Reservoir Management a Key to Rejuvenation of Mature Fields*

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Abstract

Reservoir Management begins with exploration leading to discovery followed by appraisal of the reservoir, development of the field under primary and secondary means, IOR and EOR, and finally to abandonment. New discoveries of conventional oil fields are declining, while demand for oil is estimated to increase approximately 1.5% per year. Development of mature oil fields has been, and will increasingly be, a focused subject. Most of the world's oil production comes from mature fields, and increasing production from these fields is a major concern for the E & P companies.

Maximizing the hydrocarbon recovery over the field life is the primary objective and the biggest challenge of any organization. Seamless integration of the skill sets from all disciplines (Geophysists, Geologists, Petrophysists, Reservoir, Production, Drilling, Completions, facilities and Economists – Figure 1) and the corresponding data sets can be a complex affair, but is essential for the optimum field development planning.

Boosting oil recovery from mature fields needs bold investment decision and induction of new technologies. A judicious mixture of classical and new technologies have created the opportunity for new life for the mature offshore reservoirs. Mature field development practices can be divided into two major groups: 1) Surface/well engineering, and 2) Subsurface/reservoir engineering. With increasing rig cost, conventional perforations have been practically eliminated by exposing larger reservoir section for production/water injection and in the process increasing drainage area and reducing well spacing. This leads ultimately to higher recovery and cost saving through drilling fewer wells. Modern tools and technologies have come in handy in achieving this goal and appropriate technology application to our need has paid rich dividends.

A multi-disciplinary approach to describe the reservoir and review of production and injection performance led to identification of unexploited area in a mature field. Detailed geology and geophysics work along with reservoir simulation studies were carried out to identify the undrained oil saturation areas. Exploitation of this bypassed oil arrested the field decline and stabilized the production rate (Figure 2).

Horizontal sidetracks offer a very viable technique for rejuvenating production. In brown fields, significant reserves exist as bypassed oil or locked in relatively stacked tight reservoirs. The exploitation of this oil with cost-intensive new wells drilled through new platforms will hardly satisfy the investment decision. The repositioning through short/medium radius drain-hole completions (SRDH/MRDH) of sub-optimally/high water cut wells that have drained the oil from their drainage area enhances production and maximizes the reserves portfolio. Technology has helped in drilling of ERD wells to far places from existing platforms in complex subsurface architecture. Ideal drilling fluid technology has been adopted for high drift well stabilization in upper sections and non-damaging fluid in reservoir section to minimize formation damage. Well placement technology with online monitoring at base has improved proper well steering though thin sweet zones.

In the field of well completion, higher level multilateral technology has been adopted to control individual reservoir performance. Segmented completion was used to control water production (Figure 3). The present paper will discuss mainly how induction of different technologies has helped in boosting production and also in recovery factors from the offshore carbonate reservoir producing for last 20 to 30 years.

Case Study

Field A offshore field was discovered in 1977 and put on commercial production in 1984. As a part of a development strategy, the field was developed in phases. The production performance is shown in Figure 4.

The field is heterogeneous with multi-pay reservoirs and provides the opportunity for application of reservoir management to enhance the production and improve the recovery. Over its life the field has encountered the major problems of increase in water cut due to preferential movement of water through high permeability streaks, sub-optimal production from existing wells, large well spacing and pressure sinks in some of the areas. The field offered significant flexibility for a revitalization plan under redevelopment. Identification of bottlenecks/constrains imposed by existing infrastructure such as existing locations vs target locations, existing capacity vs new required capacity, etc. necessitated an optimal redevelopment proposal to remove them and to maximize and optimize reservoir exploitation.

From the sub-surface point of view, after having produced just about 15 % of OIIP, the wide gaps between the platforms offered the tremendous opportunities to redevelop the field under a Saturation-Exploitation program through brownfield development and large scale in-fill wells drilling. Keeping in view the challenges and the opportunities in terms of enhancing the recovery of the field, a major redevelopment measure was undertaken to sustain and improve production through relocating the poor performing injectors and producers, selective infill drilling, optimization of well trajectories, water injection management and the state-of-the-art reservoir management practices. Keeping in mind the large investment decision, the rejuvenation programme was initiated with a pilot scale.

Pilot Study

One platform in the western flank of the field was taken up as a pilot project for brownfield development. The main objective of this pilot was to sidetrack the existing poor producers towards the undrained/better saturation areas and to drill horizontal drain holes utilizing the latest available drilling technologies. The platform was producing oil at 2500 bopd with 65% water cut before the well interventions. In this area, the reservoir is generally tight. Detailed reservoir studies, log analysis and micro correlation exercises were carried out to identify layers contributing high water production. Wells were sidetracked and converted to horizontal drain holes and suitably placed in better oil saturation areas. Use of state-of-the-art technology (e.g. short and medium radius drain hole) made it possible to achieve better placement of wells with low horizontal drift through high dog legs (Figure 5). This further helped to negotiate minimum shale thickness above the pay and avoid extra casing/liner.

Use of non-damaging mud during drain hole phase and surge plug helped faster activation of wells. Oil production from the platform increased from 2500 bopd in April, 2005 to 7600 bopd in May, 2006 with a reduction in water cut from 65% to 25%. Current oil production rate from this platform is about 3000 bopd at 65 % WC (Figure 6).

The success of this pilot led to taking up of additional platforms for enhancing the production. To date, 51 existing wells were taken up for successful well interventions.

Field Programme

For the full field rejuvenation programme, relatively simple classical reservoir engineering techniques were used to elaborate much detailed reservoir characterization and fine grid simulation techniques. Permeability predictions are a critical aspect of reservoir description and are particularly challenging for carbonate reservoirs. Conventional multiple regression techniques very often yield unsatisfactory results. A novel approach of developing permeability transforms has been adopted to develop the permeability correlations and applying it to the geological model for populating permeability distribution in the field. The approach followed the identification of electro-facies based on core data and well logs and correlating them using non-parametric regression technique (Figure7). The main advantage of this technique is that it is primarily data driven as opposed to model driven and does not require a prior specification of functional forms, which makes conventional multiple regressions difficult.

