

Use of GIS in valuation of North America shale plays

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RYSTAD ENERGY

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Abstract

The petroleum industry in North America has experienced the shale revolution in recent years. The additional supply of natural gas has reduced U.S. natural gas prices down. North America becomes self-sufficient in natural gas, and domestic oil from shale plays may partially replace imports. Understanding the prospectivity of shale plays is critical for successful development decisions.

This paper will present an automated GIS approach for valuation of acreage of shale plays. The presented method does not attempt to replace expert geologic exploration research, but it brings rather simplified GIS valuation model, which enables to identify play fairways and relatively compare the shale play acreage.

The GIS model is based on multiple functions of ArcGIS Spatial Analyst, such as raster geo-processing, math algebra, reclassification and spatial statistics. The final valuation map is the result of a weighted combination of input raster layers (key geological parameters) represented by the score intervals.

General principles in valuation approach

- Common approach for valuation of all shale plays
 - final valuation as the result of a weighted combination of input parameters represented by the score intervals
- Key geological parameters used as the inputs
 - thickness of the play (source: isopach map or well data)
 - depth to the top of the play (source: map with depth isolines or well data)
 - thermal maturity (source: vitrinite isoreflactance* map or maps with thermal maturity zones or well data)

**The study of vitrinite reflectance is a key method for identifying the temperature history of sediments in sedimentary basins.*

Value ranges:

< 0.6%	- thermally immature;
0.6%-0.8%	- oil;
0.8%-1.3%	- wet gas (condensate);
1.3%-2.0%	- dry gas%;
>2.0%	- thermally overmature (overcooked).

- Additional parameters
 - spatial extend of varios formations within the play and their overlapping zones
 - spatial extend of geological faults
 - presence of dense urban zones
- Data sources
 - generally available maps or well data in scientific papers, governmental institutions (USGS, EIA, etc.)

