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Petrography and geochemical decomposition parameters of crystalline rocks; Demirköy intrusive body (DIB), *NW Turkey*

Ezgi ULUSOY[a*] and Yusuf Kağan KADIOĞLU[b,c]

[a]*General Directorate of Mineral Research and Exploration (MTA), Department of Geological Research, Ankara, Turkey*
[b]*Ankara University, Faculty of Engineering, Department of Geological Engineering, Ankara, Turkey*
[c]*Earth Sciences Application and Research Centre (YEBIM) of Ankara University, Ankara, Turkey*

Research Article

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ABSTRACT

The crystalline rocks represent the most weathering rock groups due to their textural and mineralogical decomposition. This study, focused on the petrographic properties and geochemical variation of the altered rocks from Demirköy Intrusive Body (DIB) located at NW Turkey were examined based on the location of structural and morphological properties. DIB consists of intrusive rocks in the composition of ranging from granite to gabbro. The sampling made from the dominant rock units composing of granodiorite and quartz diorite, within the DIB a cross weathering section divided into three levels as regolit, saprolite and saprock. For each level of all the section Ruxton ratio (Ro), chemical alteration index (CIA), chemical weathering index (CIW), plagioclase alteration index (PIA) were determined. The results show a linear decrease from the surface to the core of the host rock. The chlorite-carbonate-pyrite index (CCPI) versus Ishikawa alteration index (AI) variation diagram shows that decomposition in profiles occurred in diagenetic alteration and where the hydrothermal alteration effect is not observed. On the other hand, Mg, Fe, Ti, Ca decreased remarkably while the ratio of the elements such as Si, Na, K, Al increased. The increasing and decreasing of geochemical elements are related to their physical strength and chemical behavior. The chemical variation diagrams of all the levels revealed that the regolites exhibit chemical compounds from hydrothermal fluids in the immediate vicinity of the source rocks.

1. Introduction

Apart from tectonic events, the main processes that shape surface morphology are rock weathering, soil formation and sediment deposition. Weathering is the physical - mechanical changes of rock masses, which occurs due to atmospheric and hydrospheric conditions, are compositional and consolidation changes that can be observed chemically and mineralogically - petrographically. Chemical - mineralogical and physical transformations occurring in all rock types associated with weathering processes that occur under various climatic conditions (Whalley and Turkington, 2001; Borrelli et al., 2007; Ietto et al., 2013).

Weathering begins in crystalline rocks along the boundaries of foliation planes, the compositional discontinuities and boundries of rock forming crystals and occur in situ decomposition. As a result of decomposition, regolith (A soil horizon), saprolite (grus, B soil horizon) and saprock (C soil horizon) zones are formed from the surface to depth (Bates and Jackson, 1987; Nahon, 1991; Power and Smith, 1994;

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**Corresponding author: Ezgi ULUSOY, ezgi.ulusoy@mta.gov.tr*

Delvigne, 1998; Hillel, 1998; Sharma and Rajmani, 2000; Taylor and Eggleton, 2001; Meunier, 2005; Velde and Meunier, 2008; Graham and O'Geen, 2010). The products of the rock, which is between the fresh rock and atmospheric conditions, in - situ weathered, and do not change volumetrically are defined as saprolites (Ollier et al., 2007; Ollier, 2010; Arias et al., 2016). Due to the weathering effect, depending on the mineralogical and chemical composition of the bedrock, the grain size of the rocks decreases and new minerals are formed. Depending on these changes, the weathering process accelerates or slows down. Decomposition of feldspar and mica minerals like biotite - muscovite play an important role in the weathering process of acidic - intermediate crystalline rocks. As a result of the process, the term 'gruss' (earthy crystals) is used for the medium - coarse grained material, which exhibits less mineralogical and chemical differences compared to the bedrock, and consists of clayey and poorly sorted quartz grains (Migoń and Thomas, 2002). Under the conditions of burial, uplift, erosion, paleoclimate, fracture development associated with weathering processes, can occur at a depth of a few meters to tens or even hundreds of meters depth from the surface related to chemical decomposition (primarily hydrolysis) and the effect of groundwater.

In the Late Cretaceous DIB granitoids in the Istranca Massif, which is covered with heavy vegetation called North Forests; spheroidal (rindlet) weathering and arenization (gruss) as weathering products, are clearly observed. In this study, the mineralogical - petrographic and chemical alteration parameters of DIB granodiorite and quartz diorite compositional crystalline rocks, due to weathering, and the mineralogical and chemical properties of the final products resulting from the weathering are examined for the first time. With the obtained data of different compositional intrusive rocks; The processes and properties of decomposition in the same environment were compared. This study can also be used to evaluate the suitability and productivity of the regolith in terms of agricultural activities according to its mineralogical and chemical properties.

2. Geographical Features and Geology of the Study Area

The study area is located around Demirköy district, in the east of Kırklareli province, NW Turkey. The region is located in the mid - altitude mountain range, has important water resources and high - density drainage networks consisting of many dry and wet streams. For this reason, the weathering process has developed faster in rocks. The region with typical climatic conditions of the Thrace Peninsula; winters are quite cold and rainy; summers are warm and rainy. Consequently, above a certain height and especially on the northern slopes of the mountains, broad - leafed woodlands, mostly made of beech and hornbeam are abundant. Coniferous and oak forests are observed on the south facing slopes where the altitude decreases. In the Istranca (Yıldız) Mountains, where the total annual precipitation is over 1000 mm, lime - free forest soil cover is common due to the dominance of magmatic rocks (Boyraz and Cangir, 2009). While there is enrichment in organic matter due to the heavy forest cover, heavy rainfall has caused the soil to wash in places and podsolic soil formation.

As one of the Turkey's tectonic units, The Strandja Massif (Zone) located in the west of the Pontide belt is separated from the Pontides by the West Black Sea fault and extends towards Eastern Europe (Okay and Tüysüz, 1999). The Strandja Massif, outcropped in the Strandja (Yıldız) Mountain range, basically consists of crystalline core complex and an overlying Triassic - Jurassic low - grade metamorphic clastic and carbonate cover (Aydın, 1982; Çağlayan and Yurtsever, 1998). The units belonging to the Massif are cut by Late Cretaceous - aged, different compositional intrusions and are covered by Late Cretaceous sedimentary - volcanosedimentary units, which no metamorphic effect is observed. DIB, which is the most widespread, Late Cretaceous intrusions, outcropped in an area of approximately 120 km^2 in east of the Massif with WNW - SSE trending ellipsoidal shape (Figure 1) (Ulusoy, 2012).

