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PS Architecture of Deep Water Lacustrine Fans Fed by Multidirectional Clinoforms in Dacian Basin, Romania*

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Abstract

The models for lowstand and highstand basin floor fans are well known from multiple studies. In this study an additional complexity is added to basin floor fan architecture where sediment is fed to basin floor from multiple directions. Late Miocene clinoforms (300-450 m height) are easily recognized in 3-D seismic of western Dacian Basin, a para-Tethys basin in Romania. The clinoforms are more difficult to recognize in well logs, but in seismic data a 100-150 m thick lower interval with coarse sandy deposits overlain by 150-200 m thick muddy deposits and capped by 50-100 m thick sandy deposits, is well imaged. Depositional systems on shelf, shelf edge, slope and basin floor were mapped on seismic data and also recognized on well logs. The Dacian Basin was a closed basin with clinoforms prograding from multiple directions toward its center. 3-D seismic combined with five strike-oriented and two depositional dip-oriented well cross-sections are the main tools to investigate basin floor fans architectures. SP and resistivity logs of some 400 closely spaced (~300 m) wells have been correlated over an area of thick basin floor fans. The overall fan thickness is >200 m and the fans can be followed on the seismic data for hundreds of kilometers. The fans are composed of 10-30 m thick sandstone units interpreted as fan lobes. The lobes have complex sandstone distributions with coarsening or thinning upwards, blocky or ratty log patterns suggesting variable facies. Individual lobes extend from the lower slope and onto the basin floor. In the 'distal' area of one of the clinoforms the fans have thicker sandstone as these represent lobes formed by sediment shed from a different segment of the basin margin. Multiple directional deep water fans coalesce to create thicker than normal sandstone bodies but with complex internal architecture. We are able to document sandstone lobes with different orientation and variable thicknesses through time, as these are linked with variable rates and directions of basin margin progradation. As a consequence, new plays and prospects with unusual fan configurations are described. There are no recognized hydrocarbon deposits in the described fans but elsewhere in the basin, equivalent age deposits form reservoirs.

1. Abstract

The models for lowstand and highstand basin floor fans are well known from multiple studies. In this study an additional complexity is added to basin floor fan architecture where sediment is fed to basin floor from multiple directions. Late Miocene clinoforms (300-450 m height) are easily recognized in 3-D seismic of western Dacian Basin, a para-Tethys basin in Romania. The clinoforms are more difficult to recognize in well logs but in seismic data a 100-150 m thick lower interval with coarse sandy deposits overlain by 150-200 m thick muddy deposits and capped by 50-100 m thick sandy deposits, is well imaged.
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Multiple directional deep-water fans coalesce to create thicker than normal sandstone bodies but with complex internal architecture. We are able to document sandstone lobes with different orientation and variable thicknesses through time, as these are linked with variable rates and directions of basin margin progradation. As a consequence, new plays and prospects with unusual fan configurations are described. There are no recognized hydrocarbon deposits in the described fans but elsewhere in the basin, equivalent age deposits form reservoirs.

2. Location

Dacian Basin is the area between south of Lower Danube River to the Souther Carpathians and to the east of the Eastern Carpathians bend zone. It's bounded to the west by the arc-shaped mountains at the transition between the Capathians and the Balkans Mts. Dacian Basin is separated from the Black Sea by the Dobrogean high. Therefore, the Dacain Basin is almost surrounded by mountains and also source of sediment. (Jipa & Olariu, 2009) (Figure 1 & 2)

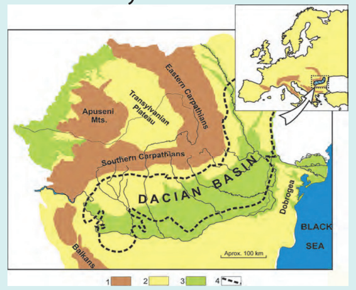


Figure 1: Dacian Basin location on the physical map of Romania
Legend: 1. Highland relief 2. Hilly relief 3. Lowland relief 4. Dacian Basin outline during Maeotian (Jipa & Olariu, 2009)

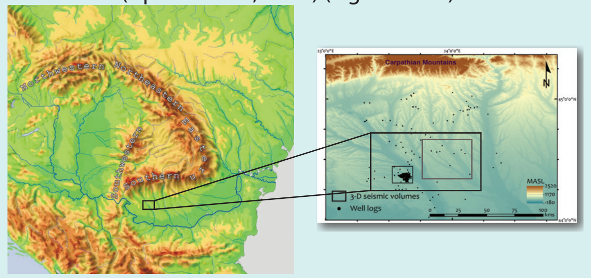
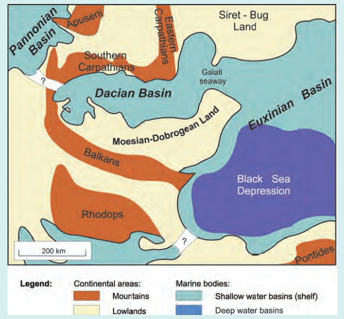


