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Seismic Stratigraphic Analysis Fordepositional Environment and Hydrocarbon Occurrence Appraisal using Attributes

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Abstract

Seismic stratigraphical interpretation of rock deposits has been done using migrated 3D seismic data in SEGY format. This has taken into consideration the analysis of both seismic sequences and seismic facies within the hydrocarbon reservoir of the Dongian oil block, North-east China. Methods adopted include that which identifies contacts of the upper and lower boundaries of the depositional sequences that were not absolutely correlatable. The style of the reflection patterns is discovered to be borne out of the very chaotic and dipping basement rocks. This is responsible for the arrangements of the overlying sequences which were continuous or truncated either on the basement or by the gently dipping listric fault amidst the middle portion of the sequences. In all two unconformities were observed. It was discovered that sequence 1 is the prolific reservoir and the overlying sequence 2 characterized by the sub-parallel to sigmoidal internal reflection pattern is a combination of reservoir and the seal that impedes hydrocarbon migration and makes the trapping system effective.

Keywords: Sequences, Seismic, Facies, Reflection, Reservoir, Unconformity, Correlation, Basement

1.0 Introduction

The strength and density of subsurface layers are what makes it possible for propagated waves to characterize formations in seismic survey. The study of the arrangement pattern of reflection events is what gives understanding of the explored formation, variation in depositional environment, likely fluid inclusions and assists in making a decision on the exploration philosophy to adopt for the asset. Mitchum *et al*., (1977), defined seismic facies unit as a mappable, three dimensional units composed of groups of reflections whose parameters differ from those of adjacent facies units. They also defined seismic facies analysis as the description and geologic interpretation (including environmental/depositional setting, lithofacies, etc.) of seismic reflection patterns. Seismic stratigraphic analysis is often carried out in two phases. The first is termed seismic sequence analysis, and the second is known as seismic facies analysis. Seismic facies analysis utilizes the internal arrangement and patterns of the reflections within the intervals mapped in the sequences of migrated seismic data (Catuneanu *et al.,* 2010; Catuneanu 2006). Good source rock units are also identifiable in an extensive analysis that may inculcate other data points like well logs and core samples (Rotimi, 2010). A wide variety of seismic features are used in achieving the aims of seismic stratigraphy, and such features have significances that are unique to them. Primary features on the seismic data are amplitude based that delineates significant strata surfaces. The secondary feature is reflection geometry and it is basically used in understanding the prevalent depositional processes in the time of formation of the rock units. Close to the reflection geometry is the reflection continuity that assists in understanding depositional processes but it also defines lateral continuity of strata. Wavelet frequency is also a very useful feature of the seismic property as it is significant in resolving bed thickness, and fluid content. Accurate stratigraphical analysis of seismic data is anchored on a proper understanding of the internal reflection patterns in the data. Several authors such as Mitchum, et al., (1977a,b); Vail, et al., (1977a,b); Neidell and Poggiagliolmi, (1977); Van Wagoner, et al., (1990); Norton, (1983); Ramsayer, (1979); Stone, (1983); Saggaf and Nebrija, (2000)have studied this and have it documented in AAPG memoir 26. Seismic reflection patterns are classified under stratified and unstratified. Stratified has subdivisions of simple, progradational and complex, while these three are in turn divided based on their actual local reflection patterns (Figures 1- 3). Some of these patterns when recognized on seismic data varies from one point to the other and may be separated by some sort of unconformity (hiatus) or their correlative conformities.

Figure 1: Different types of geological boundaries defining seismic sequences (After Sheriff 1980; Kearey *et al*., 2004)

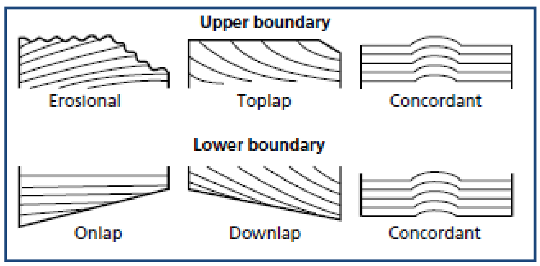


Figure 2: Divers internal bedforms that typifies different seismic facies within sedimentary sequences identified on seismic section (After Sheriff, 1980; Kearey *et al*., 2004).

