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Estimation of Current Condition of Undermined Rock Massif by Deflection of the Earth's Surface

T.M.Yermekov, M.Zh.Bitimbayev
Kunaev Institute of Mining, Almaty, Republic of Kazakhstan

M.K.Alipbergenov, M.Zh.Satov
Kazakhmys Corporation, Zhezkazgan, Republic of Kazakhstan

ABSTRACT: Analytical estimation of the current condition of undermined districts by subsidence of the earth's surface was carried out with due account of creepage of the rock massif, and an increase in subsidence in time was determined. The processing of experimental data by actual subsidence of the earth's surface by the method of extrapolation made it possible to describe qualitatively and quantitatively the behaviour of the propagation of caving in space and in time. On the basis of theoretical and experimental investigations, the current condition of studied districts of the undermined massif was estimated by deflection of the earth's surface.

1 INTRODUCTION

When catastrophic technical-in-genesis cavings take place, the unavoidable condition of cones forming on the ground surface is the destruction of supporting pillars, and then propagation of the process of deformation and destruction of enclosing rocks up to the surface. The current condition of worked-out space may be estimated by the results of experimental observations of ground surface movement.

For the purpose of analytical estimation of the current condition of mining districts by deflections of the ground surface, we take Muskhelishvili's formula:

$$\eta = \gamma H_b l_c (1 - \nu^2)/E_c, \, m \qquad (1)$$

where n - deflection value, m; *y* -specific gravity of rock, kg/m^3; H_m - depth of rock-bridge bedding, ra; l_e - equivalent span, m; v and Ee - elastic properties of stratified fissured rock strata.

In accordance with the hereditary theory of rock creepage of Yerzhanov (1964) the value of subsidence in time may be obtained from this expression by means of replacing the elastic modulus Ee with the elastic operator-function İn time Et:

$$\eta_t = \gamma H_b l_e (1 - \nu^2)/E_t, \, m \qquad (2)$$

where $E_t = E(1-E^*) = E[1- \beta Э^*_\alpha(-\beta)]$,
$\beta = \delta\Gamma(1-\alpha)$;
3 $_Q$(-ß) - special operator of Rabotnov;
a and ß - parameters of creepage;
l_e - span of worked-out space.

The special operator of Rabotnov 3 $_a$(-ß) has a number of remarkable properties, assisting problem solving in the theory of creepage. For the simpler two-parameter core of creepage of Abel with parameters a and 5 and with approximation of function $Э^*_\alpha(-\beta)$, we may obtain:

$$E_t = Ee^{-\omega\beta t^{1-\alpha}} \qquad (3)$$

where $\omega = (1-\alpha)^{1-\alpha}$.
Then subsidence with due account of massif creepage is determined by the expression:

$$\eta_t = \gamma H_b l_e \frac{1-\nu^2}{E} e^{\omega\beta t^{1-\alpha}} \qquad (4)$$

As is clear, with time increase $t \to \infty$ with due account of $\omega > 0$, $\beta > 0$, $e^{\omega\beta t} \to \infty$, $\eta_t \to \infty$, that is , subsidence increases in the course of time.

The final algorithm for determination of subsidence for a moment of any tj and time t>t, may be written as:

$$\eta_{t>t_i} = \eta_{t-t_i}^{общ} e^{\omega\beta (t-t_i)^{1-\alpha}} \qquad (5)$$

Considering subsidence as a factor of geomechamical inhomogeneity, it should be noted that it is taken into account most reliably by means of instrumental observations in natural conditions

The main source of information about prolonged processes of deforming and movement of ground surface from the effect of underground mining operations are instrumental observations. An important parameter of the process of movement is the maximum subsidence n. As far as we could judge on the basis of the results of instrumental observations, the geometrical dimensions of worked-out space (thickness and depth of mining), the presence of overlapping ledges and other factors have a substantial effect on the process of movement value.

Instrumental observations and processing of the results were carried out by standard methods (temporary regulations, 1986), which made it possible to determine the pattern of ground surface movement in the limits of the zone of effect of underground mining operations, in order to determine the principal behaviour and parameters of the process of movement by lines of observation.

However, such methods, in spite of their ability to provide information, do not make it possible to generalize data from measurements by the area of a deposit or to present a visual representation of the process of ground surface movement in time and space. They do not allow evaluation and long-term forecasting of damaging dynamic occurrences, such as caving. As a result, it was necessary to carry out expert evaluation, based on the opinions of specialists.

Practical instrumental observations of ground surface movement and visual observations in mines suggest the existence of a direct connection between increases in the parameters of flexure of movement and the condition of voids formed by underground winning operations. Thus, İt would be a great omission to disregard this connection. Voids in the rock massif in the first stage are filled by rocks bedding immediately above. As a result of these rocks caving, pores are formed in the caved massif, the compactness of rocks of all strata decreases, and this causes rock stress re-distribution (Satov, Alipbergenov, 1999).

The flexure of subsidence forming point to a fact that the process of movement of elementary volumes of massif to a side of worked-out space reached the ground surface. Today, the total area of undermining of the ground surface of the Zhezkazgan deposit by contour of flexures, with 5mm subsidence of points, has reached 8 km^2. Consequently, hundreds of different protecting objects are now m zones suffering dangerous effects of mining operations. The measures taken to avoid ground surface deformations, in spite of the use of data from instrumental observations, have not been effective enough in the field of forecasting cavings. For this reason, the results of these observations were the subject of further analysis and interpretation.

