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Fault Pattern Analysis and Distribution of Reservoir Facies Based on Advanced Seismic Attributes in a Part of Chambal Valley, Vindhyan Basin, India

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Abstract

Interpretation of 3D seismic data with special emphasis on advanced seismic attribute analysis has led to a significant enrichment in understanding tectonic episodes and distribution of favourable reservoir facies in Suket area of Chambal Valley Sub basin.

Various discontinuity attributes run on the 3D volume like amplitude contrast, variance and curvature attributes has brought out a number of NE-SW trending cross faults orthogonal to the trend of the Mukundara fault which were hitherto not mapped using the sparse 2D data. These faults have been interpreted to pre-date the imprints of tectonics responsible for Mukundara faulting. Given favorable charge timings, the cross-fault pattern provides additional prospective locales for HC entrapment.

Analysis of distribution of reservoir facies based on seismic attributes namely RMS Amplitude, Frequency, Sweetness, Spectral Decomposition and Acoustic Impedance has led to the identification of tidal Channel/bar reservoir geometry. A low impedance trend has been identified along the interpreted channel which has also been delineated by Spectral Decomposition study. These Tidal channel/ bar sands (Jhalrapatan Sandstone) within Suket Formation appear to be prospective strati-structural prospects for future exploration in the down dip of Suket structure.

Introduction

The Vindhyan Basin is the largest Proterozoic basin of India,located in central India.The great Vindhyan basin is cradled in a circumventing manner around the Bundelkhand Massif (3.3 - 2.5 Ga). Based on the field geology, Basin has been sub-divided into two parts, i.e., the Son Valley towards the East and the Chambal Valley towards West. The two sub-basins are broken in their apparent continuity by a thin veneer of Deccan trap. Larger part of Chambal Valley Vindhyan Basin falls in the states of Rajasthan and Madhya Pradesh (Singh et al, 2014).

Despite a larger volume of surface geological data and the recently acquired subsurface GM and Seismic data, considerable ambiguity/uncertainty as to the regional tectonic and structural set-up of Chambal Valley exists. Varying models of Basin evolution describe the Valley to have evolved in a rift set-up to subduction related foreland basin set-up. However, imprints of transpressional tectonics appear to have obliterated the original tectonic fabric in the area. In view of this an attempt to revisit the tectono-sedimentary set-up in a small part of the Chambal Valley with good seismic coverage, including 2D and 3D data has been made as presented in the following section, with a focus on inferring potential reservoir facies towards hydrocarbon prospectivity in the area.

Tectonics

The Chambal Valley is bounded by a NE–SW trending major lineament known as Great Boundary Fault (GBF) to the west and north-west, and Bundelkhand Massif to the east. Towards north, the valley passes into the Gangetic Plains while to the south it is enveloped by a drape of Deccan Basalt. The entire sedimentary succession of the sub-basin comprising mainly sandstone, shale and limestone is divisible into four groups: Semri, Kaimur, Rewa and Bhander from bottom to top.

The Vindhyan Supergroup rocks cover an important period of geological evolution during Palaeo-Neoproterozoic eras. The maximum thickness of Vindhyan sediments is reported to be more than 6000m near Bhopal (KDMIPE MT Report 2010), comprising mainly sandstone-shale-limestone formations of shallow marine origin. The margins of the basin are demarcated by two thrust belts: Aravalli-Delhi Fold Belt (ADFB) along Great Boundary Fault (GBF) in the northwest and the Satpura Orogenic Belt (SOB) along Son Narmada Lineament (SNL) in the east-southeast.

Methodology

Based on 2D seismic data, acquired in the area a lead over Suket anticline was identified. It is a NNE-SSW trending anticlinal closure disposed en-echelon to the Chechat Anticline. As 2D data was sparse with a minimum grid of 6*10 Km^2, it was decided to further detail this prospect by acquiring 3D seismic data to firm-up a drillable location. Total 212 SK 3D seismic data was acquired. Based on this interpretation, one well was drilled at the crest of this large anticline. Interpretation of the 3D volume was carried out incorporating drilled well data for relook of the prospectivity of this area and identifying suitable structural/ strati-structural prospects for future exploration. Various seismic attributes have been used for fault analysis and assessment of dispersal pattern of favorable reservoir facies. Landmark and Hampson Russell are the softwares used for the study.