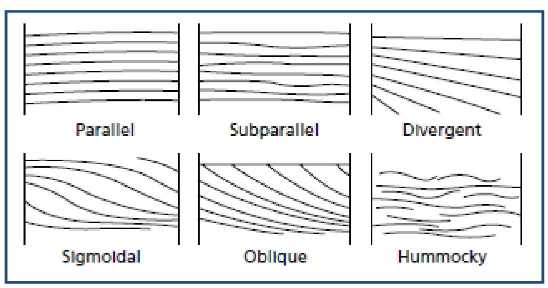
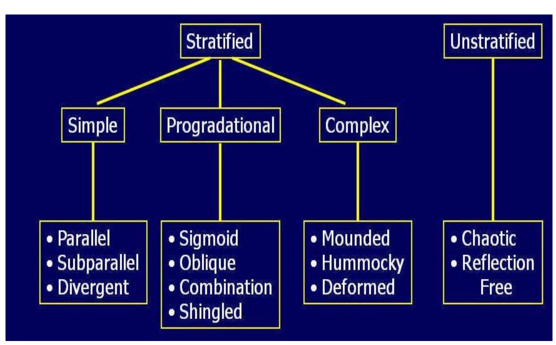


Figure 3: Classification of internal reflection patterns of seismic data (after Mitchum *et al*., 1977a)

