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Multi-fractal Modelling of Gold Mineralization and Lineaments in 1:100,000 Chaapaan Sheet (NW IRAN)

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Abstract

In this research work, the fractal modeling of Au anomalies in the Chaapaan 1:100,000 sheet (NW Iran) is conducted through an investigation of the concentration-distance to lineament (C-DL) relationship. The classification of Au anomalies is based on their proximity to major lineaments. Stream sediment data is utilized to identify Au anomalies, and the C-DL model demonstrates a strong correlation between the main gold anomalies and their distance from remote sensing lineaments. The findings indicate that gold anomaly values exceeding 12 ppb are found within a distance of less than 1 km from the remote sensing lineaments, establishing a significant association between fault structures and mineralization. Moreover, the average distances to remote sensing lineaments are found to be less than 1.3 km, underscoring the suitability of the C-DL fractal modeling for identifying hydrothermal gold deposits.

1. Introduction

Hydrothermal deposits are the result of various processes including deformation, fault development, magmatism, fluid flow, and mineralization [1, 2, 3, 4]. The identification of mineral anomalies and their correlation with faults has been accomplished using stream sediment data and remote sensing mapping on a regional scale. Recent studies have introduced two spatial analysis approaches to investigate mineral evidence [5, 6].

Multi-fractal modeling in geo-chemistry primarily focuses on the relationship between element concentration and features such as area and perimeter of the region from which geo-chemical values are derived. This is of great importance in geological exploration, particularly for metallic deposits. Various approaches have been employed for multifractal modeling [6, 7], and several models based on fractal geometry [8] have been suggested for geochemical exploration [9, 10].

The investigation of lineaments aims to identify the relationship between rock permeability based on fractures and mineralization. Tectonic processes show a high level of compatibility with diapirism and mineralization [11]. The researchers have explored the connection between fractures and mineralization in the Central Iran basin, as evidenced by studies conducted by [12, 13, 14, 15, 16]. The formation and development of fractures are influenced by active tectonics, which has been investigated in various areas by [17, 18, 19, 20, 21, 22, 23, 24].

This study introduces a novel fractal approach called "concentration-distance from remote sensing lineament" (C-DL), which is proposed to detect Au geochemical anomalies. Its effectiveness is compared with the gold index in the 1:100,000 Chaapaan sheet in Northwest Iran.

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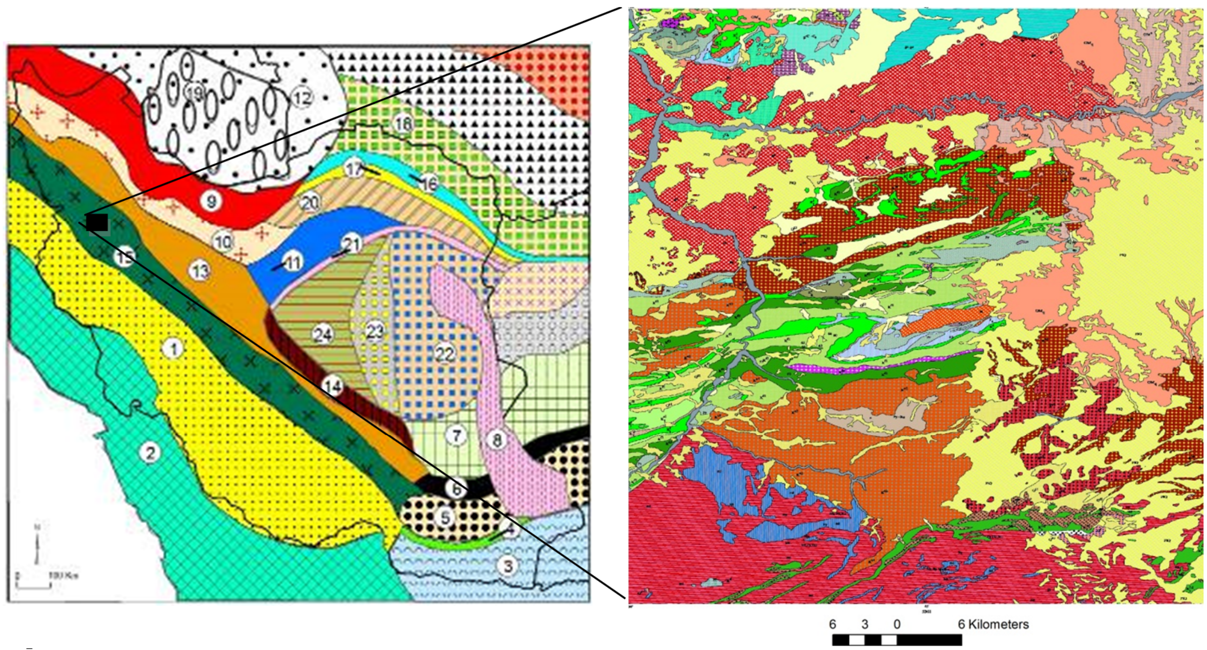
2. Regional Geology of Chaapaan 1:100,000 Sheet

