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Seismic Stratigraphic Analysis of the North Apsheron Trend

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Abstract
The Caspian Basin"s structural settings are – compared to the Southern Caspian Basin – less complex. Except for the Apsharon trend, which is a prominent overall anticlinal structure with an eastward dip of its axis, the area of investigation comprises a major northwest-southeast trending syncline and thus exhibits very limited structural potential. Structural closures are limited to the Pre-Cretaceous levels only which so far have not been tested by wells in the offshore. The Cretaceous forms anticlinal structures along the Apsharon trend. These structures appear open up-dip to the northwest with a potential culmination in the shallow water area not covered by the seismic data available. Wells on the Apsharon trend reaching the Cretaceous did not encounter a reservoir so far.

The better potential is supposed to be related to stratigraphic traps. Overall three plays are defined based on the seismic stratigraphic analysis:

***Cretaceous reef play:** Within the Cretaceous, there are good indications for buildups along a trend close to the Turkmenistan border. The definition of structural closures along the trend or potential up-dip pinch-outs along the trend requires further investigations [reprocessing] and a denser seismic grid to outline.*

***Pontian highstand delta:** The Pontian highstand delta identified in the centre of the study area is interpreted from the progradation reflection pattern and can be reasonably well delineated as a progradational body with some slumping of distinct lateral extend. The Pontian Unconformity in the area east of the incised Paleo-Volga river and north of the delta is characterized by high amplitude becoming weaker again to the N. This area can be referred to as the delta plain area on the Pontian shelf with a high probability of reservoir-quality sands.*

***Productive Series Onlap/Pinch-out Play:** With rising lake level in the South Caspian Basin the Central Caspian Basin was continuously flooded and the pre-existing relief [incised valleys, synclinal trough] became again an area of sedimentation. The relevant formations show northward onlap pinch-outs, the Pereryva pinch-out as the probably most promising reservoir was mapped in detail. The onlap positions of the higher Productive Series as well may represent further exploration potential, a detailed review of these pinch-outs.*

Keywords: Central Caspian, Apsheron Trend, Seismic Stratigraphy, Stratigraphic Traps

1. Introduction

The north of the South Caspian"s Apsheron Sill is different from the southern area in terms of structural settings and structural development and thus as well in terms of its depositional history. Major parts of the Tertiary deposits in the South Caspian Basin were transported through this area by the Paleovolga River. The Paleo-Volga bypassing the Central Caspian and the Paleo-Volga channel delivered the most mature sand content from the drainage of the Russian Platform, in contrast, the Kura system provided more lithic silty sands with more ductless derived from the Caucasus Compared to the basin South of the Apsheron trend it was subject to limited subsidence only and thus represents the "transition zone/shelf area" for the South Caspian Basin. Fluctuations of relative lake level during Tertiary, therefore, are documented mainly here as the area fall dry and was subject to deep erosion during periods of lowlands of the lake level. Deposition on the other hand was mainly limited to periods of relative lake-level highstand and transgressive systems tracts. This paper aims to provide a detailed seismic sequence analysis not only for the Tertiary but as well for the Mesozoic series as well [1].

1.1. Database

The study area was limited mainly to the area North of the Apsheron Sill. The geophysical database consisted of a 2D seismic data set over this part of the Caspian Sea in 1996 with a 2D line grid spacing of predominantly 10 km. Only near the Apsheron Bank prospect, and at the northern edge of the data set near the Yalama offshore block did the 2D line spacing have a grid of 5 km [fig. 1]. The total line km in the northern part amounted to around 8020 km.

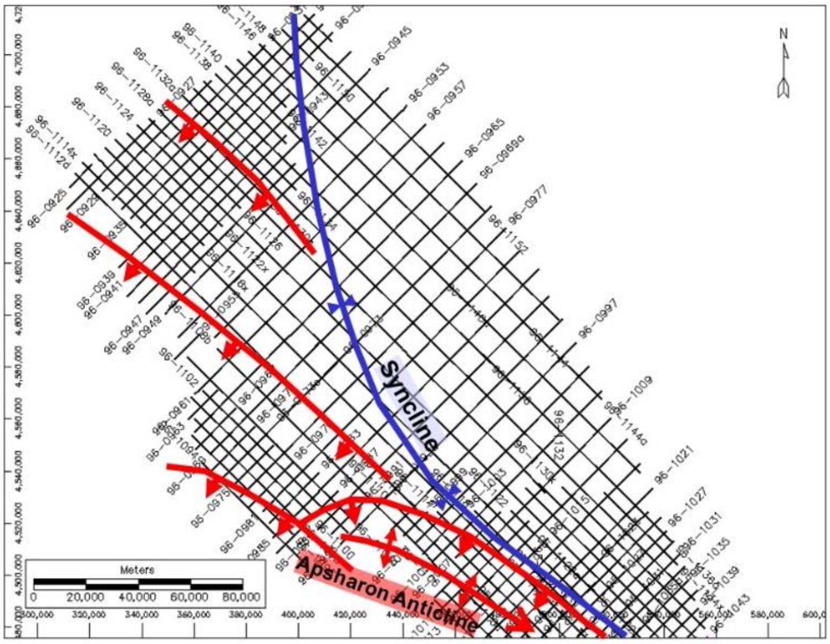

Figure 1: Geophysical Database, Structural Overview

The area was subject to exploration to a very limited extent only, well information is related to the Apsheron trend only. A few wells only reached the Pre-Tertiary sequences and supplied limited information on the Cretaceous. Offshore deeper levels were not drilled. The wells were of limited use for seismic to well tie as the complexity of the structural settings results in insufficient imaging by the 2D seismic available. No well was drilled in the remaining area, most likely because of a lack of prominent anticlinal structures.