Drilling and Well Placement

Time lapse seismic, facies modeling using Petrel, and the dynamic model for the field has been extensively used for accurate placement of the wells. The close grid 3D seismic has brought out finer structural details for placing wells in the most favorable areas. The disposition of minor faults could be defined more accurately and the spatial distribution of digenetic effects could be understood more accurately. Different seismic attributes were generated to locate appropriate facies for well location.

Some of the examples of well placement using model based parameters are shown in the Figure 8. To address the problem of optimum drain hole placement, a new methodology was adopted in which Down Hole Fluid Analysis (DFA) and permeability profiling have been added to the conventional Wire line Formation Tester (WFT) pressure survey. DFA has been used to determine the present location of contacts, and based on samples, the drain hole was placed successfully.

Completion Technologies

Level-3 Completion

The advancement in multilateral well completion technology has helped worldwide in increasing per well productivity and reducing development costs. The technology is suitably adapted in multi-pay reservoirs and there has been tremendous improvement in healthy well completions. The Level-3 completion (Figure 10) helps in independent monitoring and intervention.

Segmented Completion

A Segmented/intelligent completion is an integrated completion system capable of enabling remote action to enhance reservoir control and well production performance. Segmented Completion in Horizontal Open Hole is a promising technology used to combat different problems in the long section of a horizontal open hole.

In this completion the horizontal open hole is divided into segments using packers. Either surface controlled internal control valve (ICV) or CTU operated Sliding Sleeves are used in the segment (in between the Packers) for selective production/stimulation. In the case of CTU, operated sliding sleeves intervention of coil tubing is required to open/close the sleeves for either opening the desired section or to shut the undesired section of the horizontal well, whereas in the case of intelligent ICV system the above operation can be done from the surface without any intervention (Figure 11).

The effective reservoir management efforts have resulted not only in arresting the decline in oil production from the field, but also in an upward swing from 43,000 bopd to a current oil rate of 57,000 bopd (Figure 12). The measures taken over the period helped to arrest the overall field water cut in the range of 51-55% over the last 10 years thereby limiting the water production from the field.

Key Features

1. Success of multi-disciplinary approach.
2. Identification of bypassed oil with the help of detail reservoir characterization and reservoir simulation.
3. Improvement of recovery through brownfield and greenfield development
4. Water injection management.

Conclusions

1. Multi Disciplinary Team (MDT) approach is key to successful management of mature fields.
2. Integrated approach adopted to define reservoir heterogeneity, hydrocarbon storage, and flow units.
3. Facies analysis based on logs coupled with core and field data has given satisfactory permeability distribution.
4. ST and new wells were identified to exploit bypassed oil.
5. Sub-optimal wells were considered initially for relocation in better oil saturation area.
6. The success of brownfield development has helped in formulating the redevelopment scheme.
7. All the wells were drilled horizontally/multi-laterals/drain holes for improving productivity.
8. Heera Field redevelopment envisions increase in recovery by 5% in first redevelopment scheme.

Figure 1. The management team.

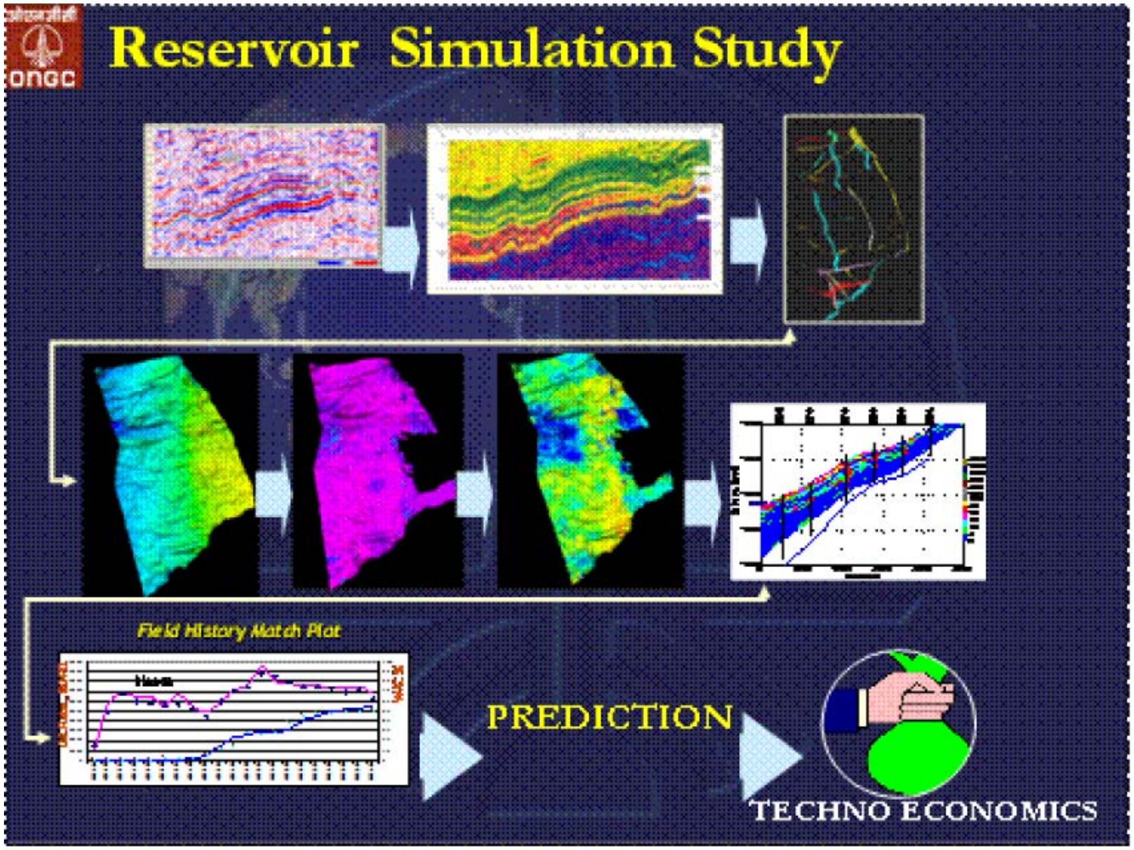

Figure 2. Workflow of the reservoir simulation.

