# CONTRIBUTIONS TO THE STUDY OF THE OPERATING CONDITIONS OF HYDROCARBONS FROM THE PANNONIAN BASIN (CASE STUDY)

# *CONTRIBUȚII LA STUDIUL CONDIȚIILOR DE EXPLOATARE ALE HIDROCARBURILOR DIN BAZINUL PANONIAN (STUDIU DE CAZ)*

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**Abstract:** *As is known, the Pannonian Basin is the most extensive basin in the intra-Carpathian region, framed by the Alpine-Carpathian chain. This unit represents a structure of Neogene age, superimposed on Mesozoic compressional formations originating from the Dinaric Alps and from the internal area of the Carpathians. Paleogene strike-slip formations develop over these structures. During the Mio-Pliocene, the intracarpathian zone was characterized by an intense process of subsidence, controlled by the orogenetic evolution of the region. According to Săndulescu (1998), the spatial and temporal relationships between the shortening of the folded belt and the installation of calc-alkaline magmatism in the intracarpathian space are important indications of the interdependence between these two dynamic processes. The research presents a geological and physical model of the T structure, prepared based on the information available from the geological-technical works carried out from the wells as well as based on the information obtained from the mining process carried out. The objectives of the research are: - drawing up the geological-physical model; - analysing the current state of exploitation. From an administrative point of view, structure T is supposed to be located in Timis county, approximately 60 km west of the city of Timisoara near the border with Serbia. From a geological point of view, structure T is located in the eastern part of the Pannonian Basin on the Algyo – Ferencszallas – Mokrin structural alignment between the Mako – Tomnatec Depressions to the E – NE and the North Banat to the W – NW. Hydrocarbon accumulations (free gas and gas-condensate) were highlighted at the level of the Paleozoic and the Pannonian.*

**Keywords***:* Pannonian Basin, wells, structură, depth, map.

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***Rezumat:*** *După cum se știe, Bazinul Panonic este cel mai extins bazin din regiunea intracarpatică, încadrată de lanțul Alpino-Carpatic. Această unitate reprezintă o structură de vârstă neogenă, suprapusă peste formațiuni compresionale mezozoice provenite din Alpii Dinarici și din zona internă a Carpaților. Peste aceste structuri se dezvoltă formațiuni paleogene de tip „strike-slip”. În perioada Mio-Pliocenului, zona intracarpatică s-a caracterizat printr-un proces intens de subsidență, controlat de evoluția orogenetică a regiunii. Potrivit lui Săndulescu (1998), relațiile spațiale și temporale dintre scurtarea centurii pliate și instalarea magmatismului calco-alcalin în spațiul intracarpatic constituie indicii importanți ai interdependenței dintre aceste două procese dinamice. Cercetarea prezintă un model geologic și fizic de pe structura T, întocmit pe baza informaţiilor avute la dispoziție din lucrările geologo-tehnice realizate din sonde precum şi pe baza informaţiilor obţinute din procesul de exploatare desfăşurat. Obiectivele cercetării sunt: - întocmirea modelului geologo-fizic; - analizarea stadiului actual al exploatării, Din punct de vedere administrativ structura T se presupune că este localizată în judeţul Timiş la aproximativ 60 km Vest de oraşul Timişoara lângă graniţa cu Serbia. Din punct de vedere geologic structura T este situată în partea estică a Bazinului Pannonian pe aliniamentul structural Algyo – Ferencszallas – Mokrin între Depresiunile Mako – Tomnatec la E – NE și Banatul de Nord la V – NV. Acumulările de hidrocarburi (gaze libere şi gaz-condensat) au fost evidenţiate la nivelul Paleozoicului și Panonianului.*

**Cuvinte cheie:** Bazin Panonian, sonde, structure, adâncime, hartă.

## 1. Introduction

During the Miocene–Pliocene, the Pannonian Basin functioned as a closed system characterized by alternating extensional and compressional tectonic phases. Multiple sub-basins within the region acted as a thermogenic petroleum system (as described by Morariu, 1998). The basin's development occurred in two main rifting stages, interrupted by tectonic inversions (figure 1):

- the first rifting phase (Middle Miocene) was dominated by a strike-slip stress regime, primarily affecting the Carpathian region and continuing into the Badenian period. This extensional phase compensated for N–S shortening in the Western Carpathians and E–W shortening in the Eastern Carpathians (Figure 3). A tectonic inversion at the end of the Sarmatian led to uplift of the basin and further contributed to its isolation.

- the second rifting phase, during the Pannonian stage, was also marked by a strike-slip or extensional stress regime, with the principal stress axis-oriented E–W to NW–SE [6].

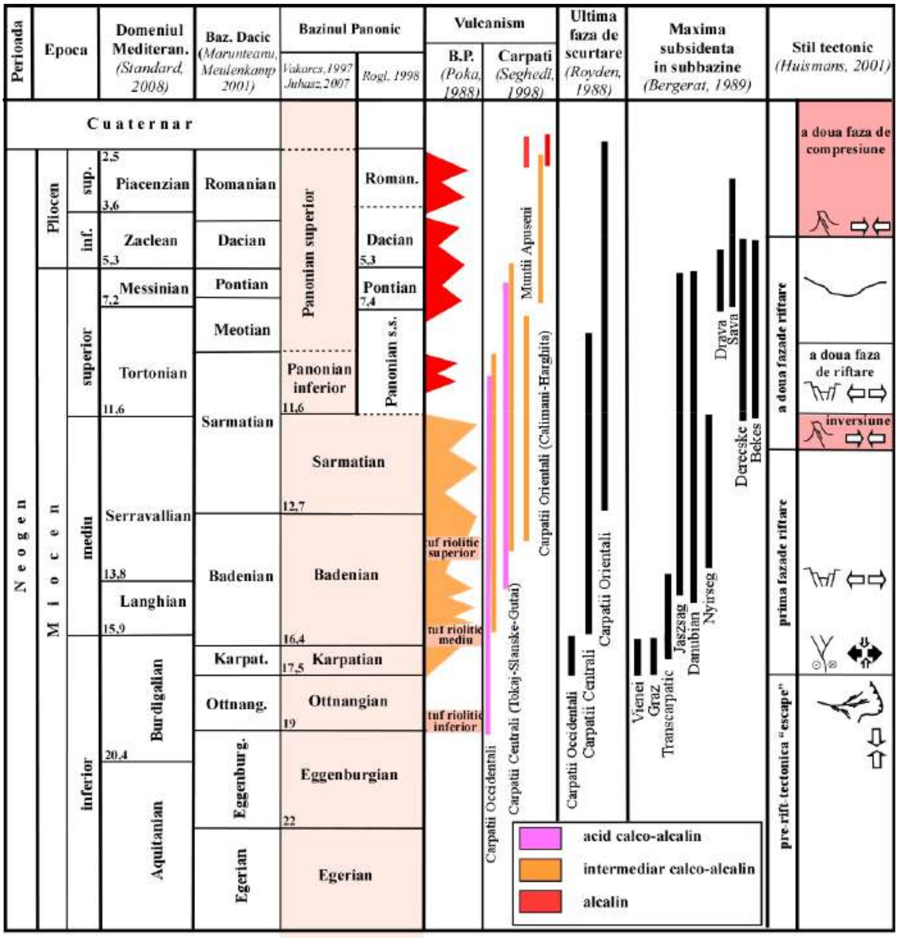


**Figure 1** – The tectonic evolution of the Pannonian Basin about neogen magmatism [6]

From an administrative point of view, structure T is assumed to be located in the eastern part of the Pannonian Basin on the Algyo – Ferencszallas – Mokrin structural alignment between the Mako – Tomnatec Depressions to the E – NE and the North Banat to the W – NW.

A number of oil and gas fields are associated with this alignment, which stretches from Serbia through the western part to Hungary. Hydrocarbon accumulations (free gas and gas-condensate) were highlighted in the Paleozoic and Pannonian as follows:

- crude oil and associated gas, in Conglomerate and Basal Breccia (Miocene) + Foundation (Paleozoic);

- gas-condensate, in lower Pannonian landmark Rx (Pt 1-1);
- free gases, in the lower Pannonian the benchmarks R3c+d (Pt1-3), R2 (PT 1-4), R1a+R0c (Pt 1-6) and R0b (Pt 1-9).

