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New oil and gas – Technology leads the way *

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Introduction

Following the sharp rise in oil prices in 1973, oil companies endeavoured to increase their reserves and production. This was attempted through the development of unconventional oil from bituminous shales or tar sands and the extensive use of enhanced oil recovery. However, when oil prices dropped in 1985, such projects were no longer viable due to the huge investments required. Subsequently, new reserves were found by applying new techniques to the search for traditional oil and gas accumulations.

Improvements in seismics

In exploration, a substantial improvement in the quality of acquisition and (re)processing of seismic data has taken place over the past decade.

The improvement of the resolution of 3D seismic data ensures a better definition of traps and can result in the discovery of new oil and gas reserves. An example on a field offshore Nigeria clearly demonstrates the extent of improvement achieved between 1975 and 1992. Figure 1 displays a 2D seismic line shot in 1975. Three wells were drilled very close to this line, proving different oil-bearing zones (indicated in thick black). On the early version of this seismic section, the quality of the data was rather poor, especially with respect to fault definition, and was not good enough for locating additional wells. A seismic section taken from a 3D survey recorded in 1987 is shown on Fig. 2. This line is almost superimposable on the previous 2D line. On this line, the fault definition is sharply increased, and markers which previously seemed to be continuous (e.g. the marker shown in dotted line) now appear to be broken by faults. Improved fault definition is particularly critical in deltaic environments in order to accurately delineate the various compartments created by growth faulting.

Nevertheless, the seismic resolution of the producing levels was still not sufficiently reliable to enable a decision to develop the field. Therefore a 3D high-resolution survey was shot in 1992. A line taken from this survey (Fig. 3) clearly indicates a substantial improvement throughout the section, particularly in the producing levels. This is a critical factor for estimating the volume of 'Original Oil in Place'. It has since been decided to go ahead with development.

Because of the increased use of 3D seismic acquisition, a major new challenge has emerged in geophysics: optimisation of the velocity models (where regional geological and geophysical knowledge is crucial), requiring the use of Massively Parallel Processing computers, has become a necessary step in defining new traps. As an example, the seismic definition of pre-salt series can be significantly improved. In the Precaspian Basin (Kazakhstan), a 2D line was processed by Elf using two different methods. In the example shown in Figs 4 and 5, the objective lies within the pre-evaporitic series (discontinuous event at a depth between 3000 and 4000 m). A conventional 2D post-stack depth migration, using the MIGPACK TM software (Fig. 4), failed to restore a satisfactory image of the section below the salt diapir and the flanks of the diapir itself. On a further attempt, the line went through a pre-stack depth migration (Fig. 5). A significant improvement was obtained at the objective level and around the edges of the salt dome.

Pre-stack depth migration is being used more and more often to improve resolution in pre-salt series (e.g. North Sea, Gabon) and to obtain a better image of events within areas of complex tectonics.

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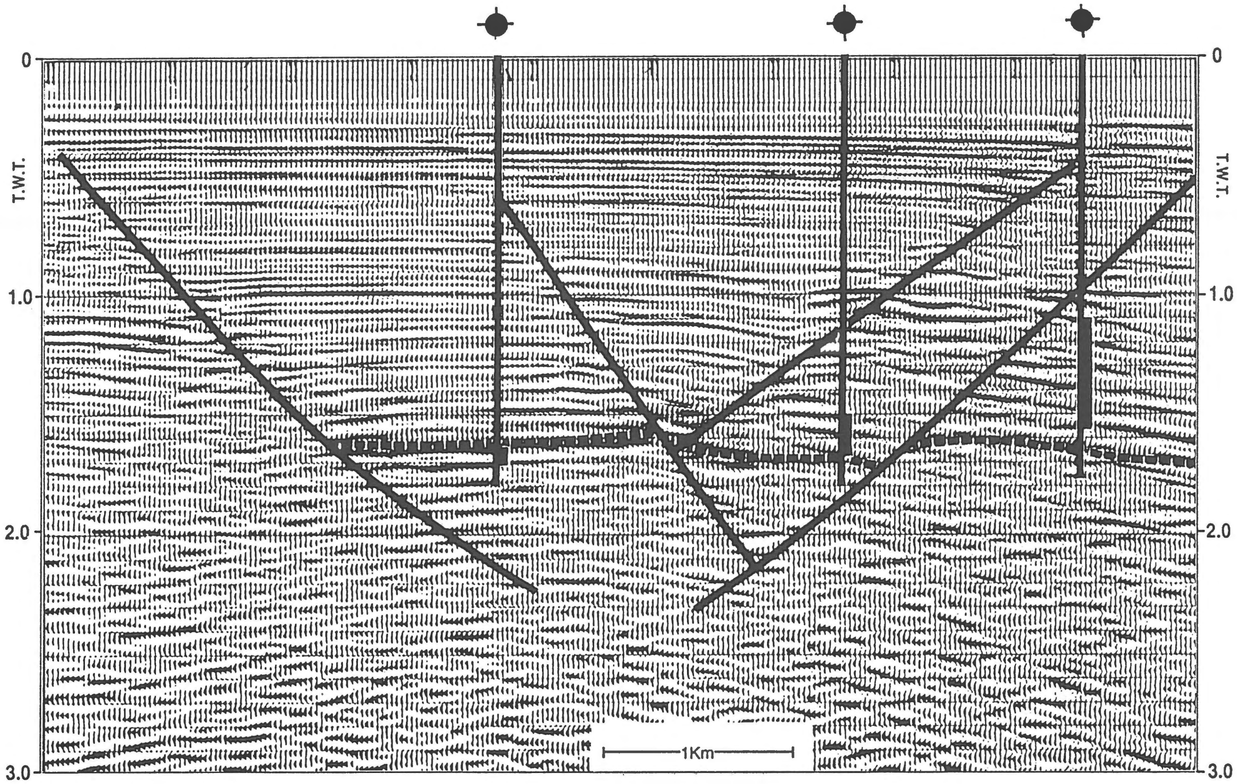


