Exploration in a Thrust Belt Area: A Case Study from Jairampur, Arunachal Pradesh, India*

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Abstract

The Assam Shelf, Naga Schuppen Belt and the Assam-Arakan Fold Belt are the prime geological features of the Assam-Arakan shelf-slope basinal system. Exploration history of the Upper Assam and fold belt areas dates back to the late nineteenth century (1856-1889) when Asia's first commercial oil fields were discovered by the Burma Oil Company in Digboi and Makum. The Jairampur area is situated at the Himalayan foot hills in the eastern fringe of Arunachal Pradesh in the northeast part of India and lies within a zone of regional NE-ENE structural trends immediately north of the strongly deformed "Schuppen" zone.

The geological importance of the Jairampur area is the exposure of Barail Group of rocks, which is hydrocarbon prolific in the entire Assam-Arakan Basin, and has been thrust to the surface near the Indo-Burmese plate margin. Several oil fields have already been established in and around the study area. Presence of oil (32.60 API) was reported from a shallow well (364 m) drilled over an antiform by Geological Survey of India (GSI) in 1986.

During19th century a number of shallow wells (around 300 m) were drilled in Digboi area and produced from the Tipam Sands using clayey-water based mud and slotted liner completions for production. During 1998 Oil India Limited (OIL), drilled its first well, Jairampur #1. However, due to bad hole conditions owing to the geological complexities, the well could not be tested properly. In 2009, Mineral Exploration Corporation Ltd (MECL) drilled a shallow well (335 m) from the same plinth mainly to evaluate shale-oil prospectivity of the area and encountered two gas kicks at a shallow depth (154 m and 162 m). Analysis of gas samples and core

samples confirmed the gas to be thermogenic in nature. Encouraged from this result, coupled with the fresh log interpretation of well Jairampur #1, in 2010 OIL drilled a shallow well of 700 m from the same plinth of well Jairampur #1 using conventional drilling and completion methods to probe the supra thrust hydrocarbon prospectivity of the area, but commercial hydrocarbon production could not be established.

Detailed log interpretation of the shallow well, including FMI log interpretation, opens up few facts with regard to the adopted drilling and completion technology in thrust-fold belt areas. This article attempts to technically analyze and suggest the selection of drilling and completion technology for successful drilling and testing of wells in thrust-fold belt areas in the future.

Introduction

The Jairampur area lies within a zone of regional NE-ENE structural trends immediately north of the strongly deformed “Schuppen” zone with steep, southeast-dipping reverse faults and anticlines with a steep to overturned northern limb. The geological importance of the Jairampur area is the exposure of Barail Group of rocks (which is hydrocarbon prolific in entire Assam-Arakan basin) exposed on the surface as a result of thrusting (Barail Supra Thrust) along Jairampur Thrust and the presence of number of thrusts (viz. Disang Thrust, Angrang Thrust, Sinyang Thrust, Namgoi-Nampong and Tirap Thrust) in the southern part of Jairampur area, near to the Indo-Barmese plate margin (Figure 1 and Figure 2).

Hydrocarbon Prospectivity

Jairampur area is located within the proven petroliferous Assam-Arakan Basin. Several oil fields, such as Digboi, Kharsang, Kumchai, in the Schuppen Belt have been established so far. Numerous oil seepages were reported from the Schuppen Belt within and around the Jairampur area. The presence of oil (32.60 API) from the Supra Thrust Tikak Parbat Formation was reported from a shallow well drilled to 364 m over an antiform by Geological Survey of India (GSI) in 1986.

The Barail Argillaceous coal-shale unit (Oligocene) and deep marine Disang Shale of Paleocene- Eocene age are expected to be potential source rocks. The established oil fields like Digboi have oil production from the Tipam sandstone, whereas in the Kharsang and Kumchai fields the main producing horizons are sandstone lenses of Girujans. Additionally, sand ranges within Barails (both sub-thrust & supra-thrust) are expected to have reservoir characteristics within the area.

Exploration in Jairampur

Exploration in Jairampur and Jairampur Extension areas started in 1987. Initially not much work was carried out in the area due to surface logistics and subsurface geological complexity. However, on the basis of available geological data and also with limited 2D seismic (around 26 GLKM crooked line of 2D seismic data), well Jairampur #1 (Loc.: JRA) was drilled during 1998-99 to a depth of 2596 m (Figure 3).

Well Jairampur #1 encountered several hydrocarbon bearing sands in Sub-thrust Barail and Tipam and Supra-thrust Barail formations. The integrated log interpretation and drill cuttings and side wall core analysis also suggested possible hydrocarbon in both supra-thrust and sub-thrust sands. Nevertheless, during initial testing, sub-thrust Barail and Tipam sands were tested but produced only formation water. Supra-thrust prospects were not tested at that time and it was decided to test those at a later date.

Identification and Drilling of JRB Location

As a part of accelerated exploration efforts in logistically difficult and geologically complex frontier areas, during 2004-2005 and 2005-2006, about 75 GLKM seismic data was acquired in the Jairampur and Jairampur Extension PEL areas (Figure 4). On the basis of interpretation results, a well at the JRB location was planned in Jairampur Extension PEL in January, 2007 to test the sub-thrust and supra-thrust prospectivity (Figure 5, Figure 6 and Figure 7).

During the reconnaissance survey of the JRB location, it was observed that the level difference from the foothills to the proposed location is around 456 m and aerial distance is approximately four km. It was further observed that the location was situated in thick jungle and construction of road and plinth would take a long time. Therefore, it was decided to shift the surface position by around 1500 m and to drill a J-bend well at location JRB.

However, by drilling a J -bend well at that location, because of the deviation angle, it would not be possible to test the shallow supra-thrust prospect (Figure 8). Therefore, to ascertain the supra-thrust prospectivity of the area, it was decided to drill a shallow well in the same plinth of well Jairampur #1 to test the supra-thrust Barail prospect which could not be tested during the testing period of well Jairampur #1 during 1990.

Jairampur #2 Well and Log Response

Well Jairampur #2, at the JRC location, spudded at the same plinth from a distance of around 40 m from the Jairampur #1 well. After termination of drilling at 726.4 m, basic logs with FMI and CST were run. Subsequently, a MDT survey was also conducted. Drill-

cutting samples showed fluorescence with cut, and gas chromatograph showed considerable amount of gas picks during drilling to 500 m. Later, wireline-log interpretation carried out by using ELAN-Plus suggested presence of possible hydrocarbon both in the clean sand (419.0 m and 272.0 m sand) and fractured sand (285.0 m sand) (Figure 9(a), and 9(b) to 9(e)).

Observations

• Gas Chromatographic and chemical analysis of CST sample at 281.5 m showed probable hydrocarbon indication.

• MDT could not collect a fluid sample due to less formation pressure, and the pressure gradient calculated at 188 m and 257 m Barail Sand shows water gradient.

• Production testing carried out in eight Barail Sands (470 m, 451 m, 419 m, 339 m, 272 m, 256 m, 226 m, and 188.5 m) produced only formation water.

• CBL-VDL-USIT log indicates that cementing was not proper (25 mv-50 mv) from 337 m onwards to 9H" casing shoe (132 m) and rest free pipes to the top. Carried out isolation repair job but observed less improvement in the post-cement job.

• Interpreted FMI log indicated presence of brecciated zone with probable fault plane at the range of 283 m to 308 m. A number of fractured zones with brecciated zones (fractured zones: 278-281 m, 272-273 m, 260-264 m, 258 m, 225-232 m, 189-224 m, 163-175 m; brecciated zones: 254-249 m, 240-264 m) are frequently present up to 136 m (Figure 10, Figure 11, and Figure 12).

