ASSESSMENT OF CHANGES IN DIAMETER OF THE BOREHOLE AND PROPERTIES OF ROCKS ACCORDING TO WELL LOGGING

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Abstract

The diameter of the exploration borehole varies during drilling from largest to smallest. Diameter depends on the physical and mechanical properties of rocks along which the intersection of geological section of the field. There is measured the diameter of the borehole from the start to the end of the drilling using the caliper method and determine the state of the borehole walls. There rocks with different physical and mechanical properties in section of the wellbore. In the intervals of the well that had strong rocks its diameter changes slightly. A place that folded soft rock, broken up quickly and intensively. This requires the adoption of appropriate measures to prevent the accident. In this regard, the diameter wells estimate changes in the drilling process is an actual problem.

Introduction

In the Karaganda coal basin (Kazakhstan) for the purpose of studying the section of exploratory wells is used caliper method or borehole diameter measurements along with other geophysical methods. However, the practical use of its results is still very limited. The method is based on a study on the changes of the section in the drilling borehole diameter (Baibatsha, 2003, 2008). The diameter of the well is measured by caliper CM-1 and data is recorded on the tape as a continuous diagram - caliper log. Interdependence of cavity downhole and lithological features gives us the opportunity to study the section of well according to the caliper. Time standing of unprotected wellbore depth interval reveals the impact on the value of the cavity. Therefore, borehole diameter variation was studied on a full drilling depth of 1200 m or more.

Method

Increasing the actual borehole diameter from normal occurs across the depth of well, particularly in unstable rocks and soluble (Figure 1). Mudstones have the highest cavernous, sandstones are less and siltstones occupy an intermediate position. Coal layers have different cavernous: high as in shales to insignificant as sandstones (Bayram, Karayingit, Mastalerz, 2016). Sometimes, coal layers and seams there is a narrowing well diameter and the formation of "balling". Often, even within a single powerful layer (for example, coal bed d_6) observed a high degree of cavernous and "balling". This phenomenon is apparently due to a change in drilling fluid viscosity varying ash content and mechanical strength of the coal seam individual packages complex structure (Bieniawski, 1990). As a consequence, there appears selective adsorption ability of individual packages or coal seams.

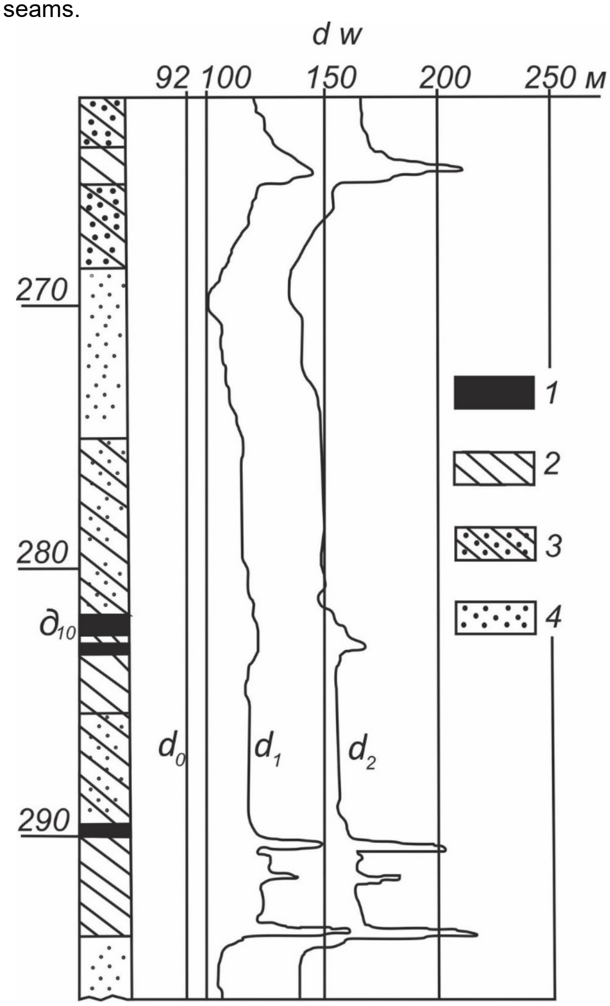

Figure 1 - Increase the diameter of the borehole and the drilling of cavity: 1 - coal; 2 - argillite; 3 - aleurolites; 4 - sandstone

Examples

On the Figure 1 shows for example two caliper log recorded after 6 and 15 days after the penetration of the wellbore - d_1 and d_2. Compare the above caliper log shows that with increasing time of standing walls of the well there is an increase of its diameter and of cavity. Formed originally a small cavernous continues to develop over time within the same interval, where they originated.

