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Virtual Reality & Systematic Approach Lead to Better Success Ratio in the Exploration of Hydrocarbons

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Summary

State-of-the-art 3-D volume visualization and systematic approach of analysing gathers, 2-D and 3-D seismic and well data help in achieving better success ratio in the upstream sector of petroleum industry. Thorough 3-D volume visualization is impossible without the establishment of Virtual Reality Centres which need to be equipped with (i) multi-processors, (ii) good amount of RAM (iii) High speed Display system and (iv) ample storage space (in tera bytes) to handle complex graphics operations on hardware side and open architecture with inter-operability like features on software side.

There has always been a big question mark that why many of the wells result dry despite painstaking efforts put in by expert team of geo-scientists. In this paper, the authors have highlighted some of the ways and means to help explorationists in anticipating better inside picture of the sub-surface for systematic seismic data interpretation, reservoir imaging and characterisation which may answer some of the points which the G & G scientists may be looking for and thus provide leading light to the explorationists of petroleum industry for having brighter results in the future efforts.

The motive of this paper is to ultimately attain better success ratio and reduce the risk of putting in exorbitant cost in drilling wells which many a time result dry.

The study is confined to E&P industry with inputs as gathers, quality processed 2D/3D seismic and existing wells data. However, similar study can be carried out by the other mining industries targeting their objectives, parameters and technological breakthroughs.

Introduction

Exploration and production of hydrocarbons is one of the highly challenging, capital intensive, risky but high return activity provided the success ratio is good. In fact, the scientists and engineers have to put in lots of efforts to explore new areas as the easy available oil and gas has already been explored and being exploited. Synergy between science, technology, knowledge and experience is of utmost importance to meet the challenges of the upstream sector of the oil and gas industry. Thorough study and analysis is the primary requirement for release of locations for drilling as they involves huge investments.

The following points need to be carefully and critically studied, analysed and addressed to improve the success ratio in this industry:-

- Quality input Data .
- Hardware with high speed processors, advanced graphical features and abundant storage space.
- Display system with high speed graphical features.



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- Application Software having capabilities to handle voluminous data sets in a speedily manner to address the following needs:-
 - a) 2D/3D (line & volume) seismic and well data visualisation.
 - b) Amplitudes scanning and scaling.
 - c) Multi survey volumes visualisation.
 - d) Visualisation on arbitrary line, slicing, proportional slicing and infusion of slices in inline/cross-line/time.
 - e) 2D line and volume Interpretation of Seismic data.
 - f) Synthetic seismogram generation
 - g) Calibration of seismic data with the available well data.
 - h) Time-Depth relationship and background velocity model generation.
 - i) Seismic Attribute volume creation and analysis.
 - j) Blending of different seismic attributes.
 - k) Application of mathematical operations on attribute volumes.
 - l) Geo-bodies detection & application of opacity and transparency features on seismic volumes and interpretations.
 - m) Determination of AVO anomaly and its visualization in 3D volume.
 - n) Volume generation based on AVO attributes and on elastic coefficients.
 - o) Making Cross plots on different attributes and locating anomalous points in the volume.
 - p) Acoustic Impedance and other log properties analysis along geobodies.
 - q) Seis-facies classification and analysis.
 - r) Log curve prediction and reservoir characterisation
 - s) Well planning and monitoring drilling operations.
 - t) Log analysis and processing of actual logs.

The systematic and judicious approach will not only result in the improvement of the success ratio but also gives (i) better returns and (ii) better inside picture of the sub-surface of the area for further exploration and exploitation of hydrocarbons.

Theory

For any process to be successful and alive, there has to be (i) an input, (ii) infrastructural and state-of-the-art

technological support with open architecture and (iii) output with desired results.

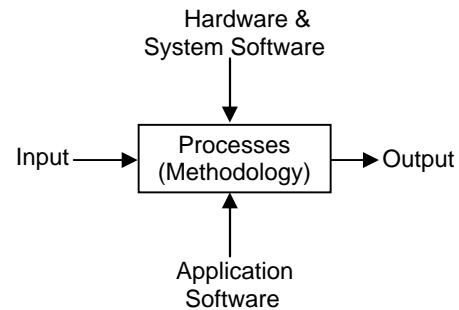


Figure - 1

(i) Input: Gathers, Processed seismic and well data. The good quality of seismic data is of paramount importance for its cost effective utilization in various aspects of the hydrocarbon exploration and production activities.

(ii) Infrastructure & Technology: Hardware, system Software and Application Software with connectivity to the drill site server.

(iii) Processes & Output:- The working of the processes as shown in figure-2, in the above said environment, is described below under "METHODOLOGY" section of the paper which shall result in improved subsurface imaging, better reservoir characterisation and to ultimately achieve the objectives.

