A Summer Internship Report
On
SEISMIC DATA INTERPRETATION USING IHS MARKIT KINGDOM

Department of Petroleum Engineering & Geoengineering

RAJIV GANDHI INSTITUTE OF PETROLEUM TECHNOLOGY, JAIS, AMETHI

Under the Guidance of

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Submitted by:
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(B.Tech.4th Semester)

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राजीव गांधी पेट्रोलियम प्रौद्योगिकी संस्थान
(संसद के अधिनियम द्वारा स्थापित राष्ट्रीय महत्व का एक संस्थान)
(पेट्रोलियम एवं प्राकृतिक गैस मंत्रालय, भारत सरकार)

विद्यारत्नम् महाधनम्

Rajiv Gandhi Institute of Petroleum Technology
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SUMMER INTERNSHIP CERTIFICATE

This is to certify that **Mr. Md. Mainuddin Khan** (Roll No. **PE22-32**) S/o. Shri **Md. Babu Khan** student of B. Tech. programme at **Department of Petroleum Engineering**, **Dibrugarh University Institute of Engineering and Technology (DUIET)** has undergone Summer Internship 2024 conducted by the Department of **Petroleum Engineering & Geoengineering**, Rajiv Gandhi Institute of Petroleum Technology, Jais, Amethi from 18th June 2024 to 12th July 2024. During this internship he worked on the topic **"Seismic Data Interpretation Using IHS Markit Kingdom"** which was evaluated as **Excellent**. His conduct during this internship programme was found to be satisfactory. We wish every success in his career.

8/8/24

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This report is a result of collective effort, and I am grateful to everyone who has been a part of this journey.

Thank you.

NAME - Md Mainuddin Khan

DATE – 12/7/24.

ABSTRACT

Seismic data interpretation is a crucial process in geophysics that involves analysing seismic waves to map and understand the Earth's subsurface structures. This process begins with the collection of seismic data using sources and receivers placed on the Earth's surface. The collected data is then processed to enhance the signal quality and remove noise. Interpretation involves examining the processed data to identify and characterize geological features such as faults, folds, and layers of rock. This information is essential for applications in oil and gas exploration, earthquake seismology, and environmental studies. Effective seismic data interpretation provides valuable insights into the composition, structure, and dynamics of the Earth's interior.

Modern interpretation platforms, such as HIS Markit Kingdom Geophysics-Geology (ADV), integrate various datasets and provide robust tools for mapping, visualization, and volumetric analysis. These platforms facilitate collaboration among geoscientists, enabling dynamic updates and real-time data integration to refine geological models continuously.

As an intern at Rajiv Gandhi Institute of Petroleum Technology under Dr Satish Kumar Sinha (Professor of Geophysics at Rajiv Gandhi Institute of Petroleum Technology), my job was to get a detailed overview about seismic waves, seismic data, seismic data acquisition, seismic data processing and seismic data interpretation.

During this period of my internship, I learned to use the IHS Kingdom software. Importing data on the software, displaying it in different views. Comparing 3D and 2D data and maps, picking horizons, importing wells and the time to depth conversion methods, marking of geological structures using different seismic attributes, defining polygon, grids and calculating the volume of horizons using grids by volumetric method of lower and upper contact of single structure.

Contents

1. Seismic Waves

Seismic waves are waves of energy that travel through the Earth's layers and are a result of various geological processes, such as earthquakes, volcanic activity, magma movement, large landslides, and large man-made explosions.
Seismic waves are primarily categorized into two main types: body waves and surface waves.

Body Waves

Body waves travel through the Earth's interior and are subdivided into two types:

1. P-Waves (Primary Waves)

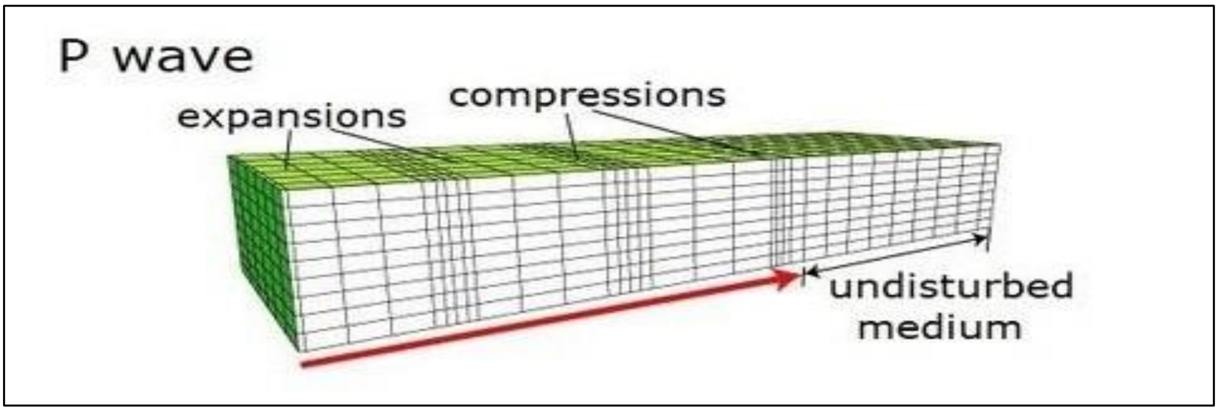


Fig. 1 showing P-wave.

Nature: P-waves are compressional waves, meaning they cause particles in the material they travel through to move back and forth in the same direction as the wave itself. As a P-wave passes through rock, it compresses and expands the material in the direction of wave travel, creating alternating regions of high and low pressure.

Velocity: They are the fastest type of seismic wave and thus the first to be detected by seismographs. P-waves are the fastest seismic waves, traveling at speeds of 5-7 km/s in the Earth's crust. They can move through solids, liquids, and gases. The velocity depends on the medium's density and elastic properties and is described by the equation:

$$V_p = \sqrt{\left[\frac{(\lambda + 2\mu)}{\rho}\right]}$$

where λ is the bulk modulus, μ is the shear modulus, and ρ is the density of the medium.

Path: P-waves can move through solids, liquids, and gases.

2. S-Waves (Secondary Waves)

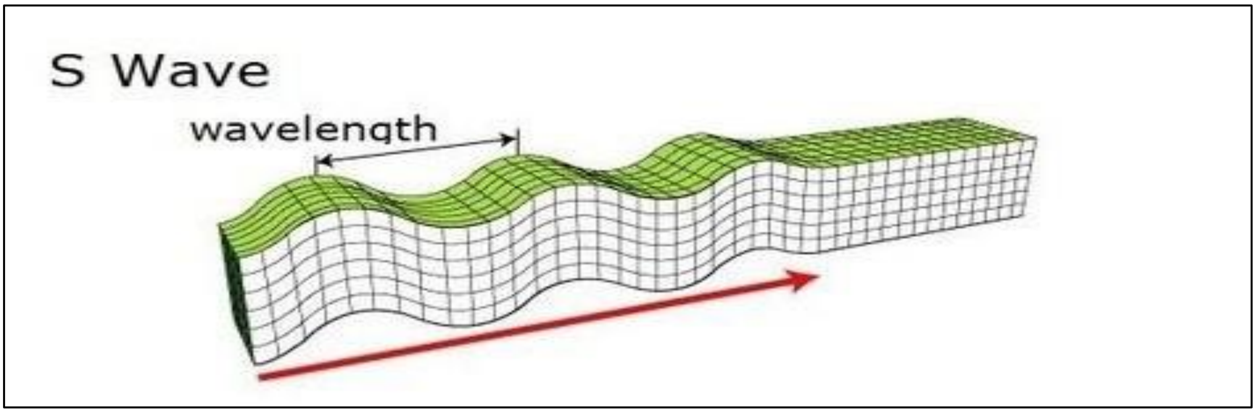


Fig. 2 showing S-Wave.

Nature: S-waves are shear waves, meaning they cause particles to move perpendicular to the direction of wave propagation. As an S-wave passes through rock, it shears the material side to side or up and down, perpendicular to the wave's direction.

Velocity: S-waves are slower than P-waves and are typically the second set of waves recorded by seismographs. S-waves travel slower than P-waves, at speeds of 3-4 km/s in the Earth's crust. They can only move through solids. Their velocity is given by:

$$V_s = \sqrt{\left[\frac{\mu}{\rho}\right]}$$

Path: S-waves can only move through solids because fluids do not support shear stress.

There are two types of shear waves:

SH (Shear Horizontal) Waves: Particle motion is in a horizontal plane.

SV (Shear Vertical) Waves: Particle motion is in a vertical plane.

Surface Waves

Surface waves travel along the Earth's surface and tend to have larger amplitudes and longer wavelengths than body waves, causing more damage. They are divided into two main types:

1. **Rayleigh Waves**

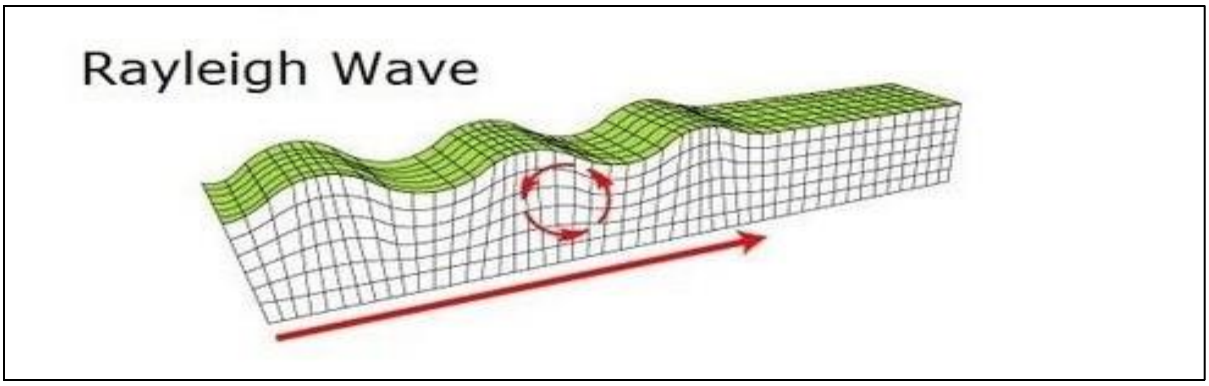


Fig. 3 showing Rayleigh Waves.

Nature: These waves cause a rolling motion, with particles moving in an elliptical path that is opposite to the direction of wave propagation. They combine longitudinal and transverse motion. As Rayleigh waves move through the surface layers, they create a rolling motion, lifting and dropping particles in an elliptical path, which can be very destructive.

Velocity: Rayleigh waves travel slightly slower than S-waves, at about 0.92 times the velocity of S-waves. Rayleigh waves travel slower than both Love waves and body waves and are confined to the Earth's surface.

Depth Penetration: The amplitude of Rayleigh waves decreases exponentially with depth.

2. **Love Waves**

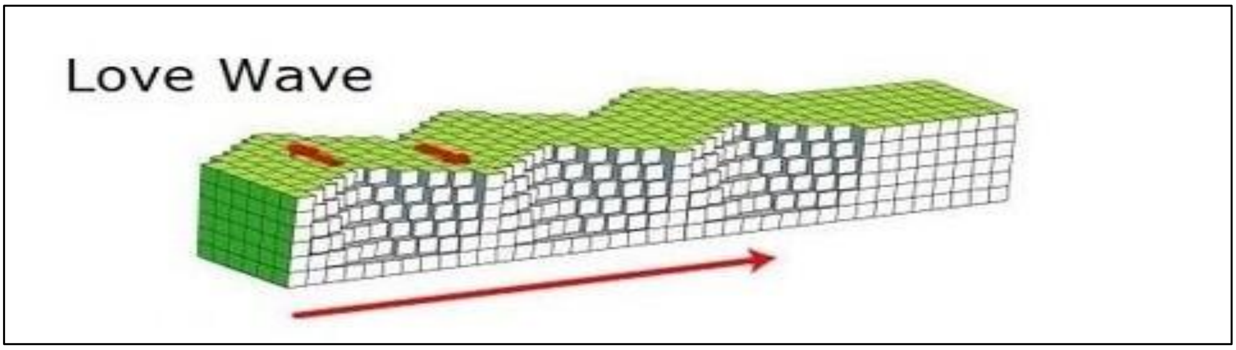


Fig. 4 showing Love wave.

Nature: Love waves cause horizontal shearing of the ground, with particle motion occurring perpendicular to the direction of wave propagation and confined to a horizontal plane. As Love waves move through the surface layers, they create horizontal, back-and-forth motion, which can cause significant damage to structures.

Velocity: They travel faster than Rayleigh waves but slower than body waves. Love waves generally travel faster than Rayleigh waves but slower than body waves. They are confined to the Earth's surface and shallow subsurface layers.

Depth Penetration: Like Rayleigh waves, the amplitude of Love waves also decreases with depth, but they do not involve vertical motion.

Energy Losses

As seismic waves propagate, they gradually lose energy. This loss of energy can occur due to several mechanisms:

Absorption: Conversion of mechanical energy into heat due to friction at grain contacts, cracks, and fractures.

Scattering: Redistribution of wave energy due to heterogeneities in the rock.

Geometrical Spreading: Energy loss due to the spreading out of wavefronts as they travel through the Earth.

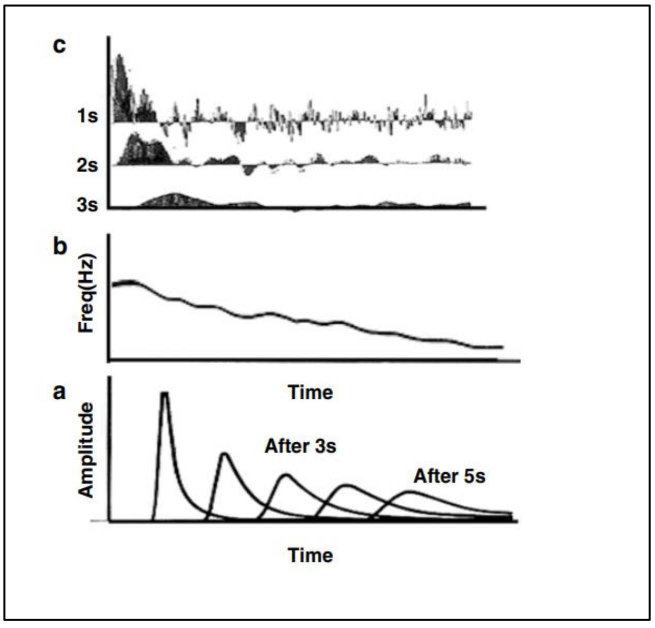


Fig. 5 A schematic showing the loss of energy due to absorption during wave propagation. (a) Shows a lowering of amplitude with time (b) the lowering of frequency with time and (c) the overall look of a seismic trace with time (Modified after Anstey 1977).

2. Seismic data

Seismic Data Acquisition Process

Seismic data acquisition involves several key steps to capture and record seismic waves generated by a controlled source and reflected from subsurface geological structures.

1. **Seismic Source Generation**
   The process starts with generating seismic waves using various energy sources. Traditionally, dynamite explosions in shot-holes have been used, but there are alternative methods as well. The choice of the seismic energy source depends on the surface conditions of the survey area.
   The main criteria for selecting a source include:
   a) Generating a strong enough signal to be detectable at the farthest receiver.
   b) Producing a signal rich in high-frequency components to resolve closely spaced reflectors.
   c) Minimizing generated noise.

2. **Wave Detection**
   After generating the seismic waves, the next step is detecting the reflected waves. This involves using receivers like geophones on land or hydrophones in marine environments. Geophones detect ground vibrations, while hydrophones detect pressure changes in water caused by seismic waves.

Geophones

A geophone is a deceptively simple, yet highly effective device used extensively in seismic exploration. Like gravity meters, its primary component consists of a mass suspended on a spring. When the ground experiences movement due to seismic waves, the mass, owing to its inertia, strives to remain stationary relative to the Earth. To an observer, it might appear as though the mass itself is moving, but this is an illusion caused by the observer's motion with the ground.

The ingenious aspect of the geophone lies in its internal workings: the mass is enveloped by a coil of wire, encased within a magnet fixed to the Earth. As the Earth moves, the magnet oscillates around the stationary mass. This movement induces variations in the magnetic field around the coil, generating an electrical voltage as per Faraday's law of electromagnetic induction.

