UPPER CRUST REGIME OF STRESSES ACCORDING TO THE BOREHOLE MEASUREMENTS COMING FROM THE TRANSYLVANIAN BASIN

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Le régime du stress de la croûte supérieure mis en évidence par les sondages dans le Bassin de la Transylvanie. Les études géodynamiques basées sur les enregistrements diagraphiques dans les puits de forage ont connu un remarquable intérêt depuis 1997 avec les recherches menées par l'Institut de Géodynamique de l'Académie Roumaine.
Dans ce contexte, l'article se propose de détailler les mesures et les interprétations diagraphiques permettant d'établir le régime actuel de contraintes accomplies lors d'un grand nombre de sondages dans le Bassin de la Transylvanie.
Ont été retenues, à la fin, les évaluations faites pour 53 forages différents qui peuvent s'intégrer dans lesdites normes A, B, C du "World Stress Map (WSM) Quality Ranking-Scheme".
Les orientations (azimuths) des contraintes horizontales maximales et minimales ont été déterminées en analysant l'ovalisation du trou de forage (*break-out method*) enregistrées à l'aide des diagraphies pendagemétriques.
La plupart des outils pendagemétriques combinés mis en service sur le territoire de la Roumanie par Western Atlas (Diplog) et Schlumberger (SHDT et BGT) comportent un microdiamétreur à quatre bras couplés par paires jusqu'à 20" et au besoin 40" par adjonction de rallonges, donnant deux courbes de diamètres indépendants mesurées dans deux plans perpendiculaires.
Un intégrateur de volume du trou, placé dans l'outil du fond, offre la possibilité de déterminer les zones fracturées, cavées et ovalisées en liaison avec les phénomènes tectoniques du stress.
Les orientations de la contrainte horizontale maximale et minimale pour chacun des cinq compartiments géologiques (nord, ouest, sud, est et centre) qui partagent le Bassin de la Transylvanie ont été calculées et présentées en forme tabulaire et graphique.
De même, quelques déterminations concernant la magnitude des contraintes ont été effectuées et finalement exprimées sous la forme de gradients de la contrainte maximale, de la contrainte minimale et de la pression du fluide remplissant l'espace poreux des formations géologiques.

Key words: stress, borehole, breakout, world stress map, Transylvanian Basin.

1. INTRODUCTION

The geodynamic information related to the present-day stresses acting within the Transylvanian Basin-terrestrial upper crust is very scarce and the few data provided by the previous published papers (Neguț *et al.*, 1994, Zugrăvescu *et al.*, 1999) have not been included in the World Stress Map (Fuchs *et al.*, 1999).

That is why in the last years the research programs concerning the stress studies undertaken by the Romanian Academy – the Geodynamic Institute, were straighten on topics aiming to clear up the multiple geodynamic processes taking place in the Transylvanian Basin.

This area is located in the eastern part of the Alps-Carpathian-Pannonian system, on the Romanian territory, exhibiting a roughly circular shape and a sedimentary fill of about 8 km thickness. Its margins are constituted by the Eastern Carpathian Mountains, the Southern Carpathian Mountains and the Apuseni Mountains.

As a consequence of its tectonic evolution, the Transylvanian Basin is characterized by the following peculiar features: normal thickness of lithosphere of 100 km, a low value of the heat flow between 30 and 60 mWm^2 and a crustal thickness of 33–36 km, increasing from the central area towards the basin borders (Demetrescu *et al.*, 1999).

It is valuable to mention among other things the fact that it represents an intensively geological explored region for hydrocarbon resources, in which a lot of gas deposits were discovered and exploited during the last century. More than two thousands wells, drilled in the above mentioned region, investigated geologically and geophysically the entire Pliocene-Miocene sedimentary fill from the ground surface to 5 km deep.

For this reason the stress-research study was entirely based on the countless recordings of borehole geophysical measurements existing in the archives of the oil and gas companies, so that it was achieved with no extra-costs.

