MAXIMISING OFFSET WELL INFORMATION IN UNRAVELLING ONSHORE GEOHAZARDS INDICATORS: CASE STUDY OF THE GALE FIELD.

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ABSTRACT

An attempt is made in this study towards maximising offset wells information in unravelling onshore geohazards indicators in the Gale field. The Gale field is located about 100km north-west of Port Harcourt, Nigeria. The field consists of a highly faulted and elongated rollover anticline, bounded to the north by a regional growth fault. The data used for this study integrates the quadrature and reflectivity amplitude attributes from seismic data, with offset well data. The conventional reflectivity seismic data was 90° phase rotated to derive the quadrature volume. The quadrature seismic was considered a more appropriate reflectivity seismic attribute for use in shallow geohazard analysis as it is known for its characteristic preservation of high frequency spectrum inherent in the data. Offset wells (GALE-01, GALE-03, GALE-04, GALE-05, GALE-06, and GALE-08) analysis revealed mud losses, stuck pipe, overpull and gas cut as gathered from the daily drilling reports. These could translate to potential triggers of some geohazards where poorly managed. Review of field geotechnical report did not reveal any geohazards issues. Based on the geohazards assessment carried out for these wells; chances of encountering shallow gas for all the units as shown in the well summary is rated low. Results from a geohazards analysis indicate the presence of possible shallow gas within the area of interest and particularly along the shallow section of planned well trajectory. This is further supported by the presence of faults within the vicinity of gas bearing reservoirs at deeper level and a potential for these faults extending to the shallower interval. These faults are likely to serve as migration pathways for gas to seep to the shallower section, hence forming a potential geohazard. In addition, some of the offset wells targeting deeper gas reservoirs penetrated pockets of gas at the shallower interval that stratigraphically correlates with the shallow section that would be penetrated by the planned wells. The results of this work were used to move the proposed drilling location of the Gale planned wells to a nearby area free of shallow gas signatures.

KEYWORDS: Geohazard, Amplitudes, Shallow gas, Hydrates, Diapirism

INTRODUCTION

Geohazards can be defined as "events caused by geological conditions or processes which represent serious threats to human lives, properties, natural and built-up environment" (Solheim *et al*., 2005). Geohazards exist both onshore and offshore. Onshore, the most common are volcanic eruptions, earthquakes, landslides and debris flows, floods and snow avalanches. Offshore, slope instability and earthquakes are the main threats because of their potential for damaging seafloor installations, and for generating devastating tsunamis, such as the 1998 Papua New Guinea event responsible for more than 2000 deaths, and the past Storegga Slide tsunami (Løvholt, *et al*. 2017). Features like shallow gas, gas hydrates and mud diapirism also represent geohazards in both onshore and offshore regions.

Geohazards are disasters induced by natural processes or human activity (Canals *et al*., 2004). According to Orange *et al*. (2001), marine geohazards include any feature or process that could harm, endanger, or affect seafloor facilities, risers, anchors, etc. Additionally, the facilities can be designed to avoid or withstand some geohazards. Marine geohazards can also be a local and/or regional site and soil conditions having a potential to develop into seafloor failure events, which cause losses of life or damage to health, environment, or field installations (Kvalstad, 2007). Various geological processes and features can inflict hazards (Wu *et al*., 2018). Some of them are well known due to their great destructive power. These include earthquakes, volcanoes, landslides, and associated tsunamis (Ismail-Zadeh, 2016). Others

generally do not cause direct damage to societies but can affect engineering structures. These include pockmarks, mud volcanoes, and mobile bedforms (Vanneste *et al*., 2014; Benjamin *et al*., 2015; Shmatkova *et al*., 2015). Some manifest themselves on the surface of the seafloor, while others are concerned with processes that occur in the subsurface (Jia *et al*., 2016). This paper highlights an approach in evaluating geohazards in the Gale field through the integration of seismic, well-log data and offset well information.

An existing well bore close to a proposed well that provides information for planning the proposed well. In planning development wells, there are usually numerous offsets, so a great deal is known about the subsurface geology, and pressure regimes, Energy Glossary (2023). High resolution seismic processing allows to perform the enhanced definition of the formation internal structure. Amplitude anomalies are also detected. Picked abnormal seismic features are matched with geohazards already identified in the offset wells and also high-quality offset data are desired in the planning and optimization of well designs. In addition to offset well information, good quality seismic data is necessary for accurate pre-drill geohazards prediction. Pre-drill assessment of geohazards has, therefore, become an essential component of well planning, George Schultz & Steve Pickering (2002). In general, while planning a well in cases where offset data is sparse, care should be taken to ensure that more contingencies (such as alternative casing designs and mud engineering) are included. This paper seeks

to explain the importance of maximizing the use of Offset well information in the planning of new well trajectories.