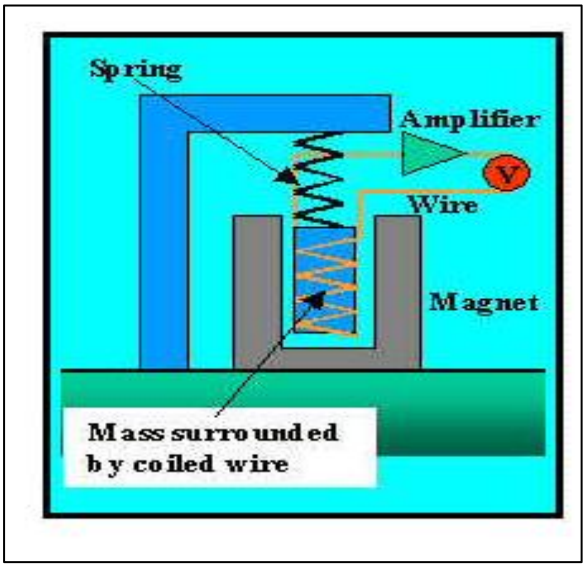


Fig. 9 Showing the working of geophone. **Fig. 10 Showing cross- section.**

The voltage produced by these fluctuations is directly proportional to the velocity of the ground's movement. This signal can be amplified and measured using a basic voltmeter or transmitted for detailed analysis.

Physically, a typical geophone includes a sensitive mass suspended by a spring inside a magnetized housing. In the illustration provided, the cutaway view reveals the wire-wrapped mass and the magnetized case within the external plastic enclosure. The silver-coloured housing inside the blue case serves to capture the induced electrical signal, which is then conveyed through black wires to a recording system. For stability, a long silver spike extends from the base of the geophone, facilitating secure attachment to the ground by embedding it firmly.

Geophones are available in various designs tailored to different environments, such as models with spikes for soft ground and spike-less variants for hard surfaces. These devices play a pivotal role in seismic refraction and reflection studies, providing crucial insights into subsurface structures and seismic events by accurately detecting ground movements.

3. **Data Recording**

   The detected seismic signals are then recorded digitally. Modern seismic surveys use high-capacity digital recording systems to capture the data. The recording system includes analog-to-digital converters and digital storage media. The data are typically recorded in SEG-D format, which supports high-density and high-capacity storage.

4. **Determination of Field Parameters**

   To ensure the quality and accuracy of the recorded data, field parameters must be optimized. This includes determining the optimal source-receiver configurations, shot intervals, and receiver spacings. These parameters are collectively referred to as survey design and are outlined in the work plan prepared for the seismic survey.

5. **Survey Execution**
   Once the survey design is finalized, the field crew carries out the survey according to the specified parameters. This involves positioning the seismic sources and receivers, generating seismic waves, and recording the reflected signals. The survey is conducted in a systematic manner to cover the entire survey area.

6. **Data Quality Control**
   During the data acquisition process, continuous quality control (QC) is essential. The recorded data are played back and displayed to check for any anomalies or distortions. This ensures that the data are of high quality and suitable for further processing.

7. **Data Playback and Display**
   For QC purposes, the recorded data (shot trace-gather) are displayed on a computer monitor or on paper. The playback system includes digital automatic gain control (AGC), digital-to-analog converters, demultiplexers, and cameras to display the data in a wiggly-mode trace format.

8. **Final Data Product**
   The end result of the data acquisition process is a set of digitally recorded seismic signals that represent the reflected waves from subsurface geological structures. This data set is then processed to enhance the signal-to-noise ratio, correct arrival times, and produce a seismic stack section, which is used for interpretation and analysis of the subsurface geology.

Data Acquisition in Marine Seismic Surveys

Marine seismic data acquisition is a comprehensive process involving multiple systems and instruments.

1. **Seismic Vessels**
   Seismic vessels are specially equipped ships designed for conducting seismic surveys. They are equipped with various instruments and systems necessary for data acquisition. The vessels deploy seismic streamers and source arrays and serve as the central hub for controlling and monitoring the survey operations.

2. **Hydrophones and Streamers**
   Hydrophones are underwater microphones used to detect and record seismic waves reflected from subsurface geological structures. These hydrophones are assembled into long cables called streamers, which can be kilometres long and contain multiple

hydrophones spaced at regular intervals. Streamers can be towed behind the vessel (towed streamer acquisition) or laid on the seafloor (ocean bottom acquisition).

Hydrophone

A hydrophone operates based on its sensitivity to pressure variations in the water column. The key component of a hydrophone is the piezoelectric element, which is a ceramic material that generates an electric voltage when it is mechanically deformed by a pressure wave.

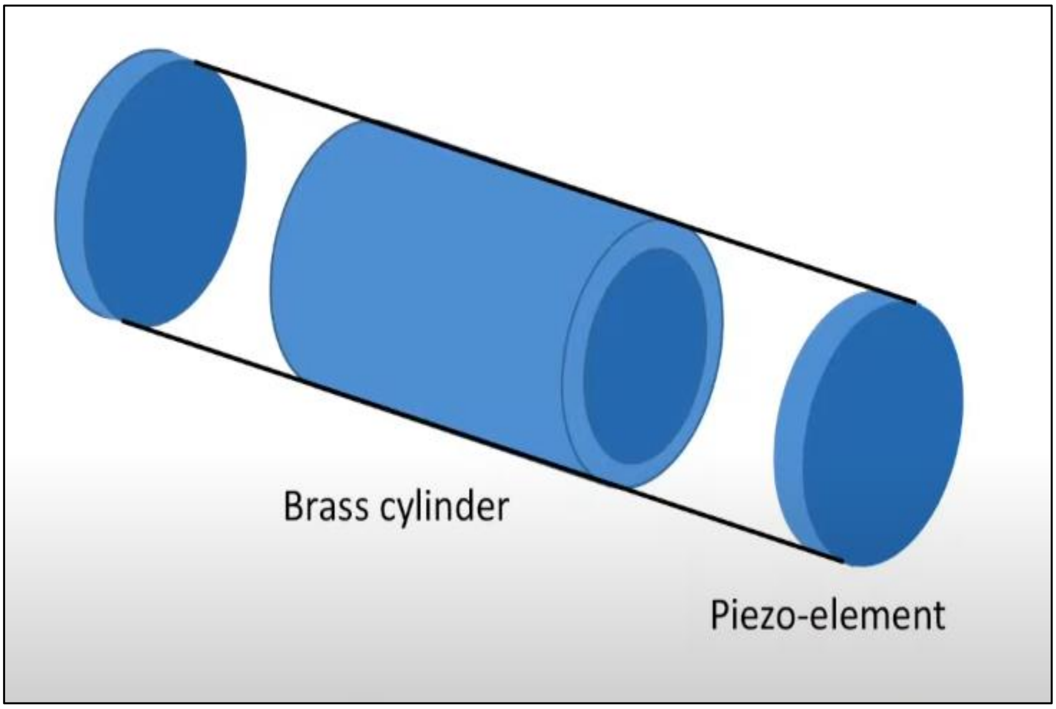


Fig. 11 showing a simple hydrophone.

Pressure Wave Interaction: When a pressure wave, such as an acoustic signal or seismic reflection, passes through the water and reaches the hydrophone, it exerts pressure on the piezoelectric element. This pressure deforms the ceramic material.

Voltage Generation: The deformation of the piezoelectric element creates a voltage difference between its surfaces. This voltage is directly proportional to the pressure exerted by the wave, essentially converting the mechanical pressure signal into an electrical signal.

Acceleration Cancellation: To ensure accuracy, especially during towing operations where the streamer (a long cable with multiple hydrophones) moves through the water, hydrophones are designed to cancel out the noise caused by this movement. This is achieved by coupling two identical piezoelectric elements in reverse directions within a single hydrophone.

The movement of the streamer induces a constant pressure that generates opposite voltages in the two elements due to their reversed orientations. This effectively cancels out the noise from the streamer's acceleration.

Hydrophone Arrays: In practice, multiple hydrophones are grouped together to form an array. This grouping enhances signal detection and noise cancellation.

The hydrophones in an array are connected in parallel, which improves the low-frequency response and reduces noise by ensuring that the pressure signals from reflections are in-phase while random noise signals are out-of-phase and thus cancel each other out.

By designing hydrophone groups with equally or unequally spaced hydrophones that have equivalent sensitivity, the system can attenuate mechanical noise and enhance the amplitude of reflected signals.

Signal Transmission: The electric signals generated by the hydrophones are transmitted through the streamer to recording equipment on the seismic vessel. Modern systems often digitize these signals within the streamer before transmitting them, improving the quality and accuracy of the data recorded.

3. **Marine Seismic Energy Sources**
   The primary energy source for marine seismic surveys is the air gun, which releases high-pressure air to generate acoustic waves. Air guns are arranged in arrays to enhance the strength and penetration of the seismic waves. The air gun arrays are synchronized to ensure the waves are generated at precise intervals.

4. **Gun Control Systems**
   These systems manage the timing and firing of air guns. They ensure that the air guns are fired in a controlled manner to produce consistent seismic signals. Proper control of the firing sequence is critical for acquiring high-quality seismic data.

5. **Streamer Depth Controllers**
   Streamer depth controllers, also known as birds, are devices attached to the streamer cables to control their depth. Maintaining a consistent depth is crucial for accurate data acquisition, as variations in depth can affect the travel time and quality of the seismic signals.

6. **Seismic Recorder**
   The seismic recorder is an onboard system that records the signals detected by the hydrophones. It digitizes the analog signals and stores the data for processing. Modern seismic recorders are capable of handling large volumes of data and provide real-time monitoring capabilities.

7. **Integrated Navigation System**
   An integrated navigation system is used to ensure precise positioning of the seismic vessel, streamers, and source arrays. This system combines data from GPS, gyrocompasses, and motion sensors to provide accurate navigational information. Proper calibration and verification of the navigation system are essential for the success of the survey.

8. **Tail Buoys, Dilt Floats, and Paravanes**
   Tail buoys are attached to the end of streamers to mark their position on the surface. Dilt floats are used to support the weight of streamers and keep them at the desired depth. Paravanes are used to spread the streamers laterally and maintain their separation during the survey.

9. **Lead-in and Deck Cables**
   Lead-in cables connect the seismic streamers and energy sources to the onboard recording systems. Deck cables are used on the vessel to route signals and power to various equipment and systems involved in data acquisition.

10. **Acquisition Techniques**

    2D Surveys: These involve a single streamer and are primarily used for preliminary exploration and academic research.

    3D Surveys: Utilize multiple streamers to provide a comprehensive view of the subsurface, offering better resolution and accuracy. These surveys are more expensive but provide superior data quality and are essential for detailed exploration and development of hydrocarbon.

    4D (Time-Lapse) Surveys: Involve repeated 3D surveys over the same area to monitor changes in the reservoir over time, which is crucial for reservoir management and enhanced oil recovery.

AIR GUN

Air gun arrays are critical for generating seismic waves in marine surveys. Here are some principles related to air guns:

Air Gun Principles: Air guns release compressed air to produce seismic waves. The rapid expansion of the air creates an acoustic pulse that travels through the water and penetrates the seabed.

Air Gun Bubble Effect: The release of air generates a bubble that oscillates and produces a series of pulses. Controlling the bubble effect is crucial for generating clear seismic signals.

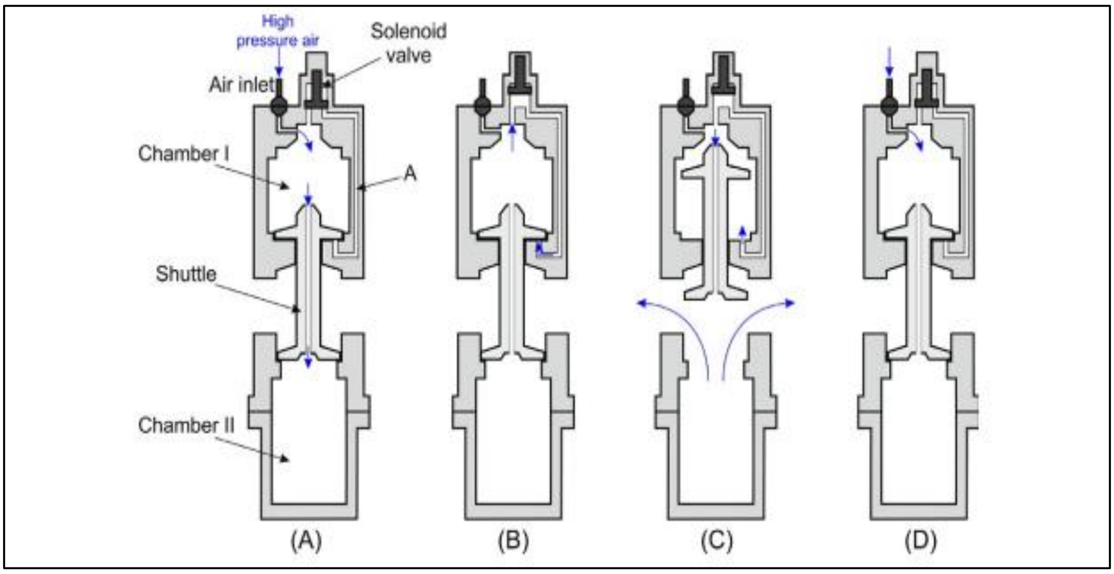


Fig. 12 Schematic drawing of an air gun (A) in armed position, (B) solenoid valve is open, and the air is fed beneath the upper flange of the shuttle via orifice A, (C) shuttle moves up and the gun is fired, and (D) air gun reverts to its initial armed position.

Ghost Reflection: Reflections from the sea surface, known as ghost reflections, can interfere with the primary seismic signal. Techniques like using dual-depth sources or de-ghosting algorithms are employed to mitigate this effect.

Near-/Far-Field Source Signatures: The characteristics of the seismic source signature can vary depending on the distance from the source. Near-field and far-field signatures are analysed to understand and compensate for these variations.

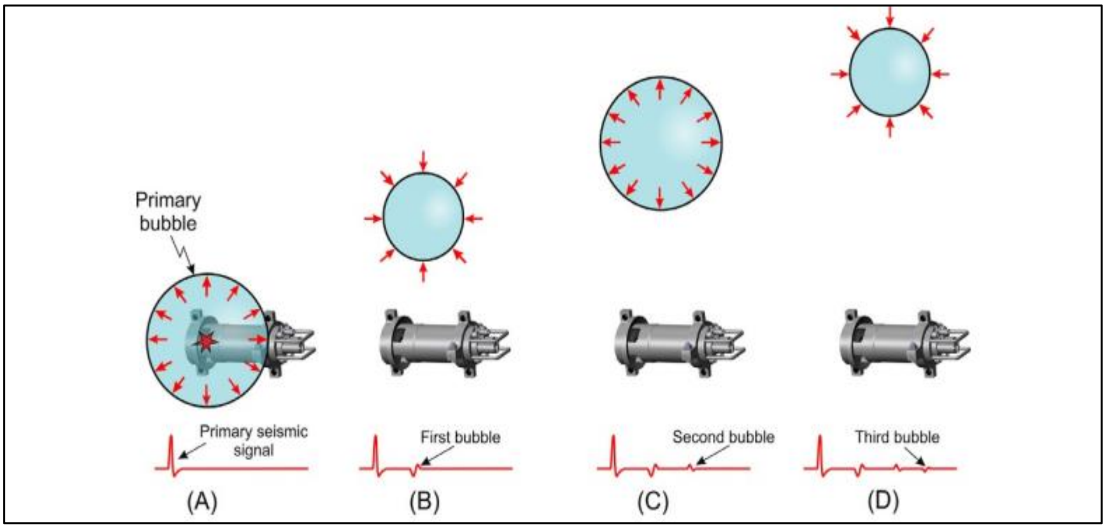


Fig. 13 Schematic illustration of bubble effect formation from an air gun source. (A) An air gun provides a sudden air discharge into the water as an expanding bubble, which produces the primary seismic signal. (B) A certain time later, the bubble suddenly shrinks (termed rarefaction) because of the higher ambient pressure than internal pressure of the bubble, which produces the first bubble signal on the signature. (C) Then bubble expands again (termed compression) because of its higher internal pressure than ambient pressure, which produces the second bubble signal on the signature. (D) The expansion and shrinkage of the bubble continues until it breaks at the sea surface.

Quality Control (QC) in Data Acquisition

QC procedures are essential to ensure the quality, accuracy, and resolution of the acquired data. These procedures involve both real-time (online) and offline assessments to detect and rectify any issues during data acquisition. Key aspects of QC include:

Online QC: Involves real-time monitoring and analysis of the data as it is collected. This includes checking shot displays, near-trace displays, hydrophone data, noise levels, and streamer depth.

