Id No. 2004609

GEO-SCIENTIFIC UNCERTAINITIES IN FIELD DEVELOPMENT PROGRAMMES: IDENTIFYING ELEMENTS FOR RISK EVALUATION

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Abstract

During exploration Risk Analysis is done for evaluating the merit and prioritisation of leads and prospects using elements of petroleum system model.Estimated In Place recoverable reserves and production profiles facilitate planning of drilling programme and developing surface facilities for managing produced hydrocarbon. The authors are of the view that concept of 'risking' needs to be extended to developmental phase also so that better fiscal planning can be dynamically done for planning focused drilling and developing surface facilities. It is perceived that during development phase there are geo-scientific uncertainties which affect the Recovery Factors. Reservoir behaviour depends largely on mineral fabric, reservoir rock texture and their spread. The authors propose that an in depth petrophysical analysis using digital log processed information, petro fabric analysis through core and thin section studies identification of primary and secondary mineral, clay mineralogy and mineral maps and field stress maps are essential for refining the risk perceptions as these are key elements which would ultimately affect the reservoir performance.

It would help in planning and designing of secondary and tertiary recovery procedures as sweeps and well bore reach are important parameters which affect the Recovery Factors. The sweep efficiency is directly affected by clay mineralogy and its spread. Mapping of these elements would also facilitate in more realistic In Place Recoverable estimation. The field stress maps would be ideal for planning Frac jobs as fracture stability and fracture spread would have overall effect on recoveries.

Introduction

Petroleum System Modelling parameters like source rock quality, timing of maturation, expulsion, availability of reservoir and cap rock, seal competence and fault quality have been effectively used to create a risk perception of exploratory target and lead. Once an exploratory success is achieved prospect delineation and appraisal is done using similar parameters for understanding the resource availability and its production potential. However beyond the exploratory and appraisal phase it is better to use different elements for a realistic perception of successes in fiscal terms during development phase. Most of the fields globally are in active development phase and local geological parameters are being used to understand the reservoir behaviour. There are also examples where old fields have been categorised as Brown Fields due to poor recoveries, negative IRR etc. Schlumberger defines of brown field is *"An oil or gas accumulation that has matured to a production plateau or even progressed to a stage of declining production. Operating companies seek to extend the economic producing life of the field using cost-effective, low-risk technologies. Stimulation or refracturing operations, completing additional zones, and installing artificial lift equipment are a few technologies commonly applied in brownfields before any drilling options are attempted".* Although it is felt that essentially these definition are dynamic and dependent more on the company's economic strength and availability of technology which can be used to improve the Recovery Factors. Yet definition underscores the need, although indirectly, to understand the geological constraints which will have an overbearing effect on field development and enhancing recoveries.

