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Petroleum & Mineral Geochemistry of Pyroxene & Plagioclase in Eocene Basin Volcanic Rocks of Baladeh Region of Central Alborz of Iran

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Abstract

The Baladeh volcanic area in Northern Iran (specifically located in Central Alborz) contains continental alkaline basaltic volcanic outcrops. The most significant minerals in this group of rocks are plagioclage and pyroxene. Accordingly, these minerals were studied and assessed via mineral geochemistry. Compliant with our analysis, the chemical composition of pyroxene and plagioclage are in the range of diopside-augite and bitonite-labradorite, respectively. The temperature and thermodynamic conditions of the parent magma were estimated based on the diagrams of mineral chemistry. High oxygen fugacity, medium to high pressure range, temperature 600-1200°C were the most important conditions governing the parent magma. Geochemical and mineralogical tectonomagmatic diagrams indicate that these basalts are formed locally in an intercontinental tensile basin (constituted as a consequence of the lithospheric thinning of eocene compaction processes). Volcanic assemblages are induced by the formation lava due to the removal of adiabatic pressure from metasomatized mantles, formed as small-scale volcanic rocks that represent an alkaline volcanism and metamorphic rocks with a similar composition to primary lava-derived (or near-primary) lava. Elemental ratios (such as Zr/Nb, La/Nb) represent and are indicative of an elemental model of magmas formed by multiple degrees of smelting of garnet-bearing harzburgite and heterogeneous mantle sources.

Disciplinary: Geology.

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1 Introduction

The study region is located in Baladeh, Mazandaran Province and approx. 80-km Northeast of Tehran, (geographical coordinates: 6°, 36° -11, 36° north latitude & 52°, 51-35°, 51° east longitude). Geologically, it is situated in the central part of Iran's primry northern mountain range (Alborz mountain range). The study area was first surveyed by Jenny (1977) and Stampeli (1978) (Figure 1). In this area, cretaceous and earlier volcanic rocks were studied by Jenny (1977). Although this lower Eocene volcanic assemblage is important in understanding the geological conditions of Alborz, but to date, detailed geochemical and mineral chemistry analysis has not been preformed on them. In this research, grounded on mineral chemistry and geochemical diagrams, it has been endeavored to determine the tectonomagmatic environment, the prevailing thermodynamic conditions and the formation environment of the Eocene basin volcanic rocks.

2 Region's Geology

The study area is part of the northern Central Alborz zone; pursuant to the end of the alpine phase, it has formed a single terrain in the northern region of Kandavan (separating it from south Kandavan). This environment is also tectonically active and Alborz's elevation is due to the action/movement of east-west faults, caused some formations to be out of their normal state. In the south of Baladeh region, the middle-upper jurassic-chilean sandstone units (with fault boundary along with basilic volcanic rocks), have spread to the middle (below the Azar Aavaari Formation of Karaj to Lower to Middle Eocene Age).

Major diversity of volcanic rocks of the Lower-Middle Eocene are in the range of alkaline-basalt, alkaline-basalt, basaltic andesite, andesitic basalts, olivine-trachy-basalt & olivine-trachy-andesite (mainly seen in the layer, or with them) (Figure 1).