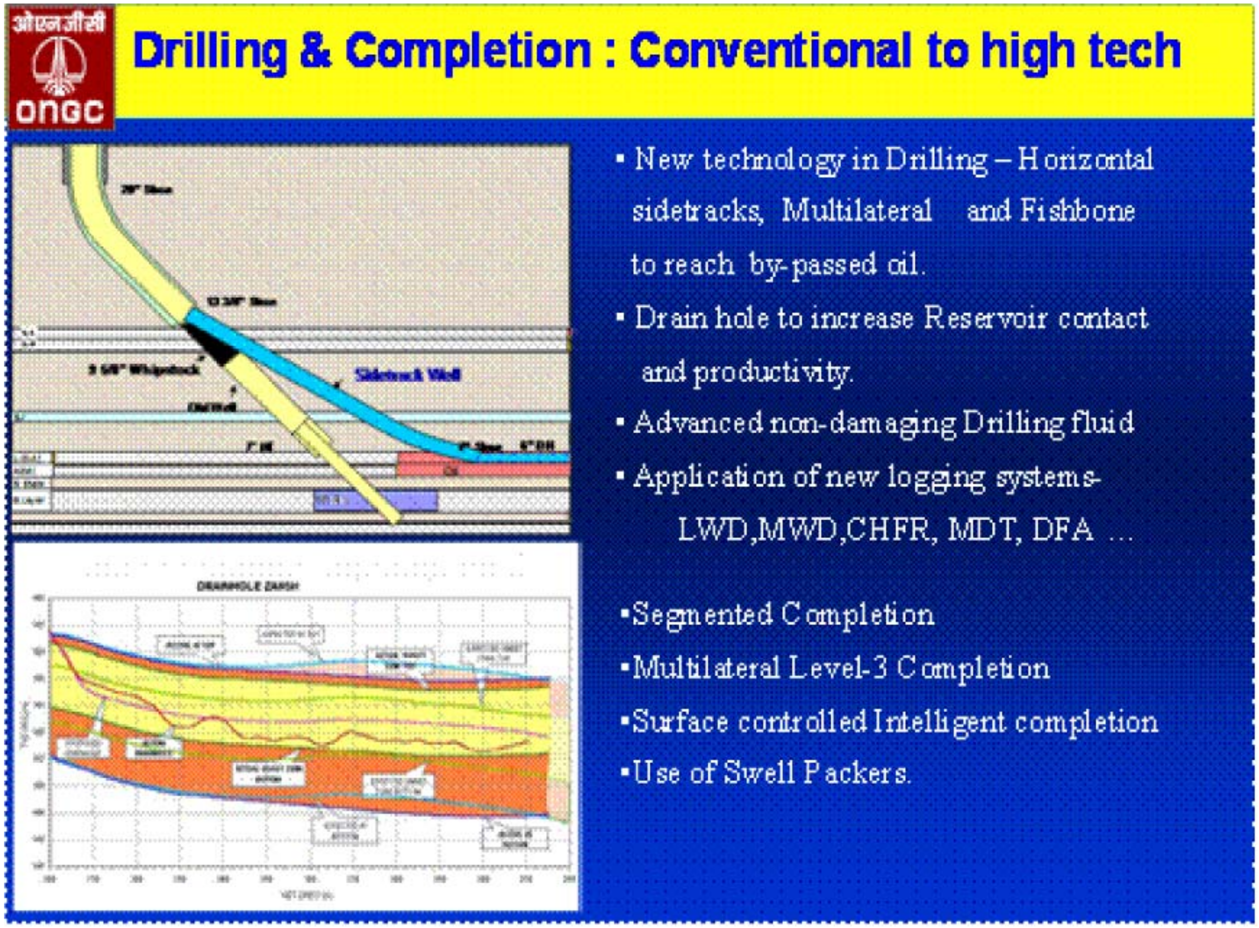

Figure 3. Drilling and completion.