Fig. 1. A 2D seismic line shot in 1975 offshore Nigeria represents a rather poor data quality. There was a real difficulty for locating additional wells. Depth in two-way traveltime (TWT) in seconds.

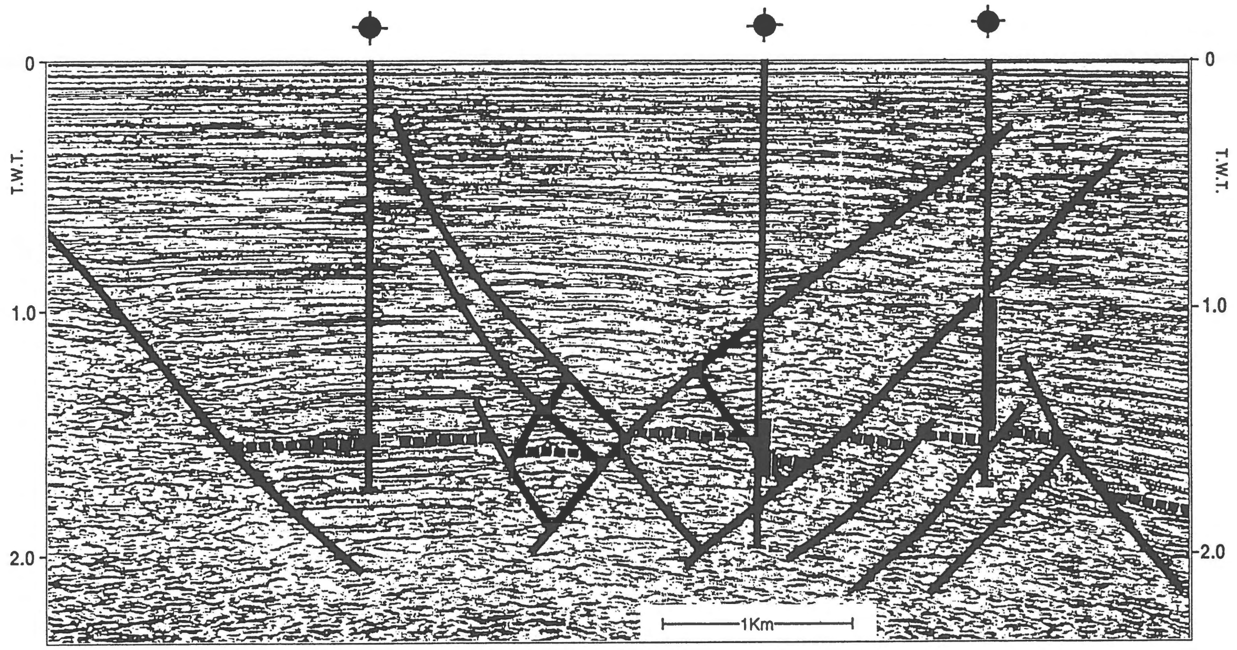


Fig. 2. A standard 3D section, shot in 1987 along the same line as that of Fig. 1, shows a better definition of the fault pattern and an increased accuracy in horizon picking. Depth in two-way traveltime (TWT) in seconds.