Offline QC: Conducted after the seismic lines are acquired, involving detailed analysis of the data and instrument performance. This helps in identifying any issues that may require reshooting or adjustments.

3. Seismic data processing

involves several steps applied sequentially to improve data quality and interpretability. The primary goal is to increase the signal-to-noise (S/N) ratio by enhancing the seismic signal while suppressing noise.

1. **Loading and Initial Setup**:

   Data Loading: The seismic data is loaded from storage media into a processing system. This involves reading the raw seismic traces from the recording devices.

   Demultiplexing: The raw data, often recorded in a multiplexed format, is separated into individual seismic traces.

   Geometry Loading: Navigation and observer logs are used to associate each trace with its correct spatial location, ensuring accurate geometric representation of the data.

2. **Preprocessing Steps**:

   Band-pass Filtering: This step removes unwanted frequency components from the data. Proper selection of cut-off frequencies is crucial for effective noise suppression.

   Gain Recovery: Amplitude variations due to geometric spreading and energy absorption are corrected to ensure consistent signal strength across all traces.

   Trace Editing/Muting: Noisy or irrelevant parts of the seismic traces are identified and removed. This may include killing bad traces and applying top muting to eliminate surface waves.

3. **Noise Suppression**:

   f-k Dip Filtering: A frequency-wavenumber filter is applied to suppress coherent noise such as ground roll.

   Multiple Suppression: Techniques like predictive deconvolution are used to remove multiple reflections that can obscure primary reflections.

4. **Deconvolution**:

   Deconvolution: This process compresses the seismic wavelet, enhancing resolution by removing the effects of the source signature and improving the temporal resolution of the data.

5. **Sorting and Velocity Analysis**:

   CDP Sorting/Binning: The data is sorted into common depth point (CDP) gathers, which are essential for subsequent stacking and migration.

Velocity Analysis: Velocities are analyzed to correct for normal moveout (NMO) and to prepare for accurate stacking and migration. This step may be repeated to refine the velocity model.

6. **Stacking**:

    NMO Correction: Adjusts the travel times of reflected seismic waves to a common reference, flattening the reflection events in CDP gathers.

    Stacking: Combines multiple traces at each CDP to enhance signal quality by summing the NMO-corrected traces, significantly increasing the S/N ratio.

7. **Migration**:

    Poststack Migration: Corrects the seismic image for the effects of dipping reflectors and complex subsurface structures, improving spatial resolution and positioning of reflectors.

    Prestack Migration: Applied to prestack data to provide a more accurate image of the subsurface, especially in areas with complex geology.

8. **Final Steps and Quality Control**:

    Gain/Top Mute: Final gain adjustments and muting are applied to the stacked and migrated data to enhance interpretability.

    Output and QC: The processed data is written back to disk in formats like SEGY. Continuous quality control (QC) is performed to ensure that each processing step achieves the desired results.

4. Interpretation of Seismic Data

Study area and its geological settings.

The Teapot Dome field is a faulted dome structure in the Salt Creek anticline present in the south-western portion of the Powder River Basin (PRB), north of Casper in Natrona County, Wyoming (Figure 14).

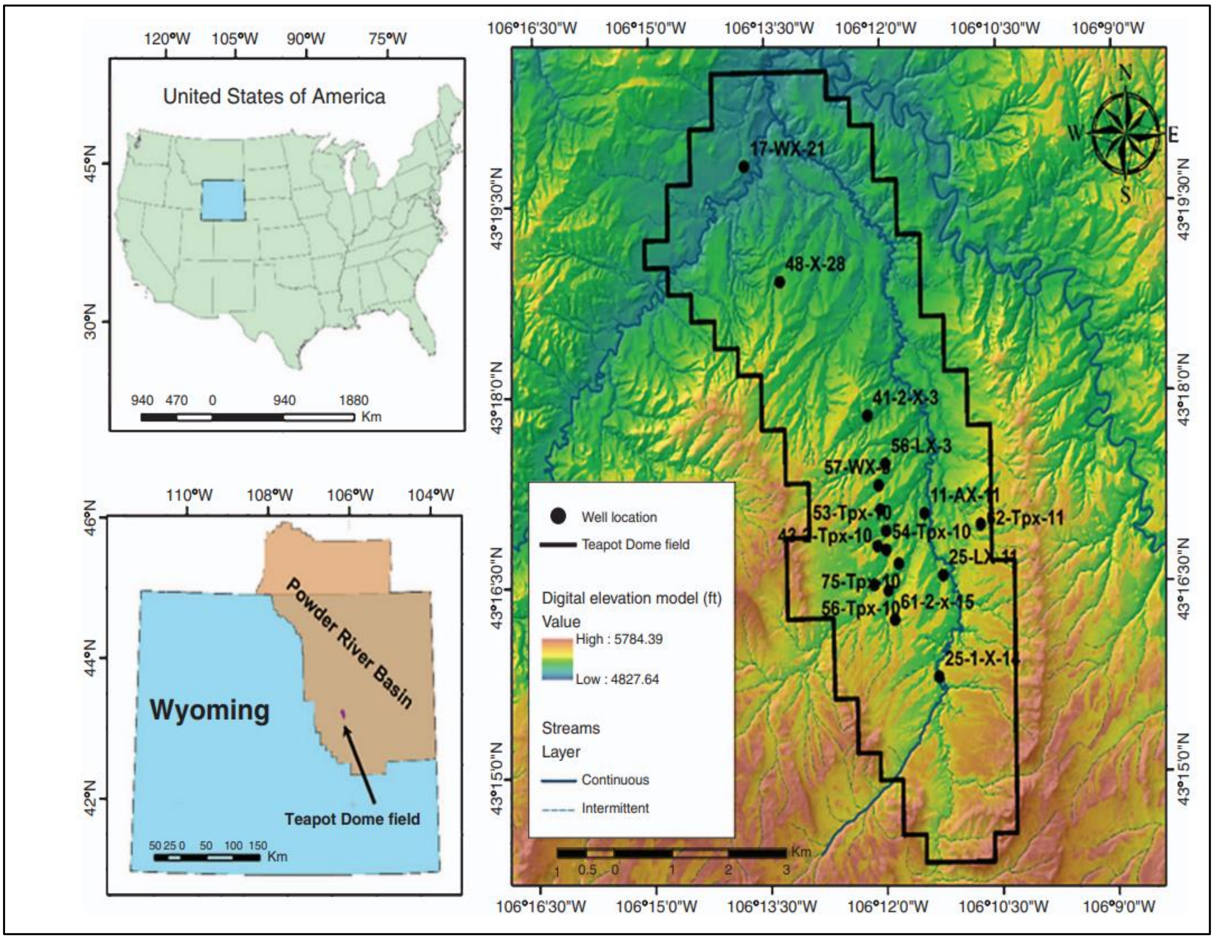


Fig. 14 Location map of the Teapot Dome field, PRB, Wyoming, USA.

The Teapot Dome is part of a basin margin anticline play of the PRB petroleum province (Dolton and Fox, 1995). The oil production from Teapot Dome started in 1908 from the 'Dutch' well. It flowed at a rate of 200 BOPD from the First Wall Creek sandstone. The Teapot Dome field was established as Naval Petroleum Reserve (NPR) in 1915 (Doll et al., 1995; Roth et al., 2005). Field operations at Teapot Dome were suspended for about 50 years due to a corruption scandal in the 1920s (Encyclopedia Britannica, 2014). Field activity was resumed at Teapot Dome in 1976, and later in 1977, when it became a facility of US Department of Energy (DOE). Teapot Dome's production met its highest levels in 1981 and then started to decline progressively. This provoked the DOE to convert its facility into the Rocky Mountain Oil Testing Centre (RMOTC). The RMOTC is engaged in collaborating with the oil/gas sector, academic and research organisations to enhance domestic hydrocarbon production by field testing advanced technology (Roth et al., 2005). Overall, 233 wells had been drilled in the field before the operations were resumed in 1976. Oil production has targeted nine different reservoirs ranging from Pennsylvanian age Tensleep Sandstone Formation (TSF) to the Upper Cretaceous Shannon Sandstone. Drilling activity was increased to 1007 development wells and 90 exploratory wells in late 1990s. Among the development wells, 27 were aimed to test the potential of TSF. Two of these wells flowed at highest initial production rates compared to any of the wells in Wyoming at that time. In October 2003, Teapot Dome was established as a national geological carbon storage test centre (Friedmann et al., 2004). The PRB was formed during the Laramide orogeny and contains thick successions of sedimentary strata, surrounded by successive uplifted mountains and basins from all sides (Figure 15) (Anna, 2009).

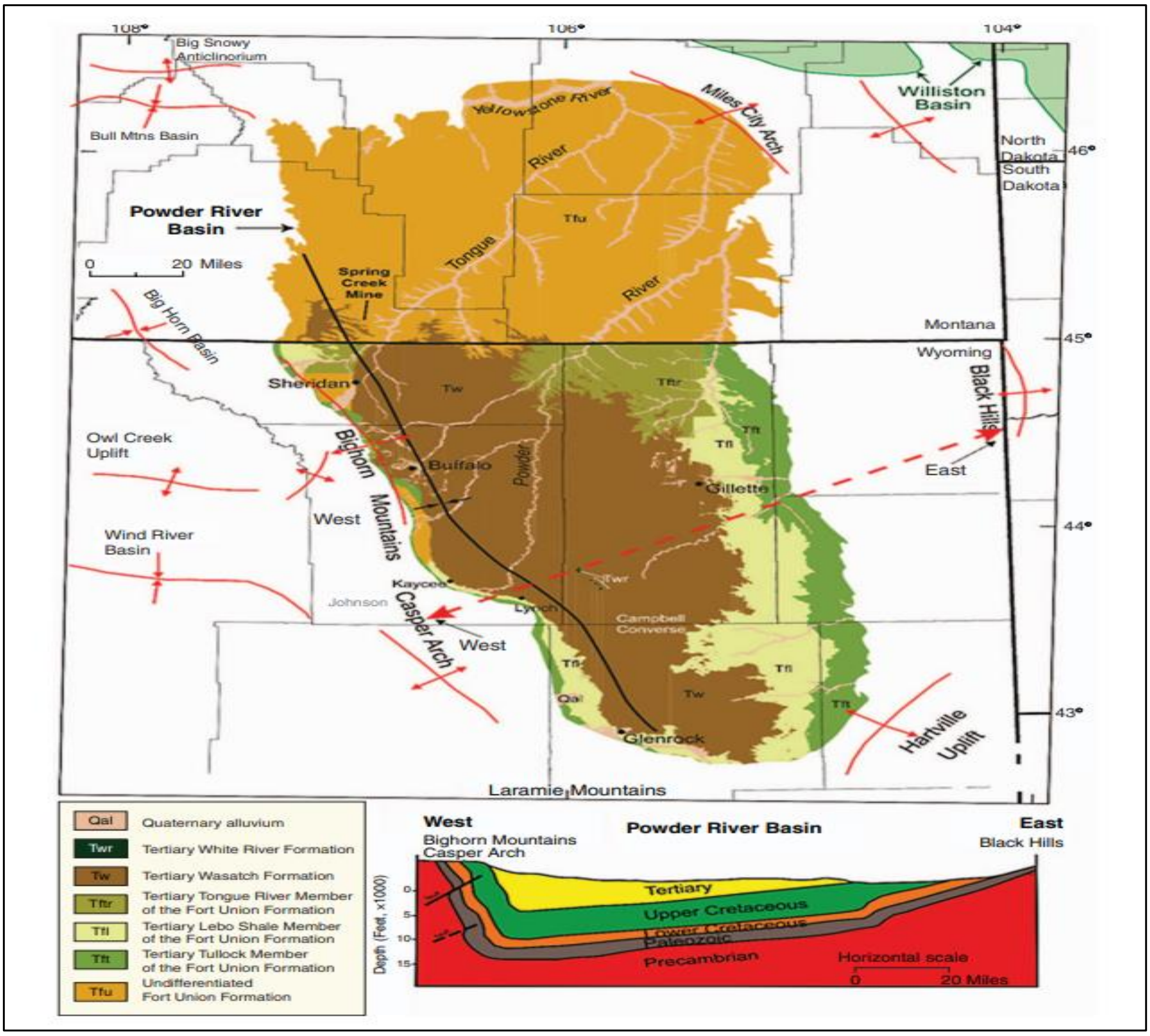


Fig. 15 Location map of the Teapot Dome field, PRB, Wyoming, USA.

The basin is an asymmetric syncline whose eastern flank near the Black Hills dips gently, while the western flank near Casper Arch dips more steeply (see crosssection in Figure 15). The basin's axis spreads over Wyoming and Montana with an NNW-SSE and NNE-SSW trend, respectively (De Bruin, 1993). Major deformation in the basin started in the early Eocene and was probably active until the Miocene (Strickland, 1958). Thom and Spieker (1931) suggested that deep seated reverse faults and extensional fissures/openings on anticlinal surfaces were formed by the forces from west side, whereas an east–west trending normal fault was mapped by Wegemann (1911) that splits the Teapot Dome field into northern and southern portions. TSF and its equivalent Minnelusa Formation are the major producing Paleozoic reservoirs in PRB. The majority of petroleum accumulations in the PRB are trapped in stratigraphic units, or at few places, in anticlinal closures. In the TSF, hydrocarbons accumulations are mainly found in structural traps (Dolton and Fox, 1995). The Permian Phosphoria Formation is the established source rock that expelled a huge amount of hydrocarbons which later became confined in the TSF and Minnelusa Formation of the PRB, as well as several Paleozoic reservoirs of the Rocky Mountains (Cheney and Sheldon, 1959; Sheldon, 1967; Friedmann et al., 2004; Anna, 2009). Alternative sources for the petroleum are suggested by Clayton and Ryder (1984). They proposed interbedded black shales of the Minnelusa Formation might have discharged the hydrocarbons into the Minnelusa reservoirs in the eastern portion of the basin. Other petroleum reservoirs include the Muddy sandstone, second Wall Creek member of Frontier Formation, and Carlie shale (Turner member) of the Cretaceous age. The major source rock for the Cretaceous reservoirs is Mowry shale (~12 billion barrels charged oil) with fewer contributions from the Niobrara and Carlie shales (Momper and Williams, 1984; Dolton and Fox, 1995). In the study area, Precambrian basement underlies thin interbedded sandstone successions, limestones, dolomites and evaporites of Paleozoic age (Figure 16). TSF is one of the major producing reservoirs at theTeapot Dome. Paleozoic strata are overlain by the dominantly terrigenous beds of Triassic and Jurassic age. The Upper Jurassic Sundance Formation has yet not produced HC in the Teapot Dome, but it surely has the potential to produce because of HC production in the adjacent Salt Creek field. A range of fluvial to marine sandstones and shales (Cretaceous) are present at the Teapot Dome field. Both the Shannon sandstone member of Cody shale and the Second Wall Creek member of Frontier Formation are the major Cretaceous producers at the Teapot Dome. Members of the Niobrara shale, Steele shale (Upper Cretaceous), as well as sandstone members of Thermopolis shale, Muddy sandstone, and Dakota sandstone (Lower Cretaceous) are also producing hydrocarbons in the Teapot Dome field (Dennen et al., 2013).

