DEEP KARST AREAS EVIDENCED BY SEISMIC RESEARCH IN MOESIAN PLATFORM

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ABSTRACT

Around half of the total carbonate rocks of Romanian territory are Upper Jurassic-Lower Cretaceous age. Most of them are able to develop karst phenomena.

In the southern-central part of the Moesian Platform Jurassic-Cretaceous deposits are at 2000-3000 m depth. The existence of the hydrocarbon accumulations in the area was just proved (Talpa, Harlesti, Videle fields).

In the calcareous deposits, the seismic profiles and the attributes of seismic traces highlighted some specific geological features:

The collapse karst areas, formed in Jurassic-Neocomian deposits. The seismic expression of these areas is one of chaotic reflections zone flanked by converging, strong tilted faults.

The paleo-valley systems formed by erosion of the Cretaceous relief, filled with different terms of the Lower Sarmatian (a succession of marls and sands). The reflections configuration is specific to the passing from the valley fill lithology to the Cretaceous calcareous formations of the adjacent areas.

The reef build-ups in Upper Jurassic-Lower Cretaceous formations, expressed by chaotic reflection mound zones draped for quasi horizontal superimposed strata.

The seismic trace attributes and velocity analyses are important tools in reservoir quality definition, giving information regarding porosity and fluid contents.

Keywords: deep karst, carbonate deposits, seismic analysis, reservoir properties

INTRODUCTION

The Mesozoic carbonates appear sporadically on the surface, the biggest part of them being under base level and containing big quantities of water.

In the southern-central part of the Moesian Platform carbonate rocks of Jurassic and Cretaceous deposits are found at depths of 2000-3000 m. They are tabular, unfolded, affected by predominantly W-E, normal faults.

On the seismic profiles, at this level was identified an area with chaotic reflections configuration, flanked by inclined, irregular faults. Towards surface these faults are suggested by flexures, and they stop in depth, at the seismic horizon corresponding to top Triassic deposits.

The interpretation of seismic information correlated with well data led to the conclusion that after Senonian deposition, during post-Cretaceous exposure, at level of Malm-Neocomian calcareous deposits a strong underground karsts network was developed. The collapse of the underground cavities created a depression zone, a paleo-valleys system filled with Sarmatian deposits.

The seismic trace attributes and velocity analyses are important tools in quality of calcareous reservoir definition, giving important information regarding increasing/ decreasing porosity and regarding fluid contents.

GEOLOGICAL SETTING

On Romanian territory, Moesian Platform (fig.1) develops between Precarpathian Depression, North Dobrogea Orogen and the Danube river, extending eastward under Black Sea water.

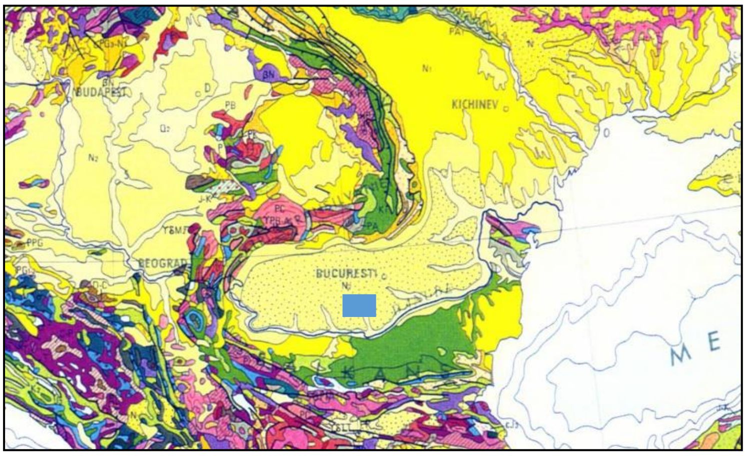

Fig.1. *Geological map of Romania. Blue rectangle represents study area.*

The sedimentary cover consists of an almost complete succession from Cambrian to Quaternary formed in four cycles: Cambrian-Upper Carboniferous, Permo-Triassic, Upper Liasic-Senonian and Neogene that lies over a mix basement.

The Upper Liasic-Dogger deposits are accumulated during a transgression from the east. The sediments are composed from three sandstone lithological units separated by two shally units. In Malm, initially the sedimentation was pelagic one in the entire platform with limestone and shale.

