PROJECT REORT ON

"Basic well log interpretation and Pore pressure Prediction Studies"

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ABOUT BPRL

Bharat Petroleum entered the upstream sector in 2003 with an aim to provide partial supply security of crude and hedging of price risks and to become a vertically integrated oil company. A wholly owned subsidiary company of Bharat Petroleum, by the name Bharat PetroResources Limited (BPRL) was incorporated in October 2006. BPRL was set up with the objective of carrying out Exploration and Production activities considering the need for a focused approach in Exploration and Production activities and implementation of investment plans of Bharat Petroleum at a faster pace. The operations of BPRL are carried out through subsidiaries and joint ventures both, incorporated and unincorporated, in India and abroad. BPRL, currently, has participating interest (PI) in seventeen Blocks spread across six Countries. Out of seventeen blocks, seven blocks are located in India which were acquired under different rounds of New Exploration Licensing Policy (NELP) and ten blocks are located overseas. Most of the blocks are in advanced stages of exploration, appraisal and pre-development. The total area of these seventeen blocks is around 24,375 sq km of which approx 88% is offshore. BPRL has a wholly owned subsidiary company, BPRL International BV, in the Netherlands which in turn has three wholly owned subsidiary companies viz. BPRL Ventures BV, BPRL Ventures Mozambique BV, and BPRL Ventures Indonesia BV. BPRL Ventures BV has 50% stake in IBV Brasil Petroleo Limitada, which currently holds PI ranging from 20% to 40% in six blocks in offshore Brazil. BPRL Ventures Mozambique BV has PI of 10% in a block in Mozambique, and BPRL Ventures Indonesia BV holds PI of 12.5% in a block in Indonesia. Further, BPRL has a wholly owned subsidiary company, Bharat PetroResources JPDA Limited in India which holds a PI of 20% in Block-JPDA 06-103, in Timor Leste. The PIs in Blocks in Brazil, Mozambique, Indonesia, Timor Leste are held through these subsidiaries. Further, the PI in respect of Blocks in India and Australia are held by BPRL alongwith other consortium members. BPRL and its consortia have a total of 22 discoveries in respect of Blocks held in five countries i.e. Brazil, Mozambique, Indonesia, Australia and in India. Recently, as concrete steps towards fulfilment of its aspiration for revenue generation, BPRL has signed definitive agreements to acquire stakes in companies in Russia which have Oil & gas producing assets in their portfolio. Subsequently, in May 2016, BPRL has formed another wholly owned subsidiary company i.e. BPRL International Singapore Pte Ltd in Singapore for enabling the acquisition of stakes in the Companies in Russia. Further, BPRL International Singapore Pte Ltd has formed two Joint Venture Companies as Special purpose vehicles (SPV) i.e. Taas India Pte Ltd and Vankor India Pte Ltd in May 2016 alongwith Oil India Ltd and Indian Oil Corporation Ltd with BPRL International Singapore Pt Ltd.

SEISMIC DATA ACQUISITION

The purpose of acquiring and processing seismic data is to learn something about the Earth's interior. Our first step is to conduct data acquisition designed for the problem, our second step to use data processing to identify and enhance the desired signal, and our third step to conduct data interpretations based on the processed data. The processes of data acquisition, processing and interpretation are interconnected.

Acquisition is the process of collecting, bringing and gathering seismic field data. Collection of data requires an energy source to generate waves and sensors to receive those waves from different reflecting events of subsurface.

After data acquisition and before data processing, we need to conduct the process of data quality control, or **QC**. This involves checking survey geometry, data format, and quality and quantity of data is satisfactory for our study objectives.

After data interpretation, we conduct seismic modelling using the interpreted model and the real data geometry to generate predictions to compare with the real measurements.

Seismic Waves

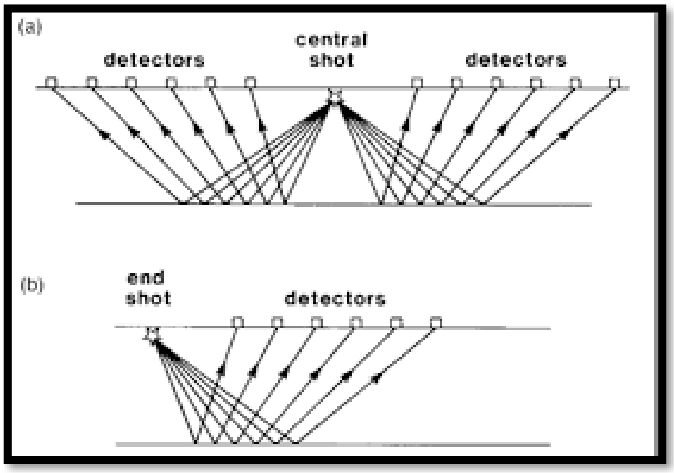
The seismic-reflection and -refraction methods in near-surface geophysical investigations are based on the introduction of mechanical energy into the subsurface using an active Source and the recording, typically using surface geophones, of the resulting mechanical Response.

The propagation of mechanical energy into the subsurface consists, to a large part, of elastic waves. The essential property of an elastic body is that it returns instantaneously to its original pre-deformed state with the removal of a mechanical force that changed its size and/or shape. A delayed return to the original state is termed viscoelasticity. Any permanent deformation, such as ductile deformation or brittle failure, is a measure of the inelasticity of the body.

Some assumptions are made such as the individual layers of rock are homogeneous and isotropic (for sake of mathematical simplicity). When seismic energy is released from a point near the surface of a homogeneous medium part of the energy propagates through body known as Body waves. The remaining part of seismic energy spreads out over the surface as surface waves.

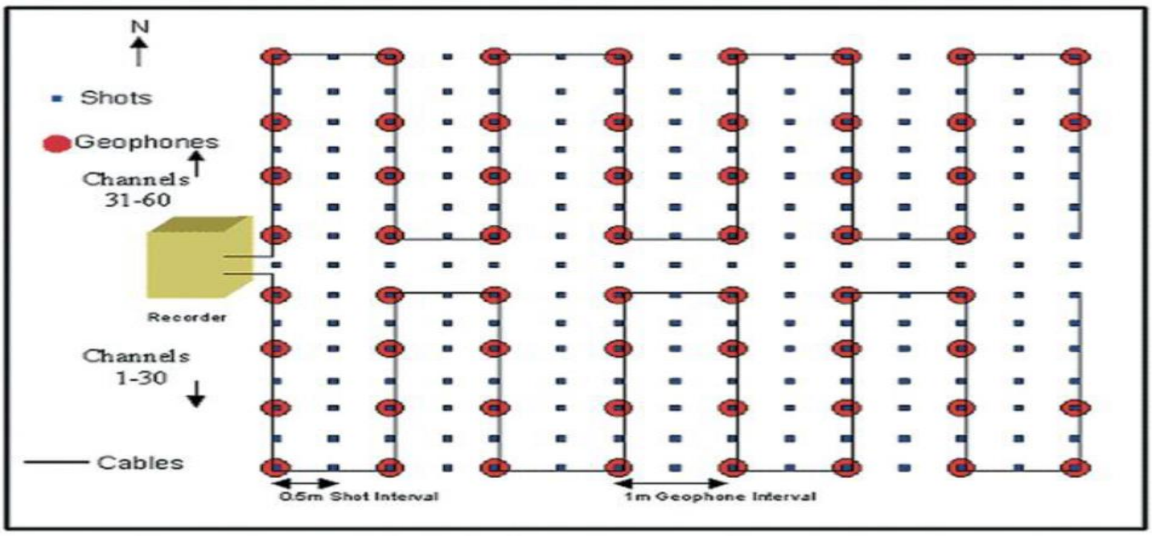
2-D seismic Survey

1. **Split-spread Survey**: It is the type of 2D reflection seismic survey, in which there is series of receiver at both side of the shot. This survey is preferred in steeply dipping area.
2. **End-on Survey:** In this kind of survey, source is placed on one end and the receivers on the other. This survey is preferred in horizontal to low dipping area.

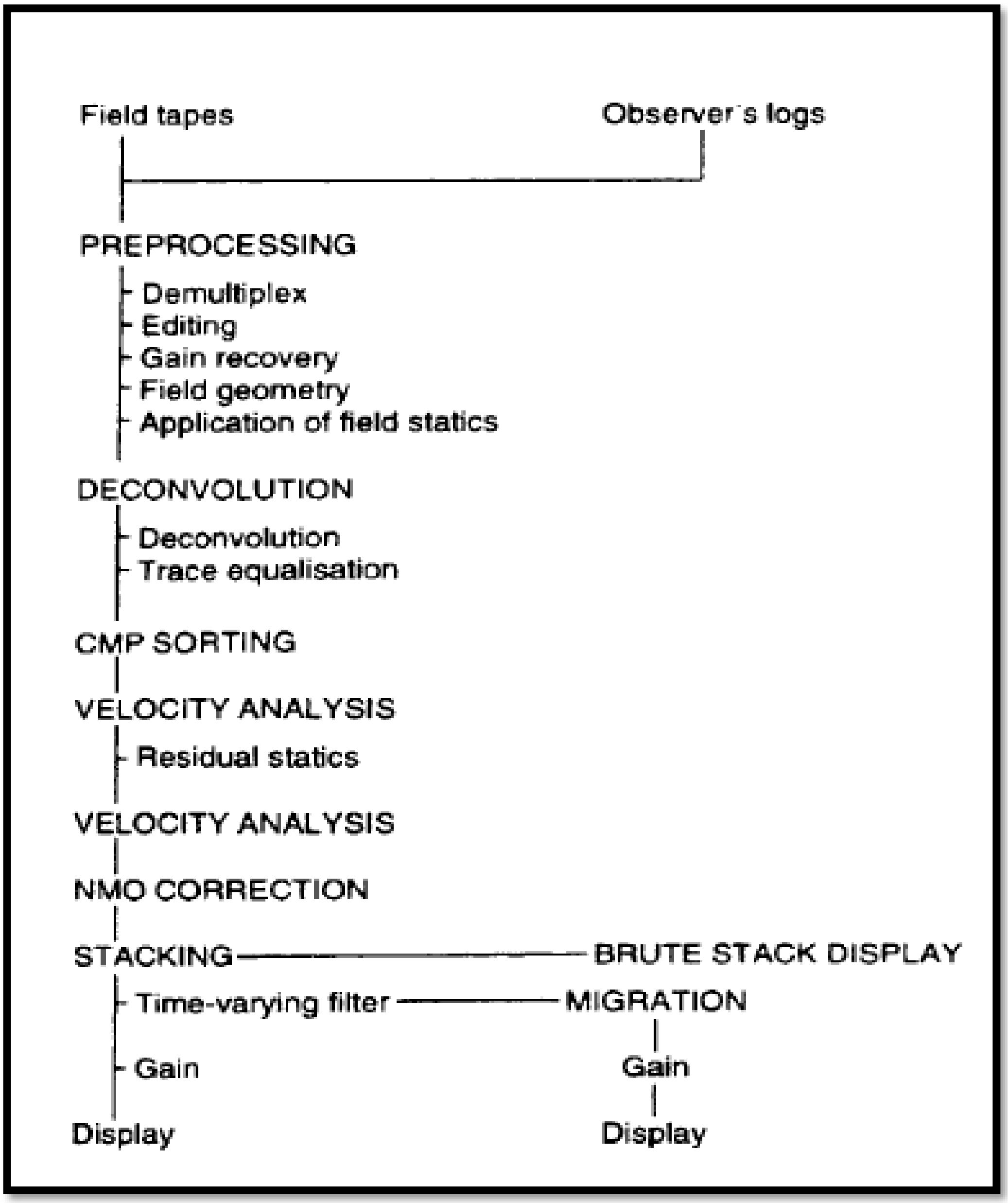


3-D Seismic Survey

This is the reflection seismic survey, in which sound source and receivers are spread over an area and with time the source is changed. The resultant product can be thought of as a cube of CDP stacked reflections. 3-D surveys are more expensive to acquire and are usually used in the later stages of exploration to provide more detailed information about the exploration target.



SEISMIC DATA PROCESSING



Signals received from detectors are digitized at small increments in time, known as the sampling interval. The recorder stores data in multiplexed time sequential form, where the record contains the first sample from each trace (trace 1, sample 1; then trace 2, sample 1; trace 3, sample 1; etc.). While this is convenient for recording purposes it is not so for processing. Consequently, the order of samples is changed by demultiplexing from time sequential order to trace sequential order to trace sequential order (trace 1, all samples in order; trace 2, all samples in order; etc.). The recognized format of demultiplexed data is SEG-Y, which is supposed to be universally compatible.

Once into trace-sequential format, the traces recorded from a single shot can be displayed as a common shot gather, for example. Traces pertaining to the same midpoint on a reflector can be collated as a common midpoint gather. Traces recorded at the same receiver but from different shot locations can be collated as common receiver gathers.

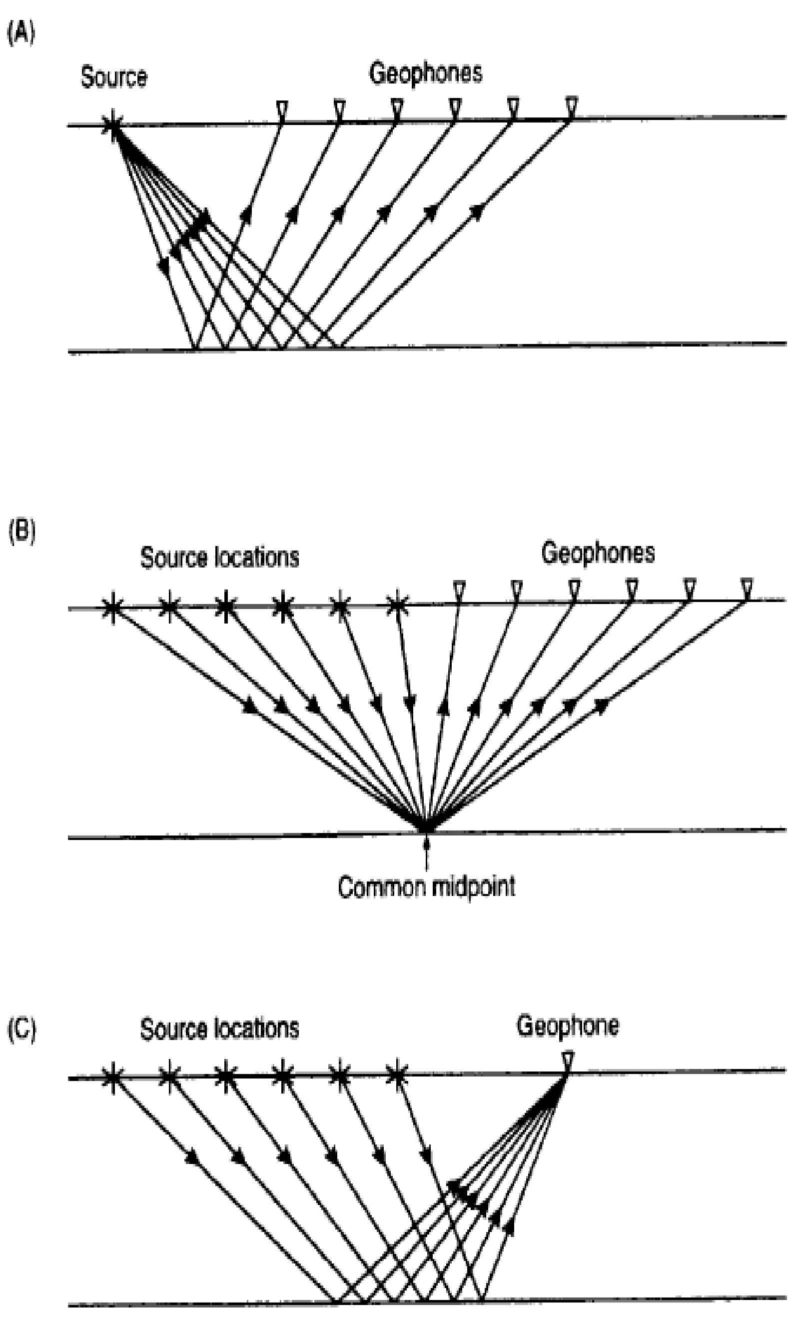


Figure 6.18 Layouts for (A) a common-shot gather; (B) a common midpoint gather; and (C) a common receiver gather

BASIC STEPS OF SEISMIC DATA PROCESSING

Geometry	On Pre stack data
Editing	On Pre stack data
Amplitude Recovery & Balancing	On Pre / Post stack data
Deconvolution	On Pre / Post stack data
Statics	On Pre stack data
Noise Attenuation	On Pre / Post stack data
Velocity Analysis	On Pre stack data
Stacking	On Pre stack data
Migration	On Pre / Post stack data
Visualization	On Post stack data

Convolution and deconvolution:

An initial waveform (W) propagating into the ground is filtered by layers with different acoustic impedances (which forms reflectivity series denoted by R) through which the signal passes, resulting in a modified waveform (S) observed on a seismogram. This convolution process is denoted by S=W*R, where * represents the process of convolution. The seismic method generates a waveform whose initial shape should be known and the resulting seismogram S is measured. The only unknown is R. In order to unravel the seismogram to obtain this time series of ground properties, the seismogram needs to be 'deconvolved'.

Deconvolution is an analytical procedure to remove the effects of previous filtering such as that arising from convolution.

There are number of different deconvolution processes:

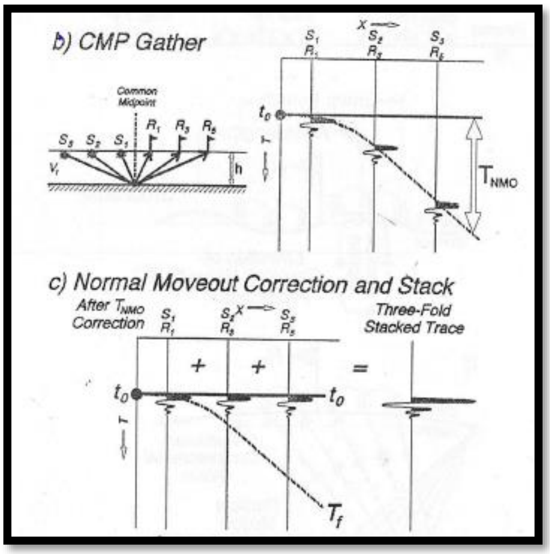
1. Dereverberation or deringing
2. Deghosting
3. Whitening (trace equalization)

The effect of each of the three processes described above is to shorten the pulse length on the processed seismograms, thereby improving the vertical resolution. The ultimate objective, which cannot as yet be achieved, is the compression of each waveform into a single spike (Dirac pulse) such that each reflection is also a simple spike. By so doing, it should be feasible to determine the reflectivity series that defines the subsurface geological stratigraphic sequences.

The type of filter that best achieves the reduction of wavelet to a spike is known as a wiener filter. This stage of deconvolution is referred to as spiking or whitening deconvolution.

Velocity analyses, NMO, stacking:

The most critical parameter in seismic surveying, irrespective of the type or scale of application, is the determination of seismic velocity. It is used in time to depth conversion.
The travel times associated with geophones at large offsets are greater than those at short offsets by virtue of the increased ray path distances. In case of horizontal reflector at a depth z below ground level, the difference in travel time at largest offset from normal incidence is known as the Normal move out (NMO).
After undergoing NMO, mute and static corrections, CMP traces are added together. The fold of stack refers to the number of seismic traces that are combined to make one stacked trace. Stacked traces are displayed side by side to make an unmigrated time section.



It is important to estimate the correct 'stacking' velocity. In the case of horizontal isotropic media, the stacking velocity is the same as the normal move-out velocity. However, when the reflector dips, it is important carry out dip move out to compensate for dip as well as the finite offset between source and detectors.

The volume of data acquired in modern seismic surveying necessitates an automated method of determining the correct stacking velocities. One such method is constant velocity gathers.

It is usual to display the velocity information as a scaled velocity semblance spectrum. Semblance is a measure of the coherence of the stacking process; when it equals 1 it implies perfect selection of the normal move out correction. Coherence is the measure of the degree of fit of a theoretically derived hyperbolic curve are a given travel time for a chosen RMS velocity.

Migration:

In two dimensions, a reflected event could have come from any position along a semicircle through the event, centered about the common source/receiver location. Migration spreads events along the potential locations on the semi-circle; events on adjacent traces will add in phase at the true position of the reflector, out of phase away from the true position. A migrated Time section thus attempts to move events to their true horizontal positions, relative to common source/receiver positions on the surface.

SEISMIC INTERPRETATION

Introduction

Simply defined, seismic interpretation is the science (and art) of inferring the geology at some depth from the processed seismic record. While modern multichannel data have increased the quantity and quality of interpretable data, proper interpretation still requires that the interpreter draw upon his or her geological understanding to pick the most likely interpretation from the many “valid” interpretations that the data allow.

The seismic record contains two basic elements for the interpreter to study. The first is the time of arrival of any reflection (or refraction) from a geological surface. The actual depth to this surface is a function of the thickness and velocity of overlying rock layers. The second is the shape of the reflection, which includes how strong the signal is, what frequencies it contains, and how the frequencies are distributed over the pulse. This information can often be used to support conclusions about the lithology and fluid content of the seismic reflector being evaluated.

The interpretation process can be subdivided into three interrelated categories: structural, stratigraphic, and lithologic. Structural seismic interpretation is directed toward the creation of structural maps of the subsurface from the observed three-dimensional configuration of arrival times. Seismic sequence stratigraphic interpretation relates the pattern of reflections observed to a model of cyclic episodes of deposition. The aim is to develop a chronostratigraphic framework of cyclic, genetically related strata. Lithology interpretation is aimed at determining changes in pore fluid, porosity, fracture intensity, lithology, and so on from seismic data. Direct hydrocarbon indicators (DHI, HCIs, bright spots, or dim-outs) are elements employed in this lithologic interpretation process.

What are my objectives?

An interpreter should clearly understand what conclusions are required from the data. Because so much information is available on the seismic, it is important to focus maximum attention on extracting the data pertinent to completing the objective task. Does the objective require evaluating the entire dataset from first sample to last, one stratigraphic sequence, or just one specific amplitude anomaly? This dictates what combination of the three basic interpretation types should be used, when the interpretation should be completed, and what supporting databases are required.

What are the regional tectonic, structural, and depositional trends?

It is important for the interpreter to have a basic understanding of what tectonic influences and depositional systems occur within the area of the seismic survey to be investigated. Although this preconceived earth model may be vague and incomplete, particularly in frontier basins, it provides interpreters with insight and constraints as to what types of structures, faulting, and stratigraphic geometries may exist. The interpretation of fault styles, structural geometries, and facies patterns must be consistent with regional tectonic forces and basin infilling.

What seismic patterns should I be looking for?

Perhaps the most common interpretational pitfall, and certainly one of the most dangerous, is the mapping of events, amplitude, or AVO changes without qualification as to what geological analogy they represent. To prevent this mistake, it is critical that all types of available geological data be gathered and merged with the seismic data. Key to this merging are well-constructed synthetic seismogram, vertical seismic profiling (VSP) data, and/or seismic models (for example synthetic seismograms, vertical seismic profile, and forward modelling of seismic data). This verifies the seismic signature of the target, the location of the mapping horizon, and the adequacy of the time-depth functions. Varying the synthetic seismogram or model parameters allows for the prediction of seismic responses for various lithologic and fluid types.

INTERPRETATION

The process of interpreting seismic data eventually comes down to putting pencil to paper or cursor to screen. After building an exploration analog by integrating the available geological data, it is advisable to scan the dataset to observe the basin setting, major structural components, and major stratigraphic components, such as reefs, shelf breaks, and major sequence boundaries. While scanning, major faults can be picked as a guide to establishing the dominant structural style.

After scanning, detailed mapping begins by working outward from a point where geological information exists, preferably a well location with a synthetic seismogram. The horizons selected for mapping and observed fault cuts are correlated from the well to the seismic. The interpreter then begins to pick these same events away from the well on the seismic, being careful to tie at all other well locations.

Critical to the interpretation process is comparing how horizons and faults tie at line intersections. Significant effort is expended correcting misties of faults, horizons, and sequence boundaries at every line intersection. In this regard, closing the interpretation in loops around the seismic grid is a particularly effective technique. On a workstation, a quick way to check for misties is a contour map. Misties will be evident by groups of unreasonable contours. In addition, workstations can be very helpful for working out the misties among varying vintages of two-dimensional data by applying time and phase shifts automatically.

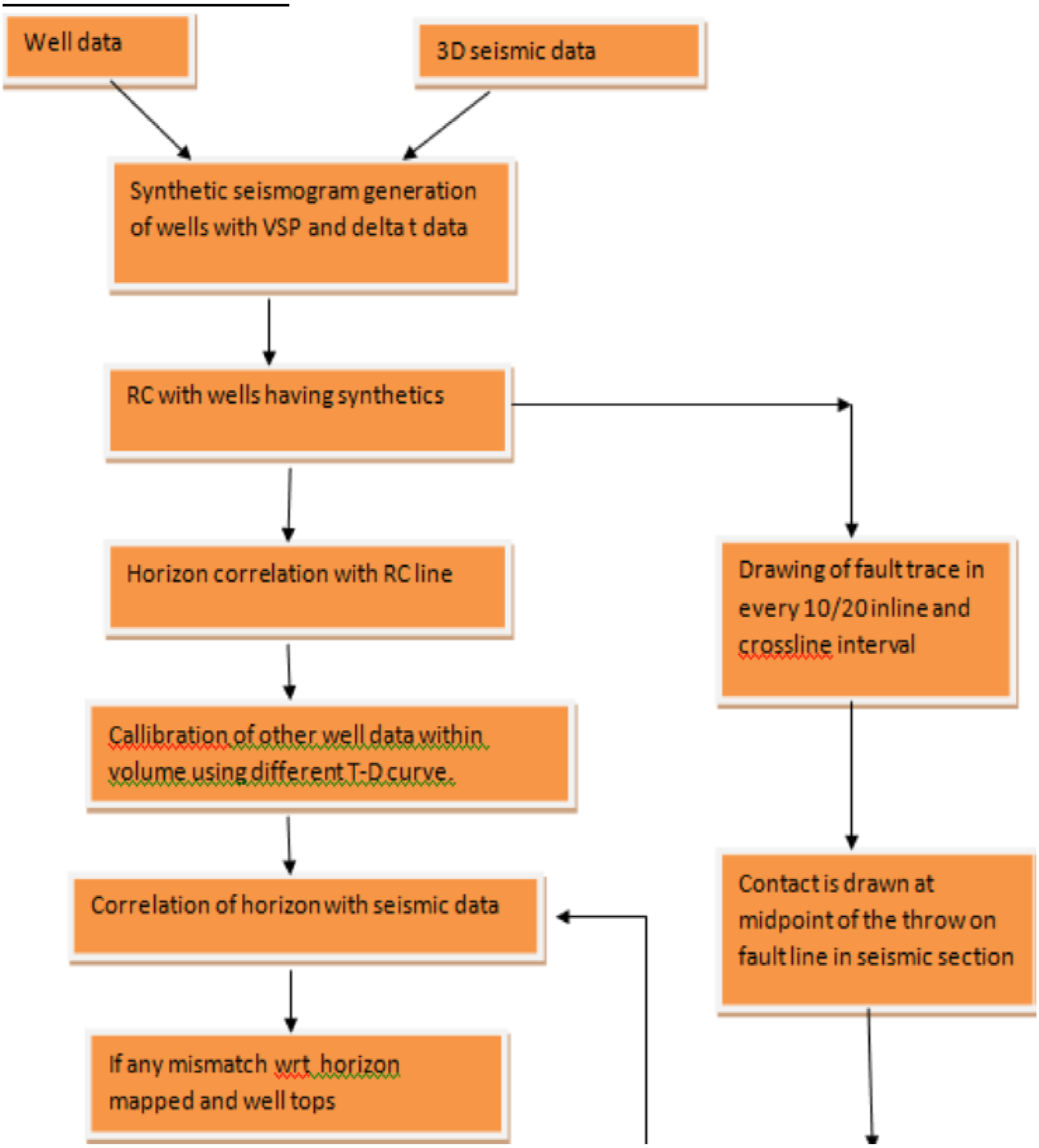
Tying all lines in both 2-D and 3-D data sets is the only way to reliably construct a three-dimensional model of the subsurface using two-dimensional images. Tying around data loops is also the best way to correlate from fault block to fault block. Otherwise, faults must be jumped using reflection character, sequence analysis, or additional well control.

After all lines are picked and tied, the results of the interpretation are then summarized and presented as maps. Basically, any observation that can be made using seismic data can be posted on a base map and mapped. Maps that are routinely made include

1. Time structure maps with faults
2. Depth structure maps
3. Seismic facies maps for reservoir, source, or seal analysis
4. Seismic amplitude maps for DHI analysis
5. Thickness maps inferred from seismic tuning analysis
6. Fault plane maps
7. Fault plane maps with cross-fault sand juxtaposition for seal analysis
8. Isochron or Isopach maps showing growth or thinning in a stratigraphic interval
9. Seismic velocity maps for lithology determination or depth conversion

In addition, many combinations of these maps can be made, such as seismic amplitude plotted on top of structure. The only limitations in constructing these maps are the imagination and skill of the interpreter.

The overall aim of seismic interpretation is to aid in constructing the most accurate earth model or reservoir description possible. This can best be accomplished when the seismic data are merged with Petro physical, geological, and engineering databases. While the process of interpreting seismic data is basically the same on paper or in a workstation environment, the workstation offers advantages in data management, manipulation, and display and it allows for a more convenient integration of other data types.



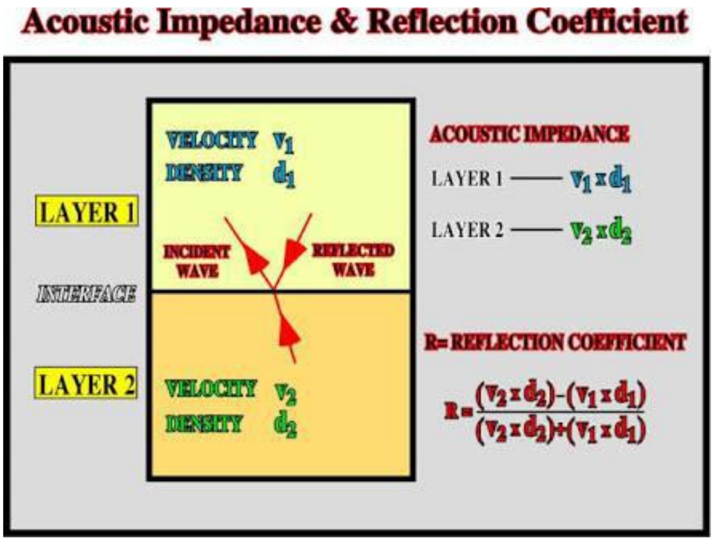
Acoustic Impedance

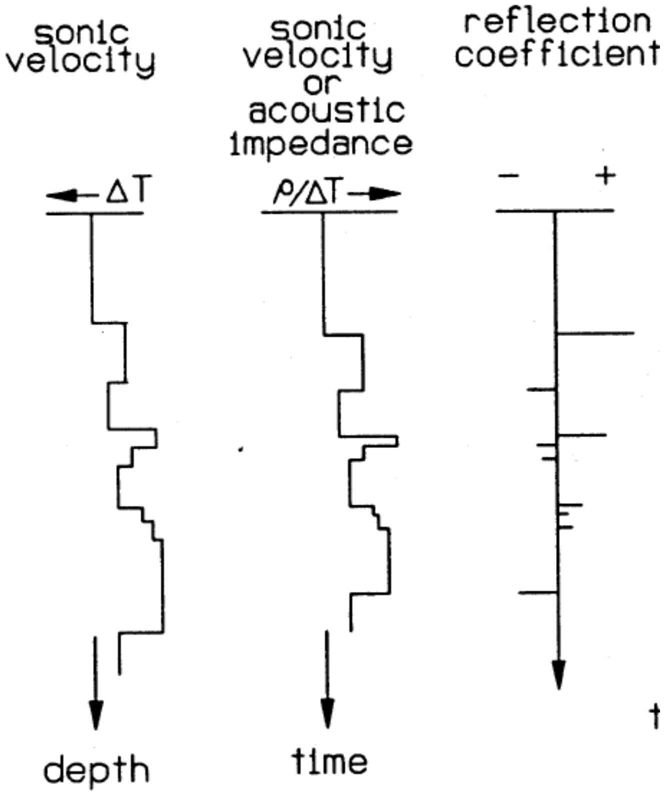
The product of density and seismic velocity which varies among different rock layers, commonly symbolized by Z.

It controls reflectivity of a rock layer. Any alteration in rock properties that causes change in ρ and/or can be the genesis of a seismic reflection event. Therefore, areal and vertical variations in seismic reflectivity can be used to infer spatial distributions of rock types and porosity trends.

Reflection Coefficient

Reflection coefficient determines the ratio of the reflected wave amplitude to the incident wave amplitude. Reflection coefficient may be negative or positive.





Concept of Depth Measurement

In the oil and gas industry, **depth in a well** is the measurement, for any point in that well, of the distance between a reference point and that point.

By extension, depth can refer to locations below, or distances from, a reference point or elevation, even when there is no well. In that sense, depth is a concept related to elevation, albeit in the opposite direction. Depth in a well is not necessarily measured vertically or along a straight line.

Because wells are not always drilled vertically, there may be two "depths" for every given point in a well bore:

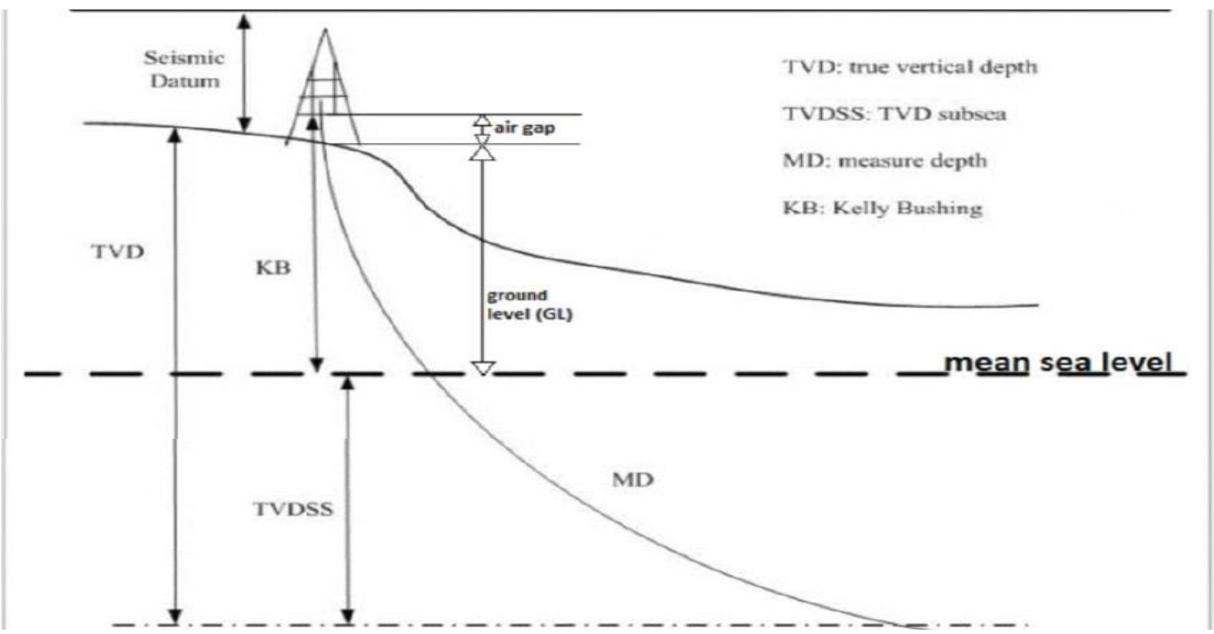
The **Measured Depth (MD):** measured along the path of the borehole.

The **true vertical depth (TVD)**: absolute vertical distance between the datum and the point in the wellbore.

In perfectly vertical wells, the TVD equals the MD; otherwise, the TVD is less than the MD measured from the same datum.

Common datum used is ground level (GL), Kelly bushing (KB) and mean sea level (MSL). Kelly Bushing is the sum of ground level (GL) and the air gap (distance of rig platform above ground).

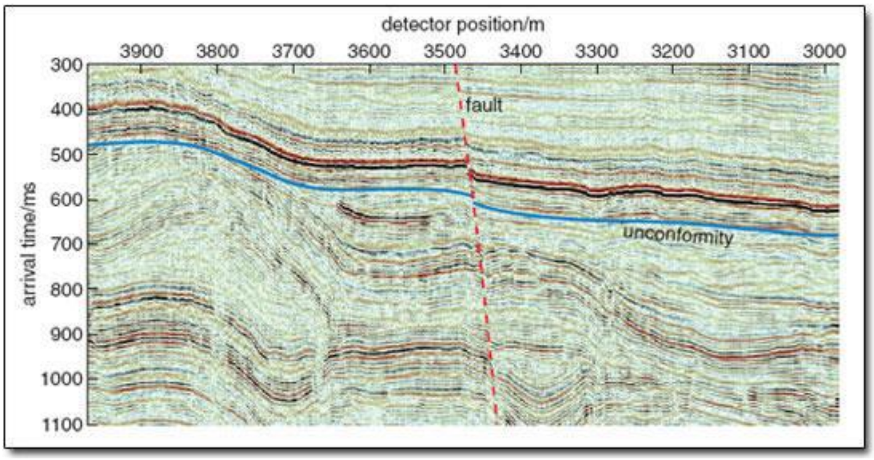
Following figure explains the depths:



Time domain to Depth Domain Conversion- Synthetic Seismogram:

Seismic Section

It is recorded in time domain. Vertical arriving time is expressed in millisecond in the ordinate. It is roughly equivalent to increasing depth.