2. BOREHOLE GEOPHYSICAL DATA-PROCESSING METHOD

Such being the favorable circumstances, the available well log suites coming from 53 exploration boreholes whose bottom holes-depth were less than 4 km were selected, collected and finally processed. They were all completely geophysically investigated in open hole conditions with Schlumberger and Western Atlas equipments including always the Stratigraphic High-Resolution Dipmeter Tool (SHDT) manufactured by Schlumberger or the Dipmeter Tool manufactured by Western Atlas. Data processing of field registrations was performed according to the Schlumberger instructions (Schlumberger, 1982, 1989, 1996), the interpretation methods devised in this paper were based on the “breakout technique” both of them being finally coupled in such a way as to comply with the requests of the World Stress Map. In this context, it is necessary to mention that special rules were assessed in order to ascertain the causes of breakouts (initiation and enlargements) on the basis of well wall stability and the pressure differential existing between the drilling mud and the fluid filling the rock pore space.

The stress study was based on the linear, isotropic poroelastic stress-strain theory assuming the strain plane orthogonal to the borehole axis. With these terms the ellipsoid of stresses was defined by giving the directions of its three axes and the corresponding stress magnitudes S_1, S_2, S_3, known as principal stresses. Generally, within the depositional basin, whether tectonically inactive or undergoing extension, the maximum stress (S_1) is represented by the geostatic load/overburden, both the intermediate stress (S_2) and the least stress (S_3) being located in the horizontal plane. The combination of the extensional and strike slip regimes existing in the Transylvanian Basin supported our assumption to consider that the principal stress is oriented vertically ($S_1 = S_v$), the greater horizontal stress being ($S_2 = S_H$) and finally, the least horizontal stress ($S_3 = S_h$). The least horizontal stress was expressed as a fraction of the geostatic load (S_1) using a variable coefficient whose value was calculated on the basis of Poisson's ratio. Both the rock elastic parameters Poisson's ratio and Young's modulus were derived in our study from the wave velocities and bulk volume densities recorded by well Schlumberger and Atlas equipments.

Objective reasons imposed a presentation of the final results under the following two forms:

The first form, seen in Fig. 1, is a graphical presentation in which all maximum stress component orientations were plotted on a regional map as long line bars indicating in the middle of the bar the geographical co-ordinates of the borehole site.

The second form seen in Table 1 is a so-called "stress file", prepared and stored in the Stress Data Bank of the Geodynamic Institute. This stress file includes a lot of information concerning: well geographical co-ordinates, borehole intervals with continuous SHDT/Dipmeter measurements, the type of other recorded well logging measurements, lithology of geological formations passed through, boundaries between them on the basis of geological age, physical and chemical characteristics of the drilling mud, borehole deviation, pressure and bottom hole maximum temperature, etc.

Other three types of information were also established and reported in the "stress data file": the azimuth of the maximum horizontal principal stress, the azimuth of the least horizontal principal stress, and the magnitude of the above mentioned stresses.

Since our stress study field data were provided by the open hole geophysical measurements performed during the drilling period of the gas producing-wells, we were constrained to present the distribution of the stress orientations within the Transylvanian Basin in close relation with the framework of the gas geological activity.

Table 1

1.	Geological structure	PETRILACA
2.	Well number	15
3.	Longitude/Latitude	24°44’52"/46°39’50"
4.	Recording equipment	SHDT (Stratigraphic High Resolution Dipmeter Tool)
5.	Equipment produced by	Schlumberger
6.	Recording date	10/02/1996
7.	Recorded interval	1602 – 3002 = 1400 m
8.	Different logs recorded	DLL – BHC – GR
		LDL – CNL – NGS
		SHDT
9.	Bit size	8 1/2"
10.	Density of drilling mud	1,48 g/cm^3
11.	Bottom hole temperature	86°C (26 hours since last mud circulation)
12.	Borehole maximum deviation	less than 3°
13.	Age of geological formations	Sarmatian and Buglovian
14.	Rocks lithology	sand, silt, marl, shale
15.	Quality rank	A
16.	Total of breakouts	680 m
17.	Standard deviation	16%
18.	Horizontal maximum stress azimuth	136°
19.	Horizontal minimum stress azimuth	46°
20.	Other data	Geological limits

3. THE TRANSYLVANIAN BASIN GEOLOGY RELATING TO STRESS DETERMINATIONS

In conformity with Săndulescu (1983), Beca (1983) and innumerable documents and official reports elaborated by ROMGAZ SOCIETY, the gas bearing geological structures of the Transylvanian Basin are joined making up five gas producing structural groups: northern, western, southern, eastern and central. We are aware of the differences existing between the gas bearing sedimentary sequences framework and the stress orientation geodynamic framework, but this connection was chosen solely for a better localization of the points and domains in which the measurements had been carried out.