Results and Discussion

1- Fault pattern analysis and Geometric Attributes

The SW-NE trending Great Boundary Fault (GBF), passing through northwestern corner of the study area, is tied with the seismic data. A major reverse fault in the northwest to southeast direction namely "Mukundara Fault" (MF) is bisecting the study area into two blocks (footwall and hanging-wall). In the footwall, number of oblique reverse faults, interpreted to be originating from Mukundara Fault, is diverging towards the northwest direction. Similarly in the hanging wall block, a number of oblique reverse faults, originating from southeast direction, are seen to be merging with Mukundara fault(Figure1). In addition to these oblique faults, southwest to northeast trending cross faults are also seen in the hanging-wall (in Suket 3D area and nearby 2D strike lines).Various Geometric (discontinuity) attribute volumes have been generated for fault pattern analysis. The study area is bisected by the NW-SE trending reverse Suket fault parallel to Mukundara Fault (Figure 2). This divides the 3D area into hanging and footwall blocks and has almost 1km throw at basement level which gradually diminishes to the upper stratigraphic levels. The hanging wall block is criss-crossed by numerous faults; two fault patterns or trends are conspicuous. One trend of faults runs NE-SW; orthogonal to Suket fault and other NW-SE trend is oblique. Main cross faults F1, F2 lies on the northern side of well S-1 (Figure 2) which is clearly seen on the seismic while other cross faults are mainly seen on the various discontinuities attributes like variance, curvature and amplitude contrast (Figure 2). The fault pattern is sharp and clear at the basement but the sharpness fades towards the shallower levels. There are 4 major fault alignments present in the area, viz., N-S, NW-SE and two faults orthogonal to the above. These fault alignments in general match with the trends identified in Suket 3D time structure maps (Figure 3 i). In the 3D volume, NE-SW oriented faults are clearly visible which are interpreted to represent the older structural grain developed parallel to the GBF which are subsequently offset by the major Suket reverse fault. The eastern side of this fault seems to be highly disturbed due to series of faults in the footwall block.

2- Reservoir facies Analysis

Subsequent to the gas indication in exploratory well in nearby area where a thin fractured sandstone reservoir within Lower Shale Member of Suket Formation indicated presence of gas, the prospectivity of Suket Play has been emboldened .Jhalarapatan Sandstone shows good primary porosity of 5-10%. XRMI studies also indicate presence of fractures at places. Thus, this sandstone can act as a good reservoir, particularly in areas where fracture driven secondary porosity is developed. Following seismic attributes has been attempted to understand the distribution of better reservoir facies for suitable exploratory leads.

i) Amplitude and Frequency

RMS amplitude and frequency maps have been generated for Jhalarapatan Member (window length 30ms). RMS amplitude map of Jhalarpatan Member clearly brings out three major areas showing higher amplitude anomalies. Out of these, two NE-SW trending anomalies are in the hanging wall block of Suket Fault while the third one is located in the footwall block with a NW-SE disposition, parallel to Suket Fault. The observed amplitude anomalies are envisaged to represent better reservoir facies (Figure 4) which was not encountered at drilled well at the crest of the anticline. Moreover, lowering of frequency corresponding to these high amplitude zones also corroborate the prospectivity of these areas. Prospects A and B have been identified to probe these geobodies. In case of any lead obtained from these locales, similar anomaly in the footwall block can be tested as well.

ii) Sweetness

Sweetness attributes was generated for two different time windows with respect to Jhalarapatan sandstone top with window length 30ms and 60 ms (Figure 5) and is showing relatively higher Sweetness near identified prospective locales, thereby corroborating the results of amplitude and frequency analysis.

iii) Inversion study

Post stack impedance study was carried out using Hampson Russell software. Impedance volume was analyzed and interpreted and impedance time and various horizon slices were generated. Two horizons slices showing distribution of low impedance regions are depicted. The analysis of these maps and sections has helped in identifying the prospective areas. The impedance maps revealed the presence of a channel like feature represented by dotted line showing low impedance trend in (Figure 6) which was further confirmed through the analysis of spectral decomposition.

iv) Spectral Decomposition

Many attribute analysis are carried out on the 3D seismic volume for reservoir characterization to reduce the uncertainties associated to the geological interpretation process, lithostratigraphic interpretation and fluid contents. Spectral decomposition of seismic traces into frequency domain is an established and popular technique for stratigraphic analysis from seismic reflection data. Apart from the qualitative nature of interpretation, spectral decomposition can also provide quantitative information about reservoir thickness and visualizing subtle seismic tuning effects and delineating phase.

