Peri-Adriatic platforms Proximal Talus reservoir potential (part 1)

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ORIGINAL SCIENTIFIC PAPER

This paper is a sequel to the Study on Peri-platform Clastics and their Petroleum-Geological Significance.18 The synthesis was made of all the contributions provided by Croatian and Italian colleagues. Ivan Kratković has interpreted 12 seismic profiles through Dinarides carbonate platform slope where proximal clastics were developing while the preliminary interpretation of 3D 1120 seismic line was made by Davorin Balić. Data on potential source rocks maturation were taken from the work of Slobodan Kolbah. Vladimir Veseli, Ph.D, presented the data on porosity and permeability of potential reservoir drilled cores while the calculation of possible recoverable reserves was made by Igor Rusan, thus this paper can be considered as a result of team work. Professors Scandone and Etta Patacca from the University of Pisa, Luca Aleotti from Eni and Ana Del Ben from the University of Trieste were kind enough to provide data for comparing Croatian and analogue geological models with Italian oil fields along the eastern Adriatic coast. Luca Aleotti and Ana Del Ben gave lecture on April 13, 2005 organized by HAZU (Croatian Academy of Sciences and Arts) where they presented the perspective of periplatform clastics (proximal talus). Unfortunately, due to confidentiality, porosity and permeability data for several Italian localities with development of proximal clastics were withheld.

In previous papers it was stated that proximal talus zone, which spreads along the entire Dinarides carbonate platform, is the biggest exploration unit in Peri-Adriatic area. Its length of approximately 550 km, as well as vicinity of Palagruža depocenters and potential generation and expulsion centers from potential source rocks of Vlasta-1 type, confirm the obvious potential of proximal talus zone. According to JJ-A maturation diagram presented in Figure 28 near Palagruža depocenter prepared by S. Kolbah, the mentioned deposits were lowered below 10 000 m which can be considered sufficient for maturation of euxinic deposits with the organic content of over 4% determined in Vlasta-1 well, were oil was discovered in 430 m thick Carnian deposits at the depth of 5 402 m.

Very significant petroleum-geological characteristic of the whole considered Peri-Adriatic area is the coverage of proximal talus by Paleogene flysch and Post-Messinian clastics of considerable thickness.

Special positive characteristic is inter-fragmentary porosity and permeability of talus presented in microscopic photograph of the core from IM-3 well. It is presented in bluish color in Figure 10 as described in the paper "Possibility of Hydrocarbon Commercial Discovery in External Dinarides in the Adriatic Basin."[18]

The time of potential migration is also important. It should be related to main structural-sedimentological events in the considered area such as tectonic movements: Late Kimerian in Upper Jurassic, Austrian in Lower Cretaceous, Pyrenean during Eocene, Sava at the beginning of Neogene when Alps and Dinarides were formed and during Pliocene and Pleistocene. Impulse migrations were followed also by very young halokinetic uplifting. According to Northern Petroleum Co, the main migration most probably occurred after Middle-Upper Miocene and Post-Pliocene.

Key words: Proximal Thalus, hydrocarbon generation and expulsion centre

INTRODUCTION

Proximal talus zone of Dinarides carbonate platform in the Adriatic offshore represents our biggest exploration unit spreading from Savudrija in Istria to Oštri Rt at the entrance to Boka Kotorska Bay in its length of 550 km, Figure 1.

Numbers framed in red indicate Croatian localities studied in previous papers of NAFTA scientific-professional journal while the blue ones show Italian localities[19]. Proximal talus platform zone, SW of Mirjana-1 well is 9400 m wide with maximal thickness of 1 750 m with possible reserves amounting to 13 365 439 m^3 according to I. Rusan. One of the key data for evaluation of petroleum-geological potential is proximal talus zone, i.e. porosity and permeability of these deposits. There is only one such data regarding IM-3 well, where well core was laboratory tested, yielding the results of 14% for porosity and good permeability of 845 $x10^{-3}\mu m^2$. However, proximal talus on IM-3 well was tested only on its apical part where those deposits completely wedge out. As there were no other wells drilled within this zone, this data was accepted as reference. We are in the process of asking the Italian company Eni to give us some of their published data regarding permeability and porosity. We are also expecting data on collector characteristics of proximal talus (peri-platform clastics) from A. Delben from the University of Trieste.

Estimate of possible recoverable maximal reserves of 457.68 million m^3 with probability of 14.5% (Fig. 37) was made on presented 2D seismic cross sections and on one 3D cross section which was presented at the International Conference in Šibenik in 2010. The presentation was made by INA expert Igor Rusan. These values shall probably be changed after additional seismic survey.

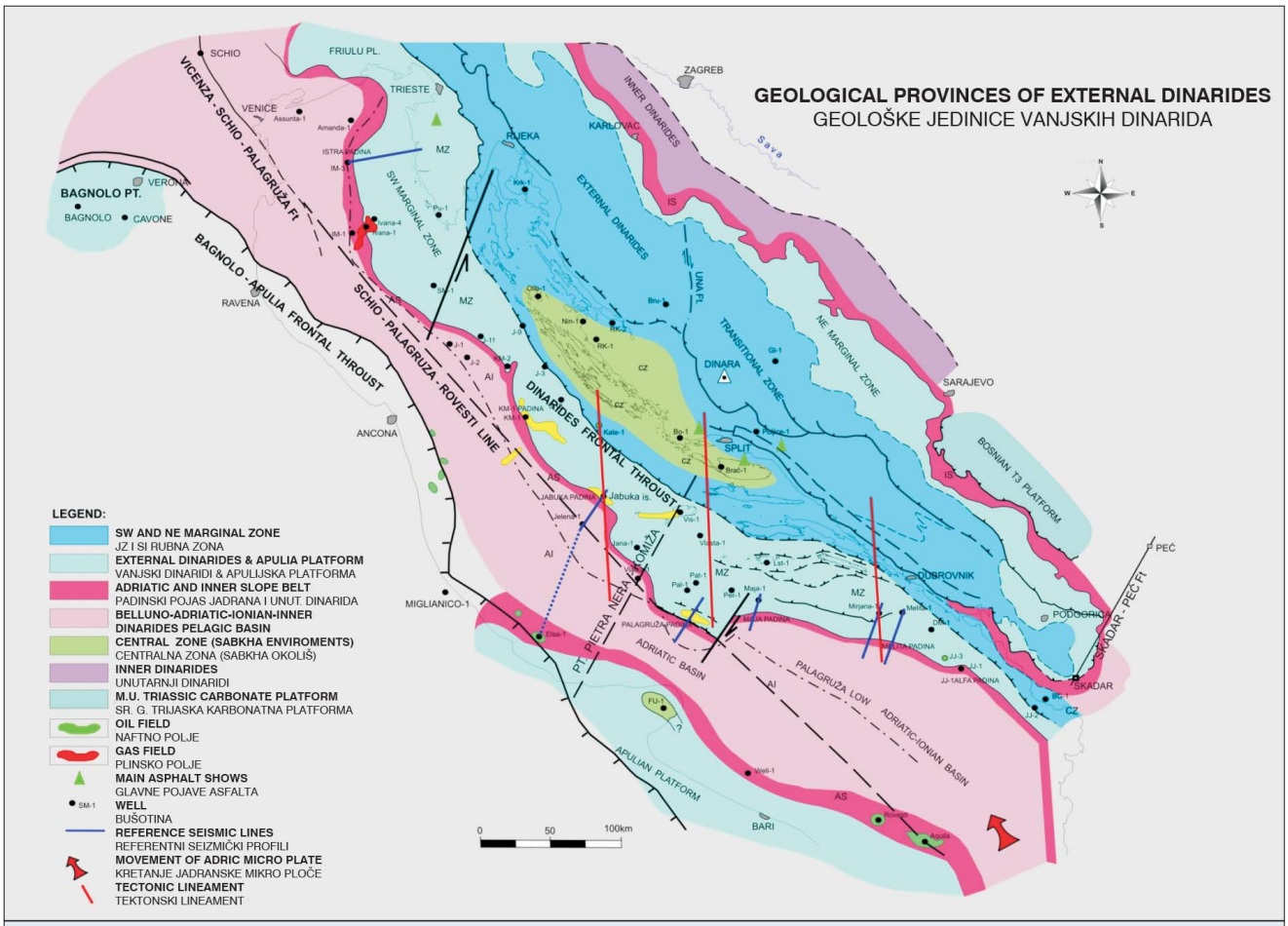

Fig. 1. **This map of geological units shows External Dinarides, Adriatic Basin and Italian and Croatian Peri-Adriatic units. Croatian and Italian zone of proximal talus is presented by narrow red-brown belt. Red lines present tension faults developed by movement of Adriatic micro plate toward the Alps. Determining the reservoir characteristics of this zone represents also one of major economy tasks. The mentioned zone spreads parallel to proximal talus zone on the Italian side where oil was discovered as in Well-1 well (Fig. 18) as determined by L. Aleotti who has also studied proximal talus in the Adriatic Basin area. On Well-1 location, oil was recognized in Alb-Cenomanian resedimented dolomites. The cross section interpreted by P. Scandone & E. Patacca shows clearly the transition of Gargano Platform into the Adriatic Basin, (Figure 26).**

Sl. 1. Na ovoj karti geoloških jedinica prikazani su Vanjski Dinaridi, Jadranski bazen te talijanske i naše peri-jadranske jedinice. Naša i talijanska zona proksimal talusa prikazane su uskim crveno smeđim pojasom. Crvenim linijama naznačeni su "tenzioni rasjedi" nastali kretanjem jadranske mikro-ploče prema Alpama. Utvrđivanje ležišnih odlika ove zone predstavlja sukladno tome jedan od prvorazrednih privrednih zadataka. Spomenuta zona proteže se paralelno sa zonom proksimal talusa na talijanskoj strani, gdje je otkrivena prisutnost nafte, kao na bušotini Well-1 (sl. 25), kako je to utvrdio L. Aleotti, koji je također izučavao proksimal talus u području jadranskog bazena. Na lokaciji bušotine Well-1 nafta je utvrđena u alb-cenomanskim pretaloženim dolomitima. Na geološkom profilu koji su izradili P.Scandone & E.Patacca prikazan je vrlo dobro prijelaz Gargano platforme u Jadranski bazen (Sl. 26) .