To correlate the units of the zone of interest of seismic with ell log data time domain of seismic is converted into depth domain with the help of Synthetic Seismogram.

Synthetic Seismogram, commonly called a synthetic, is a direct one-dimensional model of acoustic energy travelling through the layers of the Earth.

The Synthetic Seismogram is generated by convolving the reflectivity derived from digitized acoustic and density logs with the wavelet derived from seismic data.

According to the model, the seismic trace s(t) is given by

$S(t)=W(t)* e(t)$ e(t) is reflectivity
W(t) is the source wavelet

A noise component n(t), if present is additive, hence the seismic trace becomes

$$\boxed{S(t) = W(t)* e(t)+ n(t)}$$

- Wavelet is chosen that has a frequency response and band width similar to that of the data. The synthetic wavelet is convolved with the reflection series for the entire well survey and generates a synthetic seismic trace. Care should be taken to choose a wavelet whose frequency is similar to a key interval of the seismic data to which it will be compared.

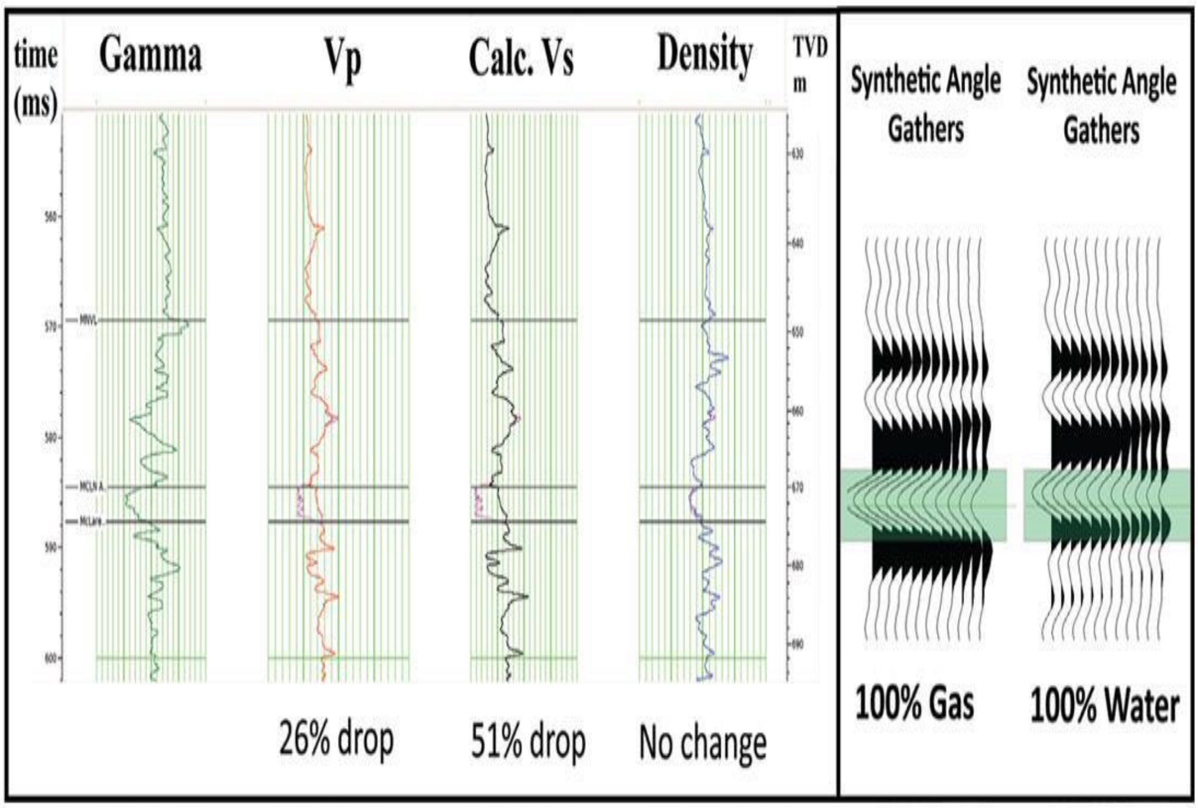
- A computer program computes the acoustic impedance log from the sonic velocities and the density data.

- The resulting acoustic impedance curve is then used by the program to compute reflection coefficients at each interface between contrasting velocities.

- The resulting trace is displayed at the same vertical scale as the seismic section for direct comparison. To improve the match with the seismic data, the synthetic seismic trace can be recomputed using different wavelets and filters used in its generation. Different wavelets have been convolved to produce additional synthetic seismogram.

- The synthetic trace can now be compared to a trace from the seismic line. This is commonly done by laying the synthetic directly on top of the appropriate seismic trace and adjusting the synthetic vertically until the two coincide. Through a trial-and-error process, it is determined at what point the synthetic trace "best fits" the seismic data.

- Variations in the quality of the well log data can have a major impact on the final synthetic display. If a VSP is available for a particular well, a synthetic is not needed. The VSP directly measures both time and depth to a formation of interest.

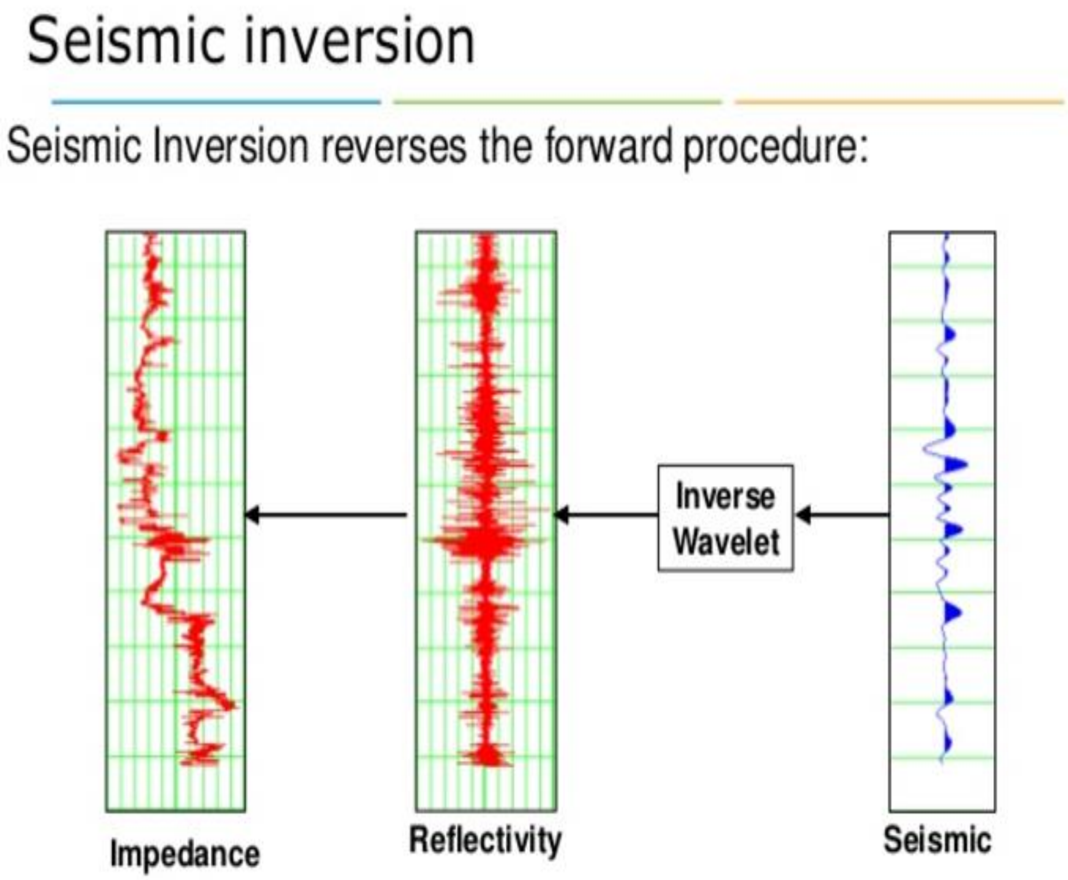


Seismic Inversion

Seismic Inversion, in Geophysics (primarily Oil and Gas exploration/development), is the process of transforming seismic reflection data into a quantitative rock-property description of a reservoir.

Seismic data may be inspected and interpreted on its own without inversion, but this does not provide the most detailed view of the subsurface and can be misleading in case of doublet. In case of doublet path difference between two consecutive interfaces is less than ¼ of the wavelength (λ). So that layer can't be resolved. In case of seismic inversion very thin bed can be resolved.

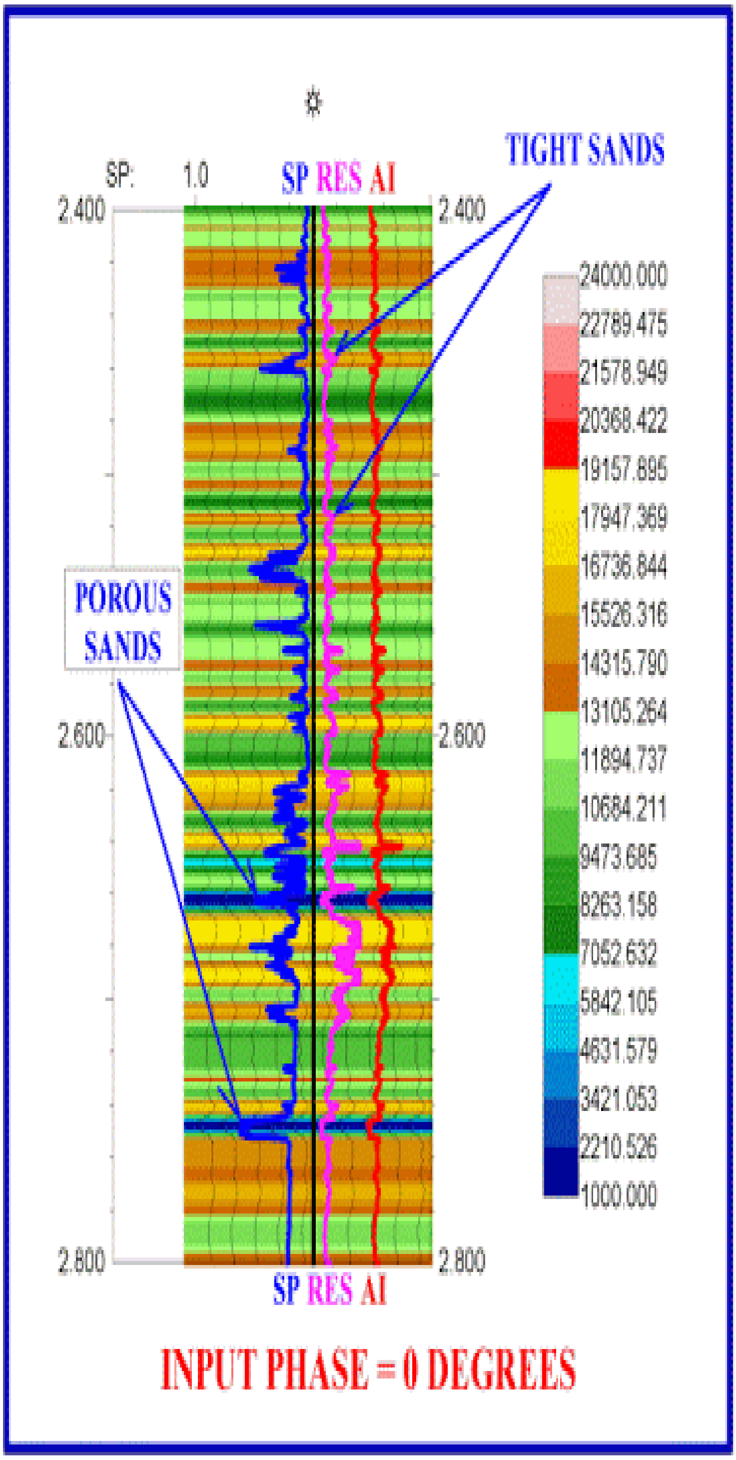
Accurate wavelet estimation is critical to the success of any seismic inversion. Wavelet amplitude and phase spectra are estimated statistically from either the seismic data alone or from a combination of seismic data and well control using wells with available sonic and density curves. After the seismic wavelet is estimated, it is used to estimate seismic reflection coefficients in the seismic inversion.



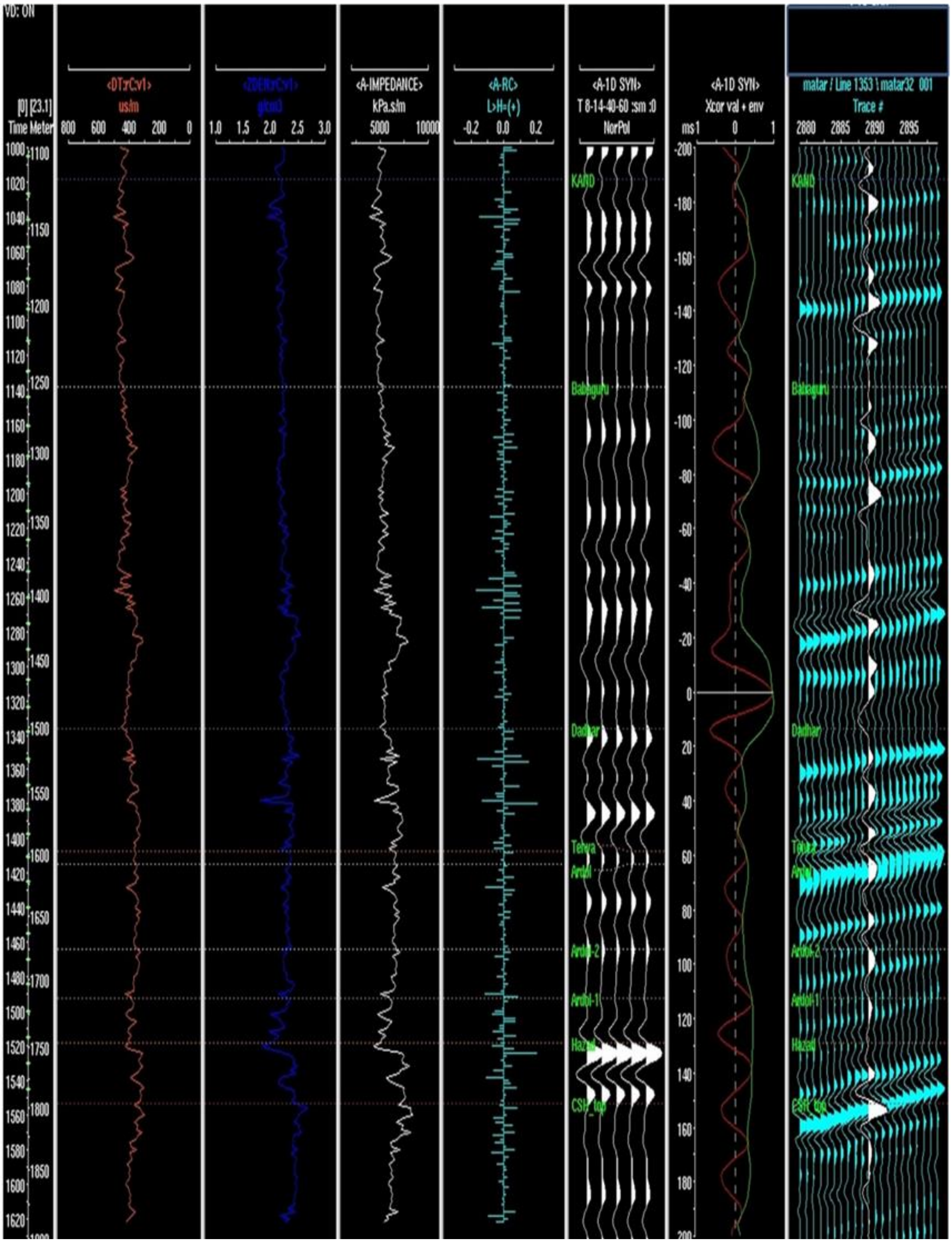
Because of its efficiency and quality, most oil and gas companies now use seismic inversion to increase the resolution and reliability of the data and to improve estimation of rock properties including porosity and net pay.

Seismic Inversion:

$$W * R = S$$
$$W_{-1} * (W * R) = W_{-1} * (S)$$
$$(W_{-1} * W) * R = W_{-1} * S$$
$$I * R = W_{-1} * S$$
$$R = W_{-1} * S$$



SYNTHETIC SEISMOGRAM OF WELL XYZ-12



SEQUENCE STRATIGRAPHY

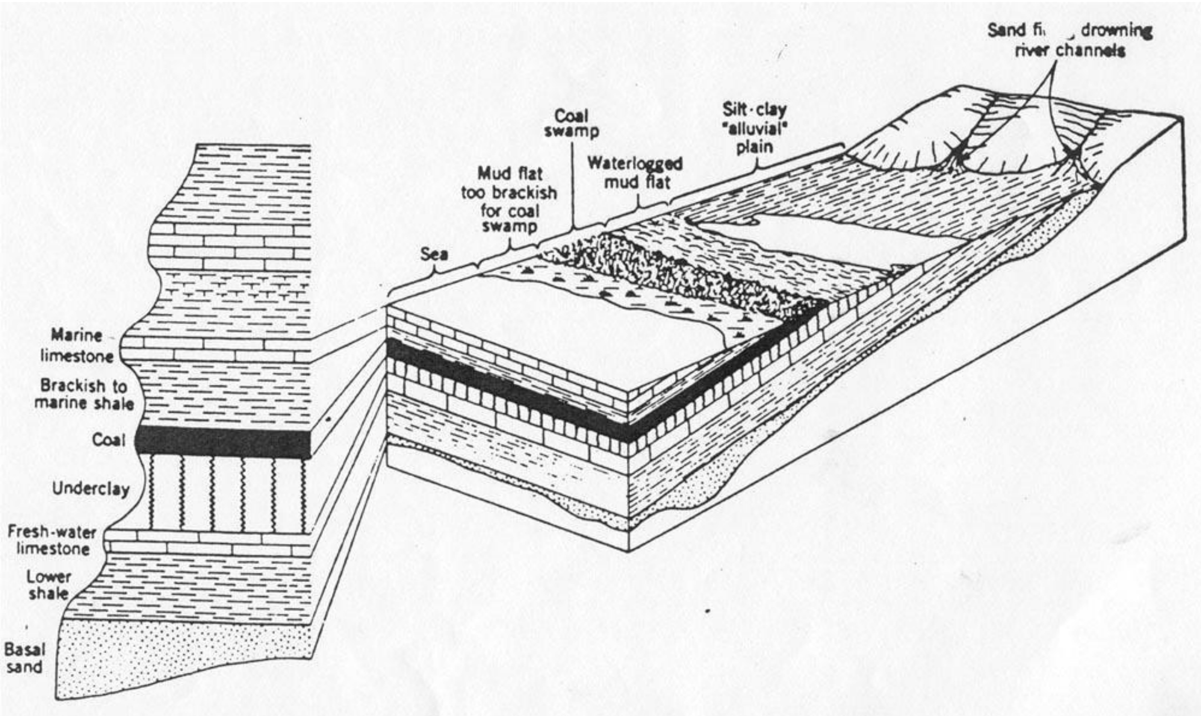
Sequence stratigraphy is a branch of geology that attempts to subdivide and link sedimentary deposits into unconformity bound units on a variety of scales and explain these stratigraphic units in terms of variations in sediment supply and variations in the rate of change in accommodation space (relative sea level, the combination of eustatic sea level and tectonic subsidence).The essence of the method is mapping of strata based on identification of surfaces which are assumed to represent time lines (e.g. subaerial unconformities, maximum flooding surfaces), and therefore placing stratigraphy in chronostratigraphic framework. Sequence stratigraphy is a useful alternative to a lithostratigraphic approach, which emphasizes similarity of the lithology of rock units rather than time significance.

Sequence stratigraphy deals with genetically related sedimentary strata bounded by unconformities.

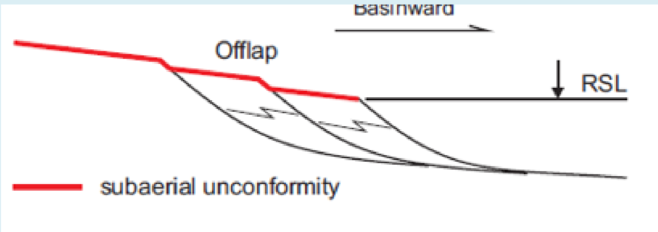
The "sequence" part of the name refers to cyclic sedimentary deposits. Stratigraphy is the geologic knowledge about the processes by which sedimentary deposits form and how those deposits change through time and space on the Earth's surface.

Facies Analysis and Walther's Law

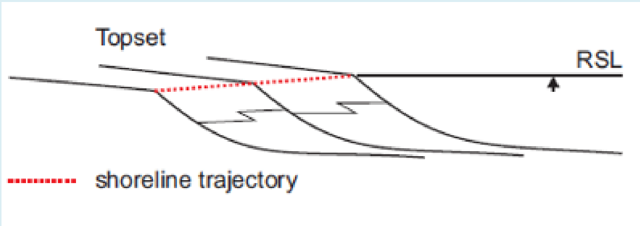
- "It is a basic statement of far reaching significance that only those facies and facies areas can be super imposed primarily that can be observed beside each other at the present time"



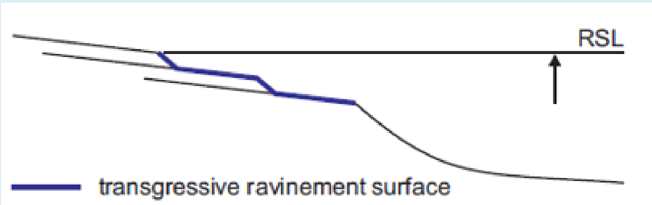
STRATAL PATTERNS



- **PROGRADATION**

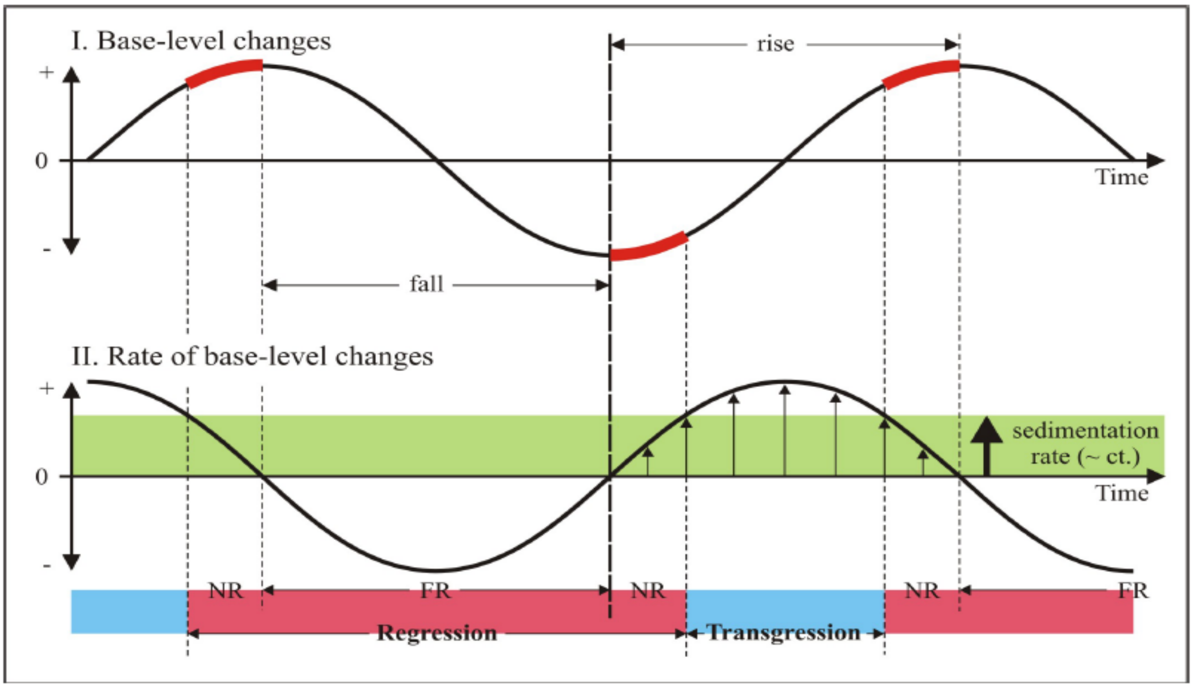


- **AGGRADATION**



- **RETROGRADATION**

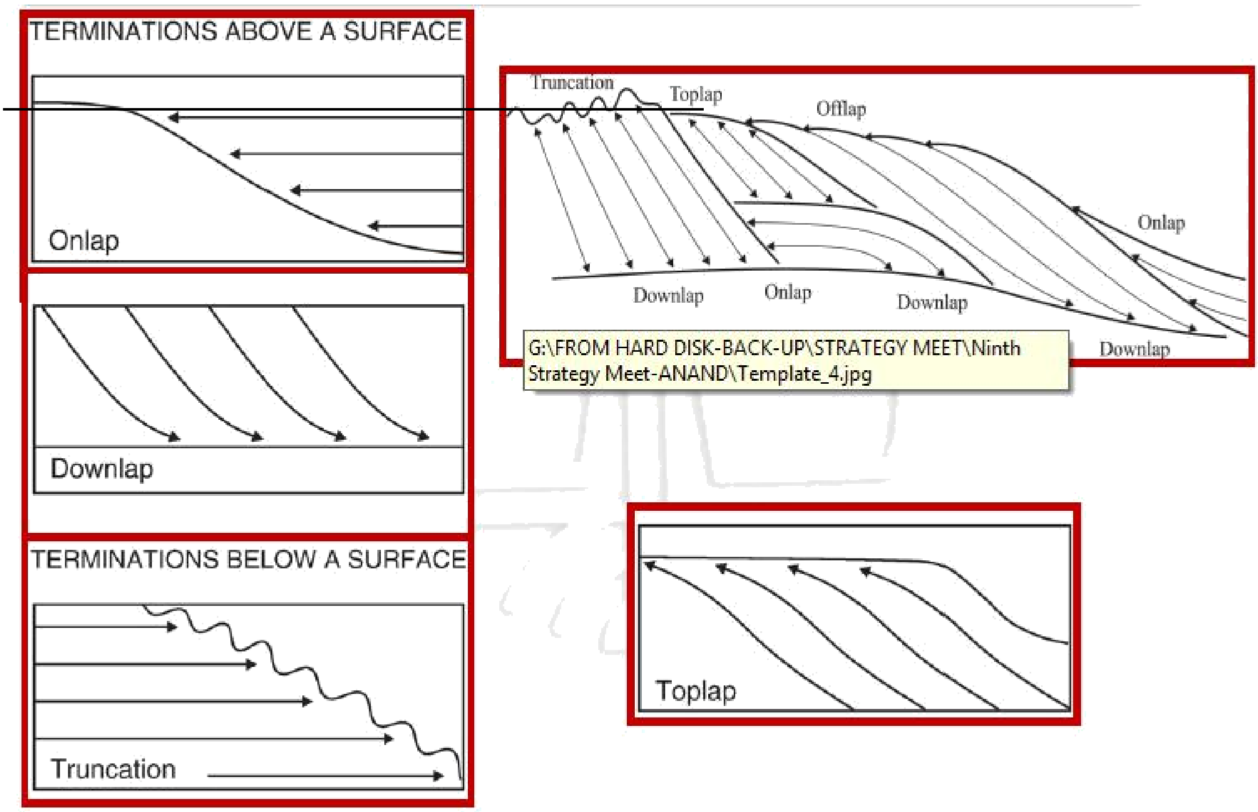
BASE LEVEL CYCLE



PRINCIPLES OF STENO

• Superposition: a succession of undeformed strata, oldest stratum it's at base, with successive younger ones above. Establishes relative ages of all strata & their contained fossils.
• Original horizontality - stratification originally horizontal when sedimentary particles settled from fluids under influence of gravity, so if steeply inclined must have suffered subsequent disturbance.
• Original lateral continuity-strata originally extended in all directions until they thinned to zero or terminated against edges of original basin of deposition.

TYPES OF STRATAL TERMINATIONS



Sequence boundaries

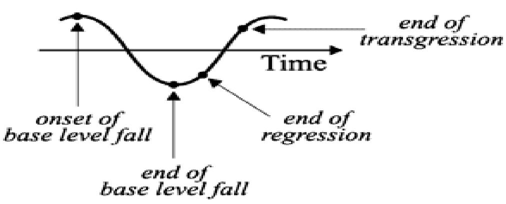
Sequence boundaries are deemed the most significant surfaces. Sequence boundaries are defined as unconformities or their correlative conformities. Sequence boundaries are formed due to the sea level fall. For example, multi-story fluvial sandstone packages often infill incised valleys formed by the sea level drop associated with sequence boundaries. The incised valleys of sequence boundaries correlate laterally with interfluves, palaeosols formed on the margins of incised valleys. The valley infills are not genetically related to underlying depositional systems as previous interpretations thought. There are four criteria distinguishing incised valley fills from other types of multi-story sandstone deposits: a widespread correlation with a regional, high relief erosional surface that is more widespread than the erosional bases of individual channels within the valley; facies associations reflect a basinward shift in facies when compared with underlying units; erosional base of the valley removes preceding systems tracts and marine bands producing a time gap, the removed units will be preserved beneath the interfluves; increasing channel fill and fine grained units upwards or changes in the character of the fluvial systems reflecting increasing accommodation space. Sandstone bodies associated with incised valleys can be good hydrocarbon reservoirs. There have been problems in the correlation and distribution of these bodies. Sequence stratigraphic principles and identification of significant surfaces have resolved some issues.

Parasequence boundaries
Lesser importance is attached to parasequence boundaries, however, there is a suggestion that flooding surfaces representing parasequence boundaries may be more laterally extensive leaving more evidence than sequence boundaries because the coastal plain has a lower gradient than the inner continental shelf. Parasequence boundaries may be distinguished by differences in physical and chemical properties across the surface such as; formation water salinity, hydrocarbon properties, porosity, compressional velocities and mineralogy. Parasequence boundaries may not form a barrier to hydrocarbon accumulation but may inhibit vertical reservoir communication. After production begins the parasequences act as separate drainage units with the flooding surfaces, which are overlain by shales or carbonate-cemented horizons, forming a barrier to vertical reservoir communications. Sequence stratigraphic principles have optimized production potential once reservoir scale architecture is identified and separate drainage units identified.

Sequence model / Events	Depositional Sequence			Genetic Sequence	T-R Sequence
	Haq et al (1987) Posamentier et al (1988)	*Van Wagoner et al (1988, 1990) Christie-Blick (1991)*	*Hunt & Tucker (1992, 1995) Plint & Nummedal (2000)*	*Frazier (1974) Galloway (1989)*	*Curray (1964) Embry (1993, 1995)*
	HST	early HST	HST	HST	RST
end of transgression	TST	TST	TST	TST	TST
end of regression	late LST (wedge)	LST	LST	late LST (wedge)	RST
end of base level fall	early LST (fan)	late HST (fan)	FSST	early LST (fan)	
onset of base level fall	HST	early HST (wedge)	HST	HST	

After Cataneanu (2002)

sequence boundary
-------- within systems tract surface



SYSTEM TRACT

The concept of systems tracts evolved to link the contemporaneous depositional systems. Systems tract forms subdivision in a sequence. Different kind of systems tracts are assigned on the basis of stratal stacking pattern, position in a sequence and in the sea level curve and types of bounding surfaces.

• A lowstand systems tract (LST) forms when the rate of sedimentation outpaces the rate of sea level rise during the early stage of the sea level curve. It is bounded by a subaerial unconformity or its correlative conformity at the base and maximum regressive surface at the top.

• A transgressive systems tract (TST) is bounded by maximum regressive surface at the base and maximum flooding surface at the top. This systems tracts forms when the rate of sedimentation is outpaced by the rate of sea level rise in the sea level curves.

• A highstand systems tract (HST) occurs during the late stage of base level rise when the rate of sea level rise drops below the sedimentation rate. In this period of sea level highstand is formed. It is bounded by maximum flooding surface at the base and composite surface at the top.

• Regressive systems tract forms in the marine part of the basin during the base level fall. Subaerial unconformities form in the landward side of the basin at the same time.

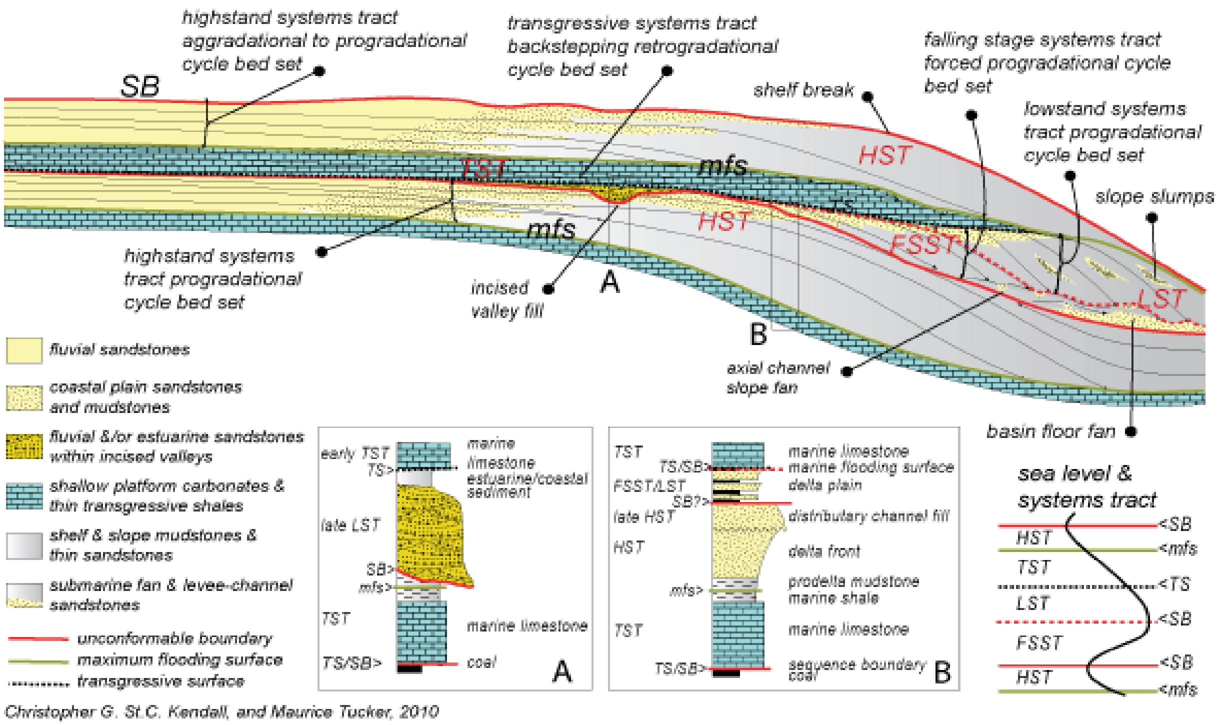


Fig: An overall sequence stratigraphy model

PARASEQUENCES AND STACKING PATTERN

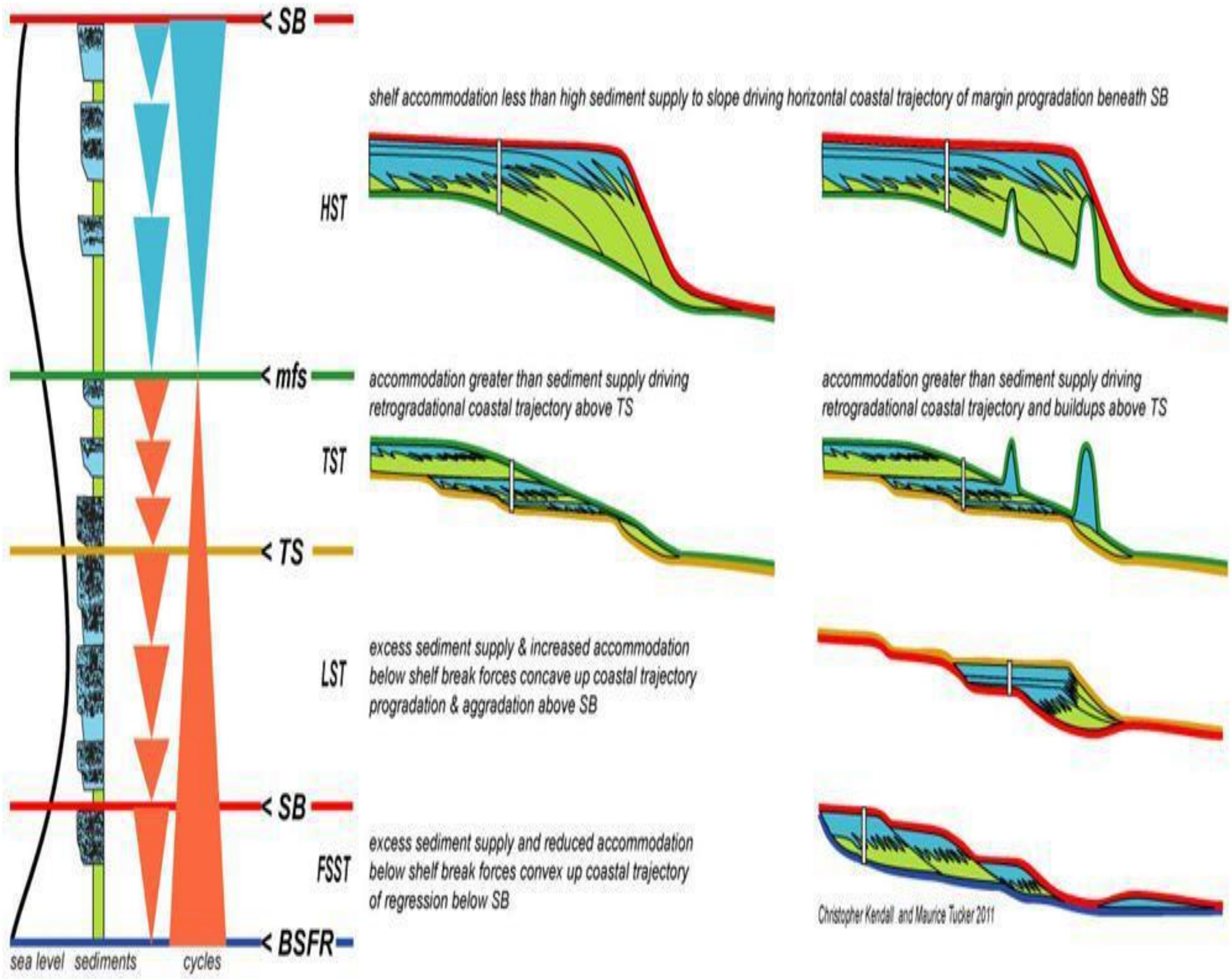
A parasequence is a relatively conformable, genetically related succession of beds and bedsets bounded by marine flooding surfaces and their correlative surfaces. The flooding surfaces bounding parasequences are not of the same scale as the regional transgressive surface that is associated with a sequence boundary.
The parasequences are the separated into stacking patterns:

- Aggradational
- Progradational
- Retrogradational

Each stacking pattern will give different information on the behaviour of accommodation space, a major control of which is relative level. So, a rapidly progradational pattern will be indicative of falling sea level, rapidly retrogradational is evidence for rapidly transgressing sea level and aggradational will be indicative of gently rising sea level.