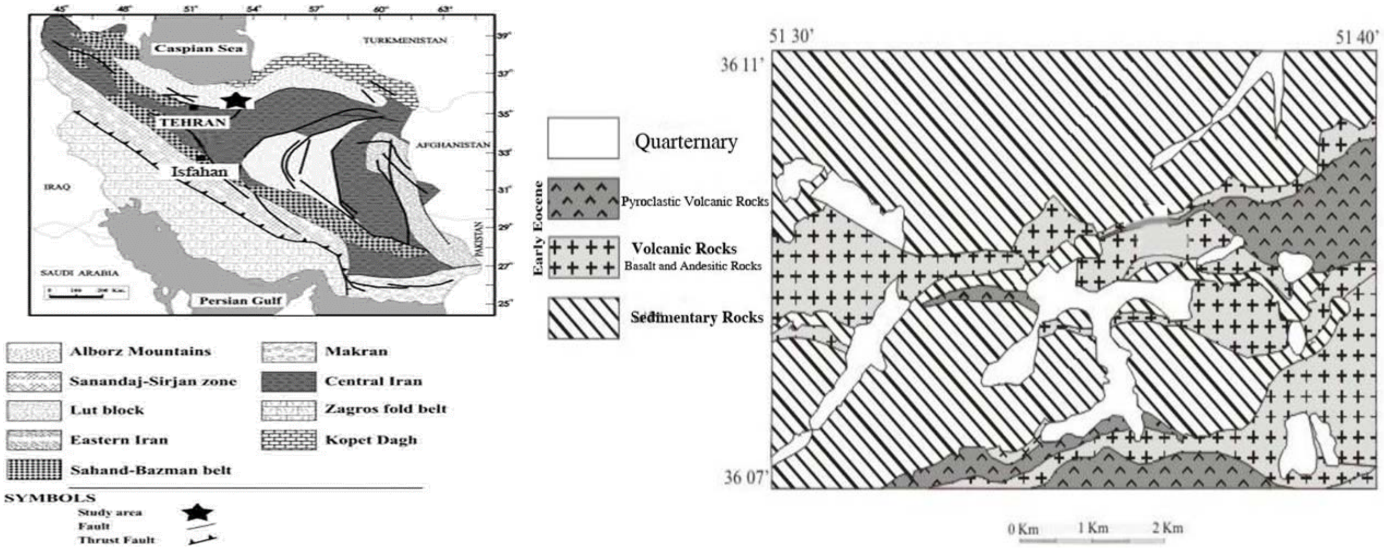


Figure 1: Geological map of the study area (Quoted By Nabavi 1998 with changes).

3 Research Methodology

During field visits, 120 rock samples were collected from various sections of basaltic volcanic outcrops. After examining the hand samples, 50 thin sections were selected and upon preparation were studied utilizing a polarization microscope. Twelve samples were chemically analyzed in the

Binalood Deposit Spectrum Laboratory, Mashhad, Iran, via the ICP-MS method. Pursuant to detailed petrographic studies, in order to study the microprop and mineral chemistry on the basalts of the study area, a thin section of the index sample was selected from the logic outcrops and analyzed via Electron Probe Microanalysis (EPMA).

4 Findings

4.1 Lithography

Consistent with the petrographic study, basalt rocks have porphyric texture with microlytic to glassy paste. The paste in these rocks is composed of plagioclase, pyroxene, olivine and OPAC minerals. Plagioclage is dispersed from shaped to amorphous and of differing sizes within the paste (Figure A2). These plagioclase have albite-pericline and albite-carlsbad macules and are labradorite based on optical properties. These minerals are observed as single crystals and in groups. The tissues present in these plagioclase include sieve, growth, dissolution margin and oscillating zonation. In line with the existence of these tissues, indicating an imbalance in magmatic conditions, their presence can be due to magma mixture. Some plagioclase have been converted to clay, sericite and chlorite minerals via alteration. Pyroxene (Px) is dispersed from shaped to amorphous with an average size of 330 μm and an approximate frequency of 10% within the rock texture (Figure 2B). Olivines are shaped amorphously with an average size of 280 μm (severely altered in most instances).

