Periplatform clastics of Croatian offshore and their petroleum geological significance

S. Grandić

PRESENTATION FROM SCIENTIFIC AND EXPERT GATHERINGS

According to their petrographic characteristics, periplatform clastics sedimented along the Dinarides carbonate platform represent potential reservoir rocks of regional spreading. They are spread in the Adriatic offshore in the basement of Tertiary clastics as cap rocks, from Istria offshore in the north to Prevlaka offshore on the southeastern boarder of Croatian territorial waters in the length of over 550 km. Periplatform clastics are also found along Apulian and Friuli platforms, as petroleum-productive sediments. It is necessary to point out that these sedimentary rocks of younger Mesozoic and Paleogene age were not the subject of systematic geophysical exploration and exploration drilling up to now in the Croatian offshore, despite their high potential regarding possible gas and oil discoveries.

Key words: slope deposits, potential reservoir rock, Dinarides platform

1. INTRODUCTION

Illustrated data and examples from Croatian and Italian offshore that are the subject of this paper were explained during presentation held on January 29, 2009. During their geological evolution, carbonate platforms were, especially at their margins, exposed to emersion, weathering and resedimentation of carbonates along relatively steep sub-sea slopes into the neighboring basins. Dinarides carbonate platform, and especially its margin was also exposed to these processes which resulted in syn-sedimentation along the platform on its transition into the basin. In the Dinarides case it was Adriatic Basin along the entire platform spreading in Croatian offshore. Examples from the Italian platform were presented by Anna Delben and I. Aleotti in 2005 in their very interesting lecture organized by Scientific Council for Petroleum of the Croatian Academy of Sciences and Arts.

As presented in Fig. 1, periplatform clastics zone is marked by AS symbol and is colored in pink. In this index map, geological units of Dinarides Adriatic Basin are marked according to regionalization performed by Grandić in 1974. This time the regionalization has been slightly modified and amended. The term "Dinarides carbonate platform" introduced for the first time by

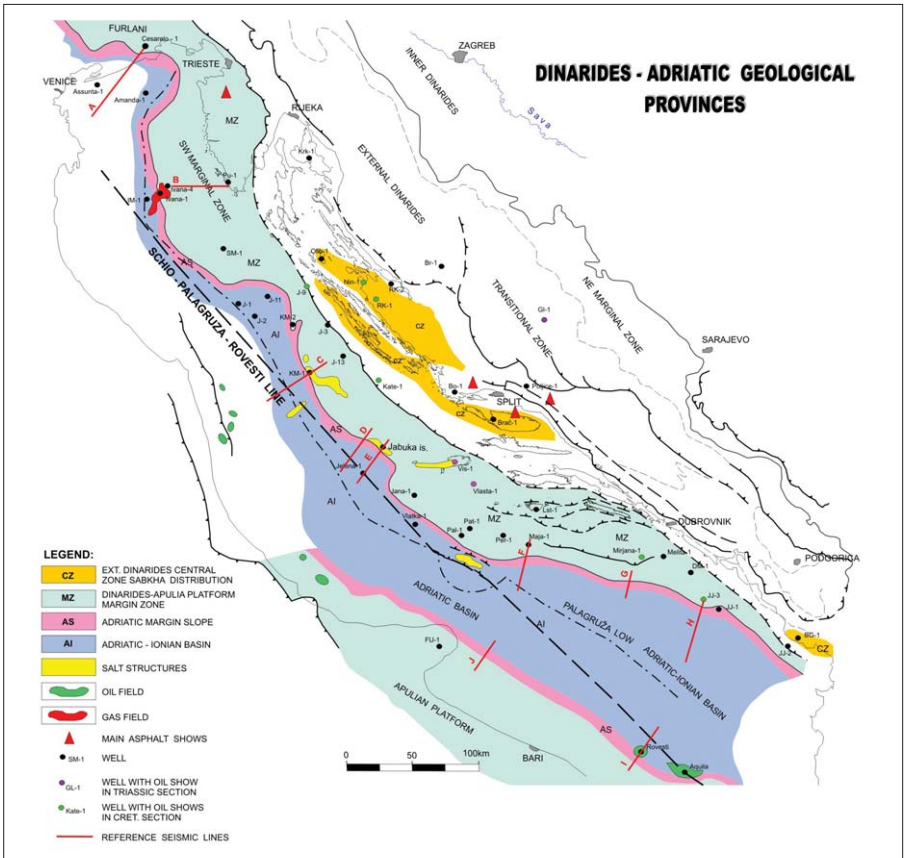

Fig.1. The position of reference seismic cross sections through periplatform clastics belt along the Dinarides carbonate platform belt is presented in this index map. This belt has AS symbol and is colored in pink. Reference cross sections which are illustrated and described in the text are marked by capital letters A to K.

Sl.1. Na slici je prikazan položaj referentnih seizmičkih profila kroz pojas periplatformnih klastita uz rub Dinarske karbonatne platforme. Ovaj pojas obilježen je simbolom AS i ružičastom bojom. Referentni profili koji su ilustrirani i opisani u tekstu označeni su velikim slovima od A do K.

Grandić at the Third Geological Conference in Zagreb in 1974[7] is used in this paper and not the term "Adriatic carbonate platform" according to Vlahović I. et al.[12] This term was used because the platform carbonates gave basic geomorphological characteristic to Dinarides as known geotectonic unit.

According to the title of this paper, the main attention shall be put on description of paleo- geographic relations which contributed to formation of periplatform clastics and their petroleum-geological characteristics. The relation between clastics and euxinic deposits as starting points for possible hydrocarbons migration into these periplatform sediment rocks and structural-stratigraphic traps shall also be topic of this paper.

The newest discoveries of commercial oil quantities on Rovesti structure on the Italian side were the incentive for this paper. The probability of commercial oil quantities in the Croatian offshore has been pointed out several times in previous papers published in Nafta journal as well as in the presentation organized by Croatian Geological Society. Oil traces were determined in numerous wells and especially important one was the discovery on Vlasta-1 well where the testing confirmed 2 m^3 of medium heavy oil within Ladinian-Carnian shales. In very similar stratigraphic position, INA-Naftaplin has discovered oil show in Glamoč-1 well which now belongs to the territory of Bosnia and Herzegovina. Oil shows and oil traces were recognized in RK-1 (12 horizons) within sabkha deposits of Albian-Cenomanin age in younger stratigraphic Cretaceous interval. Within the same interval, significant oil quantities with H_2S shows which have developed from anhydrite sequence were obtained in NIN-1 and RK-3 wells. Very often asked question is why greater quantities of commercial oil have not been determined in this area. Along with other issues, the following descriptions provide possible explanation for certain