Beginning with Kimmeridgian it remains pelagic only in western part, in rest becoming a shelf neritic sedimentation with reef limestone, oolitic limestone, biomicrite. The study area is situated to the limit between this two pelagic and shelf-neritic facies.

Cretaceous is coming in the continuity of sedimentation over Jurassic deposits. In Berriasian-Lower Aptian a similar with Upper Jurassic sedimentation takes place, that means pelagic facies in western part and a neritic one in the east (fig.2).

In area of interest the pelagic sequences represented by micrite and foraminiferal shale, are passing, during neritic facies extension, to oolitic, reef and peletal limestone [6].

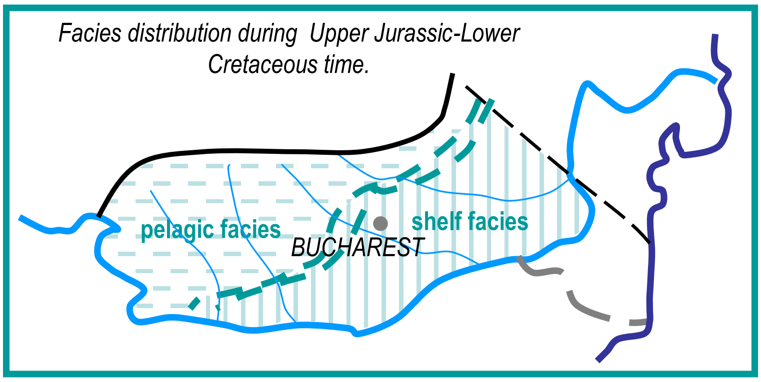

***Fig.2**. Facies distribution during Upper Jurassic / Lower Cretaceous* (*modified after* [14].

After an uplift and erosional period, the sedimentation restarted with Albian transgression from eastern part. Lower Albian is represented by a glauconitic sandstone facies. Upper Albian deposits have the same sandstone predominantly character, but with biomicrite limestone intercalation. The Cenomanian has a shale and limestone with sandstone interbedded composition. It is followed by Turonian represented by chalky limestone and argillaceous limestone with foraminifera. Senonian completes the Cretaceous succession with chalky limestone, biosparite, calcareous sandstone with tuff interbedded [6].

Paleocene-Eocene deposits are developing only in the south western side of the platform. The Senonian deposits were strong eroded during Paleocene-Eocene giving birth to a various morphology with karst features and paleo-valleys on N-S direction. The diagenetic phenomena of Jurassic-Cretaceous calcareous facies improved the quality of reservoir rocks, porosity reaching 12-18% and permeability 2-25 mD permeability [4].

A new transgression in Badenian filled initially the paleo-valleys and the negative forms. In Sarmatian, all the space situated in northern part of the Danube becomes the other flank of the Carpathian Foredeep. The sediments have a calcareous and detrital character in Badenian and a psamitic one (sandstones and sands) passing in organogenic limestones in Sarmatian. The sedimentation continued with a predominantly pelitic character until the end of the Pliocene, locally of Quaternary.

During the Middle Jurassic the source areas were proximal or intra-basinal. In Upper Jurassic the depositional system consisted mainly of carbonate and algal-skeletal mounds. The Callovian transgressive system presents a poor organic diversity, and a low sedimentation rate. In Tithonian, the rapid relative sea level falling generated dolomitization of exposed build-ups [14].

The Lower Cretaceous is composed almost exclusively of carbonate rocks. The Albian presents initially a transgressive character beginning with sandstone terrigenous rocks, and continuing with marine, inner shelf character. Upper Albian belongs to a lowstand depositional system with incised valleys and channels. Cenomanian-Senonian deposits closed the Malm-Neocomian carbonatic group [14].

The lithostratigraphic succession is synthesized in the fig.3, but structural and stratigraphic features can be better observed with the help of the seismic sections (fig.4).

