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DYNAMIC MODEL OF A KAOLIN DEPOSIT

25.1 INTRODUCTION

This paper focuses on research within the project TE02000029 Competence Centre for Effective and Ecological Mining of Mineral Resources, granted by The Technology Agency of the Czech Republic. The main goal of this project is revision of the deposits of selected non-energetic raw materials, which belong to critical EU commodities [9]. Its Work Package WP4 "Spatial modeling of mineral deposits" focuses on digital modeling of selected deposits, using appropriate mathematical techniques, based on the study and evaluation of the archived data. One of the selected deposits is a kaolin deposit Jimlíkov – east, located in the neighborhood of the village Jimlíkov, about 5 km west of Karlovy Vary.

The kaolin deposit Jimlíkov – east was created by kaolinization of the Karlovy Vary granite massif during the Cretaceous and Paleogen periods. Deposits is formed by those residuals of the original soil crust, which were preserved from denudation. The Karovy Vary massif, which belongs to the large Krušné Hory pluton, forms a basement of the deposit.

In this paper we describe individual steps for creation and visualization of 3D models of the deposit, including all steps from reevaluation of all accessible archived materials and verification and correction of the input data, up to the visualization of categories of the blocks of reserves. Using a specialized software we check all input data, compatibility of used software, and generate outputs: estimates of the deposit reserves in a textual form and various types of visualization of the deposit in 2D and 3D, respectively. This methodology and a newly developed software allow us to both create variant models of the kaolin deposits of this and a similar types and fast updates of the models when the input data and/or the parameters of the model are updated and/or amended. Our dynamic complex model for kaolin deposits can be updated when needed, based on mining explorations including variant estimates of the resources based on a priori defined utility conditions.

In our modeling standard software tools, such as MS Excel, Surfer [10] and Voxler [11] made by the Golden Software Company, and an open-source software SGeMS [5], are used. For creating macros in the MS Office environment we used the Visual Basic for Applications (VBA), while for individual software tools we used the standard Visual Basic.

25.2 METHODOLOGY AND ALGORITHMS FOR CREATING AND VISUALIZATION OF THE 3D MODEL FOR THE KAOLIN DEPOSIT

In this section we focus on individual methodological steps for creating and visualization of the 3D model for the kaolin deposit. We will demonstrate these steps on a case study with the kaolin deposit Jimlíkov - east. The algorithms corresponding to these steps for the processing of the data and software creation are described in the individual subsections:

2.1 Evaluation of all reachable archived materials.

2.2 Verification and correction of input data.

2.3 Calculation and visualization of spatial localization of the input data.

2.4 Statistical processing of the technological parameters.

2.5 Modeling of the base and the top of the kaolin occurrence and overall lithology of the deposit.

2.6 3D visualization of the input data for the kaolin deposit in the Voxler environment, creation of 3D grids of the content of technological parameters, and export of the 2D grids in individual horizons in the *grd* Surfer format (program *Kaolin_A*).

2.7 Categorization of the blocks of reserves in 2D grids (in individual horizons) based of both the grids of technological parameters (exported using the program *Kaolin_A*) and predefined parameters for the categories of reserves, transformation categories of the blocks of reserves into a 3D grid and estimation of the reserves of the deposit (program *Kaolin_Viz*).

2.8 2D visualization of horizontal sections in the Surfer software environment (program *Kaolin_Viz*).

2.9 2D visualization of the series of vertical sections in the Surfer software environment (program *Kaolin_Viz*).

2.10 3D visualization of categories of blocks of reserves in the Voxler software environment (program *Kaolin_Viz*).

2.11 (when needed) Completion of the input data on the basis of the mining exploration; going to step 2.6.

Individual methodological steps 2.1 – 2.11 can be easily re-executed in an automatized manner with any change of parameters. Therefore, it is easy to create different variants of the model (for example with different gridding parameters). This methodology can be adopted for all deposits of a similar type.

25.2.1 Evaluation of all reachable archived materials

The main sources of the data for evaluation of the input data are both the archived materials about the area from the Geofond Czech Republic from years 1960-1992 [1], [2], [3], [4], [6], [7] and the final report [8].