Step 1: Data capture

Tools: ArcMap Editor

Step 2: Initial geo-processing

Tools: ArcMap Editor, Spatial Analyst extension

Step 3: Reclassification

Tools: ArcMap Editor, Spatial Analyst extension

Step 4: Map algebra

Tools: ArcMap Editor, Spatial Analyst extension

Step 1: Data capture

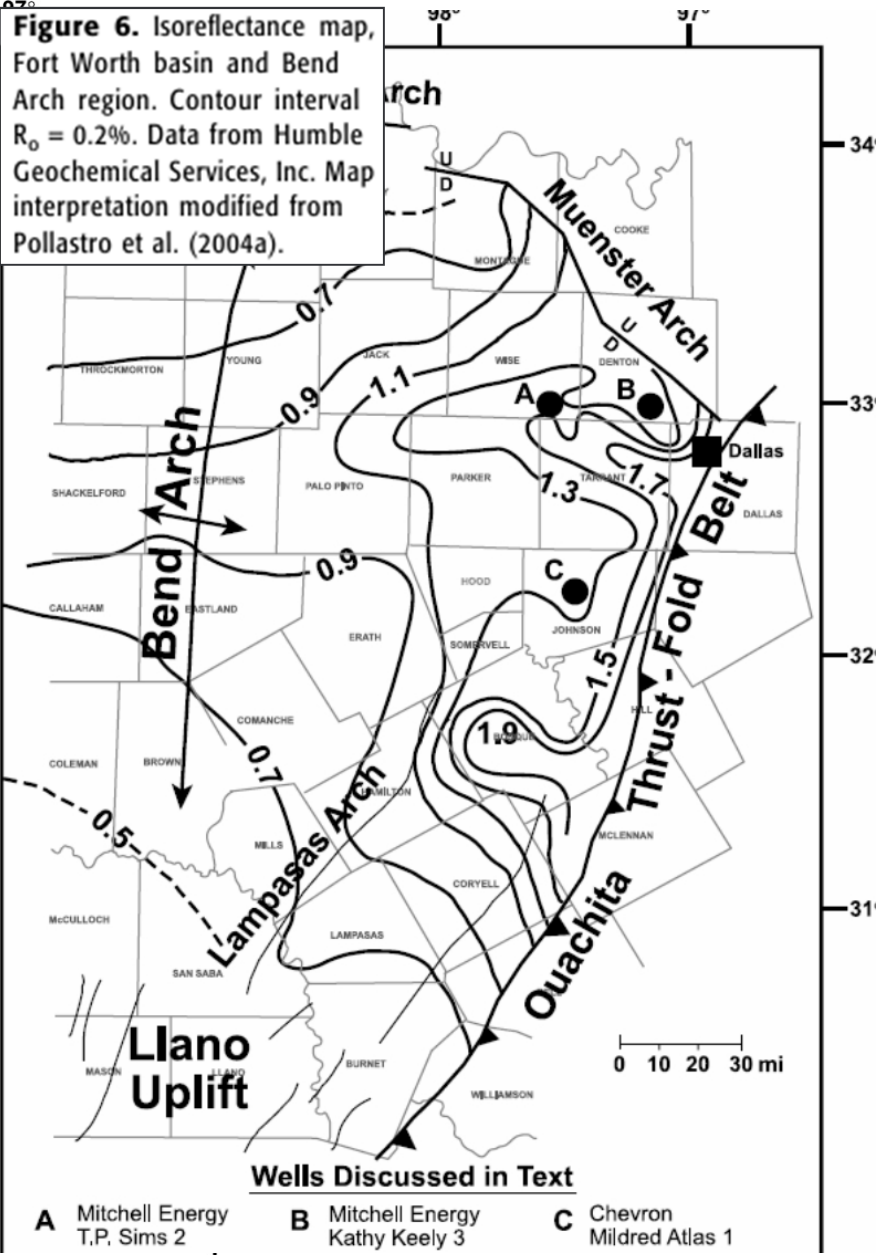
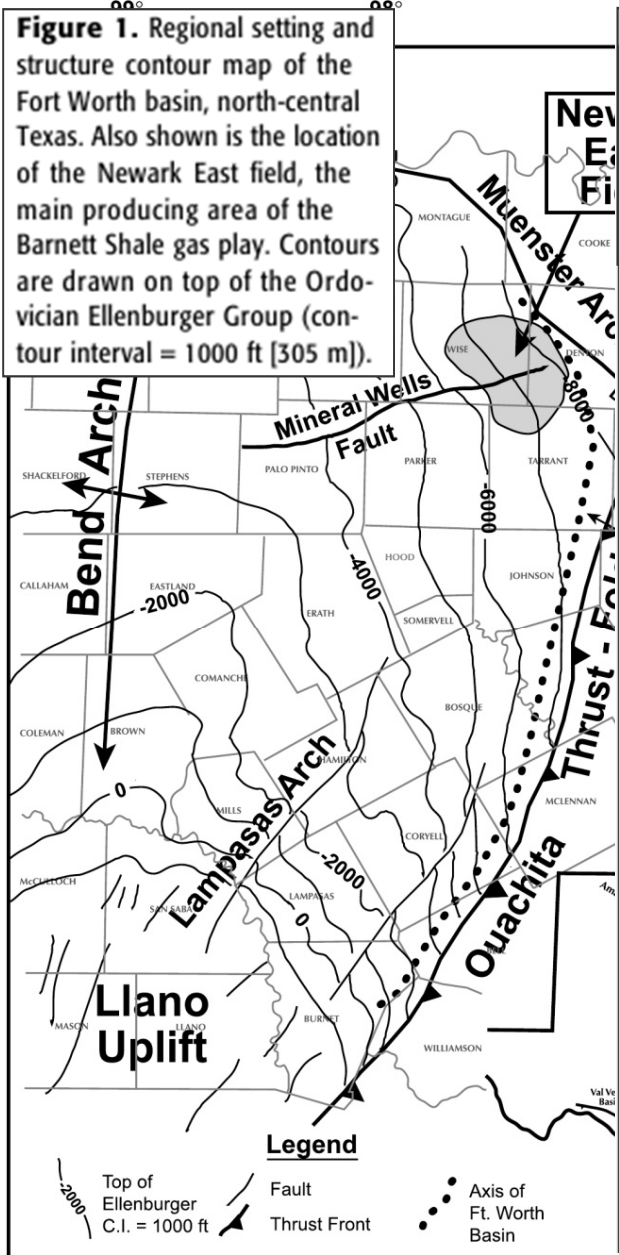
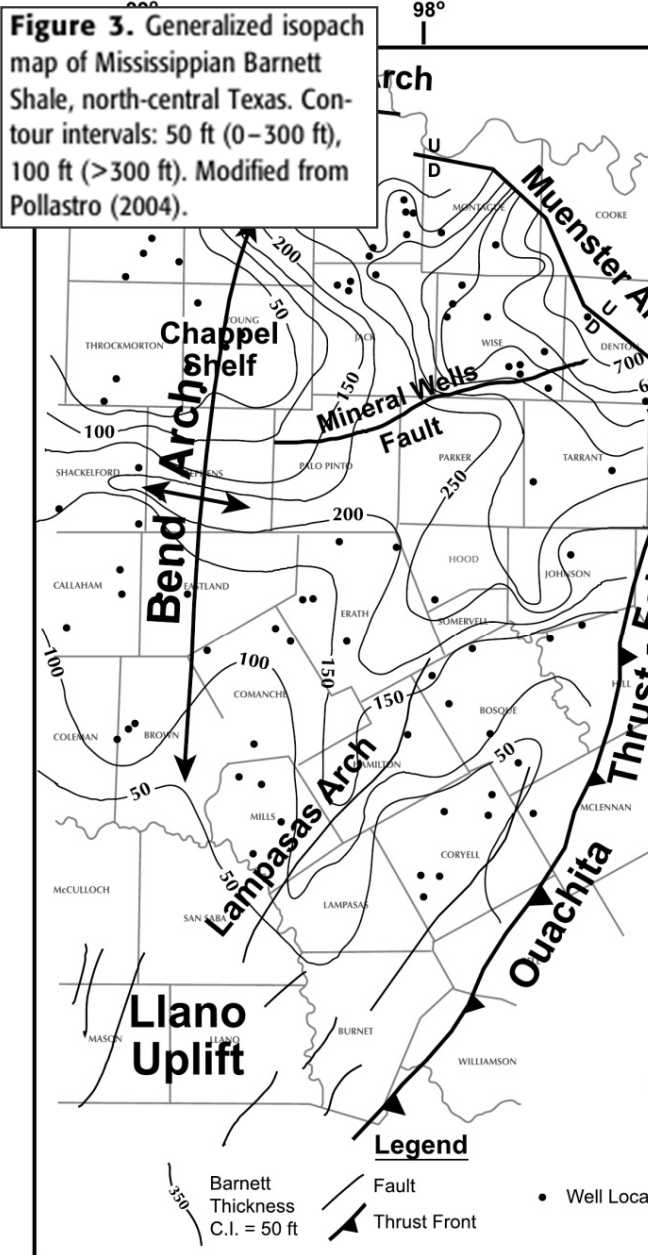
Raster map sources

- Georeferencing
 - correct geo-positioning of the source geological map
- Digitalization
 - point features with attributes (e.g. sample well locations on the map with the information about the depth to the top of a play, or total organic content (TOC), vitrinite reflectance (%Ro), etc.)
 - polyline features with attributes (e.g. isopach, depth isolines, etc.)
 - polygon features with attributes (e.g. thermal maturity windows, extend of a geologic formation, etc.)

