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3-Dimensional Sequence Interpretation of Seismic Attributes in the Structurally Complex Area

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복잡한 지질구조 지역에서의 3차원 탄성파 Attribute를 이용한 층서해석 사례

김 건 득

Abstracts : The study was performed as a part of 3-D exploration project of the South Con Son basin, where Korea National Oil Co. (KNOC) and SHELL Company are performing joint operation. In the structurally complex area, seismic facies or lap-out patterns, which are usually the tools for the conventional seismic stratigraphy developed by Exxon Group (Vail *et al.*, 1977), are not easily identifiable. Therefore, stratigraphic informations are mainly extracted from seismic attribute maps of each sequence or systems tracts, and isopach maps in correlation with the stratigraphic information from the wells. The attribute maps of the sequence or systems tract boundaries and isopach map describe the variations of paleodepositional environments. The shape of the attribute maps of the boundaries is a reasonable description of the shape of the paleodepositional surface. With other maps such as isopach and structural maps, the variations of the parasequences in the systems tracts can be projected using the surface attribute maps. The reflection intensity attribute at each sequence or system tract boundary can be related to lithology, facies or porosity distributions. The azimuth attribute of source rock sequence can be used to identify the hydrocarbon migration patterns into the prospects. The overall risks of reservoir rocks, cap rocks, structure and hydrocarbon migrations were computed using the results of the study.

요 약: 본 연구는 한국석유공사가 셸사(화란)와 공동탐사를 하고있는 남콘손분지에 대한 3차원 탐사작업의 일환으로 실시되었으며 구조가 매우 복잡한 동지역에서의 탄성파층서 해석 사례를 소개하고자 한다. 지질구조가 복잡한 지역에서는 탄성파상이나 시퀀스 경계면 형태(lap-out pattern)가 탄성파 자료상에 잘 나타나지 않으므로 Exxon Group(Vail *et al.*, 1977) 등이 개발한 탄성파 층서 분석법의 한계점이 있다. 이러한 지역에서는 시추공의 층서분석 결과와 탄성파 Attribute 및 등층후도 등을 이용하여 탄성파 층서 분석을 실시할 수 있다. 연구결과 탄성파 Attribute는 시퀀스 및 시스템트랙면의 고퇴적 환경과 암상변화와 대비가 되며 등층후도 및 구조도를 사용하여 시스템트랙 내부의 층서변화와 대비가 가능하였다. 또한 Azimuth Attribute를 사용하여 탄화수소의 이동경로 등을 예측할 수 있었다. 이러한 층서분석 결과를 종합하여 저류암, 덮개암, 구조형성시기, 및 탄화수소의 이동경로 등에 대한 리스크를 계산하는데 이용하였다.

Keywords : attribute, isopach, sequence, systems tract, parasequence

Introduction

The purpose of the study was to use the seismic attribute, isopach and structure maps as a tool to extract the stratigraphic informations of the structually complex area, using the three-dimensional seismic data (Brown, 1991). The study was performed as a part of project to evaluate the prospectivity of South Con Son Basin.

South Con Son Basin lies some 280 km offshore Vietnam, and about 60 km south-west of Dai Hung Field. 3-D survey area is located in central part of the basin (Fig. 1).

The area is structurally very complicated as shown in Fig. 3; therefore, seismic facies or lap out patterns are not easily identifiable.

Stratigraphic informations are mainly extracted from seismic attribute maps of each sequence or systems tract boundaries and isopach maps in correlation with sequence stratigraphic study of well RB-ⅠX by Shell Oil Company (Fig. 2).

The analysis were performed sequence by sequence to identity the activation time of the growth faults, migration path and the prospects, which were used to predict the prospectivity of the area.