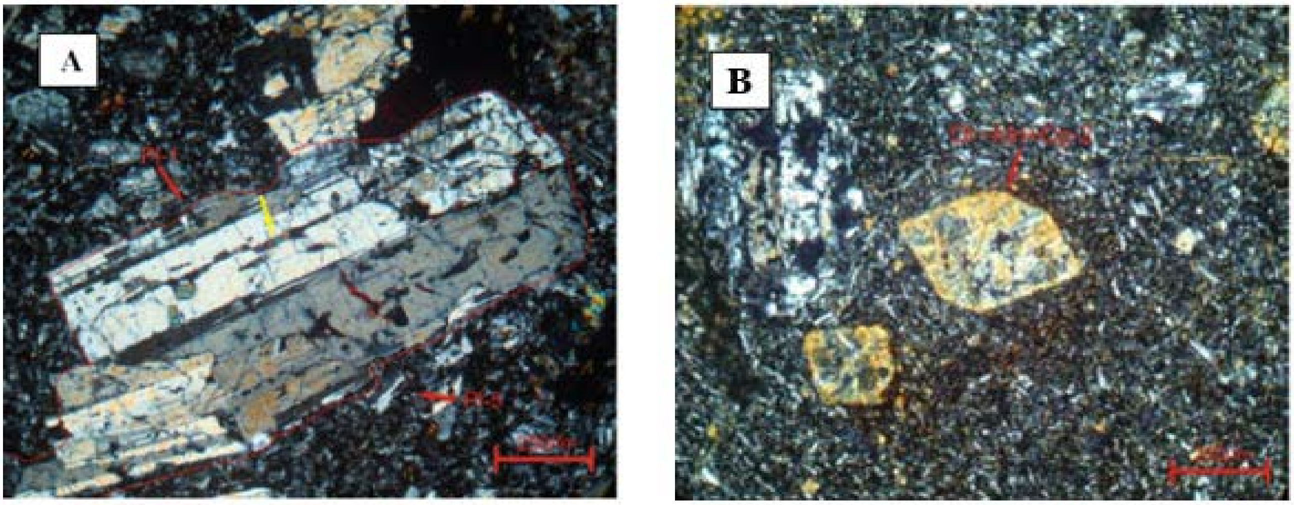


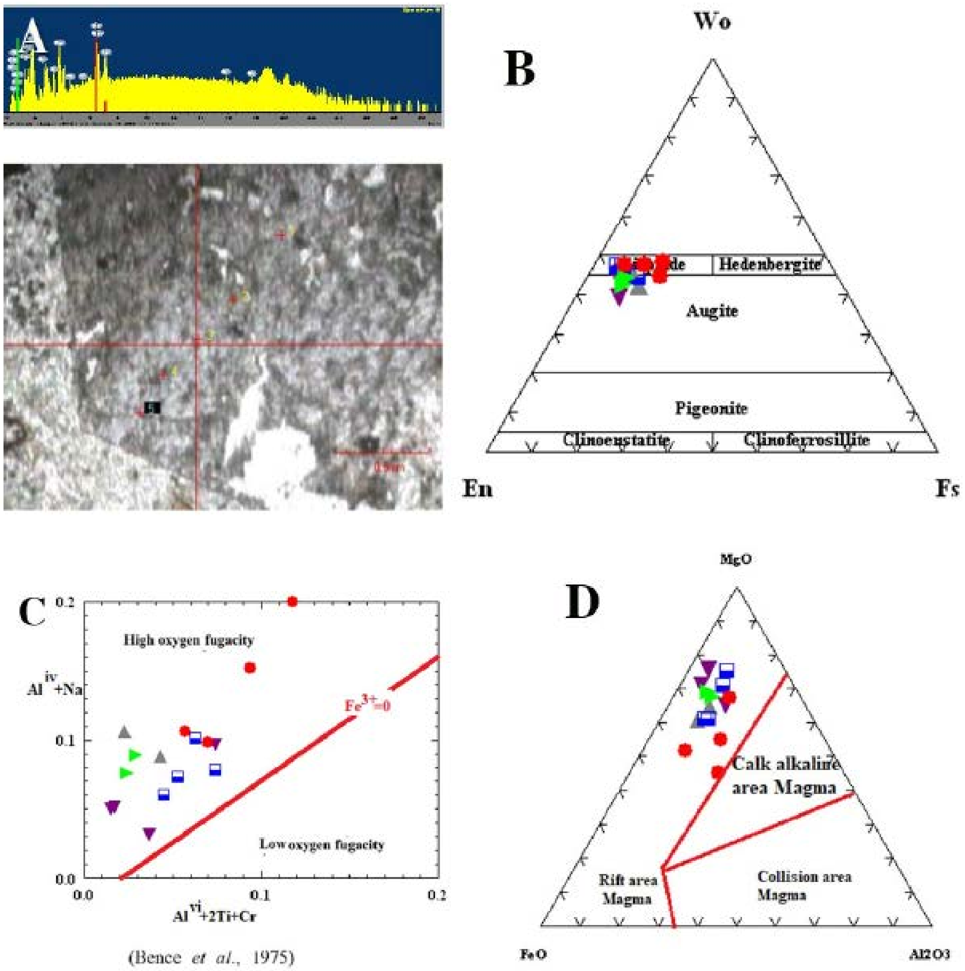
Figure 2: Microscopic studies of volcanic rocks; A) View of the first type of social plagioclase phenocryst (red dotted line) with pyroxene inclusions (yellow arrow) and the fifth type of microlithic plagioclase present in the paste. B) View of the highly altered pyroxene phenocryst itself (in XPL optical state).