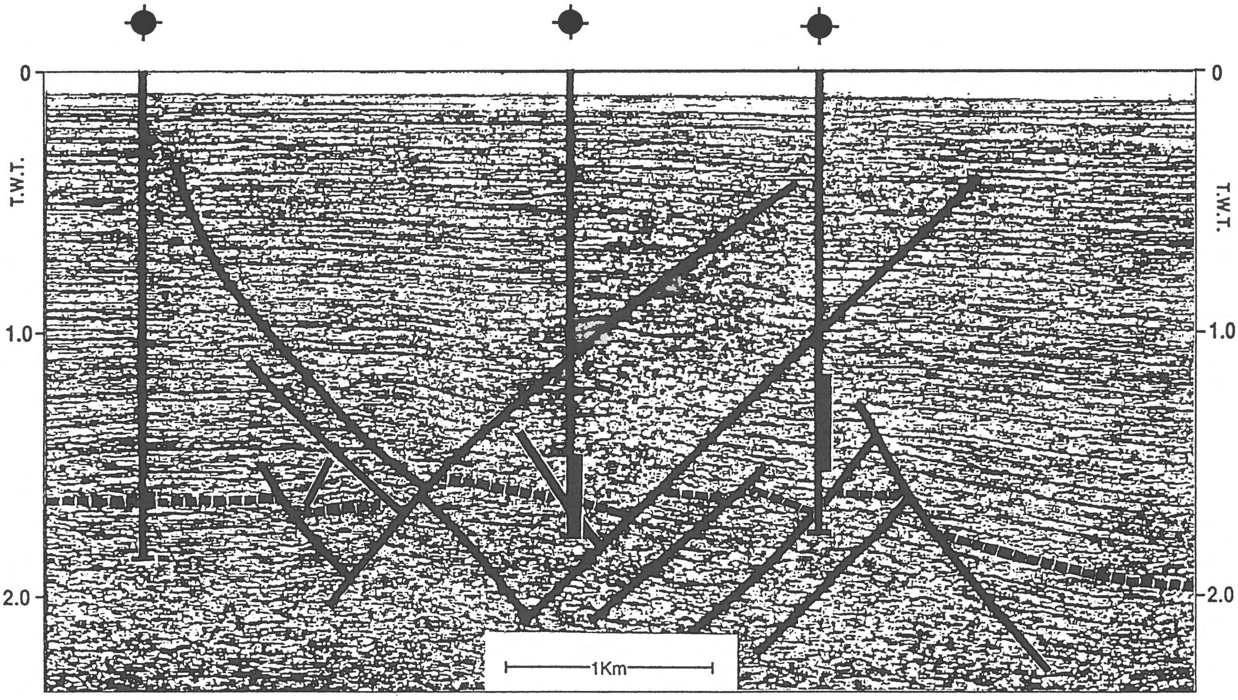


Fig. 3. A 3D high-resolution section, shot in 1992 along the same line as that of Fig. 1, shows a substantial improvement within the production levels. Depth in two-way traveltime (TWT) in seconds.

An additional example of the improvement obtained through sophisticated processing is illustrated by a new seismic tool called Deltastack, a program developed by Elf Aquitaine. Deltastack has been used for some time to predict lithology and to evaluate formation pressures in clastic series (mostly within deltaic environments).

Through the statistical processing of seismic velocities and other attributes, it has become possible to delineate the top and the lateral extension of a particular reservoir. In the example shown (Nigeria, Fig. 6), the oil-bearing interval corresponds to the yellow and pink section (higher velocity interval). It will be noticed that the top of the reservoir has an irregular shape, and that the sand distribution is controlled by growth fault activity. This kind of representation proved to be extremely helpful in visualising the reservoir geometry and optimising the location of additional delineation and development wells. Elf's research efforts are presently focused on new applications of Deltastack in various sedimentary environments.

Deltastack is also used to predict overpressured intervals. On Fig. 7, the undercompacted shales correspond to the blue intervals indicating lower velocities. On the left-hand side of the section, the lower part of the well actually intersected an undercompacted interval down to total depth, thus confirming the interpretation. This type of predictive capability is obviously quite crucial for both explorationists and drillers (e.g. exploration below overpressured zones, choice of casing programme).

Integrated studies (geology, geophysics, reservoir engineering)

We clearly can improve our analysis and results by the use of new technologies in a specific technical area. In what follows it is demonstrated how development projects can benefit from integrated studies and team work.

A comprehensive image of the reservoir can be obtained by integrating all the available field data involving geology and geophysics, and reservoir engineering. This type of integrated approach is of paramount importance for optimising the development of complex fields and in particular for choosing the best drainage mechanism and well pattern (Fig. 8).