Period	Epoch	Stage	Lith.	Major depositional systems
Quaternary	Holocene			
	Pleistocene			
Neogene	Pliocene	Romanian		
		Dacian		
	Miocene	Pontian		
		Pannonian		
		Sarmatian		
		Badenian		
		Burdigalian	Gap	
		Aquitanian		
Cretaceous	Senonian	Maastrichti		LST-neritic reefal
		Campanian		LST-neritic reefal
		Santonian		HST-carbonate shelf
		Coniacian		HST-carbonate shelf
	Gallic	Turonian		TST-carbonate shelf
		Cenomanian		LST-valley, channels
		Albian		T-H-LST-terrigen/ inner shelf
		Aptian		SMST-epicontinental,reefal
		Barremian		SMST-epicontinental,reefal
	Neocomian	Hauterivian		TST-shelf carbonate
		Valanginian		TST-shelf carbonate
		Berriasian		HST-inner shelf, reefal
Jurassic	Malm	Tithonian		LST-outher shelf/slope
		Kimmeridgia		HST/TST-shelf margine/slope
		Oxfordian		HST-lithoral bars and shelf
	Dogger	Callovian		TST-shoal on outher shelf
		Bathonian		LST/HST-fluviatil, costal/shelf
		Bajocian		HST-lithoral bars and shelf
		Aalenian		TST/LST-shelf, alluvial fans
	Lias	Toarcian		HST-marin terigenous
		Pliensbachian		
		Sinemurian	Gap	
		Hettangian		
Triassic	Tr3	Rhaetian		
		Norian		TST-carbonate shelf
		Camian		
	Tr2	Ladinian		
		Anisian		TST-carbonate shelf
	Tr1	Spathian		
		Nammalian		HST-detritic continental

Fig.3. *Main lithology and depositional systems in the carbonate sequences from the southern central part of the Moesian Platform.*

LST= Lowstand systems tract *(deposits that accumulate after the onset of relative a sea-level rise, during the early stage of the sea level curve).*

SMST=Shelf-margin systems tracts (the lowermost systems tract, weak progradation to aggradation, underlying highstand tract).

*TST=transgressive systems tract (*deposits between the transgressive surface and maximum flooding surface).

*HST=highstand systems tract (*it is bounded by maximum flooding surface at the base and composite surface at the top).

During the Middle Jurassic the source areas were proximal or intra-basinal. In Upper Jurassic the depositional system consisted mainly of carbonate and algal-skeletal mounds. The Callovian transgressive system presents a poor organic diversity, because of the high subsidence accompanied by a low sedimentation rate. In Tithonian, the rapid relative sea level falling generated dolomitization of exposed build-ups.

The Lower Cretaceous is composed almost exclusively of carbonate rocks. The Albian presents initially a transgressive character beginning with sandstone terrigenous rocks, and continuing with marine, inner shelf character. Upper Albian belongs to a lowstand depositional system with incised valleys and channels. Cenomanian-Senonian deposits closed the Malm-Neocomian carbonatic group [6].

The images obtained through seismic research put in evidence some specific geological features at Cretaceous-Jurassic calcareous deposits level:

- The collapse karst areas, formed in Jurassic-Neocomian deposits. The seismic expression of these areas is one of chaotic reflections zone flanked by converging, strong tilted faults. This faults disappear at Triassic level and below it, and in Upper Cretaceous and Lower Sarmatian strata are only suggested by flexures (fig. 4, 5, 6)
- The paleo-valley system (fig.7) formed by erosion of the Cretaceous relief, filled with different terms of the Lower Sarmatian (a succession of marls and sands). The reflections configuration is specific to the passing from the valley filling lithology to the Cretaceous calcareous formations of the adjacent areas.
- The reef build-ups (fig.7) in Upper Jurassic-Lower Cretaceous formations, expressed by chaotic reflection mound zones draped for superposed strata.