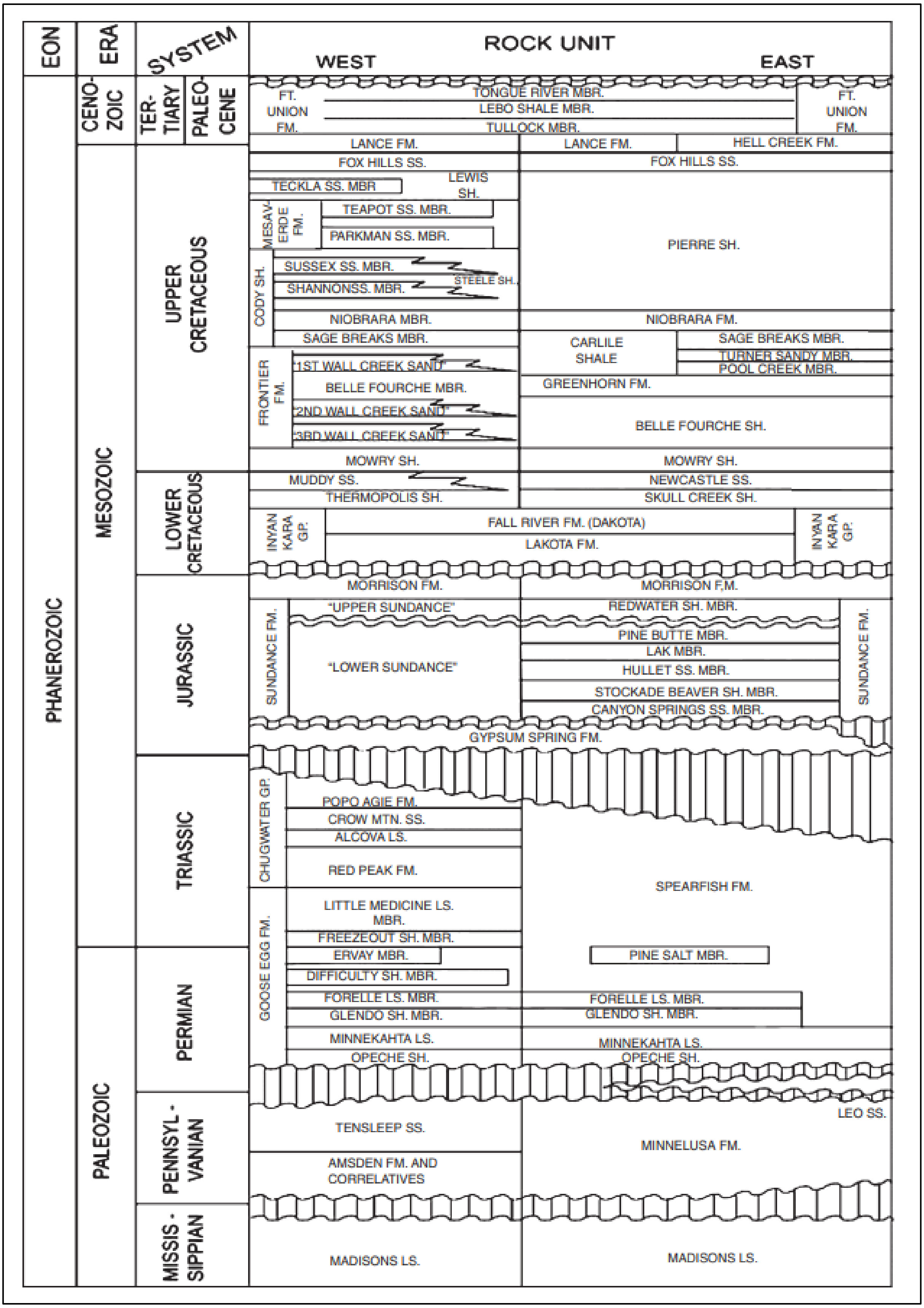
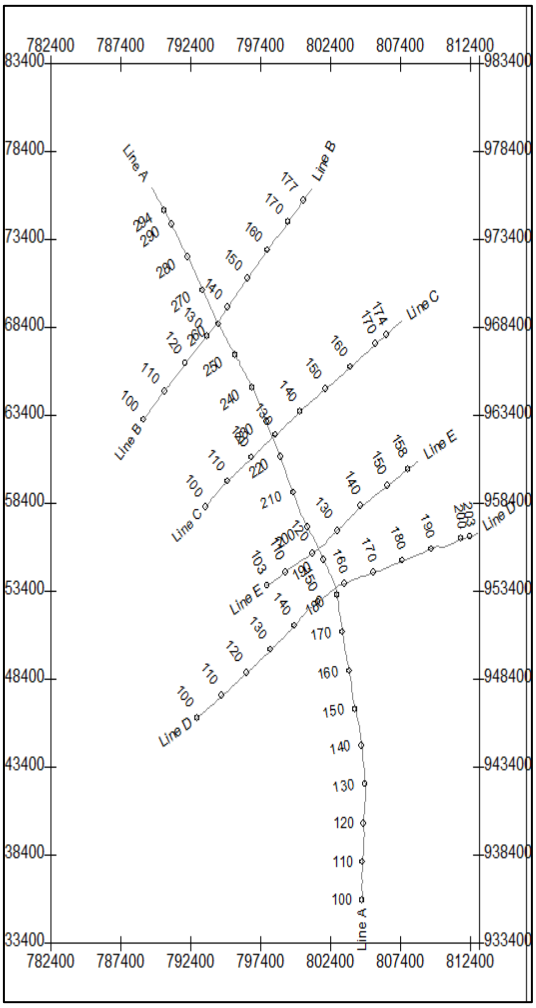
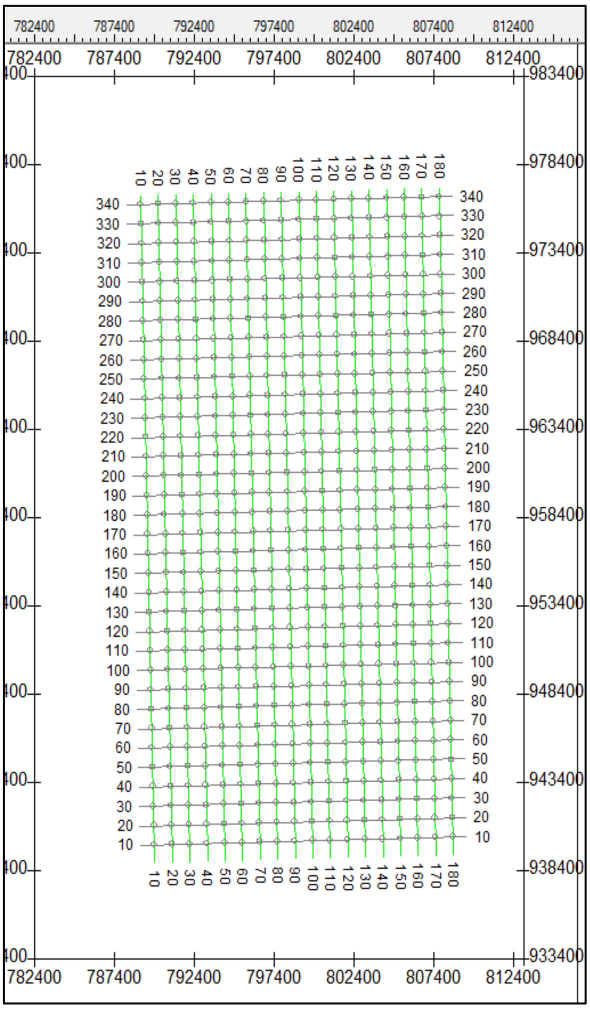


Fig. 16 General stratigraphic column at the Teapot Dome field (modified from Dolton and Fox, 1995).

Importing of seismic 2D data and 3D data in IHS Markit Kingdom Geophysics-Geology (ADV)





(A) (B)

Fig. 17 (A) showing base map of 2D and (B) showing base map of 3D data.

Viewing of 2D data in seismic sections

LINE A.

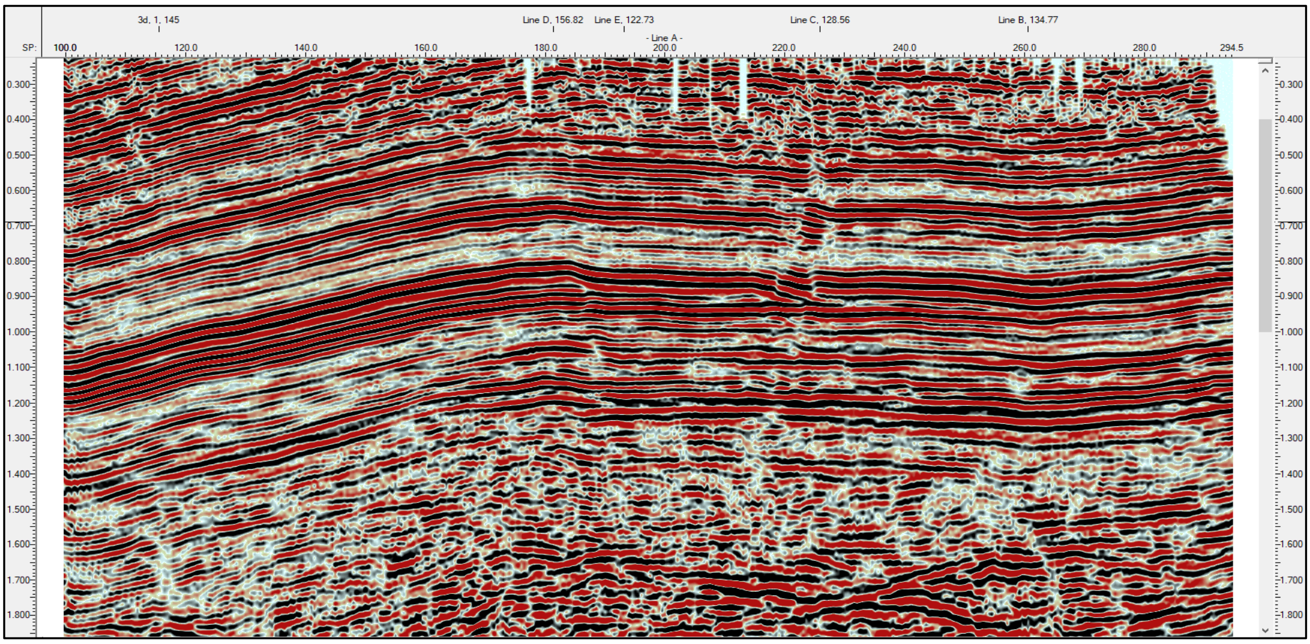
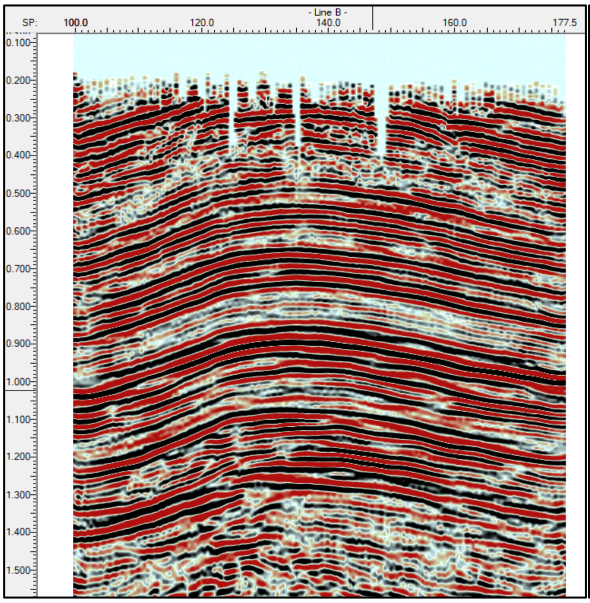


Fig. 18 showing seismic section of line A

LINE B.



LINE C.

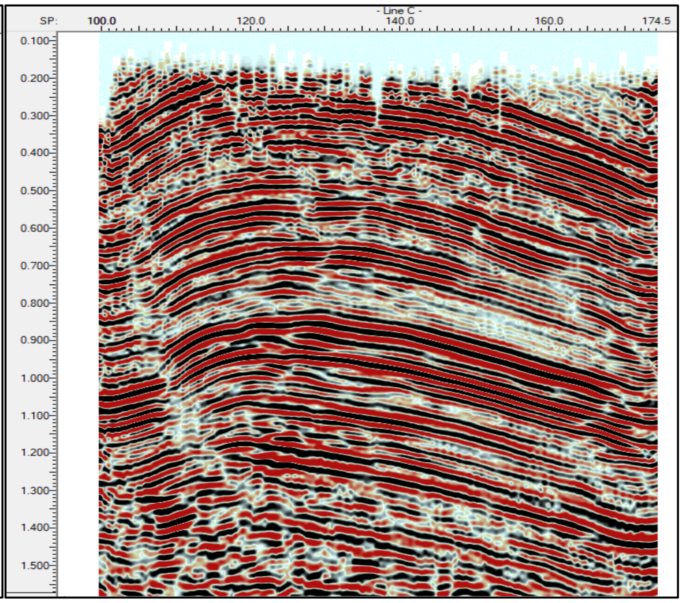


Fig. 19 showing seismic section of line B **Fig. 20 showing seismic section of line C**

LINE D.

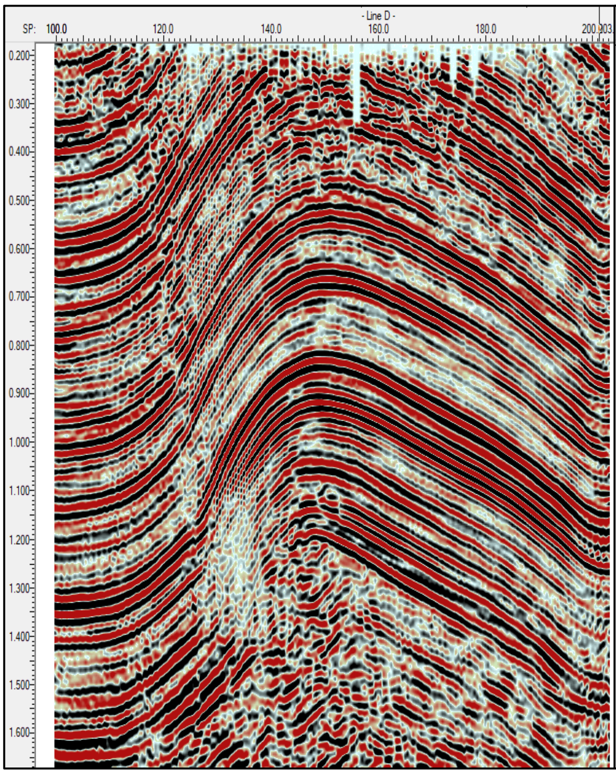


Fig. 21 showing seismic section of line D

LINE E.

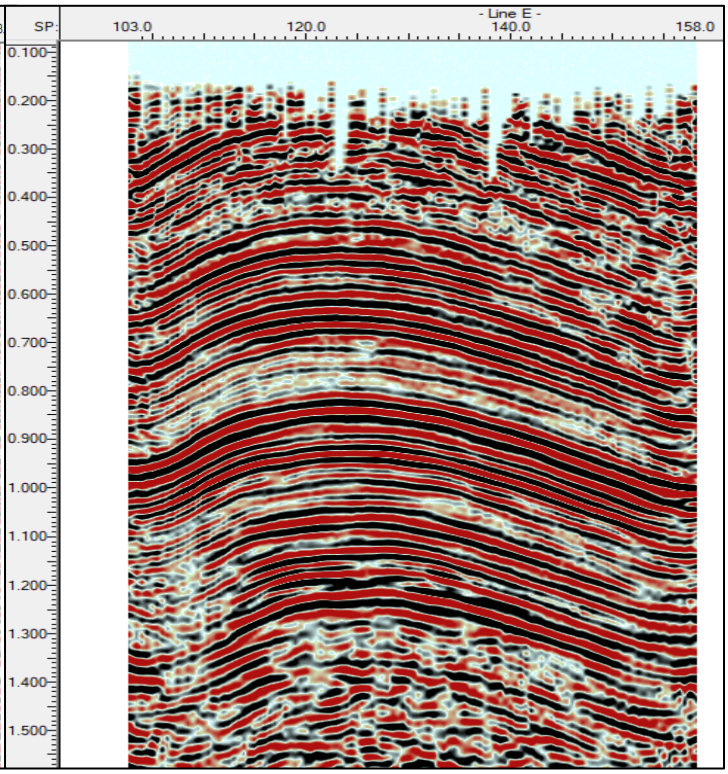


Fig. 22 showing seismic section of line E

Displaying all 2D lines in 3D view

Data is represented in X(length, ft) and Y(time, s)

