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NOVEL NON-DYNAMITE APPLICATION OF THE ACCELERATED IMPACT SOURCE FOR 2D AND 3D SEISMIC EXPLORATION SURVEYS IN THE INDONESIA CENTRAL SUMATRA BASIN REGION.

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ABSTRACT

Two of the most common seismic energy sources used by the geophysical industry for land 2D and 3D exploration surveys have been Vibroseis and explosives, particularly for application to the exploration of oil and gas. On many land seismic surveys that are located over challenging terrain and environmentally sensitive areas it can be extremely costly, difficult, or impossible to consider using Vibroseis or explosives energy sources. A less common, but much improved alternative seismic energy source is the high performance Accelerated Impact Source (AIS) system. This paper introduces AIS systems development and performance attributes for use on 2D and 3D oil & gas seismic surveys.

An AF750-AIS 3D seismic Survey method combined with the use of the recently developed OYO-GSX cable-free seismic data acquisition systems was conducted within an active Palm Plantation at Southern Mahato-Petapahan area, Central Sumatra Basin. The Survey covered 24 square kilometer area and was carried out as part of a renewed exploration program. The objective of the 3D seismic survey is to improve delineation and characterization of complex shallow and basement depth stratigraphic and fault controlled geo-structural petroleum traps and reservoir systems. The project operation attributes and seismic data results are presented in terms of environmental impact, survey design and acquisition operations, overall performance, and seismic data quality.

The results of 3D AIS show reasonably comparable quality with the existing 2D seismic data. Some of the strong deep reflectors can be observed and become an aid to map the main interval of interest. Additionally, the structural features such as basement, faults, and anticlinal traps are relatively clear to be identified. From the operational point of view, the AIS is proven to be more economical and environmentally friendly energy source, especially when combined with the use of the recently developed cable-free seismic data acquisition systems.

INTRODUCTION

Performance characteristics of seismic energy source systems are critical to the acquisition of interpretable high quality seismic data. Some of the more significant characteristics are its energy content, bandwidth, and ultimate wavelet shape. The criteria for selection of an appropriate seismic energy source include operation efficiency, economics, reliability, and operations safety. Often there is no single best criterion for choosing a seismic source, since the choice will also depend on geologic target objectives, the required maximum depth of the target objectives, and data resolution. Taking into consideration all the desirable energy source performance characteristics, as well as the more significant source selection criteria, for many 2D and 3D seismic survey projects the AIS is often the best choice.

Although the geophysical industry have used AIS systems of various designs for more than 30 years, it is only in the recent 10 years it has been considered a practical, and more economical alternative to Vibroseis or dynamite on 2D and 3D petroleum exploration projects. Explosive sources have been used extensively on land seismic surveys for many decades, providing a high-energy high-bandwidth source. However, the use of explosive sources now is becoming more and more restricted, limiting or prohibiting its applicability in many areas. In addition, the challenges and costs

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associated with permitting and drilling of shot holes often results in the compromise of fold and spatial resolution. Where applicable and practical, Vibroseis have also been used as an energy source. However, the AIS has a distinct advantage of smaller footprint an impulse signature similar to the dynamite.

With few exceptions, early versions of AIS were predominantly designed for shallow seismic reflection and refraction surveys, where mapping of geologic target depths typically ranged from 50 to 500 meters. While still a dominant application with the smaller AIS systems for use in shallow target minerals exploration, groundwater studies, geo-engineering, and environmental projects, new larger and more powerful AIS systems can achieve seismic imaging of petroleum exploration targets at depths ranging from 2500 to 4500 + meters. As challenges, regulatory issues, and costs associated with conducting 2D and 3D land petroleum exploration surveys using Vibroseis or dynamite continue to increase worldwide, the use of AIS systems on 2D and 3D petroleum exploration surveys is becoming a more practical and desirable seismic energy source alternative. As an example, Apachi Oil & Gas successfully used a design similar to the AIS in the northern Canadian territory. They found, “the resulting seismic data have a signal to noise ratio as good as or better than conventional dynamite source records in the same area” (Petzet, 2004). New Zeeland Oil Company used AF 750 for operations in the west coast and Taranaki areas of New Zealand with remarkable good success (Van Koughnet, 2010).