The initial pressure and temperature of the reservoir were determined with a high degree of certainty resulting from the measurements made during the production samples from 3 wells respectively from the interpretation and analysis report of the fluid samples from the reservoir and pressure tests. Based on the static pressure measurements performed in 2 probes, respectively the pressure tests in one probe, the pressure and temperature gradient values were calculated, as follows:

- Pressure gradients: – 0.096 bar/m in the complexes: R0b (Pt 1-9), R1a+R0c (Pt 1-6+7), R2 (Pt 1-4), R3c (Pt 1-3) and R3d (Pt 1-3); – 0.108 bar/m at the complexes: Paleozoic and Rx (Pt 1-1);
- Temperature gradient – 0.0048 °C/m.

The initial pressures at the bottom of the wells vary between 206 and 264 bar depending on the depth, and the temperature at the bottom of the wells between 112 and 127 °C.

The physical properties of the oil in reservoir conditions for the Foundation - Paleozoic were established based on the PVT analysis of the samples taken during the experimental exploitation phase of a well. Crude oil also has a specific weight of about 792 Kg/m3 and is classified as class 7.

A very high viscosity is noted at temperatures of 100 ºC, the measured values being between 530 and 943 cP. By increasing the temperature, the viscosity of the crude oil drops a lot, at temperatures of 30 ºC values between 3 and 10 cP were measured. Crude oil has a freezing temperature below 15 ºC and a high content of light fractions.

For the gas-condensate reservoir discovered at the lower Pannonian landmark Rx (Pt 1-1), to determine the behavior of the fluids with pressure and temperature, a fluid sample (condensate and gas) was collected from the separator and by recombining them, the behavior of the fluids at the pressure variation was determined. The physical properties of the fluids were determined by laboratory processing of crude oil, water and gas samples taken from wells. Associated gases have a (volumetric) methane content of 74 – 84 %, and free gases of 96 – 97 %. The relative density has values between 0.58 and 0.69.

The reservoir water is calcium chloride type, chloride group, sodium subgroup. The analyzes carried out for the samples taken indicate that the pH is slightly acidic (4.7 – 6.7), the density of the reservoir water at 20 ºC is 1.02 - 1.07, in the dissolved salts salt predominates (over 85 % NaCl).

To determine the effective porosity, both direct methods (quantitative analysis of mechanical cores) and qualitative interpretation of the complex geophysical logs of the wells were used. The information obtained allowed to put the geological, physical, physico-chemical and production data in an acceptable engineering agreement within eight hydrodynamic units (H.U.) named as follows:

- H.U. 1 – Bloc I – Northern Paleozoic + Breccia + conglomerate – undersaturated oil;
- H.U. 2 – Bloc II – Suuth Paleozoic + Breccia + conglomerate – saturated oil;
- H.U. 3 – Lower Pannonian Reper Rx – gas-condensate reservoir;
- H.U. 4 – Lower Pannonian Reper R3d – free gas reservoir;
- H.U. 5 – Lower Pannonian Reper R3d – free gas reservoir;
- H.U. 6 – Lower Pannonian Reper R2 – free gas reservoir;
- U.H. 7 – Lower Pannonian Reper R1a + R0c – free gas reservoir;
- H.U. 8 – Panonian inferior Reper R0b – free gas reservoir;

The Fundament oil fields have bottom water, and those in the Lower Pannonian are stratiform.

## 2. The geological model

### 2.1. The regional geological framework

From an administrative point of view, Structure T is assumed to be located in Timiş county, approximately 60 West of the city of Timişoara near the border with Serbia (figure 2).

#### 2.1.1. The Pannonian Basin – geotectonic evolution

From a geological point of view, structure T is located in the eastern part of the Pannonian Basin on the Algyo – Ferencszallas – Mokrin structural alignment between the Mako – Tomnatec Depressions to the E – NE and the North Banat to the W – NW (figures 3).

The multiisotoric Pannonian basin had several tectonic-sedimentary cycles, the last of which, the one that defines the current arrangement, was located in the Neogene period (figure 4) [1].

The Pannonian Basin of Central Europe is a classic back-arc basin overlying extremely thin continental lithosphere that formed during the Miocene in response to the rapid rollback of a plate attached to the European continent.

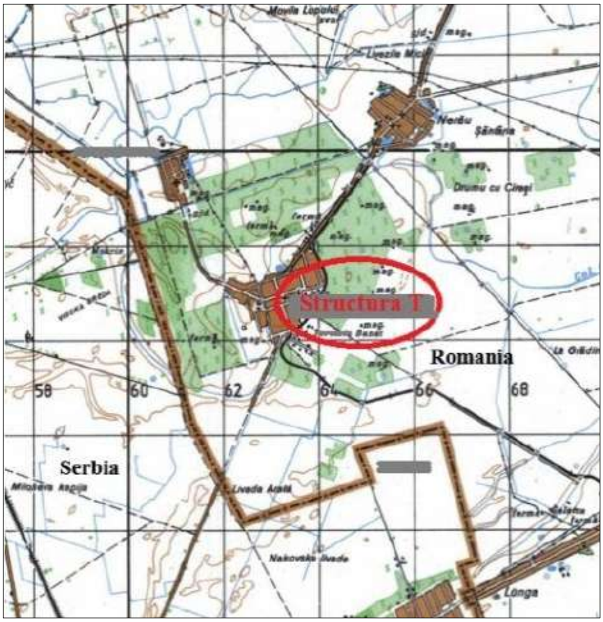


**Figure 2 –** Location of the T structure from an administrative point of view

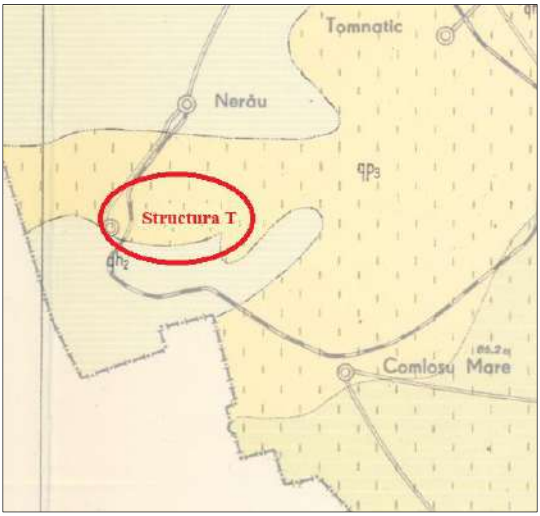


**Figure 3 –** Location of the T structure from a geological point of view [9]

**Legend:**

$qp_3$ – Upper Pleistocene;

$qh_2$ – Upper Holocene (gravels, sands);

$qp_3^3-qh_1$ – Lower Holocene (loessoid deposits).

