DIRECT DETECTION OF HYDROCARBONS IN INDIAN OIL FIELDS BY USING IPDS TECHNOLOGY

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Abstract

Infrasonic Passive Differential Spectroscopy is a technology for direct detection of hydrocarbons. It detects the spectral signatures over hydrocarbon reservoirs and is characterized by spectral peaks in the 1-8 Hz range. Hydrocarbon reservoir is a frequency converter and deforms the frequency of the natural earth noise. These deformed signals on spectroscopic analysis produce unique spectral signatures. These signatures are used as Direct Hydrocarbon Indicator. This technology has been test verified in series of oil Provinces around the world, in areas including currently producing, depleted, abandoned fields and virgin reservoirs.

This method was used for delineation of the Sanganpur oil field, Cambay basin, Gujarat and for locating the additional oil bearing areas in Bantumilli field, K-G basin, Andhra Pradesh. The entrapment condition of oil accumulation in Sanganpur field is unknown. The reservoirs are too thin to be identified from the seismic. The structural disposition of the field is also uncertain and the entrapment is conceived to be a combination type. IPDS conclusively projected the extension of the remaining oil in this field. Bantumilli field contains oil, gas, and condensate in multiple reservoirs. These reservoirs are sporadic, thin, non persistent, discontinuous and cannot be deciphered from the seismic sections. The petrophysical characters of the reservoirs vary conspicuously from one location to the other. The reservoir do not indicate any specific depositional model or trend. As a consequence, the drilled wells did not encounter suitable reservoirs and turned dry. Bantumilli field was initially conceived as a 80 Sq.kms structural trap. The first well drilled on this structure resulted in a dry hole. The subsequent seismic maps, presented a picture of dissected fault blocks with localized structural highs. The wells drilled on these highs, one after the other, ended in drilling of 5 abandoned holes. It was concluded that the accumulation of hydrocarbons is not controlled by structure alone. The presence of suitable reservoir controls the accumulation of oil in this field. IPDS was executed to identify the location of the oil containing areas. This survey, found out the presence of 5 petroleum prospects, varying in area from 8 Sq.kms. to 3 Sq.Kms, in the northern portion of the block. Incidentally, all these identified prospects correspond well with the structural traps, mapped from the seismic data. Additionally, IPDS confirmed the presence of the faults, earlier identified from the seismic data. These five prospects recognized from the IPDS survey represent the most suitable locations that contain additional oil in Bantumilli field.

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Introduction

The omnipresent earth noise registers numerous continuous seismic signals which are usually rather weak and often considered as useless background noise only. However, this “noise” carries useful information, which is contained in its characteristics, such as the frequency spectrum, or statistical properties or non-linear behavior. Moreover, it may contain a spectral signature characteristic of the media or environment, which it has passed through. Infrasonic Passive Differential Spectroscopy (IPDS) is the detection of spectral signatures observed over hydrocarbon reservoir (hydrocarbon – water multi component system in porous media). It is characterized by spectral peaks in the 1-8 Hz range, quasi continuous duration and a correlation time of several seconds. Hydrocarbon reservoir is a frequency converter, and deforms the frequency of the natural earth noise. The deformation of the natural earth noise spectra is characteristic in the low frequency range between 0.2 to 10Hz. These deformed signals on spectroscopic analysis produce unique spectral signatures, which are used as Direct Hydrocarbon Indicator (Fig..1) This technology has been test verified in series of oil provinces around the world, in areas including currently producing, depleted, abandoned and virgin reservoirs. In all cases, this characteristic signal was absent (or its amplitude, several orders of magnitude weaker) at the rim or outside of the oil bearing areas.

