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The Multiple Role of Unconventional Drilling Technologies. From Well Design to Well Productivity

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Abstract

This paper deals with new drilling technologies and is focused on their ability to reduce capital expenditure per barrel produced. During the last decade, they have greatly contributed both to improve production and reserves but also to decrease operational costs. TOTAL has been involved in these unconventional technologies all over the world and has used them for numerous original applications

- ERD to reach offshore reserves from onshore facilities (Argentina),
- ERD to test a marginal panel from existing offshore facilities (North Sea),
- Multilaterals to explore and delineate a blind zone (Libya), to improve production and to increase reserves (Libya, North Sea) or to revitalise a mature field (Middle East).

Unconventional drilling technologies play a key role today where conventional technologies are not fully efficient to keep development profitable. With time, smart drilling which appeared at the end of the 80's has progressively become a must for any field development.

Introduction

In the past, to properly develop an oil field, numerous vertical wells were required. Each of them had a specific role devoted either to exploration, appraisal or development. In such a context, there was no real need for geoscientists, reservoir engineers and drillers to work in close collaboration. Each of them had a specific role in the technical chain and, the link between drilling and well productivity was restricted to formation damage control. In that context, the choice of the drilling technique had no real impact on reducing capital expenditures per produced barrel.

With the proliferation of deviated and horizontal wells together with the appearance of MWD, the steering of a drain allows drillers to go further and further from the tie-in-point with greater reliability. Today, extended reach wells are commonly drilled with departures between 5 km and 10 km. Drilling off-shore reservoirs from on-shore facilities is now a reality. LWD allows the piloting of a single horizontal drain through several lenticular reservoirs or even navigation in several levels of a layered reservoir with pseudo horizontal dip.

Finally, multilateral technology which appeared a few years ago has spawned numerous new applications from the earliest period of a field (exploration and delineation) to the latest one (revival of a mature field).

Unconventional drilling technologies have now reached their maturity. By strongly reducing operational (less meters drilled for a same production) and developmental (use of existing surface facilities) expenditures, these new technologies allow us to increase production per well but also to improve ultimate reservoir recovery factor.

In such a context, drillers are no longer drillers. They can be considered as *"reservoir architects"*. Their capability to accomplish more and more complex wells aims at reducing by a large amount CAPEX per produced barrel. In such a way, well design can be considered today as a way to improve productivity. Following are some examples of unconventional drilling applications achieved by TOTAL world-wide. The aim is to emphasise on the impact of well design on well productivity in the sense of cost per produced barrel.

Minimize CAPEX by drilling Extended Reach Wells

During the second half of the 80's, horizontals brought a major step forward in reservoir development. Drilling cost reduction and reservoir drainage difficulties were the two main driving forces which pushed the innovation. Reservoirs in tight zones which were unprofitable when developed with conventional drilling can now be produced economically with horizontal drains. More recently[1,2] (beginning of the 90's), ERD has allowed us to reach further and further targets from the same tie in point. We present below two original applications of ERD in Argentina and the North Sea.

Drilling off shore from on shore facilities. Hidra field

The Hidra field was developed at the end of the eighties off-shore Tierra Del Fuego[3] (Argentina – **Fig. 1**). From 2 wellhead platforms a total of 16 gas lifted producers and 5 water injectors were drilled but, two satellites oil accumulations, Ara South and Hidra South were left untapped. Located respectively 6 km and 5 km away from the platforms, they lie in a thin sandstone reservoir between 1500m and 1750m vertical depth. Some five years of production brought out 80% of the recoverable oil, leaving spare capacity but also increasing radically the operating cost per barrel. As pointed out in **Table 1**, additional wellhead platforms or subseas trees would not ensure economic profitability. The economic simulation shows much higher profitability for ERD from on-shore. Consequently, an ambitious on-shore drilling campaign began in 1996. From May 1997 to January 1999, 8 wells have been successfully drilled. Two of them have reached 8 km departure[4] (2^{th} an 5^{th} worldwide longest departure) and the last one (11021m MD and 10404m departure – **Fig. 2**) is currently a world record. Today, the overall production of these ERD represent 75% of the total area company production

Testing a new panel from existing off shore facilities. The Dunbar field.

