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Zoning of Geologic Units and Magnetic Susceptibility Measurements of the Saraf Tepe Field, South of Trabzon, NE Turkey

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Absract: *Prepearing geolojical map on field by eye is very difficulty and using the rock chemical analysis in the laboratory is high cost, so researchers looked to find alternative mapping techniques. In this study, we have examined effectiveness of mapping zonation on an igneous body and arounding sedimantery rock units by magnetic susceptibility (MS). For this purpose we selected an area of 9 km^2 covered by sedimentaries rocks and basanite outcroped unit and located at the south of Trabzon city, NE Turkiye. Over forty samples were collected from the study area to be analyzed for both whole rock chemistry and MS. MS measurements have been used for zoning of geologic units and lithological classification. Lateral geochemical variations on the geological units were found out by counter plotting of Major Element Composition (MEC) abundance and MS values for the rock samples. Conclusively, based on the available but insufficient geochemical analyses of any intrusions, geochemical composition of other samples taken from the same rock body can be determined effectively by means of MS values. The geological boundaries around Sarraf Tepeare identification very well and practical by using field sensor of MS system. These results show that sedimentaries rocks and igneous body in this study area can be mapped by MS for petrological purposes supporting very few chemical data.*
Key Words: Magnetic Susceptibility (MS), Major Element Composition (MEC), Sarraf Tepe, Trabzon, Turkey.

INTRODUCTION

Mapping zonation on an igneous body and arounding sedimentary rocks is an important issue in the field of petrology. These processings help to show the boundaries of the rocks with differentiation of magmatic and sedimentary units. The classical methods for zonation mapping are to collect hand samples and determine rock mineralogy and geochemistry in the laboratory. After the development field and laboratory techniques, magnetic susceptibility (MS) measurements have used very spread area geophysics and geology. Although rock magnetism is very fairly recent branch of earth science, very important amount of researches that have been performed definite resolutions. The development of rock magnetism in last part of century has been occurred very interested studies. MS measurements of rocks in the earth magnetic field taking very practically are very important interpretation of magnetic field surveys. MS of any rock parts depend on grain size of magnetic mineral, deformation, strain, direction of particle, alteration and magnetic field.
In recent years more interests have been given to research on the fabrics of magnetic minerals (Ade-Hall et al., 1971; Chaddha ve Seehra, 1973). Magnetic measurements were used for mapping of amphibolite facies recrystallisation in basic daykes (Hageskov, 1984). Lots studies show that climatic shift, erosion and sedimentation, give rise to variations in the magnetic properties of sediments. These variations arise soil development (Olfield et. al., 1978, 1983) and sedimentological regimes (Thompson and Oldfield, 1986; Hirons and Thompson, 1986). Surface lineation was apparently employed to determine magma flow directions more recently by Gartner and Delaney (1985) and Bear and Reches (1987). Also another paper includes that MS measurements had been used for sediment stratigraphy, for bulk lithological classification and for detailed particle-size-based characterization (Yu L. et. al., 1990). The granodiorite's in the study area magnetic properties and geometry were defined by Aydın and Gelişli (1996). Explaining with chemical analysis on zoning of granodiyorite pluton using the measurements of field MS is shown by Aydın et. all. (1998). There is a study in invetigation area which includes very few samples'susceptibility measurements taken laboratory sensor for learning geological units'susceptibilities (Ergun, 1997).
The investigation area is located about 20 km at the south of Trabzon, NE Turkiye, where is named Çağlayan region covers an area of 9 km^2. Forty three samples collected from units in the study area were analyzed for Major Element Composition (MEA) compositions, and MS values were measured for the same samples. Samples used for this aim were chosen randomly in the field. Counter maps drawn for MS and MEA data by using the invers distance to power method using the Surfer 8.0 software.

Geochemical studies are very important since they help to solve many problems in geology. Thus, new method and techniques are needed to do fast, economic and sensitive measurements. In this study, relationships between MEA obtained from geochemical analyses and MS which is one of physical properties of rocks will be tried to find out. In this type of studies, it should be noted that rocks samples must be collected from the same rock unit in the field.
Geochemical analyses were carried out by RIX-1000 X-ray spectrometer system using powder pellets. MS measurements have been made on rock powder using 12 cc. cup of sample holder. Mass MS measurements were taken

by using MS2 Bartington susceptibility measurement system with $2x10^{-7}$ cgs sensitivity. Relationship between mass MS and MEA % were investigated. Counter maps of MS and MEA % were drawn by taken account the location of samples in the field.