Production Testing at Location JRC

A total of eight sands in the Barail (Oligocene) Formation were identified as prospective sands for testing in well Jairampur #2 with the help of log interpretation coupled with evidence obtained from drill cuttings and sidewall core analysis. All the eight sands were perforated and tested, however no commercial hydrocarbon production could be established.

On the other hand, the core sample collected from the shallow well drilled by M/s MECL for geological investigation purposes from the same plinth of well Jairampur #2 which were later analyzed and reported suggested waxy crude oil (similar to the Barail and Tipam formation oil character of OIL's producing fields in Assam) in the core samples. M/s MECL also encountered a gas kick at depths of 154 m and 162 m during their coring. Gas bubbles were seeping out from the slim hole drilled by M/s MECL and analysis and confirmed that the gas is thermogenic gas that may have leaked from a shallow reservoir. The gas seepage from the hole was continuous for around five months until the hole was properly cement plugged in June, 2010.

From the evidence collected from well Jairampur #2, e.g. sidewall core analysis, and GC Analysis, as well as fluorescence in drill cutting samples coupled with wire line log interpretation, it could be suggested that the Jairampur structure is not devoid of hydrocarbon potential.

Epilogue

• While drilling the Jairampur #2 well at the JRC location, no mud-loss was observed. This may be because the mud weight was almost near formation pressure (66 pcf). But, while cementing with 114 pcf cement slurry, the cement may have invaded the fractured zones, overcoming the formation pressure and it might have sealed the probable movable hydrocarbon path along the fractures, which might be the reason for loosing cement along the fractures and which was reflected in the very poor cement bonding above 310 m even after an isolation repair job.

• High salinity (around 13,000 ppm) and a high amount of bicarbonate (around 12,000 ppm) observed in the sample analysis of the last four perforations above 300 m may be because fractures are connected with the deep-seated Barail Formation which were not affected by meteoric water during or after the of rise of Himalayas and the Shillong Plateau because of the protective umbrella provided by thrusting, unlike other oilfields of the Assam Shelf.

• The original shallow wells of the Digboi Field used slotted liner completions, but recent completions used cement in deeper wells (more than 400 m) from which it has been observed that production dropped considerably.

• Unremitting seepage of gas from the MECL hole, continuing since August 2009 to June 2010 (when the well plugged with cement), and gas kicks (from around 162 m and 185 m, and near fractured zone at 163-175 m) during drilling and also the oil shows present around a kilometer west of the Jairampur #1 well indicate that hydrocarbons are present in the Jairampur Structure and fractures are the possible conduits of hydrocarbon movement. However, due to possible blocking of the fractures by cement, there was no hydrocarbon flow from the tested zones of Jairampur #1 or from the recently drilled Jairampur #2 which was drilled just 15 m from the MECL hole.

All the above observations lead to the suggestion that for further drilling in thrust belt areas, a non-conventional method of drilling, cementing and production testing may need to be adopted.

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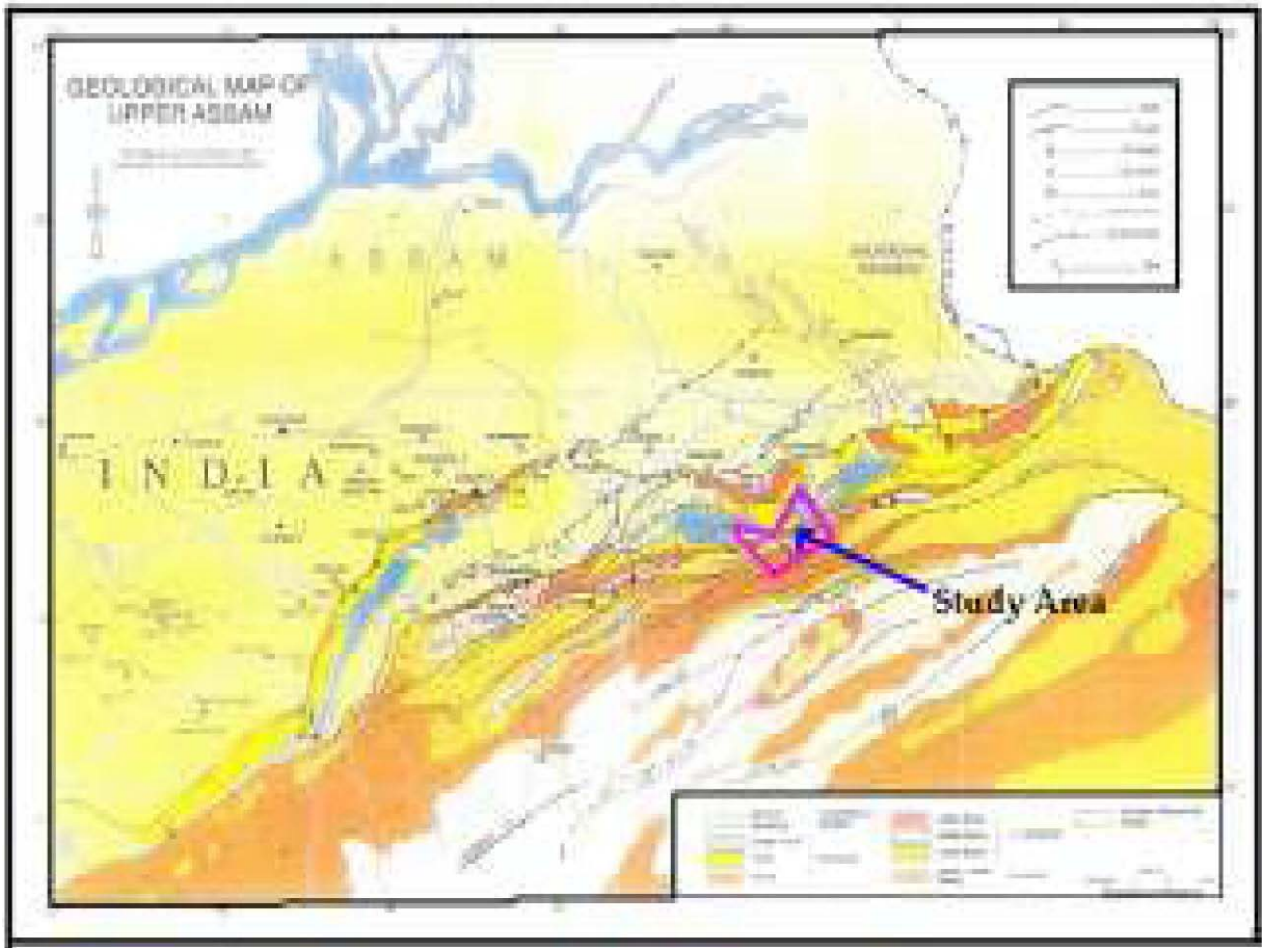

Figure 1. Regional geological map of Assam-Arakan Basin and study area.

