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Petrography and Mineralogy of Zeolite Deposits, Mareya Area Southwest Thamar, Yemen

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ABSTRACT

The Mareya zeolite deposits are located at about 16 km south west of Thamar city. The geology of the studied locality shows wide exposures of different types of acidic volcanic rocks. The studied tuff rocks and other acidic volcanic rocks belong to the tertiary volcanic group. Petrographical studies showed that, the pyroclastic rocks (zeolitic tuffs) are characterized by porphyritic and glassy textures. Corroded quartz and sanidine are the most abundant minerals in these rocks. Mineralogical studies by XRD analyses showed that the zeolites minerals are clinoptilolite and mordenite of the Mareya area. These studies indicate the zeolites minerals of the Mareya area support that they are formed by subareal hydrothermal alteration of the parent volcanic glass that was accompanied by the interaction of porous tuffs enriched with reactive glass with waters.

Key words: Mareya, southwest Thamar, zeolite, pyroclastic rocks, volcanic rocks.

Introduction

Mareya area is located at about 16 km southwestern Thamar city. It is situated between latitudes 14º 29\\ N and 14º 29\\ 25\ N and longitudes 44º 16\\E and 44º 16\\ 15\E. Zeolites are crystalline aluminosilicates that contain alkali and alkaline-earth metals .their crystal framework is based on a three – dimensional network of SiO4 tetrahedra with all four oxygen shared by adjacent tetrahedra .The alkali and alkaline earth cations are loosely bound within this structure and can be exchanged by other cations or molecular water. Most zeolites can be dehydrated and rehydrated without any change in volume (Ted and David 2006 and Tchernev, 1993).

The geology of the studied locality shows wide exposures of different types of acidic volcanic rocks. The studied tuff rocks and other acidic volcanic rocks belong to the tertiary volcanic group (Beydoun *et al.,* 1998; As Sabri, 2003). The zeolite minerals occur within the pyroclastic rocks, the pyroclastic layers are characterized by white, gray and yellowish colors. Many commercial applications for zeolite have been developed these include, chemical fertilizer, filler in the paper industry, as active additions to Portland clinker, animal nutrition and health, as herbicide and pesticide carrier, animal-waste management, radioactive-waste disposal, water treatment….etc (Janotka and Dzivak, 2003). (Al-Ta'ae, 2003 and Bowman, 2003). With few exceptions the tonnage and value of the production of industrial minerals exceeds that of metals in most industrialized countries, this fact has prompted some writers to suggest that the production of industrial minerals can be used as a measure of industrial maturity of a country (Mathers and Notholt, 1994).

This study aims at examining the petrography and mineralogical properties of the zeolite rocks to determine their mineralogical constituents, textures and structures, and to define their economic potential.

Geologic setting

The geology of the studied locality shows wide exposures of different types of acidic volcanic rocks including zeolitized tuff. It is mainly composed of tertiary and quaternary volcanic rock sequences

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(fig.1) .The studied zeolitized tuff rocks and other acidic volcanic rocks belong to the tertiary volcanic group (Beydoun *et al.,* 1998). The study area is covered by Yemen volcanic group is consists of two subunits, basalt (at bottoms) and rhyolites (at top). They are composed of alternative rhyolite, rhyolite tuff and perlite. The stratigraphic column of Mareya area is composed of the following rock units (from top to bottom (fig.2) Rhyolite rocks are brown color and 4m thick, have a porphyritic and flow textures. Rhyolites have compact, and columnar structures. They are often associated with ignimbrite.