Theory

Faulting geohazard is related to tectonic events, which can trigger earthquakes and tsunamis (Matsumoto *et al*., 2009). Active faults are susceptible to ground surface ruptures that can compromise pipelines and submarine cables (Hengesh *et al*., 2004; Trimintziou *et al*., 2015). Seabed forms that indicate pre-existing seabed instability, surface displacements, or fluid escapes are conditions that pose a significant risk to oil and gas exploration and development; can result in construction and operational problems if not properly investigated, assessed, and mitigated (Hough *et al*., 2011). Therefore, active failures have been mapped and investigated by Fu *et al*., 2017; to determine the level of their activity (recurrence times, displacements, slip rates) in the context of seismic hazard assessments (Mouslopoulou *et al*., 2009). Faults can present drilling difficulties such as borehole instability, increase local risks in terms of local slope stability, and may generate fluid-migration paths that potentially contribute to the escape of hydrocarbons in evolving reservoir units to growing diapirs.

MATERIALS AND METHODS

The representative wells' data used consists of Sonic, Density, GR, Resistivity and Calliper logs. The seismic data deployed is a full stack post stack depth migration seismic volume and some shallow horizon interpretation used to band the wells' shallow intervals into units. The Field was discovered in 1965/1968 and production commenced in 2002. Field background information was collated through review of previous field development plan documents. The seismic data was analysed for quality. This ensured time alignment, loop consistency and zero phasing. Well-log data was also reviewed and edited for washouts and spurious spikes. Well-to-seismic ties were done using the quality checked seismic and well-log data. Volume attributes were generated and analysed based on the reflectivity data. Calibration of the volume was done with the Well data and the resultant volume used to make predictions on geohazards.

Amplitude Analysis

Amplitude extraction was based on the Pre-Stack Depth Migration_Full_Gale seismic data. The seismic data was subdivided into intervals/units using shallow interpretations created for this purpose. Interval amplitudes were extracted as minimum extremum. Four intervals were analysed (for units 1, 2, 3 and 4), (Fig. 1). Observations from seismic amplitude analysis in units 2 reveal observed amplitudes in the eastern flank. This was tested by offset well (GALE-04) but did not find hydrocarbon however, the amplitudes are stronger on planned GALE PW-06. On the western flank, the amplitudes are not close to the planned wells. The offset wells did not find hydrocarbon. In unit 4, there are observed amplitude bodies which are not likely hydrocarbon related, as offset wells through this interval did not indicate hydrocarbon. In units 1 and 3, there are no observed anomalous amplitude bodies around the planned wells.