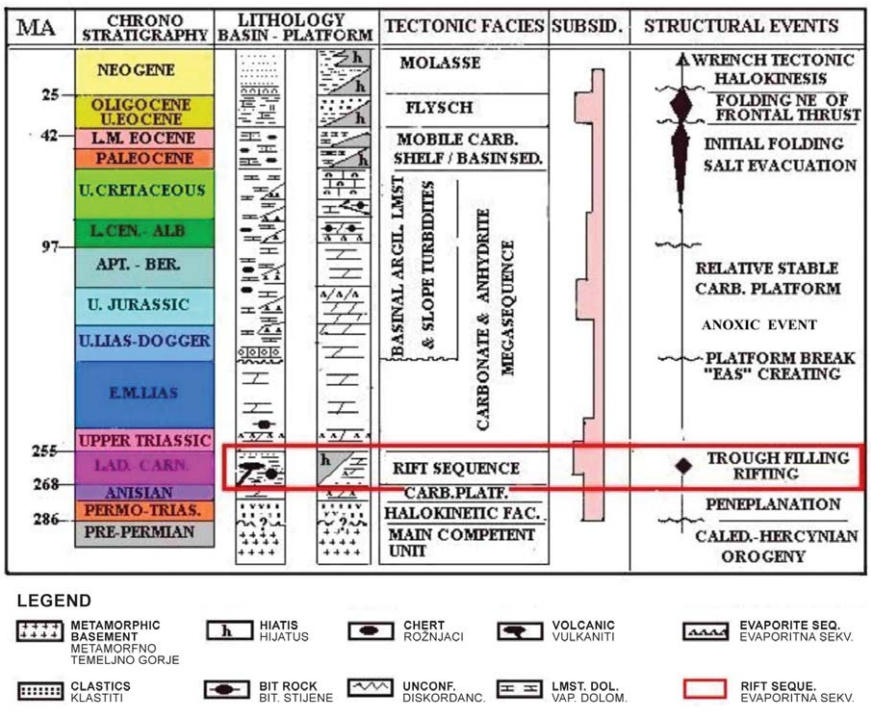

Fig. 2. Synthetic table describes main stratigraphic members and events on Dinarides carbonate platform which are going to be mentioned hereinafter. Ladinian-Carnian potential source rocks are marked by red frame.

Sl. 2. Sintetska tabela označava glavne stratigrafske članove i događaje na Dinarskoj karbonatnoj platformi koji se spominju u daljnjem tekstu. Ladiničko-karničke potencijalno matične stijene označene su crvenim okvirom.

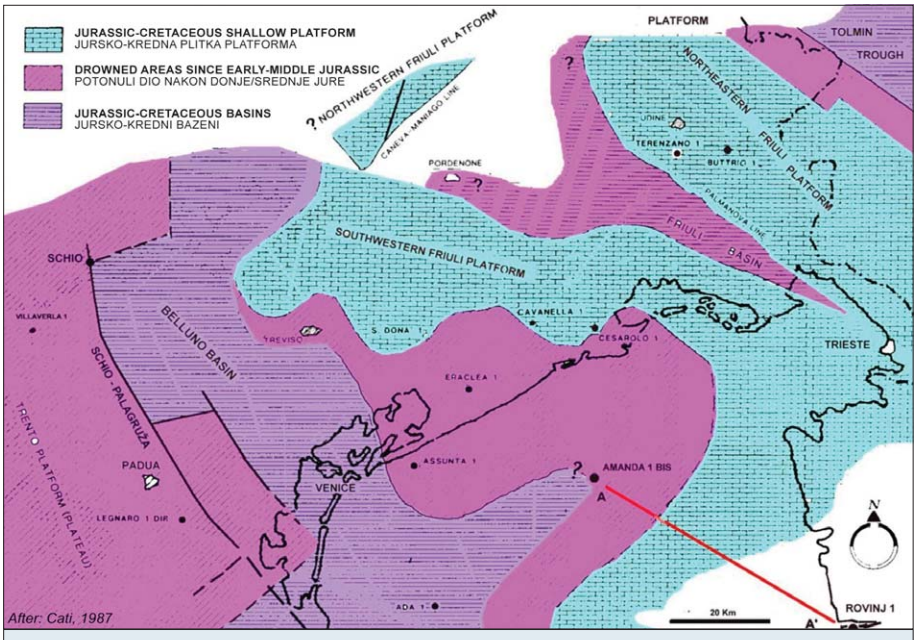

Fig. 3. Spreading of Friuli Platform in relation to Istrian Platform as a western continuity of Dinarides Platform is prsented. Schio litospheric fault at the western margin of Friuli Platform on the way to Belluno Basin is marked according to Zampieri.[13]

Sl. 3. Prikazano je prostiranje Friulijske platforme u odnosu na Istarsku platformu kao zapadni nastavak Dinarske platforme . Naznačen je prema Zampieriu[13] litosferski rasjed Schio na zapadnom rubu Friulijske platforme na prijelazu u bazen Belluno.

petroleum-geological relations of certain stratigraphic intervals and geological event as presented in Fig 2.

2. FRIULI PLATFORM CLASTICS

Regarding the regional spreading of periplatform clastics, they shall be described and illustrated in the neighboring area of Friuli Platform which is genetically related to the Dinarides carbonate platform. This genetic bond is clearly visible in Fig 3 on the paleogeographic cross section A-A' which spreads from Cesarolo-1 well at the very margin of the platform toward Ada-1 in the Adriatic, i.e. Belluno Basin.

The mentioned paleo-geographic cross section clearly shows the relation of platform margin toward the Adriatic Basin. On platform margin, organogenic rudistic and ellipsactinians limestones prevail. In the direction of basin they become basinal resedimented limestones of Socher formation. Pelagic sediments of Majolica and Scaglia type are sedimented further toward the central part of the basin. However, it is necessary to mention that within the whole distance from Cesarolo-1 well to Ada-1 well which is around 70 km, the described sediments were not tested by hydrocarbons drilling. In description of the localities south of Istria as e.g. KM-1, Jelena-1 and Maja-1 wells, it is pointed out that also in other places, periplatform slope deposits were not the subject of exploration. Within two wider areas of Venetian Bay, there are no confirmed depocenters as units from which hydrocarbon migration could have been possible. Along the entire margin of Friuli Platform, where 15 wells were completed, the exploration was directed only to platform margin. The exception was Amanda well where bituminous deposits interval of Forni formation of Rhaetian age was determined.

