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Structural lineament analysis of REE-Th-U deposits within the Ukrainian and Canadian Shield

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SUMMARY

Structural mapping, including lineament analysis, is an important geological tool used to identify the prevailing tectonic trends within a study area. Lineaments are straight to curvilinear landforms that are widely distributed across the Earth's surface and are closely related to underground concealed structures, such as faults, shear zones, and folds. In this study, lineament extraction was carried out using both manual visual identification and automatic extraction approach with the suitable software.

The results obtained are giving additional insight to the REE-Th-U mineral systems of the two Ukrainian and Canadian shield areas and providing vectoring guidelines for new discoveries.

Introduction

Structural analysis, including lineament analysis, is an important geological tool for identifying the prevailing tectonic trends within the area of study.

Lineaments are straight to curvilinear landforms that are widely distributed across the Earth's surface. They can be controlled by geological structures (lithological boundaries, faults, shear zones, folds, discontinuities, etc.) but also geomorphological or man-made features. The length, orientation, and density of lineaments reflect rock mass fracture patterns and can provide valuable information related to geological structures, tectonics, hazard assessment, and natural resource availability.

In this study, lineament extraction was carried out using both manual visual identification and automatic extraction approach with the suitable software. The identification of lineaments using the automatic technique is considered more efficient and much faster method than the manual one. However, automatically extracted lineaments tend to contain lineaments derived from other sources besides geological structures, such as railway, power, and fence lines (Radaideh et al., 2016).

One of the objectives of this study is to establish a suitable methodology for automatic/digital and manual lineament analysis of potential field geophysical data sets combined with the aerial photography data for further structural interpretation of two selected study areas – i.e., within the Canadian (Alces Lake area) and Ukrainian (West Azov area) Shields. Consequently, several methods were tested; results obtained from the manual and automated approaches were compared between each other and with the known geological structures.

Overall, the findings of the current study will aid to provide a better understanding of the geological evolution and structural controls of the mineralization in each area. Ultimately, it is anticipated this could help to improve the exploration targeting methods for new discoveries of high-tech metals.
As a result, this will let us identify/establish new exploration targeting tools for discovering the mineralization within abyssal granitic pegmatites from high-grade metamorphic terrains of Archean/Paleoproterozoic age.

Geological setting

Two study areas within high-grade gneiss terrains from separate Precambrian Shield were selected: 1) Alces Lake high-grade mineralization area of the Beaverlodge Domain (SK, Canada) and 2) the analogous West Azov Precambrian basement area in Ukraine. Both areas have comparable geology (i.e. rock types and structures) with extremely high potential for new REE and associated high-tech metal discoveries,

The Alces Lake area contains the highest-grade REE occurrences in Canada (http://www.appiaenergy.ca/). It is a part of a large regional refolded fold and forms the synformal anticline. The mineralization is located on the eastern limb, close to the hinge of a south-plunging, truncated open fold with the mineralized zones hosted by REE-rich abyssal pegmatites. The REEs are sited mainly in monazites within granitic to biotite-garnet-rich residual melt pegmatites, which are inferred to be associated spatially with regional fold, shear, and fault structures in deformed paragneiss and orthogneiss. A preliminary structural geophysical study has been conducted already by the principal researchers to identify the main structural controls of the mineralization within the Alces Lake area (Poliakovska et al., 2019, 2020).

The second area is located in the West Azov block of the eastern Ukrainian Shield. It is considered to be a promising target area for REE exploration. Deposits and occurrences of rare earth elements are associated with the formation of rare metal-rare earth granite pegmatites, confined to the Mesoarchean trough-like structures, but also with rare earth granites and rare earth metasomatites.

The most favourable conditions for localization of the REE mineralization are observed to occur within areas with intensively deformed and folded gneissic rocks, that is the structural-metallogenic zones.

Methodology

Within the current research, automated and manual extraction and geospatial analysis of lineaments and their tectonic interpretation were carried out for both selected areas (Figures 1, 2). Lineament analysis methodology helps to easily identify lineaments on different hierarchical levels. Consequently, this can significantly increase objectivity in understanding the geodynamic environment within areas of investigation (Zhantayev et al., 2017).

