Capturing the Full Range of Uncertainty – an Overview of One Company's Integrated Prospect Assessment Practices

Sykes, Mark A.[1], Steven N. Salzman[1], Katrina D. Withers[1], Kenneth C. Hood[1], Parke D. Snavely[1] (1) ExxonMobil Exploration Co, Houston, TX

Assessment is a process for estimating the likelihood that subsurface features contain hydrocarbons and, if so, the potential range of recoverable hydrocarbon volumes. Assessment can be applied to diverse investment opportunities, including producing fields, undeveloped discoveries, undrilled prospects, and conceptual plays.

ExxonMobil's prospect assessment workflow has been developed and refined over the course of four decades of research and application. While our practices utilize standard statistical techniques, they are grounded in sound geologic interpretation and engineering principles. This approach stresses representation within the numerical model of physical and genetic relationships within, and amongst, reservoir-structural segments. Each prospect segment is characterized by discrete risks and volume uncertainty based on predicted hydrocarbon contacts and estimates of independent rock volume parameters at the segment level. The overall prospect chance of success, defined relative to a minimum recoverable volume, and volume range are determined by aggregating segment-based risks and volumes. The shape of the resultant curve is not predetermined, but instead is constrained by prospect geology. Geologically defined fluid leak-fill-spill interactions, conformable relationships, and risk and volume dependencies have a crucial and often underappreciated impact on the resulting prospect assessment.

A fundamental principle of ExxonMobil's approach is that assessment should provide robust estimates of the range of possible outcomes. This is achieved through early identification of key uncertainties and incorporation of alternative, viable geological scenarios and their associated probability of occurrence. Such an approach mitigates the danger of anchoring around a single interpretation and restores the focus on accuracy and robustness of the evaluation.

Risking Prospects with a Direct Hydrocarbon Indicator (DHI): An Example from the Otway Basin, Australia

Lowry, David C.[1], Andrew Constantine[1] (1) Origin Energy Ltd, Brisbane, Australia

The traditional method of prospect risking is to use geological knowledge to assess the chance of success (COS) for the various prospect risk elements. If the prospect also has an associated Direct Hydrocarbon Indicator (DHI), the estimated COS for source, charge and seal can be increased to some degree, depending on the reliability of the DHI.

Bayes Theorem can be used to update the initial estimates of COS to arrive at a final overall prospect COS if the presence or absence of a DHI is assessed in terms of frequency of false positives and false negatives.

The effect of Bayes Theorem on prospect risking is illustrated by a prospect with a strong amplitude anomaly in the offshore eastern Otway Basin. Initial risking resulted in a fault seal COS of 22% and an overall prospect COS of 10.7%. The history of exploration wells testing the same stratigraphic level in this area shows that examining a prospect for an amplitude anomaly as an indicator of gas will have a 20% chance of a false positive and a 31% chance of a false negative.

Using Bayes Theorem, the COS of the prospect having adequate fault seal rises from 22% to 49%. Source and charge risks are also updated so that the overall COS for the prospect rises to 27.6%

Pitfalls to consider include allowing the strength of the DHI to influence the initial risk assessment; and failing to recognise that most DHIs cannot distinguish a live gas column from a breached one.

Measuring What We Think We'll Find: A 20-Year Perspective on E&P Risk Analysis

Rose, Peter R.[1] (1) Rose & Associates, LLP, Austin, TX

The fundamental geotechnical, statistical, and economic concepts that underpin today's standard E&P risk analysis and portfolio management have been in place for at least 50 years. From about 1985 to about 1995, a general methodology evolved and converged among many large companies and some consultants. AAPG publications, oral papers, and Hedberg Conferences were instrumental in this process. Additional refinements since 1993 include (1) probabilistic play analysis; (2) sophisticated risk analysis of complex traps; (3) integration of risk analysis with economic evaluations; (4) utilization of probabilistic project evaluations in company inventories and portfolios; (5) consideration of psychological and organizational influence on project evaluations and selections, and (6) education of top management in use of probabilistic project evaluation in decision making.

Extraordinary advancements in computer capacity and software refinements have now brought sophisticated risk analysis within the routine reach of every geotechnical PC user. Even so, many of the remaining challenges represent “people problems”, not technology problems:

a. Consistently and routinely assessing real-option values of E&P projects to realistically express their true value;
b. Consistently assessing the value of unconventional resource plays;
c. Usefully and routinely employing probabilistic evaluations of development and EOR projects;
d. Realistically assessing high-risk, high-potential “company-maker” plays within the context of E&P portfolios;
e. Routinely carrying out full-probabilistic DCF economic analyses in time-effective ways;
f. Effectively eliminating stubborn human biases related to excessively narrow ranges of uncertainty, and inherent optimism;
g. Developing corporate incentive systems that are compatible with delivering on geotechnical promises.

