GIS helps to understand prospectivity of shale plays

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Abstract

Production of oil and gas from shale and tight formations from North America has transformed the global energy landscape. Understanding the prospectivity of shale plays is critical for successful development decisions.

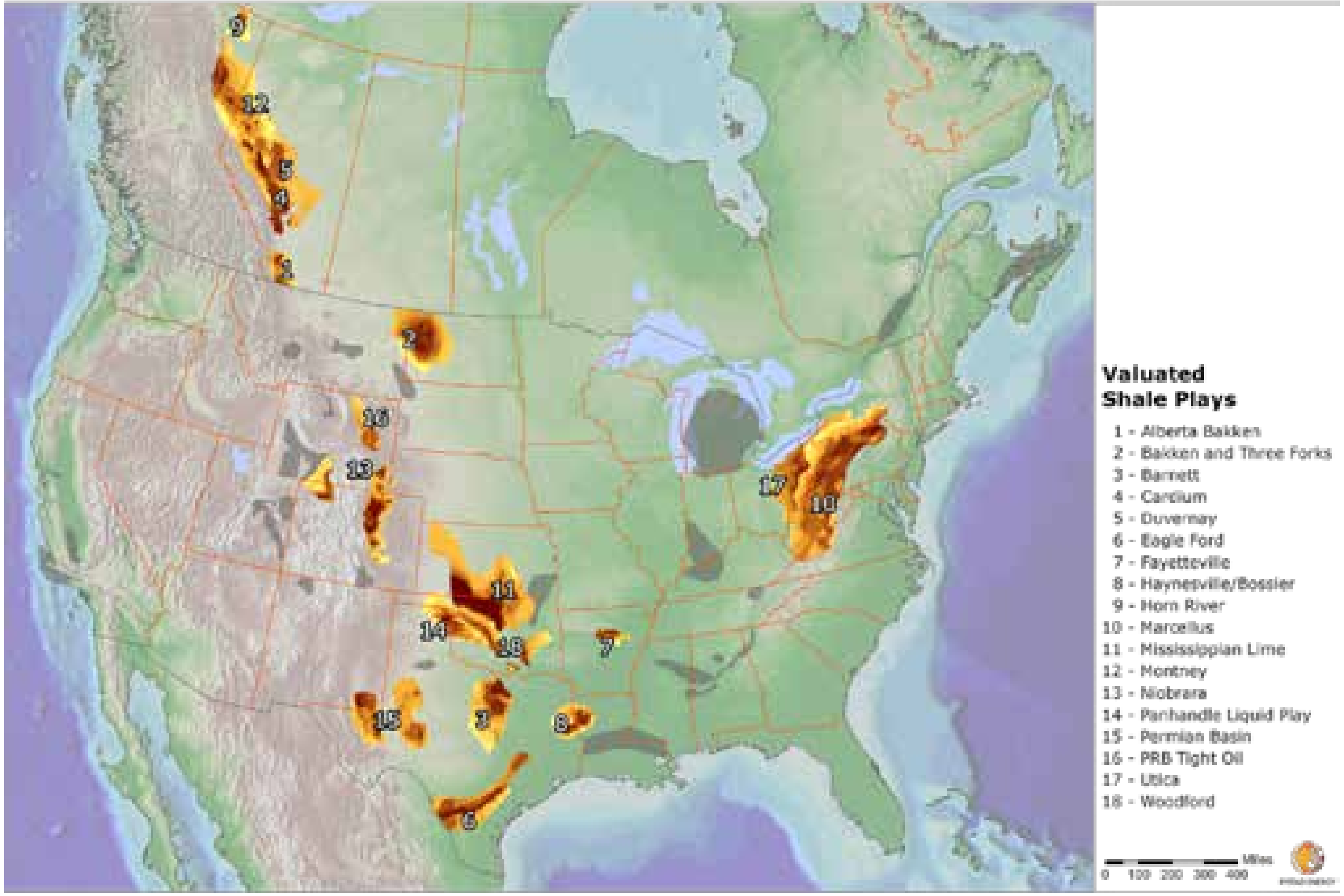
This paper will present an automated GIS approach for screening for prospective areas of shale plays globally, using the proved methodology and analogies from North America shale plays. Simplified GIS valuation model is based on multiple functions of ArcGIS Spatial Analyst.

Global prospective shale plays

Even though direct extraction of oil and gas from the source rock is currently only actively developed in America (United States, Canada and Argentina), other nations have the geological capabilities to develop shale resources, too. Rystad Energy has studied the geology and economic conditions for more than 200 known shale formations outside North America.

North America shale prospectivity

Rystad Energy developed a GIS method to estimate the prospectivity throughout the shale play.
This automated method does not attempt to replace expert geologic exploration research, but it brings rather simplified GIS valuation model, which enables relative comparison of shale play acreage. It observes variation of geological parameters across the plays and determines zones, which are more prospective than others, using the proved analogies from North America shale plays.
The GIS valuation model looks for optimal combination of key geological parameters, such as play depth, thermal maturity and thickness, in order to identify play fairways.



All US and CA prospectivity maps are part of Rystad Energy's North American Shale Analysis (NASAnalysis).
More information: http://www.rystadenergy.com/ ResearchProducts/NASAnalysis

General principles in valuation approach (shale prospectivity model)

General principles

§ Common approach for valuation of all shale plays

– final valuation (play prospectivity) as the result of a weighted combination of input parameters represented by the score intervals

§ Key geological parameters used as 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
– Total organic carbon (TOC)

§ Data sources

– generally available maps or well data in scientific papers, governmental institutions (USGS, EIA, etc.)

Workflow

Step 1: Data capture

Step 2: Initial geo-processing

Step 3: Reclassification

Step 4: Map algebra

Tools

ArcMap Editor

Spatial Analyst extension

GIS methods and the workflow

Step 1: Data capture

Step 2: Initial geo-processing

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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, total organic carbon (TOC), or 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

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Input examples: Barnett Shale play

