme level of hazards are present may be offset by other advantages. These areas are unjustifiably classified as least favorable based on current rule-based procedures.

“Stoplight” Color Scheme Map

- Traditional “Stoplight” or red-yellow-green color scheme indicating level of hazard:
  - Red = Unacceptable hazards
  - Yellow = Proceed with caution or investigate further
  - Green = No known or inferred hazards



Section 3

A Quantitative Approach to Favorability Mapping

Geohazard Weighting

- Not all geohazards are the same – there is typically a range of severity or significance that each has relative to the project objectives
- Assigning a “Geohazard Weight” or “Score” to each hazard allows subjectivity and expertise to be introduced to favorability mapping
- Weights should be developed collaboratively by an interdisciplinary team with expertise comprising:
  - Seafloor geomorphology and geohazards
  - Geotechnical and facilities engineering
  - Drilling operations
- Like Dan et al. (2014), we avoid the use of green as it implies it is acceptable to move forward with minimal caution
- Instead, we use a yellow-orange-red color scale to denote areas of increasing but still acceptable hazard risk

GIS Workflow

Geohazard Shapefiles

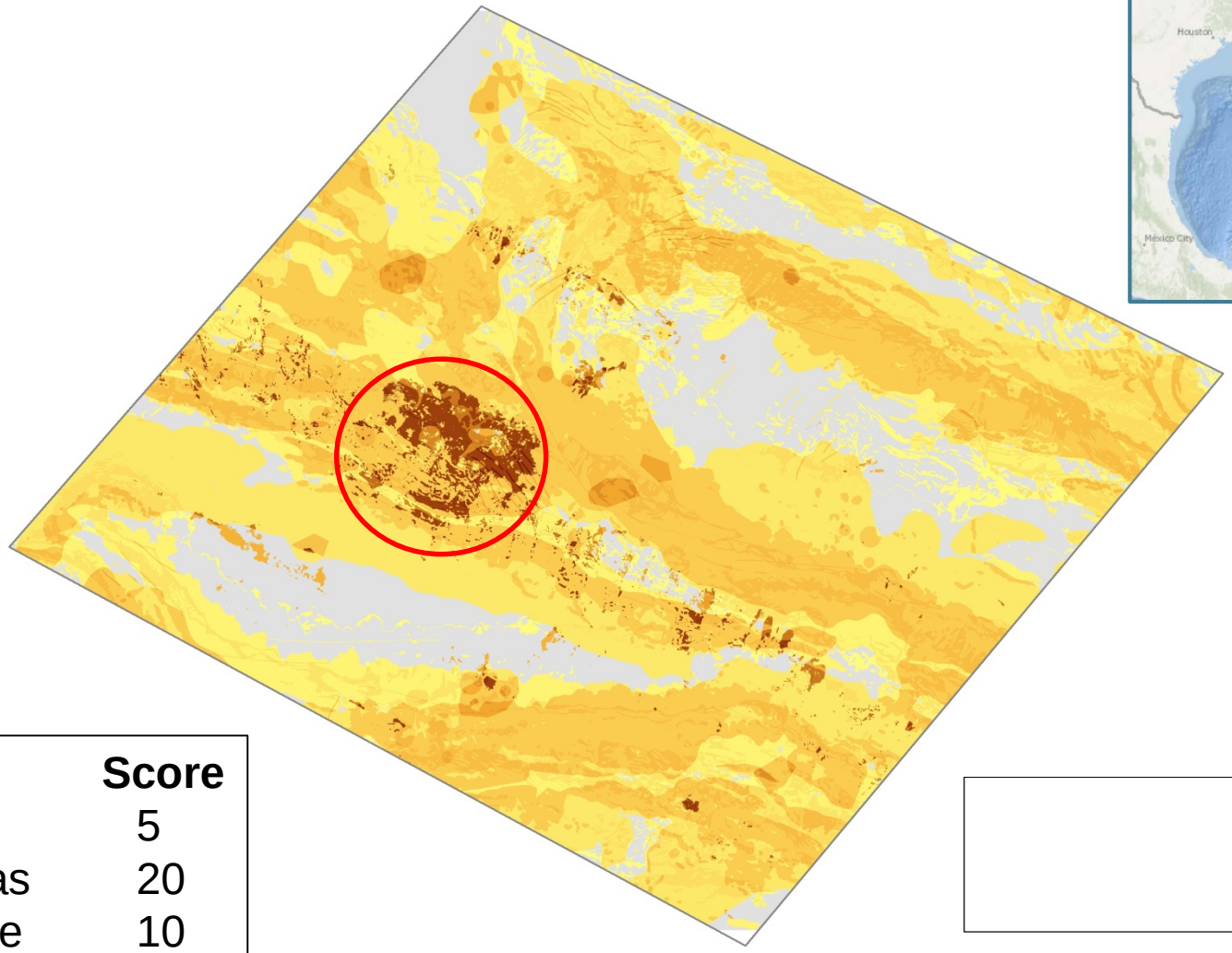
Buffer-Dissolve-SHP to Raster

Reclassify (Assign weight)

Cell Statistics (Sum overlying weights)

Symbolize Map

Weighted Favorability Map



Hazard	Score
Fault	5
Shallow Gas	20
Steep Slope	10
Pockmark	8

Python Automation

Site_Favorability_Model_Fuerte_4Sep14.py - /Users/jkelly17/Desktop/python/Site_Favorability_Model_Fuerte_4Sep14.py

```
'''*****************************************************************************
Name: Site Favorability Analysis
Author: Joshua Kelly, FGCI
*****************************************************************************'''
#-----------------------------------------------------------------