MATERIALS AND METHODS

Geology and geochemical analyses of the Sarraftepe Geological Units

The study area is located at the south of Trabzon (Figure 1). Geological field study has been done in the study and surrounding areas (Ataoğlu, E., 1988). Geological units of the studied area which are represented by Cretesa aged consisting of agglomerate, basalt and limestone-marn. These rocks are overlain by the youngest unit is alluvium that is Quaternary aged. Forty three samples were collected from the Sarraftepe study area for whole-rock geochemical analyses. These samples were powdered to smaller than 200 mesh. The loss on ignition (LOI) was determined gravimetrically using a precision scale. Major and trace elements contents were determined using a RIX 1000 XRF with Rh tube at Karadeniz Technical University, Trabzon, Turkey.

The cost of geochemical analyses is the main motivation to develop newtools to investigate petrological and chemical variations within different rocks types. The spatial variations of MS can be measured rapidly and potentially could be used as a first order proxy for elemental or mineralogical variations. The purpose of this study is to test possible correlations between MS measured in low field and major element composition on the example of the Saraftepe Geological units of southern Trabzon, NE Turkey (Figure 1). A number of geological studies have already been conducted in this area and its surroundings.

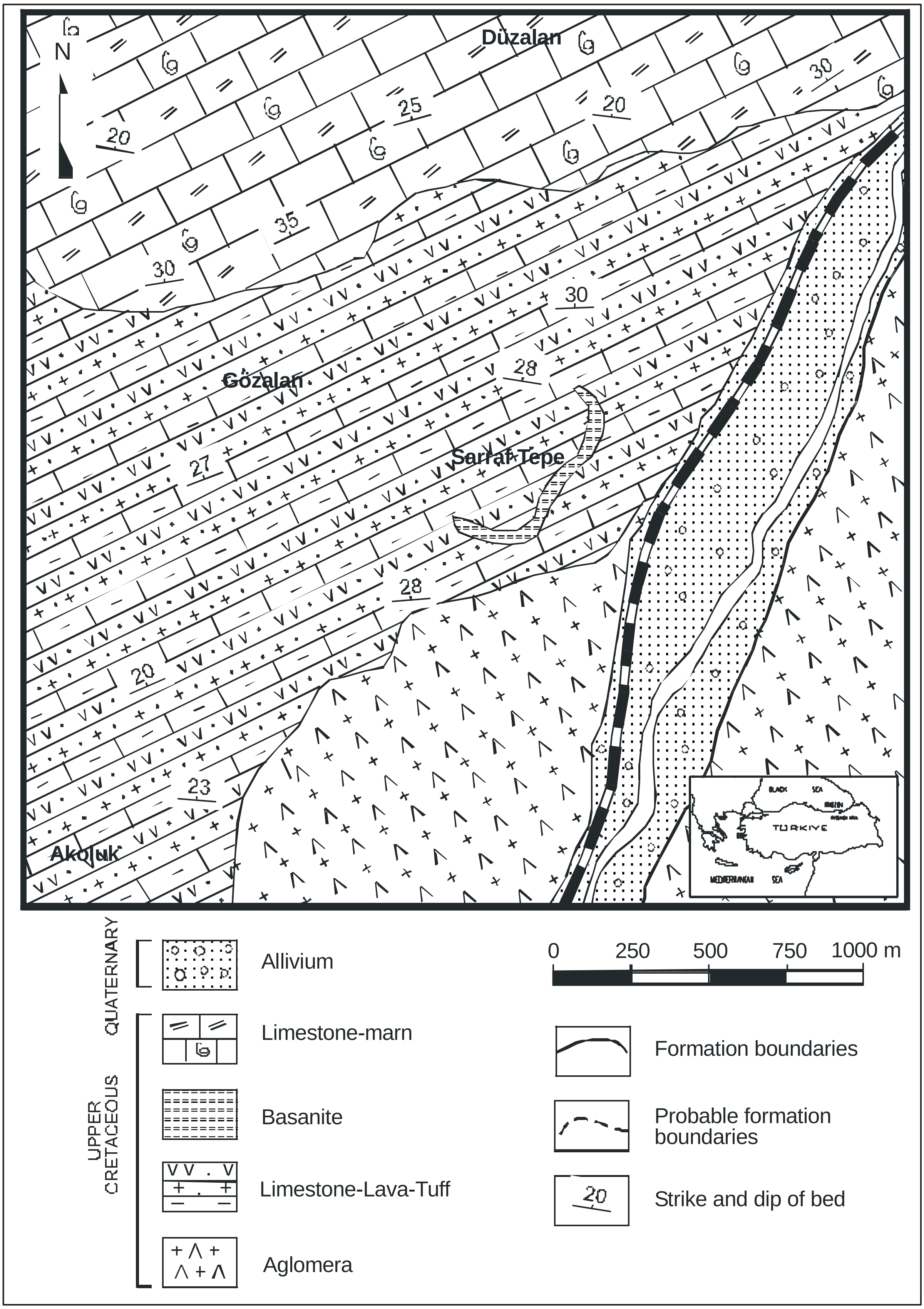


Figure 1. Geology and location maps of the study area (Ataoğlu, E., 1988)

Magnetic Measurements

The MS was measured both in the field and in the laboratory. The sensitivity for both field and laboratory measurements is equal or beter than 2×10^{-7} cgs.