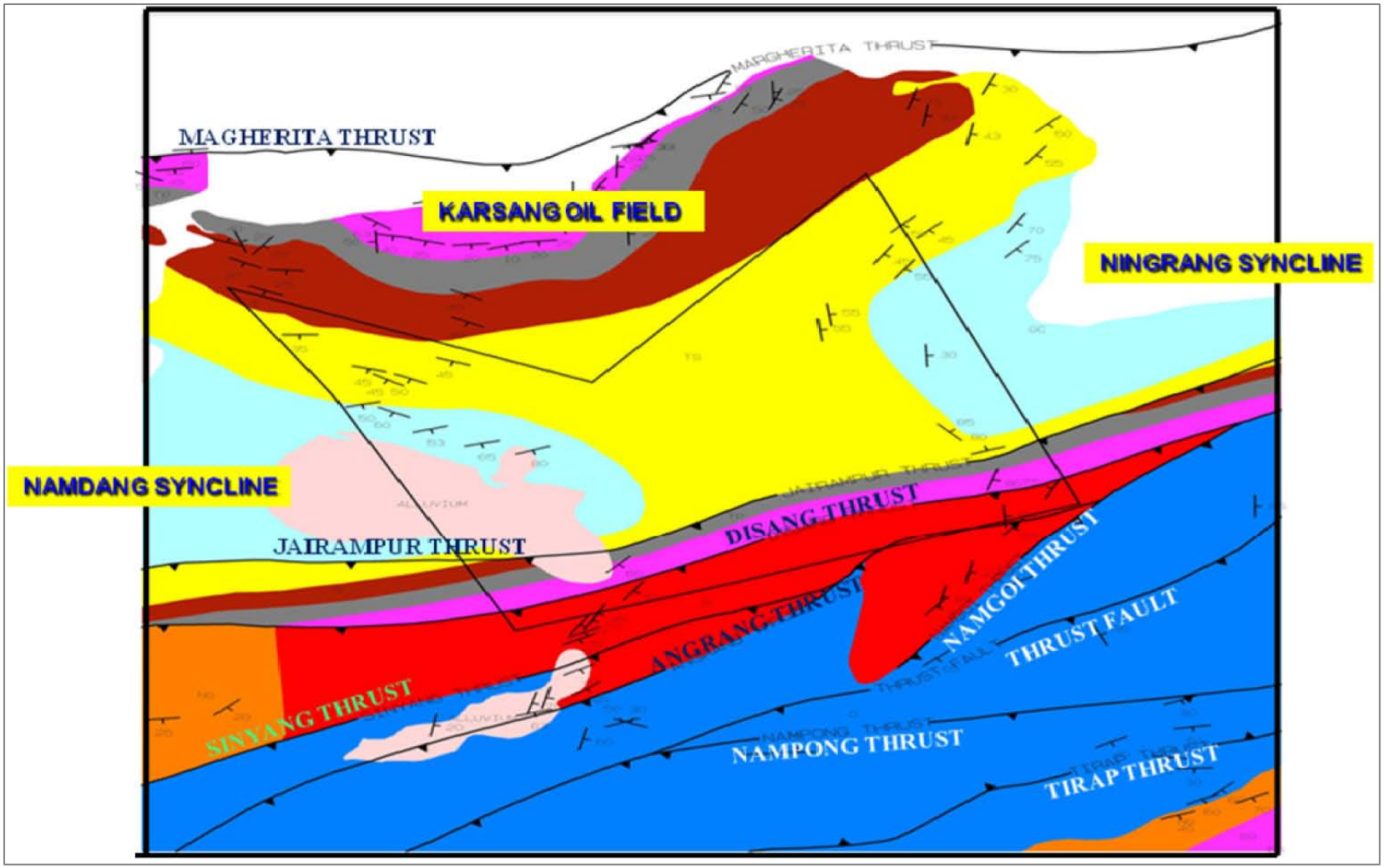

Figure 2. Tectonic map of the study area.

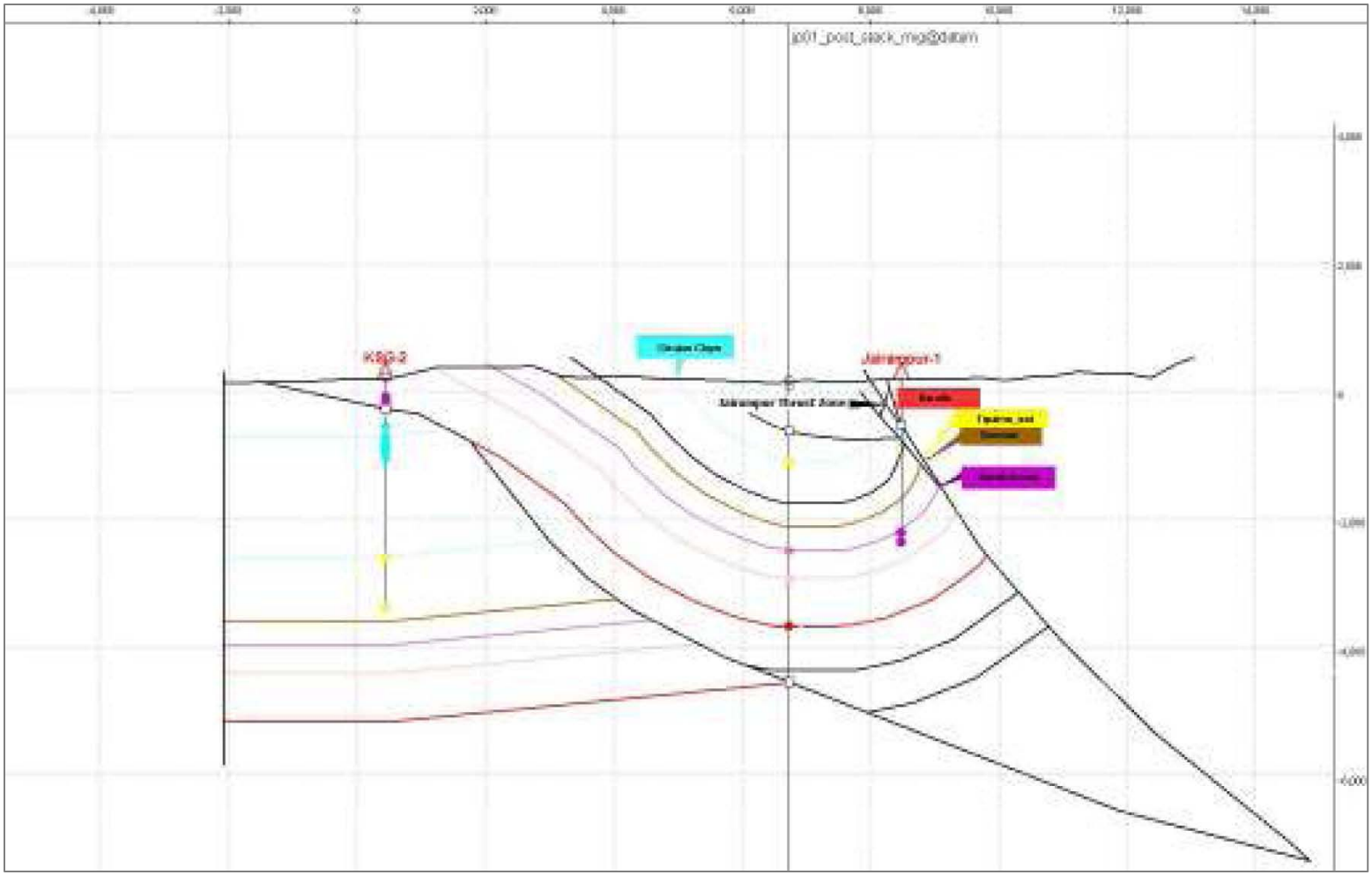

Figure 3. Geologic section with wells Kharsang #2 and Jairampur #1 across Jairampur and Disang thrust zones.