Types of Accelerated Impact Source (AIS) Systems

The AF750 Accelerated Impact Source (AIS) is a high performance “impulsive” energy source designed for application to 2D and 3D seismic surveys. By design, the AF750 is a hammer and baseplate energy source system that utilizes pressure adjustable nitrogen charged pistons as the hammer accelerant. The energy output of the AF750 ranges from 10996-40891 ft-lbs (14909-55440 joules), which is comparable to the dynamite impulse source (http://www.usallianceinc.net/accelerated-impact-energy-sources.htm).

Mechanically, the generation of seismic energy from the AIS is based on the vertical acceleration of a hammer mass that strikes a ground coupled baseplate. Operation of the AIS is similar to the Vibroseis source system, where a center mounted hammer and baseplate assembly is lowered to the ground using a hydraulic control system. The vehicle weight is used for baseplate “hold-down” during operation. However, unlike the Vibroseis, which is a vibratory sweep energy source, the AF750 AIS is an impulse source where each hit, or strike of the baseplate, transmits a seismic pulse into the earth.

The AIS systems are designed for installation on a variety of different types of vehicle carriers, including trucks, track vehicles (crawlers), and even some of the intermediate sized Vibroseis carrier vehicles. Flexibility with regard to vehicle installation gives AIS tremendous adaptability for use in a wide range of environments, and over areas with different terrain conditions. Figure 1 shows an AIS system mounted on a heavy duty 4x4 truck. Although it is often thought that accelerated impact sources could only be used on seismic surveys where target depths were less than 3,000 meters, Figure 2 presents an application of the AIS where the maximum required depth for seismic imaging reaches approximately 6,400 meters.

With the AIS system installed on the crawler-track vehicle (Figure 3), there is much greater flexibility and maneuverability over a wider range of terrain conditions. Moreover, because the crawler-track vehicles are smaller in size than either the truck or Vibroseis carriers, AIS operations require minimal, or no line clearing work along seismic source lines. In addition, maintenance and field support facilities requirements for the combination AIS and crawler-track vehicle is minimal and relatively low cost.

Environmental Impact Investigation for AF750 AIS (GSS Internal Notes, 2015)

Tests were performed by Urban Seismic Specialists Inc., Amory, Mississippi, USA on June 16th, 2012 to evaluate the Peak-Particle Velocity (PPV) associated with the AF750 AIS. Urban Seismic is an independent third-party vibration analysis company that was contracted by GSS (Geo Survey System) to investigate the potential of damage to pipes / structures near a gas storage reservoir, where GSS (Geo Survey System) was requested to acquire 3D land seismic data using the AF750 AIS. Based on vibration analysis, damage potential is best defined in terms of Peak Particle Velocity (PPV) levels attained at the point of interest due to impulse vibrations emitted by the impact source. The PPV measurements are indicators of the distance an impact source must be from sensitive infrastructure to avoid possible damage. The unit of measurement of PPV is inch / second. Figure 4 indicates that:

- Horizontally propagated energy decays exponentially with distance from the impact source point

- At distances of few meters from the impact source point, the PPV level is very low (at ~ 0.5 inch/ft). This is substantially lower than the 2 inch/sec. an accepted maximum threshold for minor structural damage (Table 1).

The AF750 has been successfully used on 2D and 3D surveys where data acquisition operations traverse through cities and towns, over and near sensitive infrastructure.

Mahato Petapahan Geological Target

Geological target of AIS 3D survey is the Sihapas Group, which include the Telisa and Bekasap Formations. The Bekasap Formation consists mainly of porous quartzose sandstone with silt and shale interbeds, while the Telisa formation consists mainly of shale with thin sandstone interbeds. The target structure is an elongated uplifted depocenter oriented northeast – southwest, and bounded by two nearly parallel strike-slip fault systems.

