Engineering Journal of Satbayev University
Volume 144 (2022), Issue 3, 30-33

https://doi.org/10.51301/ejsu.2022.i3.05

Orthogonal-contour geometrization of hydrogenetic ore mineralizations

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Abstract. The article presents an innovative approach to the geometrization of ore bodies during exploration work based on geophysical and/or core studies in wells for the purpose of areal and thickness delineation of hydrogenetic ore mineralization. The method makes it possible to obtain more accurate contours of ore bodies with a minimal increase in the number of wells constructed for this purpose. The method can be used in planning and conducting exploration work on hydrogenetic deposits. On the example of reservoir-infiltration uranium deposits of the Shu-Sarysu uranium ore province located in South Kazakhstan, shortcomings in the geometrization of ore bodies using the traditional method of placing of geological exploration wells are demonstrated, as well as the shortcomings of the proposed in literature methods of ore geometrization and the main advantages of the proposed innovative approach. The developed method solves a number of significant problems in the subsequent planning and implementation of mining and preparatory work at hydrogenetic deposits, contributes to a significant increase in the accuracy of the geometrization of ore bodies and calculation of reserves, and increases the reliability and investment attractiveness of explored hydrogenetic deposits. This method can also be used to save money by reducing the number of wells being constructed, if used for an inverse problem in order to discharge placement of exploration wells in middle part of ores bodies in hydrogenetic fields with a dense drilling grid.

Keywords: *geometrization of ores, geological exploration, ore bodies delineation, well placement, hydrogenetic deposits, orthogonal geometrization.*

1. Introduction

On the one hand, increasing the level of exploration of ore mineralization serves as the main factor in reducing the risks of possible non-confirmation of the obtained results and non-rational approach to nature management, as well as the primary way to create a more valuable and reliable asset in the subsurface. But, on the other hand, as costs increase, there is a risk of unjustified unnecessary exploration costs, as well as a reduction in the total number of studied ore objects due to the limited total amount of funds for exploration. Achieving an optimal balance between funds spent and time on the resulting detail and reliability of exploration work refers to the best solution when creating a mineral resource base and avoids subsequent unjustified expectations, as well as unforeseen and unnecessary costs for the preparation of its development.

Due to the fact that hydrogenous ore formation has a zonal nature of ore mineralization [1,2], its geometrization during exploration works is well amenable to systematization with little chance. For this reason, as an example, on hydrogenous uranium deposits in Kazakhstan at geometrization of ore bodies at the stage of detailed exploration to the category of C1 reserves, a geological exploration network of 200x50 m is used [3]. Small in power (from the first meters to the first tens of meters) and narrow in width (in average 200-1000 m), as well as long (from several to tens of km) ore bodies [4] are penetrated by a network of vertically drilled holes with 50 m distance between holes across the movement of ore water and with 200 m distance between cross-sections (Figure 1) [5].

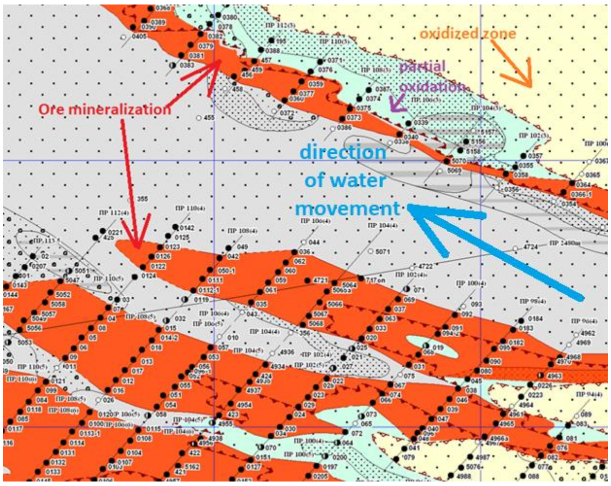

Figure 1. Example of a 200x50 m exploration network at a uranium deposit in the Shu-Sarysu uranium province

To perform geometrization of ores with this approach, boreholes are drilled along the ore profiles up to the exit from the ore bodies, and ore profiles are drilled as the zones advance up to the exit from the ore bodies by the width of the adjacent ore profiles (Figure 1).