After careful analysis of all the attributes along with other G&G data, a likely geological model of fluvial tidal channel indicating low impedance trend has been identified within Suket Formation .The two identified prospects in Suket 3D area lies within the identified channel

Spectral decomposition of 3D volume was carried out for Suket 3D. Frequency slices at different frequencies was generated and analysed. The observed tidal/channel like feature within Jhalarapatan Sandstone was observed to be tuned at 35Hz frequency. The high spectral amplitude observed along the channel is a probable indication of presence of hydrocarbon, while the intermittent relatively low spectral amplitude zones is indicative of a lithology change (possibly brine-filled sand)

Conclusions

The older NE-SW trending tectonic grain appears to have been offset by later tectonics manifested as NW-SE trending Mukundara and its cogenetic faults. Favorable entrapment conditions are envisaged at the intersection of these grains, in addition to independent four way structures. Tidal channel/ bar sands within Suket Formation (Jhalrapatan sandstone) in the Suket 3D area appear to be prospective geobodies for exploration in the down dip of Suket structures towards south and south-west of well S- Future exploration strategy demands that strati-structural plays also needs attention along with major structural entrapment locales.

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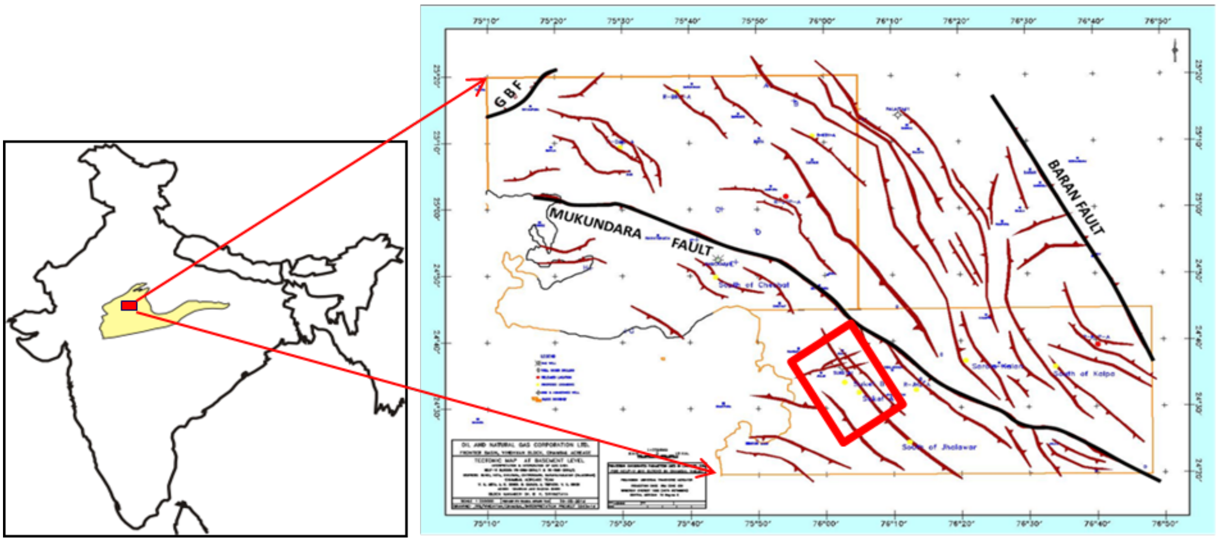

Figure1: Location map of 3D area along with Fault pattern at Suket level based on seismic data