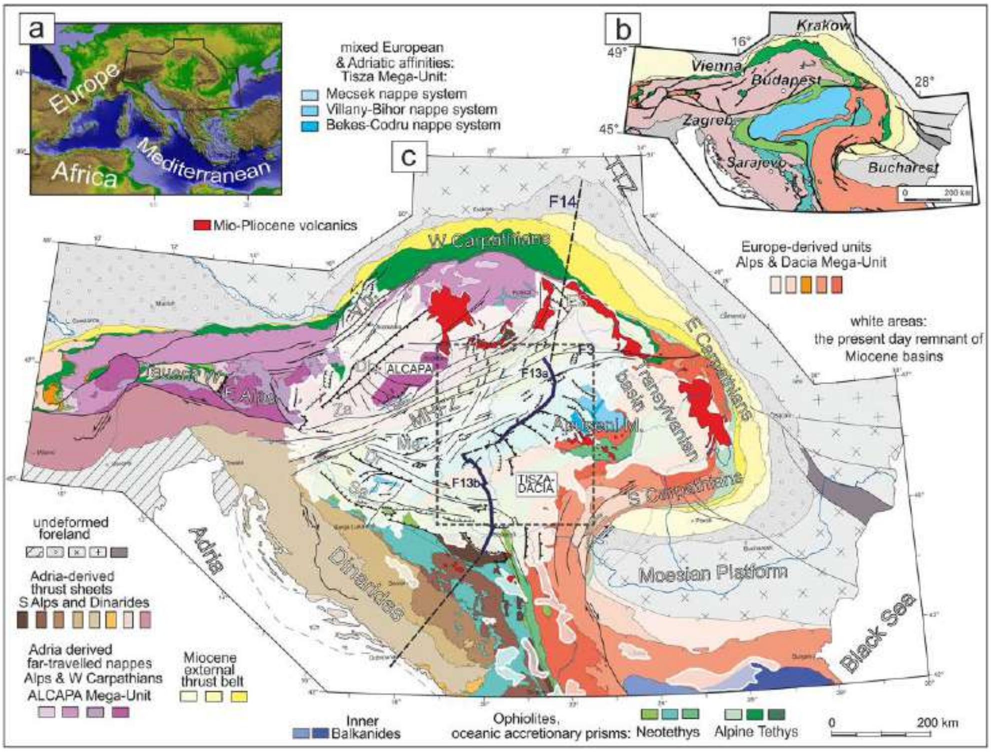


**Figure 4 –** Evolution of the Pannonian Basin [3]:
(a) Location of the Pannonian Basin system; (b) Main tectonic units of the Alps-Carpathians and Dinarides; (c) Miocene –Quaternary tectonic map of the Pannonian Basin and the Alps-Carpathians-Dinarides system showing the present-day extent of the Neogene sediment cover of the Pannonian, Vienna, and Transylvanian basins overlying the pre-Neogene structures and showing the major Miocene to Quaternary faults.

Evolutionary models of the Pannonian Basin postulate the onset of extension at about 20 Ma, followed later by peak tectonic activity along normal faults during the Middle Miocene, which was subsequently followed by a post-rift, thermal subsidence phase beginning in the Late Miocene [4].

Most of northeastern Serbia, together with neighboring parts of Hungary and Romania, incorporate large offset extensional structures such as: Szeged Depression (in Hungary; Banatsko Aranđelovo in Serbia), Algyő (in Hungary); Podeanu (in Romania), Kikinda-Mokrin (in Serbia) and the Makó Depression (Srpska Crnjain Serbia, Tomnatec in Romania). These structures are separated by low-angle, high-offset normal faults with the bedding blocks strongly eroded, while Miocene thickness reaches 7 km in the Makó Depression [7].

For a better understanding of the tectonic-stratigraphic evolution of the basin, this is presented in (figures 5).

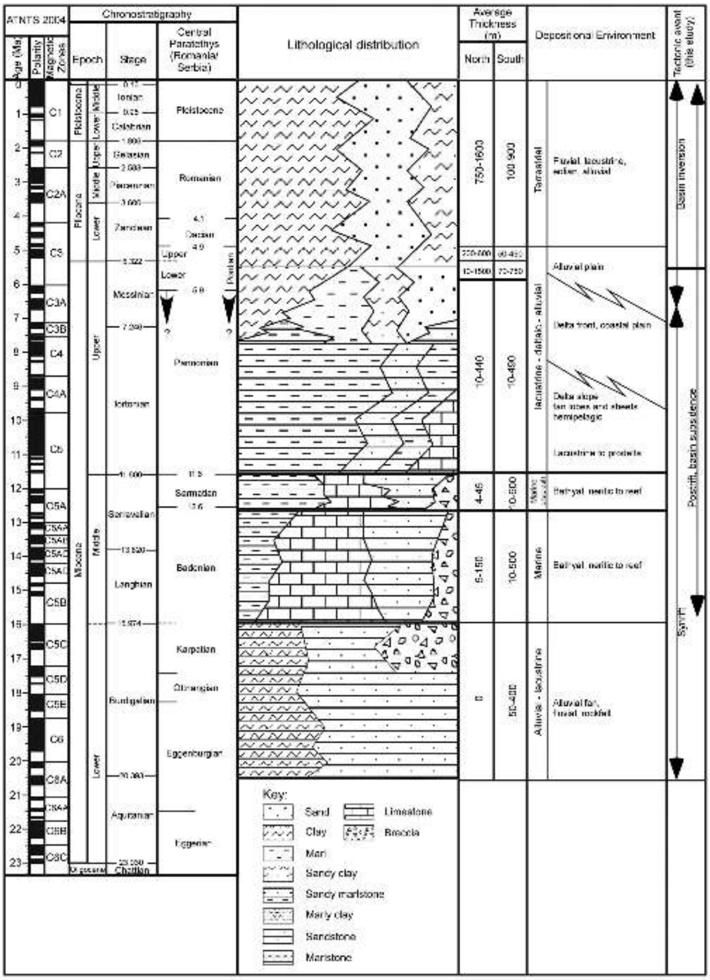


**Figure 5 –** Schematic presentation of the Neogene evolution in the SE sector of the Pannonian Basin (after Matenco and Radivojevic, 2016)

The exploration area is located in the southeastern part of the Pannonian Basin, a large basin composed of the Carpathian Belt to the north and east, the Dinarides to the south, and the Southern and Eastern Alps to the west. It was opened during the early Miocene, and subsequent Neogene-Quaternary multiphase deposition generated depocenters in the syn-rift and post-rift phases of tectonic evolution (figures 6).

The Neogene foundation consists of Paleozoic metamorphic rocks. There are several oil structures near the T structure with essentially the same genetic pattern.

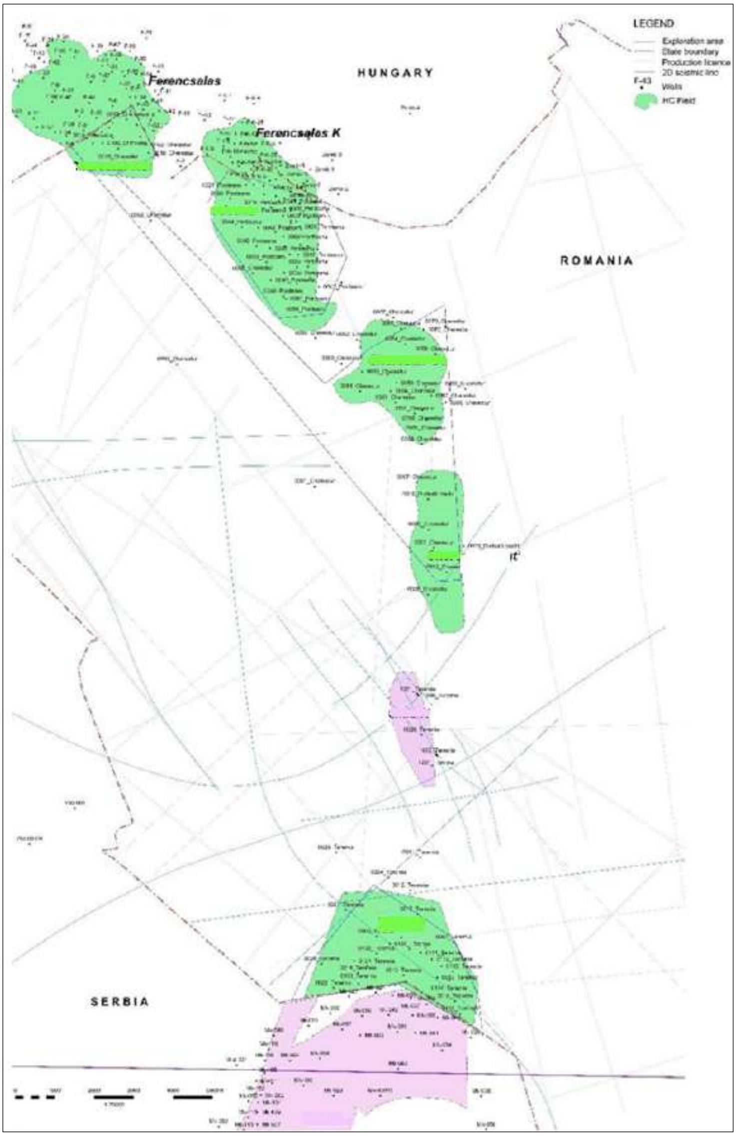


**Figure 6 –** T structure and correlation with neighboring oil fields

Middle Miocene graben orientation controls syn-rift sediment facies distribution. The second Early Pannonian syn-rift unit, consisting of a basal pelitic unit or basal marls, consists of marls and shales with associated siliciclastic reservoirs overlying the Algyo-structure T and Battonya-Turnu-Arad uplifts. Overlain sandy deposits of syn-rift origin have good reservoir rock qualities throughout the Pannonian Basin.

