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3D seismic an indispensable tool to delineate hydrocarbons

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3D seismic has been used increasingly over the last few years as an integral part of the E&P business. It is generally accepted that 3D seismic provides a subsurface image which is superior and more cost effective to that obtained from 2D seismic. The objective of seismic reflection prospecting is to delineate geological structures, making use of the ability of some horizons in the subsurface to reflect sound waves. By far the most important application of reflection seismic is in the oil industry. Seismic surveying was a technological advancement in the oil industry as important as the microscope was in understanding the spread of diseases. The principle is simple: create a shockwave, capture the reflected soundwave and use the information to create an image of the subsurface. An important breakthrough came in the sixties when seismic data, hitherto handled in an analogue fashion was then recorded digitally and processed by a computer. This was followed by the most important technological break-through in the seventies, when the first 3D seismic was acquired. The presence of more powerful computers and associated software made it possible to show the 3D seismic true potential. This paper is meant to highlight some aspects of 3D seismic technology which are important for delineating the presence of hydrocarbons and their impact on exploration or appraisal and field development planning. The SHELL Companies are involved in Exploration and Production operations in more than 50 countries all over the world and these are responsible for producing some 3.5 MMbls of oil and some 12 billion cubic feet of gas per day. With such activities, SHELL Companies are major users of seismic and are therefore heavily involved in developing the technology. Since the seventies, SHELL Companies have operated nearly 250 surveys of over some 80,000 km^2 in different environments. Since 1984, SSB/SSPC has embarked on a phased 3D seismic acquisition campaign over the major hydrocarbon accumulations and prime exploration acreages in SSB/SSPC's concession areas.

The main reason to acquire 3D seismic in our acreage is to:

— delineate geological complex structures to optimise targeting our exploration/ appraisal and development wells.

— to better define, evaluate and rank the exploration prospects.

— reduce uncertainties in structural interpretation to arrive at a much more accurate picture of the subsurface and improve the reserve estimates.

— reduce the risk of sub-optimal field developments and therefore save a significant amount of money.

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ACQUISITION AND PROCESSING

Like all seismic, 3D data is acquired using a system consisting of three main components:

1. A stable and suitable input source.
2. An appropriate set of detectors.
3. Recording equipment.

In addition, the data must be acquired effectively, economically and without damaging the environment.

Dynamite, **on land**, has been replaced by special trucks – called vibrators, with metal plates on the underside to shake the ground in a controlled way. At sea, powerful air or waterguns are the main sources of energy.

The sound waves are received by a set of detectors. The sensitive detectors, to record the reflected sound wave, are laid out to form arrays. On land these are called geophones and at sea, hydrophones. Offshore the hydrophones and sources are towed by a survey vessel. Marine 3D seismic are recorded by shooting a series of closely spaced 2D lines and the most important parameter is the line spacing. A line spacing of 25 m is nowadays considered as the minimum spacing which can be economically justified. To achieve this, multisource - multistreamer vessels are required. Within the SHELL Group considerable experience has been gained with the use of various types of sources and receivers. The information is recorded digitally on tape which allows easier manipulation of the data.

Display of the recorded data will not, in most cases, give an easily interpretable picture of the geological subsurface. This record needs further processing to achieve such clarification. Advanced processing techniques have been developed, in amongst other, SHELL E & P research laboratory and much emphasis is being put on developing software to focus and to image the 3D data properly to arrive at a true depth picture of the earth. Processing of 3D data puts a high demand on the processing organisation with regard to the handling of large volumes of data, high technology software and large computer capacity. Processing is a complex and time consuming exercise e.g. a 3D survey of some 200–400 km^2 will require some 4–6 months of processing time and about 100 hours of actual computer time.

INTERACTIVE INTERPRETATION

Once the processing is completed the image is ready for interpretation. Until recently the interpreter carried out the interpretation by eye on long paper sections, marking the different strata with coloured pencils as a basis for the structural horizon maps. Nowadays interactive workstations are required to view the 3D processed data from a variety of aspects. Once the marker horizons have been identified on the seismic sections, the computer helps the interpreter to identify the markers on the **total** data set by means of autotracking software. This is an

essential element in the 3D interpretation. The combination of more powerful computers with advanced software has led to a fundamental change in the 3D interpretation philosophy, from a method which was first line-oriented to one which is now volume-oriented. The advantage of these systems which combine powerful databases capable of handling large volumes of data with sophisticated graphics, is the variety of ways in which the seismic information can now be manipulated and displayed. Particularly important has been the development of image enhancement techniques which was pioneered in remote sensing of satellite imagery and which is presently applied with spectacular results to 3D data set.

