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Heat maps of U-Th enrichments in open source coded geographical information systems (GIS); Arıklı (Çanakkale, Turkey) district

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ABSTRACT

Uranium (U) and Thorium (Th) are both strategically important elements in the world. For this reason, it is exceedingly significant to explore for these elements, which are enriched in many geological environments. U-Th enrichments in Turkey were usually discovered in the Western Anatolian geography. U-Th anomalies were still observed in the Arıklı region in the south of Çanakkale. Remote sensing (RS) and geographic information systems (GIS) are platforms for the map-based evaluation of geological structures. In this study, RS and GIS were utilized in the QGIS program to carry out the geochemical data obtained in the field more understandable. GIS and remote sensing methods have been widely used to analyse the formation, origins, and processes of geochemical characters in ore deposits. U-Th values, which show high values in the fault zones in the Arıklı region, are immediately related to the CaO values. As in many geological studies, remote sensing and GIS studies suggest the opportunity to check out field data with a significant quality in the exploration of ore deposits.

1. Introduction

Uranium and Thorium are significant and strategic radioactive elements. For this reason, applications are carried out to explore for these elements, which are enriched in many geological environments.

Granite and volcanic rocks are essential sources for Uranium enrichment (Zhang & Zhang 1991; Qin & Liu 1998). U deposits are divided into four groups corresponding to the host rock lithology (Li et al., 2002). These are granite-rock type (G-type), sandstone type, volcanic-rock type (V-type), and carbonaceous-silica-pelitic-rock type (CSP-type) respectively. It has been described that the important uranium enrichments in Turkey are situated in western Anatolia (Şaşmaz, 2008).

Uranium exploration activities in Turkey were started by MTA in 1953 and after that, exploration studies continued (Contencin, 1960; Günaydın, 2017). In the Ayvacık-Küçükkuyu field near Çanakkale province, the U_3O_8 value was 0.08% in Miocene carbonate rocks (MTA, 2009; MTA 2010). There are phosphate nodules and natural radiation sources in the volcanic tuffs between Küçükkuyu and Ayvacık (Atabey, 2006). On the Geyikli coast close to the region, there are minerals (taurite and uraninite) consisting of heavy metals, uranium and thorium in the sands (Andaç, 1971). The origin of these radioactive minerals is the granitic rocks outcropping around Geyikli (Andaç, 1971).

Günaydın (2017) explained that there is a U enrichment in the composition of bayleite and ningyoite in and around Arıklı. High natural radiation values were also reached in the fault zones around Örencik and Feyzullah Tepe, northwest of Arıklı (Atabey, 2006). Magnesite breccias located in the northwest of Arıklı are formed by the effect of hydrothermal waters and there are U up to 700 ppm and Th greater than 1000 ppm in this fault zone (Günaydın, 2017).

Öztürk et al. (2021) examined microthermometric measurements from magnesite observed in these fault zones and determined that (Th, ^{o}C) was between 282-348 ^{o}C and % NaCl salinity equivalents were between 4.2-8.0. They also set forth that the solution system of liquid inclusions is in the form of H_2O-$MgCl_2$-$CaCl_2$ and the density of liquids is between 0.58-0.74 g/cm^3.

Yalçın et al. (2022) evaluated the U-Th anomalies by using the remote sensing and GIS applications respectively. They stated that the geochemical components of the ore zone is changed with the effects of fault systems.

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In recent years, high resolution digital applications have been widely used in geological studies. Remote sensing (RS) and geographic information systems (GIS) are principles for map-based interpretation of many geological structures.

With scientific advances in spatial analysis techniques, linearity, ore exploration and morphological investigations have developed into approximately practical. Geographic Information Systems (GIS) have also been used in many mineral exploration studies and mine probability maps (Porwal et al., 2001; Joly et al. 2012; Lindsay et al., 2014).

Many GIS-based applications have been carried out in uranium exploration studies. On the principle of these, GIS-based modeling has been proposed in addition to geology-geochemistry studies (Brown et al., 2003; Partington, 2008).

Atakoğlu & Yalçın (2021) explained the statistical properties of Sutlegen (Antalya) bauxite according to their geochemical content and set up thematic maps with the Krigging interpolation method.

Yalçın et al. (2021) created thematic maps in the Geographical Information Systems (GIS) environment by using Adobe Illustrator 2020 program in order to reveal the spatial geochemical changes of Cu enrichment in the Kuzuluk (Sakarya, Turkey) region. From these maps, they interpreted that the Cu concentration increased as the fault zone was approached, and changed into altered zones as it moved away from the fault zones.

