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Regression Analysis and Correlation of REE Contents of Malatya Fluorites

Malatya Floritlerinin NTE İçeriklerinin Regresyon Analizi ve Korelasyonu

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ABSTRACT

Geostatistics examinations have developed into a significant technique to point out the genesis, formation type and interpretation of many ore deposits. Many researchers have noted the relationship between the statistical approach and fluorite-Rare Earth Element (REE). Malatya, in the Eastern Taurus Orogenic belt, leads fluorite mineralization on two specific localities. It is recognized that these two extraordinary mineralizations have special characters related to each other. These changes are because of formation type, mineral color, host rock and geochemistry. The exceedingly significant difference is the amount of REE they have. REE compositions of Kuluncak fluorites are richer than Yeşilyurt fluorites. The aim of this study is to figure out the correlation between the fluorite deposits which call REE contents in Malatya region statistically. When the geochemical characteristics of the fluorites are taken into comparison, the Kuluncak has 15.03-25.42% and Yeşilyurt region includes 12.2-35.8%. When the arithmetic means of REE values are considered, Ce permits a maximum value of 244.91 and Lu has a minimal value of 0.245 in Kuluncak and Ce includes a maximum value of 6.33 and Lu has a minimal value of 0.064 in Yeşilyurt, subsequently. Regression analysis shows that the% F values are precisely linked to REE amounts in both Yesilyurt and Kuluncak regions.

Key Words: REE, Correlation, Statistically, Fluorite

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ÖZ

Jeoistatistik çalışmaları birçok maden yatağının köken, oluşum tipi ve karakterizasyonunu açıklamada önemli bir metod haline gelmiştir. Birçok araştırmacı istatsitiksel yaklaşım ile florit-Nadir Toprak Element (NTE) arasındaki ilişkiyi ortaya koymuştur. Doğu Toros Orojenik kuşağında yer alan Malatya'da iki farklı bölgede florit cevherleşmesi bulunmaktadır. Bu iki farklı cevherleşmenin de birbirlerine göre farklı karakter içerdikleri bilinmektedir. Bu farklılıklar oluşum tipi, mineral rengi, yan kayaç ve jeokimyasından kaynaklanır. En önemli farklılık ise içerdikleri NTE miktarlarıdır. Kuluncak floritlerinin NTE içerikleri Yeşilyurt floritlerinden daha zengindir. Bu çalışmanın amacı, Malatya yöresinde NTE içeriğine sahip florit yatakları arasındaki ilişkiyi istatistiksel olarak anlamaktır. Floritlerin jeokimyasal özellikleri karşılaştırıldığında, Kuluncak %15.03-25.42 ve Yeşilyurt bölgesi %12.2-35.8'dir. NTE değerlerinin aritmetik ortalamaları incelendiğinde Kuluncak'ta sırasıyla Ce 244.91 ile maksimum, Lu minimum 0.245, Yeşilyurt'ta Ce maksimum 6.33 ve Lu minimum 0.064 değere sahiptir. Regresyon analizi, % F değerlerinin hem Yeşilyurt hem de Kuluncak bölgelerinde NTE miktarları ile doğrudan ilişkili olduğunu göstermektedir.

Anahtar Kelimeler: *NTE, korelasyon, İstatistik, Florit*

INTRODUCTION

Fluorite, which is formed as a gangue or ore mineral in many mineral deposits, is one of the minerals with the most diverse color range. REE, are an important indicator in geological studies, reflect ore origin and crystallization conditions just like fluorite deposits.

The rare earth elements (REE)-fluorite relation benefits the formation of mineral deposits (Samson et al., 2004). The REE concentrations correlated with fluorite and the origin and formation type of fluorite are extremely significant for geochemical studies (Bau and Dulski, 1995; Grammaccioli et al., 1999; Irber et al., 1996, Möller et al., 1976; Möller et al., 1994; Schwinn and Markl, 2005; Kolonin and Shironosova, 2007). REE having fluorite was early outlined in the granite complex by Gahn and Berzelius in Sweden in 1814 (Pekov et al., 2009). In following studies, the fluorite-REE relation was checked out as an approach to solve many geochemical questions.