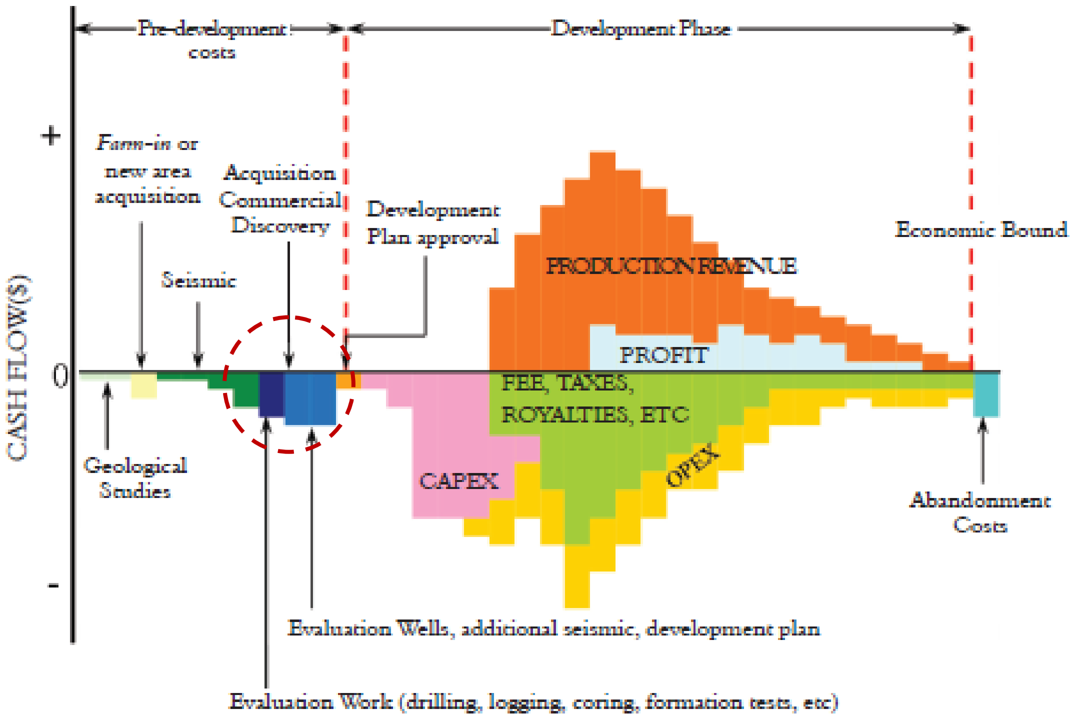

Fig: 1- Typical E&P cash flow system (modified after Suslick, 2009)

The above figure hints at geo scientific parameters being prerequisite for entering development phase. It is endeavour of the paper to deliberate on few essential elements which would help in dynamically updating the fiscal perception.

Geological Elements

Exploratory efforts through drilling reveal high resolution subsurface lithostratigraphic and mechano-stratigraphic picture. Digital log information is dovetailed with available seismic vintages to enhance spatial perception of prospects. An interpreter is able to create a process-response model using various seismic attribute and litho-facies stack as seen through digital logs. Reservoir characterization is essentially done using above mentioned tools. What becomes important is the factors which are

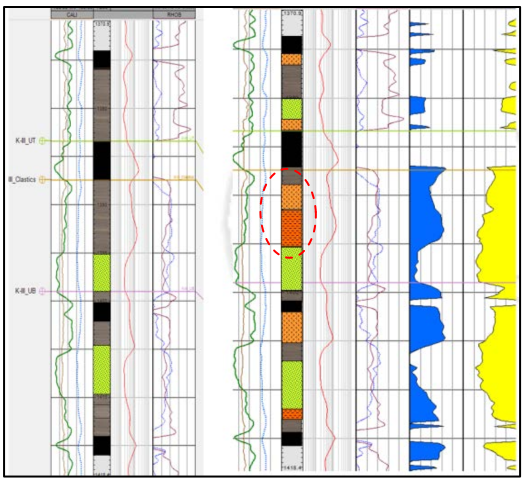

Fig-2A: Additional reservoir interpreted from the processed log

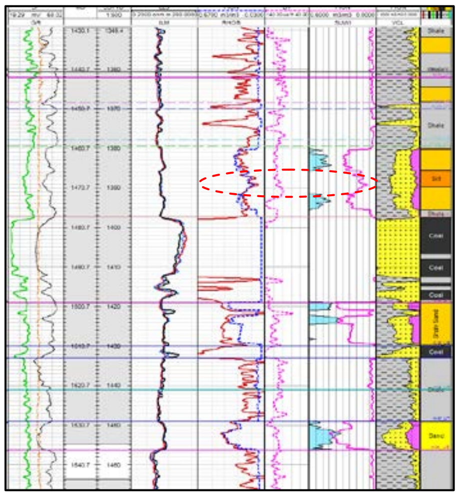

Fig-2B: Identified reservoir on GR is actually a fluid barrier considered to define “reservoir” by studying subtle variation of facies. It has been observed that subtle traps are likely to have a poorer facies definition when seen from a classical perspective.

With advancement of imaging technology and digital log processing algorithms subtle variation in litho facies are being broughtout which are likely to have a bearing on In Place reserve estimation.
Earlier log suites were unable to reveal subtle facies variations as a result of which the estimations of field In Place were largely gross. It can be seen that post digital log processing (Fig:2A) additional facies have been brought out which not only reveal saturation zones but also indicate that cleaner reservoir may not necessarily have better saturation. Hence processed log information becomes the first essential element which needs to be used while undertaking field development programmes.
There are situations where estimated reservoirs from GR log have turned out to be actually permeability barrier (Fig:2B). This creates a fiscal risk as estimated do not confirms with actual.