A semblance volume was generated to analyse near surface faulting, (Fig. 3). There was no near surface faulting observed within the area of interest in the GALE field. No near surface faulting was observed from available data within the AOI (area of interest), shallowest faulting observed starts from 1500 ms (5330 feet subsea). Faulting was analysed from shallow to near reservoir intervals, as part of the top-hole drilling requirements to demonstrate that there is no migration path for hydrocarbon from deep to shallow intervals, (Fig. 2).
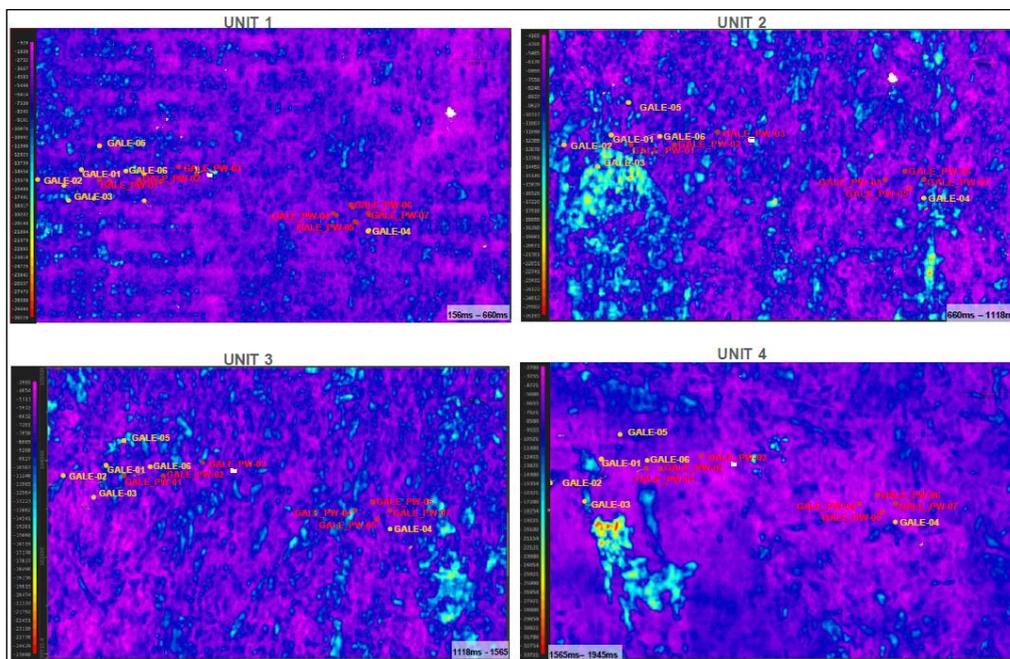
Figure 1: Amplitude extraction over units 1 to 4
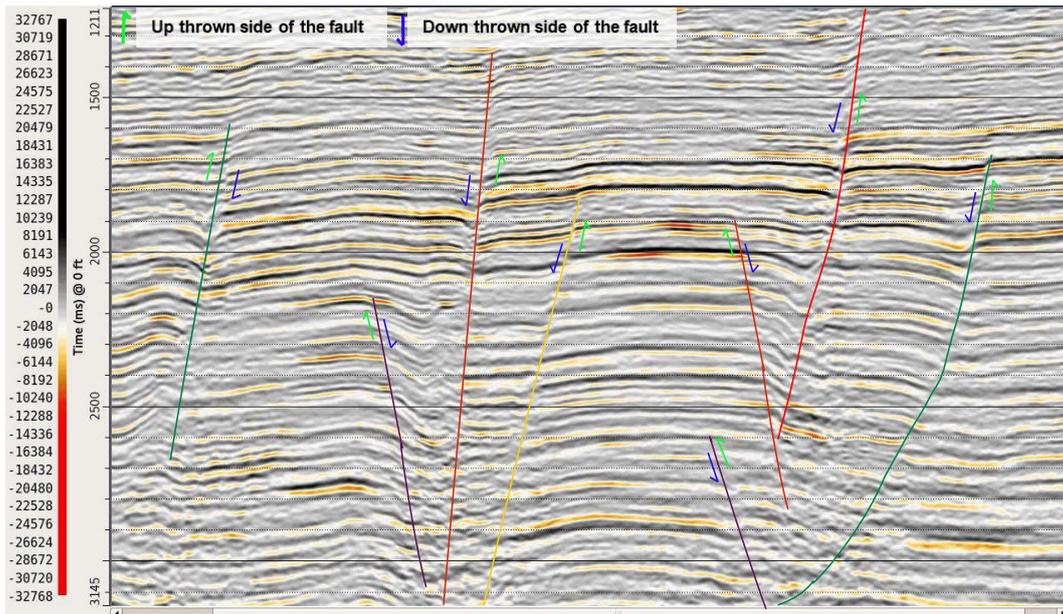
Figure 2: Interpreted seismic section showing faults.
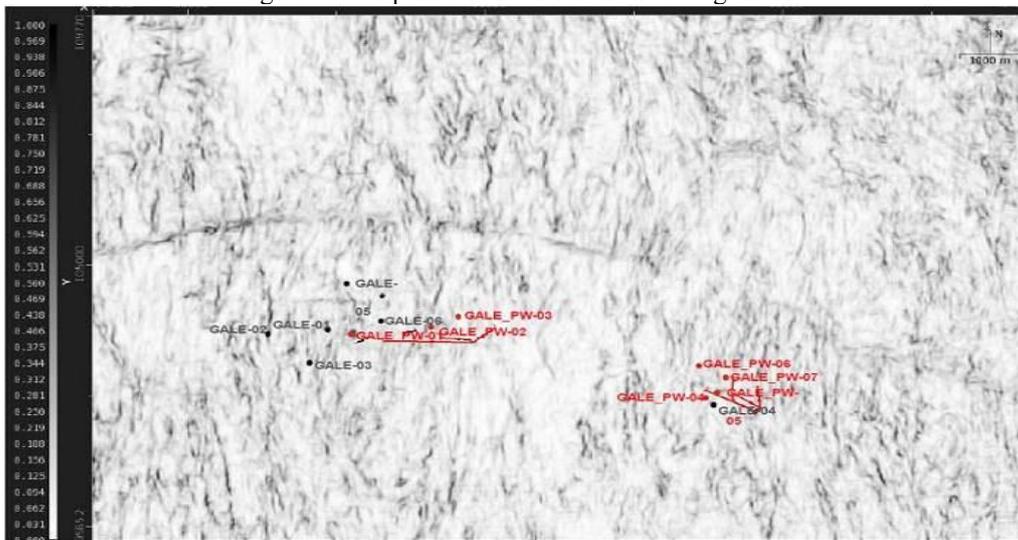
Figure 3: Semblance analysis showing that no near surface faulting was observed in the area of interest.