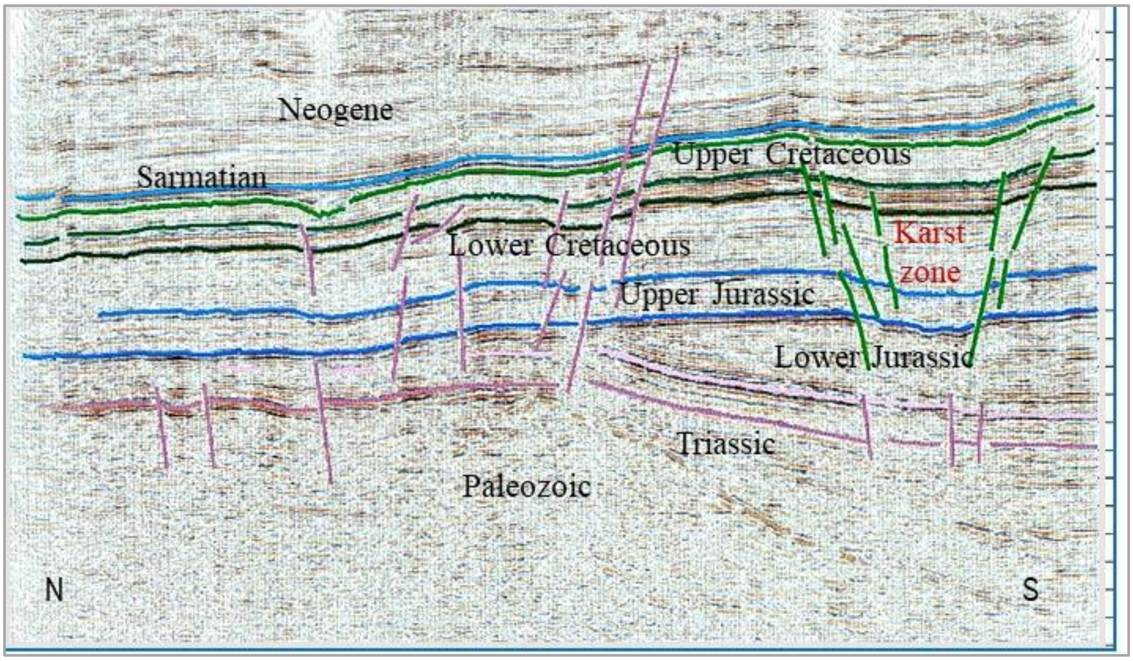

Fig.4 *Interpreted seismic section in the southern-central part of Moesian Platform.*