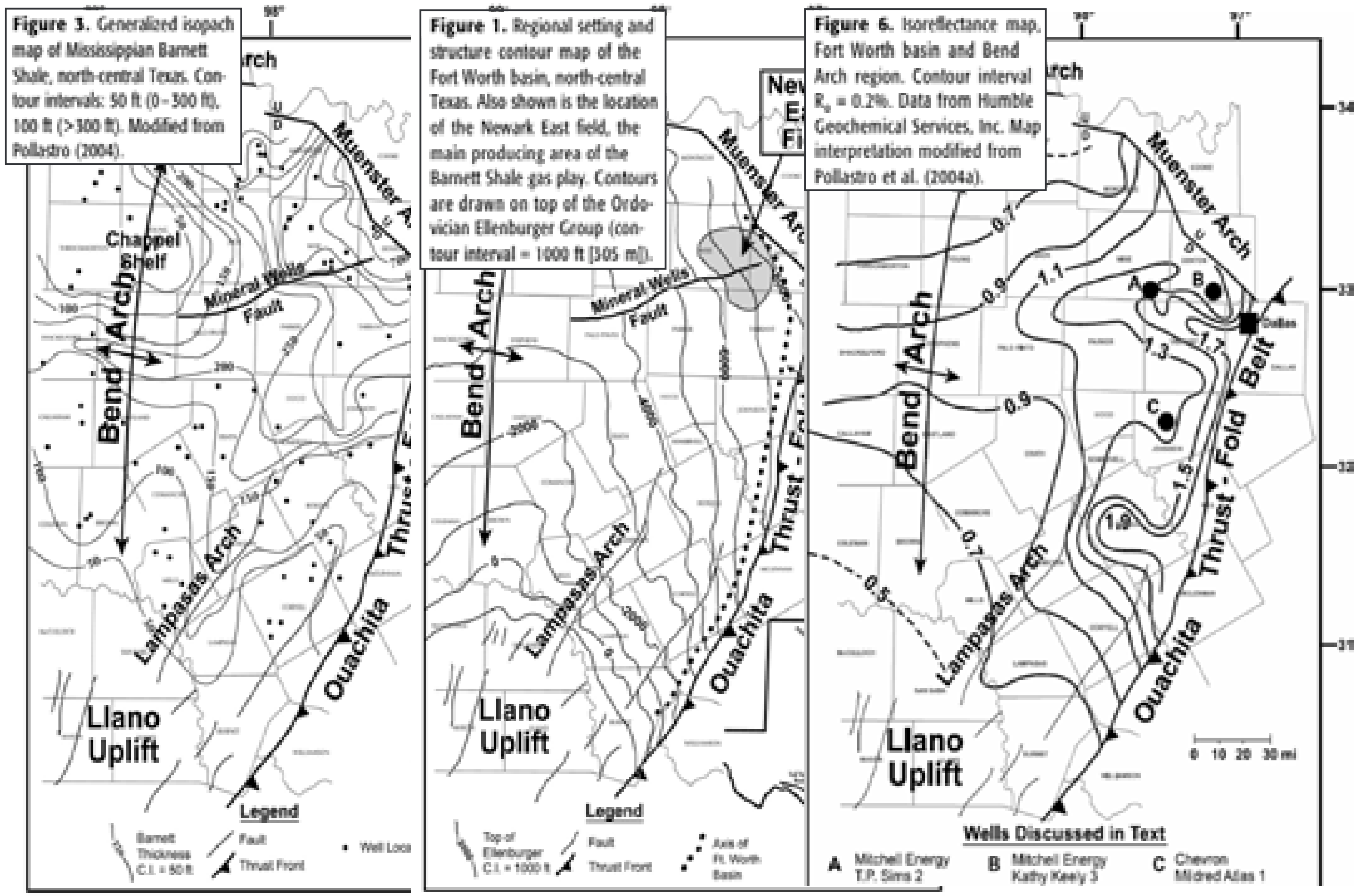

Figure 3. Generalized isopach map of Mississippian Barnett Shale, north-central Texas. Contour intervals: 50 ft (0–300 ft), 100 ft (>300 ft). Modified from Pollastro (2004).

Figure 1. Regional setting and structure contour map of the Fort Worth basin, north-central Texas. Also shown is the location of the Newark East field, the main producing area of the Barnett Shale gas play. Contours are drawn on top of the Ordovician Ellenburger Group (contour interval = 1000 ft [305 m]).

Figure 6. Isoreflectance map, Fort Worth basin and Bend Arch region. Contour interval R_o = 0.2%. Data from Humble Geochemical Services, Inc. Map interpretation modified from Pollastro et al. (2004a).

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

GIS methods and the workflow

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Point or linear input data

- Interpolation

  - TOPO TO RASTER or NATURAL NEIGHBOR interpolation tools
  - Input: previously digitalized point or line data
  - Output: continuos 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

GIS methods and the workflow

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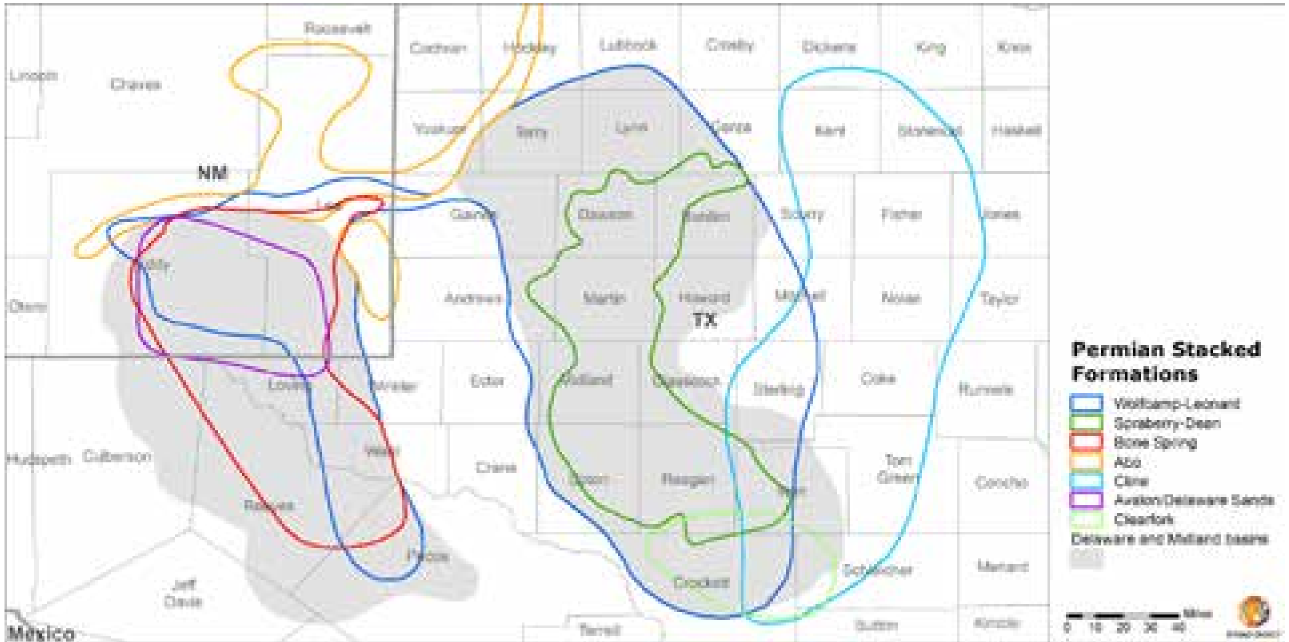
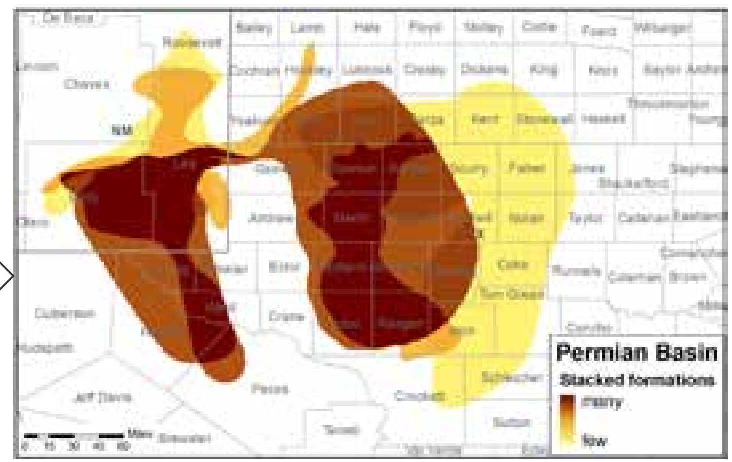
Initial geo-processing example: Permian Basin stacked formations



