3-D SEISMIC SURVEY ON THE PERSPECTIVE OIL FIELD IN VOJVODINA AREA (YUGOSLAVIA)

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A B S T R A C T

After the first positive boreholes resulting within complex, tectonically destructed structure, unsatisfactory defined by conventional geophysical methods, three-dimensional (3D) seismic survey was performed.

Porous continental breccias, existing in the lifted part of the terrain, deep about 2000-2240 m (1625-1652 ms) have been determined as the exploration object. The breccias were in a period of marine sedimentation interruption, namely, during Upper Cretaceous-Middle Miocene period.

In the paper, 3-D seismic method results, turning to not only seismogeological, but also petroleum-geological data, acquisition and processing, are presented.

3-Δ ΣΕΙΣΜΙΚΗ ΕΡΕΥΝΑ ΣΤΗΝ ΑΝΑΖΗΤΗΣΗ ΠΕΤΡΕΛΑΙΟΥ ΣΤΗΝ ΠΕΡΙΟΧΗ ΤΗΣ ΒΟΙΒΟΝΤΙΝΑΣ (ΓΙΟΥΓΚΟΣΛΑΥΙΑ)

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Π Ε Ρ Ι Λ Η Ψ Η

Μετά τις πρώτες θετικές γεωτρήσεις σε μιά πολύπλοκη και τεκτονικά διαταραγμένη περιοχή, η οποία δεν οριοθετήθηκε ικανοποιητικά από συμβατικά γεωφυσικά δεδομένα, επιχειρήθηκε μια τρισδιάστατη (3D) σεισμική διασκόπηση. Ο στόχος ήταν η μελέτη ενός στρώματος πορώδους ηπειρωτικής Breccia σε βάθος 2000-2240 m (1625-1652 ms). Η Breccia σχηματίστηκε κατά την διακοπή της θαλάσσιας ιζηματογένεσης κατά το Ανώτερο Κρητιδικό-Μέσο Μειόκαινο. Σ' αυτή την εργασία παρουσιάζονται τα αποτελέσματα της τρισδιάστατης σεισμικής διασκόπησης.

INTRODUCTION

Three-dimensional seismic investigations of experimental character were, performed in Yugoslavia for first time during 1980. Althouth it was an experimental, very useful data have been obtained. By modern equipment for the data acquisition and processing purchased (in 1991), the conditions for successful 3D seismic exploration leading out (in 1992) were realized.

The investigated area belongs to the south-western part of

the Pannonian basin (Vojvodina-Southern Bachka). The project site is shown in topographic map with 2D seismic lines (fig.1). The whole site, with total investigation area about 58 km^2, is flat, but intersected by numerous canals, traffic arteries and long-distance power lines. Two urban zones are also there.

By the seismic investigations, the potential area from the aspect of hydrocarbons accumulation has been delineated and confirmed by subsequent drilling, so. The recent boring results justify 3D seismic investigations use.

SEISMOGEOLOGICAL AND PETROLEUM-GEOLOGICAL CHARACTERISTICS

Investigated area belongs to the neogene subdepression of Southern Bachka. From the point of view of the regional geotectonic setting, the area is the part of Inner Dinnarides, only several km away from the expected Inner Dinnarides/Panonides contact boundary.

The oldest distinguished neogene sediments are Prebadenian clastites and continental deposits, marine Badenian, Pannonian and Pontian (in some parts). The Neogeneous base is consisted of Mesozoic sediments, rarely schists. Presence of the Upper and Lower Cretaceous, Upper and Middle Jurrassic, as also Upper and Middle Triassic has been determined.

By seismic methods, all the refered geologic formations,can be detected, separated and correlated, on provided that the thickness of each stratum is enough to be detected.

By enclosed sections (fig.2), character of Mesozoic and Neogeneous sediments detected, is illustrated.

The recent oil exploration has pointed to importance of continental breccias/basement contact separating. Problems appear in the parts where breccias with approximately same interval velocities as the values for Mesozoic basement are present.

In some parts, schists exist in the Mesozoic strata in the form of uplifted segments. Project area, that is, TUS, oil deposit, belongs to one such horst, bending from E-W main direction to the south-west, crossing, SR, gas deposit.

- Prebadenian Neogene - are formed of monomistic breccias and debris material consisting of schists fragments (quartz-albite-muscovitechlorite-garnet schists) joined by psammitic detritus and sparite-calcitic embroidery. Although schists are not distinguished by drilling yet, they certainly form Neogenous sediments basement. TUS structure has been originated by eroded and shortly transported coarse clastites. Tectonics had a significant influence not only on the structure forming, but also Prebadenian clastites genesis and creating.

- Badenian - Badenian sediments are reduced toward the structures central parts, with microfauna (foraminifera) characteristic for Lower Badenian lower legenids zone in places. The sediments are predominantly presented by lithoclastic breccias (rarely pyroclastic), debris consisting schists, conglobreccias, conglomerates and heterogeneous sands. Alevrolites, marly and ferrugions alevrolites are also existent.