1.2. Interpretation

Some of the previous studies suggested that the South Caspian basin is Jurassic and is overlined by Cretaceous volcanic rocks. However, despite the relatively large amount of earlier geophysical investigations of the South Caspian Sea region, the thickness and structural style of deformation of the sedimentary section as well as the crustal thickness and affinity remain equivocal [2]. Particularly north Apsheron trend zone's structural feature of South Caspian is less studied due to complications of tectonics [3].

In our interpretation, the deepest horizon which we picked is a prominent angular unconformity regarded to represent approximately Base Jurassic. Below this unconformity, local packages of steeper dipping reflections are observed [figs. 2, 3]. They represent sediments being preserved in half-graben-type structures interpreted to belong to an older rift system. In major parts of the area, however, this level appears almost reflection free or is affected by multiple reflections only obliterating primary reflections.

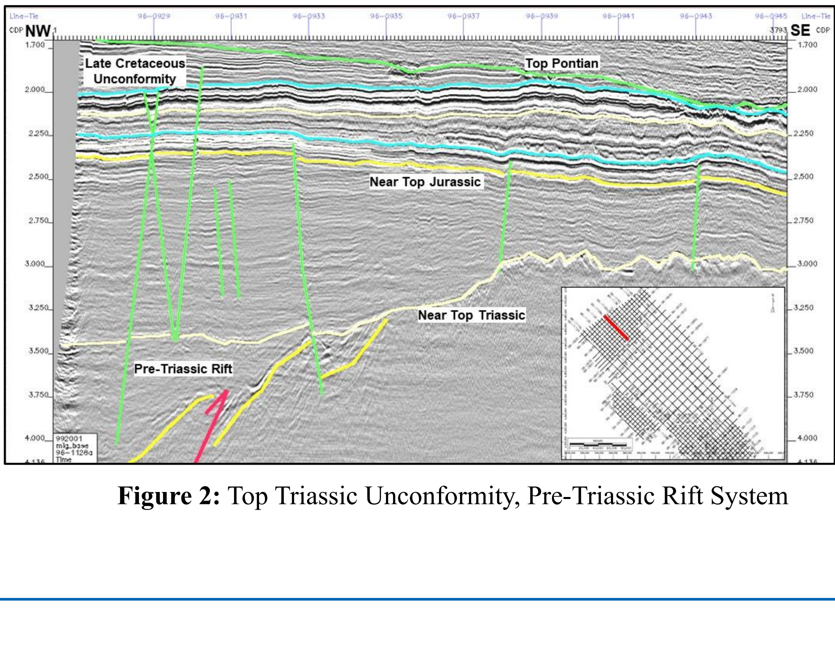

Figure 2: Top Triassic Unconformity, Pre-Triassic Rift System

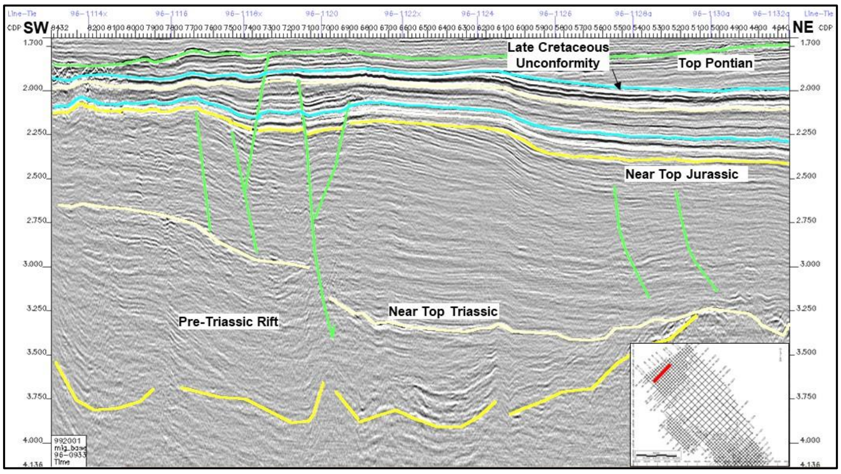

Figure 3: Base Cretaceous Unconformity: Top Jurassic

The unconformity is a typical erosional surface, which is locally characterized by high relief. The Jurassic sequence above consists of relatively uniform medium to low energy reflections, which generally show a gentle eastward dip and locally base lap the unconformity. In parts of the area, it appears possible to subdivide this sequence into an upper and lower part, the unconformity however cannot be mapped regionally because of insufficient data quality.