2. CONCEPT OF PROXIMAL TALUS PETROLEUM-GEOLOGICAL EXPLORATION ON DINARIDES CARBOANTE PLATFORM SLOPE

As the previous "anti-form" concept of exploration did not give positive results, i.e. no commercial oil discovery was made as in the Italian offshore, the possibility of different exploration approach is being considered. Based on performed studies on stratigraphic-structural results, talus concept would be more appropriate. This can be concluded from the data correlation from Jelena-1 well in Croatian offshore with Elsa-1 well in the Italian offshore. This correlation clearly shows that the Italian side of Adriatic Basin was subjected to more intense subsidence while the Croatian side was more affected by uplifting and emersions which contributed to deep destruction of carbonate structures and most probably of possible hydrocarbon reservoirs. Strong unconformity and hiatus in the top of Upper Liassic pelagic limestone are pointed out on Jelena-1 in Fig. 4. Compared to Elsa-1 well, over 1 300 m thick Eocene and Dodger beds are missing, i.e. the time interval of 160 million years.

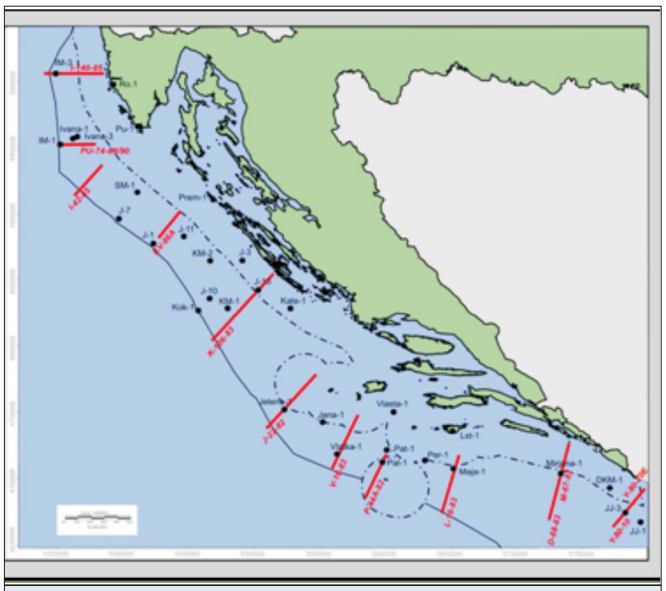

Fig. 2. The map shows 12 interpreted cross sections of the western edge slope of Dinarides carbonate platform that encompass also the proximal talus zone which is a prime subject of consideration in this study. 3D cross section 10 20 is also presented and it overlaps with 2D cross section L-16-83.

Sl. 2. Na preglednoj karti prikazano je 12 interpretiranih profila zapadnog ruba padine Dinaridske karbonatne platforme koji obuhvaćaju i zonu 'proksimal talusa' koja je primarni predmet razmatranja u ovom radu. Prikazan je i 3D profil 11 20 koji se preklapa s 2D profilom L-16-83.

"Janica", "Jelka" and "Julka" prospects are situated SE of Maja-1. Hiatus probably existed on them in Upper Cretaceous, just as is the case with Maja-1 well where most probably the resedimentation of Upper Cretaceous sediments occurred into the Adriatic Basin. At the same time, the destruction of hydrocarbon accumulation probably took place.

Kate-1, Melita-1 and JJ-3 wells are the wells where oil has reached by breaching assuming that the main quantity of accumulation is contained in porous clastics of proximal talus. Oil shows in these wells were considered a confirmation for the existence of major hydrocarbon accumulations in proximal talus zone. Their intrusion through transverse fault system into the inside of edge parts of Dinarides carbonate platform is supposed.

The above mentioned circumstances illustrated in Fig. 4 triggered seeking for new solutions, i.e. defining so called 'talus' concept. Its basic characteristics are illustrated in "concept map" Fig. 4. One of the main concept characteristics is that the hiatus and erosion of carbonate deposits, during Eocene and Upper Cretaceous emersion was compensated by resedimentation of mentioned deposits in proximal talus as effective reservoir rocks of very huge volume. As stated in the summary, hydrocarbon accumulation into proximal talus occurred as follows:

1. Hydrocarbon generation from Upper Triassic deposits source rocks of Vlasta-1 type took place in deep depocenters of Adriatic Basin (in blue).

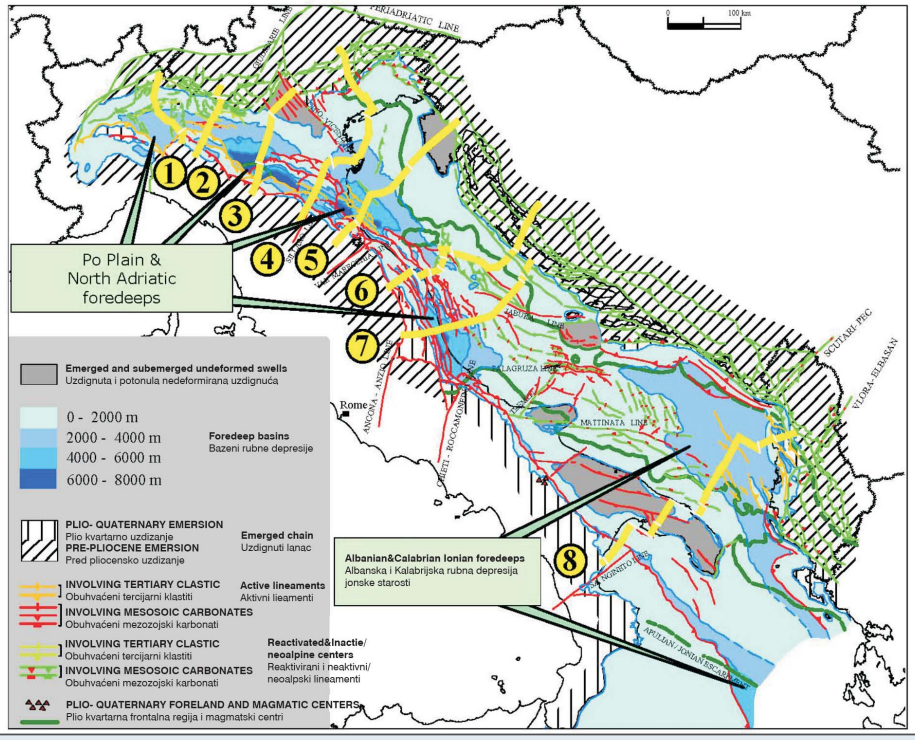

Fig. 3. This map of elevated and sunken parts of the Adriatic Basin shows subsidence along the Italian coast during Plio-Quaternary which probably explains earlier continuous sedimentation (after R. Fantoni and R. Francjosi).

Sl. 3. Na ovoj karti uzdignutih i utonulih dijelova jadranskog bazena tijekom plio-kvartara ističe se jača subsidencija duž talijanske obale što vjerojatno objašnjava i raniju kontinuiranu sedimentaciju. (prema R. Fantoni i R. Francjosi).

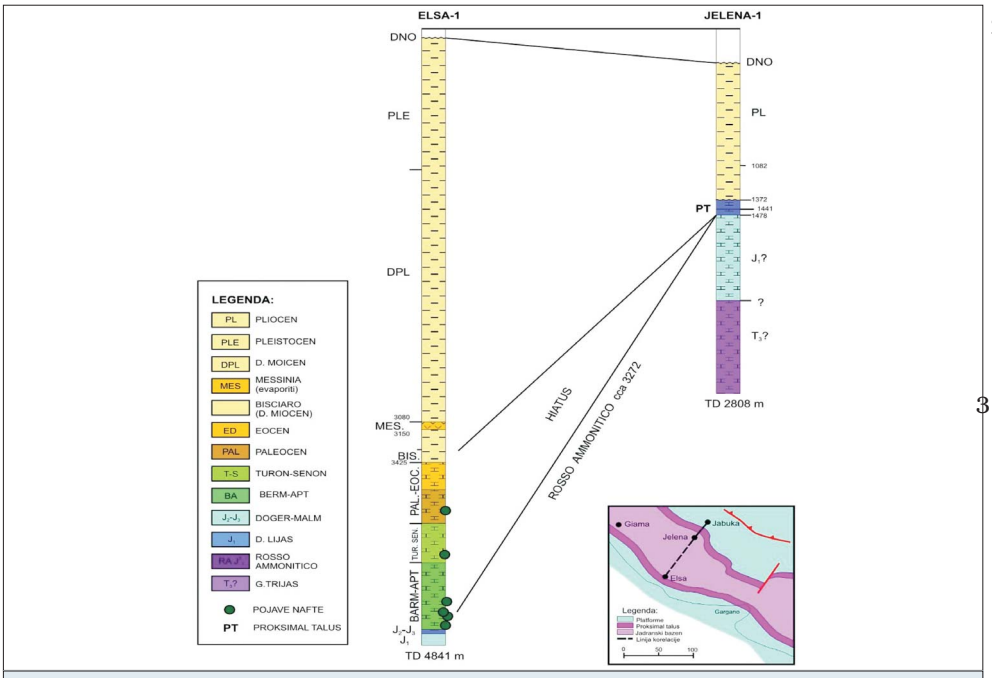

Fig. 4. The presented correlation shows that Miocene clastics directly transgressively overlap Liassic deposits in "rosso-ammonitico" facies in Jelena-1 well. Opposite to that, Miocene clastics in Bisciario facies transgressively overlap Eocene-Liassic carbonates in Elsa-1 well. According to the above, the hiatus in Jelena is around 1 270 m .