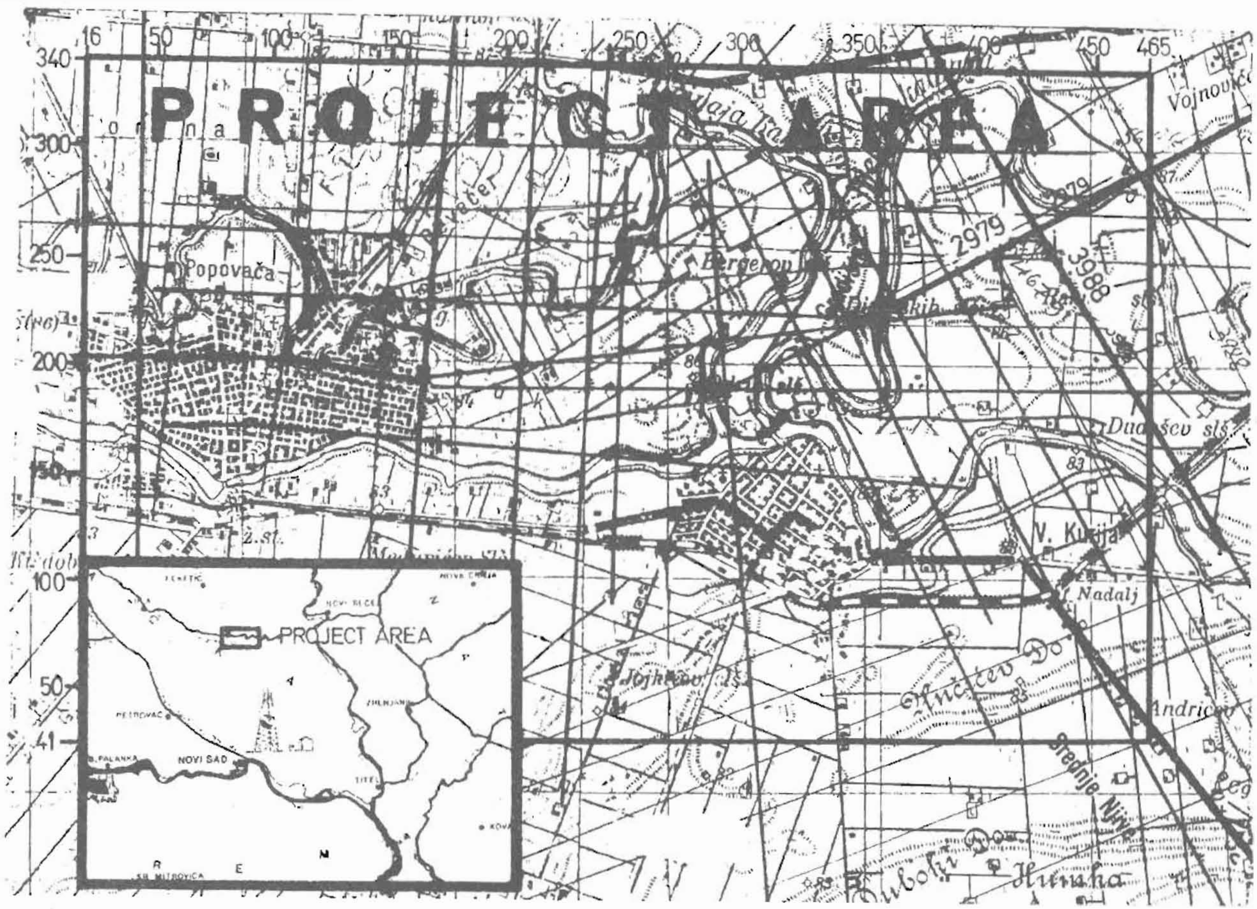

Fig.1. Position of the project area. Topograpchic map-project area with previous 2-D seismic lines.

- Pannonian - are transgressively and discordantly overlying the Badenian marine sediments. They are developed with caspibrackish facies and presented by gray, gray-white or gray-brown marls, sandy marls and marly limestones (micrites).

- Pontian - They have significant thickness, developed with the both sub stages (upper and lower) in caspibrackish facies. Formed by black-gray fine-sandy marls with white-gray fine-grained sandstone interlayers and low-sandy gray marls in the bottom horizons.

- Paludina and Quaternary deposits- are separated as unique sedimentary complex, and presented by marly and sandy clays, sands, low-cohesive sandstones, coaly-clays, clays, loams and humus at the upper horizons.

