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# THE PETROLOGY OF ZIYARAN VOLCANIC BELT (ZVB) EOCENE VOLCANIC ROCKS

# PETROLOGIA DO CINTURÃO VULCÂNICO DE ZIYARAN (ZVB) ROCHAS VULCÂNICAS DO EOCENO

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## ABSTRACT

The Ziyaran Volcanic Belt (ZVB) is located in the southern part of central Alborz and in the Ziyaran area. The geology of this layer includes various kinds of stone units. In the north, they are the reminder of Cenozoic, quaternary deposits, and in the western part, the exposure stone units are mostly Precambrian and Paleozoic deposits and in the south-eastern part of the studied area, the stones belong to the Mesozoic era and specifically, the sediments belong to the Jurassic era are exposed. Also, the basic volcanic rocks that belong to the Eocene period are located in the Ziyaran area, in the western part of Taleqan County and in the Alborz state. This study aimed to evaluate the petrology of Ziyaran Volcanic Belt (ZVB) Eocene volcanic rocks. For this purpose, which is mostly focused on the study of Cretaceous stones in the central Alborz zone, sampling of the stones in the intended area was performed with the survey and field methods and for 120 samples. After the preparation of the thin layer from the well and without alteration samples, they were examined with petrography and petrology tests. The results of the petrology studies of the volcanic rocks of the Ziyaran area expressed that the basic volcanic rocks in the intermediate area with the intermediate-upper chemical composition of Eocene Alkaline Phosphatase (ALP) located in the central zone of Alborz heights, with lithology composition of Alkali olivine basalts and Andesite.

**KEYWORDS:** ZIYARAN VOLCANIC BELT (ZVB); CENTRAL ALBORZ; PETROLOGY; EOCENE.

## RESUMO

O Cinturão Vulcânico de Ziyaran (ZVB) está localizado na parte sul do centro de Alborz e na área de Ziyaran. A geologia desta camada inclui vários tipos de unidades de pedra. No norte, eles são a lembrança do Cenozóico, depósitos quaternários, e na parte ocidental, as unidades de pedras de exposição são principalmente depósitos pré-cambrianos e paleozóicos e na parte sudeste da área

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estudada, as pedras pertencem à era Mesozóica especificamente, os sedimentos pertencentes à era jurássica são expostos. Além disso, as rochas vulcânicas básicas que pertencem ao período Eoceno estão localizadas na área de Ziyaran, na parte ocidental do Condado de Taleqan e no estado de Alborz. Este estudo teve como objetivo avaliar a petrologia das rochas vulcânicas do Eoceno do Cinturão Vulcânico de Ziyaran (ZVB). Para o efeito, que se centra principalmente no estudo das pedras do Cretáceo na zona central do Alborz, foi efectuada a amostragem das pedras na área pretendida com os métodos de levantamento e de campo e para 120 amostras. Após a preparação da camada delgada do poço e sem as amostras alteradas, foram examinadas com petrografia e testes de petrologia. Os resultados dos estudos petrológicos das rochas vulcânicas da área de Ziyaran expressaram que as rochas vulcânicas básicas na área intermediária com a composição química intermediária superior da Fosfatase Alcalina Eocena (ALP) localizadas na zona central das alturas do Alborz, com composição litológica de basaltos olivinos alcalinos e andesita.
**PALAVRAS-CHAVE:** CINTURÃO VULCÂNICO DE ZIYAN (ZVB); ALBORZ CENTRAL; PETROLOGIA; EOCENO.

## INTRODUCTION

The studied area is located in the western part of the Shokran 1:100000 sheet. From a geological viewpoint, and based on the classification performed by Stoecklin (1968), Nabavi (1976), Eftekhar nezhad (1980), Berberian (1981), Alavi (1991), and Agha Nabati (2000), Tarabi et al (2019)the studied area is located in the central Alborz zone.

The geological collection of this sheet includes various stones, which in the north are the reminder of Cenozoic and quaternary deposits. In the western part, the exposure stone units are mostly Precambrian and Paleozoic deposits and, in the east, -south part of the studied area, the stones belong to the Mesozoic period and specifically, the sediments belong to the Jurassic area are exposed. The basic volcanic stones that belonged to the Eocene period are located in the Ziyaran area and in the southern part of Taleqan province in the central Alborz (Figure 1).