25.2.2 Verification and correction of input data

Verification and correction of the input data is done by confrontation of the data with the archived materials, via visualization (in 2D and 3D), and comparison with the corresponding archived horizontal and vertical sections (see 25.2.1). In our example of the

kaolin deposit Jimlíkov – east many errors in the data were found. Some of these errors were caused by typographical mistakes when the data was digitalized, but there were many other errors. After correction of these errors, input data from all 85 exploration drill holes from years 1960 - 1990 (Fig. 25.1) and from 1098 samples analyzed (Fig. 25.2) could be included into the calculations. For these samples, we calculated categories (classes) of the reserves according to Table 25.1. This was based on the basis of the content of the so-called kaolin outwash ("výplav" in Czech; kaolin remainder after kaolin washing out with the grain size up to 20 microns), Al_2O_3, Fe_2O_3 and TiO_2.
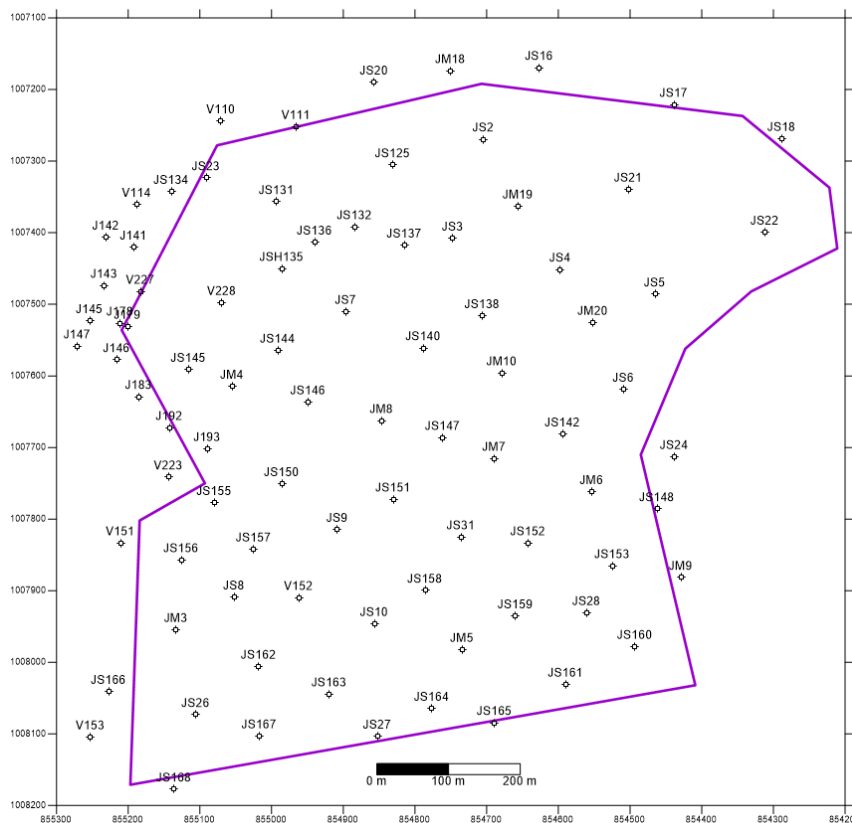

Fig. 25.1 Deposit demarcation and exploratory drill holes used in our computations

25.2.3 Calculation and visualization of spatial localization of the input data

Corrected and completed input data (geometric parameters of prospect holes and samples with content of technological parameters) are divided into 10 cm long sections (in total 21209 of such sections) using a macro. Moreover, the data are placed into the center of each section. This data is an input for further data processing: for selection of data for creating horizontal and vertical sections, for statistical analyses, gridding, 2D and 3D visualization etc. For example, Fig. 25.3 shows localized information on the Al_2O_3 content.
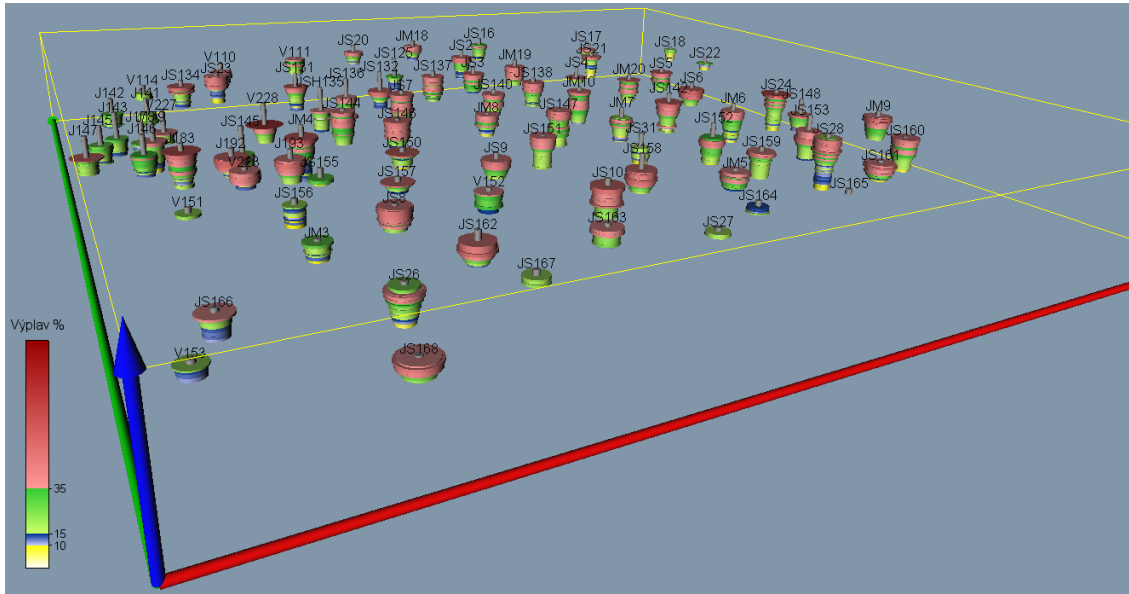
Fig. 25.2 Visualization of the kaolin outwash ("Výplav") proportion in the studied samples