Differences between Carbonate and Siliciclastic: -

Siliciclastic and carbonate sedimentary bodies are subdivided by similar surfaces that are responses to changes in base level. Differences in the sequence stratigraphy of these sediment types are related to carbonate accumulation tending to be "in situ production" while siliciclastic are transported to their depositional setting. Rates of carbonate production are greatest close to the air/sea interface since they are linked to photosynthesis and so depth-dependent. Thus, carbonate facies and their fabrics are clear indicators of sea level position. Carbonate organisms can produce and accumulate above certain hydrodynamic thresholds, an effect influenced by their biology and the chemistry of the water known as ecological accommodation (Pomar (2001 a, and b). Whereas siliciclastic, which only respond to hydrodynamic thresholds, are limited by their physical accommodation. Thus, the character of carbonate sediment changes as organisms evolve, the plate tectonic configuration of the depositional setting of the basin responds to pale-climate change, and/or changes in paleogeography related to isolation or access to the open sea. This means that carbonates can be used as indicators of depositional setting that, when combined with sequence stratigraphy, make carbonate facies analysis a powerful tool for the interpretation of the geological section and lithofacies prediction away from data rich areas.



Subdividing surfaces

As with clastic rocks carbonates can be subdivided on the basis of bounding and internal surfaces into sequences, parasequences and/or truncated carbonate cycles. These can include

- Erosion surfaces (SB) or eroded parasequence boundaries
- Some flooding surfaces including
  - transgressive surfaces
  - maximum flooding surfaces

EXERCISES:-

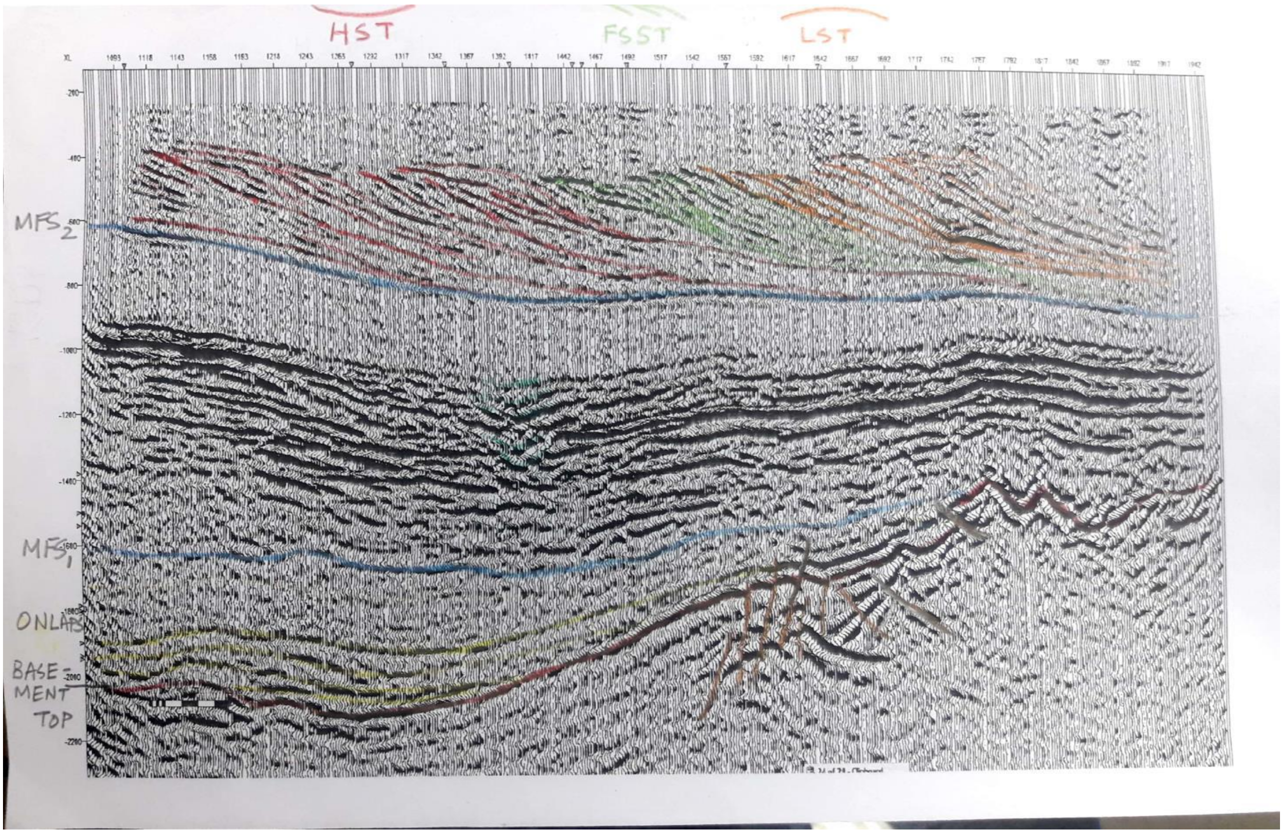


Fig: Sequence stratigraphic surface identification

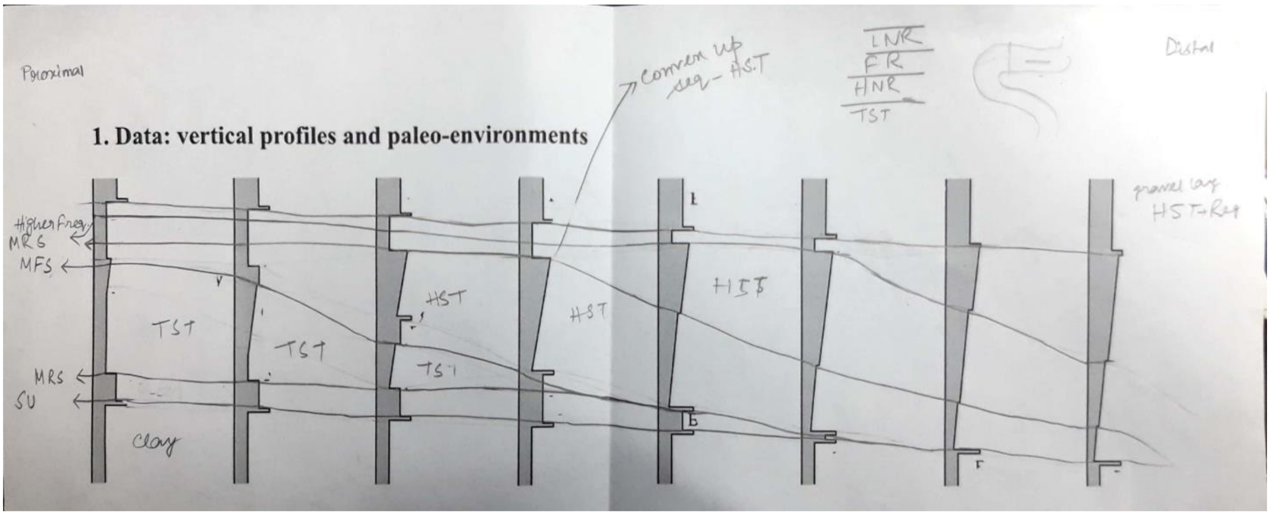
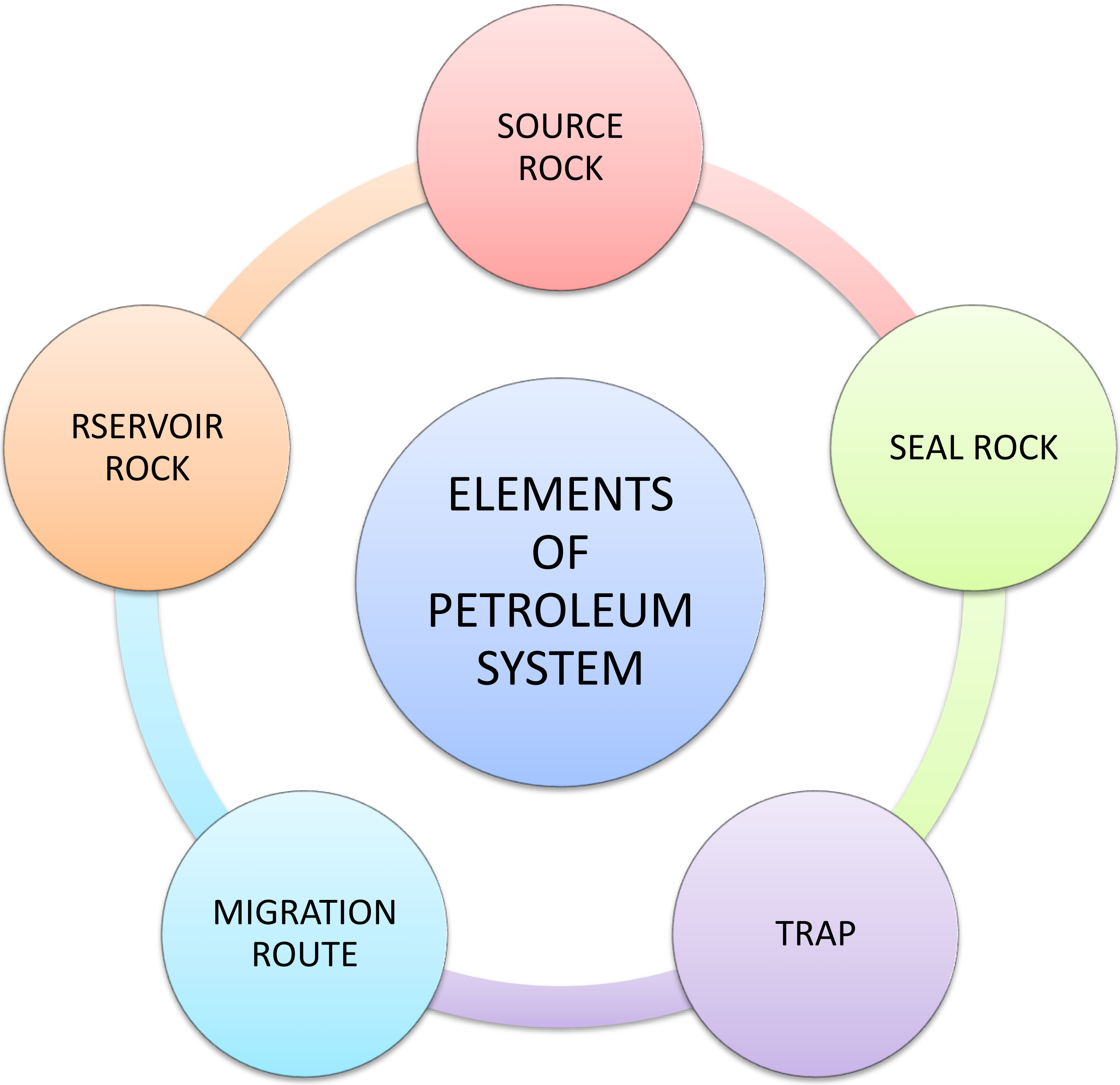
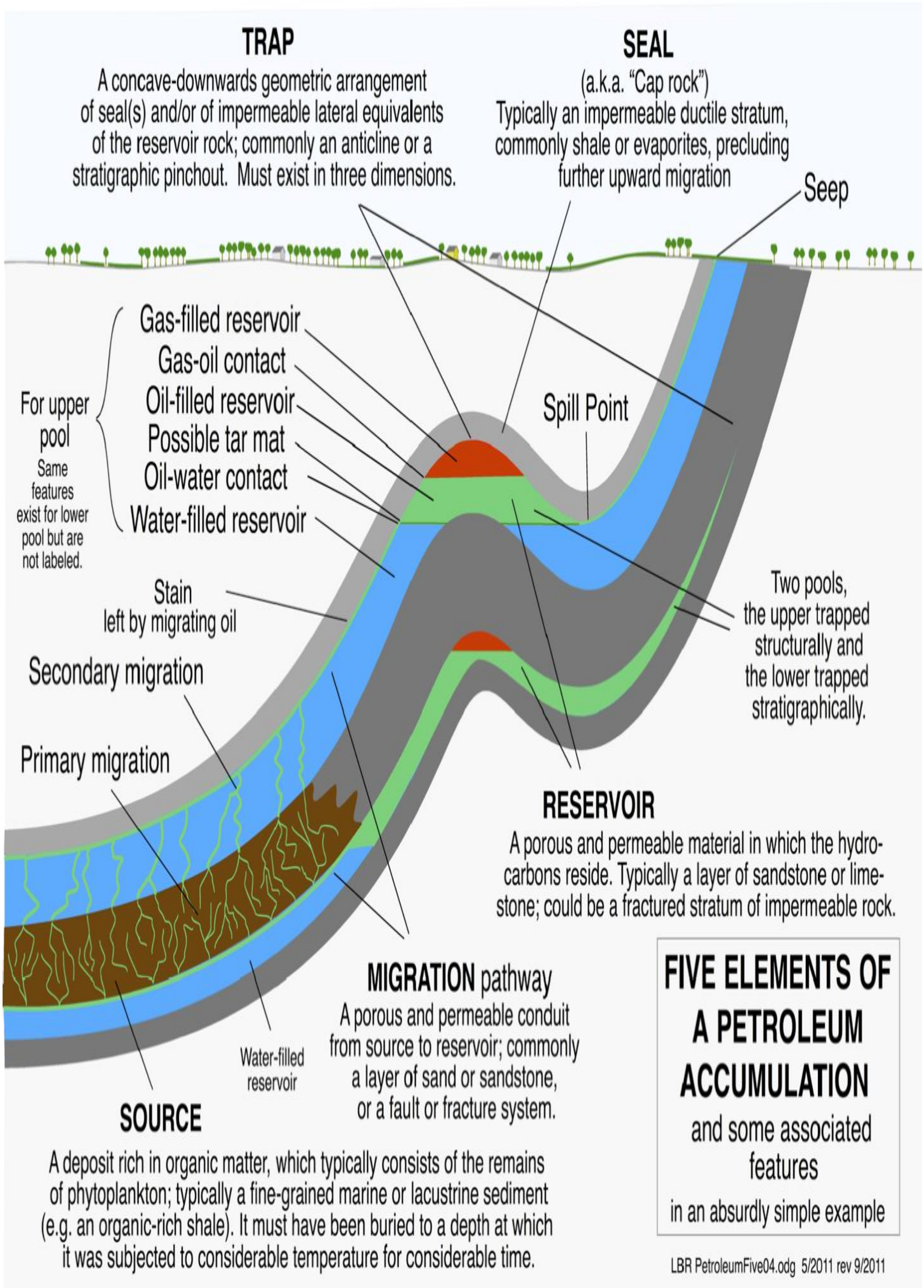


Fig: Well log correlation

PETROLEUM SYSTEM



PETROLEUM SYSTEM ELEMENTS



WELL LOGGING

- Well logging is a technique to record continuously physical properties of rock as a function of depth. It is recorded by moving a down hole logging probe and it sends output at the surface through an electrical cable.
- Well logging is a continuous record of geophysical parameters of the formation encountered in the borehole with depth of the various type of logs recorded in open hole condition (called open Hole Logs) are the ones used most frequently in hydrocarbon exploration.
- Well logging techniques are indirect in nature.

- **Why do we need well logging when we have other method?** :-

1. Cores obtained while drilling by virtue of their size and continuous nature, permit a thorough geological analysis over a chosen interval “Sidewall cores” are smaller samples and, being taken discrete depths, they do not provide continuous information. However, they frequently replace drill coring, and are invaluable in zones of lost circulation.
2. Cuttings are the principle source of subsurface sampling. Unfortunately, reconstruction of a lithological sequence in terms of thickness and composition, from cuttings that have undergone mixing, leaching, and general contamination, during their transportation by the drilling-mud to the surface, cannot always be performed with confidence. Where mud circulation is lost, analysis of whole sections of formation is precluded by the total absence of cutting. Hence log is continuous record of physical property of subsurface.

- **Primary objective of logs: -**
    1. The identification of reservoir.
    2. The estimation of hydrocarbon.
    3. The estimation of recoverable hydrocarbon.
- **Above parameters can be estimated by: -**
    1. Identifying potential hydrocarbon bearing zones.
    2. Estimate petro-physical like porosity, permeability, hydrocarbon saturation and lithology of zones.
    3. Determine depth, thickness, formation temperature and pressure of a reservoir.
    4. Distinguish between oil, gas and water zones in a reservoir and identify fluid contacts.

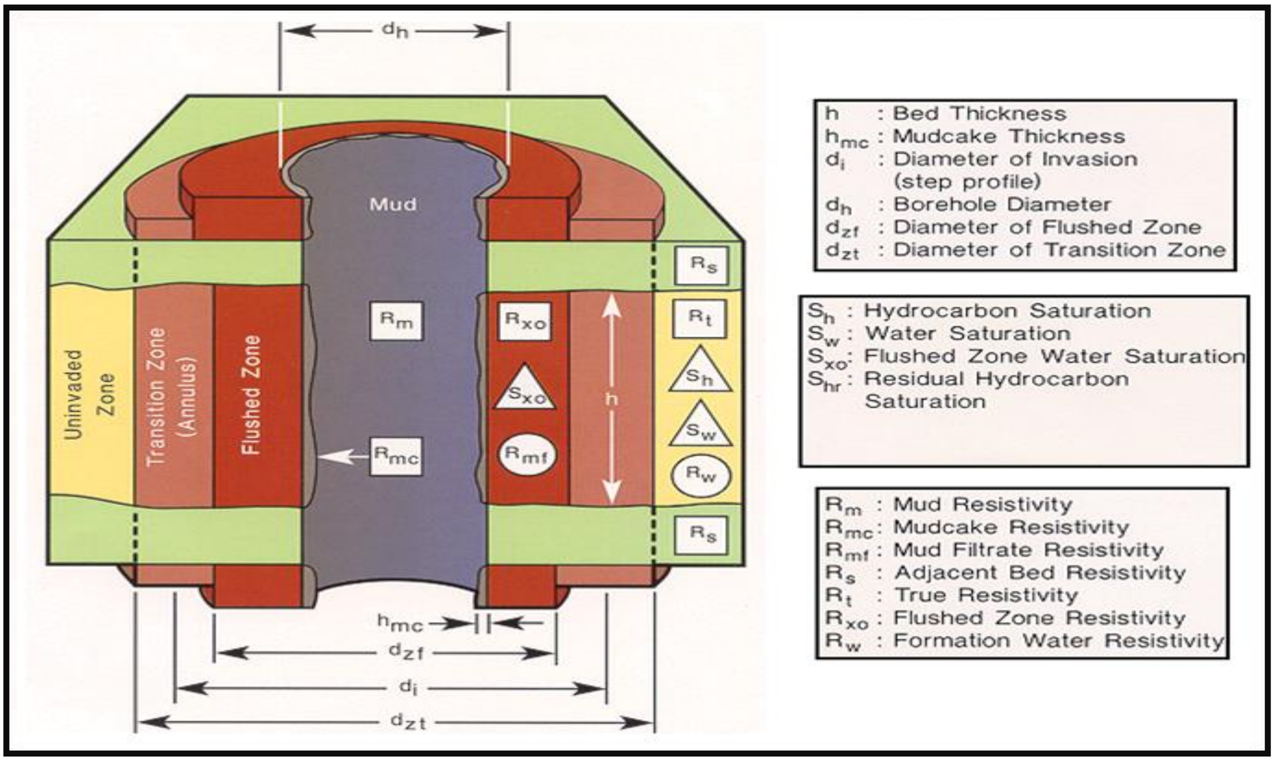
- **Borehole:**

A borehole is a represent dynamic system in which fluid used during drilling of a well affects the rock surrounding the borehole. The parameters determine from well log measurement are porosity (Φ) i.e. fraction of pore space and water saturation (Sw) which ultimately give hydrocarbon saturation **Sh = (1-Sw).** The basic logs from which these parameters can be inferred are:

- Resistivity log
- Nuclear log for porosity measurement (bulk density, neutron porosity)
- Acoustic or Sonic log for porosity measurement.
- Self-Potential, Gamma Ray logs for shale quantification

The logging tools show response associated with the characteristic physical properties of the rock formation surrounding the wellbore. Rock properties or characteristics are reflected on logging measurements. It helps in understanding lithology, mineralogy and measure permeability, porosity & water saturation.

- **Borehole Environment:**



Cross-sectional View of Borehole Environment.

The Borehole Environment plays an important role on the quality of the log data. When a hole is drilled into a formation, rock-fluid system is changed in the vicinity of the borehole gets contaminated by the drilling mud, which affect logging measurement.

- **Hole Diameter (dh):**

The borehole size is determined by outside diameter of the drill bit. Common borehole size normally varies from 8.5 inch to 23 inch. The size of the borehole is measured by caliper tool but, the diameter of the borehole may be:

  - ✓ Larger than the bit size because of washout and/or collapse of shale and poorly cemented porous rock.
  - ✓ smaller than the bit size because of a buildup of mud cake on porous and permeable formation

- **Drilling mud:**

Today, most of the wells are drilled with rotary bits. During drilling a special fluid called drilling mud is used. The drilling mud has the following applications

1. The mud helps to remove cutting from the borehole.
2. To lubricate and cool the drill bit.
3. To maintain an excess of borehole pressure over the formation pressure to mainly avoid blowouts.

- **Invaded zone:**

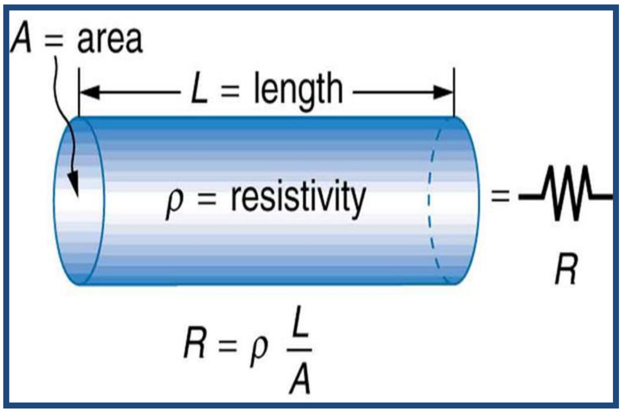
The zone in which much of the original fluid is replaced by the mud filtrate is called the invaded zone. It consists of a flushed zone, and a transition or annulus zone. The flushed zone occurs close to the borehole. If water is present in the formation, then most often the flushed zone is completely cleared of its formation water by the mud filtrate. When oil is present in the flushed zone, the degree of move out oil by mud filtrate can be determined from the difference between water saturation in the flushed zone (Sxo) and the water saturation of the virgin zone (Sw). The remaining oil is called residual oil **[Sro = (1- Sxo)].** The invasion of drilling mud filtrate into surrounding formation leads to formation of mudcake on the sides of the well bore. The mud cake consists of solid particle / clay minerals from the drilling fluid which gather on the side of the borehole wall. Formation of mud cake acts as barrier to the invasion of mud filtrate. Fluid that filters in the formation during invasion is called mud filtrate. The different parameter such as Rm, Rmc, Rxo, Rmf, Ri, Rt, Rw, Sxo, Sw and their regime are shown in fig.1 Some of these parameters are recorded on log header for log interpretation.

- **Uninvaded zone:**
  The uninvaded zone is located beyond the invaded zone. This zone is saturated with formation water, oil and/or gas if present. Even in hydrocarbon bearing reservoir, there is always a layer of formation water on grain surface. The water saturation Sw of the virgin zone is an important factor in formation evaluation because using Sw data, reservoir hydrocarbon saturation can be estimated using the relation: **Sh = 1-Sw**

Resistivity logging

Resistivity of material unchanged at constant temperature. Rock matrix, air, oil, gas and pure water are not good conductor but saline water is very good conductor of electricity so by determining the resistivity of the formation (Rt) type of fluid and saturation can be determined.
Resistance is the electric term and its unit is ohms. Resistivity is an intrinsic property of the matter and measure in ohm/s^2

- **Resistivity measurement:**
  A current is passed between two electrodes on a logging tool and the potential drop between them provides the resistivity.



- **Resistivity log:**

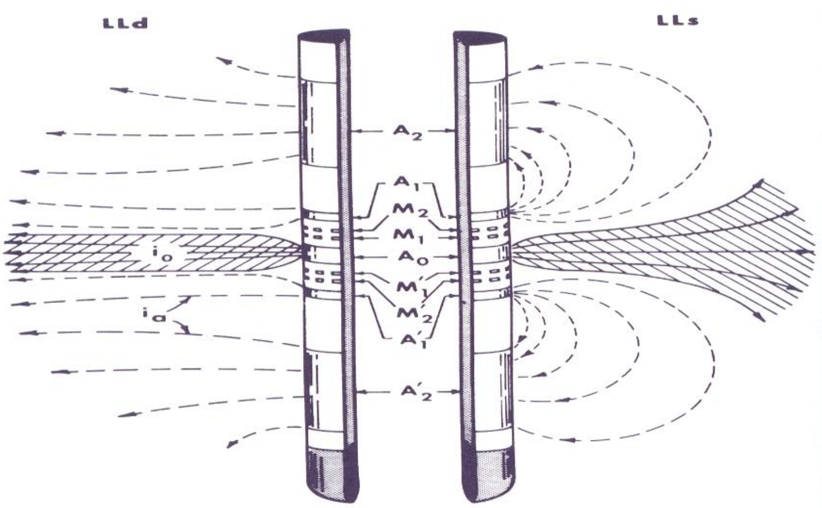
Resistivity logs are the electric logs which are used to distinguish hydrocarbon versus water bearing zones, indicate permeable zones and determine resistivity. By far the most important use of resistivity logs is **identification of hydrocarbon and water bearing zones**. Because the rock matrix or grains are non-conductive, the ability of the rock to transmit a current is almost entirely a function of water in the pores. Hydrocarbons, like the rock's matrix are nonconductive, therefore, as the hydrocarbon saturation of the pores increase, the rock's resistivity also increases. The normal and lateral logs recorded in earlier days have been replaced by focused logs in which path of survey current is controlled and focused in the formation. The focusing minimizes the borehole and adjacent bed effects. It also provides good bed resolution and deep penetration.

RESISTIVITY TOOL

- Measures formation resistivity (Ohm-m.) defined as electrical resistance offered by a unit cube of formation.
- The formation resistivity is measured either by sending low frequency current (Latero tools) or high frequency electromagnetic waves (Induction tools) into the formation.
- Resistivity depends mainly upon porosity, formation water salinity, water saturation and clay contents etc.

Latero Tools

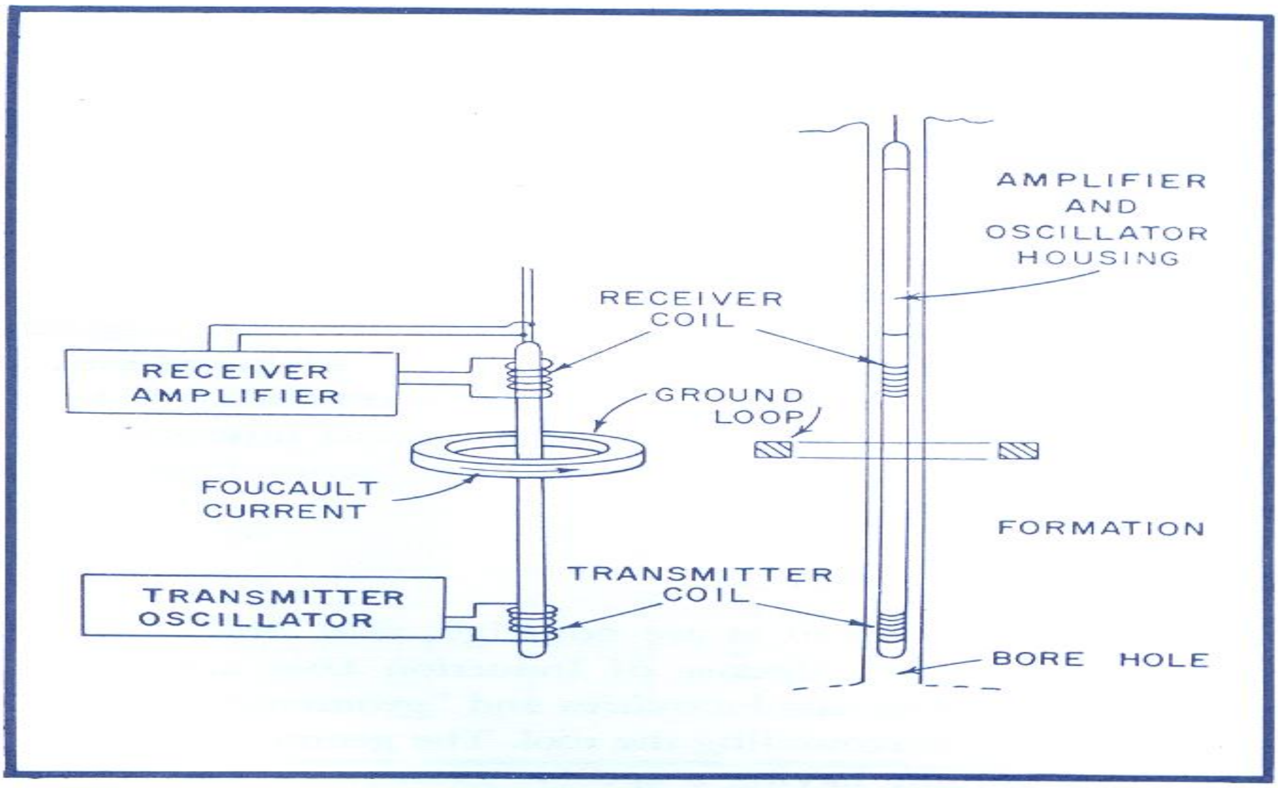
- Current is focused to flow horizontally deep into the formation with help of guard electrodes which are maintained at same potential as the current electrode.
- Dual Latero Tool (DLL) provides both deep and shallow resistivity measurements (LLD,LLS)
- DLL is generally combined with MSFL tool (Micro Spherically Focused Log) which measures the resistivity of the flushed zones.
- These three resistivity measurements have different depth of investigation and are used to determine invasion profile and accurate true formation resistivity.
- It works most effectively in high salinity mud and high resistivity formations.
- It has better vertical resolution than induction tools and can detect thin formation layers.
- It does not work in empty hole or in oil base mud filled hole.



Principle of Dual Latero Log Tool

INDUCTION TOOLS

- It works on the principle of electromagnetic induction.
- It is basically a conductivity tool.
- It works in oil based muds and air filled holes where latero tool fails.
- Tool accuracy is excellent for formations having low to moderate resistivity (up to ~100 Ohm-m.
- The Dual Induction Latero (DIL) tool records three resistivity curves having different depths of investigation (ILD,ILM & LL3)



Principle of Induction Logging

- **<u>Formation factor:</u>**

  G. E. Archie of shell was trying to make electrical measurement on core samples, with the aim of relating them to permeability. His measurement consisted of completely saturating core samples with saltwater of known resistivity Rw and relating the measure resistivity Ro of the fully saturated core to the resistivity of the water.

  Archie found that, regardless of the resistivity of the saturated water, the resultant resistivity of a given core sample was always related to the water resistivity by a constant factor F.

$$F = Ro / Rw$$

- **Cementation Factor:**
  Cementing factor is used to describe the relationship between the formation factor and porosity. A different form of equation is suggested by introducing the cementation factor or degree of consolidation '**m**' and tortuosity factor **a**.

$$F = a / \Phi^m$$

- **Resistivity Index and relationship between rock resistivity and fluid saturation: -**

In a pore space containing hydrocarbons (oil or gas), both of which are non-conductors of electricity, with a certain amount of water, resistivity is a function of water brine saturation, Sw For a given porosity, at partial brine saturations, the resistivity of a rock (Rt) is higher than when the same rock is 100% saturated (Ro) with brine. Archie determined experimentally that the resistivity factor of a formation partially saturated with brine can be expressed by

$$Sw = (aRw / Rt\Phi^m)$$

Ro = resistivity of the rock when saturated with 100% brine in Ωm

Rt = resistivity of the rock when in partially saturated with brine in Ωm

n = the saturation exponent

The resistivity of the rock partially saturated with brine, Rt, is also referred to as true resistivity of formation containing hydrocarbons and formation water.

Spontaneous potential log

A well bore contains natural occurring potentials. These are referred to as spontaneous potential or SP. When a semi-permeable membrane separates two fluids of different salinities, the two fluids will create a current flow. In a well bore, when drilling fluid which is "fresh" comes into contact with formation water which is saline, two kinds of electrochemical effect take place. These are liquid junction (diffusion) potential and a membrane (shale) potential. The SP currents that are recorded on the SP curve result from such phenomenon in the well bore.

A conductive fluid in the bore hole, a porous permeable bed surrounded by impermeable formations and a difference in salinity between the borehole fluid and the formation water are the essential factors to get a good SP recording.

<u>Tools:</u>

Potentials are measured by means of an electrode placed in a mud pit on the surface and an electrode lowered down the bore hole. The SP tool records the variations in the electrical potential between the ground reference on the surface and the electrode in the hole.
The shape of the SP curve and the amplitude of the deflection depends on the following factors:
The thickness (h) and true resistivity (Rt) of the permeable bed, the flushed zone resistivity of the adjacent formations and lastly, the resistivity of the mud and the diameter of the borehole.
Electrochemical effects: When drilling fluid which is “fresh” comes in contact with the formation water which is saline, two electrochemical effects, liquid junction (diffusion) potential and/or a membrane (shale) potential take place.