A good example is N'Kossa, an offshore field in the Congo. This field was discovered in 1985 and is

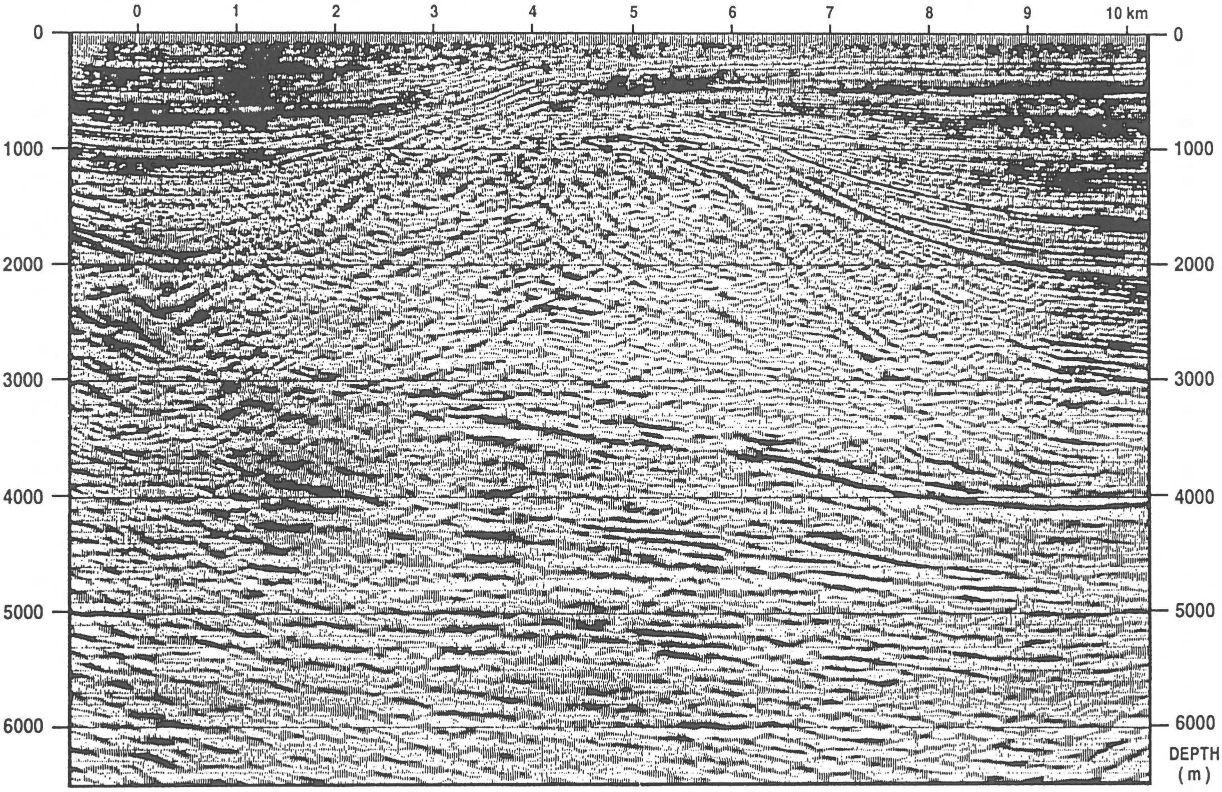


Fig. 4. A conventional 2D post-stack depth migration (with MIGPACK TM software) failed to restore a satisfactory image of the section below the salt diapir (Kazakhstan).

operated by Elf Congo. The water depth ranges from 150 to 300 m and the reservoir lies at a depth of about 3000 m (Fig. 9).

The reservoirs are of Albian age and include dolomites, limestones and sandstones. Field data analysis concluded that permeability was likely to be heterogeneous throughout the reservoir. Moreover the fluid characteristics are unusual: the fluid evolves from a gas condensate at the top to a light oil at the bottom.

Extensive studies of seismic and well data have enabled Elf to build a comprehensive geological model. Sedimentological analysis was the most important step and confidence in the sedimentological model stemmed from the knowledge of the area that Elf had acquired over decades of involvement in West Africa.

In the case of the N'Kossa project where gas and water are re-injected into the reservoir, it was absolutely essential to have an accurate geological model in order to obtain a reliable simulation. The reservoir simulation showed that due to the fluid characteristics, recovery could be increased by maintaining the initial pressure which prevents condensate deposition in the reservoir. It also showed that this pressure maintenance could be obtained by simultaneous gas and water injection and that the use of horizontal gas injection wells would provide efficient drainage while reducing drilling costs.

Innovative developments

Confidence in the results of the N'Kossa reservoir model based on integrated studies led Elf to commit itself to a major project including recovery and export of condensate and of liquefied petroleum gas (LPG) , gas compression and reinjection, and water treatment and reinjection.

For this project, it was necessary to look for innovative solutions, in particular because of the weight of the equipment to be installed (30 000 t), the water depth (200 m) and the lack of big derrick barges in West Africa.