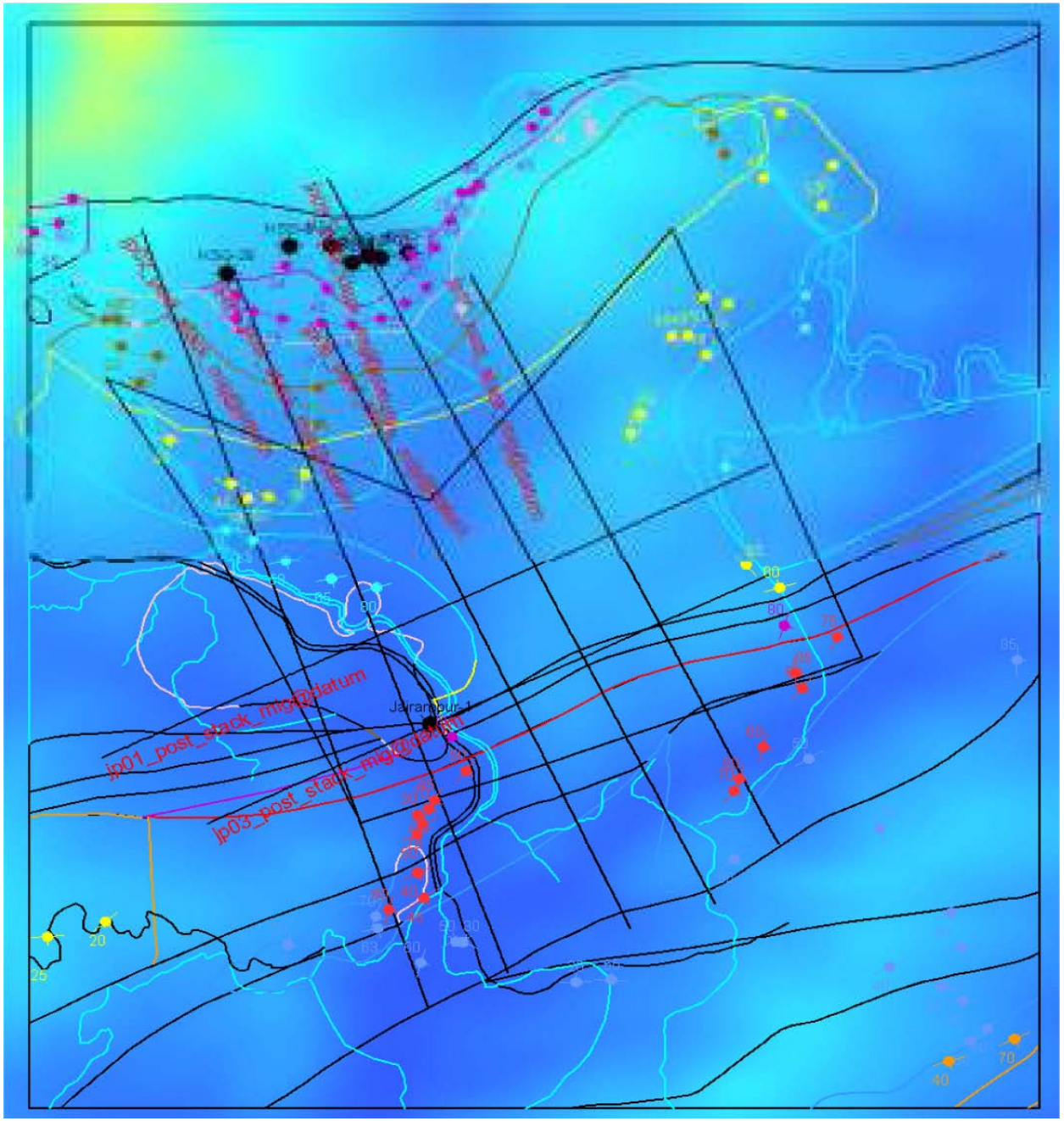

Figure 4. Seismic lines in Jairampur and Jairampur Extension PEL.

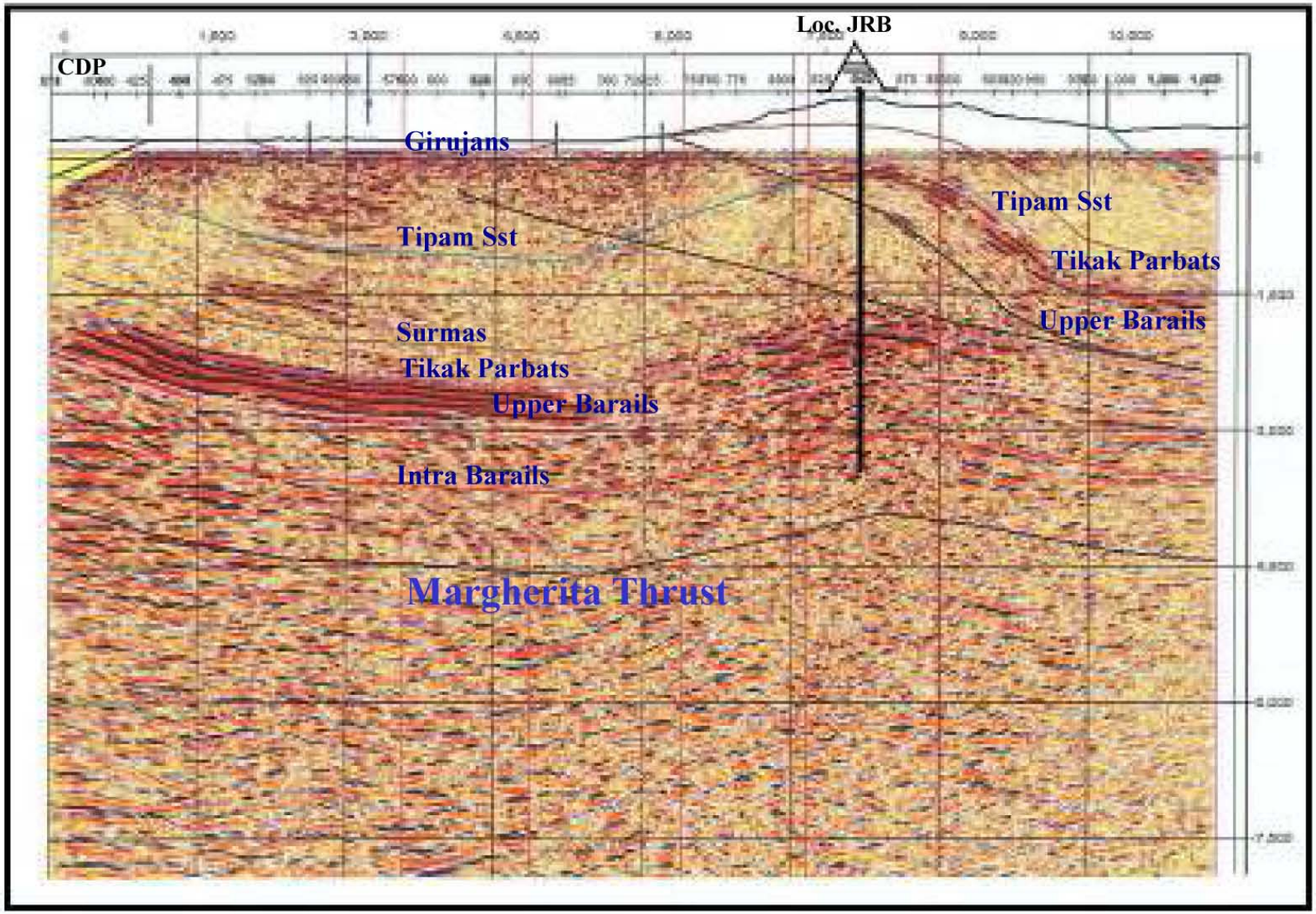

Figure 5. Seismic profile JP-01 showing the proposed drill location JRB.