4.2 Mineral Geochemistry

Due to their mineralogical significance, in this study the two minerals pyroxene & plagioclage were analyzed (Figures 3A & 4B). In line with the mineral chemistry of these two primary minerals in basalt rocks, the heat level, formation depth as well as the effective oxygen pressure in the parent magma can be projected.

To determine the type of pyroxene, the classification diagram was utilized [as an indicator of the separation of clinopyroxene minerals from the proposed diagram] (Morimoto et al., 1988). In this diagram, pyroxene has a compound spectrum within the diopside-augite range (Figure B3). Utilizing the diagram of AlIV + Na versus AlIV + 2Ti + Cr, itself a function of trivalent iron in pyroxenes level, the oxygen fugacity can be obtained. In this diagram, all samples of Clino pyroxene mineral are located above the line = 0Fe + 3 and in the fugacity range above oxygen (Figure 3C). In the diagram of changes of the main oxides of SiO2, Al2O3 in kami pyroxen to determine the tectonic environment (Le Bas, 1962), most specimens are located in the intercontinental rift environment and intercontinental tholeites (Figure 3D).

In Figure 4A, with the aid of tectonic setting diagrams and consistent with the chemical composition of pyroxene, all samples are located in the intercontinental rift environment and reveal the intercontinental tensile environments associated with deep faults in the region, which are probably due to higher degrees of melting. Part of the Tolitic to alkaline magma mantle is produced subcontinental, which can be related to the rate of opening of intracontinental tensile faults or the rate of adiabatic ascent of the parent mantle.



(Bence *et al.*, 1975)

Figure 3: Electron Prop Propagation Microanalysis (EPMA) Studies on Pyroxene;
A) The points analyzed on the electron microscope images are marked as numbers,
B) The classification of pyroxenes in basalt on the diagram (Morimoto & Associates, 1988).
C) AlIV+Na versus AlIV+2Ti+Cr diagram for estimating oxygen fugacity (Schweitzer 1979),
D) The use of clinopyrox mineralization to determine the tectonic environment (Le Bas, 1962; Hout et al., 2002).

