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USING FORMATIONS OVERPRESSURES FOR SUBSIDENCE CALCULATIONS

1. INTRODUCTION

Since the very beginning of wells' drilling, manly for oil and gas wells, formations' pressure represented one of the most important factors its estimation/evaluation being crucial for wells drilling.

Hence were developed different methods of pressure predicting, each of them being suitable for one or more types of sedimentary basins. Also the experience gained in petroleum exploration and exploitation materialized in different methods of formations' pressure, gradients, calculation as: equivalent depth, Ben Eaton, Hottman Shell, etc., based on drilling or well logs data [1] applicable for different zones/sedimentary basins. Also the experience gained in well exploitation, mainly pressure measurements enable us to improve the existing algorithms and shift them for a certain sedimentary basin.

The Romania's oilfields, exploited of more than one and a half century offer a large data base for formations' pressure calculations for different areas (corresponding to distinct basin zones) and depths (corresponding to different geological layers/ages).

The over pressures may have different origins so we tried to obtain a trustful correlation between the value, origin and basin evolution causes of these values. Also, as the case study confirm we may obtain important clues for sedimentary basins evolution by the geological significance of these pressures according them with the subsidence/burial/uplift history of the studied area.

Because both basin evolution and overpressure calculations have different patterns for different areas we will refer to the SW – outer part of Eastern Carpathians' inner fore deep flank.

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2. GEOLOGICAL OUTLINES

The studied area is a part of the so called Miopliocene Zone or Diapiric Folds Zone.

The Diapiric Folds Zone is situated in the outer part of the southern East Carpathians area, delineated by the Buzau river valley (east), Dambovita river valley (west), erosion contour of Miocene and Pliocene deposits, transgressive on the Flysch Zone (north) and by the Pericarpathian Fault in the southern part, representing, at the surface, the inner part of the Carpathians' fore deep.

On depth it represents three superimposed tectonic units: sarmato-pliocene – upper fore deep, Subcarpathian nape – lower fore deep and Tarcau nape – outer flysch (Fig. 1).

Considering the molasses basin as a consistent series, with a distinct evolution we may assume that it represents the last phase of a polihistoric basin. In this case the flysch deposits (Eocene – Oligocene) represents the basement of molasses zone basin so we may discuss the subsidence of a Miocen – Pliocene basin, mainly its sedimentation/burial/uplift/folding/faulting history.

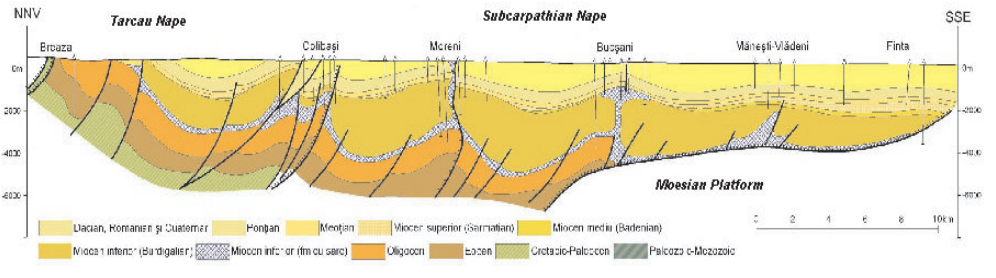

Fig. 1. Diapiric Folds Zone; cross-section between Breaza and Finta
(after Romanian Institute of Geology – 2005)

Referring to the molasses sedimentary basin it consists of an aquitanian evaporitic discontinuous layer overlaying the "Oligocene Basement" followed by a complex detritic Miocene – Pliocene series formed of pellitic (marls, shales), arenitic (sandstones, sands) or even coarser sediments (upper Pliocene deposits).

The total thickness of these deposits may vary between 1000–5000 meters [1] depending of the position in the basin's area.

The structural arrangement of the molasses zone [8] has been defined by the upper Miocene orogenic phase (Moldavic) and accomplished by the diapiric folding of the Valachian orogenic phase and consists of four alignments of diapir folds oriented west – east and faulted (reverse faults) as is shown in the Figure 1. The studied area, Bucsani – I.L. Caragiale – Margineni, is positioned in the outer part on the attenuated diapir alignment (Fig. 2) where salt deposits remain under the Upper Molasses deposits [1, 3, 4].