Models are established for prognosis and uncertainty situations with geostatistical techniques. Statistical models based on random function or variable the ory are involved in these models (Shaltami et al., 2021). Although geostatistics methods have been practiced frequently in reserve calculations from recent to present, they are still put for ore formation type and origin newly. Successful analyzes have been carried out with these applications, which are based on representing the relations of the geological structures (ore, fault, anomaly, etc.) examined with geostatistical methods. For example, Saein and Afzal (2017), as a result of the geostatistical analysis of the data gathered in the Kerman Magmatic Belt in Iran, declared that the Mo concentration is associated with faults. Lindagato et al., (2018) set up a correlation of NE-SW trending Au–As–Hg anomalies with faults related to Au mineralization by kriging and interpolation. For this reason, correlation and geostatistical analysis according to the results of geochemical analysis obtained from the field are one of the essential approach methods in problem solving.

Many researchers have been studied REE related to fluorite in Malatya region (Özgenç and Kibici, 1994; Revan and Genç, 2003; Altuncu, 2009; Öztürk et al., 2019; Uras et al., 2019). Altuncu (2009) stated that the Yeşilyurt fluorites are poor but Kuluncak fluorites are rich in terms of REE. Uras et al (2019) stated that Yeşilyurt and Kuluncak fluorites differ from each other in terms of formation and geochemical features.

Looking at the Tb/La and Tb/Ca ratios diagram (Schneider et al. 1975, Möller et al. 1976; Möller and Morteani, 1983) the Yeşilyurt fluorites fall in the hydrothermal origin field and Kuluncak in the pegmatitic origin field (Uras et al., 2019).

The aim of this study is to explain and reveal the basic relationships between the% F and REE values of 10 samples both in two regions belonging to Malatya fluorites in regression and statistic.

METHOD

The study area is located in the Eastern Taurus Orogenic Belt (Figure 1). There are fluorite mineralizations in Yeşilyurt and Kuluncak regions of Malatya. The Yeşilyurt fluorites were formed along the discordance plane between the Devonian-Carboniferous aged Kalecik

marbles and the Permian aged Düzağaç schists and the Kuluncak fluorites are related to the syenite-limestone contact (Uras et al., 2019). REE analysis results of fluorite formations in these two regions, which have specific mineral color and REE characters, are given in Tables 1 and 2 and their statistical analyses are carried out.

Fluorite samples were classified separately as pure fluorite and separated fluorite respectively both Yeşilyurt and Kızılcık region (Öncel, 2018; Paksoy, 2108; Uras et al., 2019). The selected crystals were ground in agate mortar, packed in 5 grams. 20 samples (Both Yeşilyurt and Kuluncak flourites) were sent to Acme Laboratories (Vancouver-Canada) for rare earth element analyzes were made by LIBO2 fusion with ICP-MS method.

