Analysis of Lows and Their Implications for Additional Oil and Gas within Mumbai High Field*

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Abstract

Mumbai High structure, formed on the western Indian shelf, is situated in an average water depth of 75 m. The field comprises of heterogeneous, thin multilayered carbonate reservoirs having variations in porosity and permeability. The principal reservoir is an L-III carbonate sequence. However, apart from L-III, additional reservoirs like sandstone, basal clastics and basement rocks are also present in the field.

The three sets of major fault trends control the giant structure, which are NNW-SSE, the Dharwar trend, ENE-WSW, the Narmada trend, and NE-SW, the Aravalli trend as evident from the G&G studies. Most of the faults are parallel to sub-parallel to the main trends, were generated from the basement level with the exception of some of the faults restricted to shallower levels that do not penetrate to deeper levels indicating the neo tectonic activity. Three distinct lows, not so deep in nature, developed over the entire structure along the major trends during the fault activity. The size of the lows further decipher these are due to minor undulations or adjustments taken place during the uplift. These lows are important targets in the light of hydrocarbon accumulation point of view.

Most of the Mumbai High has been probed through drilling, and some of the drilling taken place in the rising flanks of the lows proved successful. Thus, drilling has provided good understanding about the quality of facies in the lows. Hence, detailed analysis of the lows namely, southern, western and central is attempted using the relative acoustic impedance (RAI) and porosity volumes and structure maps as these can address the heterogeneity and porosity distribution along with structural aspect. In this paper, we attempt to establish the role of rising flanks in looking for additional oil by establishing relation between the rising flanks and heterogeneous carbonate facies thereby identifying prospective locales.

Introduction

Mumbai High, a giant multilayered Tertiary carbonate oil field, located in western offshore of Indian sub continent, was discovered in 1974. The NW-SE trending doubly plunging anticline structure with its conspicuous faulted eastern limb is situated in an average water depth of 75 m. The structure is further evident by an E-W trending fault forming a structural low referred as central low by the authors and is considered as the permeability barrier in the main L-III reservoir, separating the field into Mumbai High South (MHS) and Mumbai High

North (MHN) of different hydrodynamic systems. The large structure with its multifaceted reservoir framework from basement rocks, basal clastics, thin carbonate layers and gas bearing sands has been on production since 1976.

Geological Background

The Western Offshore basin of India formed in a divergent passive margin set up by extensional tectonics in two phases. Early phase was active between late Cretaceous to early Eocene, which comprises the formation of a narrow rift valley, and proto-oceanic stage. Formation of grabens was initiated in the end of the late Cretaceous during the early phase of movement. The entire shelf is split into longitudinal strips by a number of basement-controlled faults, which resulted in horsts and grabens. The rifting and block movements caused by extensional tectonics gave rise to prominent highs along with dominant fault trends. One such structure, Mumbai High, remained exposed until Oligocene times. Later the sedimentary sequences covered the basement rocks by the transgressive phases.

Mumbai High has three conspicuous fault trends, namely NNW-SSE, the Dharwar trend, ENE-WSW, the Narmada trend, and NE-SW, the Aravalli trend (Basu et.al, 1980, Verma et.al, 2001) as evident from the G&G studies. Most of the faults as observed are parallel to sub-parallel to these main trends. Some of these fault sets generate small size lows bounded by normal faults having throws towards the axis. The lows are formed by syn-sedimentary adjustments taking place on the shelf. The miniature grabens most evidently noticed in the southern part, western part and central part of the field which are defined as southern low (SL), western low (WL), and central low (CL) that separates MH North from MH South (Figure 1) are present up to the shallow levels.

The Present Work

The study is to analyze and assess the potential of the lows seen on the structure as some of the wells drilled in the lows proved success. The whole structure located on the shelf and the miniature lows formed due to adjustments. The neo-tectonic activity might not have played a major role in terms of accumulation point of view. However, the multi-layered thin limestone configuration (Figure 2), heterogeneity, noises due to migration and multiples, seismic imaging problems in the gas cap areas complicated the understanding of the reservoir in terms of distribution aerially in Mumbai High Field. However, the detailed structural analysis coupled with the Relative Acoustic Impedance and porosity volumes is attempted to address the lows to understand the quality of facies and porosities ranges in terms of hydrocarbon accumulations by calibrating with well data.