Field magnetic measurements

Measurements were performed using the loop sensor (185 mm diameter) attached to a Bartington© MS2 system. The loop sensor is designed for rapid assessment of the concentration of ferromagnetic, paramagnetic or diamagnetic minerals in the top 100 mm (approximately) of the rock surface. Field measurements were performed at ambient temperature and a frequency of 0.958 kHz. Measurements, taken with a good contact between the loop and the ground, are provided in cgs units. The two or three readings systematically taken at each locality were averaged. Distange between measuring points change between 50-250 m in randomly directions. Localities were positioned using a portable Global Positionning System unit. Contouring and griding were performed using Surfer Mapping System and a grid of 50 m. Using the field MS sensor was taken 568 measurements in the study area and it was done the chemical analysis of 43 samples taken four geological units over an area of≈9 km^2. MS measurement localities and the counter anomaly map of taken these measurements are shown in Figure 2.

Laboratory magnetic measurements

A total of 43 rock specimens were collected in the field using a gas powered drill and subsequently measured using a Bartington MS2B dual frequency sensor, at 0.47 and 4700 kHz operating frequencies (at the Magnetic Laboratory of Geophysical Department, the Pamukkale Technical University, Denizli, Turkey). Laboratory measurements were performed at room temperature (21 °C) at 4.65 kHz frequency. Specimen localities are shown in Figure 2. Samples were cylinders, 25.4 mm in diameter and 22 mm height. Magnetic susceptibilities are given in cgs units.

RESULT AND DISCUSSION

Laboratory magnetic results

The MS, measured in low field (with the Bartington MS2 system, at 80 A/m) ranges from 3 to 1267×10^{-6} cgs, with an average at 292×10^{-6} cgs and a standard deviation of 368×10^{-6} cgs, major element chemical analysis is provided for the same specimens in Table 1.

Table 1. Low-field MS and geochemical data for the Sarraftepe rock units.