The well logging measurements necessary to our stress study were accomplished on postsaliferous rock sequences belonging to the Pliocene-Upper Miocene sedimentary cycle. The thickness of this sedimentary sequence varies from a geological structure to another, from tens to hundreds or even to thousands metres.

According to the geological studies undertaken by ROMGAS SOCIETY, these sedimentary sequences are composed of four main rock types, namely:

sand/sandstones, silts/siltstones, shales, marls and clayey marls. The mineral composition of the detrital particles in these siliciclastics sediments incorporates: quartz (15–65%), detrital carbonates (5–40%), feldspar and mica (10–35%), clay minerals (kaolinite, montmorillonite, illite and chlorite 8–40%), as well as miscellaneous heavy minerals and lithic rock fragments (1–5%).

The petrophysical studies carried out by Negoiţă (1985) established the fact that sands have the highest void ratio values, being followed in a decreasing order by argillaceous and silty sands and sandstones. Formation compaction as a result of physical, chemical and mineralogical phenomena governed mainly by the burial depth and overburden pressure provided a near equilibrium compaction and a near hydrostatic fluid pressure. The same studies reported that void ratios as a function of depth or formation age, took in the studied area the values indicated in Table 2. We need to point to that void ratios in this table are expressed as the ratios between the rock-pore volume and the rock-grain volume.

Table 2

Lithological type of formations	Void ratio values	
	Pliocene	Upper Miocene
Sands	0.408 – 0.351	0.219 – 0.176
Sandstones	0.123 – 0.098	0.098 – 0.075
Silts and dirty formations	0.265 – 0.204	0.123 – 0.086

On the other hand, laboratory analyses carried out in the same area came to the conclusion that the average pore diameter is about 3.5–4.5 microns in the case of the rocks with a content of 5–10% argillaceous fractions and about 0.5–1.5 microns in the case of the rocks holding 10–20% argillaceous fractions (Oltean, 1991).

4. DISTRIBUTION OF STRESSES WITHIN THE TRANSYLVANIAN BASIN

This chapter is devoted to the presentation of the results obtained after geophysical data processing, the main characteristics of stress orientation in the five groups of gas producing geological structures being synthetically submitted below.

At the same time, the borehole geographical co-ordinates (latitude and longitude) in which stress determination was calculated as well as the values of the azimuth/direction for the maximum and minimum (S_2 and S_3) horizontal components are shown in Table 3.

