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Integrated Sequence Stratigraphy and Paleo-Geomorphic Perspectives of Passive Margins: A case study of Beta Field, Niger Delta

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Abstract
A study of Integrated Sequence Stratigraphy and Paleo-Geomorphic Perspectives of Passive Margins in Beta Field, Niger Delta has been undertaken. The method adopted involved an integration of seismic and well data in predicting stratigraphic prospects. Amplitude analysis revealed the relationship between the faults and paleo-geomorphic features with hydrocarbon bearing potentials. Paleo-geomorphology was used in the imagery, interpretation and prediction of the distribution of possible hydrocarbon deposits. The technique will enhance basin reconnaissance and facilitate field development.

Keywords: Basin, Paleo-Geomorphology, Sequence Stratigraphy, Systems Tract, Play

Introduction
As the demand for hydrocarbon increases, it has become important to discover more hydrocarbon deposits in new and existing fields. The application of Sequence Stratigraphy to Stratigraphic trap exploration through integration of seismic and well datasets provides an effective tool for basin reconnaissance and discovery of newer finds in already explored fields.
The study aims at integrating geophysical data such as, Well logs and 3-D Seismic (within the limits of the available datasets) for a sequence stratigraphy interpretation of “Beta” Field, Niger Delta; to allow for thorough understanding of the subsurface geologic features of interest (source rock, reservoir rock and seal rock), for enhanced identification, interpretation and prediction of the distribution of possible hydrocarbon–bearing deposits in stratigraphic and/or subtle combinational traps.

2. Niger Delta

The Niger Delta is situated in the Gulf of Guinea and extends throughout the Niger Delta Province (Klett et al., 1997). Originally, the Delta was formed during the breakup of the South American and African plates during the late Jurassic (Burke, 1972; Whiteman, 1982). A passive continental margin of West Africa developed as a result of the two rift arms that followed the southwestern and southeastern coast of Nigeria.
The Niger Delta depositional system is basically regressive and progrades seaward (Figure 1). The Niger Delta constitutes an advance of terrestrial deposits into a high energy marine environment. At present, deposition occurs simultaneously under fully terrestrial (fluviatile) conditions, under conditions where there is interplay between terrestrial and marine influences (paralic) and under fully marine conditions (Frankl &Cordry, 1967).

Beta Field

The study area, Beta Field, is situated within the coastal swamp depobelt Niger Delta. This study seeks to obtain a high resolution sequence stratigraphy framework of the subsurface of Beta field by integrating Well logs and 3D Seismic data that sample the subsurface at different scales. 3-D Seismic data covering an area of 55.388 kM^2 was used for this study to relate observed strata discontinuities to vertical changes observed in well logs. Several wells have penetrated the study area. Three of these wells chosen for the study includes BT5, BT4 and BT6, from west to east along the strike (Figure 2). Composite well logs comprising gamma ray log, resistivity log and porosity logs (sonic log, neutron and density log) were used for the study.

