A02

Seal Effectiveness Prediction Using a BP Proprietary Toolkit

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SUMMARY

Outline of talk
- Business importance of seal effectiveness
- Leakage processes and evidence for them
- Characterising mudrock seals
- Data uncertainties and limitations
- Introduction to BP proprietary toolkit- BP Petroleum Prediction Toolkit
  - Seal Risk basic
  - Seal Risk Advanced
- Example of usage
- Conclusions

Analysis of well results has shown that seal effectiveness issues are a major challenge when exploring in highly overpressured, deepwater Tertiary basins worldwide. In such basins, poor seal effectiveness can severely limit the column height that can be retained in a prospect and hence can directly impact the volume and value of hydrocarbons in place. Furthermore some prospects may have leaked most or all of their petroleum charge over geological timescales.

Understanding seal capacity is hence important for reducing exploration risk, as it helps exploration teams avoid drilling dry holes in prospects which may have seal effectiveness issues. Similarly the ability to constrain likely column height can improve capital efficiency by avoiding wrong well placement and the need for expensive up-dip sidetracks to penetrate the hydrocarbon column. Saving one sidetrack can typically save $10m and avoiding a dry hole could save $50-100m in unnecessary capital expenditure, so the business impact is high.

Geochemical data which is routinely collected by BP from exploration wells (e.g. head space gas; mudgas; isotubes) demonstrate that leakage of petroleum through thick mudrock sequences is a common phenomenon in deepwater Tertiary basins. Such data clearly show that leakage of petroleum from the reservoir into the overlying overburden has occurred, while the reservoir may or may not contain a residual petroleum column.

On the one hand, the commonplace occurrence of leakage reinforces the need to understand the fundamental science behind the different leakage processes and the ability to model those processes in a quantitative way. On the other hand, a pragmatic approach to seal effectiveness prediction also requires that we recognise there are large geological uncertainties which will often exert a strong and over-riding control on any predictive model. Similarly slow and inefficient workflows, using technically complex software, and requiring ready access to a small number of highly specialised practitioners, are simply not a sustainable or practical solution to a widespread technical problem, especially in an exploration environment. We need technically robust, fit-for-purpose tools that can be readily used by the general geoscientist and can incorporate geological uncertainty.

To tackle these issues, in BP we have created a variety of proprietary software toolkits and workflows for seal effectiveness and column height prediction during exploration and appraisal. A key tool is the BP Petroleum Prediction Toolkit (BP-PPT, Figure 1), which includes a simple to use, quality assured, module for column height prediction, called ‘Seal Risk’. The toolkit incorporates a number of leakage mechanisms:

- Petro-fracturing of the top seal
- Capillary and darcy leakage through the top seal
- Fault leakage by capillary processes
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Single phase (oil or gas), dual phase (oil with gas cap) or CO_2 accumulations can all be modeled.

The ‘Seal Risk’ module considers seal effectiveness and the rate of petroleum leakage through geological time. By linking ‘Seal Risk’ with another BP proprietary tool, the ‘Source and Fluids’ module, we can understand how much charge is entering the reservoir through geological time, and compare the rate of charging with rate of leakage. ‘Source and Fluids’ also supplies information on fluid properties which are needed for the seal capacity calculations. Similarly, the effect of stress history on seal integrity can be analysed in the advanced ‘Seal Risk’ workflows.

Unlike the complex tools which are commercially available and require a specialist to apply them, this module has been developed in-house and is designed to be used by the general geoscientist in their daily work. One of the toolkit’s strengths is its ability to quickly model many leakage processes and geological scenarios, allowing the geoscientist to consider

subsurface uncertainty fully and quantify the influence of these geological uncertainties on column height. Furthermore the toolkit has been rigorously tested in BP field studies. This transfer of technology from specialist to generalist frees up the former to concentrate on issues where their technical depth is truly needed, and leads to more efficient use of a scarce and valuable resource.

This simplified toolkit approach does not replace existing workflows using highly advanced and complex 3-d modelling software, but it has certainly become a part of these workflows in their pre-processing or screening phase. Having a rapid and flexible tool is particularly appropriate in an Exploration or Appraisal setting where data gaps and uncertainties and time constraints can make it challenging to build complex models while capturing the full range of subsurface uncertainty.

For this toolkit to create major business impact it has to be widely used by the company geoscientists. The sharing of concepts and recommended practises between specialists and the entire geoscience community requires appropriate training and technical support to be available. Fully integrated training sessions provide hands-on use of the application coupled with a thorough understanding of basic concepts, best practise and limitations. The development of a fully engaged user community provides valuable user feedback enabling BP to continually improve the toolkit, incorporating learning from well results as part of an ongoing calibration exercise.

The keys to the success of the toolkit are:

- Incorporating the knowledge and learning from BP's global exploration efforts
- Fully leveraging extensive in-house databases of mudrock seals and column height
- Productizing this knowledge in an easy to use quality-assured tool, designed with the end user in mind
- Deploying the toolkit to users desktops in conjunction with appropriate training materials and technical support

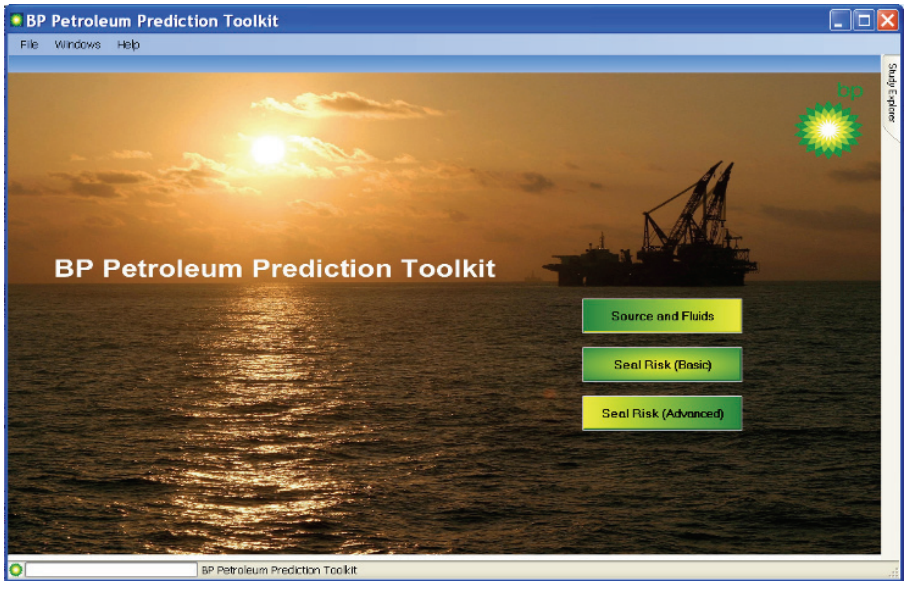

Figure 1 *The BP Petroleum Prediction Toolkit.*