Vector data sources

- Import/conversion
 - tabular data, CSV text files into geodatabase

Input examples: Barnett Shale play



Source: MONTGOMERY, S.L.; JARVIE, D.M. et al.: Mississippian Barnett Shale, Fort Worth basin, north-central Texas: Gas-shale play with multi-trillion cubic foot potential. AAPG Bulletin, V. 89, No. 2, 2005. PP. 155-175.

Step 2: Initial geo-processing

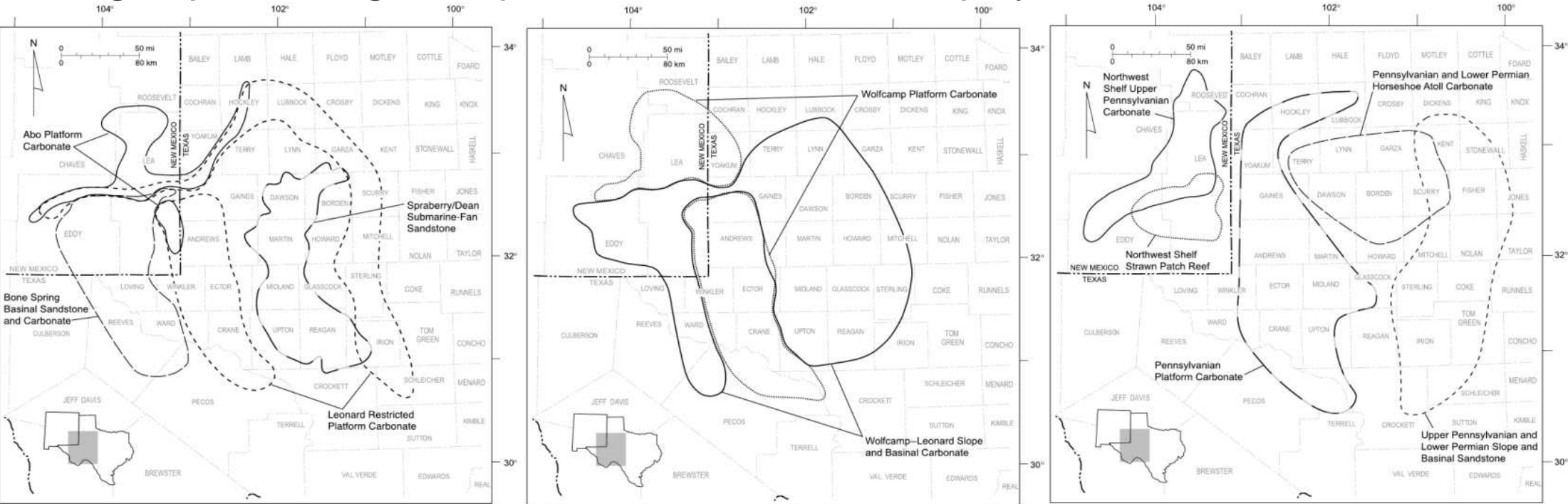
Point or linear input data

- Interpolation
 - TOPO TO RASTER or NATURAL NEIGHBOR interpolation tools
 - Input: previously digitalized point or line data
 - Output: continuous value rasters

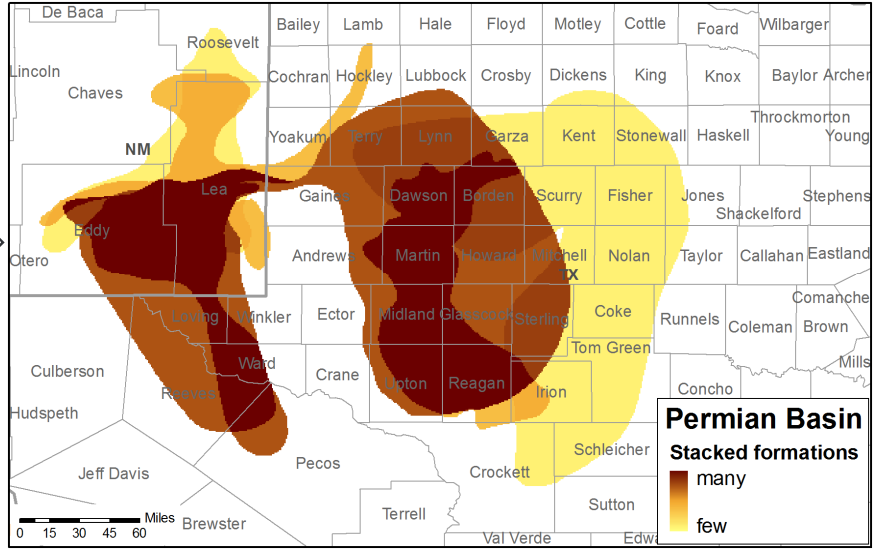
Polygon input data

- Features to raster conversion
 - Input: polygon outline of a formation, thermal maturity window area, etc.
 - Output: interval (discrete) value rasters

Initial geo-processing example: Permian basin shale plays



Polygon outlines of the selected formations converted into the rasters and overlaid together into a single discrete value raster



Source: DUTTON, S.P.; KIM, E.M.; BROADHEAD, R.F.; RAATZ, W.D.; BRETON, C.L.; RUPPEL, S.C.; KERANS, CH.: Play analysis and leading-edge oil-reservoir development methods in the Permian basin: Increased recovery through advanced technologies. AAPG Bulletin, V. 89, No. 5, 2005, PP. 553-576.