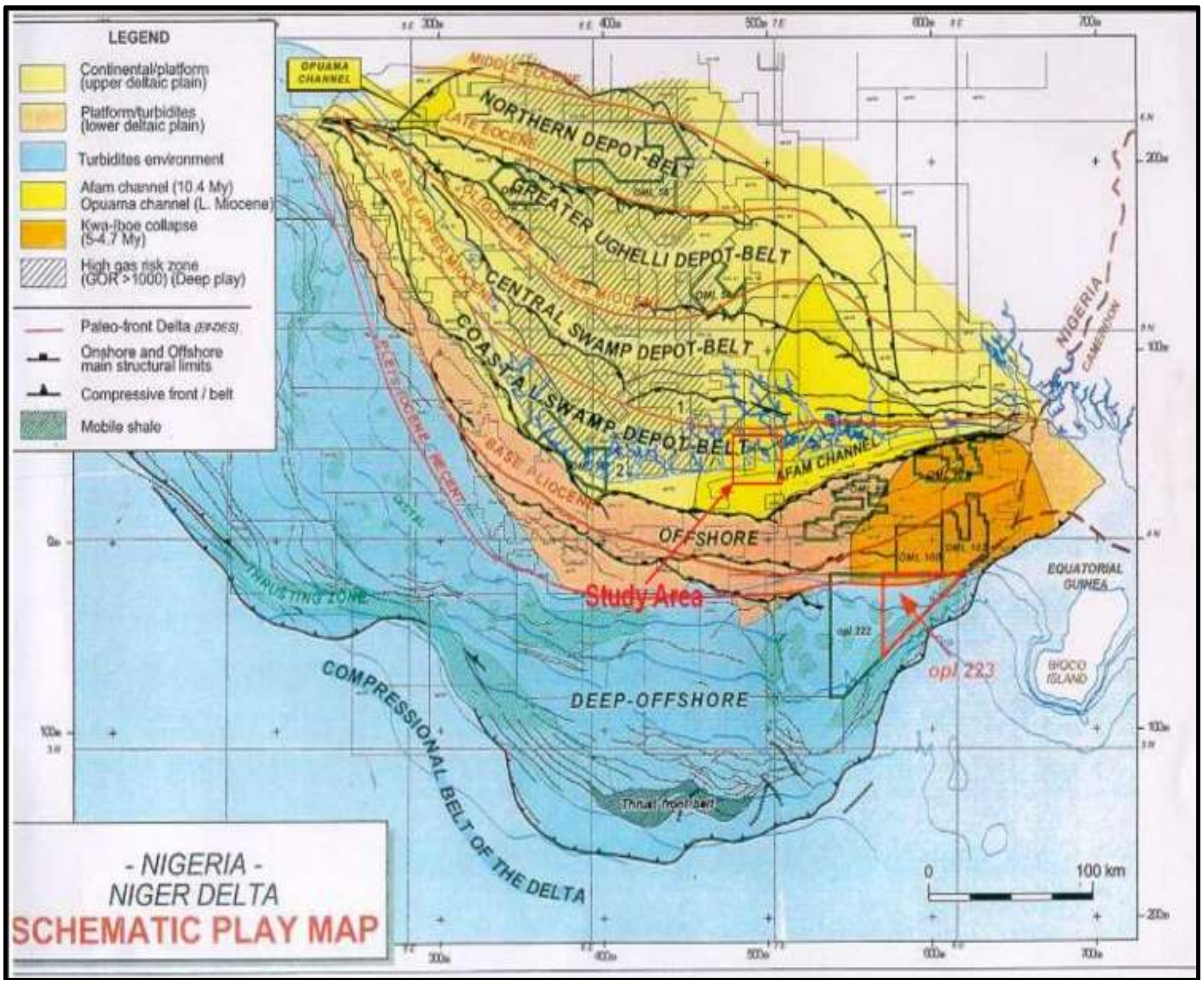

Figure 1: Map of Niger Delta Showing the Depobelts (After Weber, 1971)

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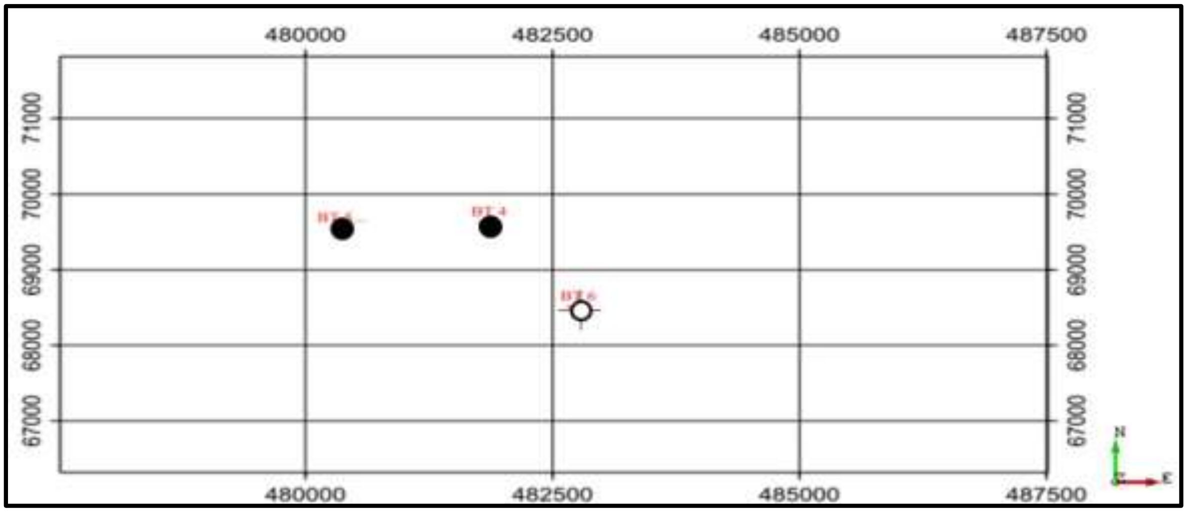

Figure 2: Base map of Beta Field, Niger Delta Scale (1:50000)

3. Methodology

The workflow employed for this study is shown in Figure 3.