Table 3

Well number	Latitude	Longitude	Maximum stress	Minimum stress	Apparatus type
1.	45º 56′ 33″	24º 28′ 47″	20 º	110 º	ATLAS
2.	46º 26′ 46″	24º 07′ 07″	112 º	22 º	SCHLUMBERGER
3.	46º 07′ 25″	25º 04′ 50″	86 º	176 º	SCHLUMBERGER
4.	48º 08′ 31″	24º 56′ 55″	138 º	48 º	ATLAS
5.	46º 33′36 ″	24º 39′ 00″	171 º	81 º	ATLAS
6.	46º 30′ 52″	24º 39′ 46″	167 º	77 º	SCHLUMBERGER
7.	46º 13′ 42″	24º 26′ 29″	72 º	162 º	SCHLUMBERGER
8.	46º 33′ 03″	24º 30′ 18″	135 º	45 º	SCHLUMBERGER
9.	46º 32′ 05″	24º 50′ 34″	172 º	82 º	SCHLUMBERGER
10.	46º 33′ 28″	24º 49′ 14″	144 º	54 º	ATLAS
11.	46º 32′ 45″	24º 50′ 55″	171 º	81 º	ATLAS
12.	46º 32′ 49″	24º 49′ 43″	179 º	89 º	SCHLUMBERGER
13.	45º 53′ 15″	24º 33′ 26″	163 º	73 º	SCHLUMBERGER
14.	46º 13′ 33″	25º 16′ 51″	132 º	42 º	SCHLUMBERGER
15.	46º 11′ 23″	25º 17′ 38″	128 º	38 º	ATLAS
16.	46º 15′ 32″	25º 17′ 03″	103 º	13 º	ATLAS
17.	46º 22′ 15″	24º 43′ 01″	149 º	59 º	SCHLUMBERGER
18.	46º 29′ 22″	24º 58′ 02″	109 º	19 º	SCHLUMBERGER
19.	46º 28′ 30″	24º 56′ 55″	48 º	138 º	SCHLUMBERGER
20.	46º 28′ 07″	24º 57′ 40″	85 º	175 º	ATLAS
21.	46º 22′ 26″	25º 15′ 30″	116 º	26 º	SCHLUMBERGER
22.	46º 22′ 52″	25º 15′ 32″	114 º	24 º	SCHLUMBERGER
23.	46º 23′ 32″	25º 15′ 37″	96 º	6 º	SCHLUMBERGER
24.	46º 22′ 59″	25º 15′ 11″	121 º	31 º	SCHLUMBERGER
25.	46º 32′ 50″	24º 54′ 02″	128 º	38 º	SCHLUMBERGER
26.	46º 32′ 03″	24º 54′ 51″	108 º	18 º	SCHLUMBERGER
27.	45º 54′ 08″	24º 29′ 57″	21 º	111 º	SCHLUMBERGER
28.	45º 54′ 19″	24º 26′ 20″	25 º	115 º	SCHLUMBERGER
29.	45º 53′ 58″	24º 26′ 09″	33 º	123 º	SCHLUMBERGER
30.	45º 54′ 19″	24º 26′ 43″	8 º	98 º	SCHLUMBERGER
31.	45º 54′ 41″	24º 30′ 41″	19 º	109 º	SCHLUMBERGER
32.	46º 10′ 25″	25º 13′ 53″	130 º	40 º	ATLAS
33.	46º 39′ 50″	24º 45′ 52″	136 º	46 º	SCHLUMBERGER
34.	46º 36′ 27″	24º 42′ 31″	137 º	47 º	ATLAS
35.	46º 39′ 06″	24º 46′ 33″	128 º	38 º	SCHLUMBERGER
36.	46º 39′ 33″	24º 47′ 18″	154 º	64º	ATLAS
37.	46º 40′ 09″	24º 46′ 40″	148 º	58 º	SCHLUMBERGER
38.	46º 15′ 33″	24º 05′ 12″	80 º	170 º	SCHLUMBERGER
39.	46º 16′ 07″	25º 05′ 02″	118 º	28 º	SCHLUMBERGER
40.	46º 39′ 49″	24º 25′ 27″	146 º	56 º	SCHLUMBERGER
41.	46º 17′ 41″	24º 54′ 33″	95 º	5 º	SCHLUMBERGER
42.	46º 18′ 10″	24º 55′ 08″	88 º	178 º	SCHLUMBERGER
43.	46º 17′ 05″	24º 54′ 23″	86 º	176 º	SCHLUMBERGER
44.	46º 53′ 01″	24º 33′ 27″	29 º	119 º	SCHLUMBERGER
45.	46º 53′ 15″	24º 33′ 26″	38 º	128 º	SCHLUMBERGER
46.	46º 47′ 24″	24º 11′ 34″	118 º	28 º	SCHLUMBERGER
47.	46º 48′ 14″	24º 11′ 17″	130 º	40 º	SCHLUMBERGER

(*continues*)

Table 3 (*continued*)

Well number	**Latitude**	**Longitude**	**Maximum stress**	**Minimum stress**	**Apparatus type**
48.	46º 24´ 30″	24º 50´ 07″	146 º	56 º	SCHLUMBERGER
49.	46º 58´ 39″	24º 14´ 40″	78 º	168 º	ATLAS
50.	46º 58´ 57″	24º 13´ 55″	88 º	178 º	SCHLUMBERGER
51.	46º 23´ 12″	24º 52´ 09″	85 º	175 º	SCHLUMBERGER
52.	46º 31´ 31″	24º 34´ 21″	155 º	65 º	ATLAS
53.	46º 31´ 07″	24º 34´ 43″	143 º	53 º	ATLAS

4.1. NORTHERN GROUP

This group (Fig. 1.1) is situated in the northern part of the Mureş river, being enclosed in the polygon formed by the following localities: Cluj–Dej–Bistriţa–Grebeniş–Luduş–Turda.

Among the most representative gas producing geological structures we mention: Sărmăşel, Buza, Strugureni, Delureni, Grebeniş, Zau-de-Câmpie.

The extreme values of the maximum stress orientation are: 80–130°.

The average value of all stress orientations is 104°.

4.2. WESTERN GROUP

This group (Fig. 1.2) is located between the Mureş and the Târnava Mare rivers, being enclosed in the polygon formed by the following localities: Turda–Luduş–Iernut–Târnăveni–Delenii–Blaj.