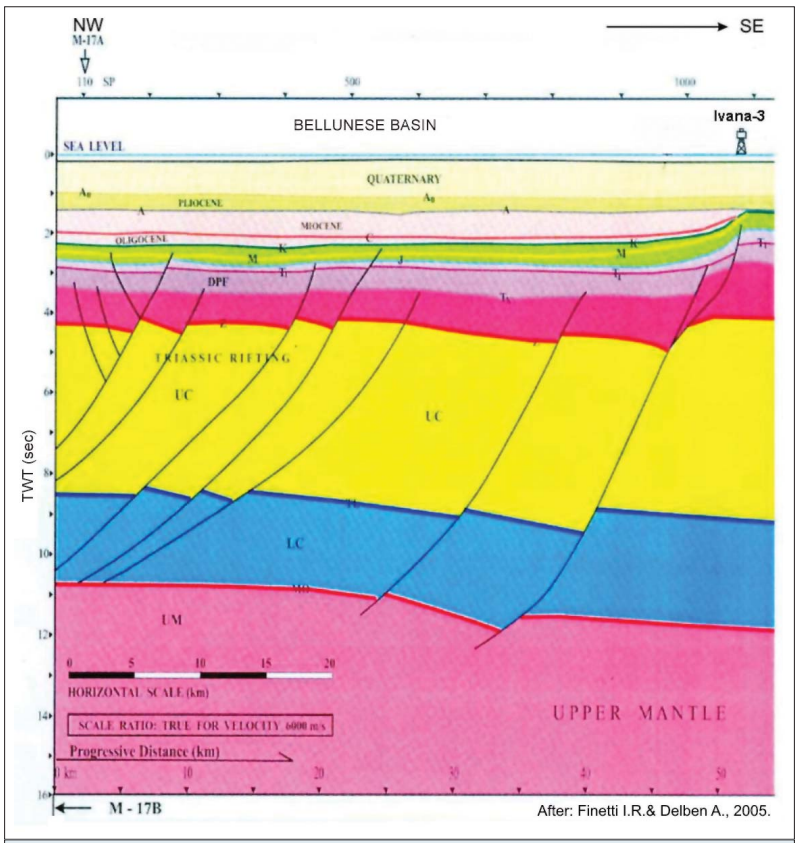

Fig. 4. This figure clearly shows that Istrian platform slope has developed during post Upper Liassic "fracturing" of Dinarides carbonate platform. This fracturing was genetically related to Lower Triassic rifting and peri-Mediterranean platforms that spread from Karpatian and Alps to Atlas and were situated in the top of MOHO horizon.

Sl. 4. Na ovoj slici jasno se razabire da je padina Istarske platforme nastala tijekom postgornjolijaskog 'razlamanja' Dinarske karbonatne platforme. Ovo je razlamanje bilo u genetskoj vezi sa starijim trijaskim riftingom i perimediteranskmi platformama koje su se prostirale od Karpata i Alpa do Atlasa a nalazile su se u krovini horizonta MOHO.

3. ISTRIAN PLATFORM SLOPE

Seismic interpretation of cross section CROP 17b (Fig. 4) according to Finetti and Delben (2005) confirms author's previous assumptions about the relation between formation of platform slope and deep tectonic faulting that occurred in deep basement below Ivana-3 well.

The influence of deep tectonics in Ivana-4 and Ivana-4 A wells is visible also in the shallower parts of seismic cross sections, like in J-140-85 cross section. Unfortunately, the uplift developed between two faults was not included in drilling as it was primarily aimed to prove the gas presence in younger Neogene deposits recognized based on seismic anomalies of '*bright spot*' or '*flat spot*'.

IM-3 well offered more data on basement and deposits in the Upper Cretaceous carbonates top. However, neither this well included the upper parts of up-dip clinoforms with good possibilities of structural-stratigraphic trap within Oligo-Miocene and older clastics of Istrian periplatform clastics slope.

Since there was no laboratory research of periplatform clastics reservoir characteristics performed along the entire slope of Dinarides platform, the mentioned example from IM-3 well can be considered as reference data. In any case, the mentioned up-dip clinoforms are recommended for exploration during the upcoming period with previous interpretation of seismic reflexes in the Upper Triassic dolomites basement to confirm the thickness of Forni formation and its possible relation with clinoforms as potential traps in the area between Ivana-4 and IM-3 wells.

4. SLOPE IN KM-1 WELL AREA

Seismic and well data presented in Fig. 7 indicate close relation between southwestern margin of Dinarides carbonate platform and intrusion of salt diapire registered in KM-1 well that lead to inversion of Middle Triassic and Upper Triassic deposits.

In the legend of the mentioned figure, periplatform clastics are marked 'a' as a side

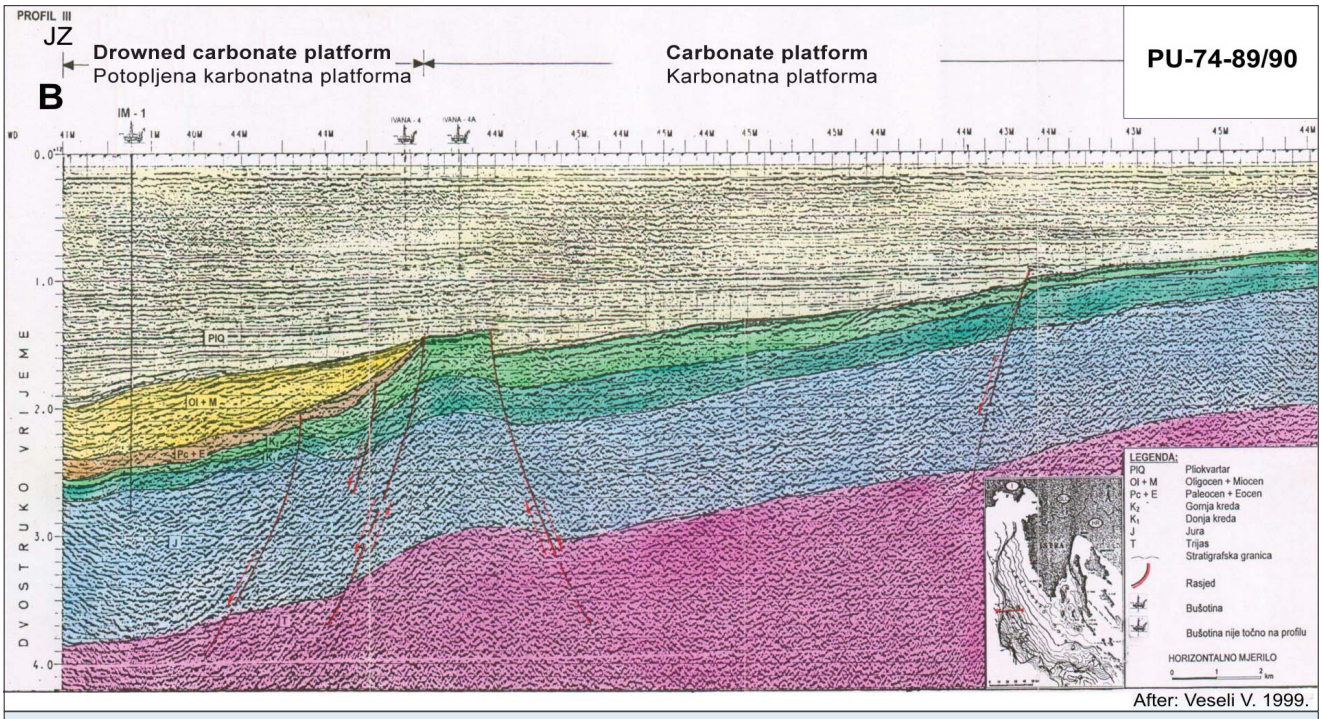

Fig. 5. The cross section shows Istrian carbonate platform deposits pinching out on the location of Ivana-4 and Ivana 4a wells.[10]
Sl. 5. Profil prikazuje isklinjavanje naslaga padine Istarske karbonatne platforme na položaju bušotina Ivana-4 i Ivana 4a.[10]

equivalent to Biancone and Scaglia basinal deposits.

