Chapter 3: Second White Specks Formation

New concepts for understanding fractured reservoirs.

Notes for Slides:

Slide 1: Shale reservoirs pose a problem for industry as they conventional concepts of pore space is no longer well defined. Similarly the exploitation of these reserves requires an integrated approach where members of the team must be conversant in a variety of disciplines such that ideas may be debated and challenged.

Slide 2: ***Life Cycle of a Resource Play*** – Resource plays have a cycle from concept to development. The challenge is as much a people issue as a technical issue. Resource plays have certain similarities but also differences. The issue is that there is not a set method for uniform exploitation of the plays. The plays move from an effort of understanding the technical constraints to development of an efficient procedure. This is a continuous improvement process but with the twist that the early stage tends to be dominated by free thinkers where the later stages are dominated by strong process implementers. The two styles of thinking are generally not compatible and will often result in poor communication and mistrust. The challenge is to be able to recognise where the play lies on the curve and adjust the thinking to best suit the maturity of the project.

Slide 3: From a management perspective the technology changes and advances very quickly. The concern is , Is this project ahead of the technology or behind and is the best technology being brought forward for a solution? This is coupled with the realization the project must be socially accepted to minimise the timeline and improve economic results.

Slide 4: There has been a tremendous increase in the supply of Oil and gas chiefly due to high commodity prices, the advancement of technology, and the change in focus from large reserve base to a strong flow rate

Slide 5: In the gas business that drilling of vertical wells has become largely inefficient. The success of horizontal drilling has flattened the fluctuations in the gas price to the point where the risk in changes in the commodity price is no longer a significant risk for gas users.

Slide 6: This change in price volatility has made gas an attractive alternative to Coal. Historically the advantage of Coal was its abundance and price stability. Now that gas is a stable price it can compete with coal as an alternative fuel for electrical generation.

Slide 7: The shift to resource plays has forced a fundamental change to companies' business approach. In the past the companies built value through establishment of reserves

and a long reserve life. Now companies build value through rate and cash flow meaning that the company is balancing debt repayment against cash flow and that the easy source of capital becomes the leverage of debt against the cash flow. The reserve base is considered vast in this case but the economic viability of any company is based on how efficiently it is able to balance debt and cash flow.

Slide 8: The fundamental question then becomes: "How do fluids move through the Crust?" This means that teams become interested in fluid pathways through the rock and how these pathways can be exploited

Slide 9: The Garrington Area in central Alberta is one of the more efficient areas for the production of oil from the Upper Cretaceous Cardium Formation. In this area 88 welss were drilled and based on detailed well bore surveys 8 wells missed the Cardium Sandstone (the producing zone) for an operational efficiency of ~90%.

Slide 10: The area has a long enough production history such that the P10 and P90 production curves can be drawn. From this a range of anticipated production is observed that is almost one order of magnitude in size. The initial rates are considered to be a viable indicator of the wells ultimate potential.

Slide 11: Plot of the average rate (Arithmetic) shows a bump in the production profile after the first year to two years. This bump is the result of more efficient pumps installed on the wells as it is felt that the frac fluids have cleaned up and sand production (and wear on pumps) is minimised.

Slide 12: Plot of the wells that missed the tight sandstone reservoir shows superior production compared to the average. Only 8 wells missed the zone so that this is not statistically verifiable but shows the trend that the shales have capacity to out produce the tight sandstone. This is likely because the shale section has more fractures and it is the fractures that dominate the flow conditions.

Slide 13 & 14: Because of the importance of the flow the significant equation is Darcy's Law. Darcy's Law is a Linear Transport Equation that has the general for of a Driving Force (Pressure Differential), Flow (rate of material per unit time through a medium), and resistance of friction (permeability). The equivalence to this would be Ohm's Law in the transport of electricity.

Slide 15: This concept suggests that the superior way to think of the reservoir is in terms of resistance as compared to enhanced flow pathways. Thinking in this way shows that flow does not occur along a pressure gradient but rather across a pressure gradient and that the direction of the resistance becomes critical meaning that the equation is a vector problem as

compared to a scalar solution and that for the efficient production of the reservoir it is important to understand the permeability of a reservoir in terms of a permeability field.

Slide 16: Typically we think of reservoir drainage as a series of radiating isobars (lines of equal pressure) around the well bore (pressure sink). Simplistically we make these isobars of constant radius around the well bore implying the drainage is a radial flow drainage and that the Linear Flow equations is a viable description of flow. In this way Point A will drain prior to Point B.

Slide 17: At times it is recognized that fractures play a role and that Radial Flow no longer describes the reservoir but the reservoir needs to be described by a more complex scenario. A dual porosity system is often used to explain these effects but it should be noted that it should be referred to as a dual permeability system. Typically the drainage system is represented as an ellipse where the long axis of the ellipse is oriented parallel to the dominant fracture direction.

Slide 18: In a fractured reservoir the permeability of the fractures are generally orders of magnitude greater than the matrix permeability (pore-to-pore). In this scenario the isobars follow the fractures patterns and the question is raised if the matrix has any significant contribution to the well productivity.

Slide 19: Knowledge of how fractured reservoirs flow is in very early stages. The principals of Darcy Flow remain but that flow is through a heterogeneous anisotropic medium as compared to a homogeneous isotropic reservoir.

Slide 20: A simple 4 layer model of a shale reservoir with varying constrasts of organic content and brittleness

Slide 21: The generation of hydrocarbons from organics creates a pressure event within the formation that generates failure within the Organic rich zones. This sets up a micro-fracture system that allows hydrocarbons to become mobile and migrate.

Slide 22: Micro-fracture system in the Upper Cretaceous Second White Specks Fm. along the Highwood River in southwestern Alberta. The fracture area of the micro-fractures is large but may have minor effectiveness.

Slide 23: As generation continues the flow paths will begin to merge similar to natural dendritic pattern (rivers, lightning as other natural examples). The pattern will be controlled by the heterogeneity and anisotropy of the geomechanics of the shale. The coalescing fractures will have a lower pressure than the microfractures consistent with Darcy Flow.

Slide 24: Larger “regional” fractures within the organic shales connect the micro-fracture system

Slide 25: The failure process continues as the organics continue to convert to hydrocarbons and push more fluids through the rock creating a complex pressure distribution and fracture with different flow characteristics.

Slide 26: The fracture pattern becomes a complex system dependent on proximity to the source rock, brittleness of the different layers, resistance in the overall system and individual layers and the interplay amongst the layers spatially.

Slide 27: The end result is not one fracture system but a series of fracture systems the overlay and influence throughout the reservoir. Outcrop along the Highwood River.

Slide 28: The difficulty becomes on how to exploit the reservoir. A horizontal well is a necessity but, is it best to target good pathways with lower pressure or poorer pathways with higher pressure. Because Darcy Flow is dependent on both pressure and resistance this becomes a subjective decision.

Slide 29 – 31: The exploitation of the section is dependent on setting up pressure differentials within the rock that will overcome the changes in the fracture permeability between macro-fractures and micro-fractures.

Slide 32: It has been suggested that a vertical well encountering a large fracture will be as successful as a horizontal well. On initial production this may be true but the purpose of the horizontal well is to intersect numerous fractures and drive the pressure sink into the reservoir consistently and pervasively. In this way the maximum volume of the reservoir is exposed to the pressure sink and resulting improvement in well bore flow should occur.