Among the most representative gas producing geological structures we recall: Bogata, Iernut, Delenii, Tăuni, Cetatea de Baltă, Luduş, Săbed.

The extreme values of the maximum stress orientation are: 72–112°.

The average value of all stress orientations is 92°.

4.3. SOUTHERN GROUP

This group (Fig. 1.3) is situated between the Târnava Mare and the Olt rivers, being enclosed in the polygon formed by the following localities: Luduş–Sibiu–Ucea–Agnita–Sighişoara–Copşa Mică.

Among the most representative gas producing geological structures we mention: Alămor, Ruşi, Ilimbav, Săsăuş, Copşa Mică, Noul Săsesc, Alţâna, Nocrich.

The extreme values of maximum stress orientation are: 10 – 45°.

The average value of all stress orientations is 25°.

4.4. EASTERN GROUP

This group (Fig. 1.4) is situated near the Eastern Carpathians border, being enclosed in the polygon formed by the following localities: Agnita–Rupea–Odorhei–Sovata–Ghindari–Sighişoara.

Some of the most representative gas producing-geological structures are: Daia-Ţelina, Buneşti, Cristur, Lupeni, Porumbeni, Şoimuş, Eliseni, Petecu, Feliceni.

The extreme values of maximum stress orientation are: 60–135°.

The average value of all stress orientations is 104°.

4.5. CENTRAL GROUP

This group (Fig. 1.5) is located exactly in the center of the Transylvanian Basin possessing common borders with all the four gas producing geological structure groups reported formerly. The approximate area is situated in the polygon formed by the following localities: Sighişoara–Măgherani–Reghin–Crăieşti–Band–Mediaş–Dumbrăveni.

Among the most representative gas producing geological structures we mention: Corunca, Tg. Mureş, Eremieni, Bazna, Dumbrăvioara, Petrilaca, Filitelnic, Nadeş, Sângeorgiu, Săcel.

The extreme values of maximum stress orientation are 110–175°.

The average value of all stress orientations is 150°.

A map of the Transylvanian Basin including the stress determinations coming from all five groups was finally established and shown in Fig. 1.

5. GENERAL REMARKS

Roughly speaking, most of the variations related to stress orientation within the depth interval "ground surface – Saliferous Upper Miocene" belonging to the Transylvanian Basin follow a normal/perpendicular direction to the Carpathian mountainous chain. The stress orientations determined on some geological structures (Bogata 112°, Sărmăşel 118°, Alţâna 20°, Nocrich 8°, Săsăuş 38°, Buneşti 86°, Feliceni 132°) are relevant in this respect.

However, some characteristic behaviours of stress orientations on the Transylvanian Basin zone need to be distinguished and discussed.

The most important remark is coming from the so-called "Central group" where the average stress orientation of 150° is equivalent to the general stress orientation trend existing in Central and Western Europe (Europe Midplate Stress Domain) with average stress orientation of 145°.

The subsequent remark originates in the most south-western part of the Transylvanian Basin where an obvious N–S direction of stress orientation was pointed out. This distinct stress distribution seems to be analogous to the stress orientation existing in the south of Poland as well as in the most eastern part of the Slovakian territory (Fuchs, 1999). So, as an alternative explanation for this south-western part of the basin, we suppose the existence of some deep local-fault processes generating stress field perturbations, and consequently, dissimilar stress orientation.