The intrusive rocks of the DIB are in sharp contact with the metacarbonate and metaclastics of the Strandja Massif. The İkiztepe Granitoid is probably tectonic contact, which is covered with forest and vegetation to the west of the intrusive body (Üşümezsoy, 1982; Ulusoy and Kadıoğlu, 2015). DIB generally consists of granitic, granodioritic, monzodioritic, dioritic and gabbroic assemblages. Felsic and intermediate members are fine - grained, phaneritic textured and consist of roundish - ellipsoidal, from a few to 50 cm in diameters, mafic enclaves. Granite and granodiorites

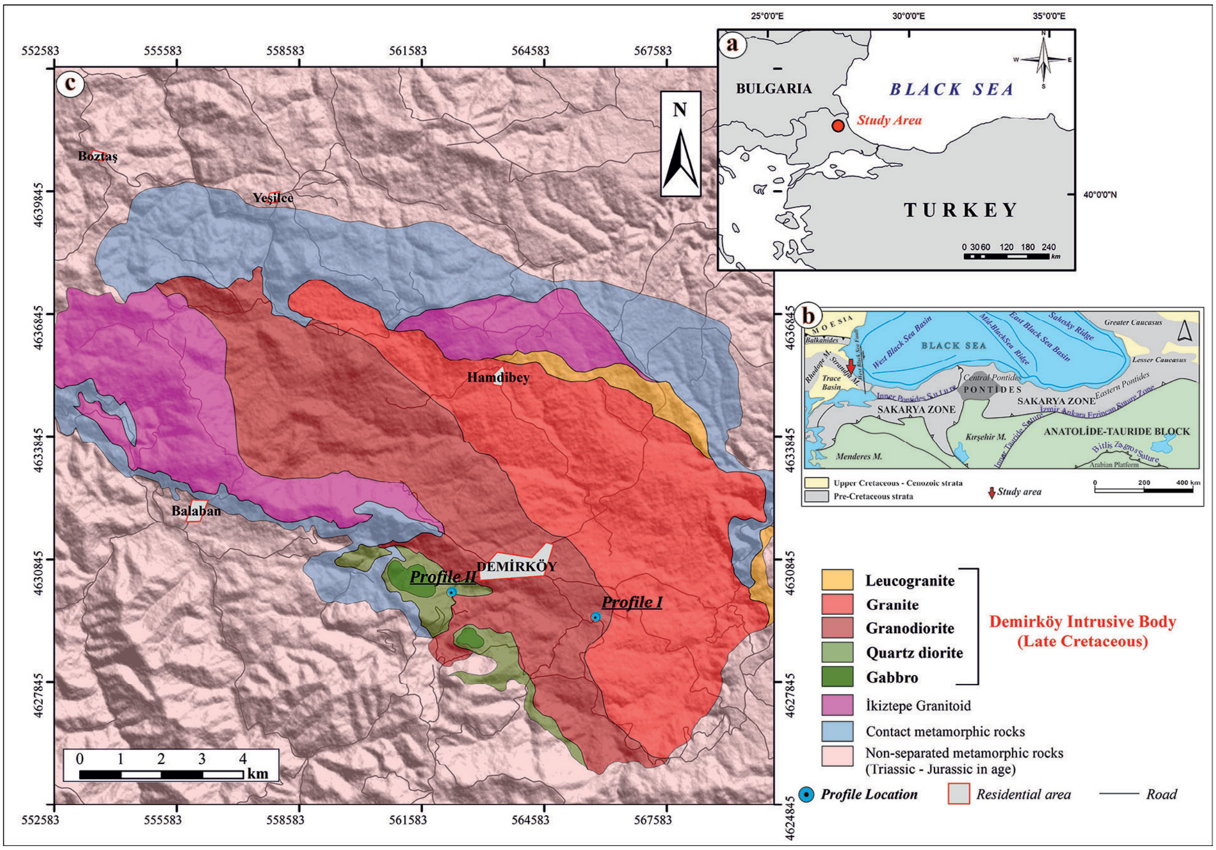

Figure 1- a) Location map of study area, b) tectonic units of Turkey with location of study area (from Okay and Nikishin, 2015) and c) detailed geological map of DIB.

of DIB are calc - alkaline, peraluminous and has medium K content. The mafic rocks of the intrusion are in gabbroic and dioritic composition and generally have calc - alkalen - tholeiitic characteristics. Cooling age of DIB is determined as Late Cretaceous (80 Ma; K - Ar, Moore et al., 1980), and in the light of petrological findings, it is stated that it may be mantle - enriched crustal contaminated H - type granite intruded due to closure of Srednogorie Arc (Aykol and Tokel, 1991; Karacık and Tüysüz, 2010). Apatite fission track studies carried out in the Strandja Massif indicate that after Late Jurassic metamorphism, slow cooling during the Cretaceous - Early Eocene time, and then fast uplift - exhumation and erosion events took place in the region (Catto et al., 2018).

3. Material and Method

Rock units are sampled to reveal the mineralogical composition, textural properties and types of weathering. Thin sections are prepared from these samples and they are selected for X - ray diffraction (XRD) and chemical analysis. Selected samples were crushed in a jaw crusher and then ground using a tungsten carbide mill in Ankara University Earth Sciences Application and Research Center (YEBİM) Laboratories. 4gr of grinded sample was mixed with 0.9 gr of cemented material (wachs), compressed under hydraulic pressure and turned into powder pellets, and major element oxide analyses were performed on the Spectro X - LAB 2000 Polarized Energy Dispersive X - Ray Fluorescence Spectrometer (PEDXRF). The major oxide composition analysis was performed using the GEO - 7220 method, and the device was calibrated by using the K02–GSR–09 and 01–GS–N–Granite standards created by USGS for plutonic rocks (granite, granodiorite, etc.). On the other hand, X - ray diffraction (XRD) analysis was made with a Bruker D8 Advance X - Ray diffractometer at shooting speed of 0.0390º2θ, under 40 mA, 40 kV, with a copper (Cu) X - ray tube and a device with a wavelength of 1.540604 Å in General Directorate of Mineral Research and Exploration (MTA), Mineral Analysis Technology Department Laboratories. The qualitative mineralogical composition of whole rock and normal (between 2º and 30º, N), ethylene glycol - treated (between 2º and 30º, EG), 550ºC baked (2º - 30º) detailed clay XRD diffractograms were measured from oriented clay samples.

4. Research Findings

4.1. Field Observations

The crystalline rocks belonging to the DIB, outcropped in the study area with heavy forest and vegetation where the altitude is partially increased, covers large areas that are weathered and turned into sand (arena, gruss, saprolite). In the region, outcrops, in which weathering effect is macroscopically weak or not observed at all, are generally observed in stream valleys within groundwater level. As the elevation increases, the weathering continues to increase significantly along the jointed and fractured surfaces. Granodioritic and quartz dioritic rocks are sampled along the significant profiles to investigate weathering processes (Figures 2b and c). As a result of systematic sampling, there are four zones observed in both sections. Accordingly, the top level is about 30 cm thick, red - brown colored, humus - rich soil (regolith - A soil horizon) layer, which is enriched by plant roots and fringes. Below this, there is 1 - 1.5 m - thick saprolite level belonging to the crystalline rock which is texturally sandy (B soil horizon). Saprolite contains small amounts of bedrock fragments and blocks (saprock) in the first levels. Towards deeper saprolite levels, the rate of saprock is gradually increasing. Samples taken from saprock are divided into two subgroups as dispersible - brittle and compact rock (C soil horizon). In dispersible - brittle samples, the rock is highly weathered and can be easily broken by hand, while in compact samples the textural integrity is preserved and consists mostly of solid rock.