Sl. 4. Prikazana korelacija ukazuje da na g. lijaske naslage u facijesu 'Rosso -Ammonitico' na bušotini Jelena-1 neposredno transgrediraju miocenski klastiti. Nasuprot tome na bušotini Elsa -1 miocenski klastiti u facijesu Bisciario transgrediraju na eocensko-lijaske karbonate. Iz navedenog proizlazi da se na Jeleni radi o hijatusu od približno 1 270 m

2. Based on seismic interpretation results SW of Lastovo and Mljet islands, the subsidence of Upper Triassic deposits, i.e. "E" horizon, has reached from 5.2 to 5.5 sec. of two way seismic time which is over 10 km. Despite relatively low geothermal gradient, this should be sufficient for maturation of Upper Triassic euxinic shale.
3. Migration took place up to Dinarides peri-platform fault plate as efficient screen (Fig. 6). Only at the places with transverse faults, hydrocarbons could penetrate deeper into marginal parts of the platform as foreseen on Kate-1, Vlasta-1 and JJ-3 or Melita-1 wells.
4. The mentioned shows in Kate-1,Vlasta-1 and JJ-3 wells are considered as evidence that in the neighboring proximal talus

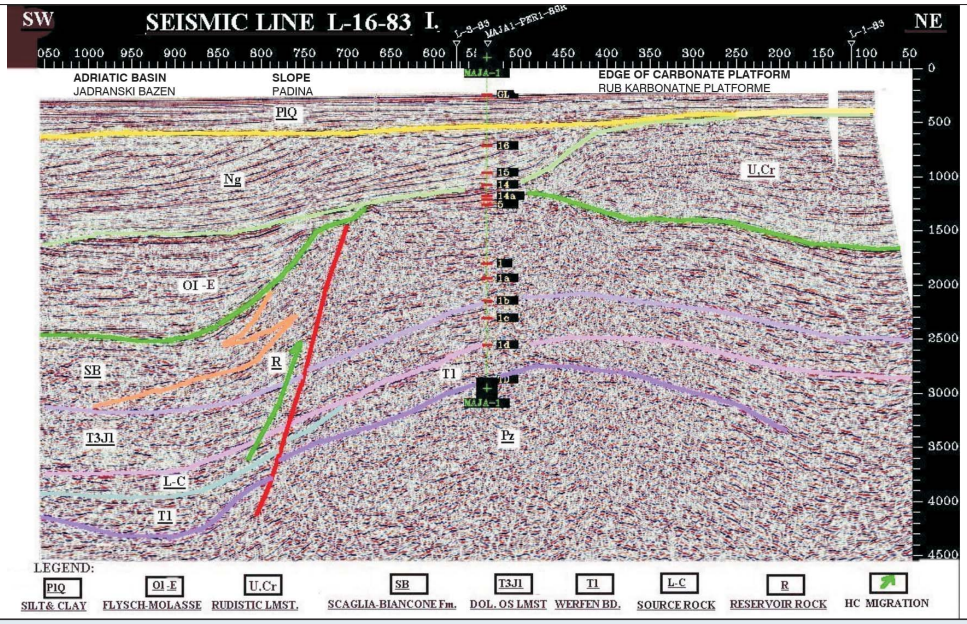

Fig. 5. Seismic line clearly illustrates the resedimentation of Upper Cretaceous deposits (UCri Tc) west of Maja-1 well in the direction of platform and Adriatic Basin slope. However, it should be mentioned that there is no well NE of Maja-1, thus Tertiary clastics were probably sedimented near Upper Cretaceous deposits. It is a reduction of approximately 1 000 m of carbonates resedimented in proximal talus indicated by symbol "R".

Fig. 5. Seismic line clearly illustrates the resedimentation of Upper Cretaceous deposits (UCri Tc) west of Maja-1 well in the direction of platform and Adriatic Basin slope. However, it should be mentioned that there is no well NE of Maja-1, thus Tertiary clastics were probably sedimented near Upper Cretaceous deposits. It is a reduction of approximately 1 000 m of carbonates resedimented in proximal talus indicated by symbol "R".

zone, main hydrocarbon accumulation occurred.

5. According to the above, prospects - leads were proposed in the mentioned talus zone, i.e. within the area where oil was discovered in the mentioned Kate-1, Vlasta.1 and JJ-3 wells.

3. SEDIMENTARY TYPES OF PROXIMAL TALUS

The most common sedimentary type of proximal talus is most probably composed of slope breccia of Beničanci type developed by weathering of carbonate platform edge.

The presented figure shows "Beničanci breccia" from the study made by Croatian sedimentologist J. Tišljar. Although those are breccias in the slope of Miocene carbonate platform in the Pannonian Basin, this model shows identical sedimentary conditions. It was

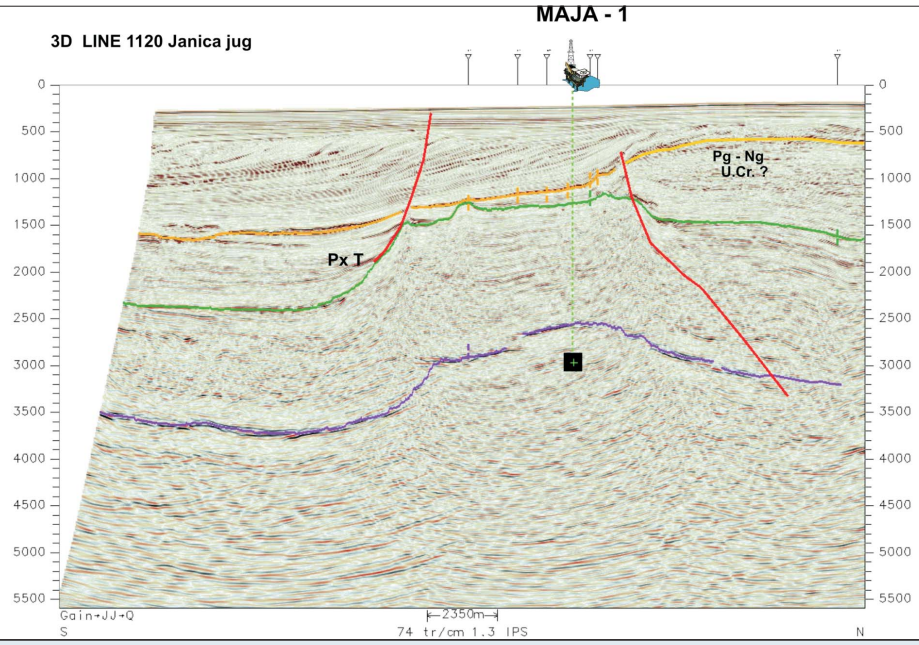

Fig. 6. Presented interpretation of 3D seismic line 1120 after Damir Balić. There is regional platform/basin dislocation as well as one dislocation NE of Maja-1 well where a great thickness of Upper Cretaceous and younger limestone was resedimented into proximal talus as possible reservoir complex. Clinoforms and wedging, as potential traps, can be seen immediately below PxT symbol.

Sl. 6. Prikazana je interpretacija 3D profila 1120, prema Damiru Baliću. Ističe se regionalna dislokacija platforma /bazen, kao i dislokacija SI od bušotine Maja-1, gdje je resedimentirana velika debljina gornjo krednih i mlađih vapnenaca u proksimal talus kao potencijalni rezervoar kompleks. Klinoforme i isklinjenja kao potencijalne zamke mogu se zapaziti neposredno ispod simbola PxT.

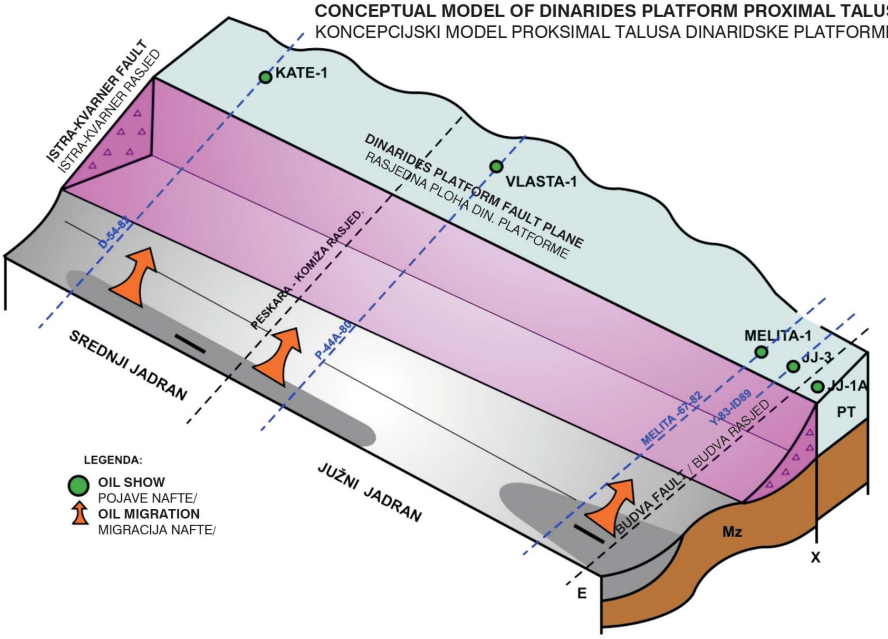

Fig. 7. This schematic model shows basic elements of new "talus" concept. It shows the position of deep "oil generating" centers in the area of Adriatic Basin (in dark gray) where lateral migration into porous sediments of proximal talus is supposed (in pink).

Sl. 7. Na ovom shematiziranom modelu prikazani su osnovni elementi nove ' talusne ' koncepcije. Istaknut je položaj dubokih 'naftno-generativnih ' centara u području Jadranskog bazena (tamno sivo na slici) iz kojih je pretpostavljena lateralna migracija u porozne sedimente proksimal talusa (ružičasto).