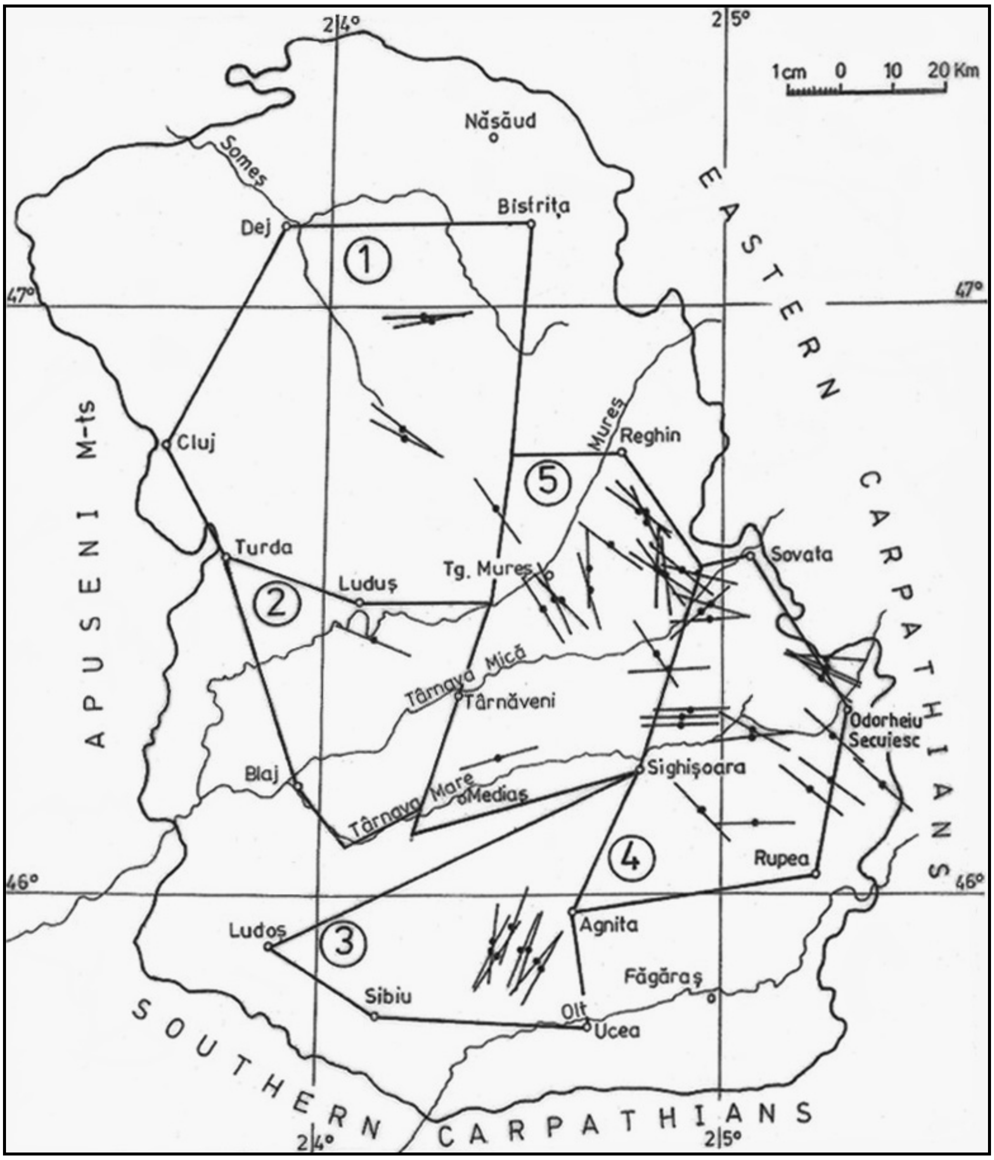

Fig. 1 – Directions of the maximum horizontal stresses in the Transylvanian Basin.

As can be seen when examining Table 3, the quality of our stress orientation-determinations assigned according to the "World Stress Map ranking quality scheme" may be placed between the A and C rank orders. It is opportune to recall that WSM quality scheme starts with the best A ranking quality and ends with the E ranking quality. The 53 selected determinations of stress orientation may be integrated in the ranking scheme as follows: A = 7, B = 22 and C = 24 determinations and therefore, the specific percentages related to the data quality are, respectively, A = 13.2%, B = 41.5%, C = 45.3%.

The ranking quality for each stress determination in the Transylvanian Basin, the geological structure where geophysical measurements were recorded, as well as the apparatus and equipments used in each borehole location, are indicated in Table 4.

