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Vibroseis Reflection Survey for Strategic Petroleum Reserve in Salt Cavern (Bikaner-Naguar Basin-Rajasthan) -A Case History

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Summary

A necessity of under ground storage of gas was felt to meet the seasonal Gas requirement of Europe and America. The concept of gas storage near the consumption areas, during the off Demand period and usage in peak Demand (winters) was a useful idea. The three basic facilities fulfill this requirement are a) Depleted reservoirs b) Aquifers c) Salt Caverns. These facilities essential are to be re-conditioned for pumping in and out the petroleum in Gaseous or liquid form. This was the point of modest beginning for the salt caverns petroleum storage. Underground salt formations offer an option for natural gas storage. These formations are well suited to storage in salt caverns, once formed; allow little injected natural gas to escape from the formation unless specifically extracted. Essentially, salt caverns are formed out of existing salt deposits. These underground salt deposits may exist in two possible forms: salt domes, and salt beds. Salt domes are thick formations created from natural salt deposits that, over time, leach up through overlying sedimentary layers to form large dome-type structures.

Oil and Natural Gas Corporation Ltd. has taken up an R & D project under OIDB Grant in Aid to study the feasibility of creation of Strategic Petroleum Reserves in Salt Caverns of India. In this connection an area north of Bikaner town of Rajasthan has been identified as possible locale.

It was decided to acquire 75GLK of 2D seismic data and drill about 9 bore holes (700-900m depth). Geophysical Party no. 26 was assigned the job of acquiring 2D Seismic survey to image the halite sequence in Bikaner area.

Introduction:

The objective of the survey is to map detailed stratigraphic and structural information of Halite sequence in the Bikaner-Naguar basin in the northwest of Rajasthan. The depth of interest was in the zone of 300mts to 1200mts.

Basic Background of Salt caverns:

Salt caverns are a proven medium for hydrocarbon storage and are constructed within massive geologic structures called salt domes or salt strata All Salt caverns are man made and those used for natural gas/hydrocarbon storage are formed using a solution mining process. First, a well is drilled from the surface down into the salt formation.

The well is equipped with multiple pipes for the injection of water into the cavern and for the return of brine from the cavern. Water is injected down a well bore into the salt formation dissolving the salt and creating a salt brine solution which is displaced to the surface through the well piping for sale or disposal. Each cavern thus created is designed and engineered according to its use.

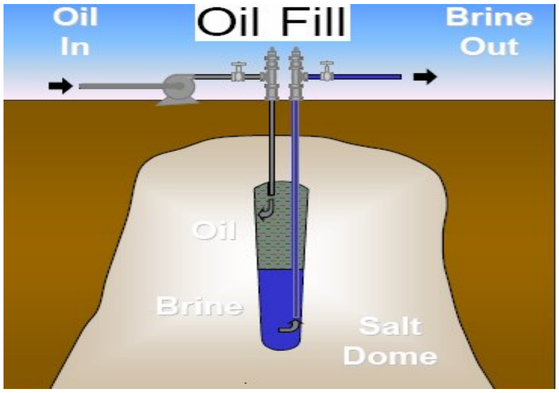

Figure : 01-A (Oil storage filling process and drawn process in Caverns

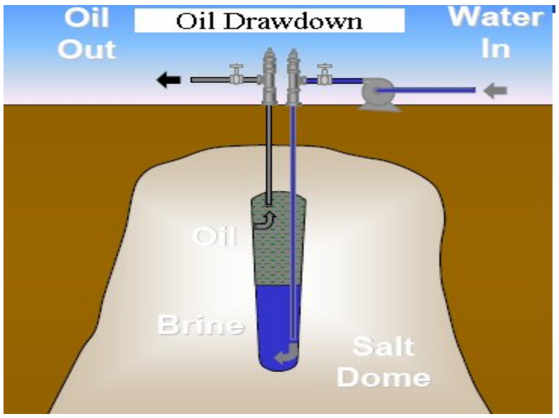

Figure : 01-B (Oil storage filling process and drawn process in Caverns)

The size, shape, and operating limits are all part of the engineered and controlled development of a salt cavern for gas storage. There are over two thousand man made salt caverns in the United States and Canada used for the storage of hydrocarbons including crude oil, refined products, natural gas, LPG, and various chemical products. Salt cavern creation, solution mining, cavern operation, maintenance, and gas metering are well-documented disciplines within the energy storage business.