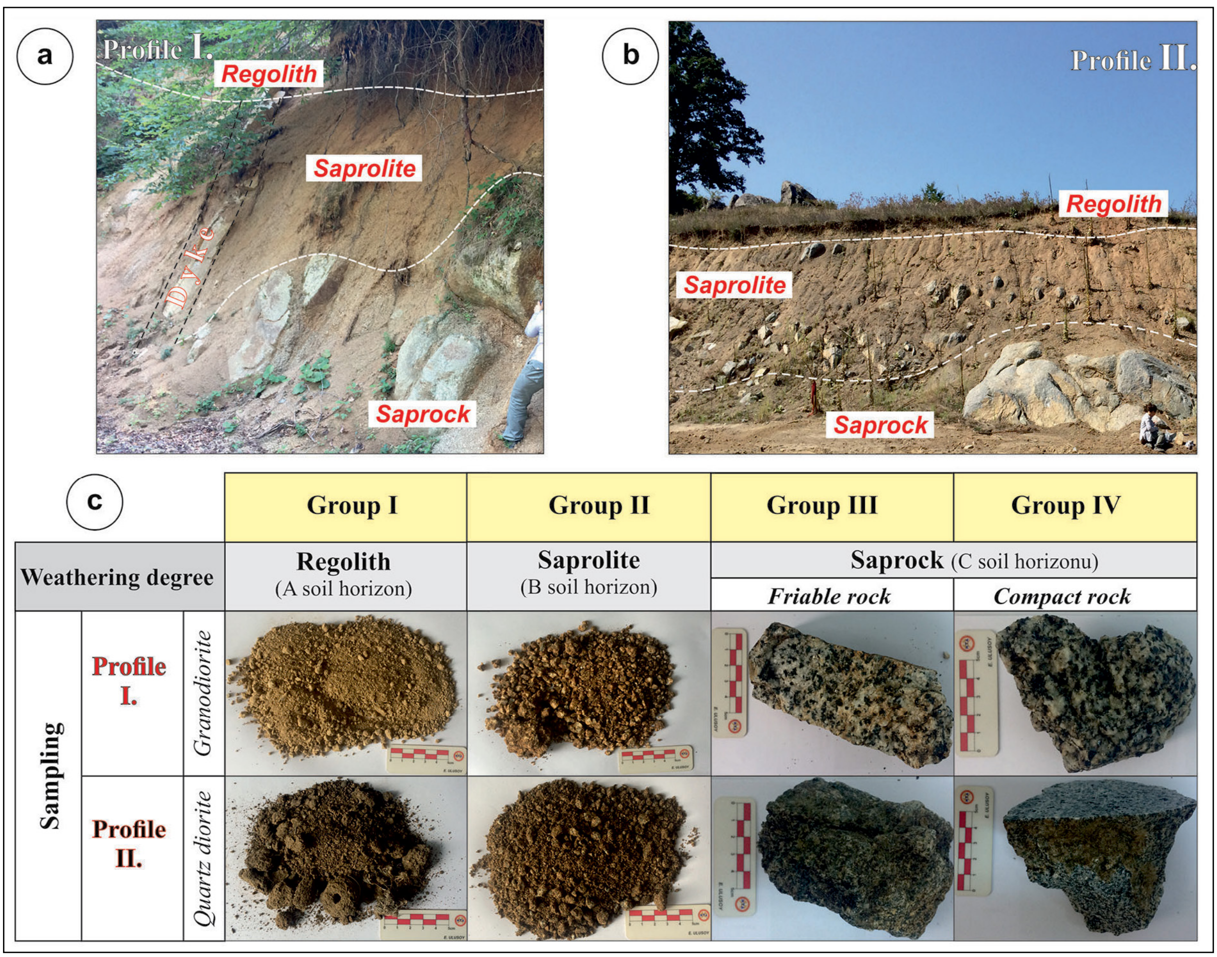

Figure 2- a) General view of regolith, saprolite and saprock levels in granodiorite profile I, b) General view of regolith, saprolite and saprock levels in quartz diorite profile II, c) Macroscopic views of the weathered samples from both sections.

4.2. Mineralogy - Petrography

Profile I is in granodioritic composition with phaneritic texture. The main composition of the rock is medium - grained, subhedral plagioclase, orthoclase and anhedral quartz crystals. Mafic mineral content of the rock is 35% with large - small subhedral - euhedral amphibole and subhedral brown biotite crystals. Fine - grained titanite and zircon crystals with very fine - grained apatite minerals are observed accessory minerals. Disseminated, fine - grained semi - euhedral opaque mineral crystals are observed in the rock. Poikilitic texture is common in partially coarse - grained quartz, orthoclase and amphibole crystals. Argillization is observed. Feldspars turn to sericite, mafic minerals, on the other hand, altered to chlorite (amphibole, biotite), biotite (amphibole) and opacitized (Figure 3a-c). Dispersible - brittle minerals (quartz and feldspars) are fractured - cracked, and iron hydroxide staining is observed along the discontinuities (Figure 3a-b).

Profile II is quartz dioritic in composition and displays phaneritic texture. The main composition of medium grained rock is subhedral plagioclase, subhedral - euhedral amphibole, clinopyroxene and biotite. Mafic mineral content of the rock is generally more than 50%. Less amount of anhedral quartz is observed in the rock. It contains small amounts of fine - grained, subhedral titanite as accessory mineral. Disseminated, fine - grained, semi - euhedral opaque mineral crystals are observed in the rock. Plagioclase crystals intensely turn to epidote, sericite and clay. Intense uralitization is observed in clinopyroxene, and pyroxene can only be observed as residues from place to place. In amphibole crystals; Chloritization, epidotization and biotitization are observed along cleavage surfaces. Opacitization and opacification are

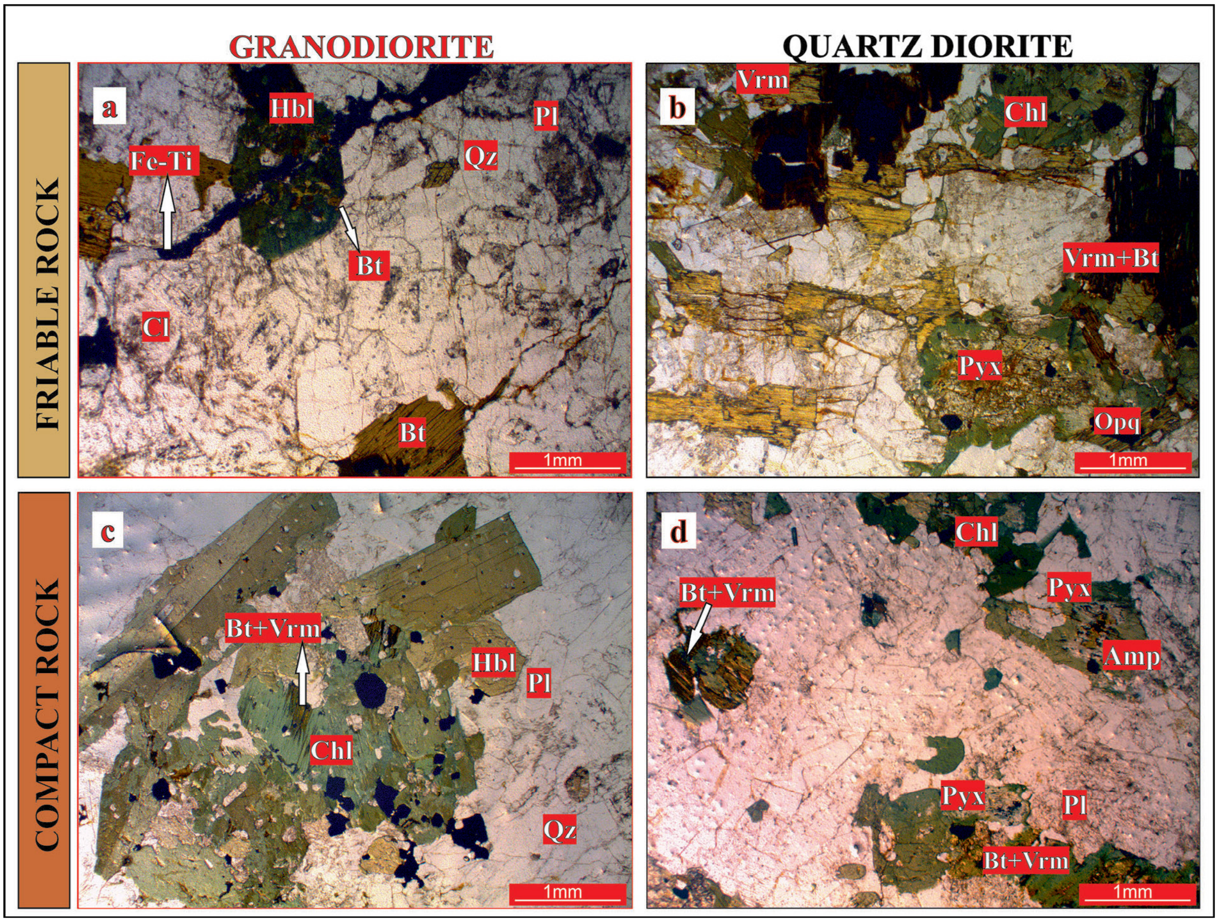

Figure 3- Microphotographs along profile lines; a) friable granodiorite, b) friable quartz diorite, c) compact rock of granodiorite, d) compact rock of quartz diorite in thin section (Qz: quartz, Bt: biotite, Hbl: hornblende, Amp: amphibole, Pyx: Pyroxene, Vrm: vermiculitization, Fe-Ti: iron-titanium oxidation, Cl: clay, Chl: chloritization).

common in mafic minerals (Figure 3b-d). Similar to profile I, iron hydroxide staining is clearly observed along the discontinuities.