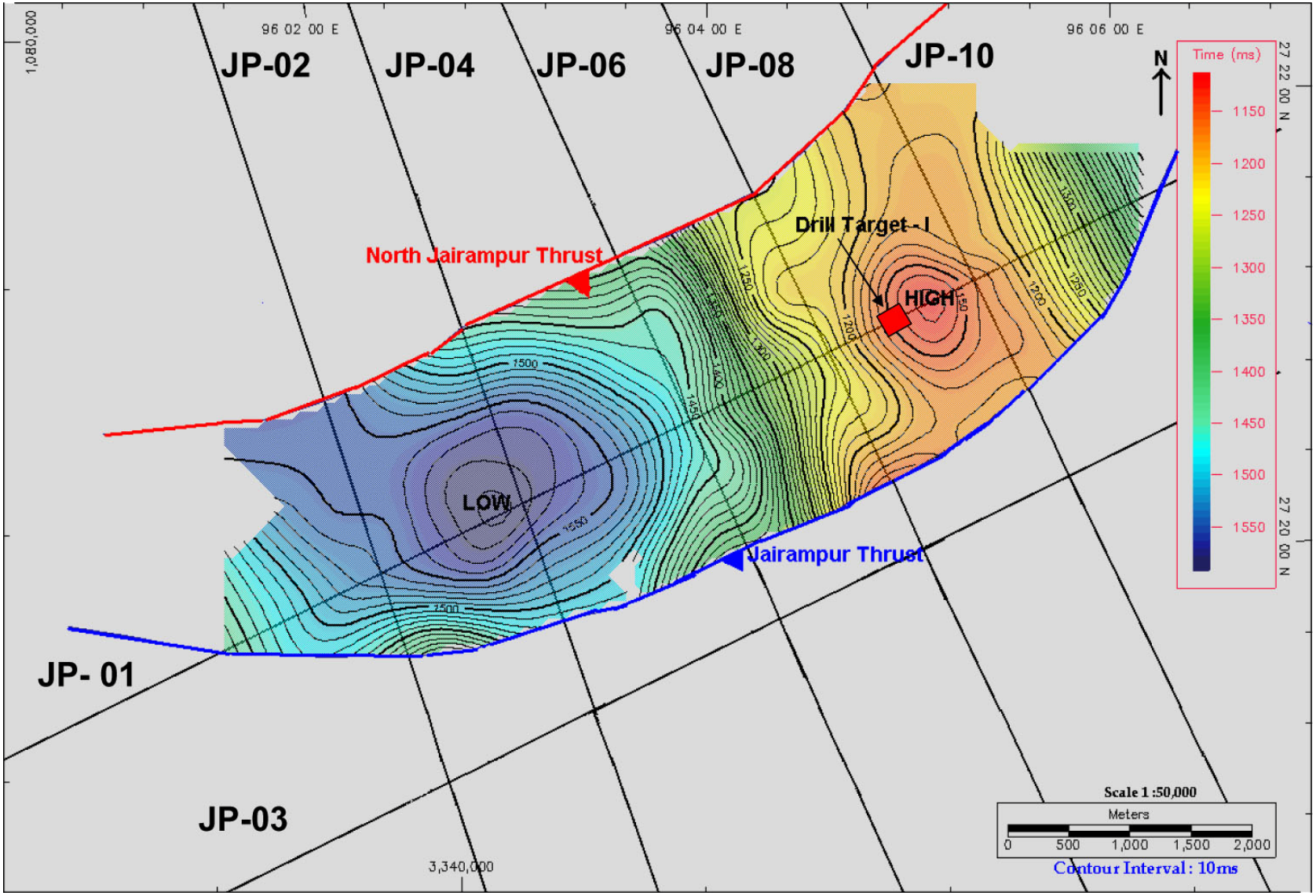

Figure 6. TWT contour map on horizon “Upper Barails” showing the structural closure and Location JRB.

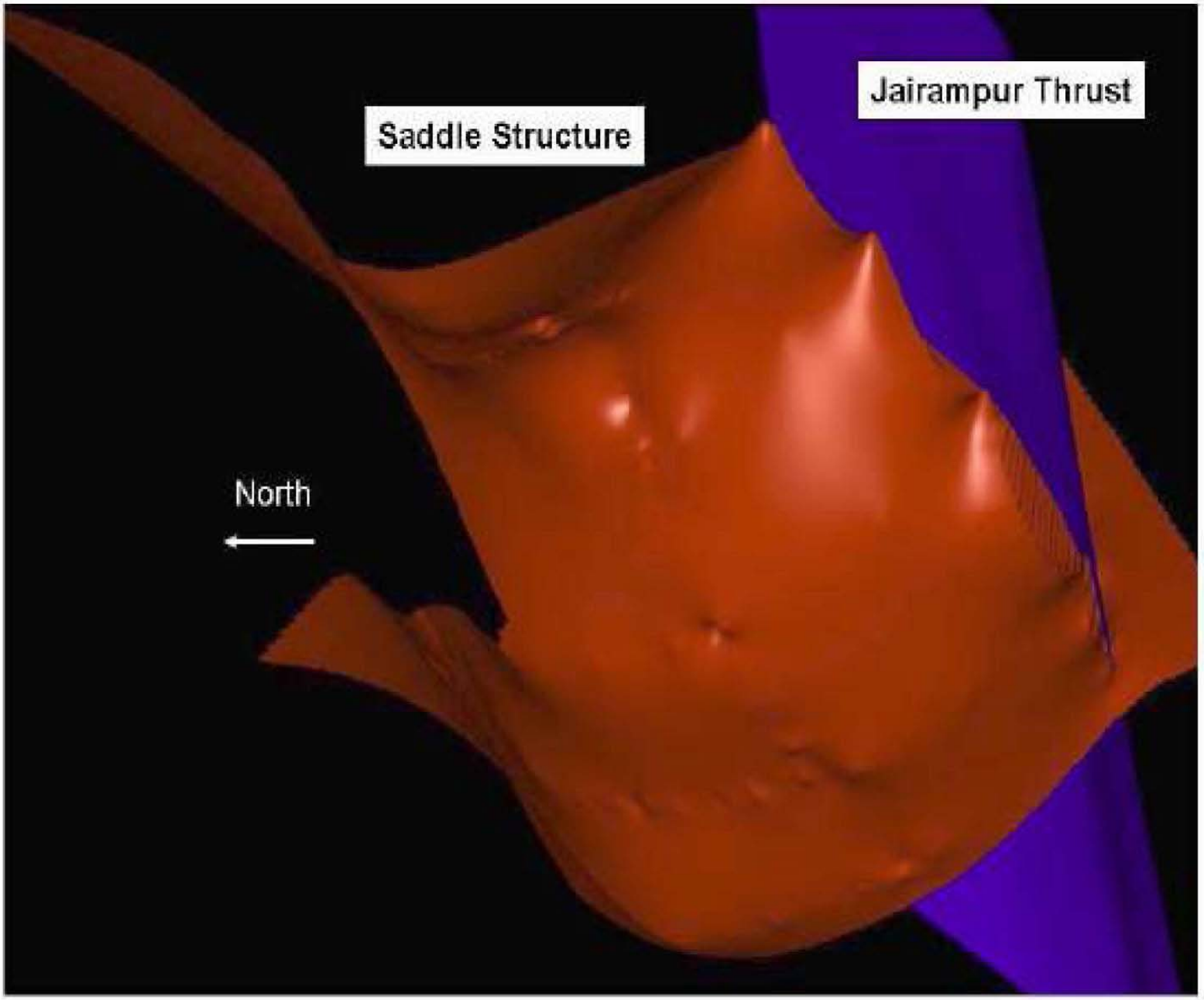

Figure 7. Preliminary “Upper Barials” (brown) TWT interpretation showing the form of the saddle structure.