In another study, Ertürk & Yalçın (2022) were revealed petrogenetic interpretations or mapping studies in complex geological structures by the way of GIS applications.

In this study, the results of the analysis obtained in the study by Öztürk et al. (2021) were evaluated. Samples collected in the field, geological maps, satellite images and thematic maps were evaluated together. This study is based on Öztürk et al. (2021)'s spatial evaluation of geochemical analysis data. Because the results of these analyses were not evaluated in a GIS environment, no spatial geochemistry interpretations were made. This study presents an innovative approach to revaluating previously obtained geochemical modeling studies using satellite images.

2. Method

Geochemical data in a region can qualify as typical spatial data when associated with geographic coordinates in any program geographic information system (GIS).

Therefore, data analysis in geochemical studies requires consideration of both geographic locations and attributes. With the development of computer hardware and software along with technology, an increasing number of spatial analysis and statistical techniques have been integrated into GIS, which makes a great contribution to geochemical analysis studies (Fotheringham & Rogerson, 2013).

At the same time, with the development and application of spatial analysis techniques, problems related to geochemical mapping, mineral exploration and many geological problems can be solved (Overpeck et al., 2011; Reichman et al., 2011).

Remote sensing techniques are applied with multispectral (Landsat-8, ASTER, Sentinel-2, etc.) and hyperspectral (EO-1 Hyperion, AVIRIS, AVIRIS-) methods in mapping, morphological features, lithological separation, mineral exploration, mineralogy or hydrogeology in geological studies (Waldhoff et al., 2008; Rani et al., 2018; Chattoraj et al. 2020; Jain et al. 2021; Guha et al., 2021; Pandey & Purohit, 2022).

The DEM image of this geologically significant region has been downloaded from the United States Geological Survey (USGS) website. Aspect, 3D map and slope map of the region were created by evaluating the downloaded images in the QGIS environment.

In boost, the geological map prepared by Öztürk et al. (2021) was digitized in the GIS environment and sample points were located. Afterwards, heat maps dwelling of major oxide and trace elements were made.

2.1. Geological framework

The application area is in the south of the Biga peninsula in Western Anatolia. The application area situated in the Ayvacık district of Çanakkale is tectonically located in the Sakarya Zone (Figure1). Okay et al. (1990) described the units in Çanakkale region as pre-Tertiary and post-Tertiary units respectively. In their following studies, it was divided into three pre-Tertiary tectonic zones observed in NE-SW direction (Okay et al. 2001; Okay & Altıner, 2004). These zones are Ezine Zone, Ayvacık-Karabiga Zone and Sakarya Zone respectively.

There are many metamorphic facies along with magmatic, ophiolite, sedimentary and volcanic rock groups established in the north of Gulf of Edremit (Figure 1) (Okay & Satır 2000; Şengün et al., 2011). In the vicinity of Arıklı, the Miocene Pliocene aged continental sediments and Cretaceous aged Çetmi melange are outcrop (Figure 1).

The Cretaceous Aged Çetmi Ophiolitic Melange, Küçükkuyu Formation and Quaternary aged alluvial deposits are located in the study area. In the Küçükkuyu formation, shale-sandstone member, and Arıklı tuff member were separated and diabases that cut these units were mapped on the Örencik Tepe (Fig 2).

Öztürk et al. (2021) stated that there are U and Th anomalies in the NE-SW and NW-SE trending dip-slip fault zones (Fig 3) observed in the northwest of Arıklı. The highest U and Th values are found in the area of magnesite breccia (Fig 4) in the northwest of Arıklı. In the light of these data, it has been understood that the U and Th mineralizations in the region are related to the fault zones developed in the Arıklı ignimbrites, therefore the fault lineaments in this region are important.

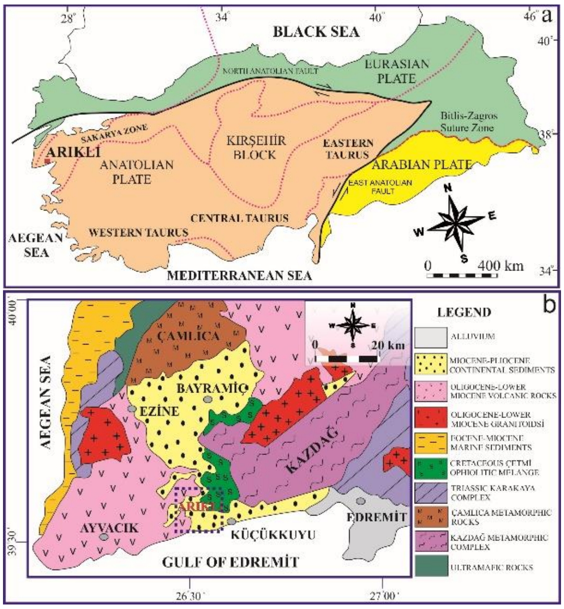

Figure 1. (a) Tectonic location of the study area (modified from Işık, 2016), (b) Generalized geology map of the Biga region and location of the study area (modified from Okay & Satır 2000; Şengün et al., 2011)