Step 3: Reclassification

- Continuous or interval raster values into the new intervals representing the score categories defined for each input raster dataset
- Score range from 5 (for the best value intervals of the input parameters) to 1 (or zero) for least suitable areas.
- Score 0 area: cut-off areas (e.g. immature, overmature, zero thickness, extremely deep play)
- Example:

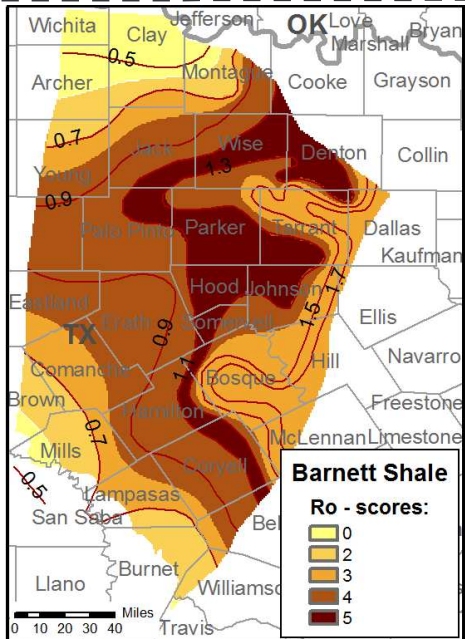
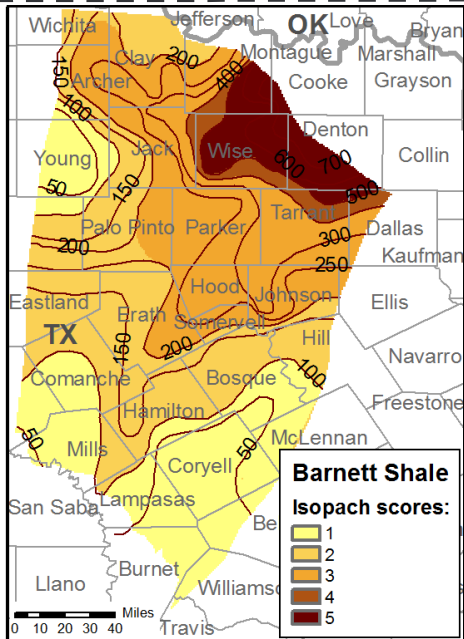
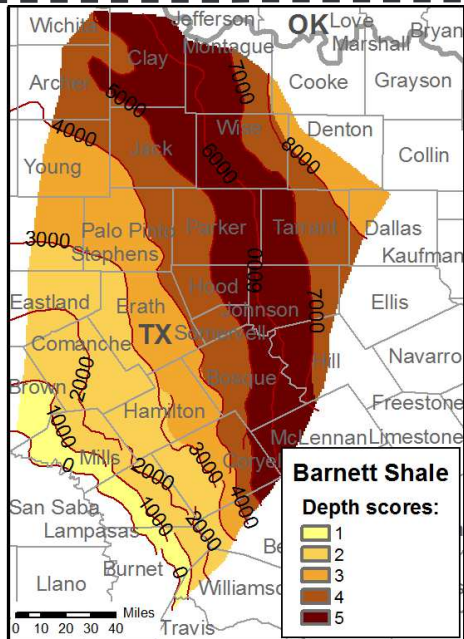
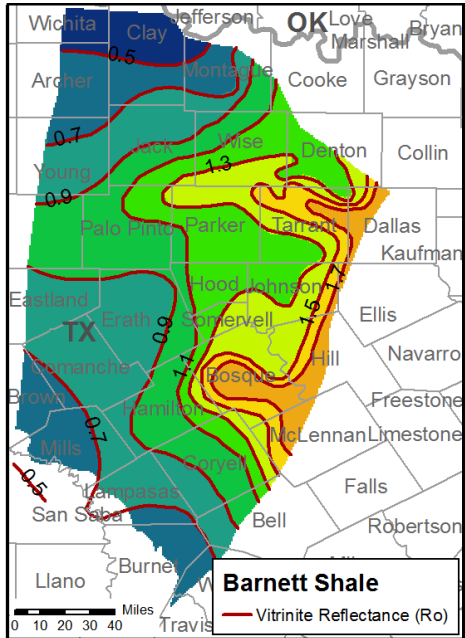
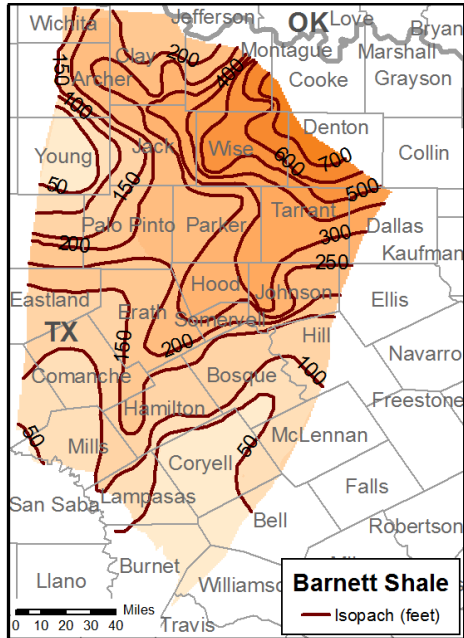
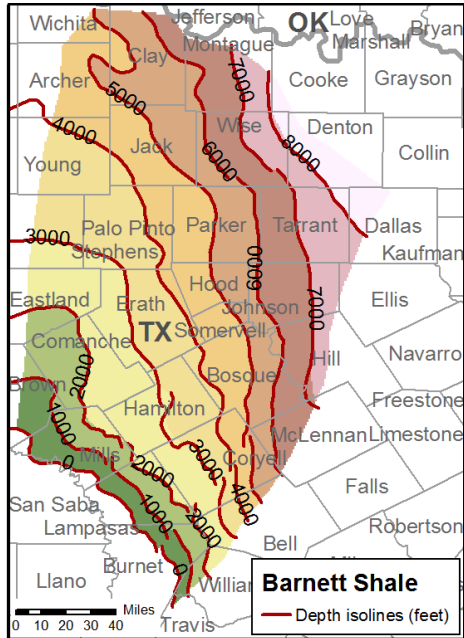
<u>Depth intervals (feet):</u>	
0 to 1,000 OR > 15,000	→ score 1
1,000 to 3,000 OR 12,000 to 15,000	→ score 2
3,000 to 4,000 OR 8,000 to 12,000	→ score 3
4,000 to 5,000 OR 7,000 to 8,000	→ score 4
5,000 to 7,000	→ score 5