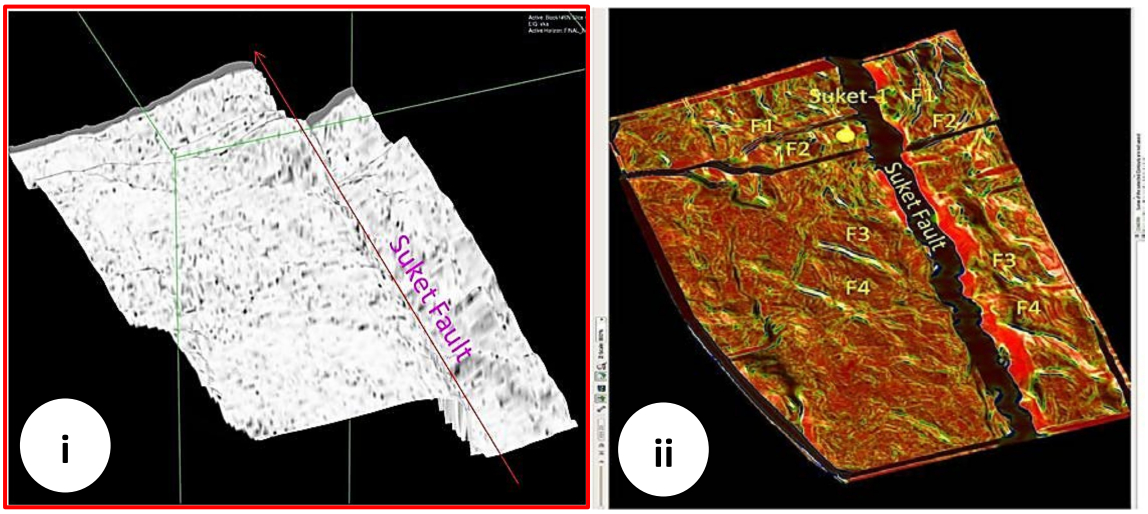

Figure2: (i) Variance surface for Jhalarapatan top plus 60ms (ii) Curvature attribute flattened at Jhalrapatan Sst

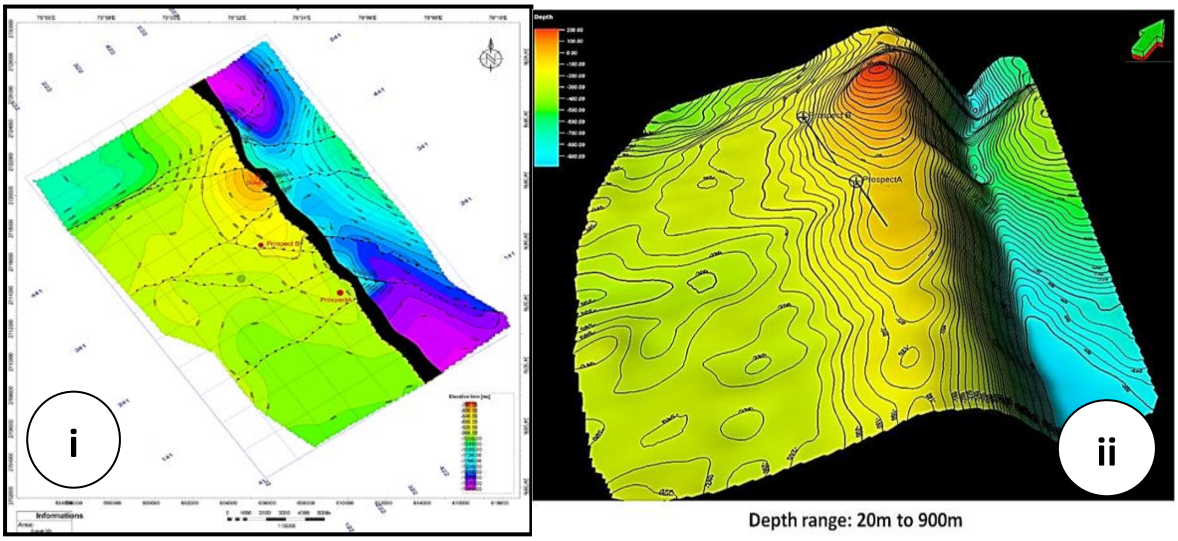

Figure3: (i) Time structure map near Jhalrapatan and (ii) Depth surface showing Suket Anticline