With the assistance of the diagram presented by Aoki & Shiba (1993), the peak pressure and temperature during the crystallization of rocks can be determined based on the composition of pyroxene. It is in equilibrium with AlVI and the Cr*100/Cr+AlVI ratio in pyroxenes is directly related to pressure (Nimis & Taylor, 2000), in such a manner that in clinopyroxenes containing aluminum at high pressure with the action of NaALSi3O8-NaALSi2O6+SiO2 and at low pressure with the reaction CaAl2Si CALl2Sio6+SiO2 it is controlled (Green & Ringwood, 1967). The first reaction occurs at a depth of about 120 km (containing garnet peridotite), and the second reaction occurs at a depth of less than 40 km. To determine the depth of the magmatic reservoir, aluminum in the structure of pyroxenes was utilized. Researchers, including Helz (1983) emphasized that the distribution of aluminum in the quadrilateral and octahedral positions of clinopyroxenes is a satisfactory measure of the amount of magma water and the amount of pressure on the igneous rock formation environment. With this model, magma production at medium depths and crystallization process of some minerals continue at lower depths, and therefore all pyroxenes are crystallized at a pressure of 5 kb and with magma water content between 5 & 10% (Figure 4C). In response to increased temperatures in the crystallization medium of pyroxenes, AlVI values decrease (Heltz. 1973). In order to thermometrize the rocks of the region, the OW-Eb-Fs ternary system was deployed. Temperatures of about 600-1100°C at atmospheric pressure 1 are estimated for the rocks in the area (Figure 4D).

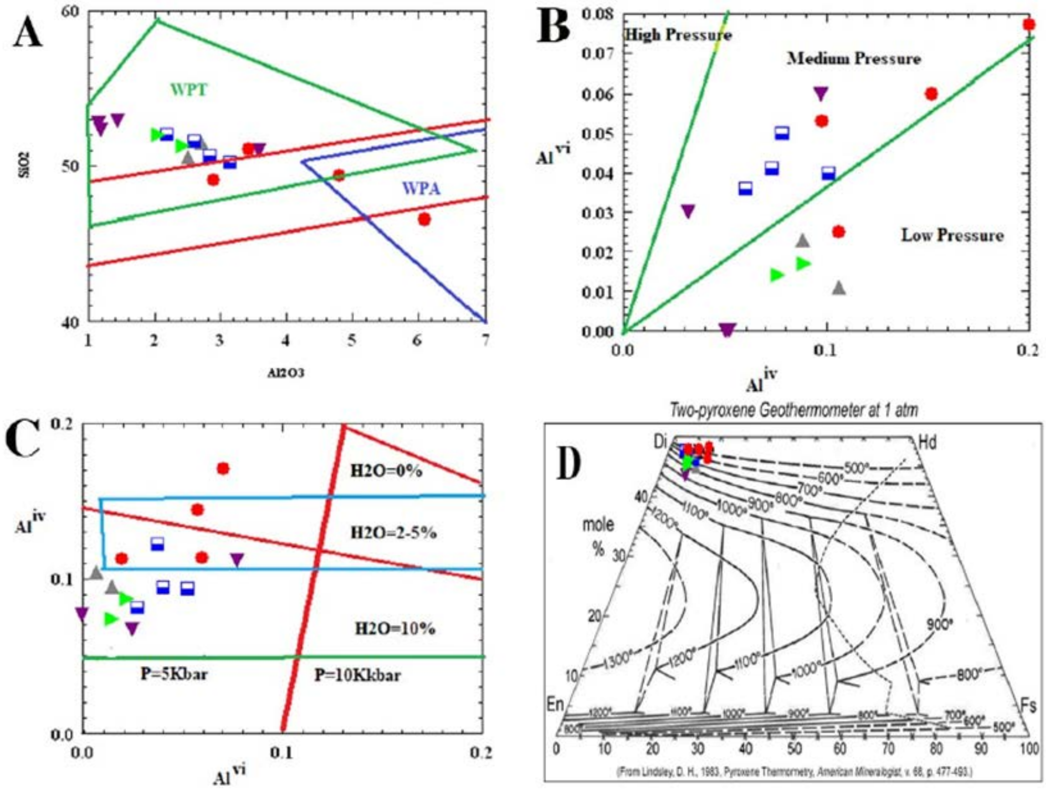


Figure 4: Diagrams of mineral chemistry in pyroxene.