The Chaapaan sheet is a semi-mountainous area on the Sanandag-Sirjan Overthrust belt. The Sanandaj - Sirjan physiographic province with NW-SE striking (Figure 1) contains thrust faults formed by metamorphic rocks of the southwestern margin of the Cimmerian plate [25]. The magmatic belt, according to the geological sequence, was formed within intercontinental shallow basins, and exhibits three primary outcrop distributions in Takab, Qorveh, and Delijan. The sedimentation in these basins commenced during the Oligocene period with the deposition of detrital deposits known as the Lower Red Formation (LRF). The LRF comprises basal conglomerate, sandstone, and marl, overlying older units unconformably. In Takab, the older units are of Neoproterozoic age, while in Qorveh-Delijan, they are of Triassic-Jurassic age, owing to varying levels of upwelling in these localities.

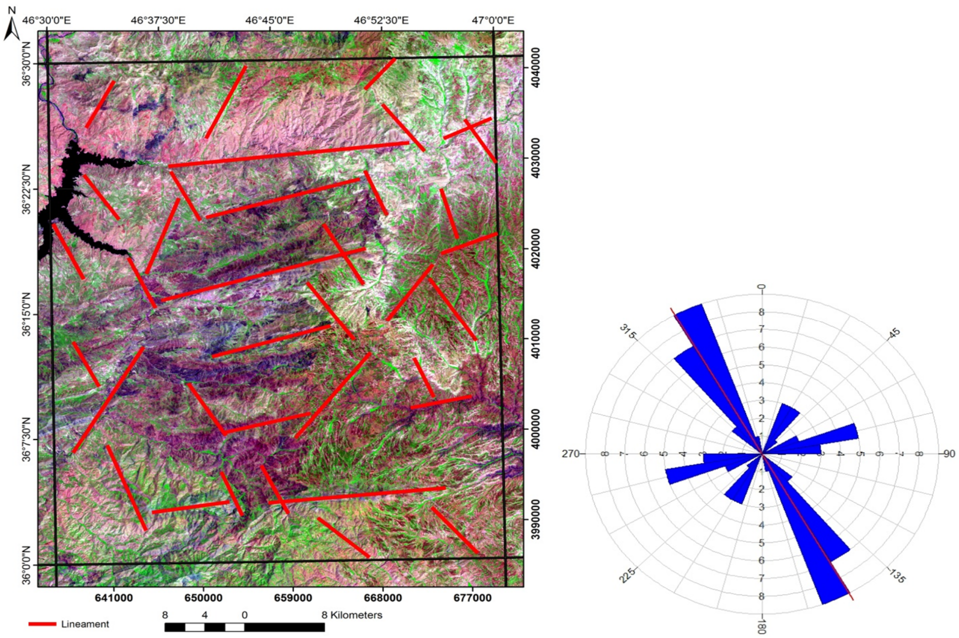
Results conducted in the Takab area confirm the synchronous formation of the LRF with the upwelling process, as fragments of crystalline basement rocks were found within the LRF. The Oligocene magmatism in this region is not extensively exposed and is primarily confined to structural zones and thrust faults resulting from juxtaposition and exhumation. Previous studies, along with the findings from fieldwork, indicate that this Oligocene magmatism does not exhibit the potential for gold mineralization in the area.



(a) (b)

Figure 1. a) Generalized geology map of Iran, modified from [25]. The study area is shown in the square box at the Sanandaj-Sirjan overthrusted belt (No.15). b) Geological map of studied area based on 1:100,000 geological map of Chaapaan, modified from [26].