Planned well trajectories are coloured red, while existing wells have their trajectories in black. No near surface faulting was observed from available data within the AOI (area of interest), shallowest faulting observed starts from 1500 ms (5392 ftss)

RESULTS AND DISCUSSION
Offset Well Ties
Offset well analysis was carried out using offset wells from the GALE field. Offset wells used are GALE-01, GALE-03, GALE-05, GALE-06, and GALE-08. Analysis was done in two segments: the eastern flank and the western flank. On the western flank, GALE-04 was used as the main calibration well due to proximity. Observations from the offset well analysis indicate subsurface no geohazard. High amplitude observed in Unit 2 is not Hydrocarbon related as it was tested by GALE-04.
On the western flank, the main calibration well is GALE-05.

Observations from the offset well analysis indicate no geohazard issues were generally observed down to the surface casing (13 3/8") depths. However, gas cut and overpull were observed at the reservoir sections. Planned well trajectories are coloured red and the existing wells are in black. The drilling issues highlighted are based on the offset well data from the daily drilling reports. These are overlain on the seismic data to know their intervals of occurrence Planned wells trajectory is coloured red and the existing well is in black. The drilling issues highlighted are based on the offset well data from the daily drilling reports. These are overlain on the seismic data in order to know the intervals these are occurring planned wells trajectory is coloured red and the existing well is in black. The drilling issues highlighted are based on the offset well data from the daily drilling reports. These are overlain on the seismic data in order to know the intervals these are occurring.