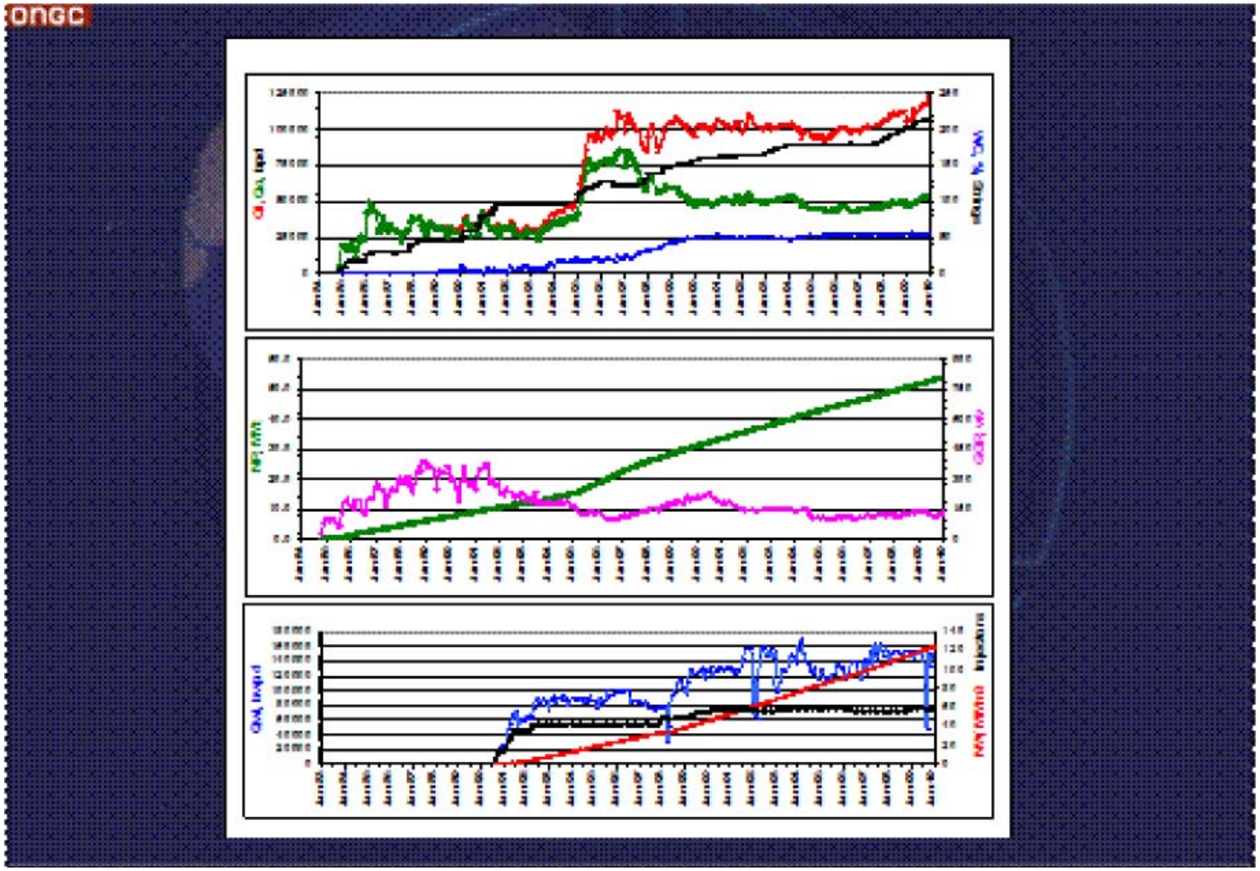

Figure 4. Production performance of Field A.

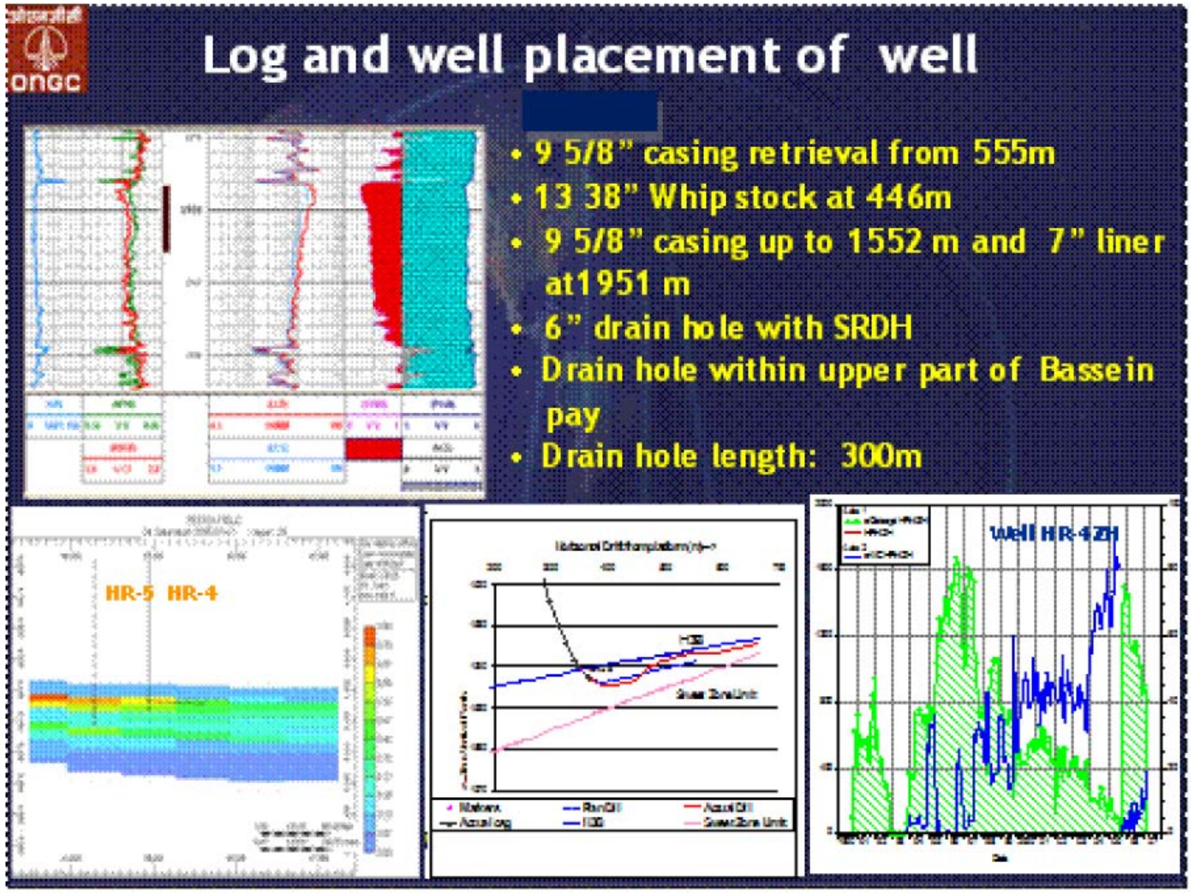

Figure 5. Typical log and well placement.

