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Palynology – A non-Seismic method in Hydrocarbon Exploration

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Summary

Many fields globally are in production or post plateau stage, the industry needs a greater resolution in reservoir description in order to access remaining reserves. In recent years biostratigraphers has realized that the science has considerably more to offer at the reservoir scale and should play a major role in all phases of field life from exploration through appraisal, development and in to production.

Palynofossils have many applications to petroleum geology. The most common uses are high resolution and high impact biostratigraphy and paleoenvironmental analyses. High resolution and high impact biostratigraphy is the differentiation of rock units based upon the fossils which they contain. Paleoenvironmental analysis is the interpretation of the depositional environment in which the rock unit formed, based upon the fossils found within the unit. There are many other uses of fossils besides these, including: sequence biostratigraphy, paleoecology, paleoclimatology, biogeography, and thermal maturation.

Based on the study of palynofossils from Indian sedimentary basins viz. Assam-Arakan, Bengal, Mahanadi, Krishna-Godavari, Cauvery, Mumbai offshore, Kutch, Cambay and Jaisalmer one hundred and seven biochronohorizons have been established. These biochronohorizons have been used for dating (chronostratigraphy) of the subsurface sediments, mapping of hiatuses, construction of basin specific chronostrtigraphic and sequence stratigraphic framework, interpretation of depositional environments, construction of analogues and also for inter basinal correlation. The palynofossils are also used for understanding reservoir architecture, heterogeneity, extension of reservoirs in time and space and also for micro-correlation of pay horizons to establish the reservoir continuity through high impact biostratigraphy at field and reservoir level.

With the advancement and application of sequence stratigraphic principal in the exploration of stratigraphic traps, Palynofossils play a very significant role in dating sequence stratigraphic surfaces and in understanding the process sedimentology. Few case histories are depicted here in the present work.

Keywords: *Palynology, Biochronohorizons*

Introduction

Time is the most precious element in every sphere of life, so true for hydrocarbon exploration and exploitation. Thus, every correlation, and model which is constructed without the time factor may fail during actual drilling. Palynology is a branch of Geology which helps us in determining the time of formation of various lithounits. Palynological studies are carried out through plant microfossils. When the term fossil comes, most people think of dinosaurs, fossil wood, or at the very least plant mega fossils, leaf impression and other vertebrate, invertebrate fossils. However, most readily available rock samples for those engaged in finding and developing hydrocarbon resources are in the form of "cuttings" the small pieces of rock broken up by the drill bit, and brought to the surface. If the bit encounters mega fossils, they are so broken up in the process as to be almost unusable. Palynofossils on the other hand, by virtue of their small size (in microns), are recovered completely. Palynofossils also happen to be abundant, in marine to continental sedimentary rocks.

Palynofossils have many applications to petroleum geology. The most common uses are: biostratigraphy and paleoenvironmental analyses. High resolution and high impact biostratigraphy is the differentiation of rock units based upon the fossils which they contain.

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Paleoenvironmental analysis is the interpretation of the depositional environment in which the rock unit formed, based upon the fossils found within the unit. There are many other uses of fossils including sequence biostratigraphy, paleoecology, paleoclimatology, biogeography, and thermal maturation.

Palynofossils are organic walled fossils and include fossil pollen and spores, as well as certain marine organisms such as dinoflagellates, acritarch, diatoms, silicoflagellate etc. They are surprisingly resistant to decay and are common as fossils. Fossil pollen and spores can also give us information about ancient climates. Additionally, the organic chemicals which comprise palynomorphs get darker with increased heat and due to this colour change they can be used to assess the temperature to which a rock sequence was heated during burial. This is useful in predicting whether oil or gas may have formed in the area under study, because it is heat from burial in the Earth that makes oil and gas from orignal organic rich deposits.

Methodology

Biostratigraphy plays a critical role in the building of geologic models for hydrocarbon exploration and in the drilling operations that test those models. With the understanding of the stratigraphy we know that different layers of sedimentary rocks contain different fossils. When drilling a well into the Earth's crust in search of hydrocarbons, we encounter different fossils in a predictable sequence below the point in time where the organism became extinct. The point at which last occurrence of a particular fossil is called its LAD (Last Appearance Datum). In a simplified case, the LAD of a fossil species in one sequence of rock represents the same geologic moment as the LAD of the same species in another sequence. These are the points of correlation between wells. Another well drilled in this area should penetrate the same sequence, but may be at different depths than the original well.