During the Upper Miocene, two deltaic systems were developed under the influence of thermal subsidence and tilting: the first one is a deep-water, low-energy system, and the second one is characterized by the progradation of deltaic bodies into shallower waters. Upper Miocene sediments are represented by marls with subordinate intercalations of sandstones, interpreted as turbidites. These turbidites have reservoir properties in all the Mako-Tomnatec and Northern Banat depressions, and taper to the high areas.

Pontian is represented by marls, silts, calcareous marls with sandstone intercalations. The upper part of the section comprises alternations of sands and clays.

Bearing in mind that the exploration area is in close proximity to the area of the most productive area, in the east of the Pannonian Basin, - Mako - Tomnatec, the reservoirs discovered are related to the metamorphic foundation, to the carbonatites of the middle Miocene (Sarmatian) and to the overlying Pontian sandstones. No deposits were discovered in the deltaic areas.

Along the major uplift there are a series of structural uplifts, represented by structure T, structure C, structure P, with hydrocarbons in the altered zone of the basement and in the Miocene horizons. The oldest reservoir is the one on structure T, which represents the extension of the Serbian Mokrin structure on Romanian territory.

### 2.1.2. Formation conditions of oil structures/reservoirs

a) Triassic clays, Cretaceous argillaceous marls, and Mio-Pliocene black argillaceous marls and shales [1].

b) Reservoir rocks: the upper areas of the altered foundation (Șandra, Satchinez, Variaș, Turnu, Pordeanu, Ciocaia), conglomerates and sandstones from the middle Miocene “Helvețian” and Badenian (Calacea, Șandra, Satchinez, Variaș, Abrămuț, Borș), arenitic and psammitic strata from the lower Pliocene - Pannonian (Calacea, Satchinez, Turnu, Suplacu de Barcău).

c) Screens: All impermeable sequences of the stratigraphic column.

d) Types of traps: Hydrocarbon accumulations are hosted in different types of traps such as folds, anticlinal type, shielded by faults, discordances, tapers, lithological bounded and massive (usually found in the upper, altered zone of the crystalline foundation). They can also be combined making specific arrangements. In many cases, the reservoir communicate, the altered bedrock and the overlying sedimentary layer forming a unit and a unique hydrodynamic objective.

The productive reservoirs exploited to date are located in the crystalline basement, Miocene and Pliocene. In some areas, both in the crystalline foundation and in the upper sedimentary layer, accumulations of $CO_2$ were highlighted. It has an endogenous origin and is exploited together with gaseous hydrocarbons, and in some structures, it is almost pure being exploited as such.

The depth is variable from about 100 m (Suplacu de Barcau) to over 4000 m (in the southern area).

## 2.2. Geology of the structure

Structure T is located on the shoulder of the rift in the eastern, faulted margin of the Pannonian basin, reactivated in the Miocene tectonic phase.

The structure has an area of about 10 $km^2$ within the major Algyő uplift. The productive horizons are the Lower Pannonian/Pontian sands, calcareous sands with intercalations of shale sands located at depths of 2000 to 2500 m.

### 2.2.1. Stratigraphy and lithology

Structure T consists of a series of Miocene-Pliocene sedimentary deposits overlying an altered crystalline basement.

Since in the Pannonian Basin, the Pannonian age/formations have various meanings, in (figure 7) the correlations proposed by different authors are presented.

The crystalline foundation is represented by granites, cataclased granites and feldspathic-epidotic-sericitic quartzite schists. The upper part of the foundation consists of heavily weathered rocks. On the T structure, the existing wells opened the crystalline bedrock at various thicknesses of up to over 150 m.

The Sarmatian sediments (Upper Miocene) are potential reservoir rocks and are represented by a sequence of conglomerates/breccias and sandstones with occasional occurrences of fine-grained argillaceous marls with sandstones and siltstones. The conglomerate pebbles are composed of fragments of cataclastic granite and, to a lesser extent, feldspathic quartzite schists.

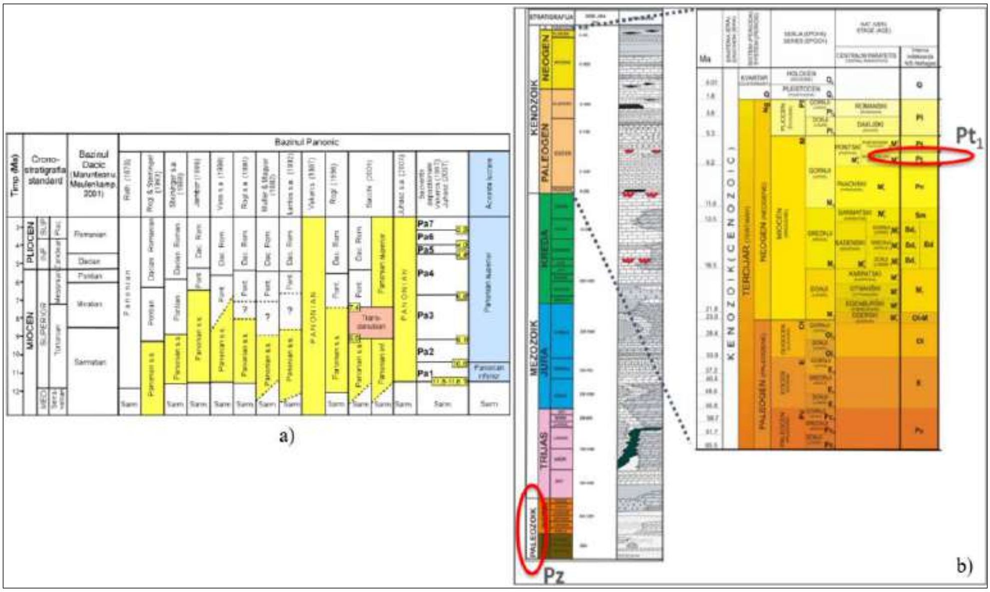


**Figure 7** – Correlation patterns of Neogene formations:
a – after Rabagia 2009; b – current interpretation [5]

The thickness of these reservoir is different in different areas and may range from a few meters to more than 60 m (according to seismic data).

The crystalline basement, Breccia and Miocene Conglomerate (Sm) form a single porous and/or fractured unit, thus forming a single reservoir.

Screen rocks are represented by marls.

Lower Pontian reservoirs consist of sandstones, marls, and sandy marls. Screen rocks are represented by marls.

Upper Pontian reservoir are represented by clays, marls, clays, sands, and sandstones with occasional occurrences of coal.

During the Quaternary and Pliocene, clays, sands and gravels are deposited.

We can highlight two main lithological units, a lower one, from the foundation to about 1700m (Upper Pliocene), consisting of pelitic layers (clays) alternating with coarse layers (arenites), where hydrocarbon accumulations are present, and an upper zone from about 1700 m to the surface, mainly a pelitic unit, which becomes coarser towards the surface and which does not contain hydrocarbon accumulations.

### 2.2.2. Tectonics

The northern T-structure consists of a drape anticline formed by the deposition of Mio-Pliocene, post-conglomerate sediments (as previously described) overlying the crystalline basement.

It is oriented on a N-S axis and in accordance with the existing raised areas, the foundation has two culminations, one northern and one southern, separated by a lower area (saddle) At the lower level (foundation + breccia + conglomerate) the structure is divided by a dextral strike slip/normal fault that separates two blocks Northern (I) and Southern (II).

The fault has a limited vertical extension affecting only the foundation, Breccia, conglomerate formations. The overlying Mio-Pliocene reservoirs are not affected by this fault forming a continuous drape fold.

This arrangement does not affect the oil accumulations located in the upper part, not interfering with the saturated zones of the hydrocarbon reservoirs.

Due to variations in the depositional conditions, an intraformational disharmony can be observed consisting of a displacement of the peak peaks in different layers.

### 2.3. Petroleum considerations

Since the conditions of generation and accumulation of oil in the formations of the Pannonian basin are known, we will present only the particular aspects of the structure/oil reservoirs [2].

From a structural point of view, at the level of the reservoir, Paleozoic-Brecia, the culminations of the paleo-relief and respectively the saddle zone represent, from the existing knowledge, accumulations separated from the oil, the saddle zone between them having a sufficient depression that blocks the existence of a drain point between the culminations.