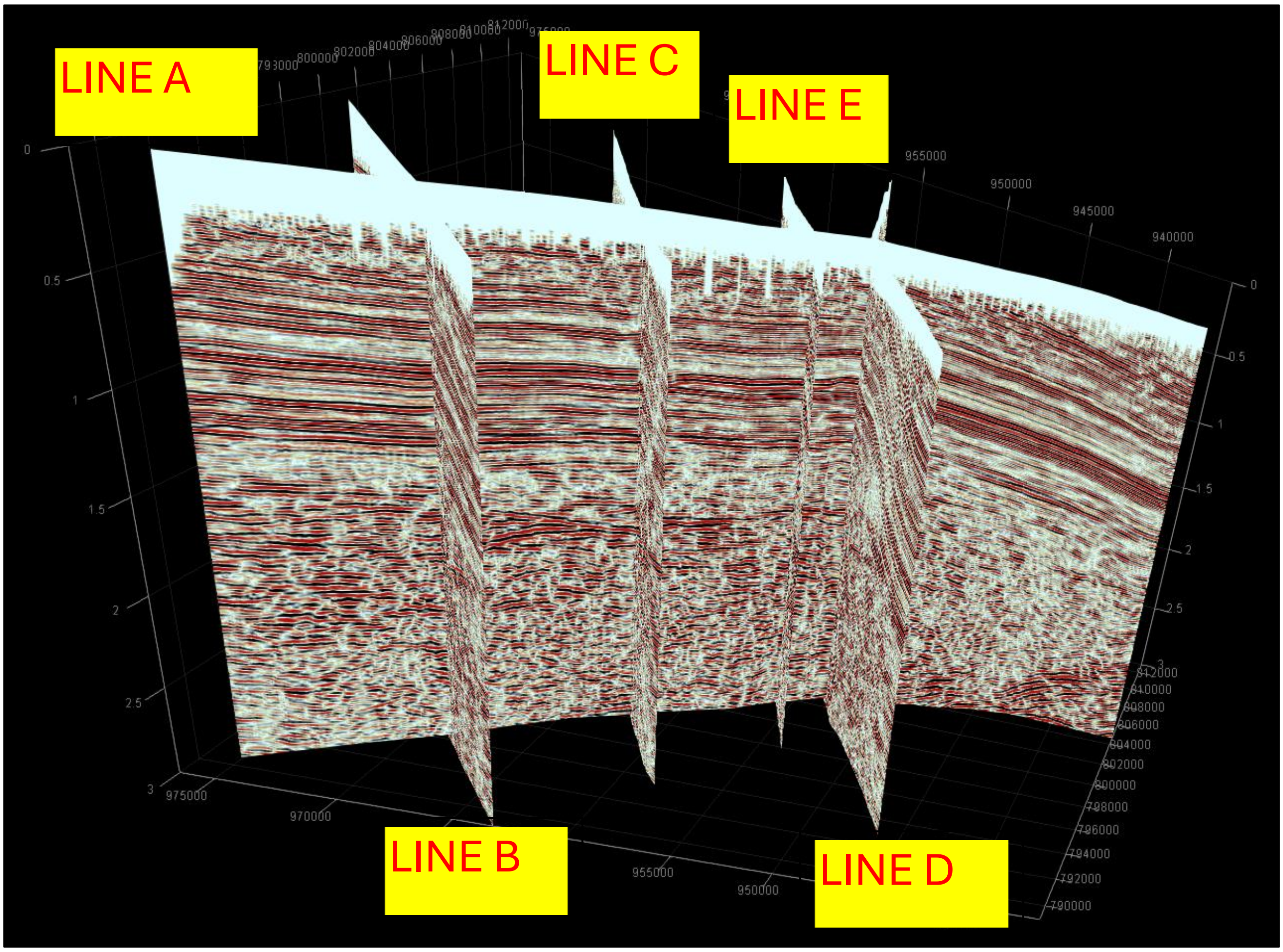


Fig.23 showing seismic section of LINE A, LINE B, LINE C, LINE D, LINE E in 3D.

Picking of Horizons

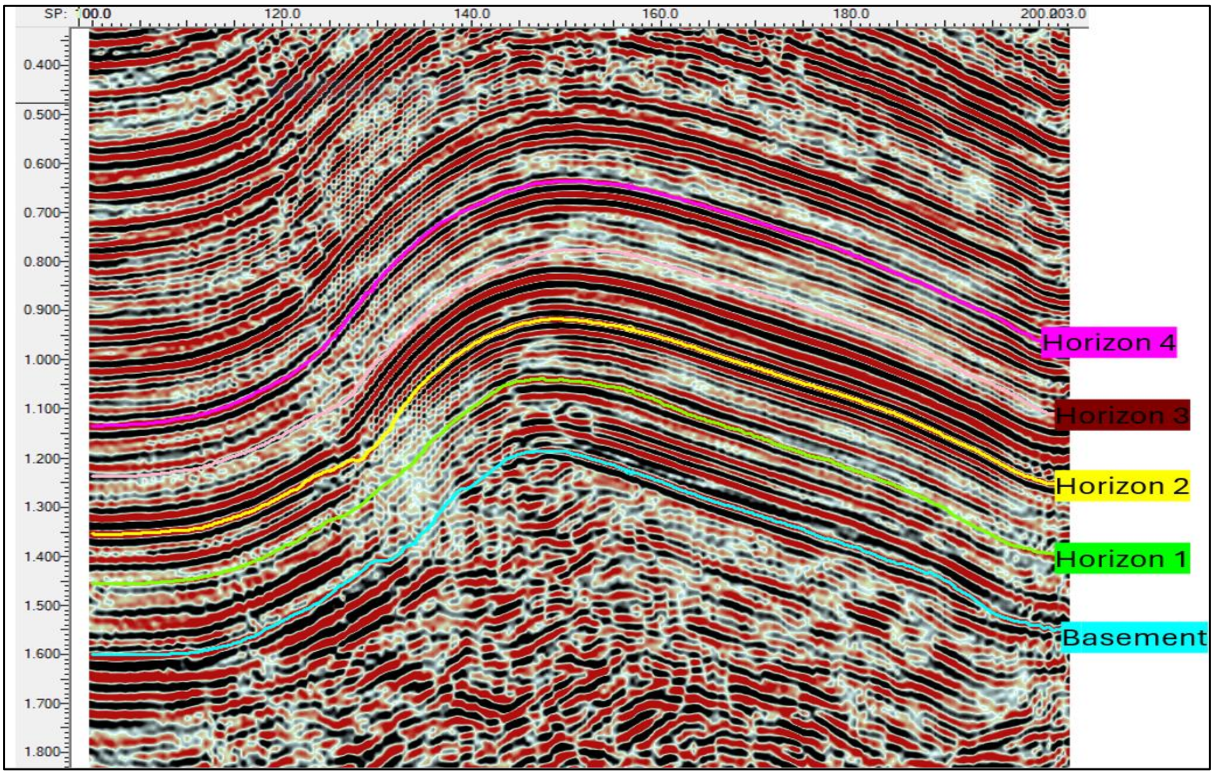


Fig. 24 showing all the picked horizons.

Viewing 2D horizons in 3D

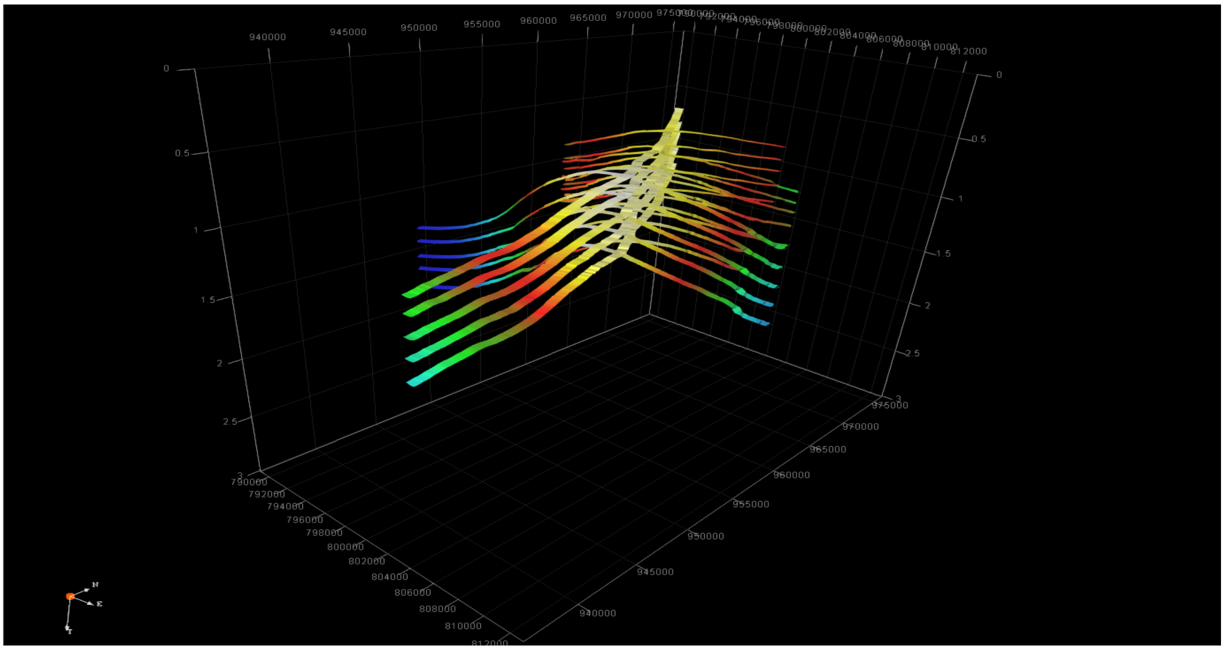


Fig. 25 showing of picked horizons on 2D data in 3D.

Viewing 3D horizons in 3D

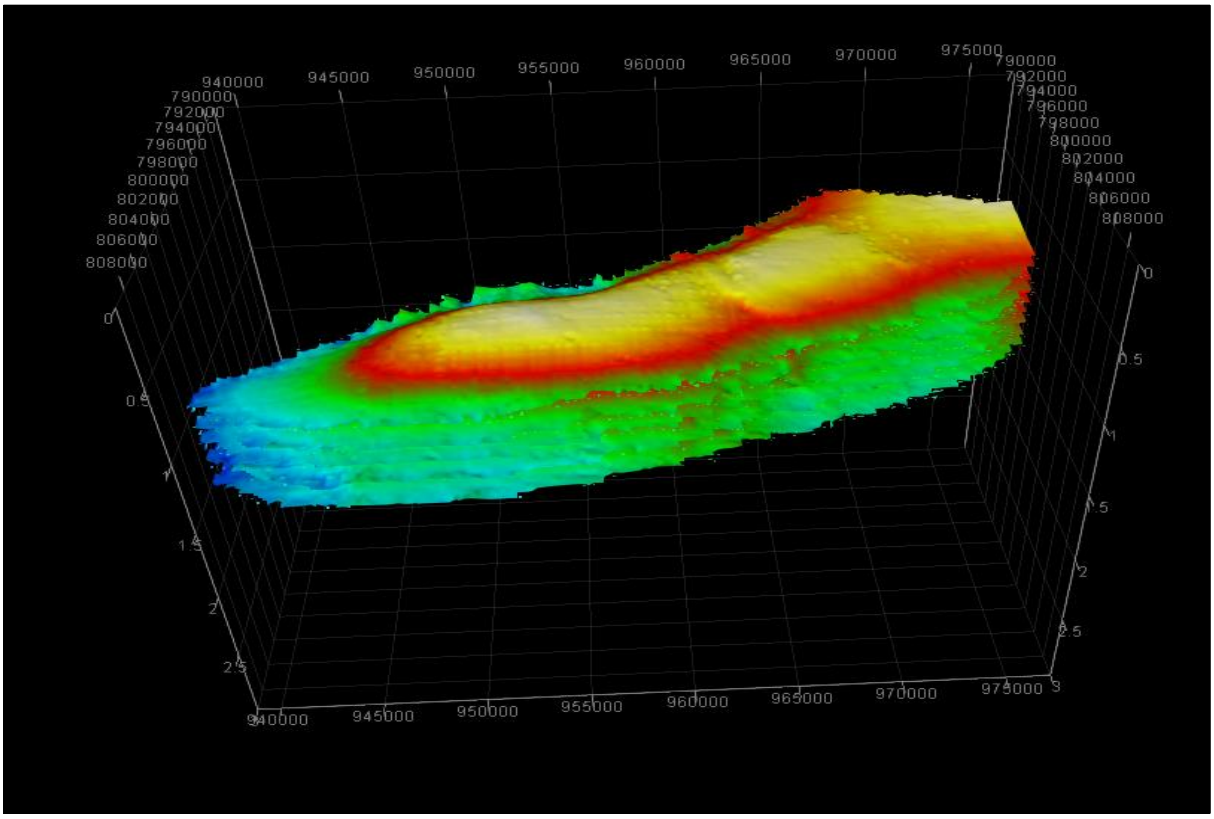
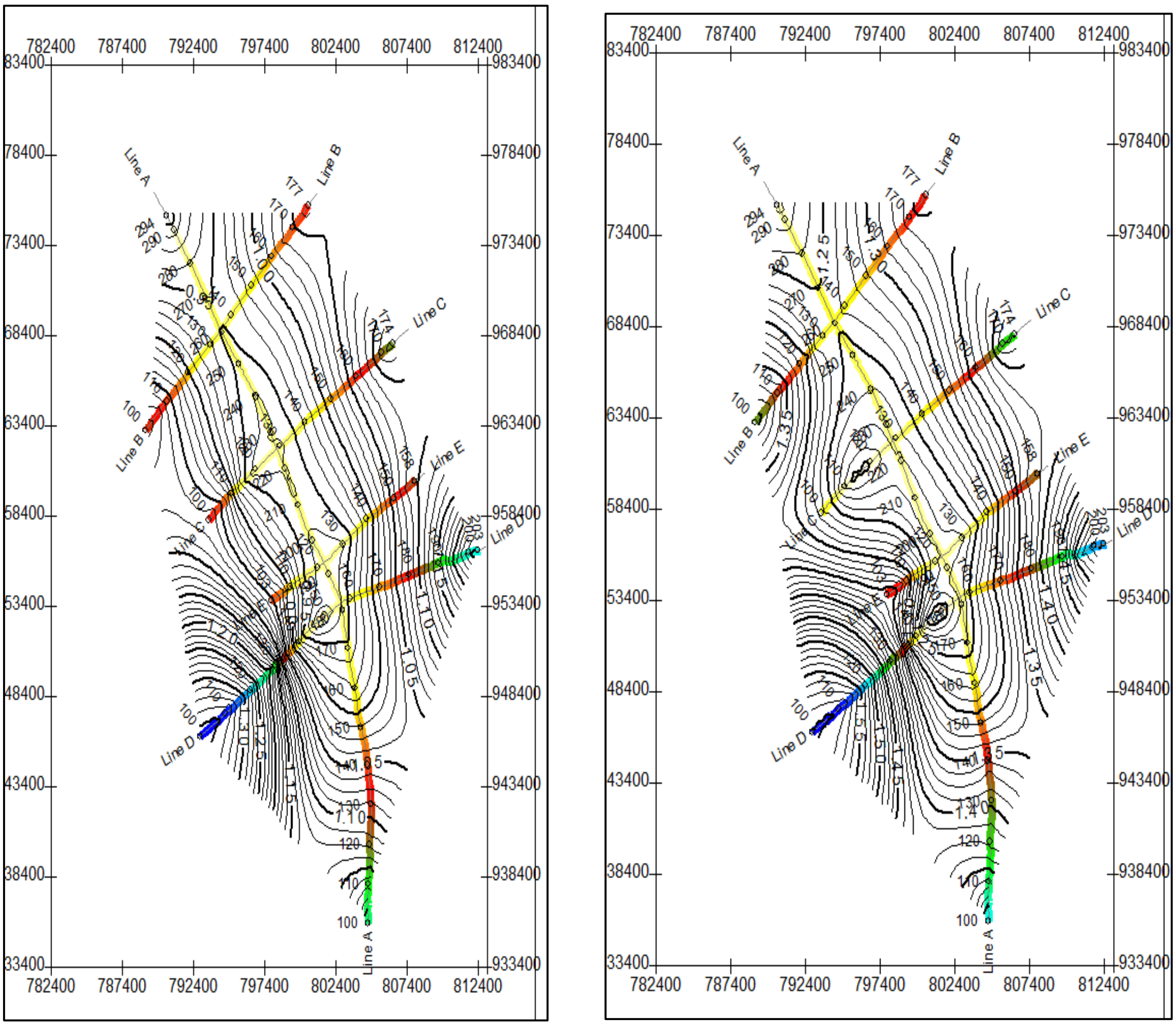


Fig. 26 showing of picked horizons on 3D data in 3D, starting from bottom we have the Basement, Horizon 1, Horizon 2, Horizon 3, Horizon 4.