Figure 2: Study area with seismic cubes and wells

3. Geological Setting

Dacian Basin is a foreland basin that formed in the Middle Miocene (Sarmatian) by the closure of the Neotethys Ocean. The Dacian Basin was isolated from Pannonian Basin by Danube Gateway and from Euxinian/Black Sea Basin by Galati Seaway (Figure 3). Since Dacian Basin was seperated from Black Sea at times, the eustatic effect can be ignored. The main keys that drive accomodation are tectonic subsidence and lake water volume. Therefore, Dacian Basin is a closed source-to-sink system without any sediment transfered to Pannonian and Black Sea Basin. Although many works have been done in this basin, the chronostratigraphic and geochronologic framework has not yet been achieved. (Figure 4)

Figure 3: The Paleogeographic context during the Early Maeotian of the Dacian Basin (Jipa & Olariu, 2009)



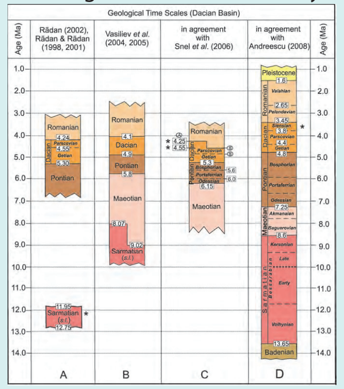


Figure 4: Chronostratigraphic and geochronologic framework of the Dacian Basin as inferred from published studies (Jipa & Olariu, 2009)

4. Previous Work

Fong-ngern et al. (2015) did clinoforms mapping in seismic cube A (Figure 5) that shows 400 m thick prograding clinoforms from northeast to southwest (Figure 6). The age and depositional environment of clinoforms are interpreted in Figure 7. The seismic amplitude maps of these clinoforms indicate coarser-grained in hot colors and finer-grained in cool colors (Figure 8). According to the amplitude maps, most of the coarse-grained deposited on shelf in deltas and basin floor in basin floor fans.

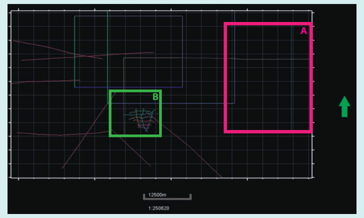


Figure 5: Seismic cube A is the main study area of the previous study done by Fong-ngern et al, 2015. In this study, the focus area is located in seismic cube B.

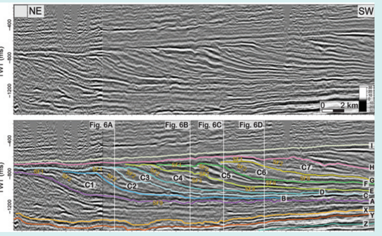


Figure 6: Uninterpreted (above) and interpreted (below) dip-oriented cross-sections of studied clinoform interval by Fong-ngern et al, 2015 includes seven clinothems (C1–7) between bounding surfaces (BS) A–H. Clinoforms prograde fron northeast to southwest direction.

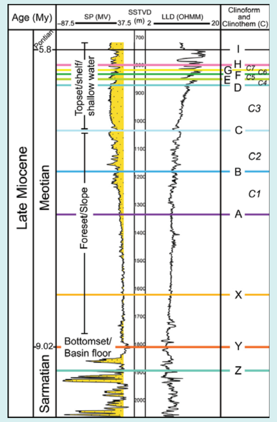


Figure 7: Mapped seismic horizons with age and depostional environment (Fong-ngern et al, 2015)

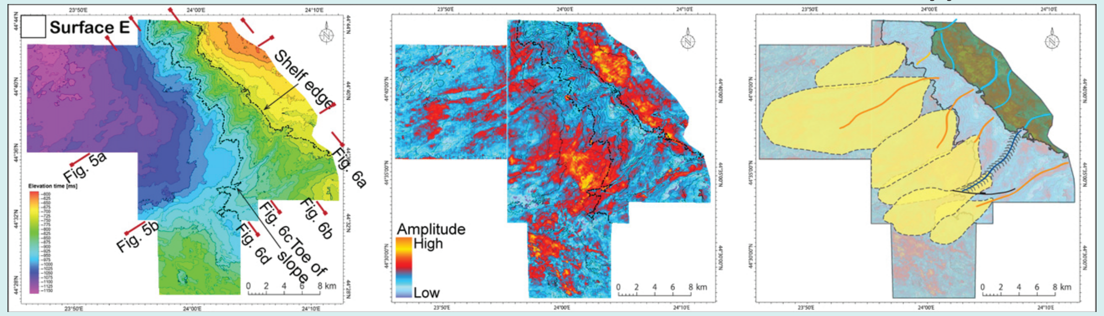
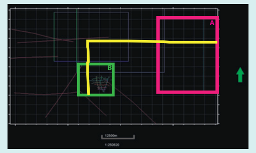