There are Mesozoic and Cenozoic metamorphic rocks that cropped out by uplifting along the main thrusts [27]. Also remote sensing lineaments of the studied area and their rose diagram are shown in Figure 2. Chapaan area, as well as other mineralization occurrences in this sheet, have been surrounded by a regional deformed and metamorphic continental sedimentary sequence of Mesozoic, which has been intruded by Paleocene I-type, calc-alkaline, metaluminous to slightly peraluminous, felsic intrusions of ilmenite-series affinity. The gold mineralization in the Sanandaj-Sirjan Zone is related to the deep-level hydrothermal activity (mesothermal), which is different from porphyry (Sar-Cheshmeh, Meiduk, Sungun) and epithermal (Touzlar, Chah-Zard, Bazman) systems of the Uromeih Dokhtar Magmatic/Volcanic Arc.



(a) (b)

Figure 2. a) Lineament mao of study area. b) Rose diagram of lineament

3. Materials and Methods

3.1. Number-size fractal method

The model for distinctive major mineralization with primary from secondary geochemical halos using the geo-chemical zonality index of various ore descriptive models proposed by [28] . Primary haloes of ore deposits are found by an interaction among host rocks and ore fluids recognized by the variation of elemental values. Therefore, the geo-chemical zonality index can be an appropriate implement for geochemical exploration and classification of mineralization stages. This index contains of a ratio between supra- and sub-ore halo elements in dissimilar mineral deposits.

This method that it has introduced by [8] can be used to spatial separation of geo-chemical changes. There is a relationship between the cumulative number of samples and ore elements.

3.2. Concentration - distance to remote sensing lineament

The fractal model of concentration-distance to remote sensing lineaments (C-DL) is used in this research work. This fractal model has the below formula:

$DL(\geq\rho) = F\rho\text{-}D$

$DL(\geq\rho)$ indicates the cumulative distance from remote sensing lineaments, and ρ shows element concentration. D is the scaling exponent, and F is a constant [18].

4. Results and Discussion

Stream sediment geo-chemistry is an effective method for identifying potentially mineralized regions. The silt fraction of alluvial sediments represents the geo-chemistry of the drainage pattern [29]. Base metals tend to be enriched in the fine sand fractions found on the stream bed. Concentrations in coarser size fractions exhibit greater variability, both spatially and temporally, depending on local hydraulic conditions. Therefore, the finer fractions provide a more reliable representation of the drainage basin's geochemistry and help reduce sampling uncertainties [30]. Miocene tectono-magmatic events caused gold/poly-metal mineralizations in the Takab-Delijan belt [31], and fractal modelings are very useful in such situations [32, 33, 34, 35, 36, 37].The collected samples were analyzed, and a logarithmic plot was prepared (Figure 3). Breaking points between straight-line segments in the plot were used to identify threshold values that separate different sets of samples. This logarithmic plot clearly separates distinct groups with high Au anomalies. Four such groups were identified.

For the interpolation of gold values, grid cells of 180 × 180 m^2 were utilized. The interpolation method employed was the inverse squared distance, which helps mitigate unwanted smoothing effects associated with Kriging. The areas with high Au values were primarily located in the eastern margins of the Chaapaan sheet (Figure 3). The terms "extreme" and "high" were used to describe the values of Au anomalies based on stream-sediment data.