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



GIS methods and the workflow

Step 1: Data capture

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- Continuos 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)

GIS methods and the workflow

Step 1: Data capture

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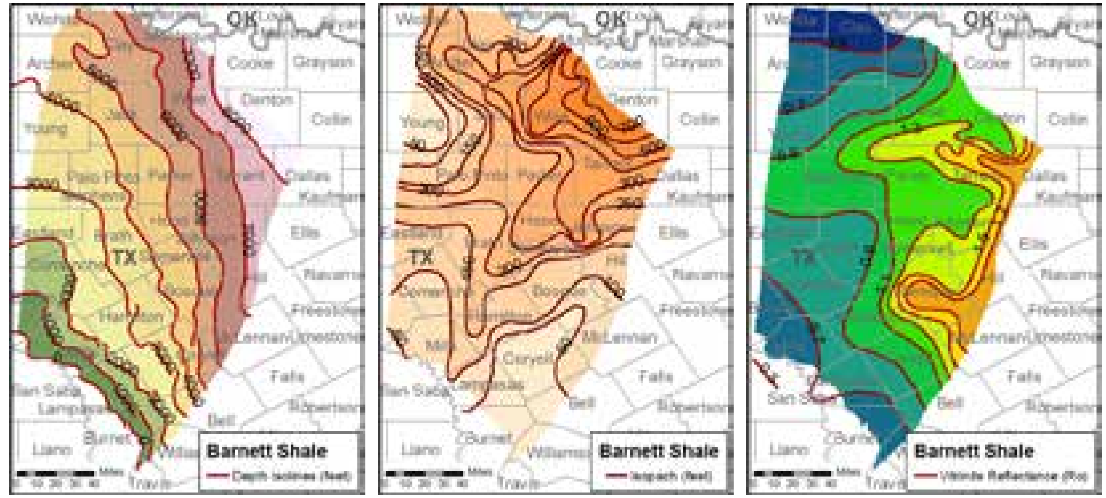
Reclassification example:
Barnett Shale play



Reclassification

Depth intervals (feet):

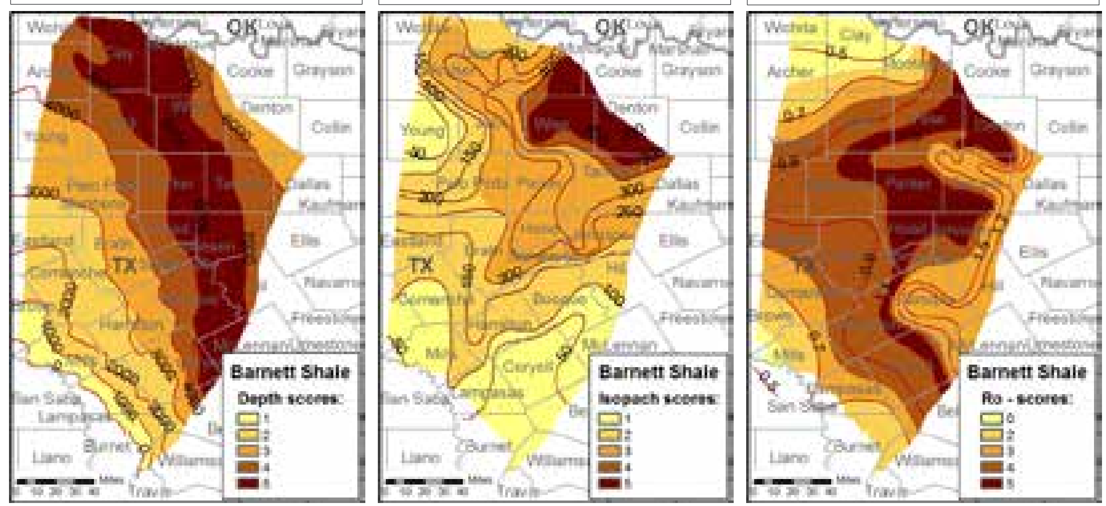
0 to 1,000 OR > 15,000	→ score 1
1,000 to 3,000 OR 12,000 to 15,000	→ score 2
3,000 to 4,000 OR 8,000 to 12,000	→ score 3
4,000 to 5,000 OR 7,000 to 8,000	→ score 4
5,000 to 7,000	→ score 5

Thickness intervals (feet):

0 to 100	→ score 1
100 to 200	→ score 2
200 to 400	→ score 3
400 to 500	→ score 4
> 500	→ score 5

Vitrinite Reflectance intervals (Ro):

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



GIS methods and the workflow

Step 1: Data capture

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- 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

<u>Raster calculator:</u>

[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])