Figure 8: Time-structure (left), amplitude (middle) and geomorphological interpretation (right) maps of clinoform E which considered as the base of basin floor fans in this study. The dashed lines represent shelf edge and toe-of-slope. The high amplitude or warm color tones represent coarser-grained deposit than the low amplitude or cool tones. (Fong-ngern et al, 2015)

5. Objective

The objective is to **use well logs to characterize multiple directions fed basin floor fans**. The different well logs patterns define variable depositional facies. Furthermore, this study aims to find **a relationship between the direction of sediment feeding and facies distribution in each fan lobe**.

In this study, the seismic arbitrary line (Figure 9) is extended to cover the area on the western side (seismic cube B) so the bottomsets of the clinoforms are emphasised. The bottomsets of clinoforms are posted on well section and confirm the present of basin floor fans that fed by prograding clinoforms (Figure 10).



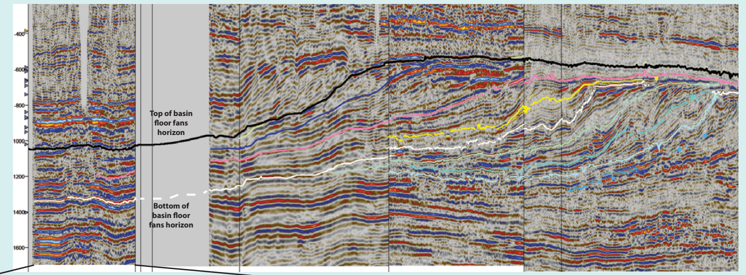


Figure 9: Left: Seismic arbitrary line (yellow line) from seismic cube A to seismic cube B. **Right:** Top of basin floor fans horizon is interpreted in black and the bottom of basin floor fans is in white. This seismic line shows that the basin floor fans are the part of bottom-sets of westward prograding clinoforms.

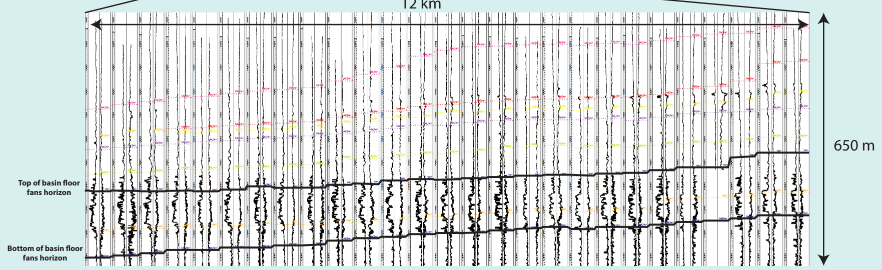


Figure 10: Top and bottom of basin floor fans horizon posted on well section inside seismic cube B.

6. Methodology

Nine well sections consiting of 217 wells are correlated throughout the seismic cube B (Figure 11). Well correltation is based on flooding surface which is defined by present of shale and characteristic of well logs. Seventeen flooding surfaces are correlated and used as a boundary of each fan lobe (Figures 12 and13).

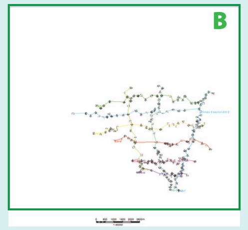


Figure 11: Correlated well sections inside seismic cube B.

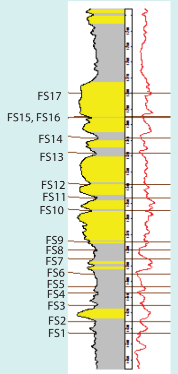


Figure 12: Example of flooding surface characteristics. Foolding surfaces are picked based on shale layers and well logs characteristics.