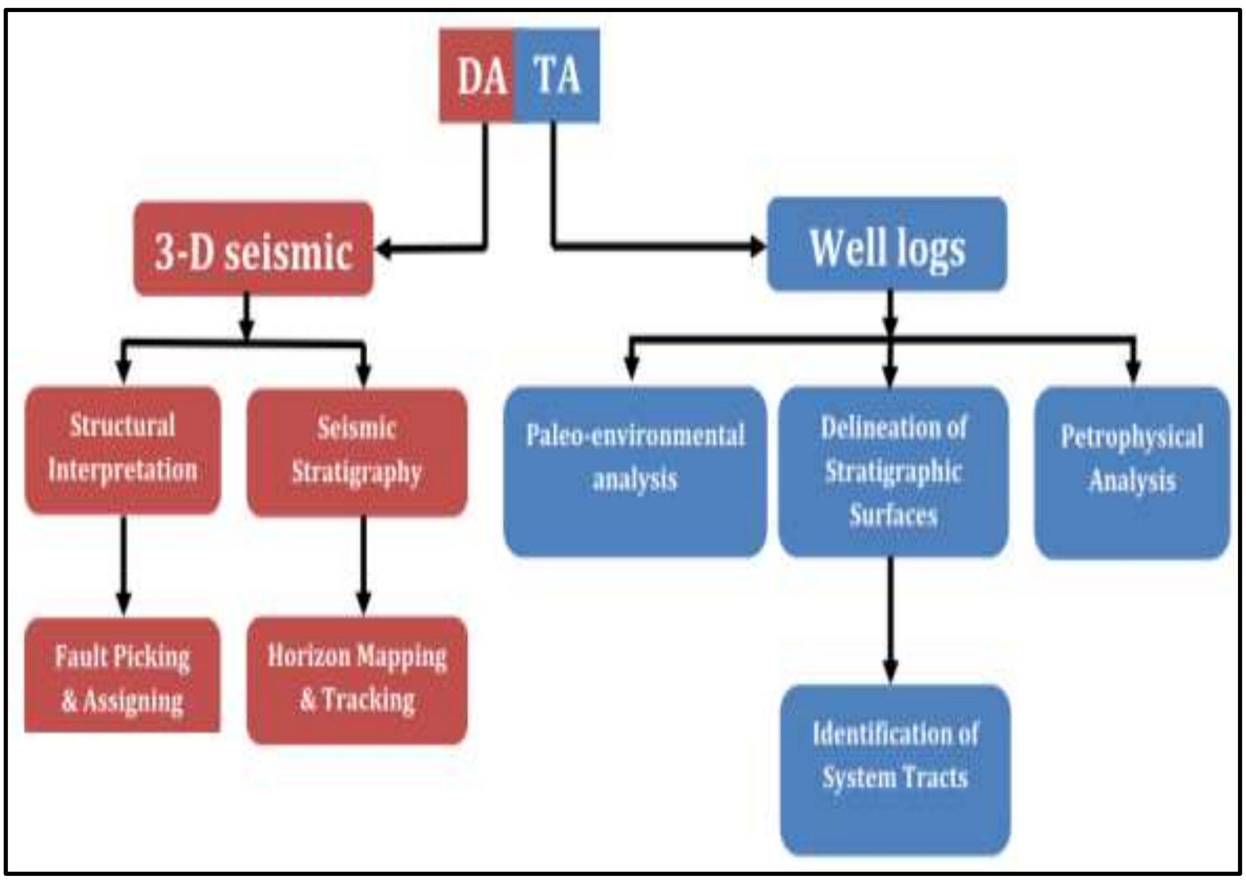

Figure 3: Chart Showing the Workflow Employed for the Study

4. Discussions

Lowstand Systems Tract (LST)

This is the basal (stratigraphycally oldest) system tract within the depositional sequences. It is bounded at the base by the sequence boundary (SB) and by the transgressive surface (TS) at the top.