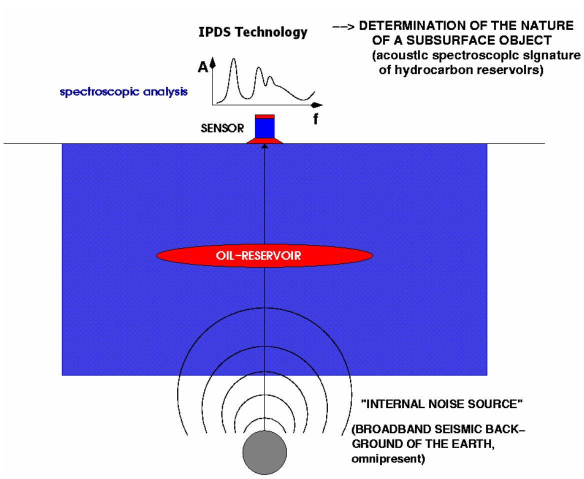

Fig 1: Spectral signature of subsurface hydrocarbon reservoir

This noninvasive technology can be utilized, as an oil field monitoring tool for investigation of the extent of the remaining hydrocarbons in producing fields. It screens the oil producing areas, determines the current net pay thickness of hydrocarbon column at different wells and evaluates the status of the infill wells. The most remarkable application in the field monitoring is the identification of present oil/ water contact (OWC) and gas/water contact (GWC). It also identifies bypass oil or gas areas, uneven flood fronts and areas that are not effectively drained by the existing wells. It avoids the risk of drilling unsuccessful infill wells and avoids workover and redrill operation of old wells.

IPDS technology is very effective in the development of a oil/gas producing fields. It detects the moveable hydrocarbons, indicates the thickness of the oil/gas column at different locations, delineates the oil/gas bearing areas. It thus locates the optimal position of production wells, injection wells and delineation wells. The existing oil/gas wells serve as calibration units. Correlation between thickness of pay horizons and IPDS RHI (Reservoir Hydrocarbon Indicator) is usually better than 70%. In fill well location can be identified by interpolation of calibrated grid data. In abandoned and depleted fields, this technology can be utilized to know the present oil/gas content at different locations. IPDS measurements confirmed presence of adequate oil in some of the abandoned fields. The subsequent new wells drilled in such abandoned fields, renewed production, from the recently drilled wells.

This method is particularly very useful at the commencement of new exploration ventures. Since this technology is independent of geographic location, lithology, depth or tectonic activity, it can work in any geological regime. The areas that conceal prospective sedimentary rocks below the basaltic flows, the areas intensely affected by severe tectonic activity, the logistically difficult areas or environmentally restricted areas, can be efficiently surveyed by this technology. It does not use any artificial noise and measurements are easily done through light sensor and recorders. Since the source of the sound is from the bottom of the earth, there is no absorptions , dispersion or refraction from the subsurface layers or structural complexity. Before drilling an exploratory wild cat well, IPDS can identify the hydrocarbon potential of the prospect and can avoid drilling a dry hole.

For better understanding of a potential hydrocarbon pool, this technology has high flexibility, fast turnaround online data processing, high mobility due to moderate equipment and small crews, low cost and environment friendly. The in-house designed ultra sonic seismometers are the core of the signal acquisition devices and the key for the detection and monitoring of subterranean hydrocarbon reservoirs.

The IPDS technology has been applied successfully in almost 100 survey campaigns in a variety of geological and environmental situations, in different parts of the world.

Implementation of IPDS in Indian oil fields

The results of IPDS survey in the exploration, development and monitoring of different oil/gas fields in different oil provinces, established the success of this technology for direct detection of hydrocarbon. This technology was implemented in two oil and gas fields of India. These fields are located in two different sedimentary basins of India, in totally different geographical location, subsurface configuration, lithological sequence, tectonic regimes, depths and structural orientation. Both the fields have adequate seismic coverage, drilled wells and producible reserves. Yet it is difficult to ascertain the actual hydrocarbon potential of both fields and initiate production. In order to establish the petroleum potential of these fields in minimum time, IPDS was executed over these two fields. The fields are Sanganpur in Cambay Basin, Gujarat and Bantumilli in K.G. Basin, Andhra Pradesh.(Fig..2)

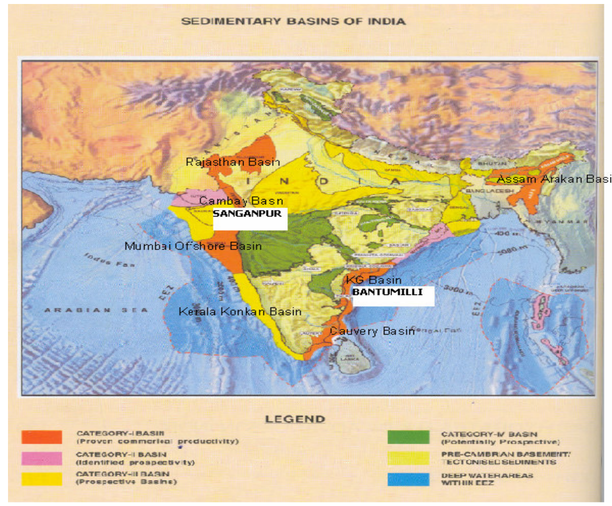

Fig 2: Sedimentary basins of India

Sanganpur oil field, Cambay Basin, Gujarat:

Sanganpur oil field is situated in the Gujarat state, in the northwestern region of India, in well explored, petroliferous Cambay sedimentary basin. Cambay basin is an intracratonic rift graben, between Saurashtra uplift and Aravalli ranges, extending in a roughly N-S alignment, as a long and narrow depression from north Gujarat to Gulf of Cambay. The Sanganpur field is situated in the Ahmedabad-Mehsana tectonic block of Cambay basin. The sediments from Lower Eocene to Recent represent the stratigraphy of the field. The structural configuration of Sangapur field is not conclusive from the seismic maps. The Time contour map of a reflector with in Mehsana Member, shows that this area constitutes a gentle flank, deepening towards south (Fig..3). However, a Isochron map, corresponding to the bottom of Viraj shale formation indicates that a narrow longitudinal anticline, having a gentle 10 m.sec. amplitude, represents the Sanganpur structure(Fig..4) . The two wells, viz. S-1 in the northern plunge and S-2 in the southern plunge, drilled at the similar structural position, proved to be incoherent in depth.. Accordingly, it was surmised that the oil accumulation in the Sanganpur field is not contained by structure alone and may be due to the combination of structure and stratigraphic control.

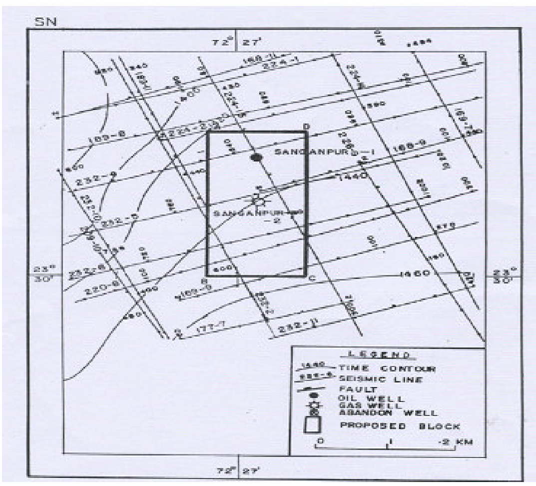

Fig 3: Time contour map of a Reflector with in Mehsana member of Kadi

Four sand reservoirs viz., R-I to R-IV developed within Mandhali Member, constitute the pay horizons . These reservoirs can be identified in the surrounding Akhaj, Jetalpur, Kherwa and Sobhasana wells. Reservoirs I & II are the main producers and the other reservoirs e.g. R-III & R-IV have marginal potential . All these reservoirs have limited thickness, cannot be recognized in the seismic sections, do not show any specific depositional trend and posses varying petrophysical properties. Consequently, these are not mappable and areas containing better developed reservoirs are not predictable. A substitute well S-IA, drilled in the west, only 20m away from well S-I , encountered a new reservoirs of clean sand of 5m.thickness having good petrophysical characters.

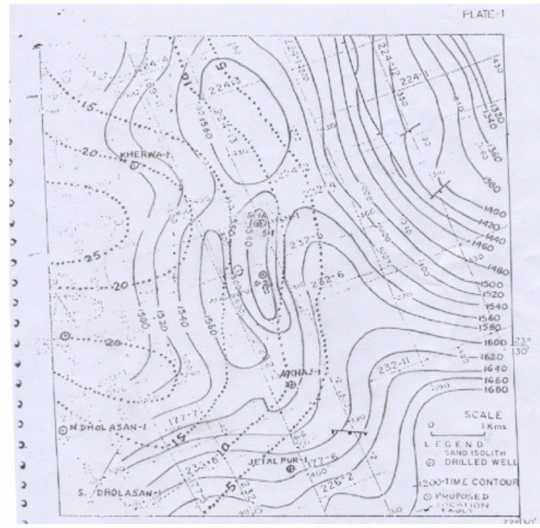

Fig 4 : Isochron map of reflector corresponding to the bottom of Viraj shale formation.