In addition to the LAD, another useful event is the First Appearance Datum (FAD). This may be difficult to recognize in a well, because of caving etc. However, in studies of exposed rock units these FADs are extremely useful biostratigraphic events. When the range of various species overlaps during relatively short period of geological time denotes “Concurrent Range Zones”. The biozone between two concurrent LADs is denoted as “Interval Zone”. These are another "events" which can be used to subdivide geologic time into biostratigraphic units.

The study of palynofossils is broadly divided in two qualitative and quantitative analysis. By studying the palynofossils qualitatively in many wells biochronohorizons are established based on globally recorded and dated bioevents. On the basis of these biochronohorizons and interval zone concept, biochronostratigraphic framework applicable for the entire basin is constructed and simultaneously the dating of the encountered lithohorizons is carried out, which helps in identification of hiatuses, determination of their span, period of non-deposition / erosion. The species diversity leads to identification of third order system tracts and construction of sequence biostratigraphy. The quantitative analysis of the fossil assemblage, its composition leads to understand the environment of deposition. As we drill more and more wells on different structures, different setting, the wider and bigger data base is created and palynology will continue to play a critical role in not only in exploration but also in production and development geology through high impact biostratigraphy and biosteering.

Case History

1. Cambay Basin

The Cambay rift Basin, a rich Petroleum Province of India, is a narrow, elongated rift graben, extending from Surat in the south to Sanchor in the north. In the north, the basin narrows, but tectonically continues beyond Sanchor to pass into the Barmer Basin of Rajasthan. On the southern side, the basin merges with the Bombay Offshore Basin in the Arabian Sea.

Based on palynological studies twenty three biochronohorizons have been identified and on their basis the biochronostratigraphic framework has been constructed (Aswal et al., 2009), and depicted in Fig.1. These biochronohorizons helped in identification of five hiatuses

of varying magnitude. The hiatuses, chronozones and tectonic events, helped in constructing the basis for sequence stratigraphic framework of the basin.

The biochronohorizons, thus identified are calibratedon the well logs and there on seismic profiles (Fig.2). After calibration the respective seismic markers becomes time planes for correlation along and across the field. Fig. 3 shows an example of role of biostratigraphy in constructing geological model from Cambay basin, where because of the large variation in thickness across the basin, microfossils are extremely useful in correlating time equivalent horizons from one side to the other.

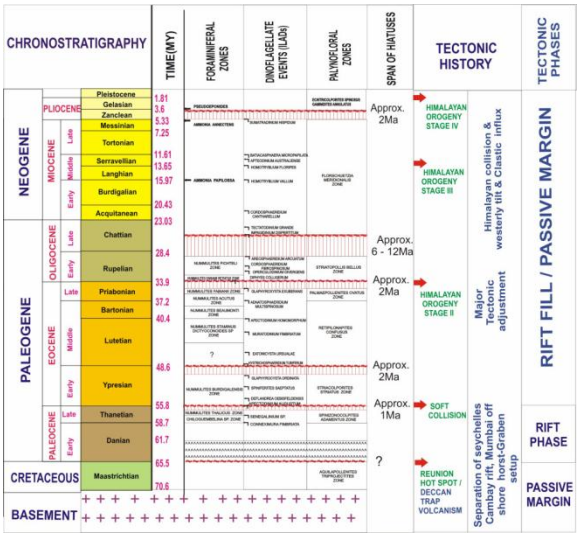

Fig. 1: Biochronostratigraphic framework and span of hiatuses in Cambay Basin (Aswal et al., 2009).

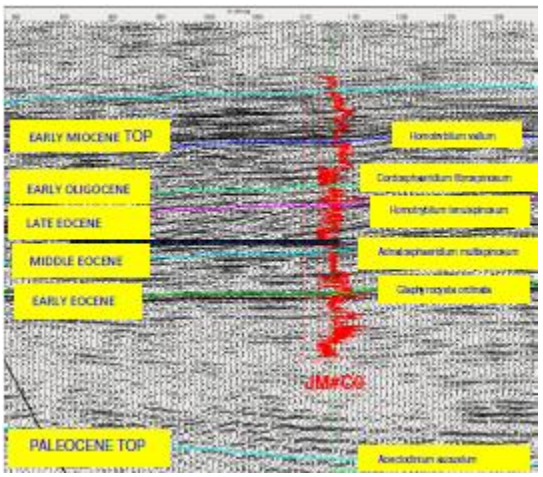

Fig.2: Calibration of biochronohorizons with well logs and seismic markers (Seismic line from ONGC unpublished report, 2008)