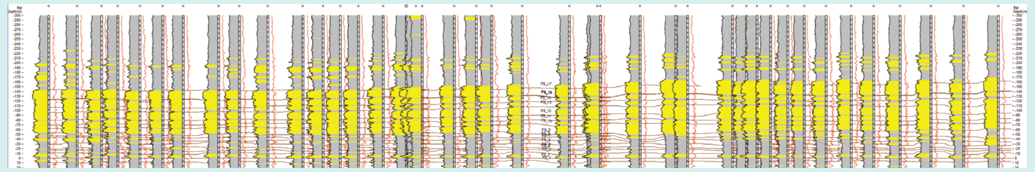


Figure 13: Example of well correlation using flooding surfaces

Isochore, net sand thickness and net to gross maps are generated (Figure 14). Net sand maps are used to determind the direction of sediment feeding in each fan lobe. The proximal part of the fan should have thicker sand then distal part. Finally, the well logs are posted on net sand map to identify facies distribution on fan lobes.

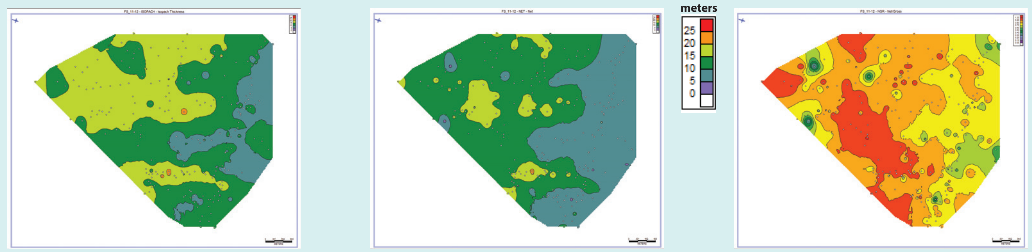


Figure 14: Example of isochore map (left), net sand map (middle) and net to gross map (right) The warm colors represent thicker thickness or higher net to gross ratio than cool colors.

The main study area is located in seismic cube B which has the most well control. The seismic horizon of top and bottom of thick sandy part which is considered to be basin floor fans are interpreted throughout in that cube in order to investigate the regional distribution of basin floor fans. These two horizons are extended into seismic 2D lines around study area to look for clinoforms feeding from another direction (Figure 15).

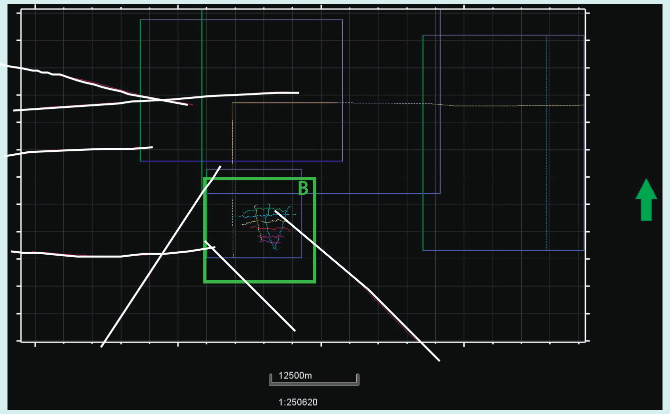


Figure 15: Location of seismic cube B and 2D seismic lines which are marked in white.

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PTTEP

7.1. Result - Correlation Sections

Well correlation is based on flooding surface. Seventeen flooding surfaces are defined using SP and resistivity log. The oldest flooding surface is FS 1 and the youngest flooding surface is FS 17. Some features are highlight as arrows on well section to emphasize the log characteristic of fan lobe (Figure 16).