Abbreviations

TB: Tertiary Supercycle B

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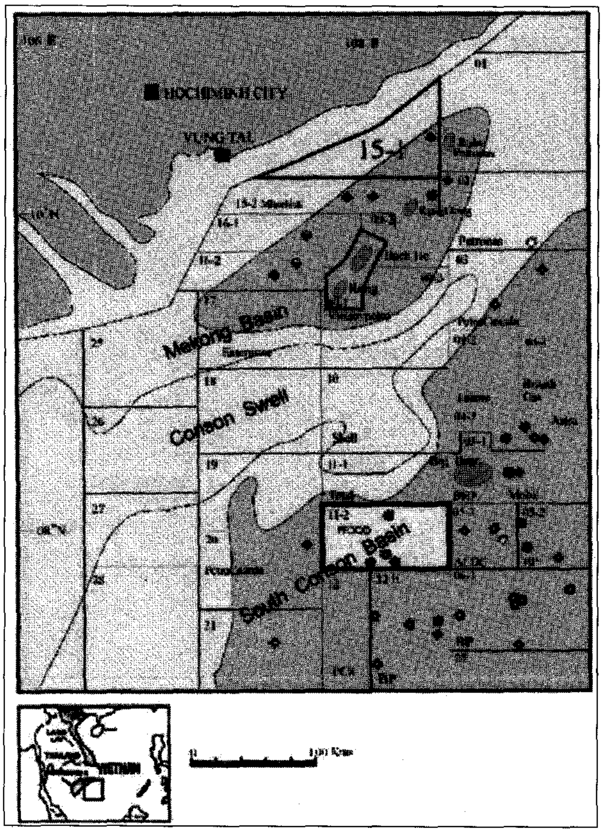

Fig. 1. Basemap and location of 3D area.

HST: Highstand systems tract
MFS: Maximum flooding surface
TST: Transgressive systems tract
LST: Lowstand systems tract
SB: Sequence boundary

Sequence Architecture of the well RB-1X

The sequence stratigraphic and environmental interpretation of RB-IX (Partington *et al.*, 1994) is summarized in Fig. 2.

Six third-order sequences are identified within the syn-rift megasequence and two in the overlying post-rift megasequences. These are characterized by a rapid alteration of relatively thinly bedded coarse and fine grained clastic sediment, deposited in a predominantly lower coastal plain to inner shelf environment punctuated by marine shales deposited in an outer shelf or deeper environment of deposition.

All of the interpreted seismic horizons have been tied into this interpretations of the RB-1X well. The horizons are shown at the RB-1X well location in Fig. 2. The correlation between mapped horizons and sequence boundaries are as follows

According to the stratigraphic analysis of RB-1X well

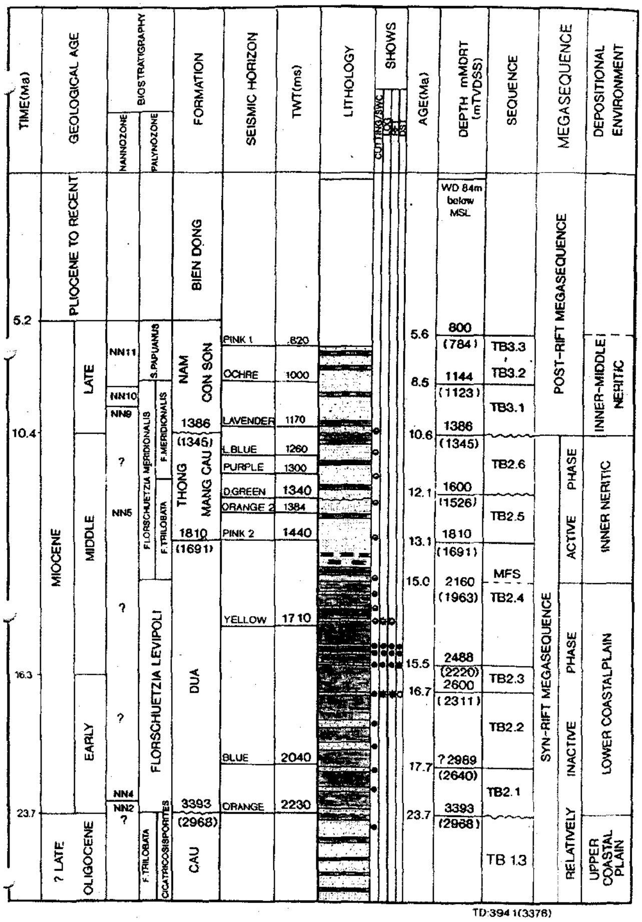

Fig. 2. Stratigraphic summary of RB-1X and seismic horizons mapped.