Overlying, with lateral and discontinuous development, the Miocene conglomerate is present, with a much-reduced development in relation to the underlying Breccia

A dextral fault with a sealing role was also highlighted, F.

Fault F1 separates the northern block from the central block.

The wells (1000, 1001 and 1003) in the Nordic block produce crude oil at Paleozoic with RGT close to the initial solution ration.

In the southern compartment (block II) moved to the SW in relation to the northern one, a second culmination more extensive than the northern one is highlighted, both being protrusions of the altered foundation + breccia. The limits of GOG, OWC have different values in the two blocks, being probably in communication at the level of the bottom water.

The distribution of seismic reflectors can estimate the existence of this fault.

Also, the GOC, OWC limits confirm the existence of the previously mentioned fault. Regarding the overlying Mio-Pliocene, from a lithological point of view, in the sea, we can highlight two main lithological units, a lower one, from the foundation to approximately 1700m (Upper Pliocene), consisting of pelitic layers (clays) alternating with coarse layers (arenites), where hydrocarbon accumulations are present and an upper zone from approximately 1700 m to the surface, mainly pelitic, becoming coarser towards the surface, and which does not contain hydrocarbon accumulations.

### 2.4. Hydrocarbon reservoirs

According to the concession area highlighted by the topographical perimeter and in accordance with the structural layout mentioned above, the area of interest (saturated hydrocarbons) is in the areas with central culminations where we can describe several productive complexes forming different reservoirs both in terms of surface and depth and types of hydrocarbons [8].

These will be described in correlation with their original names used in existing data. These are:

- Paleozoic: this represents an altered (fissured) superficial part of the crystalline foundation and consists of granites, cataclastic granites and quartzitic-feldspat-epidotic-sericitic schists. In general, this type of reservoir can be divided into 4 layers / zones: upper, highly altered, less obvious at the level of the T structure, probably eroded, where the feldspars are partially transformed into clay minerals that decrease the properties of the reservoir, upper middle, intensely fractured and partially chemically altered, lower middle, fractured and the oldest, compact (figures 8). The best properties of the reservoir belong to the second and third layers. The overlying sediment consists of breccia – resulting from the subaerial erosion of the crystalline paleo-relief and a layer of conglomerates, discontinuous, present only on the flanks of the southern culmination with smaller and rounded pebbles compared to the breccia. Also, the porosities and permeabilities of the two petrographic types are different. This reservoir also includes the Miocene (Sm) “breccia/conglomerate” formations described above, forming a single hydrodynamic unit.


**Figure 8 –** Representative mechanical cores:
a) Conglomerate; b) Breccia; c) Paleozoic

An average “porosity” of 4.5 – 4.6 % can be accepted from the geophysical logs and cores.

- Rx (Pt 1-1): Located in the lower Pontian formation (Pn), this reservoir is an arenitic one with moderate clay content and good properties (porosity Φ, and permeability K). Gas accumulation is present only at the level of the southern peak of the anticline;

- R3c+d (Pt1-3): Detected on the geophysical diagraphs, the two potential reservoirs are of arenitic type (siliceous sandstones). To date they have not been mechanically cored or tested. Like the underlying Rx reservoir, the gas accumulation is present only at the level of the southern culmination of the anticline;

- R2 (Pt 1-4): With a lithology like sandstones/sands with clay content) is placed above R3 (Pt 1-3) and according to the structural image there is a communication between the ridges forming a single hydrodynamic unit.

- R1a+R0c (Pt 1-6+7): It also belongs to the lower Pontian and is formed by arenitic rocks, sandstone to sand, forming like the previous horizon a hydrodynamic unit including several culmination zones that communicate through spill points.

- R0b (Pt 1-9): It is the highest Pontian reservoir, it has similar rock properties to the previous one, but, at this level, we can speak of a single accumulation.

### 2.5. Objectives of petroleum interest

The main oil targets are the following formations/packages:

- Paleozoic foundation + basal breccia + conglomerate – landmark Paleozoic;
- Lower Pannonian – landmark Rx (Pt 1-1);
- Lower Pannonian – landmark R3 c, d (Pt1- 3)
- Lower Pannonian – landmark R2 (PT 1-4);
- Lower Pannonian – landmark R1a, R0c (Pt 1-6);
- Lower Pannonian – landmark R0b (Pt 1-9).

### 2.6. Areas favorable for the existence of new hydrocarbon accumulations

As was highlighted in the sub-chapter regarding regional geology, the north T structure is part of a major structural alignment, namely the Algyo - Mokrin uplift, an area of call for hydrocarbons, favorable for the appearance of oil reservoir.

The main favorable factor in the appearance of hydrocarbons is the elements of the petroleum system. Most of its elements being present on the entire investigated surface, the appearance of potential reservoirs is conditioned by the existence, pre-migration of traps.

The main factor that conditions the occurrence of traps is of a combined type, respectively at the lower levels, syn or epi sedimentary discordance/foundation respectively the screening of the foundation and, at the level of the overlying sedimentary, thinning on the discordance, in the immediate vicinity of the Paleozoic culminations, respectively the formation of draping folds at the upper levels.

The draping folds being generally known, the possible remaining unexploited accumulations are those related to the lower Pannonian outcrops on the underlying culminations.

Thus, as illustrated in the seismic section (figure 9), at the Pt1-1 level in particular but also above, possibly hydrocarbon-bearing pinch-outs are highlighted.

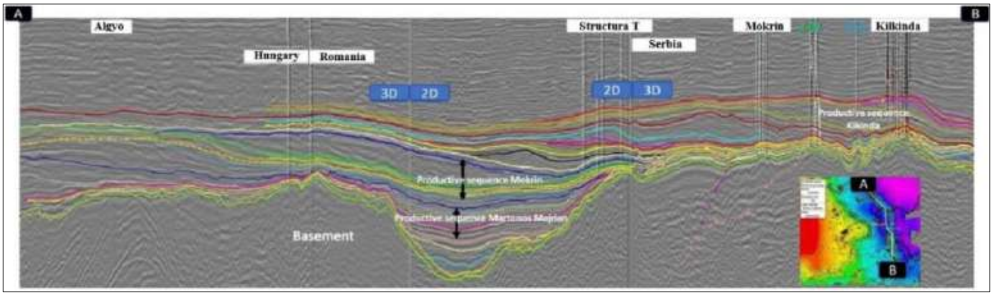


**Figure 9 –** Seismic section – level Pt1-1 (possible hydrocarbon-bearing pinch-outs) [11]

These possible accumulations of hydrocarbons are shown in (figure 10).

After carrying out the geological risk analysis, the most favorable area for the expansion of the reservoirs is area C. Here, well 8 C was dug and tested and gas flows were obtained. The testing was done relatively hastily, and the results are mentioned briefly.

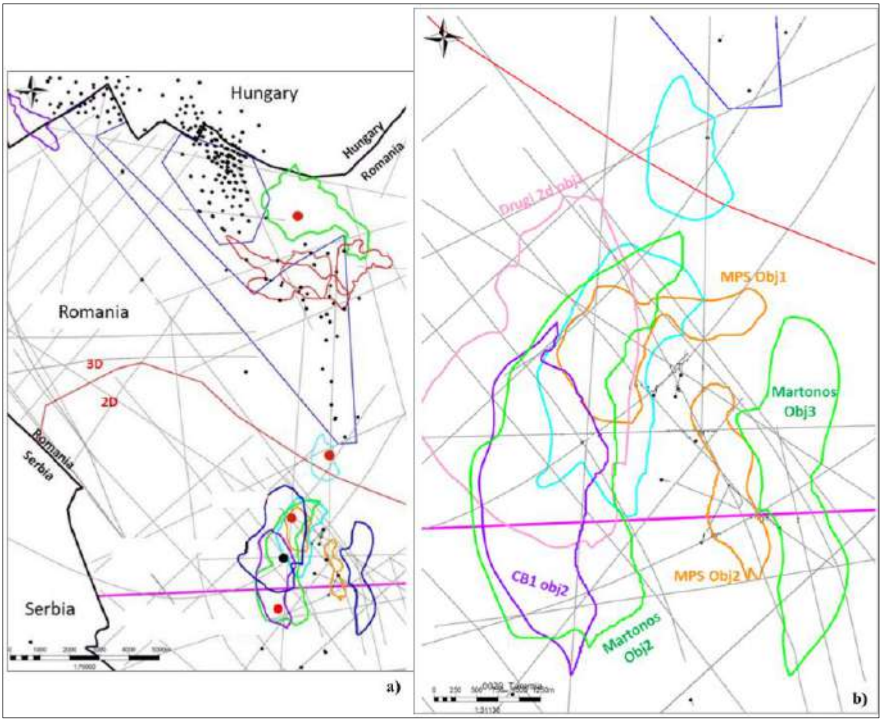


**Figure 10 –** Possible hydrocarbon accumulation areas/reservoirs [11]:
a) regional level; b) local level

Very conclusive is the interpretation of the DST sample (figures 11) in which a flow rate of about 28,000 mc/day was mentioned. We consider it opportune to dig a well on this structure in the vicinity of well 8 C.