A significant increase in the time of cavity observed in mudstones. In the intervals of occurrence of aleurolites and sandstones in the beginning, and later there is no formation of local caverns, and is characterized by a general increase in the diameter of well over time.

Thus, there is a definite relationship between the change in diameter of the well and the time of its walls standing after opening, i.e., age walls. To establish this relationship, well studied sections folded typical argillites, aleurolites, sandstones of the Dolinka and Tentek coal-bearing formations. In the Karaganda basin caliper is held in deep wells during drilling every 300-400 m. Each time the caliper is carried out only by re-drilling of the well conducted with a very small "an overlap", i.e. an interval well, on which there are two segment caliper curves taken after a time equal to the time of drilling of 300-400 meter intervals. Material from these wells makes it impossible to establish a complete picture of cavities increase in time. So were analyzed caliper log from wells, in which every time the caliper held from the beginning of the well bore to the entire depth of the well achieved.

For each installed actual average well diameter for each particular species packs, which was determined graphically from the caliper log. In this fixed depth mid characterized packs species (H, m) and the time from the moment the state of the walls of the new drilling until removal caliper log (t, days). When selecting these parameters based on the assumption, first, caving process should be clearly expressed a temporary nature (the cavernous increases over time), and secondly, with the depth of strength and, consequently, the stability of the species is increasing (Bronnikov, Bogdanov, 1982).

Data d = f (H, t) are grouped by major lithotypes: argillites, aleurolites and sandstones (Gaydin, Pevzner, Smirnov, 1983). Thereafter, for each equation lithotype two-factor correlations were found:

$$d_t = f(t) \text{ и } d_H = f(H).$$

The final equation when choosing a criterion type pair correlations equations failed the test on the boundary conditions

$$d_t = f(t) \text{ и } d_H = f(H):$$

on condition t = 0, d = d_0,

on condition H = ∞ , d = d_0, d_0 - drilling diameter.

Therefore, further form of the equation were specified

$$d'_t = 1 + f(t) \text{ и } d_H = 1 + f(H),$$

d' - the ratio of the actual hole diameter d to its nominal diameter d_0.

Results in a form of the equation to have the form of specific lithotypes:

for argillites: $d'_t = 1 + 1{,}54\,\dfrac{t}{t+7{,}69}$, R = 0,83; (1)

$d'_H = 1 + 3{,}07\,H^{-0{,}178}$, R = 0,65; (2)

for aleurolites: $d'_t = 1 + 0{,}83\,\dfrac{t}{t+7{,}92}$, R = 0,65; (3)

$d'_H = 1 + 5{,}64\,H^{-0{,}398}$, R = 0,67; (4)

for sandstones: $d'_t = 1 + 0{,}63\,\dfrac{t}{t+8{,}33}$, R = 0,74; (5)

$d'_H = 1 + 4{,}48\,H^{-0{,}379}$, R = 0,62, (6)

R - correlation ratio

Results

Studies have shown that a change in the diameter of the well depends on the lithological composition of of the section, the age well walls and the depth of the study of the earth formation. Simultaneous consideration of these factors significantly increases the accuracy of the calculation of cavity. Therefore, we usde three-factor correlation method (Gzovskii, 1971; Grechukhin, 1970; Ermekov, Makhov, 1988; Ivanov, 1990).

The essence of this method lies in the fact that the overall function is equal to the quotient of the multiplication of private functions in the overall average in degree, one less than the number of functions

$$d' = \frac{d'_1\, d'_2 \ldots d'_n}{\overline{d'}^{\,n-1}} \quad (7)$$

Thus, the following relationships are obtained:

for argillites: $d'_a = 1 + 4{,}11\,\dfrac{t\,H^{-0{,}178}}{t+7{,}69}$, R = 0,86; (8)

for aleurolites: $d'_{ал} = 1 + 8{,}39\,\dfrac{t\,H^{-0{,}398}}{t+7{,}92}$, R = 0,75; (9)

for sandstones: $d'_{П} = 1 + 6{,}73\,\dfrac{t\,H^{-0{,}379}}{t+8{,}33}$, R = 0,79 (10)

These equations have stood the test and on the boundary conditions. In particular, the analysis showed them (Figure 2) that the gradient of increase in hole diameter with depth and time is reduced. In addition, these equations are found and some flexibility, they do not relate to the drilling diameter.