Unfortunately, this approach does not allow to obtain the most accurate contours of ore bodies between profiles, the distance between which is 4 times or more than the distance between the wells. As a result, a part of profitable for mining ores turns out not to be covered by geological blocks and not considered on the balance sheet. Besides, during the mine-preparation planning and opening of ore bodies some part of technological holes appears out of the ore mineralization zone and some other part of delineating ore bodies occupy not advantageous position relatively to the edges of ore bodies. In literature [6] the most advantageous solution for a more accurate geometrization of ores is an orthogonal system, in which in addition to the transverse exploration profiles, longitudinal profiles are carried out perpendicularly to the same network. But this approach does not consider the true width of ore bodies and leads to unnecessary costs for geometrization in wide ore bands, and also does not justify itself in cases when the contour of ore bodies passes between longitudinal profiles.

The traditionally used 200x50 m exploration network ignores the literature recommendation based on mathematical modeling and turns the savings of exploration funds into a decrease in the quality of reserves calculation, the plan of mining operations and into an increase in the cost of mining preparation processes with a decrease in their quality. In order to improve the quality of geometrization of ore bodies without unjustified costs of their implementation, this paper proposes an innovative orthogonal-delineation approach for delineation ore bodies in plan. The orthogonal- delineation method will allow to obtain even more accurate results of geometrization of hydrogenous ore bodies than the literature recommended orthogonal, while using a smaller number of wells constructed for this purpose.

2. Materials and methods

To implement the orthogonal- delineation geometrization of ore bodies when drilling holes on the ore profile, the exit from the ore body from the last ore hole is also carried out in perpendicular directions (Figure 2). I.e. if an ore well is adjacent to a non-ore or an off-balance well on the geological exploration profile, then near such an ore well perpendicularly to the adjacent well at the same distance delineation wells are constructed. And then the delineation continues along the network of inter-well spacing according to the same rule until the complete delineation is completed.

Eventually 2 more perpendicularly neighboring wells are drilled near each well adjacent to a non-ore or off-balance well, and each well adjacent to two or three non-ore wells is always surrounded by neighboring wells on all four sides. I.e., when the orthogonal delineation geometrization of ore bodies with 200x50 m net drilling (distance between the exploration profiles of 200 m, and 50 wells in a row) at the boundary of ore bodies (at the exit of the ore body) is used a network 50x50m. Similarly, with a network of 400x50 m, 800x50 m, etc. Thus, to delineate the boundaries of the balance ore bodies, the minimum distance between the wells in the adopted exploration network along the entire boundary of the ore body in all four directions of the exploration network along and across the strike of the ore bodies is applied. In this case, the exit from the off-balance ore to the "waste" rocks is carried out in the usual way (along the profiles of the exploration network).

To visualize the result on the conditional ore body, similar to the real one, the construction of exploration wells by the conventional network of 200x50 m and orthogonal- delineation holes was simulated (Figure 2.), after that the geometrization of geological blocks was carried out by the traditionally accepted methodology (Figure 3). In geological blocking, the block boundary between ore and non-ore wells is drawn for a quarter of the network, as the average off-balance areas will be in the middle of the network, and the balance areas in this case will be on average limited to a quarter of the network. The areas of the simulated geological blocks are then compared with the contours of the conventional true ore bodies and the discrepancies are analyzed to compare the delineation methods.

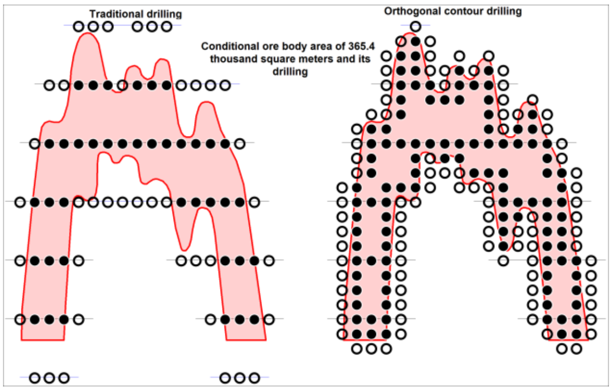

Figure 2. Example of orthogonal delineation geometrization

3. Results and discussion

The results of blocking are shown in Figure 3 and are clearly visible at a glance. With the traditional method of geometrization using a 200x50 m grid, a conditional balance ore body of 365.369 square meters was penetrated by 39 ore holes, delineated by 17 off-balance and 23 "empty" holes. The area of the geological block was 316.250 square meters. At the same time 64.137 square meters of the ore body (18%) were not covered by the geological block, and 15.018 square meters of the block (4.7%) were outside the ore body. Thus, the geometrization error was 79.155 square meters (21.7%). In the orthogonal delineation geometry, the same ore body was penetrated by 110 ore holes, delineated by 44 off-balance holes and 49 "empty" holes. The area of the geological block was 335.781 square meters. However, 40.397 square meters of the ore body (11%) were not covered by the geological block and 10.809 square meters of the block (3.4%) were outside the block.