Specimens	**K** $x10^{-6}$ cgs	**SiO_2**	**Al_2O_3**	**Na_2O**	**Fe_2O_3+FeO**	**CaO**	**MgO**	**K_2O**	**TiO_2**	**MnO**
1a-1	1192	32.39	7.64	1.44	3.85	33.41	18.82	0.29	1.66	0.66
1a-2	1267	27.45	7.83	1.55	4.87	36.11	19.72	0.22	1.97	0.74
1a-3	900	36.04	7.31	1.04	2.17	31.73	18.02	0.34	1.32	0.53
1a-4	1234	29.74	7.71	1.65	4.04	34.28	19.68	0.17	1.71	0.76
1a-5	1045	32.28	7.43	1.25	3.15	33.19	18.74	0.32	1.55	0.62
1b-1	3	11.65	8.43	0.51	2.26	50.56	22.32	2.96	0.29	0.06
1b-2	7	15.35	8.82	0.76	2.50	45.95	22.55	2.29	0.49	0.06
1b-3	5	13.54	8.66	0.77	2.43	47.48	22.53	2.76	0.45	0.07
1b-4	13	21.01	9.35	0.97	2.69	40.02	22.66	2.13	0.74	0.08
2a-1	325	47.43	6.56	3.68	3.17	21.70	14.38	2.85	0.54	0.05
2a-2	450	55.42	7.31	4.10	3.32	11.27	15.25	2.75	0.72	0.06
2b-1	4	28.35	4.88	3.02	2.21	50.89	7.17	2.84	0.58	0.05
2b-2	8	31.96	6.14	3.34	2.39	38.92	13.02	2.39	0.61	0.06
2c-1	188	38.56	6.71	3.36	2.20	33.01	12.56	3.33	0.48	0.05
2c-2	214	40.95	6.18	3.63	2.30	30.65	13.30	2.26	0.58	0.05
2c-3	178	36.72	5.51	3.12	2.10	35.77	12.10	3.54	0.41	0.05
2c-4	235	42.17	6.49	3.75	2.40	26.88	14.20	2.17	0.62	0.05
2c-5	166	36.21	5.14	2.92	1.90	37.77	11.34	2.97	0.35	0.04
2d-1	10	34.11	6.39	3.52	2.15	37.16	13.62	1.87	0.75	0.06
2d-2	7	29.95	7.11	3.33	1.79	41.24	12.41	2.39	0.58	0.06
2d-3	7	30.36	6.45	3.07	1.57	43.19	11.78	2.29	0.48	0.06
2d-4	5	31.99	5.99	2.88	1.17	44.37	9.18	2.86	0.34	0.05
2d-5	4	26.20	3.63	2.15	2.12	54.28	7.22	3.07	0.26	0.04
2e-1	334	49.46	6.52	3.55	3.52	18.88	13.92	2.95	0.46	0.05
2e-2	254	45.36	6.39	3.61	3.37	23.93	13.19	3.29	0.35	0.05
2e-3	422	55.86	7.12	3.87	3.86	12.91	14.17	2.09	0.51	0.06
2e-4	397	53.08	6.85	3.76	3.72	15.08	14.69	2.61	0.49	0.05
3a-1	295	60.81	12.10	5.09	3.18	9.03	4.23	5.06	0.49	0.05
3a-2	345	58.20	11.92	5.95	3.45	9.77	6.24	4.08	0.51	0.06
3a-3	450	54.28	13.15	6.76	3.60	10.09	8.99	2.29	0.52	0.10
3a-4	320	59.21	12.26	5.26	3.35	9.24	5.76	4.45	0.51	0.05
3a-5	120	62.66	10.67	4.07	2.14	8.38	4.05	6.70	0.42	0.04
3b-1	70	62.39	11.06	4.37	1.23	7.02	5.06	6.40	0.52	0.03
3b-2	41	67.64	10.31	2.66	1.62	3.05	3.80	8.72	0.43	0.02
3b-3	58	65.20	10.51	3.36	1.80	5.99	4.20	7.83	0.43	0.03
3b-4	63	63.87	10.58	4.00	2.15	6.62	4.61	7.33	0.45	0.03
3c-1	160	61.94	11.49	4.09	2.64	8.19	5.03	4.73	0.41	0.04
3c-2	190	61.36	12.86	4.51	3.11	8.44	6.05	3.09	0.45	0.04
3c-3	187	61.70	12.14	4.35	2.99	8.44	5.04	4.40	0.43	0.04
4a-1	1534	54.24	11.48	1.44	9.17	9.56	11.82	0.14	1.06	0.62
4a-2	1744	48.32	12.94	1.75	10.87	11.24	12.02	0.22	1.21	0.81
Min	***3***	***11.65***	***3.63***	***0.51***	***1.17***	***3.05***	***3.80***	***0.17***	***0.26***	***0.02***
Max	***1267***	***67.64***	***13.15***	***6.76***	***4.87***	***54.28***	***22.66***	***8.72***	***1.97***	***0.76***
Average	***292***	***41.89***	***8.07***	***3.14***	***2.66***	***27.24***	***12.45***	***3.18***	***0.65***	***0.13***
Median	***178***	***38.56***	***7.31***	***3.36***	***2.40***	***31.73***	***13.02***	***2.84***	***0.51***	***0.05***
S.D.	***368***	***15.89***	***2.36***	***1.46***	***0.86***	***15.59***	***5.93***	***2.07***	***0.42***	***0.21***

Geological units of study area, number of susceptibility measurements and minimum, maximum and average susceptibility values of geological unitsis given Table 1.

It is taken 101 measurements from Limestone-Marn Unit. This unit was defined two susceptibility sites. From first site 1A has 53 field susceptibility measurements was taken and other site 1B has 48. While Taken these measurements form dominantly seeing Limestone unit in south part change between1-18x10^{-6} cgs, these of seeing limestone with marn in 1A site in the north of the region placed raged of 827-1379x10^{-6} cgs. Average MS values are changing between 7x10^{-6} cgs ve 1045x10^{-6} cgs respectively.

Seeing claylimestone-lave-tuff with One on the top of the other and placed in centre of the study area, 2 site from where was taken 269 measurements. The susceptibility values of the unit has a zoning which is directed toward north-east change 0-527x10^{-6} cgs and show five susceptibility groupTaking 22 susceptibility measurements from 2A units which placing lave-tuff rich limestone geologic units placed 249-527x10^{-6} cgs. Average susceptibility of this unit is 392x10^{-6} cgs. Placed northeast and mostly defined limestone, 2B unit's magnetic field susceptibility values take part between 1-19x10^{-6} Twenty two measurements is taken from that unit and average of these measurements is 7x10^{-6} cgs. Ninety-eight measurements is taken from 2C site and average of these measurements is 180x10^{-6} cgs. Dominantly tuff and limestone units are seen in this part of area, also the limestone has high alteration. Taken measurements on that unit changed 103-259x10^{-6} cgs. 2D limestone unit that surrounded the Sarraftepe Basanite which is in the middle of the study area was taken 77 measurements and these measurements change between 1-18x10^{-6} cgs. The average of this unit is 4x10^{-6} cgs. Interbedded limestone-marn-tuff in 2E region was taken fifty measurements, this unit has 327x10^{-6} cgs average susceptibility values which is changes between 181-444x10^{-6} cgs.