Like on the previous cross section of KM-1 well, also here periplatform clastics represent good potential reservoir rocks which were not yet tested by exploration drilling. Due to the above mentioned, this part of Dinarides platform margin is considered as a potential target of further exploration.

It is assumed that the accompanying salt diapires are related to deep Triassic tectonics like in the other parts of Dinarides platform. As a lineament of Triassic origin, Zampieri's "lithospheric" fault Schio–Adamelo is assumed. Geophysicist Finetti R.[6] has recognized "Triassic batholites" on cross section CROP M17C that in the central part of Adriatic Basin represent the continuation of Adamelo batholites. It is supposed that this batholite zone spreads in the direction of Palagruža island.

5. SLOPE IN JABUKA ISLAND AREA

Seismic cross section D - 10 shows close relation between the slope and Dinarides platform margin. The similar situation was determined on the southwestern side of Jabuka island which is composed of spilites thrown up to the surface by strong halokinetic movements. Capital letter 'R' marks the position of peri-platform clasts as potential reservoir rocks. Diapiric intru-

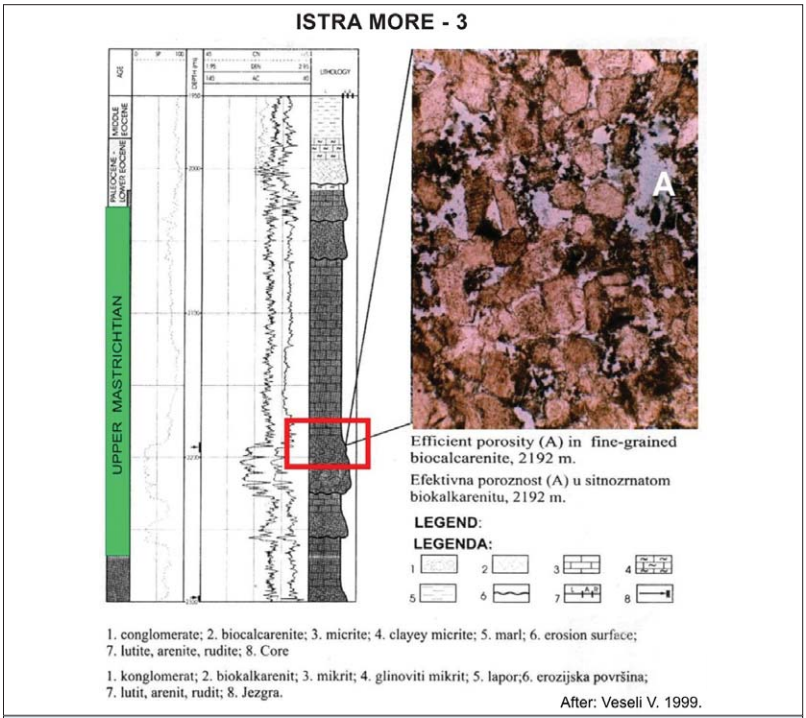

Fig. 6. Micro-photo shot was taken at 2 192 m in Upper Maastrichtian clasics on calcarenite and bio-calcarenite cores from IM-3 well and good reservoir characteristics were determined. In Figure 'A', determined porosity 'p' is 15% and permeability 'P' up to 45 x 10^{-3} μm².
Sl. 6. Na jezgrama kalkarenita i biokalkarenita iz bušotine IM-3 snimljen je mikro-foto snimak na 2 192 m u gornjomastrihtskim klastitima gdje su ustanovljene dobre ležišne karakteristike. Na slici 'A' ,poroznost 'p' utvrđena je 15% a permebilnost 'P' do 45 x 10^{-3} μm².

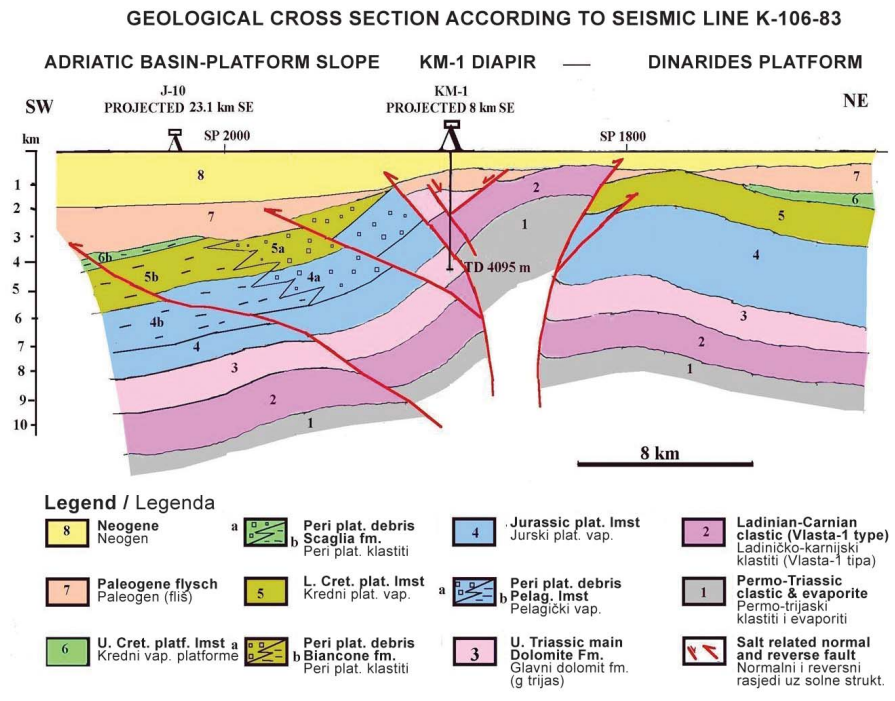

Fig. 7. The show of diapiric intrusion in KM-1 well proves the tight connection between Dinarides carbonate platform margin and halokinetic movements that were probably caused by reactivation of older Triassic faults.

Sl. 7. Prikaz dijapirskog proboja u bušotini KM-1 dokazuje na usku povezanost ruba Dinarske karbonatne platforme i halokinetskih pokreta koji su vjerojatno uvjetovani reaktiviranjem starijih trijaskih rasjeda.