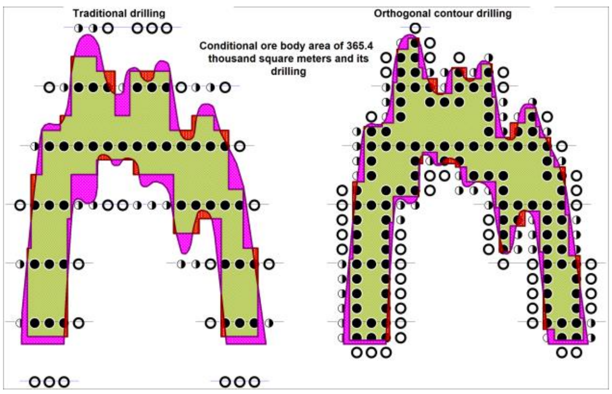

Figure 3. Geological blocking of the conventional ore body

Thus, the geometry error was 51.206 sq. m. (14%), which is 27.949 sq. m. (7.6% of the ore body) less than the traditional method. Thus, the geometry error was 51.206 sq. m. (14%), which is 27.949 sq. m. (7.6% of the ore body) less than the traditional method.In addition to refining the balance mineralization, the amount of data on off-balance grades has increased significantly, which will allow for more accurate blocking of off-balance blocks and facilitate mining planning. Moreover, additional data will necessarily clarify the geological structure of productive horizons, their lithologic-filtration and facies structure, and the morphology of ore bodies, increasing the reliability of the results and reducing the risks of incorrect correlation of bodies and horizons. Of the disadvantages, it should be noted the need to use exclusively independent of the uniformity of the network ways of calculating reserves (for example, by the method of Voronoi polygons [7] or three-dimensional block modeling, etc.), or to combine a large number of wells to create a uniformity of the network.

4. Findings

Despite the fact that to reduce the error from 79.155 sq. m. to 51.206 sq. m. (by 27.949 sq. m., which is 35.3% of the unconfirmed sum) it was necessary to drill 128 more wells (203 with the orthogonal delineation method vs. 79 with the traditional method), it is important to note a number of nuances in this situation. Firstly, it is impossible to obtain the same geometrization refinement by any other method with fewer wells. Secondly, the form of blocks itself has taken much more true form and significantly increased the understanding of profitability of individual sections, due to which the narrow parts can be transferred to the technological off-balance relative to the profitable network of geotechnological cells. Thirdly, expansion of technologically profitable zones and preparation of technologically profitable ores not considered earlier was carried out, which should instantly recoup the costs generated in the subsurface assets.

Fourthly, practically the whole part of orthogonal-delineation drilling is always carried out in problematic, narrow and not large in area ore parts, most of which would have been planned for mining works and penetrated by technological wells with approximately the same inter-well spacing, and then would have led to big problems. Fifth, this approach allowed a large number of wells with off-balance grades to be mapped with high accuracy (44 vs. 17), which will greatly improve the quality of further planning of mining operations and ore opening. Sixth, as an example of geological exploration of formation-infiltration uranium deposits, in contrast to prospecting and preliminary exploration, at the stage of detail is much cheaper, non-core drilling (delineation by geophysical survey data) and, therefore, without the implementation of core documentation, without sampling and without chemical-analytical studies.

If we consider that only a part of the deposit belongs to the demonstrated narrow ore bodies, orthogonal-delineation geometrization will not affect the total cost of exploration works so much, will increase the total cost of exploration works approximately by 5-10%, but will solve about 35% of problematic cases and give the above-described improvements and some other improvements.

5. Conclusions

Innovative approach of geometrization of ore bodies allowed on conditional ore body by means of conditionally drilled additional 128 orthogonal delineation holes to account for additional 23.740 sq.m. of ore body. For example, if average cost of a hole was 1.5 million tenge, additional 192 million tenge would have been required to construct them, but with average ore thickness of 6 m and average uranium content of 0.03%, increment of profitable ores would have been about 68.37 tons of uranium, total cost about 3.424 million tenge. Also, this approach prevented mining planning and uncovering of non-existing ores in an area of 4209 km. m (11 injection wells, thereby preventing errors in several planned technological cells) and brought a number of other improvements.