Table 4

Well number	Geological structure	Stress direction	Ranking quality	Apparatus type
1.	ALȚÂNA	20º	B	ATLAS
2.	BOGATA	112º	B	SCHLUMBERGER
3.	BUNEȘTI	96°	A	SCHLUMBERGER
4.	CLOASTERF	128°	C	ATLAS
5.	CORUNCA	171º	B	ATLAS
6.	CORUNCA	167º	C	SCHLUMBERGER
7.	DELENI	72°	C	SCHLUMBERGER
8.	EREMIENI	135º	A	SCHLUMBERGER
9.	EREMIENI	172º	C	SCHLUMBERGER
10.	EREMIENI	144º	C	ATLAS
11.	EREMIENI	171º	C	ATLAS
12.	EREMIENI	179º	C	SCHLUMBERGER
13.	EREMIENI	163º	B	SCHLUMBERGER
14.	FELICENI	132º	C	SCHLUMBERGER
15.	FELICENI	128º	B	ATLAS
16.	FELICENI	103º	B	ATLAS
17.	FILITELNIC	149º	C	SCHLUMBERGER
18.	GHINDARI	109º	C	SCHLUMBERGER
19.	GHINDARI	48º	B	SCHLUMBERGER
20.	GHINDARI	85º	B	ATLAS
21.	LUPENI	116º	B	SCHLUMBERGER
22.	LUPENI	114º	A	SCHLUMBERGER
23.	LUPENI	96º	B	SCHLUMBERGER
24.	LUPENI	121º	C	SCHLUMBERGER
25.	MĂGHIRANI	128°	B	SCHLUMBERGER
26.	MĂGHIRANI	108°	B	SCHLUMBERGER
27.	NOCRICH	21°	B	SCHLUMBERGER
28.	NOCRICH	25º	C	SCHLUMBERGER
29.	NOCRICH	33º	C	SCHLUMBERGER
30.	NOCRICH	8º	C	SCHLUMBERGER
31.	NOCRICH	19º	B	SCHLUMBERGER
32.	PETECU	120°	B	ATLAS
33.	PETRILACA	136º	A	SCHLUMBERGER
34.	PETRILACA	137º	B	ATLAS
35.	PETRILACA	128º	B	SCHLUMBERGER
36.	PETRILACA	154º	C	ATLAS
37.	PETRILACA	148º	A	SCHLUMBERGER
38.	PORUMBENI	80º	B	SCHLUMBERGER
39.	PORUMBENI	118º	C	SCHLUMBERGER

(*continues*)

Table 4 (*continued*)

Well number	Geological structure	Stress direction	Ranking quality	Apparatus type
40.	SĂBED	146°	A	SCHLUMBERGER
41.	SĂCEL	95°	C	SCHLUMBERGER
42.	SĂCEL	88°	C	SCHLUMBERGER
43.	SĂCEL	86°	C	SCHLUMBERGER
44.	SĂSĂUŞ	29°	B	SCHLUMBERGER
45.	SĂSĂUŞ	38°	C	SCHLUMBERGER
46.	SĂRMĂŞEL	118°	C	SCHLUMBERGER
47.	SĂRMĂŞEL	130°	B	SCHLUMBERGER
48.	SÂNGEORGIU	146°	B	SCHLUMBERGER
49.	STRUGURENI	78°	C	ATLAS
50.	STRUGURENI	88°	C	SCHLUMBERGER
51.	ŞOIMUŞ	85°	A	SCHLUMBERGER
52.	TG. MUREŞ	155°	C	ATLAS
53.	TG. MUREŞ	143°	B	ATLAS

In some special cases, on the basis of well logging data and pressure measurements recorded during the drilling period of the boreholes, stress magnitudes were evaluated.

On the whole, within the Transylvanian basin the vertical stress increases with depth taking for the vertical stress gradient values between 22 and 24 MPa/km. Formation fluid pressure gradients in the Pliocene-Post Salifeorus Upper Miocene depth interval seldom exceed 13 MPa/km, few occurrences of 15–16 MPa/km in the Filitelnic–Corunca gas fields being recorded. At the same time, the minimal horizontal stress gradients calculated on the basis of Poinson’s ratio and the vertical stress gradient indicated values of 13–15 MPa/km, confirming several leak-off tests carried out during the drilling period of boreholes.

Nowadays, the analysis of stress magnitudes stated that maximum principal stress is vertical, while the minimum horizontal stress is roughly 62% of the vertical stress magnitude; the average values of these two stress-gradients are, respectively, 23 and 14.2 MPa/km.

A more extensive activity concerning the stress magnitude determinations is being carried on and the results will be published in the future.

6. CONCLUSIONS

Using the borehole measurements carried out in the last 50 years, a stress field study was undertaken in the Transylvanian Basin owing to the fact that the latest World Stress Map, provided by Fuchs *et al.*, 1999, did not include any information about this region.

For this reason the available well log suites coming from 53 boreholes were selected, collected and finally processed on the basis of the “breakout method” in such a way as to comply with the requests of the World Stress Map quality regulations.

According to the geological reports quoted in the references, the studied region was divided into five distinct zones on which the stress directions (azimuths) were calculated, the final results being for the first time exhibited as a Transylvanian Basin stresses map.

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