4.3. XRD Results and Clay Mineralogy

The result of qualitative mineralogical analysis performed by X - Ray Diffraction (XRD) method of samples from the surface to deep levels in the study area is shown in Figure 4. In all zones for both rock profiles, besides primary minerals, it is observed that secondary minerals are developed as the result of decomposition. Besides in some of the samples belonging to the regolith (soil) and saprolite zone, a proportional decrease can be observed in the minerals studied with the effect of dispersion and washing by surface water.

Profile I, along to the granodioritic rock, consists of quartz, K - feldspar, plagioclase, hornblende, biotite and magnetite (Figure 4a). Depending on the main composition, chlorite and illite are observed as the dominant clay minerals. Besides, kaoline is observed at some levels in regolith and saprock (Figure 5a).

Profile II, along to quartz dioritic composition, consists of plagioclase, alkali feldspar, hornblende, tremolite - actinolite and clinopyroxene (Figure 4b). There is diversity in minerals released as a result of weathering in the mafic mineral - riched quartz dioritic profile II. Secondary vermiculite and chlorite formation are observed in mafic minerals (Figure 5b). In the saprolites of both rocks, depending on the weathering of calcium - rich plagioclases, smectite is formed at different rates. It is possible to observe illite developed from chlorite and feldspars developed from mafic minerals in both profiles of saprock level.

4.4. Whole Rock Geochemistry

From the profiles in the study area, major oxide element concentrations and the major oxide values and calculated weathering parameters of 17 samples of soil, saprolite, saprock and fresh rock were determined and are given in Table 2. For each group of rock, major oxide values indicate similar composition but significantly differ proportionally from the fresh rock. Loss on ignition (LOI) rates were calculated in order to determine whether the samples were affected by alteration and the volatile component ratio. While loss on ignition values are ≤0.5 in fresh rock, it was observed that this ratio reached up to 13.83 in regoliths towards the upper levels of the profile where the weathering is denser (Table 1).

The weathering and alteration parameters given in Table 2 were calculated in order to follow the chemical

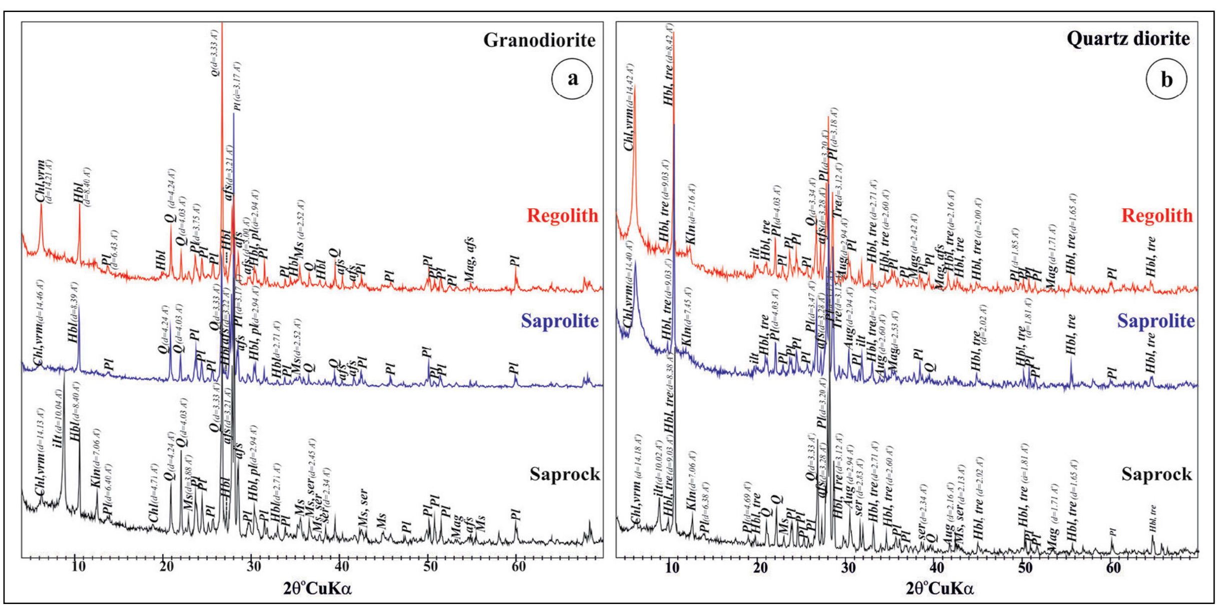

Figure 4- Qualitative mineralogical composition of whole rock analyzed by X-ray diffraction method; a) granodiorite, b) quartz diorite (Q: quartz, aph: alkali feldspar, pl: plagioclase, ms: muscovite, ser: sericite, mag: magnetite, hbl: hornblende, tre: tremolite, aug: augite / clinopyroxene, chl: chlorite, vrm: vermiculite, ilt: illite, sme: smectite (montmorrilonite), kln: kaoline)

