ABNORMAL PRESSURES ENCOUNTERED IN TORTONIAN - MESSINIAN - PLIOCENE CROSS-SECTIONS OF PREADRIATIC DEPRESSION AND ITS ESTIMATION WITH CONVENTIONAL GEOPHYSICAL METHODS

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A B S T R A C T

In cross sections of shale-sandstones of Tortonian - Messinian - Pliocene ages at Preadriatic depression with which structural belt of gas fields is connected, abnormal pressures zones are found.

The existence of abnormal pressures becomes a great obstacle for well drilling. The abnormal pressures are encountered from shallow depths (700-800) to 3500-4000m. Gradients of pressures change from 1,3 to 2Kg/cm^2/10 m.

The techniques applied and results achieved from investigations of wells with geophysical methods are presented in this paper.

These methods are comparable to the other geological and technological methods.

ΧΡΗΣΗ ΣΥΜΒΑΤΙΚΩΝ ΓΕΩΦΥΣΙΚΩΝ ΜΕΘΟΔΩΝ ΓΙΑ ΤΟΝ ΚΑΘΟΡΙΣΜΟ ΖΩΝΩΝ ΑΝΩΜΑΛΗΣ ΠΙΕΣΗΣ ΚΑΤΑ ΜΗΚΟΣ ΤΟΜΩΝ ΤΟΡΤΟΝΙΟΥ-ΜΕΣΣΗΝΙΟΥ-ΠΛΕΙΟΚΑΙΝΟΥ ΣΤΗΝ ΠΡΟ-ΑΔΡΙΑΤΙΚΗ ΚΑΤΑΒΥΘΙΣΗ

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Π Ε Ρ Ι Λ Η Ψ Η

Σε τομές αργίλλων-ψαμμιτών, ηλικίας Τορτονίου-Μεσσηνίου-Πλειοκαίνου της Προ-Αδριατικής καταβύθισης, με την οποία δομικές ζώνες φυσικού αερίου είναι συνδεδεμένες, βρίσκονται ζώνες ανωμάλων πιέσεων.
Η ύπαρξη αυτών των ζωνών αποτελεί σημαντικό εμπόδιο για τις γεωτρήσεις. Αυτές οι ζώνες συναντώνται από χαμηλά βάθη (700-800m) μέχρι τα 3500-4000m. Η βαθμίδα της πίεσης μεταβάλλεται από 1.3 έως 2Kg/cm^2/10m. Εφαρμοσμένες τεχνικές και αποτελέσματα από γεωφυσικές έρευνες σε γεωτρήσεις συγκρίσιμες με άλλες γεωλογικές και τεχνολογικές μεθόδους παρουσιάζονται σ' αυτή την εργασία.

INTRODUCTION

Technological drilling difficulties have been encountered during the past years in the structural coastal belt of Preadriatic depression. A considerable part of cross-sections beginning from Pliocen to Helvetian showed high abnormal pressure. Several wells did not reach the drilling programmes because of the formations with abnormal pressure occurring at depth 700-800m, with relatively high pressure, Fig 2.

Therefore the study of compaction and calculation of layer pressures, was one important task which should be fulfilled.

To draw an accurate conclusion on the nature and spread of abnormal pressure, it was necessary to get acquainted with a broad drilling information. A portion of the data is obtained by technological methods, while more and important and complete information is obtained by well logging measurements.

All the existing measurements have been used in this study, but the most significant are apparent resistivity and travel times measured with acoustic devices.

It was necessary to study the regularities of shale compaction and separation of non-compressive zones with abnormal pressure. (Magara,K., 1988).

STUDY OF DEPENDENCE OF POROSITY WITH DEPTH

In order to indicate compaction conditions, it was necessary to construct a series of dependence of well logging measurements, the indexes of which depend on porosity versus the depth. Analytical and statistical dependence in studing the conditions of compaction and estimation of layer pressures were used. Only analytic dependences are refered here. The change of porosity of rocks with depth as the result of compression was studied by the following equation. (Dobrin,V.M., 1989).

$$\frac{d\phi}{\phi(1-\phi)} = -a(\tau-t)\ d(s-p) \qquad (1)$$

Where a(τ,t) - is coefficient of irreversible compression of rocks. (S-P) is pressure of compactions. φ - porosity, τ- times and t- temperature.