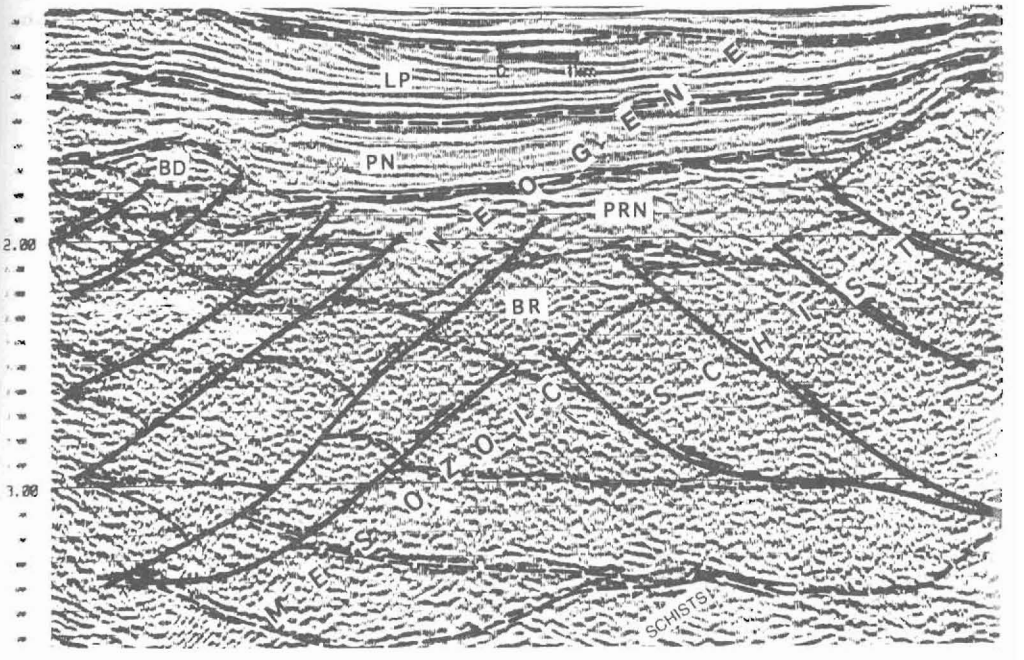

Fig.2. 2-D seismic line 2970. Seismic expression of the sediments in domain of Inner Dinnarides/Pannonides contact zone.

SC-schist, MZ-Mesozoic, BR-breccia, PRN-Preneogeneous clastics, BD-Badenian, PN-Pannonian, LP-Lower Pontain.

ACQUISITION

The most important information related to seismic exploration are following:
- investigation area: 9.08 x 6.06 km = 58.05 km^2
- planned VP.....5.376
- realized VP.....4.929

- coverage.....1200%
- source.....vibrators
- 240 channels equipment.....I/O system one

Investigations were carried out according to the spread layout, presented in fig.3. Taking the field conditions into consideration, the field work had been planned in advance. Therefore,
- Points to be omitted had been predicted in advance;
- Additional vibration points (in order to assure the same coverage degree) within urban areas were determined.
- The amplitudes of seismic waves generated by vibrators had been controlled by accelerometers, so there were no damaged house after the field work realization;

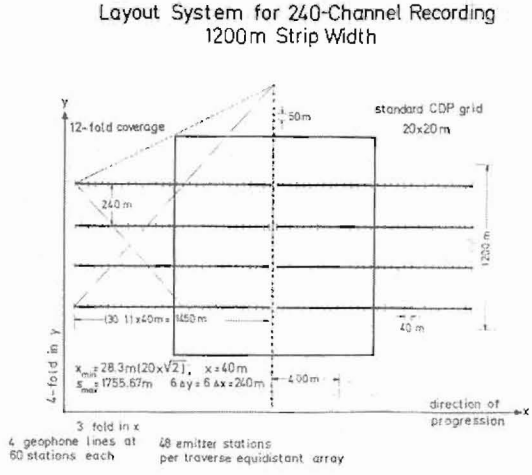

Fig.3. System layout for 240-channel recording. The parameters of data aquisition were set as follows.

Source:
- 3 vibrators/source point
-12 sweeps/source point outside urban area
-12-96 Hz non-linear sweep interval, 3dB/oct.
-duration/sweep: outside urban area: 9s
inside: 23 s

Receivers:
- spacing 40 m
-36 geophones/trace surface arrangement

Recording:

- record length	4 sec correlated record
- sampling interval	2 ms
- filters	3-185 Hz
- notch filter	out
- spectral shaping filter	10 Hz 12 dB

Shallow seismic refraction method data have been applied for static corrections calculation.

DATA PROCESSING

3D data processing is characterized by the vast amount of input data. Successful 3D processing can be realized only by strong high-capacity discunits computing system and fast I/O channels.

The following equipment were used for the numerical processing of the field data.

- VAX-9000 32-bit vector computer (model 400 with 4 Fujitsu discs with 1,2 MB and 256 MB CPU memory capacity);
-VAX/VMS 5.4 - 2 operating system;
-3D-DISCO package application software made by Cogniseis Development.

The program package is characterized by such type of modularity and flexibility that it can accept all 3D-field data separated in various ways and control each individual stage of data processing.