A) Use of clinopyroxene mineralization to determine the technical environment of AB. (Le Bas, 1962) Alkaline Basalt, WPA Alkaline Intermediate Basalt WPT Interstitial Tolitic Intermediate Basalt: Oceanic Basalt,
B) Barometric Diagram of AlVI vs. AlVI (Aoki & Shiba, 1993)
C) Clinical Barometric & Hydrometric Diagram (Helz, 1973)
D) Wo-En-Fs diagram of clinoproxen for temperature estimation (Lindsley, 1983)

With the aim of assessing the exact composition of plagioclase in the rocks of the region, an 18-point analysis was performed on these minerals (Figure 5A).

On the Or-Ab-An triangular diagram (Deer et al., 1999), there are plagioclase of igneous rocks in the area, in the range of bitonite, labradorite and two andesine samples (Figure B5). Toward thermometrically measuring the basaltic rocks of the study area (with the help of chemical composition of plagioclage mineral), the Or-Ab-An ternary system was utilized. Temperatures are estimated to be between 650-900°C for various rocks (Figure 5C).

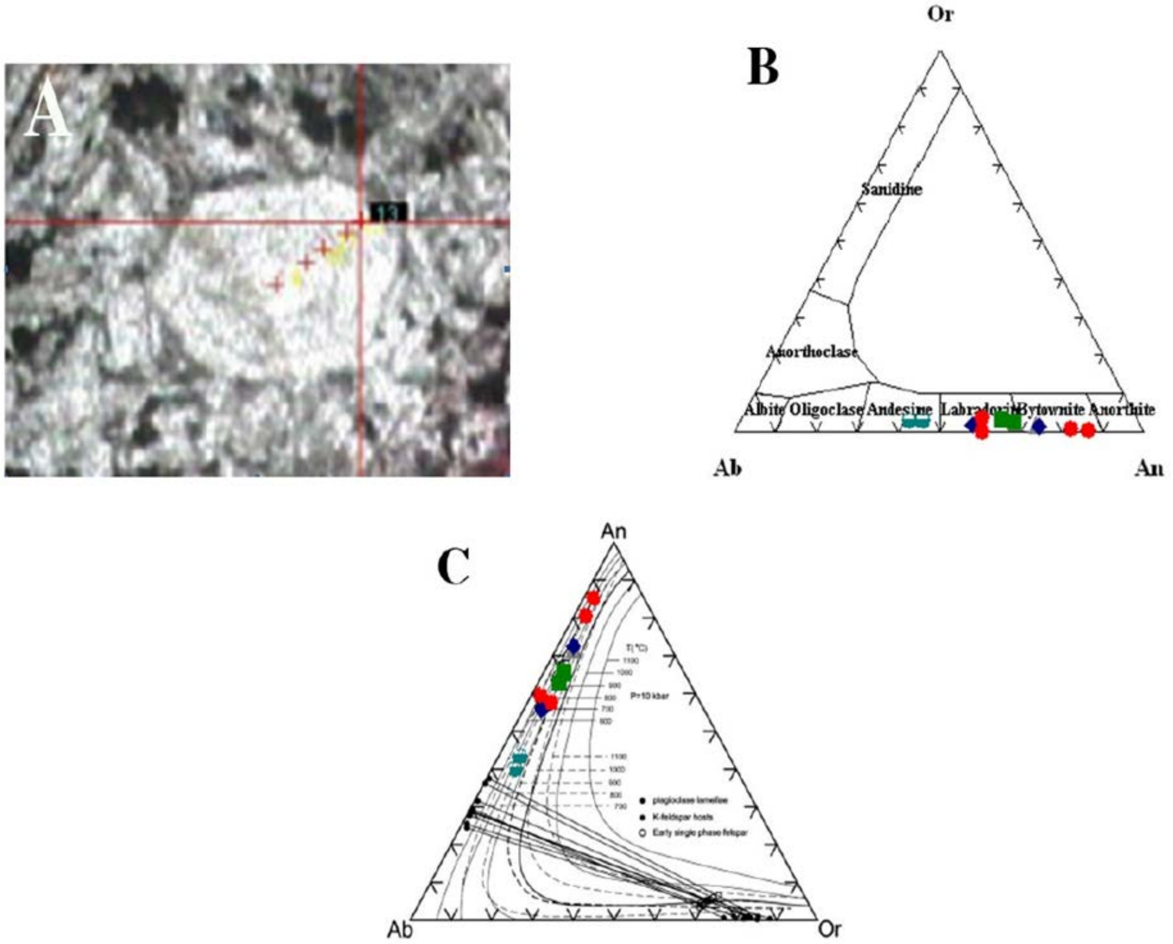


Figure 5: Image and diagrams of plagioclase mineral chemistry, A) Image of electron prop analysis (EPMA) of plagioclase (points analyzed on electron microscope images as marked numbers), B) Determination of feldspar composition of igneous rocks in the area (Deer et al., 1999), C) Or- Ab-An diagram for estimation of temperature (Seck, 1971).

4.3 Tectonomagmatic Environment