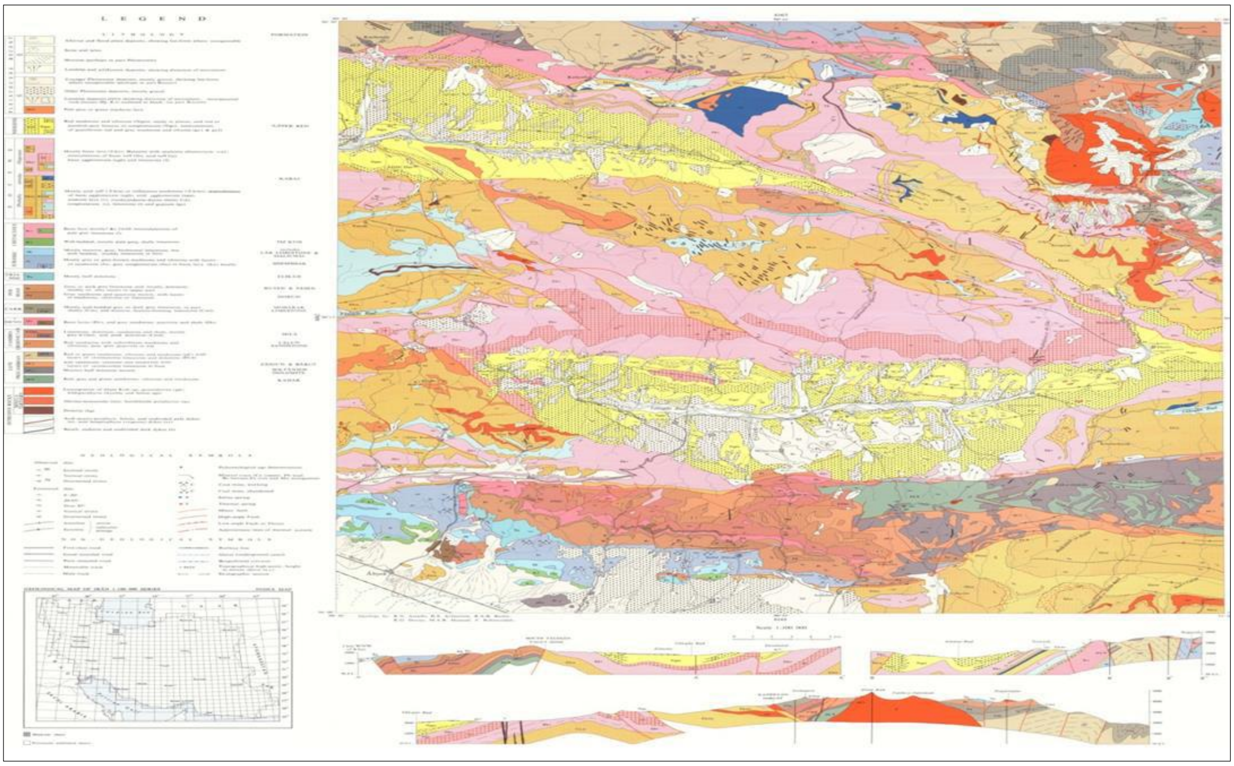

*Figure 1*. Geological map and geographical location of the studied area and access routes to the EKv volcanic unit
Source: Iran Geology Organization (1978).

## GEOLOGY

The Alborz Mountains form a twisted east-west area in the northern part of Iran and the western part of the Caspian Sea. The Alborz Mountains are themselves considered a part of Alps – Himalaya orogeny in western Asia.

The abundance of volcanic and tertiary pyroclastic rocks in the western hillside of Alborz has resulted that in the first earth map created by Europe (Jaen, 1972), the Alborz to be considered as a part of the Caucasus – Turkey geosyncline. However, the existence of Magma stones equals to it in other parts of Iran. Especially with more findings of Iran geology, it was assured that most of the stratigraphic stone units of Alborz and central Iran are the same in facies and formation condition terms. In such a way that the Alborz can be considered as stratigraphy of central Iran, a margin that the collapse of Iran and Turan sheets had a great impact on its formation. The equality of Alborz with central Iran is more especially in western hillsides but is different in northern sides (Stoecklin, 1968).

The central Alborz includes the southern convexity of the Caspian Sea. The morphology in this area, like most of the other areas, is affected by stone units' facies, the flow of wrinkles axis and fault mechanism type. In general, this area is made by an anticline with west-northwest and east-southeast axial length. This volcanic unit with stone units belongs to the Paleozoic period and Jurassic sandstones units with fault boundary and rarely have normal boundary with lower carbonate Cretaceous units. Therefore, this volcanic unit has a clear boundary with intermediate – upper carbonate cretaceous stones. The basic volcanic strip of Ziyaran zone is developed on the volcanoclastic units of Karaj and shows most of the exposures in the western – central parts.

The studied area is a part of central Alborz, which in stratigraphic terms, after the orogeny phase (upper tertiary), has generated a unit land in the western part of Kandovan and has separated it from the northern part of Kandovan. These lands due to phases after the tertiary has come out of water and wrinkles have been generated in them. This region is active in tectonics terms, the Alborz uplift is due to the eastern – western fault performance, and this has resulted that some of the formations to become abnormal. The main facies are mostly composed of tuff, tuffite, carbonate and shale interlayers accompanied with basic and acidic penetration dikes that have crossed this formation (Geological Survey and Mineral Exploration of Iran, 2003).

The studied area was first investigated by Stampeli (1978) that his purpose was to study the general geology of the Rasht – Gorgan area. Although this study was not a petrological study, the volcanic stones of the area were investigated in microscopy terms and main elements of geochemistry. Moreover, for the first time, the Cenozoic volcanic rocks and other stone units of Alborz were studied. Although this volcanic complex is located in the Karaj formation and is extended in Iran geology, no precise geochemistry work has been performed on it until today (Emami, 2000; Nazemi *et. al.*, 2019, Poorbehzadi *et. al.*, 2019, Yazdi *et. al.*, 2019 -a & b, Olufemi Ojo *et. al.*, 2020, Baratian *et. al.*, 2020).