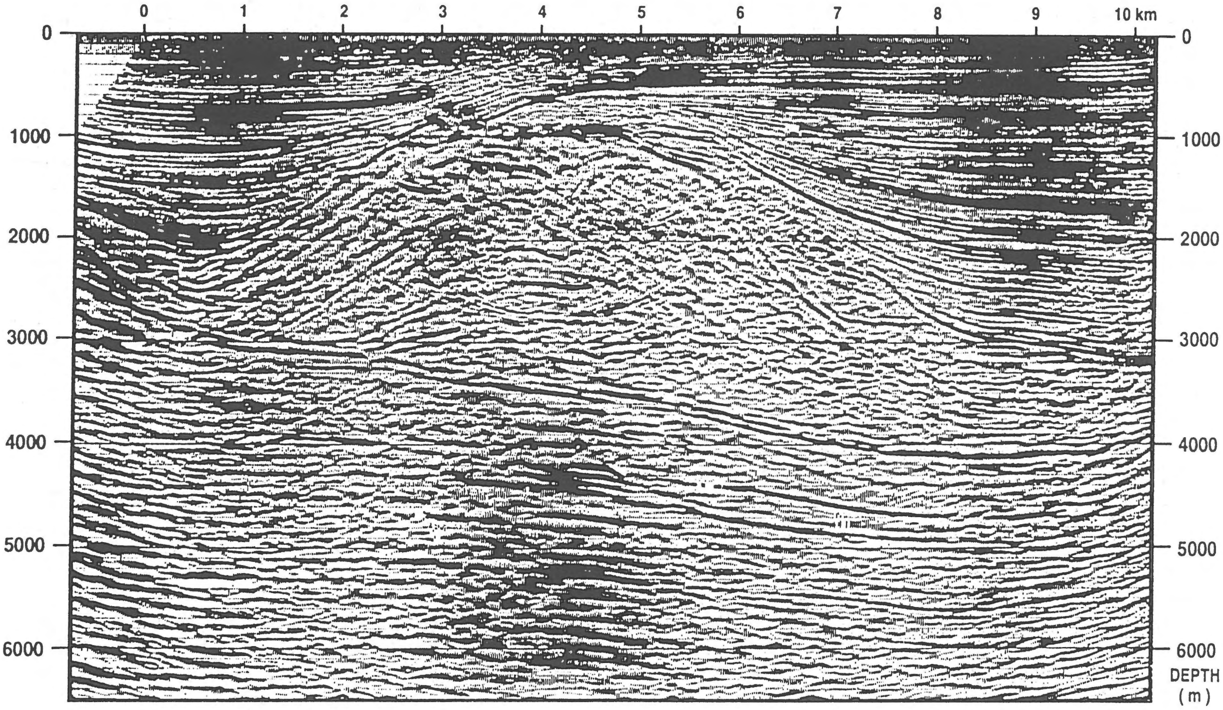


Fig. 5. A pre-stack depth migration (with MIGPACK TM software) induced a significant improvement at the objective level below the salt diapir with respect to the post-stack migration of Fig. 4 (Kazakhstan).

All the equipment will be installed on a floating concrete barge with a life span of more than 30 years, moored alongside one of the two drilling platforms (Fig. 10). The cost of installation of the equipment will be reduced because all the work will be done on the building yard and there will be no expenditure for barge mobilisation and demobilisation.

The future

It is clear that a major oil company must endeavour to stay one step ahead in technical expertise and innovation. Nevertheless, mastering a specific technique does not in the long term guarantee a competitive advantage because most innovations in the oil industry are rapidly available on the market. A good example is horizontal drilling that Elf was the first company to develop and to use industrially in 1980 (Fig. 11).

In any case, the effort to discover and produce oil and gas in traditional areas will reach its limits in the near future and we need to look for new leases. The next technical challenge will be deep offshore exploration and production. West African countries have recently signed contracts with major oil companies. However,