Another large unit is agglomerate is defined two sites from which is collected 175 measurements. Taken measurements from agglomerate unit show three different geologic units. Forty four numbers measurements were taken from named 3A. That unit's average susceptibility values are between 204-413x10^{-6} cgs. From 3B site, 89 measurements were collect and average of these measurements is 53x10^{-6} cgs and is placing 18-79x10^{-6} cgs. Forty-two measurements are collected from 3C site and that average value 170x10^{-6} cgs which are place between 144-211x10^{-6} cgs rages.

Lastly named unit of Sarraftepe Bazanite was collected 23 measurements which have very high values against to other site's measurements values. This unit's average MS value is 1565x10^{-6} cgs, the measurements ranged from 1398x10^{-6} cgs to 1780x10^{-6} cgs.

The counter map which was plotted using the MS measurements reflects very well the boundaries of geologic units and the zoning of these units. Obtained surfer MS map shows that 1B and 2D geologic unit resembles each other.

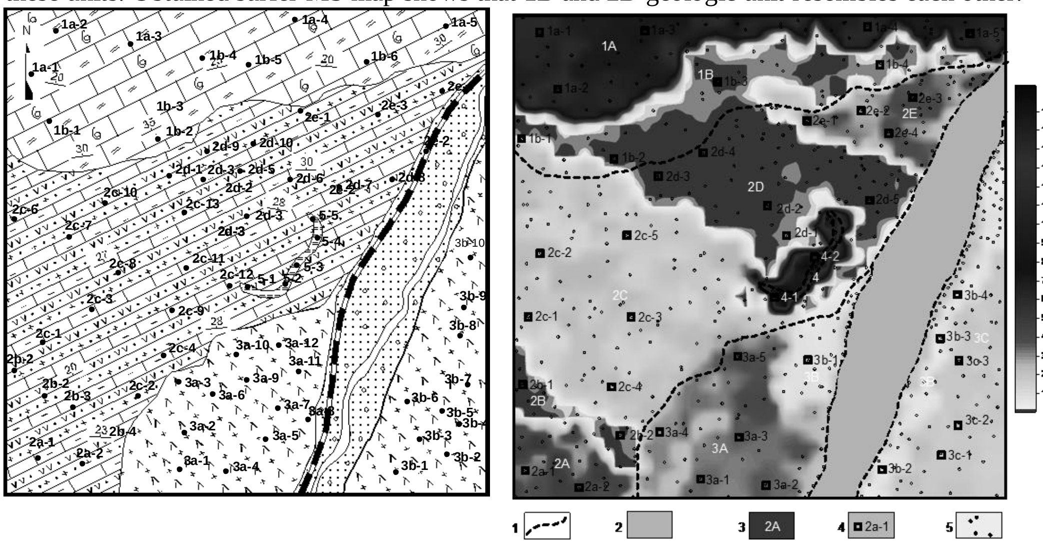


Figure 2. Geologic map with samples places and MS contour map of study area. 1- Geological boundaries. 2- Bed of Değirmendere stream. Mesurements are not taken from that site because of alluvium unite. 3- The boundaries of site are defined by susceptibility measurements. 4- The location of the chemical sample 5- The location of field susceptibility measurements.

Table 1. Geological units of study area, number of susceptibility measurements and minimum, maximum and average susceptibility values of geolojical units.

Unit	SITE	Number of Measuremens	Minimum MS ($x10^{-6}$ cgs)	Maximum MS (10^{-6} cgs)	Average MS (10^{-6} cgs)
Marn	1A	53	827	1379	1045
	1B	48	0	18	7
Limenstone-Lave-Tuffit	2A	22	249	527	392
	2B	22	0	17	7
	2C	98	103	259	180
	2D	77	0	18	4
	2E	50	181	444	327
Agglomerate	3A	44	204	413	313
	3B	89	18	79	53
	3C	42	144	211	170
Basanite	4	23	1398	1780	1565

Every units defined in the study are done chemical analysis. MS measurements for chemical analysis powder sample using the laboratory sensor is done for ever site. The chemical analysis results of ever taken samlples from the region which change against to them susceptibility values are shown graphically.