The comprehensive study that was performed using the internal seismic wave and studied the shell and lithosphere structure in the central part of the Alborz Mountains represents the high and active seismicity with deep complex structure.

The main studies in this research are performed about the alkaline basalts of this formation in the Ziyaran area. This formation is a complex of basic alkaline volcanic rocks (EKv) that are converted to basanite rocks in some intermediate and limited parts of this exposure and especially in the northern part of Taleqan and has interlayers of basic agglomerates and acidic tuffs. They are isoclinal expanded on the clastic volcanic rocks of Karaj formations.

## MATERIALS AND METHODS

The present research is a descriptive study that has been performed with the aim of getting access and analysis of the petrology information of Ziyaran are volcanic rocks (a member of EKv volcanic rocks unit belonged to upper Eocene). According to this, rock samples were obtained by various surveys in longitudinal and transverse profiles. For this purpose, 120 rock samples were obtained from the studied area that from them, 60 samples were selected according to strength and non-duplication purposes and the thin layers were prepared from them. The location specification of the samples was recorded and numbered using the GIS system. In sampling, it was tried to do sampling from the lower weathered and healthier exposures and mostly from the samples feeding dikes. The variables of the present study were the microscopical study of mineralogy and texture and lithology of the obtained rocks.

The thin layer was prepared from all the rock samples and using the polarizing microscope, the lithology, mineralogy and texture specifications of them were qualitatively evaluated. Finally, using the reference tables and graphs, the lithographical classification of the samples was performed. 20 samples were sent to an international valid laboratory for

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EMPA analysis and 200 points in 20 thin sections were sent and analyzed for electron microprobe analysis. In order to analyze the findings of the research, the Excel, SPSS software was used for database and statistical processes and PETROGRAPH and MINPET and other specialized software was used for petrological studies.

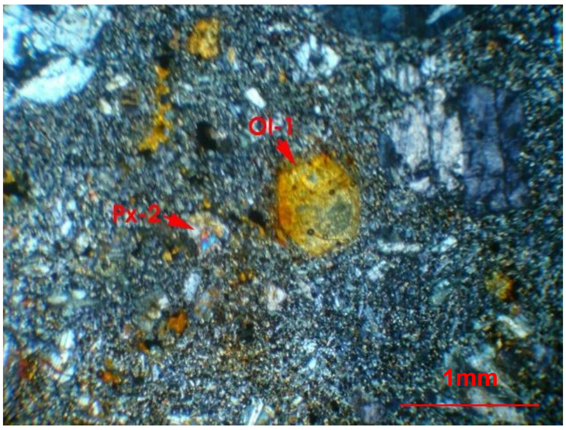
## RESULTS AND DISCUSSION

### PETROGRAPHY

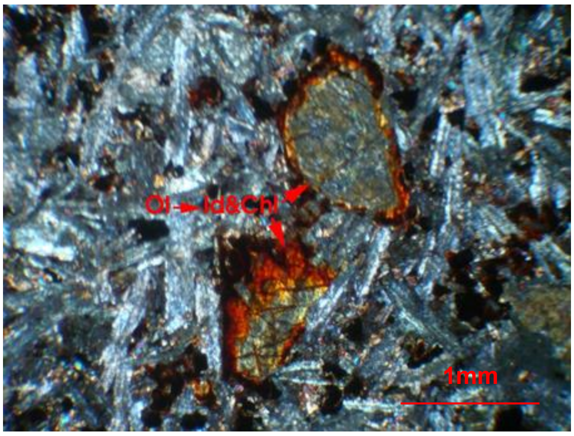
During the petrography studies of the volcanic rocks of the studied area and after performing the thin layer studies, it was revealed that the rocks of the area are composed of Andesite, Basaltic Andesite, thracy Andesite, Basalt, Olivine Basalt, and thracy Basalt. Based on this, the mentioned rocks were studied in two Basaltic and Andesite groups.

### BASALTS

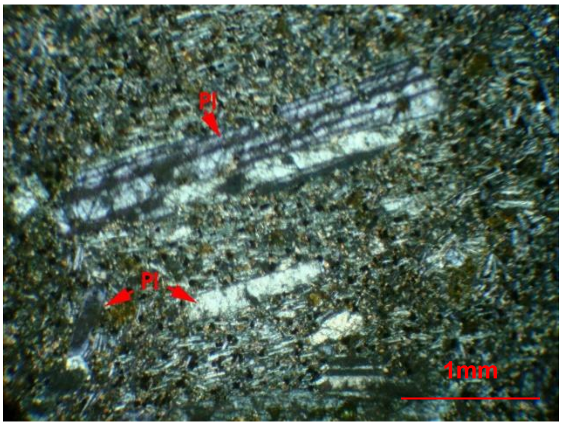
According to the petrographic studies, Olivine, Plagioclase, and Clinopyroxene are the main minerals of the Basalt in the studied area and opaque mineral is the main side mineral in these basalts. Also, secondary minerals mainly consisted of Chlorite, Quartz, Calcite, and Sericite (Figure 2). Because the abundancy and importance of various minerals in the rocks of the studied area are not equivalent, therefore, in selecting the intended spots for performing the chemical decomposition test, it was tried to focus on the minerals that their abundancy, type and composition change is important and basically, is the representative of initial magma changes and characteristics.