Table 1. Correlations between mapped horizons and sequences

Horizon	Age and type of horizons	Sequences	Mega-sequences
Lavendar	8.5 SB	TB 3.1	Post-rift
Light Blue 2	10.6 SB		
Purple	Near 11.5 MFS	TB 2.6	
Dark Green	12.1 SB		Syn-rift
Orange	Near 12.8 MFS	TB 2.5	
Pink	13.1 SB		
Yellow	Intra TB 2.4 LST	TB 2.4	Pre-rift
Blue	17.7 SB?	TB 1.3, 2.3	

(Partington *et al.*, 1994), Sequences TB 1.3 to 2.3 were deposited in a predominantly lower coastal plain environment, comprising a series of rapidly alternating coals, lagoonal mudstones and thin silty sands which were periodically punctuated by middle outer shelf marine shales. The depositional geometries of these sequences are influenced by syn-depositional tectonism where basin subsidence often exceeded sedimentation

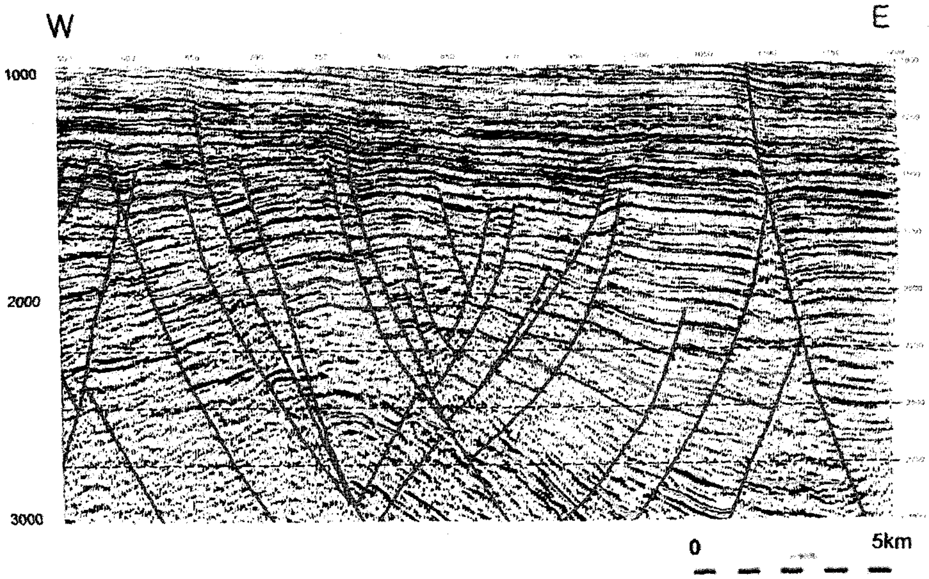

Fig. 3. An arbitary 3-D section showing the interpreted horizons and faults.

Sequence TB 2.4 is characterized by the basinward translation of coastal mangrove, interdistributary bay fill and coeval coastal plain facies above marine, shelfal mudstones. This sequence provides both the hydrocarbon source rock and reservoir to the main hydrocarbon accumulation in the Big Bear Field. Sequence 2.5 to 2.6 shows a progressive deepening from lower coastal plain to inner/middle neritic. The post-lift sequence TB 3.1 to 3.2 comprise a series of aggradational parasequences, deposited in an inner neritic environment.

Sequence Interpretation of the Attributes and Isopachs

Sequences TB 2.1 to TB 2.3

Blue horizon represents 17.7 SB which is the top of Sequence TB 2.1. The attribute map of blue horizon shows that a big straight fluvial channel crosses the entire 3-D area (Fig. 7).

In RB-IX well, these sequences were deposited in a predominantly lower coastal plain environment, comprising a series of rapidly alternating coals, lagoonal mudstones and thin silty sands which were periodically punctuated by middle-outer shelf marine shales (Partington *et al.*, 1994).

Isopach map between Yellow and Blue horizon shows no thickening on the downthrown side of the growth faults, which indicates that these units are not influenced by syn-depositional tectonism. Fluvial channel pattern is also independent of faults which indicates that the syn-depositional tectonism was inactive at this time. Considering thin HST soft marine shale in these unit, LST alluvial/fluvial sandstones appear to be dominant reservoir candidates in this area in TB 2.2 to TB 2.3.

The Azimuth map (Fig. 8) shows that the principle hydrocarbon migration direction of these units is eastward in the southern part and westwards in the northern part of the area.

Sequence TB 2.4

Sequence TB 2.4 is located above the thin condensed TB 2.3.

