GEOINFORMATICS 2020

EAGE

18391

3D geological modeling for mineral resource assessment of the Galeshchynske iron ore deposit, Ukraine

O. Ivanik, ***D. Vasiukhina** *(Taras Shevchenko National University of Kyiv)*

SUMMARY

Three-dimensional geological modeling is a technology for study of geological structure, mineral resource exploration, and quantitative estimation of mineral resources of different genetic types. 3D modelling integrates different techniques and approaches such as two-dimensional modelling, geostatistics, spatial GIS analysis, database development, etc. It allows modeling of complex geological objects using stratigraphy, lithology, tectonic data as well as geophysical and geochemical information. The geological structure of the Galeshchynske deposit has been studied in detail, borehole data were analyzed, and the soluble iron contents were interpolated. Based on the statistical processing of these boreholes, it can be argued that this territory is characterized by a bimodal distribution of values. This indicates the presence of two geological domains (populations), low and high values of soluble iron content.

The interpolation of values by the inverse distance method makes it possible to estimate the resources of the K22 ore deposit in advance, which gives the basis for further in-depth study and calculation of reserves of the given subsoil.

Introduction

Three-dimensional geological modeling is a developing technology for study of geological structures, mineral resource exploration, and quantitative estimation of mineral resources of different genetic types (Gongwen and Huang, 2012). 3D modelling integrates different techniques and approaches like two-dimensional modelling, geostatistics, spatial GIS analysis, database etc. (Ivanik et al., 2019). It allows modeling of complex geological objects using stratigraphy, lithology, tectonic data as well as geophysical and geochemical information.

Geological settings

The Galeshchynske iron ore deposit is located within the middle of the Dnieper area (left bank of the Dnieper River) in the territory of the Kremenchug district of Poltava region, to the north of Horishni Plavni city. It belongs to the group of deposits of the Kremenchug magnetic anomaly, which is a part of the Kryvyi Rih-Kremenchug metallogenic zone or province of ferruginous-siliceous formations of the Ukrainian Shield. This zone can be traced towards the sub-meridional direction from south to north through the entire Ukrainian Shield for a distance of more than 300 km. According to geophysical data, the northern extension is noted in the form of magnetic anomalies of varying intensity under the Dnieper-Donetsk depression down to the southwestern slope of the Voronezh crystal massif.
The Galeshchynske iron ore deposit is dated to the eponymous complex-built syncline, which is the largest structure of the Kremenchuk synclinorium. The ore deposits are dated to the rocks of the ferruginous horizons of the Saksagan suite of the Kryvyi Rih series, which are stretched in a submeridial direction by a narrow strip. The Saksagan suite (PR_1sx) is characterized by a rhythmic structure of the incision, expressed in the regular change of shale and glandular horizons. The ore deposits are predominantly red-striped, gray-striped, and iron-magnetite thin-layer magnetite quartzites (Alexandrov, 1975, Belevtsev et al., 1974).

Methodology

Three dimensional modeling assumes different approaches and techniques. 3d modeling allows building industrial and economic objects models as well as creating and conducting on-line subject maps. It can include:

- three-dimensional models development of deposits of various genetic types and geological building complexity; spatial deposit modeling by prospecting testing data
- modeling of solid mineral deposits (ore and non-ore)
- on-line correction of deposit geological models to the extent of their reserves progression
- bedded deposit modeling
- placer deposit modeling

Three-dimensional geological modeling assists geologists to quantitatively study in three-dimensional space structures that define temporal and spatial relationships between geological objects. 3D geological modelling technology provides technical support for extraction of diverse geoscience information, 3D modeling, and quantitative calculation of mineral resources (Gongwen and Huang, 2012).
The methodology that was followed for 3D geological modeling involved the following steps:

1. Geological data acquisition and compilation. All geological, geophysical and geochemical data on the study area has been gathered and analyzed.
2. Geological data interpretation and extraction.
3. Development of geological database. The geological database has been developed using software "Datamine". The imported digital database includes files: collars, survey, geological description, and assay file. The assay file contains information about the determination of total

iron and soluble iron. The said database contains the analytical information of the territory of the Galeshchynske deposit for the iron ore horizon (K_2^2 layer) (Fig. 1). Geological and mathematical modeling was subjected to only one component - soluble iron, because this component is removed during metallurgical processing and most fully characterizes the pattern of distribution of iron in the volume of the deposit.