(b)




(a)

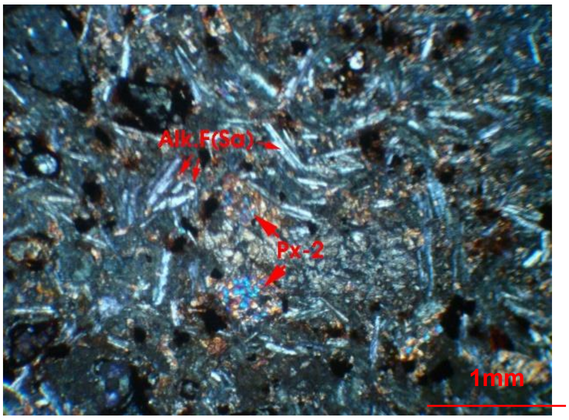



(c)

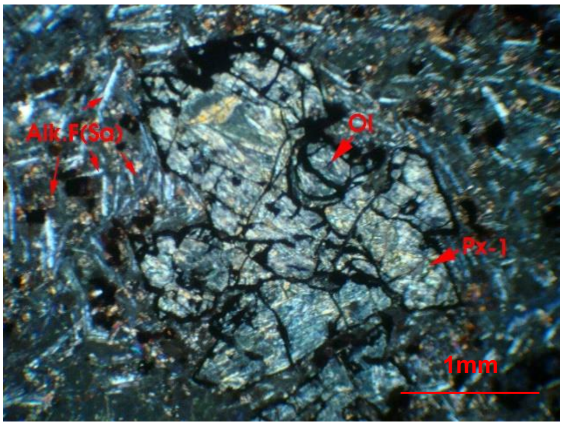
*Figure 2.* Cross-section images of the volcanic rocks related to the intermediate – upper Eocene of Ziyaran area: (a) Olivine Basalt, Olivine (olv), with Iddengsite margin, (b) Ttiano Augite type Clinopyroxene (CPX) (TI, Aug), (c) Plagioclase (Pl) (Andesine), and Opaque minerals (opq) (plane-polarized light)
Source: Authors (2018).

## ANDESITES

The andesite rocks are mostly composed of porphyritic texture with microlite essence and the main mineral is mostly plagioclase of andesine, pyroxene and olivine types as the secondary mineral of it (Figure 3).




(e)




(d)

*Figure 3.* Cross-sectional images of volcanic rocks belong to the intermediate – upper Eocene of Ziyaran zone (e-d) andesite, plagioclase (pl), olivine (olv) and pyroxene (px) (plane-polarized light).
Source: Authors (2018).

## PETROLOGY

The basic volcanic rocks, until the chemical composition of intermediate – upper alkaline eocene in the Ziyaran zone located in the central part of Alborz mountains, have the lithology composition ranges between alkali olivines basalts and andesite.

The utilization of microprobe electron results that is also known as the Electron Probe Micro Analysis (EPMA), is a precise and very effective tool in petrologic studies for detection and determination of the type and precise chemical composition of the minerals and also utilization of the results in the temperature – pressure metering studies.

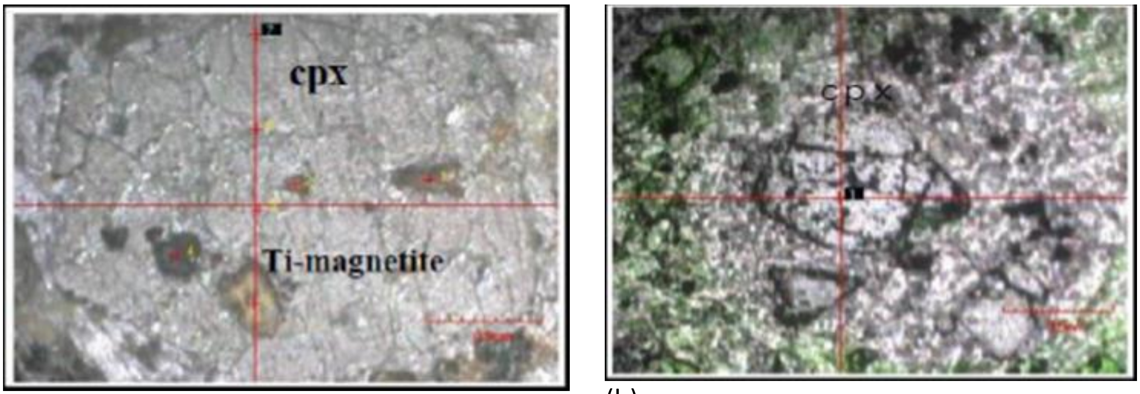
For microprobes studies on basalts and andesites of the studied zone, after precise petrographic studies, 10 thin cross-sections of the exposures of the selected area were selected and analyzed with Electron Probe Micro Analysis in the Binalood Kansaran Center.