Exploration Concept

The tectonic configuration and the play of the reservoirs reveal that further exploration to delineate the field is riddled with many uncertainties. These uncertainties involve limitation in seismic display, undecipherable reservoir trends and inconsistent petrophysical characters of the reservoirs. The discovery of a new horizon containing oil just 20m west of Sanganpur-1 envisaged that many such additional oil bearing layers may be present in the western limb of sanganpur. However, these are too thin to be deciphered from any additional seismic data. Consequently, IPDS Technology was implemented to discover presence of any additional oil.

IPDS Survey and Survey Results

The main part of the survey was conducted in the Sanganpur area. Several data points were measured outside the area to improve the boundary conditions for the coalescing of the data within the field area. Part of the measurement outside the area was performed close to wells with the aim of correlating the IPDS data with well data.

The RHI map (Fig..5) corresponds well with the subsurface configuration of the block and Sanganpur field. The RHI contours display a NW-SE trend, that matches well with the regional tectonic alignment of the area and the structural trend of the oil fields. The south eastern part of the block indicates the presence of only marginal oil. This corroborates well with the present status of well Sanganpur-2, which is an almost depleted well. The oil water contact of both the persistent reservoir R-I and R-II is located close to this well. The other reservoirs, e.g., R-III and R-IV at present are devoid of any oil or gas or have marginal oil .In the northern portion of the block, the area contained by the RHI contour 0.3, indicates presence of oil and this is confirmed by the presence of oil producing well i.e.Sanganpur-1 Further, it displays that accumulation of Hydrocarbon increases towards the western part of the block. A transition area bounded by the contours 0.2 and 0.3 is present in the western part of block. This rim may contain a thin column of oil.

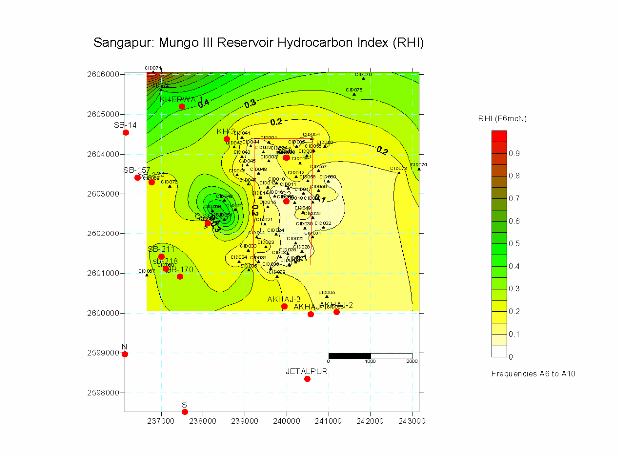

Fig 5: Reservoir Hydrocarbon Index map, Sanganpur

The most significant feature of the RHI map is the identification of a prospect located about 1 km west of the block. This prospect encloses an area of about 1.5 Sq.kms. around the measurement points CID 049,050.051 and 052. The accumulation is aligned in a NW-SE direction and is enclosed by the 0.45 RHI contour. The oil accumulated area may be much larger, extending towards NW. The presence of considerable amount of oil in the west, south and north west of block is confirmed by the oil wells i.e., Kherwa-1, KH-3, SB-134, 157 in the west and north west. The other oil wells e.g., SB-17.SB-211, 218 and 170 confirm the accumulation of oil in the southwestern part of the block. The Akhaj wells e.g., Akhaj-1, 2, 3 confirm the presence of oil in the south.

The RHI map indicates that the southern portion of the block contains very small amount of oil. Moderate quantity of oil is present in the northern and western rim of the block. This survey further confirms the close correspondence between the actual status of the wells and the RHI values. It is concluded that the Sanganpur oil pool has limited aerial extension. and does not contain much additional oil.

Bantumilli Oil field, K-G Basin, Andhra Pradesh:

Bantumilli field is located in the highly prospective Krishna Godavari (K-G) sedimatary basin (Fig..2). It is situated over Bantumilli high, in the southeast plunging part of Tunuku high in the west Godavari sub-basin. Five wells have been drilled upto Archean basement. Sediments from Lower Cretaceous to Recent have been encountered in the field.