Undiscovered Resources and Play Analysis in the Norwegian Barents Sea

Ramirez, Abryl O.[1], Erling Kvadsheim[1], Per Blystad[1], Gunnar Søiland[1] (1) Norwegian Petroleum Directorate, N-4003

Stavanger, Norway

The demand for energy world wide will increase in the years to come. Recent studies indicate that a significant part of the world's undiscovered resources are located in the Arctic region. This paper will focus on the undiscovered petroleum resources in the Norwegian Barents Sea based on the Norwegian Petroleum Directorate (NPD) play analyses.

The NPD estimates regularly the total amount of recoverable yet-to-find petroleum on the Norwegian Continental Shelf (NCS). This is an estimate of what will be technically possible to find and produce if all prospects are identified and drilled. The remaining undiscovered resources reflect the exploration potential with today's knowledge and understanding. As new exploration activity proves up new petroleum plays, this potential will be adjusted accordingly.

The Barents Sea is a large area covering 750,000 km2 and it is the least explored region opened for petroleum exploration on the NCS, and it is characterized as a frontier province with a large petroleum potential yet to be found. A large number of plays have been mapped, however, only five plays have been confirmed to date. As most of the plays are still unconfirmed, the resource estimates carry a large degree of uncertainty, and they may rise significantly if more plays are confirmed. Most of the yet-to-find resources are expected to be found in the Triassic play models. Geologic and seismic data indicate large structures and favourable conditions for generating and trapping of petroleum. The paper will show examples of several of the plays in the Norwegian Barents Sea.

Optimizing Play Assessment Data and Work Processes Using GIS

Hood, Kenneth C.[1], Bernard C. South[1], Charles Stabell[2] (1) ExxonMobil Exploration Co, Houston, TX (2) GeoKnowledge AS, Oslo, Norway

The granularity of play assessment can vary widely depending on data availability and the business questions being addressed. For example, to ascertain the natural endowment for a country, evaluating an entire play as a single entity may be sufficient. To better support an exploration effort, however, the assessment results should more fully represent the internal variations within the play. The inherently spatial nature of this process makes it well suited to GIS applications.

At its basic level, play assessment attempts to project the number, size, and hydrocarbon type of future discoveries. Geologic trends can identify those areas containing the least risky and (or) largest prospects. This knowledge is incorporated into the analysis by subdividing the play into progressively smaller and less heterogeneous entities. Finer partitioning of the stratigraphic play interval may also provide better linkages to lateral reservoir and seal controls. Increased stratigraphic partitioning can both increase the number of maps that must be managed and, more importantly, give the appearance of having a larger number of smaller hydrocarbon accumulations. Such a perception could have a significant impact on economic evaluations. GIS can be used to improve economic evaluations by resolving the overlap of areas representing the sweet spots in different stratigraphic intervals, and with proper database design, re-assembling future accumulations across assessment intervals so as to best represent entities that can be tested by individual wells. Effective use of GIS can significantly increase the utility and business value of play assessment.

Geologic Chance Assessment for Resource Plays

Wold, Christopher N.[1], Jay E. Leonard[1], Robert J. Coskey[1], P. Jeffrey Brown[2] (1) Platte River Associates, Inc, Boulder, CO (2) Decision Strategies Inc, Houston, TX

Over the last several years, resource plays (especially shale gas plays) have become a "hot commodity" in North America and other parts of the world. Resource plays require a company to acquire exploration & production rights for larger areas of land than for conventional plays. With prices for acerage increasing, the need to perform timely geologic chance assessment and to identify productive fairways is critical to the decision of where to lease. Shale gas plays are typically self-contained, providing hyrocarbon source, reservoir, and seal. As modelling and drilling technology advances, companies are able to extract larger portions of retained hydrocarbons from identified “hotspots”.

To evaluate the geologic probability of an effective source rock; both modelling and spatial chance assessment become important tools. A stochastic compaction, thermal, kinetic model is used to estimate the range in potential charge from various spatially identified “hotspots”. Uncertainty of the data quality and quantity are input to this process. Other important components include the burial, thermal, and maturation history, extent of the pod of active source rock, and the amount of hydrocarbon retained by the source rock or lost during primary migration. We will present examples from a real exploration & production project.

Rapid Basin Evaluation Across Large Regions as a Basis for Play Analysis

Loutit, Tom S.[1], Jane Blevin[1] (1) FrOG Tech Pty Ltd, Canberra, Australia

Play analysis requires a consistent geological interpretation process within and between basins. But large areas of the world are largely unexplored because of poor spatial distribution and quality of traditional exploration data. Even in mature exploration areas the geological framework may be poorly understood particularly in the older and deeper parts of a basin.