The log motifs are generally coarsening upward typical of a prograding clastic wedges in a shallow – marine environment setting (Figure 4). This lowstand prograding wedges are recognized by the presence of a topset – clinoform which are progressively downlaping on the sequence boundary. The thickness of the tract varies between 56ft to 318ft.

These sediments were deposited when relative sea level was at or near the shelf margin and rising slowly but were slow enough for sedimentation to keep pace with shelf edge deltaic process (Posamentier and Vail, 1988).

Transgressive Systems Tract (TST)

The transgressive systems tract is bounded by transgressive surface at the base, and by the maximum flooding surface at the top.

The TST observed in all the wells shows a typical finning upward retrogradational stacking pattern, a diagnostic depositional trend of transgression (Figure 1).The transgressive systems tract is composed of truncation of parallel reflection terminating on the transgressive surface which represents retrograding topset parasequences (Figure 5). The thicknesses of this tract vary between 63ft to 383ft.

The type of sediment associated with this systems tract developed during periods of increase in the rate of sea-level rise and the shelf was no longer in tune with the rising sea- level causing the shelf to be flooded.

Highstand Systems Tract (HST)

The Highstand systems tract (HST) is the youngest systems tract in a depositional sequence. It is bounded at the top by the sequence boundary (SB) and at the base by the maximum flooding surface.

The HST has a characteristic aggradational to progradational stacking pattern. This systems tract is characterized by erosional truncations with reflection patterns terminating beneath the sequence boundary (Figure 5). While the overlying sequence boundary had series of reflections onlaping on it. The thicknesses of this tract vary between 106ft to 933ft.The rate of sea level rise decreases during the development of Highstand System Tract (Vail, 1987).