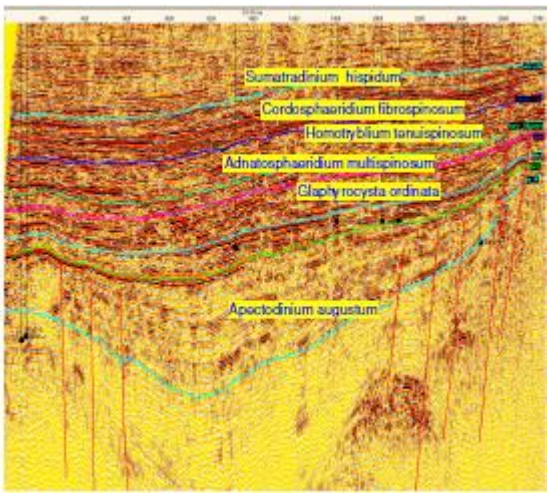

Fig. 3: Depiction of role of biostratigraphy's in constructing geologic models. (Seismic line from unpublished ONGC Report, 2008).

2. Jaisalmer Basin

Rajasthan Basin forms the eastern flank of Indus geosyncline and comprises the sedimentary tract to the west and northwest of Aravalli up to Indo-Pakistan border. This pericratonic basin also forms a part of the great Thar Desert. The Jaisalmer Basin represents westerly dipping eastern shelf of Indus basin. The Mesozoic and Tertiary sequences of the basin represent a shelf zone sedimentation dominated by both carbonates and clastic resting on a peneplained Precambrian basement.

In the Cretaceous section of the well AT#A, based on qualitative and quantitative analysis of Palynofossils, twenty two biochronohorizons based on dinoflagellate cyst species have been identified and twenty two interval zones established in Pariwar, Goru and Parh formations. On the basis of these chronohorizons the sediments are dated and a biochronostratigraphic framework is established (Aswal et al.,2008). On the basis of the species diversity of the dinoflagellate cysts and absolute pollen frequency, depositional environment of the sediments is also inferred (Fig. 4). Based on dinoflagellate cyst bioevents, foraminiferal and spore-pollen zones (palynozones) from various wells drilled in the basin, a detailed chornostratigrpahic framework of Jaisalmer basin has been established for sequence stratigraphic analysis, regional correlation and geological modeling (Fig. 5).

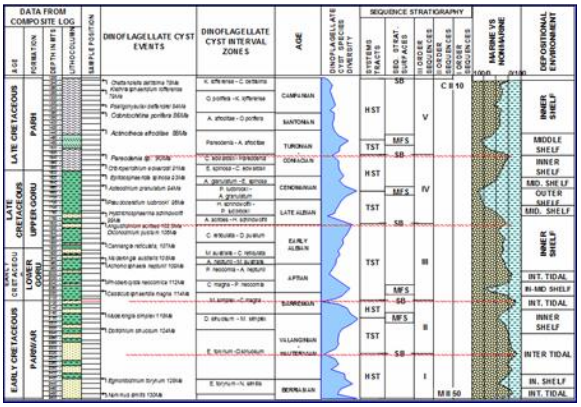

Fig. 4 Dinoflagellate cyst biochronohorizons, Interval zones, Age dates, species diversity, depositional sequences and paleoenvironment in well AT#A, Jaisalmer Basin (Aswal et al., 2008, unpublished ONGC Report, 2008)

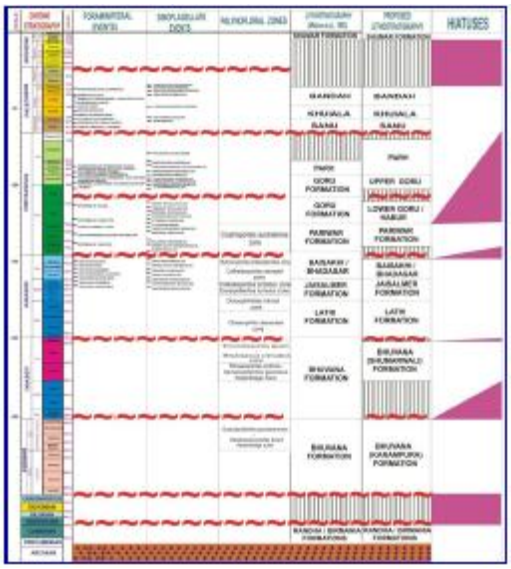

Fig. 5. Biochronostratigraphic framework of Jaisalmer Basin (after Aswal et al., 2008).