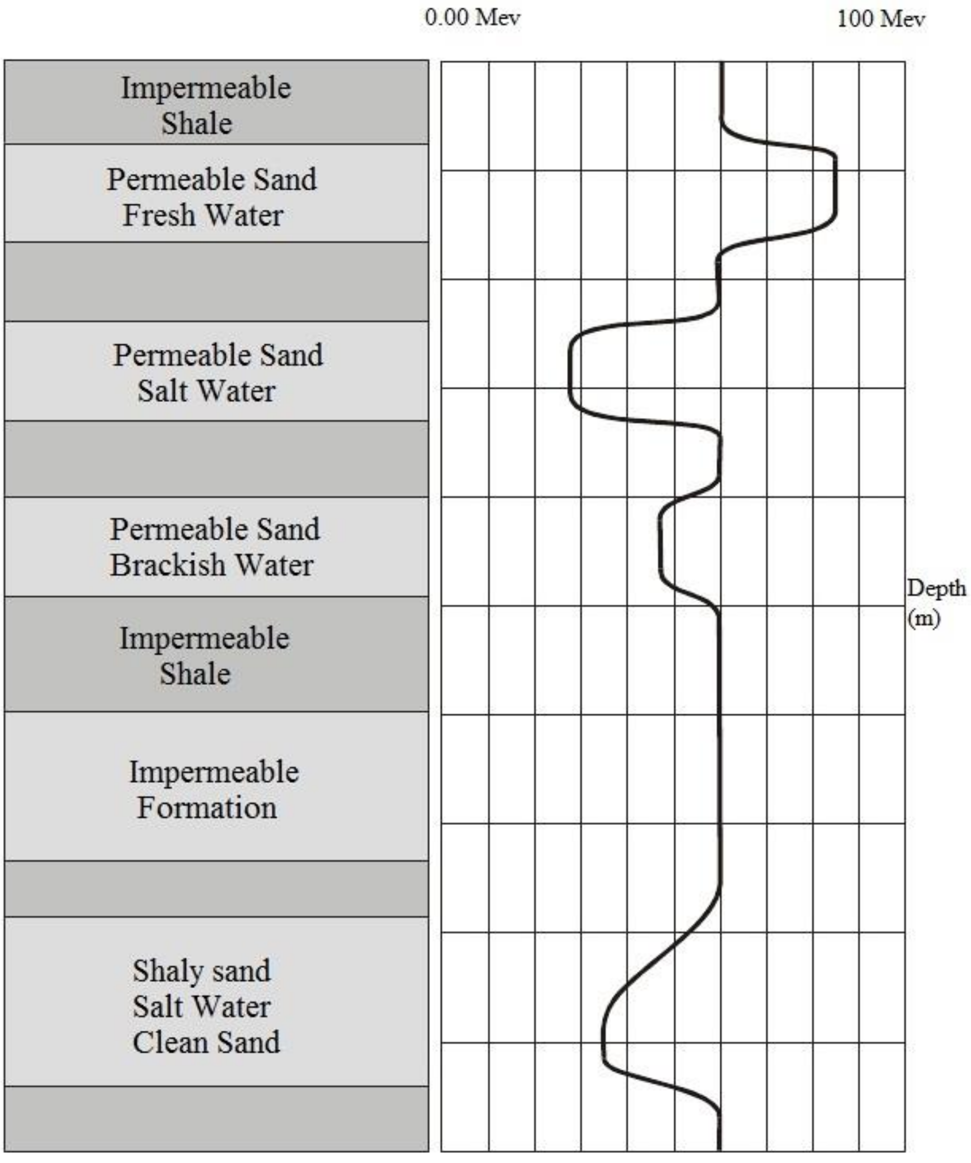
<u>Diffusion potential:</u> When two liquids with different salinities come directly into contact with each other across a porous zone, a liquid junction potential or diffusion potential occurs. The Na+ and Cl- ions may move from one solution to another in either directions. This is known as ionic diffusion. The Cl- ion are smaller and more mobile than Na+ ion and hence they diffuse into less concentrated solution much faster. Eventually the concentration of Cl is higher in one solution and the Na ions in the other. This creates a potential between the negatively charged (Cl-) solution and the positively charged (Na+) solution and causes current to flow.

<u>Shale potential:</u> Shale potential is created when two saline solutions come into contact with each other through a semi-permeable membrane. Due to the layered clay structure and high negative charges on the layers, shale are permeable to the Na+ cations, but impervious to the Cl- anions. Cations will move through the shale, from the high concentration of the salt water to the lower concentration of the fresh water, giving rise to a shale potential. The movement of the charged ions is the electric current and the force is the potential across the shale.

<u>Shale base line shift:</u> The SP curve is primarily used to detect permeable beds typically deflect the SP curve to the left, whereas impermeable deflect the curve to the right. That means a maximum deflection to the right is an indication of shale, whereas a left or negative deflection occurs opposite porous and permeable sands and limestone. Self-potential is always negative or positive with respect to the shale base line. However, in some wells, shale base line shift occurs. A base line shift occurs when, formation waters of different salinities are separated by a shale bed which is not a perfect cationic membrane.

Uses:

The SP curve is primarily used to detect potential porous and permeable reservoirs and delineate them from non-porous clays and shale. The curve is also useful to define bed boundaries and in the correlation of beds. The SP curve is used in making a quick look estimate of the formation water resistivity (Rw). The curve is also a good indicator of permeability. One of the important uses of the SP curve is in quantification of the formation water resistivity (Rw) and in shale volume calculation. Traditionally the SP curve has been used in the correlation of sand shale sequences and facies identification.



Typical response of SP log

Interpretation and character of the SP deflection-

- ✓ Again, shale SP deflection is near to shale base line.
- ✓ SP deflection depend on contrast between Rmf and Rw.
- ✓ If mud is relatively fresher then formation water, a negative SP deflection occur (Rmf > Rw)
- ✓ If formation water is fresher than mud filtrate, positive SP deflection occur (Rmf < Rw).

$$\mathbf{Ec = K \log_{10} (Rmf / Rw)}$$

Application of SP: -

- ✓ To delineate porous and permeable reservoir rocks
- ✓ To delineate bed boundaries and bed thickness
- ✓ To evaluate the formation water resistivity
- ✓ To estimate the fraction of clay volume
- ✓ Correlation of permeable beds

<u>Gamma Ray Log</u>

Natural radiation in rock comes essentially from three elemental sources:

I. The radioactive isotope of potassium 40 (40 K)
II. The radioactive element of the thorium family
III. The radioactive element of the uranium-radium family

Gamma ray tool measures the gamma ray radiation from the radioactive minerals present in the sub surface formations. Clay minerals or shale contains higher amount of K and other radioactive elements and generally shows higher radiation or higher gamma counts. So, high gamma ray counts indicate the presence of higher volume of shale. The tool uses Geiger Muller detector or scintillation counters with BGO crystals. The detector is unshielded and will thus accept radiation from any direction. Generally, gamma ray varies from 0 to 150 GAPI (API = American Petroleum Institute) in the formations. The gamma ray tool is connected with other logging tools in every run made in the bore hole so that log depth can be matched for each run.

Applications

- ✓ Identification of shale and computation of shale volume.
- ✓ Open-hole as well as cased-hole correlation.

- ✓ Depositional environment determination by identifying fining or coarsening upward sequences.
- ✓ Delineation of non-radioactive minerals including coal beds.

<u>Acoustic properties of rock</u>

Acoustic logging is used to measure velocity of Shear and primary wave, their attenuation and amplitude of reflected wave, Velocity measurement helps in interpretation and measurement of porosity, lithology, and pore compressibility.

Amplitude measurement helps to locate vugs and fractures. Acoustic logging in open hole measurement of velocity is known sonic log.

Factor affecting velocity of acoustic wave: -

1. **Lithology influence**: - transit time Δt-

   fluid > shale > sandstone > limestone > dolomite.

   Coal has very high transit time Δt-

   Gas > Oil > Water

2. **Salinity effect: -** the speed of sound in water depends on the salinity, higher the salinity the higher the speed.
3. **Pressure influence: -** As the confining pressure increases acoustic velocity increases.

<u>Sonic Log</u>

- ➢ The sonic device consists of one or more sound transmitters, and two or more receivers. The tool measures interval transit time of a compressions sound wave which is time of travel of sound wave through one foot of the formation. Interval transit time in microseconds per foot is the reciprocal of the velocity of a compressional sound wave in feet per second. The interval transit time is dependent upon both lithology and porosity.

Sonic transmitter in the tool converts electrical energy into acoustic energy and the receivers do the reverse. The sound wave emitted by the transmitter travels to the receivers through borehole fluid and surrounding formation. The p-wave that travels through the formation usually arrives at receiver and is of interest in sonic logging. By measuring the time of transmit of a pulse and time of first arrival of P-wave at the receivers, sonic transit time of the formation is computed and plotted versus depth as a sonic log. Sonic log is affected by borehole condition such as

- washouts and tool position when tool consist of one transmitter and one receiver. These effects are reduced by increasing the number of receivers in the tool.

- **Applications: -**

  - ✓ To determine porosity in a reservoir.
  - ✓ In combination with total porosity measurement from Neutron-Density logs, it helps to compute secondary porosity like vugs in carbonates and fractures.
  - ✓ As an aid in lithology determination when combined with other porosity logs.

Density log

The density logging tool uses radioactive source which emits gamma rays of medium energy (662kev). When these gamma rays collide with the electrons in the formation, the scattered gamma rays that return to the detector in the tool are measured in two energy range. The gamma which loses of its energy to the electrons and are detected in higher energy range (up to 0.2 kev) because of Compton scattering. These range gamma rays are detected in the tool using two detectors. Detector closer to source is known as short space detector and the other far distance known as long space detector. The counts at two detectors help in measuring formation density and for compensating the measured density for mudcake thickness and caving effects. The modern tools also measure the gamma rays at low level of energy (below 0.1kev). The gamma rays detected below **0.1kev** correspond to photoelectric effect. This energy is strongly dependent on formation lithology. The parameter derived from this measurement is photoelectric absorption index (PE) which provides information about formation lithology. Formation density logging tool has a relatively shallow depth of investigation about 15 cm in formation. The density tool is calibrated in workshop using with aluminium (2.67 g/cc) and magnesium (1.7 g/cc) blocks.

- **Applications:**

(1) The porosity can be calculated directly if the density of the mineral component matrix) and fluid are known, or, if not, by combination with the neutron log.

(2) The density provides a base log for the determination of mineral component for non-porous formations or in combination with other logs for porous formations.

(3) In the study of compaction and abnormal pressure zones.

Neutron Porosity Log

The tool uses a neutron source which emits neutrons at 4.6 Mev and two He3 detectors for counting the neutrons. When emitted neutrons collides with the nuclei in the formation the neutrons lose their energy and are brought down to epithermal and finally to thermal energy level after which neutrons are captured by the nuclei in the formation.

Neutron loses maximum energy when it collides with the nucleus having similar mass (equal to the mass of the neutron). As hydrogen nucleus has mass closer to neutron, maximum energy is lost when neutron interacts with hydrogen nuclei. In this way neutron tool measures the hydrogen ion concentration in the formation.

- **Applications: -**
  - ✓ Porosity determination
  - ✓ Shale identification & Shale volume computation
  - ✓ Lithology determination
  - ✓ Identification of gas bearing formations

Interpretation of log

Working procedure-

1. Reading scale-

   As describe in basic of petroleum formation evaluation different track has different log and different scale as given below-

   a) Gamma ray (API) – 0 – 200
   b) SP Log – 10-110
   c) Resistivity – 0.2-200 (Ω m)
   d) Density – 1.8-2.8 (g / cc)
   e) Porosity – (0.54) -(-0.06)
   f) Caliper- Bit size depended

2. Lithology determination-

Following lithology can be identified

- **Shale-**

1. GR value- High
2. SP Log- deflection near to shale base line
3. Resistivity- More than adjacent bed (sandstone), Less than adjacent bed (coal)
4. Separation between density and porosity both porosity and density increases.
5. Caliper- As shale is very less permeable there will be no mud cake formation and caving can easily find.

- **Sandstone**-

1. GR value- Low
2. SP Log- deflection to left (Rmf > Rw) or right (Rmf < Rw)
3. Resistivity- In clean sandstone resistivity is very low. But HC bearing formation shows very high resistivity. OWC can be found if there is much change in resistivity in sandstone section.
4. Density and porosity log show less separation or overlap.
5. Caliper- Because formation of mud cake caliper show less reading the bit size.

- **Coal-**

1. GR value- Low
2. Resistivity- Very high resistivity
3. Very low density, high porosity and high transit tie mostly time they show reading in back up scale.

- **Calculation of Rw-**

In clean sand Sw = 1 and using Archie equation Rw can be determined.

- **Calculation of Vsh-**

1. GR log- Vsh = (GRlog- GRmin) / (GRmin - GRmax)
2. SP log- Vsh = [1-(SP / SSP)]
3. Vsh = (Φn - Φd) / (Φshn - Φdsh)

Φn log given; Φshn- neutron porosity reading at shale section

- **Determination of Φ-**

1. Can be read from Neutron porosity log
2. From sonic log:- $\Phi s = \Delta t - \Delta tma / \Delta tf - \Delta tma$
3. By density porosity log- $\Phi d = (\rho b - \rho ma) / (\rho f - \rho ma)$

By using ρb of shale section Φdsh can be determine.

ρma is 2.65 gm/cc taken for below log.

ρt = 1 gm/cc

- **Calculation of Sw:-**

To calculate Sw, we use Archie Equation- $Sw = (aRw / Rt\Phi^{m})$

Contact identification

OWC, GWC and OSC

Oil-water contact is a surface where oil and water exist at the upper and lower part of the same surface respectively. Since the density is in the increasing order for the fluids like gas, oil and water respectively, so oil with less density present above oil-water contact line and water is present below simply governed by gravitational separation.

Presence of reservoir facies is inferred when there is a crossover of neutron log and density log in a sand pack lithology.

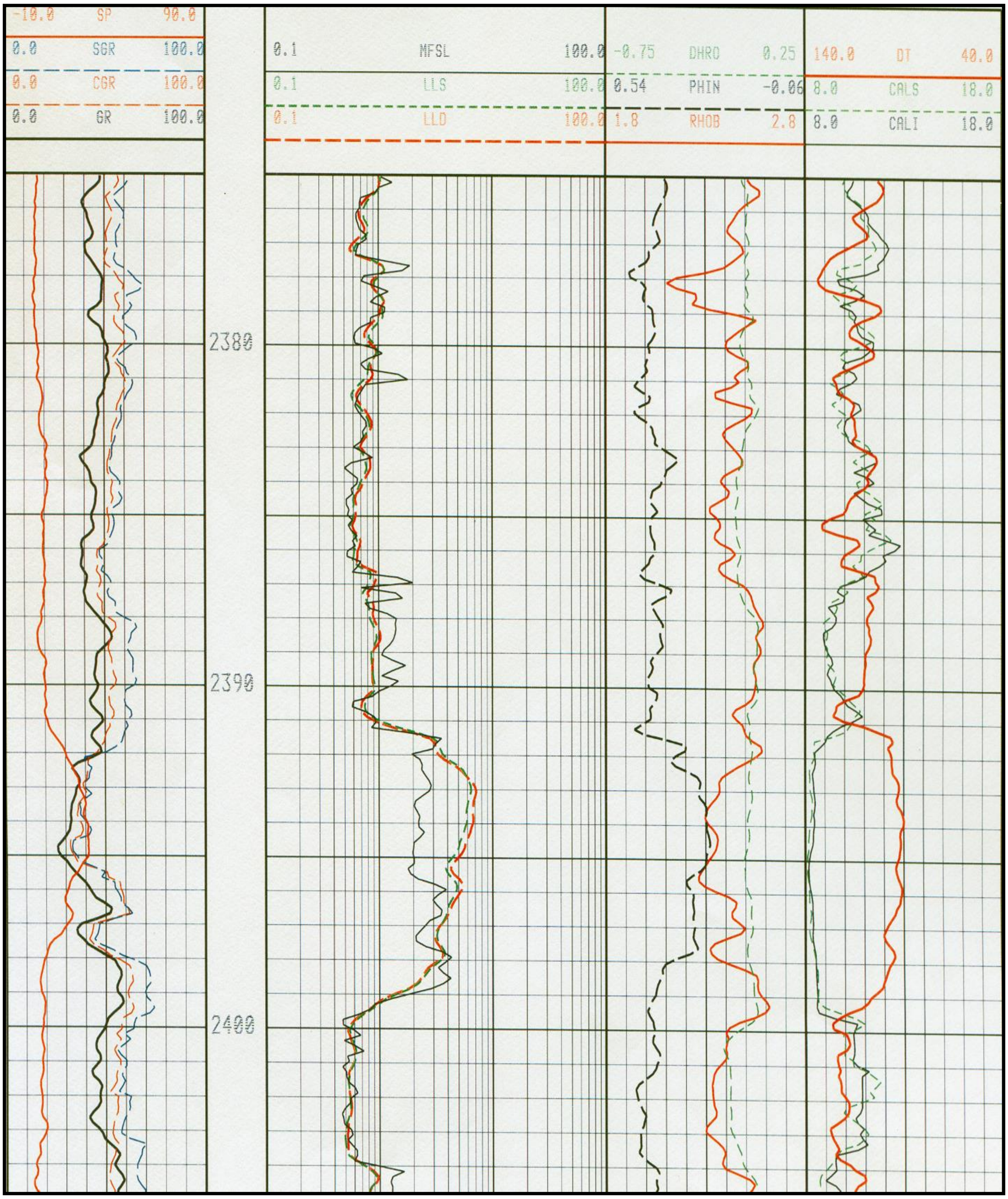
If the resistivity in that region is high, then it will be hydrocarbon bearing sand but if the resistivity is normal (with respect to the general base line trend), then it will be water bearing sand.

The fluid in the sand in comparison with the base line can be interpreted using the following criteria:
1. Very high resistivity, large neutron-density crossover: Gas bearing sand
2. High resistivity, neutron-density crossover: Oil bearing sand
3. Normal resistivity, neutron-density crossover: Water bearing sand

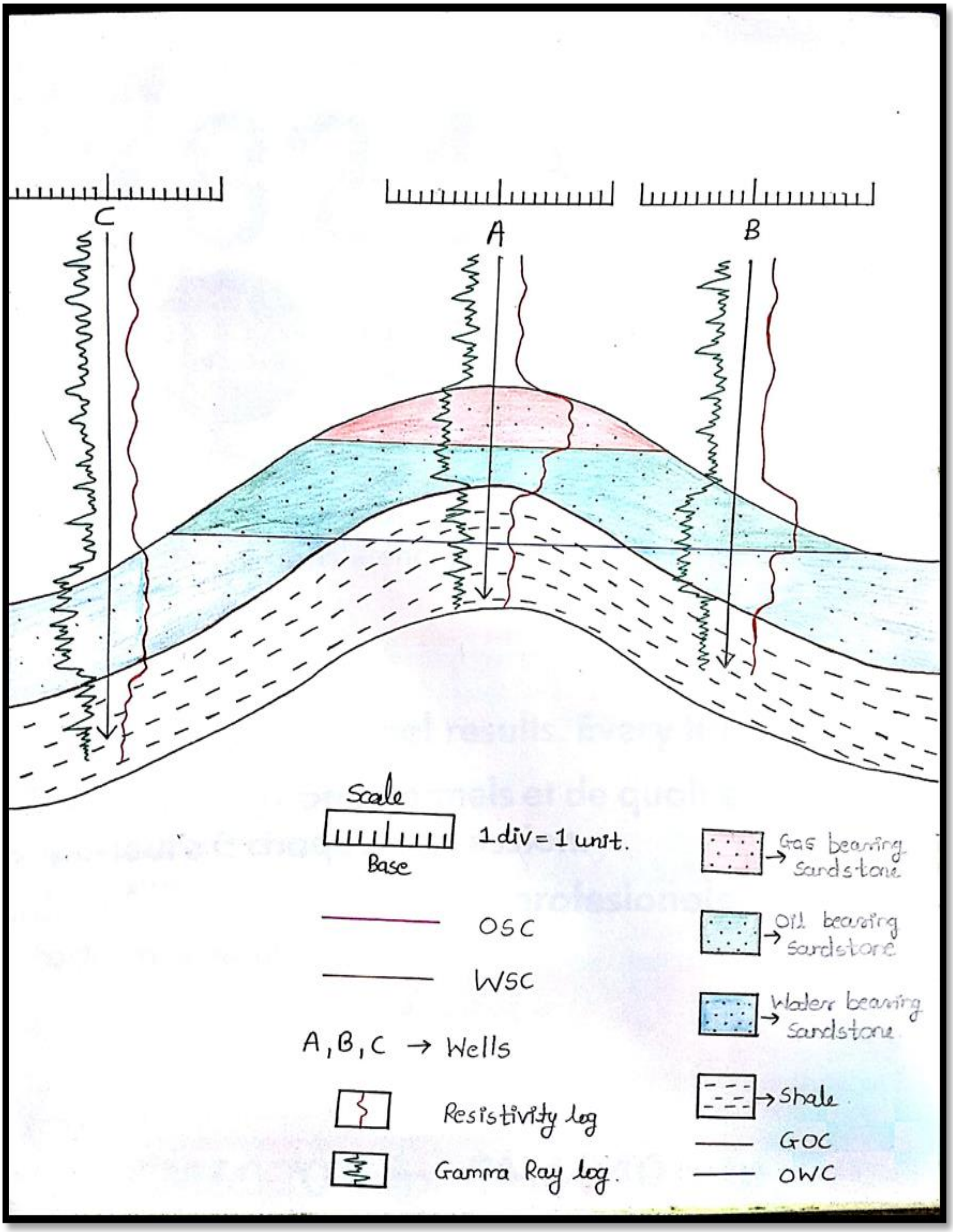
Simply we can say that, when the lithology of the reservoir is continuing but we observe the sudden fall in $\mathbf{R_t}$ **log**, we infer that this deviation is due to OWC.

Gas-Water contact is identified by the decrease in the crossover separation and sharp fall in resistivity.

Oil-Shale contact is identified by increase in Gamma log, decrease in resistivity and sharp decrease in the crossover separation.



Example of Composite Log


C
A
B
Scale
1div = 1 unit.
Base
Gas bearing Sandstone
Oil bearing Sandstone
Water bearing Sandstone
Shale
GOC
OWC
OSC
WSC
A, B, C → Wells
Resistivity log
Gamma Ray log.

The Fullbore Formation MicroImager (FMI) instrument

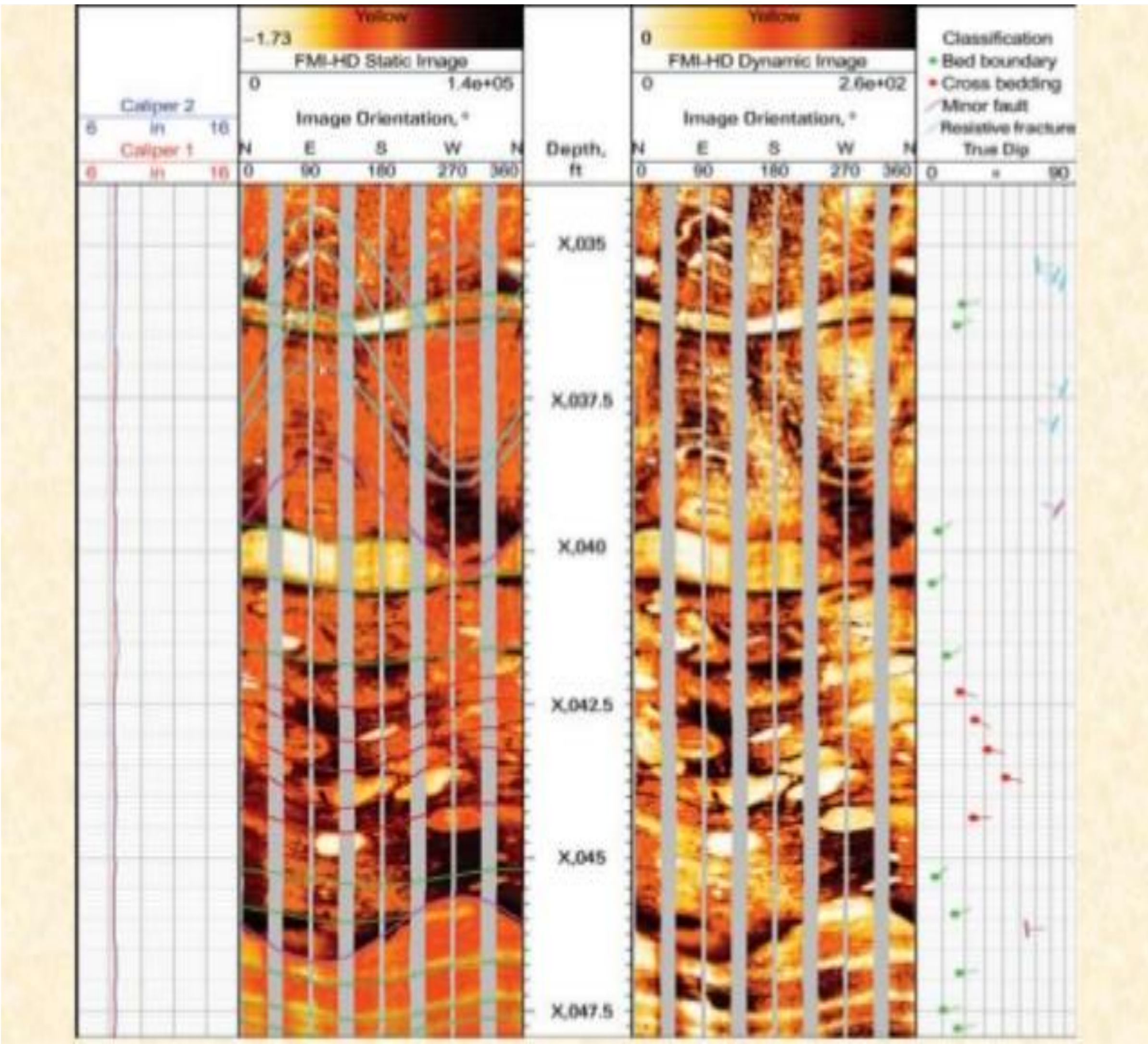
• Electrical method used in boreholes to image bedding and fractures around the perimeter of the borehole
• Measure the borehole size
• Measurement in the water-based drilling fluid
• High resolution picture based on resistivity contrasts from the borehole wall
• Vertical resolution, 5 mm

APPLICATION:

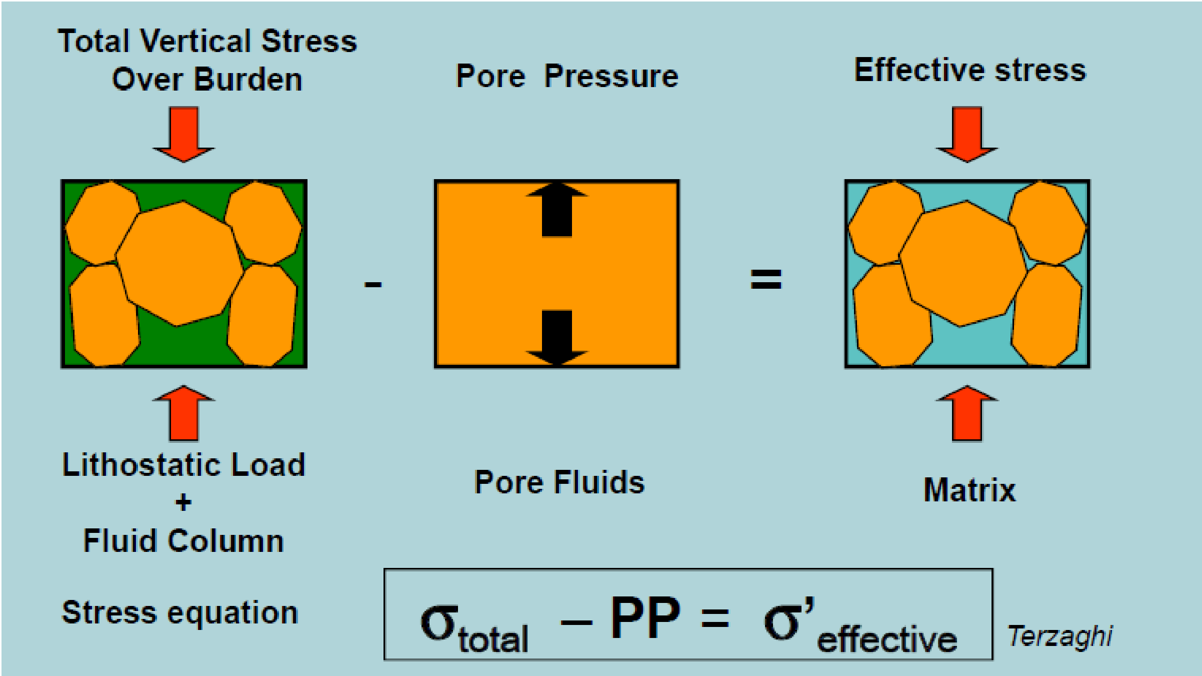
➢ Structural analysis and modeling
  - 3D near-wellbore and interwell structural modeling
  - Structural cross sections
  - Detection and determination of faults, folds, and unconformities
  - True, accurate structural dip in almost any formation

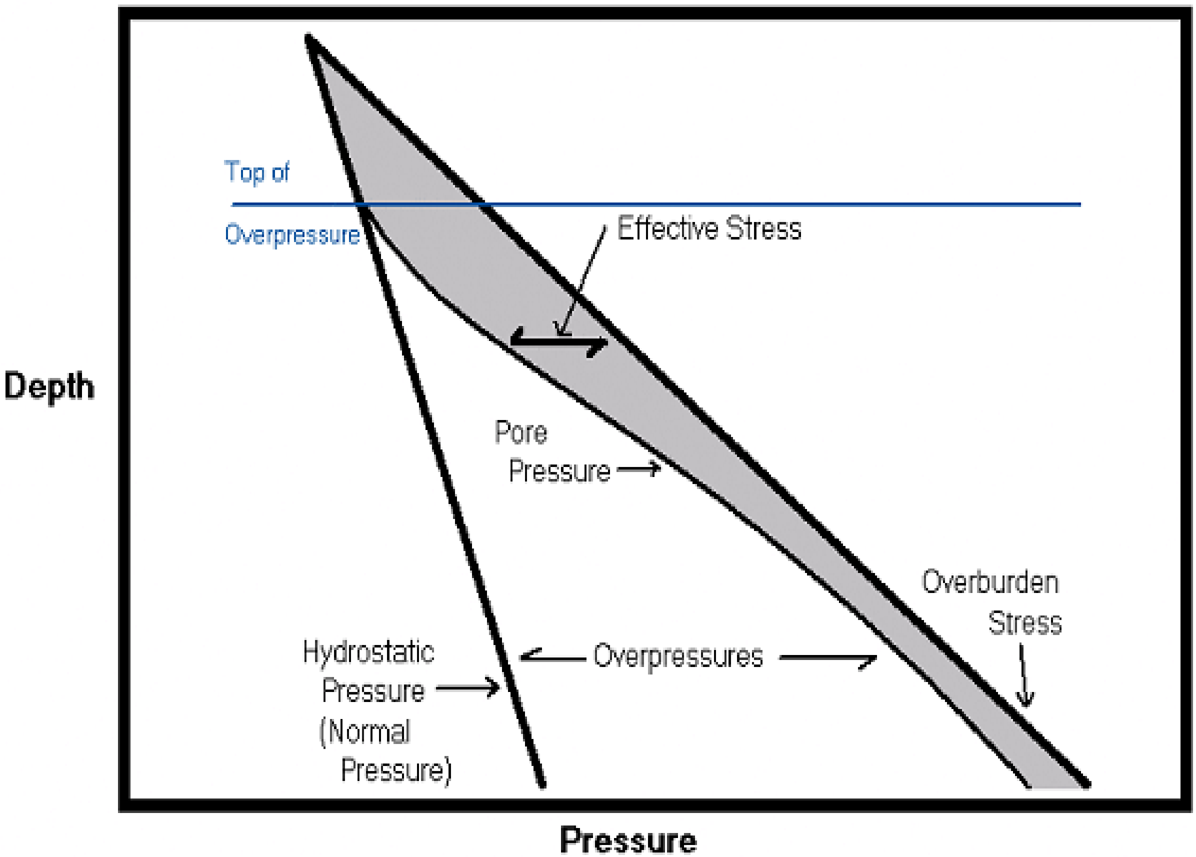
- Naturally fractured reservoir characterization and modeling
    - Discrete fracture network (DFN) modeling
    - Direct visual quantification of fracture orientation and density
    - Quantification of fracture aperture and fracture porosity

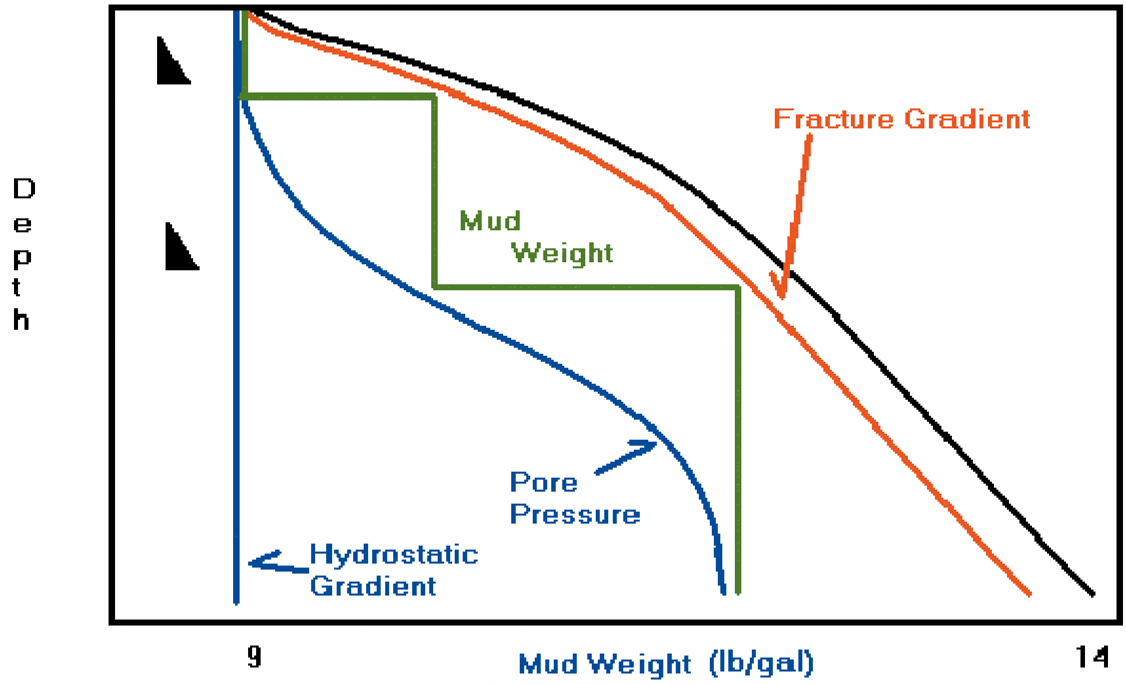
- Secondary porosity evaluation in carbonate and igneous reservoirs
    - Quantification of matrix and vuggy fractions of porosity
    - Partitioning of isolated, connected, and fracture-connected vuggy porosity
    - Direct visual identification of macroporosity and nonporous nodules
    - Estimation of permeability and variable cementation exponent m



PORE PRESSURE PREDICTION







Overpressure is defined as the difference between the internal fluid pressures of a rock's pore space and the hydrostatic or normal pressure.

Depth vs. Pressure Gradient plot depicting the relationship between various types of pressures. Black curve is the overburden gradient.

HYDROSTATIC PRESSURE

Hydrostatic pressure, Pn=*p*gh

where Pn = hydrostatic pressure, *p* = density of water

g = force of gravity and h= height of the water column.

A typical hydrostatic pressure gradient is around 0.465 psi/ft. In the Depth vs. Pressure Gradient plot, the hydrostatic gradient is assumed to be constant and therefore it is a vertical line.

OVERBURDEN PRESSURE

Overburden pressure is the pressure due to the sum of all overlying rocks and fluids. This can be expressed as:

$$P(z) = g \int_0^z p(z) dz$$

where:

$P(z)$ = pressure as a function of depth
g = force of gravity
z = depth
$p(z)$ = density as a function of depth

The gradient is called OBG or overburden gradient.

Pore Pressure

Pore pressure is the pressure exerted by the fluids within a rock's pore space.
Methods to determine pore pressure

1. Equivalent depth methods

2. The ratio method

3. Eaton's method

4. Resistivity method with depth-dependent normal compaction trend line (NCT)

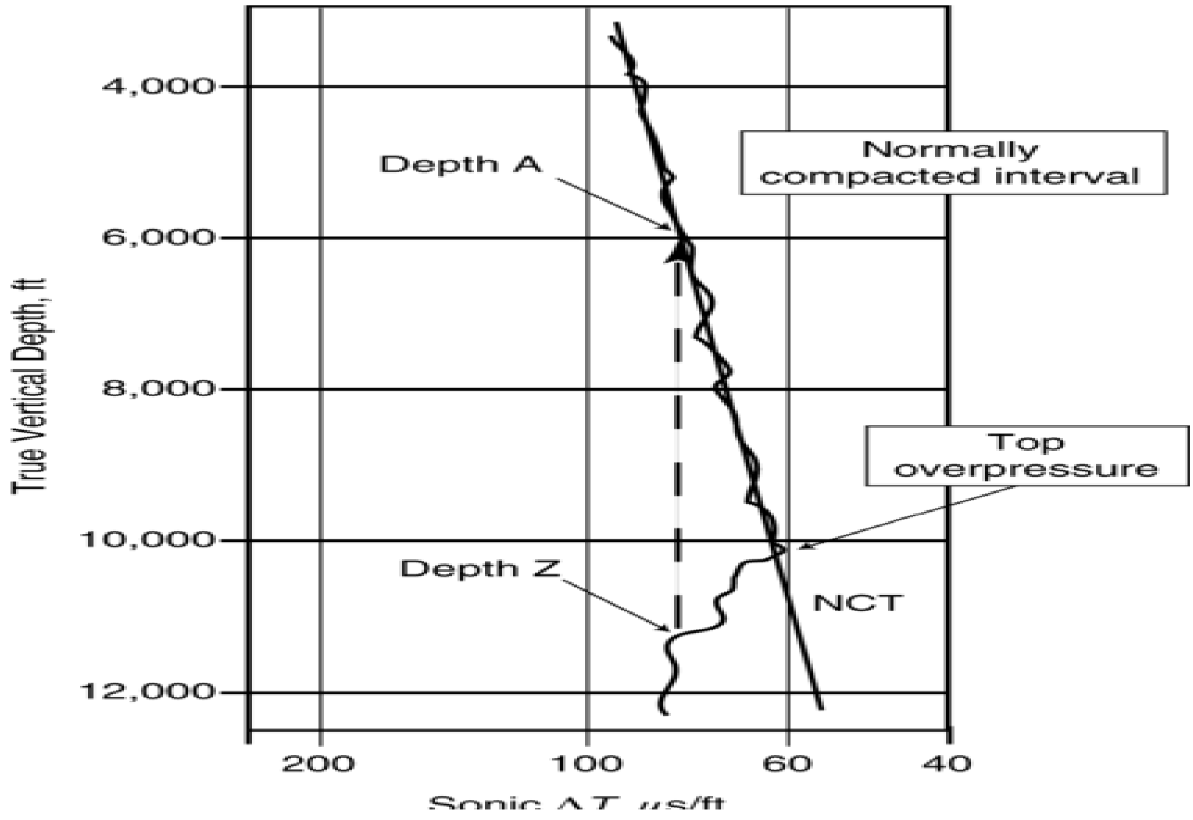
5. Sonic method with depth-dependent normal compaction trend line (NCT)

6. Effective stress methods

Equivalent Depth Methods

The normal compaction trend (NCT) is a straight line in log-linear space that has been fitted to the decrease in slowness as a function of depth where sediments are normally compacting.