Table 25.1 Categorization of ceramic kaolin in the Karlovy Vary region

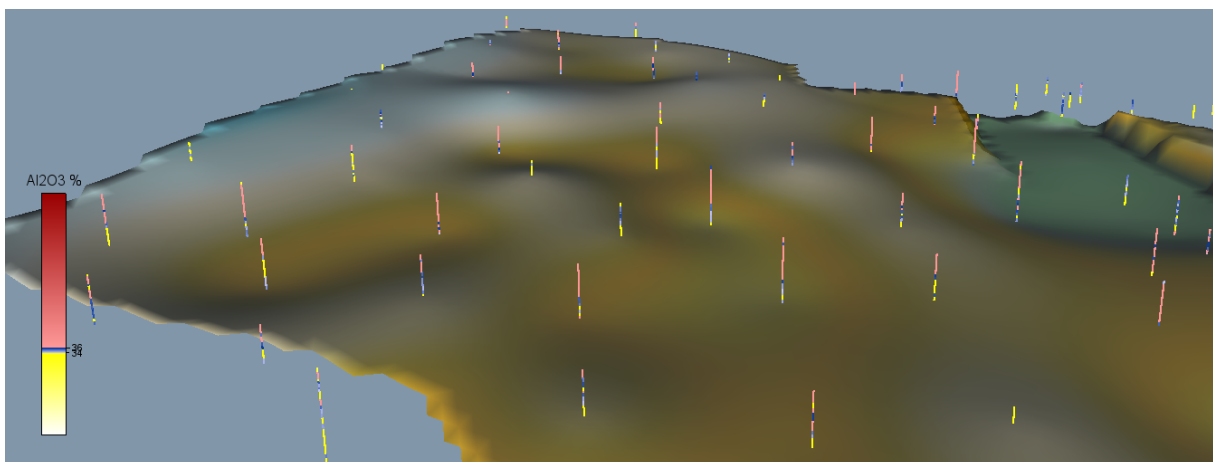| Category (class)	Kaolin outwash [%]	Al_2O_3 [%]	Fe_2O_3 [%]	TiO_2 [%]	$Fe_2O_3 + TiO_2$ [%]	Usage
K1	>15	>36	<0.9	<0.3	<1.1	Kaolin for production of pottery
K2	>15	>36	<1.1	<0.4	<1.2	
K2A	>15	34 - 36	-	<0.5	<1.2	
K51	>10	>36	-	<0.3	<1.0	
K2B	>15	>36	-	>0.4	<1.6	Kaolin with high content of TiO_2
K3B	>15	>36	-	>0.5	<2.0	
K4B	>15	>34	-	>0.5	<2.5	
K3	>15	>34	-	<0.5	<1.6	Kaolin for other ceramic industry
K4J	>35	>34	-	-	<5.0	
K4	>15	-	-	-	<3.0	
K5 (NEG)	>10	-	-	-	>3.0	Inappropriate kaolin

Source: based on [8]

Fig. 25.3 Localized data Al_2O_3 content together with the base occurrence of kaolin

25.2.4 Statistical processing of the technological parameters

Basic statistical processing of the technological parameters takes place in the SGeMS environment [5]. An example of the outputs is in Fig. 25.4 - histogram of frequency of the kaolin outwash and with regression dependence of the outwash on the depth