Strategic Petroleum Reserve caverns range in size from 6 to 35 million barrels in capacity; a typical cavern holds 10 million barrels and cylindrical in shape with a diameter of 200 feet and a height of 2,000 feet. The construction of the strategic reserves is to enhance the energy security of the country and to safeguard against short-term supply disruptions. A fig.no.1 depicts the oil storage filling process and draw down process is shown. Thus, ownership of India's strategic oil reserves would be on a pattern similar to that in the US, Japan and South Korea.

Location and Topography of the Area

The complete survey consists of two parts, one in north having 4 seismic lines and second part in southern side having three seismic lines shown fig no. 02.

In the northern area, there were two wells falls in the area, namely SPR-1 and SPR-2 and in southern area SPR-3 well falls within the area. Southern portion of the area is around town Lunkaransar.

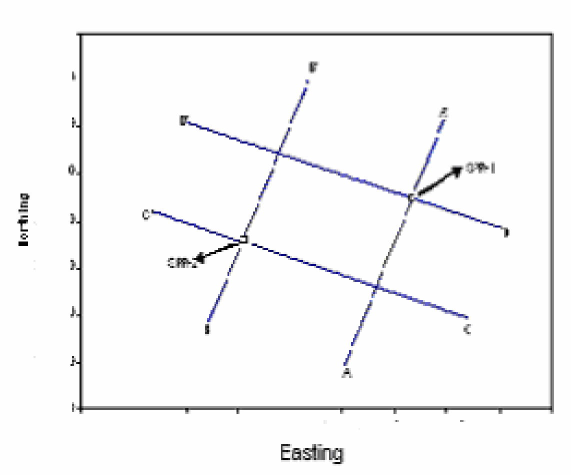

Fig 02A Location Map : Northern

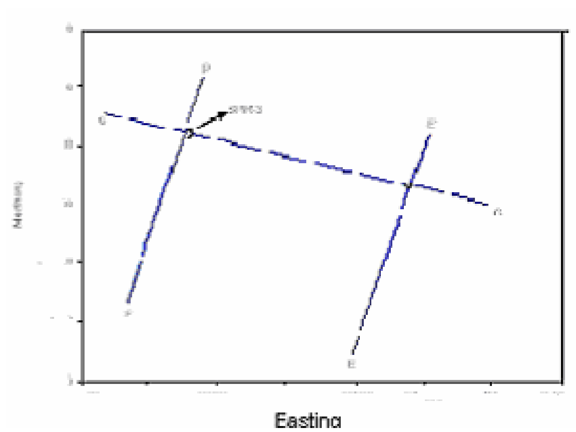

Fig 02B Location Map : Southern Grid

Geology of the Area:

The Nagaur-Ganganagar Basin (Figure 03) covers much of northwestern Rajasthan and extends further through Haryana and Punjab into Pakistan. The basin contains the oldest sedimentary rocks known from the area. The basin developed in the western foreland of the Early to Middle Proterozoic Aravalli-Delhi Fold Belt. While the basin fill shows onlap onto igneous and metamorphic basement rocks to the south, the eastern basin margin is overprinted by the NNE-SSW trending Sardasahar-Bidasar Fault Zone. To the northwest, the Nagaur-Ganganagar Basin is interpreted to extend into the basin exposed in the Salt Range of Punjab, Pakistan.