The top of the next sequence [Near Top Jurassic] again could be mapped as a regional unconformity, which is angular in the westernmost part of the area [fig.3]. Here in the westward continuation of the Apsheron Trend already at this stage relative uplift occurred and caused local erosion. In the remaining part northeast of the high the unconformity can be traced as a prominent reflector with concordance above and below indicating more or less continuous deposition. The unconformity, interpreted to represent Near Top Jurassic, was picked at the base of a prominent package of generally parallel strong reflections. This reflection package is terminated to the southwest by the regional fault forming the northwest continuation of the Apsheron trend [fig.4]. The terminations of the reflections indicate syn-depositional and post-depositional relative uplift movements for the southern fault block resulting in non-deposition/partial erosion of the interval.

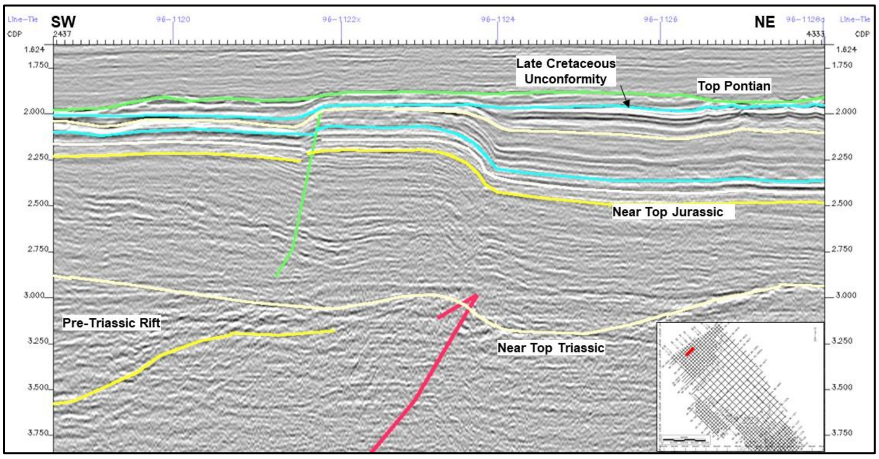

Figure 4: Cretaceous syn- / post-depositional uplift

The overall parallel layering of the Cretaceous reflection packages slightly changes in northern and northeastern directions. Together with a thickening of the overall package a change from parallel to oblique internal reflection pattern occurs. This allows for the subdivision of the interval into four cycles based on down-lapping reflection terminations [fig.5].

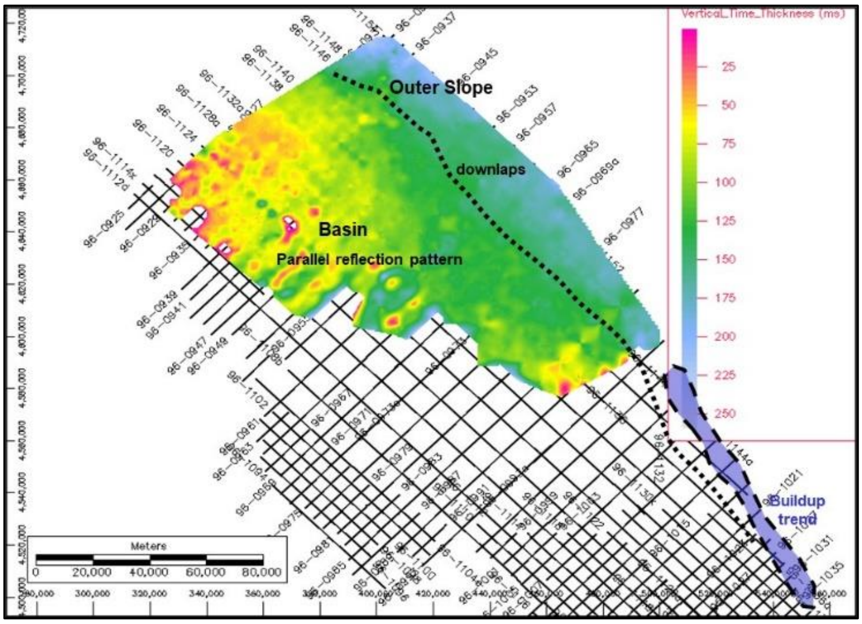

Figure 5: Time difference map Cretaceous Cycle 1

The reflection pattern is supposed to be related to the transition from basinal to distal slope / lower ramp facies in the carbonate depositional environment during the Cretaceous. The oldest cycle is preserved below the Late Cretaceous Unconformity in the south at a variable extent. Locally buildups can be interpreted below the unconformity southeast of lines 96-1001 close to the northeast limit of the seismic survey on hand. These buildups line up along a northeast-southeast trend [figs 6;7;8].