25.2.5 Modeling of the base and the top of the kaolin occurrence and overall lithology of the deposit

The outcome of the geologists' work was creation of the 2D grids of eight geological layers from the crystalline basement up to the surface. On the basis of these 2D grids the grids of both the base (Fig. 25.3) and top of the kaolin occurrence were created. These two grids bound the 3D model of the deposit. During mining it will be necessary to regularly update the grid of the top of the kaolin occurrence.
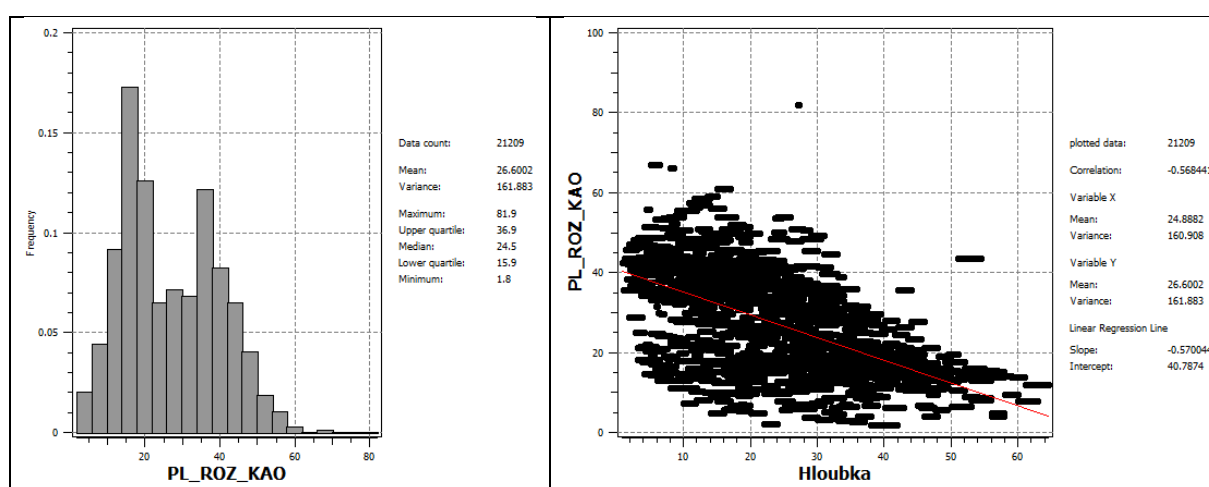

Fig. 25.4 Histogram of frequency of the kaolin outwash = PL_ROZ_KAO (left) and regression dependence of the kaolin outwash on the depth = Hloubka (right)

25.2.6 Program Kaolin_A

Program *Kaolin_A* generates 3D grids of individual technological parameters according to the parameters anisotropy, grid geometry and selection of samples for interpolation – these parameters are defined by the user and can be adjusted in order to create different variants of the deposit models - and exports them also in the form of the series of the horizontal 2D grids for further processing. Each point of the 3D grid represents a block of kaolin deposit of the prespecified size (e.g. 10 x 10 x 1 m). Program *Kaolin_A* additionally generates also various manners for the presentation of both updated data (see Section 25.2.3) and 3D grids for individual technological parameters in the Voxler environment. Fig. 25.5 depicts one of the outputs of the program *Kaolin_A* – visualization of the Al_2O_3 content, where its left part shows a structure of individual modules in Voxler generated by the program *Kaolin_A*.

25.2.7 Categorization of the blocks of reserves (program Kaolin_Viz)

First module of the program *Kaolin_Viz* categorizes blocks of reserves on the basis of the grids of technological parameters exported by the program *Kaolin_A* (see Section 25.2.6) and prespecified parameters of the categories of reserves (Table 25.1). Codes for categories of

the blocks of reserves are for further manipulation saved in both series of horizontal 2D grids and in the form of 3D grid. This module also estimates reserves of the kaolin deposit in the textual form.
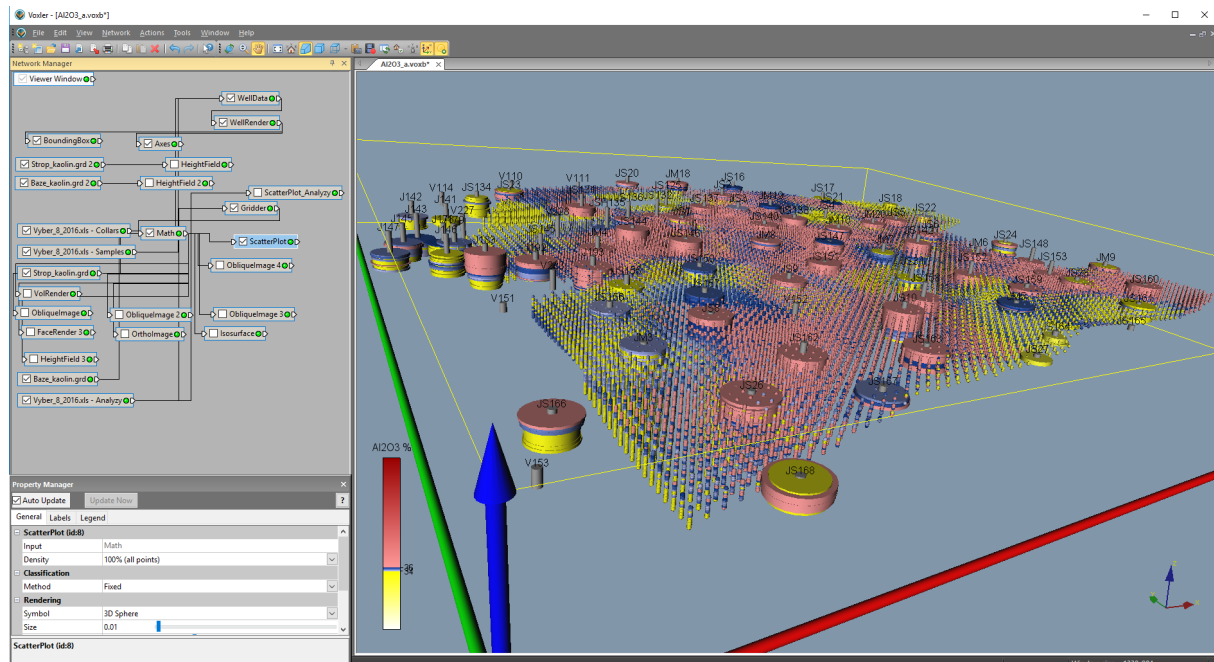