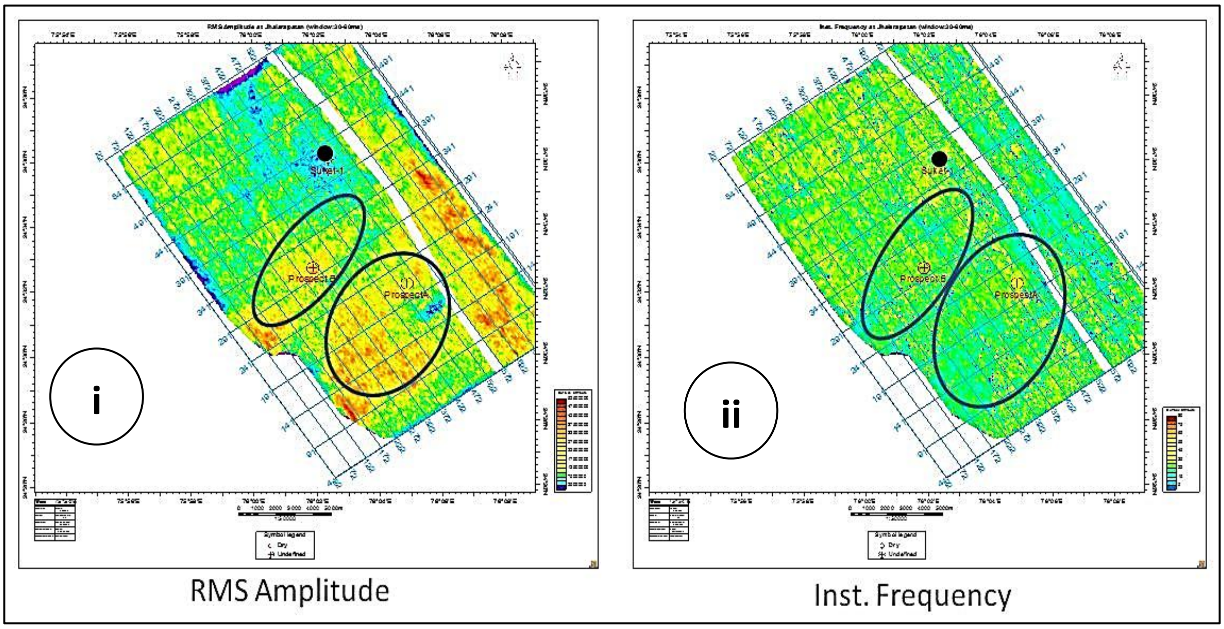

Figure4: i) RMS amplitude and ii) Inst frequency for Jhalrapatan top plus 30ms

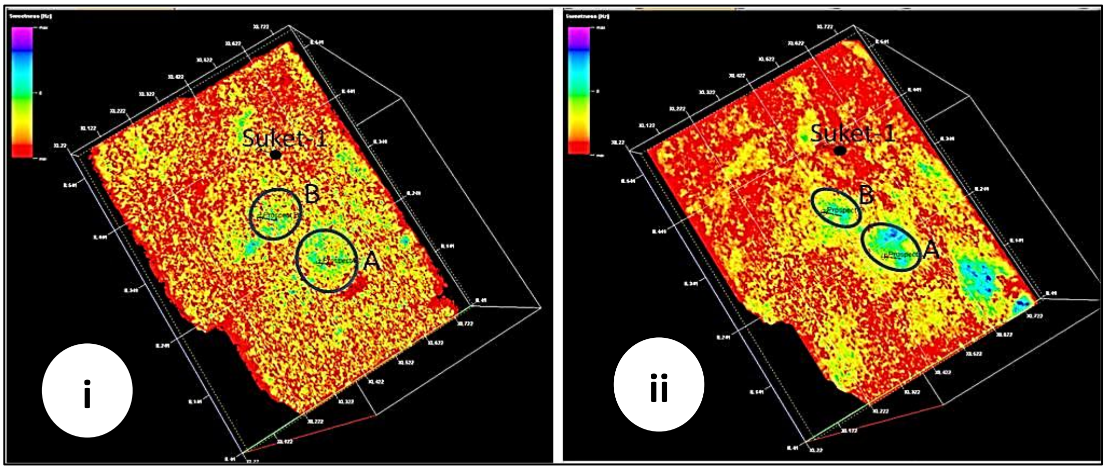

Figure5: i) Sweetness for Jhalrapatan top+30ms and ii) Jhalrapatan top+60ms with in Suket Formation