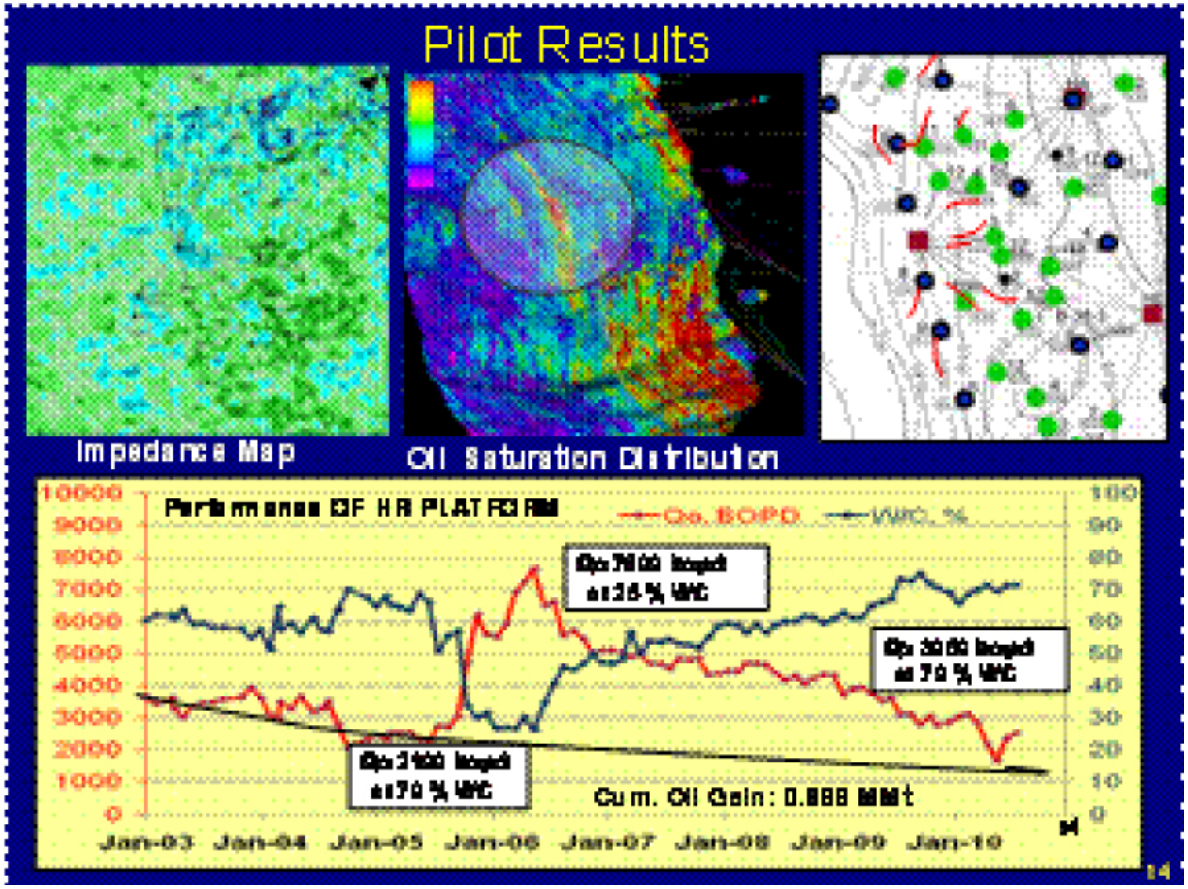

Figure 6. Performance before and after WOJ.