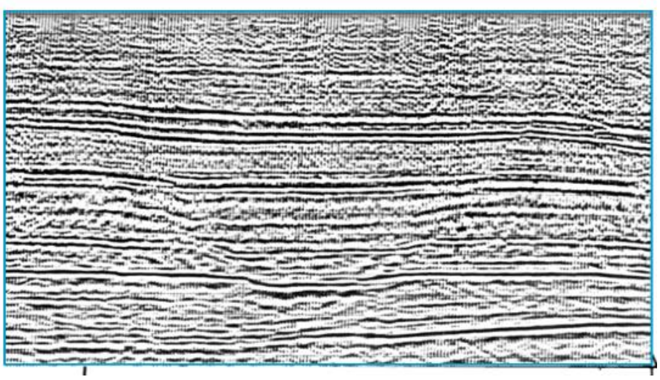

Fig.5. *Seismic section in a collapse karst area.*

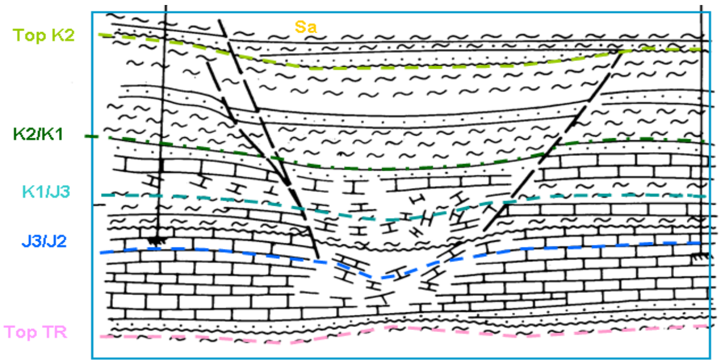

Fig.6. *Geological interpretation of seismic section above.*

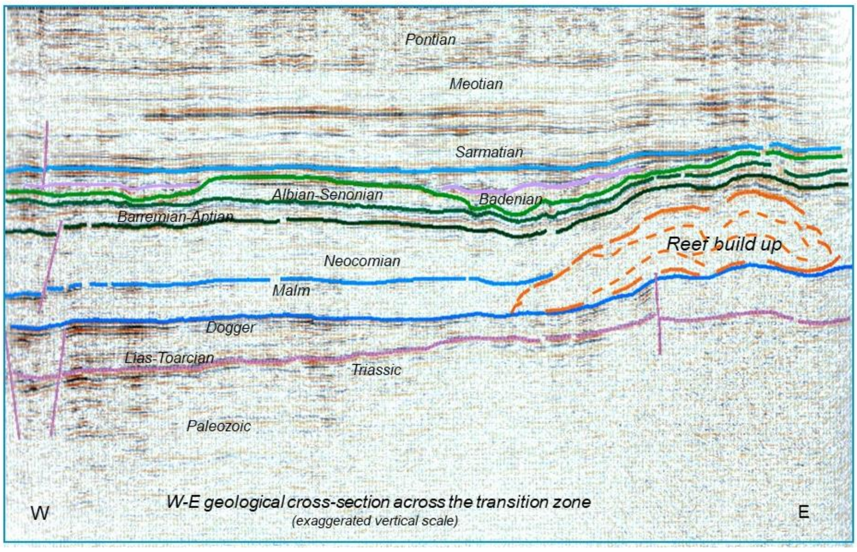

Fig.7 *W-E seismic section showing a paleo-valley at Badenian / Lower Sarmatian level and a reef structure in Malm / Neocomian deposits.*

The velocity and the seismic trace attributes analysis are very useful in delineation of different specific phenomena developed in carbonate rocks. All the changes visible on seismic trace attributes prove changes in physical and lithological parameters.

Velocity of seismic wave and strata density are directly responsible for the quality of the reflection and for the travel time. The most important factor that determines seismic velocity is the porosity. In the carbonate rocks, the higher velocities are associated with dolomitization phenomena, while the lower velocities could be produced by fracturing porosity increase, or by the presence of the fluid in the rock pores. The lowering of the velocity at Jurassic level produced an apparent uplift of the top Triassic seismic marker due to the shortening of the travel time. The velocity analyses demonstrated an increase velocity in Upper Jurassic reef build-ups, corresponding to a lowering of porosity produced by dolomitization. On the processing of seismic data, a velocity decrease can be observed. At Albian level, in the karst area, where the fracturing porosity increases, a normal velocity of 4000m/s reach 2900-3200m/s only.

Polarity is an attribute that display very well the changes in impedance and reflectivity. It could be positive or negative, depending of the subjacent and suprajacent strata velocity [9]. The velocity lowering changes the reflection coefficient from positive to negative (from red to blue), a reverse polarity resulting.

Reflection strength is the amplitude envelope of the seismic trace [10]. High reflection is associated with major lithologic changes or with gas accumulations, being a direct indicator of the porosity variation. Sharp changes in amplitude may indicate a faulting.

On profile 17 (fig.8), the horizon with high amplitude (red colour) is interrupted into karst area, where probably the dolomitization produced a lowering of the porosity.

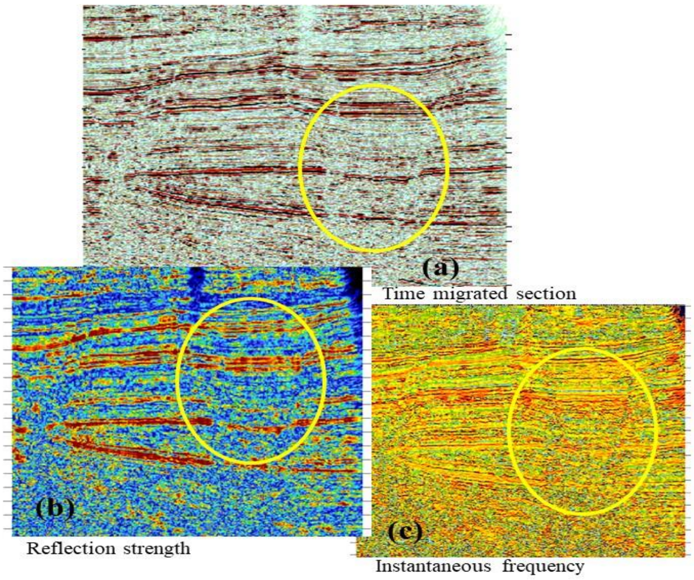

Fig. 8. *Seismic line 17 (see fig. 11 for position). TWT migrated section and image of different seismic trace attributes of the same seismic line: Reflection strength, Instantaneous frequency. The yellow circle marks the collapse karst zone.*

Instantaneous phase (fig.9) describes the angle between the phasor and the real axis as a function of time [9]. Instantaneous phase tends to clarify weak coherent events. It emphasizes the continuity of events and is therefore very helpful in revealing faults, pinch-outs, channels and internal depositional geometries.