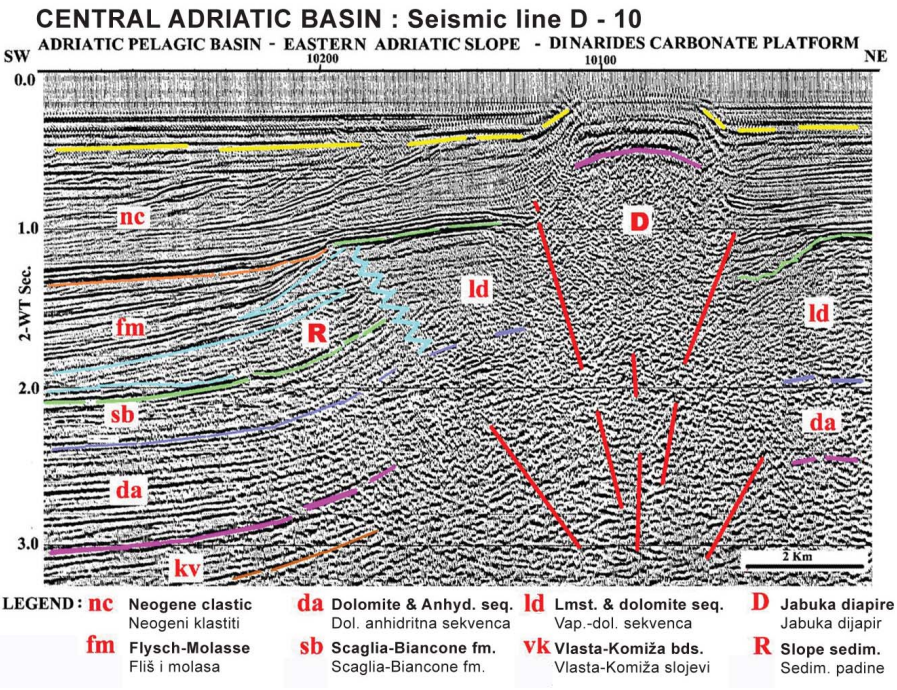

Fig. 8. Interpretation of D-10 seismic cross section illustrates, like in previous example, the relation between platform margin and halokinetic movements.

Sl. 8. Interpretacija seizmičkog profila D - 10 ilustrira kao i u prethodnom slučaju povezanost ruba platforme i halokinetskih pokreta.

sion 'D' was uplifted next to diabase fragments and the youngest deposits of Neogene age.

On the cross sections J-22-82 and J-22A-82 there is an "antiform" structure at SP 800 where exploration was performed on Jelena-1 location. 'Biancone and Scaglia' deposits were recognized in this well. Older Burano formation deposits are known for their frequent exchange of salt and anhydrite rocks. Most probably these rocks form Jelena-1 structure core as is the case with the Italian Gargano ME-1 well close to Palagruža island.

In the lowest part shown in the cross section, the presence of synrift bituminous deposits of Vlasta-Komiža type is anticipated as potential source rocks. According to the presented relations, carbonate platform slope deposits, marked by 'sl' symbol are regarded as oil-promising. Also as a promising part of the explored area shown on the map is considered a part between Jelena-1 well and point 1 200 where a tectonically caused hydrocarbons trap is supposed.[2]

According to the relations in this Figure, it is possible to conclude that above Jelena structure there were several uplifts and related emersion and probable degradation of possible hydrocarbon traps. This data leads to conclusion that all geophysically determined uplifts should be thoroughly studied so the structure preservation and spreading continuity of cap rocks could be determined.

6. PLATFORM SLOPE IN MAJA-1 WELL AREA

Seismic cross section L-16-82 which crosses the place where Maja-1 was drilled is one more example where, before drilling, geological interpretation did not take in consideration two intense phases of emersion and erosion. One phase occurred at the end of Lower Cretaceous layers deposition in the basement of Tertiary clastics. The older phase of emersion and erosion occurred,

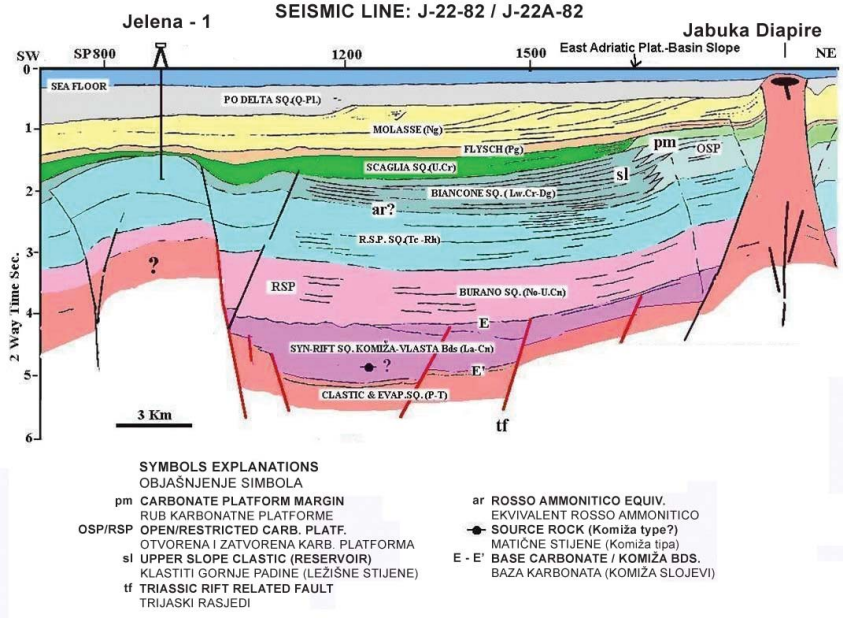

Fig. 9. Promising part of the field as well as total geophysical relations in this part of Dinarides carbonate platform are presented here. Potential source rocks are marked as synrift sequence of Komiža – Vlasta type interpreted in the deepest part between Jabuka intrusion and Jelena-1 structure.

Sl. 9. Prikazan je spomenuti perspektivni dio terena kao i ukupni geološki odnosi na ovom dijelu Dinarske karbonatne platforme. Treba istaći da su potencijalno matične stijene označene kao sinriftna sekvencija tipa Komiža -Vlasta interpretirane u najdubljem dijelu između proboja Jabuka i strukture Jelena-1.

however, in the basement of Upper Triassic dolomites, immediately below Upper Triassic dolomites, Maja-1 well has encountered Verfenian clastics which indicates the lack of Ladinian-Carnian shale. DST testing on the neighboring Vlasta-1 well obtained 2 m^3 of medium heavy oil from this shale.

The mentioned Upper Cretaceous deposits were resedimented into the neighboring sedimentation area and they form potential reservoir rocks like the ones described in IM-3 column and shown in Fig. 6. This complex is marked 'sd' (slope deposits) on the cross section and represents very promising reservoir rocks of regional spreading.

The favorable circumstance is that periplatform reservoir rocks are close to 'Palagruža east' depocenter which is shown on geological model (Fig. 11), i.e. on "time structural map".