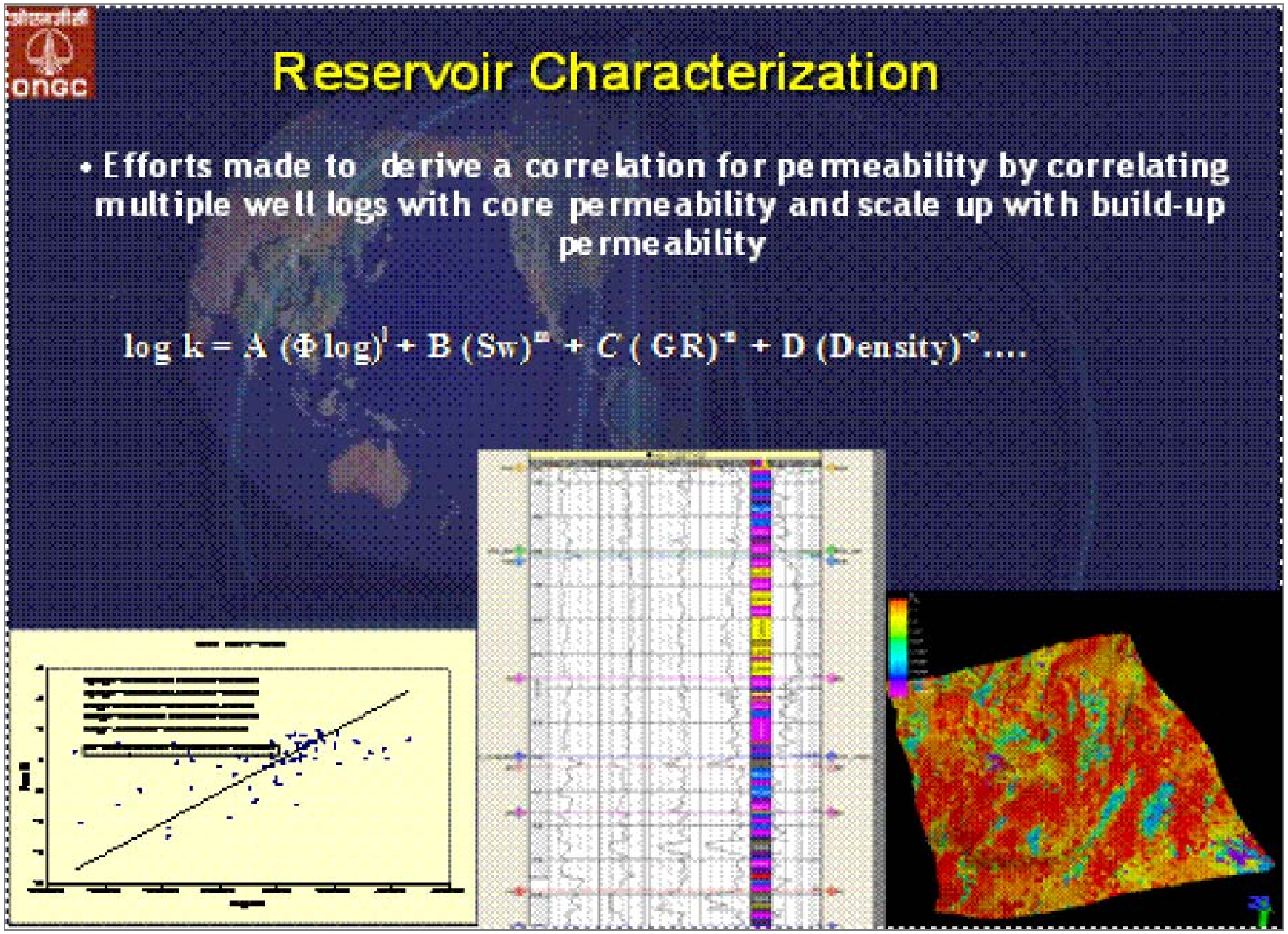

Figure 7. Permeability transform.

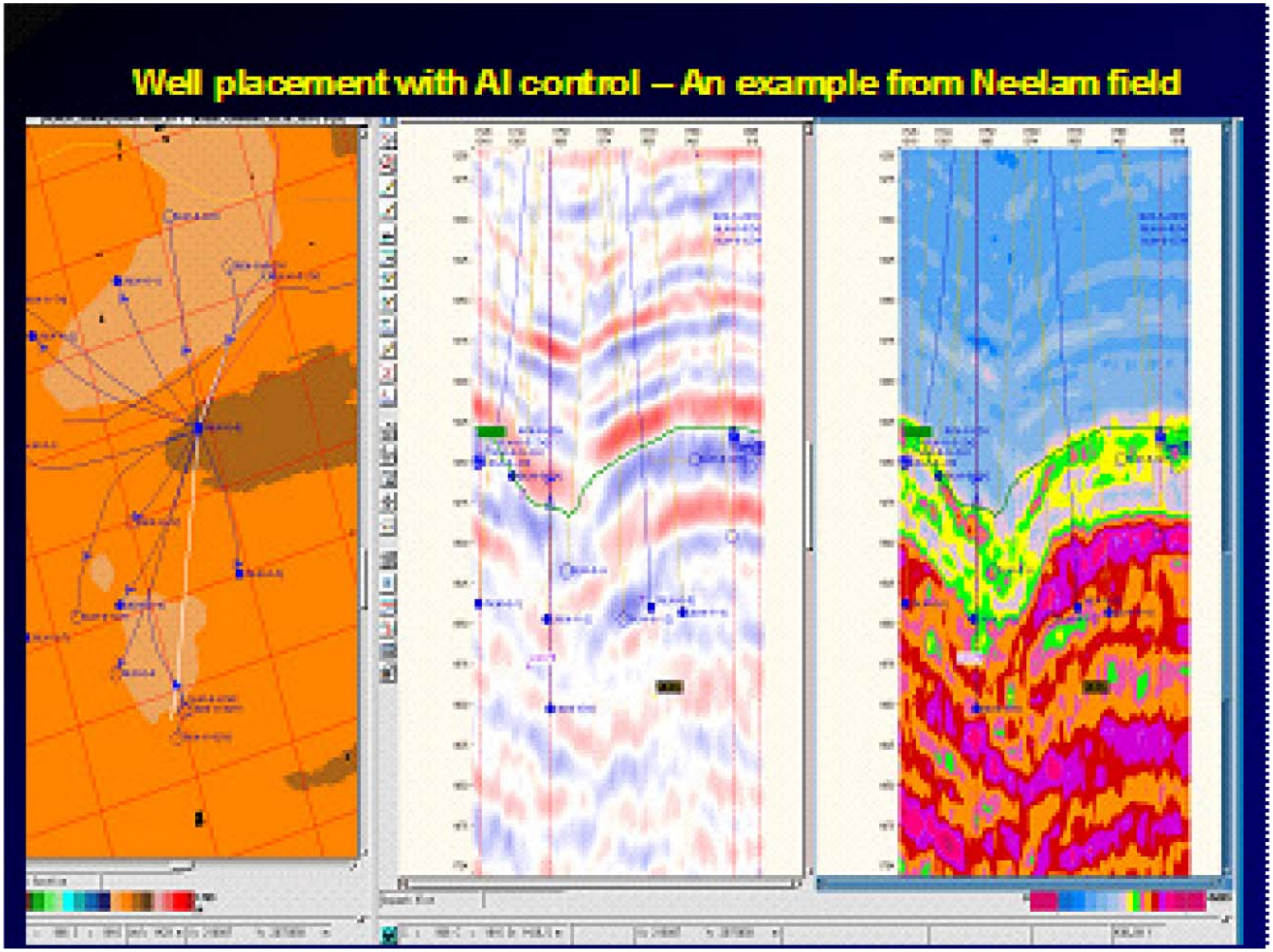

Figure 8. Well placement based on seismic attributes.

