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GEOCHEMICAL PROPERTIES AND GENETICAL INTERPRETATION OF THE CENTRAL SAKARYA REGION GRANITOID BELT

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ABSTRACT

The investigated area is situated in the middle western Anatolia approximately 50 kilometres to the north of Eskişehir, and extends at E-W direction from Sarıcakaya (Eskişehir) town to Çaltı (Bilecik) village. The oldest lithological type in the investigated area is Paleozoic aged metamorphic rocks. The different type of rocks which are characterized by blueschist, greenschist and contact metamorphic facies,

The igneous rocks in the granitoid belt are named as quartzdiorite, granodiorite, adamellite and calc-alkaline granite. The mineralogy consist of quartz, orthose, microcline, oligoclase, biotite, hornblende and minor zirkon, sphene, apatite, opaque minerals chlorite, serisite and calcite. These granodiorites and quartzdiorites, however, are traversed by numerous veins of pegmatite, aplite. These pegmatites have pink coloured alkaline feldspar and quartz in large quantities.. The Na' rich pegmatitites also occur in the regional metamorphic rocks.

In this study, the petrographical, mineralogical, chemical and geochemical properties of the igneous rocks have been researched. In addition, some samples have been collected and studied in thin section to research the petrographical properties. According to the mineralogical, petrographical, geochemical properties and some trace elements results, the igneous rocks are characterized I-type, volcanic arg (VAG) granitoid

Key words: Granitoid belt, Greenschist, Pegmatite, I-type granitoid,

ORTA SAKARYA HAVZASINDAKİ GRANİTOİD KUŞAĞININ JEOKİMYASAL ÖZELLİKLERİ VE KÖKENSEL YORUMU

ÖZET

İnceleme alanı,iç batı Anadolu'da, Eskişehir'in yaklaşık 50 km kuzeyinde yer almakta ve D-B istikametinde Sarıcakaya'dan (Eskişehir) Çaltı (Bilecik) köyüne kadar uzanmaktadır. İnceleme alanamda en yaşlı litolojik kayaç birimi alt Paleozoyik yaşlı başkalaşım kayaçlarıdır. Bu kayaçlar mavişist, yeşilşist ve değme başkalaşım fasiyeslerini karakterize eder.

Granitoid kuşağında yer alan bu derinlik kayaçları; kuvarsdiyorit, granodiyorit, adamellit ve kalkoalkalen granit şeklinde isimlendirilmiştir. .Mineralojik bileşimlerinde; kuvars, ortoz, mikroklin, oligoklas, biyotit, hornblend, zirkon, sfen, apatit, opak mineraller, klorit, serisit ve kalsit bulunur. Granodiyorit ve kuvarsdiyorit pegmatit ve aplit damarları tarafından çeşitli doğrultularda kesilmektedir. Pegmatitler bol oranda pembe renkli alkalen feldspat ve kuvars içerirler. Sodyumca zengin pegmatitler ise, bölgesel başkalaşım kayaçlarının şistozite düzlemlerine uyumlu olarak yerleşmişlerdir.

Bu çalışmada, derinlik kayaçlarının petrografik, mineralojik, kimyasal ve jeokimyasal özellikleri araştırılmıştır. İlave olarak, petrografik özelliklerinin detayına araştırılması için örnekler şeçilmiş ve incekesitleri üzerinde çalışılmıştır. Mineralojik, petrografik, jeokimyasal incelemeler ve bazı iz element sonuçlarına göre, granitoid kuşağı, I-tipi, volkanik yay (VAG) granitoidlerinin özelliklerini karakterize etmektedir.

Anahtar Kelimeler: Granitoid kuşağı, Yeşilşist, Pegmatit, I-tipi granitoid

1 . INTRODUCTION

The central Sakarya region granitoid belt's rocks are composed of four major different igneous suites- quartzdiorite **(Pzdi),** granodiorite **(Pzgd),** quartzmonzonite and calc-alkaline granite **(Pzgr)-** They cover in area of approximately 80 square kilometres. These rocks are situated in the central Sakarya region. Some of the granodiorites and quartzdiorites, quartzmonzonites and calc-alkaline granites extend to the north of the Sakarya River. The granitoid belt is located along the Sakarya River at the west of the Alpagut village and extends at the south of the Sakarya River, from Inhisar to Tuzaklı and Küplü villages (Fig..1-2-3).