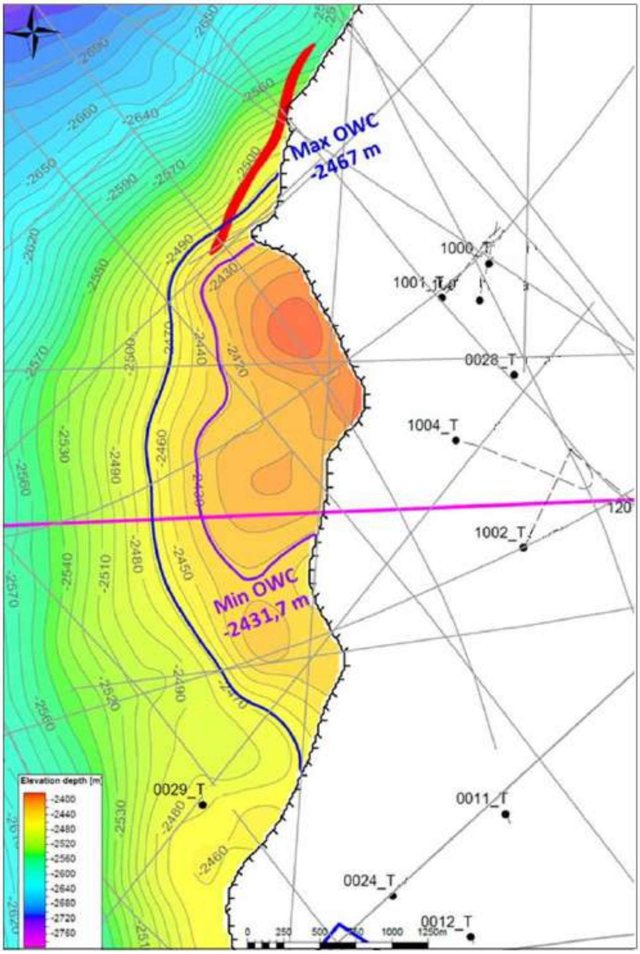


**Figure 11 –** Structural map at Pt1 reservoir head for prospect C (CB1) [11]

Oil and gas prospect CB1 object 2, are located near the oil and gas field.

According to the seismic data, the oil and gas prospect CB1 object 2 (Pt1), has a stratigraphic trap. On the seismic section (figure 12) the identified horizon tapers to the east. The highest point of the trap in Pontian is at a depth of – 2380 m, and the amplitude of the trap is approximately 87 m. The surface of the trap is about 6 km$^2$. The maximum crude oil-water contact was assumed as the leak point – 2467 m.

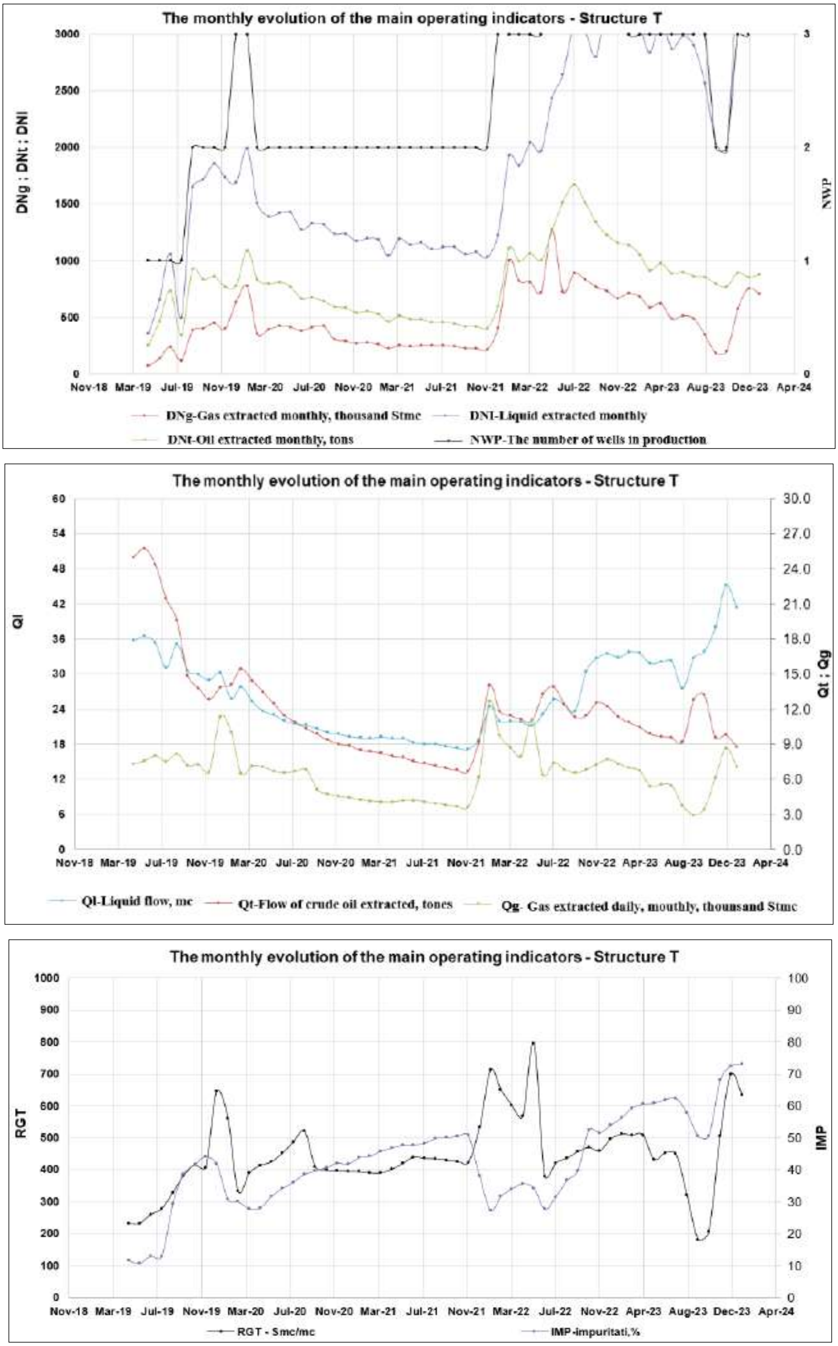


**Figure 12 –** Operational behavior curves – T structure [11]

The geological chance of success (GCoS) of prospect CB1 object 2 (Pt1) was calculated as follows:

GCos of CB1 object 2 (Pt1) – 0.32:

- Trap = 0.63; Layer thinning was identified in the seismic data without attribute analysis. A/T>1.6.

- Source rock = 1; The prospect is located in a basin with proven productivity and close to existing oil fields.

- Migration = 1; The presence of migration was proven by hydrocarbon reservoirs discovered near the exploration area. The trap was formed before the migration started.

- Tank = 0.8; Turbidite fans. The presence of the reservoir was confirmed by wells drilled in the vicinity.

- Conservation = 0.63; Sealing rocks, regionally represented by clay, the insulating properties being proven in the depression area. Significant tectonic movements after trap formation are lacking. There are no signs of biodegradation of the oil.

- Critical moment post Pt1.