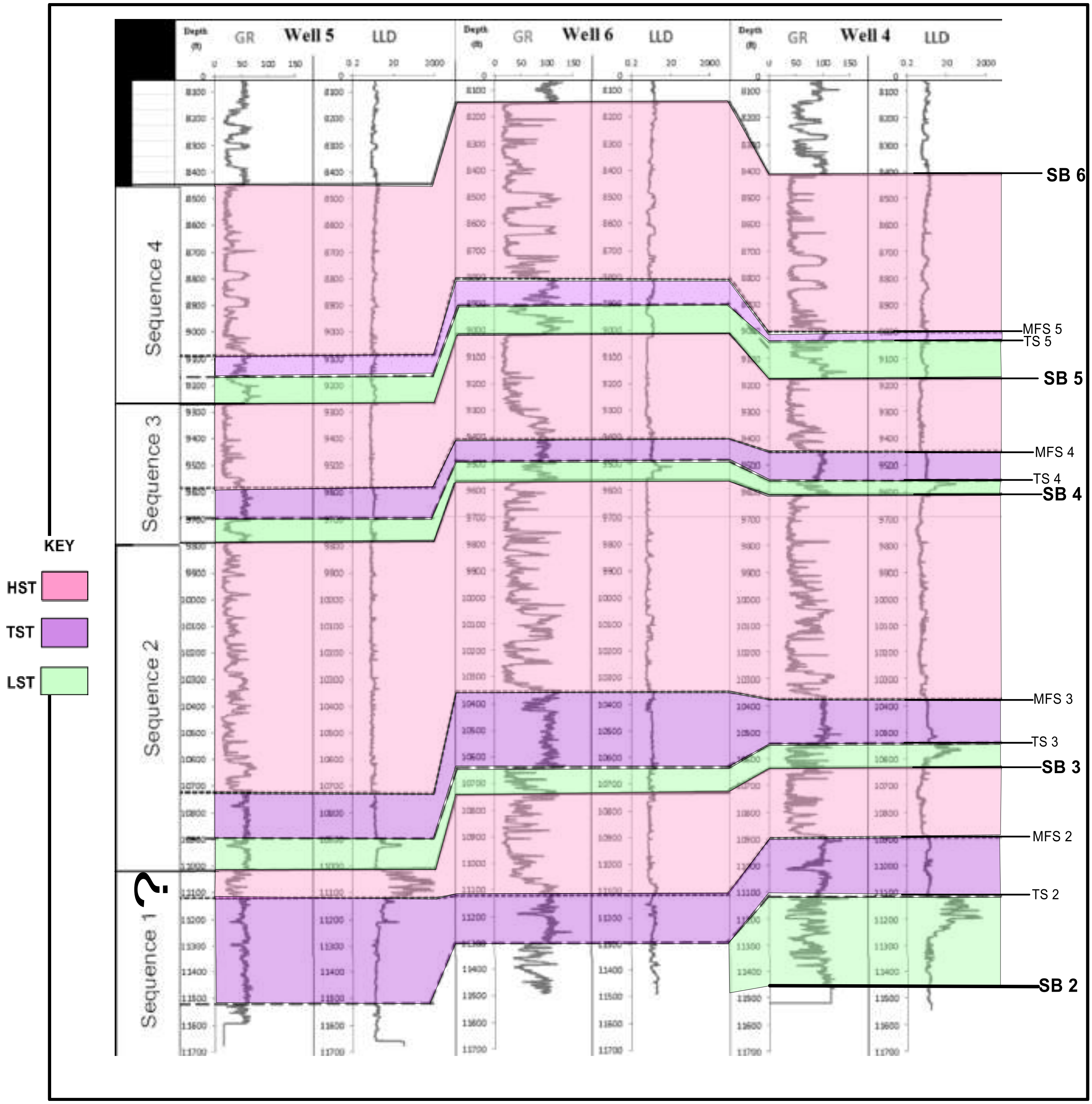

Figure 4: Well Log Section Showing Correlation of Wells BT5, BT4 and BT6 along Strike Line

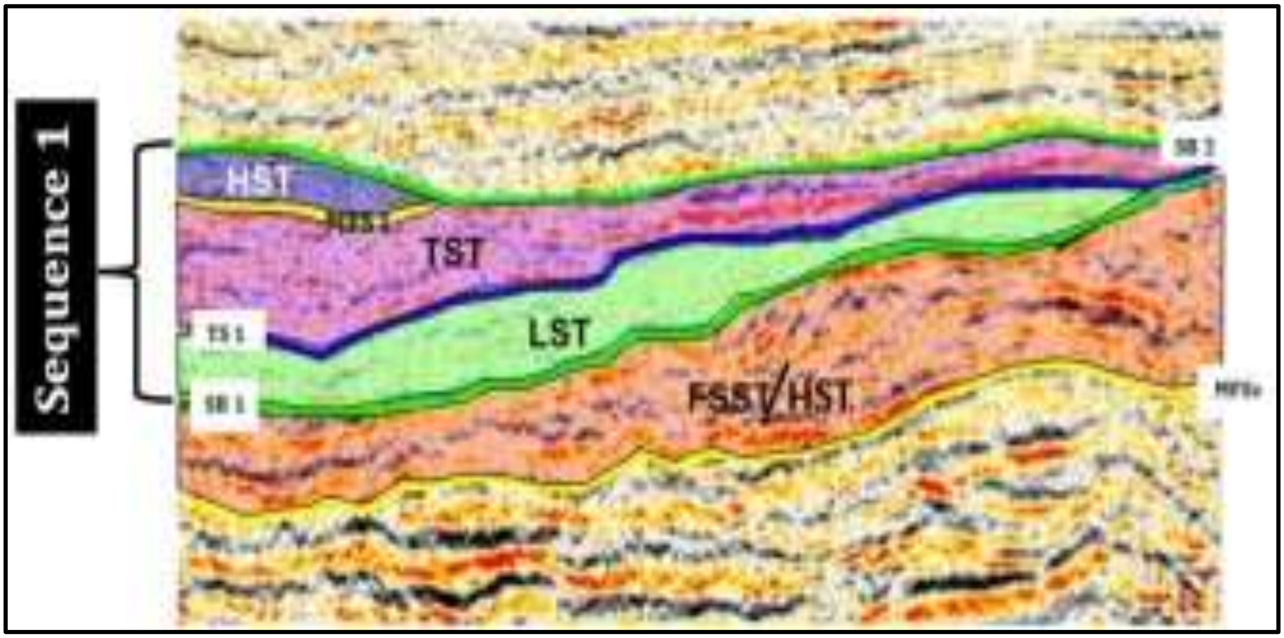

Figure 5: Systems Tracts and their Bounding Surfaces at Sequence One at Crossline 1520

Paleo-depositional environment

The identification of specific depositional elements (e.g. channel fills, beaches, splays etc) is also critical at this stage, as their morphology has a direct bearing on the economic evaluation of the stratigraphic unit of interest (Catuneanu, 2006).