The effective stress at depth *Z* is equal to the effective stress at depth *A*, and thus, the pore pressure at depth *Z* is simply $P_z = P_a + (S_z – S_a)$. here $P_{a,z}$ and $S_{a,z}$ are the pore pressure and the stress at z (the depth of interest) and at depth A.



The Ratio Method

In this method, pore pressure is calculated using the assumption that, for sonic delta-t, density, and resistivity, respectively, the pore pressure is the product of the normal pressure multiplied (or divided by) the ratio of the measured value to the normal value for the same depth.

$$P_p = P_{\text{hyd}} \Delta T_{\log} / \Delta T_n,$$

$$P_p = P_{\text{hyd}} R_n / R_{\log},$$

where the subscripts n and log refer to the normal and measured values of density, resistivity, or sonic delta-t; Pp is the actual pore pressure, and Phyd is the normal hydrostatic pore pressure.

Eaton's Method (Most widely used Method)

$$P_p = S - (S - P_{\text{hyd}})(\Delta T_n / \Delta T_{\log})^{3.0},$$

where Pp is pore pressure; S is the stress; Phyd is hydrostatic pore pressure; and the subscripts n and log refer to the normal and measured values of resistivity (R) and sonic delta-t (ΔT) at each depth.

Conventional 1D pore pressure analysis:

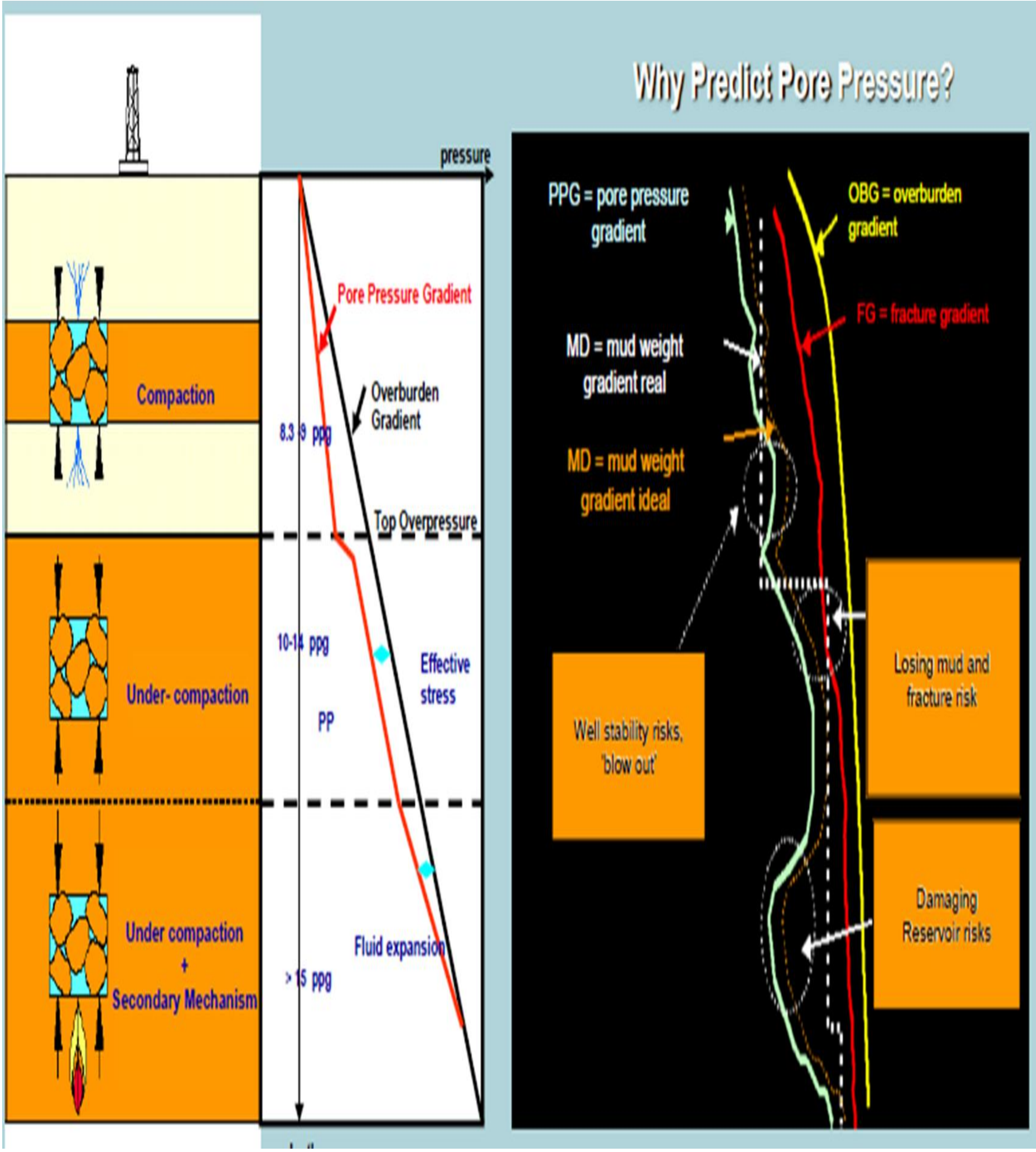
1. Calculate total vertical stress (σv) from rock density.

2. Estimate vertical effective stress (σe) from log measurements (DT or RES) or seismic (velocity).

3. Pore pressure is then PP = σv - σe.

4. Calibrate PP to credible information like mud weight, LOT data used for offset wells.

Importance of Pore pressure Prediction: Safe well Drilling



TECHLOG PORE PRESSURE PREDICTION

The Techlog Pore Pressure Prediction module comprises three main workflow steps: overburden stress estimation, pore pressure prediction, and fracture gradient estimation

Features

Overburden stress

- Overburden stress computation integrating synthetic and measured density using the Extrapolation, Amoco, Miller, and Traugott methods
- Synthetic density methods from Gardner, Sayers, and Wendt

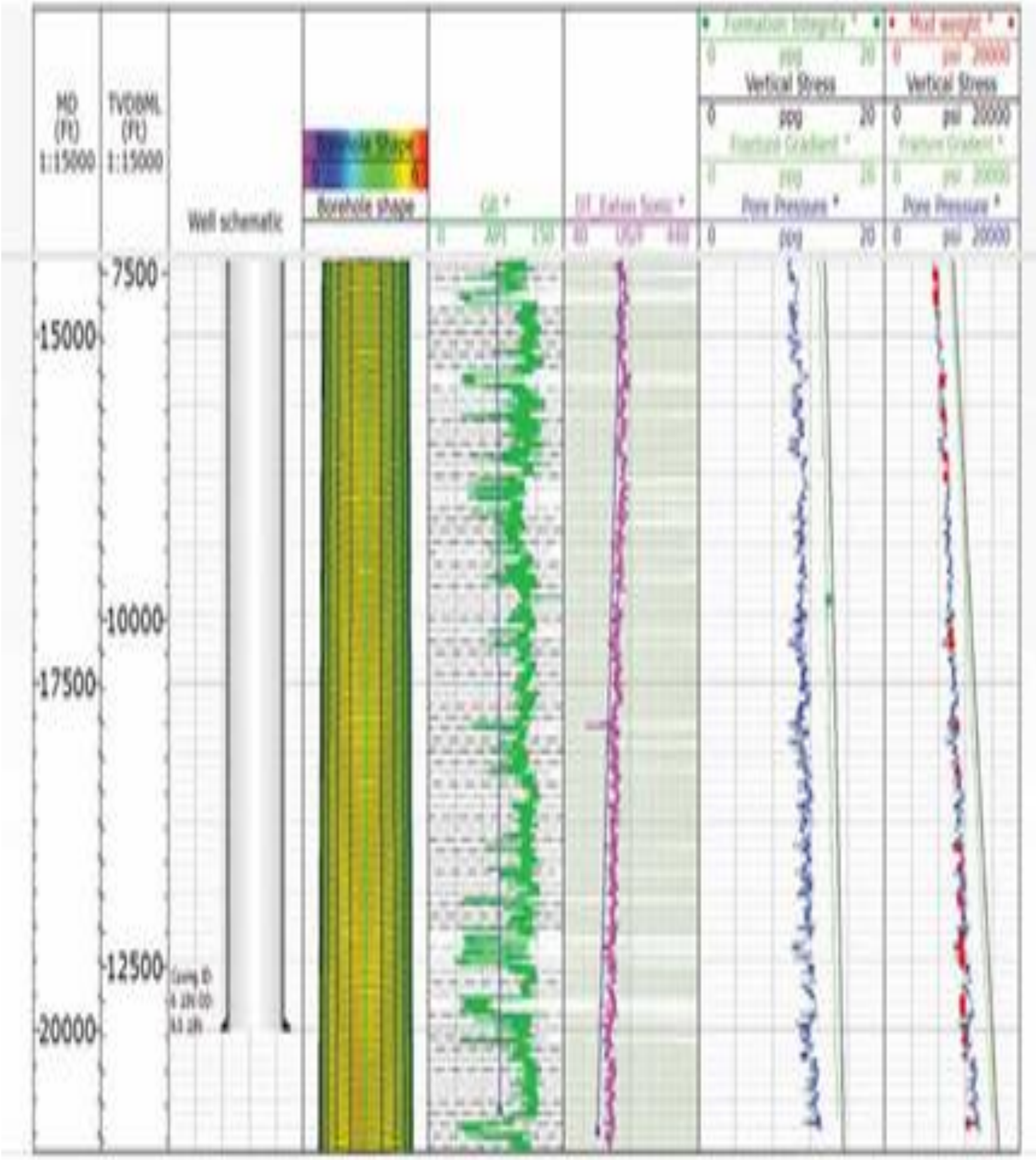
Pore pressure and fracture gradient

- Industry standard methods for shale overpressure calculation: using resistivity, sonic, seismic, or D-exponent data
- Shale discrimination
- Easy mapping of trendlines to offset wells
- Display of calibration data from drilling or other Techlog wellbore software platform tools such as the Techlog Formation Pressure module
- Buoyancy and centroid effect computation
- Monte Carlo uncertainty analysis

Fracture gradient

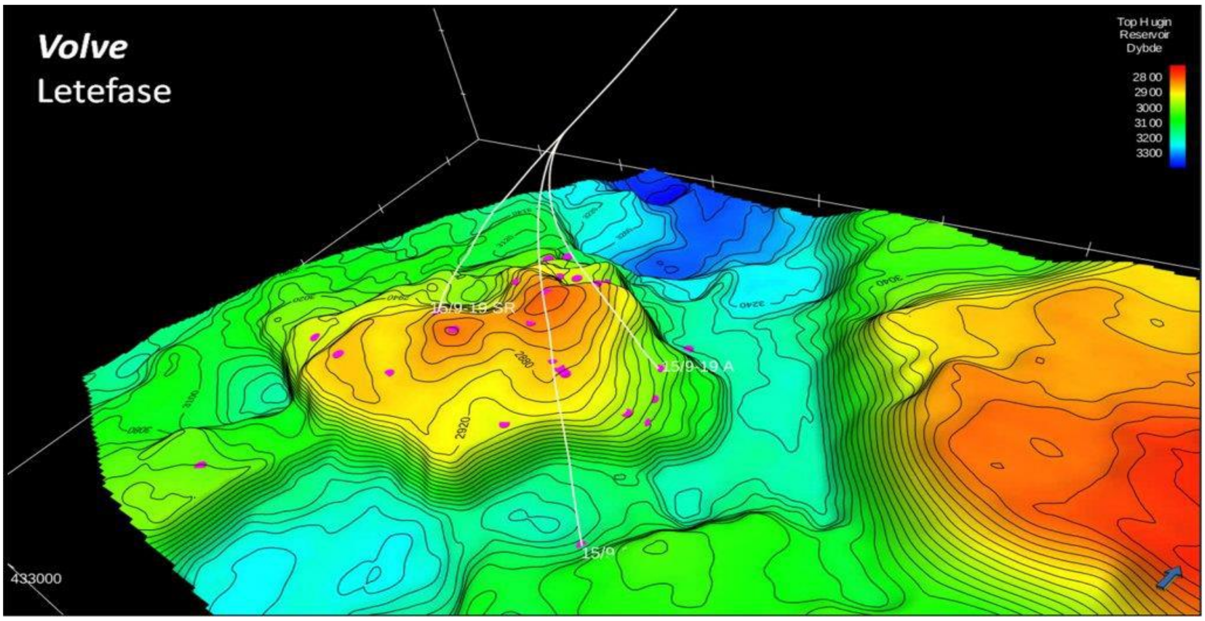
- Industry standard methods for fracture gradient computation, including constant k0 method, Eaton method, Matthews and Kelly method

Pore pressure calculation from sonic data using the Eaton method



UNCONVENTIONAL BASEMENT RESERVOIR IDENTIFICATION IN PETREL

Variance attribute, which is an edge method measures the similarity of waveforms or traces adjacent over given lateral and/or vertical windows. Therefore, it can image discontinuity of seismic data related faulting or stratigraphy. Variance attribute is a very effective tool for delineation faults and channel edges on both horizon slices and vertical seismic profile. Variance attribute is proved to help imaging of channels and faults (Pigott et al., 2013) and is also used to display directly the major fault zones, fractures, unconformities and the major sequence boundaries



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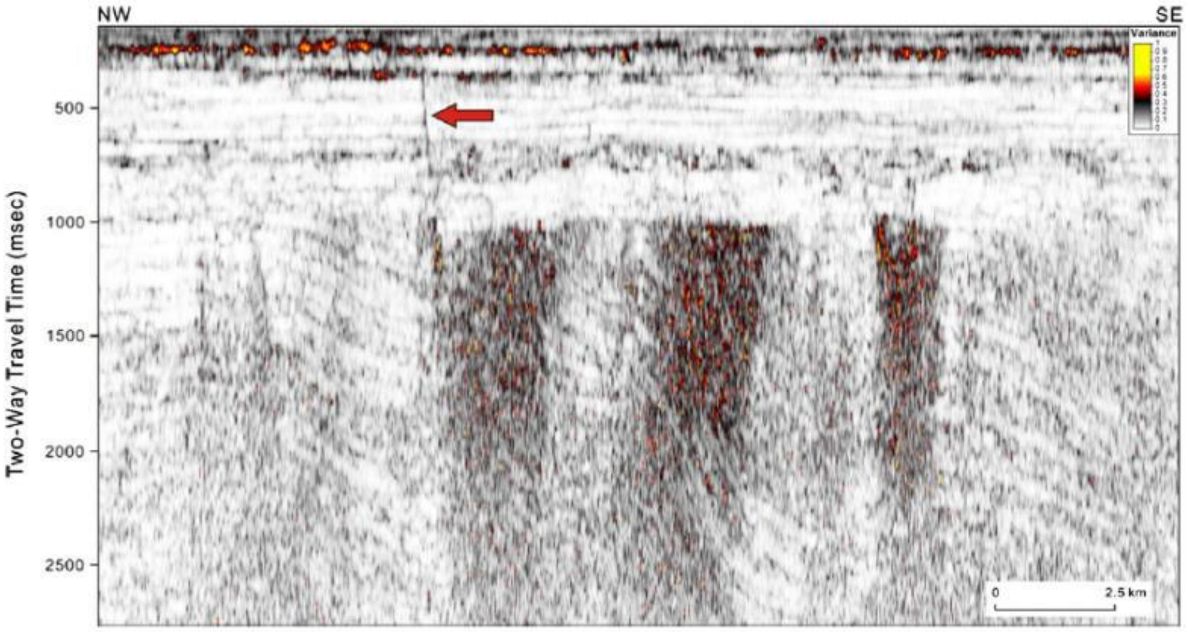
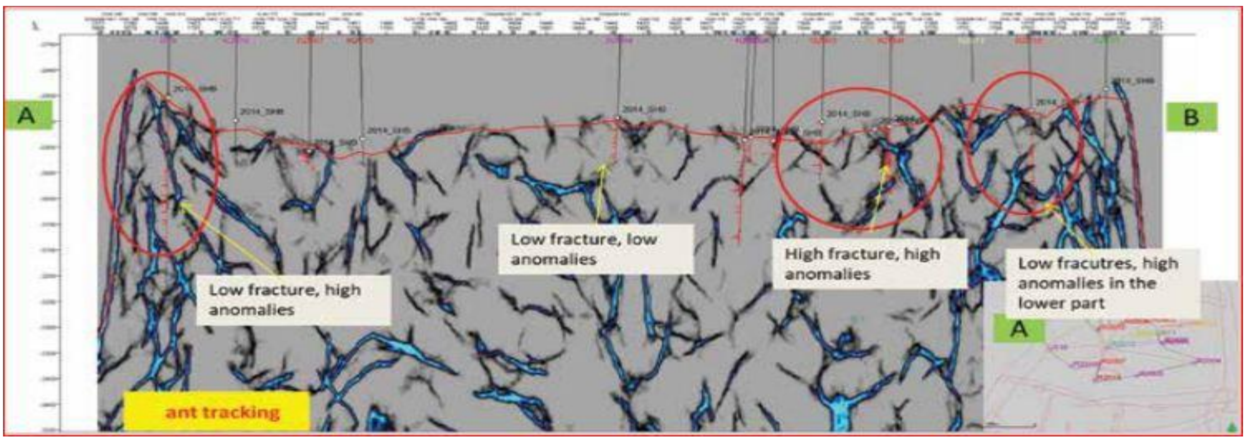


Fig: An example of variance

Then we did ant tracking to determine the different fractures present in the basement. Ant algorithm is an algorithm based on heuristic bionic evolutionary of groups and its achieved principle is to simulate foraging behaviour of ant in nature. Ant tracking technology precisely is a method based on ant algorithm that can implement automatic fracture interpretation in 3D seismic data. The principle is sowing a lot of electronic “ants” in seismic data volume, then the “ants” will move forward along the possible fault plane and leave the “pheromone”. Other Ants called by this “pheromone” will be concentrated in the vicinity of the fault to track this fault plane until the fracture tracking completed. However, if the plane cannot be considered as a fracture plane, it would not be marked or just be unclearly marked. Finally, we will get a data volume with Low noise and clear fracture traces.

Fig: An example of ant tracked fractures in basement reservoirs.



PETROLEUM RESERVES

Reserves are those quantities of petroleum which are anticipated to be commercially recovered from known accumulations from a given date forward. All reserve estimates involve some degree of uncertainty. The uncertainty depends chiefly on the amount of reliable geologic and engineering data available at the time of the estimate and the interpretation of these data. The relative degree of uncertainty may be conveyed by placing reserves into one of two principal classifications, either proved or unproved. Unproved reserves are less certain to be recovered than proved reserves and may be further sub-classified as probable and possible reserves to denote progressively increasing uncertainty in their recoverability.

Proved Reserves

Proved reserves are those quantities of petroleum which, by analysis of geological and engineering data, can be estimated with reasonable certainty to be commercially recoverable, from a given date forward, from known reservoirs and under current economic conditions, operating methods, and government regulations. Proved reserves can be categorized as developed or undeveloped.

Unproved Reserves

Unproved reserves are based on geologic and/or engineering data similar to that used in estimates of proved reserves; but technical, contractual, economic, or regulatory uncertainties preclude such reserves being classified as proved. Unproved reserves may be further classified as probable reserves and possible reserves. Unproved reserves may be estimated assuming future economic conditions different from those prevailing at the time of the estimate. The effect of possible future improvements in economic conditions and technological developments can be expressed by allocating appropriate quantities of reserves to the probable and possible classifications.

Probable Reserves

Probable reserves are those unproved reserves which analysis of geological and engineering data suggests are more likely than not to be recoverable. In this context, when probabilistic methods are used, there should be at least a 50% probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable reserves.

Possible Reserves

Possible reserves are those unproved reserves which analysis of geological and engineering data suggests are less likely to be recoverable than probable reserves. In this context, when probabilistic methods are used, there should be at least a 10%

probability that the quantities actually recovered will equal or exceed the sum of estimated proved plus probable plus possible reserves.

Reserve Status Categories

Reserve status categories define the development and producing status of wells and reservoirs.

Developed: Developed reserves are expected to be recovered from existing wells including reserves behind pipe. Improved recovery reserves are considered developed only after the necessary equipment has been installed, or when the costs to do so are relatively minor. Developed reserves may be subcategorized as producing or non-producing.

Producing: Reserves subcategorized as producing are expected to be recovered from completion intervals which are open and producing at the time of the estimate. Improved recovery reserves are considered producing only after the improved recovery project is in operation.

Non-producing: Reserves subcategorized as non-producing include shut-in and behind-pipe reserves. Shut-in reserves are expected to be recovered from (1) completion intervals which are open at the time of the estimate but which have not started producing, (2) wells which were shut-in for market conditions or pipeline connections, or (3) wells not capable of production for mechanical reasons. Behind-pipe reserves are expected to be recovered from zones in existing wells, which will require additional completion work or future recompletion prior to the start of production.

Undeveloped Reserves: Undeveloped reserves are expected to be recovered: (1) from new wells on undrilled acreage, (2) from deepening existing wells to a different reservoir, or (3) where a relatively large expenditure is required to (a) recomplete an existing well or (b) install production or transportation facilities for primary or improved recovery projects.

The Most Common Project Risks in the Oil and Gas Industry

Political Risk

The oil and gas industries do not have the luxury of operating in any specific portion of the world. Instead, these industrial projects must take place at the site of drilling, extraction, or refinement. As a result, the industry may face challenges with numerous political entities and governments.

If a government in one portion of the world refuses to allow access to oil deposits, the company could suffer a severe setback. Additionally, political climates change, and today's political opinions do not necessarily reflect those of future administrations.

Supply and Demand Risk
As society moves towards “green” initiatives and sustainability, the oil and gas industry face extreme uncertainty. Newer technologies may make access to fossil fuels easier, yet the consumers hold the power to enact the change in price. For example, a widespread boycott or strike may result in severe problems in price of oil and gas. Furthermore, the economies of various countries can impact the price of oil and gas.
If one economy tanks and another economy suddenly rise, the offset could result in a drop-in price. As a result, the overall profits to the extraction company fall.

Extraction Risk

Depending on geological boundaries, the cost to extract oil and gas remains a top priority for project managers in the industry. In some cases, extracting more material from large deposits may incur an additional cost to bypass natural barriers. Unfortunately, some of these barriers may not be easily identified prior to drilling, and the losses for drilling in one area may easily exceed the potential losses for traditional methods of drilling in a reputable area.

Operational Risk
Similarly, cost risk impacts the profitability of an operation in the oil and gas industry. Skilled workers must be retained during periods of slow production, and new regulations may warrant higher wages and reduced insurance premiums for such workers.
If a given project suffers an accident, such as offshore explosion, the financial impact for the company could devastating. Each of these potential costs and operational risks correlate directly to extraction risk.

Environmental Risk
Environment risk is one of the trickiest risks to understand in the oil and gas industry. Society cannot survive without oil and gas in modernity; however, many different movements and alternative energies have been created to reduce the environmental impact from the oil and gas industry. Environmental risk can change with a social media campaign or in synchronicity with political events.
Risk management in the oil and gas industry is constantly changing, and specific risks will always be present. Understanding these risks can dramatically reduce their impact; however, some risks may be entirely unavoidable and cause failure of a project.

RESERVE ESTIMATION

Introduction

Most of the subsurface hydrocarbon accumulations are found in sedimentary rocks. To locate the petroleum reserves an understanding of the nature of rocks is essential. To search a 'Petroleum system' is a very useful framework for describing geological situation of a prospect.

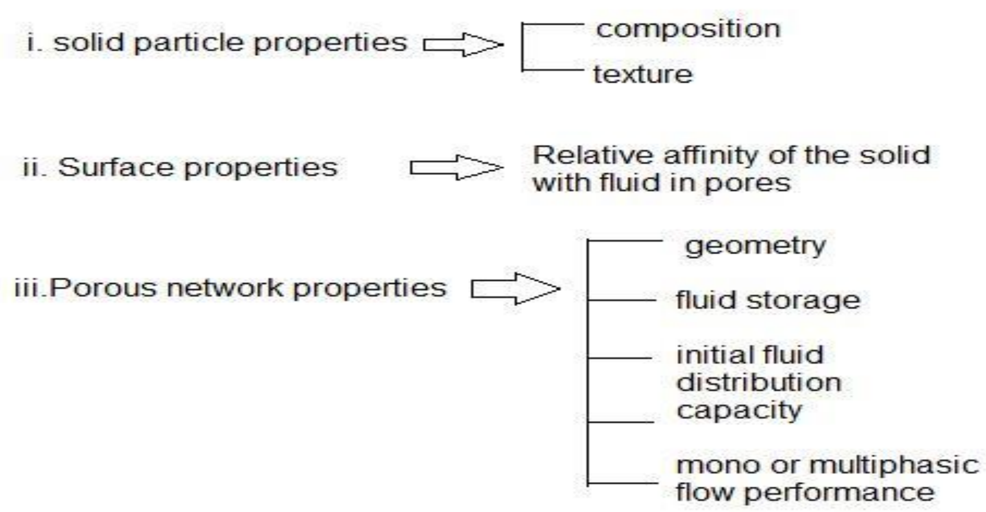
A **'Petroleum system'** consists of

- Mature source rock
- Reservoir rock
- Cap rock
- Trap/ Entrapment

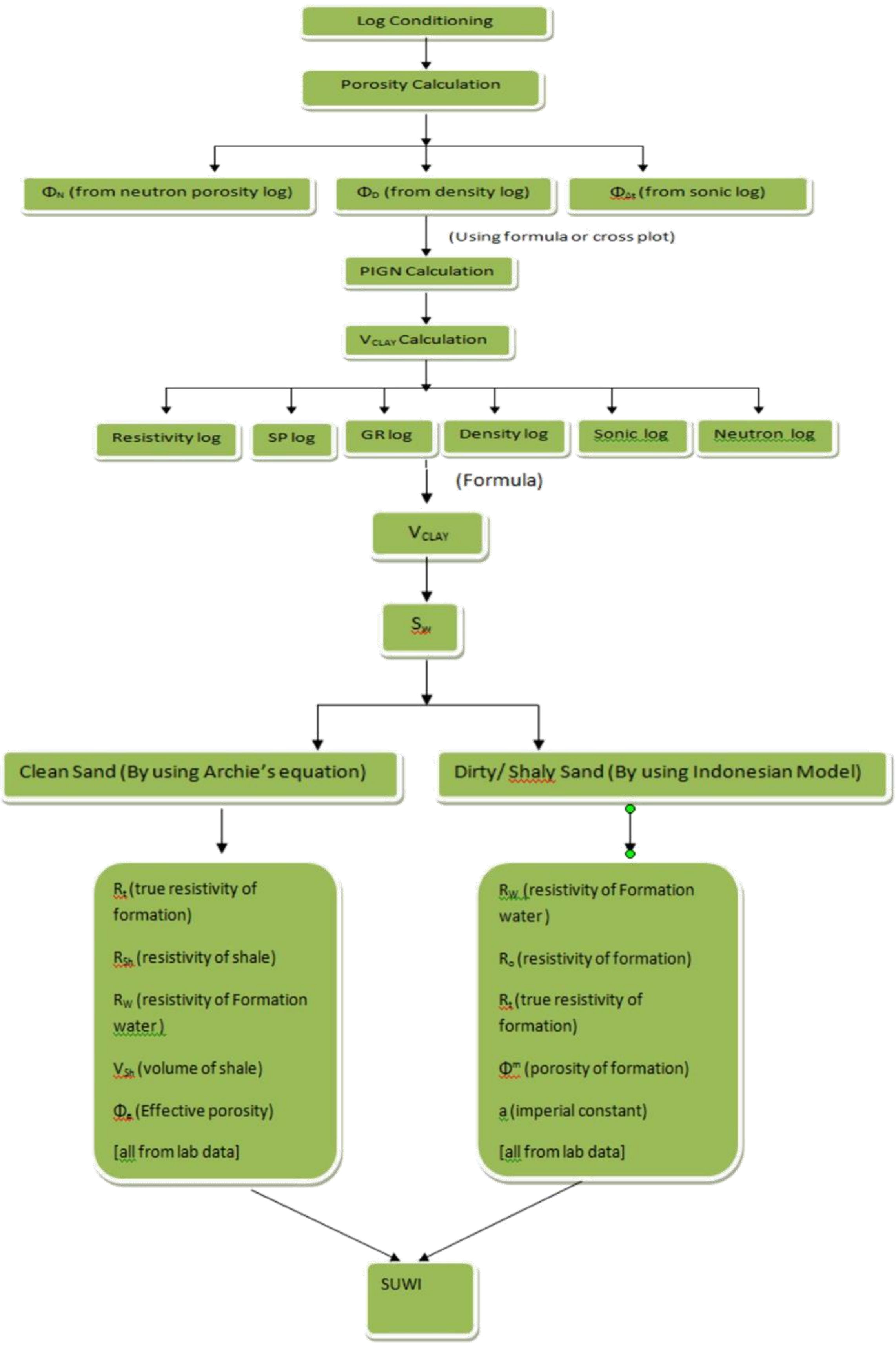
Formation Evaluation

To evaluate reservoir condition, its various properties like mineral composition, texture, age, thermal, mechanical, electrical behavior in relation to fluid storage and flow are studied.

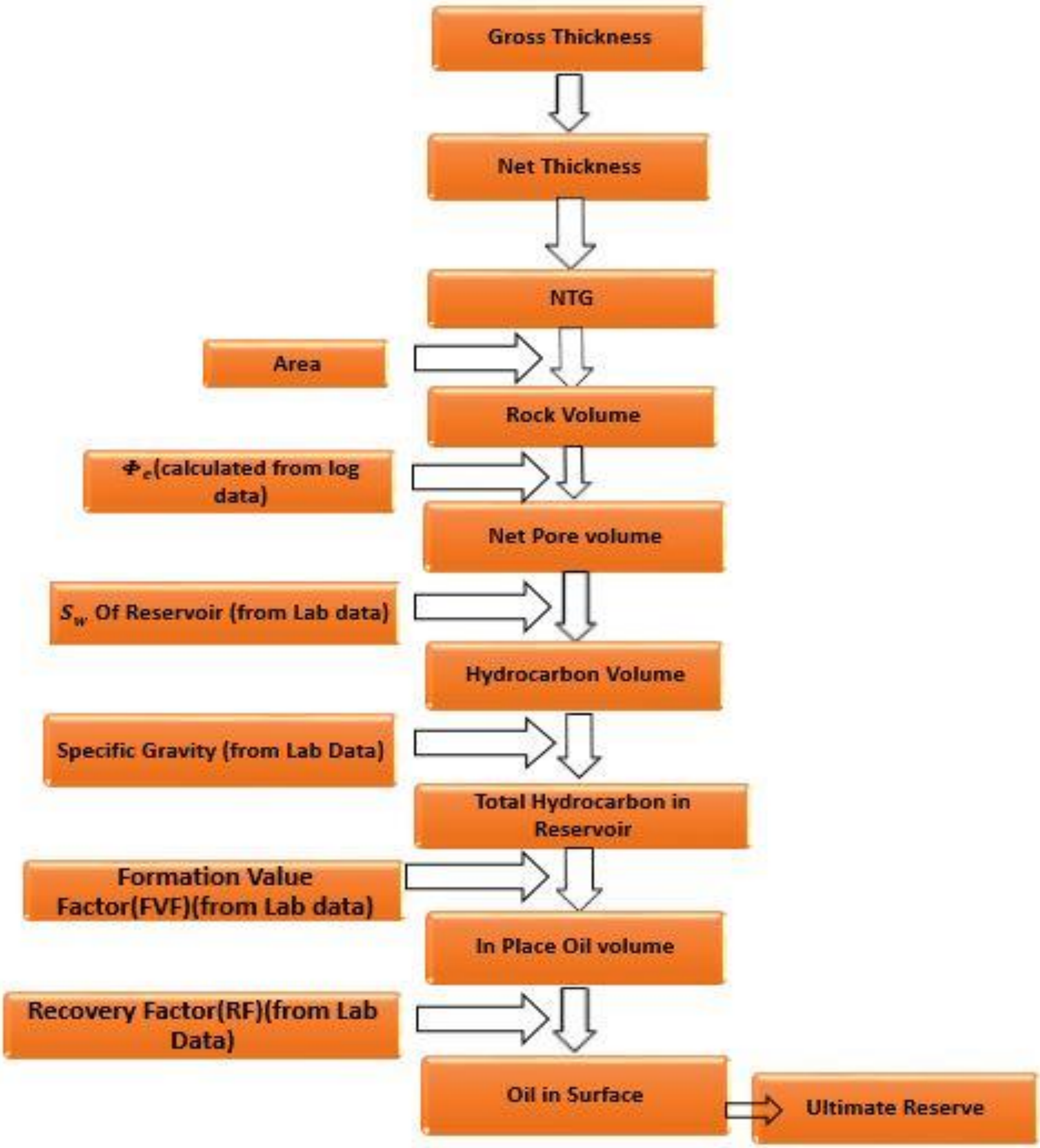
Reservoir rock study is focused on:



Flow Chart of formation Evaluation:



Hydrocarbon estimation



RESERVOIR DRIVE MECHANISM & RECOVERY

Oil Recovery

Petroleum reservoirs are porous and permeable rock bodies containing oil and gas through which fluids move towards recovery openings. The natural energy of a reservoir can be used to move oil and gas toward the wellbore. Used in such a fashion, these sources of energy are called drive mechanisms. Early determination and characterization of the drive mechanism(s) present within a reservoir may allow a greater ultimate recovery of hydrocarbons. Drive mechanisms are determined by the analysis of historical production data, primarily reservoir pressure data and fluid production ratios.

Recovery of hydrocarbons from an oil reservoir is commonly recognized to occur in several recovery stages.
These are:

- **Primary recovery**
- **Secondary recovery**
- **Tertiary recovery (Enhanced Oil Recovery, EOR)**
- **Estimated Oil recovery**

Primary recovery: This is the recovery of hydrocarbons from the reservoir using the natural energy of the reservoir as a drive.

Secondary recovery: This is recovery aided or driven by the injection of water or gas from the surface.

Tertiary recovery (EOR): There are a range of techniques broadly labeled 'Enhanced Oil Recovery' that are applied to reservoirs in order to improve flagging production.

Estimated Oil recovery: This is carried out when recovery from the previous three phases have been completed. It involves drilling cheap production holes between existing boreholes to ensure that the whole reservoir has been fully depleted of its oil.

Recovery factor

Recovery Factor (RF) of a reservoir is the ratio of recoverable oil to estimated oil in place. It is determined by various factors such as

- Reservoir dimension
- Drive mechanism
- Nature of hydrocarbon etc.

The recovery factor is function of displacement mechanism. It is a measure of extraction efficiency.

In petroleum geology only a % of in place oil is recoverable. Between 20-40% is common for primary recovery techniques. But if enhanced by water injection, detergents injection, to reduce viscosity, it may be upto 60% for oil.

1)PRIMARY RECOVERY:

During primary recovery the natural energy of the reservoir is used to transport hydrocarbons towards and out of the production wells. There are several different energy sources, and each gives rise to a drive mechanism. Early in the history of a reservoir the drive mechanism will not be known. It is determined by analysis of production data (reservoir pressure and fluid production ratios). The earliest possible determination of the drive mechanism is a primary goal in the early life of the reservoir, as its knowledge can greatly improve the management and recovery of reserves from the reservoir in its middle and later life. There are five important drive mechanisms (or combinations).

These are:

- Depletion drive or Dissolved gas drive
- Gas cap drive
- Water drive
- Gravity drainage
- Combination or mixed drive

Depletion drive or Dissolved Gas Drive:

This drive mechanism requires the reservoir rock to be completely surrounded by impermeable barriers. As production occurs the reservoir pressure drops, and the exsolution and expansion of the dissolved gases in the oil and water provide most of the reservoirs drive energy. Small amounts of additional energy are also derived from the expansion of the rock and water, and gas exsolving and expanding from the water phase.