## CHARACTERIZATION OF CHEMICAL COMPOSITION AND CHEMISTRY OF THE ROCKS CONSTITUENT'S MINERALS IN THE STUDIES ZONE BASED ON THE MICROANALYSIS PROBE

Generally, the results of the electron microprobes on the existing minerals in the studied zone confirmed the results of the petrography analysis. As stated in petrographic studies, olivine, plagioclase, and clinopyroxene are the main minerals of the basalts of the zone and the opaque minerals are the subsidiary minerals in these basalts. In addition, secondary minerals mostly consisted of chlorite, quartz, calcite, and sericite.

## THE CHEMISTRY OF PYROXENES

In order to study the existing pyroxenes in the stones of the area precisely, 27 number of point analysis was performed on the pyroxenes. In Figure 4, the point analysis location in some of the pyroxenes on the EPMA is shown.




(a) (b)

*Figure 4.* The EMPA images of the zone pyroxenes.
Source: Authors (2018).

Since various compounds of pyroxenes are the solid solution with final members of $Ca_2Si_2O_6$, $Mg_2Si_2O_2$, and $Fe+22Si_2O_6$ and with Ca-Mg-Fe changes, in order to determine the exact type of the pyroxenes, the classification graphs of Morimoto (1988) are used. The versatility of pyroxenes and a sample of pyroxenoid (wollastonite) existing in the AB45, AB32 samples have the compositional spectrum from the pigeonite to wollastonite (Figure 5).

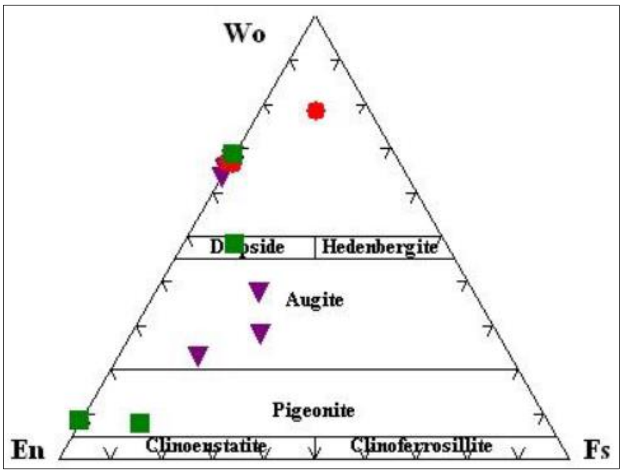



*Figure 5.* Classification of existing pyroxenes in the zone on Morimoto (1988) graph.
Source: Authors (2018).

One of the common classifications for clinopyroxenes is grouping them into two High Calcium (High – Ca) and low Calcium (Low – Ca) groups. The boundary between these two groups, due to the presence of a miscibility gap, is between 15 and 24-mole percent of Ca2Si2O6 (the boundary between the augite and pigeonite) and natural pyrogenic pyroxenes are rarely between this miscibility gap (Gill, 2010). Because the pyroxene of the studied zone is from diopside to pigeonite, therefore, the basalts of the zone have pyroxenes in the range of High-Ca to the Low-Ca.

Also, one of the specifications of the augites is the possibility to classify them according to their titanium content into two groups of normal augites and titan augite. The normal augites have 0.5 to 0.8 weight percent of TiO2 and the titan augites have 3 to 6 weight percent of TiO2 (Gill, 2010). The TiO2 content in the studied area varies between 0.7 to 3.69 weight percent. Therefore, the augite of the studied area is considered as the titan augites.

It should be noted that the amount of titanium in the pyroxenes has close relations with the alkalinity of the magma. In such a way, the amount of titanium in the existing pyroxenes in the alkane basalts containing titanium is higher than the amount of titanium in the sub-alkanes basalts and tend to titan augite in chemical composition terms.

The importance of the relationship between the chemical compositions of pyroxenes with alkalinity of the basaltic magma is in such a way that some of the petrologists like Mellus & Sethna, 2011 has considered the presence of High-Ca clinopyroxene and absence of Low-Ca pyroxene as a method to identify the high alkalinity magma in various parts of Deccan basalts.

The studies of Duda and Schmincke (1978) shows that the presence of Al2O3 more than 4.5 and TiO2 about 2 weight percent is normal in alkaline stones that in the pyroxene samples of the studied zone, the amount of Al2O3 is about 6.9 on average and the amount of TiO2 is more than 1.7 weight percent.

The clinopyroxene minerals are also used to determine the magmatic series. In the Al2O3 versus SiO2 graph, the samples are located in the alkaline range (Figure 6).