Specific 3D seismic data processing schemes were applied such as:

- 3-D geometry and segmentation (bining);
- source and receiver coordinate assignment, segments (bins) dimensions defining depending on recording geometry and planned coverage;
- 3-D parameters interpolation: space interpolation using triangulation method on a few controllion points (inverse filtering, dynamic correcting, band-pass filtering);
- velocity analysis parameters and NMO parameters: "3-D method" gives velocity function corrected for the slope in subline and crossline direction and analysis on the basis of previously separated segments (bins) group centered on location for velocity analysis;
- summation without previous sorting: enables processing simultaneously with acquisition;
- 3-D residual static corrections: using "surface consistent" approach and "bin" consistent trim static;
- 3-D migration: program with algorithm using wave equation by the least square method (in two passes);
- data presentation: over horizontal intersects by constant reflection time and over "subline" and "crossline" sections, as also in any reflection time and over "subline" and "crossline" sections.

DATA INTERPRETATION

The interpretation carried out on an INTERPRET-2 workstation. For the first stage of interpretation, the workstation has enabled the following:

The correlation with drilling and well-logging data.

The automatic interpolation for the construction of the structural and isopache map.

The compilation of mean velocity preliminary maps and maps transformed from time to depth domain.

In the following figures, the seismic response recorded and interpretation results are presented, namely:

- two 2-D sections (fig.2. and fig.7.);

- one subline (fig.4) and two crossline sections (fig.5 and 6);
- one shallow horizontal time-section (fig.8) and two deep ones from productive breccias domain (fig.9 and 10):

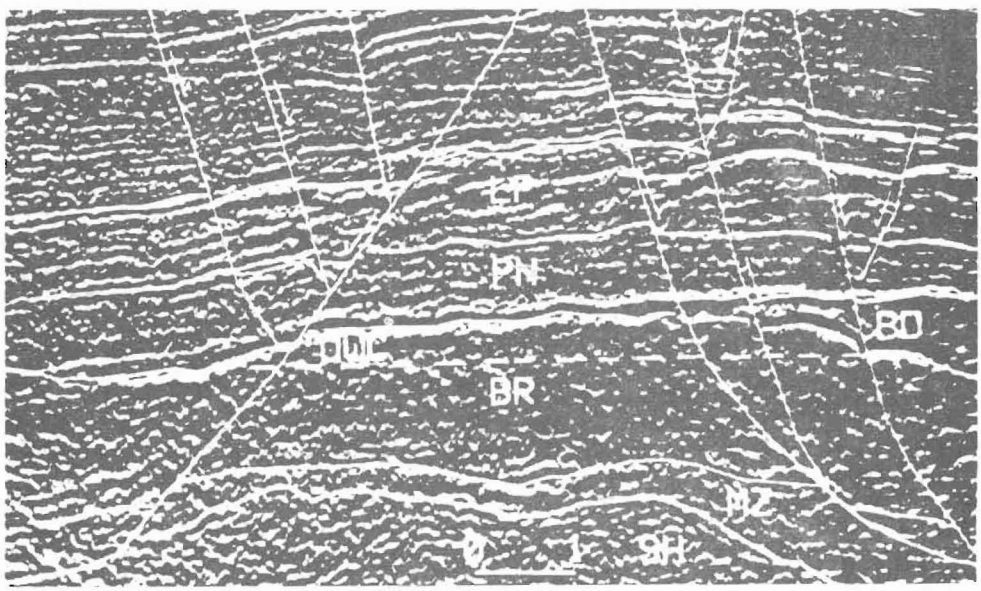

Fig.4. Subline 233. Faults registered on vertical section. (OWC-oil/water contact).

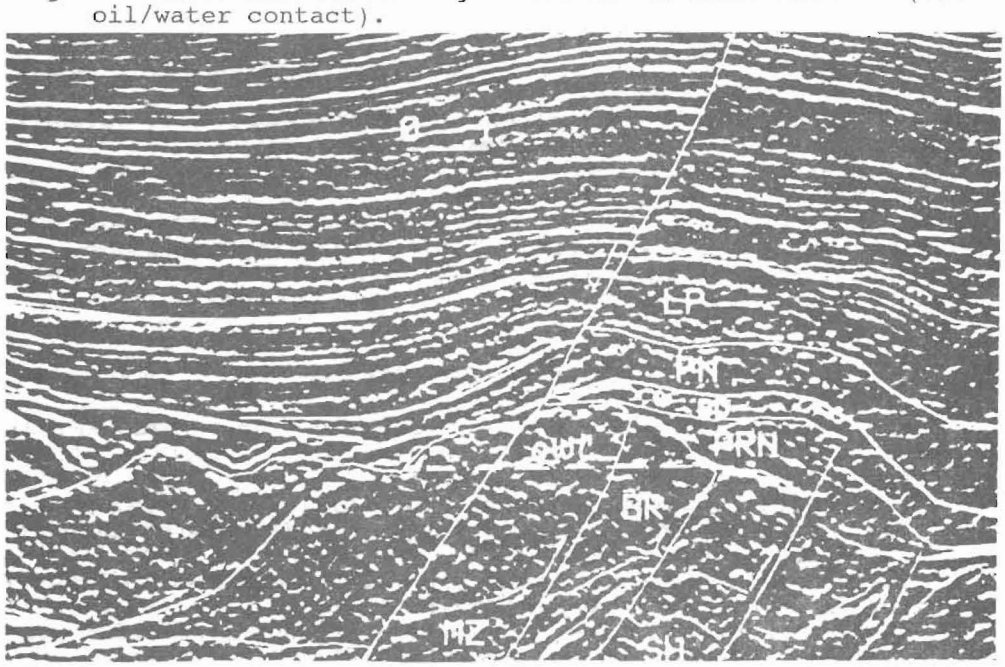

Fig.5. Crossline 221. Faults registered on vertical section.

