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The use of 2D/3D GIS software for exploration purposes: case studies from Canada and Ukraine

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SUMMARY

2D and 3D geomodelling is a great tool for visualization of different geological systems and allows us to better understand a given prospective mineralized area.

In this research study, 2D/3D geological-geophysical models of some areas within the Canadian (Alces Lake property (SK, Canada) and Ukrainian (Azov Block) Shields were constructed.

The Alces Lake property is located within the Beaverlodge Domain, about 28 km north of the Athabasca Basin margin and has one of the highest rare earth element (REE) grades in the world. The REEs within Alces Lake are hosted in monazites within granitic to residual melt pegmatites, which are associated with biotite-rich (+/- sulfides) paragneisses.

In Ukraine, most of the REE deposits and occurrences are located within the Ukrainian Shield with the Azov Block being one of the most promising areas. The Yeliseyev field of differentiated REE pegmatites, the Zelena Mogyla and The Balka Kruta deposit were studied.

During the process of geomodelling, three-dimensional structures, surfaces, and mineralization objects were built based on drill hole core/down-hole data, geophysical data (magnetics/gravity/EM), geochemical data, topographic data, assessment and technical reports, and geological maps etc. The resulting models show the distribution of REEs within the different properties and outline some potential targets.

Introduction

The rare earth elements, also known as rare earth metals, rare earth or REEs, are a group of 17 elements that comprise Sc, Y, and the Lanthanide Group.
REEs are critical for modern industry (especially for the high-tech, green and military technologies) due to their unique physical and chemical properties (Voncken, 2016).

Despite the fact that uranium and rare earth-thorium-uranium ores have been explored in Ukraine and in the world for some time, there are still ongoing debates/questions about their genesis and conditions of formation. That is why this study can generate new information and add to the overall knowledge and refinement of the formation (PTx) conditions of these rocks.

REE mineralization occurs as primary and secondary deposits and can be found in many different geological environments.

Alces Lake deposit is the REE pegmatite deposit where REEs occurre mainly in monazites which are associated with biotite-rich paragneisses. The deposit is located within the Beaverlodge Domain, about 28 km north of the Athabasca Basin margin. According to the latest channel samples and drill hole results total rare earth oxide concentrations exceed 20 wt% TREO in multiple zones with the maximum concentrations of up to 54 wt% TREO (http://www.appiaenergy.ca/).

In Ukraine most of the REE deposits and occurences alre located within the Ukrainian Shield with the Azov Block being one of the most promising areas.
The Yeliseyev field of differentiated REE pegmatites, associated with the Saltichan granite-gneiss dome was studied in this research. Several tens of pegmatitic veins with albitite and muscovite alterations are located along the periphery of the dome. REE minerals include: columbite-tantalite, samarskite, xenotime, monazite.

2D and 3D modeling is a great tool for visualization of different geological systems and allows us to better understand a given prospective mineralized area. It is very useful at every stage of exploration and helps us develop efficient geo-metallurgical delineation plans for future exploitation.

Geology

Alces Lake is located at the junction of the Beaverlodge, Train, Zemlak and Ena Domains in the Rae Province.
The Beaverlodge domain is dominated by rocks of the Maurice Bay Group (ca. 2.77 Ga), Archean supracrustal succession, known for its association of basal polymictic conglomerate, orthoquartzite, mafic volcanic rocks, minor carbonate and komatiitic rocks, dolostone, oxide and silicate facies iron formation, pelite and psammite to psammopelite. These rocks unconformably overlie and are strongly deformed with granitoid basement rocks of ca. 3.0 Ga.

Within the Beaverlodge Domain, the mineralization is closely associated spatially with the contact between Archean rocks and Paleoproterozoic supracrustal packages composed of quartzite, amphibolite, psammite, psammopelite, and pelite rocks of the Murmac Bay group.
Alces Lake property has one of the highest REE grades in the world and the highest ever reported grades in Canada (http://www.appiaenergy.ca/). The REEs within Alces Lake are hosted in monazites which are associated with biotite-rich paragneisses.

Within the Ukrainian Shield three granite intrusions are involved in the geological structure of the Precambrian rocks of Western Azov Region, which correspond to three phases of pegmatite formation, differing in terms of occurrence, structures and mineral composition. Of the three pegmatite formation phases mentioned above, only one resulted in the formation of mica-bearing pegmatites. This phase was the second one to intrude and is associated with biotite-orthite granites of the Saltychy Mogyla type. The magma of the second granite intrusion was highly enriched in volatiles and contained some amount

of rare elements concentrating in the pegmatites associated with this intrusion, as well as in the apical parts of the granite massifs. Among the many veins of the second granite intrusion, those that have undergone albitite metasomatism are the most enriched with rare elements.
REE pegmatites represent the most studied formation among REE deposits in the world.
The Balka Kruta deposit in the Western Azov Region, associated with the Sorokin Zone (line) of the northwestern extension, was studied in detail. Ore minerals are represented by columbite-tantalite, tsirtolite, monazite and xenotime.
Also, the Yeliseyev field of differentiated REE pegmatites, associated with the Saltichan granite-gneiss dome, was studied, as well as the Zelena Mogyla deposit with the 30–50 m zone of rare-metal-rare-earth mineralization localized in pegmatitic granits (Gursky et al., 2005, Mikhailov, 2010).

