A Prospectivity Checklist for Unconventional Plays*

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Abstract

Determining the prospectivity of an unconventional play or block within the play can be improved using a systematic approach that incorporates recent developments and findings in successfully developed plays worldwide. Key considerations including new techniques and technologies, as well as lessons learned. New understanding of the nature and extent of heterogeneity, combined with findings about importance of geochemistry, lithology, petrophysical attributes, pore architecture, structure, fracturing, and geomechanics must come together to create a coherent picture. Analytical methods, including data mining of "big data," can play an important role. Finally, the checklist includes identifying bias and potentially damaging or dangerous assumptions that can mediate/negatively impact the decision-making process. The resulting checklist forms the foundation of a systematic approach useful for evaluating new plays and re-assessing existing ones.

Introduction

Of the more than 50 unconventional potential plays worldwide, which ones are truly prospective, given the state of technology today? With emerging technologies and analytical techniques, which ones could reveal themselves to be prospective?

Now, more than ever, as exploration and development of unconventionals gain momentum in South America, Asia, Europe, Africa, and the Middle East, it is useful to take a look at the lessons learned and the state of the art in North America.

Prospectivity is back on the table, but instead of simply adding to one's current understanding, it is often necessary to go back to the basics and build a model and an overview of the play which revisits all the previous data, as well as old assumptions.

Determining prospectivity ties to producibility as well, and the information gathered, and the analytical processes used to determine prospectivity will also serve in assessing whether or not a play is producible.

Producibility is another aspect of the development of unconventional resources, and a "Producibility Checklist" should be used as well.

A Prospectivity Checklist

Developing a "Prospectivity Checklist" will help companies take a systematic approach and to incorporate new techniques and technologies, without unduly favoring or overlooking any of the available, viable options.

Before beginning the process, it is important to keep in mind that eliminating bias is extremely important, and that within any organizations, team members may succumb to "group think" or be held by the sway of a charismatic leader. For that reason, it is always advisable to obtain the guidance and viewpoint of objective outsiders, and neutral third parties.

Since unconventionals are characterized by often extreme heterogeneity, it has become extremely important to determine the nature of the variations. In some cases, as in the south Texas Eagle Ford, Eaglebine, and other Cretaceous shales, prospectivity has extended far beyond what was believed possible. In other cases, the prospective zones are much more heterogeneous than previously believed, and an understanding of the variation is necessary in order to determine prospective acreage, and then, within the acreage blocks, the precise targets and zones to drill.

The drilling boom of the last five years or so has resulted in an influx of performance data which has not always been as straightforward as hoped, and it does not lead to easy answers. An example is the Mississippian Lime play in Kansas and Oklahoma. Far from being a simple, homogeneous play, the presence of tripolitic chert and dolomitized zones, has resulted in pockets of surprising reservoir quality. Economically prospecting for such pockets and sweet spots can mean the difference between an uneconomic endeavor and one which yields a positive return on investment and long-lived, sustainable production.

All this knowledge comes to bear in a Prospectivity Checklist, which is rather extensive, but is intended as a "quick look" guide. Individuals, companies, and potential investors can decide how and where to go into more depth.

Using the Prospectivity Checklist

Step 1: The Big Picture

Basin Analysis and Geological History: All basins and potential plays have had a unique history, which shapes not only the kind and quality of organic carbon in place, but also the kinds of reservoirs one is likely to find, and their quality.

A coherent and plausible narrative that explains not only the movement of sediments but also depositional environments, structural movements, and the thermal history can help gain an idea of trends and also reasons for enrichment and the nature of heterogeneity. Some of the categories in the checklist overlap, but they are listed in order to make sure they are not overlooked and that the basin analysis is approached from multiple vantage points.

Checklist:

- Geological history
- Depositional history environment
- Heat flow
- Burial
- Maturation
- Uplift / erosion
- "Shock" events contributing to heterogeneity or discontinuity
- Structural history (structures, faults, natural fracture networks)
- Data mining to reevaluate data, find relationships, patterns

Geological Factors: Next, one must move in and become more granular and detailed. It's important to do this step within an entire basin, and not just a particular play. If possible, it is good to reprocess existing data and re-enter data in order to eliminate "legacy" errors and to clean up noise (or correct for too-aggressive noise reduction).

While these are geological factors, seismic data is important to consider.

Checklist:

- Thickness
- Maturity
- Gas Content / Rock Properties
- Areal Extent
- Depth
- Structural Complexity
- Lateral Continuity
- Heterogeneity

Stratigraphy / Structure: This step involves taking a close look, and to work with teams to discuss the actual big picture. While it is tempting to become very detailed at this point, it is important to avoid spending too much time. This step allows one to integrate field data with subsurface data.

Checklist:

- Stratigraphic models
- Structural regime
- Sequence stratigraphy

- Geomechanical regime
- Formation attributes
- Degree of heterogeneity
- Nature of heterogeniety
- Data mining to reevaluate data, find relationships, patterns

Step 2: Key Technologies and Techniques

This step involves collecting analytical data in a systematic way and organizing them. Where possible, it is useful to collect information on potential analogues, although one must bear in mind that all plays are different, and further, all plays have been developed using different generations of technology, and so the findings and experiences from one play do not necessarily apply to another.