The present study focuses on main reservoir L-III (Figure 3). The structural modeling is carried out on the top of the unit along with two other target layers to bring the structural configuration. Faults are identified and correlated on vertical sections by taking the cue from the variance slices as it helps in identifying the lineaments (Sharma S., et. al, 2010). The structure along with fault framework depicts the lows at the reservoir level, which are correlatable with the established geological trends as explained in the text. The property maps of acoustic impedance and porosity distribution generated in the interval covering the target layers with the Relative acoustic impedance and porosity volumes to understand the lithological spread.

Case Study: Structural Aspect

We discuss the southern low situated in the southern part of the field. The designated main high area (Part of Mumbai High Field) is oriented along the Aravalli trend NE-SW bounded by sets of normal faults. These fault sets form the lows and aligned to the north and south of the main high where well-A is situated. The structure is segmented by a major Dharwarian fault in the east and a plunge towards basin ward in southwest direction. The main high, which harbors hydrocarbons, put on oil production from Well-A (Figure 4). The low towards north of the main high and plunge towards the southwest are examined as both are structurally placed favorably above the contact. The low to the south of main high is of less concern as it is structurally down and below oil water contact.

Acoustic Impedance Attribute Study

It is usual practice in the industry to use the amplitude interpretation to indicate the reservoir boundaries like unconformities, faults, stratigraphic limits, porous and tight nature, fluid contacts and reservoir heterogeneities (Enachescu, 1993). In this study, we infer the reservoir heterogeneities based on Relative Acoustic Impedance (RAI) volume. The acoustic impedance, which is the product of density and seismic velocity, varies among different rock layers. The changes in the product values of the layers determine the reflection coefficients. The impedance contrast indicates the physical property contrast and hence it can be used to infer the porosity changes and layer tightness, layer boundaries, discontinuities and lithological heterogeneities. Prediction of particular reservoir property from a seismic attribute depends on the calibration with the wells. In the present case, we observed Acoustic Impedance has a good correlation with occurrence (A, D, B, and E) and absence (C and F) of hydrocarbon in six wells.

The Average Reflection Strength map generated from RAI volume taking an interval (Figure 5) comprising the target zone depicts the contrasts with bluish green on main high and some areas in the rising flanks of the low in the north which are indicative of good facies where wells A, B, D and E are situated and encountered oil and gas. Whereas, the well C and F, which are dry, drilled in the axis of the low have tight reservoir facies with impedance values high showed in pink and yellow color. It can be inferred that part of rising flanks of lows and plunge of structure are noteworthy targets instead of totally discarding them. In the matured field’s bypassed oil, areas and local small magnitude structures are of interest, which may add additional oil and gas to the main production.

Porosity Volume Study

The porosity volume was prepared using well and acoustic impedance data through geostatistical propagation. The gross porosity maps, which include shale content, were also generated in the target intervals from the porosity volume (Figure 6). The porosity values in the rising flank areas and main high are of the same order with red and yellow combination (wells B, E and A, D), where as the axis of low has low porosity ranges (Well C and F). It can be inferred the good porosity is seen on the flanks and structural highs and at some parts of axis too. The effective porosity maps are also generated by removing the shale volume for the target layers. Effective porosity map of the target layer is displayed (Figure 7) shows higher porosity range is associated with main high and flanks of lows.

Integrated Analysis

The hydrocarbon wells A, D drilled on the main high areas and wells B, E drilled in rising flanks have encountered good quality facies with good range of porosities, thereby, suggesting that the development of facies and good range of porosities are possible on the structural highs and some parts of rising flanks.

Conclusions

The rising flanks with good facies and porosities can be the additional potential locales, which may add some more hydrocarbons hitherto undrained, in the development fields, provided those areas are within the contact. The role of lows and rising flanks for hydrocarbon accumulations, in general, cannot be ruled out, and in particular, in the case of Mumbai High field, where development was targeted in the main field area. This type of study helps in exploratory environment too as rising flank of lows and plunge of the structures become future plays.