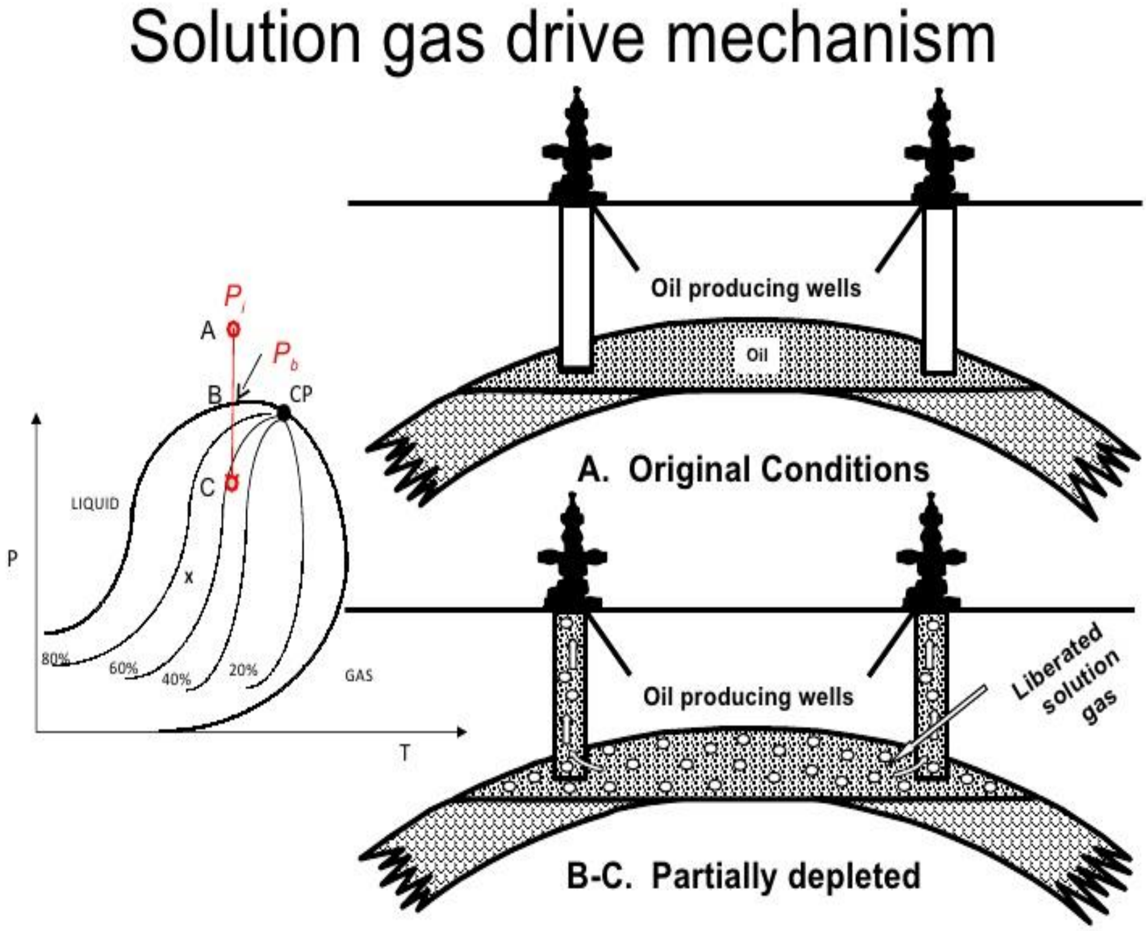
A solution gas drive reservoir is initially either considered to be under saturated or saturated depending on its pressure:

- **Under saturated**: Reservoir pressure > bubble point of oil.

- **Saturated**: Reservoir pressure £ bubble point of oil.

For an under saturated reservoir no free gas exists until the reservoir pressure falls below the bubble point. In this regime reservoir drive energy is provided only by the bulk expansion of the reservoir rock and liquids (water and oil).

For a saturated reservoir, any oil production results in a drop-in reservoir pressure that causes bubbles of gas to exsolve and expands. When the gas comes out of solution the oil (and water) shrink slightly. However, the volume of the exsolved gas, and its subsequent expansion more than makes up for this. Thus, gas expansion is the primary reservoir drive for reservoirs below the bubble point. Solution gas drive reservoirs show a particular characteristic pressure, GOR and fluid production history. If the reservoir is initially under saturated, the reservoir pressure can drop by a great deal (several hundred psi over a few months).



This is because of the small compressibility of the rock water and oil, compared to that of gas. In this undersaturated phase, gas is only exsolved from the fluids in the well bore, and consequently the GOR is low and constant. When the reservoir reaches the bubble point pressure, the pressure declines less quickly due to the formation of gas bubbles in the reservoir that expand taking up the volume exited by produced oil and hence protecting against pressure drops. When this happens, the GOR rises dramatically (up to 10 times). Further fall in reservoir pressure, as production continues, can, however, lead to a decrease in GOR again when reservoir pressures are such that the gas expands less in the borehole. When the GOR initially rises, the oil production falls and artificial lift systems are then instituted.

Oil recovery from this type of reservoir is typically between 20% and 30% of original oil in place (i.e. low). Of this only 0% to 5% of oil is recovered above the bubble point. There is usually no production of water during oil recovery unless the reservoir pressure drops sufficiently for the connate water to expand sufficiently to be mobile. Even in this scenario little water is produced.

Gas Cap Drive:

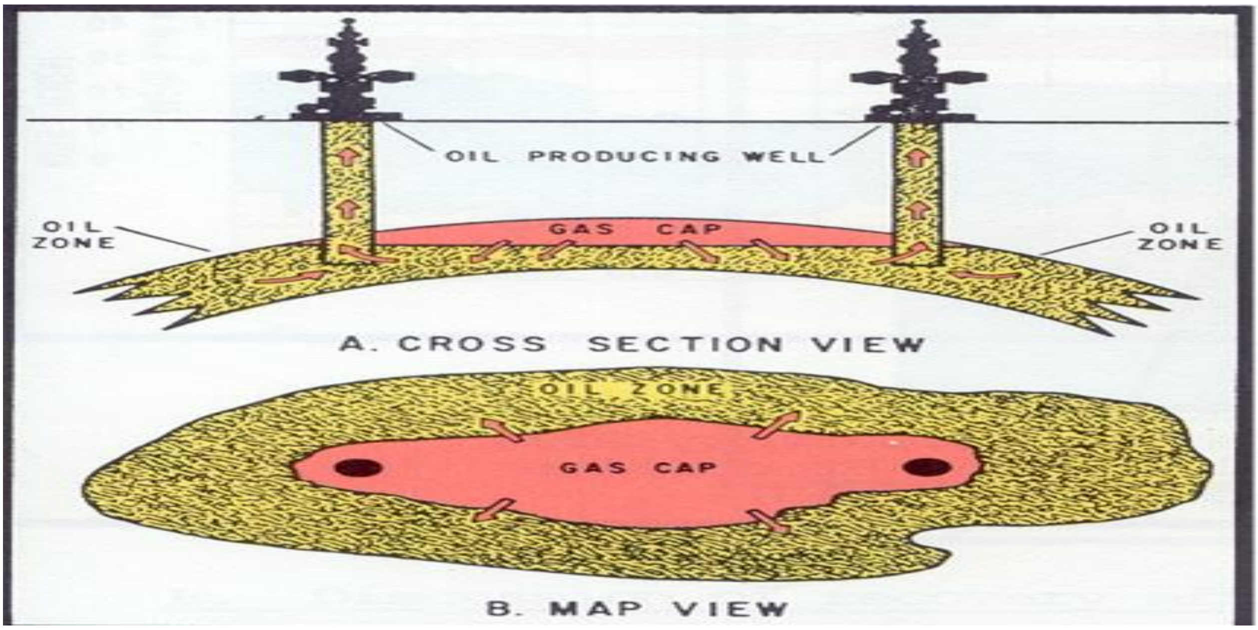
A gas cap drive reservoir usually benefits to some extent from solution gas drive, but derives its main source of reservoir energy from the expansion of the gas cap already existing above the reservoir.

The presence of the expanding gas cap limits the pressure decrease experienced by the reservoir during production. The actual rate of pressure decrease is related to the size of the gas cap. The GOR rises only slowly in the early stages of production from such a reservoir because the pressure of the gas cap prevents gas from coming out of solution in the oil and water. As production continues, the gas cap expands pushing the gas-oil contact (GOC) downwards. Eventually the GOC will reach the production wells and the GOR will increase by large Amounts. The slower reduction in pressure experienced by gas cap reservoirs compared to solution drive reservoirs results in the oil production rates being much higher throughout the life of the reservoir, and needing artificial lift much later than for solution drive reservoirs.

Gas cap reservoirs produce very little or no water.

The recovery of gas cap reservoirs is better than for solution drive reservoirs (20% to 40% OOIP). The recovery efficiency depends on the size of the gas cap, which is a measure of how much latent energy there is available to drive production, and how the reservoir is managed, i.e. how the energy resource is used bearing in mind the geometric characteristics of the reservoir, economics and equity considerations. Points of importance to bear in mind when managing a gas cap reservoir are:

- Steeply dipping reservoir oil columns are best.
- Thick oil columns are best, and are perforated at the base, as far away from the gas cap as possible. This is to maximize the time before gas breaks through in the well.
- Wells with increasing GOR (gas cap breakthrough) can be shut in to reduce field wide GOR.
- Produced gas can be separated and immediately injected back into the gas cap to maintain gas cap pressure.



Water Drive:

The drive energy is provided by an aquifer that interfaces with the oil in the reservoir at the oil-water contact (OWC). As production continues, and oil is extracted from the reservoir, the aquifer expands into the reservoir displacing the oil. Clearly, for most reservoirs, solution gas drive will also be taking place, and there may also be a gas cap contributing to the primary recovery. Two types of water drive are commonly recognized:

- Bottom water drive
- Edge water drive

The pressure history of a water driven reservoir depends critically upon:

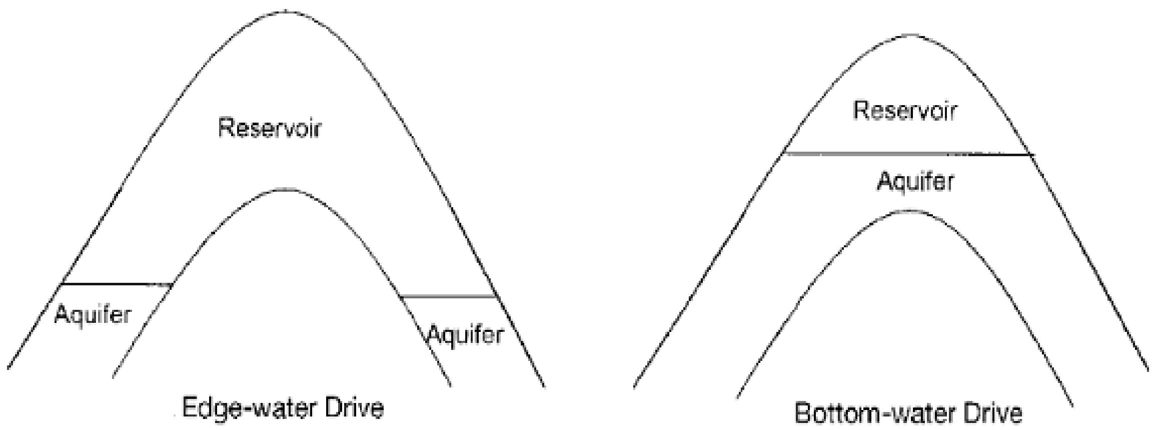
- The size of the aquifer.
- The permeability of the aquifer
- The reservoir production rate.

If the production rate is low, and the size and permeability of the aquifer is high, then the reservoir pressure will remain high because all produced oil is replaced efficiently with water. If the production rate is too high then the extracted oil may not be able to be replaced by water in the same timescale, especially if the aquifer is small or low permeability. In this case the reservoir pressure will fall.

The GOR remains very constant in a strongly water driven reservoir, as the pressure decrease is small and constant, whereas if the pressure decrease is higher (weakly water driven reservoir) the GOR increases due to gas exsolving from the oil and water in the reservoir. Likewise, the oil production from a strongly water driven reservoir remains fairly constant until water breakthrough occurs.

Using analogous arguments to the gas cap drive, it can be seen that thick oil columns are again an advantage, but the wells are perforated high in the oil zone to delay the water breakthrough. When water breakthrough does occur the well can either be shut-down, or assisted using gas lift. Reinjection of water into the aquifer is seldom done because the injected water usually just disappears into the aquifer with no effect on aquifer pressure.

The recovery from water driven reservoirs is usually good, although the exact figure depends on the strength of the aquifer and the efficiency with which the water displaces the oil in the reservoir, which depends on reservoir structure, production well placing, oil viscosity, and production rate. If the ratio of water to oil viscosity is large, or the production rate is high then fingering can occur which leaves oil behind in the reservoir.



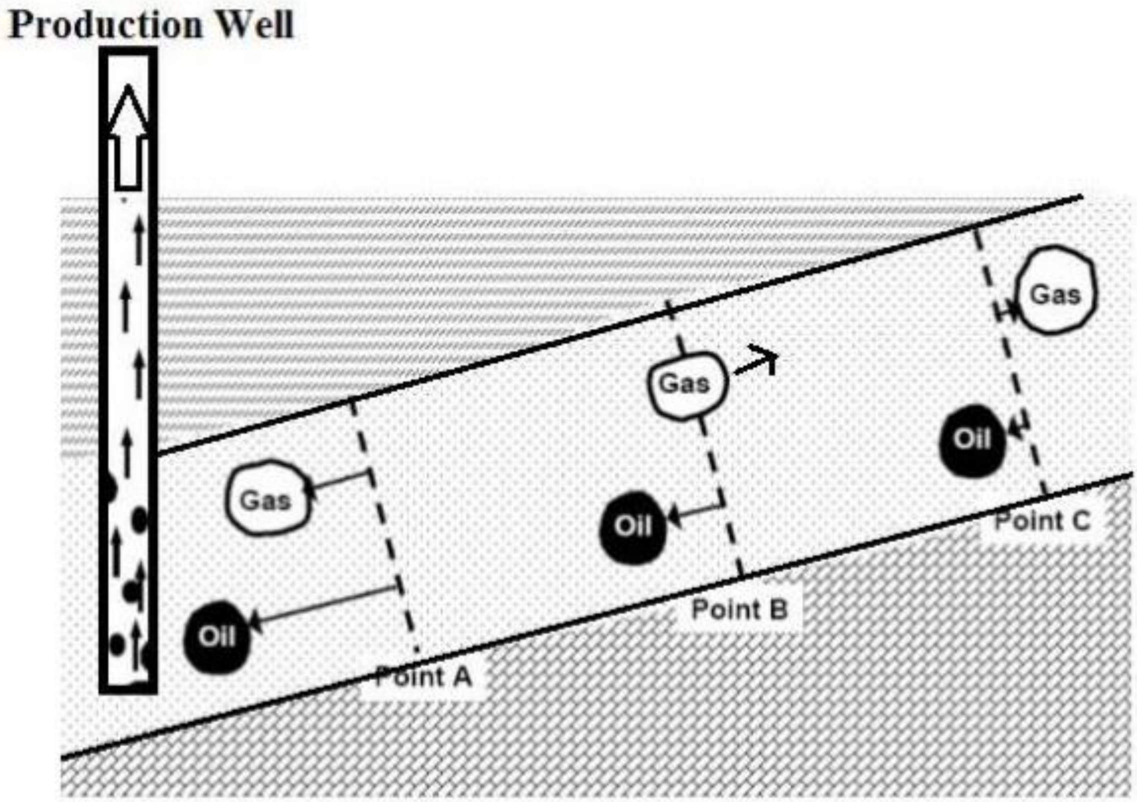
Gravity Drainage:

The density differences between oil and gas and water result in their natural segregation in the reservoir. This process can be used as a drive mechanism, but is relatively weak, and in practice is only used in combination with other drive mechanisms.

The best conditions for gravity drainage are:

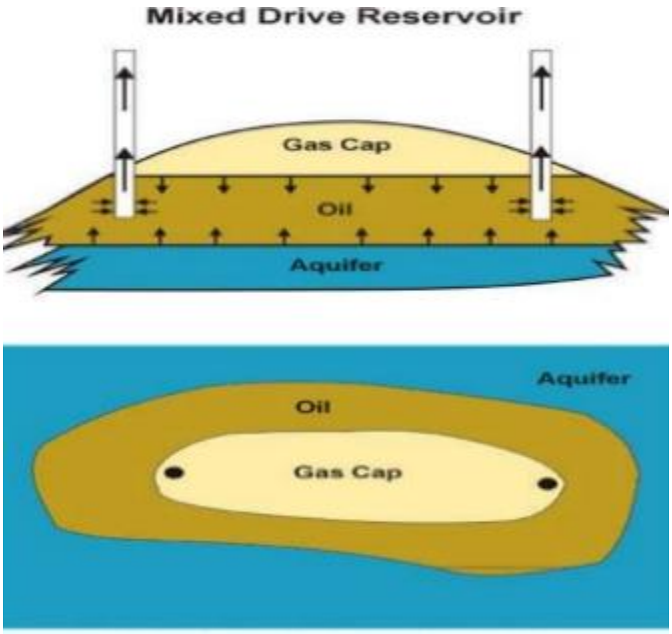
- Thick oil zones.
- High vertical permeability.

The rate of production engendered by gravity drainage is very low compared with the other drive mechanisms examined so far. However, it is extremely efficient over long periods and can give rise to extremely high recoveries. Consequently, it is often used in addition to the other drive mechanisms.



Combination or Mixed Drive:

In practice a reservoir usually incorporates at least two main drive mechanisms. We have seen that the management of the reservoir for different drive mechanisms can be diametrically opposed (e.g. low perforation for gas cap reservoirs compared with high perforation for water drive reservoirs). If both occur, a compromise must be sought, and this compromise must take into account the strength of each drive present, the size of the gas cap, and the size/permeability of the aquifer. It is the job of the reservoir manager to identify the strengths of the drives as early as possible in the life of the reservoir optimize the reservoir performance.



2)Secondary Recovery:

Secondary recovery is the result of human intervention in the reservoir to improve recovery when the natural drives have diminished to unreasonably low efficiencies. Two techniques are commonly used:

- Water flooding
- Gas flooding

Water flooding:

This method involves the injection of water at the base of a reservoir to;

- Maintain the reservoir pressure, and
- Displace oil (usually with gas and water) towards production wells.

The detailed treatment of water flood recovery estimation, mathematical modeling, and design are beyond the scope of these notes. However, it should be noted that the successful outcome of a water flood process depends on designs based on accurate relative permeability data in both horizontal directions, on the choice of a good injector/producer array, and with full account taken of the local crustal stress directions in the reservoir.

Gas Injection:

This method is similar to water flooding in principal, and is used to maintain gas cap pressure even if oil displacement is not required. Again, accurate relperms are needed in the design, as well as injector/producer array geometry and crustal stresses. There is an additional complication in that re-injected lean gas may strip light hydrocarbons from the liquid oil phase. At first sight this may not seem a problem, as recombination in the stock tank or afterwards may be carried out. However, equity agreements often give different percentages of gas and oil to different companies. Then the decision whether to gas flood is not trivial (e.g.Prudhoe Bay, Alaska).

3) Tertiary Recovery:

It increases the mobile of the oil in order to increase extraction.

Thermally enhanced oil recovery methods include heating of oil. Steam injection is the most common form of TOER.

Another method to reduce viscosity is carbon dioxide flooding or detergent injection. Tertiary recovery allows another 5 to 15% of the reservoir oil to be recovered.

Estimated Oil Recovery:

Although recovery of a well can’t be known with certainty until the well ceases production. Petroleum
Engineers’ estimated ultimate recovery (EUR) based on decline rate projections years into the future.

MULTI MEHTOD RISK ANALYSIS SOFTWARE

MMRA is designed to construct probabilistic resource distributions from a variety of volumetric estimating methods, a chance of geological success from your chance factor estimates, and to incorporate multiple fiscal decision thresholds for Exploration, Appraisal, and Development settings. It quantifies the value of uncertainty to generate Probability distribution of the Net Reservoir Estimate.

The user begins by selecting the method of resource investigation from a dashboard of options:

- Quick Look is used to quick estimate without a lot of bells-and-whistles modeling flexibility
- Area versus Depth (or Gross Rock Volume versus Depth) uses workstation-generated Top Reservoir (or Top and Base Reservoir) area-depth pair values for irregularly shaped traps or fixed fluid contacts.
- Define the primary water contact variable as productive area, HC column, rock volume or percent fill to simulate the oil and/or gas saturated net rock volume.
- Volumetric Methods using area, average net pay and determination of the recovery yield, or alternatively, gross rock volume, net/gross and the recovery yield;
- Batch MMRA provides importation of input parameter values for many prospects simultaneously from external workbooks simulating resources in a fast and efficient manner;
- Scenario-based interpretations to explore multiple working hypotheses which are mutually exclusive;
- Resource forecasts from Production profiles (Rate-Time option).

Through this software we assign the probability to the parameters of Area, Net Pay, Porosity, Hydrocarbon Saturation and Formation volume factor and stimulate it to find the OIP (Oil in Place) with different probability values.

WELL LOG DATA

G03[SSTVD]													
Depth	Gamma Ray	Laterolog Shallow Resistivity (LLS) DLT-E	Laterolog Deep Resistivity (LLD) DLT-E	Micro-spherically-focused Resistivity (MSFL) SRT-C	Standard Resolution Formation Photoelectric Factor (PEFZ) HDRS-B	Thermal Neutron Porosity (Original Ratio Method) in Selected Lithology (NPHI) HGNS-B	Standard Resolution Formation Density (RHOZ) HDRS-B	Expected Lithology	$V_{Shale}=\frac{GR-GR_{min}}{GR_{max}-GR_{min}}$ $GR_{max}=150, GR_{min}=4$	$\emptyset_{density}=\frac{\rho_b-\rho_{matrix}}{\rho_{fluid}-\rho_{matrix}}$ $\rho_{fluid}=1.1, \rho_{sand}=2.65, \rho_{shale}=2.06$	$\emptyset_{eff_{density}}=\emptyset_{density}(1-V_{shale})$	$S_W=\left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W=0.67\ \Omega m$ a=1,m=2,n=2	$S_{hydrocarbons}=1-S_W$
1400	37.5	18	18	0.3	1.8	-0.03	2.45		0.229452055	0.129032258	0.099425541	1.495212267	-0.495212267
1403	97.5	5	5	3	3	0.51	2		0.640410959	0.0625	0.022474315	5.85696167	-4.85696167
1408	30	26	26	4	1	0	2.3		0.178082192	0.225806452	0.185594344	0.710909604	0.289090396
1409	128	4	4	4	5.5	0.54	2.55		0.849315068	-0.510416667	-0.0769121	0.801830476	0.198169524
1411	75	3	3	3	5.5	0.54	2.55		0.48630137	0.064516129	0.033141847	7.325014221	-6.325014221
1415	120	2	2	2	5	0.48	2.35		0.794520548	-0.302083333	-0.062071918	1.916000591	-0.916000591
1420	90	2.5	2.5	1.6	5	0.45	2.75		0.589041096	-0.71875	-0.295376712	0.720260402	0.279739598
1425	90	2.5	2.5	2.5	6	0.48	2.5		0.589041096	-0.458333333	-0.188356164	1.129499267	-0.129499267
1430	105	2	2	2	6	0.54	2.4		0.691780822	-0.354166667	-0.109160959	1.634235798	-0.634235798
1435	130	1.5	1.5	1.5	5	0.51	2.4		0.863013699	-0.354166667	-0.048515982	1.887052956	-0.887052956
1440	112.5	2	2	2	6	0.51	2.4		0.743150685	-0.354166667	-0.090967466	1.634235798	-0.634235798
1445	120	1.8	1.8	1.8	6	0.5	2.65		0.794520548	-0.614583333	-0.126284247	0.992705368	0.007294632
1450	127.5	2	2	2	6	0.51	2.45		0.845890411	-0.40625	-0.062607021	1.424718388	-0.424718388
1455	117	2	2	2.5	6	0.48	2.45		0.773972603	-0.40625	-0.09182363	1.424718388	-0.424718388
1460	112.5	2	2	2	6	0.51	2.35		0.743150685	-0.302083333	-0.077589897	1.916000591	-0.916000591
1465	120	2	2	2.5	5.5	0.54	2.45		0.794520548	-0.40625	-0.083476027	1.424718388	-0.424718388
1470	142.5	2	2	2	6	0.51	2.4		0.948630137	-0.354166667	-0.018193493	1.634235798	-0.634235798
1471	105	2.5	2.5	3	7	0.45	1.9		0.691780822	0.166666667	0.051369863	3.106122985	-2.106122985
1472	150	1.8	1.7	2	5	0.48	2.45		1	-0.40625	0	1.545324061	-0.545324061
1475	120	2	2	2	6	0.51	2.35		0.794520548	-0.302083333	-0.062071918	1.916000591	-0.916000591
1480	97.5	2.5	2	2	6	-0.03	2.4		0.640410959	-0.354166667	-0.127354452	1.634235798	-0.634235798
1485	112.5	2.5	2.5	2.5	6	0.48	2.45		0.743150685	-0.40625	-0.104345034	1.274306866	-0.274306866
1490	97.5	2.5	2.5	2.5	6	0.51	2.45		0.640410959	-0.40625	-0.146083048	1.274306866	-0.274306866
1495	105	2.5	2.3	3	6	0.51	2.45		0.691780822	-0.40625	-0.125214041	1.328556747	-0.328556747
1500	105	2.5	2.5	2.5	5.5	0.48	2.45		0.691780822	-0.40625	-0.125214041	1.274306866	-0.274306866
1505	105	2.5	2.5	2.5	5	0.48	2.35		0.691780822	-0.302083333	-0.093107877	1.713723026	-0.713723026
1510	97.5	2.3	2.3	2.3	5.5	0.51	2.35		0.640410959	-0.302083333	-0.108625856	1.786679764	-0.786679764
1515	112.5	2.7	2.7	2.7	5.5	0.42	2.35		0.743150685	-0.302083333	-0.077589897	1.649030751	-0.649030751
1520	97.5	2	2	3.5	5	0.48	2.5		0.640410959	-0.458333333	-0.164811644	1.262818571	-0.262818571
1525	97.5	3.5	3.5	3.5	4	0.42	2.4		0.640410959	-0.354166667	-0.127354452	1.235366144	-0.235366144
1530	105	2.7	2.5	3	6	0.45	2.4		0.691780822	-0.354166667	-0.109160959	1.461704934	-0.461704934
1535	112.5	2.2	2	2.2	6	0.48	2.4		0.743150685	-0.354166667	-0.090967466	1.634235798	-0.634235798
1540	97.5	3	3	3	5	0.48	2.4		0.640410959	-0.354166667	-0.127354452	1.334347942	-0.334347942
1545	112.5	2	2	2	4.5	0.48	2.45		0.743150685	-0.40625	-0.104345034	1.424718388	-0.424718388
1550	105	2.5	2.5	4	4.5	0.42	2.45		0.691780822	-0.40625	-0.125214041	1.274306866	-0.274306866
1555	97.5	3	2.5	3	5.5	0.48	2.45		0.640410959	-0.40625	-0.146083048	1.274306866	-0.274306866
1560.5	97.5	4	4	65	5.5	0.33	1.85		0.640410959	0.21875	0.078660103	1.870937776	-0.870937776
1565	112.5	3.5	3.5	3.5	5.5	0.42	2.45		0.743150685	-0.40625	-0.104345034	1.076985869	-0.076985869
1570	112	2.5	2	2.5	5.5	0.51	2.4		0.739726027	-0.354166667	-0.092180365	1.634235798	-0.634235798
1575	112.5	3	3	3	5.5	0.45	2.35		0.743150685	-0.302083333	-0.077589897	1.564407931	-0.564407931
1600	105	2.5	2.5	2.5	5	0.51	2.35		0.691780822	-0.302083333	-0.093107877	1.713723026	-0.713723026
1605	105	3	3	3	5.5	0.42	2.55		0.691780822	-0.510416667	-0.157320205	0.925874082	0.074125918
1625	112.5	1.5	1.5	1.5	4.5	0.48	2.45		0.743150685	-0.40625	-0.104345034	1.64512309	-0.64512309
1635	105	3	3	4	6	0.42	2.55		0.691780822	-0.510416667	-0.157320205	0.925874082	0.074125918
1644.5	90	3	3	3	4.5	0.42	2.45		0.589041096	-0.40625	-0.166952055	1.163277693	-0.163277693
1655	110	3	3	3	5	0.45	2.35		0.726027397	-0.302083333	-0.082762557	1.564407931	-0.564407931
1665	105	1.5	1.5	1.5	5.5	0.54	2.45		0.691780822	-0.40625	-0.125214041	1.64512309	-0.64512309
1676.5	150	1.5	1.2	1.8	4.5	0.42	2.45		1	-0.40625	0	1.83930353	-0.83930353
1681	82.5	1.5	1.5	2	5	0.51	2.4		0.537671233	-0.354166667	-0.163741438	1.887052956	-0.887052956
1687	142.5	1.5	1.5	2	4.5	0.45	2.45		0.948630137	-0.40625	-0.020869007	1.64512309	-0.64512309
1700	105	1.5	1.3	1.8	5	0.54	2.5		0.691780822	-0.458333333	-0.141267123	1.566333663	-0.566333663
1715	90	1.9	1.8	2.3	5	0.48	2.35		0.589041096	-0.302083333	-0.124143836	2.019641955	-1.019641955
1725	90	2	1.8	2.2	5	0.51	2.35		0.589041096	-0.302083333	-0.124143836	2.019641955	-1.019641955
1731	22.5	1.6	1.4	1.9	4.5	0.45	2.5		0.126712329	0.096774194	0.08451171	7.148481912	-6.148481912
1731.5	135	1.7	1.5	1.7	4.5	0.42	2.6		0.897260274	-0.5625	-0.057791096	1.188144454	-0.188144454
1732	60	2	1.9	2.5	4.5	0.42	2.6		0.383561644	0.032258065	0.019885108	18.40866501	-17.40866501
1734	90	2	2	2	4.5	0.45	2.35		0.589041096	-0.302083333	-0.124143836	1.916000591	-0.916000591
1737	15	1.6	1.6	2.3	5	0.45	2.55		0.075342466	0.064516129	0.059655325	10.03018881	-9.030188807
1739	90	1.2	1.2	4	4.5	0.54	2.25		0.589041096	-0.197916667	-0.081335616	3.775412509	-2.775412509
1740.5	142.5	1.5	1.5	2	5	0.45	2.5		0.948630137	-0.458333333	-0.023544521	1.458177284	-0.458177284
1743	90	2	2	3	5	0.51	2.35		0.589041096	-0.302083333	-0.124143836	1.916000591	-0.916000591
1746	148	2	2	2	5.5	0.45	2.65		0.98630137	-0.614583333	-0.00841895	0.941763002	0.058236998
1750	97.5	2	2	3	5.5	0.48	2.45		0.640410959	-0.40625	-0.146083048	1.424718388	-0.424718388
1758	142.5	1.5	1.4	1.7	6	0.45	2.45		0.948630137	-0.40625	-0.020869007	1.702864178	-0.702864178
1759	82.5	2	2	2.6	5	0.51	2.35		0.537671233	-0.302083333	-0.139661815	1.916000591	-0.916000591
1760.5	7.5	1.7	1.5	2	5	0.51	2.55		0.023972603	0.064516129	0.06296951	10.35913446	-9.359134455
1762	90	2.3	2	3.5	4	0.48	2.35		0.589041096	-0.302083333	-0.124143836	1.916000591	-0.916000591
1763	127.5	2	2	2	5.5	0.45	2.65		0.845890411	-0.614583333	-0.094713185	0.941763002	0.058236998
1764	75	3	3	9	4	-0.03	2.15		0.48630137	0.322580645	0.165709236	1.465002844	-0.465002844
1765	127.5	1.8	1.7	1.7	5	0.42	2.55		0.845890411	-0.510416667	-0.078660103	1.229951804	-0.229951804
1766	87.5	2.3	2	2.3	4.5	0.48	2.35		0.571917808	-0.302083333	-0.129316495	1.916000591	-0.916000591
1771	142.5	1.5	1.5	1.6	5	0.45	2.55		0.948630137	-0.510416667	-0.026220034	1.309383684	-0.309383684
1775	75	1.8	1.7	2.2	4	0.48	2.45		0.48630137	0.129032258	0.066283694	4.865356223	-3.865356223
1781	67.5	2	1.9	2.6	4.5	0.45	2.45		0.434931507	0.129032258	0.072912064	4.602166252	-3.602166252
1783	67.5	1.8	1.7	1.9	5	0.48	2.35		0.434931507	0.193548387	0.109368095	3.243570815	-2.243570815
1787	30	1.5	1.5	2	5.5	0.45	2.55		0.178082192	0.064516129	0.053026955	10.35913446	-9.359134455
1792	75	1.5	1.5	2	5	0.45	2.45		0.48630137	0.129032258	0.066283694	5.179567228	-4.179567228
1797.5	37.5	1.5	1.5	1.6	5	0.51	2.55		0.229452055	0.064516129	0.049712771	10.35913446	-9.359134455
1799	90	1.4	1.4	1.7	5.5	0.51	2.5		0.589041096	-0.458333333	-0.188356164	1.509356885	-0.509356885
1800	127.5	1.6	1.6	2.5	5.5	0.48	2.65		0.845890411	-0.614583333	-0.094713185	1.052923046	-0.052923046
1805	97.5	1.5	1.4	1.9	5	0.48	2.5		0.640410959	-0.458333333	-0.164811644	1.509356885	-0.509356885
1809	142.5	1.5	1.4	2	5.5	0.45	2.65		0.948630137	-0.614583333	-0.031571062	1.125622084	-0.125622084
1810	7.5	1.5	1.4	2	5.5	0.45	2.65		0.023972603	0	0	#DIV/0!	#DIV/0!
1812	75	2	1.7	2	4.5	0.45	2.45		0.48630137	0.129032258	0.066283694	4.865356223	-3.865356223
1814.5	148	1.6	1.5	1.5	5.5	0.45	2.6		0.98630137	-0.5625	-0.007705479	1.188144454	-0.188144454
1820	75	1.7	1.5	1.7	4.5	0.51	2.45		0.48630137	0.129032258	0.066283694	5.179567228	-4.179567228
1826.5	142.5	1.5	1.4	1.6	5	0.45	2.55		0.948630137	-0.510416667	-0.026220034	1.355340876	-0.355340876
1827.5	67.5	1.5	1.5	2.5	5	0.42	2.55		0.434931507	0.064516129	0.036456032	10.35913446	-9.359134455
1830	82.5	1.5	1.4	1.7	4.5	0.45	2.45		0.537671233	-0.40625	-0.187821062	1.702864178	-0.702864178
1832.5	22.5	1.6	1.6	2	5.5	0.42	2.6		0.126712329	0.032258065	0.02817057	20.06037761	-19.06037761
1835	67.5	2	1.7	2.3	4	0.45	2.25		0.434931507	0.258064516	0.145824127	2.432678111	-1.432678111
1839	4	1.5	1.5	1.6	6.5	0.45	2.65		0	0	0	#DIV/0!	#DIV/0!
1845	90	1.5	1.5	1.6	4.5	0.48	2.5		0.589041096	-0.458333333	-0.188356164	1.458177284	-0.458177284
1855.5	4	1.3	1.3	1.8	4.5	0.48	2.55		0	0.064516129	0.064516129	11.1274954	-10.1274954
1861	30	1.3	1.3	2	5	0.42	2.5		0.178082192	0.096774194	0.079540433	7.418330266	-6.418330266
1864	90	1	1	1.6	5	0.45	2.65		0.589041096	-0.614583333	-0.252568495	1.33185401	-0.33185401
1867	142.5	1	1	1.6	5.5	0.51	2.55		0.948630137	-0.510416667	-0.026220034	1.603660951	-0.603660951
1870.5	82.5	0.9	0.9	1.5	5	-0.6	2.55		0.537671233	-0.510416667	-0.235980308	1.690407067	-0.690407067
1873.5	7.5	1	1	1.5	5.5	0.48	2.6		0.023972603	0.032258065	0.031484755	25.37459359	-24.37459359
1880	75	1.5	1.5	1.7	4.5	0.51	2.45		0.48630137	0.129032258	0.066283694	5.179567228	-4.179567228
1887	7.5	1.6	1.5	2	5	0.45	2.55		0.023972603	0.064516129	0.06296951	10.35913446	-9.359134455
1890	82.5	1.5	1.4	1.7	4	0.45	2.45		0.537671233	-0.40625	-0.187821062	1.702864178	-0.702864178
1893	127.5	1.5	1.4	1.8	6	0.45	2.7		0.845890411	-0.666666667	-0.102739726	1.037682858	-0.037682858
1895	82.5	1.5	1.4	2	4.5	0.45	2.5		0.537671233	-0.458333333	-0.211900685	1.509356885	-0.509356885
1897.5	148	2	2	2	4.5	0.33	2.5		0.98630137	-0.458333333	-0.006278539	1.262818571	-0.262818571
1908	75	1.5	1.4	1.4	6	0.45	2.65		0.48630137	0	0	#DIV/0!	#DIV/0!
1915	120	1	1	0.7	5	0.45	2.65		0.794520548	-0.614583333	-0.126284247	1.33185401	-0.33185401

WELL LOG DATA

AT_02[SSTVD]																		
Depth	Gamma Ray	Laterolog Shallow Resistivity RESS	Laterolog Middle Resistivity RESM	Laterolog Deep Resistivity RESD	DTCO	NPHI	RHOB	$V_{Shale} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$ $GR_{max} = 105, GR_{min} = 30$	$\emptyset_{density} = \frac{\rho_b - \rho_{matrix}}{\rho_{fluid} - \rho_{matrix}}$ $\rho_{fluid} = 1.07, \rho_{sand} = 2.65, \rho_{shale} = 2.06$	$\emptyset_{eff_{density}} = \emptyset_{density}(1 - V_{shale})$	$\emptyset_{sonic} = \frac{\Delta t - \Delta t_{matrix}}{\Delta t_{fluid} - \Delta t_{matrix}}$ $\Delta t_{fluid} = 189\mu s/ft, \Delta t_{sand} = 55\mu s/ft, \Delta t_{shale} = 115\mu s/ft$	$\emptyset_{eff_{sonic}} = \emptyset_t(1 - V_{shale})$	$S_{W_{total}} = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{W_{eff}} = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{hydrocarbons} = 1 - S_W$	GROSS $V_{Shale} < 0.6$, $\emptyset_{density} > 10$	NET $V_{Shale} < 0.6$, $\emptyset_{density} > 10$, $S_{hy} > 0.5$
3000	105	2	1.5	1.5	120	0.42	2.4	1	-0.343434343	0.088607595	0.067567568	0	N.A.	N.A.	N.A.		
3050	105	2	1.5	1.5	120	0.42	2.4	1	-0.343434343	0	0.067567568	0	N.A.	N.A.	N.A.		
3100	90	1.5	1.5	1.4	120	0.48	2.4	0.8	-0.343434343	-0.068686869	0.067567568	0.013513514	N.A.	N.A.	N.A.		
3150	105	1.9	1.8	1.5	120	0.48	2.45	1	-0.393939394	0	0.067567568	0	N.A.	N.A.	N.A.		
3195	80	1.9	1.5	1.5	120	0.48	2.45	0.666666667	-0.393939394	-0.131313131	0.067567568	0.022522523	N.A.	N.A.	N.A.		
3245	75	2	1.6	1.5	100	0.3	2.5	0.6	-0.444444444	-0.177777778	-0.202702703	-0.081081081	N.A.	N.A.	N.A.		
3250	65	5	4	4	100	0.24	2.6	0.466666667	-0.545454545	-0.290909091	-0.202702703	-0.108108108	N.A.	N.A.	N.A.		
3262.5	82.5	2	2	1.8	118	0.48	2.45	0.7	-0.393939394	-0.118181818	0.040540541	0.012162162	N.A.	N.A.	N.A.		
3315	60	10	10	10	80	0.18	2.5	0.4	-0.444444444	-0.266666667	-0.472972973	-0.283783784	N.A.	N.A.	N.A.		
3340	105	2	2	2	118	0.42	2.5	1	-0.444444444	0	0.040540541	0	N.A.	N.A.	N.A.		
3350	75	10	10	10	90	0.18	2.3	0.6	0.221518987	0.088607595	0.26119403	0.104477612	0.991001143	2.477502857	0.008998857		
3355	60	200	200	150	50	0.12	2.3	0.4	0.221518987	0.132911392	0.021126761	0.012676056	3.163434608	5.272391013	-2.163434608		
3362.5	75	15	15	15	100	0.18	2.3	0.6	0.221518987	0.088607595	0.335820896	0.134328358	0.629338146	1.573345365	0.370661854		
3365	45	200	200	150	90	0.06	2.4	0.2	0.158227848	0.126582278	0.26119403	0.208955224	0.255875395	0.319844244	0.744124605		
3375	60	200	200	200	40	0	2.6	0.4	0.03164557	0.018987342	-0.111940299	-0.067164179	0.517054048	0.861756747	0.482945952		
3390	67.5	60	60	60	80	0.12	2.2	0.5	0.284810127	0.142405063	0.186567164	0.093283582	0.566404331	1.132808663	0.433595669		
3392.5	45	600	400	400	60	0.06	2.6	0.2	0.03164557	0.025316456	0.037313433	0.029850746	1.096837271	1.371046589	-0.096837271		
3400	45	100	100	80	80	0.06	2.2	0.2	0.284810127	0.227848101	0.186567164	0.149253731	0.49052054	0.613150675	0.50947946		
3405	45	200	200	150	60	0	2.6	0.2	0.03164557	0.025316456	0.037313433	0.029850746	1.791127764	2.238909705	-0.791127764		
3410	60	10	10	10	100	0.3	2.55	0.4	0.063291139	0.037974684	0.335820896	0.201492537	0.770778667	1.284631111	0.229221333		
3430	105	2	2	2	100	0.24	2.5	1	-0.444444444	0	-0.202702703	0	N.A.	N.A.	N.A.		
3450	105	1.5	1.5	1.5	120	0.42	2.45	1	-0.393939394	0	0.067567568	0	N.A.	N.A.	N.A.		
3500	97.5	1.8	1.8	1.5	118	0.42	2.4	0.9	-0.343434343	-0.034343434	0.040540541	0.004054054	N.A.	N.A.	N.A.		
3550	105	1.8	1.8	1.5	118	0.36	2.5	1	-0.444444444	0	0.040540541	0	N.A.	N.A.	N.A.		
3600	105	2	2	1.5	118	0.36	2.45	1	-0.393939394	0	0.040540541	0	N.A.	N.A.	N.A.		
3650	105	2	2	1.8	118	0.36	2.5	1	-0.444444444	0	0.040540541	0	N.A.	N.A.	N.A.		
3677.5	30	20	20	6	100	0.06	2.6	0	-0.545454545	-0.545454545	-0.202702703	-0.202702703	N.A.	N.A.	N.A.		
3700	105	2	2	2	100	0.3	2.5	1	-0.444444444	0	-0.202702703	0	N.A.	N.A.	N.A.		