The processing of a large subsidence database of by standard methods (temporary regulations, 1986) did not give positive results when evaluating the actual discrete deformation process taking place in the undermined rock massif.

Therefore, the "method of determination of boundaries of zones of dangerous rock movements at a deposit" (Satov, Alipbergenov, 1999) was worked out for more reliable evaluation of the deformation process. This is based on taking account of the prognostic properties of the criterion n. The main advantage of this simple but effective method is that it enables determination in a volume of deposit anomalous zones of deformation, which are attributed to local breaks of undermined strata in time and space.

Subsidence data from a large number of registration points may be represented in the form of a map with isohypses describing difficult patterns of undermined rock massif deformation. Such patterns are the most suitable for characterizing the space location of the flexure of subsidence. Using this plan, it is possible to solve the following problems:

- to evaluate the quantitative pattern of the deformation processes taking place in the rock massif;
- to determine the development of the process of destruction practically İn all directions;
- to evaluate the location and space dimensions of cones;
- to forecast possible cavings in the long term.

The presence of a large number of subsidence values by different oriented profile lines indicates the effective use of the method of extrapolation with the purposes of evaluation of forecasting, extending a large number of selected subsidence data of remarkable points in zones of the ground surface, which were not studied at once. The worked-out method (Satov, Alipbergenov, 1999) makes it possible to: carry out in-depth statistical analysis of obtained values of subsidence; exclude random errors when measuring deformations; and obtain a substantial quantity of results conforming to different combinations of zones of profile Unes.

For this method, the procedure used is given below.

1. A coordinate grid (X,Y) İs drawn on the plan and all profile lines with points of observations (remarkable points) are drawn.
2. Subsidence values for a moment of observation, taken from logs or albums, are put down on every point of observation. The deflection of flexure of movement (vertical component Z) is determined at the same time.
3. Extrapolation İs carried out after detailed analysis of numerical subsidence values at separate points and for the zone as a whole.

4. Isolines are obtained by joining points of equal subsidence value.
5. The plan of subsidence isolines is superimposed onto a plan of the mining operations and a plan of the ground surface, and then corresponding conclusions are made.

The worked-out method of determining boundaries of zones of dangerous movement (Satov, Alipbergenov, 1999) has the following advantages in comparison with other common methods:

- it İs based on subsidence values obtained from data from long-term natural observations, in contrast to type curves and analytical methods;
- extrapolation is carried out from known conditions to be determined with due account of factors affecting the process of movement;
- it characterizes the development of the process of deformation in time;
- it locates the place and geometrical dimensions of flexure of movements;
- it allows reliable long-term forecasting of cavings reaching the ground surface.

Thus, the study of deformations and movements of rocks by this method makes it possible to obtain relatively simple and effective mathematical apparatus for the determination of places of possible caving in space and time, running down the development of deformation processes in overlying strata.

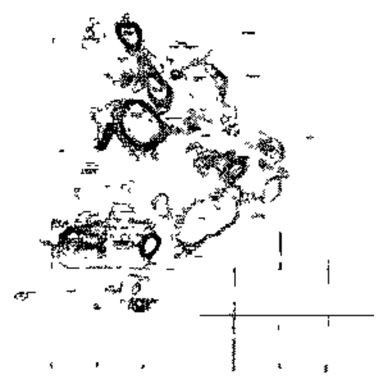
The worked-out method makes it possible to carry out long-term forecasting of cavings, and also to choose such parameters of extraction mine workings and a relative position which will ensure that deformations of the ground surface do not exceed allowable deformation values for undermined objects. In the case of impossibility of change in the parameters of worked-out space, this method allows an increase in the worked-out space stable condition and the taking of protective measures.

Use of the new method to control deformation processes based on actual behaviour of rock movements also allows a substantially increased coefficient of recovery of useful minerals under built-up areas and natural objects trouble-free in operation, and a decrease in environmental danger in administrative and industrial regions.

Now a forecasting map of the Zhezkazgan deposit has been drawn using the maximum subsidence data of the ground surface (Fig. 1).

Practical use of the method ensures safe mining conditions and prevents damage from possible cavings, especially İn conditions where there is a high concentration of protected buildings and structures.

The worked-out investigations made it possible to carry out diagnostics of the undermined rock massif and long-term forecasting of cavings. When carrying out investigations, methods were proposed for evaluation of the current condition of the rock massif by a complex of criteria, distinguished from common methods in that the value of an area of destruction in the rock massif with expected negative consequences is evaluated by space-time changes in the deflection values of the ground surface.



- - ısolmes of maximum subsidence,
- boundary of weakened area;
- cone of caving at ground surface

Figure 1 Information plan of subsidence of ground surface

As a result of evaluation of the current condition of areas by deflection of the ground surface, the geomechanical conditions at Zhezkazgan deposit were determined, and areas that are dangerous due to caving were established.

2 CONCLUSIONS

The principal scientific and practical results of this study are as follows:

- a method was worked out for determination of the boundaries of zones of dangerous rock *movement* at ore deposits, which allows determination and long-term forecasting of possible cavings and an increased coefficient of useful mineral extraction;
- a long-term forecasting map for the Zhezkazgan deposit was worked out, and on the basis of data, zones dangerous due to caving were determined.

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