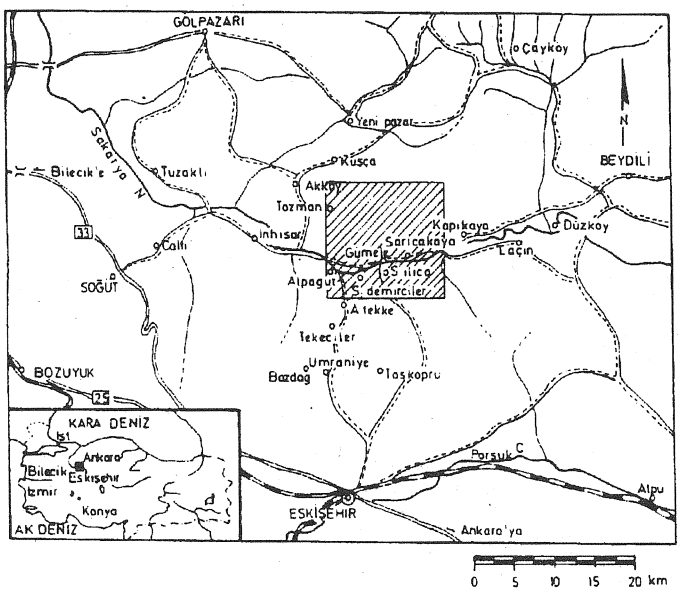

Figure 1. Location map.

This study includes the geological, mineralogical, petrographical, chemical and geochemical properties of the granitoid belt, at the 1/25.000 scaled ADAPAZARI H-24 c_3, H-24 c_4, H-25 d_3, and H-25 d_4 topographic maps.

The only ADAPAZARI H-25 d_4 topographic map work has been realized by Kibici [5] in the Ph.D. programme, from 1977 to 1982. During this period, an area of approximately 150 square kilometres has been investigated in the scale of 1/25.000. The granitoid belt has been restudied in detail, (including ADAPAZARI. H-24 c_3, H-24 c_4, H-25 d_3 and H-24 d_4 topographic maps) by the authors.in recent years The samples for chemical and geochemical analyses have also been selected during this work.

The laboratory work consist mainly of preparetion and determination of thin section. The interpretation has been based on more than 150 thin sections. In addition, major and some trace element's chemical analyses are made on eleven samples of the igneous rocks and four samples of pegmatites

This paper discusses aspects of the field geology (in scale of 1/25.000 and 1/100.000), petrology, petrography geochemisty and the origin of the granitoid belt. Although small portions of the area were studied for different

purpose previously by Kupfahl [1], Çoğulu [2], Altınlı [3,4], Kibici [5], Kibici and Vıcıl [6] Kibici [7].