Fig. 25.5 3D visualization of the Al$_2$O$_3$ content – depicting the 3D grid via ScatterPlot

25.2.8 Visualization of horizontal sections (program Kaolin_Viz)

Second module of program *Kaolin_Viz* gradually generates a 2D visualization the horizontal sections of blocks of reserves in the Surfer environment selected by user in the scale also specified by the user. Fig. 25.6 visualizes one of the series of the horizontal sections generated in this manner in the Surfer environment. By switching objects in the left screen on and off (Fig. 25.6) the following can be visualized:

- Categories of blocks of reserves in the section (object Kategorie).
- Contents of the kaolin outwash (object Vyplav), Al$_2$O$_3$ (object Al2O3), Fe$_2$O$_3$ (object Fe2O3), TiO$_2$ (object TiO2), Fe$_2$O$_3$+TiO$_2$ (object Fe2O3+TiO2) in the section blocks.
- Color Scales of categories of blocks of reserves (object Color Scale Kategorie), kaolin outwash content (object Color Scale Vyplav), Al$_2$O$_3$ content (object Color Scale Al2O3), Fe$_2$O$_3$ content (object Color Scale Fe2O3), TiO$_2$ content (object Color Scale TiO2) and Fe$_2$O$_3$+TiO$_2$ content (object Color Scale Fe2O3+TiO2) in the section blocks.
- Position and names of the drill holes in the section (object Vrty).
- Data about individual blocks of reserves (object Bloky).
- Deposit demarcation (object Obvod ložiska).
- Individual axes of the coordination system (objects Right Axis, …).