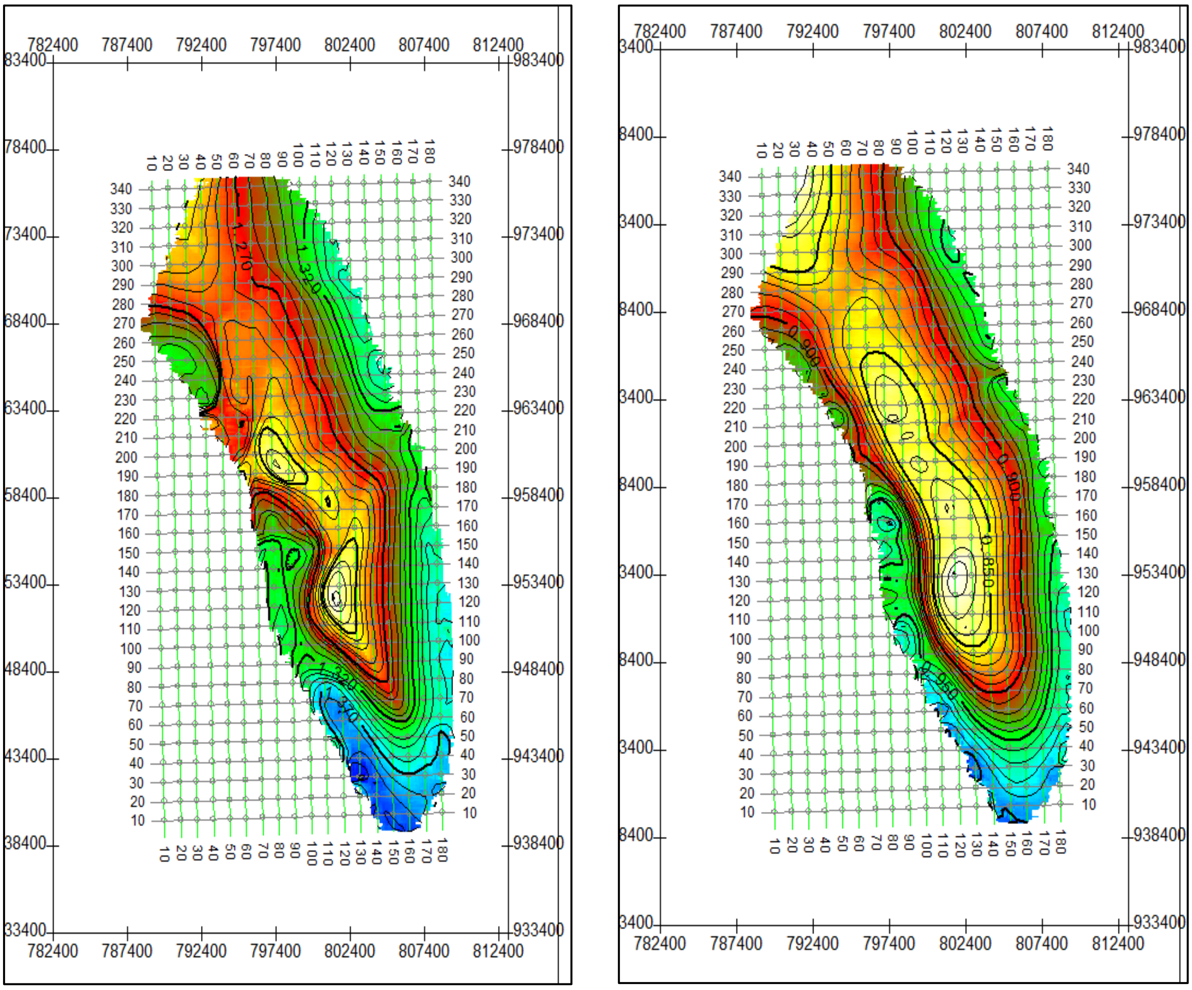
Contours (Isochron Map)

These contours are generated using the 2D and 3D seismic data after horizon picking. As we can see that 3D data provides better resolution and visualization of the study area.



(A) **(B)**

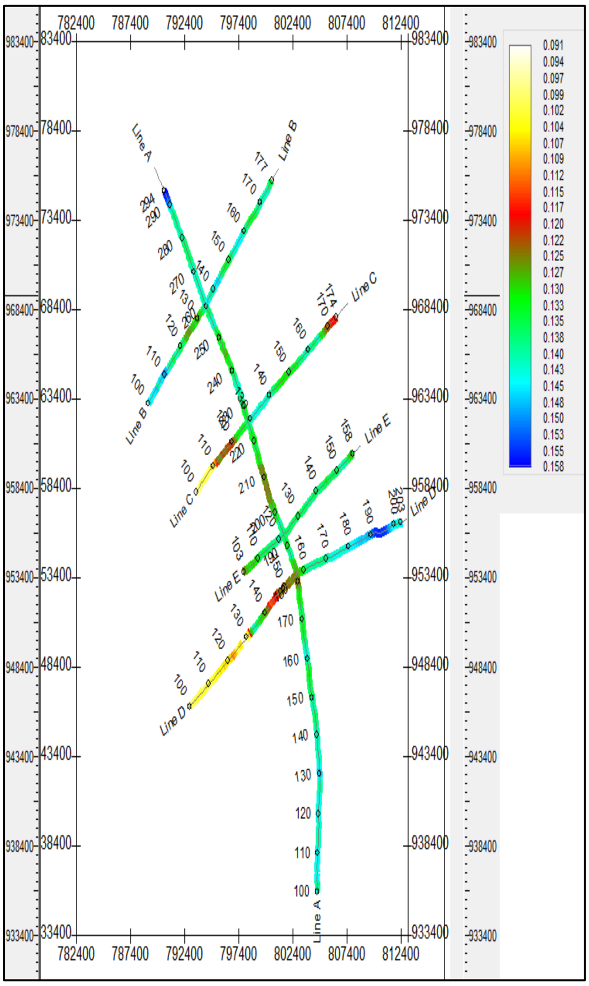
Fig. 27 (A) is the isochrone map of basement (B) is the isochrone map of Horizon 2, both the maps are plotted on 2D seismic data.



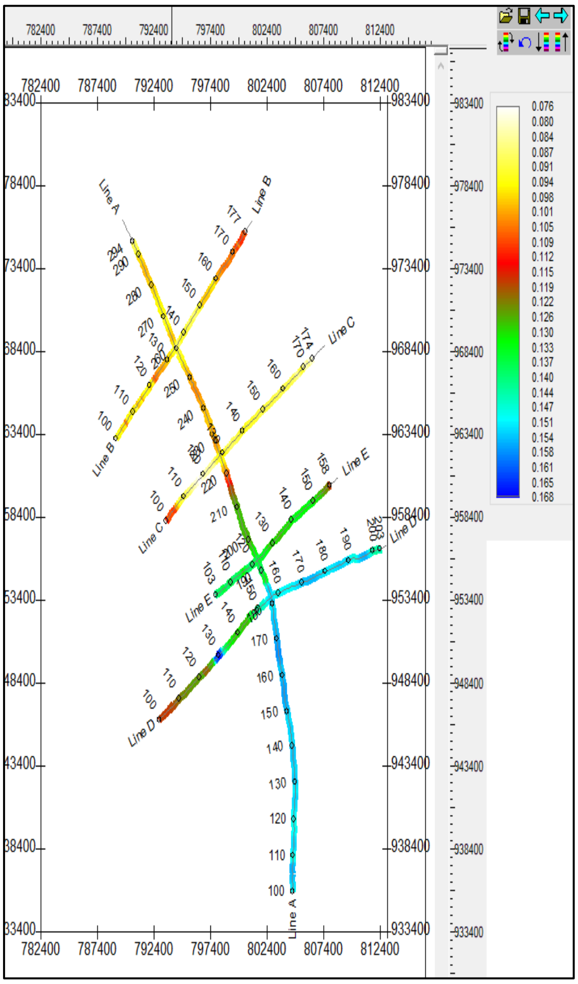
(A) **(B)**

Fig. 28 (A) is the isochrone map of basement (B) is the isochrone map of Horizon 2, both the maps are plotted on 3D seismic data.

Thickness Map

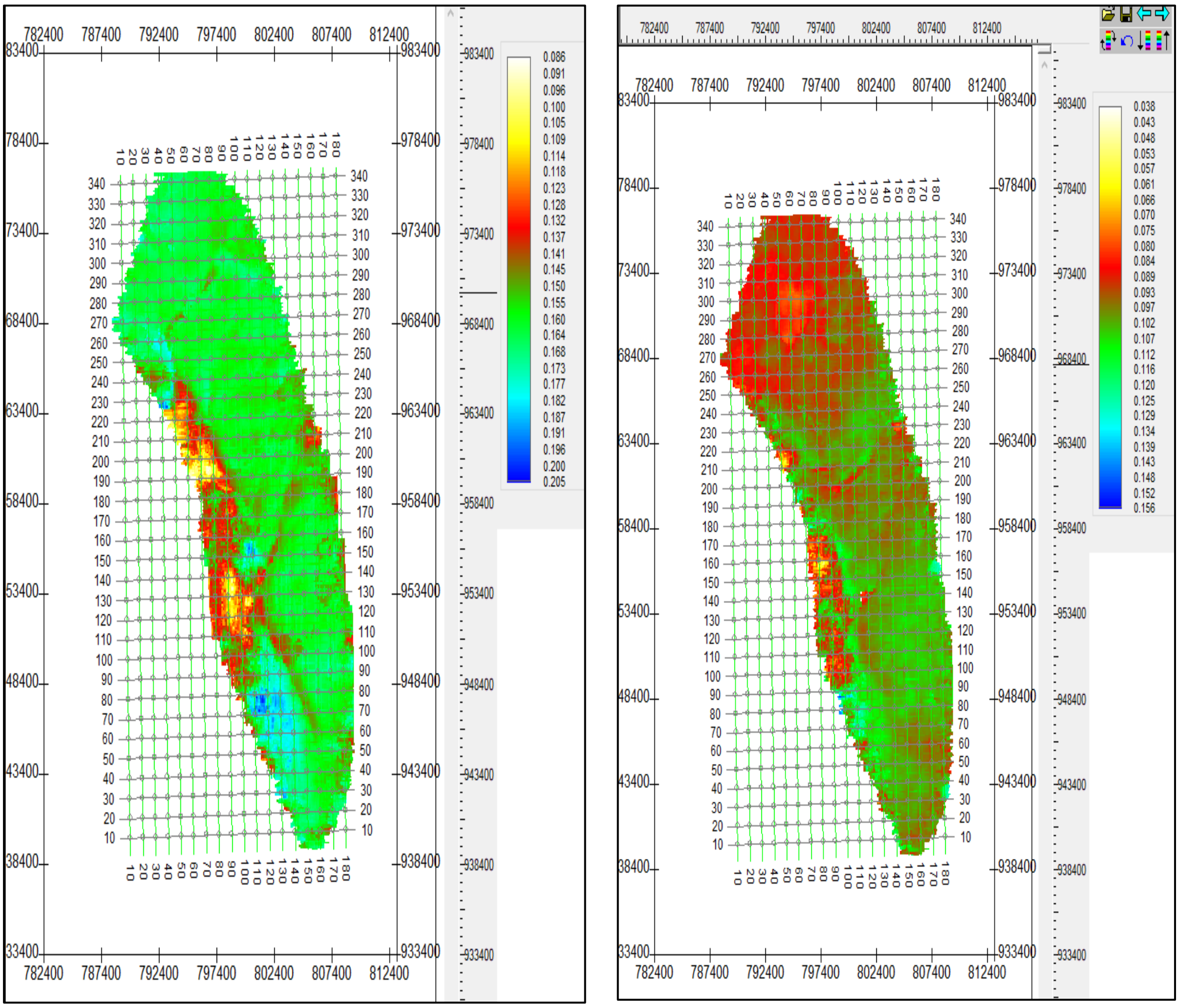


(A)



(B)

Fig. 29 (A) is the thickness map of basement, (B) is the thickness map of Horizon 2, both the maps are plotted on 2D seismic data.



(A) **(B)**

Fig. 30 (A) is the thickness map of basement (B) is the thickness map of Horizon 2, both the maps are plotted on 3D seismic data.

Importing of wells

Here we are importing three wells

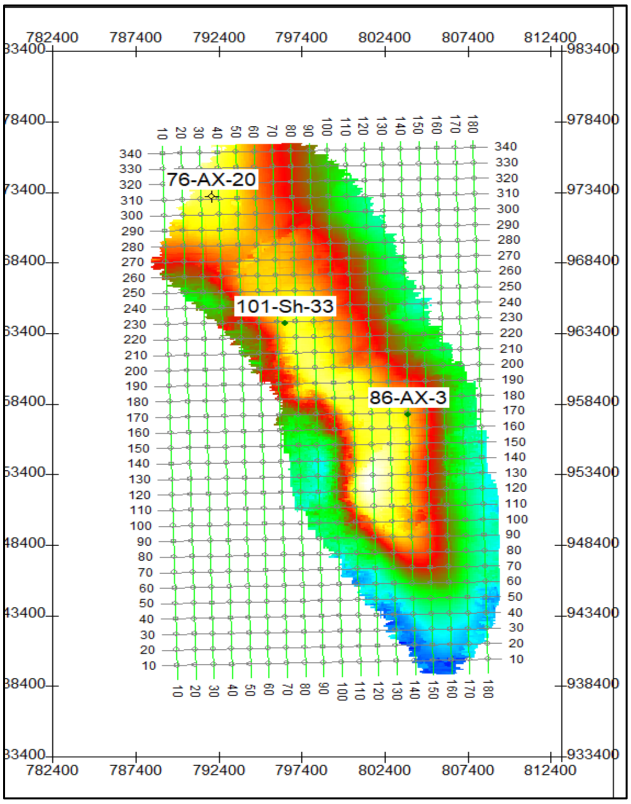
**Projection is set to - us state plane NAD27 (NAD27/Wyoming East Central) **

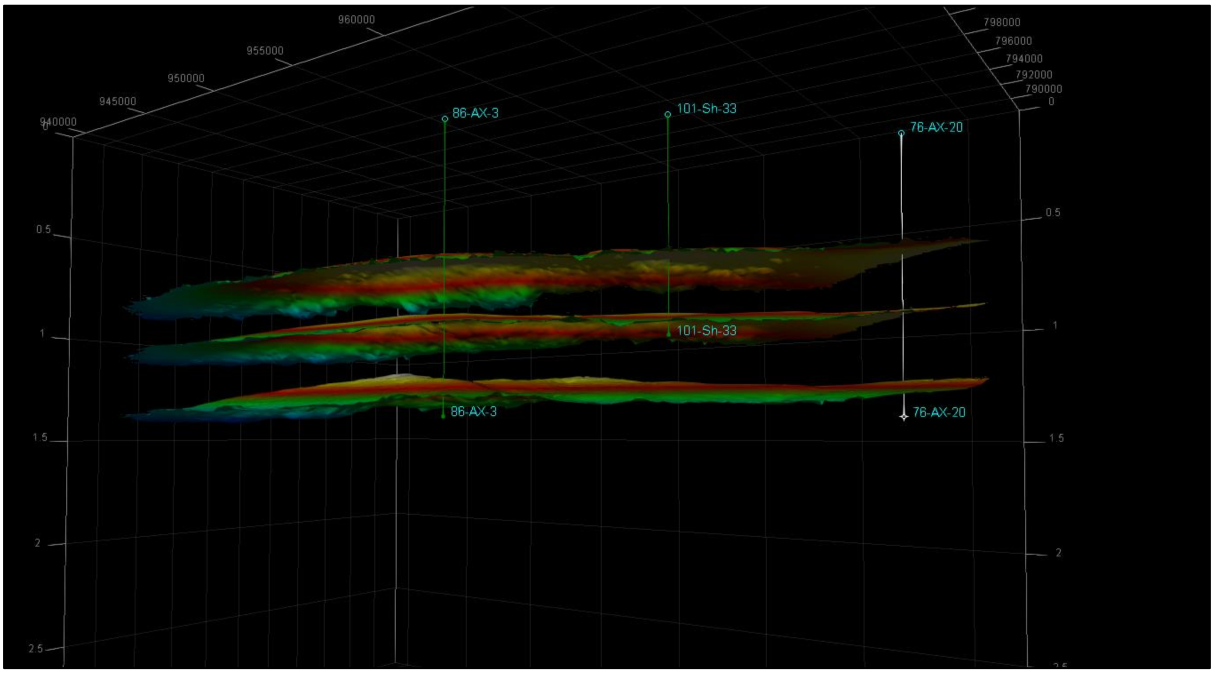
1. Name - 101-Sh-33
   UWI - 490251068700
   Longitude(X) - 796408.5 ft
   Latitude(Y) - 964135 ft
   Elevation KB – 5000 ft
   Total depth - 5759.77 ft
   Status - Oil Well

2. Name - 76-AX-20.
   UWI - 490251069200.
   Longitude(X) - 791992.7 ft.
   Latitude(Y) - 973113.4 ft.
   Elevation KB - 5062 ft.
   Total depth - 6055 ft.
   Status - Dry Hole.