## 3. The physical model

### 3.1. Initial pressure and reservoir temperature

The initial pressure and temperature of the reservoir were determined with a high degree of certainty resulting from the measurements made during the production tests of wells 1000 and 1002, respectively from the interpretation and analysis report of fluid samples from the reservoir and pressure tests from well 1001.

Based on the static pressure gauges executed in wells 1000 and 1002 as well as the pressure tests in well 1001, the values of the pressure and temperature gradients were calculated, which have the following values:

- Pressure gradients:
    – 0.096 bar/m at R0b, R1a + R0c, R2, R3c and R3d;
    – 0.108 bar/m at Paleozoic and Rx;
- Temperature gradients: – 0.0048 °C/m.

The initial bottom pressures vary between 206 – 264 bar depending on the depth, and the bottom temperature between 112 – 127 °C.

### 3.2. Characteristics of fluids

#### a) Characteristics of reservoir conditions

To determine the behavior of the fluids in reservoir conditions, fluid samples were taken during the production tests in the case of well 1000, respectively during the experimental exploitation phase of well 1001 [10].

From well 1000, fluid samples were taken from the separator both for Foundation – Paleozoic + Basal Breccia (crude oil field with associated dissolved gases) and for the Lower Pannonian, landmark Rx (Pt 1-1) (gas-condensate field).

Samples of fluids from the separator were extracted from well 1001 in experimental operation at Basal Breccia.

Determination of fluid behavior in reservoir conditions was performed by recombining fluid samples.

From the PVT analyses performed on the crude oil samples from wells 1000 and 1001, the following resulted:

- Saturation pressure: - 252 – 255 bar;
- Solution ratio: - 246 – 269 $Stm^3/m^3$.
- Volume factor of crude oil: - at initial pressure: - 1.84 – 1.98;
  - at saturation pressure: - 1.751 – 1.98;
- Crude oil viscosity: - at initial pressure: - 0.16 – 0.19;

For the characterization of fluid behavior in Paleozoic Foundation and Basal Breccia reservoir conditions, the gas sample collected from well 1001 is considered conclusive.

The sample collected from the separator at probe 1000 is not considered conclusive, given that there are excess gases in the sample taken.

For the gas-condensate field discovered at the lower Pannonian landmark Rx (Pt 1-1), to determine the fluid behavior with pressure and temperature, a fluid sample (condensate and gas) was collected from the separator and by recombination the behavior of the fluids with pressure variation was determined.

The main conclusions of the report are:

- the gas-condensate reservoir has a retrograde behavior, the dew point pressure is equal to the initial pressure, 252 bar (figure 13);
- deviation factor of gases at initial pressure and dew point pressure, Z = 0.9236;
- initial condensate ration = 4667 $Stm^3/m^3$;
- gas density at the pressure and temperature of the reservoir, $kg/m^3$.

The main physical properties of the gases contained in the lower Pontian at the landmarks R3c (Pt 1-3), R3d (Pt 1-3), R2 (Pt 1-4), R1a (Pt 1-6) and Rob (Pt 1-9) were determined starting from the gas composition, pressure and reservoir temperature.

### b) Characteristics under standard conditions

The physical properties of the fluids were determined by laboratory processing of crude oil, water and gas samples taken from wells.

The crude oil has a specific weight of 790 kg/m$^3$ and is classified as class 7.

A very high viscosity is noted at temperatures of 10 ºC, the measured values being between 530 – 943 cP. By increasing the temperature, the viscosity of crude oil decreases a lot, at temperatures of 30 ºC, values between 3 and 10 cP were measured.

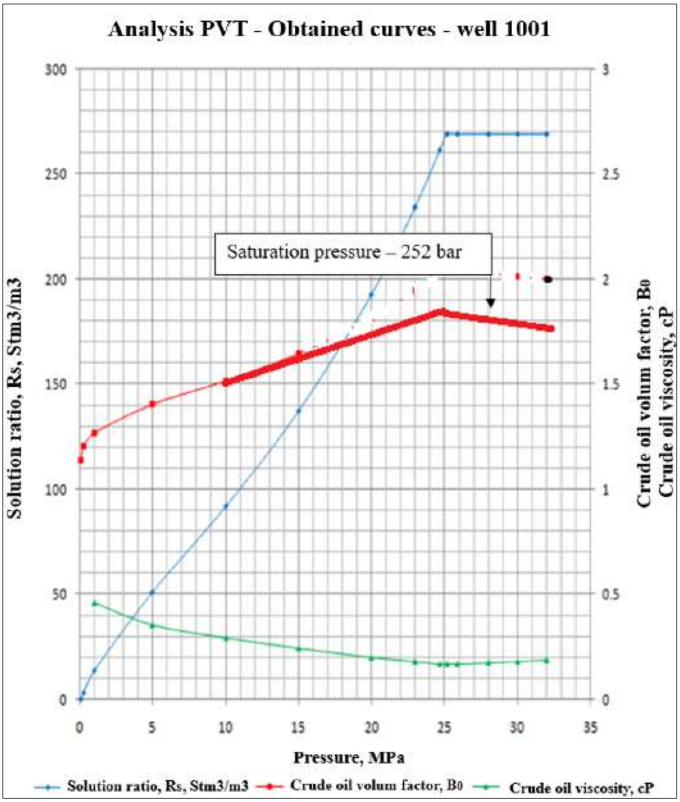


**Figure 13 –** Simulation of curves from PVT analysis – Probe 1001 [11]

Crude oil has a freezing temperature below 15 ºC and a high content of light fractions.

Associated gases have a (volumetric) methane content of 74 – 84 %, and free gases of 96 – 97 %. The relative density has values between 0.58 and 0.69.

The reservoir water is calcium chloride type, chloride group, sodium subgroup. The analyzes carried out for the samples taken indicate that the pH is slightly acidic (4.7 – 6.7), the density of the reservoir water at 20 ºC is 1.02 – 1.07, in the dissolved salts salt predominates (over 85 % NaCl).

### 3.3. Store Rock

To determine the store rock parameters (effective porosity, absolute permeability and initial water saturation) both the data from the analysis of mechanical cores and those from the complex geophysical investigation were used.

#### a) Effective porosity

To determine the effective porosity, both the direct methods and the quantitative interpretation of the complex geophysical diagraphs of the wells were used.

In (table 1) average porosity values for each productive complex are shown, resulting from the statistical processing of all available data.

*Table 1* – **Average porosity values for each productive complex**

| **Formation** | **Reservoir landmark** | **Resulting average values** |
|---|---|---|
| | **-** | **%** |
| Microconglomerate | | 16,5 |
| Basal Breccia | | 6,2 |
| Paleozoic | | 4,5 - 4,6 |
| Lower Pannonian | Rx (Pt 1-1) | 17,9 |
| Lower Pannonian | R3d (Pt 1-3) | 16,9 |
| Lower Pannonian | R3c (Pt 1-3) | 11,94 |
| Lower Pannonian | R2 (Pt 1-4) | 20,1 |
| Lower Pannonian | R1a+R0c (Pt 1-6) | 22 |
| Lower Pannonian | R0b (Pt 1-9) | 21,1 |

### b) Absolute permeability

The absolute permeability values resulting from statistical processing are shown for each productive complex in (table 2).

*Table 2* – **Absolute permeability values**

| Formation | Reservoir landmark | Values |
|---|---|---|
| | - | mD |
| Lower Pannonian | Rx (Pt 1-1) | 0,51 – 4,746 |
| Lower Pannonian | R3d(Pt1-3) | 0,8 – 39,8 |
| Lower Pannonian | R3c(pt1-3) | 0,7 – 24,8 |
| Lower Pannonian | R2 (Pt 1-4) | 19,14 – 70,537 |
| Lower Pannonian | R1a+R0c (Pt 1-6) | 24,25 – 170,806 |
| Lower Pannonian | R0b (Pt 1-9) | 70,537 – 103,3 |

## 3.4. The rock-fluid system

### a) Saturation in interstitial water

To determine the initial saturation, both the direct methods and the quantitative interpretation of the complex geophysical diagraphs of the wells were used.

In (table 3) the average interstitial water saturation values for each productive complex are shown, resulting from the statistical processing of all available data.