The mentioned depocenter in carbonates basement ('E' horizon) shown in Fig. Sl.12. is supposed as oil generating center from where hydrocarbons migration was possible. As marked on the mentioned map, this center is probably in migration related to

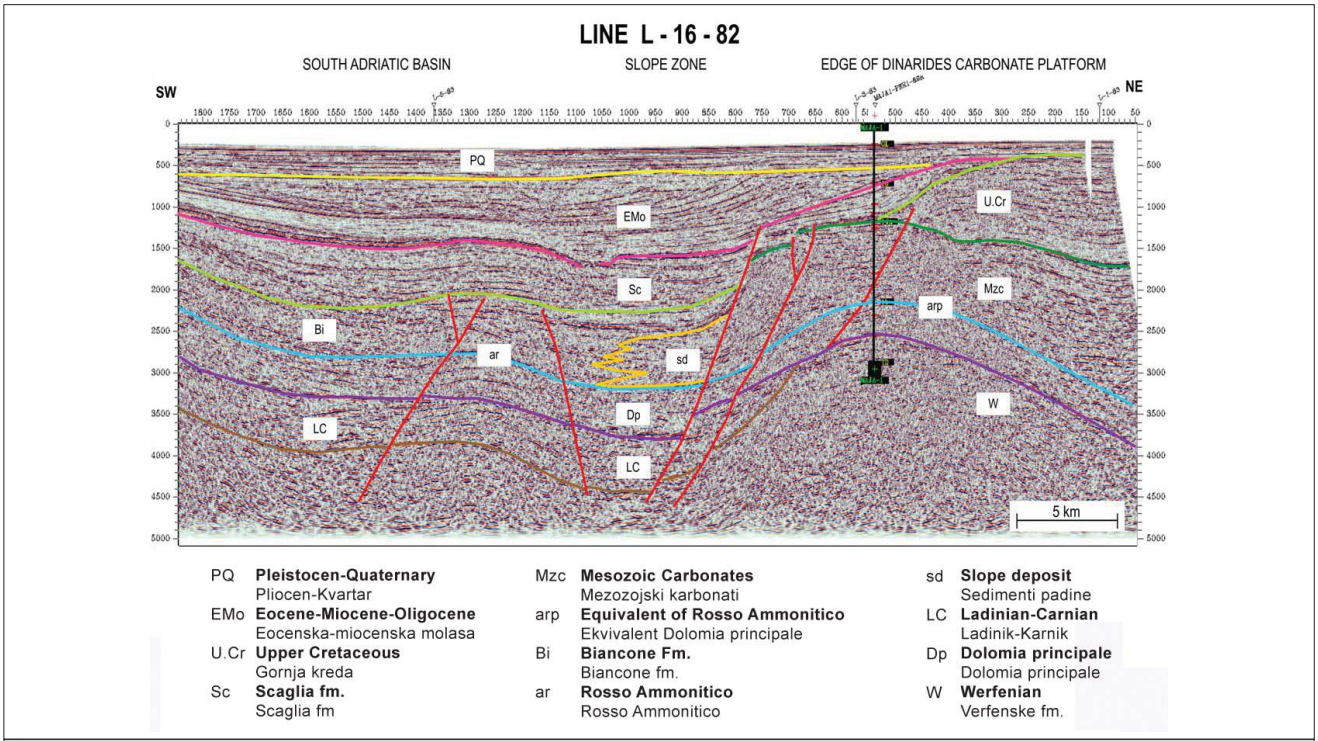

Fig. 10. Seismic cross section l-16-82 clearly shows that erosion has affected around 1200 m of Upper Cretaceous rudist sediments northeast of Maja-1 well.

Sl. 10. Iz seizmičkog profila l-16-82 jasno je uočljivo da je Sl od bušotine Maja-1 erozijom zahvaćeno oko 1 200 m rudistnih sedimenata gornje krede.

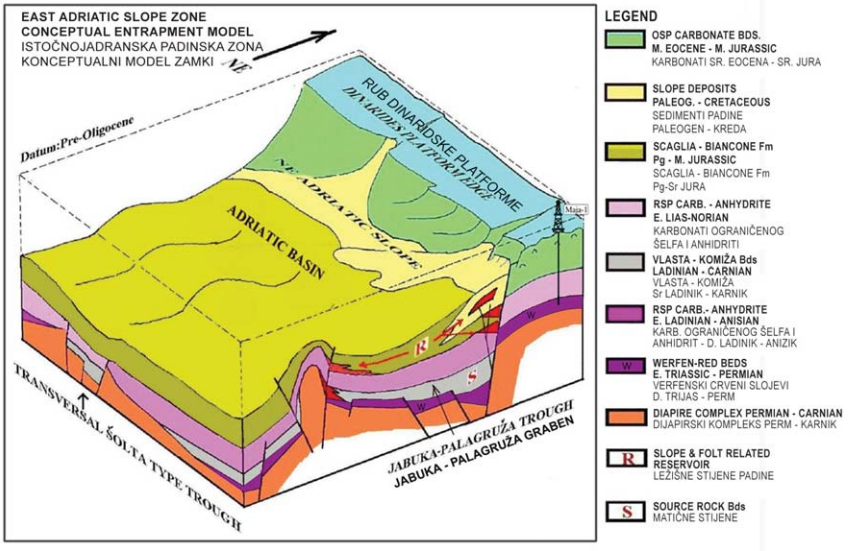

Fig. 11. Geological model in Maja-1 well area represents hiatus in the top Lower Cretaceous sediments and in the basement of Upper Triassic dolomites where Ladinian and Carnian layers are missing. Platform transition into basin is presented and the position of periplatform clastics 'R' in relation to potential source rocks 'S' in the basement

Sl. 11. Geološki model u području bušotine Maja-1 ilustrira hijatus u krovini donjokrednih naslaga i u podini gornjotrijaskih dolomita gdje izostaju ladinički i karnički slojevi. Prikazan je prijelaz platforme u bazen i položaj periplatformnih klastita 'R' u odnosu na potencijalno matične stijene 'S' u podini

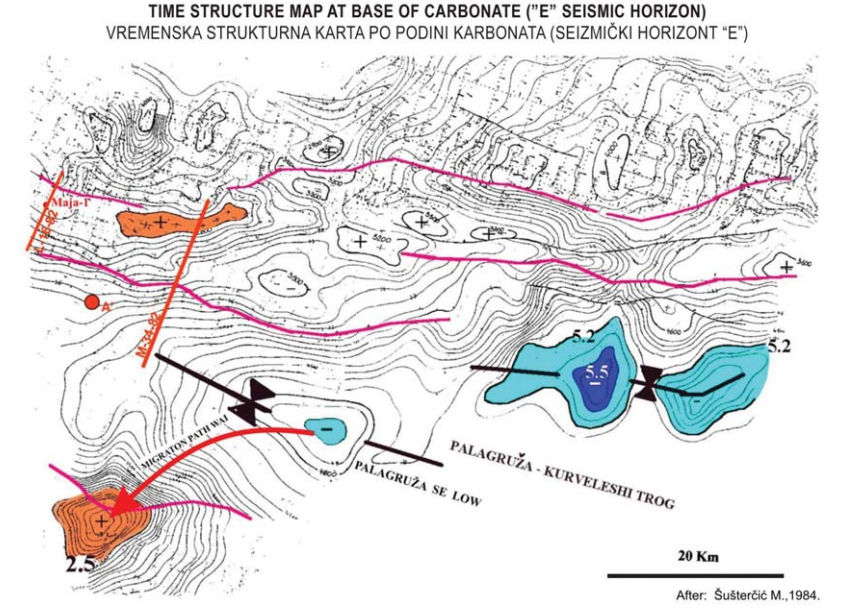

Fig.12. 'Time structural map' of Upper Triassic dolomite basement (seismic horizon 'E'. Depocenters which are lowered to over 5.0 s of seismic two-way time confirm that potential Triassic source rocks are situated below 10 000 m. Maturity diagram was made for point A which is selected in the vicinity of the mentioned depocenter.