Modeling

The modeling was conducted using the SKUA-GOCAD, ArcGIS and Geosoft Oasiss montaj softwares. Different models were created at different scales in order to show the spatial relationship and correlation between the regional-, district-, and mine-scale 3D common earth models.

The structural framework of the regional-scale model was created based on gravity and magnetic worm data and topography data. As a result, major faults and basin boundaries were generated using the method of worm-data analysis (Figure 1). Multi-scale edges (worms) are a combination of horizontal derivatives and upward continuations. For each upward continuation level produced, the total horizontal derivative of the dataset is produced, and the points of maximum slope (which correlate roughly to geological boundaries) are calculated and connected to make a series of lines that can be used to interpret geological features. With the help of this tool shear zones and faults were delineated with their orientations at depth (https://publications.saskatchewan.ca/#/products/31724).

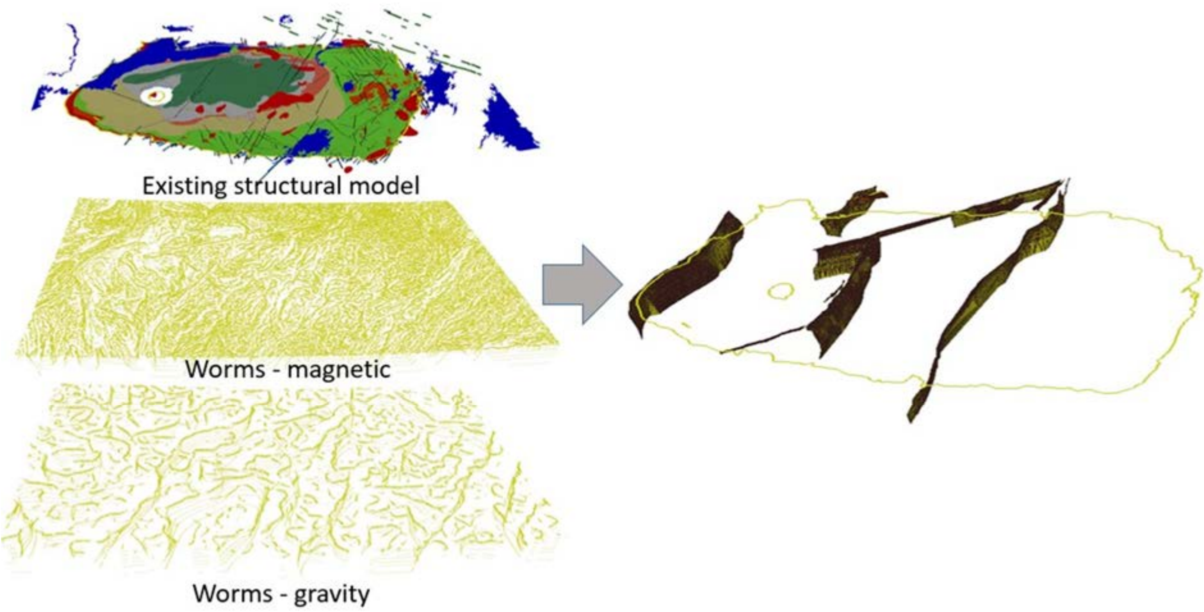

__Figure 1__ Workflow of the regional-scale modeling.

District-scale modeling was carried out on a smaller area, including mostly the Beaverlodge Domain.
To identify the locations of faults, shear zones and folds, topography data (DEM) as well as geophysical data (First vertical derivative (1VD) and Tilt derivative (TDR)) were used. During this stage of

modeling, the lineament analysis method was applied, which facilitates extraction of lineament features from the given data.

The analyses have shown that the 3 dominant trends are NNE, EW and NNW.
As a result, we obtained the locations of major structures within the Beaverlodge Domain on both district- and local scales (Figure 2).