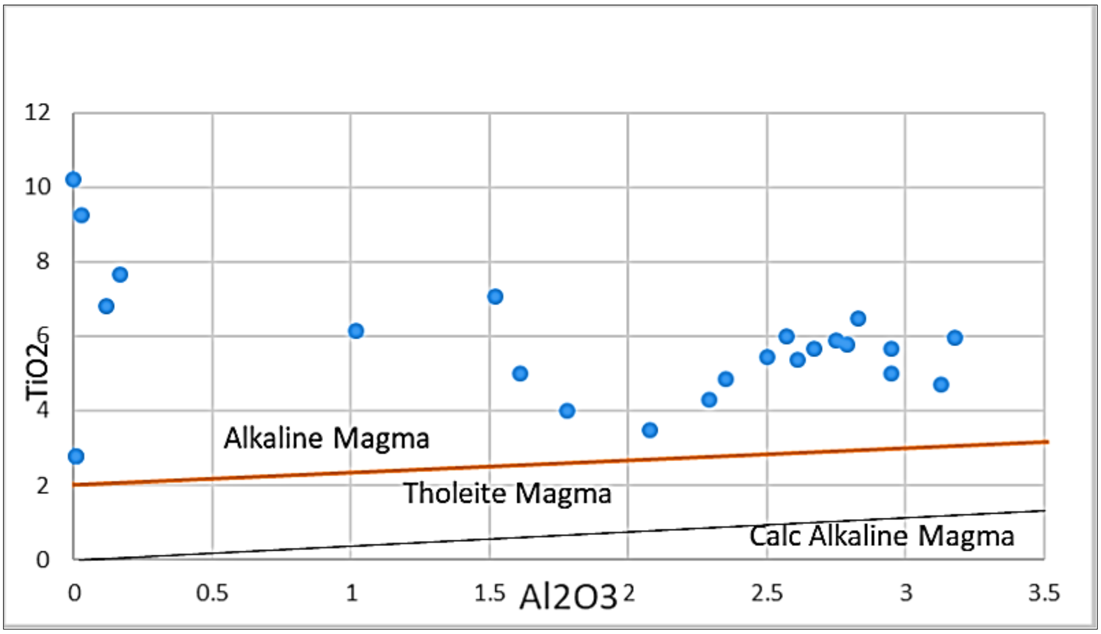



*Figure 6.* Utilization of clinopyroxene minerals to determine the magma series
Source: Le Bas (1962).

The fugacity of oxygen has great impact on the change of liquidus temperature and melt and crystal composition (France *et. al.*, 2010; Jamshidibadr *et. al.*, 2020) and is an important factor in the control of magmatic processes (Kilinc *et. al.*, 1983; Kress and Carmichael, 1991; Ottonello *et. al.*, 2001; Moretti, 2005; Botcharnikov *et. al.*, 2005). In addition, it affects the crystallization sequence and the type of crystallized mineral.

Due to the $Al^{IV}$+Na and $Al^{VI}$+2Ti+Cr indices, the variation of the oxygen fugacity in the pyroxene minerals of the AB45 and AB32 samples has some variations of 0.23 – 0.6 in the $Al^{IV}$+Na cationic range and 0.02 – 0.1 in the $Al^{VI}$+2Ti+Cr cationic range. In addition, they are located in the magmas with high oxygen fugacity that confirms exactly the geochemical conditions and originating from a watery mantle (Figure 7).

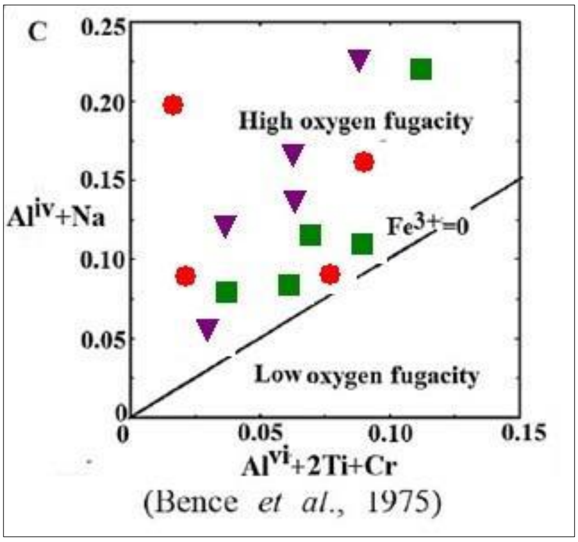



*Figure 7*. The $Al^{VI}$+Na versus $Al^{VI}$+2Ti+Cr graphs in order to estimate the oxygen fugacity
Source: Schweitze (1979).

Clinopyroxene minerals are also used to determine the tectonic environment (Le Bas, 1962). In this diagram, most of the samples are in the inter-continent rift environment and alkaline basalts are in the interlayer section and exhibit a beautiful match with the geochemistry of all the analyzed samples (Figure 8).