3. Kutch Basin

Kutch basin forms the north-western part of the western continental margin of India and is situated at the southern edge of the Indus shelf. It is bounded by the Nagar- Parkar fault in the North, Radhanpur-Barmer arch in the east and North Kathiawar fault towards the south.

In Kutch basin the biochronostratigraphic studies based on palynofossils resulted in dating of the sediments encountered in the wells drilled on onland and offshore part of the basin, interpretation of their paleo-depositional environment and identification of depositional sequences. The sediments in the studied well sections are dated Early Hettangian (Early Jurassic) to Early Maastrichtian i.e. Late Cretaceous. Based on the dating of the sediments four hiatuses of varying magnitude representing Hettangian – Early Bathonian, Late Kimmerdigian, Albian-Cenomanian, and Early Turonian-Early Maastrichtian have been mapped across the studied area. It is inferred that these sediments are deposited in inner to middle neritic conditions. On the basis of the species diversity studies of dinoflagellate cysts twenty three depositional sequences are identified ranging in Early Hettangian (Early Jurassic) to Early Maastrichtian i.e. Late Cretaceous sediments (Aswal et al., 2002). These

depositional sequences were correlated across the studied area and a sequence model is presented in Fig. 6 and also succeeded in drawing analogue from on land to offshore wells.

Based on the palyno-debris, the total organic matter, maturity of the palynofossils (Thermal Alteration Index) and identification of palynofacies studies of organic matter present in the sediments, the area having good, moderate and poor source potential to generate hydrocarbon were also brought out and is represented in Fig. 7 (Aswal et al., 2007).

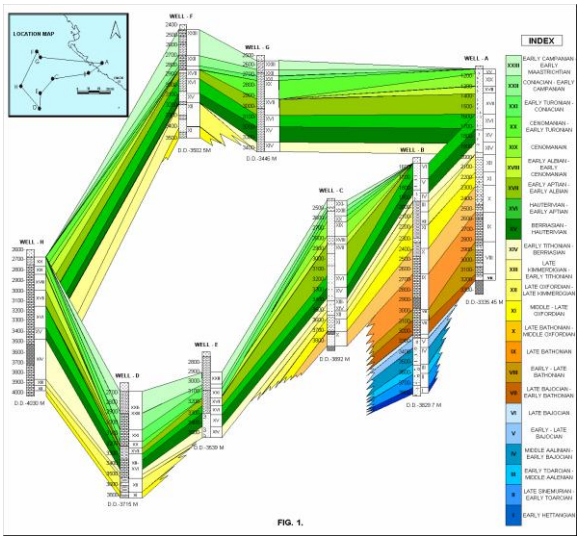

Fig. 6 Correlation of depositional sequences in Kutch onland and offshore wells (after Aswal et al., 2002).

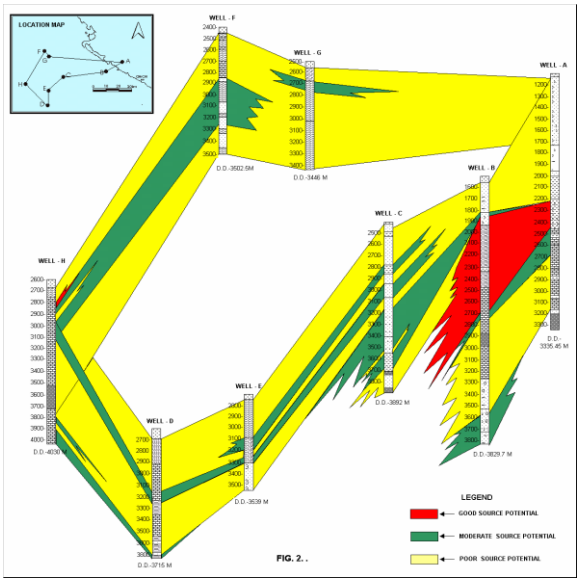

Fig.7 Correlation of organic matter facies in Kutch onland and offshore wells (after Aswal et al., 2002).