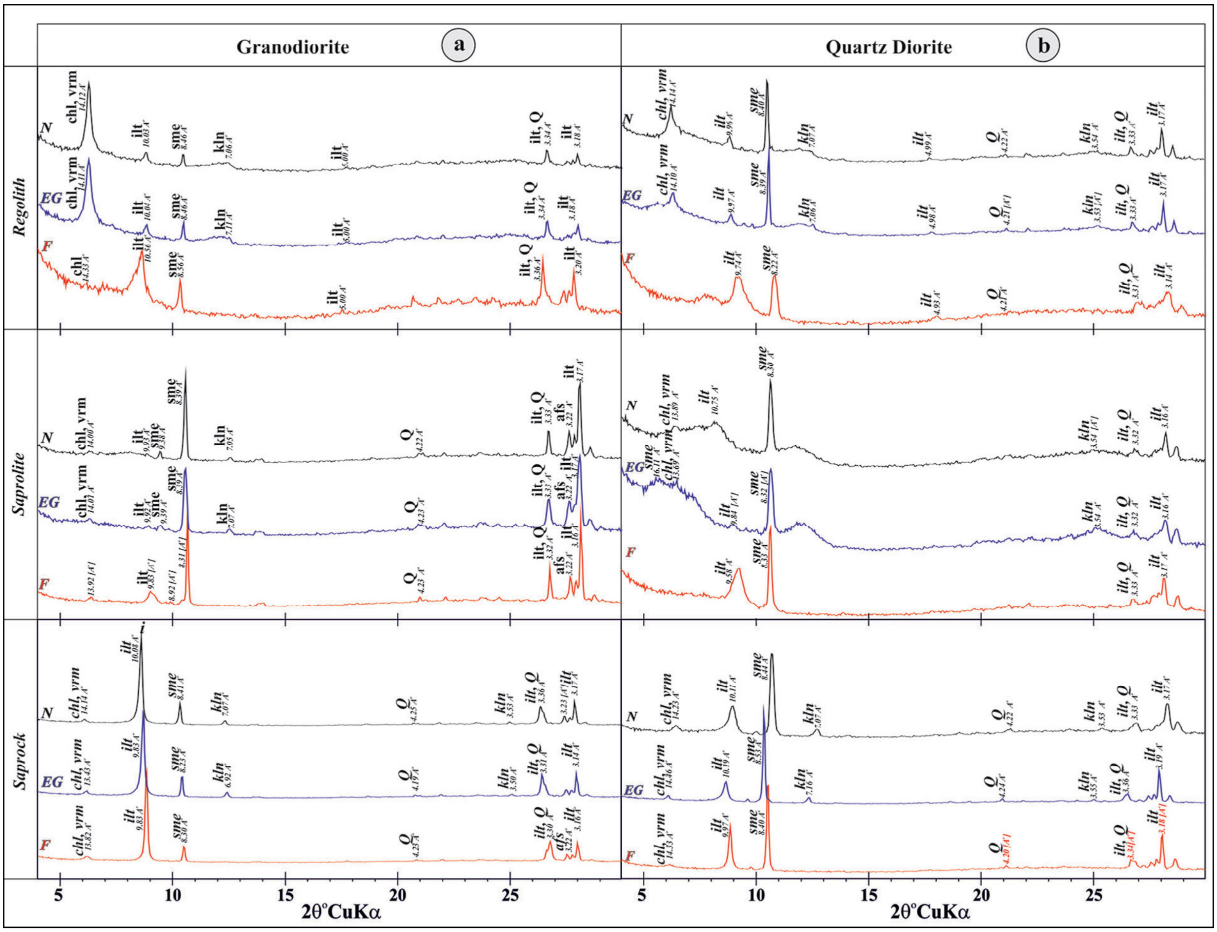

Figure 5- Detailed clay XRD diffractograms of granodiorite and quartz diorite profiles in the study area; a) granodiorite, b) quartz diorite (N: normal, EG: after treatment with ethylene glycol, F: 550ºC dried peaks; chl: chlorite, vrm: vermiculite, ilt: illite, sme: smectite, kln: kaoline, Q: quartz, afs: alkali feldspar)

changes of the zones in the weathering sections. Ruxton (Ro) ratio refers to silicification and argillization in acidic and intermediate rocks (Ruxton, 1968; Fiantis et al., 2010). In all samples in the study area, the Ruxton ratio (Ro) varies between 2.40 and 3.93, indicating that the rocks are not fresh. Chemical index of alteration (CIA) and chemical index of weathering (CIW) are the measure of the transformation of feldspars to clay (kaolinite) in the rock (Nesbitt and Young, 1982; Harnois, 1988). In the samples in the study area, the chemical index of alteration (CIA) is between 54.72 - 77.23 and the chemical index of weathering (CIW) is between 58.11 - 82.91, and depending on the alteration and weathering processes, argillization occurs as a result of the alteration of feldspar minerals in all samples. Palgioclase index of alteration (PIA) expresses the weathering degree of plagioclase crystals that show the fastest weathering in silicate rocks (Fedo et al., 1995). The ratio of PIA in the collected samples is between 55.34 - 79.75, indicating that plagioclases, one of the main minerals, are generally weathered. Ishikawa alteration index (AI), Chlorite - carbonate - pyrite index (CCPI) and advanced argillic alteration index (AAAI) values refer to the chemical and mineralogical changes that occur due to hydrothermal alteration during the weathering process and the density of alteration (Ishikawa et al., 1976; Large et al., 2001; Williams and Davidson, 2004).

In order to determine the effect of hydrothermal alteration on the weathering of the samples in the study area; Ishikawa alteration index (AI, between 27.03 - 57.63); The chlorite - carbonate - pyrite index (CCP between 33.42 - 88.07) and Advanced Argillic Alteration Index (AAAI, between 24.95 - 60.15) were calculated.

Table 1-Major oxide values and weathering parameters of samples from the study area.

			Na_2O	MgO	Al_2O_3	SiO_2	P_2O_5	K_2O	CaO	TiO_2	MnO	Fe_2O_3	LOI	*Sum*	Ro	CIA	CIW	PIA	AI	CCPI	AAAI
I. Profile: Granodiorite	***Regolith***	KW-23A	1.04	0.96	19.31	57.20	0.03	3.36	3.53	0.13	0.01	2.41	11.25	*99.23*	2.96	70.89	80.86	77.73	48.59	43.40	50.83
	Regolith	KW-23B	1.53	0.92	18.17	57.84	0.24	4.32	2.45	0.11	0.13	2.62	11.94	*100.26*	3.18	68.66	82.05	77.70	56.84	37.65	60.15
	Regolith	KW-23C	1.05	0.24	17.13	56.88	0.08	4.56	2.48	0.43	0.05	2.58	13.83	*99.31*	3.32	67.91	82.91	78.07	57.63	33.42	54.18
	Saprolite	KW-24	2.64	3.14	17.68	53.62	0.08	1.10	2.90	0.20	0.27	13.55	1.40	*96.58*	3.03	72.68	76.13	74.94	43.33	81.68	38.17
	Saprolite	KW-25	2.82	1.67	17.61	63.95	0.14	2.08	5.30	0.29	0.08	3.99	1.88	*99.81*	3.63	63.32	68.43	65.66	31.57	53.61	39.50
	Saprolite	KW-30	3.09	1.98	16.47	63.24	0.14	1.73	6.92	0.32	0.09	4.30	1.56	*99.84*	3.84	58.38	62.19	59.55	27.03	56.58	34.52
	Saprolite	KW-31	3.20	1.51	16.98	65.26	0.11	2.12	5.36	0.24	0.08	3.56	1.38	*99.81*	3.84	61.38	66.48	63.44	29.80	48.81	39.31
	Saprolite	KW-27	2.78	1.83	16.93	65.03	0.13	1.85	5.19	0.29	0.08	4.17	1.49	*99.78*	3.84	63.29	68.00	65.43	31.64	56.47	39.89
	Saprolite	KW-33	2.25	3.13	17.00	60.62	0.18	1.82	6.04	0.59	0.14	5.86	1.96	*99.59*	3.57	62.71	67.22	64.68	37.40	68.87	34.67
	Saprock	KW-26	2.68	3.43	15.91	62.32	0.16	2.65	5.71	0.51	0.13	5.54	0.75	*99.78*	3.92	59.04	65.49	61.26	42.03	62.70	34.54
	Saprock	KW-29	2.31	3.68	15.96	61.37	0.14	2.46	5.82	0.61	0.14	6.19	0.98	*99.66*	3.85	60.12	66.27	62.43	43.05	67.42	34.22
	Fresh rock	KW-28	3.25	2.43	16.47	64.73	0.12	2.32	5.57	0.39	0.09	4.05	0.44	*99.86*	3.93	59.64	65.12	61.59	35.04	35.04	36.51
II. Profile: Quartz diorite	***Regolith***	KW-41	0.73	3.62	21.09	50.67	0.17	1.12	5.47	0.65	0.15	8.56	7.07	*99.30*	2.40	74.26	77.30	76.33	43.32	86.85	34.06
	Regolith	KW-42A	1.34	3.90	19.59	50.31	0.17	1.18	6.12	0.57	0.14	8.05	8.54	*99.91*	2.57	69.39	72.42	71.16	40.53	82.61	30.69
	Regolith	KW-42B	0.04	1.89	18.50	53.02	0.17	1.02	4.39	1.20	0.08	5.94	12.83	*99.08*	2.87	77.23	80.65	79.75	39.59	88.07	45.59
	Regolith	KW-42C	0.77	2.24	18.01	51.90	0.08	1.20	4.04	0.91	0.06	6.72	13.63	*99.57*	2.88	74.99	78.93	77.76	41.73	81.99	42.40
	Saprolite	KW-46	0.77	4.35	19.77	52.69	0.16	1.03	6.80	0.69	0.16	8.74	4.36	*99.50*	2.67	69.69	72.32	71.23	41.54	87.93	30.66
	Saprolite	KW-38	1.35	4.57	18.15	54.09	0.21	1.18	7.90	0.71	0.15	8.55	2.66	*99.52*	2.98	63.50	66.23	64.72	38.32	83.84	28.13
	Saprolite	KW-36	1.94	4.79	17.01	56.08	0.19	1.41	8.46	0.39	0.16	7.94	1.46	*99.83*	3.30	59.03	62.06	60.00	37.34	79.21	26.96
	Saprock	KW-35	2.51	4.58	16.75	56.42	0.21	1.39	7.18	0.56	0.14	8.00	2.13	*99.87*	3.37	60.19	63.35	61.32	38.12	76.34	28.33
	Saprock	KW-37	1.54	6.20	15.30	56.26	0.21	1.73	7.77	0.69	0.17	8.51	1.42	*99.79*	3.68	58.10	62.18	59.33	46.00	81.84	26.62
	Saprock	KW-40	2.02	5.77	15.30	55.44	0.19	1.56	8.89	0.62	0.15	8.23	1.65	*99.81*	3.62	55.11	58.38	55.76	40.16	79.66	24.95
	Saprock	KW-45	1.98	4.70	16.26	56.14	0.20	1.30	9.29	0.47	0.15	8.16	1.19	*99.85*	3.45	56.38	59.05	57.02	34.73	79.64	26.01
	Saprock	KW-44	2.26	5.08	16.03	55.86	0.22	1.47	8.88	0.65	0.15	8.51	0.70	*99.83*	3.49	55.96	58.98	56.64	37.03	78.46	25.61
	Fresh rock	KW-43	2.04	5.16	15.95	56.64	0.23	1.58	8.72	0.57	0.15	8.31	0.55	*99.89*	3.55	56.39	59.73	57.20	38.53	38.53	26.25
	Fresh rock	KW-39	2.40	5.56	15.32	56.45	0.20	1.63	8.64	0.66	0.15	8.31	0.56	*99.87*	3.69	54.72	58.11	55.34	39.44	39.44	25.38