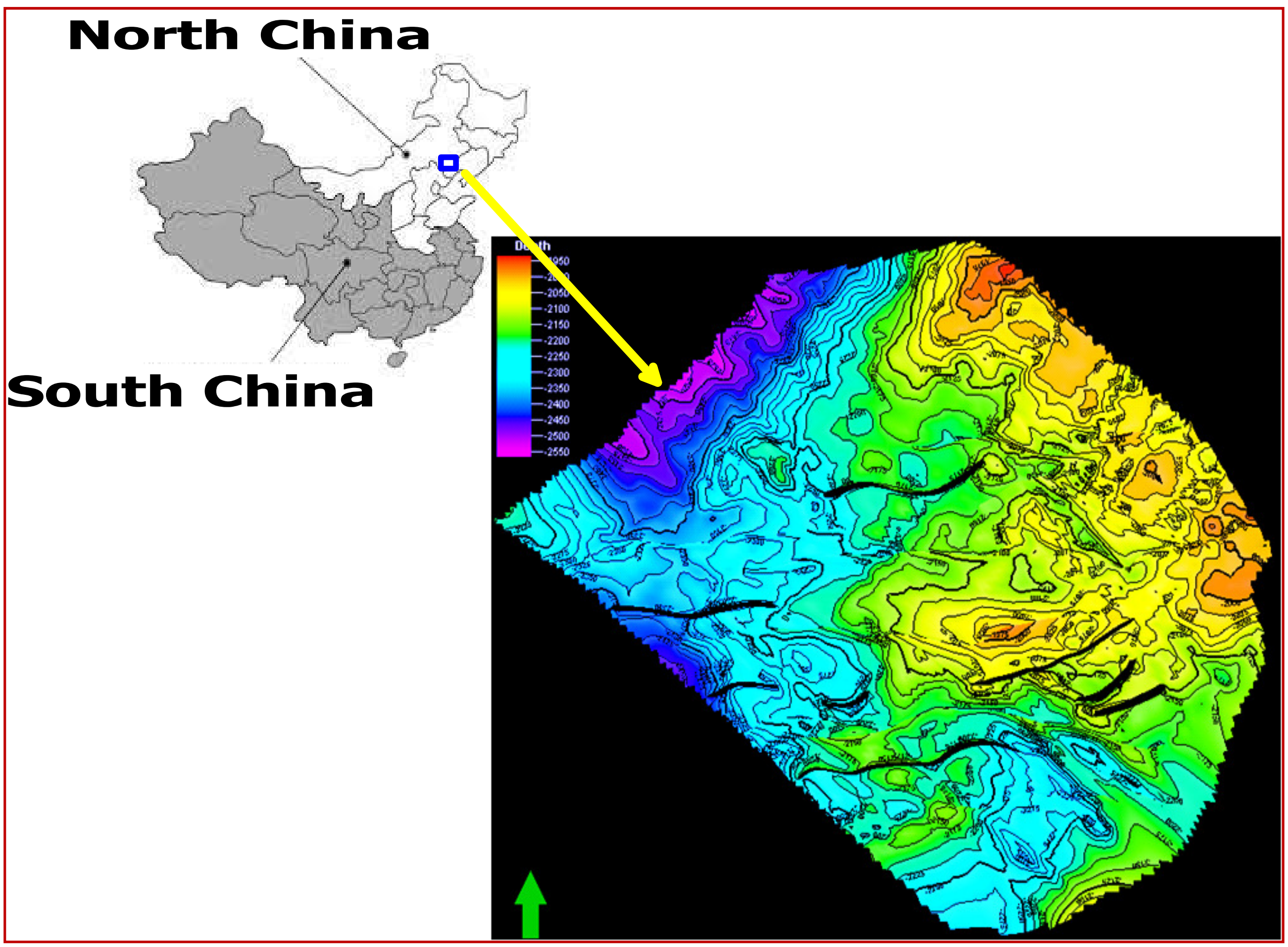


Various exploration philosophies are systematically centered on the knowledge and interpretation of seismic stratigraphy. This is because of the clearer knowledge it proffers of the arrangements and relationships of hydrocarbon bearing strata. These strata are observed to be either structurally deformed into a potent hydrocarbon trap configuration or preserved as stratigraphic trap with established porosity and permeability indices that are exploitable for economic hydrocarbon reserves. This is the premise upon which this study is based for the Dongian oilfield area.

2.0 Methodology

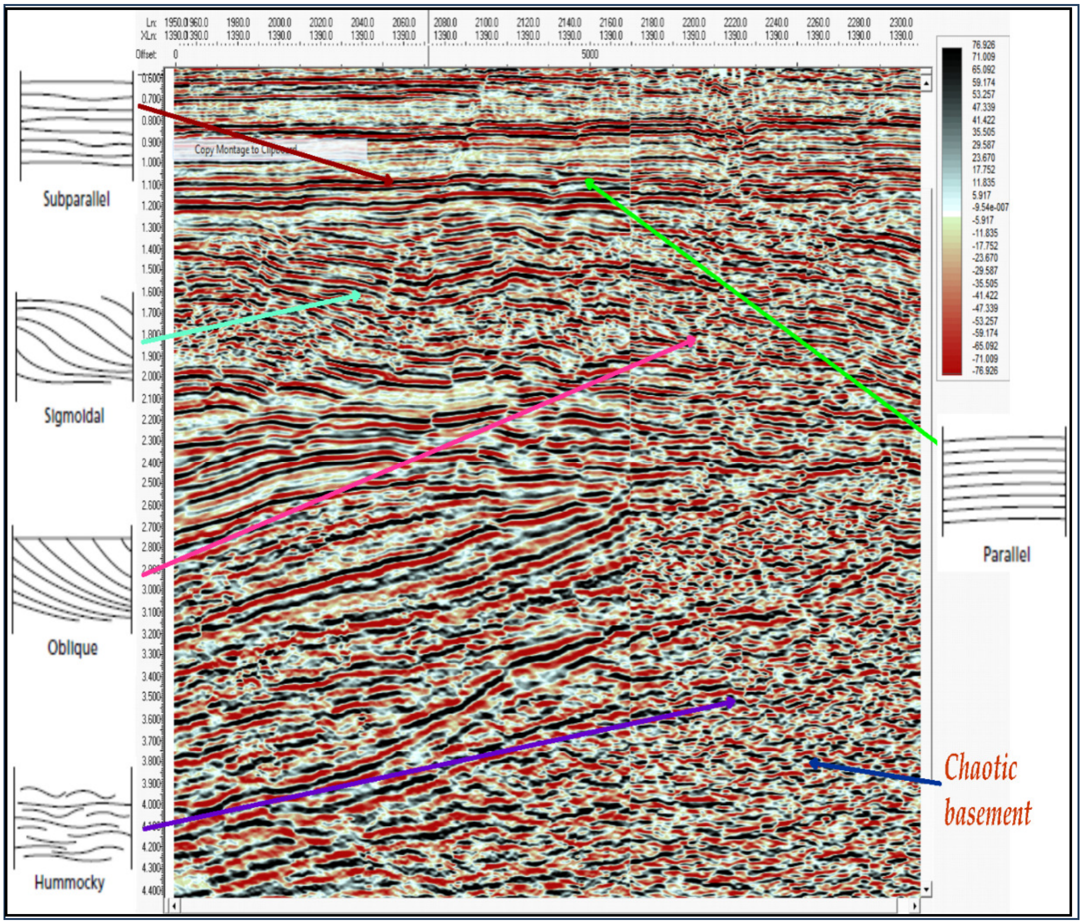
Migrated 3D seismic data in SEGY format was the main data used for this study. Seismic stratigraphic methods of analysis were carried out to better understand the stratigraphy of subsurface formations. Analyses were carefully done by observing high and low amplitude events relationship with either the top or bottom of seismic strata sequences.This approach is sequel to the opinion of Vail *et al.,* (1977b) that unconformities enveloped packages of reflectors are called seismic sequences. These foundational concepts of boundaries and sequences delineation has been utilised to analyse subsurface data from North China (Figure 4). Major sequence boundaries were identified and mapped using the reflection terminations and continuities. Key stratigraphic intervals were delineated using sequences with similar characteristics which often are bounded by unconformity surfaces. Rock types within each interval were mapped using seismic facies analysis, seismic amplitude, impedance contrast, bed spacing/tuning effects, fluid content and reflection geometry. The goal of this stratigraphic analysis and interpretation is to predict where potential reservoirs capped by potential seals are located and in what associations they are presented within the rock column that is explored.