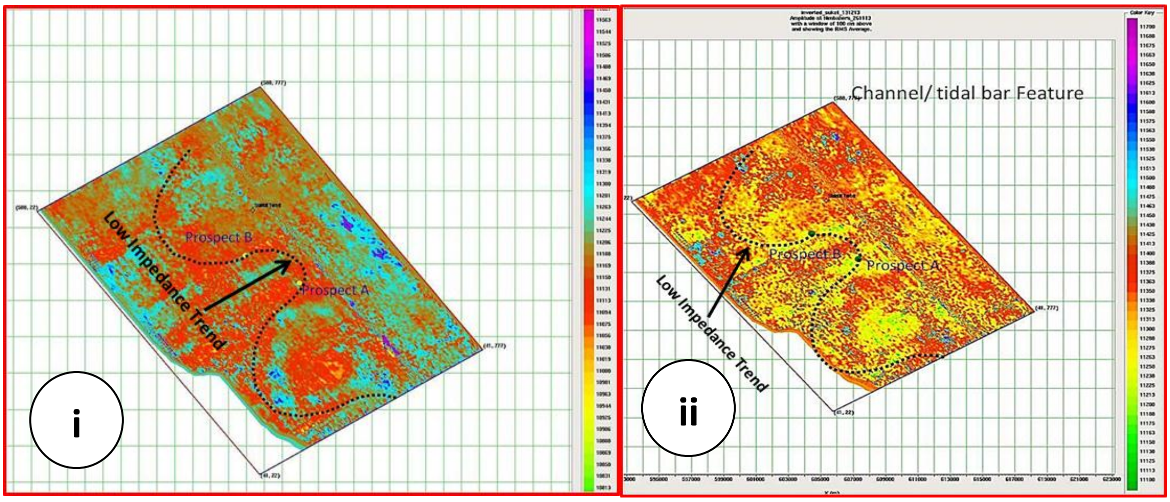

Figure6: Acoustic Impedance Horizon slicefor (i) Jhalrapatan top+30 and (ii) Jhalrapatan top+60ms

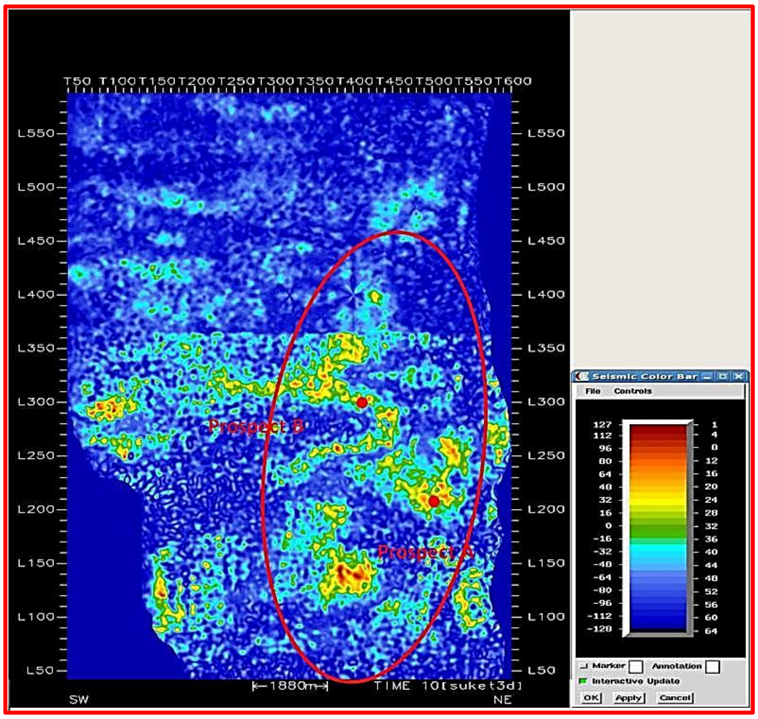

Figure7: Spectral Decomposition for Jhalarapatan Sandstone (50ms Window) in the hanging wall block of Suket Fault