The exploration commenced with the drilling of the first well on a structural high of 80 Sq. Kms.(Fig..6). The well did not encounter any suitable reservoir rocks. With the advent of new seismic data, the tectonic picture of Bantumilli area charged from one version to another. The subsequent seismic maps, revealed the presence of many structural traps, dissected by faults, The successive wells drilled on these structural culminations ended in 5 abandoned holes(Fig..7). The seismic sections display flat , gentle attitude of the horizons and do not show any major tectonic activity. The time structure map prepared on the top of sand package showed the presence of a number of structural highs.(Fig..9) All these structural highs are oriented in NE-SW direction, intersected by NE-SW aligned faults. The map revealed that, the wells BNT- 1, 2 , 3 and 4 were not suitably located . The structural highs are mostly of low amplitude and the other data do not indicate any intense tectonic activity. It was thus surmised that the Bantumilli area has not witnessed any major tectonic activity and is comparatively quiescent. Consequently, the possibility of occurrence of any major structural entrapment seemed to be remote. The dry and abandoned wells, drilled on the structural highs, further confirmed that the structures do not play a major role in hydrocarbon accumulation.

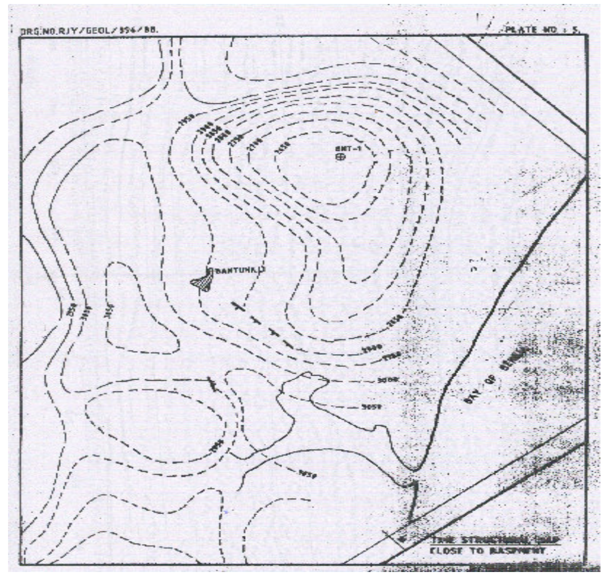

Fig 6: Time structure map close to basement, 1987

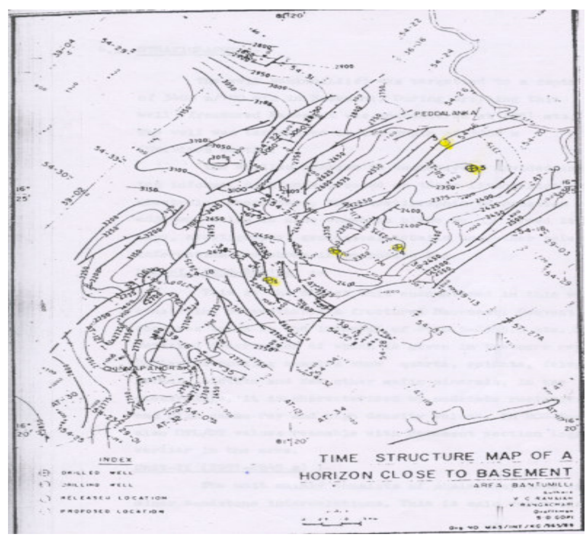

Fig 7: Time structure map of a horizon close to Basement

Lenticular sands within Raghavapuram Shales, possibly representing intervening regressive phases, form the main exploration target for petroleum exploration. The extension of the Raghavapuram Shale from Nandigama in the south west to Mahendravada in the north east has been established. Discontinuous sand layers acting as reservoir rocks have been encountered in the Raghavapuram shale. The electrolog correlation of the reservoirs revealed that these layers donot continue from one well to the other and changes to argillaceous facies. It was not possible to map the oil containing horizons of BNT-2 & 3 from one well to other. These are also not recognizable from the seismic data.

Implementation of IPDS technology and the results:

The analysis of the seismic data and the depositional model of the reservoir rocks reveal that the accumulation of hydrocarbon is not dependent on the presence of structural traps. The correlation of the reservoir also did not indicate any model of deposition or specific trends in oil and gas accumulation. Further, these reservoirs could not be mapped from the seismic sections. Under these limitations, it was decided to execute IPDS survey in the area to locate the hydrocarbon bearing reservoir rocks. The IPDS survey presented, the contour map indicating Reservoirs Hydrocarbon Index at 240 measured data points (Fig..8).