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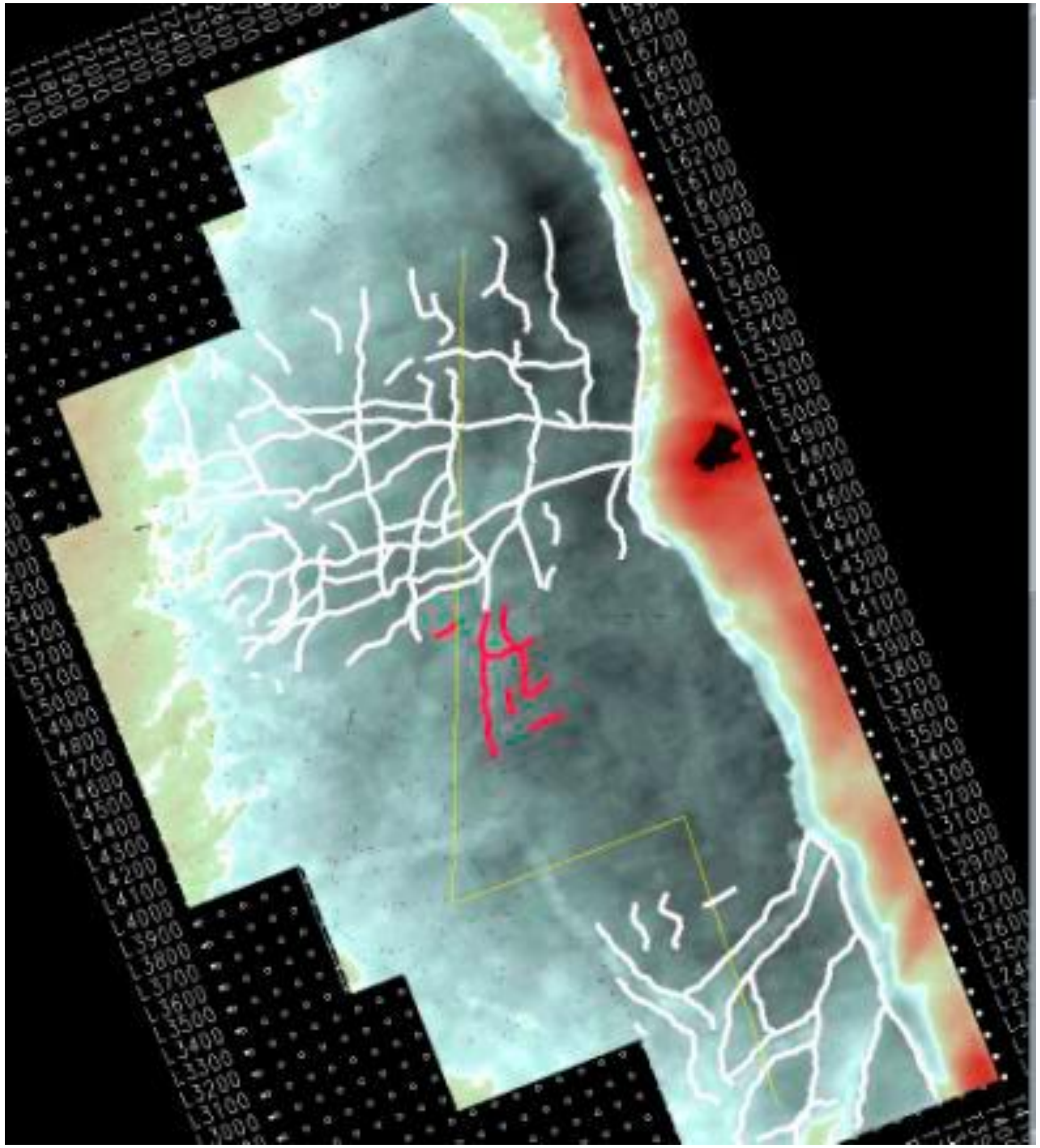

Figure 1. Mumbai High structure showing the prominent grabens.