After specifying a scale for object Map and eventually after formal completing of the section, each such a section can be directly printed via a suitable output device.
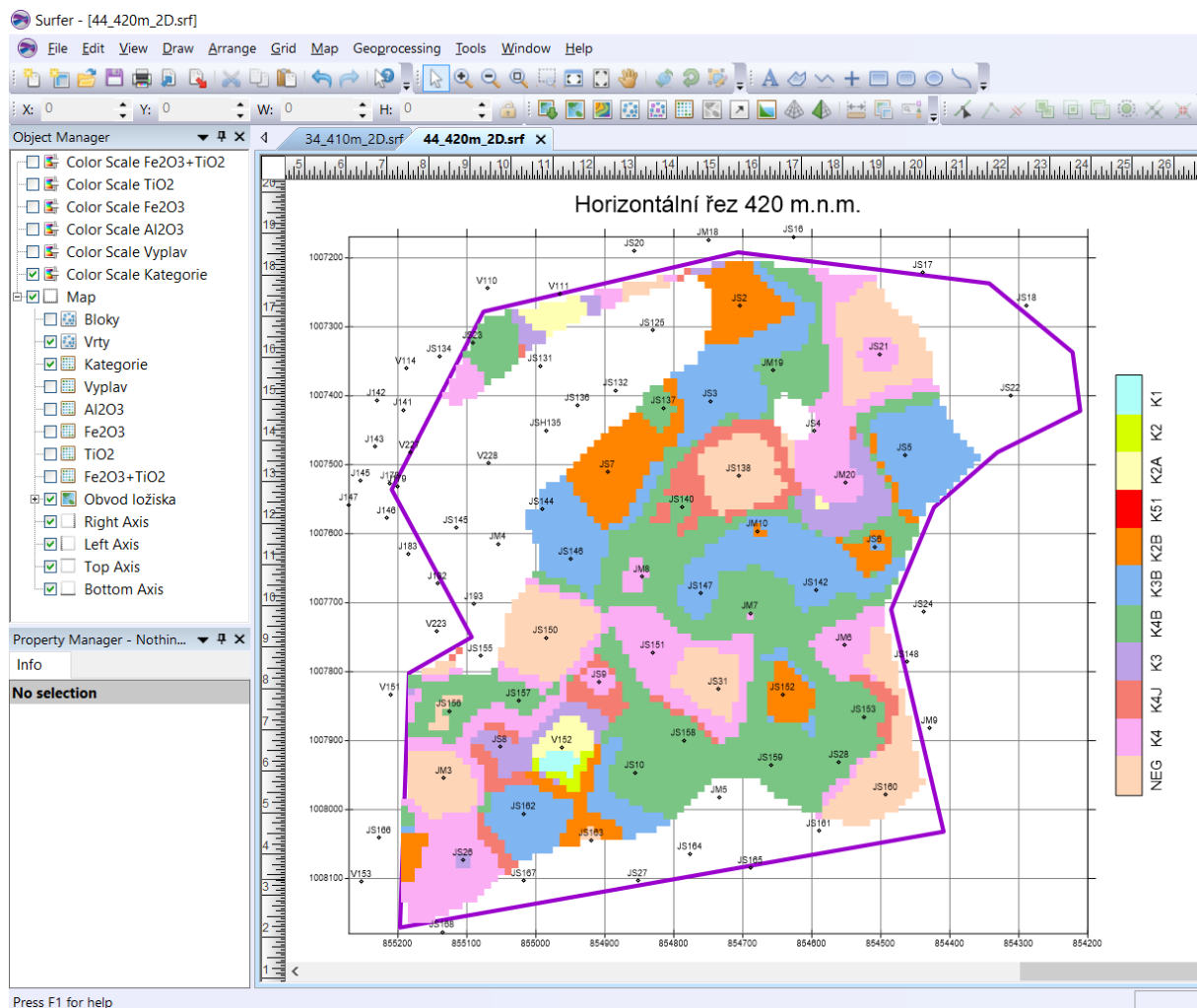
Fig. 25.6 Visualization of a horizontal section 420 m a.s.l. in the Surfer environment

25.2.9 Visualization of the series of vertical sections (program Kaolin_Viz)

The third module of the program *Kaolin_Viz* generates and visualizes a series of vertical sections of XZ and YZ blocks of reserves in 2D in the Surfer environment, as prespecified by the user. Fig. 25.7 demonstrates the visualization of one of the cross sections generated in this way. By switching objects in the left panel of Fig. 25.7 on and off one can also represent:

- Positions, names and distance of selected drill holes for the section (object Vrty_vzdálenost).
- Data about individual samples in the drill holes (object Vrty_Samples).
- Projections of the drill holes selected for the section (object Průběhy vrtů).
- Segments of selected drill holes for the section with samples of the K1, K2, …, NEG categories (objects Base_K1, Base_K2, …, Base_NEG).
- Projection of the base (object Báze kaolinu) and top (object Strop kaolinu) of the occurrence of kaolin in the section.