4. Krishna-Godavari Basin

Extensive deltaic plain formed by two large rivers, Krishna and Godavari in the state of Andhra Pradesh and the adjoining areas of Bay of Bengal in which these rivers discharge their water is known as Krishna-Godavari Basin. The Krishna Godavari Basin is a proven petroliferous basin of continental margin located on the east coast of India.
The potential source rock in Krishna-Godavari Basin is Raghavapuram Shale formation. It is exposed in several hillocks and also present in the subsurface. The palynological study of this formation was carried out through outcrop sampling as well as in the various wells drilled for hydrocarbons.

On the basis of Palynofossils especially dinoflagellate cyst biochronohorizons, the formation is dated Barremian to Late Campanian in age with a pronounced unconformity in the middle (Early-Late Albian, of approx. 8-12Ma) and also at the base of the formation of approximately 4Ma from Hauterivan – Barremian. Based on the dinoflagellate cyst biochronohorizons / bioevents, analogue of the Raghavapuram Formation has been constructed from outcrop to subsurface Fig. 8 (Aswal, 2008).

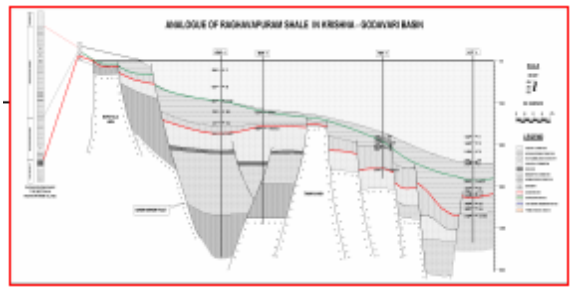

Fig.8 Analogue of Raghavapuram Shale Formation constructed on the basis of palynofloral assemblage and chronohorizons.

Conclusion

1. Palynology and palynofossils can play significant role hydrocarbon exploration and exploitation throughout the life of an oil field from exploration to development to production

2. The most common application is high resolution and high impact biochronostratigraphy, and reconstruction of paleodepsitional environment.

3. Based on bioevents / biochronohorizons biochronostratigraphic framework of Cambay and Jaisalmer Basin has been constructed, which has been applied for sequence stratigraphic analysis of the respective basins.

4. Identification of III order depositional sequences in Kutch basin has resulted in correlation of these depositional sequences from onland to offshore wells in the studied area.

5. The bioevent identification has helped in drawing analogue of Raghavapuram Formation in Krishna- Godavari Basin from out crop to subsurface.

6. Source rock studies based on palynodebris or Total Organic matter studies has resulted in identification of the area and depth intervals with good source potential in Kutch Basin.

7. Transferring bioevents / biochronohorizons on electologs are convenient for validation of seismic markers and their transformation to time planes for correlation along and across the field/basin.

8. In case of repetition /omission of strata due to thrusting / faulting, age determination can identify sediments above and below fault planes. As a result biostratigraphy becomes of paramount significance for demarcating up-thrust and sub-thrust sediments.

9. Since seismic reflectors represent isochrones, biostratigraphy will determine the exact time in Ma of that particular reflector. Thus, changing nomenclature such as reflector X, Y and Z will be named as Eocene top, Oligocene top, Miocene top etc.

10. Modification and validation of seismic correlation lines can be done based on bioevents correlation along and across the field / basin.

11. With the advancement and application of sequence stratigraphic principal in the exploration of stratigraphic traps, Palynofossils play a very significant role in dating sequence stratigraphic surfaces and in understanding the process sedimentology.

12. Based on qualitative analysis of Palynofossils identification of sequence stratigraphic surfaces and sequence biostratigraphic analysis of higher order depositional sequences is possible.

13. For drawing analogue from outcrop to subsurface in the basin, the palynofossils plays a significant role.

14. Through quantitative analysis reservoir level high impact biostratigraphic studies can contribute substantially for micro-correlation of pay horizons and in establishing reservoir continuity.

15. With establishment of wider and broad data base of palynofossils, their frequency and distribution in time and space, palynology can contribute in production and development geology by facilitating in understanding of reservoir continuity and heterogeneity through high impact biostratigraphy.

16. The refinement of sequence stratigraphy led to an increased demand for biostratigraphic studies, because high resolution biostratigraphy is a key component of this development.

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