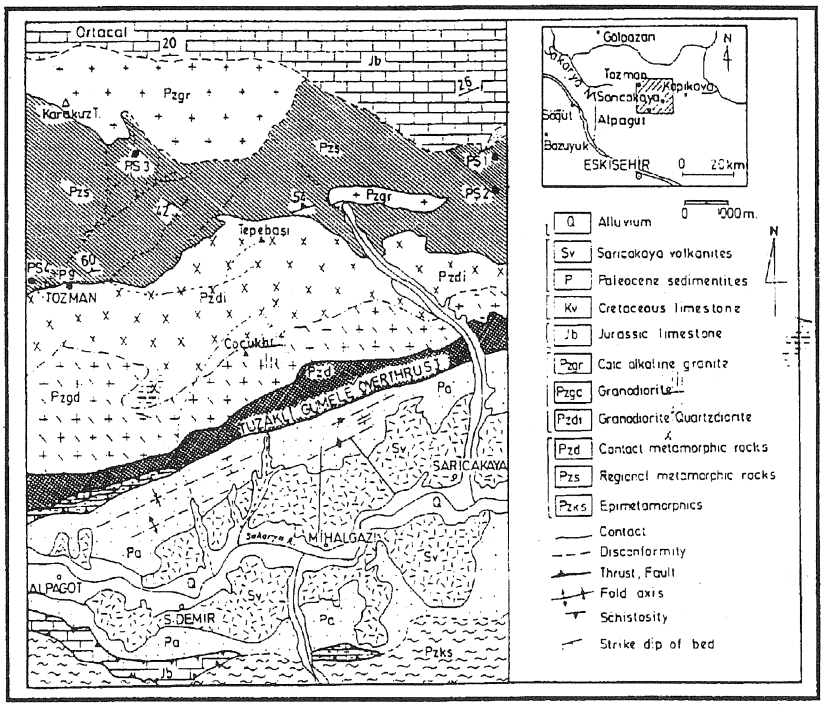

Figure 2. Geological map of the study area, Simplified from Kibici[5]

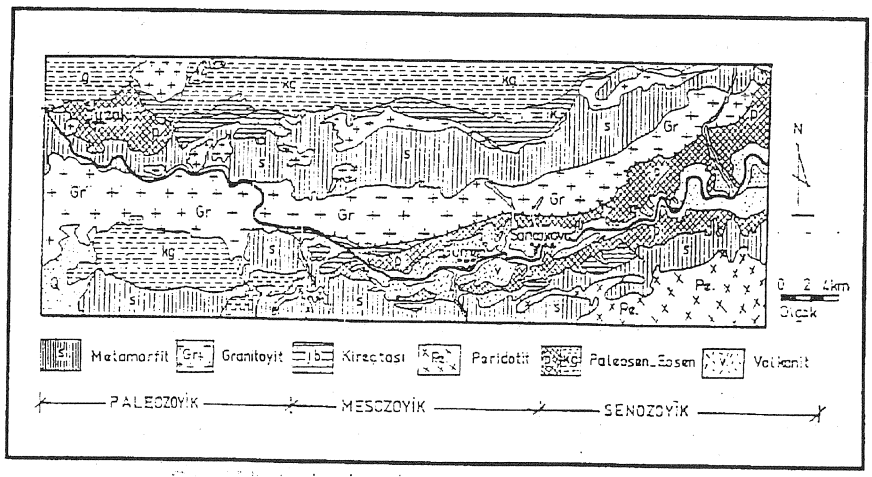

Figure 3. Regional geological map. Simplified from Altınlı [3]

2. GENERAL GEOLOGY

** Metamorphic Rocks

The oldest lithologic unit in the investigated area is the lower Paleozoic aged metamorphic rocks, are accepted in the **Karakaya Formation** [8], (Fig. 4). Three different type of the metamorphic rock groups have been distinguished by using their index minerals. The metamorphic assemblages of these rocks represent three different metamorphic conditions of formation and they show different structure and texture. These rock groups are listed from the low to high temperature rocks, as follows;