favorabilitydir =r"C:\Users\kellyj\Desktop\22Aug14\Maximino\finalcomponents"

SFgradientdir = r"C:\Users\kellyj\Desktop\test\gradients"
SFfaultsdir = r""
scarpsdir = r""
pockdir = r""
hydratedir = r""
slumpdir = r""
failuredir = r""
thrustdir = r""
SSfaultsdir = r""
fracturedir = r""
hiampdir = r""
#-----------------------------------------------------------------
valuefield = "FID"

import arcpy
from arcpy import env

arcpy.env.overwriteOuput = True

#Process SF Gradients

env.workspace = SFgradientdir + "/poly"
print "~~~~~Enter Buffer distance for SEAFLOOR GRADIENT: "
SFgradientbuffer = raw input()
files = arcpy.ListFiles("*.shp")
for file in files:
    arcpy.env.overwriteOutput = 1
    filename = file[0:-4]
    print "Buffering " + filename
    arcpy.Buffer analysis(file, SFgradientdir + "/buffer/" + filename, SFgradientbuffer, "FULL", "ROUND", "NONE", "")

arcpy.env.workspace = SFgradientdir + "/buffer"

files = arcpy.ListFiles("*.shp")
for file in files:
    filename = file[0:-4]
    print "Dissolving " + filename
    arcpy.Dissolve management(file, SFgradientdir + "/dissolve/" + filename,
                              [valuefield], "", "MULTI PART",
                              "DISSOLVE LINES")

arcpy.env.workspace = SFgradientdir + "/dissolve"

arcpy.CheckOutExtension("Spatial")
for file in arcpy.ListFiles("*.shp"):
    print "Converting " + file + " to a raster"
    inFeatures = file
    valField = "FID"
    filename = file[0:-4]
    outRaster = SFgradientdir + "/raster" + "\\" + filename + ".tif"
    assignmentType = "MAXIMUM COMBINED AREA"
    priorityField = "NONE"
    cellSize = 1
    arcpy.PolygonToRaster conversion(inFeatures, valField, outRaster,
                                     assignmentType, priorityField, cellSize)

#Process SF Faults

env.workspace = SFfaultsdir + "/poly"
print "~~~~~Enter Buffer distance for SEAFLOOR FAULTS: "
SFfaultsbuffer = raw input()
```