Figure 4: Location and basemeap of Dongian field



Aside the above mentioned features, other intrinsic seismic features (seismic attributes) were extracted and computed as via various methods such as Hilbert's transform, inversion operation and property variations. Stratigraphical analysis of the seismic data was based on their actual reflection patterns (Figures 1 – 3). Figure 5 shows an example for internal patterns within sequences. Schuchert (1916), Umbgrove (1939), and Wheeler (1958, 1964) developed models and techniques foundational to defining controls on base level positions on shore lines. This marks positions of onlapping seismic reflectors and were very helpful in picking amplitude events within sequences defined.

Figure 5: Facies reflection patterns visually identified from seismic data (crossline 1390)



3.0 Results and Discussion

A closer initial look given to the reflections on the seismic data gave a general overview of the deposition pattern hidden in the seismic data. Due to the fair to moderate resolution and data trace sample frequency, sections of the data proved difficult to analyze in isolation. Starting with the upper portion of the seed seismic line - crossline 1360, the local pattern of reflection continuity and termination was determined (Figure 6). This was observed both from the boundary/bedding contacts and from internal reflection configurations. Below it are dipping reflections tapering on the underlying near parallel reflections. Unconformity occurs between the first and second sequence with an erosional surface while there exists an angular to erosional unconformity between the second and third sequence (Figure 6).Full seismic sections of crossline 1390 are marked with arrows and annotations (Figures 7 and 8) indicating directions and demarcated portions on the seismic line.

3.1 Reflection Pattern Identification

Variations in reflection pattern continuity for different facies portion are seen clearly here. The lower, middle and upper portions shows variations in reflection patterns between crosslines 1390 and 1480 for *A* and *B* respectively. The nature of the deposit makes the stratigraphic episode progradationally systematic in facies pattern as it progressively shows a mix of chaotic and poorly resolved amplitude reflection to hummocky reflection at the base of the seismic lines (figure 8).

Figure 6a: Crossline 1360 from study area (unmarked)

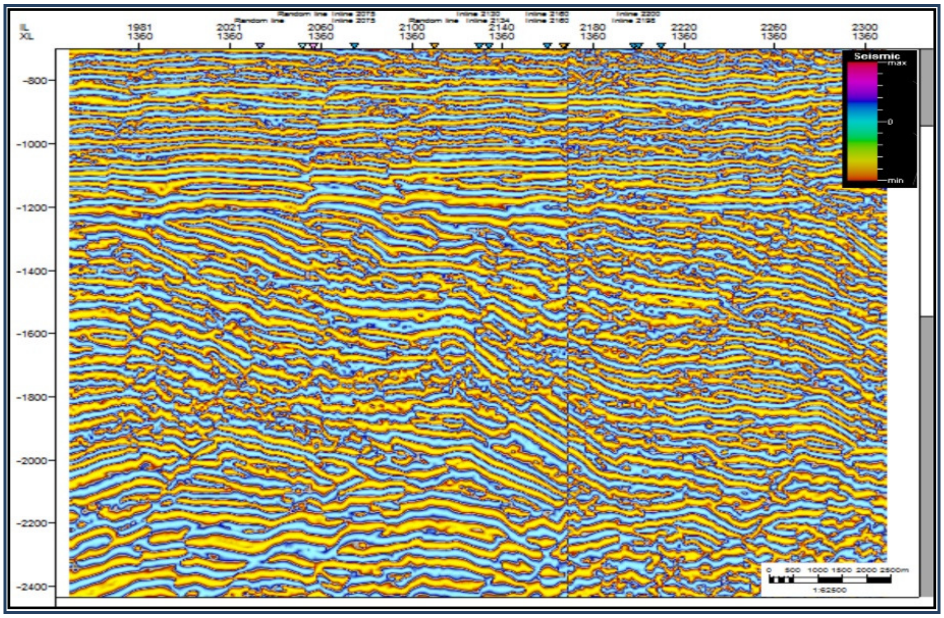
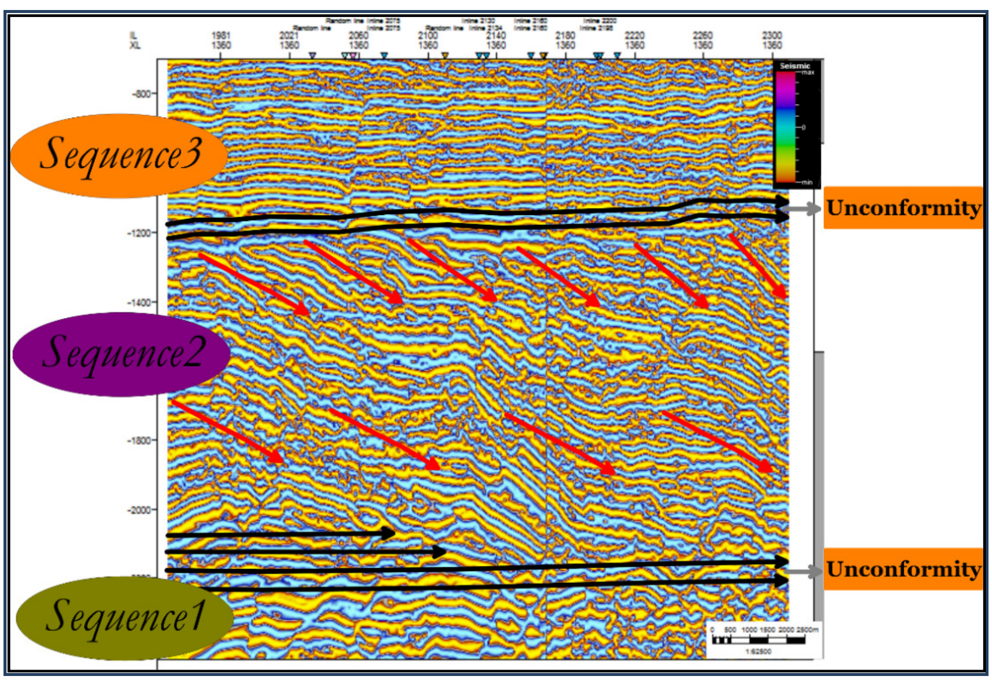