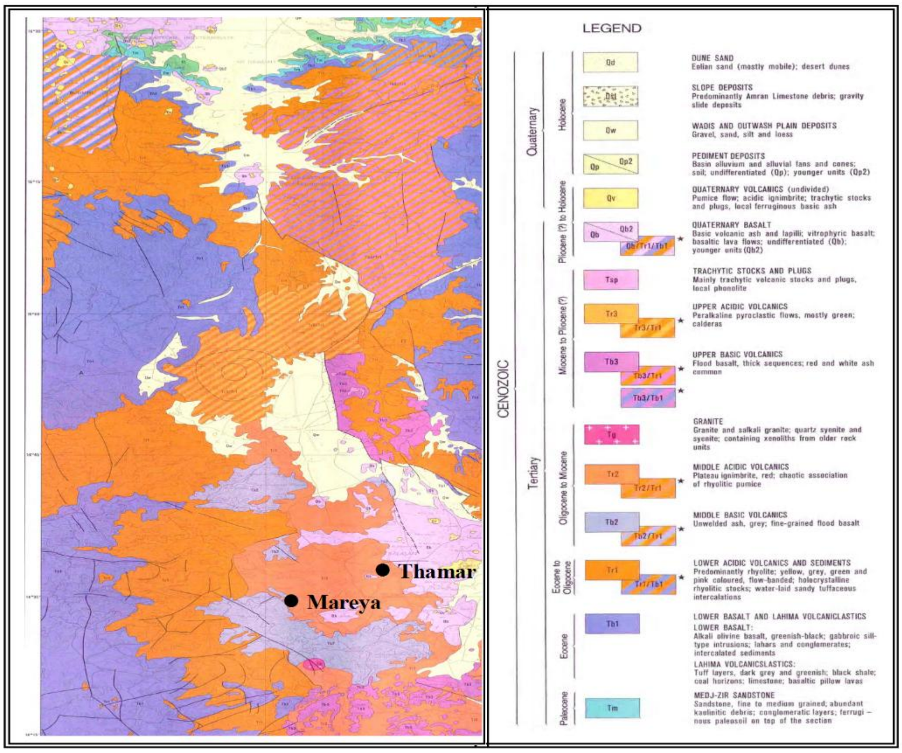


Fig.1: Geological map of South Sana'a region showing the studied localities of Mareya area, SW of Thamar city. The map is adapted from the geologic map of Sana'a sheet prepared by Kruck *et al.* (1991).

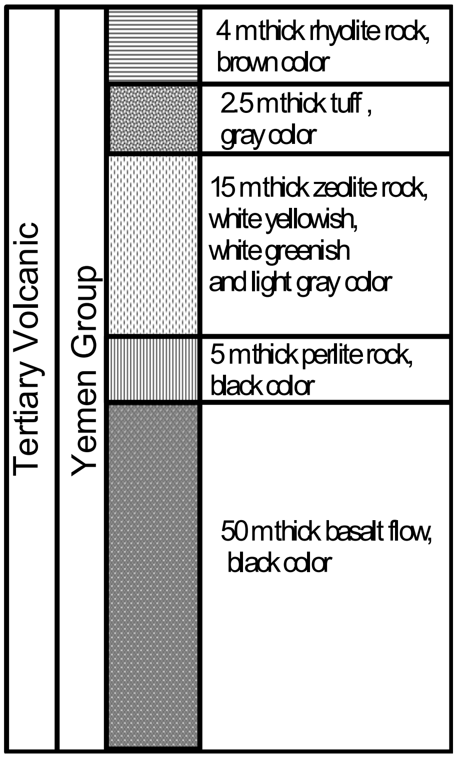


Fig. 2: Stratigraphic section of Mareya locality, showing different exposed rock units in the region (including zeolite rocks).

Tuff consist of welded fragments of various kinds of rhyolite predominate, tuff, gray color and 2-5m thick. The zeolitic layers are characterized by white-yellowish, white-greenish and light gray color and 15m thick. The lithification degree of tuffic rocks varies from place to another .It strongly lithificated, where they found as white-yellowish colors and contain small amount of lithic fragments and high content of zeolite (Fig. 3a).The lithification degree of tuffic rocks is weakly lithificated ,where tuffic rocks found as gray to white –gray color and contain much of lithic fragments .some of these fragments are up to 1mm(Fig.3 b). The zeolites along with the clay materials are found as a cementing material between these fragments (Fig. 3 b). Perlite rocks are acidic, glass rich volcanic rocks, black to gray color of 5m thick.The basaltic flows have a large thickness and contain compact basalt. Generally the rocks are characterized by massive and columnar structures and porphyritic textures, black color.

Methodology

The methods of this study are including the field work and lab. analyses. The field work was carried out including define the zeolitized tuff. Field photographs were taken for the zeolitized tuff. Ten representative samples were collected from fresh and zeolitized tuffs and thin sections were prepared following the procedure listed in Tucker, (1988). The thin-sectioned slides were studied under professional petrographic microscope type (Carl Ziess). Three samples were selected from the chosen samples to represent the zeolitized tuffs. The samples were prepared for powder XRD by grinding without treatment. The diffraction charts and relative intensities are obtained and compared with JCPDS file. The X-ray diffraction analysis was carried out in the laboratories of Al Amri in Saudi Arabia.