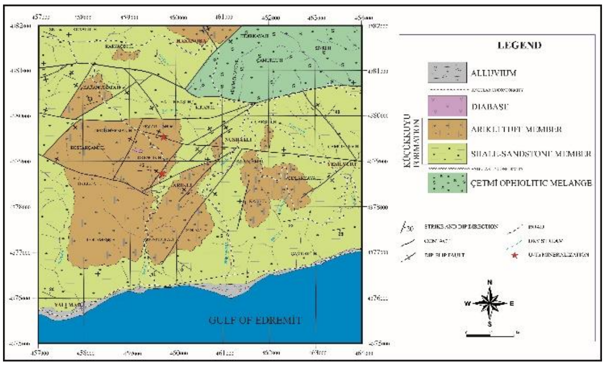

Figure 2. Geological map of the study area

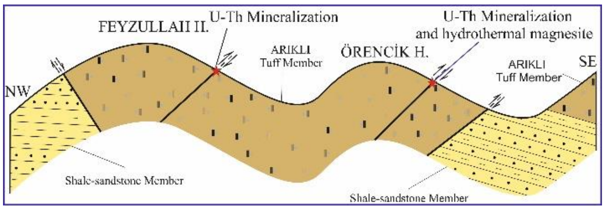

Figure 3. Geological cross-section of the study area

Figure 4. General view of hydrothermal magnesite in northwest of Arıklı

3. Results

3.1. Ore geochemistry

Öztürk et al. (2021) collected 48 samples in the field. These collected samples were analyzed by XRF and ICP-MS method in Istanbul Technical University Geochemistry Research Laboratory (ITU-JAL). Corresponding to the results of the analysis, U and Th anomalies are observed in the dip-slip fault zones. In these fault zones, U is between 64-1640 ppm and Th is between 302-11813 ppm respectively. As a result of these data, U and Th mineralizations in the region are related to fault zones observing in Arıklı ignimbrites.

3.2. Remote sensing

DEM data enables numerous geomorphic and morphometric analyses in geological studies, as well as timely and cost-effective production of consistent results (Grohmann et al., 2007).

Topographical approaches were obtained with the DEM image of Arıklı and its vicinity. The downloaded DEM images were evaluated in the QGIS environment, an open-source Geographical Information System.

The images of the region generally obtained by remote sensing were evaluated in the QGIS environment. DEM data was classified and coloured in the QGIS environment with a single band pseudocolour application. Then 3D map of the region was created to obtain a more understandable image (Figure 5).

3.3. GIS application

Sample points of major oxide and trace elements are yielded Figure 6. Heat maps were established corresponding to spatially major oxide and trace element values appropriately. CaO and U-Th enrichments are observed strongly in similar areas, and a direct ore-fault-and lithology relationship is observed. There are U-Th enrichments exclusively in CaO rich and faulted areas. This relationship still shows pretty useful in the GIS environment.

In order to obtain more detailed data, Sr, Na_2O and SO_3 values were also analyzed. While Sr gives anomalies in limited areas (Fig 7a), it reaches high values in Na_2O (Fig 7b) and SO3 (Fig 7c) fault zones.

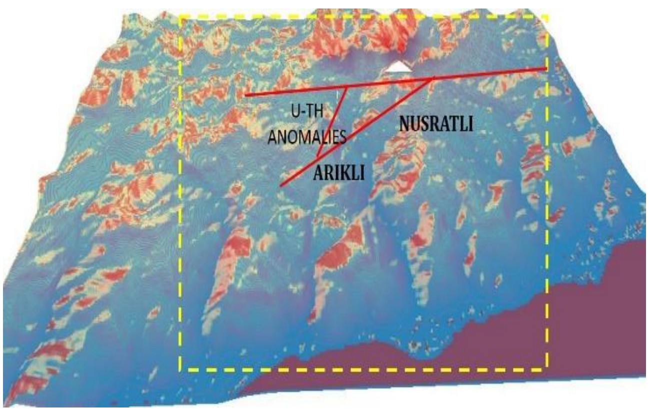

Figure 5. 3D-map of the study area and surroundings

4. Discussion and Conclusion

Mapping minerals, elements or oxides based on multi-source geoscience data (geology, geochemistry, and remote sensing) and computer technology is an effective technique that merges information and data-driven production (Bonham-Carter, 1994; Zhao 2002; Cheng et al., 2007; Asadi et al., 2016; Ford et al., 2016; Wang et al., 2016). For this reason, the data of the study conducted by Öztürk et al. (2021) in the Arıklı region were re-evaluated in the QGIS environment. Field data, remote sensing and GIS data were correlated. In the evaluations prepared, field and spatial data are consistent with each other and supported by thematic maps.