3. Name - 86-AX-3.
   UWI - 490251109200.
   Longitude(X) - 803808.1 ft.
   Latitude(Y) - 957637.8 ft.
   Elevation KB - 5153 ft
   Total depth - 6146 ft
   Status - Oil Well

(A)





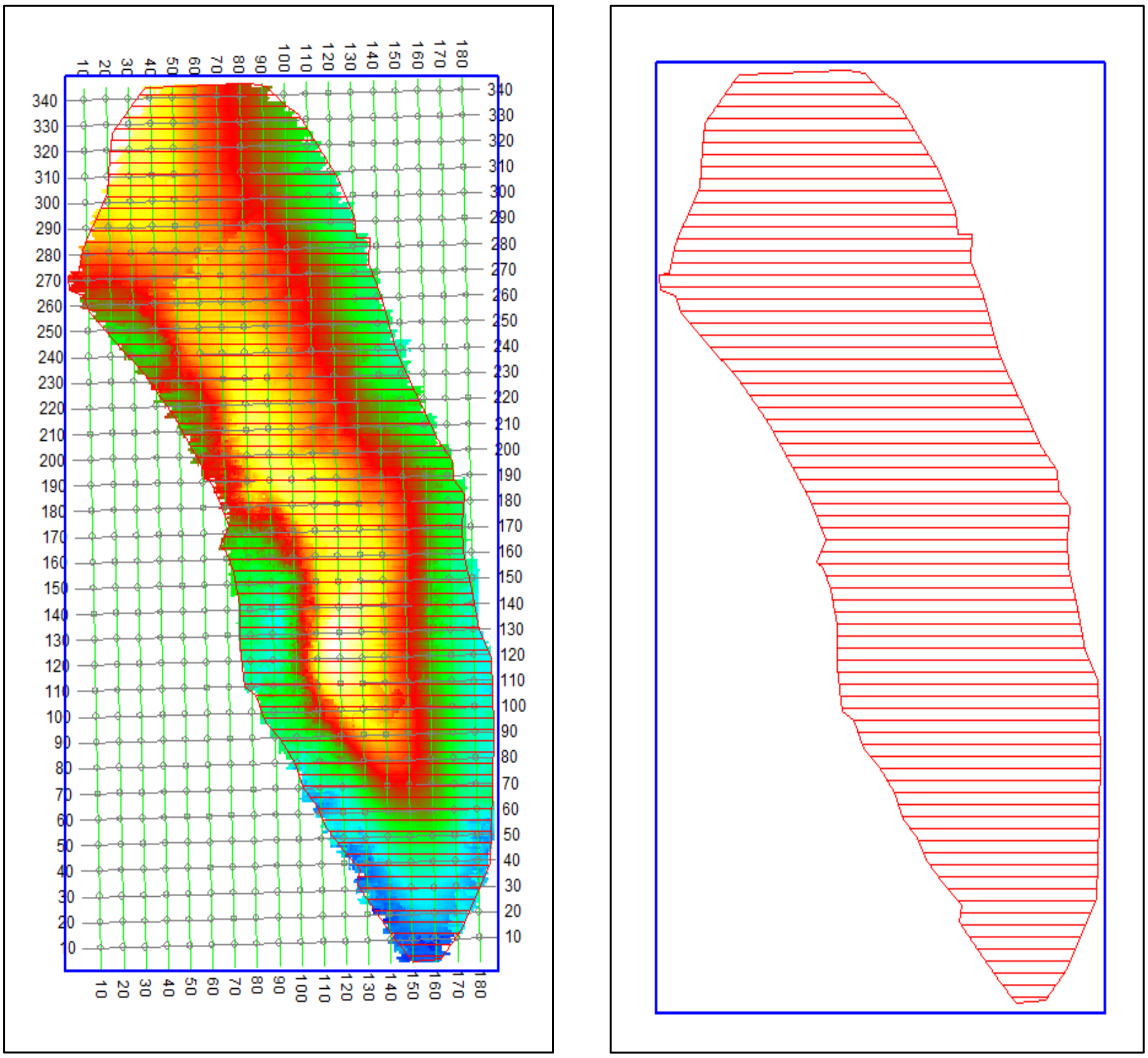
(B)

Fig. 31 (A) showing imported wells on the base map, (B) showing imported wells on the Horizons in 3D.

Polygons

Defining polygon is a process of setting limit to our data.

This polygon is of area 9,192,206 Acres



(A) **(B)**

Fig. 32 (A) is showing the defined polygon over the Horizon in base map, (B) is showing defined polygon only.

Geological structures

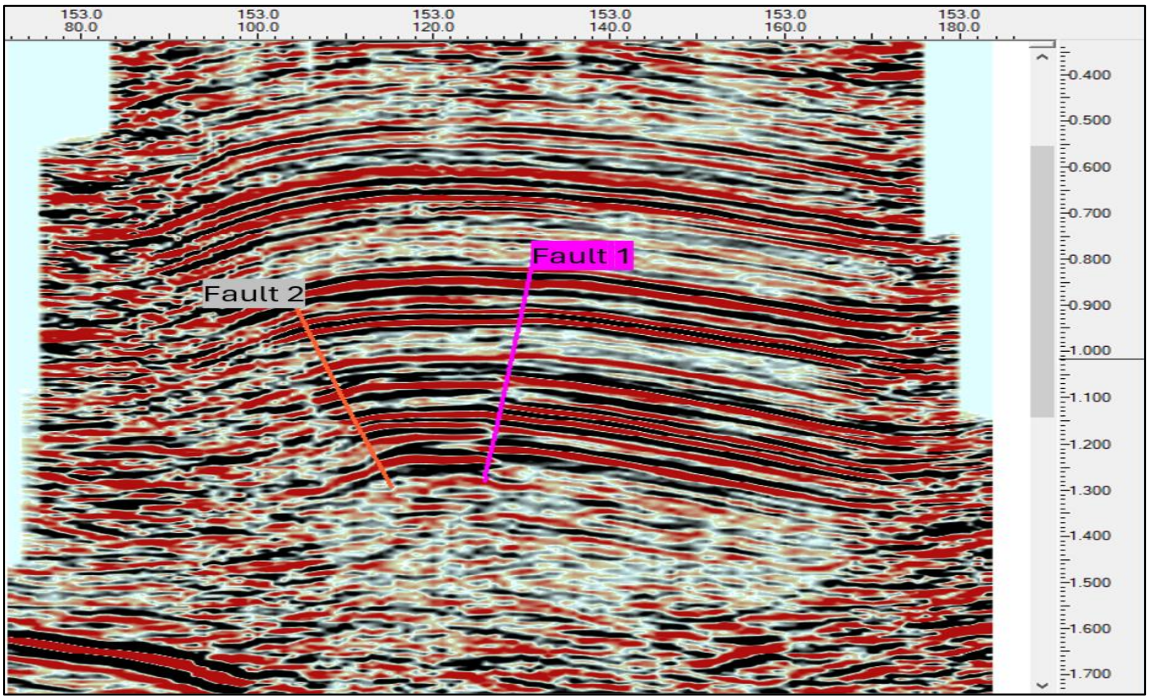


Fig. 33 showing Faults (Amplitude) 2D interpreted seismic section (inline 153) passing through the study area.

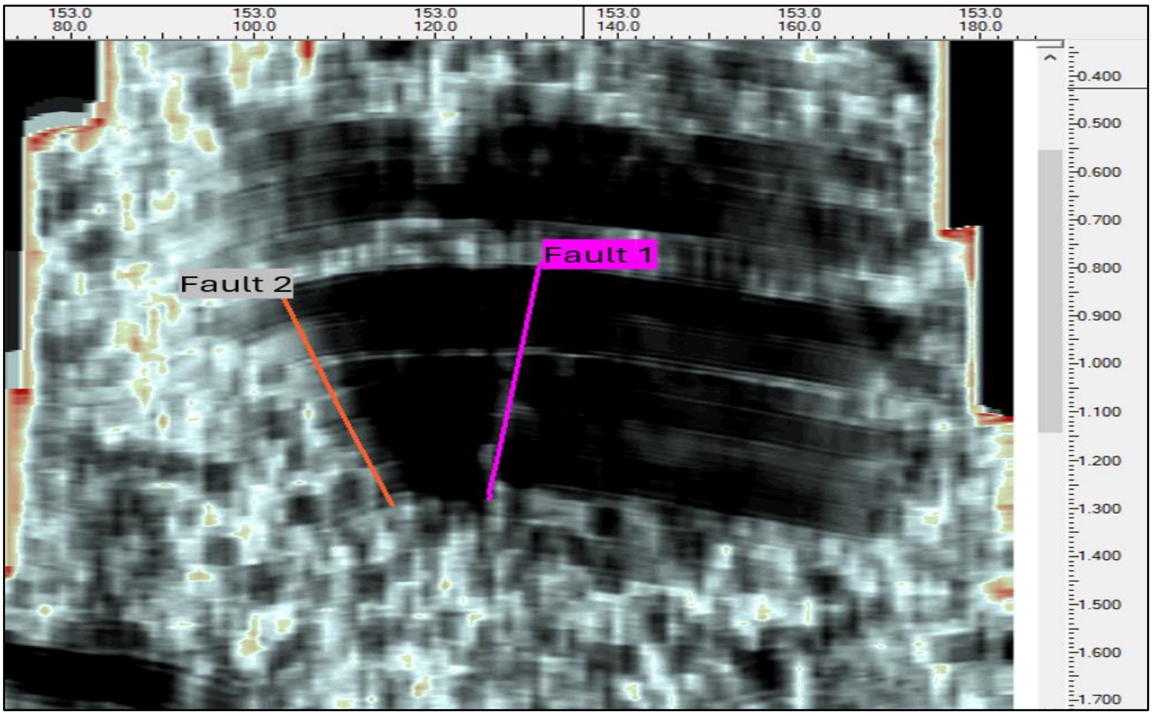


Fig. 34 showing Faults (coherency) 2D interpreted seismic section (inline 153) passing through the study area.

Converting horizons data type from time to depth from one of the imported wells, with the help of T-D chart

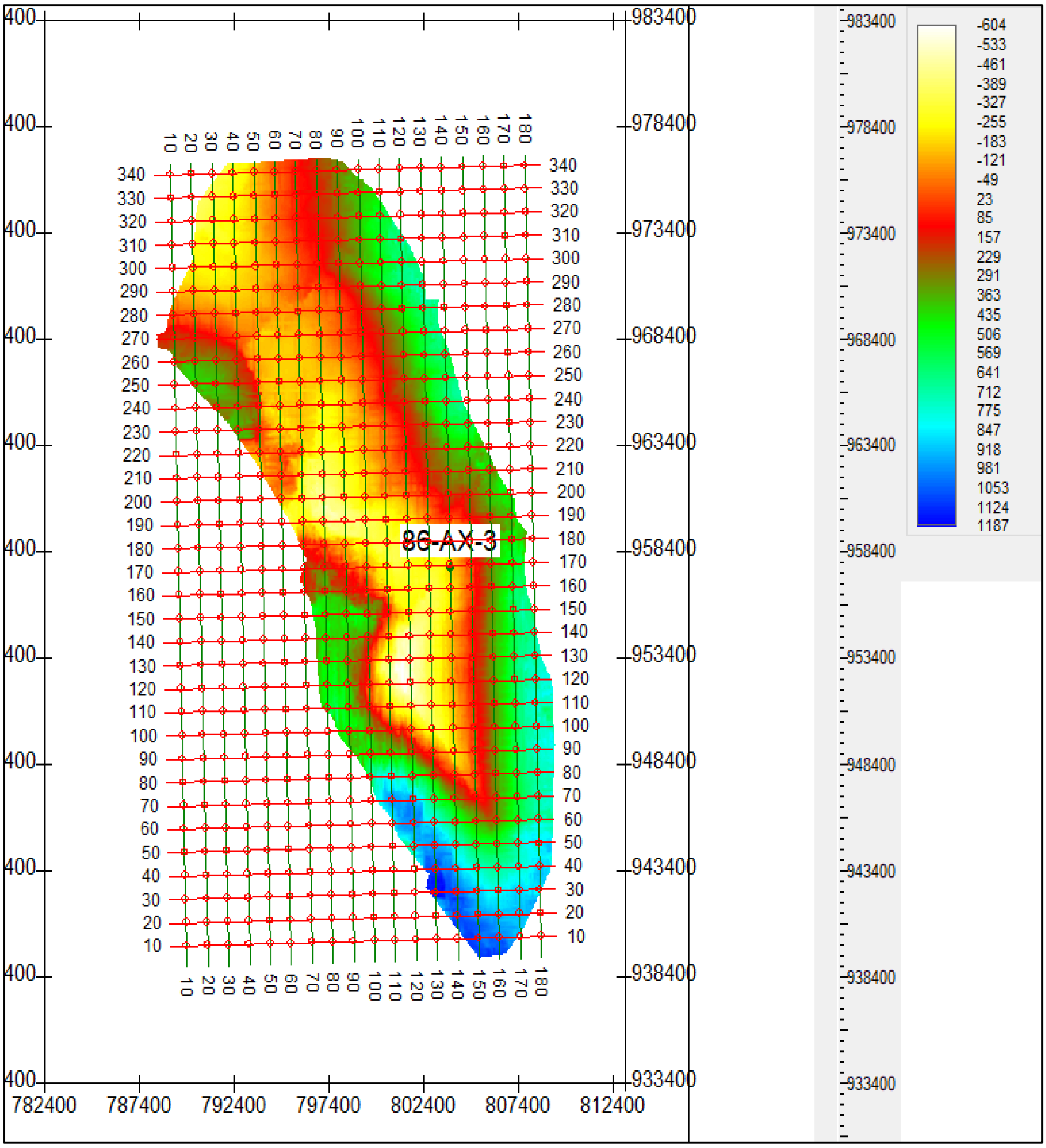


Fig. 35 showing the horizon in base map in depth data type where the color bar shows depth variation with respect to the well T-D chart of 86-AX-3 well.

Creating grids from converted horizons

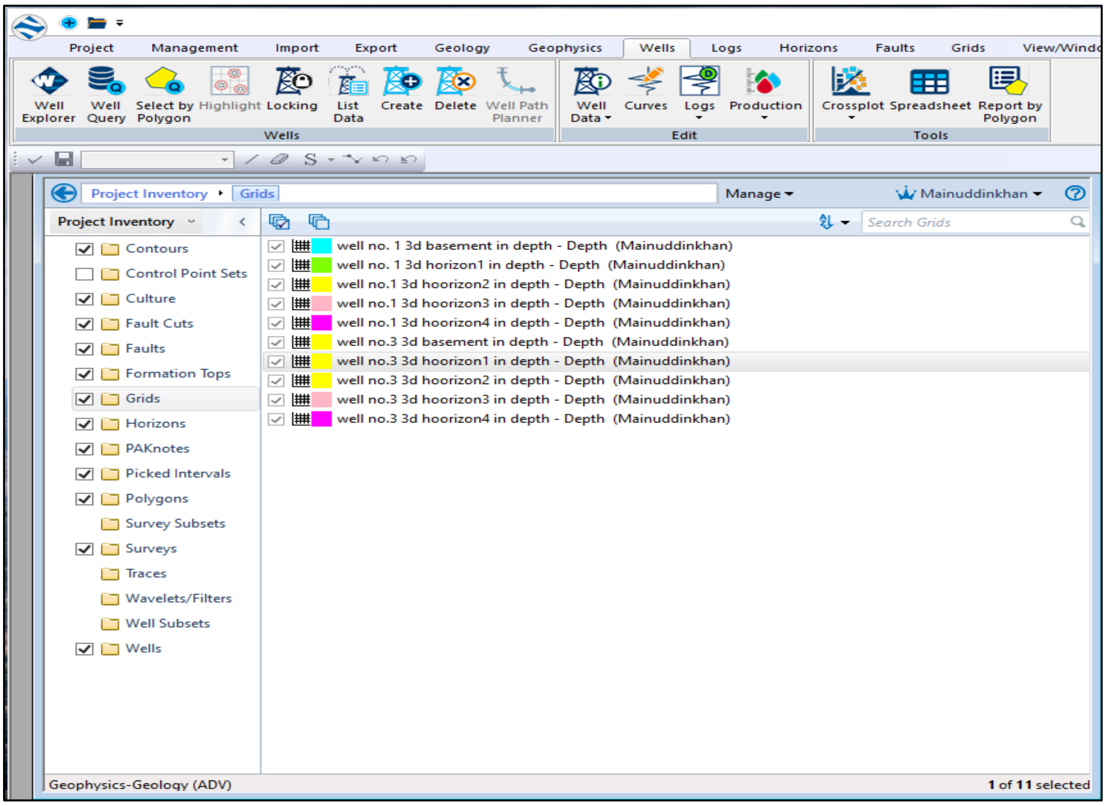


Fig. 36 showing the list of grids that have been created which will help in the calculation of volume.