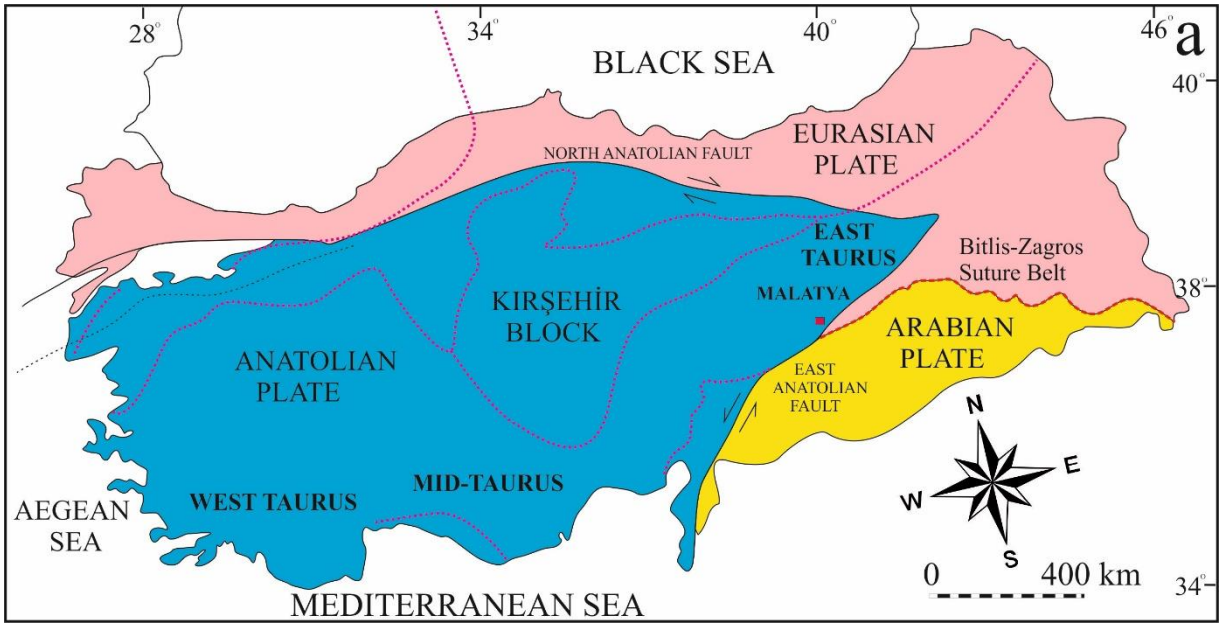

Figure 1. Tectonic location of the study area (Modified from Işık, 2016).

Şekil 1. İnceleme alanının tektonik konumu (Işık, 2016'dan değiştirilmiştir).

Statistical Analysis

The average F% of Yeşilyurt fluorites with F% values between 12.2-35.8 is 19.57. REE contents of fluorites vary between 6.33 and 0.64 ppm in average and there is 369.64 ppm ΣREE in total. When the arithmetic mean of REE are examined, Ce has a maximum value with 20,65 and Lu has a minimum value with 0.064 (Paksoy, 2018; Uras et al., 2019).

Table 1. % F and REE analyzes of Yeşilyurt fluorites (from Paksoy, 2018).

Çizelge 1. Yeşilyurt floritlerinin % F ve NTE analizleri (Paksoy, 2018'den alınmıştır).

SAMPLE	YF-1	YF-2	YF-3	YF-4	YF-5	YF-6	YF-7	YF-8	YF-9	YF-10
F%	21.69	12.2	13.05	14.09	18.8	35.8	20.00	19.88	20.5	19.78
La (ppm)	3.4	5.1	4.6	4.2	4.9	5.3	2.8	2.6	3.7	2.3
Ce (ppm)	6.0	8.2	6.0	7.0	7.5	5.1	5.3	6.4	5.6	6.2
Pr (ppm)	0.97	1.12	0.91	0.82	1.09	0.84	0.85	0.90	0.90	0.84
Nd (ppm)	4.6	4.5	3.8	3.4	3.2	3.9	4.3	4.3	4.3	3.2
Sm (ppm)	1.26	0.84	0.72	0.82	0.71	1.11	1.11	1.29	1.06	1.27
Eu (ppm)	0.32	0.18	0.14	0.12	0.14	0.24	0.27	0.34	0.31	0.31
Gd (ppm)	1.85	0.90	0.75	0.82	0.78	1.44	1.64	1.74	1.53	1.58
Tb (ppm)	0.32	0.15	0.12	0.11	0.12	0.24	0.28	0.33	0.27	0.31
Dy (ppm)	2.02	0.91	0.79	0.64	0.74	1.47	1.60	2.16	1.69	2.12
Ho (ppm)	0.40	0.20	0.18	0.14	0.18	0.21	0.39	0.44	0.38	0.41
Er (ppm)	1.07	0.59	0.38	0.28	0.45	0.71	0.99	1.16	0.95	1.15
Tm (ppm)	0.12	0.05	0.05	0.05	0.06	0.10	0.10	0.12	0.10	0.11
Yb (ppm)	0.66	0.32	0.24	0.34	0.31	0.49	0.58	0.62	0.61	0.59
Lu (ppm)	0.08	0.04	0.03	0.02	0.09	0.07	0.07	0.08	0.07	0.09
Y (ppm)	25.0	14.3	13.0	12.0	13.2	24.3	24.5	25.8	22.2	24.4
Ce\Yb	9.09	25.63	25.00	20.59	24.19	10.41	9.14	10.32	9.18	10.51
Tb \La	0.094	0.029	0.026	0.026	0.024	0.045	0.100	0.127	0.073	0.135
Tb\Ca*10^6	0.0000 00757	0.0000 00497	0.000000 395	0.0000 00371	0.000000 389	0.0000 00654	0.0000 00617	0.0000 00730	0.0000 00647	0.0000 00697
Ce\Ce*	0.8	0.8	0.7	0.9	0.8	0.6	0.8	1.0	0.8	1.1
Eu/Eu*	0.6	0.6	0.5	0.4	0.5	0.5	0.6	0.6	0.7	0.6
ΣREE	44.67	32.30	27.11	26.56	28.57	40.22	41.98	45.68	39.97	42.58