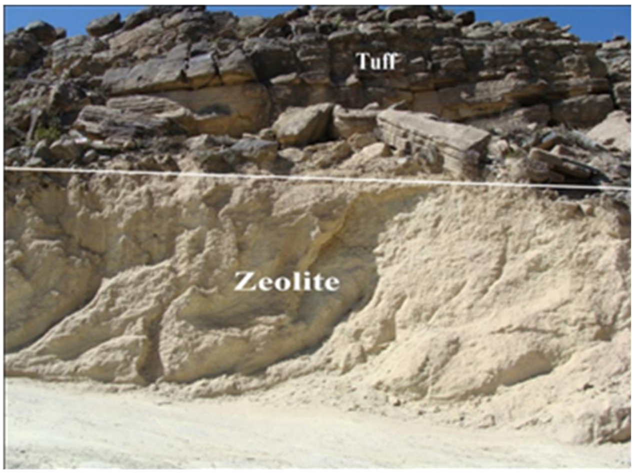


Fig. 3 (a): Photograph showing white zeolitic layer, Mareya area.

Fig. 3 (b): Photograph showing lithic fragments within cement of zeolitic tuff, Mareya area.

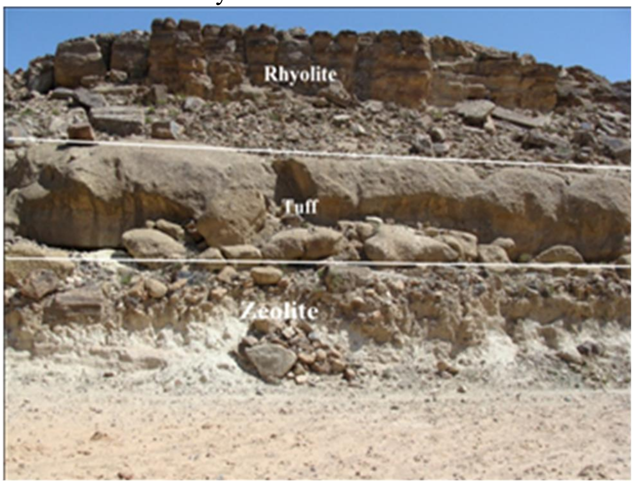


Fig. 3 (c): Photograph showing the layer tuff rocks overlying zeolitic tuff.

Fig. 3(d): Photograph showing gray lens of zeolitic tuff and white zeolitic tuff Layer

Petrography

The petrographic study of fresh tuff and zeolitized tuff rocks comprise the description of the essential minerals and textural variations. Although variable in optical properties they all have low indices of refraction and rather weak birefringence. The last six in the list are fibrous or columnar, but there are also other fibrous zeolites such as ptilolite, mordenite and laumontit. A few rare zeolites such as harmotome and brewsterite contain barium (Kerr, 1977; Frye, 1985 and Dwairi, 1991).

Fresh tuff:

The fresh tuff rocks are composed mainly of phenocrysts and groundmass. The phenocrysts are quartz, sanidine, pyroxene and iron oxide. The groundmass attains about 65% of the rock volume and is composed of silica and clay minerals.

Phenocrysts:

Euhedral to subhedral crystals are scattered in the silica groundmass forming porphyritic texture. Crystals are presents as porphyritic phenocrysts, embedded within the groundmass.

Porphyritic type is represented by quartz and sanidine. The porphyritic texture might support the primary origin of pyroclastic deposits (Pettijohn, 1975; Phillips and Griffen, 1986).

Several types of minerals attain phenocrysts form was recognized, these include:

Quartz, which is the most common phenocrystic phase in the studied fresh tuff. Quartz is present in several forms and in different modal percentages, they range in size from 1 to 5 mm (Fig.4 a, b, c, d). These are:

1- Quartz: occurs as small subhedral to euhedral corroded and fractured crystals present in a range from 5 to 20%. (Fig.4 a, c, d).
2- Cristobalite: it occurs as small, unhedral and highly fractured crystals present in a range of 1 to 3%.
3- Chert: it is present as fine crystal aggregates, it ranges from 1 to 5%.

Feldspars, they are the most common phenocrystic phase in the fresh tuff. The phenocrysts of K-feldspar (sanidine) are large and subhedral to euhedral. The percentage of feldspar phenocrysts range from 2 to 10%

Pyroxene, Pyroxene phenocrysts are present as small euhedral to subhedral crystals. The percentages of the pyroxenes range from 1 to 3%.