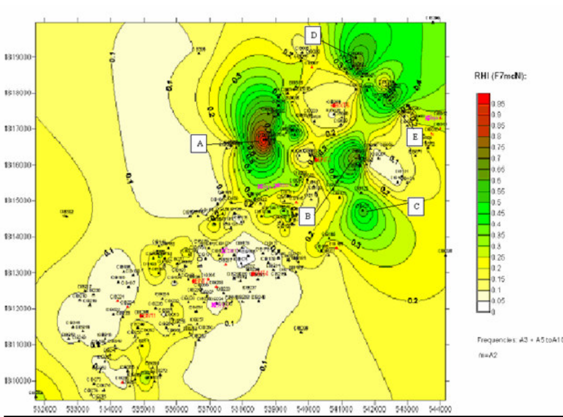

Fig 8. Reservoir Hydrocarbon Index (RHI) Map, Bantumilli

The Reservoir Hydrocarbon Index (RHI) map indicates that a number of petroleum prospects are present in the northern and northeastern part of the block. These prospects are identified as prospect A, B, C, D and E. The details of these prospects are as follows:

Prospect A:

It is located in the northwestern part of the block and is enclosed by 0.3 RHI value. The prospect covers an area of about 8 Sq.Km.. It is a N-S aligned RHI high, indicating maximum accumulation of oil at CIB 074. A separate RHI high enclosed by the contour 0.4 RHI at CIB 060 is observed to the east of the main high. Both these RHI highs are however, enclosed by 0.3 RHI contour. These two highs are separated from each other by an intervening comparatively low potential area. A fault may be present around the measurement points CIB 029, CIB 032, CIB 076 and aligned in N-S direction, in the eastern limb of the RHI high. Another fault trending in N-S direction may be present in the western limb of the RHI high. The constriction of the contours at this place and flaring of the contours south of it indicate the presence of a barrier or a fault. The trend of the RHI prospects matches well with the structural alignment of the area.

Prospect B& C:

These prospects are located in the eastern part of the block, demarcated by the Data points CIB 66, 67, 80, 82, 100,123, 125, 127, 165 and 167. The well BNT-3 is situated in the western side of these prospects. The well BNT-3 encountered about 7m of oil and gas column, and such occurrence of oil in the well, located in the limb of this prospect enhances the petroleum potential of this prospect.

These prospects together are aligned in NW-SE direction and encompass an area of about 4.55 Sq.Km. The closure formed by the 0.3 RHI contour and the maximum value of 0.65 RHI is observed at CIB 097 for prospect B. The independent closure, however, is enclosed by 0.4 RHI. The display of the prospect shows closely spaced contours in the eastern limb of the high and widening in the western and southwestern part of this high. Such display may represent some structural and tectonic deformation. These evidences indicate presence of a NNE-SSW fault. A saddle of low RHI value separates Prospect B from Prospect C. Prospect C shows a maximum value of 0.5 RHI at CIB 127. These Prospects together constitute a significant petroleum lead.

Prospect D & E:

These Prospects are located in the northeastern part of the block demarcated by the data points CIB 023, 024 and 045.The well BNT-5 is located in the southwestern side of this prospect. In the well BNT-5, a reservoir horizon in the interval 3025-3026 m, indicated presence of hydrocarbon in electrologs.

These Prospects together cover an area of nearly 3 Sq.Kms, with an intervening depression. Prospect D is oriented in NNE-SSW direction and enclosed by RHI Value of 0.5. The maximum value at the centre of this prospect is 0.6. It is observed that near the southern side of the prospect, the RHI contours exhibit close concentration. Such display indicate presence of fault . Prospect E is enclosed by the RHI contour of 0.45 and is aligned in NE-SW direction. The maximum RHI value at the centre of the Prospect is 0.6.It covers an area of about 1 Sq.km. The concentration of the contours in the western limb indicates the presence of a possible fault. The intervening low between the Prospect D&E is represented by RHI value of 0.25 . It may also represent the down thrown side of the fault that has affected the western limb of the Prospect E.

Correlation of the Prospects with mapped structural highs:

All the Prospects identified from the RHI map indicate close resemblance with the identified structural features. The Time structural map on the top of sand package (2257-2290 m) corresponding to object III and object IV of well Bantumilli -3 shows following correspondence.