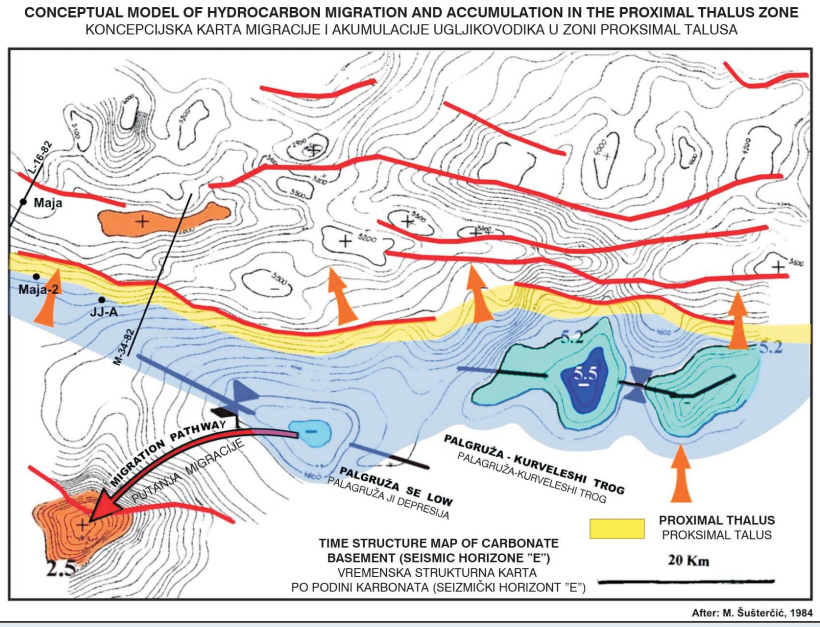

Fig. 8. Spreading of proximal talus on the western slope of Dinarides carbonate platform is indicated in yellow. Arrows show hydrocarbon migrations directions from generative centers (in blue) into porous clastics of talus proximal zone to the fault system on Dinarides carbonate platform slope. Isobaths relate to "E" horizon top, i.e. euxinic shale of Carnian age as regionally known source rocks. The closest depocenter as possible source of migrated hydrocarbons is situated 10-20 km in SE direction.

Sl. 8. Žutom bojom označeno je protezanje proksimal talusa na zapadnoj padini dinaridske karbonatne platforme. Strelicama su prikazani smjerovi migracije ugjikovodika iz generativnih centara (plava boja) u porozne klastite talusne proksimalne zone do rasjednog sistema na padini karbonatne dinaridske platforme. Izobate se odnose na krovinu 'E' horizonta odnosno euksinske šejlove karničke starosti kao regionalno poznate matične stijene. Najbliži depocentar kao mogući izvor migriranih ugljikovodika nalazi se na 10-20 km u smjeru JI.

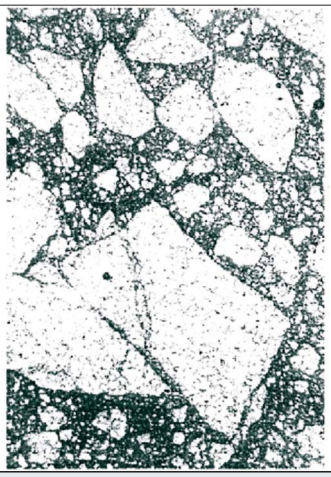

Fig. 9. The most common expected sedimentary type of clastics in proximal talus zone are limestone breccias developed by destruction of edges and slopes of carbonate platforms analogue to Miocene - lilthothamnion platform on Beničanci field. The mentioned breccias on Beničanci field have porosity - permeability up to 1 000x10^{-3}μm².

Sl. 9. Najčešći, očekivani sedimentacijski tip klastita u zoni proksimal talusa su vapnene breče nastale razaranjem rubova i padina karbonatnih platformi, analogno miocenskoj -litotamnijskoj platformi na polju Beničanci. Navedene breče na polju Beničanci imaju porozitet -permeabilnost do 1 000 x 10^{-3}μm².

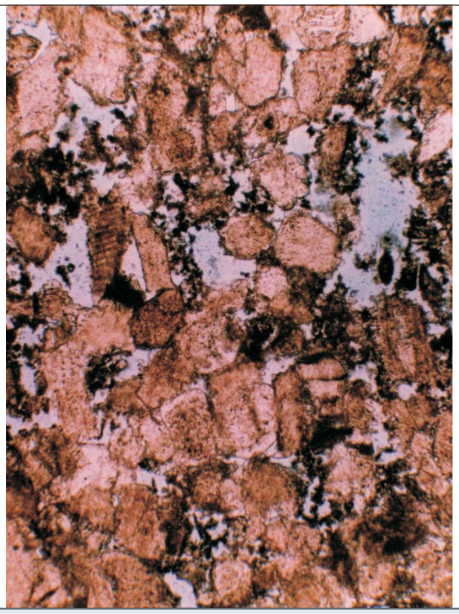

Fig. 10. Micro-photo of core cutting from IM-3 well indicates intragranular porosity (blue). According to the data offered by V. Veseli, porosity of 14% and permeability up to 845x10^{-3} μm² were determined in laboratory.

Sl.10. Mikro fotografija izbruska jezgre s IM-3 ukazuje na inter granularnu poroznost (plava boja). Prema podacima V. Veseli laboratorijski je utvrđen porozitet od 14% i permeabilnost do 845 x 10^{-3}μm².

assumed that peri-platform clastics, i.e. proximal talus that were developed in Dinarides carbonate platform slope were of the same "inter-fragmental" habitus and possibly of the same permeability as the mentioned "Beničanci breccia" described by J. Tišljar in his study.

In case of the stated analogy, peri-platform clastics would represent first rate petroleum-geological potential due to their size and total pores volume. In any case, the conclusion is that this zone should be tested by exploration drilling. Let us hope that the mentioned testing shall not be put on hold for next 25 years as that much time has passed since the last drilling in Dubravka more -1.

As presented in Fig. 13, proximal talus wedges out almost completely. However, due to the fact that apart from IM-2 well there is no other well within proximal talus area, the mentioned data from IM-3 well was accepted as reference for the entire zone from Savudrija to Oštri Rt at the entrance to Boka Kotorska Bay.

4. REVIEW OF PROXIMAL TALUS SPREADING ON PERI-ADRIATIC PLATFORMS SLOPES

4.1. North Adriatic

In geological sense, Friuli platform that spreads to Belluno Basin in the west forms NW continuance of Istrian carbonate platform, i.e. Dinarides big carbonate platform. The review starts with the northern part of Adriatic Basin, i.e. Dinarides platform. Halokinetic intrusion close to its edge, where real proximal talus 6 km wide and 1 000 m thick is real, is pointed out.

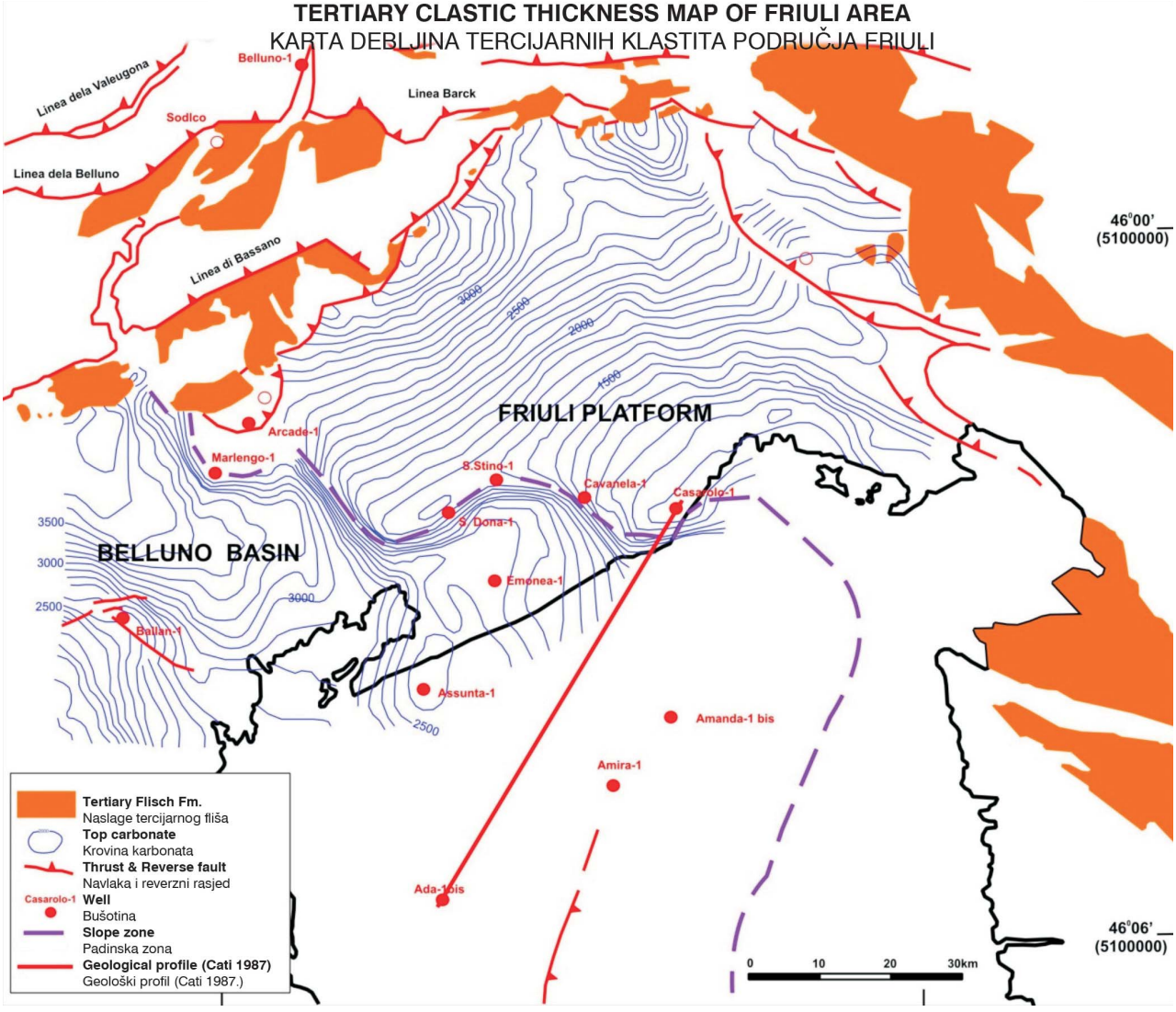

Fig. 11. This figure is chosen to present organic relation between Friuli Platform covered by Tertiary clastics (blue isopachs) and Istrian carbonate platform only partly covered by Eocene flysch (in orange).