GIS methods and the workflow

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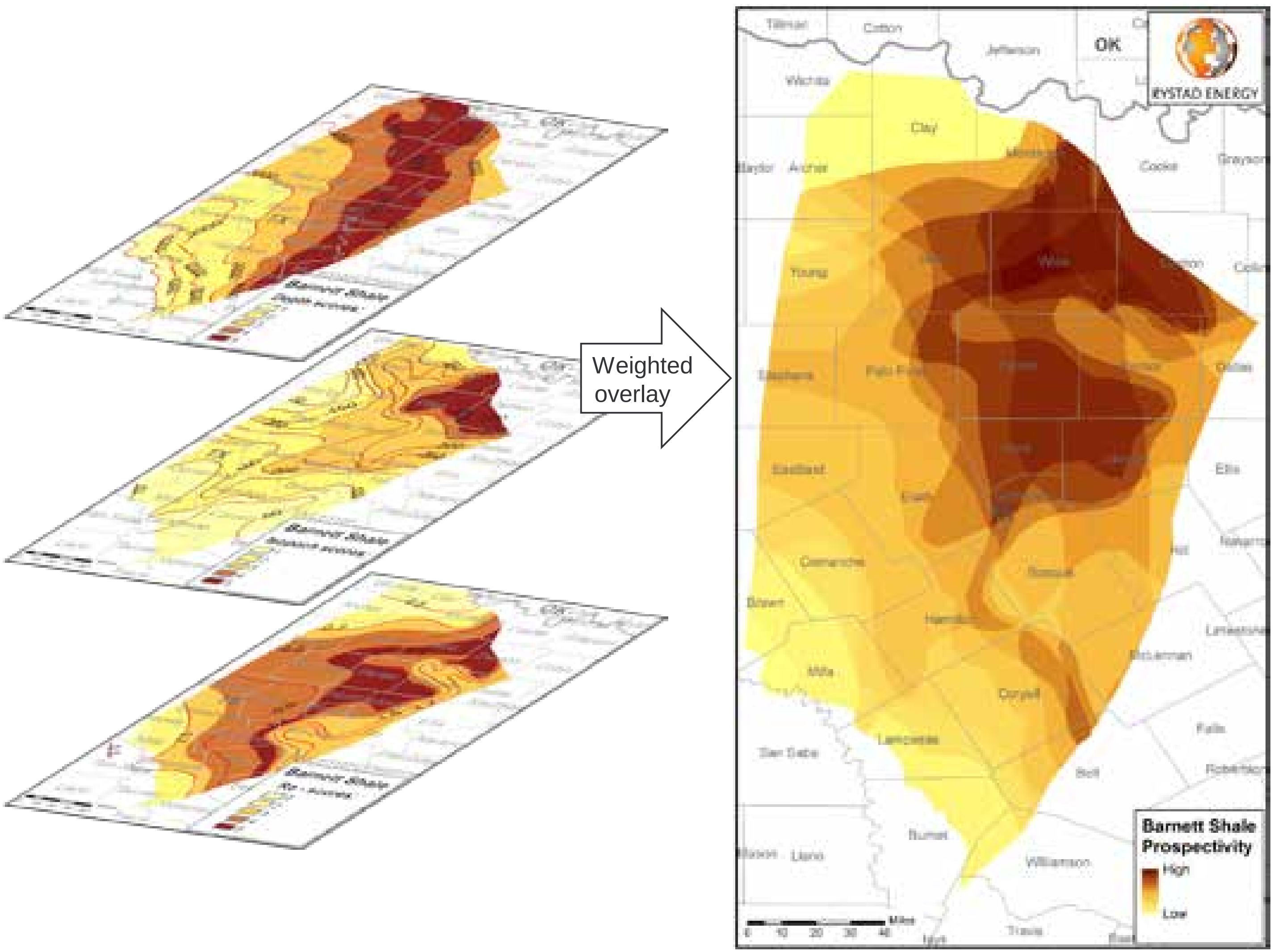
Map algebra example: Barnett Shale play

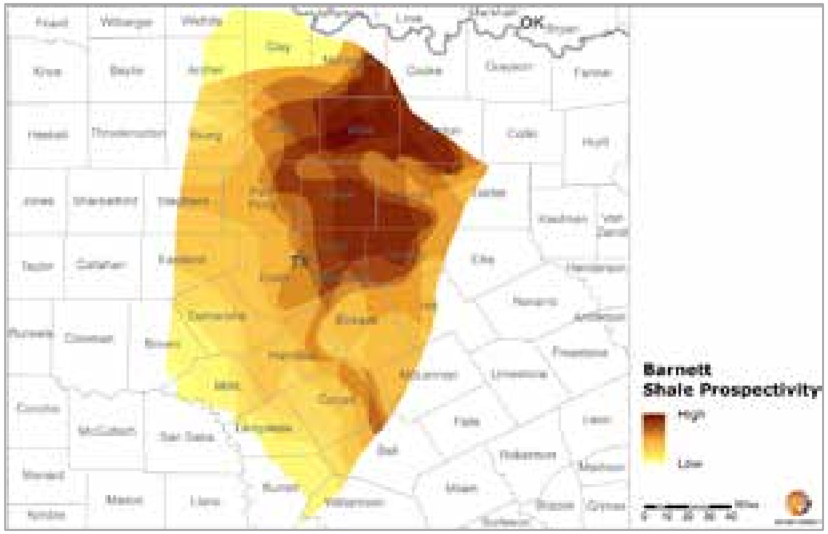


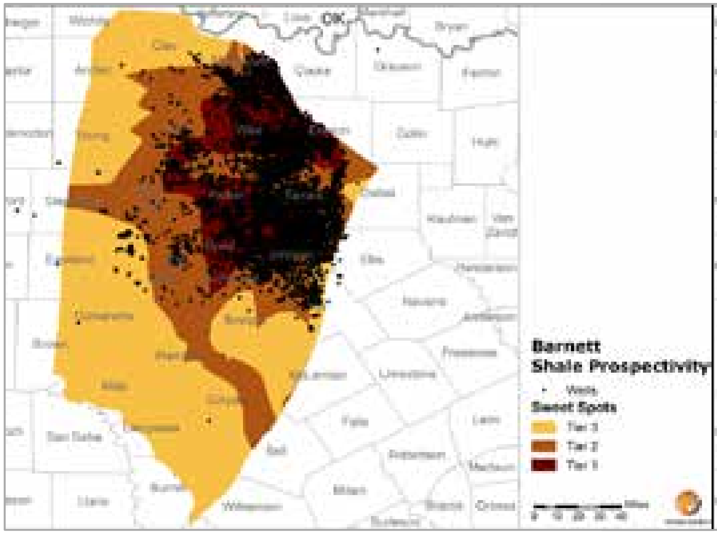
Benchmarking the result - sweet spots vs. well spacing (Barnett Shale play)

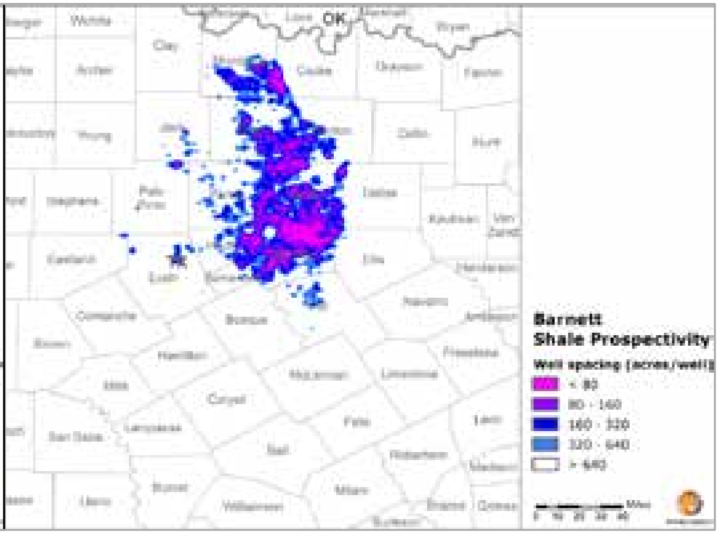
The majority of horizontal wells drilled in Barnett shale after 2010 are located in high prospectivity areas from valuation model.