Sl. 11. "Vremenska strukturna karta" po podini dolomita gornjega trijasa (seizmički horizont 'E'). Depocentri koji su spušteni na preko 5.0 s dvostrukog seizmičkog vremena potvrđuju da se potencijalne trijaske matične stijene nalaze ispod 10 000 m. Dijagram zrelosti izrađen je za točku A koja je odabrana u blizini spomenutog depocentra.

„Kurveleshi trough" of Ionian Basin known for several intervals of potential source rocks. They are also considered as places from where oil generated into oil fields reservoirs near Vlora port.

Burial history for point A which is situated 15 km southeast of Maja-1 well confirmed that Triassic deposits in Palagruža East depocenter are in the phase of early to complete maturity. The mentioned point A is shown in Fig. 12 southwest of Maja-1 well.

7. PLATFORM SLOPE IN JJ-3 WELL AREA

As shown in Fig.13., on seismic cross section Y-80-10 southwestern margin of Dinarides platform, there is a highly expressed structural uplift of Upper Cretaceous carbonates from which medium heavy biodegraded oil has been determined. It is supposed that high quantity of periplatform clastics as potential reservoir rocks was sedimented on considerably steep platform slope. Very significant is comparison of this structure with neighboring Rovesti field where big quantities of commercial oil were discovered in 2007.

In the mentioned Rovesti field, which is situated in Brindisi offshore area around 170 km southwest of JJ-3 well, the discovery occurred not at the top margin of the Apulian platform but in its basement below Bisciario formation of Lower Miocene age. These deposits overlie the oil bearing rocks of Scaglia formation of Upper Cretaceous age. Column of tested oil bearing layers is around 170 m. This is oil with 850 kg/m^3 (API 35°), density, thus this is medium light oil which was the reason that Northern Plc. company took concession on the area of around 750 km^2 in the offshore area of Bar and Brindisi area.

The mentioned data clearly confirm author's predictions that exploration drilling would be perspective and successful in Croatian offshore under the same geological conditions at the sea depth of around 800 m, considering that drilling on Rovesti structure was performed at the sea depth of 937 m, thus deeper than 800 m on the basinal side of JJ-3 structure.

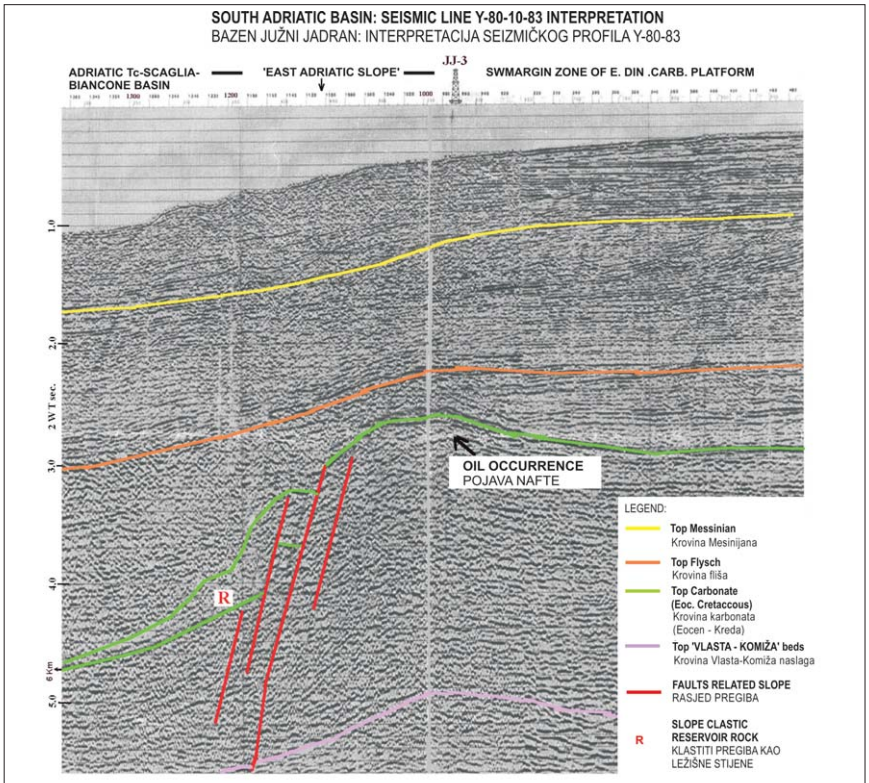

Fig. 13. Interpretation of the showed seismic cross section clearly indicated the intense sinking along the faults southwest of JJ-3. Periplatform clastics are marked by symbol 'R' and can present reservoir rocks and hydrocarbon trap for hydrocarbons from Adriatic-Ionian Basin source rocks.

Sl. 13. Interpretacija prikazanog seizmičkog profila jasno ukazuje na intenzivno spuštanje uz rasjede JZ od bušotine JJ-3. Periplatformni klastiti označeni su simbolom 'R' i mogu predstavljati ležišne stijene i zamku za ugljikovodike iz matičnih stijena Jadransko-Jonskog bazena.

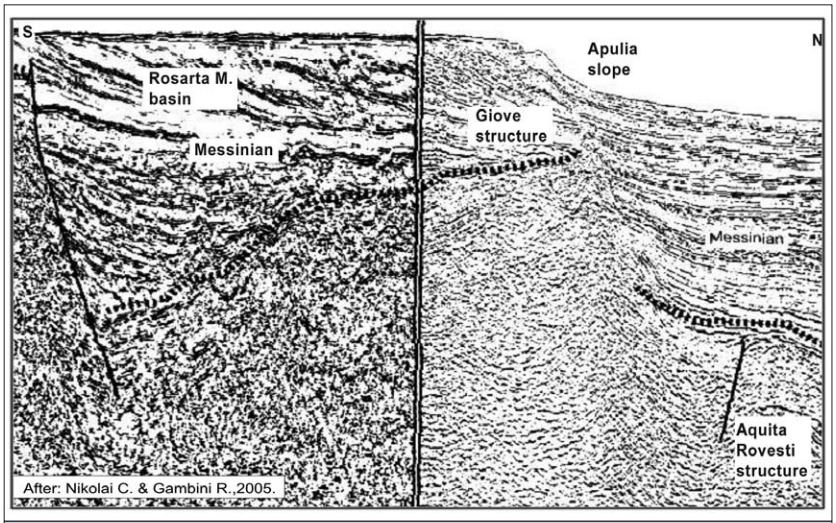

Fig 14. This figure presents that unlike the previously described JJ-3, drilling on Rovesti structure was performed like on Aquila reservoir in the slope basement where basinal sediments of Scaglia formation type prevail.