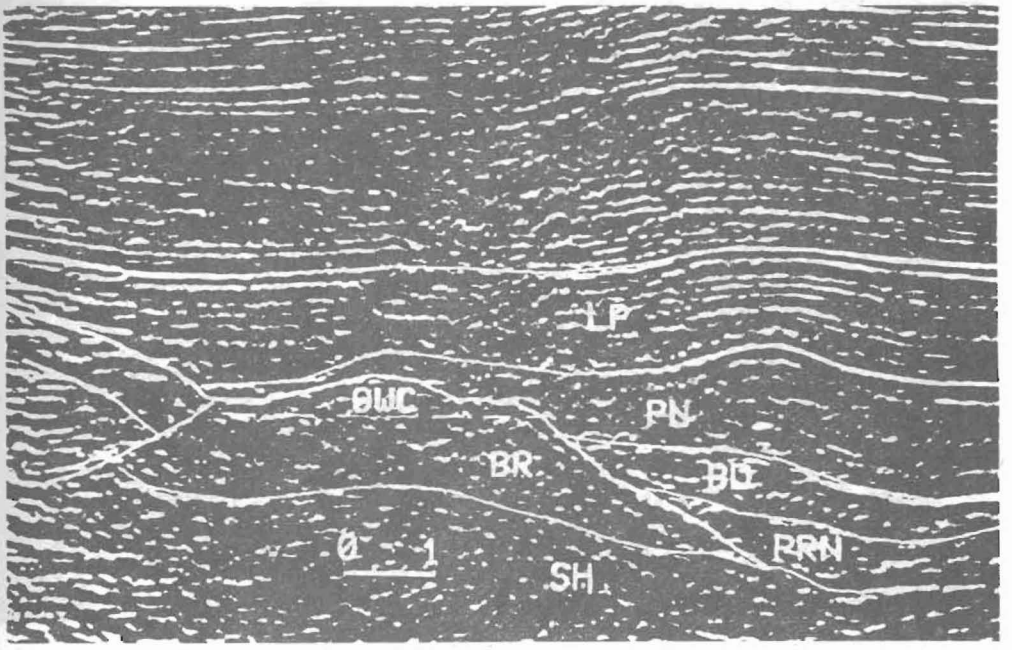

Fig.6. Crossline 32. Folded neogeneous sediments.

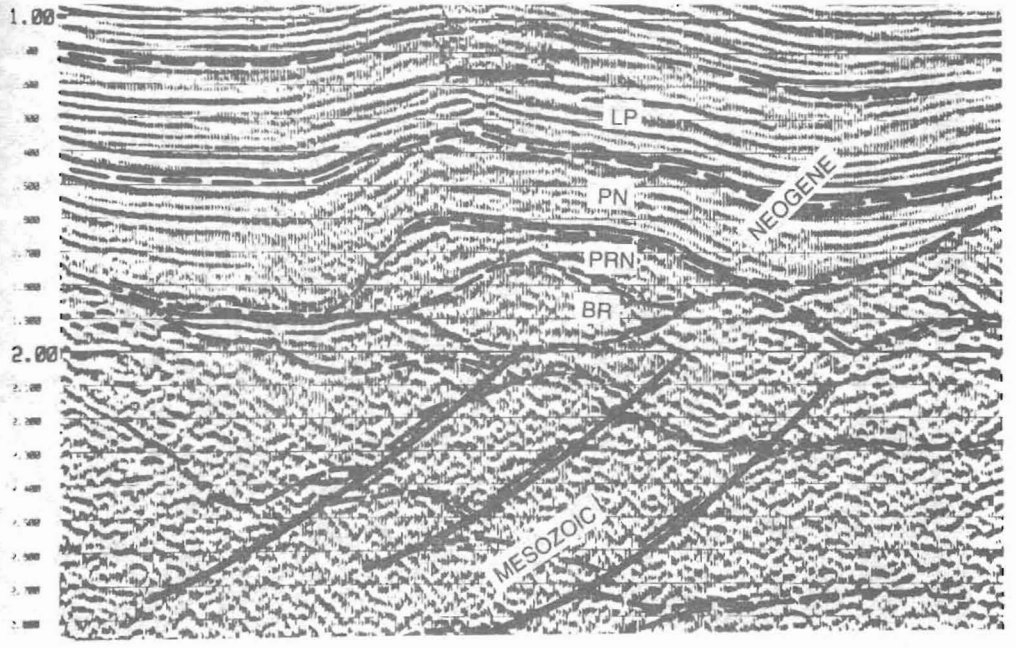

Fig.7. 2-D line 4697. Seismic expression of productive breccias in the eastern part of structure.