With the aim of determining the tectonic nomagmatic environment of the basalts of Baladeh area, diagrams from Pearee & Cann (1973), Pearee & Norry (1979), Sun & McDonough (1989), Wood (1980) and Meshede (1989) were utilized (Figures 6A & 6B). In these diagrams, incompatible and non-moving elements Ti, Y, Th, Nb, Ta and Zr are used to divide different fields. All samples are in the range of in-sheet basalts (WPB) and primarily display a process of mantle metasomatism with varied degrees of melting with changes in Zr. In the Nb*2-Zr/4-Y triangular diagram from (Meschede, 1989), the major samples are adjacent to the range of alkaline basalts within AI sheets and even wetter alkaline samples with lower melting degrees and higher Zr content are located inside the surface alkaline basalts (Figure 6C). Basalt samples in the diagrams presented by

(Agrawal, 2008), (Verma & Associates, 2006) exhibit CAB sheet active margin basalts as well as a trend toward in-sheet basalts (WPBs) (Figure 7). All diagrams confirm the source/sources of oceanic island basalts (OIB), asthenospheric mantle enrichment and varying degrees of melting in the formation of early volcanic magma formation primarily belong in the range of alkaline to transitional basalts as far as chemical composition.

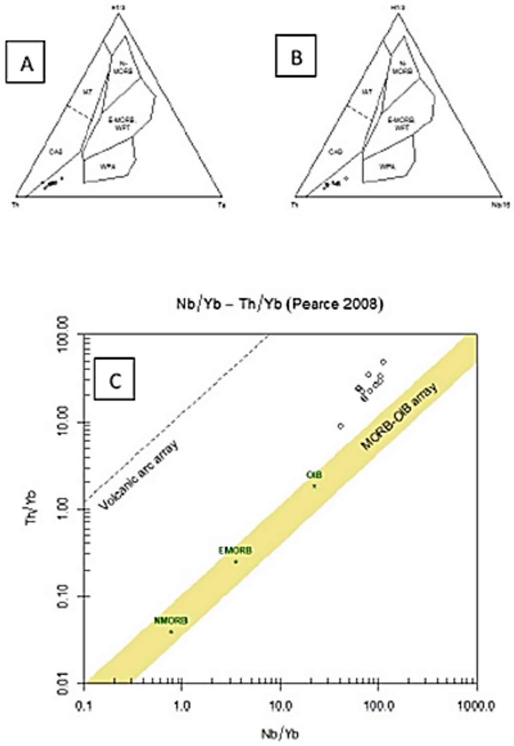


Figure 6: Determination of Tectonomagic Environment of Lower Eocene Mafic Volcanic Rocks in Baladeh Regon Utilizing Diagrams (Pearee & Cann, 1973; Pearee & Norry, 1979; Sun & McDonough, 1989; Wood, 1980; & Meshede, 1989).