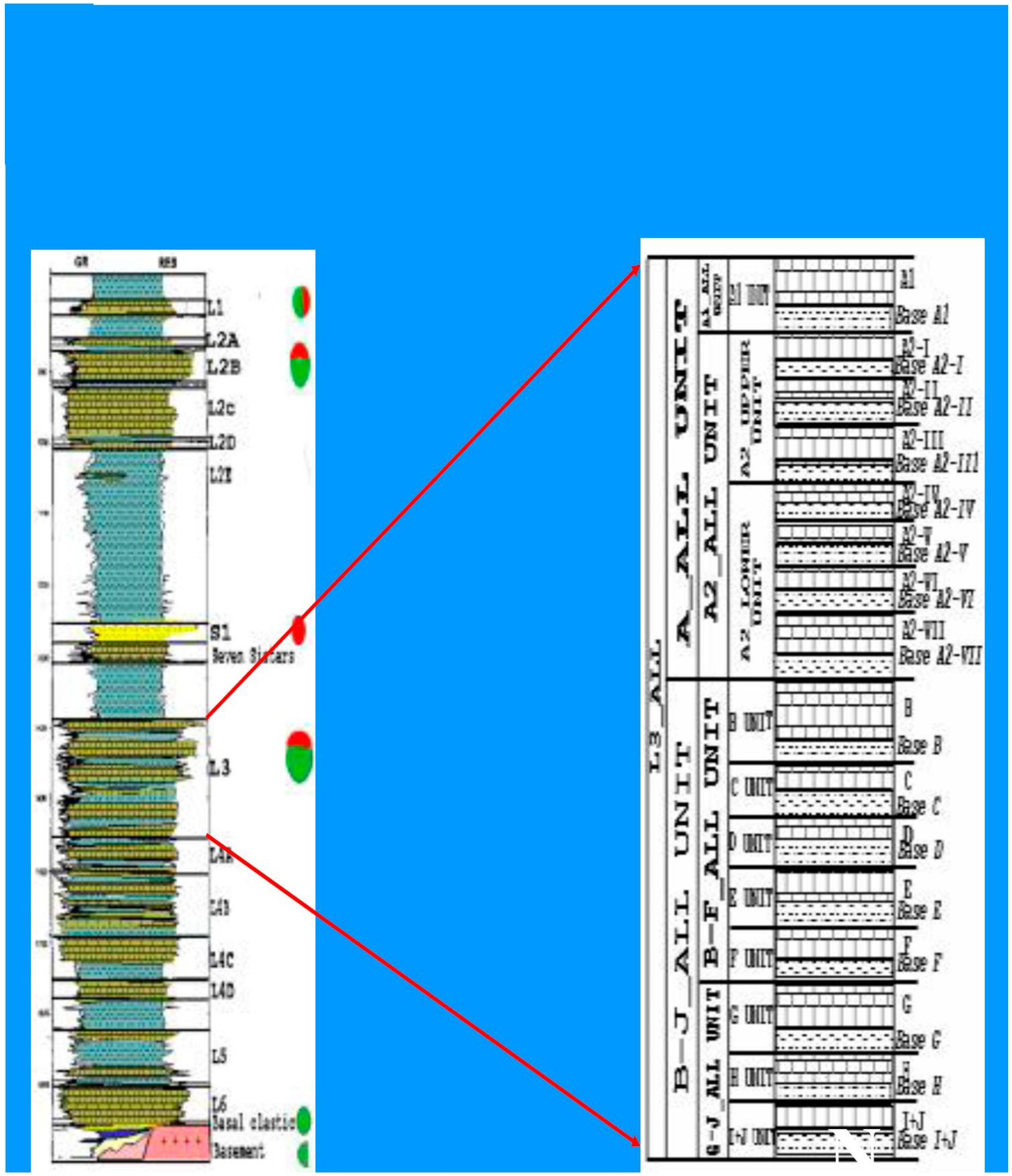

Figure 2. Disposition of the reservoir units.