Sl. 11. Ova je slika odabrana da predoči organsku vezu Friuli platforme, prekrivene tercijarnim klastitima (plave izopahe) i Istarske karbonatne platforme samo djelomično prekrivene eocenskim flišem (narančasto).

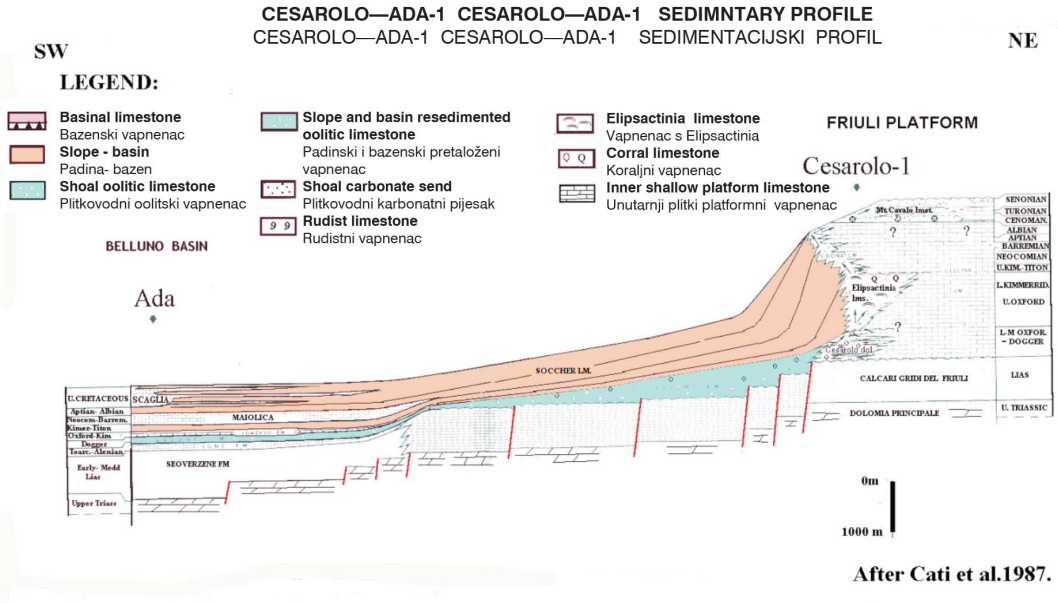

Fig. 12. This sedimentary profile made by Cati, clearly reflects the position of proximal talus and is presented in brown. However, in the promising, upper part of talus in upward clinoforms as favorable traps, no exploration drilling was performed.

Sl.12. Ovaj Cati-ev sedimentacioni profil jasno odražava položaj proksimal talusa označenog smeđom bojom. Potrebno je naglasiti da u perspektivnom gornjem dijelu talusa, u uzlaznim klinoformama kao pogodnim zamkama nije obavljeno niti jedno istražno bušenje.

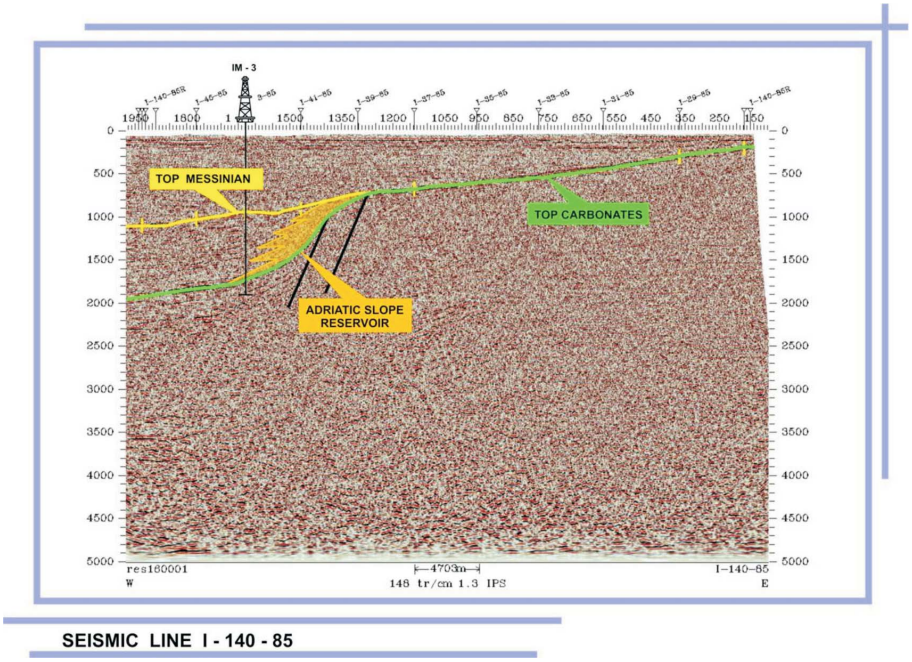

Fig. 13. IM-3 and IM-1 wells were the only wells where proximal talus was drilled in carbonate platform slope. According to laboratory testing, core from IM-3 well has porosity of 14% and permeability of 845x10^{-3}μm2. However the well has encompassed proximal talus at the wedging toward west. Exploration should be focused to the shallower part of line I-140-85, i.e. in the upper part of proximal talus cone where upward traps for possible migrated hydrocarbons are expected.

Sl. 13. Bušotinom IM-3nabušen je proksimal talus na padinama karbonatne platforme. Isto je dobiveno i na bušotini IM-1. Prema rezultatu laboratorijskog ispitivanja jezgara s bušotine IM-3 dobiven je porozitet od 14% i permeabilnost od 845 x 10^{-3}μm^2. Potrebno je međutim naglasiti da je bušotina zahvatila proksimal talus na samom isklinjenju prema zapadu. Istraživanje bi trebalo usredotočiti na plići dio seizmičkog profila I-140-85 odnosno u gornjem djelu konusa proksimal talusa, gdje se očekuju uzlazne zamke za moguće migrirane ugljikovodike.

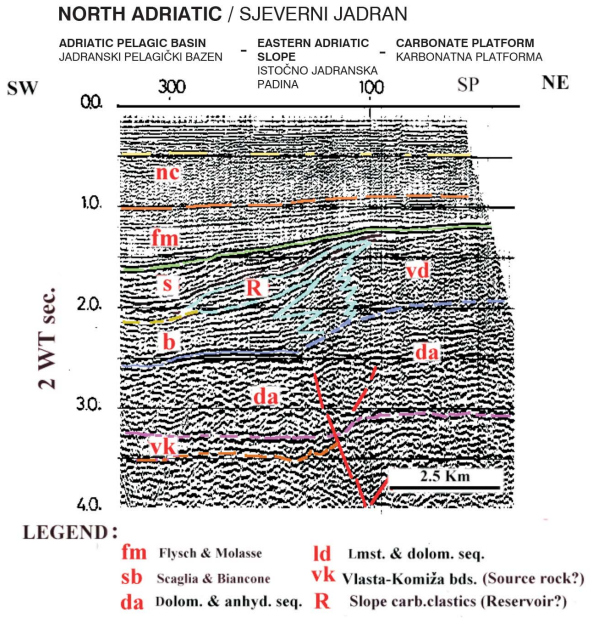

Fig. 14. This seismic profile shows spreading of proximal talus zone as possible reservoir rocks for migrated hydrocarbons from source rocks marked by 'vk' around 7 km west of SM-1. Around 35 km toward SE, there is J-11/1 well with measured porosity of 37% and permeability of 2 112.4x10^{-3}μm2. This well is situated on Dinarides platform edge that was most probably exposed to intense carstification. This exposure to carstification and erosion is present throughout the entire spreading of Friuli platform all the way to furthest SE part of our Dinarides platform.

Sl. 14. Na ovom seizmičkom profilu oko 7 km zapadno od SM-1, prostire se zona proksimal talusa kao mogućih rezervoar stijena za migrirane ugljikovodike iz matičih stijena označenih simbolom 'vk'. U projekciji oko 35 km JI, nalazi se bušotina J-11/1 na kojoj je mjeren porozitet od 37% i permeabilnost od 2 112,4 x10^{-3} μm^2. Radi se o bušotini na rubu Dinaridske platforme koja je najvjerovatnije bila izložena intenzivnoj karstifikaciji. Ova izloženost karstifikaciji i eroziji karakteristična je duž cijelog protezanja od Friuli platforme sve do krajnjeg JI djela naše Dinaridske platforme.

Wells on the southern margin of Friuli Platform that were like Cesarolo-1 with no oil shows are also clearly pointed out.

Without the Italian data from oil fields in western part of Adriatic Basin, it is difficult to summarize reservoir characteristics of this Croatian zone which is 550 km long. In any case, it is possible to assume that those deposits, due to their already mentioned considerable thickness and width, need to be tested by exploration drilling as stated in "recommendations" attached to this paper. Seismic profiles that are transversal to the Dinarides carbonate platform edge, indirectly show the amount of carbonate deposits resedimented in platform edge through abrasion and erosion. One of those profiles is L-16-82 profile through Maja-1 well that clearly shows that Upper Triassic carbonate deposits, i.e. most probably rudist limestone, were almost entirely resedimented.

As there are no reference data, it is possible to conclude that peri-platform clastics, like Beničanci breccia (Fig. 3) can reach permeability of 1 D which is a very big value. Analogy with Beničanci breccia is derived from the fact that they were formed on the edge of carbonate platform.[18] Drilling results from Kate-1 well confirm strong expulsion and hydrocarbon movements that allows oil into intercrystalline space as presented in Fig. 8.

In this area of Adriatic Basin AMANDA -1 BIS well was drilled at the depth of 2 551 - 2 640 m in Upper Cretaceous (Socher Fm.). Clastics were drilled that indicate destruction of the neighboring edge - Istrian platform slope. This can be considered as evidence found in the northeast area of "proximal clastics" development at the Adriatic Basin edge. Reservoir characteristics of these deposits can be compared with clastics from IM-3 well with measured porosity and permeability.