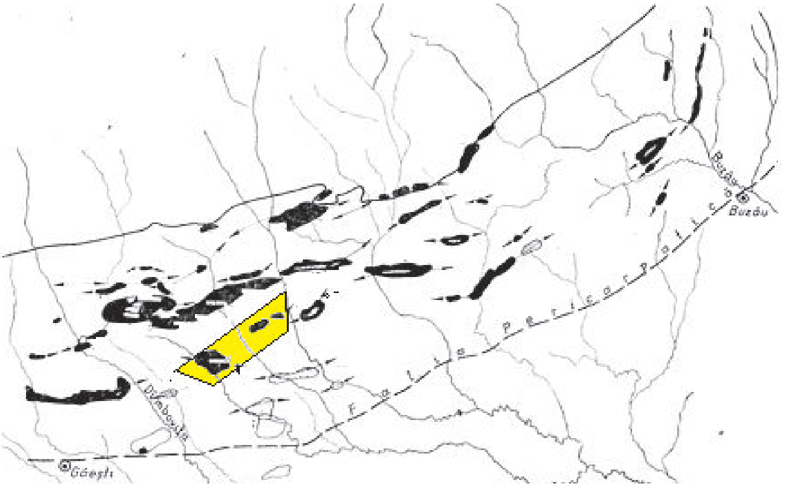

Fig. 2. Diapiric Folds Zone oilfields

3. PRESSURES CALCULATIONS

The main oil producing objectives from the studied area [4] are the Meotian ones so the majority of the wells are drilled only till the bottom of this formation. In the last 20 years, in order to explore the petroliferous potential of deeper Miocene reservoirs were drilled more than 20 wells some of them crossed all the Diapiric Folds Zone deposits and intercepted the Moesian Platform deposits.

All the Miocene and even Oligocene deposits are characterized by very difficult drilling conditions induced of the pore fluids pressures. Recorded well logs permitted us to estimate the pressure values for the Miocene formations and the producing tests verified their accuracy.

Also we benefit of the results of the cores collected from the wells some of them containing shales and/or marls.

The most reliable logs recorded in the wells are resistivity (ρ) and acoustic (Δt) ones. For both of them the most suitable relations were Ben Eaton relations [5] so we used them. Regarding the α exponent for resistivity values [7] we observed that the obtained values are to higher so we corrected it by shifting the equation with the producing tests and the obtained value is $\alpha = 1.15$. For acoustic logs the α value remained the same, 3. So the proper equations are:

for resistivity logs: $$\Gamma_p = \Gamma_{lit} - (\Gamma_{lit} - \Gamma_{nh})\left(\frac{\rho_{ob}}{\rho_{nt}}\right)^{1.15} \quad (1)$$

for acoustic logs: $$\Gamma_p = \Gamma_{lit} - (\Gamma_{lit} - \Gamma_{nh})\left(\frac{\Delta_{nt}}{\Delta_{ob}}\right)^{2} \quad (2)$$

where:

Γ_p – pressure gradient,
Γ_{lit} – lithostatic gradient,
Γ_{nh} – normal hydrostatic gradient,
ρ_{ob} – observed resistivity,
ρ_{nt} – normal tendency resistivity,
Δ_{nt} – normal tendency transit time,
Δ_{ob} – observed transit time.

Another encountered problem refers to the possibility of drawing the normal tendency line (curve). So for transient time logs we used the next equations obtained from a larger data base regarding the whole sedimentary basin available well logs:

$$\text{for Pliocene: } \Delta t_{nt} = \text{anti}\log\frac{1}{2}\left\{4.486-[20.34-4\cdot(5.086-2.66\cdot10^{-5}H)]^{\frac{1}{2}}\right\} \tag{3}$$

$$\text{for Miocene: } \Delta t_{nt} = \text{anti}\log\frac{1}{2}\left\{4.501-[20.32-4\cdot(5.080-2.81\cdot10^{-5}H)]^{\frac{1}{2}}\right\} \tag{4}$$

$$\text{for Oligocene: } \Delta t_{nt} = \text{anti}\log\frac{1}{2}\left\{4.397-[19.80-4\cdot(4.952-3.01\cdot10^{-5}H)]^{\frac{1}{2}}\right\} \tag{5}$$

The obtained pressure gradients for each formation are:

- for Pliocene (including Meotian), normal to small overpressure values of 0.1–0.11 at/m;
- for Miocene, very high values of 0.175–0.203 at/m.

These results are verified also by the production tests results as an example at 2400 m depth the well pressure was about 480 at.

4. GEOLOGICAL INTERPRETATION AND OIL GENERATING IMPLICATIONS

As we may see in the cross section the molasses is divided in two distinct sedimentary series:

- a Miocene (Aquitanian – Lower Badenian) one corresponding to lower molasses with a initial thickness of more than 3000 m, recorded in wells;
- a Meotian – Pliocene one corresponding to upper molasses with a thickness about 1800–2000 m, recorded in wells.