LOI: Loss on ignition (%), **Ro:** Ruxton rate, **CIA:** Chemical index of alteration, **CIW:** Chemical index of weathering, **PIA:** Plagioclase index of alteration, **AI:** Ishikawa Alteration index, **CCPI:** Chlorite- Carbonate-Pyrite index, **AAAI:** Advance argillic alteration index.

Table 2- Weathering parameters and optimum values used in this study.

Parameters	Formula	Optimum values F	Optimum values W	Reference
Ruxton rate (Ro)	SiO_2/Al_2O_3	10	0	*Ruxton (1986)*
Chemical index of alteration (CIA)	$100*[Al_2O_3 / (Al_2O_3 + CaO + Na_2O + K_2O)]$	≤50	100	*Nesbitt and Young (1982)*
Chemical index of weathering (CIW)	$100*[Al_2O_3 / (Al_2O_3 + CaO + Na_2O)]$	≤50	100	*Harnois (1988)*
Plagioclase index of alteration (PIA)	$100*[(Al_2O_3-K_2O)/(Al_2O_3+CaO+Na_2O-K_2O)]$	≤50	100	*Fedo et al (1995)*
Ishikawa Alteration index (AI)	$100*[K_2O+MgO)/(K_2O+MgO+Na_2O+CaO)]$	20-65	>60	*Ishikawa et al (1976)*
Chlorite- Carbonate-Pyrite index (CCPI)	$100*[(MgO+FeO)/(MgO+FeO+Na_2O+K_2O)]$	15-85	>65	*Large et al (2001)*
Advance argillic alteration index (AAAI)	$100*[(SiO_2)/(SiO_2+10MgO+10CaO+10Na_2O)]$	20-60	>60	*Willians and Davidson (2004)*

F: Fresh rock, **W:** weathered rock.

5. Discussion

Strandja (Yıldız) Mountain, is one of Turkey's most heavily forested region, is an important area to examine the alteration characteristics of crystalline rocks. In this study, the Late Cretaceous - aged granodiorite and diorite of the DIB were distinctively selected, the weathering products, differences of same - aged rocks and two different compositions derived from the same source were tried to be determined. For this purpose, detailed mineralogical, petrographic and chemical analyzes of the sections selected from the areas where both rock units weathered and altered (Figure 2). As a result of the analysis, it is seen that the chemical index of alteration (CIA) and chemical index of weathering (CIW) values increase from depth to surface. Likewise, it is seen that the loss on ignition (LOI) values increase at different rates in all levels of both rock units from depth to surface. Since granodiorite compositional rock contains more K - feldspar, it can be concluded that it is more decomposed than quartz diorite and has a higher LOI value (Table 1 and Figure 6). Samples were collected

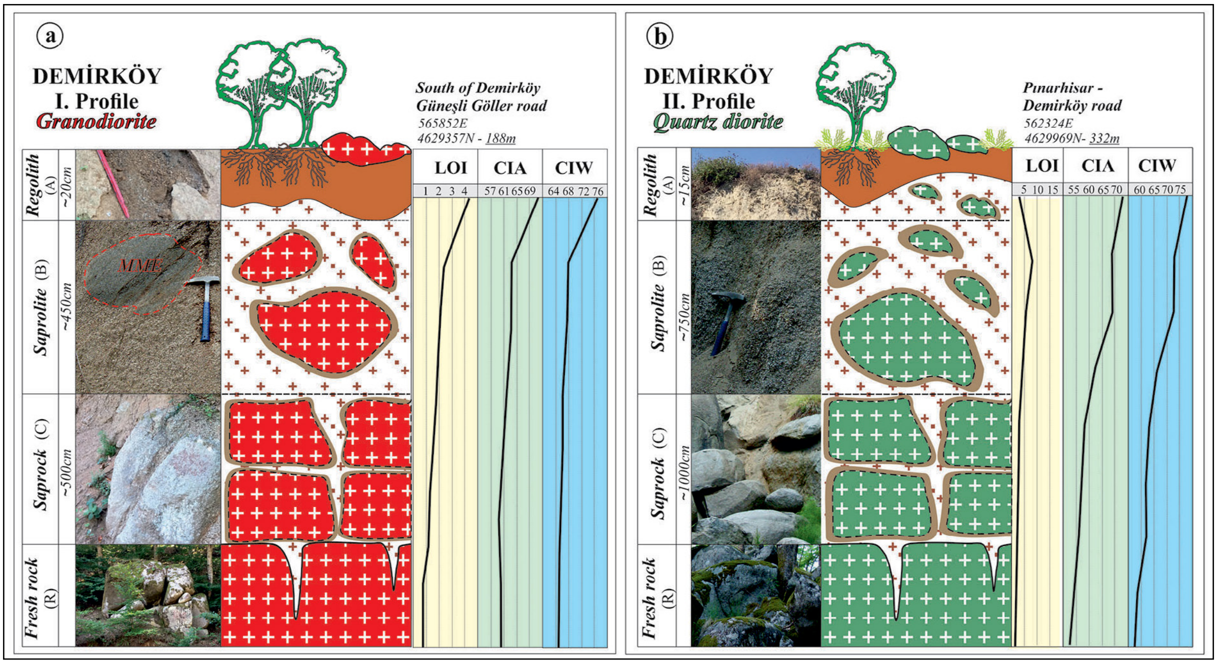

Figure 6- Samples were collected from: a) The vertical profile line of the granodiorite and the change in loss on ignition (LOI), chemical index of alteration (CIA), chemical index of weathering (CIW) parameters from the surface to the fresh rock; b) Vertical profile line of quartz diorite and change in loss on ignition (LOI), chemical index of alteration (CIA), chemical index of weathering (CIW) parameters from the surface to fresh rock. (A, B, C, R soil horizons, Hillel, 1998).

from regolith, saprolite and saprock, respectively, along both profiles, and XRD analyzes were performed and compared (Figures 4 and 5).