METHOD

The 3D survey took place from 10th Aug 2015 to 22th September 2015. The project area was 24 sqkm, requiring a total of 1082 source points and 2084 receiver points. The seismic source selected was an AF750 AIS system mounted on a Crawler-Track Vehicle. Seismic data was acquired using the Geospace GSR cable-free system, which made it easier and more efficient for deployment of receiver units within the Palm Planation area. The goal of the project was to acquire good 3D data over the Petapahan area. The weight of the AIS system is 16 tons, and is equipped with composite rubber tracks. The AF750 AIS only requires a 3-4 meter path clearance, and the track vehicle exerts only 4 lbs per sq. in. The crawler-track vehicle enable AIS to move even over buried facilities without causing any damage. A significant reason for using the AF750 AIS system is because the location of 3D seismic survey area is located over a Palm Plantation area. Terrain is relatively flat and covered with generally good access roads for locating source lines. However, the rows of palm trees, which were oriented north-south, presented some operations challenges for conducting unobtrusive and non-destructive operations for deployment of receivers. The 3D survey required the deployment of an active "static" receiver configuration consisting of an orthogonal grid with 24 north-south receiver lines, each with 72-84 receiver stations. The receiver line spacing was 250 meters.

The east-west source lines were located on the plantation access roads and were spaced at 400 meter intervals. Both the receiver and shot interval was 50 meters. The 3D survey was designed to produce maximum of 30 fold (Figure 5).

Only a small number of the personnel were required to manage the project, with an increase in field personnel required only for deployment and retrieval of receiver stations. Seismic operations using the combination of AIS and the GSR cable-free seismic recording system required 20 – 50 field personnel.

PROJECT RESULTS

3D seismic acquisition operations for the Petapahan exploration project using the combination of AF750 AIS and the Geospace cable-free GSR data acquisition system proved to be very beneficial in terms overall operations performance, operations safety, and data quality. A few of the more significant benefits were:

1. Less permitting required

2. Fewer requirements for support equipment and personnel

3. Lower equipment operating and maintenance costs

4. Less damage risk to the environment

The AIS and GSR cable-free 3D seismic survey over Petapahan area operation took approximately 1.5 months (effective). This includes one week of geodetic surveying of all source and receiver positions , two days of parameter testing, one week of receiver deployment, two weeks of data acquisition, and one week of field raw data retrieval (table 2).

Data from a 2D seismic test line was acquired prior to the start of 3D seismic operations. The objective of the 2D seismic test line was determine the optimum number of shots for each source point, and to determine the optimum nitrogen pressure setting, which controls the amount of impact energy per hammer blow on the AIS baseplate. Finally, with in-field processing, the 2D seismic test line confirms depth of penetration and overall data quality. Based on the 2D seismic test line data analysis, it was determined that a minimum of 8 hammer blows per source point would be required, and that the nitrogen pressure setting should be in the range of range of 500-600 psi.

Processing of the raw 3D data indicated a nominal usable seismic bandwidth of 10 Hz to 72 Hz (after vertical stack and post stack filtering). With the application of Bandwidth Extension and 5D Interpolation, the usable bandwidth was 10 Hz to 84 Hz. The Bandwidth Extension processing is especially useful for seismic sources that are rich in low frequencies, but may have rapid roll-off of higher frequency components due to near surface signal attenuation properties. 3D near surface static corrections processing was performed using GeoTomo TomoPlus software. Final processing included both Pre-Stack and Post Stack Time Migration, applied to improve overall lateral resolution. Processing results delivered good strata-structural imaging (Figure7), along with a well identified and delineated package of the Sihapas Group. In addition, the basement which lies at a depth 5600 ft (1.5 sec) can be clearly observed. The comparison of existing 2D data and 3D AIS data shows a good match in both frequency and phase (figure 8).

CONCLUSIONS

The results of the 3D seismic survey conducted in the Mahato Petapahan Area demonstrate the high reliability of the AIS, and highlight the opportunity to use this seismic energy source as an economical and production efficient alternative to using Vibroseis or dynamite. Because of its design and tunable energy output characteristics, the AIS is often the seismic source of choice in areas where 2D/3D seismic surveys are located in close proximity to surface infrastructure, or near buried pipelines (gas, fuel, water pipelines). In areas where there may be risk of damage to surface infrastructure and buried pipelines, the use of explosive and/or Vibroseis seismic energy sources can be restricted or prohibited unless it can confirmed that measured blast or vibration peak particle velocity (PPV) will not reach specified “risk of damage” levels. Seismic surveys are also much more efficient and adaptable to different environments when combined with applications of the cable-free system system technology. On seismic projects where budget constraints are a concern, especially where permitting and environmental conditions can be difficult, the AF750 AIS energy source has shown that seismic data can be acquired at lower costs without sacrificing data quality.