WELL LOG DATA

G06[SSTVD]																
Depth	Gamma Ray	Laterolog Shallow Resistivity RESS	Laterolog Middle Resistivity RESM	Laterolog Deep Resistivity RESD	DTCO µs/ft	NPHI	RHOB	$V_{Shale} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$ $GR_{max} = 120, GR_{min} = 75$	$\emptyset_{density} = \frac{\rho_b - \rho_{matrix}}{\rho_{fluid} - \rho_{matrix}}$ $\rho_{fluid} = 1.07, \rho_{sand} = 2.65, \rho_{shale} = 2.06$	$\emptyset_{eff_{density}} = \emptyset_{density}(1 - V_{shale})$	$\emptyset_{sonic} = \frac{\Delta t - \Delta t_{matrix}}{\Delta t_{fluid} - \Delta t_{matrix}}$ $\Delta t_{fluid} = 189µs/ft, \Delta t_{sand} = 55µs/ft, \Delta t_{shale} = 115µs/ft$	$\emptyset_{eff_{sonic}} = \emptyset_{sonic}(1 - V_{shale})$	$S_W = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{hydrocarbons} = 1 - S_W$	GROSS $V_{Shale} < 0.6$, $\emptyset_{density} > 10$	NET $V_{Shale} < 0.6$, $\emptyset_{density} > 10$, $S_{hy} > 0.5$
3050	105	1.8	1.8	1.5	118	0.42	2.45	0.666666667	-0.393939394	-0.131313131	0.040540541	0.013513514	N.A.	N.A.		
3080	105	2	1.8	1.5	118	0.42	2.6	0.666666667	-0.545454545	-0.181818182	0.040540541	0.013513514	N.A.	N.A.		
3100	105	2	2	2	100	0.42	2.45	0.666666667	-0.393939394	-0.131313131	-0.202702703	-0.067567568	N.A.	N.A.		
3150	105	2	1.5	1.5	118	0.42	2.45	0.666666667	-0.393939394	-0.131313131	0.040540541	0.013513514	N.A.	N.A.		
3200	105	2	2	2	115	0.36	2.45	0.666666667	-0.393939394	-0.131313131	0	0	N.A.	N.A.		
3250	105	2	2	2	100	0.36	2.5	0.666666667	-0.444444444	-0.148148148	-0.202702703	-0.067567568	N.A.	N.A.		
3275	105	6	6	6	100	0.24	2.4	0.666666667	0.158227848	0.052742616	0.335820896	0.111940299	0.99507098	0.888059701		
3282.5	75	20	20	15	60	0.12	2.65	0	0	0	0.037313433	0.037313433	5.664043314	0.962686567		
3290	90	6	6	6	90	0.24	2.45	0.333333333	0.126582278	0.084388186	0.26119403	0.174129353	1.279376974	0.825870647		
3300	97.5	6	6	6	90	0.24	2.5	0.5	0.094936709	0.047468354	0.26119403	0.130597015	1.279376974	0.869402985		
3315	90	6	6	6	100	0.18	2.5	0.333333333	0.094936709	0.063291139	0.335820896	0.223880597	0.99507098	0.776119403		
3320	105	4	4	4	100	0.3	2.5	0.666666667	0.094936709	0.03164557	0.335820896	0.111940299	1.218708079	0.888059701		
3325	97.5	6	6	6	80	0.24	2.5	0.5	0.094936709	0.047468354	0.186567164	0.093283582	1.791127764	0.906716418		
3330	105	6	6	6	90	0.18	2.65	0.666666667	0	0	0.26119403	0.087064677	1.279376974	0.912935323		
3340	120	2	2	2	100	0.3	2.5	1	0.094936709	0	0.335820896	0	1.723513494	1		
3352.5	105	100	100	100	90	0.12	2.1	0.666666667	0.348101266	0.116033755	0.26119403	0.087064677	0.313382078	0.912935323		
3375	75	6	6	6	90	0.24	2.3	0	0.221518987	0.221518987	0.26119403	0.26119403	1.279376974	0.73880597		
3400	105	2	2	2	100	0.36	2.5	0.666666667	-0.444444444	-0.148148148	-0.202702703	-0.067567568	N.A.	N.A.		
3415	75	2	2	2	100	0.3	2.55	0	-0.494949495	-0.494949495	-0.202702703	-0.202702703	N.A.	N.A.		
3450	105	1.8	1.8	1.5	118	0.42	2.5	0.666666667	-0.444444444	-0.148148148	0.040540541	0.013513514	N.A.	N.A.		
3490	105	1.5	1.5	1.5	118	0.36	2.5	0.666666667	-0.444444444	-0.148148148	0.040540541	0.013513514	N.A.	N.A.		
3500	120	1.5	1.5	1.5	118	0.42	2.5	1	-0.444444444	0	0.040540541	0	N.A.	N.A.		
3550	105	1.5	1.5	1.5	118	0.42	2.5	0.666666667	-0.444444444	-0.148148148	0.040540541	0.013513514	N.A.	N.A.		
3600	105	1.5	1.5	1.5	118	0.42	2.5	0.666666667	-0.444444444	-0.148148148	0.040540541	0.013513514	N.A.	N.A.		
3630	97.5	2	1.8	1.8	110	0.36	2.55	0.5	-0.494949495	-0.247474747	-0.067567568	-0.033783784	N.A.	N.A.		
3650	105	2	2	2	100	0.36	2.5	0.666666667	-0.444444444	-0.148148148	-0.202702703	-0.067567568	N.A.	N.A.		
3689	90	2	2	2	100	0.36	2.5	0.333333333	-0.444444444	-0.296296296	-0.202702703	-0.135135135	N.A.	N.A.		
3700	105	2	1.8	1.5	110	0.36	2.5	0.666666667	-0.444444444	-0.148148148	-0.067567568	-0.022522523	N.A.	N.A.		

WELL LOG DATA

G03[SSTVD]																	
Depth	Gamma Ray	Laterolog Shallow Resistivity RESS	Laterolog Middle Resistivity RESM	Laterolog Deep Resistivity RESD	DTCO	NPHI	RHOB	$V_{Shale} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$ $GR_{max} = 120, GR_{min} = 45$	$\emptyset_{density} = \frac{\rho_b - \rho_{matrix}}{\rho_{fluid} - \rho_{matrix}}$ $\rho_{fluid} = 1.1, \rho_{sand} = 2.65, \rho_{shale} = 2.06$	$\emptyset_{eff_{density}} = \emptyset_{density}(1 - V_{shale})$	$\emptyset_{sonic} = \frac{\Delta t - \Delta t_{matrix}}{\Delta t_{fluid} - \Delta t_{matrix}}$ Δt_{fluid}= 189μs/ft, Δt_{sand}= 55μs/ft, Δt_{shale}= 115μs/ft	$\emptyset_{eff_{sonic}} = \emptyset_{sonic}(1 - V_{shale})$	$S_W = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{hydrocarbons} = 1 - S_W$	GROSS $V_{Shale} < 0.6$, $\emptyset_{density} > 10$	NET $V_{Shale} < 0.6$, $\emptyset_{density} > 10$, $S_{hy} > 0.5$
3012.5	105	2	1.8	1.5	118	0.42	2.4	0.8	-0.354166667	-0.070833333	0.040540541	0.008108108	N.A.	N.A.		
3050	105	2	2	2	118	0.42	2.4	0.8	-0.354166667	-0.070833333	0.040540541	0.008108108	N.A.	N.A.		
3070	105	2	2	2	117	0.42	2.4	0.8	-0.354166667	-0.070833333	0.027027027	0.005405405	N.A.	N.A.		
3100	105	2	2	2	117	0.42	2.4	0.8	-0.354166667	-0.070833333	0.027027027	0.005405405	N.A.	N.A.		
3125	120	2	2	2	110	0.42	2.4	1	-0.354166667	0	-0.067567568	0	N.A.	N.A.		
3150	120	2	1.8	1.8	120	0.42	2.4	1	-0.354166667	0	0.067567568	0	N.A.	N.A.		
3175	120	2	2	2	110	0.42	2.4	1	-0.354166667	0	-0.067567568	0	N.A.	N.A.		
3200	105	2	2	2	110	0.42	2.4	0.8	-0.354166667	-0.070833333	-0.067567568	-0.013513514	N.A.	N.A.		
3225	120	2	2	2	100	0.42	2.45	1	-0.40625	0	-0.202702703	0	N.A.	N.A.		
3240	60	60	60	60	90	0.18	2.2	0.2	0.290322581	0.232258065	0.26119403	0.208955224	0.404574522	0.595425478		
3247.5	75	20	20	20	90	0.06	2.4	0.4	0.161290323	0.096774194	0.26119403	0.156716418	0.700743628	0.299256372		
3255	45	200	600	150	100	0.06	2.2	0	0.290322581	0.290322581	0.335820896	0.335820896	0.199014196	0.800985804		
3260	90	10	10	10	100	0.18	2.1	0.6	0.35483871	0.141935484	0.335820896	0.134328358	0.770778667	0.229221333		
3265	75	20	20	20	100	0.24	2.15	0.4	0.322580645	0.193548387	0.335820896	0.201492537	0.545022822	0.454977178		
3270	45	600	600	600	100	0.06	2.2	0	0.290322581	0.290322581	0.335820896	0.335820896	0.099507098	0.900492902		
3280	105	2	2	2	100	0.42	2.5	0.8	0.096774194	0.019354839	0.335820896	0.067164179	1.723513494	-0.723513494		
3297.5	60	100	60	60	70	0.12	2.4	0.2	0.161290323	0.129032258	0.111940299	0.089552239	0.944007219	0.055992781		
3305	75	60	60	60	100	0.18	2.2	0.4	0.290322581	0.174193548	0.335820896	0.201492537	0.314669073	0.685330927		
3310	75	2	2	2	100	0.36	2.45	0.4	0.129032258	0.077419355	0.335820896	0.201492537	1.723513494	-0.723513494		
3315	120	4	4	2	100	0.36	2.5	1	0.096774194	0	0.335820896	0	1.723513494	-0.723513494		
3330	90	10	10	10	100	0.18	2.4	0.6	0.161290323	0.064516129	0.335820896	0.134328358	0.770778667	0.229221333		
3335	45	10	10	10	80	0.18	2.4	0	0.161290323	0.161290323	0.186567164	0.186567164	1.3874016	-0.3874016		
3340	45	100	100	100	80	0.06	2.4	0	0.161290323	0.161290323	0.186567164	0.186567164	0.438734909	0.561265091		
3350	75	100	100	100	80	0.06	2.2	0.4	0.290322581	0.174193548	0.186567164	0.111940299	0.438734909	0.561265091		
3360	120	10	10	10	90	0.12	2.4	1	0.161290323	0	0.26119403	0	0.991001143	0.008998857		
3380	60	20	20	20	80	0.06	2.7	0.2	-0.666666667	-0.533333333	-0.472972973	-0.378378378	N.A.	N.A.		
3400	120	2	2	2	110	0.42	2.45	1	-0.40625	0	-0.067567568	0	N.A.	N.A.		
3450	120	2	2	2	110	0.42	2.45	1	-0.40625	0	-0.067567568	0	N.A.	N.A.		
3495	90	6	2	2	90	0.24	2.7	0.6	-0.666666667	-0.266666667	-0.337837838	-0.135135135	N.A.	N.A.		
3500	105	2	2	2	100	0.36	2.45	0.8	-0.40625	-0.08125	-0.202702703	-0.040540541	N.A.	N.A.		
3550	110	2	2	2	100	0.36	2.5	0.866666667	-0.458333333	-0.061111111	-0.202702703	-0.027027027	N.A.	N.A.		
3585	90	20	15	15	80	0.24	2.7	0.6	-0.666666667	-0.266666667	-0.472972973	-0.189189189	N.A.	N.A.		
3600	120	2	2	2	100	0.36	2.5	1	-0.458333333	0	-0.202702703	0	N.A.	N.A.		
3650	120	4	4	4	100	0.36	2.5	1	-0.458333333	0	-0.202702703	0	N.A.	N.A.		

WELL LOG DATA

AT_02[SSTVD]																
Depth	Gamma Ray	Laterolog Shallow Resistivity RESS	Laterolog Middle Resistivity RESM	Laterolog Deep Resistivity RESD	DTCO µs/ft	NPHI	RHOB	$V_{Shale} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$ $GR_{max} = 120, GR_{min} = 45$	$\emptyset_{density} = \frac{\rho_b - \rho_{matrix}}{\rho_{fluid} - \rho_{matrix}}$ $\rho_{fluid} = 1.1, \rho_{sand} = 2.65, \rho_{shale} = 2.06$	$\emptyset_{eff_{density}} = \emptyset_{density}(1 - V_{shale})$	$\emptyset_{sonic} = \frac{\Delta t - \Delta t_{matrix}}{\Delta t_{fluid} - \Delta t_{matrix}}$ $\Delta t_{fluid} = 189\mu s/ft, \Delta t_{sand} = 55\mu s/ft, \Delta t_{shale} = 115\mu s/ft$	$\emptyset_{eff_{sonic}} = \emptyset_{sonic}(1 - V_{shale})$	$S_W = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{hydrocarbons} = 1 - S_W$	GROSS $V_{Shale} < 0.6$, $\emptyset_{density} > 10$	NET $V_{Shale} < 0.6$, $\emptyset_{density} > 10$ $S_{hy} > 0.5$
2982.5	75	1.8	1.8	1.5	120	0.42	2.4	0.4	-0.354166667	-0.2125	0.067567568	0.040540541	N.A.	N.A.		
3000	105	1.8	1.5	1.5	120	0.42	2.4	0.8	-0.354166667	-0.070833333	0.067567568	0.013513514	N.A.	N.A.		
3025	75	2	2	2	120	0.36	2.5	0.4	-0.458333333	-0.275	0.067567568	0.040540541	N.A.	N.A.		
3050	105	1.5	1.5	1.5	100	0.42	2.4	0.8	-0.354166667	-0.070833333	-0.202702703	-0.040540541	N.A.	N.A.		
3100	90	1.5	1.5	1.5	120	0.48	2.4	0.6	-0.354166667	-0.141666667	0.067567568	0.027027027	N.A.	N.A.		
3150	105	1.8	1.5	1.5	120	0.42	2.45	0.8	-0.40625	-0.08125	0.067567568	0.013513514	N.A.	N.A.		
3200	90	1.8	1.8	1.5	118	0.42	2.45	0.6	-0.40625	-0.1625	0.040540541	0.016216216	N.A.	N.A.		
3250	67.5	4	4	2	100	0.24	2.6	0.3	-0.5625	-0.39375	-0.202702703	-0.141891892	N.A.	N.A.		
3300	105	2	2	2	110	0.42	2.45	0.8	-0.40625	-0.08125	-0.067567568	-0.013513514	N.A.	N.A.		
3315	60	10	10	6	80	0.18	2.5	0.2	-0.458333333	-0.366666667	-0.472972973	-0.378378378	N.A.	N.A.		
3347.5	60	10	10	10	100	0.24	2.3	0.2	0.225806452	0.180645161	0.335820896	0.268656716	0.770778667	0.229221333		
3350	75	10	10	10	100	0.24	2.2	0.4	0.290322581	0.174193548	0.335820896	0.201492537	0.770778667	0.229221333		
3355	60	200	200	150	30	0.12	2.3	0.2	0.225806452	0.180645161	-0.186567164	-0.149253731	0.358225553	0.641774447		
3362.5	75	15	15	15	60	0.18	2.2	0.4	0.290322581	0.174193548	0.037313433	0.02238806	5.664043314	-4.664043314		
3372.5	45	100	60	60	80	0.12	2.4	0	0.161290323	0.161290323	0.186567164	0.186567164	0.566404331	0.433595669		
3380	60	100	90	80	80	0.06	2.3	0.2	0.225806452	0.180645161	0.186567164	0.149253731	0.49052054	0.50947946		
3390	45	60	60	60	80	0.06	2.6	0	0.032258065	0.032258065	0.186567164	0.186567164	0.566404331	0.433595669		
3405	45	200	200	200	60	0	2.6	0	0.032258065	0.032258065	0.037313433	0.037313433	1.551162145	-0.551162145		
3410	60	10	10	10	100	0.3	2.5	0.2	0.096774194	0.077419355	0.335820896	0.268656716	0.770778667	0.229221333		
3437.5	105	2	2	2	100	0.24	2.5	0.8	-0.458333333	-0.091666667	-0.202702703	-0.040540541	N.A.	N.A.		
3450	105	1.5	1.5	1.5	118	0.42	2.45	0.8	-0.40625	-0.08125	0.040540541	0.008108108	N.A.	N.A.		
3500	105	1.5	1.5	1.5	110	0.42	2.45	0.8	-0.40625	-0.08125	-0.067567568	-0.013513514	N.A.	N.A.		
3550	105	1.8	1.8	1.5	110	0.36	2.25	0.8	-0.197916667	-0.039583333	-0.067567568	-0.013513514	N.A.	N.A.		
3555	120	2	1.8	1.8	110	0.24	2.45	1	-0.40625	0	-0.067567568	0	N.A.	N.A.		
3580	105	1.8	1.5	1.5	110	0.42	2.45	0.8	-0.40625	-0.08125	-0.067567568	-0.013513514	N.A.	N.A.		
3600	105	2	1.8	1.5	110	0.36	2.45	0.8	-0.40625	-0.08125	-0.067567568	-0.013513514	N.A.	N.A.		
3650	105	2	2	2	110	0.36	2.5	0.8	-0.458333333	-0.091666667	-0.067567568	-0.013513514	N.A.	N.A.		

WELL LOG DATA

ESPARDATE-1 Wireline Logs														
Depth	Gamma Ray (GR) EDTC-B	LLS Array Induction Two Foot Resistivity A10 ZAIT-E	LLD Array Induction Two Foot Resistivity A90 ZAIT-E	High Resolution Formation P.E. Factor (PEF8) HDRS-H	Thermal Neutron Porosity (Ratio Method) In Selected Lithology (TNPH) HGNS-H	High Resolution Formation Density (RHO8) HDRS-H	$V_{Shale} = \frac{GR - GR_{min}}{GR_{max} - GR_{min}}$ $GR_{max} = 140, GR_{min} = 20$	$\emptyset_{density} = \frac{\rho_b - \rho_{matrix}}{\rho_{fluid} - \rho_{matrix}}$ $\rho_{fluid} = 1.1, \rho_{sand} = 2.65, \rho_{shale} = 2.06$	$\emptyset_{eff_{density}} = \emptyset_{density}(1 - V_{shale})$	$S_W = \left(\frac{aR_W}{\emptyset^m R_t}\right)^{1/n}$ $R_W = 0.67\ \Omega m$	$S_{hydrocarbons} = 1 - S_W$	GROSS $V_{Shale} < 0.6, \emptyset_{density} > 10$	NET $V_{Shale} < 0.6, \emptyset_{density} > 10, S_{hy} > 0.5$
2550	97.5	1.8	1.7	3.5	0.33	2.48	0.688644689	-0.396226415	-0.123367199	N.A.	N.A.		
2555	120	1.9	1.9	3	0.27	2.48	0.853479853	-0.396226415	-0.058055152	N.A.	N.A.		
2559	75	2.8	2.2	3	0.21	2.35	0.523809524	0.181818182	0.086580087	3.035210042	-2.035210042		
2560	75	200	200	3	0.12	2.2	0.523809524	0.272727273	0.12987013	0.212223677	0.787776323		
2561	60	21	21	2.5	0.09	2.11	0.413919414	0.327272727	0.191808192	0.545780404	0.454219596		
2564.5	67.5	80	25	3	0.75	2.5	0.468864469	0.090909091	0.048285048	1.80077761	-0.80077761		
2565	67.5	40	25	2.5	0.03	2.15	0.468864469	0.303030303	0.160950161	0.540233283	0.459766717		
2567	67.5	20	15	2.5	0.09	2.1	0.468864469	0.333333333	0.177045177	0.634034699	0.365965301		
2570	55	20	20	2.5	0.09	2.13	0.377289377	0.315151515	0.196248196	0.580768435	0.419231565		
2572	52.5	20	20	3	0.03	2.6	0.358974359	0.03030303	0.019425019	6.039991722	-5.039991722		
2575	60	15	12	2.25	0.12	2.1	0.413919414	0.333333333	0.195360195	0.708872344	0.291127656		
2577	67.5	5	3.5	2.5	0.24	2.25	0.468864469	0.242424242	0.128760129	1.804792727	-0.804792727		
2580	90	2.5	3	0.3	0.5	2.18	0.633699634	0.284848485	0.104340104	1.659062933	-0.659062933		
2583	105	1.5	1.5	4	0.33	2.5	0.743589744	-0.462264151	-0.118529269	N.A.	N.A.		
3220	135	1.5	1.5	3.5	0.3	2.55	0.963369963	-0.462264151	-0.016932753	N.A.	N.A.		
3222	60	18	18	2.25	0.15	2.35	0.413919414	0.181818182	0.106560107	1.061118383	-0.061118383		
3224	52.5	20	20	2.5	0.15	2.38	0.358974359	0.163636364	0.104895105	1.118516986	-0.118516986		
3227.5	67.5	20	15	2.25	0.15	2.25	0.468864469	0.242424242	0.128760129	0.871797712	0.128202288		
3230	105	0.4	0.8	3	0.27	2.45	0.743589744	0.121212121	0.031080031	7.549989652	-6.549989652		
3232	75	20.5	20	2	0.09	2.28	0.523809524	0.224242424	0.106782107	0.816215098	0.183784902		
3234.5	75	40	30	2.25	0.09	2.6	0.523809524	0.03030303	0.014430014	4.93163259	-3.93163259		
3236	60	55	55	2.25	0.09	2.3	0.413919414	0.212121212	0.124320124	0.520321722	0.479678278		
3237.5	45	150	150	2.25	0.06	2.63	0.304029304	0.012121212	0.008436008	5.513732855	-4.513732855		
3239	60	55	30	2.25	0.03	2.45	0.413919414	0.121212121	0.071040071	1.232908147	-0.232908147		
3240	60	60	50	3	0	2.7	0.413919414	-0.03030303	-0.017760018	3.820026178	-2.820026178		
3242	60	65	55	2.25	0.09	2.45	0.413919414	0.121212121	0.071040071	0.910563013	0.089436987		
3244	45	90	55	2	0.3	2.28	0.304029304	0.224242424	0.156066156	0.492196223	0.507803777		
3245	55	60	40	2	0.75	2.45	0.377289377	0.121212121	0.075480075	1.067729776	-0.067729776		
3250	60	40	40	2.25	0.09	2.4	0.413919414	0.151515152	0.088800089	0.854183821	0.145816179		
3251	60	40	40	3	0.09	2.6	0.413919414	0.03030303	0.017760018	4.270919105	-3.270919105		
3252	60	30	30	2.25	0.09	2.4	0.413919414	0.151515152	0.088800089	0.986326518	0.013673482		
3255	55	40	45	2	0.09	2.35	0.377289377	0.181818182	0.113220113	0.671110191	0.328889809		
3255.5	45	90	130	3	0.03	2.63	0.304029304	0.012121212	0.008436008	5.922699164	-4.922699164		
3256	40	90	130	2.25	0.3	2.33	0.267399267	0.193939394	0.142080142	0.370168698	0.629831302		
3258	43	150	30	2	0.15	2.45	0.289377289	0.121212121	0.086136086	1.232908147	-0.232908147		
3259	120	1.8	1.8	3.5	0.27	2.57	0.853479853	-0.481132075	-0.070495542	N.A.	N.A.		
3290	120	3	3	4	0.26	2.6	0.853479853	-0.509433962	-0.074642339	N.A.	N.A.		
3291.2	46	40	70	2	0.08	2.5	0.311355311	0.090909091	0.062604063	1.076170459	-0.076170459		
3292.8	48	200	68	3	0	2.7	0.326007326	-0.03030303	-0.02042402	3.275645424	-2.275645424		
3296	50	20	30	2	0.1	2.55	0.340659341	0.060606061	0.03996004	2.465816295	-1.465816295		
3297	90	4	4	3	0.18	2.55	0.633699634	0.060606061	0.022200022	N.A.	N.A.		
3300	67.5	25	15	2	0.12	2.45	0.468864469	0.121212121	0.064380064	1.743595423	-0.743595423		
3301	60	40	30	2.25	0.15	2.38	0.413919414	0.163636364	0.095904096	0.913265294	0.086734706		
3302.5	52.5	35	30	2.25	0.09	2.55	0.358974359	0.060606061	0.038850039	2.465816295	-1.465816295		
3303	60	40	40	3	0.12	2.35	0.413919414	0.181818182	0.106560107	0.711819851	0.288180149		
3305	60	30	30	2.25	0.09	2.45	0.413919414	0.121212121	0.071040071	1.232908147	-0.232908147		
3305.5	45	40	70	2.25	0.03	2.6	0.304029304	0.03030303	0.021090021	3.228511377	-2.228511377		
3306	75	10	20	2.25	0.15	2.45	0.523809524	0.121212121	0.057720058	1.50999793	-0.50999793		
3308	60	40	20	2.25	0.06	2.6	0.413919414	0.03030303	0.017760018	6.039991722	-5.039991722		
3315	127.5	1	1	3.5	0.27	2.55	0.908424908	-0.462264151	-0.042331882	N.A.	N.A.		
3322.5	52.5	10	20	2	0.09	2.45	0.358974359	0.121212121	0.077700078	1.50999793	-0.50999793		
3330	60	25	25	2	0.09	2.45	0.413919414	0.121212121	0.071040071	1.350583207	-0.350583207		
3333	60	150	120	3	0.03	2.5	0.413919414	0.090909091	0.053280053	0.821938765	0.178061235		
3337	75	10	8	3	0.15	2.55	0.523809524	0.060606061	0.028860029	4.775032722	-3.775032722		
3340	67.5	15	15	2.25	0.12	2.45	0.468864469	0.121212121	0.064380064	1.743595423	-0.743595423		
3343	50	120	180	3	0.06	2.5	0.340659341	0.090909091	0.05994006	0.671110191	0.328889809		
3345	140	2	1.5	4	0.3	2.35	1	-0.273584906	0	N.A.	N.A.		
3347.5	110	3	2	3.5	0.24	2.55	0.78021978	-0.462264151	-0.101596517	N.A.	N.A.		
3353.5	20	80	70	2	0.1	2.45	0.120879121	0.121212121	0.106560107	0.807127844	0.192872156		
3392.5	50	90	40	2.2	0.15	2.38	0.340659341	0.163636364	0.107892108	0.790910945	0.209089055		
3396.5	80	20	20	2.3	0.12	2.52	0.56043956	0.078787879	0.034632035	2.323073739	-1.323073739		
3402	59	28	28	2	0.14	2.38	0.406593407	0.163636364	0.097102897	0.945319389	0.054680611		
3415	75	15	12	2.8	0.2	2.42	0.523809524	0.139393939	0.066378066	1.695129518	-0.695129518		
3424	70	30	30	2.2	0.17	2.35	0.487179487	0.181818182	0.093240093	0.821938765	0.178061235		
3435	57	40	30	2.2	0.12	2.48	0.391941392	0.103030303	0.062648463	1.450480173	-0.450480173		
3445	75	15	15	2.3	0.18	2.5	0.523809524	0.090909091	0.043290043	2.324793898	-1.324793898		
3457	60	20	35	2.1	0.16	2.3	0.413919414	0.212121212	0.124320124	0.652257797	0.347742203		

WELL LOG DATA

DEPTH	GR	RESISTIVITY	RHOB (RED)	NPHI	DT(BLACK)	VSHALE = (GR-GRmin/(	Φ(DENSITY)	PHI(EFF DENSITY)	SW(DENSITY)	SHC(DENSITY)	Φ(SONIC)	PHI(EFFECTIVE SONIC)	SW(SONIC)	SHC(sonic)
3040	118	1.5	2.45	0.4	100	0.96	0.129032258	0.00516129	5.179567228	-4.179567228	0.335820896	0.013432836	1.99014196	-0.99014196
3047	105	1.7	2.48	0.36	118	0.7	0.109677419	0.032903226	5.723948498	-4.723948498	0.470149254	0.141044776	1.335294898	-0.3352949
3075	115	2	2.47	0.4	118	0.9	0.116129032	0.011612903	4.984040889	-3.984040889	0.470149254	0.047014925	1.231081067	-0.23108107
3100	100	2	2.45	0.42	118	0.6	0.129032258	0.051612903	4.4856368	-3.4856368	0.470149254	0.188059701	1.231081067	-0.23108107
3119	115	1.5	2.45	0.45	116	0.9	0.129032258	0.012903226	5.179567228	-4.179567228	0.455223881	0.045522388	1.468137511	-0.46813751
3139	95	2	2.45	0.42	112	0.5	0.129032258	0.064516129	4.4856368	-3.4856368	0.425373134	0.212686567	1.360668548	-0.36066855
3170	105	2	2.45	0.36	110	0.7	0.129032258	0.038709677	4.4856368	-3.4856368	0.410447761	0.123134328	1.410147405	-0.4101474
3210	105	2	2.5	0.36	90	0.7	0.096774194	0.029032258	5.980849066	-4.980849066	0.26119403	0.078358209	2.215945921	-1.21594592
3248	95	2	2.5	0.36	90	0.5	0.096774194	0.048387097	5.980849066	-4.980849066	0.26119403	0.130597015	2.215945921	-1.21594592
3270	92	5	2.3	0.24	90	0.44	0.225806452	0.126451613	1.621123319	-0.621123319	0.26119403	0.146268657	1.401487257	-0.40148726
3280	90	10	2.35	0.24	90	0.4	0.193548387	0.116129032	1.337358508	-0.337358508	0.26119403	0.156716418	0.991001143	0.008998857
3282	75	10	2.32	0.28	100	0.1	0.212903226	0.191612903	1.215780461	-0.215780461	0.335820896	0.302238806	0.770778667	0.229221333
3300	95	6	2.5	0.24	85	0.5	0.096774194	0.048387097	3.453044818	-2.453044818	0.223880597	0.111940299	1.49260647	-0.49260647
3305	90	8	2.45	0.24	85	0.4	0.129032258	0.077419355	2.2428184	-1.2428184	0.223880597	0.134328358	1.292635121	-0.29263512
3313	85	8	2.5	0.2	82	0.3	0.096774194	0.067741935	2.990424533	-1.990424533	0.201492537	0.141044776	1.436261245	-0.43626125
3320	100	3	2.5	0.3	100	0.6	0.096774194	0.038709677	4.883342814	-3.883342814	0.335820896	0.134328358	1.407242875	-0.40724288
3328	116	3	2.5	0.3	90	0.92	0.096774194	0.007741935	4.883342814	-3.883342814	0.26119403	0.020895522	1.809312268	-0.80931227
3338	96	7	2.5	0.36	95	0.52	0.096774194	0.046451613	3.196898298	-2.196898298	0.298507463	0.143283582	1.036413803	-0.0364138
3345	75	8	2.35	0.24	90	0.1	0.193548387	0.174193548	1.495212267	-0.495212267	0.26119403	0.235074627	1.107972961	-0.10797296
3351	95	100	2.1	0.12	85	0.5	0.35483871	0.177419355	0.230678124	0.769321876	0.223880597	0.111940299	0.365612424	0.634387576
3357	110	4	2.5	0.3	87	0.8	0.096774194	0.019354839	4.229098932	-3.229098932	0.23880597	0.047761194	1.713808237	-0.71380824
3359	85	10	2.35	0.24	95	0.3	0.193548387	0.135483871	1.337358508	-0.337358508	0.298507463	0.208955224	0.867126	0.132874
3365	85	15	2.3	0.27	95	0.3	0.225806452	0.158064516	0.935955985	0.064044015	0.298507463	0.208955224	0.708005414	0.291994586
3370	75	10	2.45	0.21	95	0.1	0.129032258	0.116129032	2.006037761	-1.006037761	0.298507463	0.268656716	0.867126	0.132874
3372	77	10	2.5	0.24	95	0.14	0.096774194	0.083225806	2.674717015	-1.674717015	0.298507463	0.256716418	0.867126	0.132874
3376	70	10	2.5	0.24	95	0	0.096774194	0.096774194	2.674717015	-1.674717015	0.298507463	0.298507463	0.867126	0.132874
3386	105	5	2.5	0.22	85	0.7	0.096774194	0.029032258	3.782621078	-2.782621078	0.223880597	0.067164179	1.635068466	-0.63506847
3388	70	12	2.55	0.12	80	0	0.064516129	0.064516129	3.66250711	-2.66250711	0.186567164	0.186567164	1.266518588	-0.26651859
3395	110	2	2.5	0.36	95	0.8	0.096774194	0.019354839	5.980849066	-4.980849066	0.298507463	0.059701493	1.938952681	-0.93895268
3405	92	2	2.5	0.36	100	0.44	0.096774194	0.054193548	5.980849066	-4.980849066	0.335820896	0.188059701	1.723513494	-0.72351349
3410	90	2	2.52	0.33	100	0.4	0.083870968	0.050322581	6.900979692	-5.900979692	0.335820896	0.201492537	1.723513494	-0.72351349
3415	80	3	2.55	0.3	85	0.2	0.064516129	0.051612903	7.325014221	-6.325014221	0.223880597	0.179104478	2.110864313	-1.11086431
3423	105	1.8	2.5	0.4	117	0.7	0.096774194	0.029032258	6.304368464	-5.304368464	0.462686567	0.13880597	1.318603602	-0.3186036
3428	120	2	2.46	0.4	118	1	0.122580645	0	4.721722947	-3.721722947	0.470149254	0	1.231081067	-0.23108107
3438	100	1.7	2.5	0.42	118	0.6	0.096774194	0.038709677	6.487141631	-5.487141631	0.470149254	0.188059701	1.335294898	-0.3352949
3443	105	1.5	2.5	0.4	118	0.7	0.096774194	0.029032258	6.906089637	-5.906089637	0.470149254	0.141044776	1.421529971	-0.42152997
3447	100	1.8	2.45	0.38	118	0.6	0.129032258	0.051612903	4.728276348	-3.728276348	0.470149254	0.188059701	1.297673386	-0.29767339
3454	100	2	2.5	0.38	117	0.6	0.096774194	0.038709677	5.980849066	-4.980849066	0.462686567	0.185074627	1.250937214	-0.25093721
3458	117	2	2.5	0.38	117	0.94	0.096774194	0.005806452	5.980849066	-4.980849066	0.462686567	0.027761194	1.250937214	-0.25093721
3467	115	1.7	2.48	0.39	118	0.9	0.109677419	0.010967742	5.723948498	-4.723948498	0.470149254	0.047014925	1.335294898	-0.3352949
3474	120	1.7	2.5	0.4	118	1	0.096774194	0	6.487141631	-5.487141631	0.470149254	0	1.335294898	-0.3352949
3478	117	1.8	2.5	0.37	118	0.94	0.096774194	0.005806452	6.304368464	-5.304368464	0.470149254	0.028208955	1.297673386	-0.29767339
3485	119	1.7	2.47	0.4	118	0.98	0.116129032	0.002322581	5.405951359	-4.405951359	0.470149254	0.009402985	1.335294898	-0.3352949
3495	95	1.8	2.5	0.36	117	0.5	0.096774194	0.048387097	6.304368464	-5.304368464	0.462686567	0.231343284	1.318603602	-0.3186036
3505	105	1.8	2.5	0.4	118	0.7	0.096774194	0.029032258	6.304368464	-5.304368464	0.470149254	0.141044776	1.297673386	-0.29767339
3518	106	2	2.5	0.36	116	0.72	0.096774194	0.027096774	5.980849066	-4.980849066	0.455223881	0.127462687	1.271444381	-0.27144438
3525	120	1.9	2.5	0.36	118	1	0.096774194	0	6.136221669	-5.136221669	0.470149254	0	1.263062525	-0.26306252
3548	120	2	2.48	0.38	119	1	0.109677419	0	5.277219765	-4.277219765	0.47761194	0	1.211845426	-0.21184543
3553	95	2	2.5	0.36	118	0.5	0.096774194	0.048387097	5.980849066	-4.980849066	0.470149254	0.235074627	1.231081067	-0.23108107
3560	117	2	2.48	0.37	118	0.94	0.109677419	0.006580645	5.277219765	-4.277219765	0.470149254	0.028208955	1.231081067	-0.23108107
3628	95	2	2.53	0.34	115	0.5	0.077419355	0.038709677	7.476061333	-6.476061333	0.447761194	0.223880597	1.292635121	-0.29263512
3655	90	4	2.55	0.24	100	0.4	0.064516129	0.038709677	6.343648398	-5.343648398	0.335820896	0.201492537	1.218708079	-0.21870808