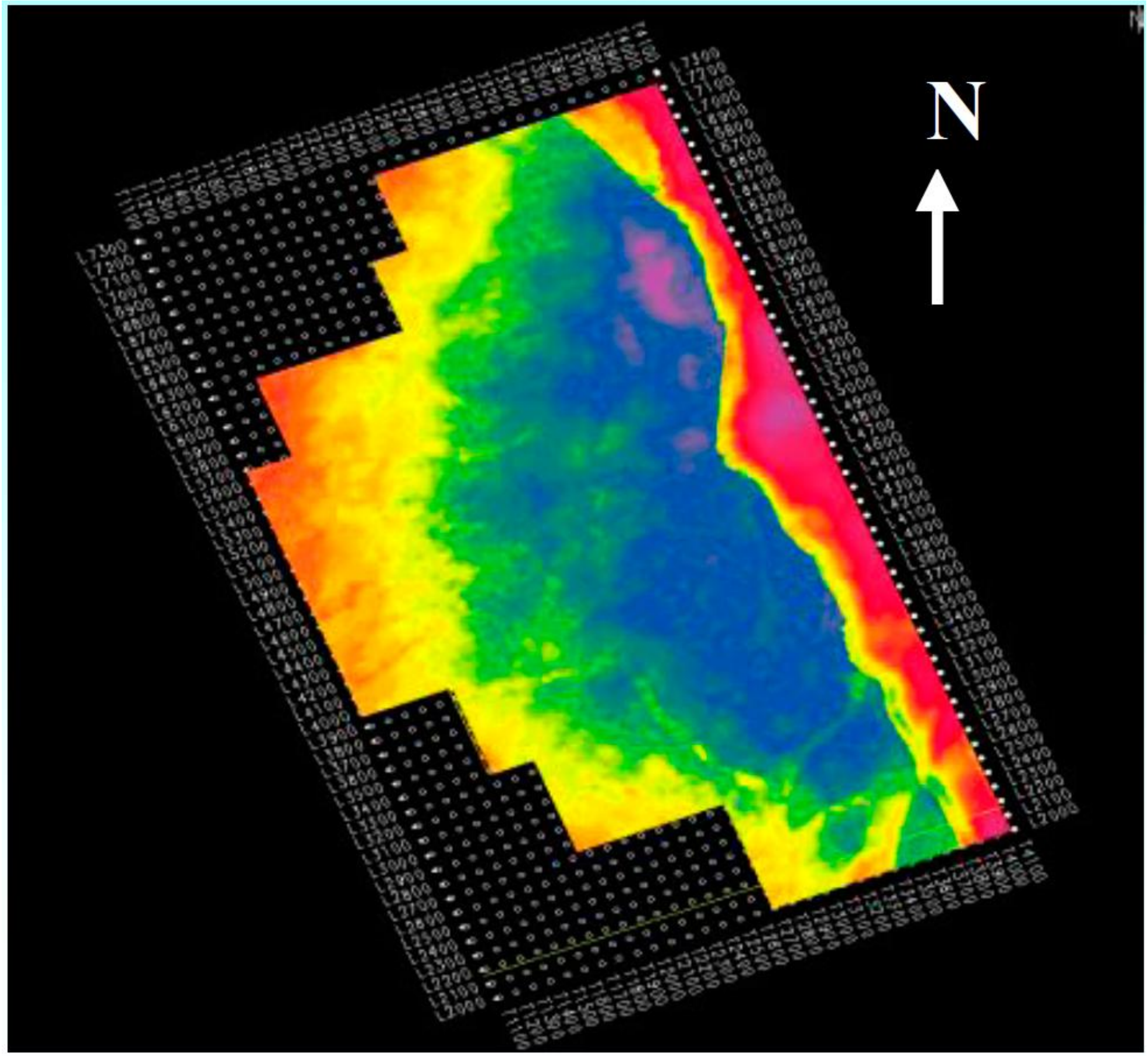

Figure 3. Structure map on Top of L-III.