After specifying a scale for object Map and eventually after formal completing of the data, each such a section can be directly printed on a suitable output device.
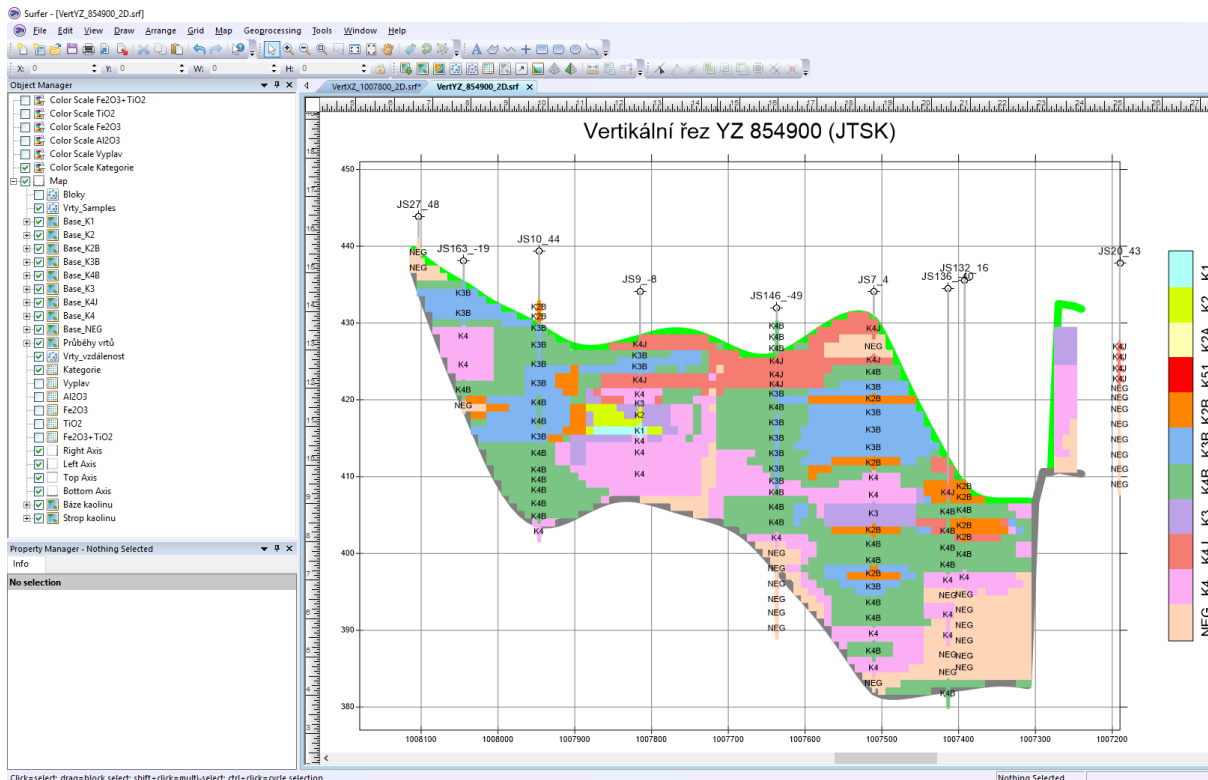
Fig. 25.7 Visualization of the vertical section YZ 854900 in the Surfer environment

25.2.10 3D visualization of categories of blocks of reserves (program Kaolin_Viz)

Fourth module of the program *Kaolin_Viz* generates various 3D visualizations of categories of blocks of reserves in the Voxler environment. Fig. 25.8 demonstrates one of the possible visualization modes. In the left panel of this figure a structure of individual Voxler modules generated by *Kaolin_Viz* is shown.

25.2.11 Updating the model

In case of updating the input data on the basis of the exploratory mining the data must be processed as described in Sections 25.2.2 - 25.2.4. During an ongoing mining activities it is also necessary to update the grid of the top of the kaolin occurrence (Section 25.2.5).

Afterwards everything is ready for the model update and its visualization as described in Sections 25.2.6 - 25.2.10.

CONCLUSION

The proposed methodology for modeling the kaolin deposit is unique due to the fact that it specifies individual steps from acquiring necessary input data from the archived documentation, through applying modern algorithms for creating the 3D deposit models, up to estimates of the reserves and visualization of the blocks of reserves.

Using a specialized software tools it is taken care of checking the input data, compatibility of the used programs (MS Excel, Surfer, Voxler, SGeMS), and automatic generation of the outputs – various 2D and 3D deposit visualizations.
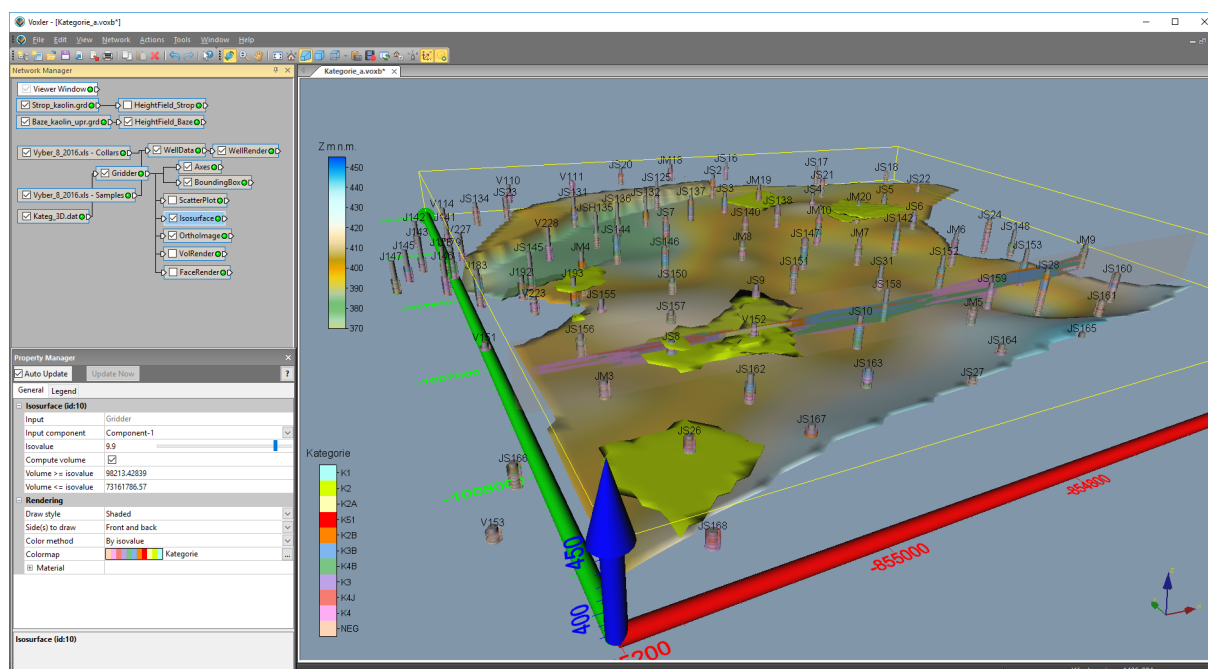
Fig. 25.8 3D visualization of categories of blocks of reserves – display of an envelope of the solids of the K1 a K2 categories (Isosurface), deposit section (OrthoImage) and base for the occurrence of kaolin