*Table 3* – **Average interstitial water saturation values for each productive complex**

| Formation | Reservoir landmark | Resulting average values |
|---|---|---|
| | - | % |
| Microconglomerate | | 30,5 |
| Basal Breccia | | 22,5 |
| Paleozoic | | 14,9 |
| Lower Pannonian | Rx (Pt 1-1) | 33,8 |
| Lower Pannonian | R3d (Pt 1-3) | 23,4 |
| Lower Pannonian | R3c (Pt 1-3) | 24,2 |
| Lower Pannonian | R2 (Pt 1-4) | 25,9 |
| Lower Pannonian | R1a+R0c (Pt 1-6) | 21,0 |
| Lower Pannonian | R0b (Pt 1-9) | 34,7 |

**b) Effective permeability**

The hydrodynamic research carried out at probe 1000 indicates the following values of the effective permeability:

- 0.5 ÷ 1.1 mD – Lower Pannonian-marker Rx (Pt 1-1);
- 27.5 ÷ 29.6 mD – Lower Pannonian-landmark R2 (Pt 1-4);
- 106 mD – Lower Pannonian-landmark R1a (Pt 1-6);
- 42.8 mD – Lower Pannonian-marker R0b (Pt 1-9).

## 4. Mining history of reservoirs

The analysis of the exploitation history was carried out only for hydrodynamic units (H.U.) 1 and 2, the only ones exploited at the reference date of this work. In (figure 14) exploitation is simulated on wells and exploitation objectives.

## 5. Conclusion and the future exploitationd design

From an administrative point of view, structure T is assumed to be located in the eastern part of the Pannonian Basin on the Algyo – Ferencszallas – Mokrin structural alignment between the Mako – Tomnatec Depressions to the E – NE and the North Banat to the W – NW.

From a geological point of view, structure T is located in the eastern part of the Pannonian Basin on the Algyo – Ferencszallas – Mokrin structural alignment between the Mako – Tomnatec Depressions to the E – NE and the North Banat to the W – NW.

The exploration area is located in the southeastern part of the Pannonian Basin, a large basin composed of the Carpathian Belt to the north and east, the Dinarides to the south, and the Southern and Eastern Alps to the west. It was opened during the early Miocene, and subsequent Neogene-Quaternary multiphase deposition generated depocenters in the syn-rift and post-rift phases of tectonic evolution.

Related to the analysis of the future behavior in the exploitation process and the design of the future exploitation, was carried out according to the existing well gauge and under the current operating conditions.

The production forecast was drawn up by wells and summed up at the level of exploitation objective and structure. The simulation of the comparative evolution of the main exploitation indicators is in (figure 15).

For the exploitation in good conditions of the oil and gas reservoirs of the T structure, it is necessary to create an infrastructure capable, first of all, of ensuring the cleaning, transport and delivery of gases in the transport network.

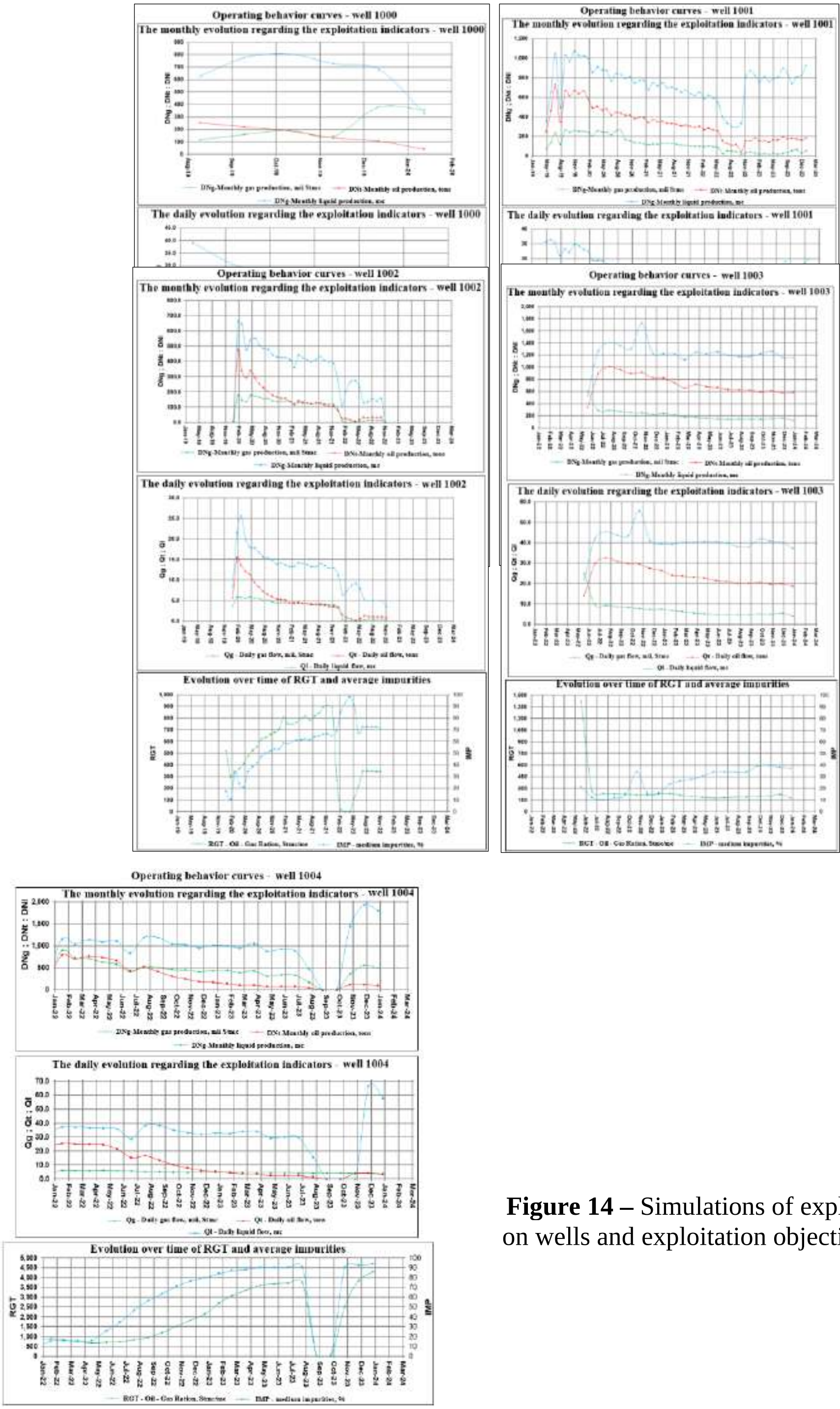


**Figure 14 –** Simulations of exploitation on wells and exploitation objectives [11]

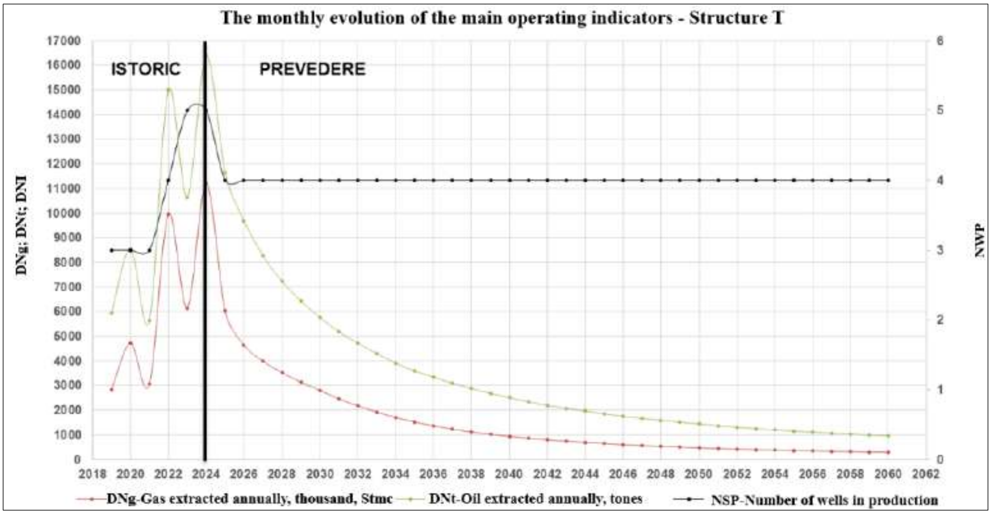


**Figure 15** – Simulation the comparative evolution of the main exploitation indicators [11]

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