"Beničanci breccias" are an important type of potential sediments created on carbonate platform edge as confirmation of good collector rocks with permeability up to 1 000 x10^{-3}μm^2 (1 D). Such permeability was forecasted in proximal talus zone on the western slope of Dinarides carbonate platform.

4.2. Middle Adriatic

Favorable spot for possible hydrocarbon accumulation is position on KV-106-83 line where possible stratigraphic-structural traps were formed with potential migration from source rocks deposits as marked in Fig. 14. Migration was most probably of subvertical type triggered by synsedimentary faults that encompassed 'vk' facies where oil was determined in Vlasta-1 well. Breccias and chert beds below unconformity in top of Upper Senonian were recognized in Istra More-1 at the depth of 3 500 m. This probably relates to earlier phase of platform slope and proximal talus formation on Dinarides carbonate platform edge.

5. PROXIMAL TALUS SW OF KATE-1 WELL

NW of Kate-1 well there is a seismic profile crossing the Dinarides platform slope with proximal talus, J-13 well and it represents an example of talus development in Middle Adriatic. Along with H_2S, heavy oil shows were determined at the bottom of J-13 well at 4625 m, although there was information about light oil. Intense oil traces shows on Kate-1 well may be considered also as clear sign of the existence of depocenters with source rocks in the central part of Adriatic Basin from where the hydrocarbon migration might have been possible. Evidence of such migration was found in Kate-1 well cores. Oil intruded also in dense dolomitic limestone. These shows were determined through the entire interval in fractured carbonate rocks from Upper Eocene to Lower Cretaceous, i.e. from 2 000 m to 5 800 m. However, it is still uncertain whether the mentioned hydrocarbon show originated only from Cretaceous or maybe from Upper Triassic deposits in Vlasta-1 well. Those shows confirm that in the central part of Adriatic Basin there are centers of possible hydrocarbon generation.

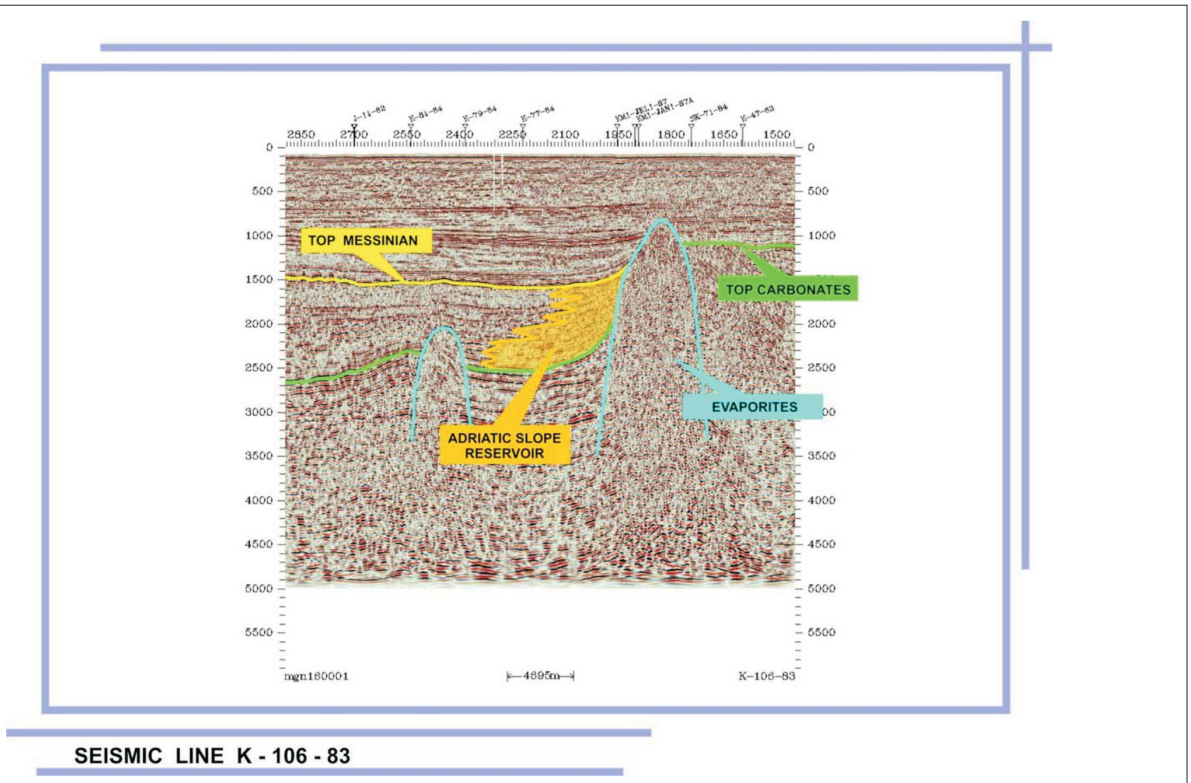

Fig. 15. K-106-83 seismic line crosses the slope and proximal talus at Dinarides platform edge which is affected by diapirism and also Dugi Otok Tertiary Basin. As already mentioned, the seismic line passes NW of Kate-1 well.

Sl. 15. Seizmički profil K-106-83 presjeca padinu i proksimal talus na rubu Dinaridske platforme koji je zahvaćen dijapirizmom , te Dugootočki tercijarni bazen. Seizmički profil prolazi kao što je napomenuto SZ od bušotine Kate-1.

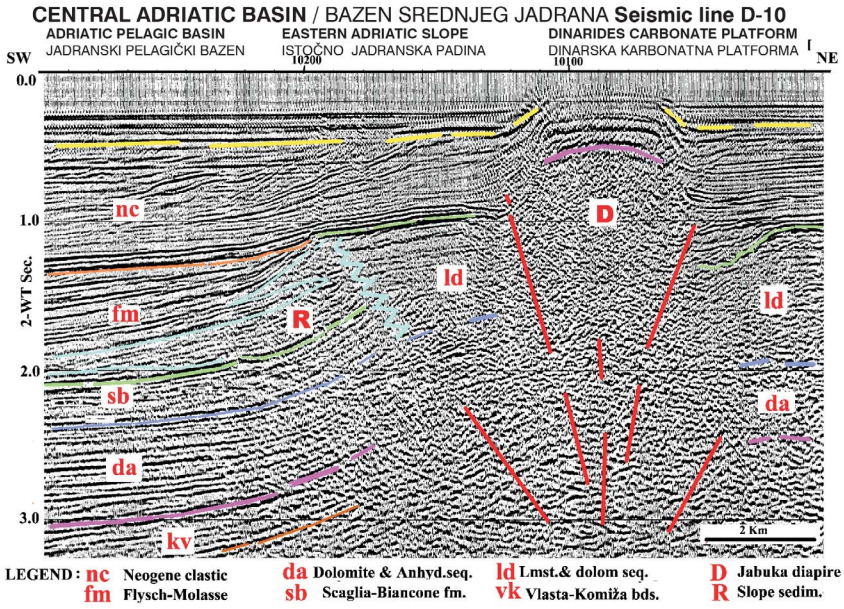

Fig. 16. Proximal talus zone as potential source rocks 6 km wide and of considerable thickness was determined on D-10 seismic line. Possible reservoir rocks are marked by 'R'. As in the previous figure, oil migration was supposed from source rocks 'vk' that were oil bearing in Vlasta-1 well.

Sl.16. Zona 'proksimal talusa' širine preko 6 km i značajne debljine, utvrđena je na seizmičkom profilu D-10. Na slici su potencijalno ležišne stijene označene slovom 'R'. Kao i na predhodnoj slici migracija nafte je pretpostavljena iz matičnih stijena 'vk' koje su na bušotini Vlasta-1 bile naftonosne .

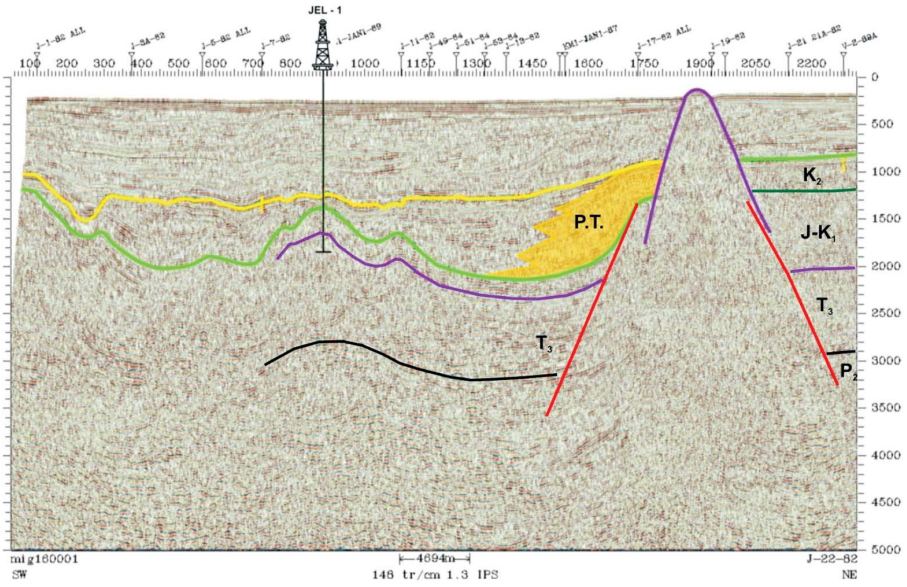

Fig. 17. According to interpretation, a location is proposed as potential prospect. It is situated above clinoforms in proximal talus close to Jabuka island diaper (Fig. 17).

Sl. 17. Sukladno interpretaciji, kao potecijalni prospekt predlaže se lokacija na profilu J-22-82 koja se nalazi iznad klinoforma u proksimal talusu u blizini dijapira otoka Jabuka.