As a result, this method showed a number of advantages over the traditional and system of geometrization of ores proposed in literature. The cost of work on the example of layer-infiltration uranium deposits is projected at an acceptable and justifiable level. The increase in the number of involved market production facilities, funds and time is compensated by the reduction of involved facilities, funds and time for mining works. Under similar conditions the method is recommended for application.

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Гидрогенді кенденулердің ортогоналды-контурлы геометризациялануы

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Аңдатпа. Мақала материалы гидрогенді минералды жаралымдарды алаңдық және қалыңдық бойынша контурлау мақсатында ұңғымалардағы геофизикалық және/немесе керндік зерттеулерге негізделген геологиялық барлау жұмыстары кезінде кен денелерін геометризациялаудың инновациялық тәсілін сипаттаудан тұрады. Бұл әдіс осы үшін салынған ұңғымалар санының минималды өсуімен кен денелерінің дәлірек контурларын алуға мүмкіндік береді. Бұл әдісті гидрогенді кенорындарында геологиялық барлау жұмыстарын жоспарлау және жүргізу кезінде қолдануға болады. Оңтүстік Қазақстанда орналасқан Шу-Сарысу уран кенді провинциясының қабаттық-инфильтрациялық уран кенорындары мысалында геологиялық барлау торабын орналастырудың дәстүрлі әдістемесін пайдалану кезінде кен денелерінің геометризациялануындағы кемшіліктер көрсетілді, сондай-ақ кендерді геометризациялаудың әдебиеттерде ұсынылған тәсілдерінің кемшіліктері және ұсынылатын инновациялық тәсілдің басты артықшылықтары түсіндірілді. Әзірленген әдіс гидрогенді кенорындарында тау-кен дайындық жұмыстарын кезекті жоспарлау мен жүзеге асырудың бірқатар маңызды мәселелерін шешеді, кен денелерінің геометризациясы мен қорларды есептеу дәлдігінің едәуір артуына ықпал етеді, барланған гидрогенді кенорындарының сенімділігі мен инвестициялық тартымдылығын арттырады. Бұл әдісті, егер сіз оны бұрғылаудың тығыз торабы бар гидрогенді кенорындарындағы барлау ұңғымаларының ішкі контурлық торабын сирегірек жасау үшін кері тапсырма үшін қолдансаңыз, салынатын ұңғымалардың санын азайту арқылы шығындарды үнемдеу үшін де қолдануға болады.

Негізгі сөздер: *кендерді геометризациялау, геологиялық барлау, кен денелерін анықтау, ұңғымаларды орналастыру, гидрогенді кенорындар, ортогональды геометризация.*

Ортогонально-контурная геометризация гидрогенных оруденений

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Аннотация. Материал статьи представляет собой инновационный подход к геометризации рудных тел при геологоразведочных работах основанных на геофизических и/или керновых исследованиях в скважинах с целью площадного и мощностного оконтуривания гидрогенных минеральных образований. Метод позволяет получать более точные контуры рудных тел при минимальном увеличении количества сооружаемых для этого скважин. Метод может быть использован при планировании и проведении геологоразведочных работ на гидрогенных месторождениях. На примере пластово-инфильтрационных урановых месторождений Шу-Сарысуйской урановорудной провинции, расположенной в Южном Казахстане, продемонстрированы недостатки в геометризации рудных тел при использовании традиционной методики размещения геологоразведочной сети, а также объяснены недостатки литературно предложенных способов геометризации руд и главные преимущества предлагаемого инновационного подхода. Разработанный метод решает ряд значительных проблем последующего планирования и осуществления горно-подготовительных работ на гидрогенных месторождениях, способствует значительному повышению точности геометризации рудных тел и подсчета запасов, повышает достоверность и инвестиционную привлекательность разведанных гидрогенных месторождений. Данный метод также может быть использован для экономии средств путем уменьшения количества сооружаемых скважин, если использовать его для обратной задачи с целью разряжения внутриконтурной сети разведочных скважин на гидрогенных месторождениях с густой сетью бурения.

Ключевые слова: *геометризация руд, геологоразведка, оконтуривание руд, геологоразведочная сеть, гидрогенные месторождения, ортогональная геометризация.*