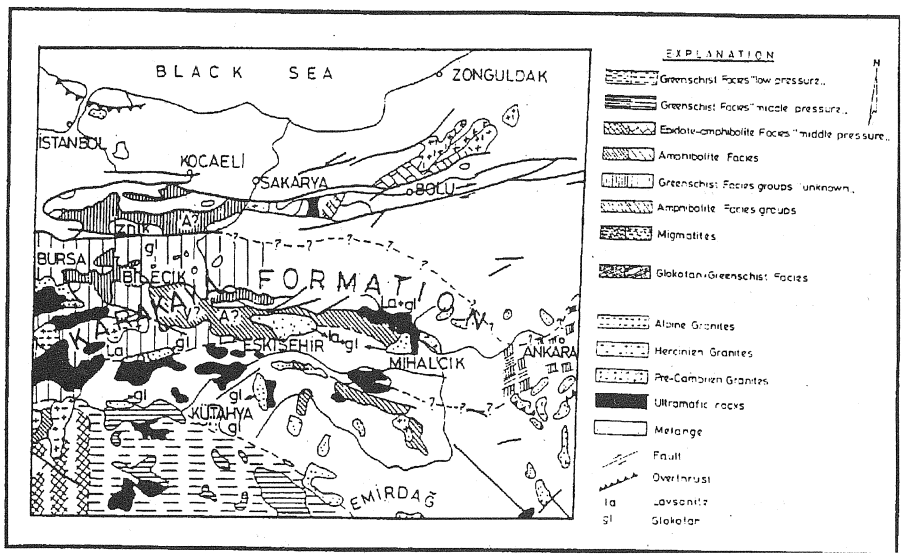

Figure 4. Metamorphic rocks and facies map- Simplified from Bingöl [8]

a. The low grade metamophites which were occured in the south of Sakarya River, consist mainly of biotiteschist, chloriteschist, sericiteschist, graphiteschist and metabasites. They represent the blueschist facies rocks The schistosity of these metamorphites are ENE-WSW.

b. The regional metamorphic rocks lying in E-W direction in the north of granodiorites, characterized Barrow type metamorphism They are identified by green schist facies. These rocks are composed of garnet schist, biotite schist, chloriteschist and sericiteschist. They are named by their index minerals[9].

The white pegmatite veins are parallel to the schistosity planes. of these metamorphic rocks This occurence extends from East to West in three different direction [2]. The mineralogy consist mainly of alkaline feldspar (orthoclase, microcline), plagioclase (albite, oligoclase), quartz and minor biotite, garnet as primary mineral, epidote, chlorite and calcite as secondary minerals. In addition, they have paragonite, large amount of the muscovite, turmaline and vermiculite.

c. The contact metamorphic rocks are different from the other metamorphic rocks. These rocks are composed of amphibolites, sillimanitschist, garnetschist and hornfels. Most of the contact metamorphic rocks are squezed in between *Tuzaklı - Gümele Overthrust Line* and granodiorites in the form of narrow band. Also, the contact metamorphic rocks present in the north of quartzdiorites, around of the calc-alkaline granites and quartzmonzonites (adamellites), contain sillimanite and biotite in large quantites and some garnets. The contact metamorphic rocks have massive structure. They are not foliated and fresh. The origin of the regional and contact metamorphic rocks are detritic sedimentary rocks [5].

** Igneous Rocks

Their age is accepted as Carboniferous and they cut lower Paleozoic aged metamorphic rocks [4]. The rocks of the granitoid belt cropp out in the central Sakarya region. The igneous rocks are further divided into four groups. The predominant rock types in the granitoid belt show a variety quartzmonzonite (adamellite) and calc-alkaline granite, and can be distinguished from others by grain size, colour and texture.

The mineralogical and petrographical properties are studied. In order to explain the petrographical properties of the igneous rocks, 150 thin section have been investigated. As a conclution of this investigation, these rocks consist mainly of quartz, alkaline feldspar (ortoclase, microcline) plagioclase (albite, oligoclase), biotite, hornblende, epidote and minor zircon, sphene,apatite, opaque minerals as primary minerals; chlorite, sericite, calcite as secondary minerals. Felsic minerals decrease whereas mafic minerals increase towards the quartzdiorite **(Pzdi).** On the other hand, they show different structure and texture, according to the amount of the different felsic and mafic minerals contents. These rocks are listed from the oldest to youngest as follows; quartzdiorite **(Pzdi),** granodiorite **(Pzgd),**

quartzmonzonite (adamellite) and calc-alkaline granite **(Pzgr).** The passage from calc-alkaline granite to quartzdiorite is gradual. Granodiorite is usually closer to quartzdiorite (Fig. 5- 6-7-8).