Ln: 1 Col: 0

- Fully automated
- Prompts user to input buffer distances and hazard scores
- Create new map in ~15 minutes

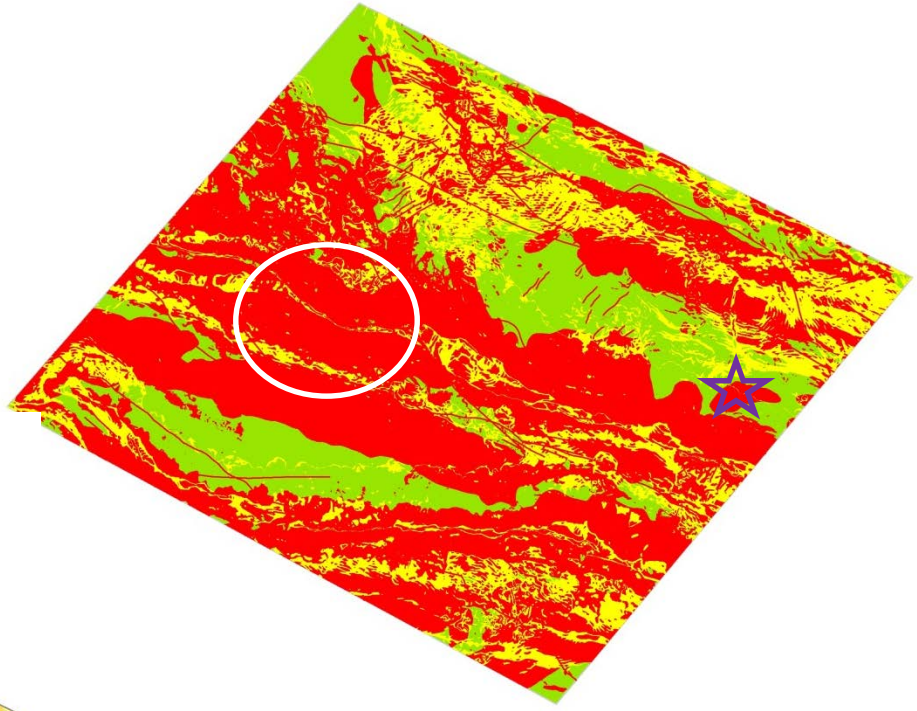
Section 4

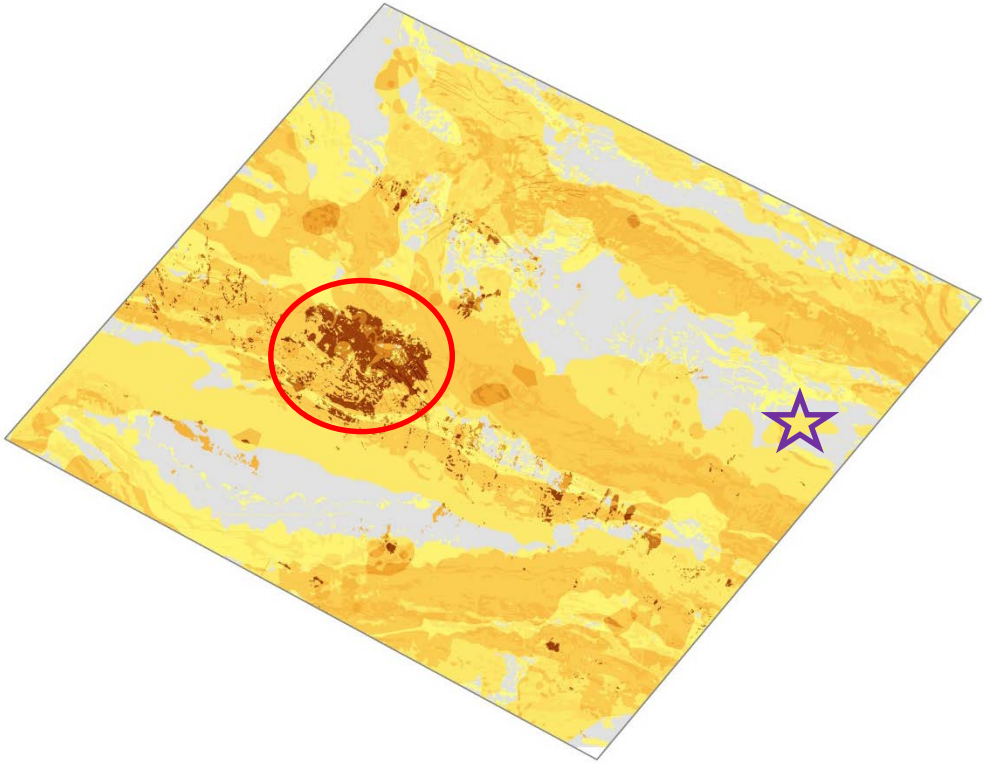
Conclusions

Comparison and Conclusions

"Stoplight" Maps

- Easy to read
- Simplified
- Commonplace

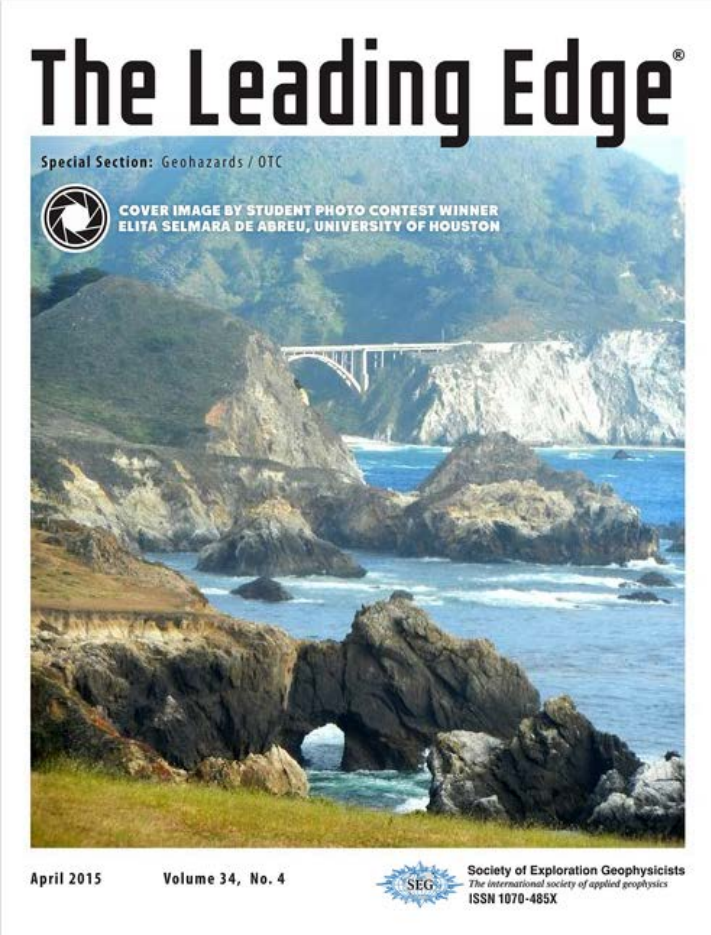




Weighted Maps

- Much greater insight
- Also easy to read
- Weights adjustable to client and consultant opinion
- Known significant hazards not lost in the classification

Questions?



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William C. Haneberg , Joshua T. Kelly , Hallie L. Graves , and Gabriela Dan (2015). **"A GIS-based decision-support approach to deepwater drilling-hazard maps."** 34(4), 398–402, 404–404.
doi: 10.1190/tle34040398.1