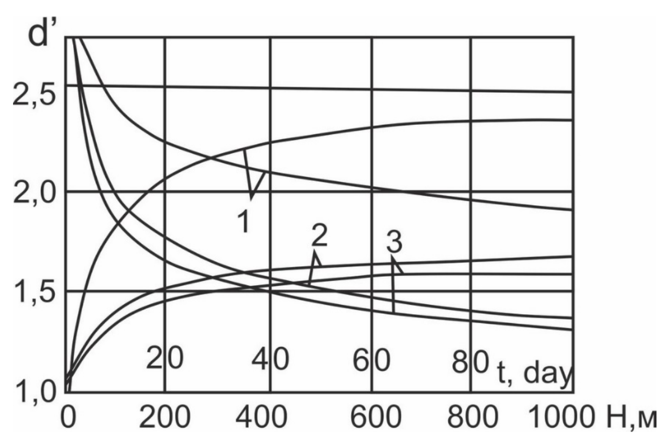

Figure 2 - Changing the diameter wells while drilling at t = 20 days and H = 500 m: 1 - argillites; 2 - aleurolites; 3 – sandstones

As can be seen from Fig. 2, $d^{/}$ calculations by sandstones and aleurolites give very close results.
This estimate is a significant difference of these empirical relationships by of Student criterion confirmed the possibility of calculating $d^{/}$ one common sandstones and aleurolites formula. We compared the formula doubles expect the correlation $d^{/}_{t}$ = *f(t)* и $d^{/}_{H}$ = *f(H)* for sandstones and aleurolites and argillites and aleurolites (Lomtadze, 1990) (Table 1).
To determine the Student criterion used for the analysis of hypotheses about its average (I.P. Sharapov, 1965) according to the formula (Table 2).

$$\hat{t} = \frac{|F_1 - F_2|}{\sqrt{\frac{n_1 S_1^2 + n_2 S_2^2}{n_1 + n_2 - 2}\left(\frac{1}{n_1} + \frac{1}{n_2}\right)}}, \quad (11)$$

and the number of degrees of freedom

$$К = n_1 + n_2 - 2, \quad (12)$$

The numerator of the formula (11), we are invited to submit as the average cumulative excess compared curves:

$$\Delta_t = \frac{F_1 - F_2}{t} \text{ and } \Delta_H = \frac{F_1^{/} - F_2^{/}}{H}, \quad (13)$$

where F_1 и $F_1^{/}$ - respectively the area enclosed between the ordinates of the beginning and end of the curve, and the abscissa by the curves of a higher level; F_2 и $F_2^{/}$ - the same curves for the lower level (Miller, Kahn, 1965; Mueller, 1971).
Areas are calculated by the formulas obtained by integrating the formulas (1) - (6) in the range: a function of time in the state of open borehole walls from t 0 to 100 days, the depths H rocks occurrence function from 0 to 1200 m.
The formula for calculating the area of a function of time is determined as follows:

$$F = \int_0^t dt + a_1 \int_0^t \frac{t}{t + b_1} dt = t + a_1 \left[t - b_1 \ln(t + b_1)\right]\Big|_0^t, \quad (14)$$

Substituting in (14) the limit value t = 100, we finally obtain

$$F = 100 + a_1[100 - b_1 \ln(100 + b_1)] + a_1 b_1 \ln b_1, \quad (15)$$

Areas depth functions are calculated similarly.

$$F^{/} = \int_0^H dH + a_2 \int_0^H H^{-b_2} dH = H + \frac{a_2 H^{1-b_2}}{1 - b_2}, \quad (16)$$

Substituting in (16) the limiting value H = 1200 and get

$$F^{/} = 1200 + \frac{a_2 1200^{1-b_2}}{1 - b_2}, \quad (17)$$

The values of the areas calculated respectively by the formulas (15), (17) and (13), are summarized in Tables 1 and 2. Application of the method of integration greatly facilitates the operation of calculating the area and increases the accuracy of the determination. For sandstones and aleurolites $\hat{t}_{KP} > \hat{t}$, thus both formulas can be considered as equivalent, and the calculations carried out enough for one of them or one of their common formula.