WELL LOG DATA

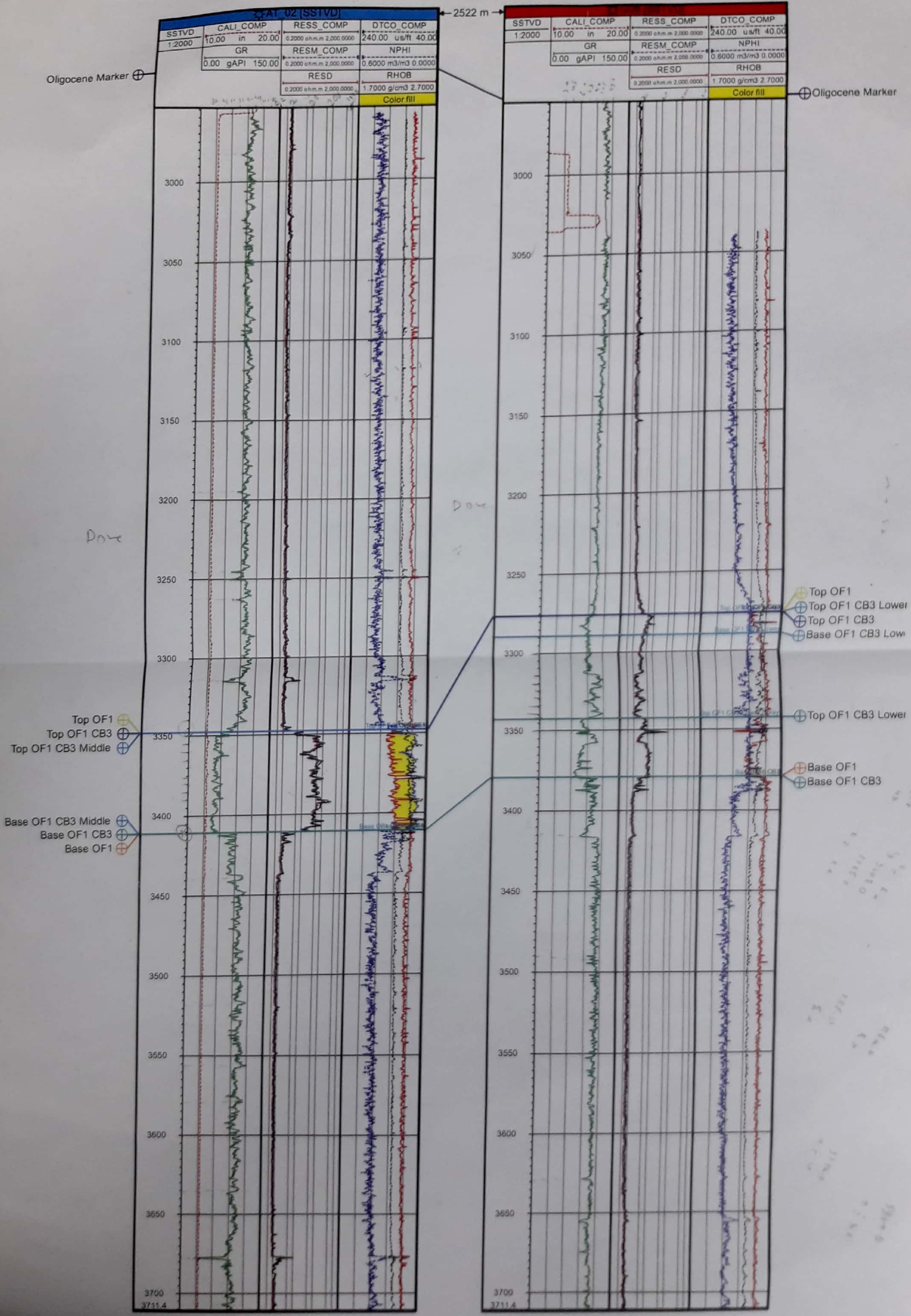
DEPTH	GR	RESISTIVITY	RHOB	NPHI	DT	VSHALE	PHI DENSITY	PHI EFF DEN	Sw DEN	Shc den		PHI SONIC	PHI EFF SONIC	Sw SONIC	Shc sonic
3155	105	1.5	2.4	0.4755	118	0.785714	0.146341463	0.031358885	4.566930244	-3.56693024		0.470149254	0.100746269	2.390343298	-1.390343298
3195	90	1.5	2.6	0.4755	118	0.571429	0.024390244	0.010452962	27.40158146	-26.4015815		0.470149254	0.201492537	2.296567556	-1.296567556
3205	105	1.5	2.4	0.4755	120	0.785714	0.146341463	0.031358885	4.566930244	-3.56693024		0.485074627	0.103944563	2.245508296	-1.245508296
3220	105	2	2.5	0.4755	118	0.785714	0.085365854	0.018292683	6.780133043	-5.78013304		0.470149254	0.100746269	2.342048557	-1.342048557
3295	95	3	2.7	0.38	100	0.642857	-0.036585366	-0.013066202	12.91722938	-11.9172294		0.335820896	0.119936034	4.417129058	-3.417129058
3322	92	3	2.69	0.36	100	0.6	-0.030487805	-0.012195122	15.50067525	-14.5006753		0.335820896	0.134328358	4.425331718	-3.425331718
3345	100	2	2.5	0.36	110	0.714286	0.085365854	0.024390244	6.780133043	-5.78013304		0.410447761	0.117270789	3.072922552	-2.072922552
3357	85	4	2.55	0.32	105	0.5	0.054878049	0.027439024	7.457765859	-6.45776586		0.373134328	0.186567164	3.681602525	-2.681602525
3374	90	3	2.65	0.3	110	0.571429	-0.006097561	-0.00261324	77.50337627	-76.5033763		0.410447761	0.175906183	2.984686231	-1.984686231
3390	110	2.5	2.3	0.36	110	0.857143	0.207317073	0.029616725	2.497079263	-1.49707926		0.410447761	0.058635394	3.203743227	-2.203743227
3403	90	2	2.67	0.3	95	0.571429	-0.018292683	-0.007839721	31.64062087	-30.6406209		0.298507463	0.12793177	5.621748138	-4.621748138
3410	105	4	2.6	0.32	90	0.785714	0.024390244	0.005226481	16.77997318	-15.7799732		0.26119403	0.055970149	7.440878882	-6.440878882
3414	104	3	2.5	0.3	90	0.771429	0.085365854	0.019512195	5.535955448	-4.53595545		0.26119403	0.059701493	7.588237323	-6.588237323
3427	92	20	2.3	0.24	80	0.6	0.207317073	0.082926829	0.88285084	0.11714916		0.186567164	0.074626866	15.50611722	-14.50611722
3433	95	8	2.12	0.15	90	0.642857	0.317073171	0.113240418	0.912710217	0.087289783		0.26119403	0.093283582	8.240299162	-7.240299162
3437	70	20	2.2	0.2	100	0.285714	0.268292683	0.191637631	0.682202922	0.317797078		0.335820896	0.239872068	4.893399014	-3.893399014
3440	60	100	2.2	0.2	100	0.142857	0.268292683	0.229965157	0.305090421	0.694909579		0.335820896	0.287846482	4.893399014	-3.893399014
3450	120	10	2.2	0.24	90	1	0.268292683	0	0.964780624	0.035219376		0.26119403	0	8.089088166	-7.089088166
3455	65	100	2.24	0.12	90	0.214286	0.243902439	0.191637631	0.335599464	0.664400536		0.26119403	0.205223881	8.016538824	-7.016538824
3490	92	5	2.52	0.36	90	0.6	0.073170732	0.029268293	5.002821426	-4.00282143		0.26119403	0.104477612	7.558065286	-6.558065286
3525	70	15	2.5	0.18	100	0.285714	0.085365854	0.06097561	2.47575454	-1.47575454		0.335820896	0.239872068	4.590415171	-3.590415171
3540	110	5	2.4	0.36	100	0.857143	0.146341463	0.020905923	2.501410713	-1.50141071		0.335820896	0.047974414	4.685072865	-3.685072865
3555	80	10	2.35	0.2	90	0.428571	0.176829268	0.101045296	1.463805085	-0.46380509		0.26119403	0.149253731	7.826669197	-6.826669197
3582	110	1.2	2.35	0.4	110	0.857143	0.176829268	0.025261324	4.225641299	-3.2256413		0.410447761	0.058635394	3.169477609	-2.169477609
3605	95	1.8	2.52	0.4	115	0.642857	0.073170732	0.026132404	8.33803571	-7.33803571		0.447761194	0.159914712	2.57184166	-1.57184166
3635	115	1.8	2.35	0.42	100	0.928571	0.176829268	0.012630662	3.450221673	-2.45022167		0.335820896	0.023987207	4.734651736	-3.734651736
3655	88	2	2.58	0.4	110	0.542857	0.036585366	0.016724739	15.82031043	-14.8203104		0.410447761	0.187633262	3.024905183	-2.024905183
3665	115	2	2.3	0.42	110	0.928571	0.207317073	0.014808362	2.791819488	-1.79181949		0.410447761	0.029317697	3.203743227	-2.203743227
3690	115	2	2.5	0.45	115	0.928571	0.085365854	0.006097561	6.780133043	-5.78013304		0.447761194	0.031982942	2.582108534	-1.582108534

WELL LOG DATA

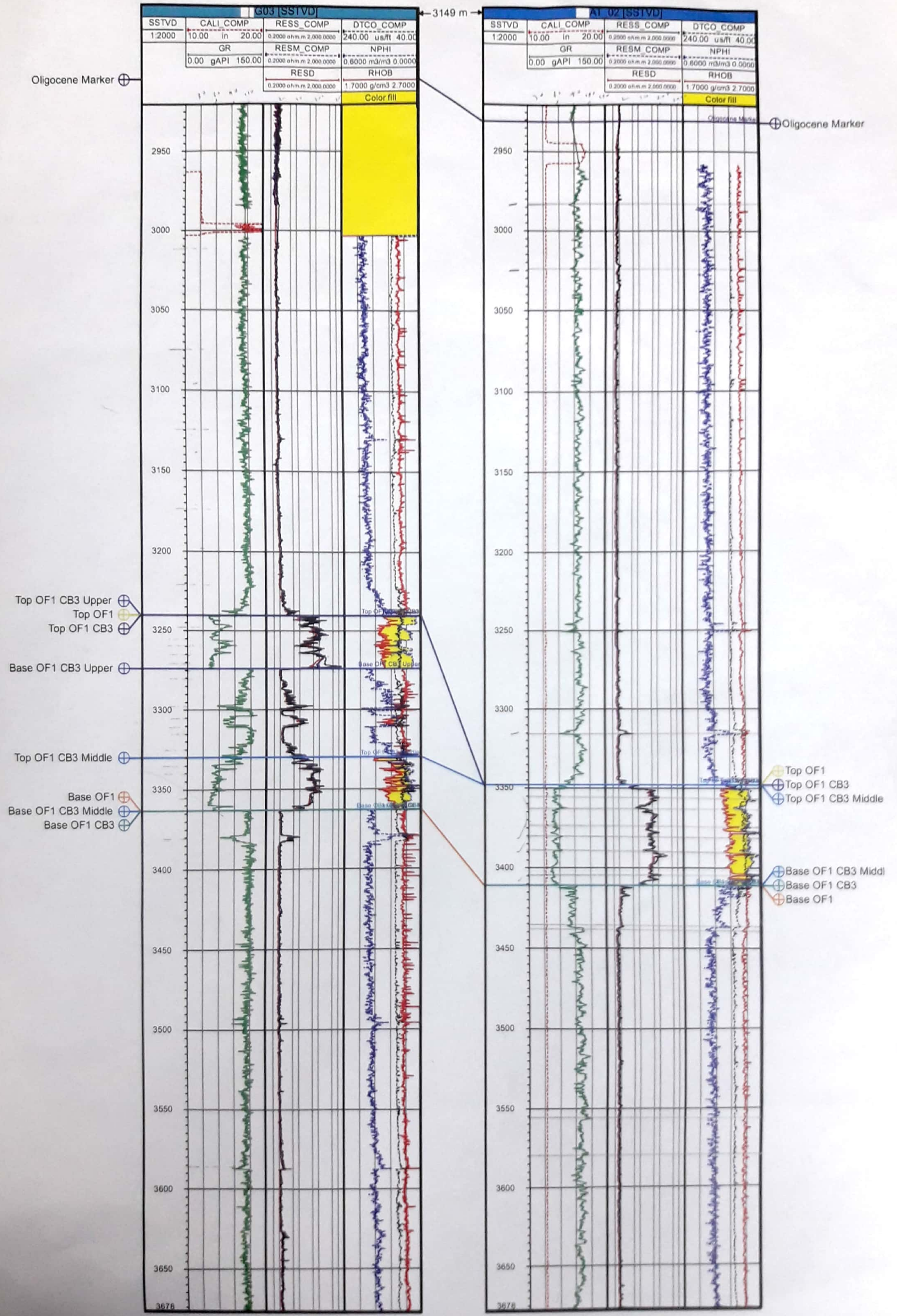
DEPTH	GR	R	NPHIblue	DTPHI black	RHOB red	SW	VSHALE	PHI SONIC	PHI SONIC EFF	DENSITY PHI	DENSITY PHI EFF	SW'	Sw	Shc	GROSS	NET
3141	100	2	0.48	117	2.4		0.714286	0.462686567	0.330490405	0.161290323	0.115207373	1.564844	1.250937	-0.250937		
3180	95	2	0.46	120	2.38		0.634921	0.485074627	0.30798389	0.174193548	0.110599078	1.42373	1.193202	-0.193202		
3207	95	1.8	0.42	120	2.35		0.634921	0.485074627	0.30798389	0.193548387	0.122887865	1.581922	1.257745	-0.257745		
3240	113	2	0.48	118	2.35		0.920635	0.470149254	0.432835821	0.193548387	0.178187404	1.515561	1.231081	-0.231081		
3280	93	2	0.4	110	2.7		0.603175	0.410447761	0.247571665	-0.032258065	-0.019457245	1.988516	1.410147	-0.410147		
3292	110	5	0.5	120	2.45		0.873016	0.485074627	0.423477849	0.129032258	0.112647209	0.569492	0.754647	0.245353		
3323	90	2	0.4	110	2.65		0.555556	0.410447761	0.228026534	0	0	1.988516	1.410147	-0.410147		
3385	105	2	0.36	100	2.5		0.793651	0.335820896	0.26652452	0.096774194	0.076804916	2.970499	1.723513	-0.723513		
3392	107	2	0.36	100	2.5		0.825397	0.335820896	0.277185501	0.096774194	0.079877112	2.970499	1.723513	-0.723513		
3413	97	5	0.3	90	2.5		0.666667	0.26119403	0.174129353	0.096774194	0.064516129	1.964167	1.401487	-0.401487		
3425	60	40	0.18	50	2.69		0.079365	-0.037313433	-0.002961384	-0.025806452	-0.002048131	12.03052	3.468504	-2.468504	M	20M
3430	55	100	0.12	80	2.45		0	0.186567164	0	0.129032258	0	0.192488	0.438735	0.5612651		
3435	60	100	0.16	90	2.3		0.079365	0.26119403	0.020729685	0.225806452	0.017921147	0.098208	0.313382	0.6866179		
3440	60	98	0.12	85	2.3		0.079365	0.223880597	0.017768301	0.225806452	0.017921147	0.1364	0.369324	0.6306757		
3445	63	20	0.2	95	2.25		0.126984	0.298507463	0.03790571	0.258064516	0.032770097	0.375954	0.613151	0.3868493		
3450	75	45	0.22	90	2.2		0.31746	0.26119403	0.08291874	0.290322581	0.092165899	0.218241	0.467162	0.5328376		
3455	62	98	0.12	80	2.4		0.111111	0.186567164	0.020729685	0.161290323	0.017921147	0.196417	0.443189	0.5568108		
3460	60	500	0.6	80	2.6		0.079365	0.186567164	0.014806918	0.032258065	0.002560164	0.038498	0.196208	0.8037918		
3468	105	4	0.3	95	2.5		0.793651	0.298507463	0.236910685	0.096774194	0.076804916	1.879769	1.371047	-0.371047		
3490	95	5	0.24	85	2.52		0.634921	0.223880597	0.142146411	0.083870968	0.053251408	2.673449	1.635068	-0.635068		
3500	70	15	0.32	85	2.34		0.238095	0.223880597	0.053304904	0.2	0.047619048	0.89115	0.944007	0.0559928		
3515	70	20	0.2	90	2.2		0.238095	0.26119403	0.062189055	0.290322581	0.069124424	0.491042	0.700744	0.2992564		
3540	90	9	0.3	90	2.52		0.555556	0.26119403	0.145107794	0.083870968	0.046594982	1.091204	1.044607	-0.044607		
3570	100	2	0.42	100	2.52		0.714286	0.335820896	0.239872068	0.083870968	0.059907834	2.970499	1.723513	-0.723513		
3585	118	1.5	0.45	115	2.25		1	0.447761194	0.447761194	0.258064516	0.258064516	2.227874	1.492606	-0.492606		
3605	95	2	0.38	115	2.52		0.634921	0.447761194	0.284292822	0.083870968	0.053251408	1.670906	1.292635	-0.292635		
3635	100	2	0.4	110	2.5		0.714286	0.410447761	0.293176972	0.096774194	0.069124424	1.988516	1.410147	-0.410147		
3655	85	3	0.44	115	2.68		0.47619	0.447761194	0.213219616	-0.019354839	-0.00921659	1.113937	1.055432	-0.055432		
3700	95	2	0.38	110	2.4		0.634921	0.410447761	0.260601753	0.161290323	0.102406554	1.988516	1.410147	-0.410147		
3760	100	2	0.42	110	2.5		0.714286	0.410447761	0.293176972	0.096774194	0.069124424	1.988516	1.410147	-0.410147		

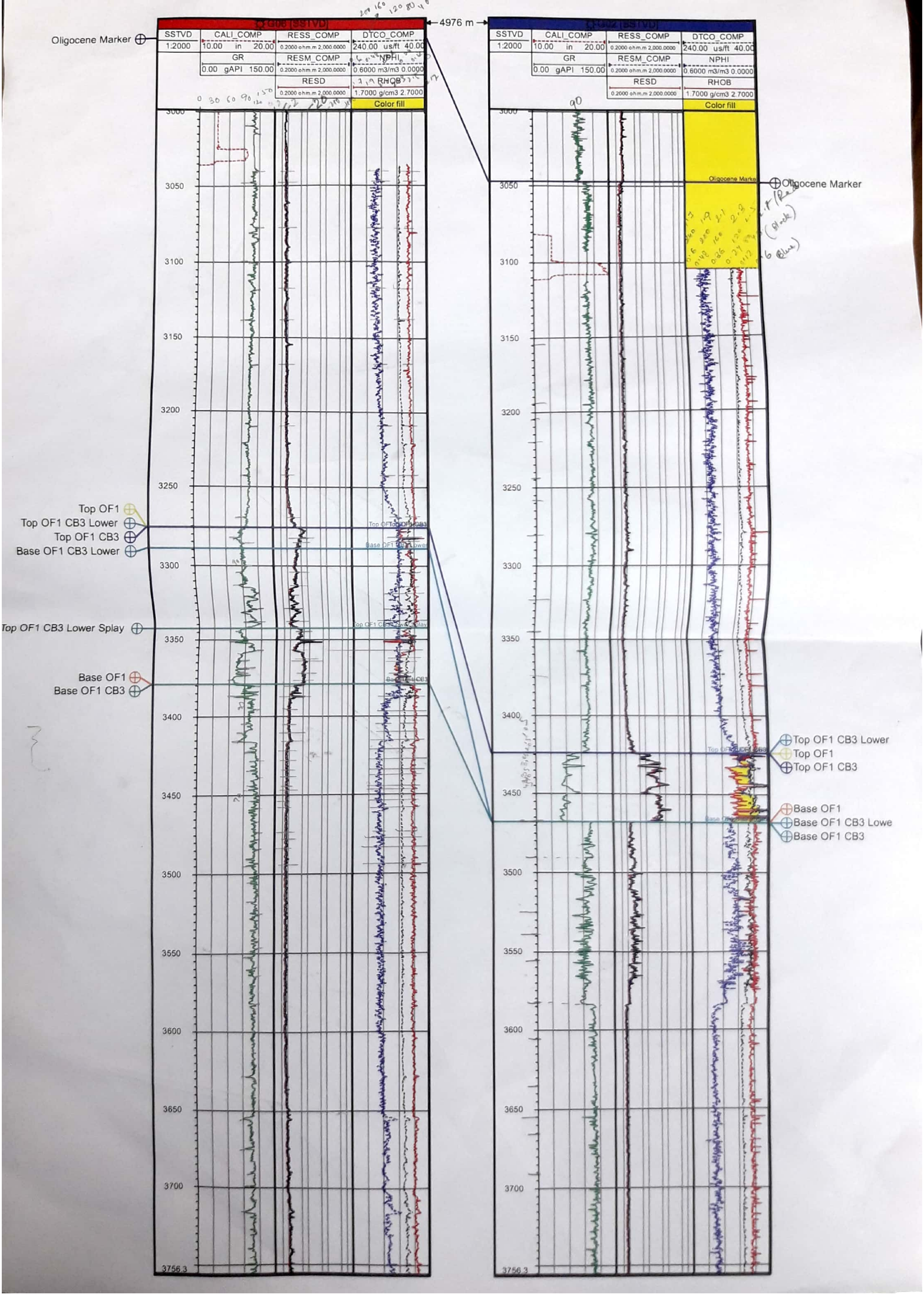
WELL LOG DATA

DEPTH	GR	R	NPHI	DTPHI	RHOB	Vshale	PHI SONIC	PHI DENSITY	PHI SONIC EFF	PHI DENSITY EFF	Sw''	Sw	Shc		NET
3355	115	1.5	0.38	120	2.5	1	0.485074627	0.096774194	0.485074627	0.096774194	1.898306903	1.377791	-0.37779		
3375	98	3	0.36	115	2.68	0.757143	0.447761194	-0.019354839	0.33901919	-0.014654378	1.113937037	1.055432	-0.05543		
3412	100	15	0.44	118	2.5	0.785714	0.470149254	0.096774194	0.369402985	0.076036866	0.202074746	0.449527	0.550473		
3465	90	2	0.4	110	2.5	0.642857	0.410447761	0.096774194	0.263859275	0.062211982	1.988515702	1.410147	-0.41015		
3525	100	2	0.36	118	2.5	0.785714	0.470149254	0.096774194	0.369402985	0.076036866	1.515560595	1.231081	-0.23108		
3585	98	2	0.39	115	2.38	0.757143	0.447761194	0.174193548	0.33901919	0.131889401	1.670905556	1.292635	-0.29264		
3622	85	10	0.2	80	2.7	0.571429	0.186567164	-0.032258065	0.106609808	-0.01843318	1.9248832	1.387402	-0.3874		
3625	95	12	0.32	100	2.45	0.714286	0.335820896	0.129032258	0.239872068	0.092165899	0.495083128	0.703621	0.296379		
3630	75	10	0.3095	100	2.4	0.428571	0.335820896	0.161290323	0.143923241	0.069124424	0.594099753	0.770779	0.229221		
3635	60	100	0.3095	100	2.4	0.214286	0.335820896	0.161290323	0.07196162	0.034562212	0.059409975	0.243742	0.756258		
3640	45	200	0.2265	100	2.2	0	0.335820896	0.290322581	0	0	0.029704988	0.172351	0.827649		
3645	45	100	0.2265	100	2.5	0	0.335820896	0.096774194	0	0	0.059409975	0.243742	0.756258		
3650	75	60	0.268	90	2.2	0.428571	0.26119403	0.290322581	0.111940299	0.124423963	0.163680544	0.404575	0.595425		
3655	45	200	0.268	90	2.1	0	0.26119403	0.35483871	0	0	0.049104163	0.221595	0.778405		
3665	105	6	0.3925	100	2.55	0.857143	0.335820896	0.064516129	0.287846482	0.055299539	0.990166255	0.995071	0.004929		
3700	60	6	0.351	90	2.3	0.214286	0.26119403	0.225806452	0.055970149	0.048387097	1.636805442	1.279377	-0.27938		
3730	90	2	0.434	100	2.5	0.642857	0.335820896	0.096774194	0.215884861	0.062211982	2.970498765	1.723513	-0.72351		
3750	105	1.5	0.4755	110	2.5	0.857143	0.410447761	0.096774194	0.351812367	0.082949309	2.65135427	1.628298	-0.6283		

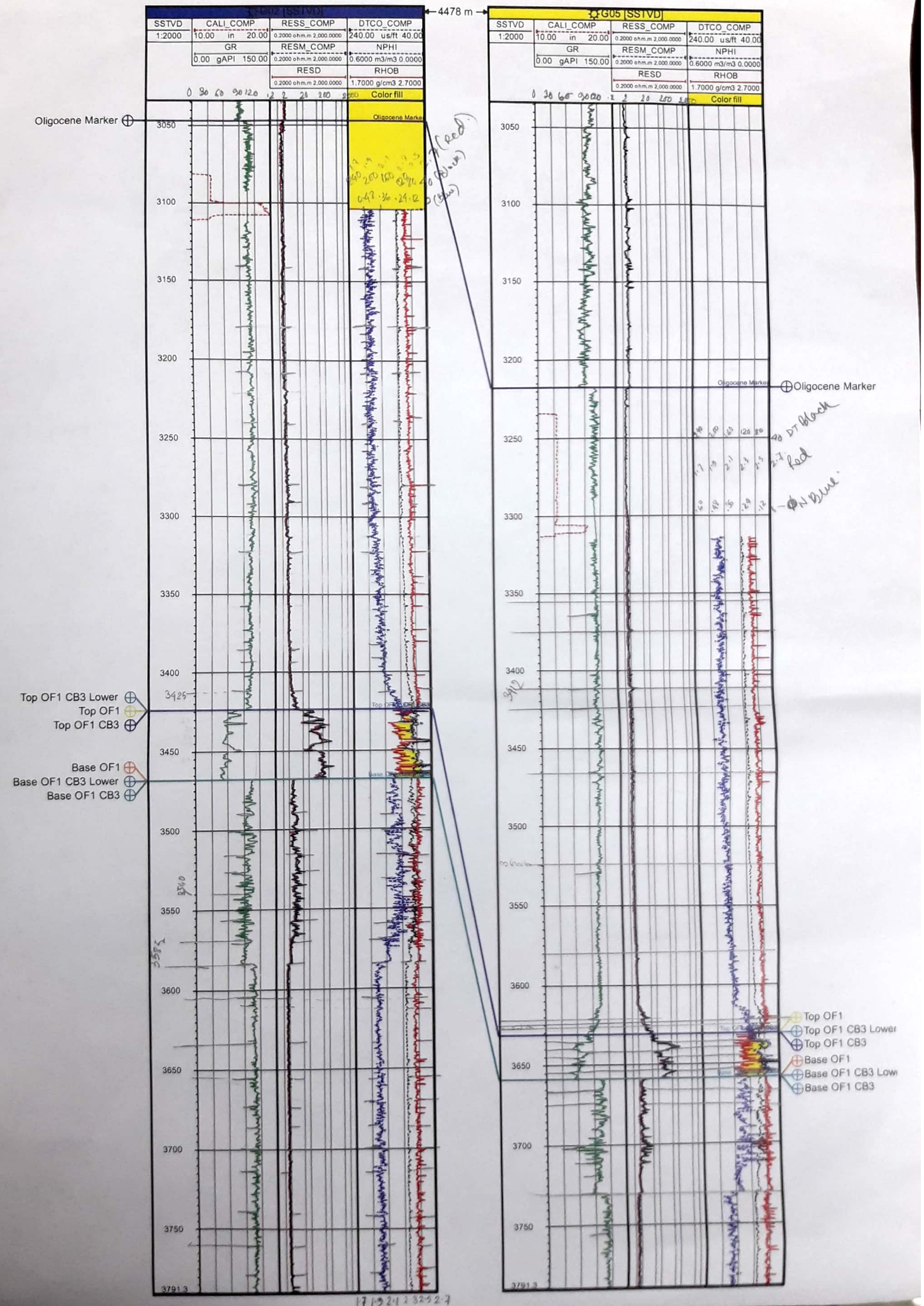


2522 m
SSTVD
1:2000
CALI_COMP
10.00 in 20.00
GR
0.00 gAPI 150.00
RESS_COMP
RESM_COMP
RESD
DTCO_COMP
240.00 us/ft 40.00
NPHI
0.6000 m3/m3 0.0000
RHOB
1.7000 g/cm3 2.7000
Color fill
Oligocene Marker
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3711.4
Top OF1
Top OF1 CB3
Top OF1 CB3 Middle
Base OF1 CB3 Middle
Base OF1 CB3
Base OF1
Top OF1 CB3 Lower
Base OF1 CB3 Low
Done


3149 m
SSTVD
1:2000
CALI_COMP
10.00 in 20.00
GR
0.00 gAPI 150.00
RESS_COMP
RESM_COMP
RESD
DTCO_COMP
240.00 us/ft 40.00
NPHI
0.6000 m3/m3 0.0000
RHOB
1.7000 g/cm3 2.7000
Color fill
Oligocene Marker
Top OF1 CB3 Upper
Top OF1
Top OF1 CB3
Base OF1 CB3 Upper
Top OF1 CB3 Middle
Base OF1
Base OF1 CB3 Middle
Base OF1 CB3
2950
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3676



4976 m
Oligocene Marker
SSTVD
1:2000
CALI_COMP
10.00 in 20.00
GR
0.00 gAPI 150.00
RESS_COMP
0.2000 ohm.m 2,000.0000
RESM_COMP
0.2000 ohm.m 2,000.0000
RESD
0.2000 ohm.m 2,000.0000
DTCO_COMP
240.00 us/ft 40.00
NPHI
0.6000 m3/m3 0.0000
RHOB
1.7000 g/cm3 2.7000
Color fill
Top OF1
Top OF1 CB3 Lower
Top OF1 CB3
Base OF1 CB3 Lower
Top OF1 CB3 Lower Splay
Base OF1
Base OF1 CB3
Base OF1 CB3 Lowe
3000
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3756.3


4478 m
G05 [SSTVD]
SSTVD
1:2000
CALI_COMP
10.00 in 20.00
GR
0.00 gAPI 150.00
RESS_COMP
RESM_COMP
RESD
DTCO_COMP
240.00 us/ft 40.00
NPHI
0.6000 m3/m3 0.0000
RHOB
1.7000 g/cm3 2.7000
Color fill
Oligocene Marker
Top OF1 CB3 Lower
Top OF1
Top OF1 CB3
Base OF1
Base OF1 CB3 Lower
Base OF1 CB3
3050
3100
3150
3200
3250
3300
3350
3400
3450
3500
3550
3600
3650
3700
3750
3791.3
DT Black
Red
ΦN Blue

SUMMARY OF WORK

Two-month training in BPRL has been a great learning experience for a student like me. I have been exposed to the various techniques which are used in the oil and gas industry in the exploration process. For an entire month, I have been acquainted entire exploration gamut in a single basket which usually covers highly sophisticated scientific G&G interpretation and engineering techniques. At the outset, I was exposed to API of Exploration involving precise geophysical and geological techniques. I had the opportunity to interact with highly sophisticated and précised interpretation software in “work station” module and generate relief and time map by myself using this work station facilities. The basic objective of doing any work, its implication and desired outputs have been inculcated in our mind before taking up that assignment. Interpreting the maps and using them to extract the maximum geological information for its effective interpretation is an art where, I would like to excel in the time to come. Nonetheless, it has been a great way to begin. I have learned to generate Synthetic Seismogram and interpret seismic section by marking horizon for the basement and mapping the fault.

Understanding various subsurface structures like faults, folds, unconformities from maps has been a very exciting experience. I have also worked on various types of logs (SP log, GR log, resistivity log etc.) and have learned to interpret the lithology from the log, identify the reservoir facies and their hydrocarbon potential.

Correlating the logs from various wells to create a picture of subsurface is another interesting and important concept that I have learned. I have been able to equip myself with the knowledge of using the log data to calculate the effective porosity, Vsh, hydrocarbon saturation and most importantly, the net hydrocarbon reserves. I have the opportunity to learn the basic concepts of a geological section. Amalgamation of all the geological and geophysical (G&G) inputs from different seismic maps, log correlation data and seismic data etc. for creating a geological section, is an interesting task which yields a complete subsurface imagery. This is although very difficult to produce and at the same time challenging for quality check.

Before coming to BPRL, I had very basic knowledge of these concepts. College is a great place to learn the basics of a subject but it is in the industry that one gets a chance to learn its application. I have also had a chance to be exposed to the wonderful work culture of this prestigious organisation. This knowledge has significantly improved, thanks to the all the mentors in BPRL who have helped and guided me on every step. I am confident that the knowledge that I have gained will help me becoming a very good geologist in the future. I shall make sure that my hunger for knowledge will remain intact and I shall always strive for more and its effective utilisation by proper assimilation.

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