The display of instantaneous phase attribute put in evidence very well the fault zones in carbonate sequence and the pinch-out terminations in the valley filled area.

Instantaneous frequency represents the rate of change of instantaneous phase as a function of time and is obtained by taking the derivative of the phase. It is a measure of slope of the phase trace [9]. Low frequency shadows may be associated with reflectors below gas sands, condensate and oil reservoirs. The loss of higher frequencies may indicate the onset of pore fluid overpressure. The instantaneous frequency is useful for trace to trace correlation, showing the stratigraphic changes. The hydrocarbon accumulation could produce a very strong lowering of the frequency.

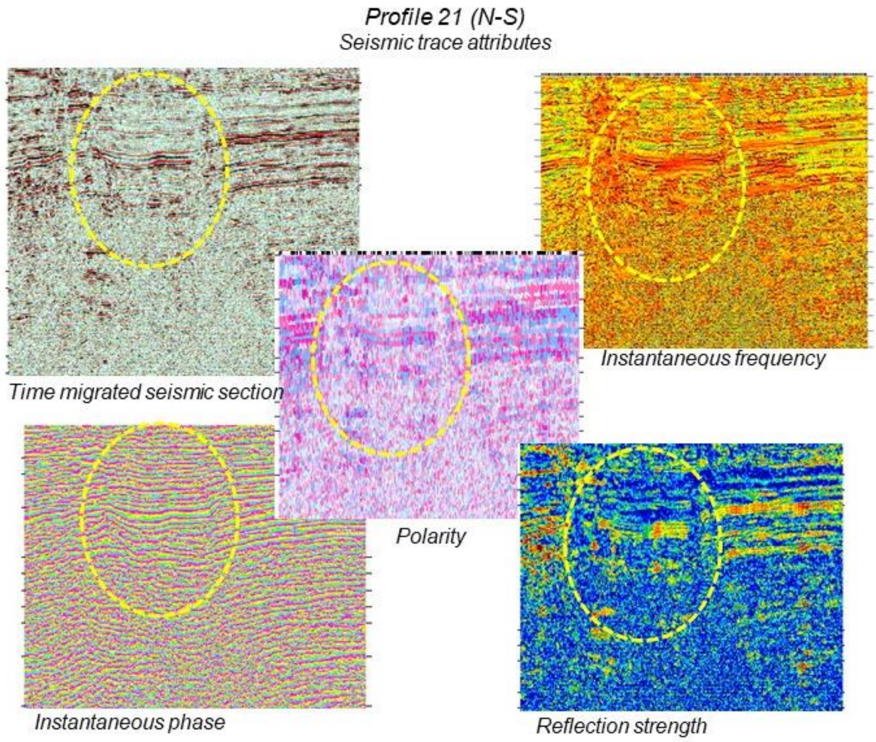

Fig. 9. *Seismic line 21 (see fig. 11 for position). TWT migrated section and seismic attributes of the same seismic line: Reflection strength, Instantaneous frequency, Instantaneous phase, polarity. The yellow circle marks the collapse karst zone.*

On seismic line 22 (fig.10), along the left side fault of the karst zone, low frequencies can be observed (red colour) on “instantaneous frequency“ attribute. The fault sealing could be doubtful, allowing migration of hydrocarbons to the surface.

The paleo-valley formed by erosion of the Cretaceous relief, filled with different terms of the Lower Sarmatian (a succession of marls and sands). The reflections configuration is specific to the passing from the valley fill lithology to the Cretaceous calcareous formations of the adjacent areas. The instantaneous phase is more suggestive and clear, and the pinch-out and the truncations are easier to see.

The reef build-ups in Upper Jurassic-Lower Cretaceous formations, are expressed by chaotic reflection mound zones draped for superposed strata.