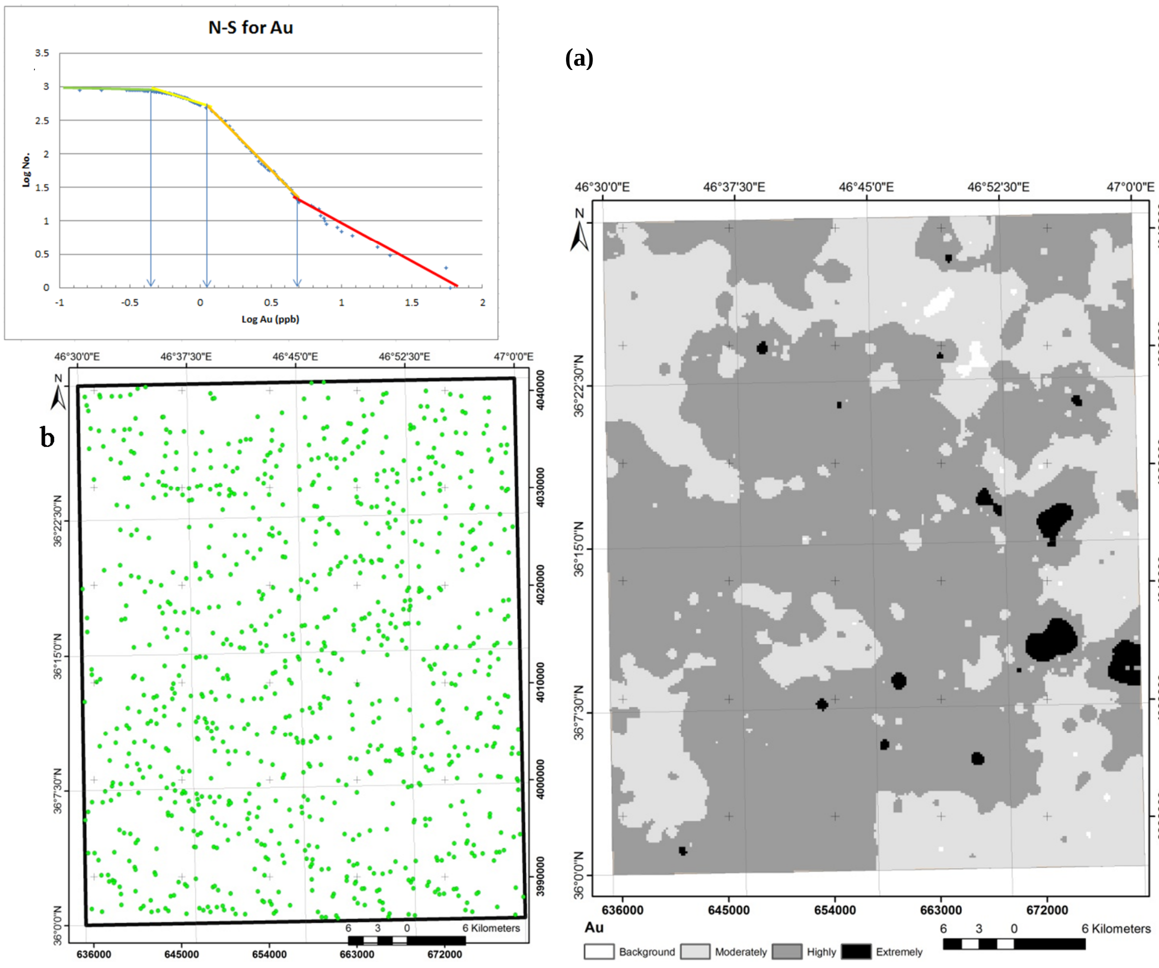
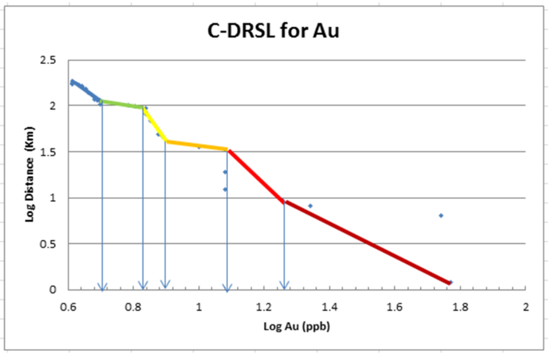


Figure 3. a) Logarithmic plot of N-S model for Au sream sediment data. b) Sream sediment location map of the chaapaan sheet. c) Au stream sediment population distribution map based on the N-S fractal model.