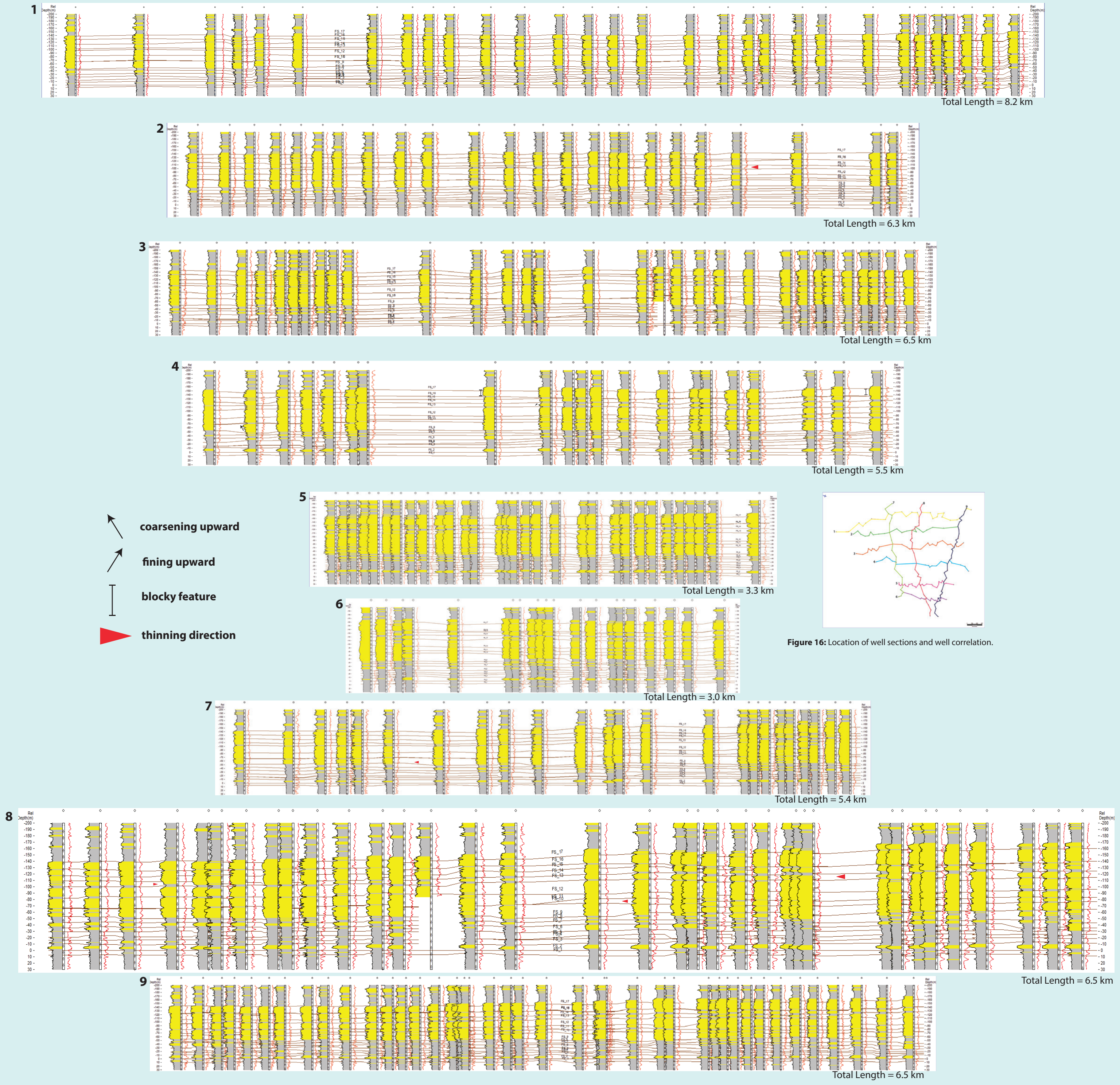

Figure 16: Location of well sections and well correlation.

7. Result - Maps

Isochore maps and net sand thickness maps are generated for each fan lobe between two flooding surfaces (Figures 17, 18). Isochore and net sand thinkness show similar trend. The direction of sediment feed is also interpreted using net sand maps. The arrows are represent the feeding direction. Each fan lobe has diferrent feeding direction that can be happened due to Dacian Basin are surounded by mountain belts and the clinoforms prograde from multiple directions.