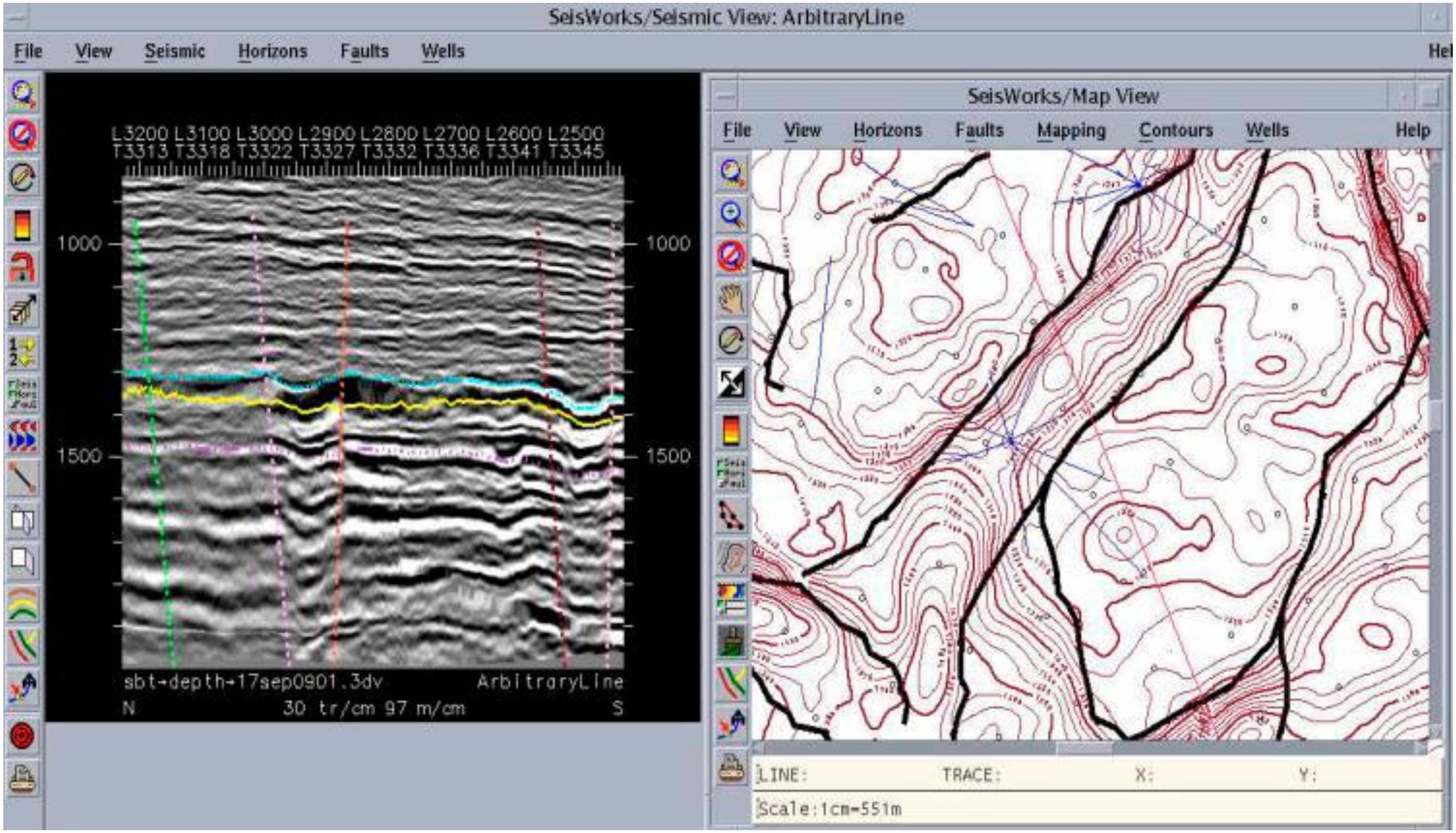

Figure 4. Structure with adjacent lows.