The coefficient of irreversible compression a(τ,t) was determined for every region in order to accomplish the calculations and study the compaction. The following formula was used:

$$a(\tau,t) \approx \frac{1}{0.014\phi(1-\phi)} \cdot \frac{d\phi}{\phi} \qquad (2)$$

In Divjaka region the value of this coefficient is 40.73 x 10^{-3}, while in Frakulla is 31.14x10^{-3} and in Povelce is 34.4x10^{-3}.

Using regional studies of a(τ,t) it is obtained that gradients of porosity of shales at intervals 500 - 2500m differ 2 - 3 times, while a(τ,t) changes are too small. Therefore, a(τ,t) do not depend on depth.

Acquaintance of numerical values a(τ,t) permitted the compaction to be studied and rocks of high abnormal pressures to be defined. Referring equation (1) under the conditions ds = 0, calculations of the porosity changes were carried out by :

$$\frac{\phi a}{\phi n} = \frac{\exp[a(\tau,t)(Pa-Pn)]}{1-\phi n\{1-\exp[a(\tau,t)\ (Pa-Pn)]\}} \qquad (3)$$

$$\frac{\Phi a}{\Phi b}=\frac{\exp[a(\tau,t)(Pa-Pn)]}{1-\Phi n\{1-\exp[a(\tau,t)(Pa-Pn)]\}} \quad (3)$$

Φa,Φn - porosities of rocks in the same level in zones with abnormal and normal hydrostatic pressures.

For separation of rocks with abnormal pressures based in that equation one must put boundary values. Studies for average density of rocks and fluids showed the values 2.5 and 1.1 g/cm^3 respectively. Therefore, the boundary values are:

$$Pa\,\mathrm{min}=0.013h, \qquad Pa\,\mathrm{max}=0.02h \quad (4)$$

while hydrostatic normal pressure is

$$Ph=0.011x_i\cdot h \quad (5)$$

For that reason during the calculations through equation (3) the following values are considered:

$$(Pa-Pn)\mathrm{min} = 0.013\ h - 0.011\ h = 0.002\ h$$
$$(Pa-Pn)\mathrm{max} = 0.02\ h - 0.011\ h = 0.009\ h \quad (6)$$

Therefore the equations which served for calculation of porosity in zones with abnormal pressures are:

$$\left(\frac{\phi a}{\phi n}\right)_{Pa=0.013h}=\frac{\exp[0.002(a(\tau,t)h]}{1-\phi n\{1-\exp[0.002a(\tau,t)h]\}}$$

$$(7)$$

$$\left(\frac{\phi a}{\phi n}\right)_{Pa=0.02h}=\frac{\exp[0.009(a(\tau,t)h]}{1-\phi n\{1-\exp[0.009a(\tau,t)h]\}}$$

In table 1 some of results of estimation connected with changes of porosity caused as result of increasing and decreasing of pore pressures are given.

Table 1. Results of estimation of abnormal pressure connected with changes in porosity.

Region	Depth	Φn	Φa / Φn		Ra,a / Ra,n	
			0.013h	0.02h	0.013h	0.02h
Divjake Well 9	500	0.31	1.03	1.12		
	1000	0.26	1.05	1.29	0.88	0.90
	1500	0.21	1.09	1.49	0.85	0.75
	2000	0.16	1.14	1.75	0.83	0.62
	2500	0.12	1.17	2.09	0.80	0.46

(continue...)

Region	Depth	Dtn	Dta	φn	φa
Divjake Well 15	2400	280	280		
	2500	265	278	0.145	0.185
	2600	255	306	0.125	0.20
	2700	250	313	0.11	0.21
	2800	240	312	0.10	0.18
	2900	236	282	0.08	0.12

φa / φn and Ra,a / Ra,n are values calculated with (7) equations, while Dtn and Dta are readings of travel time taken in the normal and abnormal trends in wells Div-9 and Div-15.