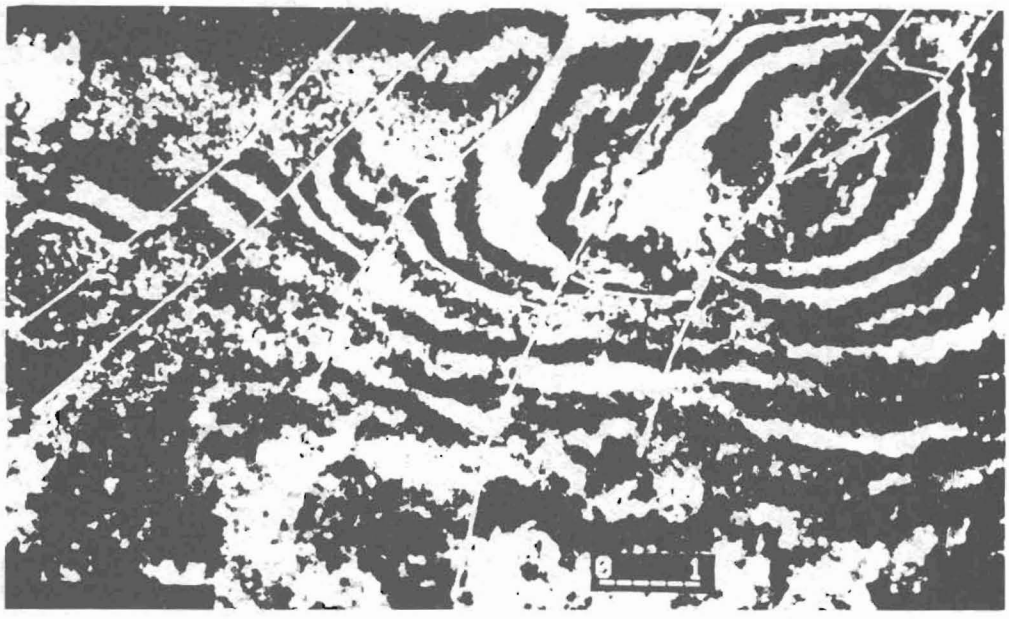

Fig.8. Registered shallow faults on horizontal section 2T=916 ms.

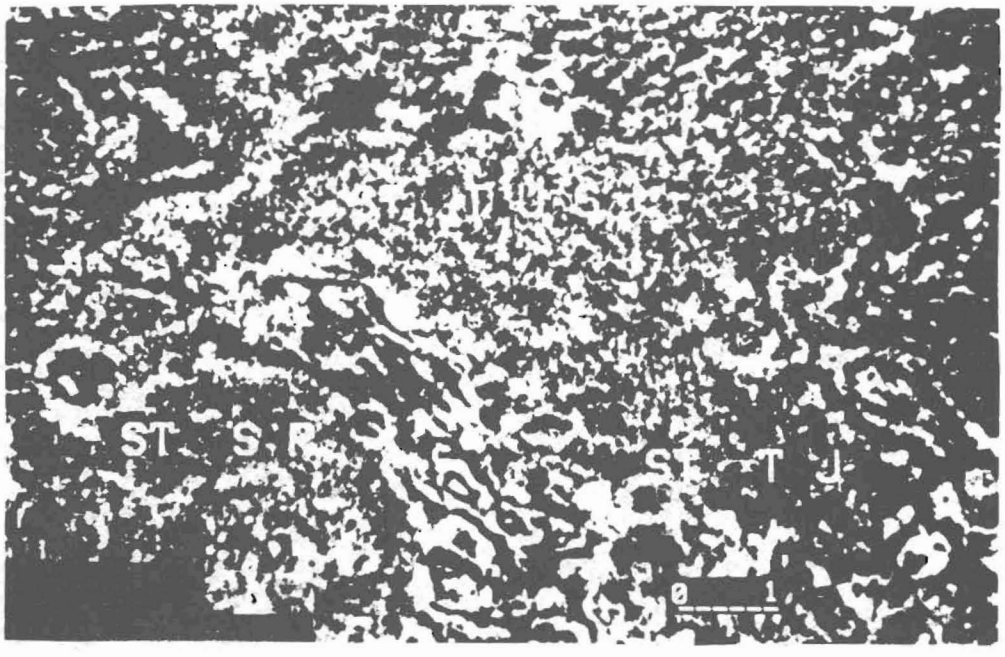

Fig.9. Structures and faults registered on horizontal section 2T=1688 ms.