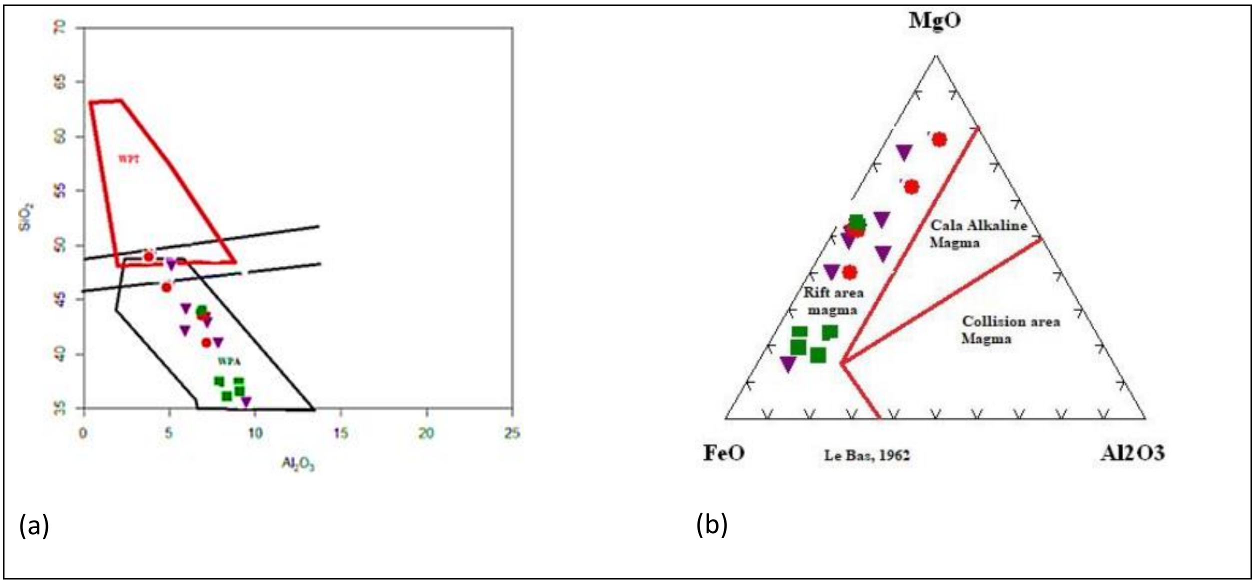



*Figure 8*. The utilization of clinopyroxene mineral to determine the tectonic environment and determination of the tectonic environment AB, Alkaline basalt, WPA interlayer alkaline basalt, WPT interlayer tholeiitic basalt, OFB: oceanic bed basalt.
Source: Le Bas (1962).

Revista Geoaraguaia
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Barra do Garças – MT
v.11, n.1, p.77-94. jun-2021

<u>TEMPERATURE – PRESSURE METERING</u>

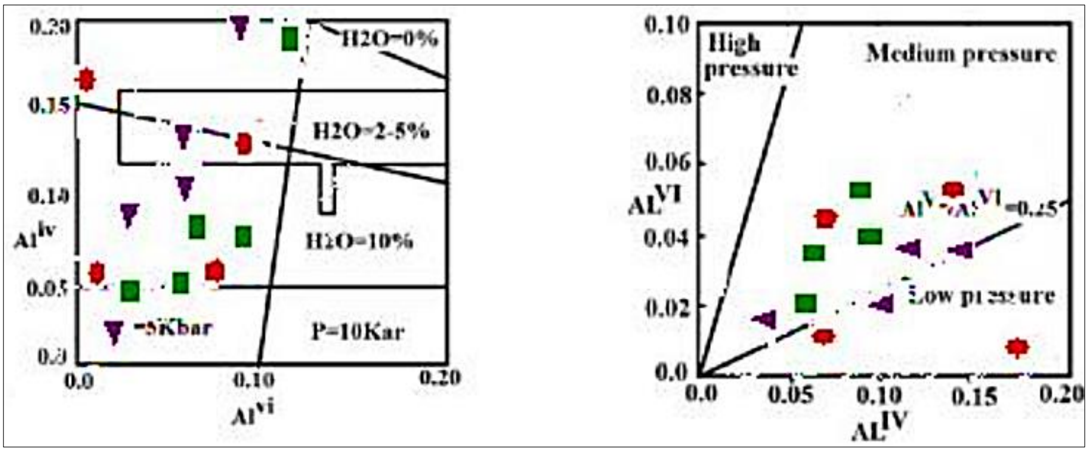


*Figure 9***.** A) the barometric graph of clinopyroxene $Al^{VI}$ versus $Al^{IV}$ (Aoki and Shiba, 1993), B) The barometric and hydrometric graphs of clinopyroxene.
Source: Heltz (1973).

In order to determine the temperature of the stone of the studied area, the OW-Eb-Fs tertiary system has been used. The temperature has been estimated to be about 500 to 1300oC for the stones of the area and this vast range is an implication of the formation of clinopyroxene mineral in various depths and magmatic reservoirs and the frequency of the magmatic reservoirs being empty and full (Figure 10).