Well spacing in play fairways (Tier 1, 2 and 3) is analysed by the Kernel Density tool (Special Analyst extension).

Tier	Well spacing (acres/well)
1	290
2	761
3	21,947

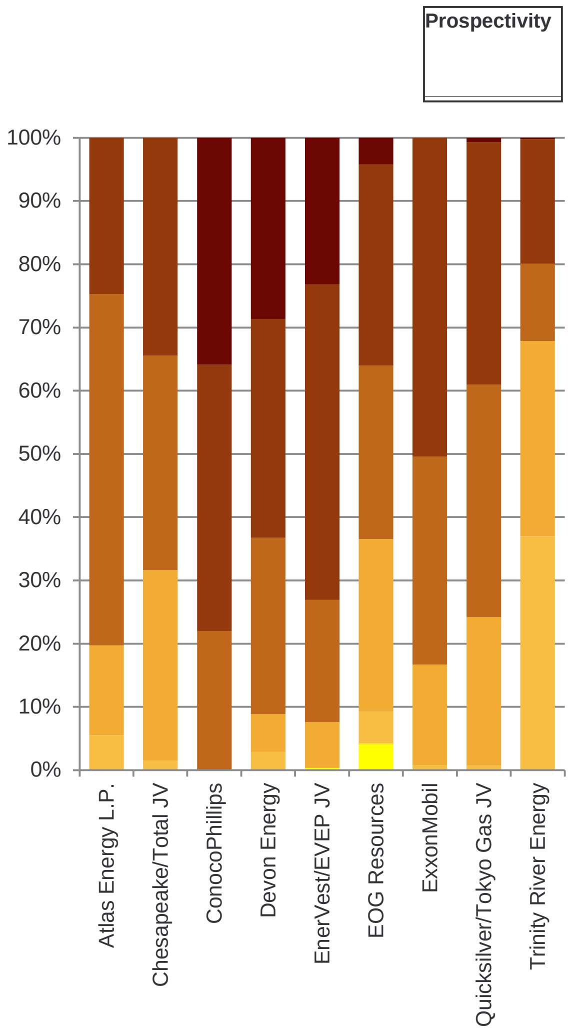


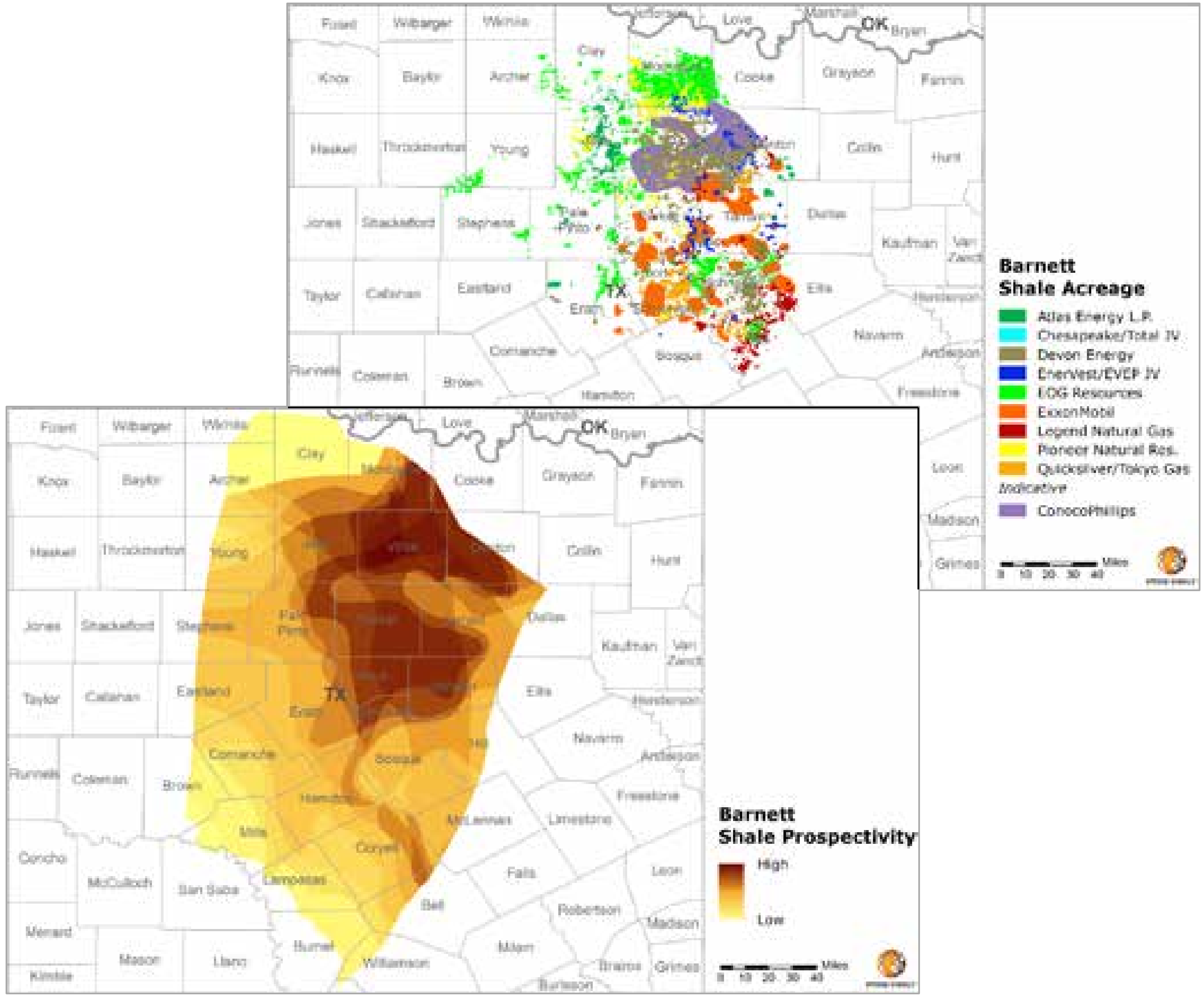




Practical application – relative comparision of company portfolios (Barnett Shale play)