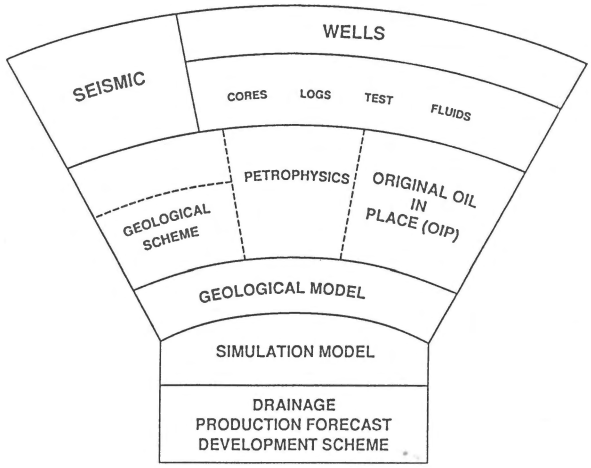
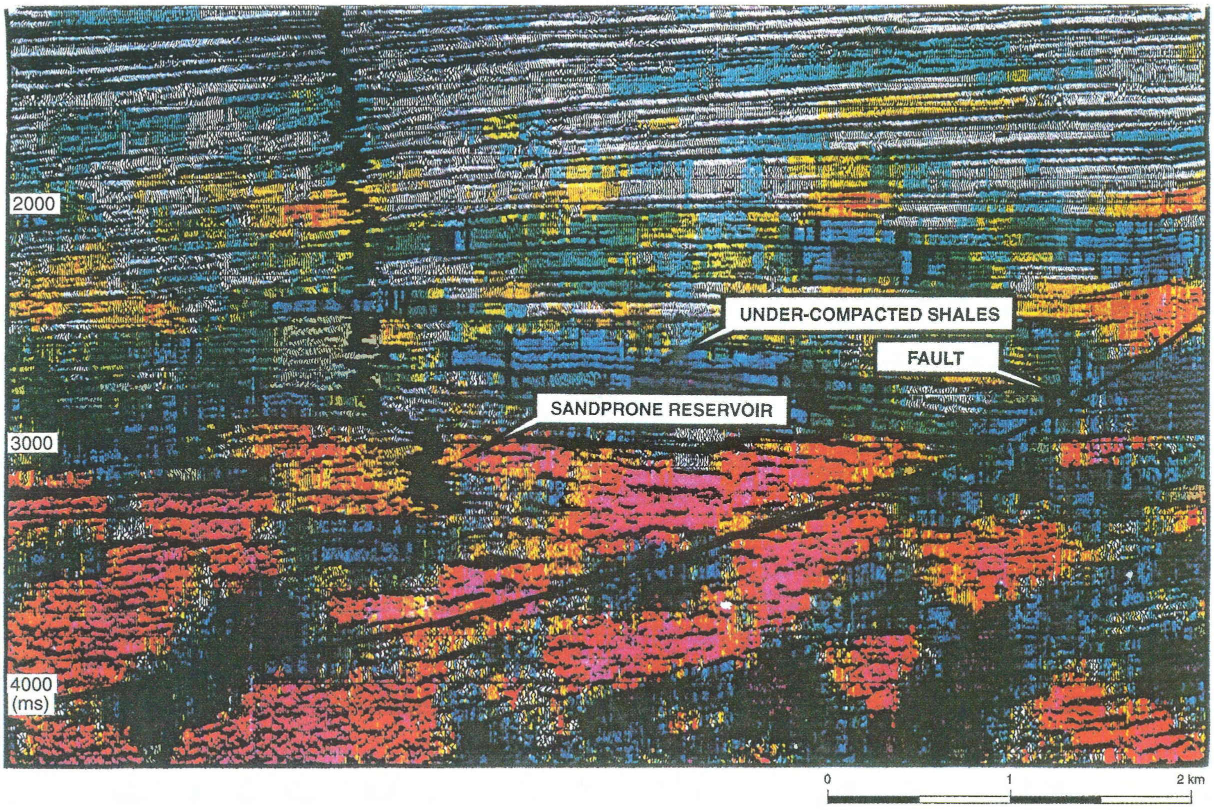
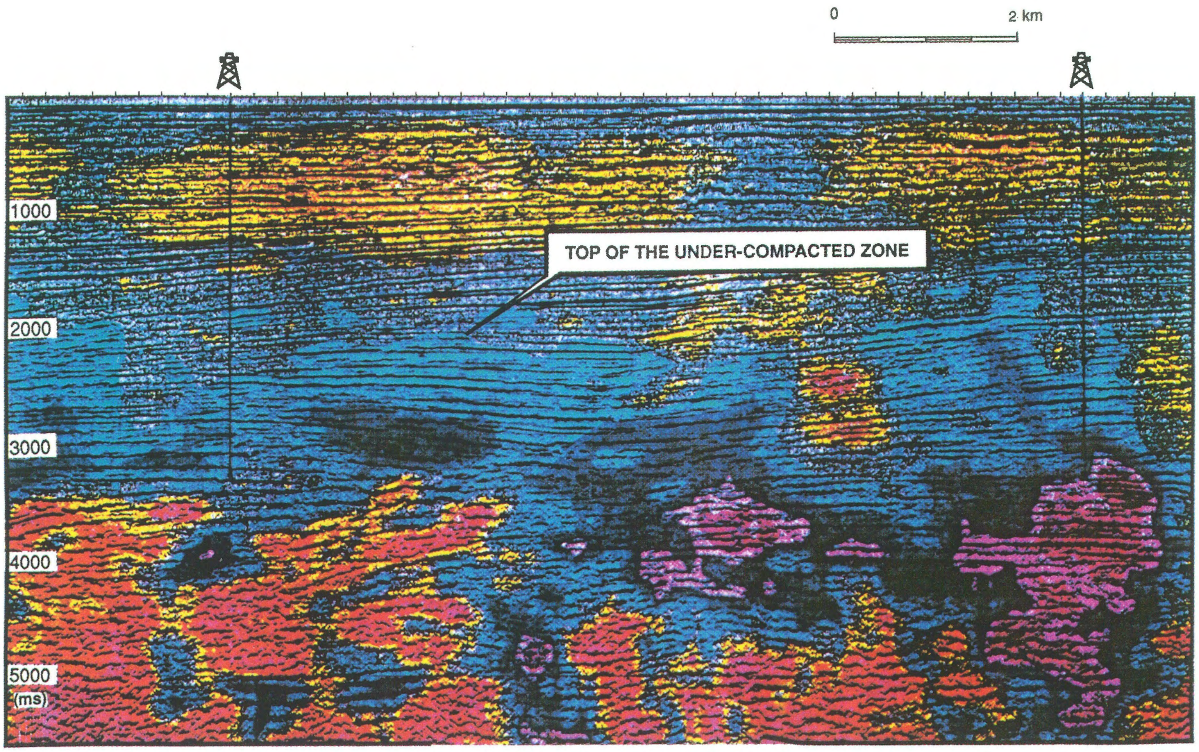