Table 2. % F and REE analyzes of Kuluncak fluorites (from Öncel, 2018).

Çizelge 2. Kuluncak floritlerinin % F ve NTE analizleri (Öncel, 2018'den alınmıştır).

SAMPLE	BF-1	BF-2	BF-3	BF-4	BF-5	BF-6	BF-7	BF-8	BF-9	BF-10
F%	19.33	25.2	25.39	17.1	15.03	17.34	19.37	25.42	18.25	19.86
La (ppm)	105.7	45.4	46.7	380.6	758.7	125.0	43.3	216.8	144.6	138.2
Ce (ppm)	157.6	53.1	56.0	463.7	789.5	178.4	80.9	255.6	203.2	211.1
Pr (ppm)	15.31	6.15	6.19	34.90	56.09	14.46	5.96	18.88	17.29	16.21
Nd (ppm)	46.5	19.8	20.5	91.1	142.6	39.4	17.6	54.1	53.0	50.1
Sm (ppm)	7.64	4.08	3.82	12.18	14.67	5.41	3.41	6.22	7.97	7.65
Eu (ppm)	1.62	0.94	0.89	2.30	2.67	1.28	0.71	1.13	1.54	1.25
Gd (ppm)	8.48	5.19	5.39	10.29	12.93	6.40	3.38	6.54	7.78	6.98
Tb (ppm)	1.41	0.87	0.87	1.68	2.06	1.12	0.64	0.92	1.12	1.09
Dy (ppm)	9.13	5.30	5.57	8.68	11.87	6.86	4.04	5.04	6.59	5.63
Ho (ppm)	1.94	1.24	1.34	1.90	2.65	1.95	0.90	1.31	1.55	1.35
Er (ppm)	5.10	3.42	3.64	5.43	7.30	5.38	3.36	3.84	3.79	3.52
Tm(ppm)	0.59	0.34	0.39	0.70	0.97	0.87	0.38	0.41	0.47	0.41
Yb (ppm)	2.80	1.39	1.63	3.15	5.29	3.98	2.42	2.85	2.81	2.62
Lu (ppm)	0.23	0.12	0.14	0.37	0.62	0.41	0.11	0.18	0.14	0.13
Y (ppm)	96.0	92.4	94.9	103.6	139.9	93.8	43.2	92.8	76.7	74.4
Ce\Yb	56.29	38.20	34.36	147.21	149.24	44.82	33.43	89.68	72.31	80.57
Tb \La	0.013	0.019	0.019	0.004	0.003	0.009	0.015	0.004	0.008	0.008
Tb\Ca*10^6	0.0000 00312	0.0000 01773	0.0000 01827	0.000003 886	0.0000 05058	0.0000 02453	0.000001 298	0.0000 01812	0.0000 02380	0.000002 448
Ce\Ce*	1.0	0.8	0.8	1.0	0.9	1.0	1.2	1.0	1.0	1.1
Eu/Eu*	0.61	0.62	0.60	0.62	0.59	0.66	0.64	0.54	0.59	0.52
ΣREE	354.35	194.34	201.27	739.98	1188.82	359.72	167.01	446.82	383.95	382.46