Gathers, good quality processed seismic and available well data as input to high speed, parallel and graphic processing computers with (a) huge RAM and disk space, (b) high speed processors and (c) enlarged graphic visualization features are primarily required for proceeding with the systematic approach to achieve better success ratio. Advancements in computing industry have paved the way to the virtual reality centers wherein the reservoir images and seismic volumes can be visualized in 2D and 3D environment on 15' x 6' viewable or bigger screens for meeting the above said requirements.

The schematic diagram for improvement in success-ratio for hydrocarbon exploration has been depicted in figure-2. Before going into the details of the process flow (i) a suitable hardware with advance high speed graphic features to provide virtual reality effects with connectivity to drill site server and (ii) an appropriate mix of application software are pre-requisites to harness the maximum



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Further, interpretation of horizons, faults, pinch-outs, wedge outs, on-laps, rifts, envelops and basin inversions etc and their simultaneous/merged viewing with seismic and well data is required before identifying geo-bodies for further study [Figure-3(a) & Figure-3(b)—available under "Examples of Seismic Images from A&AA Basin, INDIA" section of the paper]. Here, it is once again emphasised that the careful use of calibration at well location with all the available information and expertise is very vital in deriving meaningful information from the seismic attributes and to have confidence in the results obtained from interpretation of the seismic data.

Generation of different seismic attribute volumes using spectral decomposition or other techniques, visualization of attribute volumes, blending of selective attribute volumes with varying opacity and colours and even sometimes mathematical operations on the attribute volumes are required to be carried out for exhaustive identification of geo-bodies which are likely to bear hydro-carbons. Recently developed, spectral decomposition technique has helped interpreters to analyse the extremely thin reservoirs, well below what has traditionally been considered the quarter-wavelength resolution of processed seismic data (Partyka et al., 1999, Partyka, 2001, Castagna et al., 2003). This technique makes use of various frequency components within a band limited seismic wavelet in the frequency domain via the Discrete Fourier Transformation (DFT) or maximum entropy method (MEM) or Continuous wavelet transforms (CWT). Spectral decomposition provides a robust and phase independent approach to seismic thickness estimation. The traditional techniques for estimating thin reservoirs thickness require zero phase data and careful picking of temporally adjacent peaks and troughs, whereas thickness estimates derived from spectral decomposition require only one guide pick within the seismic zone of interest.

Amplitude versus offset analysis can be carried out using gathers to determine AVO anomalies. AVO is a technique used to analyse seismic amplitudes before stack to obtain information on rock and fluid properties in the subsurface. Input to AVO analysis is pre-stack CMP gathers, preferably after migration and NMO correction. The data should be pre-processed with care in an "amplitude preserving manner". The objective of this work is to prepare the seismic pre-stack data in a way that the amplitude is proportional to the reflection coefficient. This means that all the other wave propagation effects which affect the amplitudes should be removed as much as possible. These effects are due to (i) geometrical spreading, (ii) attenuation, (iii) Array effect, (iv) Multiples, (v) Shot and receiver response etc.

Different AVO attributes can be generated from pre-stack data. These AVO attributes are seismic volume where the amplitude of attribute is proportional to an AVO parameter. These are (i) V_p reflectivities, (ii) V_s reflectivities, (iii) I_p : Impedance P reflectivities and (iv) I_s : Impedance S-reflectivities and (v) other attributes which are the derivatives of these parameters e.g. Pseudo-Poisson Reflectivity, Fluid factor, Gradient, Poisson reflectivity, Elastic impedance reflectivity, λ - ρ reflectivity and μ - ρ reflectivity etc. These attributes provide important information on rock properties such as porosity, rigidity and incompressibility etc. These attributes can be calibrated with the well data using generated synthetic seismograms. Using P wave reflectivity and S-wave reflectivity, post-stack amplitudes can be inverted to P-wave impedance and S-wave impedance using (i) calibrated seismic data with well data and (ii) background model generated by krigged log values of the available well data. For identifying AVO anomalies different cross plots like near angle stack with wide angle stack, near angle with full angle stack and P wave vs. S wave velocity etc can be generated. These cross plots and AVO attributes help to analyse fluid contents, AVO anomalies and other rock properties. They even help in locating thinner prospects. These anomalies can be viewed in 3D volume for further analysis and validation/re-validation for the presence of the hydrocarbons.