These are:
- Dip displays
- Azimuth displays
- Combined dip/azimuth displays
- Artificial allumination
- Amplitude extraction

Dip and Azimuth displays

The principle is simple. The dip and azimuth parameters are respectively the magnitude and direction from a local reference of the time gradient vector calculated at each data point of the interpreted horizons. The computation is carried out by looking from each trace of an interpreted horizon, to the neighbouring traces (as if fitting a plane through the corresponding reflection positions) and calculating the mean gradient. The dip and azimuth values are normally displayed on separate maps. Both maps should be studied separately as e.g. faults do not necessarily show up equally clearly. To overcome the fact that different features are often apparent only on either the dip or the azimuth map, these two attributes can be displayed in combination.

Artificial illumination (shaded relief)

The principle is somewhat similar to looking at a map of a seismic marker, which would be illuminated by the sun shinning from a certain direction and from a given elevation above the horizon.

Amplitude extraction

3D seismic, now provides continuous amplitude maps of such high resolution that hydrocarbons and reservoir delineation can be interpreted in spectacular detail. The importance of the use of horizon attribute displays to detect subtle structures and stratigraphical features has been amply demonstrated within the Group and within SSB/SSPC in particular. Its the combination of automatic volume horizon and subsequent attribute extraction which is the key to detection of subtle detail usually beyond the resolution of vertical data interpretation. The effect of this is paramount to more accurate reserve estimates and subsequently more optimal reservoir management. The cost of 3D seismic amounts to some 30,000 M$ per km^2

which includes acquisition costs and processing costs. The cost of an average 3D survey may be in the order of some 6-8 million M$ and may easily be justified on the basis of saving e.g. one well based on better subsurface information.

EXPERIENCE IN SSB/SSPC

Since 1984, SSB/SSPC has embarked on a phased 3D seismic acquisition campaign for exploration and production, over the major hydrocarbon accumulations and prime exploration acreages. This has resulted in an extensive 3D coverages of some 4,000 km^2 not only over the major oil fields, but also over the inter-field areas. In the complex areas like the Balingian and Sabah offshore areas, 3D seismic is essential for appraisal and development purposes. Gradually 2D seismic is being replaced by 3D surveys for both exploration and appraisal/development purposes. For 1991/1992 only 3D seismic is planned. This trend is also reflected in the statistics of the total SHELL Group which will have operated close to 200 3D surveys by the end of 1991. This does not mean that 2D will disappear as it will always be required, albeit in a limited way, e.g. as infill seismic and for some exploration purposes. The extensive use of 3D seismic in SSB/SSPC underlines the Company's commitment, to the company's business objective, i.e. to ensure a profitable and responsible exploration and production presence in Malaysia throughout and beyond the current Production Sharing Contract.

FUTURE

The development of 3D seismic can be seen as one of the most important technical breakthroughs in the oil and gas industry. It is unlikely that these developments will slow down, bearing in mind the pace that computer technology is experiencing. More powerful computers will allow to look at even larger volumes of data and better interactive systems will speed up even more the interpretation processes and give better displays of this data. Important developments are also the interactive link of seismic interpretation and geological/petrophysical modelling of reservoirs. These developments are already appearing on the market. We are also thinking of repetitive acquisition of 3D with 3-4 years time intervals, to better understand and visualise the movement of hydrocarbons.

MESSAGE

New reserves of hydrocarbons must more and more be sought in smaller accumulations and in geologically more complex areas. It is only with the rapid enhancement of technology combined with the professional who is able to master this technology that one will be able to find and economically produce these reserves. The value of 3D has been demonstrated many times in different geological environments. It will not always add new reserves but it will create a much 'sharper' image of the geological subsurface which facilitate the interpretation. Superior horizon maps and better fault definition will positively affect the well planning and subsequent drilling costs.

SSB/SSPC is committed to use 3D seismic.

The temptation of deferring 3D seismic acquisition on the grounds that it often implies high front-end investments, should be resisted, or at least critically assessed.

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