Isochore Maps

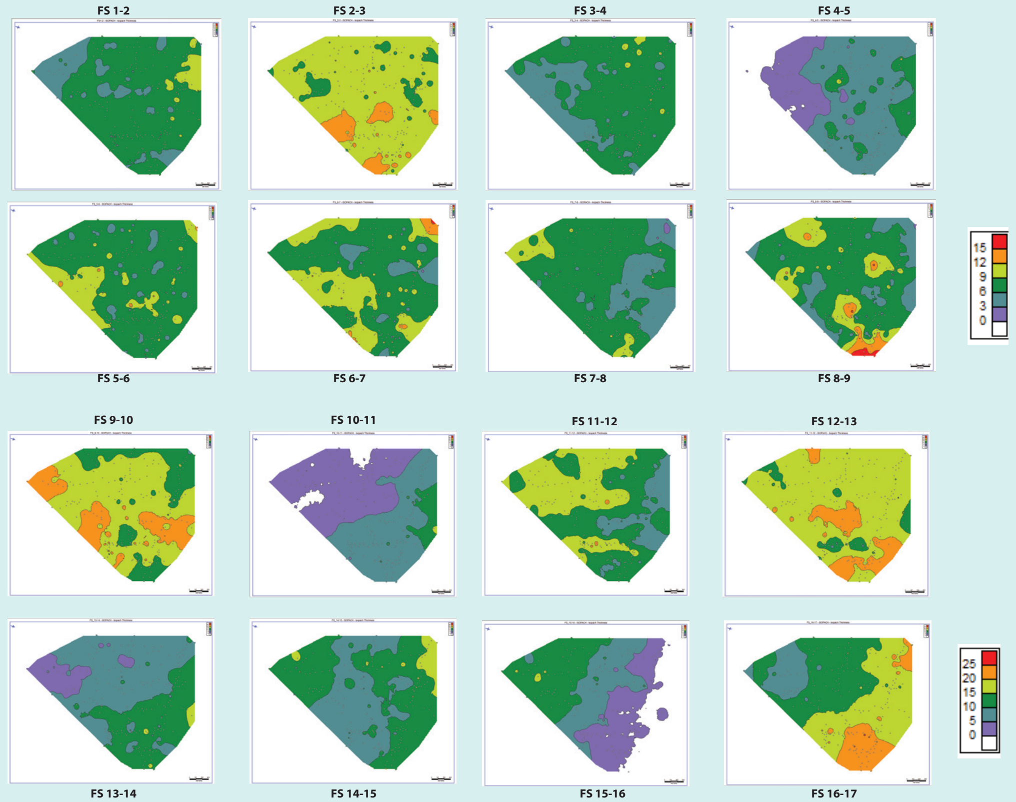

Figure 17: Isocorce maps of fan lobes. The warm colors represent thicker interval than cool colors. Fan lobes between FS 1 and FS 9 are inside shaly interval and relatively thin so the scale of isochore maps is ranged from 0 to 15 m with 3 meter of contour interval. However, fan lobes between FS 9 and FS 17 are sandy and relatively think so the thickness scale ranges from 0 to 25 meter with 5 meter of contour interval.

Sand Thickness

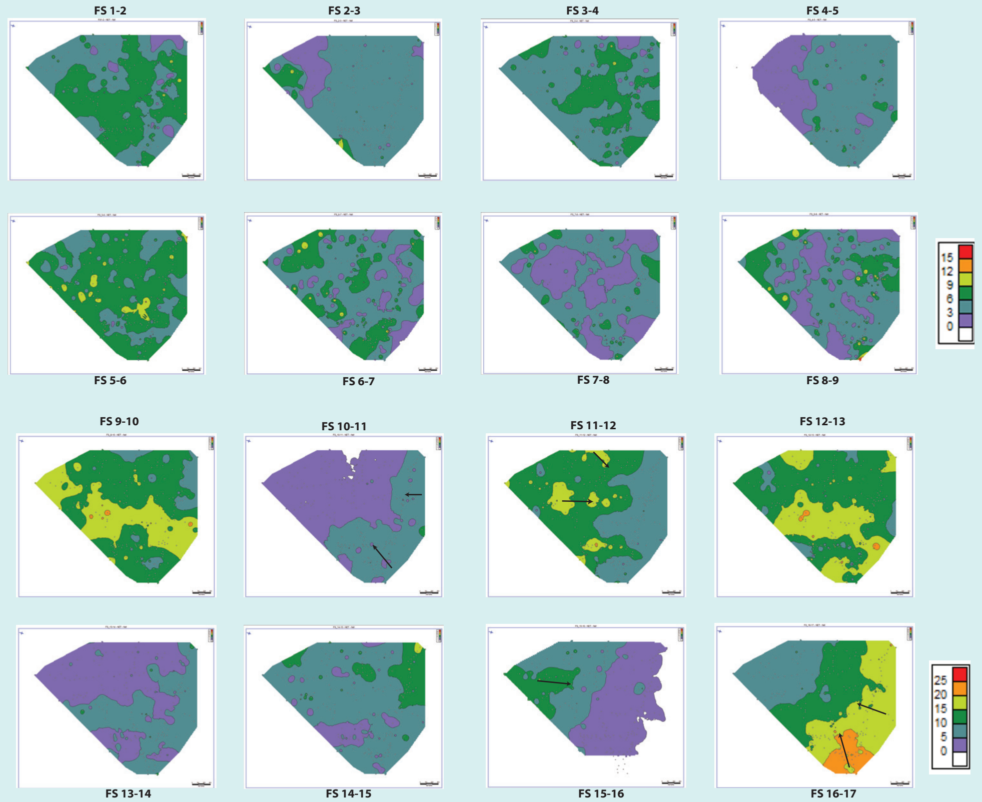

Figure 18: Sand thickness maps of fan lobes. The warm colors represent thicker sand than cool colors. Fan lobes between FS 1 and FS 9 are inside shaly interval and relatively thin so the scale of sand thickness maps is ranged from 0 to 15 m with 3 meter of contour interval. However, fan lobes between FS 9 and FS 17 are sandy and relatively think so the thickness scale ranges from 0 to 25 meter with 5 meter of contour interval. Arrows represent direction of sediment feed by assuming that thicker sand deposited in more proximal part of fan lobe.

Well logs characteristics are overlaid on net sand map (Figure 19) shows various log characteristic in different part of fan lobe. The future study will try to interpret sub-depositional environment on fan lobe by these characteristics. The shape of fan lobe and sand distribution are also considered to be a part of this interpretation.