<u>Thickness intervals (feet):</u>	
0 to 100	→ score 1
100 to 200	→ score 2
200 to 400	→ score 3
400 to 500	→ score 4
> 500	→ score 5

<u>Vitrinite Reflectance intervals (Ro):</u>	
0.0 to 0.6 OR > 2.0	→ score 0
0.6 to 0.7 OR 1.9 to 2.0	→ score 2
0.7 to 0.8 OR 1.4 to 1.9	→ score 3
0.8 to 1.1 OR 1.3 to 1.4	→ score 4
1.1 to 1.3	→ score 5

Reclassification examples: Barnett Shale play

Reclassification



Step 4: Map algebra

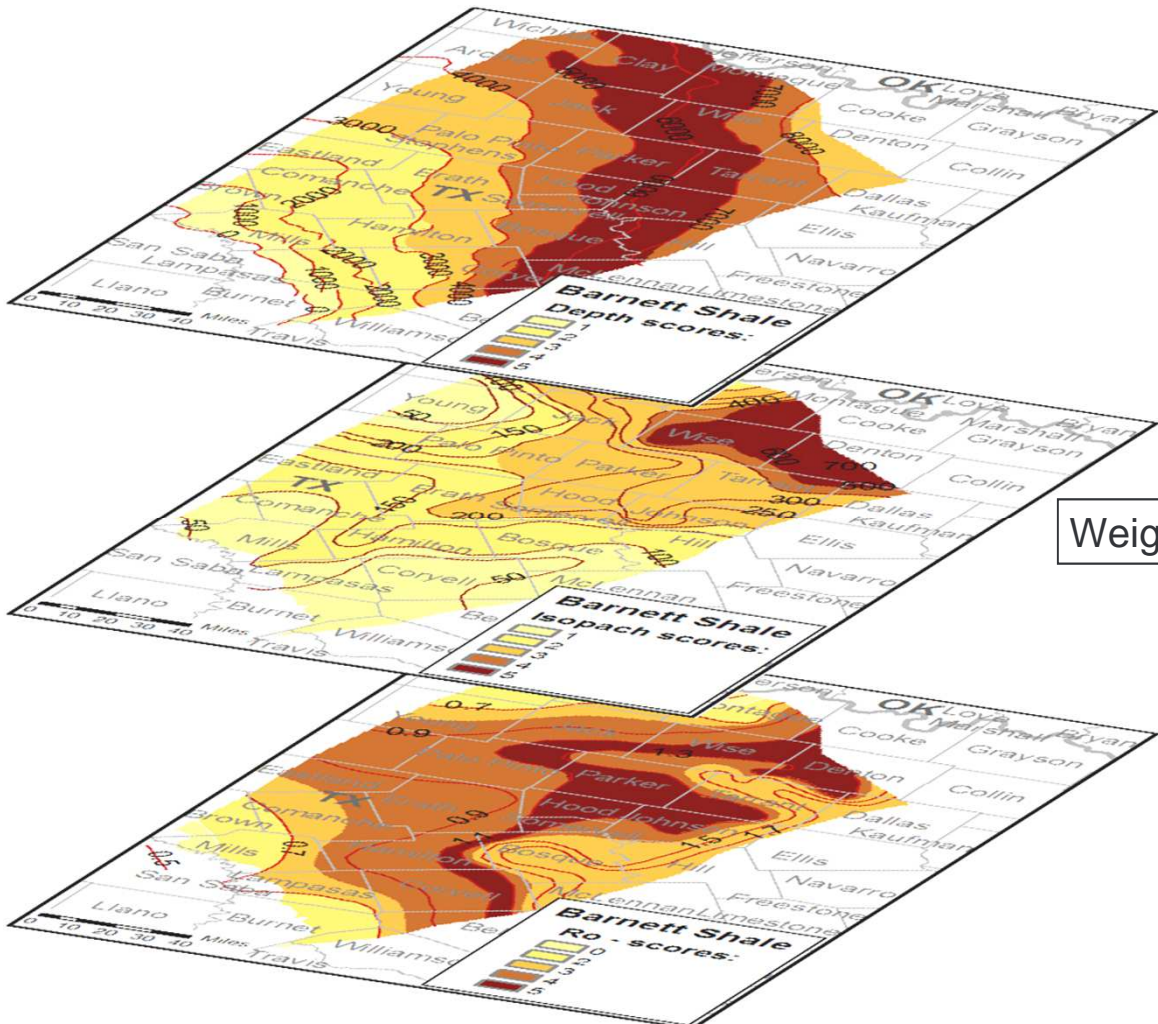
- Weighted combination of reclassified score raster datasets → valuation raster map
- Weight factors equal for all inputs or specific for certain plays
- 0 score areas (cut-off areas) must stay with 0 value