Percentage of company acreage by play prospectivity





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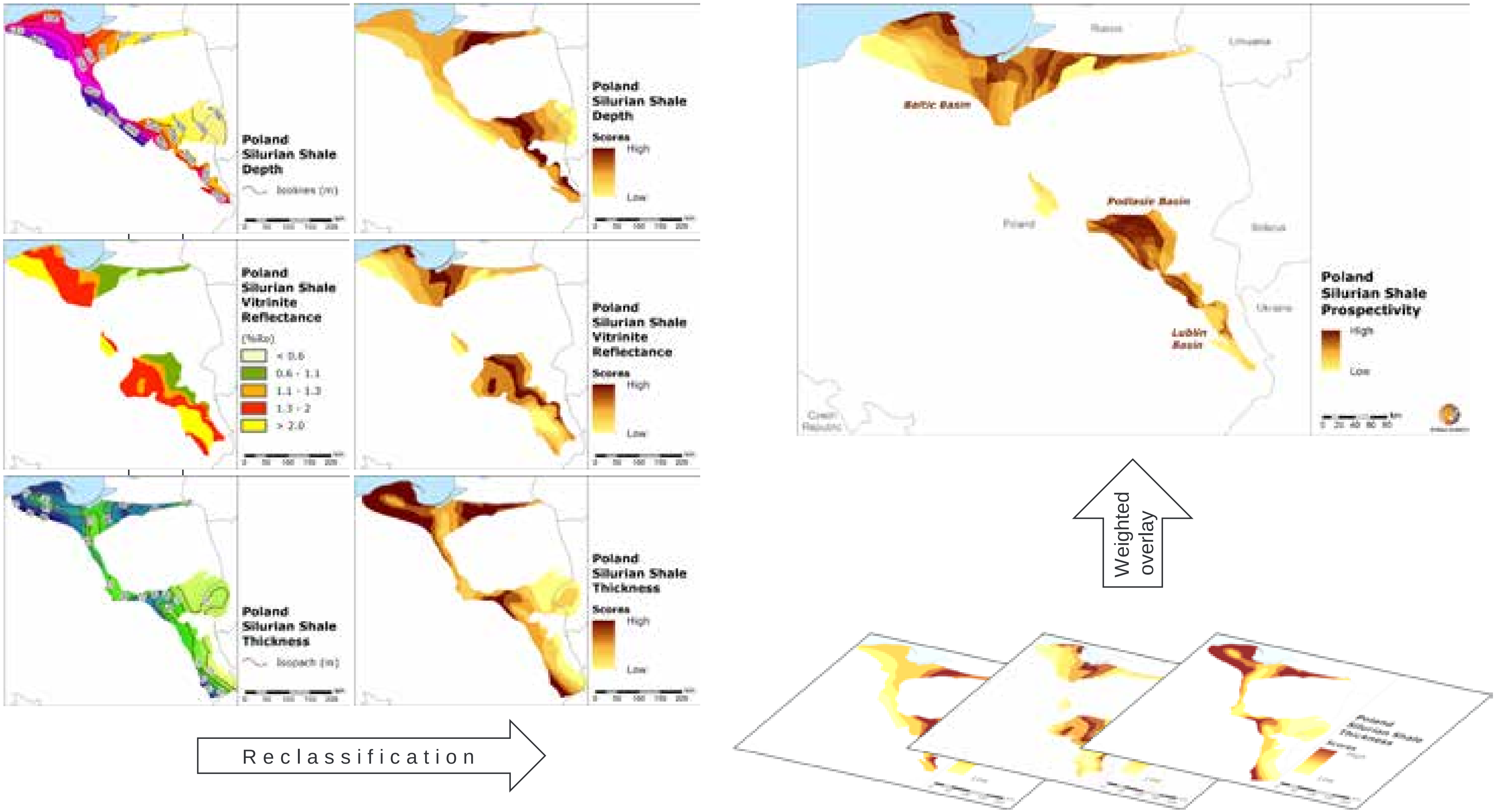
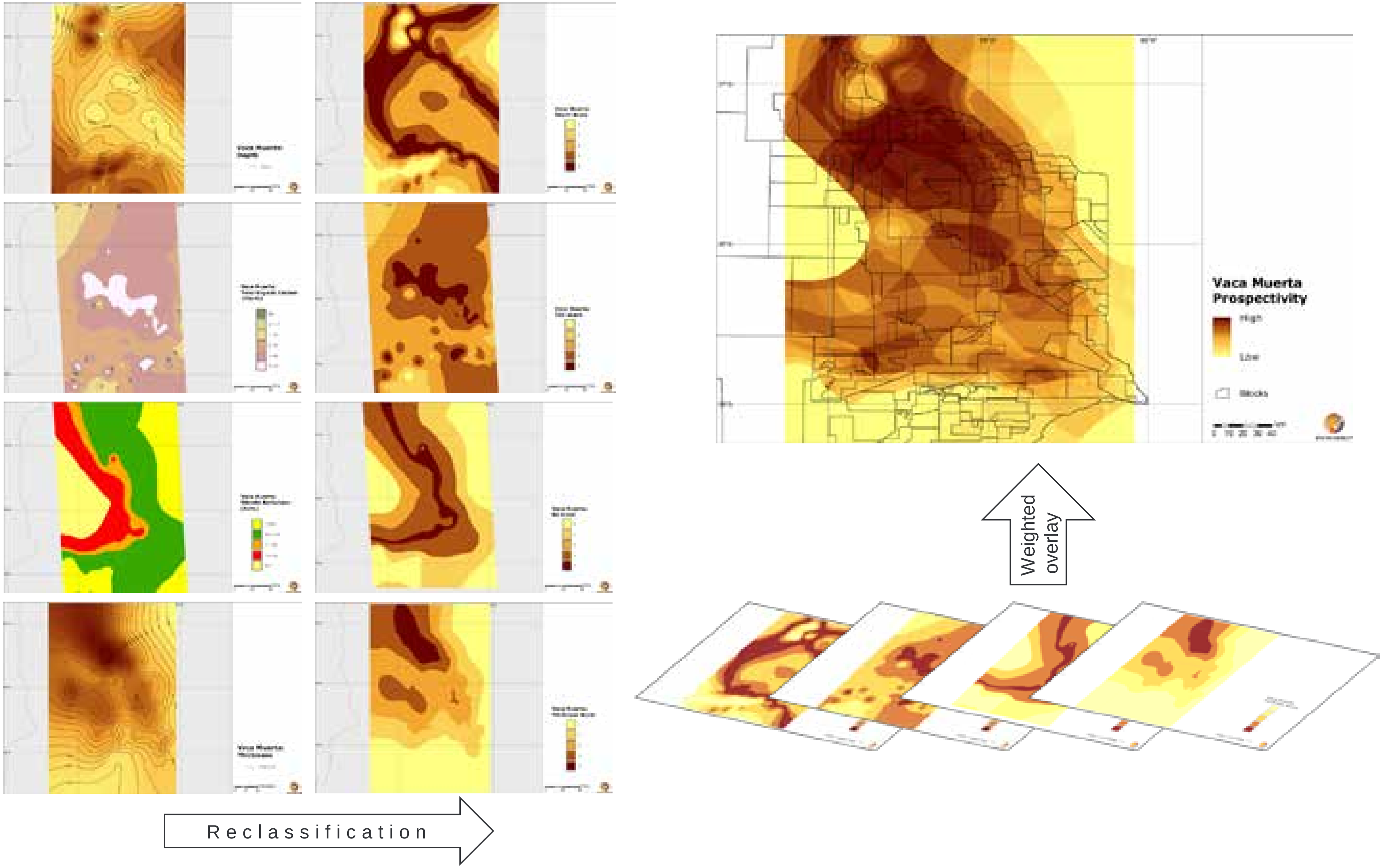
Applying the analogies from NA shale plays to global shales plays (Poland Silurian Shale)