Fig. 8. Studies integrating geology, geophysics and reservoir engineering are of paramount importance for optimising the development of complex fields.

there are areas where technical expertise is not the only relevant factor, areas where efficient organisation and financial capacity are essential. For instance, at the present time, this is the case of a number of projects considered in Central Asia. The current projects in Kazakhstan are represented on Fig. 12.


2000
3000
4000
(ms)
UNDER-COMPACTED SHALES
FAULT
SANDPRONE RESERVOIR
0
1
2 km


0
2 km
1000
2000
3000
4000
5000
(ms)
TOP OF THE UNDER-COMPACTED ZONE

← *Fig. 6.* The new seismic tool Deltastack allows to delineate the top and the lateral extension of a particular reservoir (higher-velocity interval in pink and yellow). Depth (TWT) in milliseconds.

← *Fig. 7.* The Deltastack has a second application: prediction of overpressured intervals (= low-velocity intervals in sustained blue).

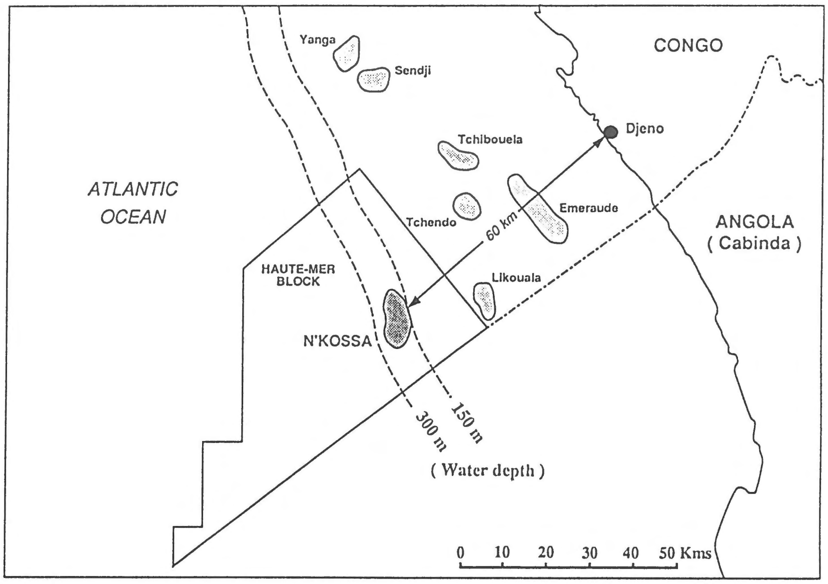


Fig. 9. N'Kossa field, offshore Congo, discovered by Elf Congo in 1985. Water depth ranges from 150 to 300 m.

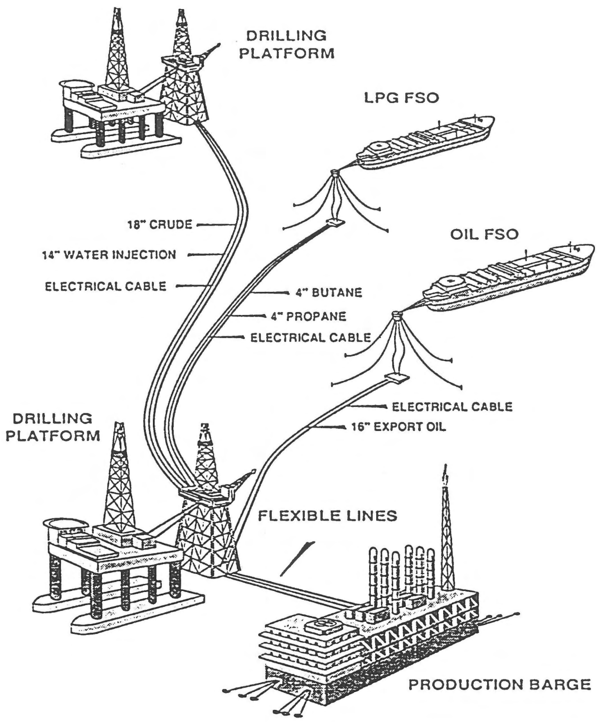


Fig. 10. The N'Kossa field is being developed with a concrete production barge moored alongside one of the two drilling platforms. Production is stored on two floating storage offloading (FSO) vessels.