Raster calculator:

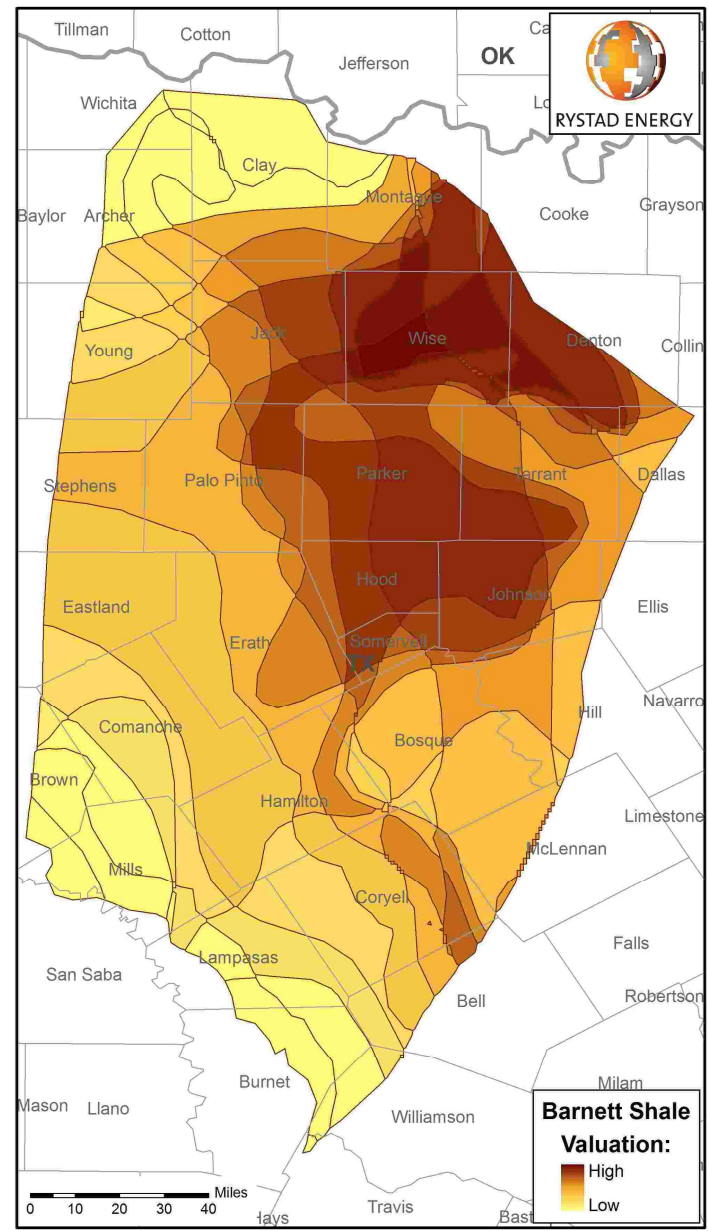
[Ro_bin] = test ([Ro_score], 'value > 0')
[Depth_bin] = test ([Depth_score], 'value > 0')
[Thickness_bin] = test ([Thickness_score], 'value > 0')

[Valuation_raster] = [Ro_bin] * [Depth_bin] * [Thickness_bin] *
* (0.33 * [Depth_score] + 0.33 * [Thickness_score] + 0.34 * [Ro_score])