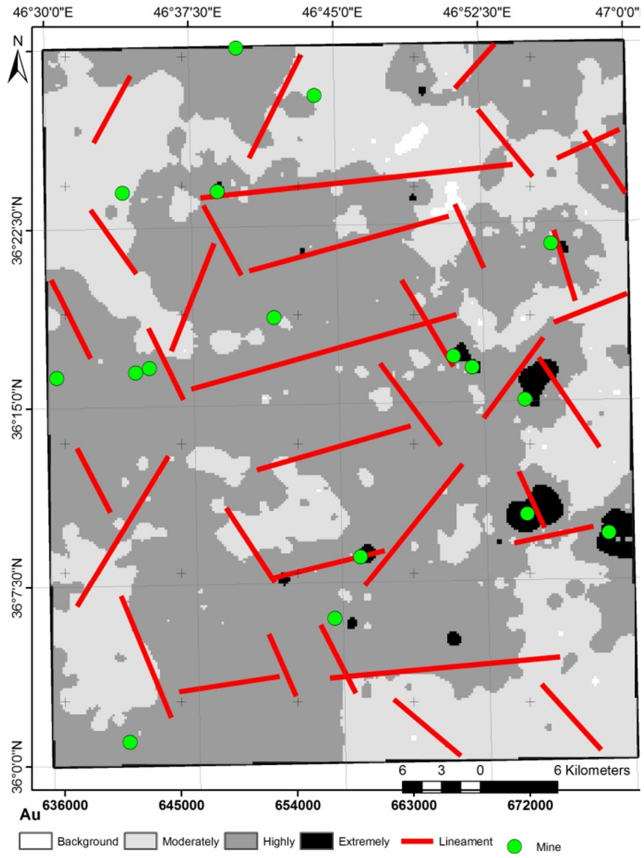
Table 1 displays five distinct geo-chemical groups identified for extreme Au anomalies, utilizing C-DL fractal modeling in the Chaapaan 1:100,000 sheet. Figure 4 illustrates the presence of two significant phases of Au mineralization. The anomalies are predominantly situated within distances of less than 1 km from remote sensing lineaments.

Table 1. Geo-chemical anomalous areas and their distances to lineaments.

Au (ppb)	Distance to lineaments (km)
Au < 5	3.3
5 - 7.1	2.1
7.1 - 8	2.1
8 _ 12	1.9
Au > 12	1



(a)



(b)

Figure 4. a) Logarithmic plot from C-DL. b) Distribution map of Au anomalies and mines.

Hence, a correlation exists between higher grades of gold anomalies and a decrease in the distance between remote sensing lineaments. Furthermore, gold mines exhibit an average distance of less than 1.3 km from the remote sensing lineament. The obtained data from these studies was compared with the existing gold indices in the region. This comparison validates the methodology employed in the study, suggesting that it could serve as a suitable model for future exploration in areas lacking reported gold indices. By evaluating the proposed method, it has the potential to yield promising results.

5. Conclusions

The classification of Au anomalies in the Chaapaan 1:100,000 sheet (NW Iran) was conducted by employing a fractal modeling approach based on their proximity to major lineaments. Stream sediment data was utilized to identify Au anomalies, and the compatibility between the primary gold anomalies and their distance from remote sensing lineaments was confirmed using the C-DL model. The findings indicate that gold anomaly values exceeding 12 ppb are typically found within a distance of less than 1 km from the remote sensing lineaments.As a result, the identification of remote sensing lineaments holds great significance in the reconnaissance for hydrothermal gold mineralization in the Chaapaan 1:100,000 sheet.

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مدل‌سازی مولتی فرکتالی کانه‌زایی طلا و خطواره‌ها در برگه 1:100000 چاپان (شمال غربی ایران)

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چکیده:

در این پژوهش، مدل‌سازی فراکتالی ناهنجاری‌های طلا در برگه 1:100000 چاپان (شمال غرب ایران) با بررسی رابطه عیار-فاصله تا خطواره(C-DL) انجام شده است. طبقه بندی ناهنجاری‌های طلا بر اساس نزدیکی آنها به خطواره‌های اصلی است. از داده‌های آبراهه ای برای شناسایی ناهنجاری‌های طلا استفاده شد و مدل C-DL ، یک همبستگی خوبی را بین ناهنجاری‌های اصلی طلا و فاصله آنها از خطواره‌های شناسایی شده توسط سنجش از دور نشان داد. یافته‌ها نشان می‌دهد که مقادیر ناهنجاری طلای بیش از 12 ppb در فاصله کمتر از 1 کیلومتری خطواره‌های شناسایی شده توسط سنجش از دور یافت می‌شوند که ارتباط معنی‌داری را بین ساختارهای گسلی و کانی‌سازی نمایان می‌سازد. افزون بر این، میانگین فاصله تا خطواره‌ها کمتر از 1,3 کیلومتر است که بر مناسب بودن مدل‌سازی فراکتالی C-DL برای شناسایی ذخایر طلای گرمابی تأکید می‌کند.

کلمات کلیدی: مولتی فراکتال، ناهنجاری های طلا، خطواره، چاپان، ایران.