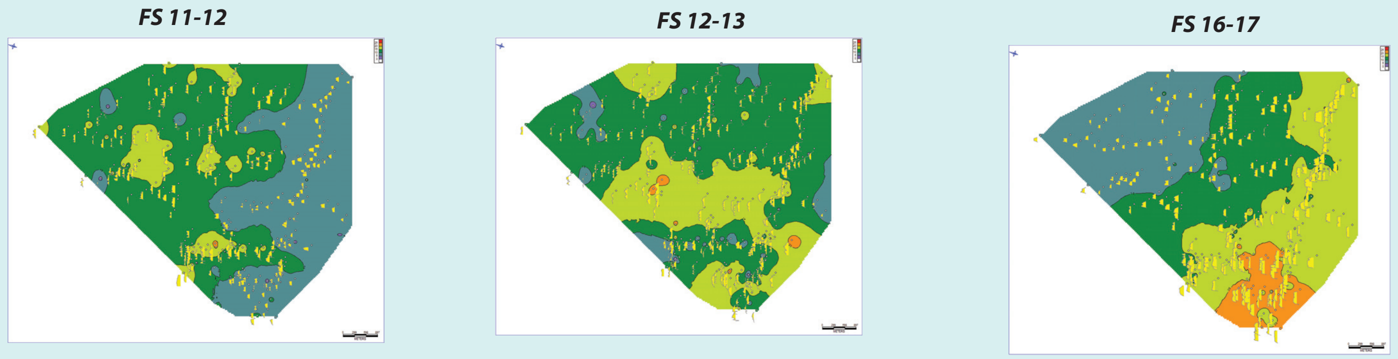

Figure 19: Well logs characteristic maps of fan lobe between FS 11-12, FS 12-13 and FS 16-17 indicate that log characteristics vary with sand thickness.

8. Conclusion

The present of clinoforms suggest that the stratigraphy is not layer cake model in this basin. Seismic and well logs confirm that the Dacian Basin is a closed source-to-sink sediment system with clinoforms prograding from multiple directions toward the center. The thick bottomsets (basin floor fans) are the result from meagre topsets and a strong shelf edge progradation. The overall fan thickness is over 200 m and the fans can be followed on the seismic data for thousands of square kilometers. The fans are composed of 5-25 m thick sandstone units interpreted as fan lobes. The lobes have complex sandstone distributions with coarsening or thinning upwards, blocky or ratty log patterns suggesting variable facies and depositional elements. Some peculiar fan geometries might emerge such the observation that in the 'distal' area of one clinoform, the fans have thicker sandstone as these represent lobes formed by sediment shed from a different segment of the basin margin. The amalgametion of fan lobes are expected to present in any closed source-to-sink basins.

9. Discussion

Top of basin floor fan are marked in black and bottom of fans are in white. Seismics lines show clinoforms prograded from multiple directions as marked by yellow arrows. The relative age of clinoforms are defined in seismic section that show more than one direction of prograding. In seismic line B, clinoforms prograde from both west and east side but clinofroms from the west are overlying on clinoforms that progrded from east side. Therefore, we assume that the relative age of clinoform are 1, 2 and 3 chronologically (Figure 21). Figure 22 shows amalgamation of bottomsets of clinoforms in seismic line B and the schematic drawing of amalgamated clinoforms.