The Dunbar field is located in the northern part of the North Sea (**Fig. 3**). The three main targets (below 3500mTVD) are in the middle and bottom Jurassic (respectively Brent and Statfjord reservoirs) and in the Triassic (Lunde reservoir). Depending on the location they can be oil bearing, gas bearing or both. The field is divided into several panels. The platform is located (**Fig. 3**) in the West Flank panel. To date more than 20 wells have been drilled mainly in the West Flank, the Central and the Frontal panels. Developement of potential reserves trapped in the Dunbar South panel necessitate the building of new off-shore facilities. In the past, a vertical well was drilled in that panel and a short term test showed quite interesting results. However to go further, a long term test (several months) is absolutely necessary. Given the daily cost of a specially devoted semi-sub, such a test would not be economical. The only possibility was therefore to drill an ERD from the existing platform located some 6km away from the target.

To drill the well (8000MD at 3200mTVD- **Fig. 4**), it was necessary to kick off the inclination at a shallow depth. With such a design, the inclination reaches 65° at the 13"3/8 shoe and the slant section has to be held at 75°. This trajectory poses numerous problems particularly in the highly unstable shales[5] (Eocene) drilled in the middle of the 17"1/2 section and in the reservoir section where high ECDs can induce large mud losses. Quite sophisticated pre-engineering (including wellbore stability analysis, hydraulic calculations[6] with realistic advanced models) and downhole real time monitoring of the main drilling parameters (ECD, torque, WOB, vibrations) become in these extreme cases of a strategic importance.

The multilateral techniques

Parallel to the proliferation of extended reach and horizontal drillings, new emerging techniques have appeared at the beginning of the nineties[7] : the multilateral which consists of producing several horizontal sections from a common parent well. Today, the multilateral technique offers a large variety of solutions from the simplest (open hole main trunk and laterals) to the most sophisticated (perfect mechanical and hydraulic integrity of the junction). According to the sophistication of the junction, multilaterals have been classified in 6 levels (**Fig. 5**). Levels 1 and 2 are the simplest (they do not guarantee mechanical and hydraulic integrity), levels 3 and 4 only guarantee mechanical integrity and levels 5 and 6 (**Fig. 6**) deliver both mechanical and hydraulic integrity. Today, only levels 1 to 4 are considered as reliable and cost effective solutions. Among the applications of multilaterals, the most common are

-exploration delineation,
-increasing well productivity and reserves,
-revitalising a depleted mature field.

Exploration of a blind zone. Mabrouk field - Libya

Drilling horizontal branches from an existing trunk is a powerful way to explore and delineate at low risk and cost.

Mabrouk is an oil field located south of Golf of Sirte on-shore Libya. In a certain part of the field (called *"blind zone"*), the seismic interpretation was difficult. However, several exploration vertical wells had shown that 20% of field reserves were trapped in that "*blind zone*". The idea was to drill a production horizontal parent hole parallel to the blind zone (**Fig. 7**) then, a perpendicular branch towards the unknown area. This original architecture has the advantage of ensuring the production of the parent hole (located in a known area) in the case of an unsuccessful investigation in the blind zone. From an economic viewpoint, this exploration technique is very attractive since the additional drain (left in open hole) only increases the global cost by 15% compared to a single drain.

Maximising productivity and increasing reserves. Mabrouk (Libya) and Dunbar (UK) fields.

Drilling multilateral branches allows us to step up over a large range the number of drainage points from a single parent well but also strongly reduces the development cost per produced barrel.

Again, this technique was used on Mabrouk. The final production of a 4-branches multilateral (**Fig. 8**) is equivalent to that of 3 horizontal wells with a final cost only 20% above that of a single horizontal.

Another interesting example is the drilling of an intermediate radius, long lateral side-track drain in the Dunbar field (Viking Graben - North Sea) initiated from a low inclination (32.3°) parent hole[8] which had been drilled four years earlier and producing several commingled reservoirs. The main goal was to constrain the drain within the upper part of the UMS formation (Upper Massive Sand - Brent reservoir) over a distance of 1000m from the parent hole (**Fig. 9**). To reduce the cost, the side track was kicked off directly in the reservoir. This allowed keeping the whole drain open hole and avoiding covering the highly unstable Kimmeridge shales[9] from the overburden. A window was first milled through the parent hole casing. The kick-off (51°/30m DLS) was successfully achieved in two runs. Thereafter, 910m of horizontal drain were drilled in 4 runs (10 days). Production from the tight zone, as measured prior to the lateral drain through a temporary completion, was 65bbl/day. The well test performed immediately after the clean-up indicated a production of 3500bbl/day from the lateral alone. This massive increase demonstrates a clear success for the lateral drain as the appropriate well architecture for the problems posed by tight sands. More important is the amount of oil that has been *"unlocked"* by this technique. Reservoir estimates prior to the lateral figured on 4.4 Mbbl being drainable from the tight areas. Now estimates are in the range of 9 Mbbl. This was achieved without losing the possibility of draining zones in the parent bore below the depth of the tight part of the UMS. D05z lateral is the first extremely long lateral drilled in the North Sea after an intermediate radius curve. The combination of high DLS (up to 51°/30m), TVD (3570m) and length of the drain makes it as a world record. The opportunities that the success of this well are considerable. The re-utilisation of investments made in existing wells, to side-track them into new panels without having to re-drill formations presents very strong economic driving forces for considering these *"avant-garde"* well designs.