THE BEHAVIOUR OF GEOPHYSICAL PARAMETER VERSUS PORE PRESSURE

As resistivity parameter has been the only one to be used in the old oil wells and now it still remains as the main one, it is clear that the resistivity method has been used in the detection and estimation of abnormal pressure.

According to studies performed in our country it has been concluded that expected porosity for the values of resistivity at zones with higher pressure effects also the pore pressure. (Lico,R. and Shehu,A., 1991)

In table 1 Ra decreases with increasing layer pressure, according with the equation:

$$\frac{Fa}{Fn}=\frac{Ra,a}{Ra,n}=\left(\frac{\phi n}{\phi a}\right)^{1.5} \qquad (8)$$

Fa; Fn; Ra,a and Ra,n are formation factors and resistivities of shale rocks on conditions of abnormal and normal pore pressure. The resistivity in the zones of abnormal pressures changes twice or more. At Ardenica and Durres wells resistivity changes up to 3-4 times. On average it is decreased over 70% in zones with abnormal pressures. From the performed analysis it is concluded that index of decreases of resistivities is directly related with the coefficient of anomaly intensity that present the ratio between abnormal layer pressure and normal layer pressure. (Lico,R. and Shehu,A., 1991)

Average acoustic times at zones with high abnormal pressure changes too. In some cases it varies up to 40%. Fig. 1 shows curves of change Ra,Φa and Dt versus depth in the zones with abnormal and normal pore pression.