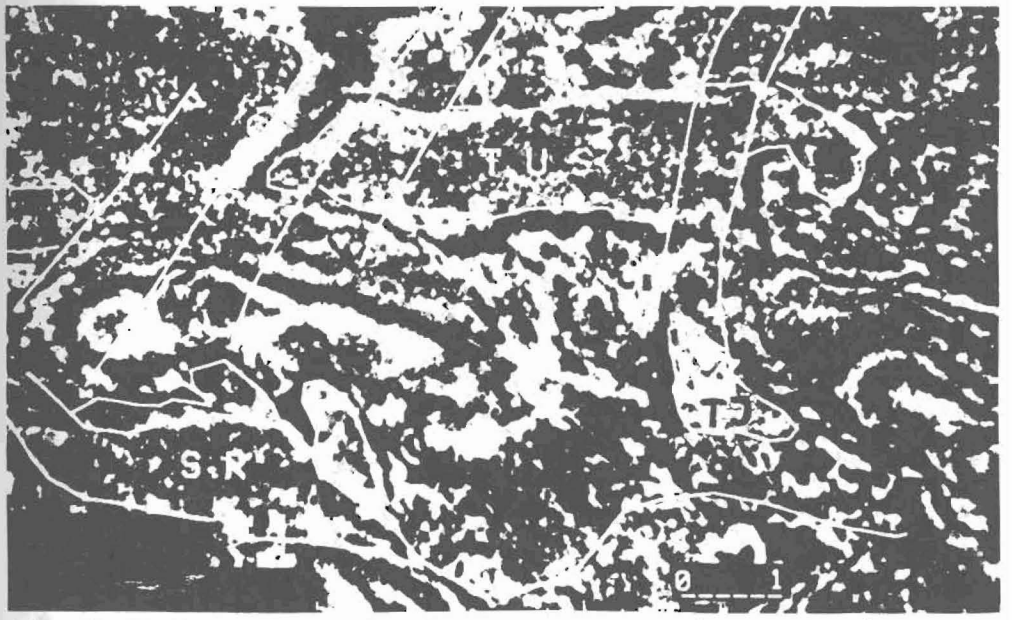

Fig.10. Horizontal section 2T=1752 ms. Potential productive area expected oil-water contact.

On the basis of interpretation, the following has been obtained:

- Principal informations on tectonics evolution and tectonics nature;
- "TUS" structure fundamental shape with connected faults;
- Potential zone within project area, which has to be drilled.

Three faulting directions are distinguished: E-W, SE-NW and SW-NE. Faulting resulted from mesozoic tectonics and controls the Mesozoic sediments development. Except from its south-western side, the "TUS" formation is surrounded by thick deposits of Mesozoic sediments. Under the pressure of the sediments, "TUS" formation has sinked. Additional load and intensive sinking have been caused by horizontal movement from north-eastern Pannonian mass over the Mesozoic formations along Inner Dinarides and Pannonides boundary.

Simultaneously with the subsidence the "TUS" horst and the "SR" uplifted block schists have been characterized by SW-NE horizontal displacement. This is in contradiction just opposite to the Pannonian movement, which causes Miocenian sediments folding along "TUS" formation northern edge (Fig. 6). This displacement forced the breccias to be formed along the eroded and tectonically fractured trench southern footwall moving into the formation apex part. The majority of faults with SE-NW direction have reverse character.

Faulting in SW-NE direction was also intensive during Pliocene (Fig.4). The pliocenian faults, are connected over cammon root to older and deeper main faults.

Skip-shifts are present in younger sandy formations, while deeper plastic rocks forming marly-clayey facies are only bending, which preserved the deposit.