Revitalise a mature field

Additional branches in mature fields allow us to delay production decline at a reasonable cost (drainage of secondary structures, better sweepage in the scope of a gas or water injection program, save a slot). This is the case for the Abu Al Bukhoosh field (ABK - off shore Abu Dhabi) which was put on stream in 1972. More than 30% of the current production comes from new drains added to existing wells. As pointed out on **Fig. 10** these laterals offer a second life to existing wells. For instance, two new drains drilled from an existing parent hole then covered by a multizone completion separate production of the two drains and the main trunck.

Drilling a lateral from a completed well

Drilling a lateral from an existing well can be costly because of the necessity to perform a work over prior to the reentry. By using the coiled tubing drilling technology, it has become possible to reenter a well without pulling out the completion. This offers opportunities in an economical environment where light interventions and low cost solutions are the main drivers. Ciled tubing working with a closed loop fluid system, it easily allows drilling in underbalanced conditions which has the advantage of improving ROP and preventing formation damage. To date several hundred re-entries through completion have been performed all over the world.

Conclusions and perspective for the future

Ten years ago, horizontal wells were considered as a *"high tech"* architecture. Today half of development wells drilled by Total are horizontal. It has become a *"standard"*. In the same way, over the last five years, the number of ERDs and multi laterals has grown over a large range. Today with several world records in ERDs and more then 20 multilateral wells world-wide, TOTAL has acquired major experiences in these new technologies. Both technical feasibility and economic benefit have been demonstrated in very different contexts. As for horizontals today, ERDs and multilaterals will be the standard of tomorrow. However, these complex well architectures are also a challenge for geoscientists, reservoir and production engineers. Indeed, if geosteering real time, reservoir modelling or selective stimulation of a horizontal is far from easy what can we say about multilaterals? New well architectures represent a tremendous opportunity for geoscientists, drillers, production and reservoir engineers to work in close collaboration in integrated teams. In a very depressed oil market, they have a real opportunity to choose the best solutions to minimise the risk and re-establish profitability.

Acknowledgement

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	Capex	NPV	PayOT
Platform	2.3	1.9	5.8
Subsea	2	5.7	2.4
ERD	1	1	1

Table 1 – Comparaison between platform, subsae and ERD (Hidra – Argentina)

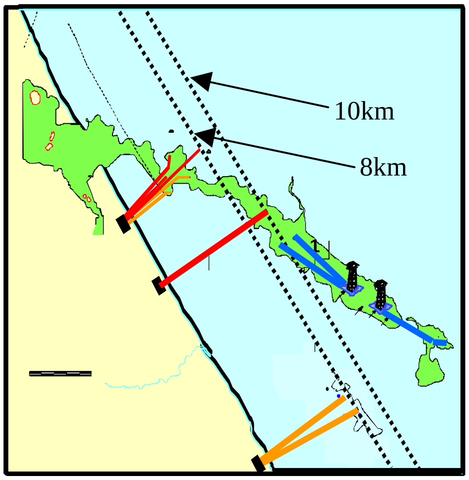

Fig. 1 Location of the Hidra field
(Tierra del Fuego – Argentina)

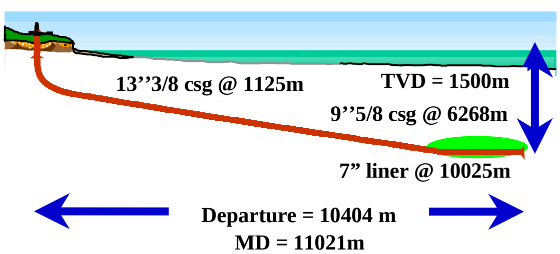

Fig. 2 ERD profile and casing strategy
(Hidra field – Argentina – World record)