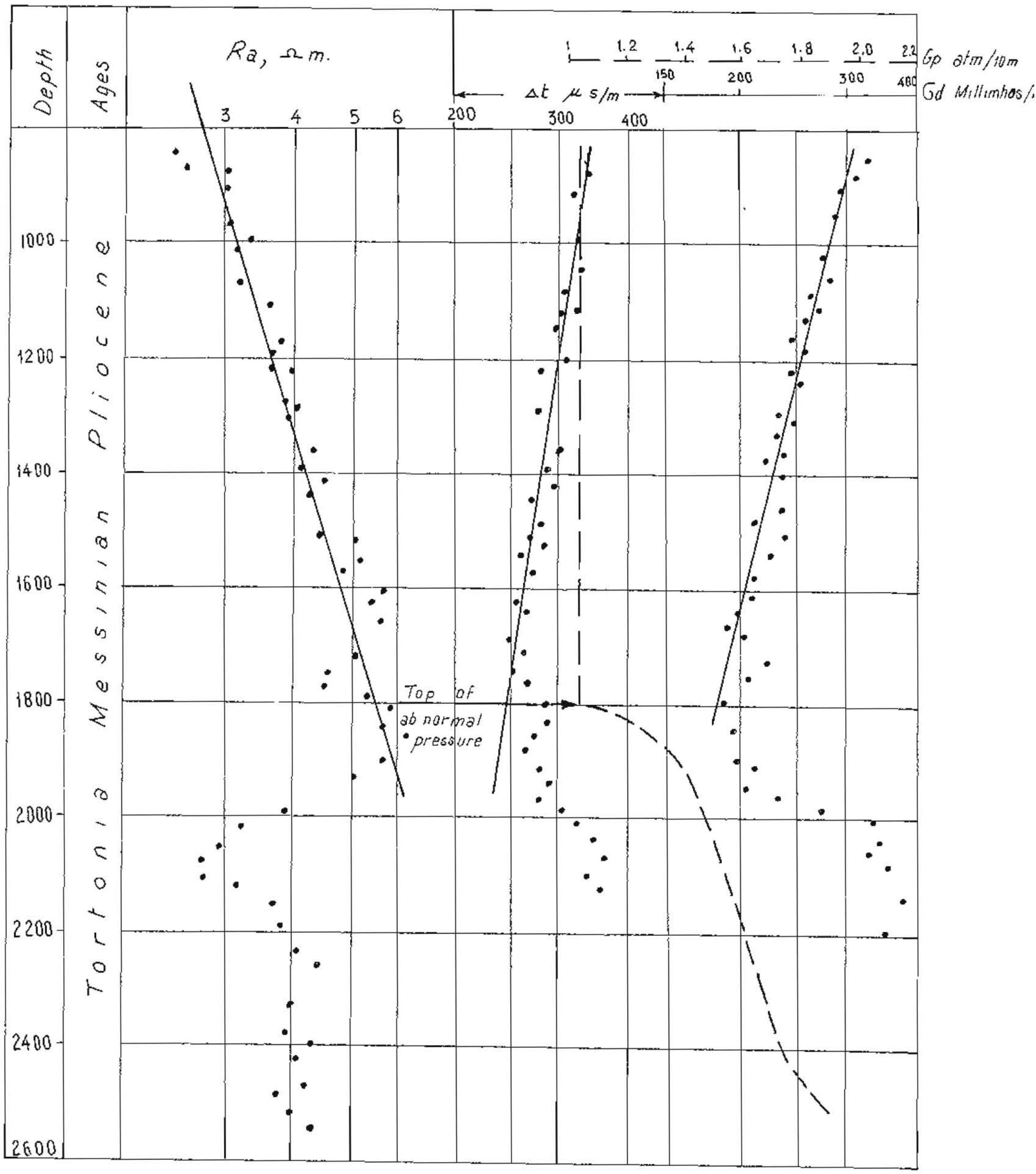


Fig.1. Dependence of resistivity, conductivity, travel time of sounds and gradient of pressure in well Dv.55 in Divjaca region. Ra. is apparent resistivity, Ga. if apparent conductivity; Δt. is travel time, Gp.- Gradient of layer pressure.

ESTIMATION OF ANOMAL PRESSURE

The equivalent depth approach was used for the estimation of layer pressure and normal compaction curve one.

Studies which were performed, showed that mineralogical factors up to the depth of 2500m have not had influence to geophysical measurements. The salinity of water, which has great influence on resistivity has very small gradients. While temperature is taken into consideration, the calculations of abnormal pressures with resistivity and the travel times with normal compaction curves approach are performed through the formula (Dobrin. V.M, 1989) :

$$Pa = Pn \pm \frac{1}{10} \frac{AVG(\delta v - \delta u)\ dh}{lg\ Rsh,h2/Rsh,h1 + \alpha(Rsh/2.3)\ G\ dh} lg \frac{Rshn}{Rsha} \quad (9a)$$

$$Pa = Pn \pm \frac{1}{10} \frac{AVG(\delta v - \delta u)\ dh}{lg\ Dt1/Dt2 + \alpha(Dt/2.3)\ G\ dh} lg \frac{Dta}{Dtn} \quad (9b)$$

Respectively Rsh,h2; Rsh,h1; Dt2 and Dt1 are reading values obtained at depth h2 and h1 and dh = h2-h1. The geothermic gradient is taken different for differently regions based on geothermal measurements carried out in oil and gas wells. α(Rsh) is calculated for different depths assuming linear change of resistivity versus temperature. α(Dt) is taken from the literature. Some of the results calculated through the above equations are given in Fig. 2. These belong to Durres, Divjaka and Kavaja regions.

RESULTS

More than 70 wells were studied which have either encountered abnormal pressure or have passed at only transitory zones. Abnormal zones with high layer pressures at all regions of depression are determined with apparent resistivity measured by short normal devices and with travel times recorded by borehole compesated acoustic log. Complete analysis of measurement indicate that at first 800-900 m resistivity does not obey to the law of normal compression. This is explained by the changes of salinity in the water filling up the rocks pores. A characteristic of these zones, is that starting from southern up to the northern sections of depression in the belt of gas structure and from the east towards the west they maintain the structural shape of the regions. It is shown clearly in the map given at Fig.3.