Sequence boundary horizon one (SBH1) shows regional faults F2and F3 together with F1, and F4 dipping south while F5, F6 and F7 are antithetic faults dipping north. At the interception of the meandering channel and F2, is an adjustment in the flow-path of the channel as water and sediment move across a narrower path to the downthrown block (Figure 6a). The increased flow triggered incessant erosion of the outer-bank and subsequent deposition of point bar deposits on the inner bank to the west of the channel.

Maximum flooding surface horizon ($MFSH_0$) shows during periods of flooding developed and aligned to the west of the outer channel bends are levees (Figure 7). Also, the channel was overloaded and the breaching of the levees leads to the construction of fan shaped crevasse splay. At the bends of the meandering channel are point bar deposits.

Stratigraphic Plays and Prospects

Within sequence one, the reflection dips East – West (Figure 5). This sense of dip could play a key role in determining drainage and sediment deposition within the fiel d (Aminu and Olorunniwo, 2012). The paleo – geomorphic features are characterized by high amplitude and are marked as possible stratigraphic prospects. However, easterly stratigraphic prospects are believed to be better stratigraphic prospects due to the east-west dipping reflections. Since hydrocarbon moves updip, the east will be a preferred position for accumulation. Besides, regional faults are believed to act as pathways for the migration of hydrocarbon up-dip, Hence F2 and F3 are believed to have played a key role in the occurrence of hydrocarbon in the study area.

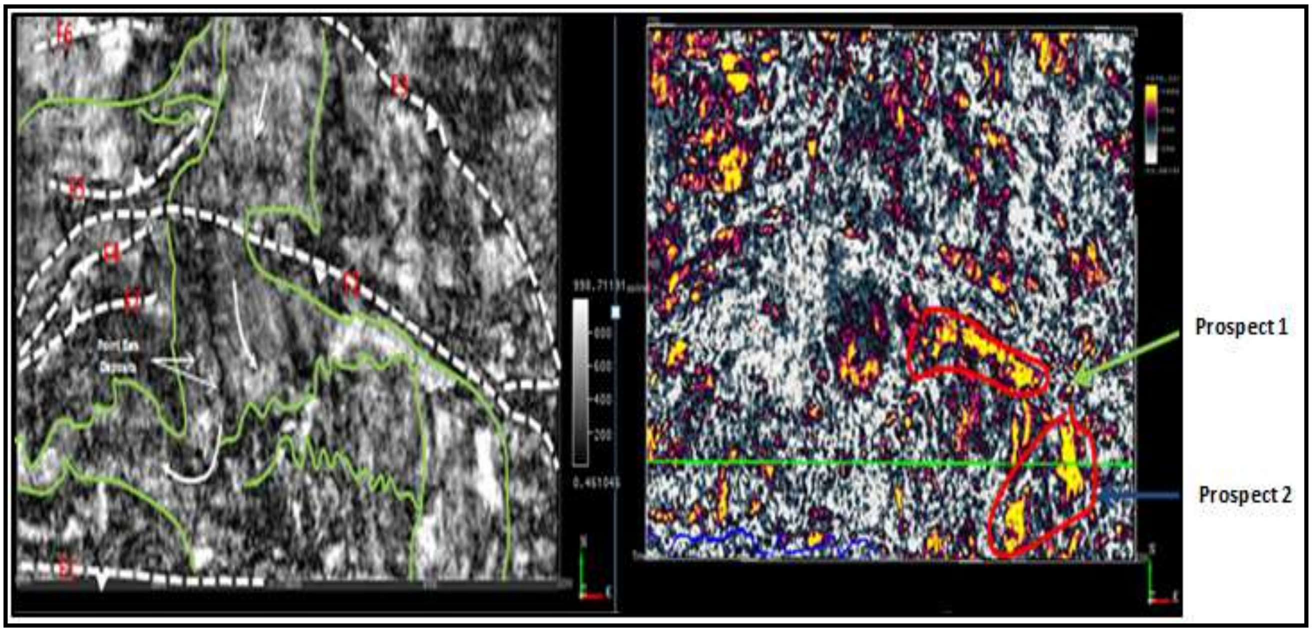

Figure 6: Seismic Geomorphology of Sequence Boundary One (SBH1)