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TABLE 1

EQUIPMENT AND STRUCTURE DAMAGE CRITERIA (CANMET, BAUER AND CALDER 1977 IN GEO SURVEY SYSTEM, 2015)

Type of Structure	Type of damage	Particle velocity at which damage starts (in/sec)
Rigidity mounted mercury switches	Trip out	0.5
Houses	Plaster cracking	2
Concrete blocks in a new home	Cracks in block	8
Cased drill holes	Horizontal offset	15
Mechanical equipment pumps compressors	Shafts misaligned	40
Prefabricated metal building on concrete pads	Cracked pads building twisted and distorted	60

TABLE 2

TIME TABLE OF 3D SEISMIC SURVEY PROJECT

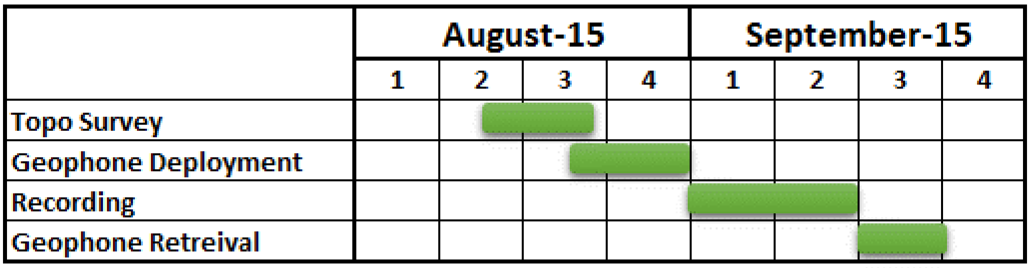


Figure 1 - 4X4 truck mounted AIS system (Geo Survey System, 2014)

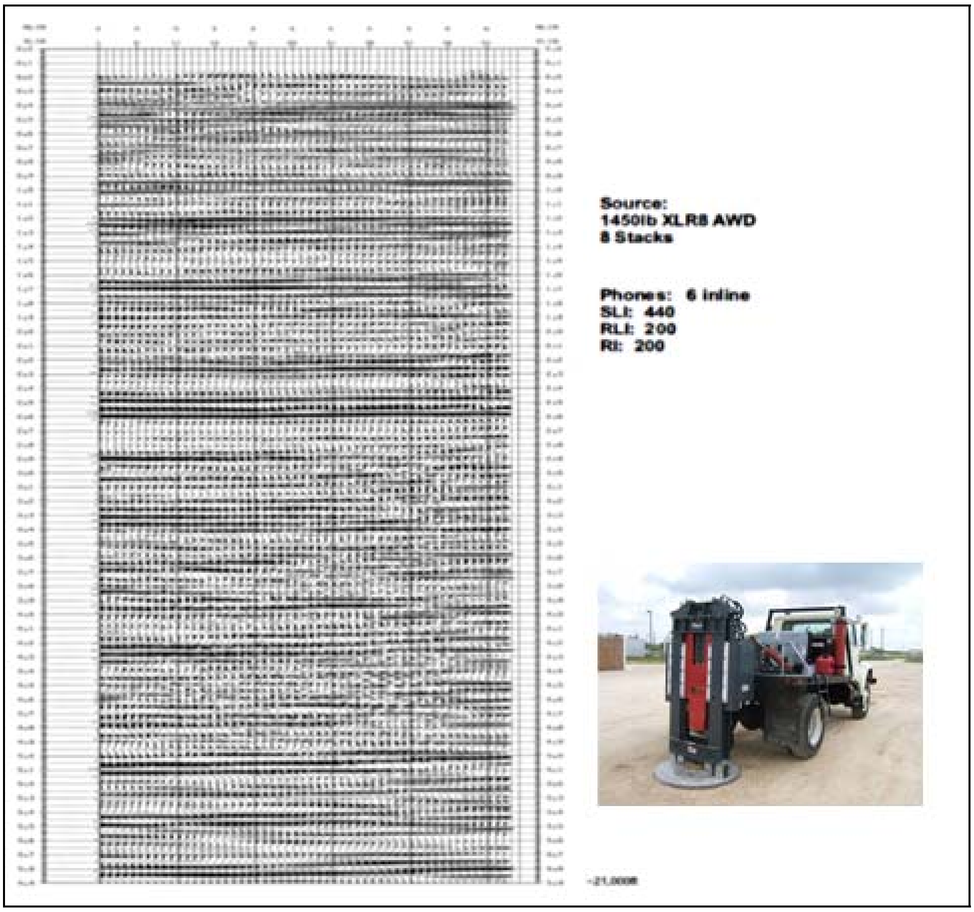


Figure 2 - An early version of the AIS truck mounted system used for acquisition of deep seismic data in West Texas, USA. Seismic section depth is approximately 6,400 meters (6.0 second TWT record). (Geo Survey System, 2014)

Figure 3 - Crawler-track vehicle with AF750 AIS center mount hammer mass (Geo Survey System, 2014).