The OZ SEEBASE™ project was designed to provide the first consistent structural model for the evolution of Australia's Phanerozoic sedimentary basins in a single GIS project. The model provides a time-space framework for the evaluation of the petroleum potential of Australia's basins. It was based on the systematic integration, calibration and interpretation of non-seismic and seismic/well data using a range of new techniques that rely primarily on non-seismic data to improve spatial control and provide geological information in areas not covered by seismic and wells. Product layers include depth to basement images, basement-involved faults, basement geology, tectonic events and responses, sediment thickness and crustal thickness that can be used to provide insights into key play elements or risks such as trap size, distribution, type and timing, crustal heat flow, reservoir and seal quality, volcanics, salt and basin phase morphology.

The OZ SEEBASE™ project has generated a number of new play-based exploration strategies. It has provided the basis for planning new cost-effective data acquisition strategies to systematically reduce exploration risk within families of basins that have been formed by similar geodynamic processes. The CRAP™ (Confidence, Reliability, Accuracy and Precision) layer is key to assigning risk to each play and play element.

Play Analysis as a Tool in the Petroleum Resource Management in Norway

Kvadsheim, Erling[1], Abryl O. Ramirez[1], Per Blystad[1], Gunnar Søiland[1] (1) Norwegian Petroleum Directorate, NO-4003 Stavanger, Norway

The Norwegian Petroleum Directorate (NPD) uses play analysis for estimating undiscovered resources and for guiding the development of regional exploration strategies. The geological discussion around play mapping is thus a key element in the petroleum resource management of Norway.

The play is a geographically delimited area where a specific set of geological factors exist so that petroleum may be present in commercial quantities. All fields, discoveries, prospects and leads that share these factors belong to the same play, and they provide important input to the estimation of the undiscovered resources. Most important for this calculation is the number of discoveries expected to be made and their size. This is estimated based on the size and properties of the existing discoveries. Statistical uncertainty is taken account of by probability distributions for the various parameters. The minimum economic cut-off size is also taken account of.

In unconfirmed plays the input to the resource calculations are based on the mapped prospects, on geological analogues and on the regional models for how the geological and reservoir elements are distributed. Unconfirmed plays are also given a probability of success for the play to actually work. This is an important factor when resource estimates for the plays are aggregated to total resource estimates but also very important for strategic decisions and the development of exploration policies.

This paper presents the NPD methodology and gives some examples of the pitfalls and the successful uses of play analysis for resource estimation and as a strategic tool.

Managing Exploration Risk: Lessons Learned from Surface Geochemical Surveys and Post-Survey Drilling Results

Schumacher, Dietmar[1] (1) Geo-Microbial Technologies, Inc, Ochelata, OK

It has been long known that most oil and gas accumulations leak, that this leakage is predominantly vertical, and can be detected with any of several direct and indirect methods. It has also been documented that the areal extent of the surface geochemical anomaly can approximate the productive limits of the reservoir(s) at depth. How reliably this can be done depends on the geologic setting, the choice of method, survey design and sample spacing. Proponents of surface geochemical surveys contend that proper use of surface geochemistry leads to better prospect evaluation and risk assessment. This may be true but the significance of surface geochemical anomalies in hydrocarbon exploration is not always readily apparent.

How can one quantify the value added by surface geochemical data when it is integrated with conventional exploration methods? One way to do so is to compare survey results with results of subsequent drilling. The results of such a comparison are summarized here for more than 1000 U.S. and International wells, all drilled on conventionally developed prospects after completion of surface geochemical surveys The prospects are from both frontier basins and mature basins, onshore and offshore, and a wide variety of geologic settings. Targets ranged in depth from 300 meters to more than 4700 meters and covered the full spectrum of trap styles. Prospects were surveyed using a variety of geochemical exploration methods including free soil gas, sorbed soil gas, microbial, radiometrics, micromagnetics, etc.

Of wells drilled on prospects associated with positive geochemical anomalies 83% were completed as commercial discoveries. In contrast, only 13% of wells drilled on prospects without an associated geochemical anomaly resulted in discoveries. Had drilling decisions included consideration of the geochemical data, exploration success rates would have more than doubled!

Distribution of Petroleum Source Rocks in Time and Space

Armentrout, John M.[1] (1) Cascade Stratigraphics, Inc, Clackamas, OR

Kinetic modeling suggests that for a potential petroleum source rock to be an effective oil source it must have an original minimum 2.4wt% Total Organic Carbon (TOC) with a hydrogen index of 400 mg HC/g TOC. This capacity to generate hydrocarbon is necessary to saturate the rock matrix and migrate significant volumes of oil. Source rocks with this generative capacity occur most often within transgressive mudstone.