According to the detailed clay analysis (XRD) results; clay mineral association observed in profiles belonging to both rock groups are illite±kaoline+smectite+chlorite+chlorite/vermiculite. From this point of view, vermiculite and smectite are formed because of textural breakdown of the rock (Figure 5). Illite and chlorite are predominant in the weathering products of the granodiorite profile I, whereas in the weathering products of the quartz diorite profile II, there is a proportional increase in the amount of smectite - vermiculite in addition to illite and chlorite (Figure 5).

Multi element variation diagrams were drawn by dividing the main element analysis results of each unit into fresh rock values in order to reveal the behavioral and compositional differences of regolith, saprolite and saprock units formed as a result of weathering according to source rocks (host rock) (Figure 7). Regolith products in the granodiorite profile are depleted in terms of CaO%, MgO% and MnO% elements as a result of washing, and on the other hand, an increase in clay content and an enrichment in Al_2O_3% is observed. As a result of the decomposition in saprolite and saprock products of the same rock, it is seen that there is a decrease in Fe_2O_3%, MgO%, P_2O_5%, TiO_2% and MnO% values. On the other hand, regolith products in the quartz diorite profile become depleted in terms of Na_2O%, CaO%, MgO%, P_2O_5% and MnO% elements as a result of washing, and the Al_2O_3% value is enriched due to the increase in the clay content ratio. When the weathering rates of both units are compared, it can be said that the quartz diorite undergoes less alteration and weathering compared to the granodiorite (Figure 6). As a result of the decomposition of both rock units, a significant change was observed in the total Al_2O_3% and % LOI values (Table 1). Variation diagrams were drawn separately (SiO_2 + Na_2O + K_2O + CaO)% versus % LOI and Al_2O_3% values to reveal the alteration boundaries based on the change rates of these elements (Figures 8a and b).

Accordingly, in regolith, saprolite and saprock, it is possible to show the discrimination areas in which loss on ignition rates show a significant change with a clear line interval depending on the LOI% values (Figure 8a). Thus, it is possible to separate

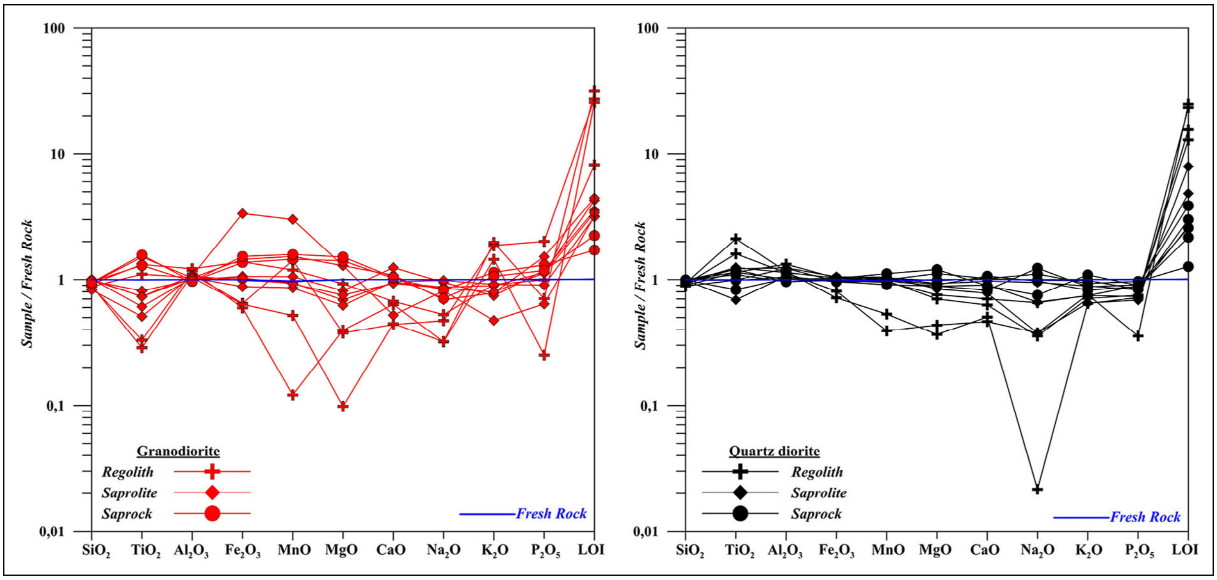

Figure 7- % Major oxide change diagram normalized to fresh rock values of weathering zones of granodiorite and quartz diorite sections.

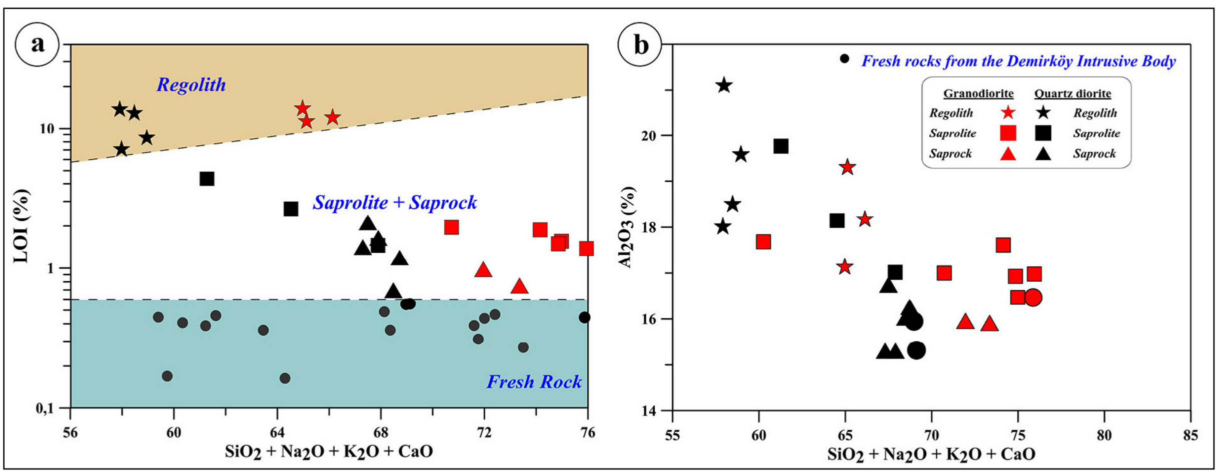

Figure 8- In the rock groups belonging to the study area; a) The change of the (SiO_2+Na_2O+K_2O+CaO)% major oxide total according to the LOI% value, b) The change of the sum of the (SiO_2+Na_2O+K_2O+CaO)% major oxide elements according to the Al_2O_3 value.

the boundaries of regolith and saprolite - saprock from fresh rock by using (SiO_2+Na_2O+K_2O+CaO)% values against LOI%. On the other hand, since both rock groups contain different amounts of clay due to weathering, a distinct boundary of differentiation was not determined in the Al_2O_3% variation diagram (SiO_2+Na_2O+K_2O+CaO) (Figure 8b).