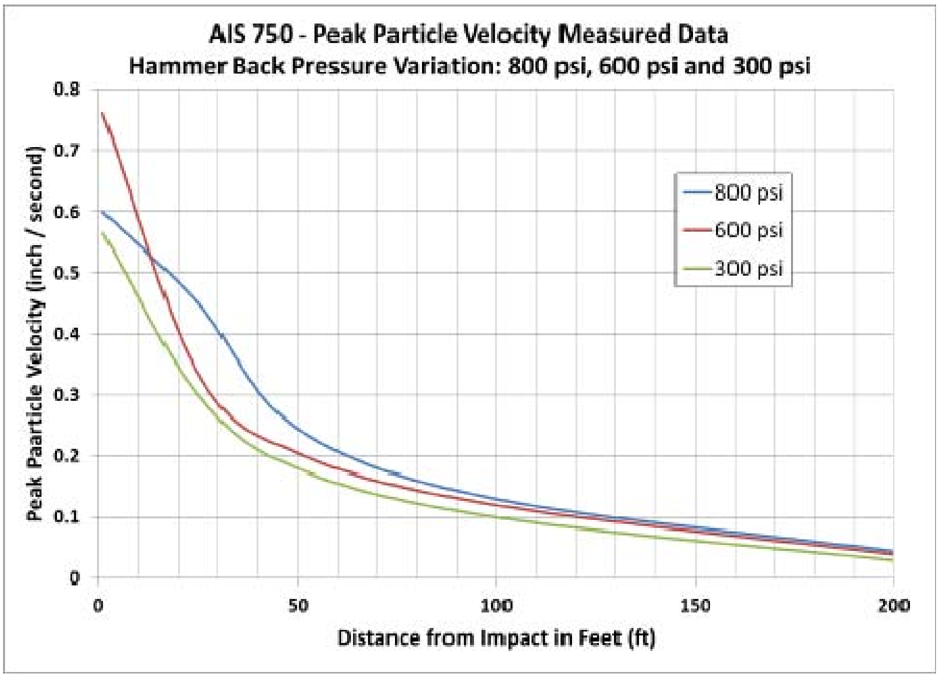
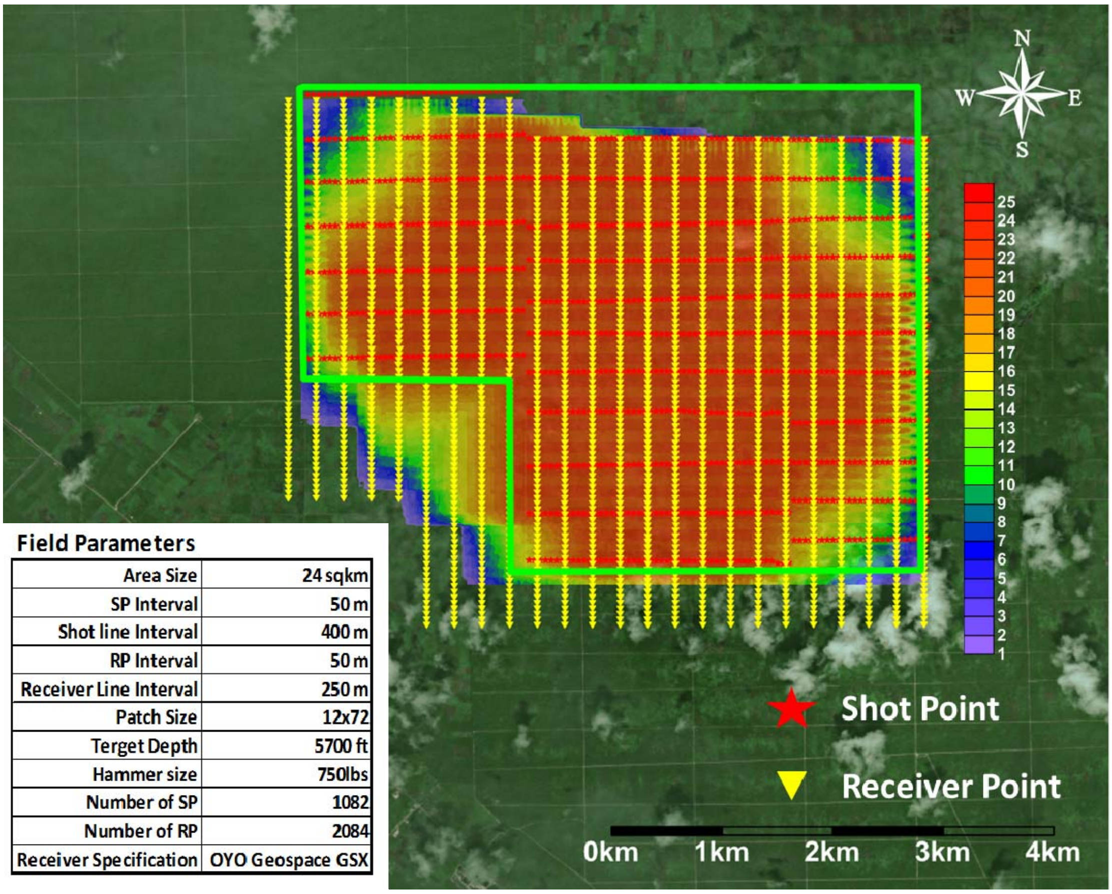