4. Virtual borehole construction based on geological information and borehole data (Fig. 3)
5. 3D ore body modelling and interpretation (Fig. 3). The next step was the process of digital interpretation, which consisted in the sequential digitization of geological domains, statistical domains of mineralization and other structural elements. Standard framework modeling methodology includes the creation of digital surface models and closed frames of geological and statistical domains.

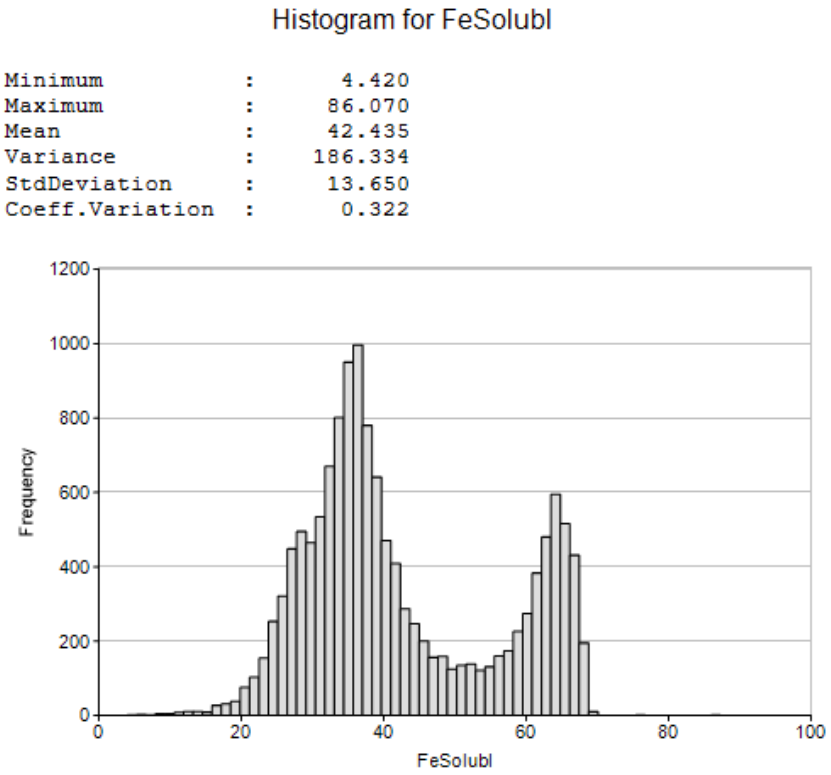

Figure 1: *Histogram shows the statistical distribution of iron soluble K_2^2 ore pack (Saksagan suite). Two geological domains (populations) are observed.*

The empty block model was filled in wireframes, then interpolation of soluble iron by inverse distance weighting (IDW) method has been carried out. Interpolation is widely used for both predictive and visualization purposes in geology studies. A variety of algorithms have been developed to construct such interpolations, e.g., inverse distance weighting (IDW), splines, kriging or polynomial regression. Constructed volumetric model of the Galeshchynske deposit allows to clarify the peculiarities of its structure and spatial location of the ore body. The block model created has lithological code data and interpolated values of soluble iron, which allows us to calculate approximate values of resources.