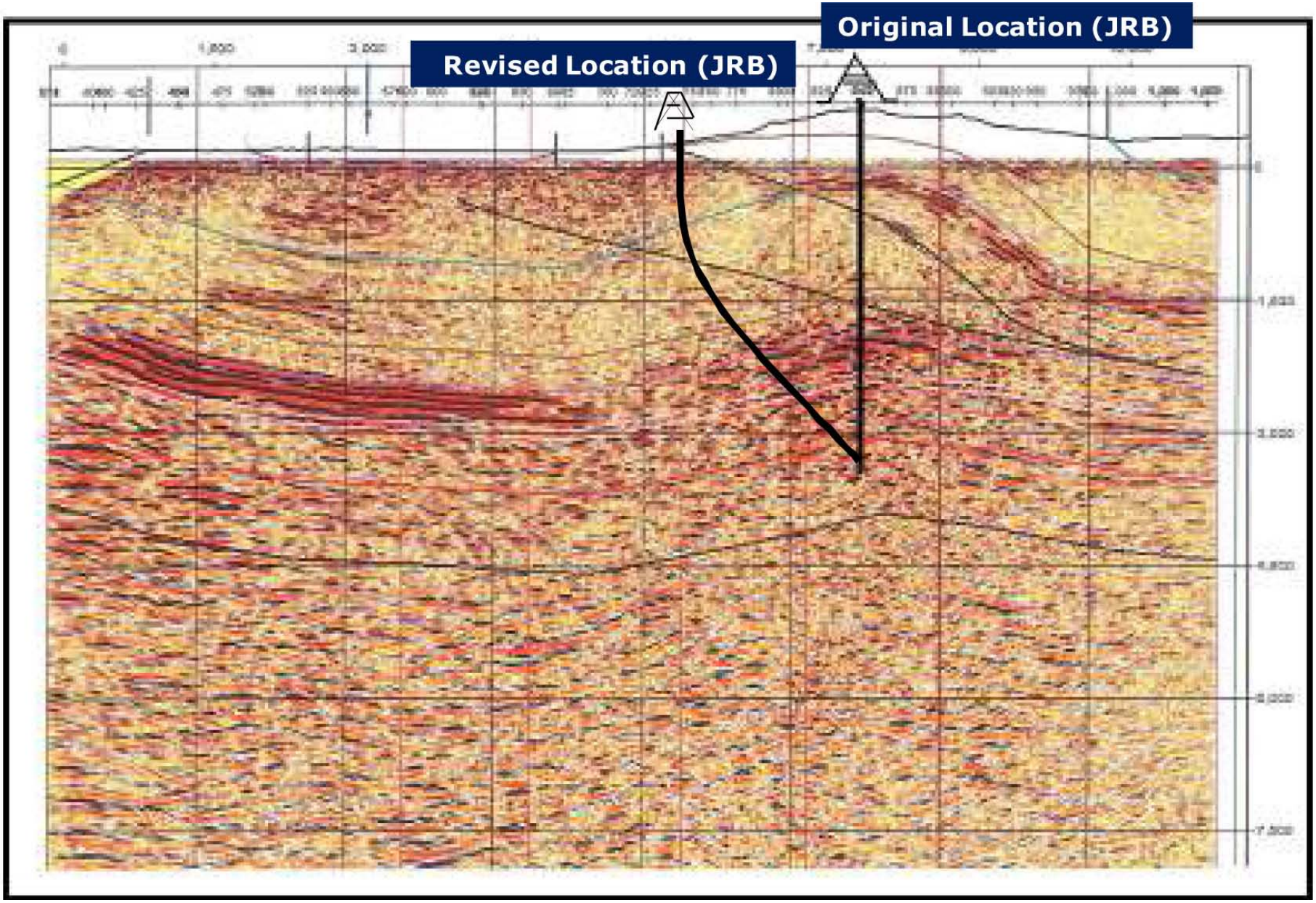

Figure 8. Revised Location JRB.

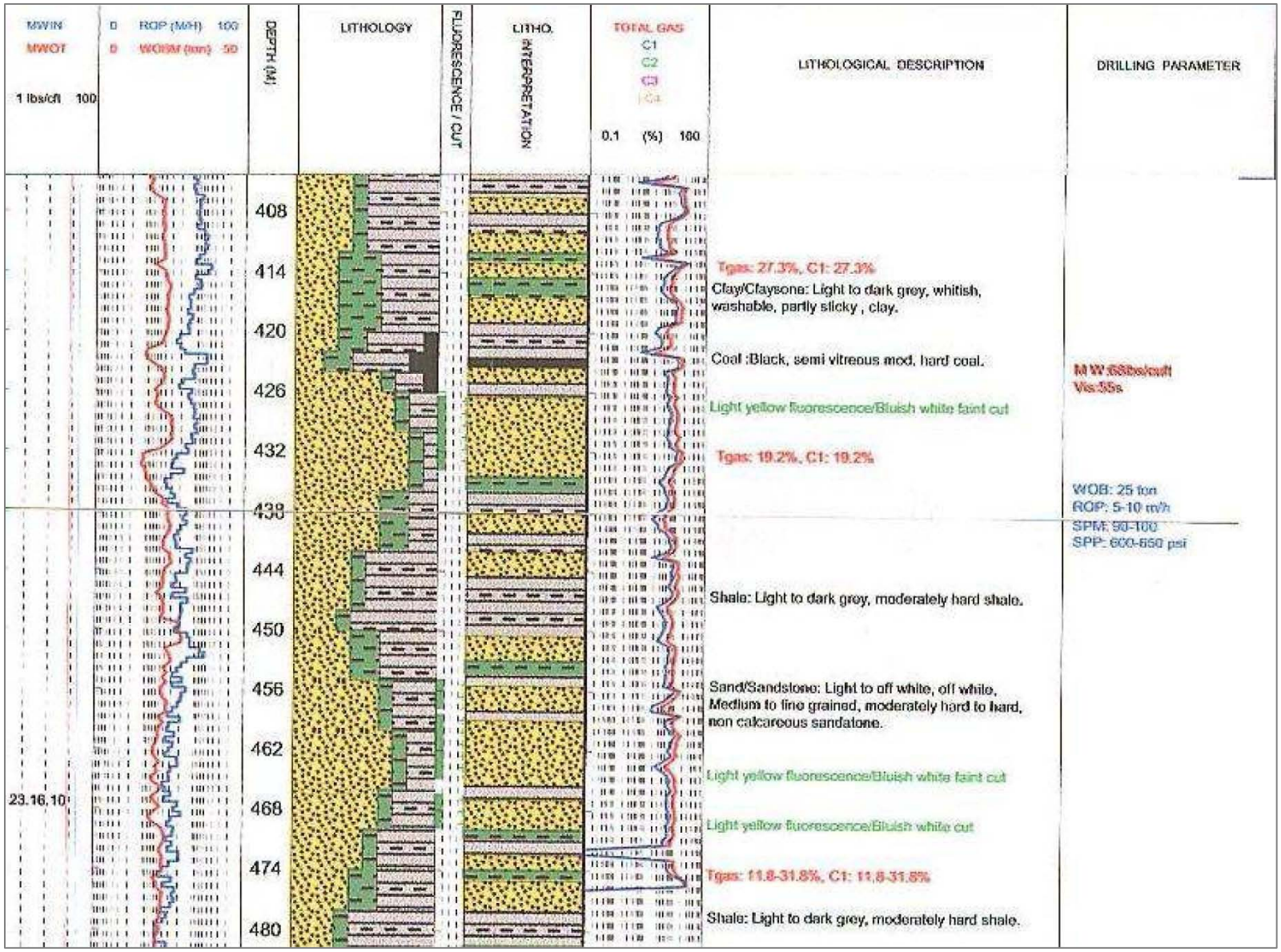

Figure 9(a). Good gas picks observed in GC-FID during drilling.