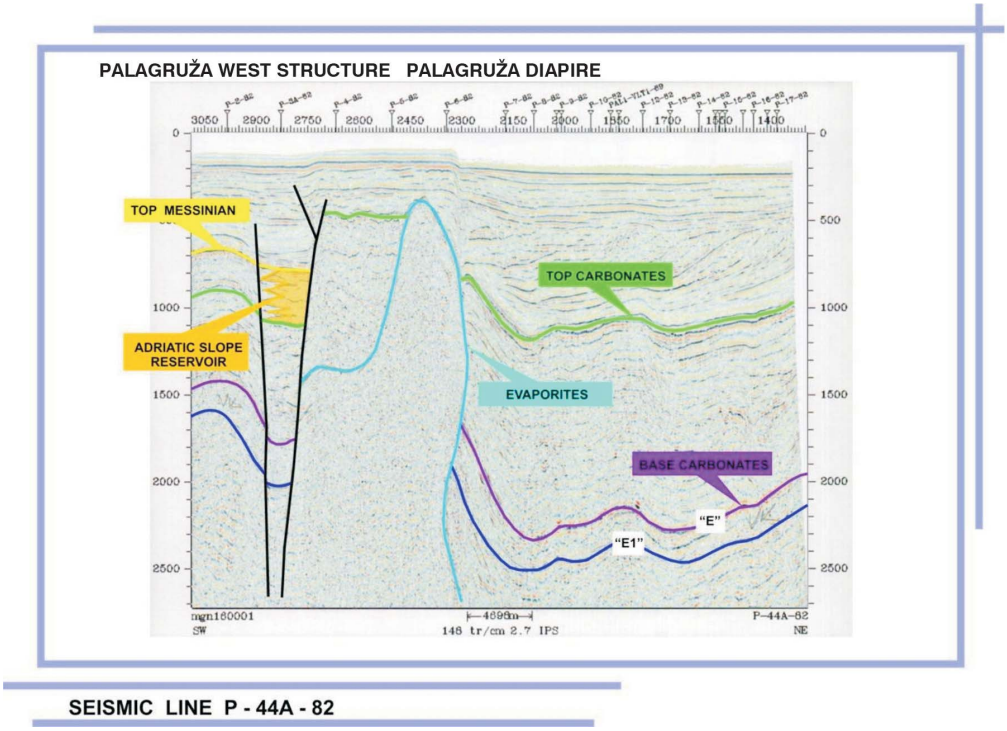

Fig. 18. On this seismic profile there is considerably narrow zone of proximal talus (indicated in yellow) situated at the western edge of Dinarides platform near Palagruža diapir. 'E' seismic horizon represents the top of Carnian and euxinic shale where 2m³ of oil were determined in Vlasta-1 well at the depth of 5 402 m. On Palagruža prospect in diapir there are Upper Triassic oil bearing deposits marked as 'E' horizon at the dip of 70° at considerably shallow sea depth of 180 m.

Sl.18. Na ovom seizmičkom profilu ističe se razmjerno uska zona proksimal talusa (prikazana žutom bojom) smještena na zapadnom rubu Dinaridske platforme u blizini Palagruža dijapira. 'E' seizmički horizont predstavlja krovinu karničkih euksinskih šejlova. U njima je na bušotini Vlasta-1 nađena nafta na dubini od 5 402 m. Na prospektu Palagruža u boku dijapira nalaze se gornjo trijaske naftonosne naslage, označeno kao horizont 'E', pod nagibom od 70°, na razmjerno maloj dubini mora od 180 m.

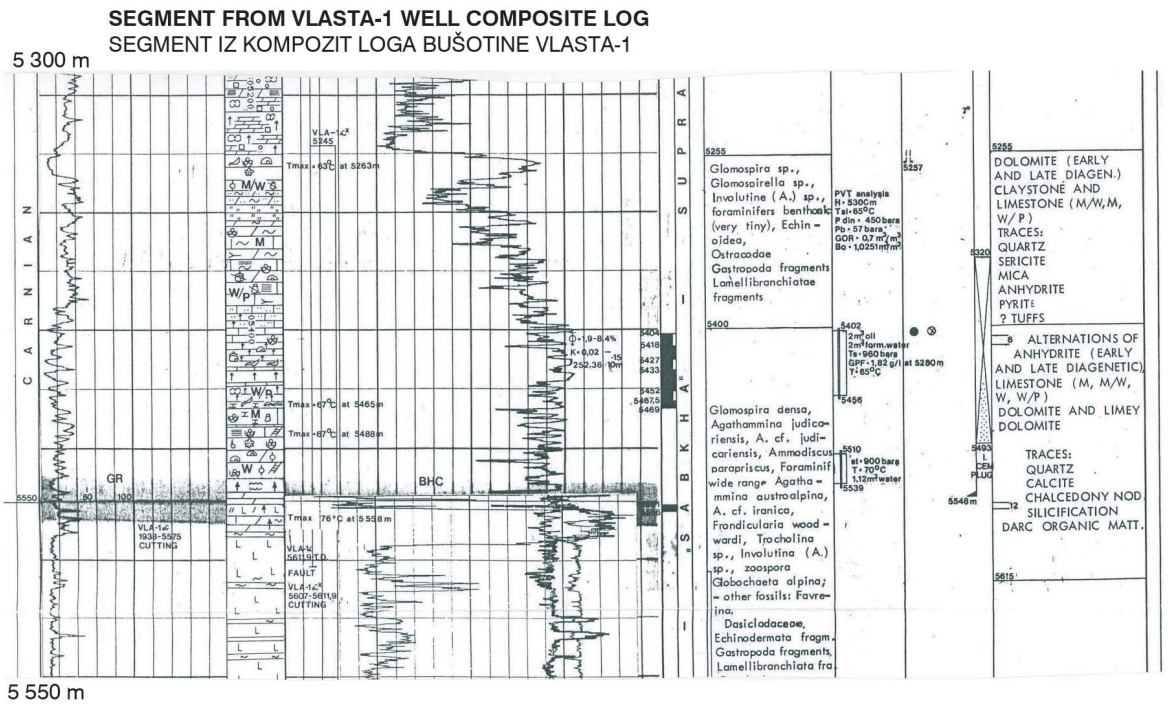

Fig. 19. This segment of Vlasta-1 well shows oil presence in Carnian anoxic shale at 5402 m, quantity of 2 m³ with pressure of 960 bar and temperature of 65 °C.

Sl.19. Na ovom segmentu bušotine Vlasta-1 prikazana je prisutnost nafte u karnijskim anoksičim šejlovima na 5 402 m, s tlakom od 960 bara i temperaturom od 65 °C.

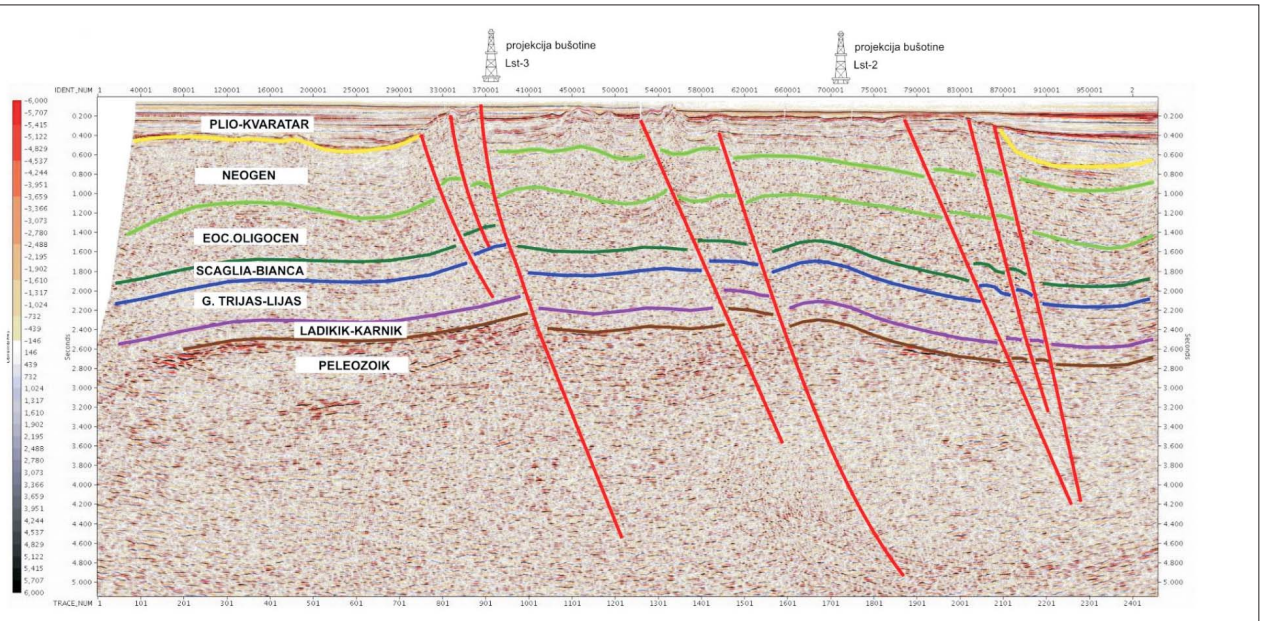

Fig. 20. In this Figure Plio-Quaternary basement is indicated in yellow, Neogene clastics basement (green), proximal talus (dark green in basement), Scaglia-Biancone reservoir (dark blue), Upper Triassic - Liassic in carbonate sequence (purple in basement), Ladinian - Carnian source rocks (brown in basement), Basement - Basement (brown horizon in top). Favorable position for exploration are considered to be antiform structures developed due to faults.

Sl. 20. Na ovoj slici podina plio-kvartara prikazana je žutom bojom , podina neogenih klastita (zeleno), proksimal talus (tamno zeleno u podini), Scaglia-Biancone rezervoar (tamno plavo), gornji trijas-lijas u karbonatnom razvoju (ljubičasto u podini), ladiničko - karničke matične stijene (smeđi horizont u podini), podloga -temeljno gorje (smeđi horizont u krovini). Kao pogodna pozicija za istraživanje mogu se smatrati rasjedima uvjetovane antiformne strukture.