Clay Mineralogy: While undertaking log processing it is vital to utilise core and thin section studies so as to know the mineral suite which is available. Most of the times the focus of processed information is on reservoir zones alone and usually shale zones are processed as monomineral unit. In-depth knowledge of clay mineralogy is important for understanding and developing hydrocarbon fields, particularly where silicate diagenesis is a major process in the evolution of the host rocks (Jeans, 1982).Understanding clay mineralogy which constitutes shales is important. Clay minerals have unique properties individually for example, structure and composition of kaolins, smectites, and palygorskite and sepiolite are very different eventhough they each have octahedral and tetrahedral sheets as their basic building blocks. However, the arrangement and composition of these octahedraland tetrahedral sheets account for major and minor differences in the physical and chemical properties of kaolin, smectites and palygorskite in the petroleum industry. Illite is of interest for two reasons: (i) It can provide an isotope date constraining basin heating events, and (ii) it may precipitate in the pores of sandstone reservoirs, impeding fluid flow *(David, R.P., 1999).* The importance of kaolinite and mixed-layer illite-smectite in lowering the liquid permeabilities of the Lower Jurassic Bridport Sands were brought out by Morris and Shepherd for Wytch Farm Fields of southern England. Thus understanding clay mineralogy becomes second important factor. Presence of specific clay mineral clan within reservoir /subtle facies will affect permeability (K. A. Morris and C. M. Shepperd, 1982).

Fault seal analysis: In developing a brown field the fault sealing analysis adds to better planning and recovery of hydrocarbons. Initially due to small vertical throw the faults were not considered as sealing faults. However presences of different gas-water-contacts across the faults have shown that the sand shale juxtaposition on these faults establishes seal. This helps in optimizing the trap risks for exploration prospects in similar areas.

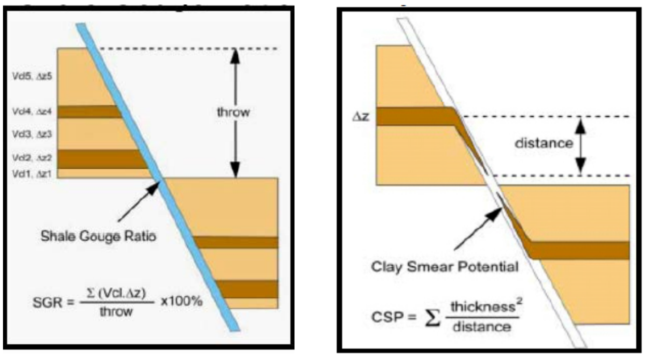

Fig-3: Shale gouge ratio and Clay smear acting as reservoir seal (modified after Farrukh Daud et al, 2010)

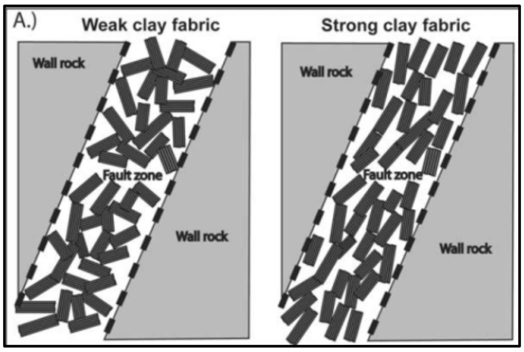

Fig-4: Preferred orientation of clay minerals in fault zone acting as reservoir zone (modified after Haines et al, 2009)

The Shale Gouge Ratio (SGR) (Fig-3) is an estimate of the net shale content that has slipped past that point on the fault plane. Clay smear potential (CSP) (Fig-3) is the entrainment of clay or shale into the fault plane, thereby giving the fault itself a high entry pressure.The clay minerals with unconfined compression without shear do not produce a strong preferred orientation (Fig-4). But clay minerals in the fault gauge shows strong preferred orientation along the fault plan resulting in compaction and porosity loss thus acting as reservoir barrier.

Shale seal analysis will help in better understanding of seal behaviour of various faults. As a result this will help in the more precise identification of fault dependent traps as well as locating future developments.