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https://dx.doi.org/10.4314/WOJAST.v15i1.104
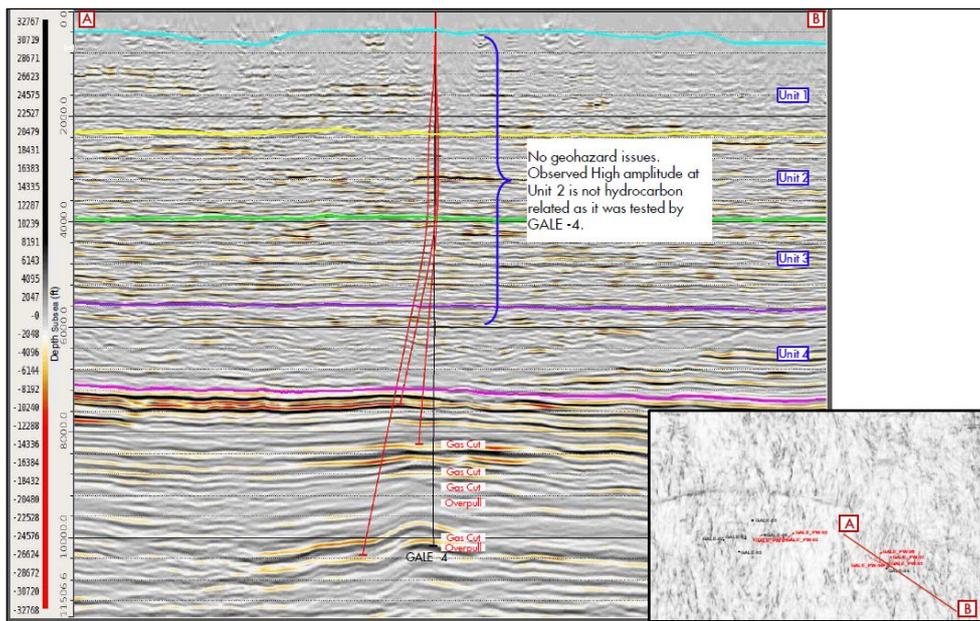
Figure 4: Offset well (Gale-04) tie for the western flank.
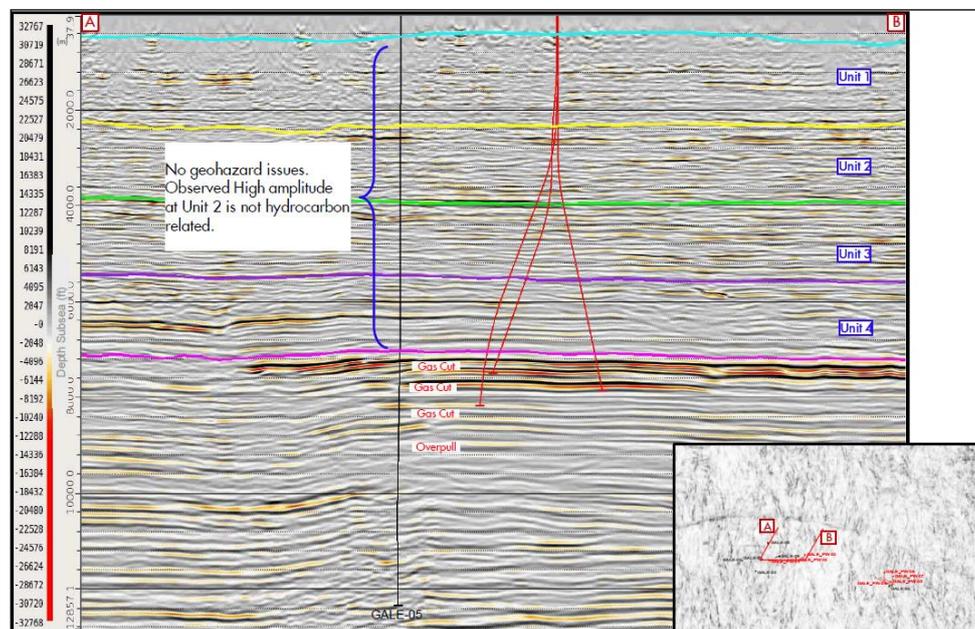
Figure 5: Offset well (Gale-05) tie for the eastern flank.

Tophole (Well) Summary
Tophole summary was generated for the 7 GALE planned wells. They were analyzed for shallow gas and other geohazards in the GALE field. The probability of encountering shallow gas and other geohazards was rated low in the tophole/well summary section of the wells.

GALE_PW-01
Geohazard assessment was carried out for the planned GALE_ PW-01 well. Quadrature data was analysed for the presence of Shallow Gas bodies. Also, semblance analysis was carried out to check for potential hydrocarbon migration pathways (in the upward direction). Offset analysis was also done for neighbouring wells within the field. A well summary was generated for the planned well trajectory detailing the outcome of the geohazard assessment for each interval along the planned well.

Observations from quadrature 3D seismic data and semblance data show that there is no migration path for hydrocarbon from deep to shallow intervals. Observed high amplitude traversed by the planned well at Unit 2 was tested by offset well (GALE-04) but did not encounter hydrocarbon. Offset well analysis in the field revealed intervals with gas cut and overpull were observed at the reservoir sections in GALE-05.

Unit 4 is characterized by the presence of a clay filled canyon with sand intercalations. GALE-04 penetrated this canyon without incidents. High amplitude body is found close to the suggested 13 3/8" casing point. Based on the geohazards assessment carried out for this well; the chance occurrence