Sl. 14. Na ovoj slici ističe se da je za razliku od ranije opisane strukture JJ-3, bušenje na Rovesti obavljeno kao i na ležištu Aquila u podnožju pregiba gdje prevladavaju bazenski sedimenti tipa formacije Scaglia.

8. APULIAN PLATFORM SLOPE NEAR ROVESTI FIELD

For the sake of comparison, Fig. 14. shows geological model of Rovesti structure where commercial oil quantities were discovered. The intention is to point out the possibility of determining possible potential oil reserves in appropriate geological conditions in Croatian offshore. According to the above mentioned information given by Northern Plc. company, 33.56 MMbbl (3.94 million m^3) were determined. Interpretation of petroleum-geological relations in Rovesti structure was presented according to work of Nikolai C.[9]

Productive interval in these deposits on Rovesti - 1 is 170 m, while the drilling started at the sea depth of 970 m.

The similarity with geological relations along Dinarides plafrom is visible in žWell-1' well which is situated on the slope of Apulian platform closer to Gargano island.

9. CONCLUSION

In accordance with petroleum-geological conditions described and illustrated in previous chapters, it is possible to conclude that Croatian offshore and especially periplatform deposits offer very good possibilities for the discovery of oil and gas commercial quantities.

The author gave a lecture on the mentioned possibilities on January 29, 2009 organized by Petroleum Scientific Council, Section for geology, geophysics and geochemistry of Croatian Academy of Sciences and Arts and Croatian Association of Petroleum Engineers and Geologists (HUNIG).

10. ACKNOWLEDGEMENTS

I would like to thank grad. eng. M. Sušterčiću and MSc. S. Kolbah for allowing me the use, with minor changes, of their enclosures which is noted on certain figures. I would also like to thank MSc. Niko Dalić, President of Croatian Geological Association for his support and DSc. Uroš Barudžija, new secretary of HGD for introductory word before lecture and grad. eng. Željko Krušlin for organizing the lecture. Especially I would like to Prof. DSc. Josipa Velić for her constructive review and professional and linguistic improvements of this paper. I would also like to thank my colleague grad. eng.

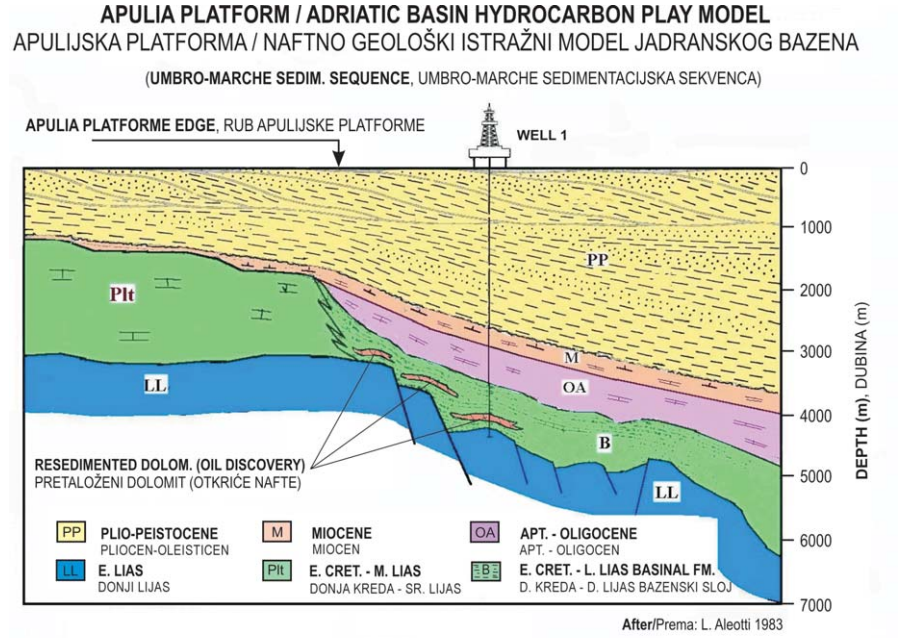

Fig.15. Significant oil show was determined in resedimented dolomites (dolstones) of Albian age.

Sl. 15. U pretaloženim dolomitima (dolstonima) albske starosti utvrđena je značajna pojava nafte.

Vesna Dević for her great help in computerized-graphical editing of certain figures.

11. REFERENCES

1. Aleotti.L. and Marini, L.: Integration of Well and Seismic Data for studying Carbonate Reservoir. Proceedings from the 55 Meeting of the EAEG, Stavanger Norway. 1993.
2. Babić K.: Tektonika kretanja i solne strkture u području Vis-Biševo-Sušac. Magistarski rad. Prirodoslovno-matematički fakultet Svečilišta u Zagrebu. 1990.
3. Bosellini, A. and Stefani, M. :The Rosengarten, a platform to basin carbonate section (Middle Triassic, Dolomites, Italy).Dolomieu Conference on Carbonate Platform and Dolomitizaton, Guide Book, Field Trip C. 1991.
4. Carulli G.B.: Stratigraphy and Geochemical Characterization of the Middle Triassic-Carnian Sequence of the Lumei Valley (Carnia, Northern Italy). 1993.
5. Cati, A.,Sartorio,A. and Venturini,S. :Carbonate Platforms in the Subsurface of the Northern Adriatic area. Mem.Soc.Geol.It., 40 ,295-308.1987.
6. Finetti I.R. and Delben, A.: Lithosferic Tectono-Stratigraphic Setting of the Ligurian Sea-Northern Apennines –Adriatc Foreland from Integrated CROP Seismic Data ELSEVIR B.V. 2005.
7. Grandić S. and Veseli V. : Hydrocarbon potential of Dugi Otok basin in offshore Croatia. Nafta, 53 (6-7) 215-224 (2002).
8. Grandić S.: Review of the hydrocarbon plays in the Croatian offshore and Periadriatic areas. Nafta, 58 (3) 146-158 (2007).
9. Nikolai, C., and Gambini R.: Structural architecture f the Adria platform basin system. Boll.Soc.Geol.It.Spec Isue, No 7 (2007) pp.21-37, 15 figs (2005).
10. Veseli V.: Facijes karbonatnih sedimenata mlađeg mezozoika i paleogena u pučinskim bušotinama sjevernog Jadrana. Disertacija, RGN fakultet Sveučilišta u Zagrebu. 1999.
11. Velić, I.,Vlahović. I. and Matičec, D.: Depositional sequences and paleogeography of the Adriatic carbonate platform. Memorie della Societa Italiana., 57, 1, 141-151, 2002.
12. Vlahović I., et al. Evolution of the Adriatic Carbonate platform: Paleogeography, main events and depositional dynamics. Elsevir –3Paleo. 2005.
13. Zampieri D.: Tertiary extension in the southern Trento Platform,Southern Alps,Italy. TECTONIC VOL.14, NO 3.pp 645-657. 1995.

❖

Author:
Sanjin Grandić, Retired graduated engineer of geology.
Viktora Kovačića 14, 10010. Zagreb, Croatia.
E-mail: sanjin.grandic@gmail.com