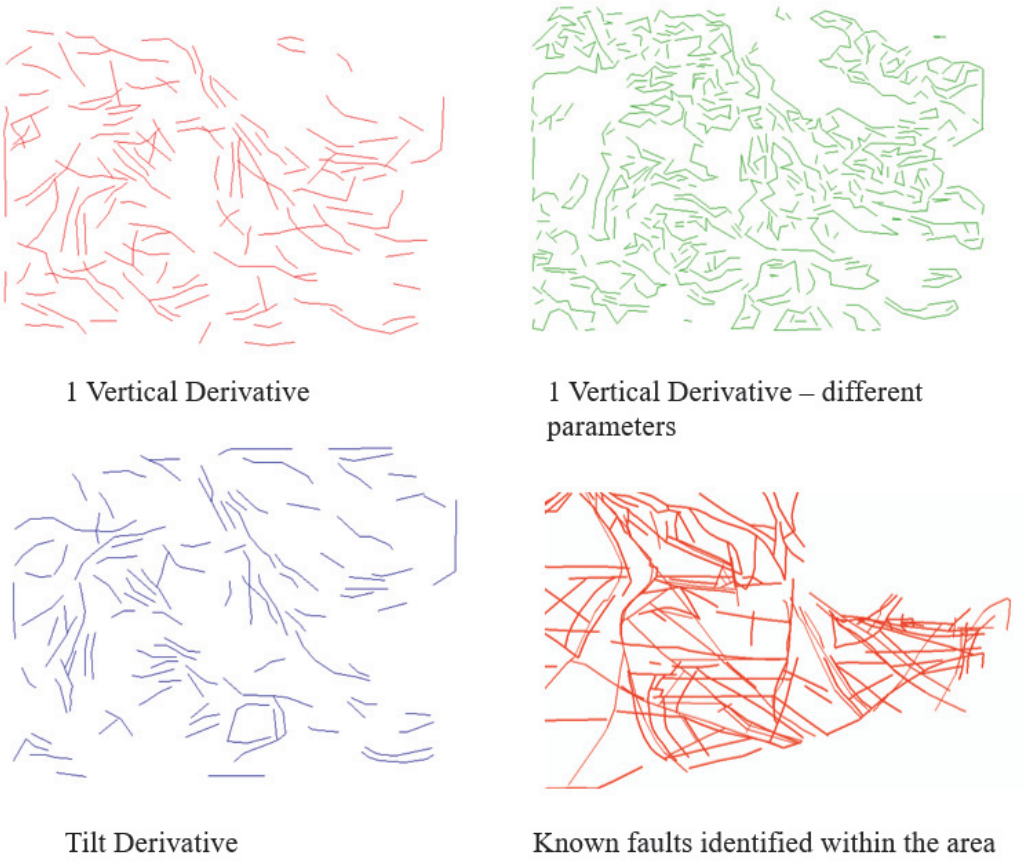

Figure 1 *Automatically created lineaments for the West Azov area (magnetic 1 Vertical Derivative, Tilt Derivative); scheme of known faults and shear zones within the area.*

Mainly two types of data are utilized to extract the lineaments in both manual and automated approaches – satellite images or aerial photographs and geophysical gravity and magnetic survey data. Several geomodeling software packages were used for the analysis: Geosoft Oasis Montaj, ArcGIS, and Geoscience ANALYST Pro. Remote sensing and GIS techniques were applied during the process of analysing and interpreting the geophysical and topography data.

The workflow used in this study is composed of four main steps:
1) The first step is the selection of the most suitable data for analysis, - e.g. SRTM/DEM/Landsat images, various geophysical data.
2) The second step is lineament extraction by using the manual and automated approaches and their further comparison. Several image processing and enhancement techniques were used, e.g. gradient edge detection filters in ArcGIS and MAGMAP tools in Geosoft Oasis Montaj software for processing the geophysical data.
3) The third step – comparing the final map with available geological and tectonic maps of the area.

4) The fourth step is the geospatial analysis, which includes density, direction, intersection length, and orientation analysis using the ArcGIS software tools.