Figure 6b: Crossline 1360 with marked parallel and conformable upper reflections events of sequence1



This hummocky reflection pattern depicts clearly the basement upon which the overlying rock units are emplaced. Most of the other sequences are laid out unconformably on these fractured basement rocks and it has served as the receptacle onto which the sediments are deposited. Typically the influence of the basement on the overlying sedimentary rocks is the architectural patterns (Rotimi *et al.,* 2014). This serves as basis for the arrangement of the overlaid sequences and their internal reflections pattern. The architecture was believed also to have contributed to the development of the various stratigraphic patterns and structural associations encountered, mapped and interpreted (Figure 8). In Figure 8*(A)*, contacts markings are shown on reflections, *(B)* shows wiggles overlain clearly displaying the continuity and polarity of the reflections as each seismic sequence are delineated and separated one from another.

Figure 7: Seismic stratigraphic volume attribute showing Chaos attribute for the vintage seismic volume

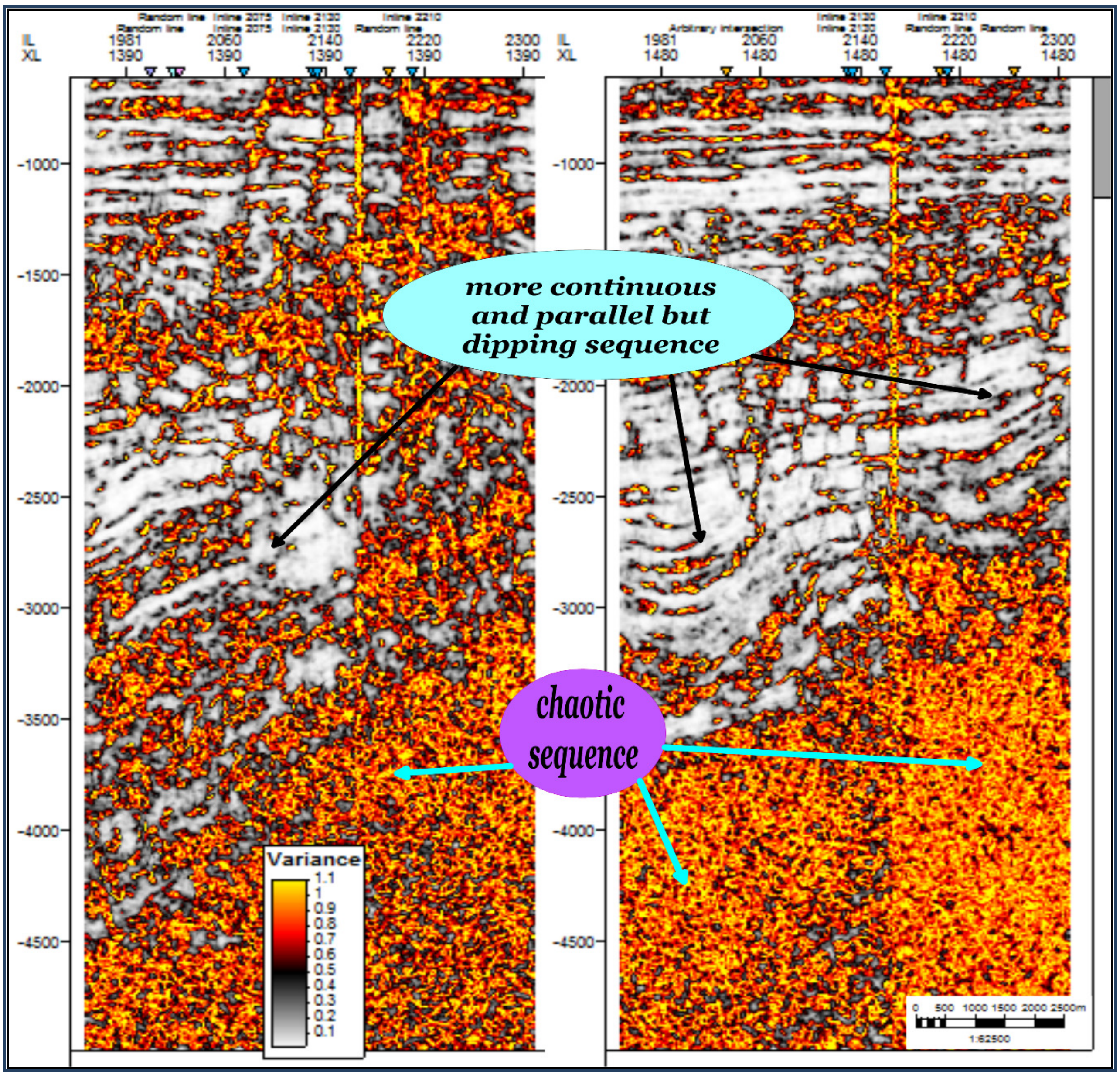
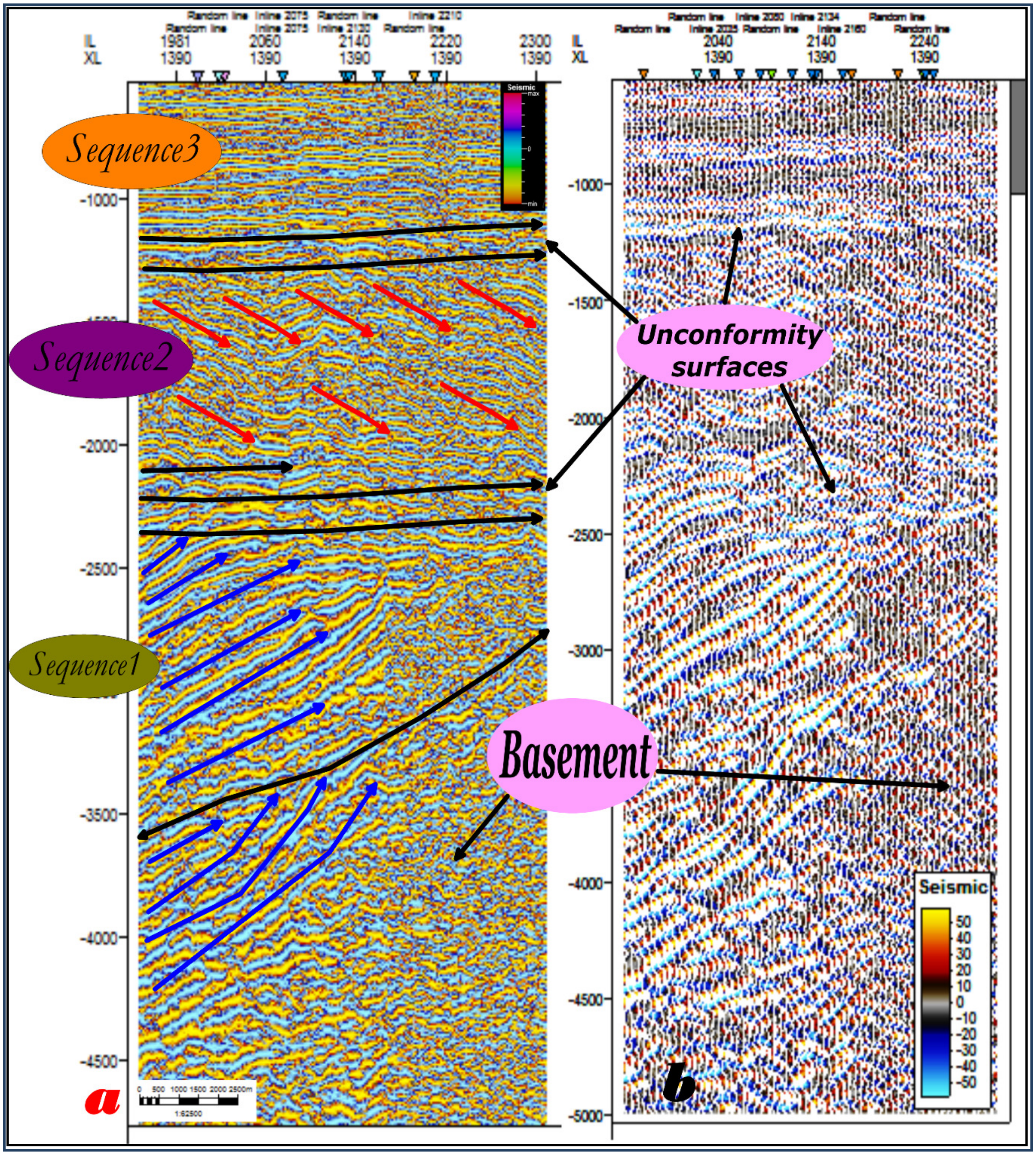