The chemical analysis ratio of 5 samples belonged to 1A site versus against to MS measurements is shown Figure 3. Susceptibility measurements values of taken from powder samples change ranging 900-1267x10^{-6} cgs and average MS value is 1127x10^{-6} cgs. While the MS values of 1A site increase, it seen that ratio of SiO_2 and K_2O decrease and the ratio of Fe_2O_3, Al_2O_3, MnO, MgO, CaO, Na_2O, TiO_2 increase.

The chemical analysis ratio of 4 samples belonged to 1B site versus against to MS measurements is shown Figure 3. Susceptibility measurements values of taken from powder samples change ranging 3-13x10^{-6} cgs and average MS value is 7x10^{-6} cgs. As seen on the figure for 1 site, CaO and K_2O decrease with increasing susceptibility, whereas SiO_2, Fe_2O_3, Al_2O_3, MnO, MgO, Na_2O and TiO_2 increase with increasing susceptibility.

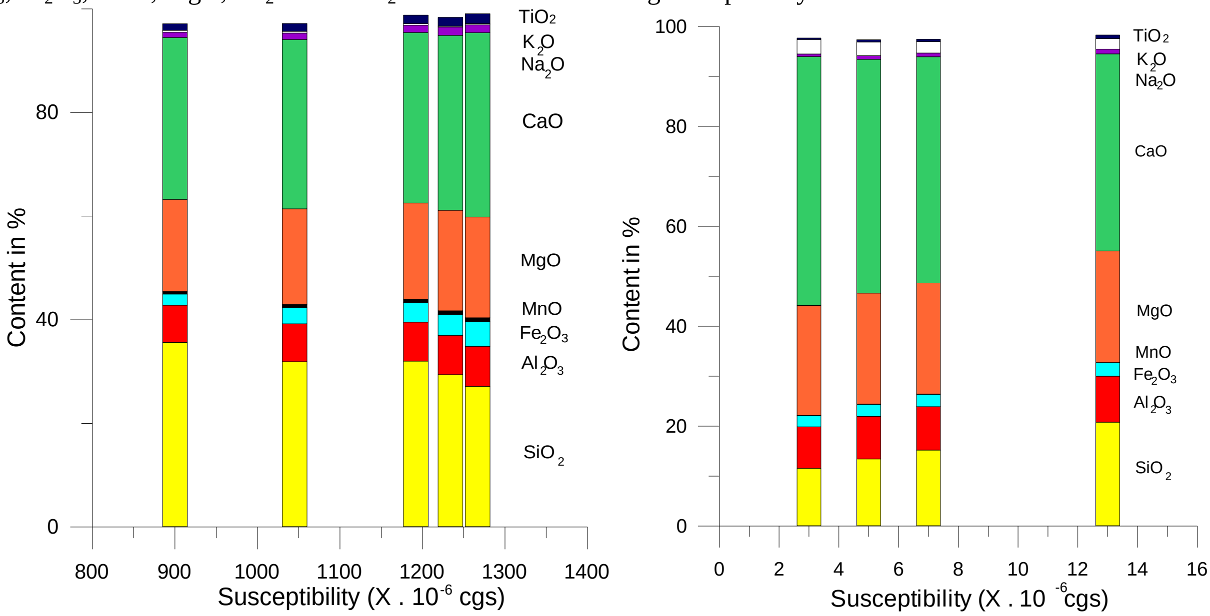


Figure 3. The chemical analysis ratio of 4 samples belonged to 1A and 1B site versus against to MS measurements.

The chemical analysis ratio of 18 samples belonged to 2 site versus against to MS measurements is shown Figure 4a. Susceptibility measurements values of taken from powder samples change ranging 4-450x10^{-6} cgs and average MS value is 177x10^{-6} cgs. As seen on the figure for 2 site, SiO_2, and K_2O decrease with increasing susceptibility, whereas Fe_2O_3, Al_2O_3, MnO, MgO, CaO, Na_2O and TiO_2 increase with increasing susceptibility.

The chemical analysis ratio of 12 samples belonged to 3 site versus against to MS measurements is shown Figure 4b. Susceptibility measurements values of taken from powder samples change ranging 41-450x10^{-6} cgs and average MS value is $191x10^{-6}$ cgs. For 3 site, SiO_2, and K_2O decrease with increasing susceptibility, whereas Fe_2O_3, Al_2O_3, MnO, MgO, CaO, Na_2O and TiO_2 increase with increasing susceptibility

The chemical analysis ratio of 2 samples belonged to 4 site versus against to MS measurements is shown Figure 4c. Susceptibility measurements values of taken from powder samples change ranging $1534\text{-}1744x10^{-6}$ cgs and average MS value is $1639x10^{-6}$ cgs. For 4 site, SiO_2, and K_2O decrease with increasing susceptibility, whereas Fe_2O_3, Al_2O_3, MnO, MgO, CaO, Na_2O and TiO_2 increase with increasing susceptibility.