6. PROXIMAL TALUS ON PLATFORM SLOPE NEAR JABUKA ISLAND

Along this slope, proximal talus was created on Dinarides platform edge near Šolta depocenter as possible source for hydrocarbon migration into talus clastics. Potential source rocks of Šolta center are situated at the depth of over 10 km which is enough for their maturation regardless of relatively low geothermal gradient of this area.

Development of proximal talus along Jabuka island diapir, i.e. along the western edge of Dinarides platform is presented. It is supposed that at the mentioned position, upward clinoforms would be developed as favorable traps for migrated hydrocarbons. Jelena-1 well has reached Upper Liassic horizon (Rosso Ammonitico 'ar'). (Fig. 4).

South Adriatic Basin

7. DINARIDES PLATFORM SLOPE NEAR PALAGRUŽA DIAPIR

Dinarides platform slope from Palagruža diapir is related to considerably narrow belt presented in Fig. 7 as "Dinarides Slope". As in KM-1, close relation to diapirism along the "Middle Adriatic Basin Lineament" is noticed.

According to the drilling results from Vlasta-1 well situated 28 km NE of Palagruža island, presented 'E' horizon composes the top of Upper Triassic deposits where oil show was determined in the mentioned well. Due to the above mentioned, it is possible to expect commercial hydrocarbon accumulations also in this geological model. This model may be considered as analogue model of halokinetic "flower" structure of Tremiti islands as presented in work " Crustal tectono-stratigraphic setting of the Adriatic Sea" on CROP M-13 deep seismic profile from 1986 (Fig. 21).

Data from Vlasta-1 well are important for forecasting possible hydrocarbon migrations into proximal talus zone from Palagruža deep depocenters.

8. PROSPECT IN LASTOVČIĆI ISLANDS OFFSHORE AIMED TO THE EXPLORATION OF CARNIAN SHALE

The stated high is situated around 80 km SE of Pescara. Other formations of Adriatic Basin are also presented. Blue horizon represents top of Liassic shelf limestone

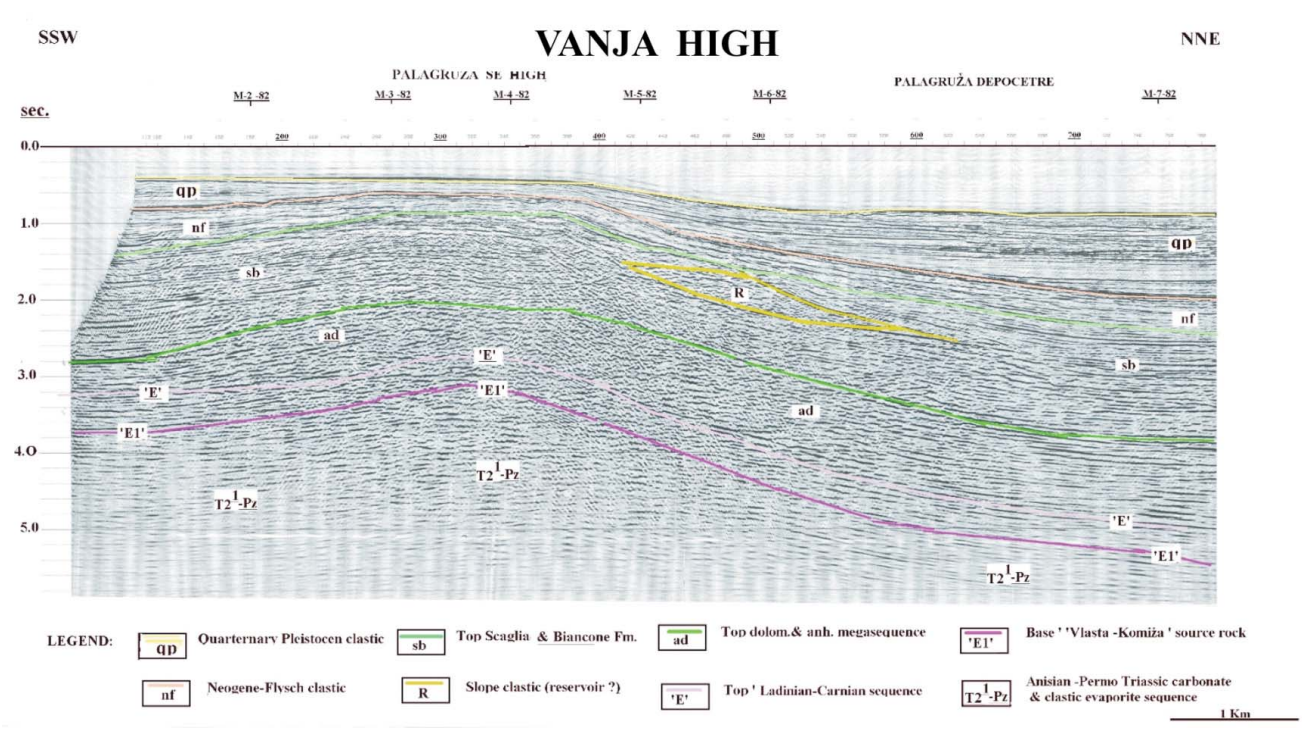

Fig. 21. This geological model shows an example of proximal talus development on Vanja High flank marked by "R" and framed with yellow-brown line. As this high is in the immediate vicinity of Palagruža depocenter, possible hydrocarbon migration is expected into the mentioned proximal talus as potential exploration drilling object. Sea depth is around 180 m. Limestones of Scaglia-Biancone (Maiolica) facies are supposed in the top of VANJA BASIN HIGH. They are characterized by extraordinary porosity and permeability.

Sl. 21. Na ovom geološkom modelu prikazan je primjer nastanka proksimal talusa na boku 'Vanja uzvišenja ', koji je označen simbolom 'R' i uokviren žutosmeđom linijom. Budući da se ovo uzvišenje nalazi u neposrednoj blizini 'Palagruža depocentara' očekuje se moguća migracija ugljikovodika u spomenuti proksimal talus koji je predviđen kao potencijalni objekt istražnog bušenja. Dubina mora je mala, oko 180 m. U krovini VANJA BASIN HIGH pretpostavljeni su vapnenci Scaglia-Biancone (Maiolica) facijesa koji se odlikuju izvanrednim sekundarnim porozitetom i permeabilitetom.

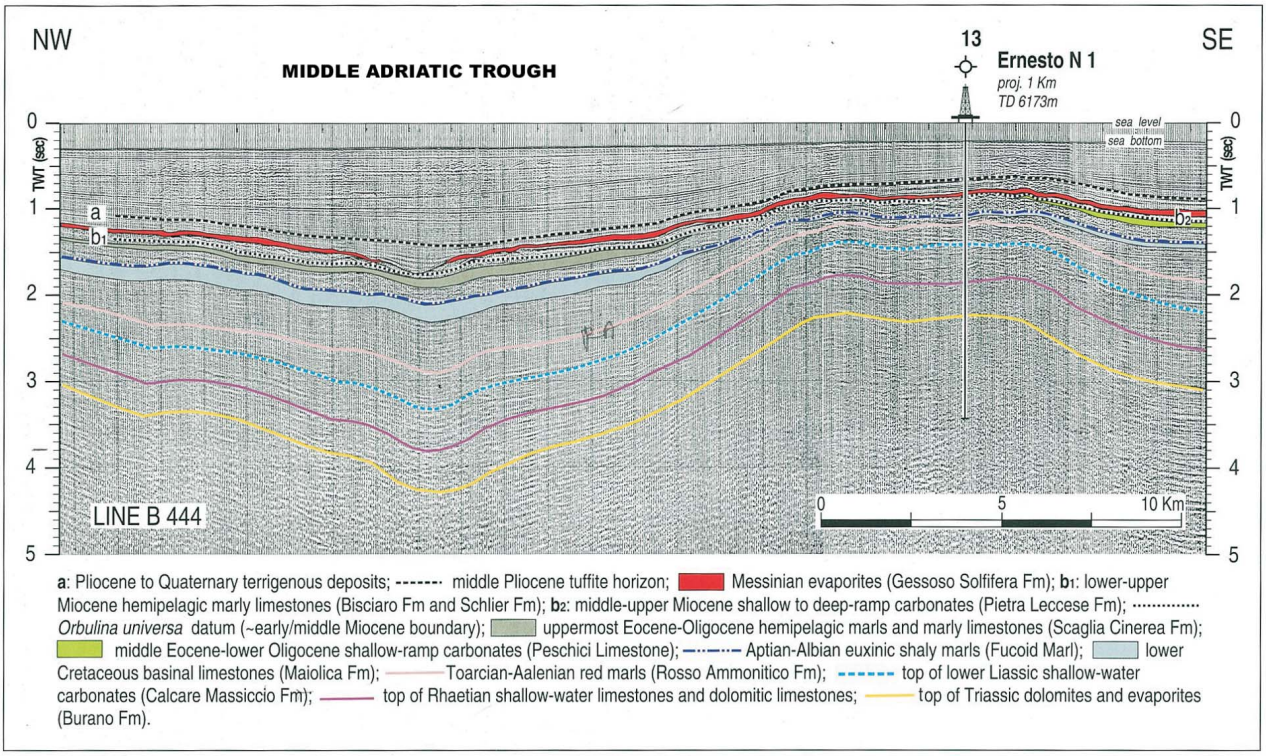

Fig. 22. This seismic profile shows the geological model of 'Ernesto N-1' high within the Central Adriatic Basin which was developed by halokinetic uplifting of Upper Triassic evaporates (brown horizon in figure).

Sl. 22. Profil prikazuje geološku strukturu uzdignuća 'Ernesto N-1' unutar Srednje jadranskog bazena, koja je nastala halokinetskim izdizanjem gornje trijaskih evaporita (na slici svijetlo smeđi horizont).

followed by younger Mesozoic pelagic deposits and Tertiary clastics. This is a geological episode of creation of Adriatic pelagic and later Tertiary clastics basin.[26]

******* End of part 1******

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