This methodology combined with a newly developed software allow us to create variant models of the kaolin deposit, allows us fast updates of these models when the input data and/or model parameters are adjusted or changed. Using the described methodology leads to creating an active dynamic complex model of the kaolin deposit. This model can be updated based on an ongoing mining exploration, incl. variant estimates of reserves based on the predefined conditions for usability.

Since January 2017 is this dynamic model utilized in practice by company Sedlecký kaolin for the kaolin deposit Jimlíkov – east.

ACKNOWLEDGEMENTS

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DYNAMIC MODEL OF A KAOLIN DEPOSIT

Abstract: This paper focuses on research within the project TE02000029 Competence Centre for Effective and Ecological Mining of Mineral Resources, granted by The Technology Agency of the Czech Republic, and, more specifically, on the research within its work package WP4 - Spatial modelling of mineral deposits. The focus of this work package is digital modelling of selected non-energetic raw materials, which belong to the critical commodities, as defined by the European Union. For modelling these deposits, suitable mathematical procedures, based on study and reevaluation of archived data, are needed. One of the selected deposits is a kaolin deposit near the village Jimlíkov near the city Karlovy Vary. In this paper, we show a step-by-step procedure for creation, visualization and evaluation of a 3D model of the deposit. This methodology, along with our recently developed software allows a user to create a variant of this dynamic model for the same or similar types of deposits, enables rapid updating of these models when adding or changing the input data on the basis of new mining exploration or when changing modelling parameters such as using multiple variations interpolation parameters. Our methodology leads to a more advanced deposit evaluation, including adaptive estimates of the reserves based on the usability requirements we choose. In January 2017 our software was tried out in the company Sedlecký kaolin a. s. in Božičany and our dynamic model is fully applied in practice.

Keywords: spatial modelling of deposits, EU critical commodities, kaolin deposit, visualization, estimates of reserves.

DYNAMICKÝ MODEL LOŽISKA KAOLINU

Abstrakt: Článek popisuje část řešení projektu TE02000029 - Centrum kompetence efektivní a ekologické těžby nerostných surovin (CEEMIR) financovaného Technologickou agenturou ČR, přesněji výsledky řešení Work Package WP4 - Prostorové modelování ložisek nerostných surovin. Hlavním cílem WP4 je digitální modelování vybraných neenergetických surovin, které se řadí mezi kritické komodity EU. Pro modelování ložisek se využívají vhodné matematické postupy na základě studia a přehodnocení dat z archivních materiálů. Jedním z vybraných ložisek je ložisko kaolínu v okolí obce Jimlíkov na Karlovarsku. V článku jsou popsány jednotlivé kroky metodického postupu tvorby, vizualizace a zhodnocení 3D modelu tohoto ložiska. Tato metodika spolu s nově vyvinutým programovým vybavením umožňuje vytvářet variantní dynamické modely ložiska tohoto a obdobných typů, umožňuje rychlé aktualizace těchto modelů při doplnění nebo změně vstupních dat na základě prováděného těžebního průzkumu (případně i parametrů modelování - například použití více variant parametrů interpolace). Uplatnění popsaného metodického postupu vede ke komplexnímu zhodnocení ložiska včetně variantních odhadů zásob podle zadaných podmínek využitelnosti. V lednu 2017 proběhlo zaškolení a instalace software u Sedleckého kaolinu a. s. v Božičanech a dynamický model je tak plně využíván v praxi.

Klíčová slova: prostorové modelování ložisek, kritické komodity EU, ložisko kaolínu, vizualizace, odhady zásob.

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