Yellow horizon is located in the LST setting of this unit and Pink horizon at top of the unit. The attribute map of Yellow horizon (Fig. 6) shows numerous braided fluvial channels in the entire 3-D area which are independent of the faults. Isopach map between Yellow and Pink shows thickening on the downthrown side of the growth faults, which indicates onset of syn-rift deposition occurred shortly after the Yellow event around 15.0 MFS (Fig. 2).

In RB-IX, LST of this unit comprises a series of mudstones, silts, thin sands and coals which provide the hydrocarbon discovery as with adjacent Big Bear Field. The Attribute map of Yellow horizon (Fig. 6) indicates the reservoir in RB-IX is likely of fluvial origin. HST of this unit shows a series of sand-rich interval deposited in a shallow marine environment.

Sequence TB 2.5

The syn-rift sequence starts from HST of TB 2.4 and continues to TB 2.5 and TB 2.6. The master fault consists of a planar upper section which extends from Light Blue horizon into the basement. The growth ratio indicates the maximum structural growth occurred within 10~12 Ma, after which the

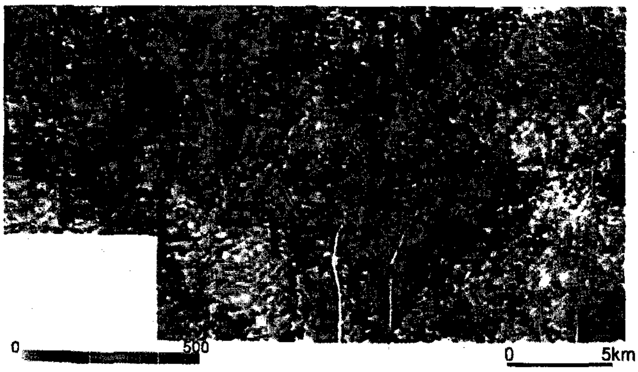

Fig. 4. Reflection intensity Map of Lavender.

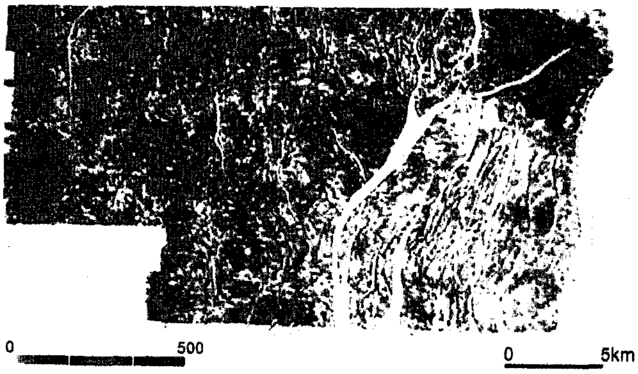

Fig. 5. Reflection intensity Map of Dark Green.

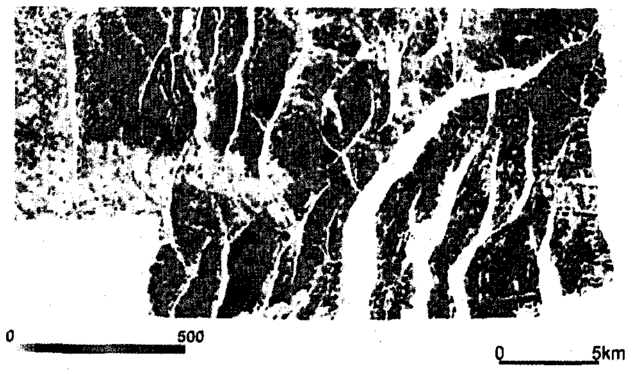

Fig. 6. Reflection intensity Map of Yellow.

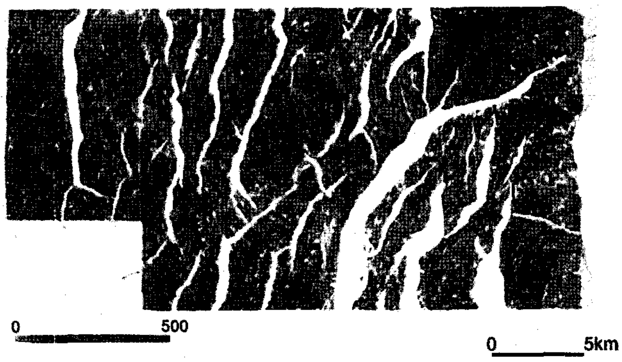

Fig. 7. Reflection intensity Map of Blue.