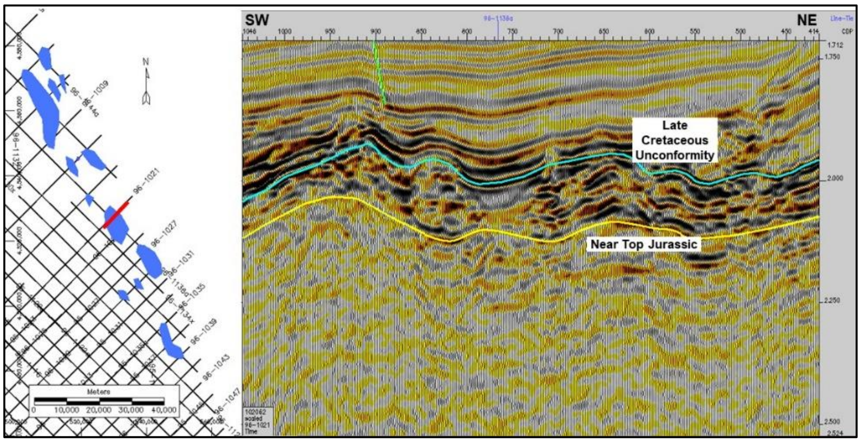

Figure 6: Cretaceous Cycle 1 buildup. A

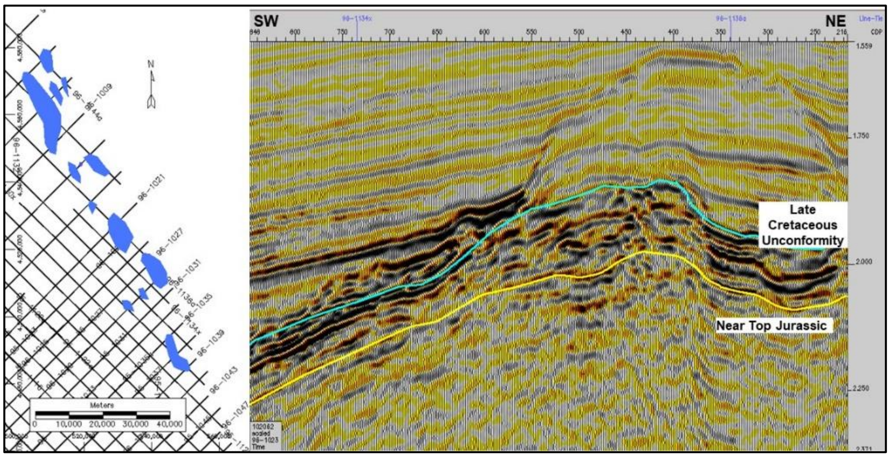

Figure 7: Cretaceous Cycle 1 buildup. B

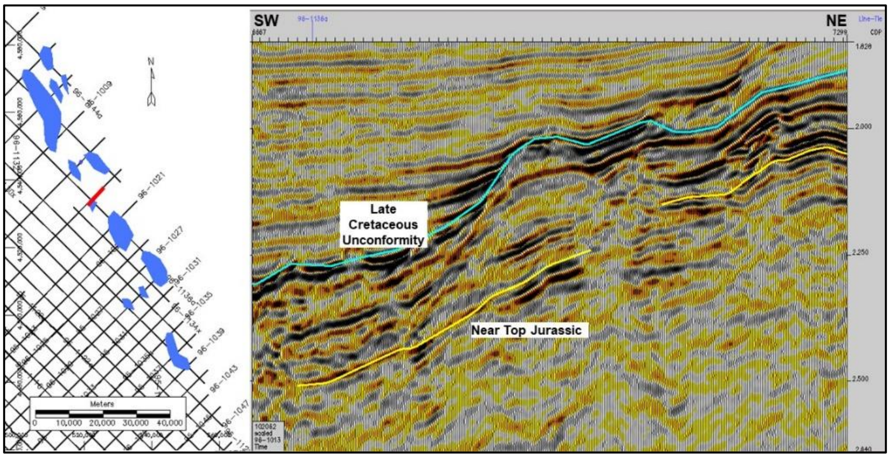

Figure 8: Cretaceous Cycle 1 buildup. C

Further, north the trend may continue off the existing database, within the existing seismic survey an interval thickening to the northeast and down lap reflection terminations to SW can be observed. The same is valid for the second cycle [fig.9].

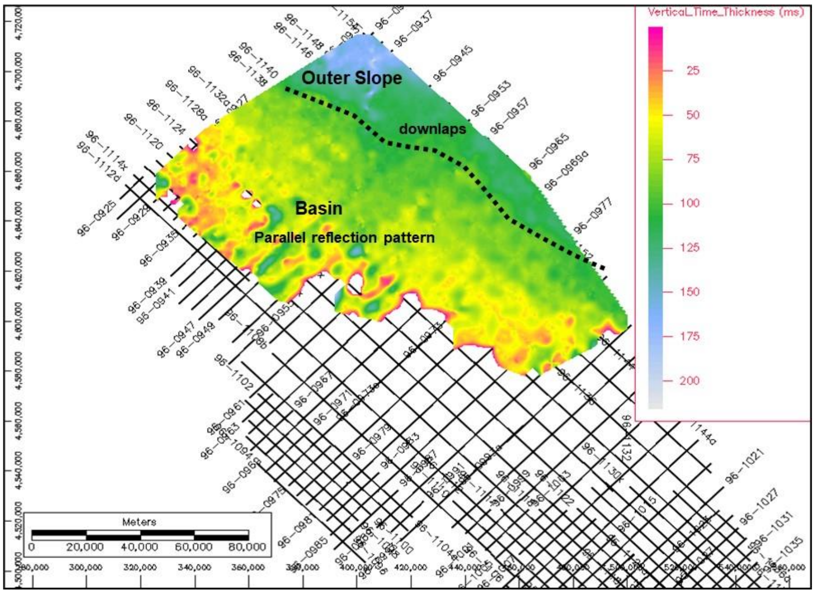

Figure 9: Time difference map Cretaceous Cycle 2

The ramp/basin margin with associated potential reef buildups is not covered by the given seismic grid for this cycle but has to be expected further to the northeast. The younger cycles sub-crop below the Late Cretaceous Unconformity in a southeastward direction [fig.10].