Fig. 3 . Configuration set-up of Nagaur and Ganganagar Basin showing Evaporites

In this area, the basement was interpreted to be at a depth of 400 to 600 m. To the west, closer to the basin centre, it is expected to be found below 2,000 m depth. The basin fill of Late Proterozoic to Early Cambrian age (Marwar Supergroup) consists of the clastic Jodhpur Group in the lower part, the Bilara and Hanseran Groups of mainly carbonates and evaporites in the middle part, and the Nagaur Group, again predominantly clastic, in the upper part. These units are unconformably overlain by Lower Tertiary and Quaternary sedimentary rocks and a thick cover of Recent aeolian sands of the Great Thar desert.

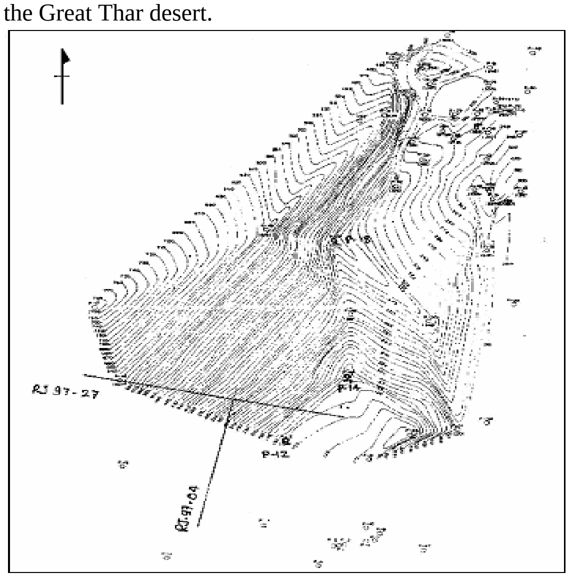

Fig No. 04 : Structural Contour Map Of H6-Halite Cycle Of Hanseran Evaporite In Nagaur-Ganganagar Basin, Rajasthan

The Bilara and Hanseran Groups in the middle part of the Marwar Supergroup form two coeval facies units.. The Hanseran Evaporite Group has an areal extent of some 50,000 km². Total thickness is 100 to 650 m in the east but is likely to be more than 1,000 m in the western parts of the basin. Seven layers of rock salt, numbered serially H1 to H7 (from bottom to top) have been identified in wells. The thickness of the individual layers varies from one well location to the other. Structural Contour map of H6-halite cycle of Hanseran Evaporite in Nagaur-Ganganagar Basin is shown in fig.no 04. Each rock salt layer is part of a single evaporite cycle comprising beds of dolomite (with or without magnesite), anhydrite, gypsum and halite, with occasional interbeds of claystone. Significant potash seams (sylvite, some polyhalite) of up to 1 m thickness have been identified in H2, while minor potash mineralization (mostly polyhalite) occurs in halite layers H1, H3, and H5. Within the facies boundary of the Hanseran Evaporite Group, potash salt has so far only been recognised within two restricted areas to the north and to the south