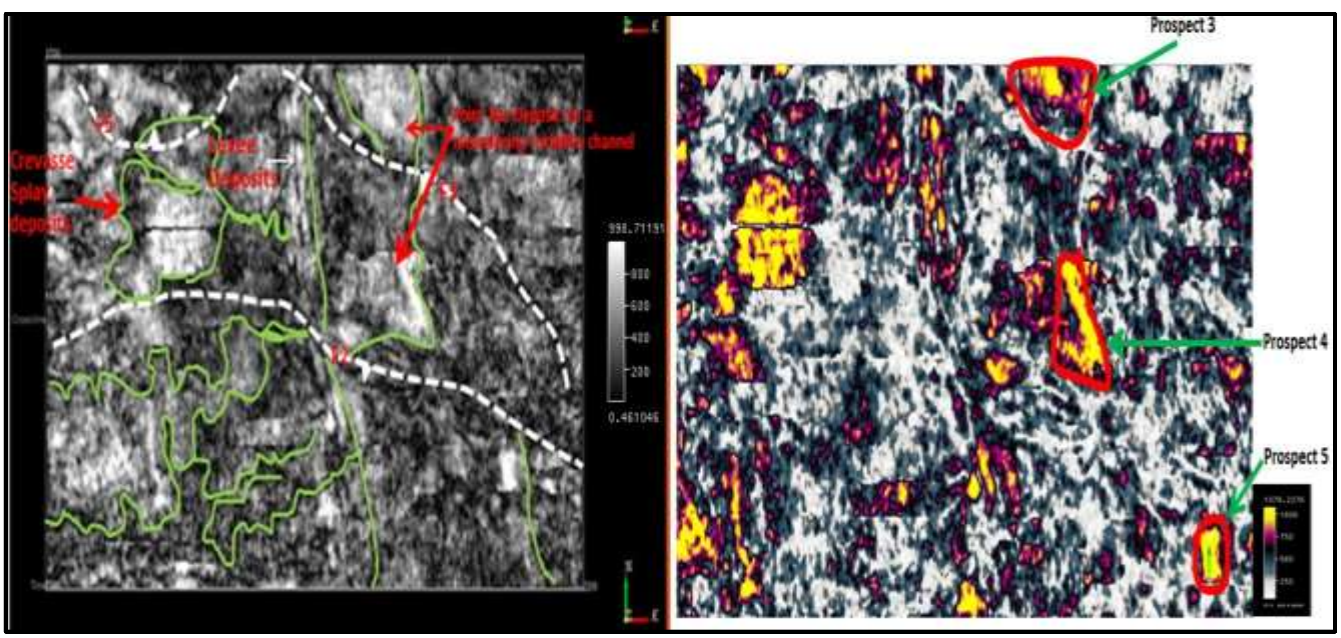

Figure 7: Seismic Geomorphology of a Maximum Flooding Surface ($MFSH_0$) beneath SBH1.

5. Conclusion

The workflow employed for this study shows that potential stratigraphic prospects can be predicted. Sequence stratigraphy interpretation of well logs and 3-D Seismic revealed five depositional Sequence with sequence one (deepest) and sequence five (shallowest) as well as composite tripartite depositional sequence which includes the LST, TST and HST. Sequence one is characterized by a meandering tubidite channel running North – South direction, which is believed to have significant potential as stratigraphic trap for hydrocarbon accumulation, a primary focus of this study. Paleo-geomorphology of sequence one revealed the presence of crevasse splays, point bar deposits, and levees which are associated with a turbidite channel. Amplitude analysis revealed the relationship between the faults and paleo-geomorphic features with hydrocarbon bearing potentials. Paleo-geomorphology was used in the imagery, interpretation and prediction of the distribution of possible hydrocarbon deposits. The technique will enhance basin reconnaissance and facilitate field development

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