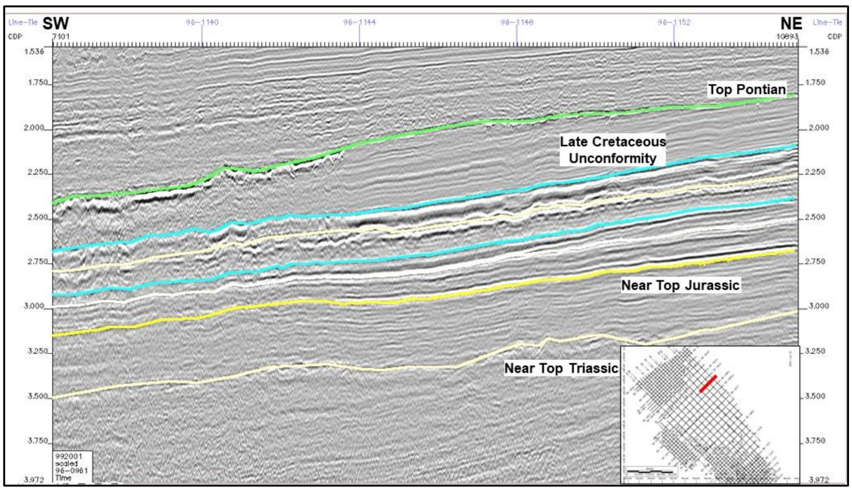

Figure 10: Down lap Reflections in Cretaceous Cycle 2

The third cycle shows indications for buildups in a few sections in the north of the study area [fig.11] where the relevant interval shows overall higher and relatively constant thickness.

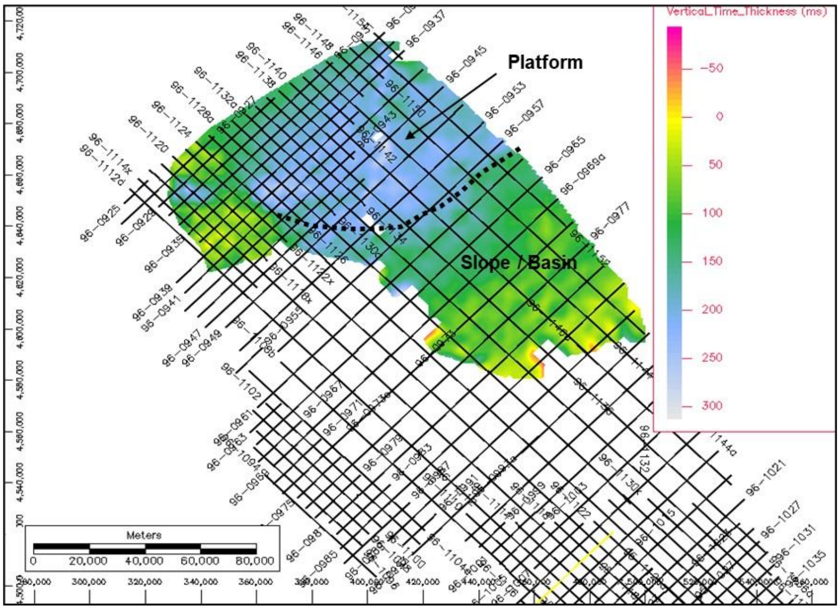

Figure 11: Time difference map Cretaceous Cycle 3

This may be interpreted as a carbonate platform area [fig.12]. The Top Cretaceous was picked over major parts of the area as the uppermost strong reflection of the high amplitude reflection package. Above again only very low amplitude reflections occur, which locally show