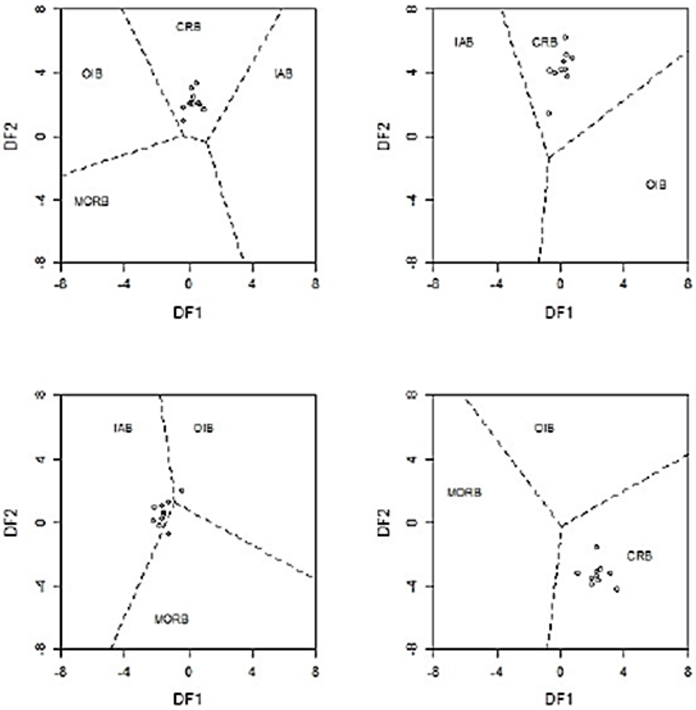


Figure 7: Determination of Tectonomagic Environment of Volcanic Rocks Utilizing Diagrams (Agrawal, 2008; Verma et al., 2006).

5 Conclusion

Petrographic studies of the studied basalt rocks in the Baladeh region demonstrate that they have porphyric texture with microlytic to glass paste which is in a paste of plagioclase, pyroxene, olivine and Opac minerals. Compliant with the mineral chemistry studies, the chemical composition of pyroxene and plagioclage are in the range of diopside-augite and bitonite-labradorite, respectively. Mineral chemistry diagrams reveal that high oxygen fugacity, moderate to high pressure range, 600-1200°C were the most important conditions governing parent magma. Geochemical and geochemical tectonomagmatic diagrams all indicate that these basalts are locally formed in an intercontinental tensile basin, constituted in connection with the lithospheric thinning of eocene compaction processes. The Alborz mountain range in central Iran is a member of the Arabic plate. In the Hersinian cycle, the two continents of Europe and Asia converged towards each other and in the late triassic and simultaneously with early-cimmerian, this collision became complete and in the younger orogenic phases, this orogenic process as well as tensile phases with pressure caused the formation of young magmanisms in the eocene period (together with volcanic assemblages) creating formations such as the Baladeh region (Agha-Nabaati, 2005). Enrichment in Th/Yb-Nb/Yb elemental ratios indicate the association of primary magmas with OIB enriched sources and different degrees of melting from a lherzolite garnet source, primary magma from these heterogeneous garnet sources, low melting degrees of rich sources of lherzolite garnet, hence these changes in melting degrees are a function of alterations in the depth and enrichment of incompatible elements in various mantle sources. Changes in melting degrees are moreover the consequence of frequency and pulses of flow changes in temperature of clove mantle or mantle as well as high melting degrees of mantle material related to the early stages of asthenospheric ascent and reduced with the decreasing intensity of asthenosphere ascending melting degrees. Therefore, in a general conclusion, we can point to the role of ascent of water-saturated asthenosphere with amphibole-phlogopite garnet lerzolite combination in order to generate primary magma of Baladeh region basalts. It is a passageway for magma to reach the surface, and the asthenosphere, with high levels of water present, melts to varying degrees as part of an amphibole-phlogopite peridotite garnet source.

6 Availability of Data and Material

Data can be made available by contacting the corresponding author.

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