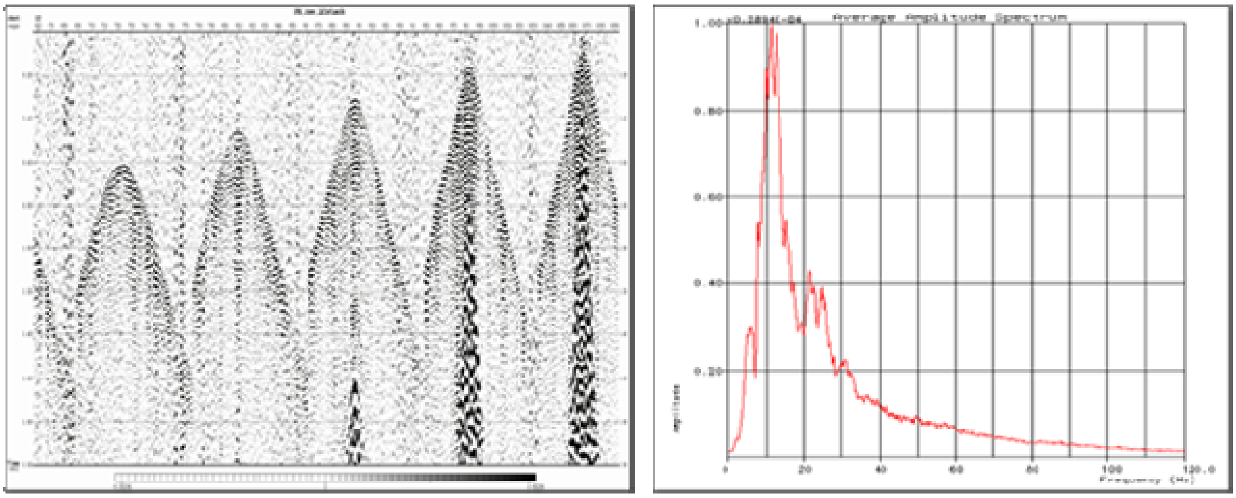