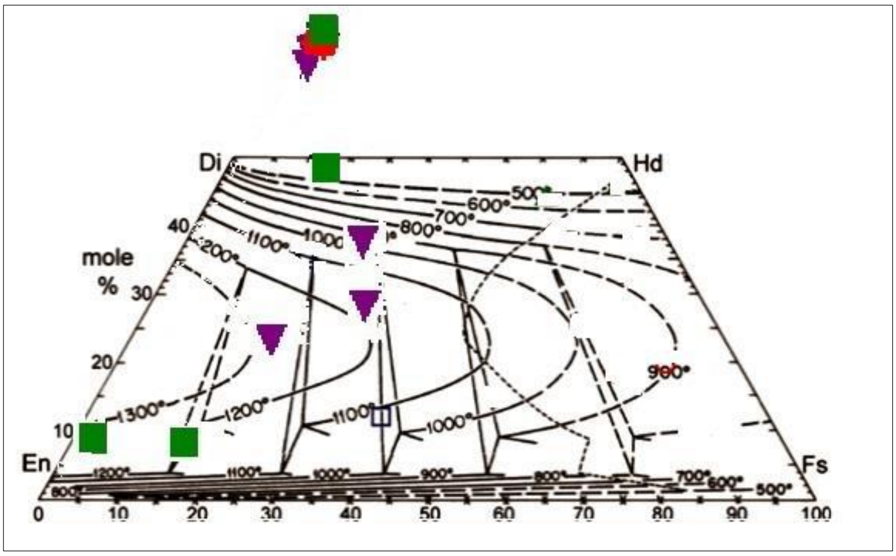


*Figure 10***.** The Wo-En-Fs graph of the clinopyroxene for temperature estimation.
Source: Lindsley (1983).

THE CHEMISTRY OF PLAGIOCLASE

The plagioclase is the most abundant mineral in the basaltic stone of the area that exists in two types of coarse-grained and microlein. Also, the petrographic evidence shows the intermediate alteration performance on these plagioclases. As a result, the secondary minerals of sericite, calcite, chlorite and clay minerals and as a result, the saussuritization phenomenon could be observed on them. Using the results, the minerals type was determined using different graphs. The experimental test showed that the amount of the An and FeO elements in plagioclase has direct relationship with the water content in the magma (Koepke *at al*., 2004). In other words, the magma being saturated or unsaturated of water can have a great impact on the iron release between the magma and crystals (Pietranik *et. al.*, 2005). On the triangular-graph of Or-Ab-An from Deer *et. al.* (1992) the plagioclase of the pyrogenic stones of the area was positioned in the labradorite and bitonite (Figure 11).

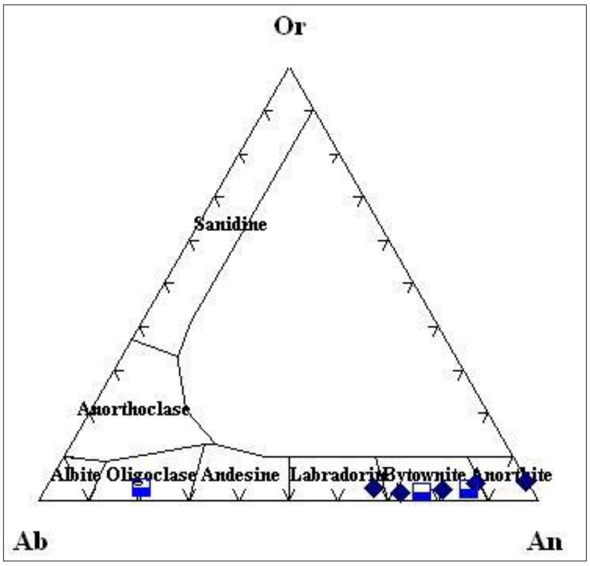


*Figure 11.* Determination of the composition of the pyrogenic stones feldspar of the studied area Source: Deer *et. al.* (1992).

Temperature-metering: In order to determine the temperature of the stones of the studied area, the tertiary system of Or-Ab-An has been used. The temperature has been estimated to be about 650 to 850°C for various stones of the area (Figure 12).

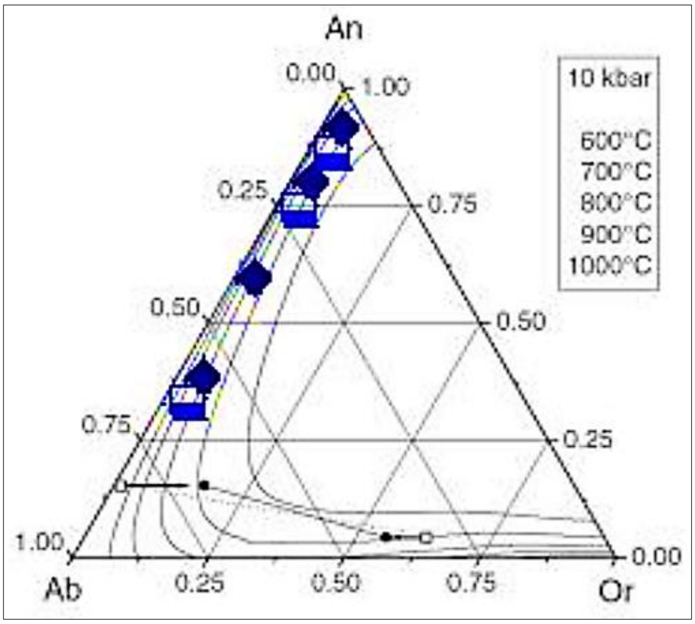


*Figure 12.* The graph for determining the temperature.
Source: Or- Ab- An Seck (1971).

Generally, it could be said that the basic volcanic stones with the intermediate chemical composition of intermediate-upper Eocene alkaline in the Ziyaran region located in the central parts of the Alborz heights have the lithological composition range between range basalt olivine alkali and andesite.

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