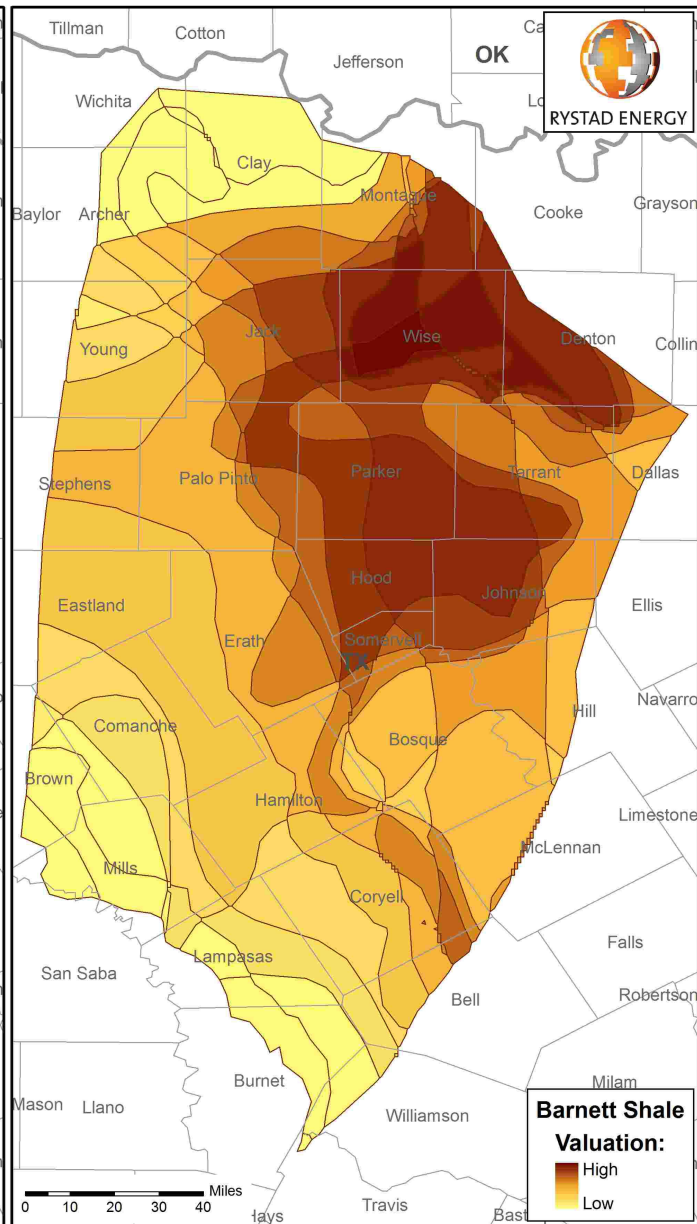
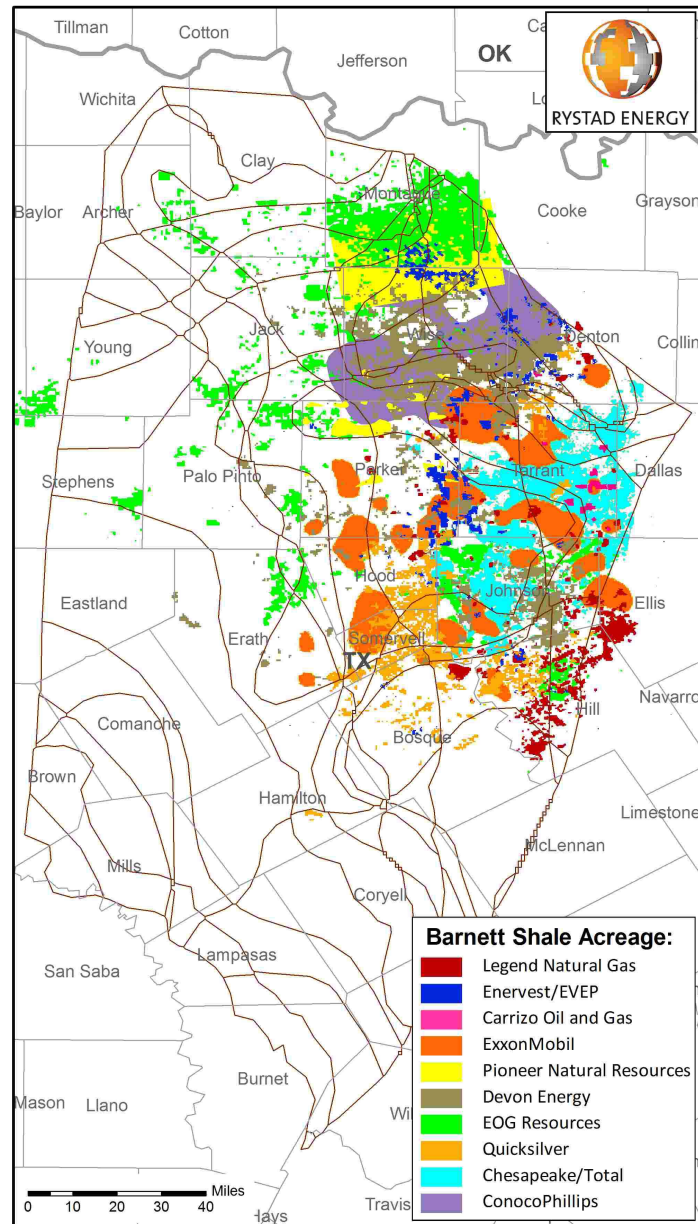
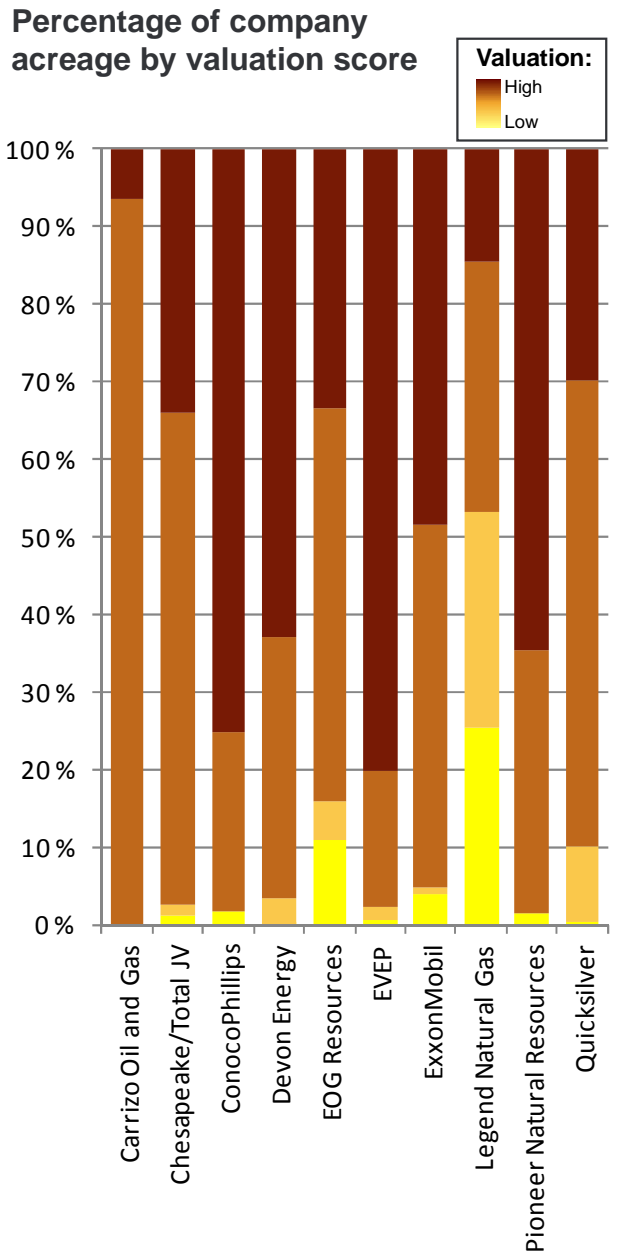
Map algebra example: Barnett Shale play