Original Source Data: Polish Geological Institute

Applying the analogies from NA shale plays to global shales plays (Vaca Muerta play in Argentina)

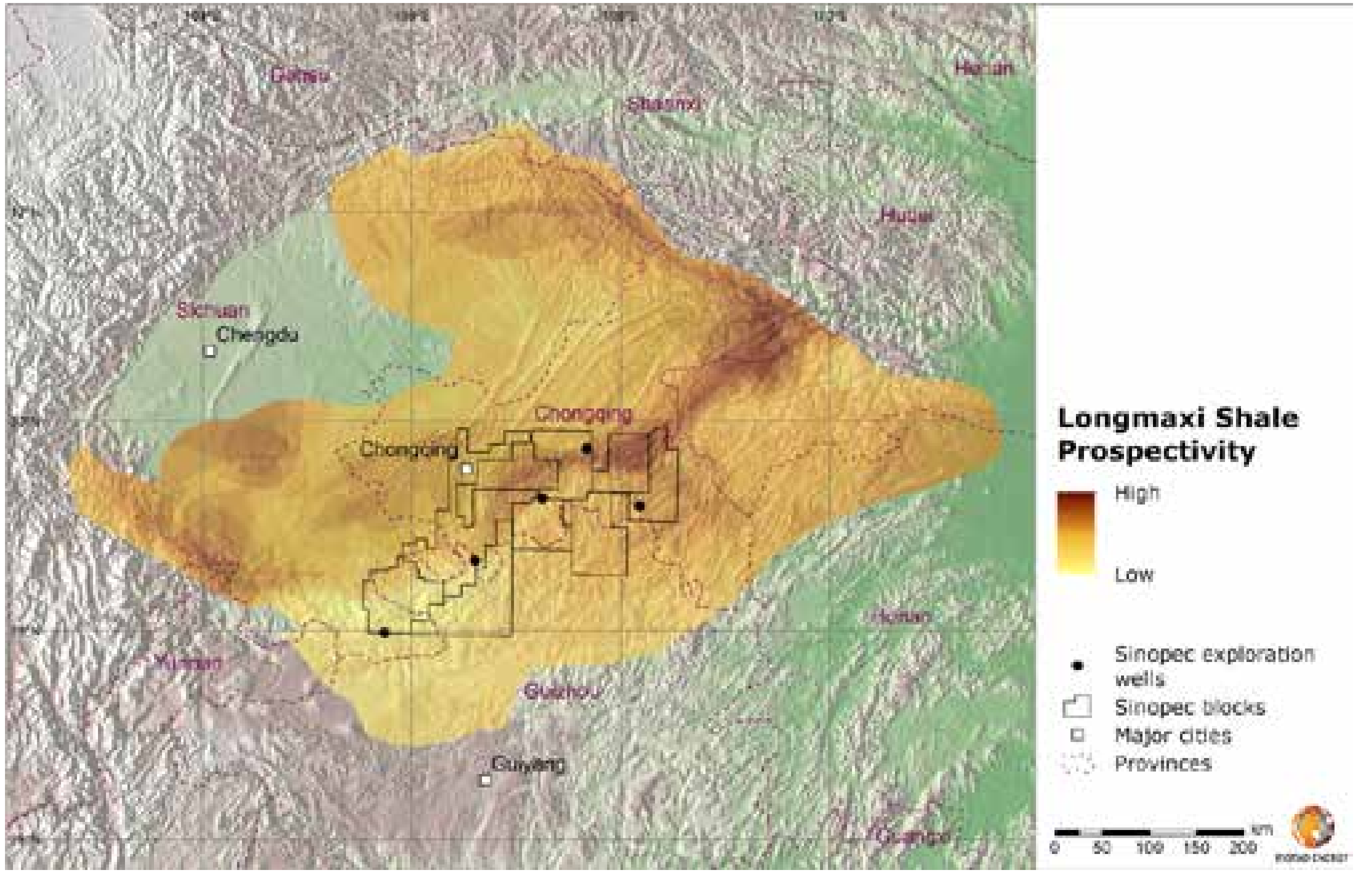


Limitations of the model

Play prospectivity model is based on combination of selected key geologic parameters, common approach for all shale plays.

It does not take into account any external objective factors, such as topography:
– hardly accessible mountain area, or dense urban areas may limit E&P activity significantly.

Example:
Northeastern and western areas of Longmaxi shale (China) with relatively high prospectivity are located in mountainous terrain, which prioritizes the prospectivity trends just east of Chongqing city.



Distribution of the results

All US and CA prospectivity maps are part of Rystad Energy's North American Shale Analysis (**NASAnalysis**).