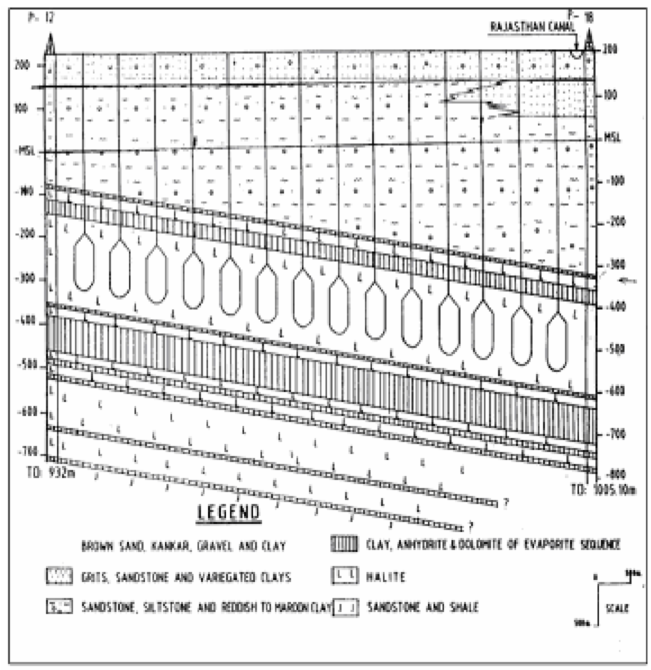

Fig.no. 05 Geological cross Section between borehole P12 and P18

Halite –bearing evaporates with rare potassic salt form a well stratified thick sequence of chemical precipitate. The sequence is at least 100 m thick(maximum about 650 m) and with a distinct possibility that the sequence will be as much as twice the thickness in western side towards the deeper part of the basin. The entire sequence is confirmable with vague transitional boundaries between the individual units of the evaporites.

The Henseran Evaporite Group is characterized by beds of (1) dolomite with or without magnesite (2) Anhydrite (or gypsum) and (3) Halite; less often any of these beds may be intercepted by a thin bed of reddish clay or claystone. In general, thesse

rocks form a cycle, and seven cycles of these halite in s[association with other mineralsm namely dolomite , magnesite- anhydrite have so far been recognized .
This repetitive cycle deposition of sediments and salts form the most important characteristic feature for the evaporate sequence. The aggregate thickness of the evaporite group varies from 103 m to652 m in the eastern part but towards west with deepening of the basin, it increased considerable and is likely to be more than 1000 m. A geological cross section between boreholes 12 and 18 shown in Fig.no.05

Methodology :

It has been decided to adopt symmetric split-spread geometry having 120 channels on either side of VP with total number of active channels 240. A shot interval of 25 m and group interval of 12.5 m has been considered for getting 60-fold coverage. Record length of 3 secs and sample rate of 1ms has been decided for acquisition of 2D data in this project. The total surface coverage of survey is 81.425 GLK.

Symmetric split-spread shooting has been carried out throughout the survey as below mentioned geometry (figno.06)and up keeping 120 number of active channels on either side of VP the near trace offset being 12.5m on either side of VP. The direction of shooting was up dip to avoid any scattering of the signal (i.e. from WNW to ESE for dip lines and from NNE to SSW for strike lines).

Spread geometry as recommended is as below.

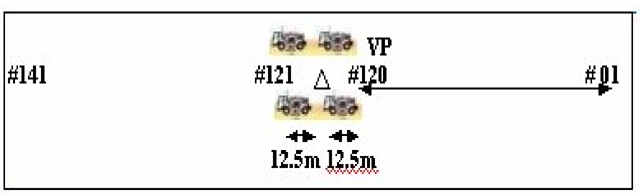

Fig no. 06 Spread Geometry

At VP picket, Vibrators kept both side as shown in picture. Accordingly bulldozing has also been carried throughout operation in the Northern Side of area. In the southern Side, due to plain area, it was not necessitated to use bulldozed path for vibrators movement.

To ensure the data quality, it was decided to conduct Noise test (wave test) at suitable spot in order to find out the Velocity, Frequency and Wavelength of the Coherent Noise (Ground roll) that is predominant in the area. The seismic section (fig.no.07) pertaining to the noise profile which was shot as per geometry mentioned and some of the noticeable noise trends observed in the section is tabulated below.