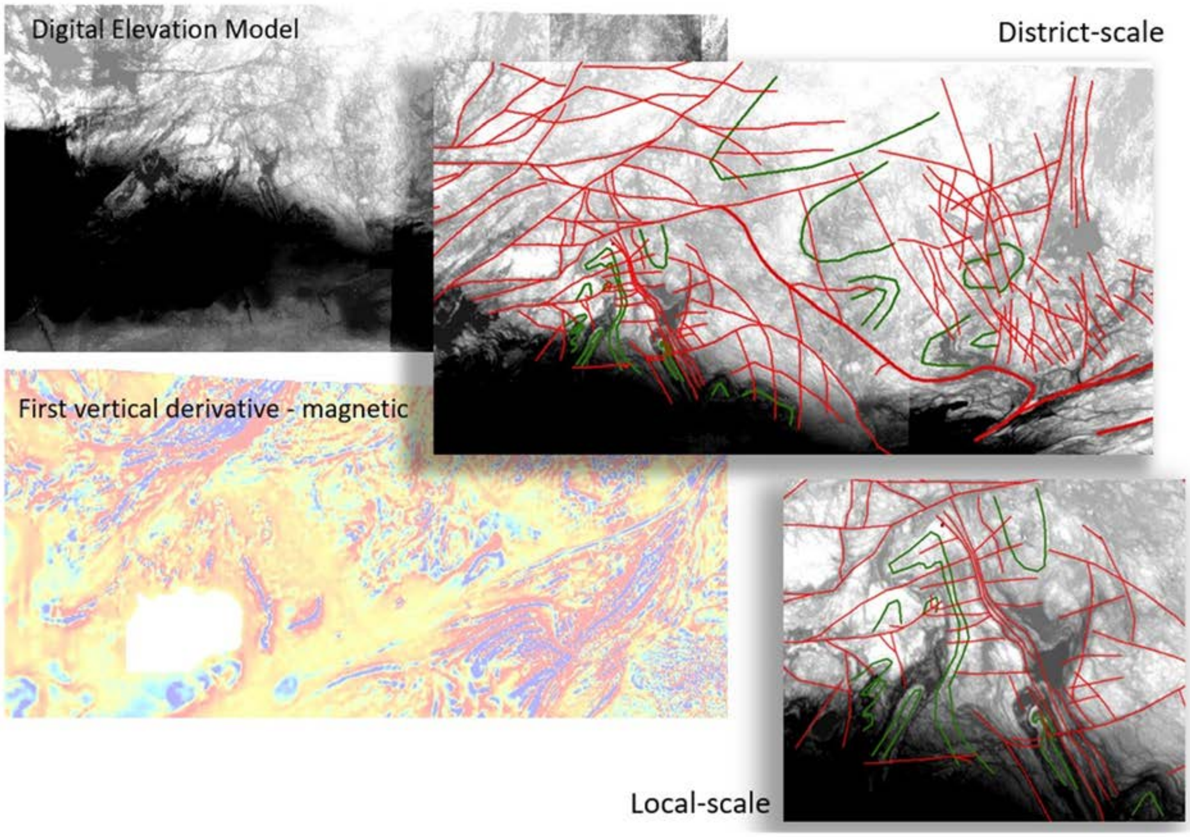

Figure 2*-Major structures shown on the district- and local-scale model.*

Geosoft Oasis montaj was used in this study to create a subsurface geological model. It was done using the GM-SYS Profile extention that helps calculate the gravity and magnetic response from a geological cross-section model.

Conclusions

In this study, an analysis of the geological structure of REE-Th-U deposits of the Ukrainian and Canadian Shields was conducted. 3D and 2D geological models were constructed based on the application of specialized software (i.e. SKUA-GOCAD, Geosoft Oasis Montaj, ArcGIS). As a result of the research, complex regional- to district- to deposit-scale models were created within the Ukrainian (West-Azov district) and the Canadian (Alces Lake, northern Athabasca Basin district) shields. Many different data sets were used for this multidisciplinary study, including drill hole core/down-hole data, geophysical data (magnetics/gravity/EM), whole-rock and mineral geochemical data, topographic data, assessment and technical reports, and geological maps, as well as legacy data from historical studies.

Several main structural controls for mineralization were distinguished based on the locations of shear zones, faults, and folds. Partucularly for the Alces Lake area several distinct trends in the distribution and orientation of structures were identified and then classified with the help of geophysical datasets at each scale of modeling; i.e., from the regional-scale to district-scale to local-scale to mine-scale models. Deliniating of these structural trends is extremely important and can contribute valuable information for characterization of geologic controls on mineralization. Those in turn can be used for future exploration, mine planning, and pre-mining activities.

3D geologic modeling may be helpful for understanding the structural controls of mineralization, so the importance of such method should not be underestimated. However, additional more detailed work must be conducted for the given study areas, as new geophysical and DDH results become available. This could improve the exploration targeting methods for new discoveries of high-tech metals.

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