They are separated by an unconformitiy corresponding to Badenian and/or Sarmatian, depending of the position on the studied area related with the Moldavic final stage. Usually is missing the Upper Badenian and Sarmatian but in the northern part of the studied area sarmatian deposits are present and their thickness is about 150–200 m. Also in the south west zone we depicted (from cores) an Upper Badenian about 400 m thick consisting of marls and shales very similar with the older formations known as the so called “Helvetian”.

Referring to the pressure gradients we may consider that a rocks column thicker than 3000 m, compacted column, without the hiatus corresponding to the unconformity, depositioned in about 15 my provide an initial sedimentary rate of more than 230 m / my. This able an important shales undercompacting corresponding to a 0.12–0.13 at/m pressure gradient. This value has been confirmed in the nearby areas where is no tectonic uplift.

Comparing these values with the calculated pressures gradient of the Lower and Middle Miocene from the studied area, mainly on I.L. Caragiale structure, placed in the centre of the zone which goes up to 0.203 at/m appears a difference of 0.07 at/m which may be assigned to the tectonic uplift of the formations. This is reported to the shales situated bellow the discordance, around 2000 m, representing a 140 at overpressure corresponding to a normal uplift of 1400 m. The erosion of Upper Miocene represents more than 500 m of sediments (reporting to the nearby existing sedimentary rocks) so the total uplift of the basin in the studied area may be considered about 2000 m.

With these data and according to the actual lithostratigraphic column we constructed the burial history of the zone [2] and estimated the oil window (Fig. 3). For a restrictive pattern we choose the south-west zone where the pressure gradient is about 0.19 at/m for the pre-meotian deposits and badenian deposits occur. Also we benefit of the existence of a deep well, around 6000 m using its data for this model so the resulting tectonic uplift is smaller, around 1100 m.

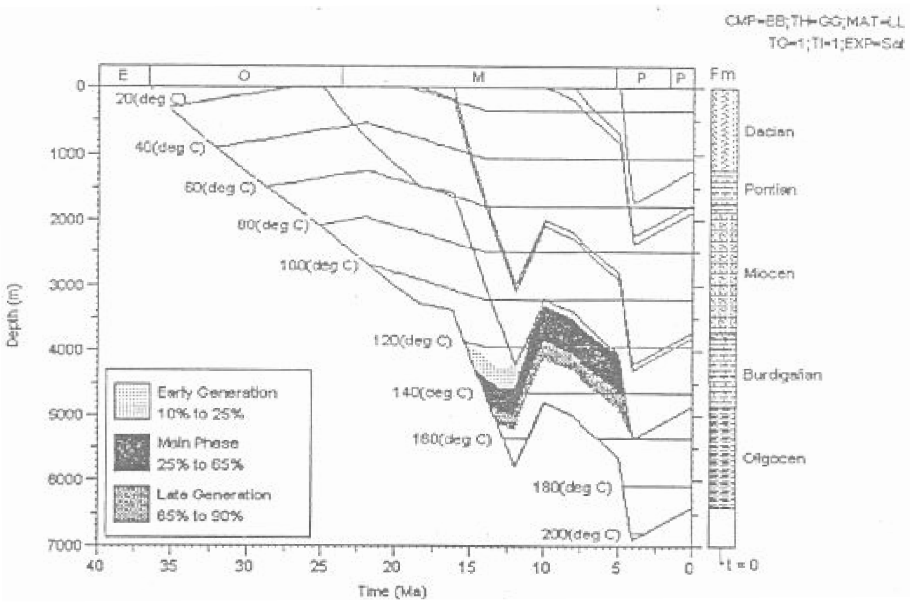

Fig. 3. Burial history and oil generation window for the studied area

Even so we may see that the source rock crossed the oil window [6] allowing oil generation and migration. Even the existing overpressures indicate a migration seal oil accumulated in the Miocene and Pliocene reservoirs providing important hydrocarbons resources.

5. CONCLUSIONS

Overpressures values provided by the existing wells may offer important data related both to drilling conditions and geological evolution of a certain zone.

For an appropriate estimation we have to take into account the basin conditions and direct measurements in order to obtain a reliable values set. Also depicting overpressures origin may explain the sedimentary basin geohistory.

The studied area is placed in the so called Diapiric Folds Zone and is characterized by high pressure gradients for pre-meotian deposits. We calculated them for the molasses basin corresponding to Early Miocene – Pliocene interval.

The calculated pressures have a dual origin from shales' under compaction and tectonic uplift. Making the difference between them we estimated the relative uplift of the zone corresponding to upper Miocene orogenic phase.

These calculations provided us important clues in order to obtain a realistic subsidence calculus which enabled a proper burial history construction and hence we may estimate oil generating potential of the zone.

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