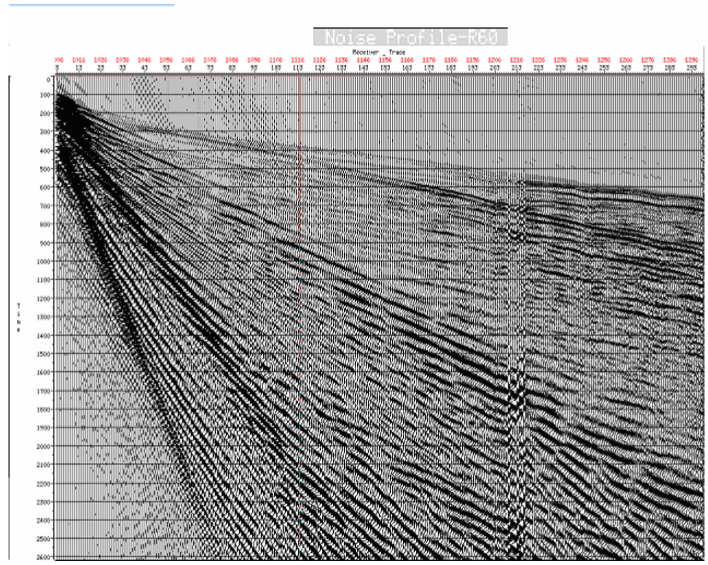

Fig. No. 07 Noise Profile

Noise Analysis:

Trend	Velocity m/s	Frequency in Hz	Wavelength (m)
Trend-1	986	25	40
Trend-2	410	15	27
Trend-3 (air wave)	300	20	15

Wavelength is in between 15 to 40

Experimental Studies

Following experimental work was carried out which are mandatory for vibroseis surveys.
1. Radio Similarity test for all Vibrators.
2. Wire line Similarity test for Vibrators.
3. Geophone Array optimization
4. Testing of Vibrator parameters
    a) Low End Frequency
    b) High End Frequency
    c) Sweep Length
    d) No. of Stack
    e) Start Taper & End Taper
    f) Sweep type
5. Source array optimization
7. Pre-amp Gain test

Parameters selected :

Location	SPR survey, 2006 Rajasthan
Regional Geology	Clastic overburden (partly unconsolidated), Bedded evaporate sequence, clastic basement
Top of target Horizon	300 to 500 m
Base of target horizon	900 to 1100 m
Max. depth of penetration	1200 m
Total GLK of survey (tartget	75 km
Number of channels	240
Group Interval	12.5 m
Geophones per group	8
Shotpoint Interval	25 m
Coverage	60-fold
Spread Length	3000 m
CDP interval	6.25 m
Record Length	3 secs
Sample Interval	1ms
Energy source	Sercel NOMAD 65
Sweep bandwidth	10-125 hz
Sweep length	12sec

Shallow Refraction

Over the entire operational area, Shallow Refraction survey has been carried out within every 1-1.5 km range to asses weathering depth, weathering velocity and sub-weathering velocity in the operational area. A depth model is shown (fig. 8)as an example.

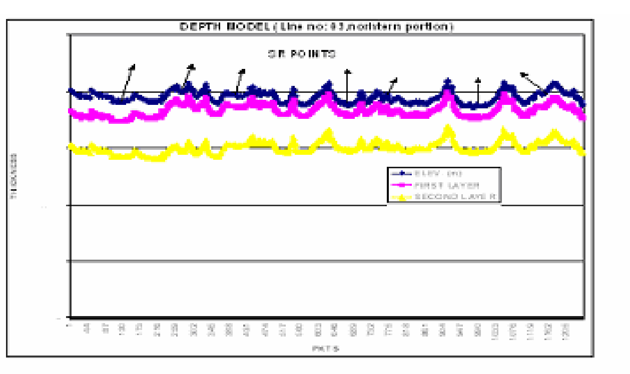

Fig.no.08 : SR-Depth model

Stacking and Leveling:

GPS control points were fixed at an interval of 120m and 150m in the area by the party's surveyor as per the conditionality of ground. A total of 18 number of control points were fixed within the operational area.