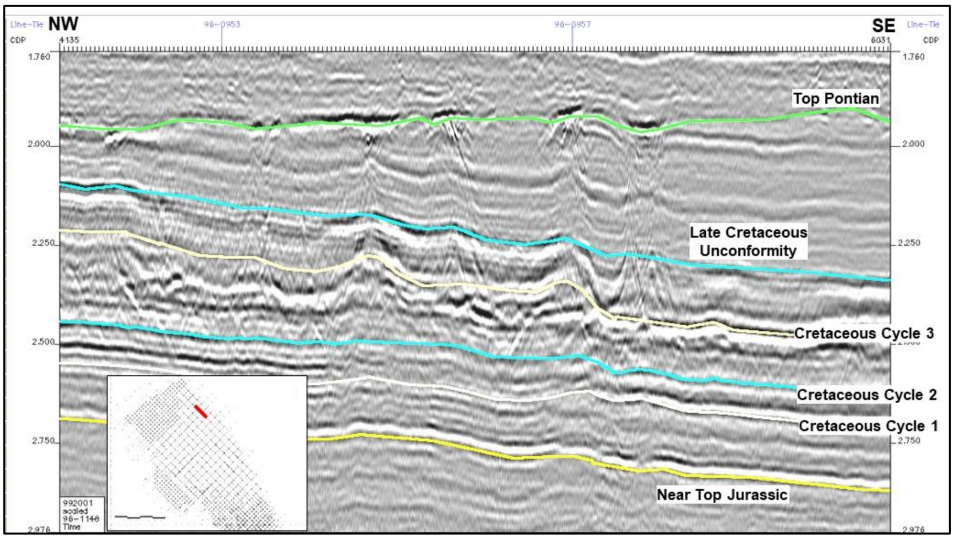

Figure 12: Buildups (?) in Cretaceous Cycle 3

Onlapping indicating transgression after the fall of sea level by the end-Cretaceous. In the remaining part of the area - again in the southwest on the continuation of the Apsheron trend and southeast-ward direction - the underlying reflections are sub-cropping below the picked event and finally pinch out except for the oldest Cretaceous cycle. The unconformity still can be correlated further as a high amplitude event representing the Late Cretaceous / Early Tertiary Unconformity.

The Cretaceous and older sequences subsequently were subject to intensive structuring along the Apsheron trend resulting in a series of anticlinal features and intercalated minor synclines. The structures are anticipated to be the result of strike-slip movements with major compression. The anticlinal axis shows a more or less continuous dip in the southeastward direction. There is a potential for up-dip closed fault blocks which however can not be clearly defined based on the given database with its limited data quality at this level, which does not allow for a reliable correlation of the reflections. Besides the fact that the migration of the data obviously could be improved, the interpretation is mainly complicated by severe out-of-plane reflections mainly on strike lines.

The youngest cycle shows major erosion and thus cannot be investigated in terms of interval thickening trends. There are no indications for build-ups at this level [fig.13; 14].

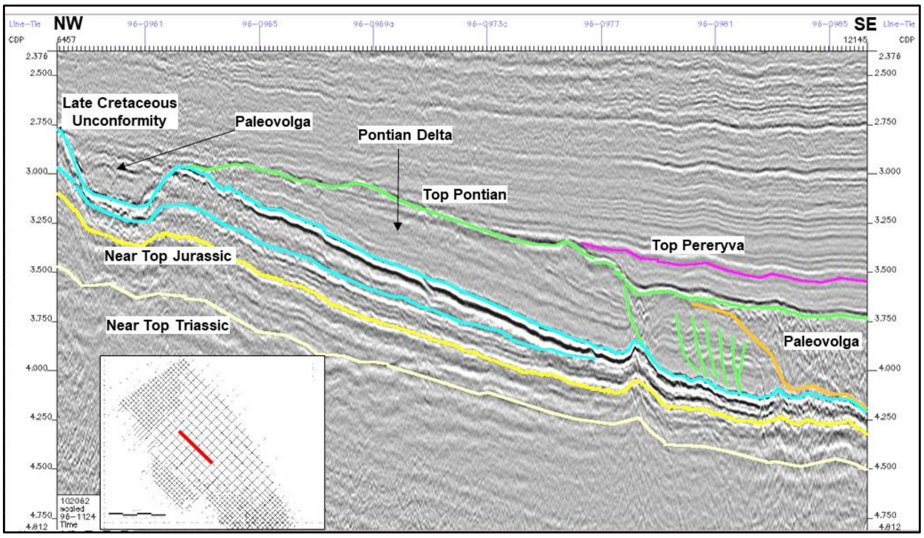

Figure 13: Pontian Delta: Prograding reflection pattern, slumping structures

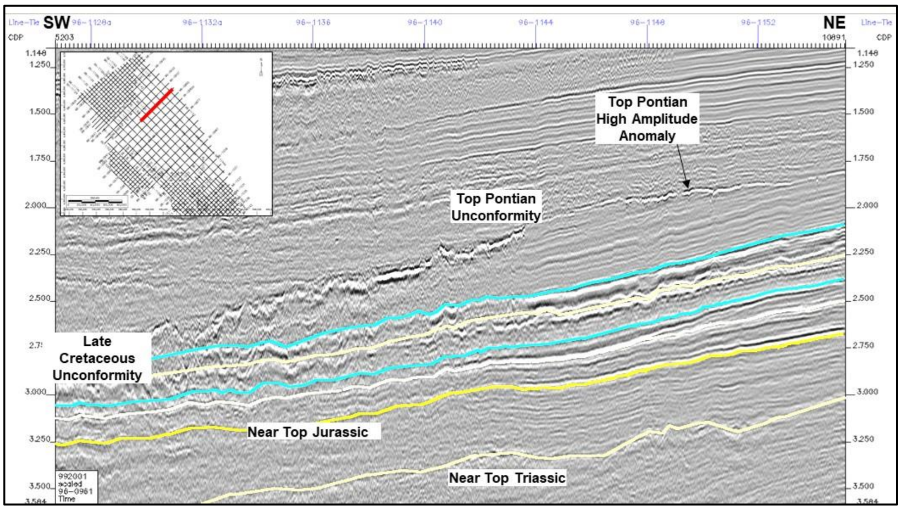

Figure 14: High amplitude event up-dip of the prograding delta at Top Pontian Unconformity

The next sequence of the Miocene age shows onlapping in the deep syncline North of the Apsheron trend. This onlapping can be observed as well further to the north in the deeper section of the sequence indicating ongoing transgression. In the northern part of the area, southeastward progradation in the upper part of the sequence is observed locally. The shape and extension of the progradation pattern, locally combined with slumping features can be interpreted as a highstand prograding delta.