Nevertheless, there are general understandings about the nature and quality of reservoirs that can be used to gain insight into new plays.

This checklist is a starting point and is not exhaustive.

Geochemical Findings: While some reservoirs produce in spite of less than ideal geochemical findings, in general, it is good to list the ideal ranges and cut-off points when evaluating data.

Checklist:

- Total Organic Carbon (TOC)
- Thermal maturity (vitrinite reflectance)
- Rock-Eval
- Kerogen type
- Hydrocarbon Index
- Tmax
- Spectroscopy / gas distribution
- Hydrocarbon characteristics
- Associated gases
- Data mining to reevaluate data, find relationships, patterns

Lithology, Mineralogy, and Reservoir Fluids: A very good understanding of the nature of the lithology and the mineralogy of your prospective reservoirs is vital. Investing in this stage can yield very positive returns later.

Checklist:

- Pore architecture (nano scale)

- Lithology
- Mineralogy
- Water saturation
- Oil saturation
- Gas analytics
- Scanning electron microscopy
- Diagenetic alteration: types and history
- Data mining to reevaluate data, find relationships, patterns

Seismic: There are several major applications of seismic data in the determination of prospectivity (and in producibility). The first involves understanding the nature of the structure and also thickness variations of the various formations. Sequence stratigraphy is useful in obtaining basin-wide understanding. Further, it is useful to understand alterations, thinning, and faulting.

The information used to determine prospectivity can also be used for producibility since it is important in determining how/where one will drill in order to stay in the zone / sweet spots, and also to avoid geohazards.

Checklist:

- Commercial data
- Wide Azimuth processing / WAZ imaging
- 3D images (for thinning, degrees of heterogeneity)
- Seismic stratigraphy
- Attributes (amplitude, velocity, impedance)
- Bandwidth extension
- Inversions
- Reprocessing
- Data mining to reevaluate data, find relationships, patterns

Petrophysics: Coring where possible, as well as running as many logs as feasible, will help you obtain more information.

Checklist:

- Petrophysical qualities
- Porosity
- Permeability
- Derived values
- Water saturation

- Reprocessing / re-analyzing existing well log data
- Rock properties: Strength/stress/grains

Geomechanics and Lithological Properties: It's debatable whether this area should go into a "producibility" checklist or should remain in "prospectivity." The information will also be used while drilling and completing, to place laterals, avoid geohazards, and orient fracs in hydraulic fracturing.

Checklist:

- Brittleness
- Fracability
- Pore pressure
- Stress regimes
- Fracture networks
- Natural fractures
- Induced fractures
- Data mining to reevaluate data, find relationships, patterns

Step 3: Questions: Interrogating Your Play

This is the stage in which the information is evaluated, separately and in different combinations. Ideally individual team members bring reports/thoughts to a group meeting. In the group meeting, questions are posed and new insights are sought.

In the process, outside experts should give their opinions and also participate in discussions, partly to provide insight and partly to debunk or defuse cognitive bias.

Checklist:

- Understanding the "story" of the play
  - What is the overall basin history?
  - What is the nature of the organic matter?
  - Which elements in the basin history make it interesting for the generation and accumulation of petroleum?

- Teasing out the underlying assumptions
  - What is the evidence used to make assumptions about petroleum generation?
  - What do we really know about the tectonic history? How old are some of the reports and the discussions of the tectonic activity?
  - What kind of information do we have about the rocks? Who collected it? What are the most popular (and easiest to obtain) views? Can they be said to be overly conservative? Overly optimistic?

- Eliminating bias
    - What do you really want to see? What does your organization hope to gain?
    - What are the analogues you're using?
    - What are the beliefs of the leader of the group?
    - Who are the main naysayers?
    - What are the core interests/motivations?

- Finding the overlooked or new key factors
    - Are there any new studies? Consortium findings?
    - Can any of the data be reprocessed?
    - Can you use new analytical techniques or data mining to find more/new patterns? Are they meaningful?

- Diamonds in the rough
    - As you review the formations that could be prospective, are there attributes or characteristics that point to a degree of heterogeneity that could lead to extreme enrichment?
    - Are there new combinations of data that you can evaluate using different analytical techniques (data mining, cluster analysis, neural networks) to uncover relationships that lead to possible areas of prospectivity?

- Ranking
    - Of the possibly prospective formations you're evaluating, how do you rank them?
    - What are your most important criteria?
    - Are you weighting your results in favor of other factors, such as availability of water, infrastructure, and political stability?

Concluding Remarks

It is best to look at the checklist as a starting point, rather than an ending point. The rush to certainty and a kind of psychological closure can lead to the hardening of assumptions and attitudes. Hardened assumptions are never healthy in an organization, primarily because they tend to masquerade as the company's mission, when they are in reality a strategic tactic and a business unit.

The more iterations of the process (or subsets of the checklist process) the better. The process of developing a checklist and then reviewing it often can be a key element in team-building and very effective way to improve communication, particularly in the transitional stages of a play or project.

The checklist also becomes a very useful training and professional development tool, which has the virtue of being a hands-on "learning by doing" approach while also contributing to the company's overall goals, objectives, and overall mission.