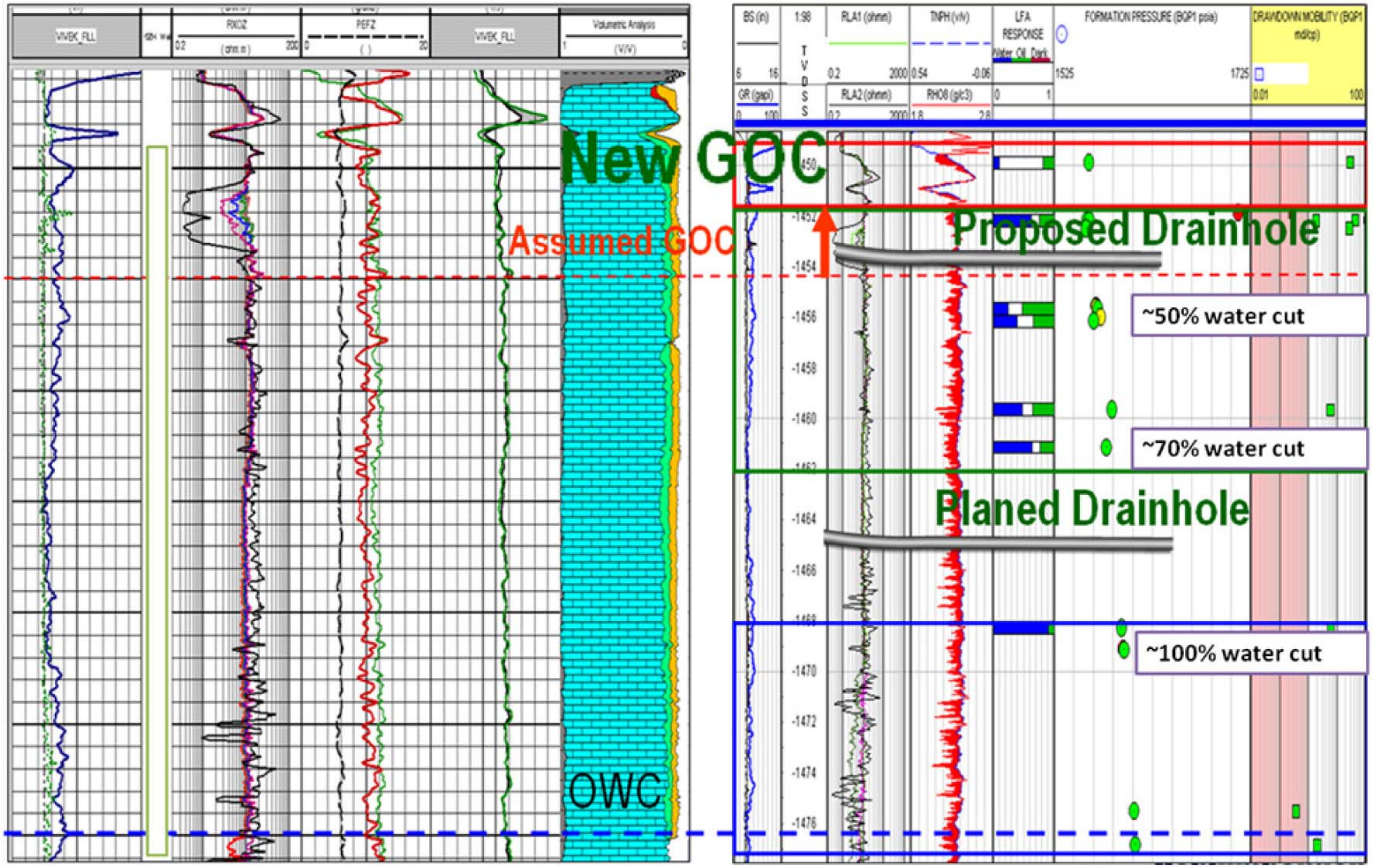

Figure 9. Well placement based on DFA result.