of encountering shallow gas for all the units as shown in the well summary is rated low. Please refer to Figure 4. and 6 respectively for details of the offset well analysis and well summary for PW-01 planned well.
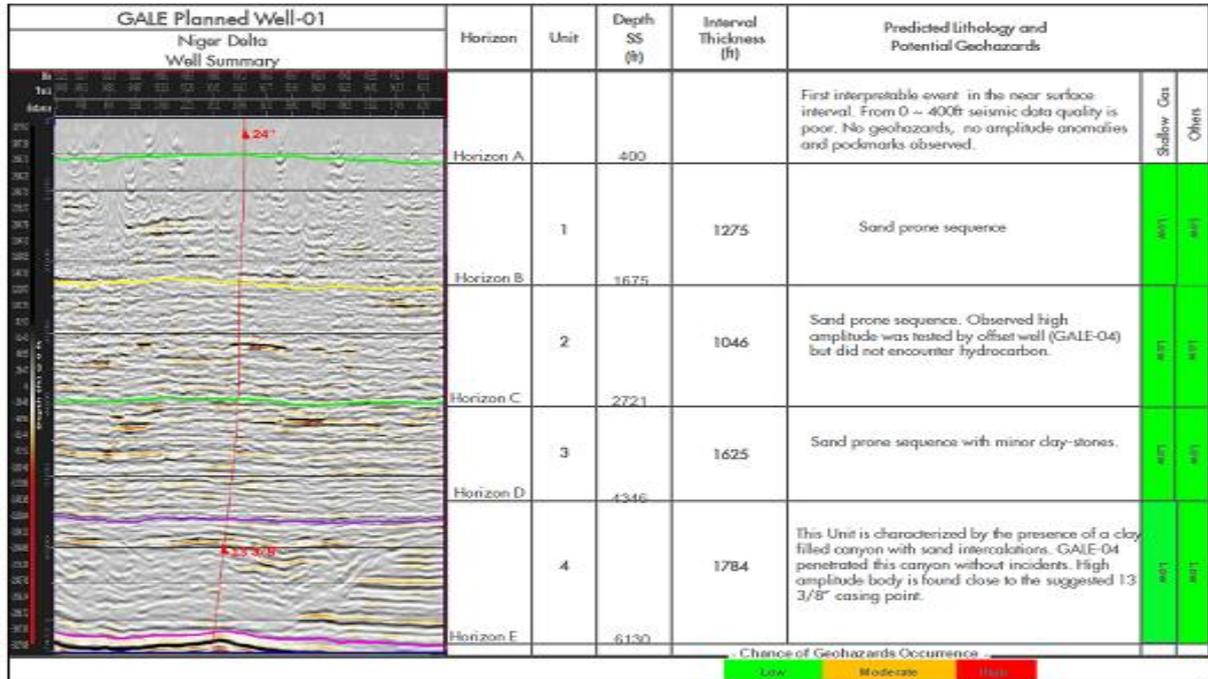
Figure 6: Gale_PW-01 Tophole Summary

CONCLUSION

Geo-hazards in oil exploration principally result from shallow gas (hydrates) found both onshore and offshore, which may adversely impact well placement and drilling activities. They can result in loss of well control and 'blow-outs' which can lead to fatality. Seismic data, when properly processed, provide a means with which these gases could be identified. The high standard of processing applied to the seismic data proves to be of great value for geohazards assessment. In general, reflector continuity within the data was well highlighted. The data has a broad bandwidth and high peak-to trough ratio on the test line compared to some existing 3D data. The adapted processing flow applied to the seismic data helped in identifying and delineating the presence and or the absence of geohazards. Offshore, new generation broadband marine and seabed techniques exist for their identification. Onshore (and offshore) geo-hazards identification using seismic data is the best available tool and requires accurate processing; Adebayo, *et al (2015)*.

In some parts of the GALE field, generated Quadrature data, show some very high amplitudes, proxy of gas. There was however no other evidence of other forms of geohazards observed or inferred from the seismic data. Further findings include:

(i) Some parts of GALE fall within the High flood risk area and as is the case with some High flood risk areas, the clays at the surface generally have low compressibility

and low swelling potential. This therefore should be borne in mind when constructing the platform.

(ii) Semblance analysis did not indicate any geohazard issues around the planned wells surface locations and top-hole sections.

(iii) From the Top-hole summary, planned wells GALE_PW-01, GALE_PW-02, GALE_PW-03, GALE_PW-04, GALE_PW-05, GALE_PW6 and GALE_PW-07, did not show indications of any geo hazards.

(iv) Observations from the offset well analysis indicate issues which include Gas Cut and Over Pull from 7570ftss.

(v) GALE wells 01, 02, 03, 04, 05 and 06 were used for the offset well analysis.

(vi) The locations should be reassessed for geohazards should the current well trajectory change, or the field is put on production before drilling.

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