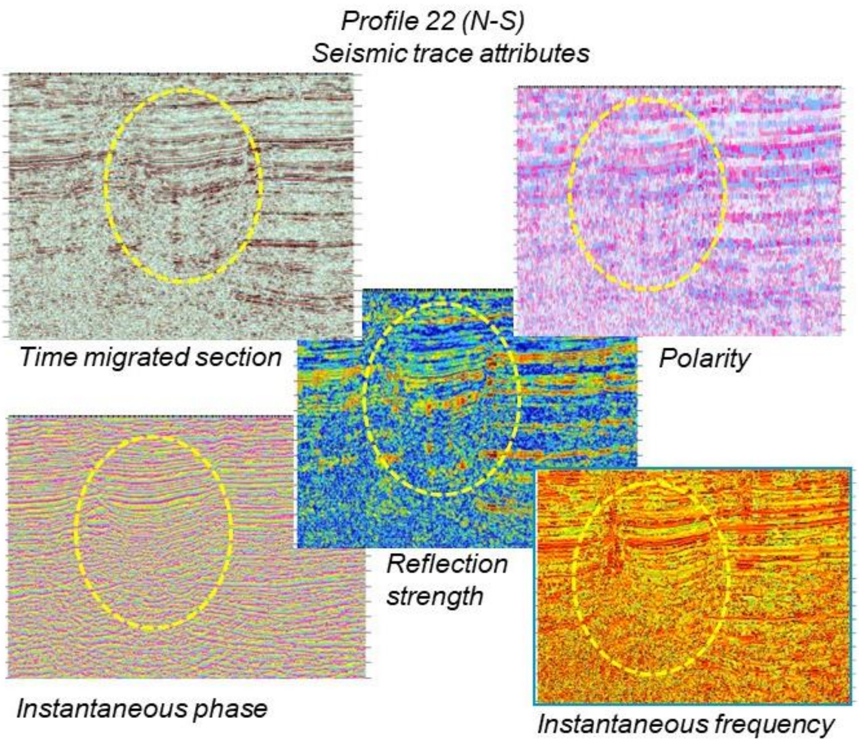

Fig. 10. Seismic line 22 (see fig. 11 for position). TWT migrated section and seismic attributes of the same seismic line: Reflection strength, Instantaneous frequency, Instantaneous phase, polarity. The yellow circle marks the collapse karst zone.

Using all this information on a seismic profile network, the collapse areas where delimited in surface. On the isopach map drown at Middle Jurassic -Top Triassic level we can see a reducing of the thickness with 100-150 m in the collapse areas comparing with the adjacent zones.

The explanation of these phenomena is related to the post Senonian emerge. During this time at Malm-Neocomian level, a strong underground karst network developed, being sometimes in communication with the surface. The karstification led to the increasing of the fluid circulation in the subterraneous channels.

Through the collapse of the underground caves a W - E elongate depression area was formed (fig.11). The strong erosion in these areas created a deep paleo-valley network mapped using seismic profiles.