Table 1 - Calculation of statistical parameters

Parameters	Time t, days				Depth H, m			
Charactristics Rocks	n	S^2	F	Δ_t	n	S^2	F'	Δ_H
sandstones	10	0,044	49,61	0,165	5	0,099	543,6	0,056
aleurolites	10	0,075	66,07	0,465	7	0,094	599,4	0,492
argillites	10	0,235	112,6		7	0,056	1091	

Table 2 - Calculation of statistical parameters

Parameters	Time *t*, days			Depth H, m		
Rocks	$\hat{t}$	K	$\hat{t}_{KP}$ - allowed when P=0,05	$\hat{t}$	K	$\hat{t}_{KP}$ - allowed when P=0,05
sandstones - aleurolites	1,43	18	2,10	0,28	10	2,23
argillites - aleurolites	2,50	18	2,10	3,12	12	2,18

As for argillites and aleurolites $\hat{t}$ exceeds permissible (for argillites and sandstone to a greater extent), calculations should be performed separately for each lithotype.
Based on the above estimates for the calculation (Zhang, Lu, Xido, 2016) of the following formula finally chosen to:

$$\text{argillites } d^{/} = 1 + 4{,}11 \frac{t H^{-0{,}18}}{t + 7{,}69}, \quad (18)$$

$$\text{sandstones - aleurolites } d^{/} = 1 + 7{,}56 \frac{t H^{-0{,}39}}{t + 8{,}13}, \quad (19)$$

Conclusions

Prediction of cavity well needed to determine the amount of grout for grouting well, determine the time of drilling mud circulation in the well (for example, by logging the gas), the correlation of the section in full-hole drilling and other. For example, these formulas (18) and (19) make it possible to calculate the diameter before and the volume well to the target seam meetings and determine the "time backlog" mud, and this is an urgent problem, the solution of which the accuracy of the results depends on the gas logs. As for the calculation of the volume of the annular well (between well walls and the drill rod) is more convenient to use an area of the circular cross-section well S_K, calculate its:

$$S_K = S_C - S_Ш = \frac{\pi d_c^2}{4} - \frac{\pi d_ш^2}{4} = \frac{\pi}{4}(0{,}092^2 d^{/2} - 0{,}05^2) = 1{,}96 \cdot 10^{-3} (3{,}38 d^{/2} - 1), \quad (20)$$

where $d^{/}$ determined by the formulas (18) и (19); 0,092 и 0,05 – respectively the nominal borehole diameter (d_c) and the diameter of the rod ($d_ш$).
S_K values calculated by argillites and aleurolites, sandstones, and are summarized in Table 3 and 4.

Table 3 - Calculation area of the annular cross-section well, passed on argillites $S^{/}_{\kappa}$, m²

Time t, days	Depth H, m					
	50	100	200	500	800	1200
1	0,0084	0,0080	0,0075	0,0071	0,0068	0,0067
3	0,0154	0,0139	0,0126	0,0112	0,0106	0,0101
5	0,0212	0,0187	0,0166	0,0145	0,0135	0,0128
7	0,0258	0,0226	0,0199	0,0171	0,0158	0,0149
10	0,0316	0,0272	0,0237	0,0202	0,0186	0,0173
15	0,0381	0,0326	0,0282	0,0236	0,0216	0,0201
20	0,0414	0,0363	0,0312	0,0260	0,0237	0,0220
25	0,0458	0,0390	0,0335	0,0277	0,0249	0,0234
30	0,0483	0,0411	0,0351	0,0289	0,0264	0,0244
40	0,0518	0,0438	0,0374	0,0308	0,0276	0,0258
50	0,0542	0,0458	0,0390	0,0320	0,0289	0,0268
60	0,0559	0,0478	0,0401	0,0329	0,0294	0,0274
80	0,0581	0,0490	0,0416	0,0341	0,0308	0,0284
100	0,0596	0,0503	0,0426	0,0349	0,0316	0,0289

Research has shown that, given the impact on the age the cavernous bare walls of the well and the depth of the rocks traversed, can be quite objectively characterize the physic-mechanical properties of rocks and their stability in mine workings.

Table 4 - Calculation of the area of the circular section well, passed by aleurolites and sandstones S, mS $^{//}_{\kappa}$, m²

Time t, days	Depth H, m					
	50	100	200	500	800	1200
1	0,0073	0,0066	0,0061	0,0057	0,0055	0,0054
3	0,0118	0,0099	0,0085	0,0073	0,0068	0,0065
5	0,0155	0,0125	0,0104	0,0085	0,0078	0,0073
7	0,0185	0,0146	0,0118	0,0094	0,0083	0,0078
10	0,0220	0,0170	0,0135	0,0105	0,0094	0,0086
15	0,0263	0,0198	0,0154	0,0117	0,0103	0,0094
20	0,0292	0,0217	0,0168	0,0125	0,0110	0,0099
30	0,0316	0,0242	0,0184	0,0135	0,0118	0,0105
40	0,0350	0,0257	0,0194	0,0141	0,0122	0,0109
50	0,0365	0,0267	0,0201	0,0145	0,0126	0,0122
70	0,0385	0,0279	0,0209	0,0149	0,0130	0,0115
100	0,0399	0,0289	0,0216	0,0154	0,0133	0,0118

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