Data Acquisition :

Party used first time New sunful –geophones and New Vibrators and acquired the data to achieve high resolution. Performance check was made for both SM24 and SUNFUL geophones by laying two spreads together for comparison (fig no.9)

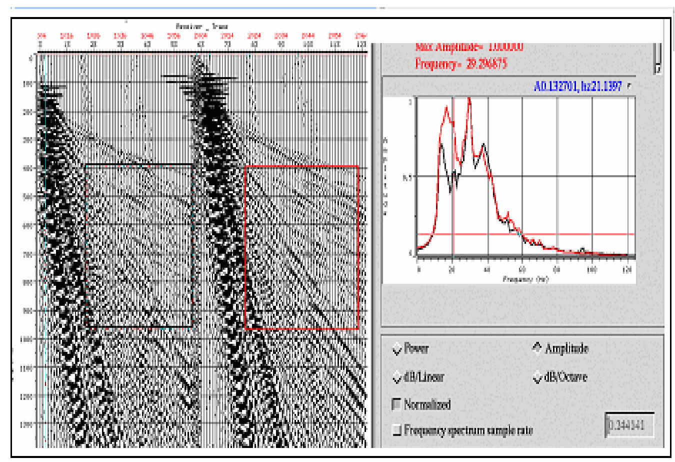

Fig.no. 9 : Comparison analysis Sunfil vs SM24 Geophone

After the analysis the SUNFUL geophones were chosen for survey. These geophones were tested on Geophone Analyzer (SMT-200) before putting into operation. Prior to experimentation, all Vibrators performance and Radio/ line similarity tests were carried out. Drive force was kept 60%-70% for most of the time due to hard formation encountered at very shallow level. This caused distortion in plate movement and in turn signal phasing out due to non-linear coupling of the vibrator. Second & third order harmonics (fig.no 10) were observed in FT spectrum.

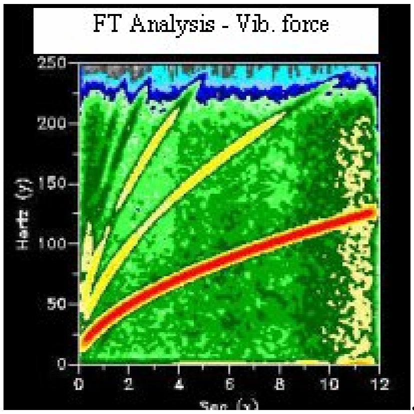

Fig.no. 10 : FT Analysis showing different harmonics

To improve further the vertical resolution, Non-linear mode of sweep was selected for survey for suppression of ground roll energy. Every day, instrument parameters and field parameters like leakage, noise were were checked. All QC checks viz. average and peak phase error, average and peak total distortion, average and peak force, ground stiffness and viscosity were carried out in real time from first record to last record of the day. All the hardcopies of the tests preserved for onward check by Quality control group. Dead channels and any reverse channels were usually rectified on the spot and tried to minimize the skips, however most of the skips were due to Indira Canal which passes through some of lines especially east west lines in southern part of the area. Analysis of monitor records was also carried day to day basis through Field Processing Unit. One of the raw record with amplitude spectrum is reproduced in fig no. 11.

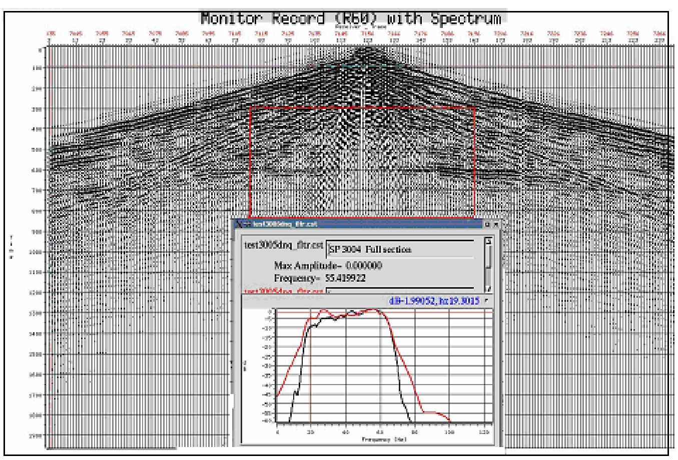

Fig.no. 11 (A monitor Record on line no 07)