The top of the sequence again is a major type 1 sequence boundary with overall deep erosion. North of the prograding delta high amplitudes characterize the erosional surface. Besides numerous minor incised valleys the most prominent erosional feature is the deeply incised Paleo-Volga valley running in approximately north-south direction starting at the northernmost extension of the seismic survey. Post-Cretaceous and partly even Cretaceous deposits are removed within this valley. The direction of the valley indicates the Apsheron trend not being a positive feature at this stage as the valley runs almost perpendicular to the anticline. Further to the East, another even more prominent valley follows the overall trend of the syncline. The valley fill is characterized by a chaotic internal reflection pattern [fig.15].

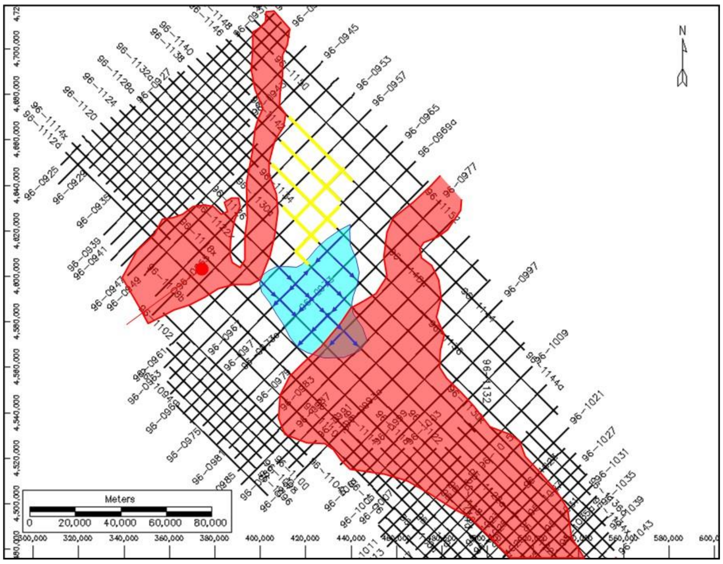

Figure 15: Pontian Delta / Amplitude Anomaly at Pontian Unconformity with Paleo-Volga

Both valleys are interpreted as the result of a major base-level fall before the deposition of the Productive Series. The eastern valley may have been filled earlier than the western one. The character of the fill could be interpreted as deposits of an anastomosing river. Anastomising could be caused by a decreasing gradient of the Paleo-Volga due to the uplift of the Apsheron trend. An overall tilting of the basin may have caused a westward shift of the Volga Valley. The actual age relationship of the valleys however is not clear from the current database [fig.16] The area north of the Apsheron subsequently was flooded again, Pereryva transgressively overlies the prominent unconformity but still does not cover the entire area of investigation. The higher Productive Series however is present within the entire study area.

1.3. Structural Settings

The structural setting is similar for all interpreted horizons [figs.5 – 18]. The entire area consists of a smooth syncline with the axis dipping to the south and turning into a southeastward direction when approaching the Apsheron anticlinal structure. Adjacent to this anticline as well the deepest part of the syncline is reached. The southern flank is in parts reverse fault. The Apsheron trend extends in the northwest direction as a reverse fault affecting Jurassic and partly Cretaceous deposits, the latter sup cropping at this fault and not being present on the hanging wall block. An additional reverse fault further to the northeast mainly affects the Triassic level, later uplift caused flexing and thinning of the Cretaceous interval.

These structural settings of course impact the structural trapping potential for the area, which has to be regarded as rather low. Top Triassic and Top Jurassic still show some minor four-way-dip closures at least in the time domain. Depth conversion will not change this picture drastically except for the area below the Paleo-Volga valley in the West. Here higher velocity carbonates of the Cretaceous were eroded and subsequently replaced by lower velocity clastics of the Productive Series resulting in a push down of deeper events in the time domain.