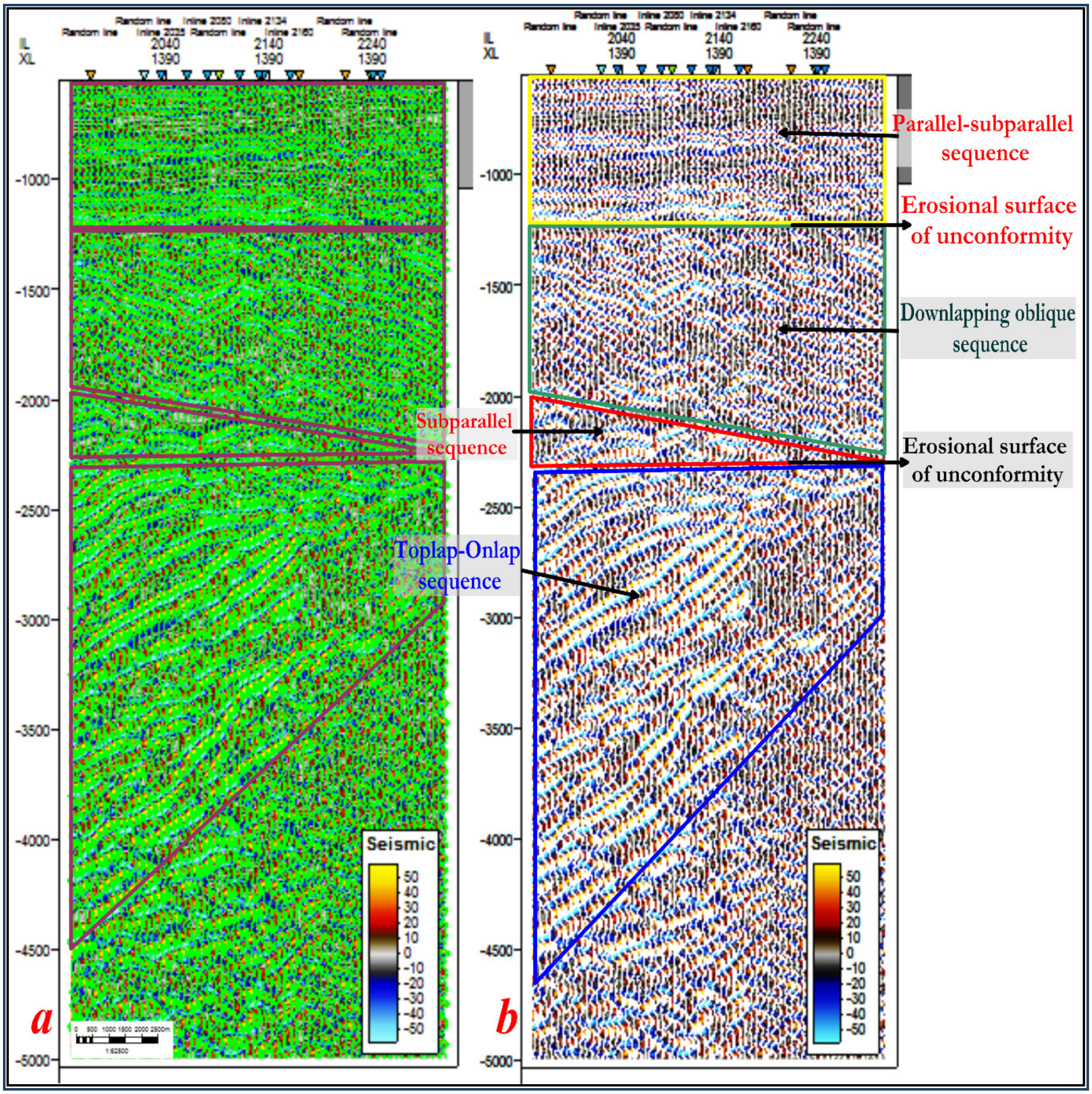
Figure 8: Crossline 1390 showing a broader view of the stratigraphy as interpreted from the reflection patterns in the study area.