Figure 4 - Peak Particle Velocity Measurements for AF750 Accelerated Impact Source (AIS) as a function of hammer back pressure) (Geo Survey System, 2015).



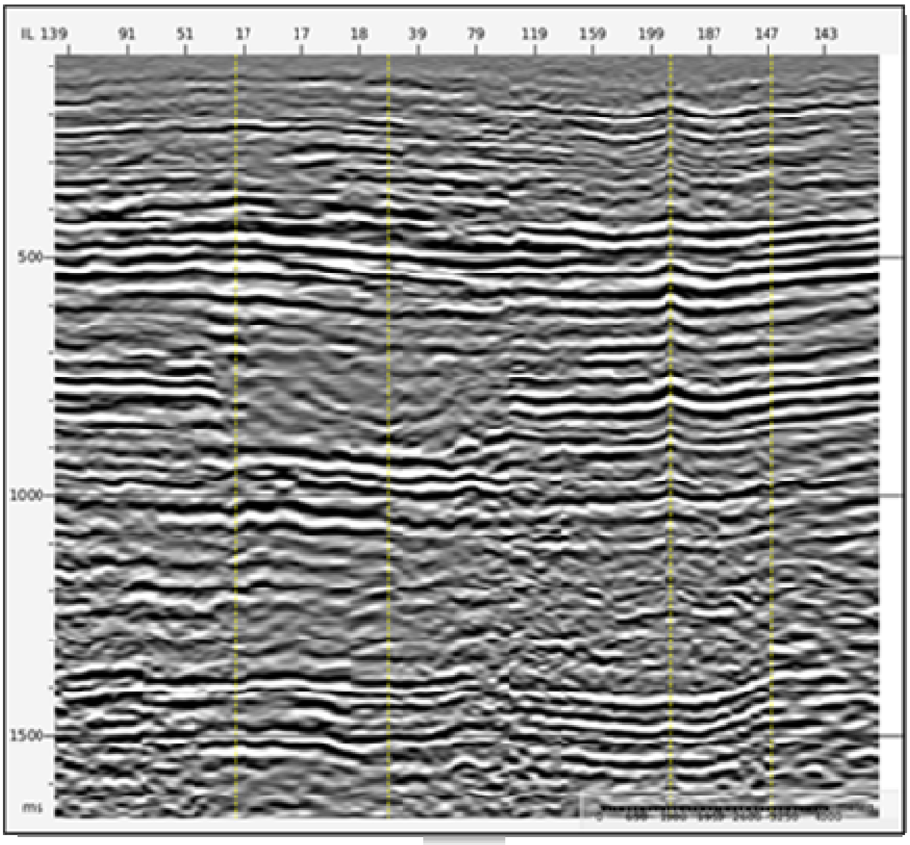
Area Size	24 sqkm
SP Interval	50 m
Shot line Interval	400 m
RP Interval	50 m
Receiver Line Interval	250 m
Patch Size	12x72
Terget Depth	5700 ft
Hammer size	750lbs
Number of SP	1082
Number of RP	2084
Receiver Specification	OYO Geospace GSX

Figure 5 - 3D Seismic Survey Outline & Fold Coverage

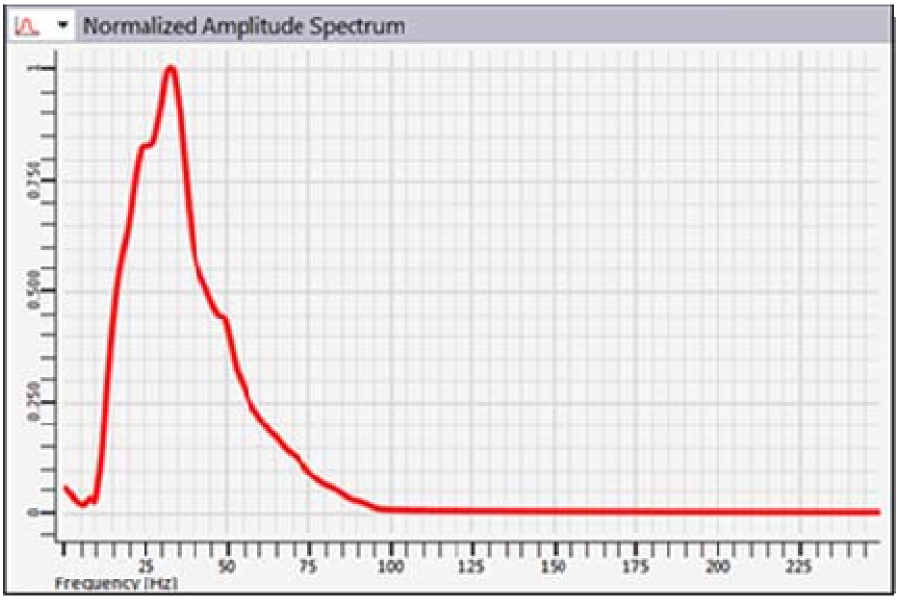


(a) (b)