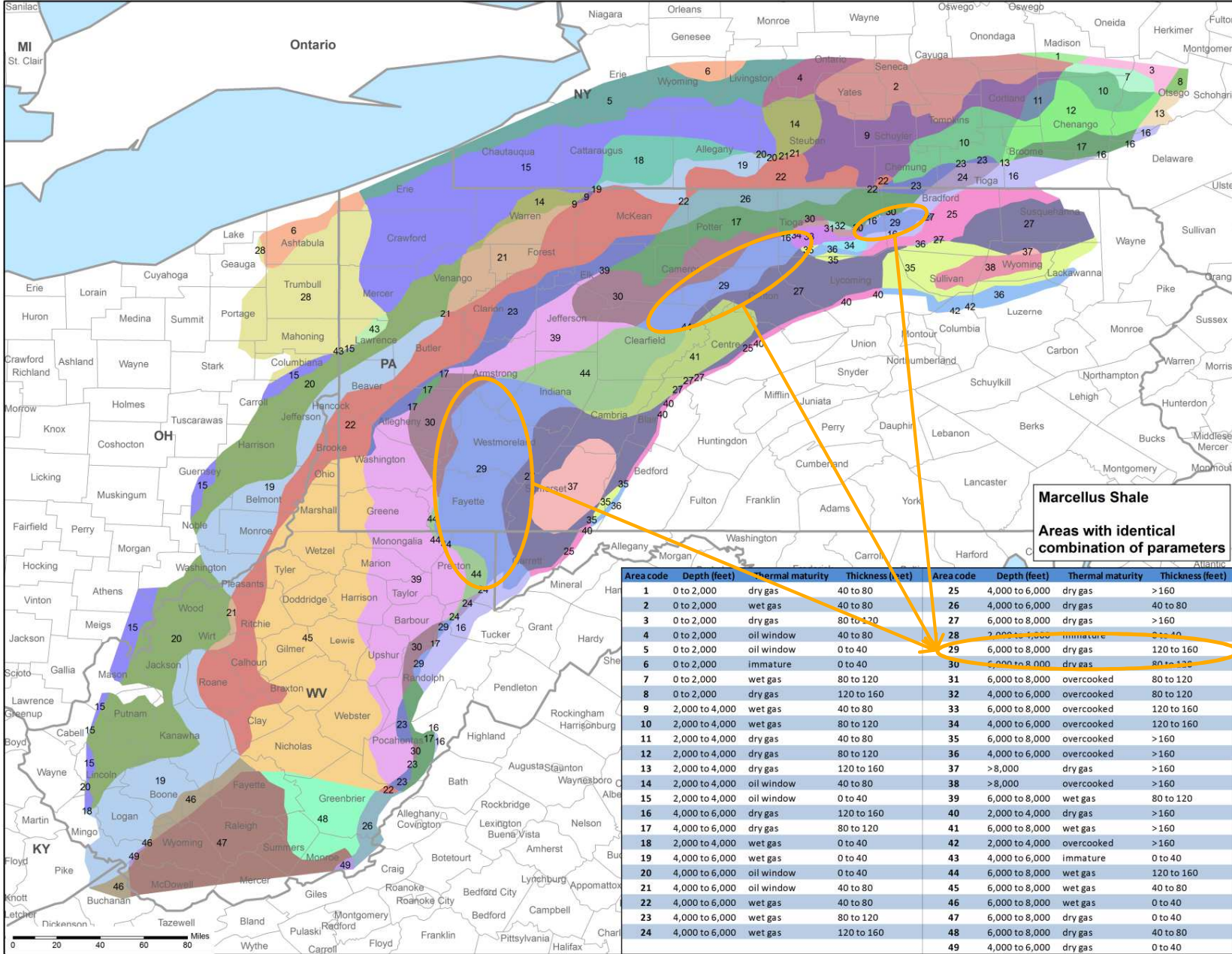
Weighted overlay



Practical application – Relative comparison of company portfolios (Barnett Shale play)



Practical application – Identification of areas with identical combination of input parameters (Marcellus Shale play)



Example:
3 distinct areas with the identical combination of input interval parameters

North American Shale Analysis

All valuation maps are part of Rystad Energy's North American Shale Analysis (**NASAnalysis**).

NASAnalysis is a range of data products on shale gas and tight oil developments in the USA and Canada. Data can be utilized to improve market analysis, investment decisions or peer group benchmarking.

More information:
<http://www.rystadenergy.com/ResearchProducts/NASAnalysis>