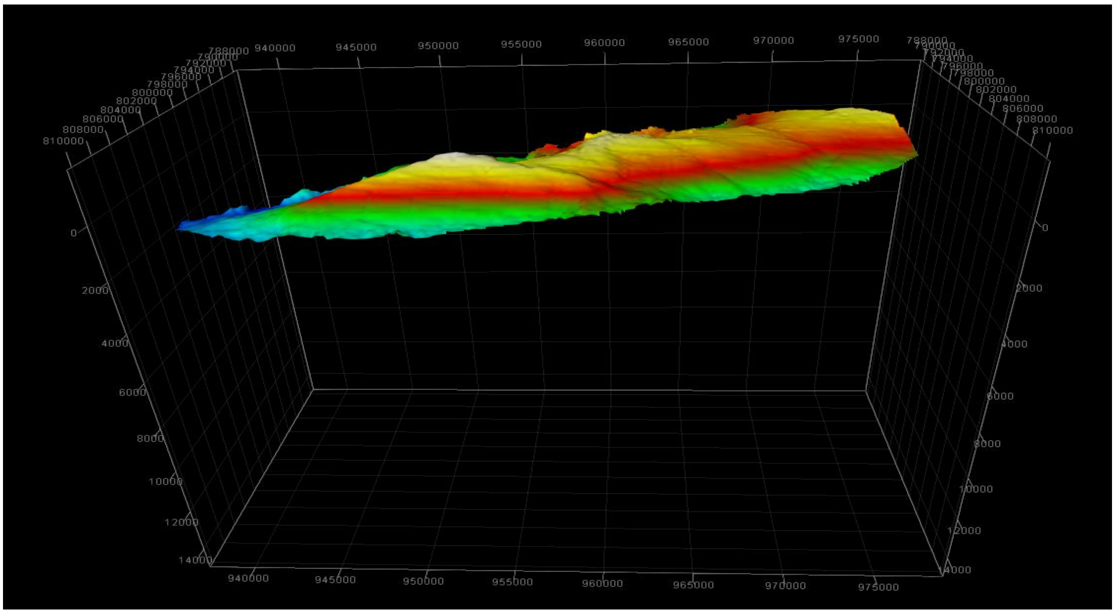


Fig. 37 showing one of the created grids in 3D.

Calculating volume from grids

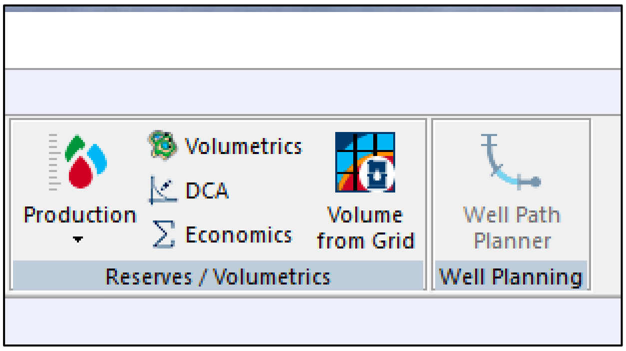


Fig. 38 showing the option from where we will be calculating the volume of horizon (as we have the converted horizons in depth and made grids. Also, we have defined area of horizon from the polygon).

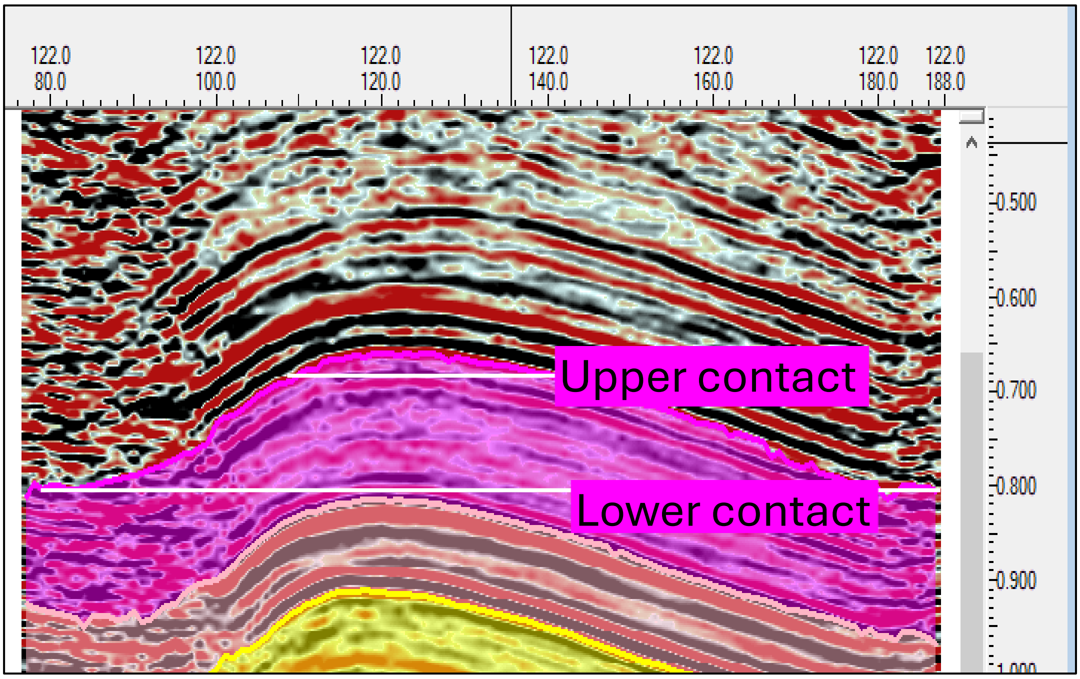


Fig. 39 Showing the type of structure we have in our seismic data.

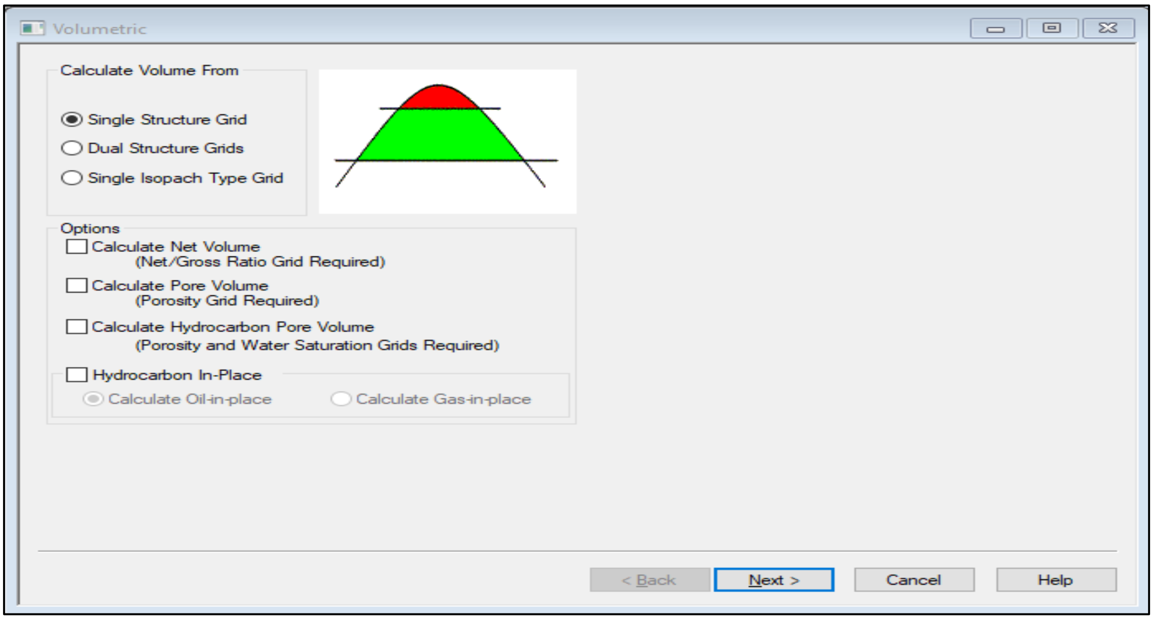


Fig. 40 **Here we select the single structure grid option because it matches our structure in the seismic section (see Fig. 36).**

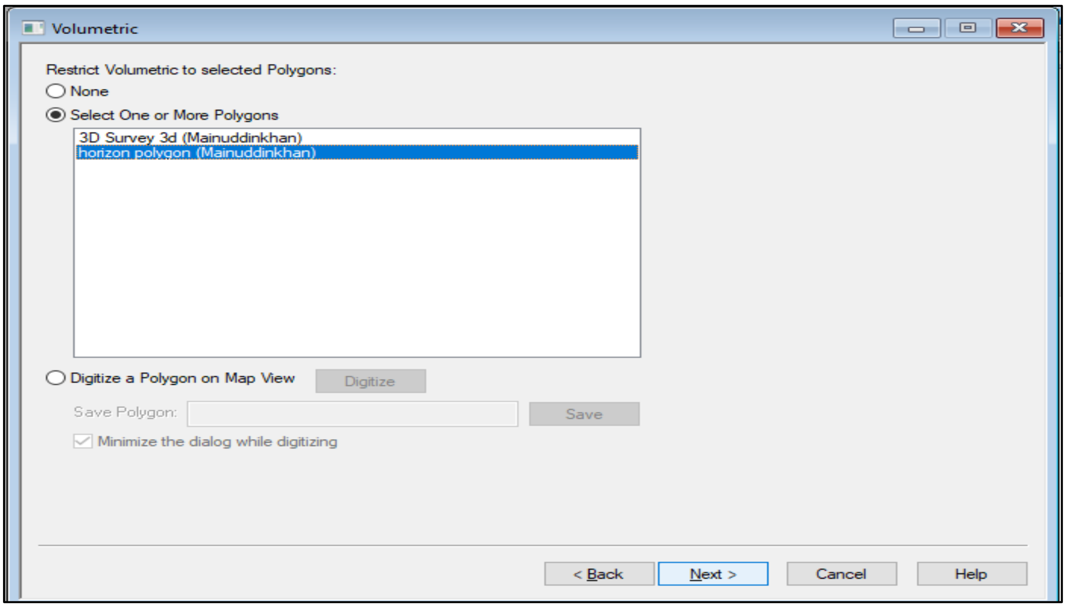


Fig. 41 **Here we select the defined polygon.**

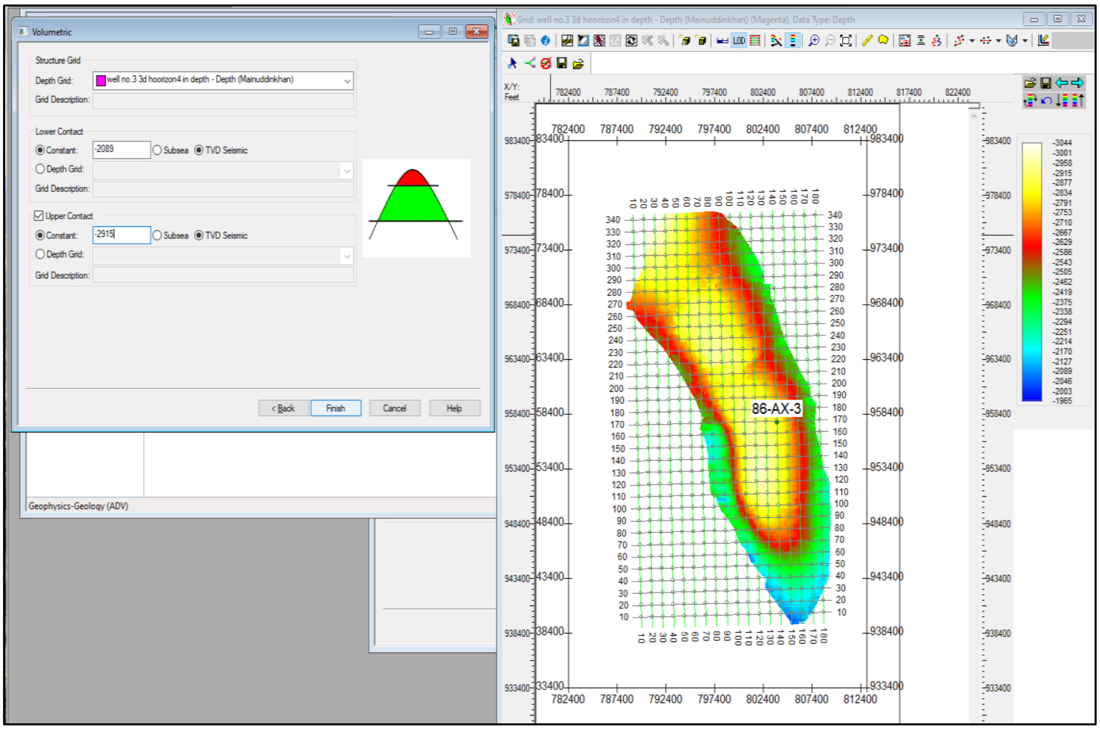


Fig. 42 Here we set the upper-lower contact of our horizon from the color bar showing depth variation.

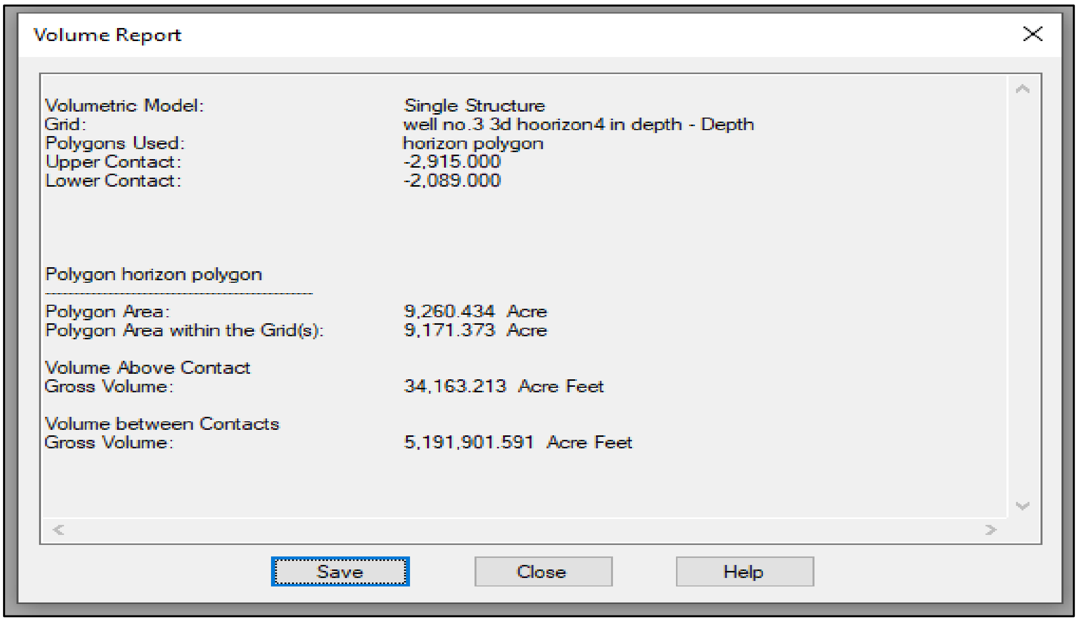


Fig. 43 Showing the volume report from all our defined parameters.

5. Conclusion

Seismic data interpretation is a fundamental process in petroleum exploration that allows for the detailed analysis and understanding of subsurface geological structures. By utilizing advanced techniques and technologies, such as seismic acquisition, processing, and visualization, geoscientists can accurately characterize subsurface formations. This process is essential for applications in hydrocarbon exploration and volume estimations. Modern tools and platforms like the HIS Kingdom software have significantly enhanced accuracy, efficiency, and collaboration in seismic data interpretation, enabling more informed decision-making and better risk management. Ultimately, seismic data interpretation plays a crucial role in exploring, managing and prospecting Earth's subsurface resources effectively.

Moreover, during this period of my internship at Rajiv Gandhi Institute of Petroleum Technology, I have developed good basics of seismic data and its types, volumetric methods, etc. Also, I feel very comfortable with the software I learned, and I am sure that whatever I learned during my internship will help me in my career in petroleum industry.

6. References

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