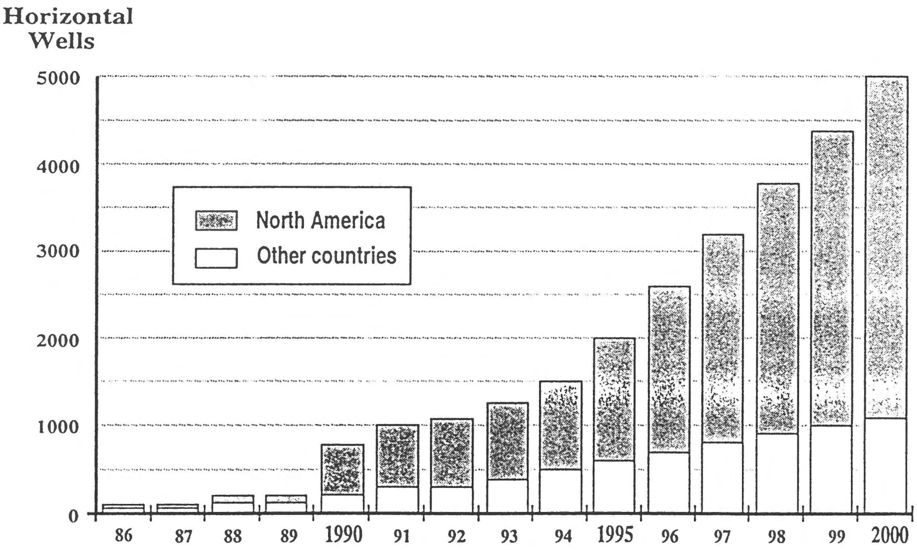


Fig. 11. Number of horizontal wells: past and future. Elf was the first oil company to develop and industrially use horizontal wells in 1980. This technology is now widely used in the industry.

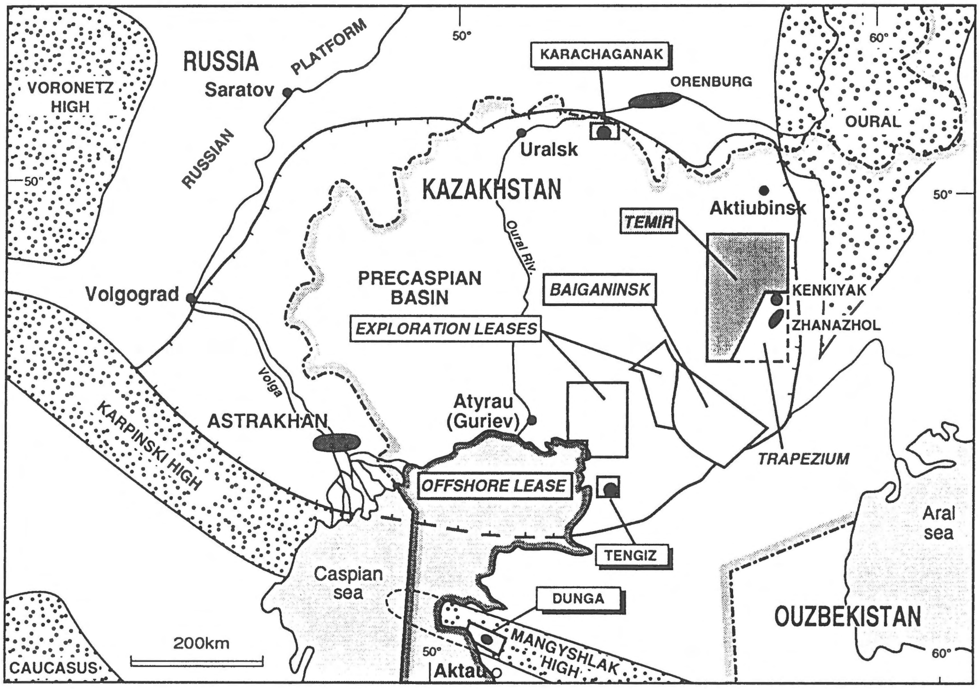


Fig. 12. Major oil and gas fields in the Kazakhstan Precaspian Basin and status of exploration and production leases by 1993.