In order to determine the alteration degree of the rocks, they were evaluated according to the chemical analysis results on the ACNK diagram (Figure 9a). According to the ACNK diagram, saprock samples belonging to granodiorite and quartz diorite profiles are observed in transition to slightly and medium altered rock area. Regolith samples that are assumed to fall into the highly altered rock area, fall into the moderately altered rock area, probably due to washing. In the change of the rate of loss on ignition versus the plagioclase weathering index; It is observed that the arenization tendency of the samples increased parallel to the increasing segregation (Figure 9b).

In order to distinguish whether alteration is diagenetic or hydrothermal (Large et al., 2001), alteration index variation diagrams versus CCP (chlorite - carbonate - pyrite) index were drawn

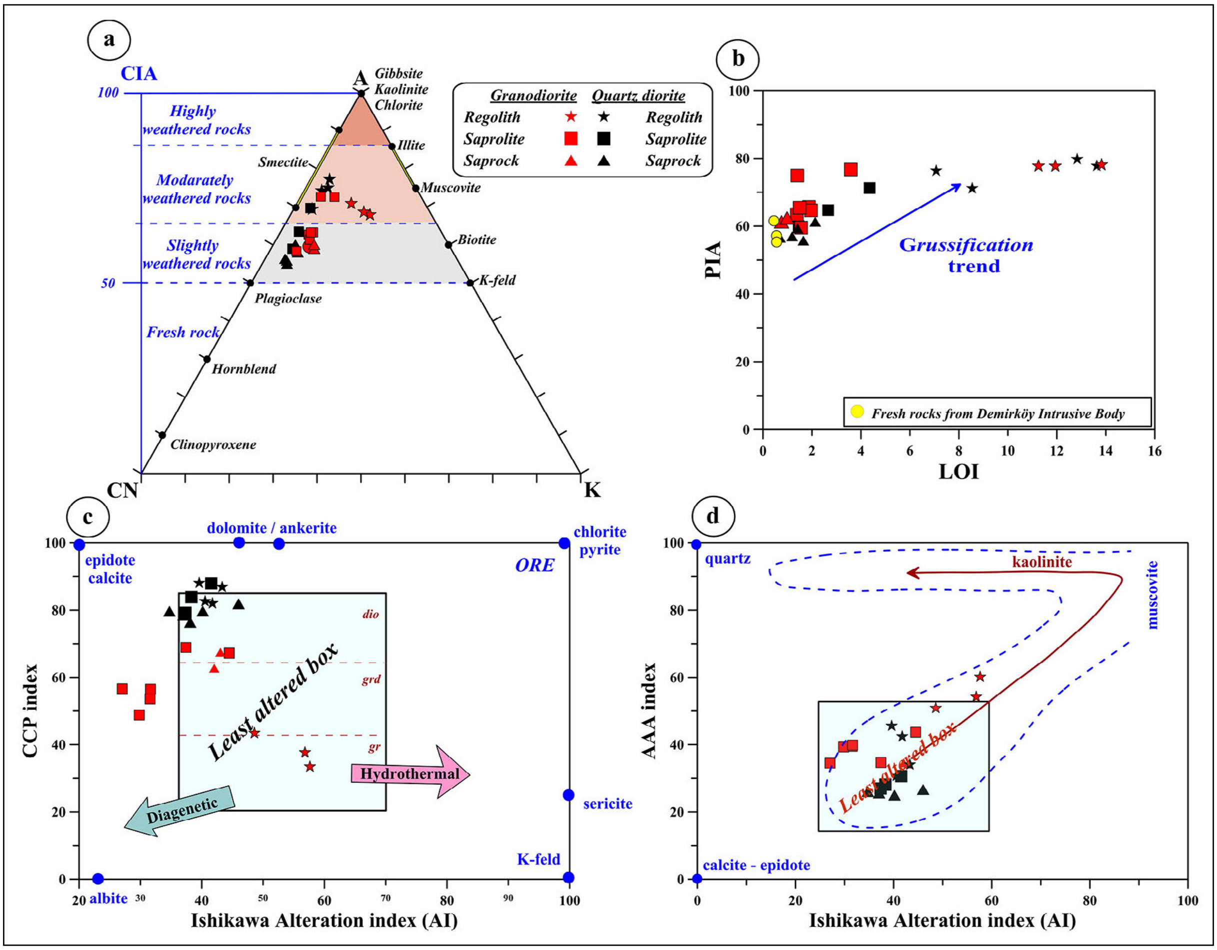

Figure 9- a) The distribution of samples in the ACNK diagram and their classification according to the CIA value (Nesbitt and Young, 1982), b) the variation diagram according to the loss on ignition value versus the plagioclase decomposition index (Fedo et al, 1995), c) Distribution of the samples relative to the box plot in the CCP (calcite-chlorite-pyrite) index versus alteration index (Large et al., 2001), d) Distribution of the samples relative to the box plot in the alteration index change versus the advanced argillic alteration index (AAAI) (Williams and Davidson, 2004).

(Figure 9c). According to this diagram; It has been demonstrated that the alteration properties of the samples collected from the DIB are not hydrothermal in general, but tend towards albite, calcite - epidote and are due to diagenetic alteration. Alteration index (AI) is accepted between 20 - 60 for fresh rocks, and when it is more than 50, it is accepted that the effect of hydrothermal alteration begins. In field observations, metasomatic effect and hot fluid - relatedmalachite - azurite - pyrite formations (Fe, Cu enrichments) are observed at the contact and close to the contact of granitic and granodioritic rocks. In Figure 9c, the discordant position of the granodiorite in regoliths was formed as a result of the metasomatic effects. Figure 9d shows that the distinct tendency of rock groups to become clay at the regolith level may be related to the increase in the Al_2O_3 ratio. This relationship has emerged as a result of the increase in the ratio of clay content at these levels and the decrease in quartz and other mineral ratios in the rocks.

6. Conclusion

Crystalline rocks can undergo significant changes due to atmospheric and hydrothermal factors. These changes are significantly related to the primary composition of the rocks as well as the degree of weathering. Strandja Massif, is part of Turkey's tectonic units which lies through the East Europe, separated from Pontides with West Black Sea Fault. Alteration may caused due to faulting and magmatic intrusions within the tectonic unit. At the same time, weathering occurs depending on the changes in climatic conditions. In this study, granodioritic and quartz dioritic rocks in the DIB within the Stranja Massif, outcropped in the Strandja (Yıldız) mountain range. The alteration of two different rock units from the surface to the depth was investigated mineralogically, petrographically and geochemically, and their weathering features and genesis were determined. The alteration degrees of two different rock units belonging to the same intrusive body and the different weathering products were determined. The weathering lithologies of both rock units are divided into 3 different levels as regolith, saprolite and saprock, they were mineralogically and chemically investigated. Regolith, saprolite - saprock and fresh rock boundaries are determined based on LOI% versus (SiO_2+Na_2O+K_2O+CaO)% values of both rock units. While the weathering products of the granodiorite mostly are illite and chlorite - type clay, smectite and vermiculite - type clay are also observed in quartz diorite. It was determined that both rock units were generally altered as a result of diagenetic alteration, and did not show any metal - bearing alteration due to hydrothermal alteration. There is a weak hydrothermal effect at the regolith levels, and it is thought that this may occur as a result of the combination of the transported products with the advanced alteration due to effects of metasomatism and hydrothermal fluids. Agriculturally, it has been determined that the regolith products formed by the weathering of the granodiorite are richer in K_2O% content and quartz compared to quartz diorite and are efficient due to their sandy texture.

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