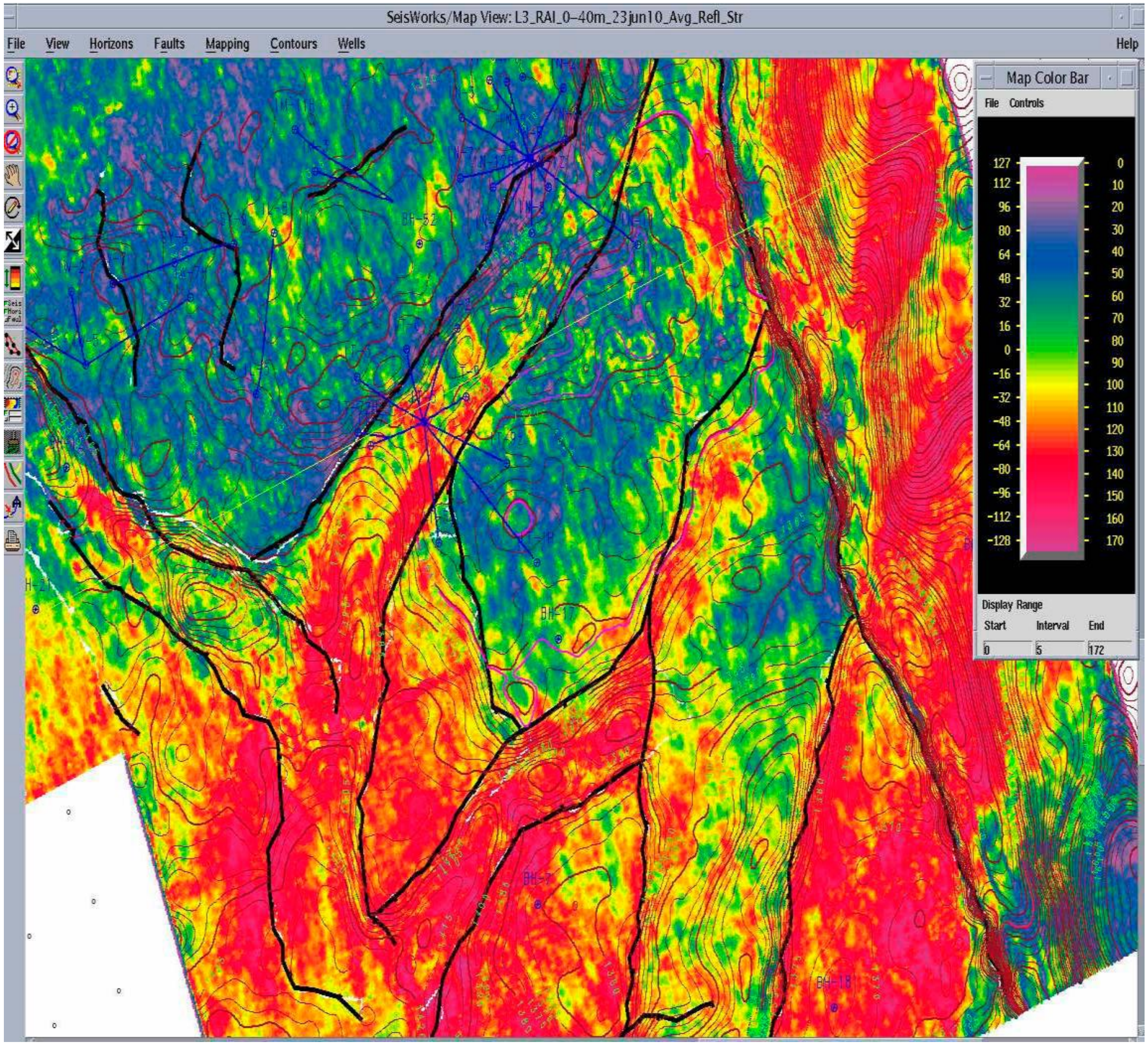

Figure 5. Wells A,D and B,E drilled in the central high and flanks encountered good carbonate facies whereas well C drilled in low axis and F drilled in flanks, encountered poor facies, suggesting that areas with bluish green colour are prospective and reddish pink color are poor or tight facies.

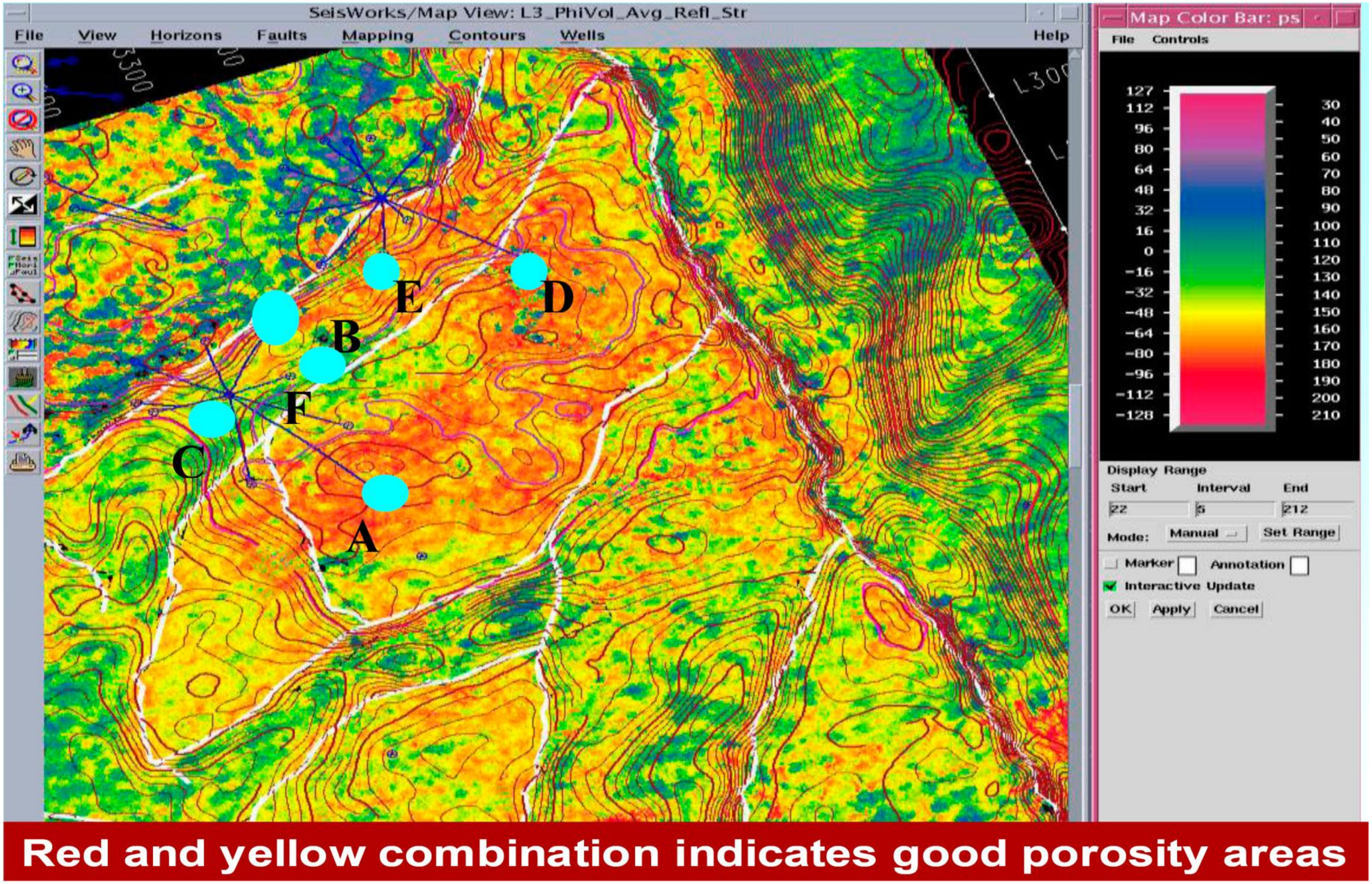

Figure 6. Gross porosity map.