The petrographical and petrochemical investigation shows that, these rocks characterize Mesozone granite and Pasific type magma. The igneous rocks are products of calc-alkaline,acid magma resulted from normal differantiation. They were derived from Sial origin. There is only one type magmatic intrusion [9]

The granodiorite and quartzdiorite are traversed by numerous veins of pegmatite and aplite in different direction. Especially, the amount of pegmatite and aplite veins increase in the granodiorites. The pegmatite, that occur in the granodiorites and quarzdiorites, has pink coloured alkaline feldspar and quartz in large quantites. The igneous rocks which are cropped out in the investigated area, have joint systems in two directions. The joint systems and fractures were formed to cooling of the magmatic body during the granitoid belt emplacement.

The size of the pegmatite veins depend on the continuity of fracture. The thickness of these veins varies between 10 cm - 40 cm. Especially, the aplite veins were occured east of the Tozman village. The aplites and quartz veins cut the quartzdiorite The quartz veins have some ore minerals as antimonite, pyrite, arsenopyrite [6]. They trend E-W direction whereas the aplite veins are at different strike.

The microscobic investigation shows that, pegmatites consist mainly of alkaline feldspar (orthoclase, microcline), plagioclase (albite, oligoclase), quartz and minor biotite, muscovite, apatite as primary minerals, chlorite and calcite as secondary minerals.

** Sedimentary Rocks

Calc-alkaline granites and regional metamorphic rocks are overlain by unconformity arkose and sandstone. On the top of these, there are Jurassic limestone. Cretaceous limestones and Jurassic limestones at the overthrust line and in the south of Sakarya River occured a klippe as a result of overthrust over the Paleozoic and Paleogene series. Jurassic and Cretaceous limestones are mostly crushed. The Jurassic limestones are concordant with the sandstone and arkose present at the bottom [4,5]

Conglomerate-sandstone-claystone-marn sequence of Paleogene series occur to the south of the *Tuzaklı-Gümele Overthrust.* The series is named as *Mihalgazi Formation.* These series are covered by Eocene andesities lavas These andesites were product of calc-alkaline and Pasific type magma of the Sial origin. Andesites were in two or more stages. They are rich in K_2O [5,10]

The Quaternary aged conglomerates overlain the andesites as a thin layer in some direction such as west of the Sakarı Ilıca village.The Quaternary aged terraces which are extended along the Sakarya River, are seen. These terraces can be observed in the stream beds in E-W direction.

The most important tectonic unit of the investigated area is Tuzaklı-Gümele Overthrust. As a result of Alpin orogenesis, the rocks of the granitoid belt, regional and metamophic rocks, Jurassic limestones and Cretaceous limestones were thrusted over the Paleogene series. The tectonic line is in ENE-WSW strike.

Another tectonic lines are some small scale faults. They are resulted by the Alpin Orogenesis. These faults are normal and strike slip faults. They can be observed around Mihalgazi and Bozaniç villages.

3. THE GEOCHEMICAL PROPERTIES OF THE GRANITOID

In this paper, the outer will attent to show that the mineralogy and geochemistry of the igneous rocks can be succesfully used to characterize the genetical interpretation.

Eleven rock chip samples have been collected from the different igneous rocks of the central Sakarya region from outcrops and road cuts. Rock samples generally were fresh without any obvious surface weathering. Sample powders were pelletized and analyzed by X-ray flouresance for trace elements (Table 1) using ARL 8420 spectrometer. Instruments setting and procedures described by Dr. John A. Winchester in the Keele University.

Sr has a slightly greater ionic radius than Ca. During late magmatic differantiation culminating in hydrothermal processes [11]. Sr is depleted

relative to Ca. Thus, the geochemical behavior of Rb and Sr indicates that they have a greater sensitivity to magmatic processes than K and Ca [12].