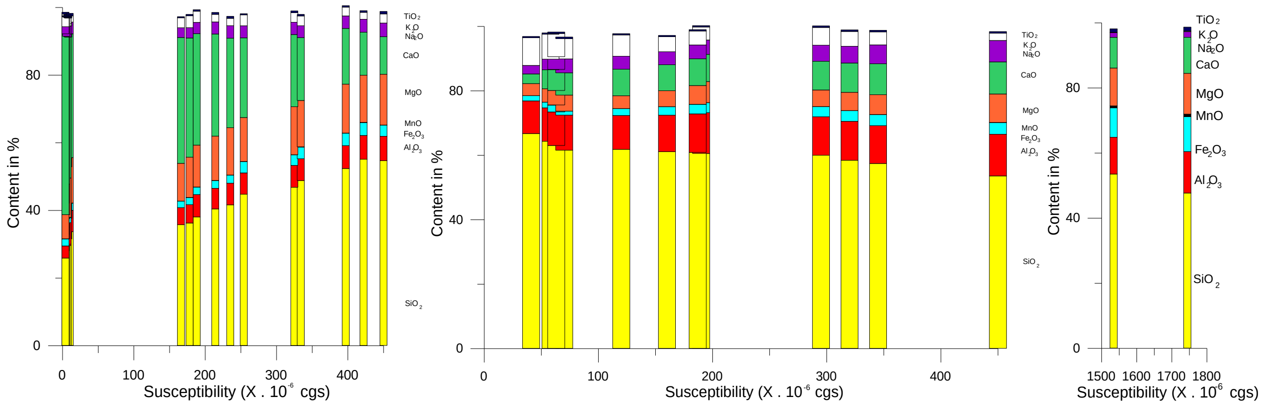
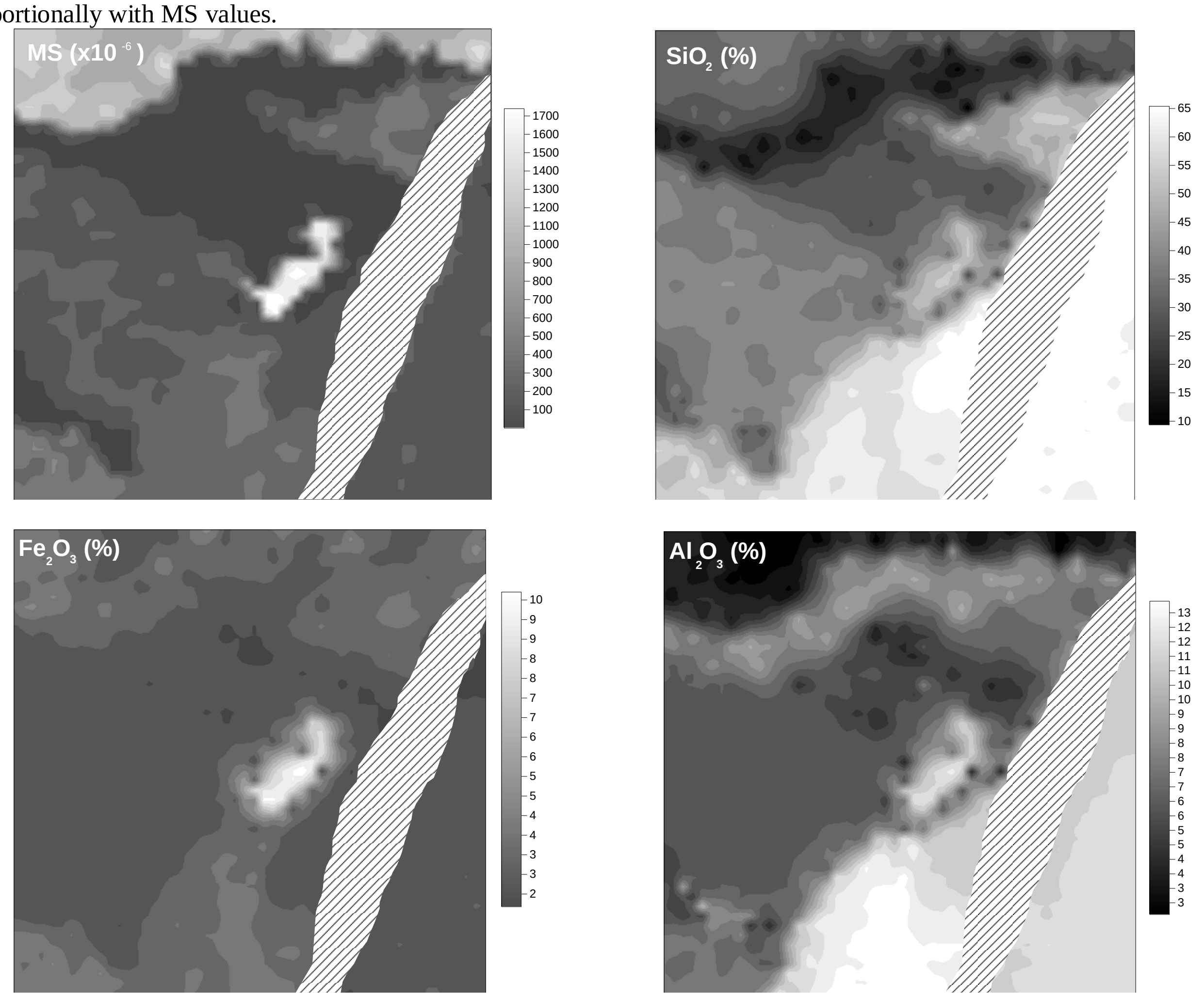