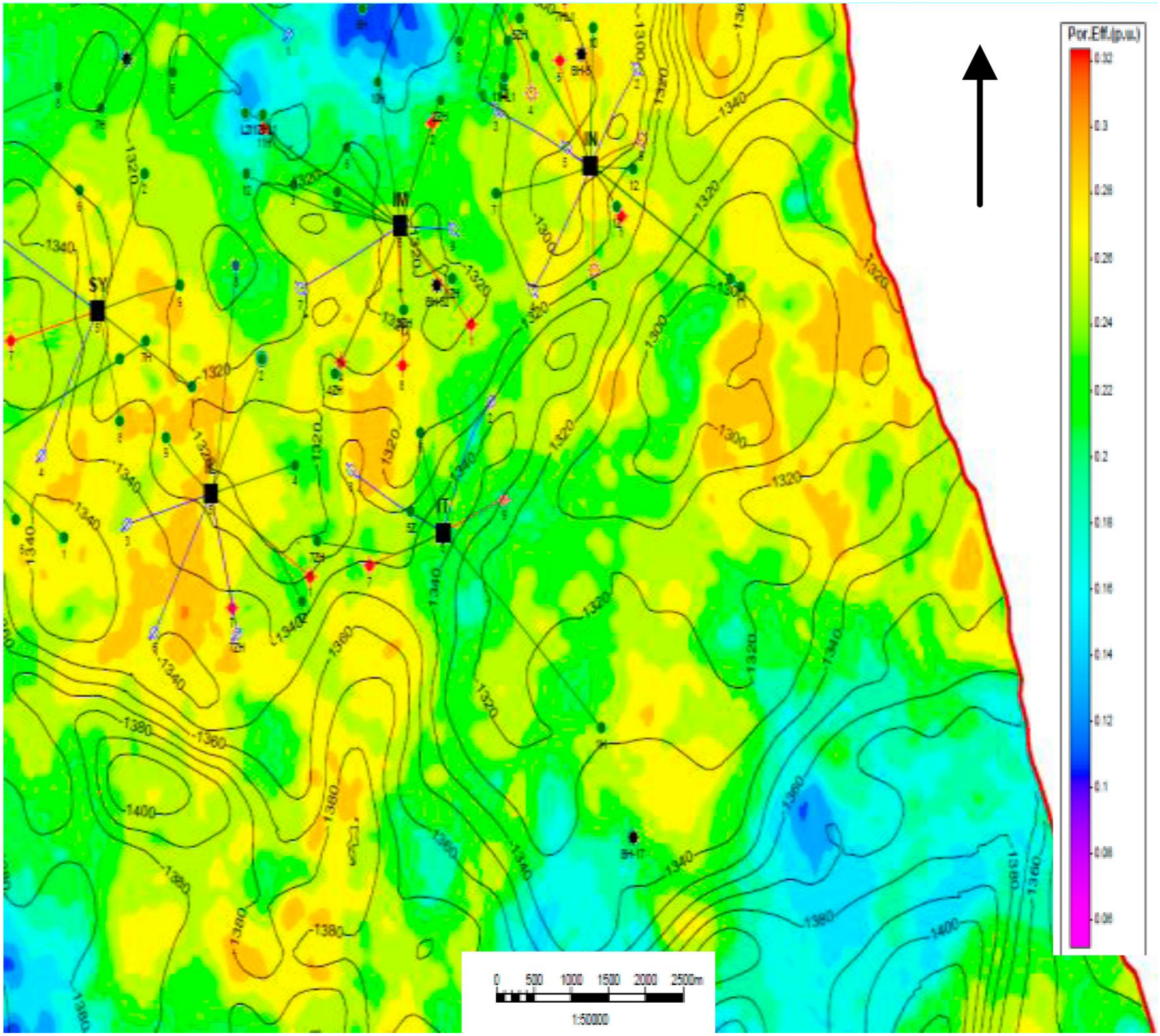

Figure 7. A2-III effective porosity map.