The above study can be further revalidated with the help of seismofacies analysis of the identified geobodies. To do so, slicing and proportional slicing can be carried out in the sub-volume of interest. This can further be strengthened by doing seis-facies classification based on Neural Network technology and thus generating seismic facies map. However, the other methods such as hierarchical, imported seed and manual are also available for doing seis-facies classification. But, from the researches it is seen that neural network process quickly converges on the 80% solution just after about 10 iterations. Practical experience shows that 10 to 20 iterations ensure a stable classification. Under Seis-facies classification, a seismic interval parallel to a horizon in a 3D volume based on the shape of wiggle traces is carried out for geologic use. Since the seismic traces contain all relevant information, such as, reflection patterns, phase, frequency, amplitude etc., the trace shape is a fundamental property of the seismic data. A map showing the distribution of similar trace shapes is like a facies map showing similar geologic features and is also known as seismic facies map. The process of creating this map is based on Neural Network Technology in which a set of model traces are created by an unsupervised learning process on a subset of the data and then organises the model traces showing progressive changes in them. Each model trace is assigned a color and a number. These model traces represent the diversity of trace shapes observed



within the interval, which may vary from a few milliseconds to hundreds of milliseconds. Then every trace within the actual seismic interval is correlated to all the model traces and is classified to belong to the same class to which it bears highest degree of correlation. The trace is assigned the same number and color of the model trace. At the end a similarity map or a seismic facies map is created. No input from well data is needed in making a seismic facies map. In this model some of the traces can also be selected out of the actual traces.

Synthetic seismogram generation and anticipation of log curves can be carried out at the proposed well locations. Well path/trajectory can be planned and worked out based upon the detected hydrocarbon bearing geobodies, analysed results and prognostications. This can proceed with drilling activities after carrying out the techno-economic study. The anticipated log curves need to be kept corrected with the actual borehole data. The bore hole data can be obtained through SCADA (Supervisory Control and Data Access) i.e. through a link between drill site server and the Virtual Reality Server. A group of experts sitting and monitoring in Virtual Reality Centre can command and control drilling activities as per the visualised data and analysed results using the virtual reality on bigger screen. This will ultimately lead to the minimisation of cost, better success ratio and maximization of the returns. It also helps in the necessary corrections in the anticipated logs based upon the input data from the drill site and facilitate quick look to the management as the time is considered very precious in the oil industry. The results of the finally processed logs based on real data can be further used as input for performing the study of the nearby areas in future.

Examples of Seismic Images from A&AA Basin, INDIA

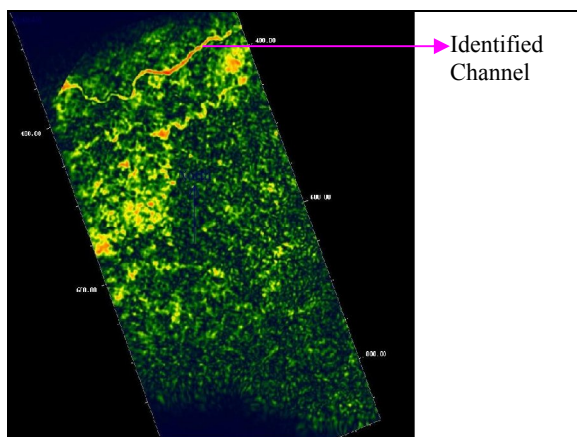


Figure: 3a

Figure-3(a): shows the time slice along an identified channel.

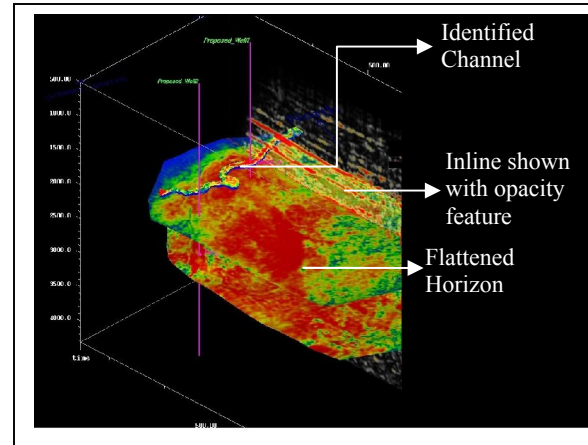


Figure 3(b)

Figure-3(b): shows flattened horizon in 3-D and the identified channel with amplitudes in different colours and One of the Inlines is also shown with opacity feature.

Conclusions

A high-quality combination of hardware and mix of software tools with graphics, volume visualisation, interpretation and the discussed systematic approach, will not only improve the success ratio but also (i) provide improved information on the structure, stratigraphy and lithologic of the area and (ii) ensure the maximum returns in minimum investments as:-

- It will be helpful in identifying ideal prospective locations for release.
- It will enable organisations to plan for hitting multiple geo-bodies (hydrocarbon bearing) with minimally drilled wells.
- Drilling priorities can be set in descending order of probabilistic potential of the anticipated hydrocarbon bearing reservoirs.

With the said aim, a number of Virtual Reality Centres(VRC) are being established by the leading companies involved in the exploration of hydrocarbons. 5 VRCs in ONGC have been established (out of total 7 in India, with oil industry so far), wherein the existing data is being revisualised and studied systematically. This is generating/opening up new vistas and new locations to strike unexplored hydrocarbon reservoirs and enhance the success ratio.



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