3.2 Depositional Sequences

Unconformably overlying the almost featureless basement rock in the study area is the first sedimentary sequence that is characterized by an erosional top as upper boundary, an onlap pattern at the base onlapping the basement. The internal reflection (parasequences) arrangements varied between convergent to oblique reflection patterns. Figure 9 *(A)* shows contact markings in block of wedge, *(B)* shows wiggles overlain clearly displaying the boundary relationships and also the character of the internal reflection patterns. The nature of the boundary contacts is also determined. The thickness of this deposit varies from one location to another as it gets thicker progressively in the southwestern direction. Consequently, this has enforced thinness on the other overlying sequences as it appears continuously dominant with bright reflections and thick wedge shaped deposits. Overlying the first sedimentary sequence is a brief deposit-sequence two, having an erosional boundary in the upper portion and a concordant boundary at its base. The internal reflection of this sequence is sub-parallel. It is unconformably laid ontop of the aggradational sequence below it.

Figure 9: Crossline 1390 showing a broader view of the stratigraphy and sequence definitions as interpreted from the reflection patterns in the study area.



The third sequence is a combination of reflection patterns farther in the southern direction. It tappers with the short underlying sequence and gently obscures the effect of the interval with distance. On some other lines (lines beyond crossline 1390), the third sedimentary sequence is seen to directly overlay the first sedimentary sequence. Sequence three has its upper boundary depicted by toplap and lower boundary depicted by down lap either on the thin underlying sequence or in some instances merging unconformably with the sequence one (around crossline 1480). The internal reflection pattern varies between divergent to hummocky. This sequence can be said to have truly preserved the character of the turbidite deposits formed by turbidity current on the area. Intercalations of sand and shale sequences typical of the turbidite sequence of the alluvial fan deposit in this area is more preserved here than in other sequences. Although in some region solitary shale deposits are seen as interfile on some of the sequences. The fourth sequence that caps the whole rock succession is characterized by dominant and continuous reflections that span the whole extent of the survey. The deposit has a character that is in close resemblance to shingled bedform of a near shore environment. The upper and lower boundary of this sequence has a concordant character with the internal reflection patterns exhibiting parallel to sub-parallel relationships (Figure 9). Proposed environment of deposition for the field of study ranges between marginal marine deposits characterized by toplap in sequence four to the alluvial fan beach sand (shingled beds) in the sequence one. Within these there is possibility of fluvial to non-marine wedge deposits of sequence three with divergent reflection patterns and the transition (terrestrial-marine) post-hiatus deposit of sequence two (Figures 7 and 9). It is believed that potential reservoirs are the deposits of sequence 1 and also part of the interbeded deposit of sequence 2. Both are aggradationally capped by potential seals of sequence 2 located in the middle of the depositional sequence of the seismic 3D volume. These deposits can be explored employing the specific expertise and philosophy which handles the peculiarity of facies sequences.

4.0 Conclusion

Two unconformities and three sequences have been delineated via the analysis of high resolution amplitude and impedance contrast of the seismic reflection event in the study area. The volcanic basement substrate made the overlying deposits characteristically unique within each bounding unconformities. Lateral continuity and terminations has been mapped by identifying onlaps, downlaps, toplaps and truncations. Sequence 3 is the topmost with predominantly parallel reflection events having little faulting episodes. Sequence 2 appears as a deposit of more continuous sub-parallel sequence with intercalations of clastic and argillaceous deposits serving as the cap rock while sequence 3 is the reservoir deposit. The character of sequence 3 is more of a gently dipping continuous oblique deposit that rests unconformably on the basement. Sequence 3 is the target of exploration in this area and is proven from further studies to be hydrocarbon prolific.

Acknowledgements

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