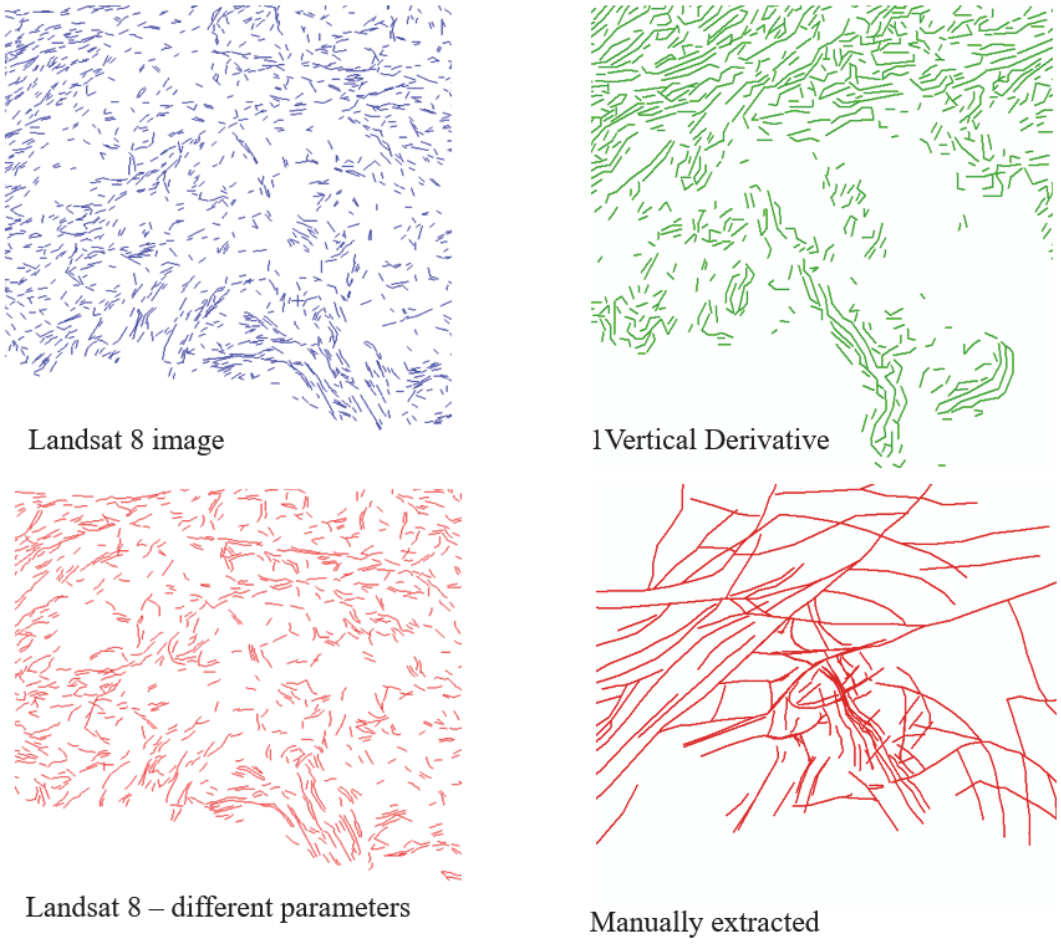

Figure 2 *Automatically extracted lineaments for the Alces Lake area (from magnetic 1 Vertical Derivative, Landsat 8 images); manually extracted lineaments*

Conclusions

In our current research, we conducted the preliminary lineament analysis of the two study areas utilizing using both topographic (SRTM, DEM) and geophysical data (derivatives of magnetic and gravity). The resultant manually created lineaments were compared to the automatically extracted ones and to the existing geological maps. The automatically extracted lineaments did not successfully identify all the geological structures within the areas of study. Thus, it is recommended by the authors to utilize the combined manual and automated approach to achieve the best results.

Obtained results indicate that the mineralization is related mainly to the following lineament features: 1) NNW-SSE (345) and E-W (060 - 080) - oriented structural elements within the Alces Lake area and 2) NW-SE, E-W and NNE - oriented structural elements within the West Azov area. This is giving additional insight to the REE-Th-U mineral systems of these two shield areas and providing vectoring guidelines for new discoveries.

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