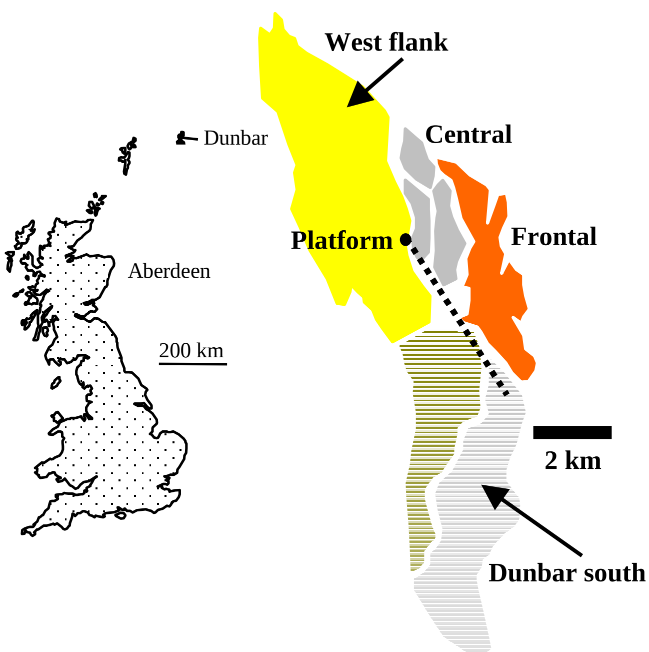

Fig. 3 Access of the Dunbar south panel
from the existing platform

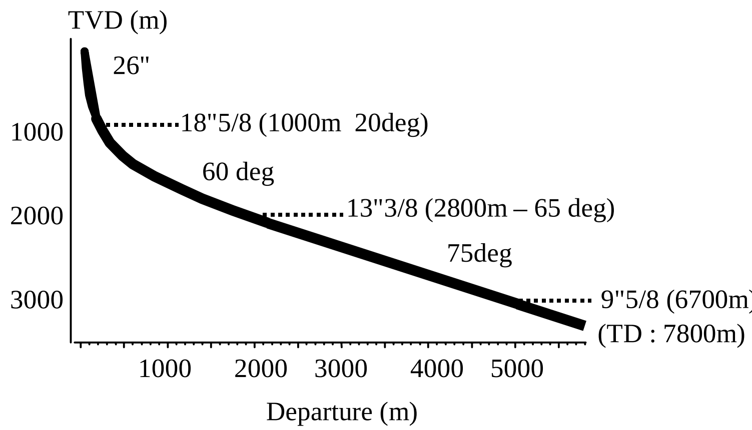

Fig. 4 Dunbar D22 – Well profile

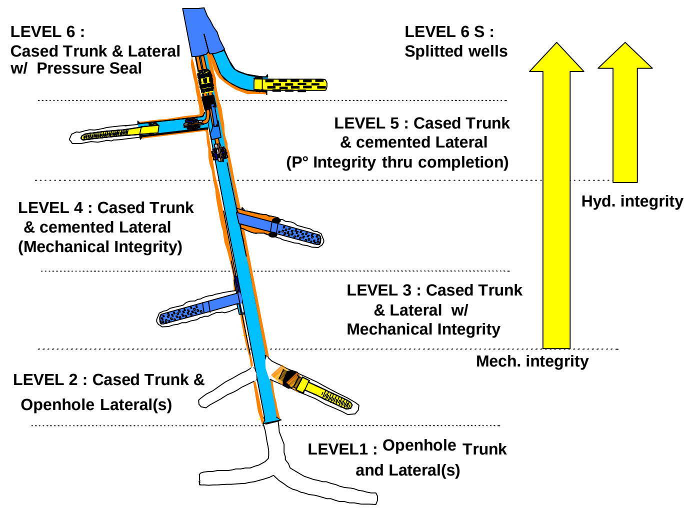

Fig. 5 Multilateral : complexity levels
One to six.

Fig. 6 Bi branch casing
(developed by Marinovation)

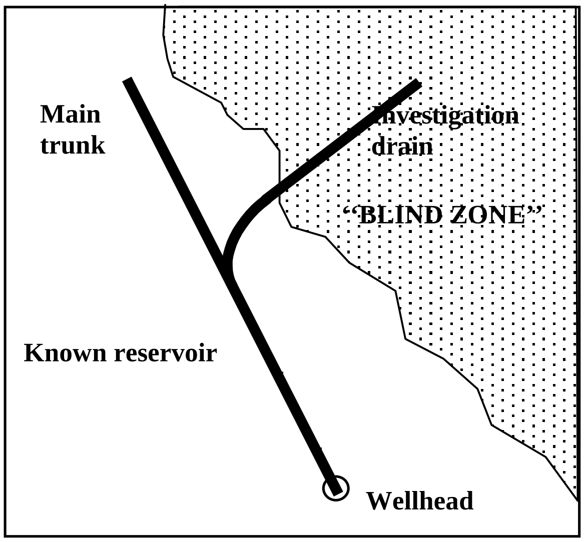

Fig. 7 Exploration of a blind zone from a producing main trunk (Mabrouk field – Lybia)