Table 1. Major and trace element analyses results of the igneous rocks in the study area

	Pzdi-11	Pzdi-12	Pzgd-1	Pzgd-2	Pzgd-3	Pzgd-4	Pzgr-1	Pzgr-5	Pzgr-7	Pzgr-8	Pzgr-9
SiO_2	58.90	58.55	61.75	61.56	60.05	60.34	73.28	74.96	74.38	74.09	76.57
TiO_2	0,65	0,82	0,64	0,72	0,69	0,79	0,21	0,16	0,20	0,18	0,16
Al_2O_3	17,36	18,95	16,85	16,60	17,23	16,34	14,54	13,49	14,16	13,72	12,55
Fe_2O_3T	6,72	6,94	5,77	6,22	6,37	6,78	1,98	1,93	1,98	2,12	1,90
MnO	0,11	0,11	0,10	0,10	0,11	0,11	0,05	0,05	0,04	0,06	0,04
MgO	3,33	3,07	2,77	2,98	3,09	3,20	0,24	0,25	0,30	0,30	0,17
CaO	6,51	6,33	5,18	5,02	6,39	5,85	1,30	1,31	1,36	1,01	0,48
Na_2O	2,67	2,67	3,02	2,81	2,65	2,86	3,79	3,46	3,88	3,82	3,57
K_2O	1,51	1,15	1,99	2,18	1,92	1,81	3,98	4,02	3,56	3,69	3,56
P_2O_5	0,10	0,13	0,10	0,11	0,11	0,12	0,03	0,03	0,03	0,03	0,02
LOI	3,00	3,39	2,12	1,61	1,55	2,23	0,66	0,57	0,62	0,84	0,84
Total	99,87	100,12	100,30	99,90	100,16	100,44	100,06	100,23	100,51	99,98	99,86
Cr	45	39	30	32	37	42	12	10	16	15	18
Cu	12	16	11	13	10	13	0	1	0	0	0
Ga	19	20	21	17	18	19	17	17	18	18	17
Nb	9	10	8	9	8	11	7	8	7	8	7
Ni	9	9	8	8	8	9	2	1	3	2	1
Pb	14	9	15	14	14	13	17	19	20	19	13
Rb	56	82	73	81	71	70	140	142	124	135	141
Sr	309	265	249	251	267	221	102	98	120	116	68
Th	24	0	7	0	0	0	5	12	9	9	9
V	179	158	136	133	135	151	7	13	4	11	5
Y	27	26	21	23	24	30	17	25	21	26	22
Zn	67	72	62	66	68	71	38	39	38	44	22
Zr	105	105	105	114	118	119	99	104	104	115	101
Ba	416	706	553	577	506	490	636	681	694	653	397
Ce	93	36	48	36	29	23	34	36	29	40	45
Nd	24	26	25	31	21	11	18	12	19	23	21

Our investigation shows that the igneous rocks of the study area have high concentration of K, Rb, Sr, Ba, Zr, Nb, Th, Rb/Sr, and a low concentration of K/Rb and Sr/Ba. According to the CaO-Na_2O-K_2O triangle diagrams, the igneous rocks occur in the granite, alkalen granite, adamellite, granodiorite, diorite and tonalite area. The passage is gradual (Fig.5). In addition, Nb/Y - Zr/TiO_2, Ga-Zr/TiO_2 and Nb/Y- SiO_2 diagrams show the similar properties for these rocks (Fig. 6-7-8).