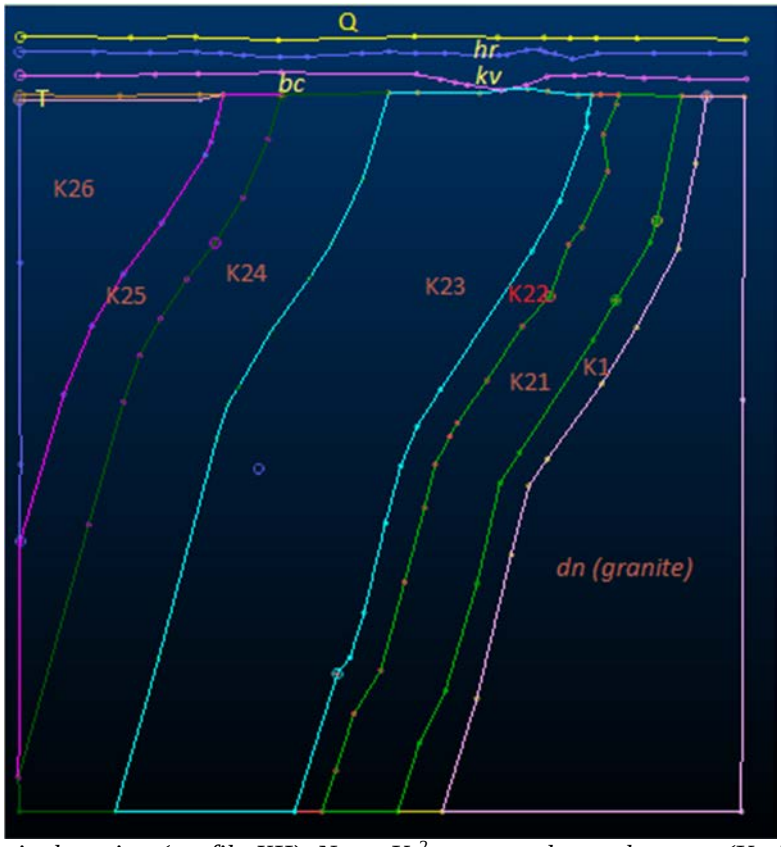

Figure 2: *A geological section (profile XII). Note: K_2^2 – ore pack, one last one (K_1, K_2^3,K_2^4,K_2^5, K_2^6) – waste packs (Kryvyi Ryh series); dn – Archean Dnieper complex granites; Q – quaternary sediments; hr – Kharkivska suite; kv – Kyivska suite; bc – Buchak suite; T – trias sediments.*

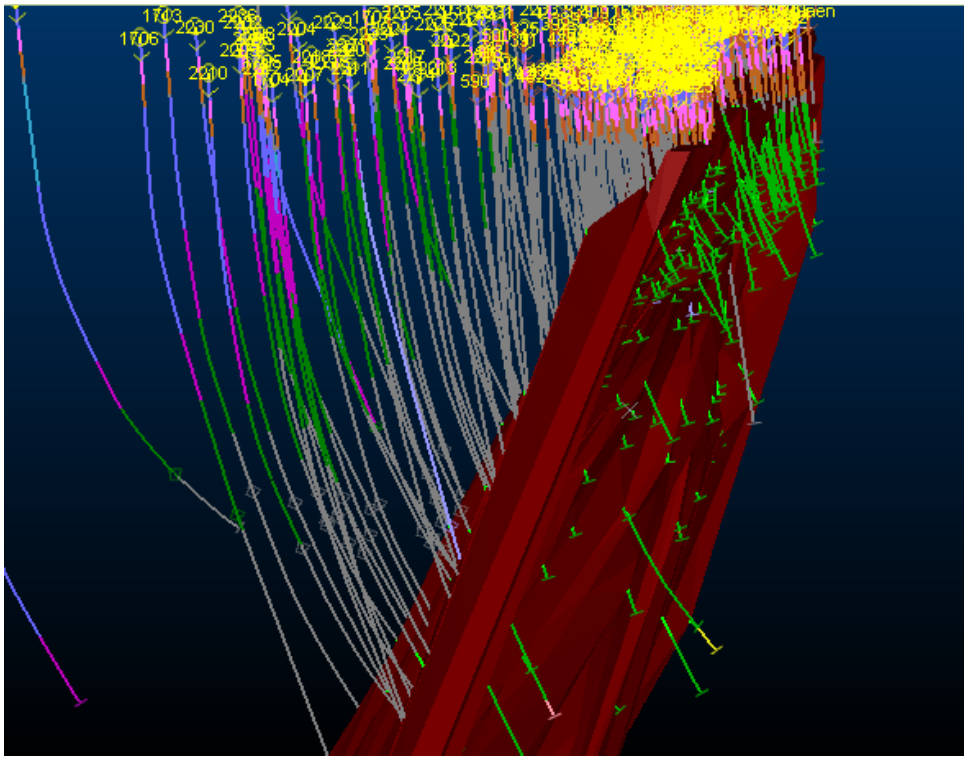

Figure 3: *A wireframe model of the K_2^2 ore deposit, which is crossed by boreholes.*

Conclusions

On basis of the methodology and research results described in this study the geological structure of the Galeshchynske deposit was has been studied in detail, borehole data were analyzed, and the soluble iron contents were interpolated. Based on the statistical processing of these boreholes, it can be argued that this territory is characterized by a bimodal distribution of values. This indicates the presence of two geological domains (populations) - in this case, low and high values of soluble iron content (Fig 1). The interpolation of values into the block model by the inverse distance method makes it possible to estimate the resources of the K_2^2 ore deposit in advance, which gives the basis for further in-depth study and calculation of reserves of the given subsoil.

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