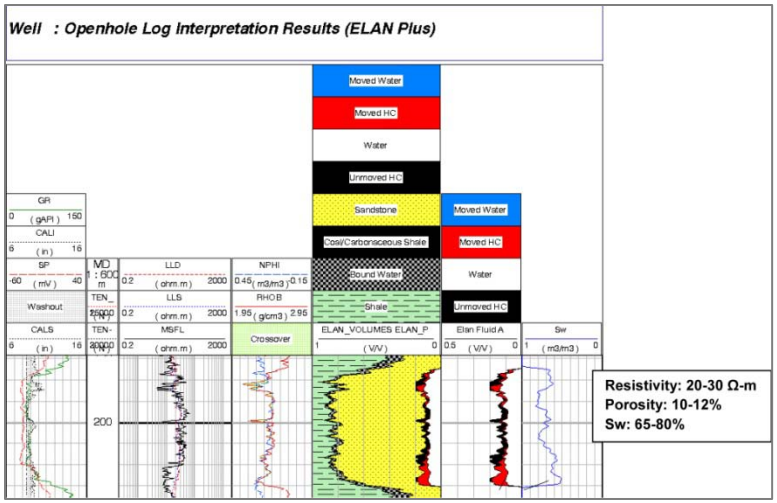

Figure 9(b). Fractured tight sand with low effective porosity in the range of 188.5-214.0 m.

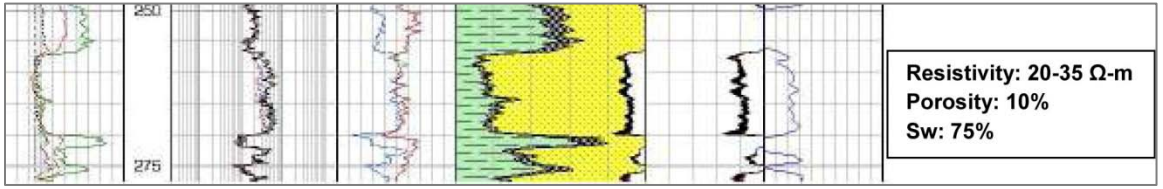

Figure 9(c). Clean sand but low effective porosity with fluorescence in side wall cores in the range of 255.5-270.2 m.

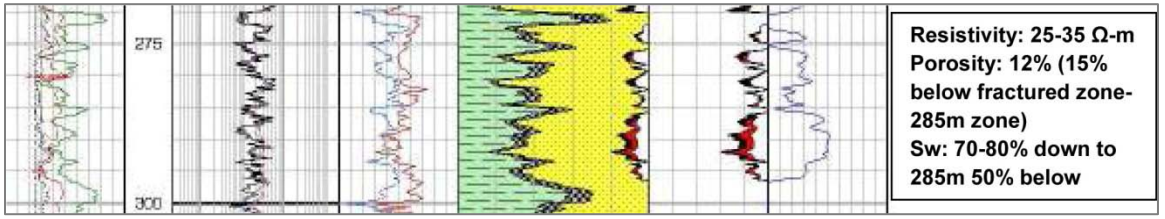

Figure 9(d). Shaly sand, highly fractured below 285.0 m. Log interpretation suggested possible hydrocarbon. Sand range is 272.0-296.0 m.

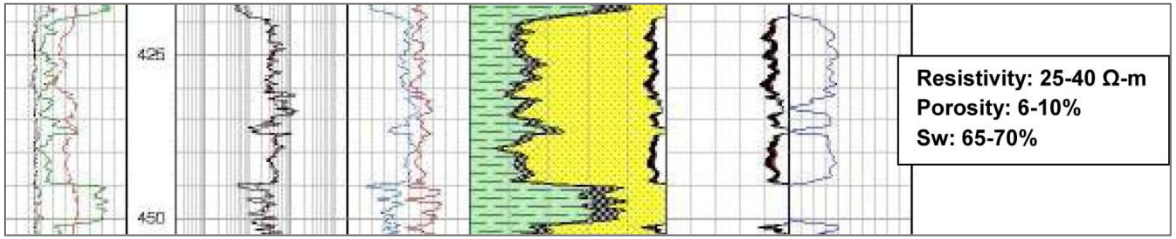

Figure 9(e). Clean sand with numerous thin shale lamina. Log interpretation suggested possible hydrocarbon. Sand range is 419.0-445.0 m.

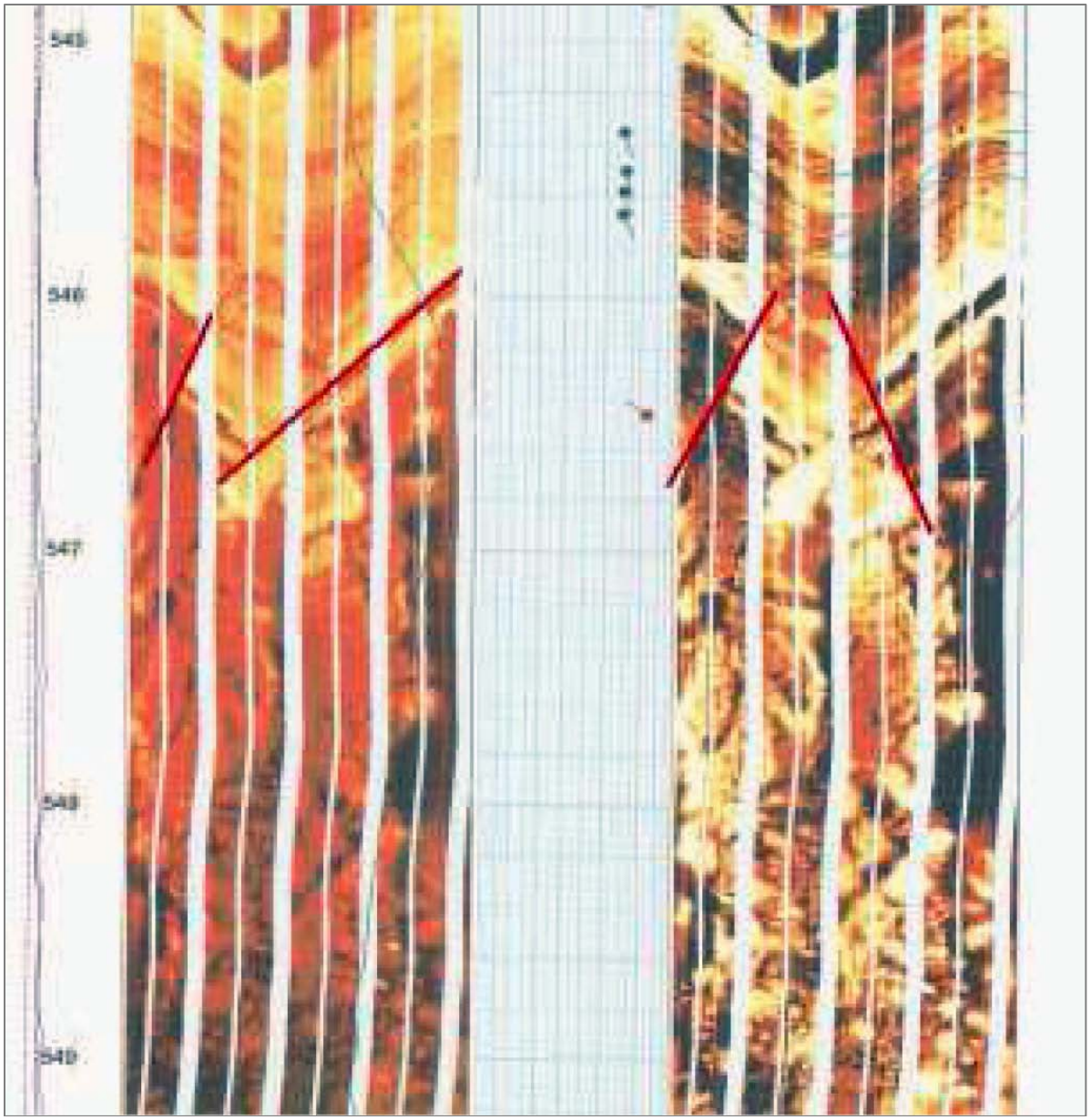

Figure 10. A clear displacement along the fault plane in the interval 545-548 m shows a high angle planar feature.