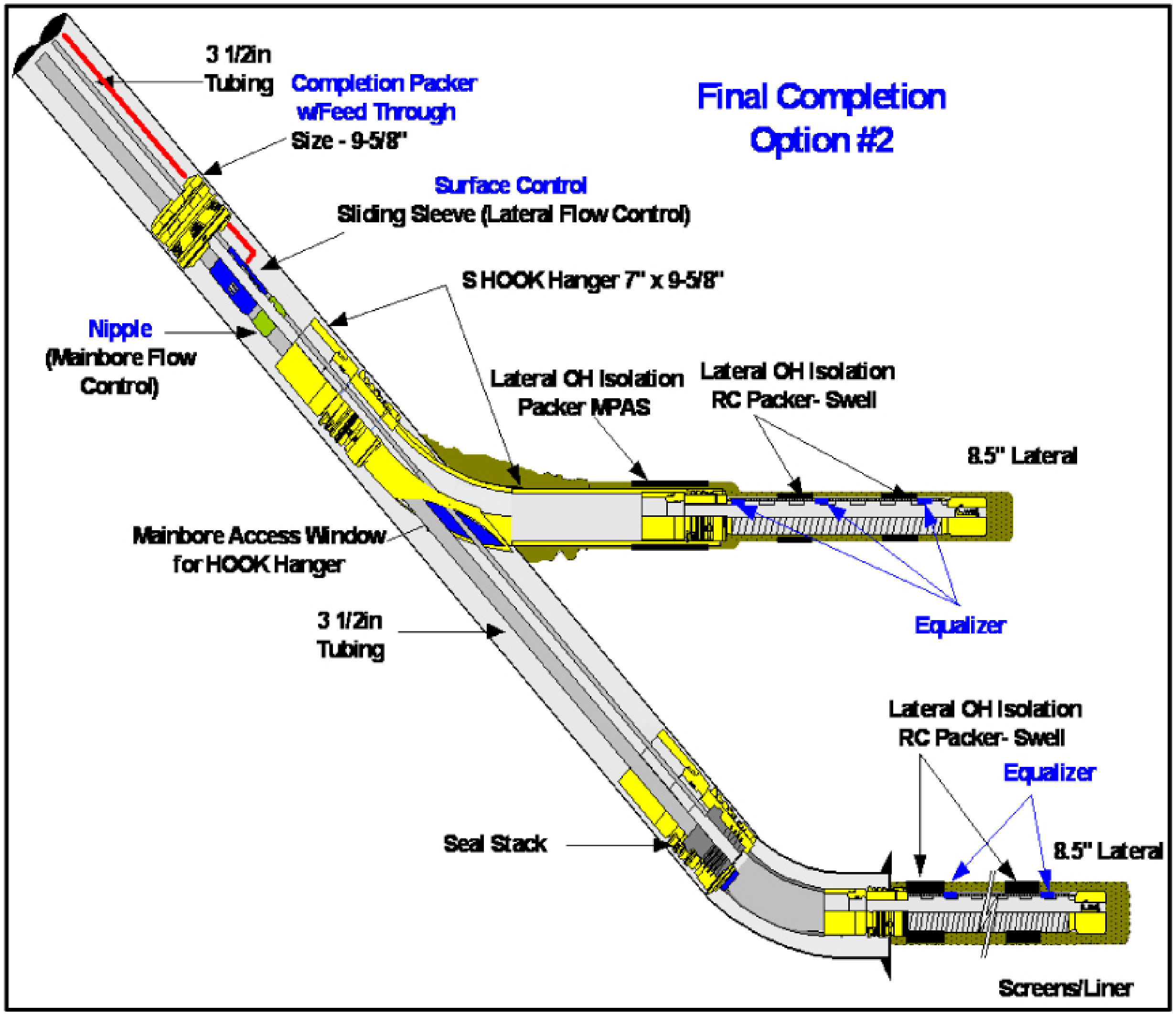

Figure 10. Level-3 completion in a typical well.

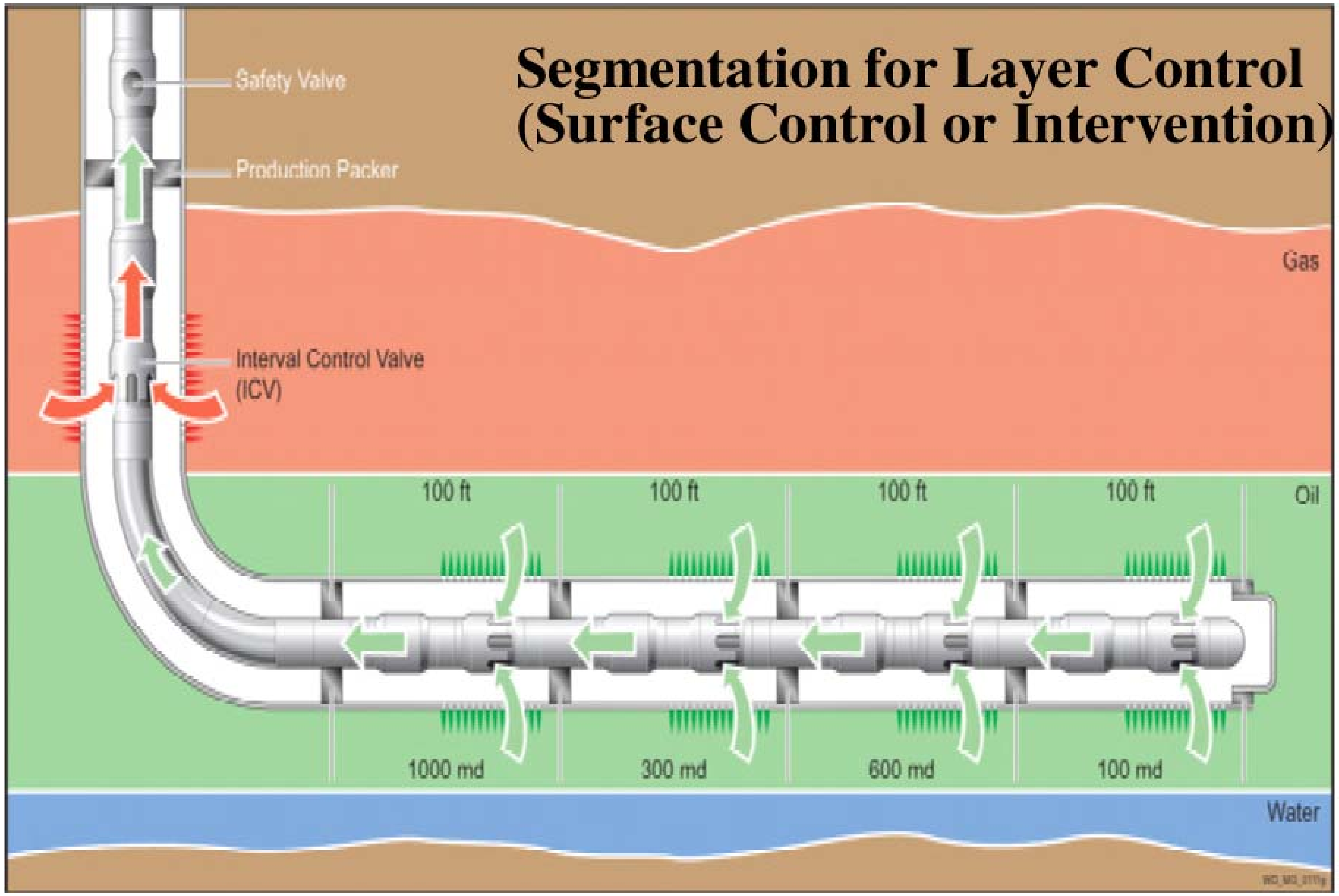

Figure 11. Segmented completion.

Figure 12. Production trend since 2005-2006.