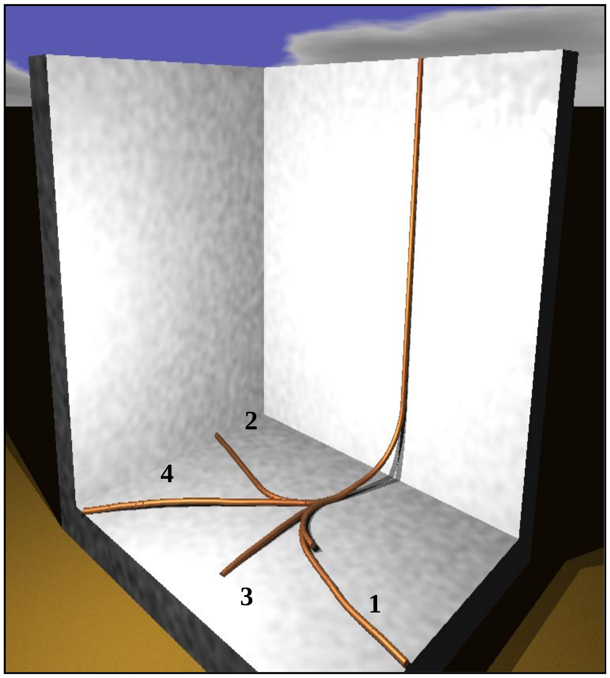

Fig. 8 4-branches multilateral (Mabrouk field – Lybia)

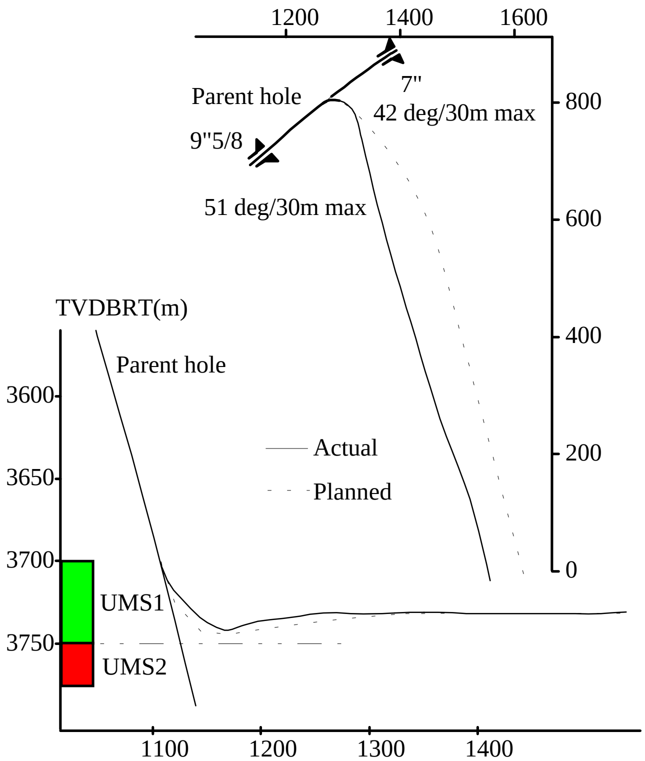

Fig. 9 D05 : planned and actual trajectories

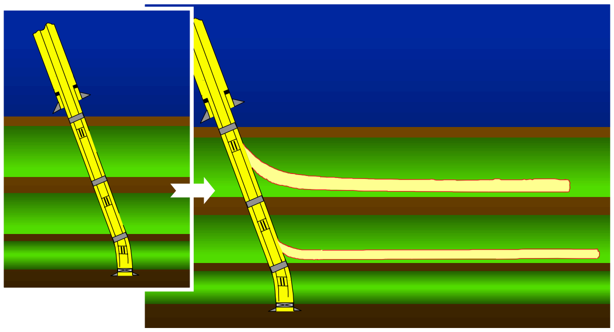

Fig. 10 Revitilise a mature field by drilling Multibranches in layered reservoirs (Abu Al Bukhoosh field – Middle east)