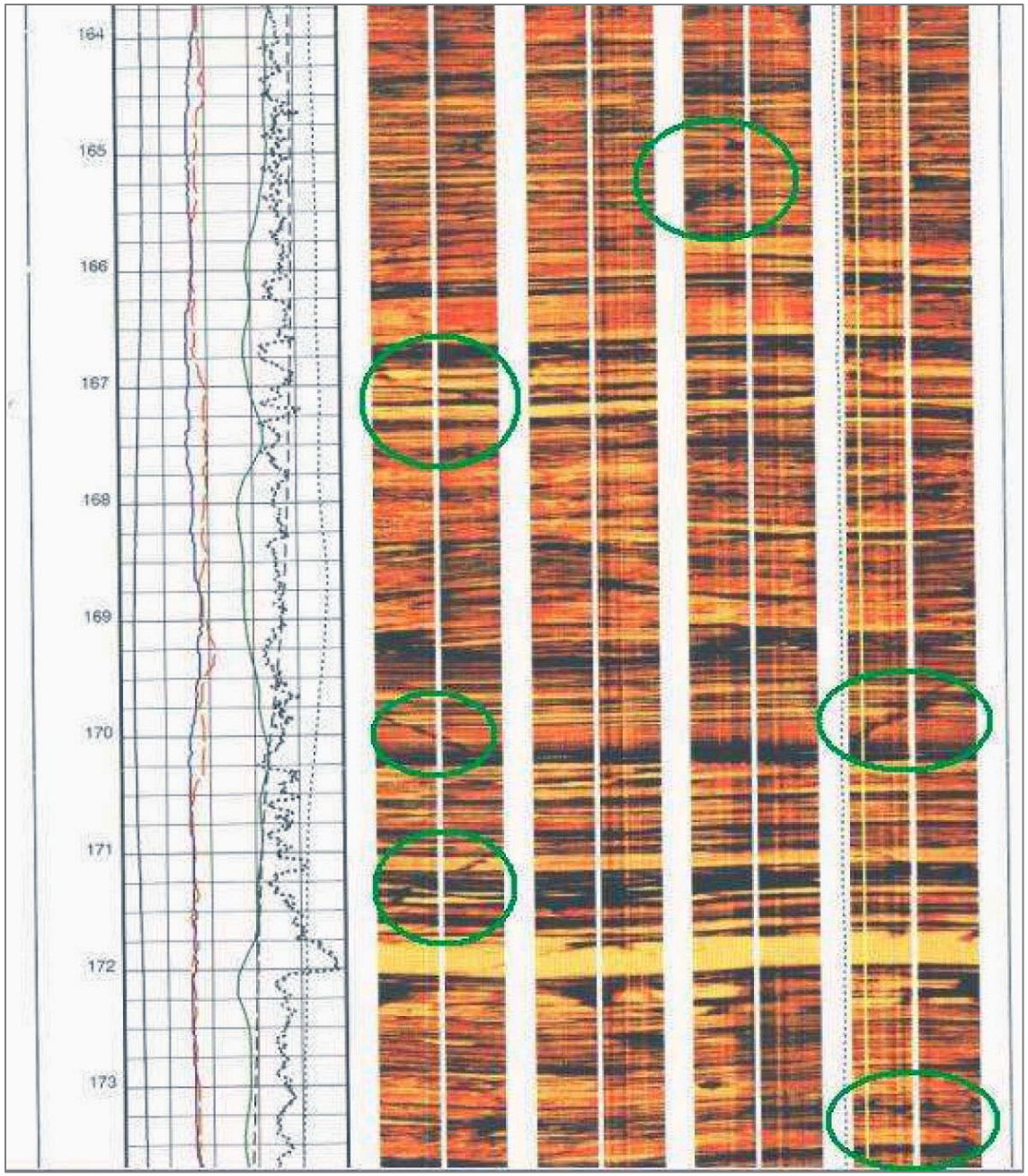

Figure 11. Fractured zone in the range of 164-174 m.

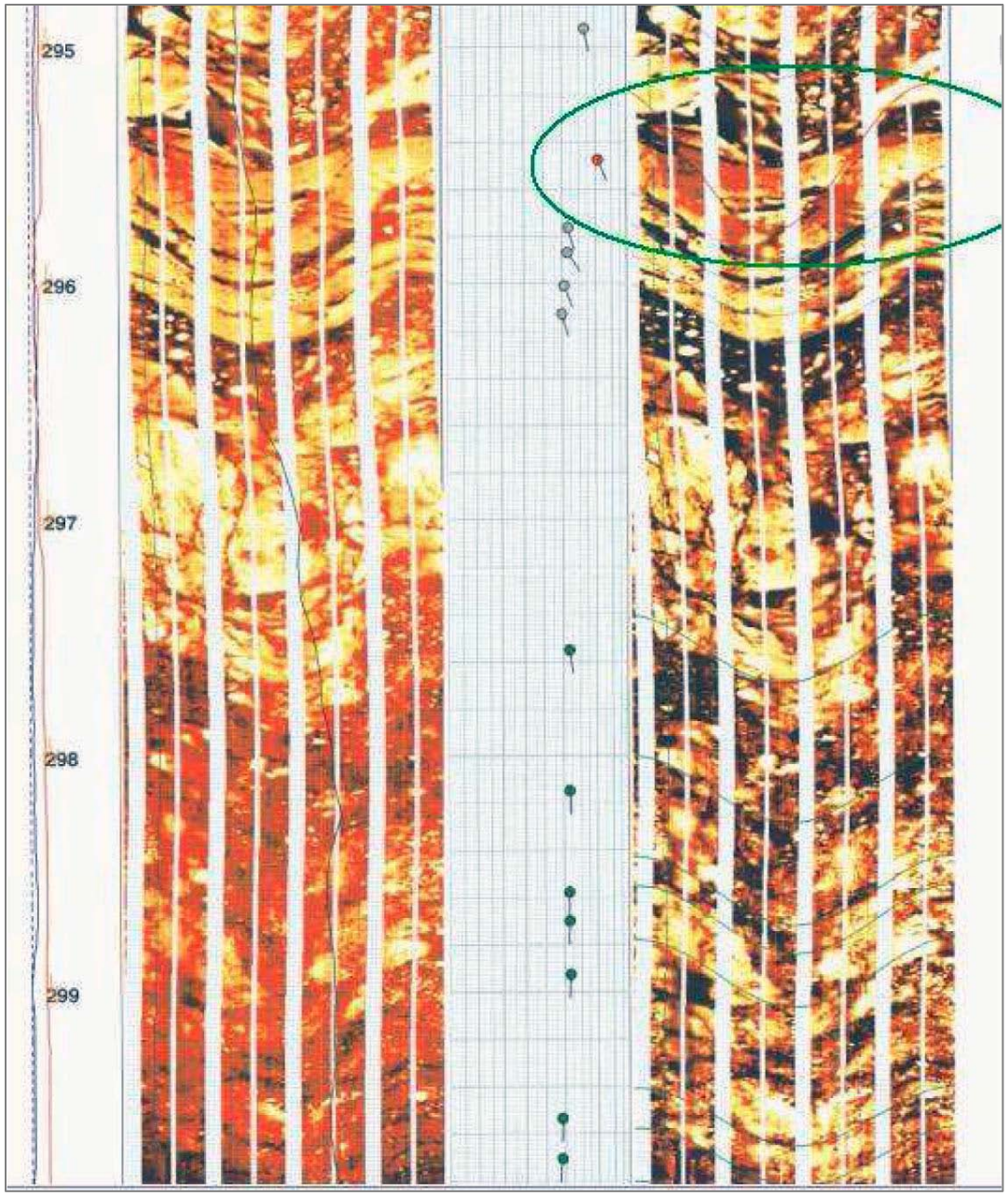

Figure 12. Brecciated zone (308-283 m) with probable fault plane at 295 m.