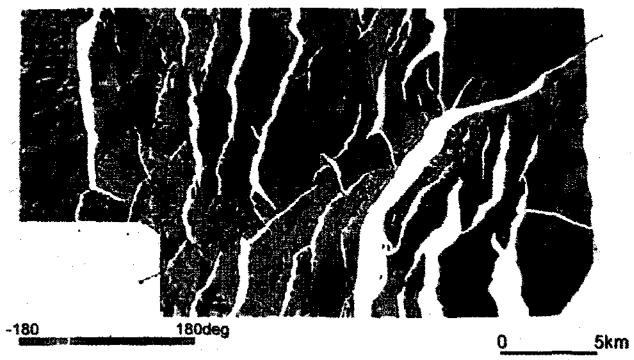

Fig. 8. Azimuth map of Blue. The angle is measured clockwise from south.

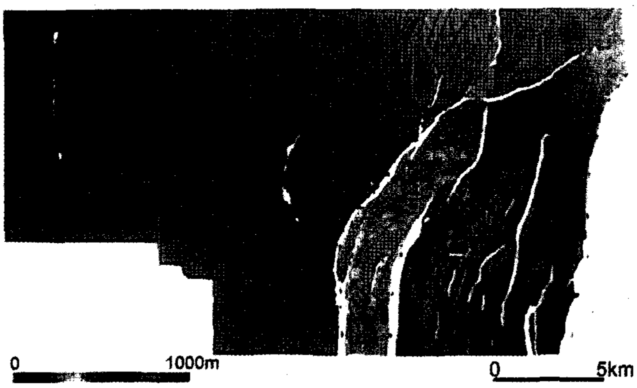

Fig. 9. Isopath map of Sequence 3.1.

growth rate steadily decreased.

Second order antithetic faults are also present and subdivide the structure in the several fault blocks.

The Attribute map of Dark Green shows that a strong impedance contrast between clastics and carbonate section on upside of growth fault is greatly reduced on downside, indicating a facies change to mud dominated bathyal environment (Fig. 5). This indicates differential bathymetric relief across the master fault during the time of maximum growth. The fault formed along a basement hinge and moved rapidly enough that it produced its own bathymetric break.

Seismic facies character also shows that a succession of strong amplitude events disappears on the downthrown side of the master fault.

Sequence TB 2.6

The attribute map of Light Blue2 (Fig. 7) and seismic facies of the unit indicates that carbonate facies disappears eastward of the master fault, which indicates HST carbonate of the unit changes to mud dominated bathyal facies.

In RB-IX, thick sandstones of good porosity (25%) are present in this unit which were deposited in a shallow marine environment. Because of similar setting as in TB 2.5, thick shale and thick porous reservoir are expected in the downthrown side of the master fault.

Sequence TB 3.1

Isopach map of this unit (Fig. 9) shows syn-depositional tectonism is inactive in this unit except minor reactivation at the eastern part of the master growth fault. The microfaunas suggest deposition in a predominantly shallow marine inner shelf environment.

Due to lack of shales and structures, this sequence is not considered as a target for the hydrocarbon exploration.

Conclusions

The seismic stratigraphy was analysed using the seismic attribute, isopach maps in correlation with stratigraphic informations from the wells, in the structurally complex area where the conventional seismic stratigraphic methods developed by Exxon Group (Vail *et al.*, 1977) does not work.

The fluvial channels in the LST setting are clearly shown on the attribute maps in the area. Isopach maps shows whether the depositional processes were syn-tectonic or post-tectonic.

Sequence 2.3 or older, was deposited in the pre-rift setting, where the fluvial channel pattern is independent of faults. Sequence 2.4 to 2.6 was deposited in the syn-rift setting where the maximum structural growth occurred within 10~12 Ma.

The areal distribution of the reservoir facies can be predicted using these maps, which also can be used to estimate the overall net to gross ratio of the area.

The attribute maps also show the environmental changes from clastics to carbonate depositional environment, which indicates transition from a carbonate shelf to mud dominated bathyal environment in the area.

The Azimuth attribute map of the sequences TB 2.1 to 2.3, where the mature source rocks exist, shows the principle migration is eastwards in the prospect area.

The stratigraphic informations derived from the study are used to predict the overall risks of reservoir rocks, cap rocks, structure, and hydrocarbon migration of the area.

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