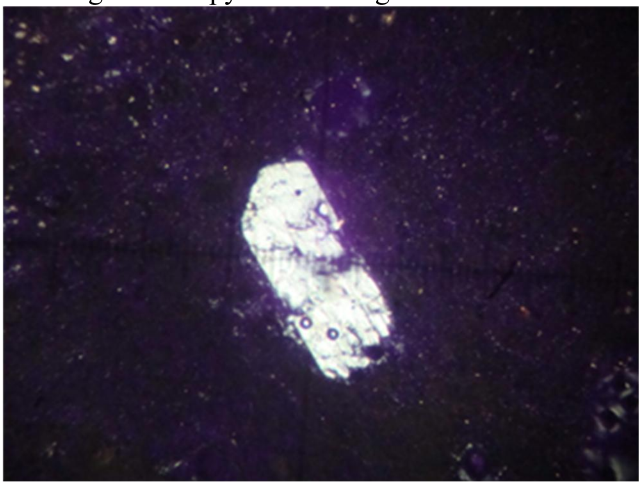


Fig. 4(a): Photomicrograph of fresh tuff: Corroded quartz phenocrysts embedded in a glassy matrix (CP-40X).

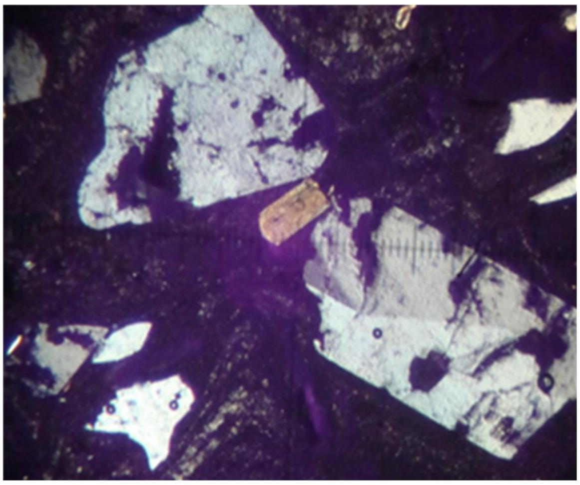


Fig. 4(b): Corroded quartz phenocrysts, sanidine and euhedral diopsite in lithic fragments (CP-40X).

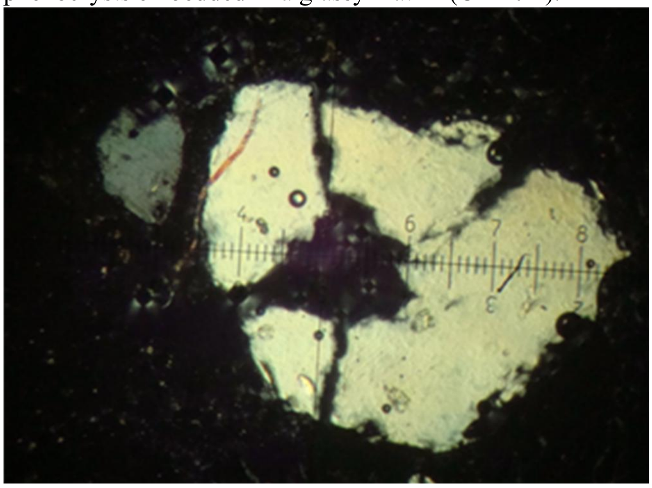


Fig. 4 (c): Photomicrograph of fresh tuff: Broken crystal of quartz Embedded in glassy matrix(CP-40X)

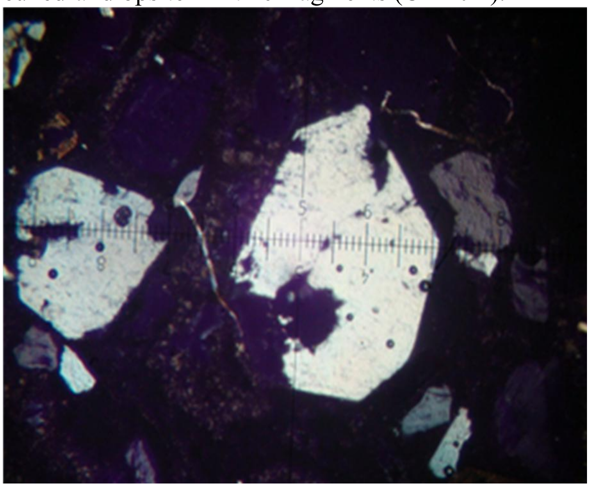


Fig. 4(d): Photomicrograph of fresh tuff: Corroded crystal of quartz Embedded in glassy matrix (CP-40X).

Groundmass

The groundmass is composed essentially of very fine to amorphous silica and minor clay mineral, and reveals the following forms:

1-Amorphous silica of dark color that confirms the tuffaceous texture
2- Small crystals of quartz are scattered in the groundmass.
3- Chert forms fine crystalline silica in the groundmass.
4- Small crystals of clay minerals.