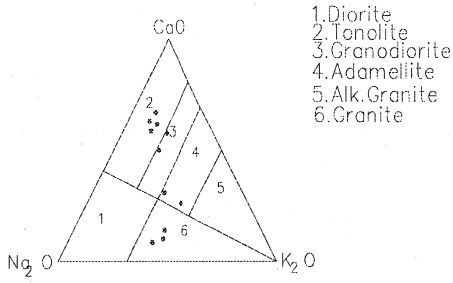

Figure 5. CaO-Na_2O-K_2O diagram of Ingeneous rocks in the investigated area

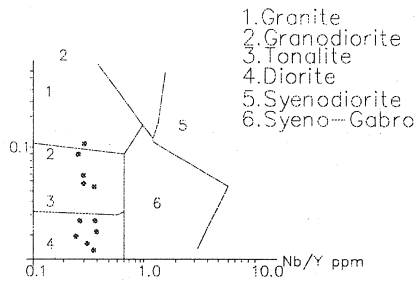

Figure 6. Nb/Y-Zr/TiO_2 diagram of Ingeneous rocks in the investigated area

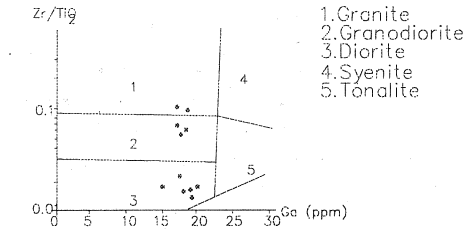

Figure 7. Ga-Zr/TiO_2 diagram of Ingeneous rocks in the investigated area

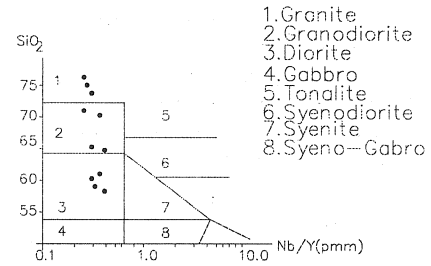

Figure 8. Nb/Y-SiO_2 diagram of Ingeneous rocks in the investigated area

** Genetical interpretation of the granitoid

The discrimination of the igneous rocks are based on the major and minor element chemistry. Various discrimination plots are presented in illustrating the different tectonic environments.

Granitoids maybe subdivided according to their intrusive setting into four main groups- *ocean ridge granitoids* (ORG), *volcanic arc granitoids* (VAG), *within plate granitoids* (WPG) and *collision granitoids* (COLG) - and the granitoids within each group maybe further subdivided according to their precise setting and petrographical characteristics [13].

Discrimination of *ORG, VAG, WPG* and *COLG* is most effective in (Y-Nb)-Rb and (Yb-Ta)-Rb space, particulary on projections of Yb-Nb, Yb-Ta. Discrimination boundaries, though drawn empirically, can be shown by

geochemical modelling to have a theoretical basis in the different petrographic histories of various granitoids [13].

The mineralogical and major element classification generally make poor discriminants because they rely on only a few variables, none chosen for the purpose of the tectonic classification. The classification into *S-type, I-type, A-type, and M-type* granitoids is difficult to apply because there are no well-defined boundries between these granitoid types.

Chappell and White [14] proposed a genetic subdivision of granitoid's rocks into those extracted from igneous protolits. (I-type) and those extracted from sedimentary protolits (S-type).

A quite different type of granitoid classification can be constructed in analysing the large number of chemical analyses of granitoids from the well-defined tectonic setting [13].

The granitoid belt in central Sakarya region is related to calc-alkaline magma. It changed from Atlantic type of magma to Pasific type magma along with north Anatolian fault.According to their occurence, the granitoid in the investigated areaare similer to Gümüshane and Rize plütons [15,16].

The Pontids (Rhodop-Pontid segments and Sakarya continent) is one of the very rare occurence in the world. The volcanic arg granitoid (VAG) which is related with subduction zone, derived from on the Atlantic type continent of sedimentary [17].

Our study shows that, the igneous rocks (quartzdiorite aaand granodiorite) are volcanic arc granitoids (VAG) and syn-COLG granitoids (calc-alkaline granite and quartzmonzonites). These rocks can vary in setting calc-alkaline according to chemical properties, plotting diagrams and geochemical analysis results (Fig.9)

The granitoids from the volcanic arc setting vary significantly and systematically in their major elements and mineralogical characteristics. The igneous rocks predominantly in the granite, adamellite, granodiorite, diorite, and tonalite fields on diagram, have hornblende as principal ferro-magnesian mineral. This mineral related to I-type granitoid in the investigated area.

Granitoids have hornblende and biotite as their characteristic ferro-magnesian mineral and generally belong to *"calc-alkaline"* [13]. According to petrographical investigation; biotite hornblende, epidote; minör sphene, zircon, apatite, opaque minerals have occured in the igneous rocks as a primary minerals.