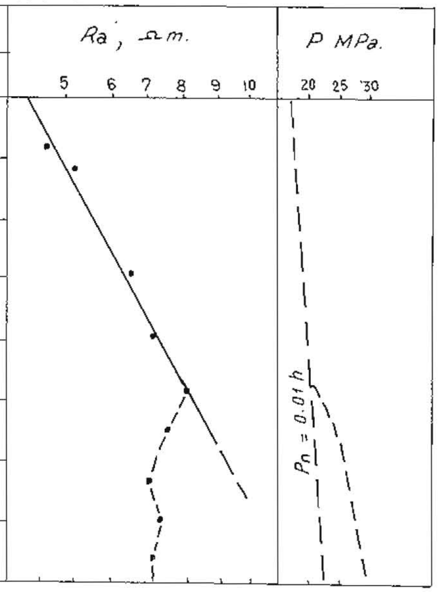
Throughout, the regions of the depression with abnormal pressure mainly belong to the Tortonian formations.

The trends of abnormal pressures increases towards the west and becomes zero towards the east. The gradients of abnormal pressures on the western slopes of structural belt reach up to

2Kg/cm2/10m. In the southern structural sections the abnormal zones emerge at depth over 1500 m. Towards the north they encounter at relatively small depths, about 700-800 m.

Well Div-2

Depth	Ra, Ωm		P. MPa	
	Ra^h	Ra^a	P_n	P_a
1700	5 0		17	
1800	5 7		18	
1900	6 35		19	
2000	7 1		20	
2100	8.0		21	22
2200	9 0	7 2	22	25
2300	10.0	7 1	23	27
2400	12.5	7 0	24	30



Well Kav-4

Depth	Ra, Ωm		Δt, μs/m		P_n	P. MPa	
	Ra^n	Ra^a	Δt_a	Δt_n	MPa	P_a^R	$P_a^{\Delta t}$
500							
600	4.4		400				
700	4.8		390	440			
800	5.3	4	375	455	8	10.2	10 6
900	5.7	4	360	465	9	11.5	11 6

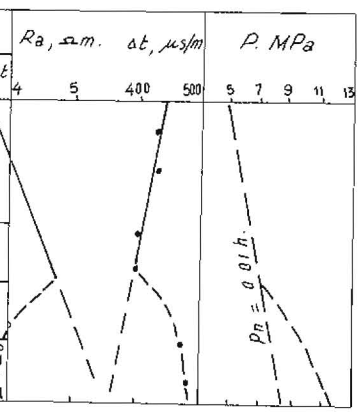


Fig.2. Results of calculation of pressure with resistivity and travel time in wells Div-2 and Kavaja-4, in Divjaka and Kavaja regions. Ra,n; Ra,a; Dtn; Dta ;Pn ;Pa respectively resistivity, travel time and pressure at normal and abnormal conditions.

The interruption of normal compaction in some structures does not emerge to over pressures but due to disjunctive faults. Based on the methodology of compression curves the directions and fault levels were determined. The anomaly of pressure and level of fault are presented in figure 4.