Figure 3. The chemical analysis ratio of 4 samples belonged to 2 site versus against to MS measurements.

Using each sample's chemical analysis result, the values of all regions is calculated from survey susceptibility measurements. Surfer counter maps of the calculated chemical ratio's surfer maps which are SiO_2, Fe_2O_3, Al_2O_3, MgO and CaO is shown Figure 5. MS values are changing reverse-proportionally with SiO_2, CaO and K_2O every where of the region. The oxide minerals rations of sourcing MS which are Fe_2O_3, Al_2O_3, MgO, MnO and TiO_2 is changing proportionally with MS values.



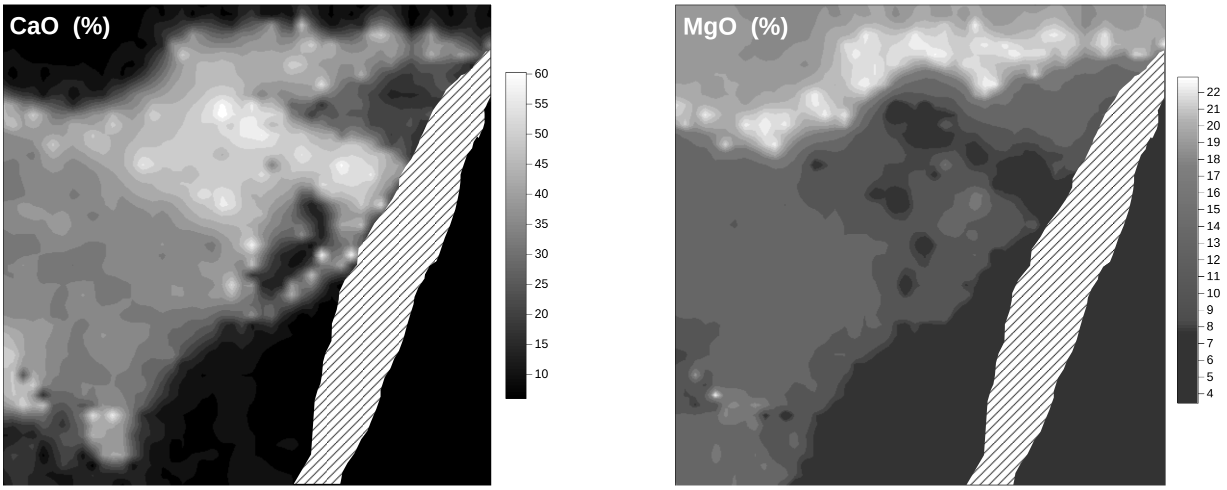


Figure 5. Surfer counter maps of the calculated chemical ratio's surfer maps which are SiO_2, Fe_2O_3, Al_2O_3, MgO and CaO.

CONCLUSIONS

Geochemical analyses and field susceptibility measurements made on the geological units of the study field resulted in following conclusions; MS values of the rocks vary dependent on all elements in the rocks composition. Every intrusion has susceptibility zones and susceptibility measurements can be used as an co-operative method in geochemical analyses for drawing the boundaries of geological units. Susceptibility measurements which are taken very practical can be help to find out geochemical zoning in every intrusion. The field susceptibility measurements using of field sensor with very cheap and pratic are used to generalize all area taken several chemical analiyzed sample and their susceptibility values.

Based on the comparison of counter plots around Sarraf Tepe, we conclude that rock MS increases with increasing rock iron oxide content in general, but in detail, anomalously high magnetic susceptibilities were observed where rocks have undergone high alteration and secondary iron oxide minerals have formed. Two major factors playing important role in the formation high alteration zones are the rock crack systems and rock mineralogy.

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