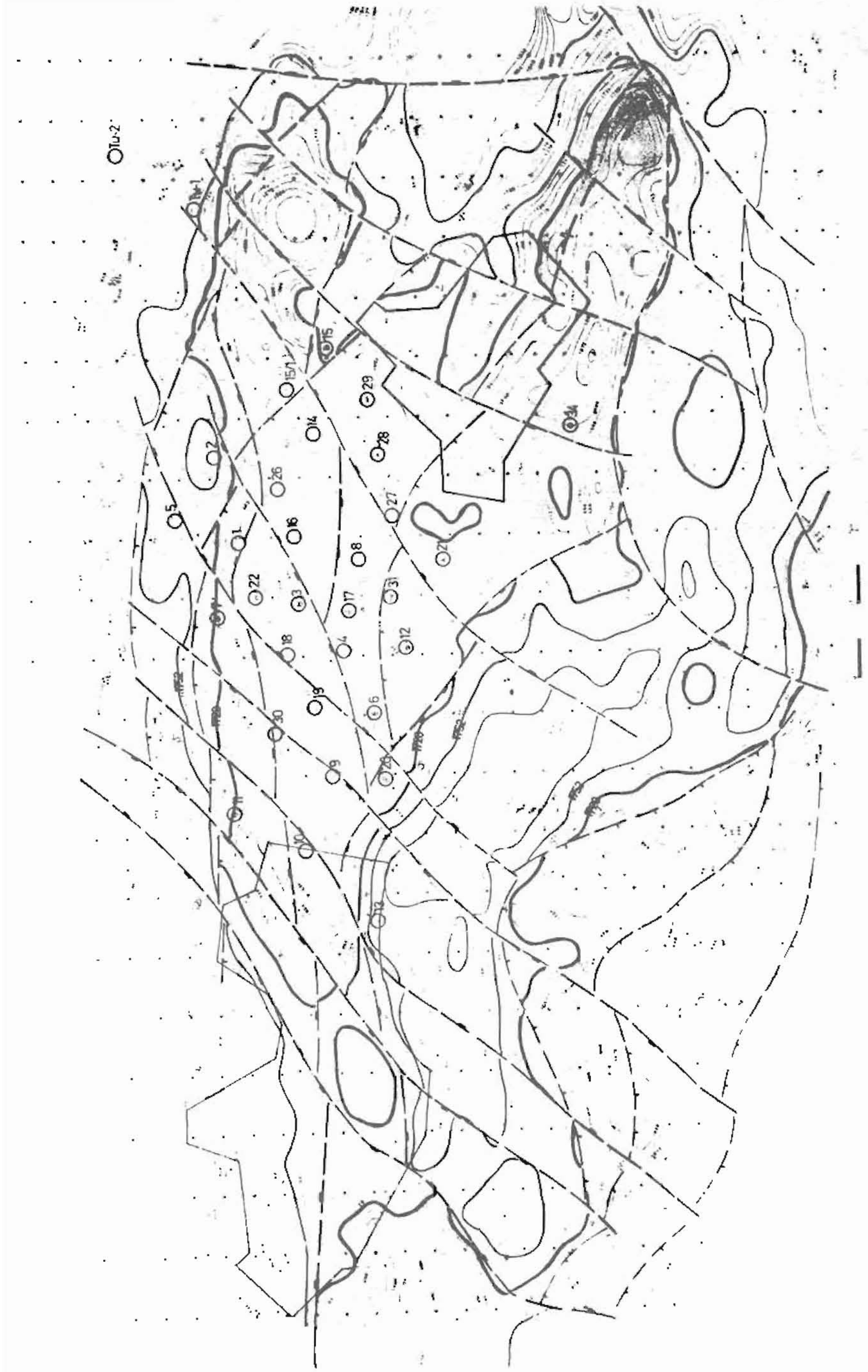

Fig.11. Structure map over productive breccias overburden. Investigated and potential areas.

Faults within breccias have a great influence in water-filling. Faults with SW-NE direction have originated from "TUS" ridge with surrounding terrain uneven subsidence. Younger tectonics can be distinguished on horizontal cross-sections (Fig.8). Maximum sinking gradient is characterized by SW-NE direction.

Reflection over productive breccias overburden is followed by intensive reflected signal. Geologically, this is the breccias contact with various formations (Preneogeneous clastites, Badenian, Pannonian and Lower-pontian sediments). Except for Prebadenian clastites, all of these formations present rock protection. They are characterized by 3500-4000 m/s interval velocity values. Interval velocities of breccias are very high-to 5000 m/s, similarly with Mesozoic sediments.

Breccias thickness and basement nature have not been determined yet. Reflection level, correlating in the depths greater than 500-600 m geological meaning in regard to their handing-wall has not been also distinguished (Fig.4). The breccia reflection is characterized by reflection arrivals absence (Fig.7). In the structure map, the drilling-potential area, according to petroleum-geologically important breccia hanging-wall marker (Fig.11) was outlined. Favourable is that the deposit is structural. Potential area is approximately separated by 2T=1752 ms contour, presenting oil-water contact (Fig.10).

By 1988 ms two-way time contour (Fig.8), "TUS" structure with E-W direction has been distinguished. It consists of central, eastern and western part. Only the central part is drilling-explored. Recently, the first borehole "TUS-3A", drilled the structure. The results were positive encouraging, thus, for further exploration.

The project area, was outlined which is separated form the "TUS" formation by a synclinal. That is the "S2" formation which presents north-eastern slope of the "TUS" structure. On the basis of seismic expression, continental breccias presence could be also expected. Pannonian marls are wedging out along the base of the structrure, in other words, in the 2T=1752 m contour domain, while in overburden, lower-pontian marls are present. According to Pannonian marls development, subsidence of the terrain dividing "SR" and "TUS" structures is connected with Pliocenous tectonics, which makes the whole area more perspective.

In handing-wall of the "TUS" structure eastern part (which is still waiting for boring), Prebadenian clastites (not presenting protective rock) are present (Fig.7). Drilling data point out to deposition possibility at the beginning of isolation stratum depositing at the boundary with footwall.

Potential area of the "TUS" structure western part has not been completely included by 3-D seismic investigations, but it is also distinguished by available conventional sections. In the breccias overburden the Pannonian marls are present. During the whole Miocene, this part of the terrain was the shallowest part of "TUS" formation, which may be important for hydrocarbons accumulation.

In the structure map (Fig.11), the contours 2T=1752 were separated. The first contour presents oil-water approximate contact, and the other is important for transition zone distinguishing. Between the contours transition zone, possible

negative results (because of velocity values variations) can be expected.

General reduction of mean velocity values along the productive breccias hanging-wall in NW-SE direction is noticeable (5% in explored area). This is directly proportional to decrease of thickness values in the oldest neogenous formations breccias hanging-wall (characterized by high interval velocities). Further exploratory drilling will provide data about velocity distribution in order to follow the water contact with more precision.

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