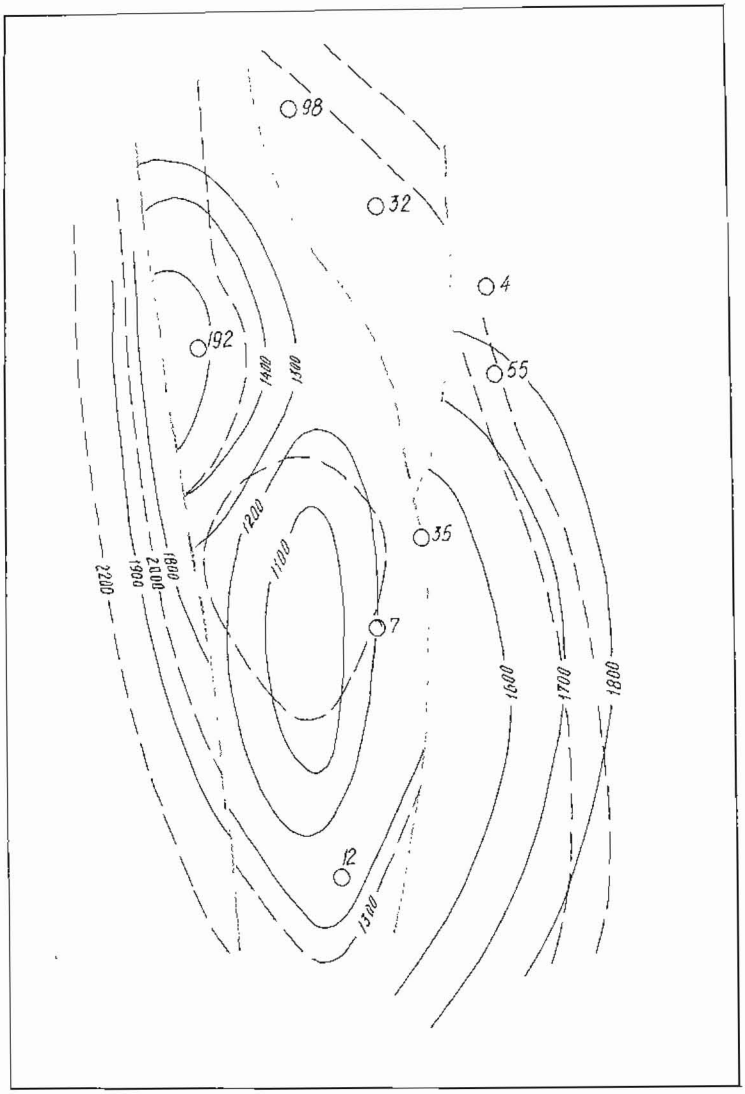


Fig.3. Map of top overpressure zones and that of Tortonian in Divjaka region. With dashed lines are presented top of overpressures zones, while the full lines are the top of Tortonian in Divjaka region.

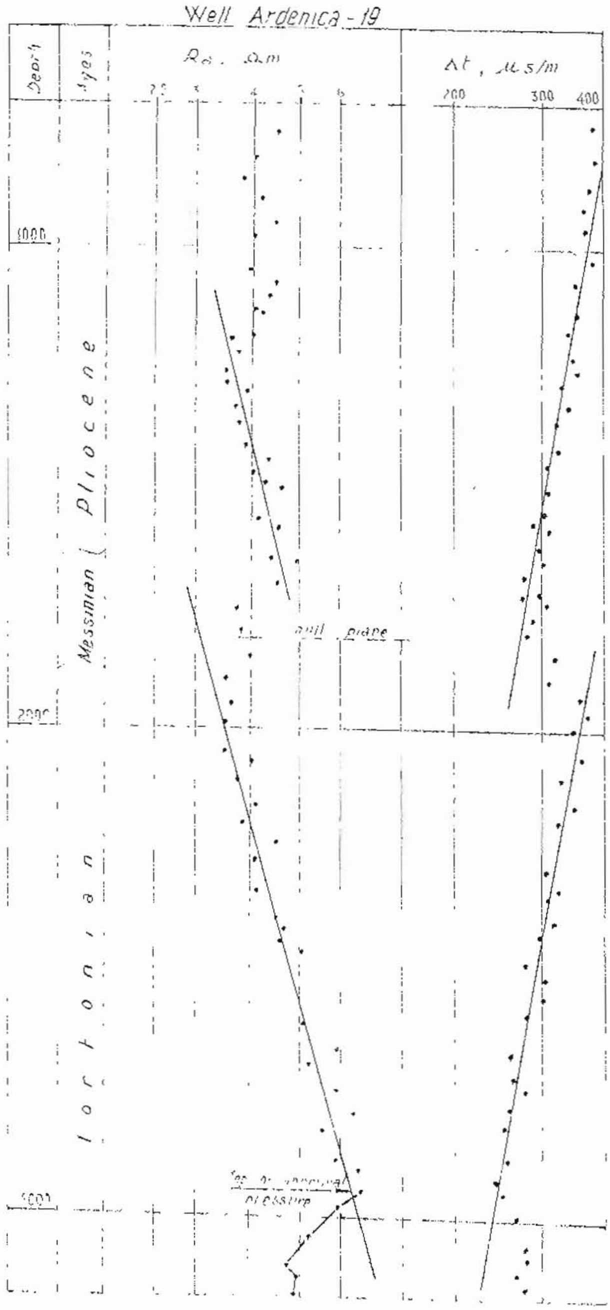


Fig.4. Dependence of resistivity and travel time versus depth in cross-section of well Ard-19 with tectonic fault in Ardenica region.

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