The concentration of oil-prone source rocks in the transgressive facies results from two factors. Relative rise of sea level impounds gas-prone terrigenous organic matter in fluvial valleys and coastal plains rather than offshore where it dilutes the oil-prone kerogens. Additionally, the relative rise of sea level associated with transgression brings oceanic upwelling systems onto the outer shelf where the nutrient rich waters support high organic productivity. When this productivity impinges on the outer shelf and over shelf basins, the relatively shallower water column enhances the potential for undegraded oil-prone marine algal matter to be buried in anoxic bottom water and sediment. If the rate of burial is sufficiently fast to bury the organic matter but not to significantly dilute the concentration, a potentially effective source rock is deposited.

Understanding the geological relationships behind these processes provides a model for predicting the location of probable petroleum system kitchens. If we have confidence of where the kitchen is located, and we know where current production has found economic products, we can use the stratigraphic analysis of seismic record sections to predict where oil and gas may occur along the more probable migration avenues.

Probabilistic OOIP Assessment and Reservoir Characterization Workflow used for Lianzi Development, Angola/Congo 14 / K A IMI Unit

Mabe, Kathleen Elizabeth[1], Luis Fernandes[2] (1) Chevron, Houston, TX (2) Cabinda Gulf Oil Co. Ltd, Houston, TX

The Lianzi development lies on the border of Angola Block 14 and Republic of Congo within the 14K / A-IMI Unit. Chevron as Unit operator along with participants; Total, ENI, SNL P&P, SNPC, and Galp have been exploring and appraising the region since the unit agreement was signed in 2002. Lianzi field was discovered in 2004 by drilling the Lianzi-1 discovery well followed by successful delineation in 2005 with the Lianzi-2 appraisal well.
The Lianzi base case development comprises a Miocene CN3 F1B channel-levee system with two separate oil pools. Lianzi Central and West F1B are combination structural and stratigraphic traps. Lianzi F1B reservoirs are 6000-7000 feet below mud line in 2000 feet of water and contain 37º API oil. The reservoir has been evaluated using both 2D map-based and 3D model-based probabilistic OOIP assessments to finalize the Reservoir Basis of Design.
Subsurface uncertainties are prioritized using design of experiments and mitigation plans are developed to reduce associated risks with deepwater development. Advanced modeling techniques are used to capture the range of subsurface uncertainties and understand of development risks associated with fluid contacts, channel deposition, velocity, net to gross, reservoir fluids, rock properties, etc. Multiple models are built using reservoir properties from 3D seismic to represent subsurface uncertainties and define probabilistic ranges of hydrocarbon volumes, recoveries, and forecasts. Improved reservoir characterization workflows are streamlined to quickly update models with new data.
This improved workflow builds upon ten years of work efforts by Chevron and Unit Participants in the Lower Congo Basin.

The United Nations Framework Classification for Fossil Energy and Mineral Resources (UNFC)

Kvadsheim, Erling[1], Per Blystad[2], Sigurd Heiberg[3], Thomas S. Ahlbrandt[4], Timothy R. Klett[4], John E. Ritter[5] (1) Norwegian Petroleum Directorate, NO-4033 Stavanger, Norway (2) Norwegian Petroleum Directorate, NO-4003 Stavanger, Norway (3) Statoil ASA, NO-4035 Stavanger, Norway (4) US Geological Survey, Denver, CO (5) Chevron, Houston, TX
The UN Framework Classification for Fossil Energy and Mineral Resources (UNFC) is aiming to be a new, globally accepted tool for the classification of resources that will also harmonize various existing classification schemes and systems.
The UN Economic and Social Council recommended in July 2004 the UNFC for worldwide use by UN Member States, international organizations and regional commissions. UNFC will be helpful in improving energy studies, resource management, business process management and financial reporting through one common code. UNFC is designed around three basic criteria: economic viability, field project maturity and geological knowledge, which are further divided into categories and subcategories. A simple codification makes UNFC applicable world wide and enables it to meet the demand for a global code for fossil energy and mineral resources. Non-conventional energy resources are emerging as supply sources, some blurring the boundary between mineral and energy. UNFC is sufficiently robust to categorize such non-conventional resources. Aggregated classes of remaining recoverable quantities are also distinguishable in UNFC, including all SPE/AAPG/WPC discovered classes (Reserves and Contingent Resources).
Collaboration with the financial community supports the development of an international financial reporting standard for extractive activities. Specifications, guidelines and case studies for the classification are being developed by the Combined Reserves International Reporting Standards Committee (CRIRSCO) and UN for minerals, and by the Society of Petroleum Engineers (SPE) for petroleum.