The average F% of Kuluncak fluorites with F% values between 15.03-25.42 is 20.22. REE contents of fluorites vary between 244.91 and 0.245 ppm in average and there is 1188.82ppm ΣREE in total. When the arithmetic mean of REE are examined, Ce has a maximum value with 244.91 and Lu has a minimum value with 0.245 (Öncel, 2018; Uras et al., 2019). % Fluorite and Rare Earth Element (REE) analysis values of 10 fluorite samples observed in the Yeşilyurt (Paksoy, 2018) and Kuluncak (Öncel, 2008) district were evaluated in regression analysis with using Microsoft Excel.

REE analysis results of fluorites were evaluated with the help of the Microsoft Excel. % F and REE were used for regression analysis. In the regression analysis, the standard error was 0, and it was determined that F% and REE results were directly related (Table 3 and 4).

Table 3. Regression analysis in Yeşilyurt fluorites.

Çizelge 3. Yeşilyurt floritlerinin regresyon analizi.

Regression Statistics					
Sample Number	**R**	**R square**	**Adjusted R Square**	**Std. Error of the Estimate**	
10	1	1	65535	0	
ANOVA					
	df	**SS**	**MS**	**F**	**Sig.**
Regression	14	396,54709	28,32479214	-	-
Residual	0	0	65535		
Total	14	396,54709			

Table 4. Regression analysis in Yeşilyurt fluorites.

Çizelge 4. Yeşilyurt floritlerinin regresyon analizi.

Regression Statistics					
Sample Number	**R**	**R square**	**Adjusted R Square**	**Std. Error of the Estimate**	
10	1	1	65535	0	
ANOVA					
	df	**SS**	**MS**	**F**	**Sig.**
Regression	14	129,05849	9,218463571	-	-
Residual	0	0	65535		
Total	14	129,05849			

RESULTS AND DISCUSSION

Yazıcı et al., (2021) established interpretations of the major and trace element contents prepared from marbles by applying the Pearson correlation coefficient. They still proved by regression analysis that CaO, which plays a significant role in the formation of marbles, has a strong negative correlation with SiO_2 and MgO. Atakoğlu and Yalçın (2021) explained the statistical properties of Sutlegen (Antalya) bauxite according to their REE content and set up thematic maps with the Krigging interpolation method.

This study reveals the REE chemical characteristics of Malatya fluorites located in the Eastern Taurus Orogenic belt. The REE contents of the Yeşilyurt fluorites present a poor content. Similar contents were observed in Feke fluorites (Uras, 2002), Büyükkızılcık fluorites (Uras and Çalışkan, 2014) and in Sarıveliler fluorites (Uras et al., 2019). But the REE contents of the Kuluncak fluorites present a rich content.

When the statistical results of F% and REE values of Malatya fluorites Yeşilyurt Fluorites are poor in terms of REE, when the arithmetic means of REE values are examined, Ce has a maximum value with 244.91 and Lu has a minimum value with 0.245 in Kuluncak and Ce has a maximum value with 6.33 and Lu has a minimum value with 0.064 in Yeşilyurt respectively. Regression analysis shows that the % F values are directly related to REE amounts in both Yeşilyurt and Kuluncak regions

Statistical approaches in terms of fluorite-REE relation will lead to subsequent studies. After the statistical evaluation of all geochemical analyzes, the fluorite-REE relations will be further acceptable with the creation of thematic maps.

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