It is necessery to know the mineral paragenesis in the rocks in order to distinguish I-type or S-type granitoids. The occurence of the biotite, hornblende, small amount of sphene, apatite and zircon is a good indicator for I-type granitoids. The garnet minerals and cordierite may occur in the S-type granitoids. Our investigation area of igneous rocks have no garnet and cordierite minerals. It represents I-type granitoids. If the granitoids have some basic origin enclaves. They must be I-type granitoids. The igneous rocks of the central Sakarya Region include also enclaves at the west of Igdır village.

Pearce et al. [13] have proposed a tectonic classification of granitoids based on discrimination diagram using Rb, Y, Nb, Yb and Ta data. Plots of our data- which are taken from the investigated area- on their (Y+ Nb) - Rb and Y - Nb diagrams show that most of the samples- belong to this study- are clearly classified as volcanic arc granitoid (Fig.10-11).

4. CONCLUSION

The petrographical, petrological, mineralogical chemical and geochemical properties of the igneous rocks have been studied.
One hundred and fifty samples (includes pegmatites) have been taken from different types of igneous rocks in the investigated area. Eleven samples were used for making chemical and geochemical analyses Some collected samples have been carried out in a research of the petrographical properties based on thin sections.

CaO-Na_2O-K_2O triangle diagram, Nb/Y - Zr/TiO_2, Ga - Zr/TiO_2 and Nb/Y-SiO_2 diagrams have been used in order to name all igneous rocks. According to these diagrams, the igneous rocks were named diorite, quartzdiorite, granodiorite, quartzmonzonite (adamellite), calc-alkaline granite. In addition, Fe_2O_3(tot)-(Na_2O+K_2O)-MgO triangle diagram has been prepared in order to explain the magma type. According to this result, the igneous rocks of central Sakarya region have the calc-alkaline character.

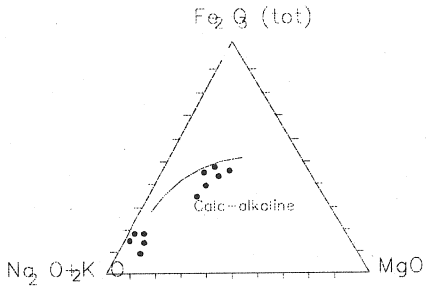

Figure 9. Fe_2O_3-(Na_2+K_2O)-MgO triangle diagram of Ingeneous rocks in central Sakarya region

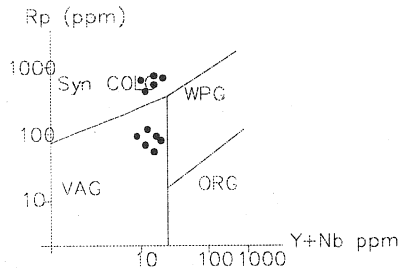

Figure 10. (Y+Nb)-Rb diagram of Ingeneous rocks

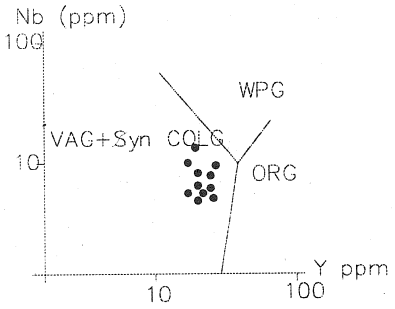

Figure 11. Y+Nb) diagram of Ingeneous rocks

The diagram of Y-Nb and (Y+Nb)-Rb have been used to explain the discrimination boundary ORG, VAG, WPG and COLG. As a result of this investigation, the igneous rocks which are located in the granitoid belt have same geochemical characteristics.

The igneous rocks show similarities to volcanic arc (VAG) granitoids.

The petrographical and petrochemical investigation shows that, these rocks characterize Mesozone granite and Pasific type magma. The granitoids were products of calc-alkaline, acid magma resulted from normal differantiation. They were derived from Sial origin.

5. ACKNOWLEDGEMENT

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