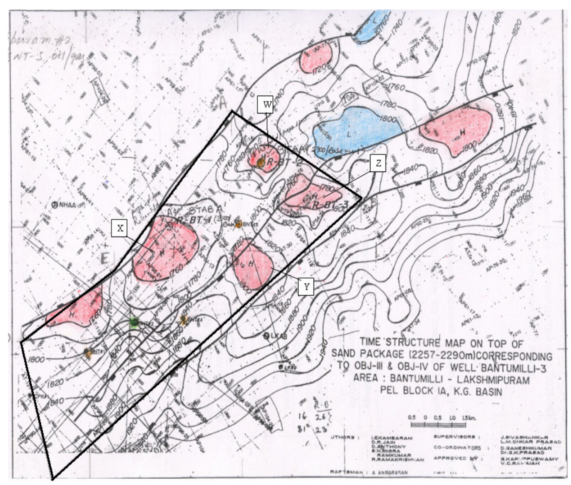

Figure 9: Time structure map on top of sand package, Bantumilli-3

Prospect A:

This Prospect corresponds to the structural high X identified in the Time structure map. This structural high is enclosed by 1780 m.sec contour, aligned in NE-SE direction and encompassed an area of 7.5 Sq.km. This structural high is truncated in the west by NE-SW aligned fault. It shows more than

20m.sec. amplitude. A location R-BT-1 was proposed for drilling by ONGC in the early nineties. However the location was not released and no well was drilled at this point. The NE-SW aligned fault in the western flank of the high also corresponds with the fault identified in the RHI map. These observations reveal good resemblance between the structural features identified from the seismic data and Reservoir Hydrocarbons Indicator map from the IPDS survey.

Prospect B& C:

This prospect matches with the structural high Y mapped from the seismic data. This high is enclosed by 1800m. sec. contour in the eastern downthrow side of the fault and 1780 m. sec. contour in the western up thrown side. The well BNT-3 is located in the intervening low potential area between the structural highs X & Y. The NE-SW aligned fault dissects this structural high into two segments. This fault can also be observed in the RHI map, between prospect B & C. Even the intervening structural low between the structural highs X & Y are indicated in the RHI map.

Prospect D & E:

Prospect D corresponds well with the structural high W. This structural high is enclosed by 1740m.sec. contour and shows amplitude of more than 20m.sec. It encompasses an area of about 1.5 sq Km and shows a domal configuration. The location R-BT-2 was proposed on this structural feature, which was subsequently drilled as BNT-5. This well indicated presence of oil bearing sand in the interval 3025m – 3026m.However, as per the RHI map, the well BNT-5 is situated in the southern low potential area of the prospect D.

Prospect E corresponds to the western segment of the structural high Z, identified from the seismic data. This is situated in the upthrown side of the NE-SW intervening fault. A location R-BT-3 was proposed for drilling a well on this structural high. This was, however, not drilled. The presence of the fault as shown in the seismic map is also evident in the RHI map.

It is concluded that the prospects and faults identified from the RHI map have good correspondences with the structural features identified from the seismic map. The RHI map shows the locales where suitable reservoirs contain hydrocarbon. The seismic maps indicate the presence of structural traps that may entrap oil and gas. The close correspondences reveal that the structural traps have adequate oil containing reservoirs. In Bantumilli area, the reservoirs are inconsistent and sporadic. These are not decipherable from the seismic data. This is the major problem in identifying suitable location for drilling. The IPDS map shows the presence of suitable oil bearing reservoirs in the structural trap identified from the seismic data. Such locations represent the ideal position for oil exploration.

The presence of hydrocarbon bearing reservoirs has been depicted from the IPDS survey. The five prospects identified from the IPDS survey represent the locales of hydrocarbon accumulation. These prospects correspond well with the structural highs, identified from the seismic studies. It is concluded that Bantumilli possesses reasonably good potential for Hydrocarbon accumulation.

Conclusion and Recommendation:

IPDS is confirmed as a technology for direct detection of hydrocarbons .It's use in Sanganpur and Bantumilli fields has aided in identifying oil prospects and absence of it . This method used in conjunction with standard 2D and 3D data, considerably enhances the Direct Detection of Hydrocarbons and prevents drilling of dry holes.

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