Figure 6 - 3D Seismic Raw Data (a) & Spectrum Frequency (b)



(a)



(b)

Figure 7 - 3D Seismic PSTM Stack (a) & PSTM Stack Spectrum Frequency (b)

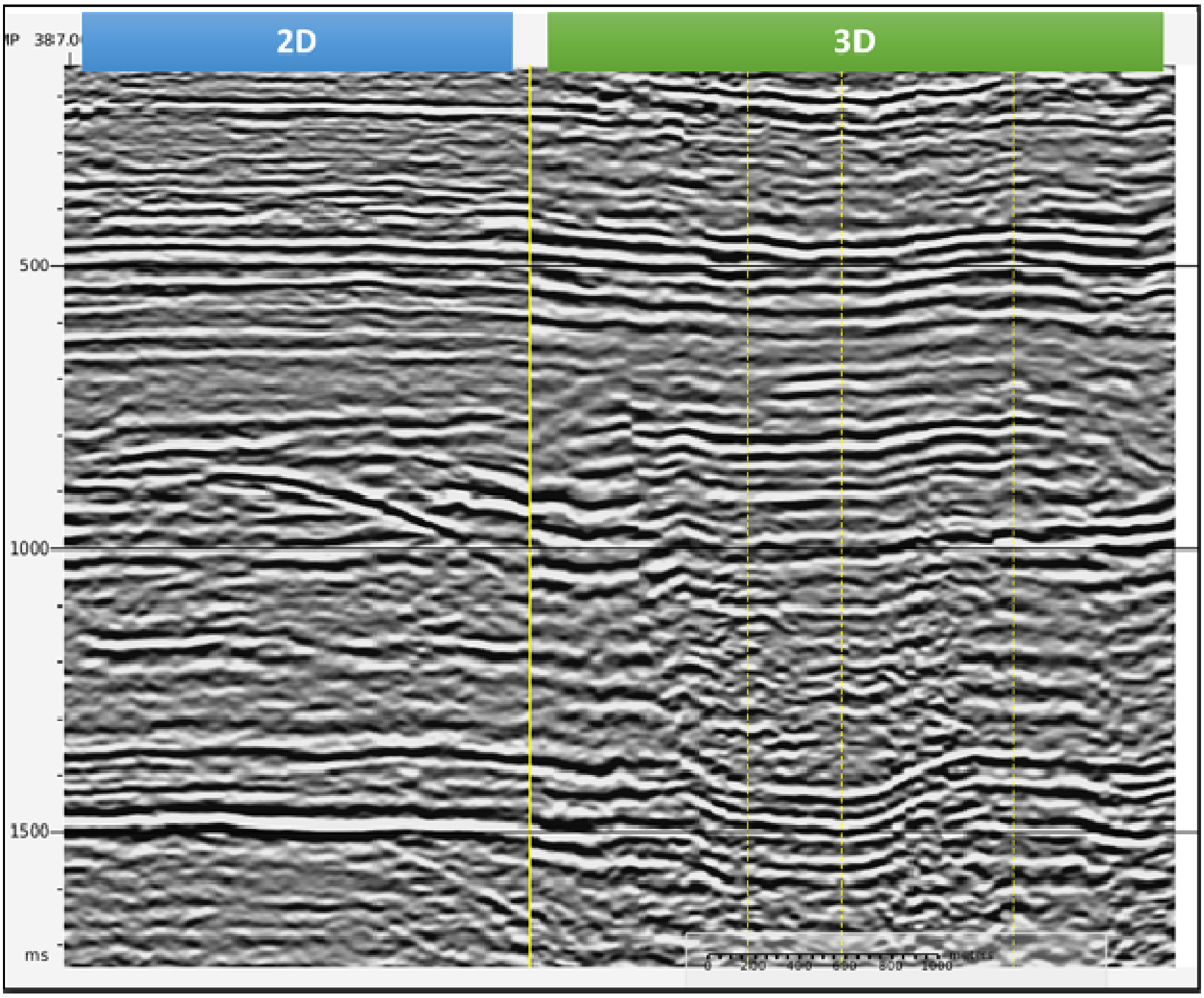


Figure 8 - Intersection of existing 2D Seismic with 3D Seismic using AIS method