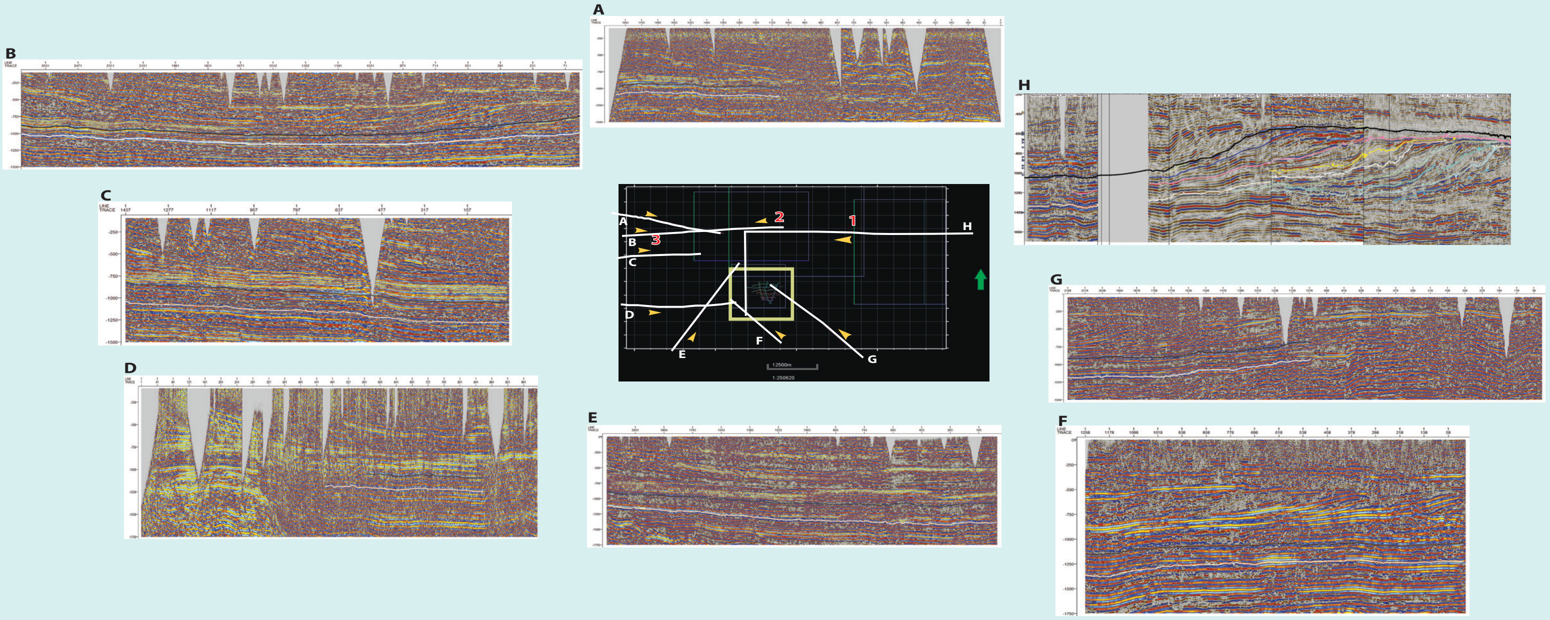

Figure 20: Seismic 2D lines are interpreted around study area (green rectangle). Multiple directions of prograding clinoforms are presented in these seismic lines. Yellow arrows represent the direction of prograding clinoforms based on 2D line.

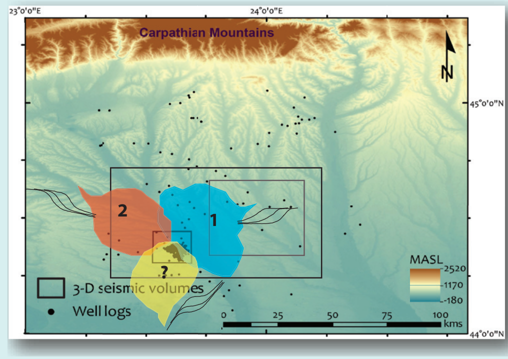

Figure 21: Schematic diagram of relative age of clinoforms based on the amalgamation of clinoforms. The overlying clinoforms tend to be younger than underlying clinoforms. In seismic lines that have only one direction of prograding clinoforms, the relative age of basin floor fan is still skeptical.

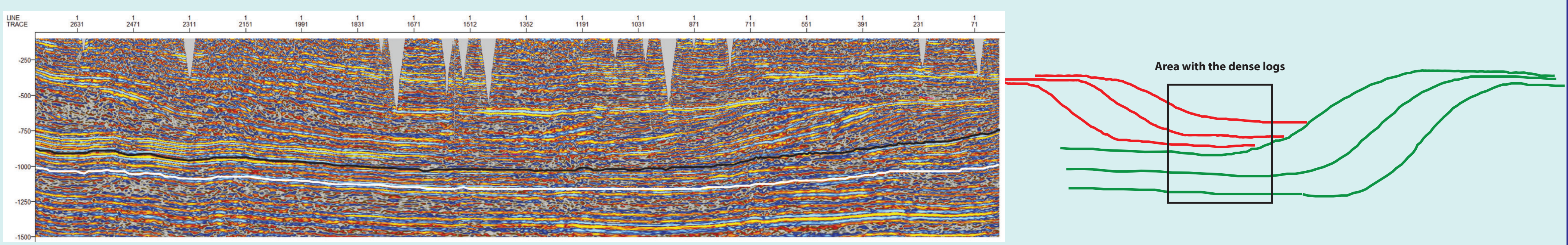

Figure 22: Seismic lineand schematic drawing of amalgamated bottomsets of clinoforms. The black box emphasize the area with highli amalgamated and cause the relatively thick bottomsets when compares to clinoforms size. The study area is also located in this setting.

10. Acknowledgement

We would like to thank OMV Petrom for data and cooperation, PTTEP for financial support of the main author.