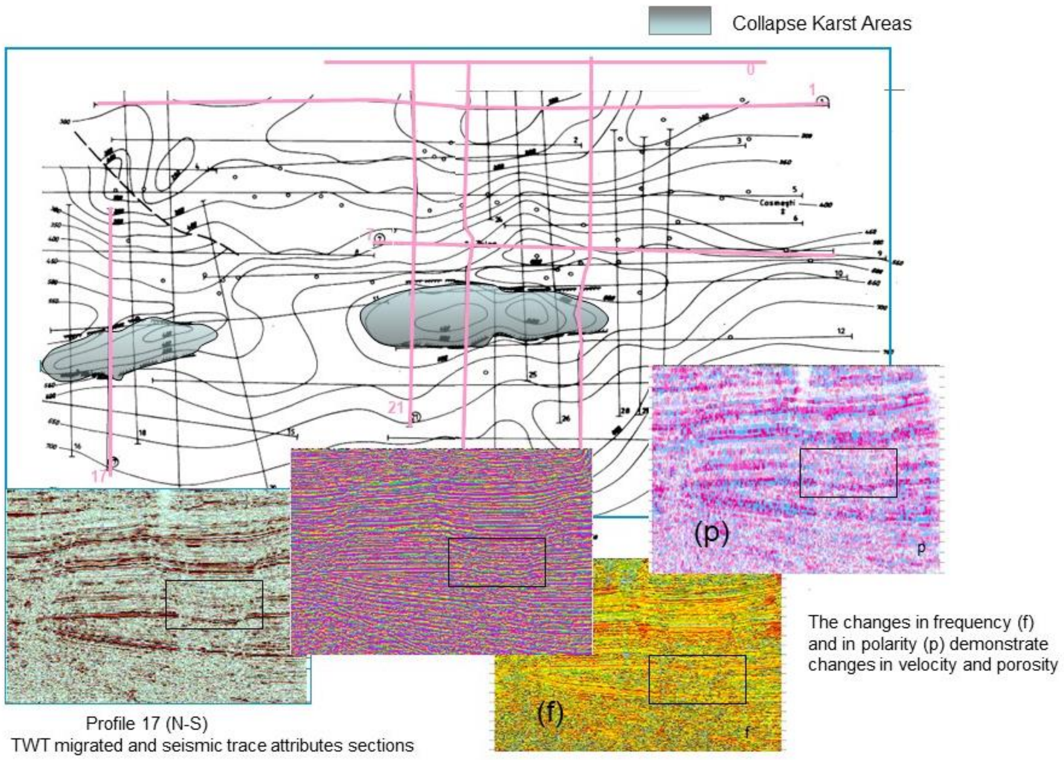

Fig. 11 *Middle Jurassic / Top Triassic isopach map showing a thinning in collapse karst areas.*

CONSIDERATION REGARDING CENTRAL MOESIAN CARBONATE ROCKS HYDROCARBON POTENTIAL

Central part of Moesian Platform is producing from Cretaceous, Badenian and Sarmatian. (in our area, Harlesti, Talpa, Videle fields.)

The Devonian dolomites and carbonate series of the Middle Triassic are very good source rocks. The formation of hydrocarbons was ensured by the positive anomalies of temperature (the geothermal gradient can exceed 5º C /100 m).

The carbonaceous reservoirs could be encountered in Middle Triassic (dolomites and fissured limestone) and in Albian-Upper Cretaceous (sandy limestone, microcrystalline limestone, organogenic or chalky limestone).

The productivity of the carbonate reservoirs depends of the diagenesis degree, often associated with gliptogenesis phases. Same areas were compacted, while others became more porous and permeable.

The most important traps are of structural type, but the stratigraphical and paleo-morphological traps are also present.

For the future reserves, the subtle traps are very important.

These can be stratigraphic: facieses variations in carbonates-reef, bars, dolomitic corps, adjacent to the unconformity-karst phenomena, diagenetics-dissolution, dolomitisation in reef formations or mixed ones: molded, diagenized carbonate structures.

CONCLUSION

In the central part, Moesian Platform is producing hydrocarbons from Cretaceous, Badenian and Sarmatian.

The Devonian dolomites and carbonates of the Middle Triassic are good source rocks.

The carbonaceous reservoirs could be encountered in Middle Triassic and in the Albian-Upper Cretaceous deposits.

The productivity of the carbonate reservoirs depends of the diagenesis degree, often associated with gliptogenesis phases. Same areas were compacted, while others became more permeable.

The velocity and the seismic trace attributes analysis are very useful in delineation of different specific phenomena developed in carbonate rocks. All the changes visible on seismic attributes prove changes in physical and lithological parameters.

The seismic research revealed some specific geological features at Cretaceous-Jurassic calcareous deposits level:

- The collapse karst areas, formed in Jurassic-Neocomian deposits;
- The paleo-valley systems formed by erosion of the Cretaceous relief;
- The reef build-ups in Upper Jurassic-Lower Cretaceous formations.

The seismic expression of the collapse karst areas is one of chaotic reflections zone flanked by converging, tilted faults that disappear in depth at Triassic level.

In Upper Cretaceous and Lower Sarmatian the faults are only suggested by flexures.

The trace attribute analysis demonstrates anomalous amplitudes and frequency and velocity variations.

The karstification led to the increasing of porosity and fluid circulation. The seismic velocity analysis demonstrated a decrease at Malm-Neocomian level comparing with the normal velocity in younger or older deposits, unaffected by collapse.

The lowering of the frequency could also be the results of the increasing porosity and of the fluid contents.

The most important traps are of structural type, but for the future reserves, in Moesian Platform the subtle traps in carbonates facies are very important.

These can be represented by reef, bars, dolomitic corps, diagenetic or karst phenomena, and also by mixed, structural and diagenetic ones.

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