The quality of data was maintained throughout the operation by the quality team of Geophysical party No 26 in consultation with QCG, Western Onshore Basin, Baroda. Instrument / field and radio similarity tests for all the vibrators were taken on daily basis before start of regular production work. Wire line similarity test of vibrators were taken on weekly basis. The checking of line by observers and efforts put by the field crew to ensure good coupling of geophones with ground resulted in acquiring good quality data.

Checking of geophones by geophone analyzer and repairing of cables and geophones were carried out on regular basis. Maintenance of ground electronics was also carried out periodically at party level.

Complete data with proper static corrections was submitted to RCC in time. Sample processed section is appended below (in fig.12 and fig.13)

Special attention was paid to the aspects of safety, health and environmental protection during the field operation.

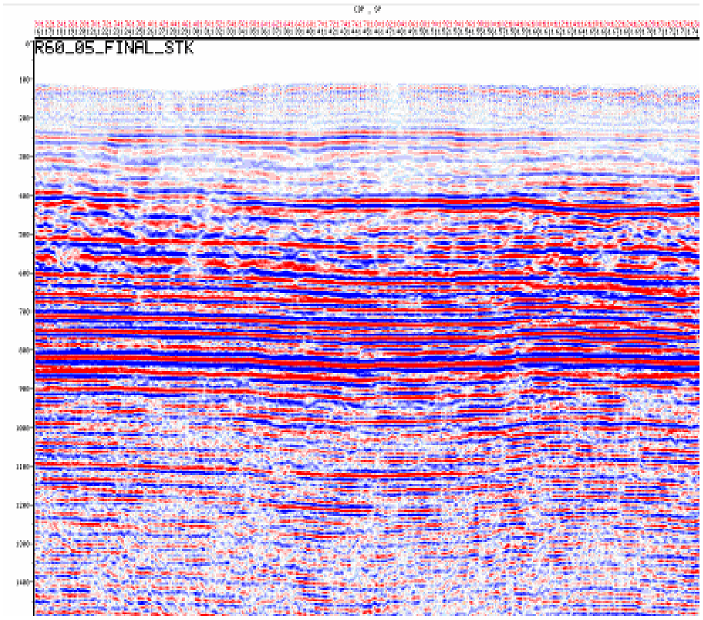

Fig no. 12 : A seismic Section on line no. R60-05

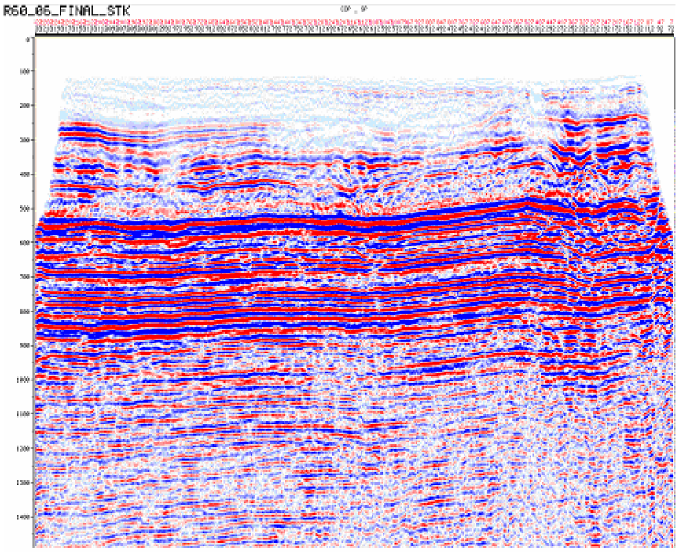

Fig no. 13 : A seismic Section on line no.   R60-06

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