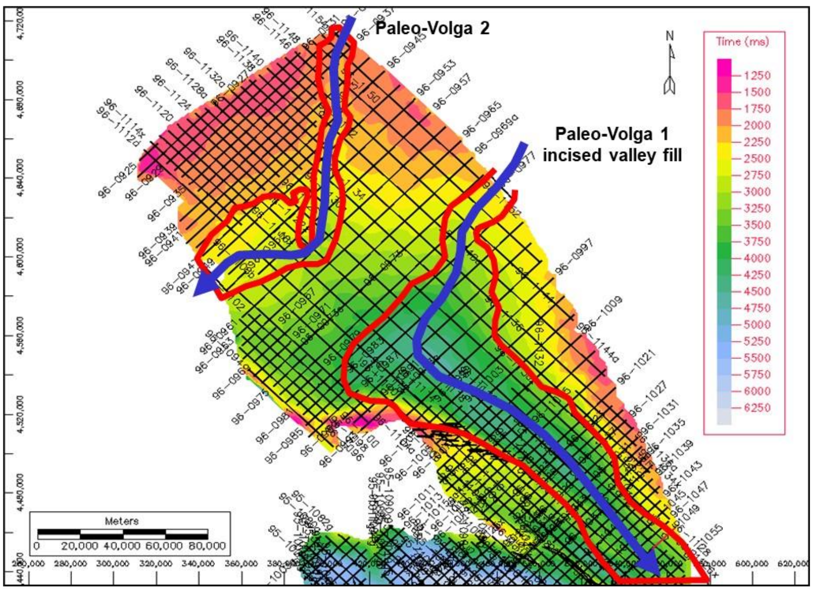

Figure 16: Time Contour Map Pontian Unconformity with Paleo-Volga incised valley system

Due to the very consistent overall dip in this area, it is not expected that depth conversion will generate additional structural closures. The relatively small size of the remaining closures, and even more the highly speculative depositional environment within these intervals and thus the lithology to be expected make these structures high-risk potential.

1.4. Play Concepts

Structural Trapping Potential: As mentioned above only minor exploration potential is supposed to be related to the study area north of the Apsheron trend except for some minor closures at Top Triassic and Top Jurassic levels. The overall synclinal structure with minor faulting only results in no valid structural traps for Cretaceous and younger formations. For the Cretaceous, the northern Apsheron reverse fault trend however is still regarded as interesting in terms of structural trapping potential even though there are no or only minor four-way-dip closures identified based on the given seismic data so far. Reprocessing with a main focus on Pre-Tertiary levels, mainly optimization of the stacking/migration velocity field is regarded essential for better delineation of the structural potential. Furthermore, the question of potential reservoir rocks in the Cretaceous needs to be resolved. According to the current model based on seismic stratigraphy, the area is rather basinal facies and thus not a favourable reservoir. The Apsheron trend as an uplift area however might have been an area with potential reef growth, although there were no indications found so far in seismic. Still, the main structuring/uplift occurred after the deposition of the Cretaceous, as younger cycles are subsequently eroded when approaching the anticline.

Stratigraphic Trapping Potential: The better potential is related to stratigraphic traps, which however are all suffering from inadequate data quality and seismic grid coverage. These stratigraphic play concepts are:

Cretaceous reef play: Within the four cycles identified there are Cycle 1 and Cycle 3 are of major interest as showing direct indications for buildups. These buildups are obvious and can be mapped along a trend for Cycle 1. There is however no structural closure related to this trend to support trapping. The laterally discontinuous trend as it is interpreted requires further investigations [reprocessing] and a denser seismic grid to outline potential up-dip pinch-outs of buildup trends. The detailed mapping may even identify structural closures related to the trend. Cycle 3 shows buildups in a few sections of questionable data quality only, careful reprocessing is required to verify the interpretation. The thickness distribution for this cycle however represents further indication for platform deposits and thus potential buildups in the area [fig 11].

Pontian highstand delta: The Pontian highstand delta identified in the center of the study area is interpreted from the pro-gradational reflection pattern and can be reasonably well delineated as a pro-gradational body with some slumping of distinct lateral extent. Due to subsequent erosion related to a major base-level fall before the deposition of the Productive Series the Pontian deposits were eroded at various extents. The Pontian Unconformity in the area east of the incised Paleo-Volga river and north of the delta is characterized by high amplitude becoming weaker again to the north. This area can be referred to as the delta plain area on the Pontian shelf with a high probability of reservoir-quality sands. Shadow zones below the high amplitude event indicate gas fill for this area.

Productive Series Onlap/Pinch-out Play: With rising lake level in the South Caspian Basin the Central Caspian Basin was continuously flooded and the pre-existing relief [incised valleys, synclinal trough] became again an area of sedimentation. The relevant formations show northward onlap pinch-outs, the Pereryva pinch-out as the probably most promising reservoir was mapped in detail. The onlap positions of the higher Productive Series as well may represent further exploration potential.

2. Conclusions

North of the Apsheron trend of the Central Caspian area is subject to a more detailed seismic stratigraphic review. The structural settings are compared to the Southern Caspian Basin less complex. Except for the Apsheron trend, which is a prominent overall anticline structure with an eastward dip of its structural axis. The area of investigation comprises a major northwest-southeast trending syncline and thus exhibits very limited structural potential. The Cretaceous deposits form anticline structures along the Apsheron trend. These structures appear to open up-dip to the northwest with a potential culmination in the shallow water area which is not covered by the seismic data yet. There are few wells drilled in the coastal area of the north Apsheron trend.

The better potential is supposed to be related to stratigraphic traps. Overall, three plays are defined based on the seismic stratigraphic analysis:

- Cretaceous reef play: Within the Cretaceous, there are good indications for build-ups along a trend close to the Turkmenistan border.
- Pontian high stand delta: The Pontian high stand delta is identified in the centre of the study area. The Pontian Unconformity in the area East of the incised Paleo-Volga River and north of the delta is characterized by high amplitude becoming weaker again to the north.
- Productive Series Onlap/Pinch-out Play. The relevant formations show northward onlap pinch-outs, the Pereryva pinch-out is a most promising reservoir.

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