Stress Mapping: All petroleum reservoirs contain natural fractures. Natural fractures result from the interaction of earth stresses. A stress map of the field with proper stress orientation isimportant for better exploitation and reservoir management strategy. Fractures have significant effect on reservoir fluid flow in the form of increased permeability & porosity. Non recognition of the fracture system leads to poor estimation of drainage area and reserve.
Earths stress in an oil field is redistributed as a result of injection and production practices, etc. Under pressured or over-pressuredformation require appropriate exploitation strategies.
Considering example from Cambay basin study indicated that the fracture pressure in Ahmedabad field is about 210-230 ksc. Now as the injection pressure for Ahmedabad Field 110-120 ksc with average depth of 1510 mts in this region, the flowing bottom hole injection pressure will roughly be around 260-270 ksc, much higher than the fracture pressure. Water injection at such condition will lead to early water breakthrough in nearby producers and will minimize the sweeping efficiency. Thus planning of horizontal wells aligned with proper stress mapswill provide better sweeping efficiency.

Discussion

The above geological factors have an element of “uncertainty” which need to be appreciated while undertaking estimations of In Place. It has been demonstrated that how reservoir thickness interpretation based on GR without using processed information can be erroneous. Processed log information should not solely be used to identify saturated zones. It is felt that processed log, utilising core and petrographic information for mineral identification and using multi mineral processing algorithms, should also be used to determine the spatial variance of mineral concentration and bringing out subtle facies variations. In field where the well density is low or where developmental phase is about to be embarked aerial spread of these can be modelled using azimuthal variogrammes. Although the statistical approach itself is fraught with “uncertainties” yet with these model can be dynamically updated gradually as well density increases. It has been observed that saturations may not necessarily occur in clean reservoirs alone. Dovetailing facies and mineral spread would help in understanding fluid distributions but also the “natural” constraints which need to be overcome for improving Recovery Factors. Suitable technologies for better recovery can be designed and adopted. All this has a direct implication on fiscal parameters. The mapping of these elements would bring out “fairways” or zones which have mineral spread which results in better effective permeability. Development wells can be suitably place within fairways to tap pooled hydrocarbons. In zones where it is felt that poorer facies are present in which lot of recoverable reserves are locked cluster drilling / pater drilling activities can be designed. The exercise assume importance especially in case of brown field development as these are the vital factors which would force the operator to assess available technology and undertake a cost benefit analysis.

Mapping of seismic level faults can be easily done using seismic vintages. But understanding the nature of faults zone is largely dependent on the mineral assemblage especially clay mineralogy. High clay smear ratio along fault plane would have a bearing not only on migrating fluid but also on water flooding jobs which are periodically done to enhance sweep efficiencies and pressure maintenance. The successes in water flooding programme is largely depended on the quality of reservoir facies. In cases where a large number of development / water injector wells are needed to be drilled it is indicative that mineral assemblages are not permitting better recoveries for a given reservoir. But only when the type of mineral and their areal spread is understood one can design suitable technologies to overcome mineral induced fluid flow impediments. This will again affect the CAPEX planning and hence reduce the Risk Uncertainties.

Similarly it is vitally important to have a stress map of the field. This would help in understanding the likely spread of fracture and their orientation. The fractures are again a mechanical response of rheology to geo stresses. As mentioned earlier conditions where saturations have occurred within poorer facies or low permeability zones hydro-fracturing becomes important. But in order to achieve proper fracture spread and its stability it felt that stress mapping is critical.

Conclusion

The authors would like to underscore the need of:

1. Having maps of various minerals especially clay minerals which would synoptically help in bringing out reservoir fairways. Any drilling activities undertaken within these fairways would result in better recoveries.

2. Having stress maps of the field for undertaking controlled hydro-frac jobs. This would help in suitable positioning of drainage in zones where fracture density and spread would be maximum.

Acknowledgements:

The authors are indebted to Shri Anil Sood, GGM-HOI-GEOPIC, Dehradun, for providing the technical input and guidance for writing this paper. We extend our sincere thanks to Asset Manager, Ahmedabad Asset & his team for time to time discussion and support. We are thankful to the members of the interpretation group, for their kind cooperation and valuable guidance. We thank ONGC management for allowing us to submit this paper in Geo-India 2015, 3rd South Asian Geosciences conference and exhibition.

The views expressed in this paper are solely of the authors and do not reflect the view of ONGC.

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