More detailed information can be obtained by making oxygen or carbon isotopes from barite and magnesite in the ore zone in the Arıklı region, which has the potential to be an important area. By making similar isotopes from host rocks, isotopic data from different locations can be evaluated in GIS environment. Thus, the original researches will be able to be interpreted in more detail. In addition, fault systems can be compared in the GIS environment by aging the fault zones. In summary, every detail information obtained in the field can be successfully evaluated in the GIS environment with spatial data.

In this study, DEM data, which is also used in many geological problems, and geological information were merged to perform spatial analysis in an area where geochemical prospecting had previously occurred. When the field, laboratory, and satellite images are analyzed together, it is clear that the U-Th enrichment in the field is enriched in the fault zones and has a characteristic distribution that is appropriate for its formation system. This method is particularly useful in geochemical prospecting and mineral exploration studies. Because fieldwork and subsequent studies can be more clearly analyzed in a GIS environment.

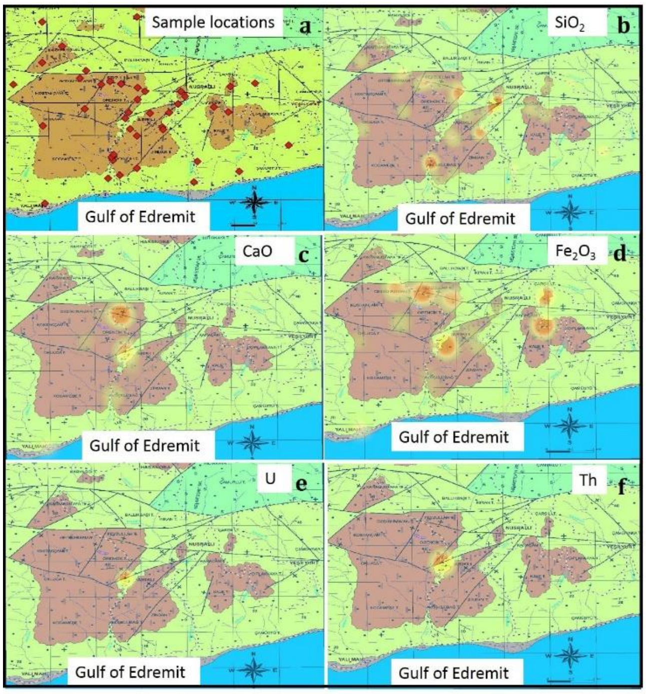

Figure 6. GIS applications of the study area

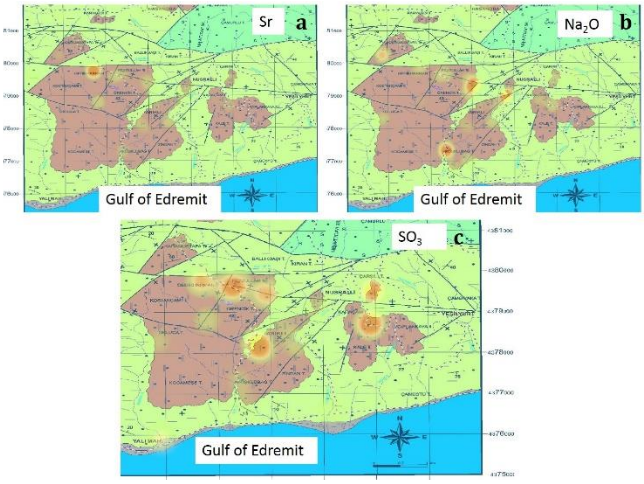

Figure 7. GIS applications of the study area

Author Contributions

The contributions of the authors of this article is equal.

Statement of Conflicts of Interest

There is no conflict of interest between the authors.

Statement of Research and Publication Ethics

Research and publication ethics were complied with in the study.

The study is an expanded version of the study presented at the 4th Intercontinental Geoinformation Days (IGD), "Evaluation of U-Th enrichments in QGIS platform Example of Arıklı (Çanakkale, Turkey) district".

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