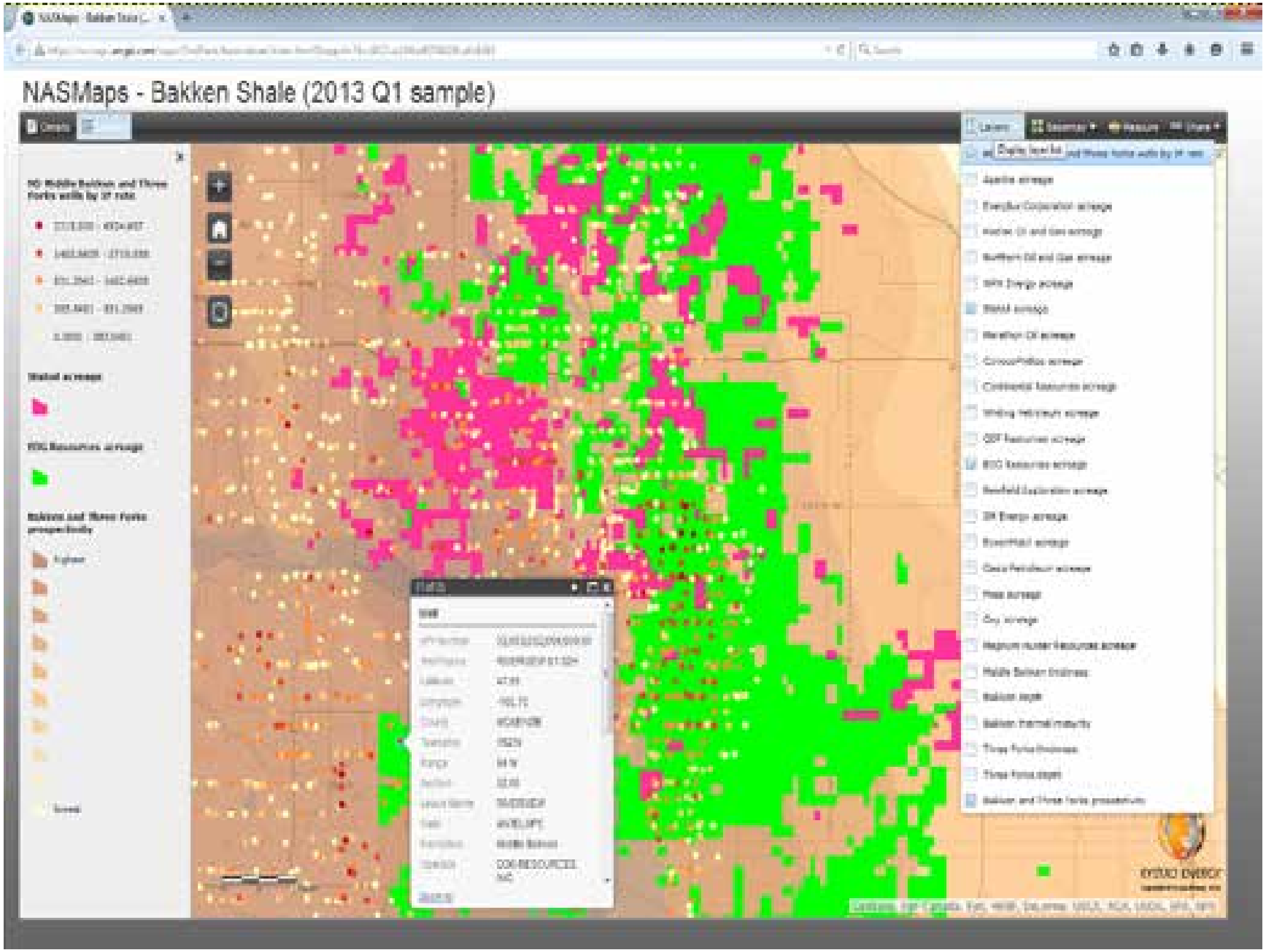
NASAnalysis is a range of data products on shale gas and tight oil developments in the USA and Canada. Data can be utilized to improve market analysis, investment decisions or peer group benchmarking.

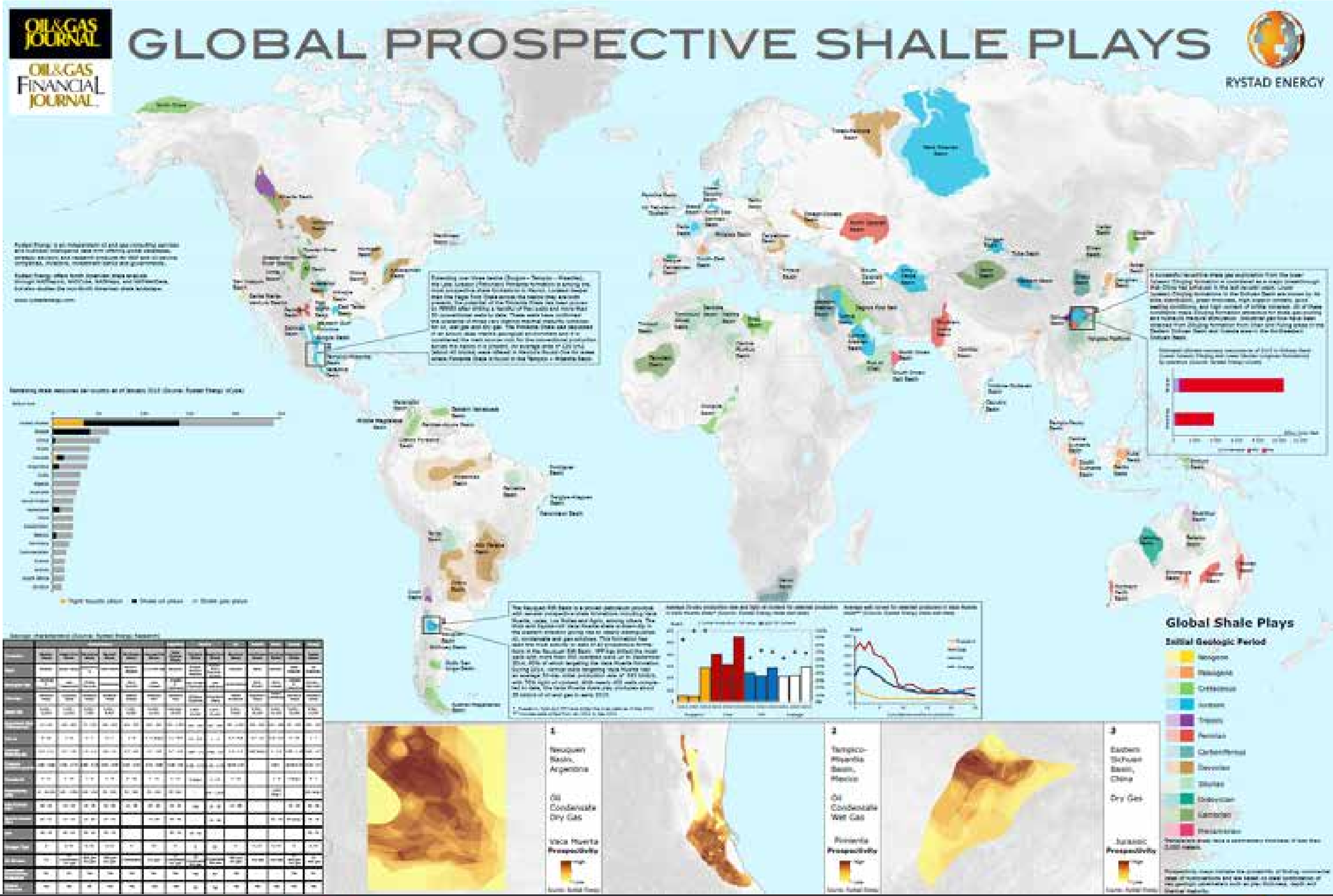
More information:
http://www.rystadenergy.com/ResearchProducts/NASAnalysis

A sample of content of [NASMaps](#) is published in Rystad Energy's **ArcGIS Online** portal. (on the right)

Global shale map was published in the OIL&GAS JOURNAL in May 2014, with updated version in 2015. (shown on the next slide)

https://re.maps.arcgis.com/apps/OnePane/basicviewer/index.html?&appid=7bcc9027aa2446af8378025fca0c8d10

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GLOBAL PROSPECTIVE SHALE PLAYS
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Global Shale Plays
Initial Geologic Period
1
Neuquen Basin, Argentina
Oil
Condensate
Dry Gas
Vaca Muerta
Prospectivity
2
Tampico-Misantla Basin, Mexico
Oil
Condensate
Wet Gas
Pimienta
Prospectivity
3
Eastern Sichuan Basin, China
Dry Gas
Jurassic
Prospectivity