Zeolitized tuff:

Zeolitized tuff consists of white-yellowish, greenish-white to gray-green tuff. Microscopically, these rocks are composed essentially of phenocrysts and groundmass. The phenocrysts are composed essentially of zeolitic minerals, quartz, iron oxides and sanidine. The lithic fragments are occasionally occur in a matrix of zeolite and clay minerals (Fig. 4b).

Phenocrysts Perfect crystals are presents as porphyritic phenocrysts, embedded within the silica groundmass. Several types of minerals attain phencrysts from was recognized, these are:

Quartz: it is present in several forms as, subhedral to euhedral small crystals corroded and broken (Fig. 5a, c and e)

Iron oxides: It is preset as fine grains or spots of opaque magnetite. Iron oxids minerals range from 1to 5% (Figs. 5 a, b and c).

Zeolitic minerals: It is present in small subhedral to unhedral crystals embedded in the groundmass (Fig. 5a, b, c, d, e and f).

Groundmass The groundmass attains about 70% of the rock volume and is composed essentially of very fine zeolitic minerals, amorphous silica and clay minerals. The glassy matrix is completely altered. Highly alteration gave an oxidation color of the groundmass range from light brown to dark brown (Fig.5d).

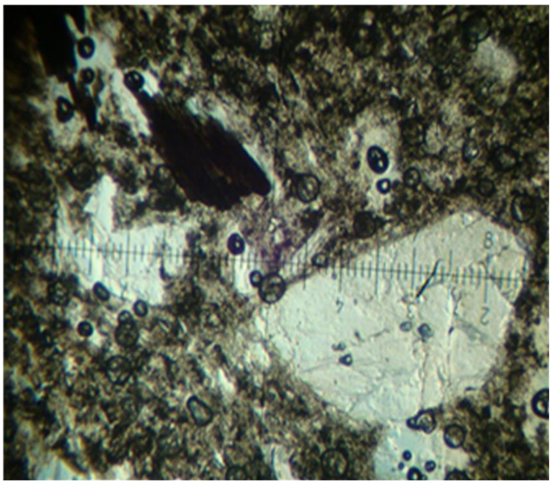


Fig. 5 (a): Photomicrograph of zeolitited tuff: quartz phenocrysts and magnetite stain with rock fragments in a matrix composed of zeolite and clay minerals (CN-40X).

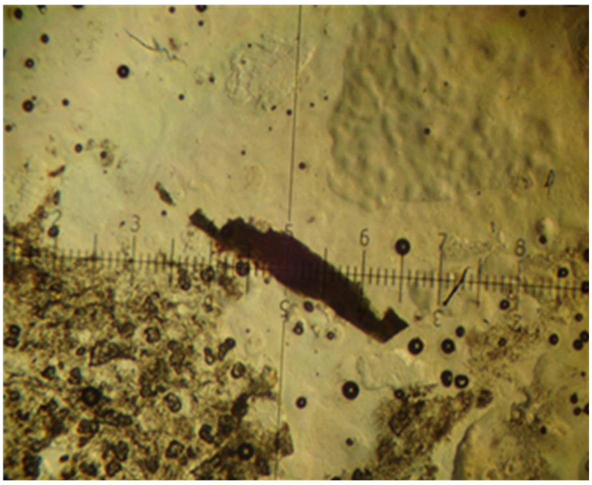


Fig.5 (b): Magnetite stain embedded in a matrix of zeolitic and clay minerals (PPX40)

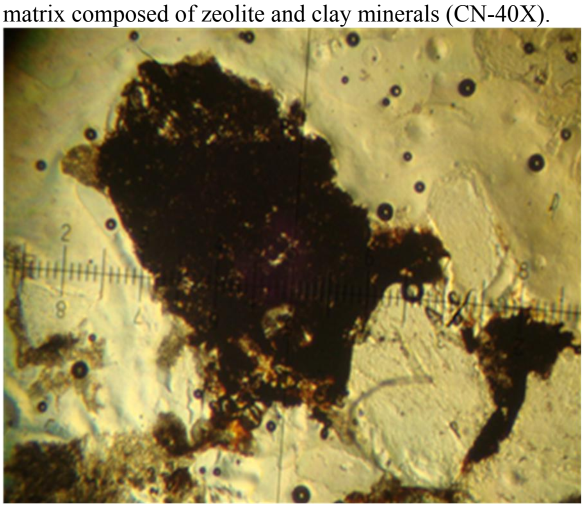


Fig. 5(c): Photomicrograph of zeolitized tuff: quartz phenocrysts and magnetite stain embedded in a matrix of zeolitic minerals (CN-40X).

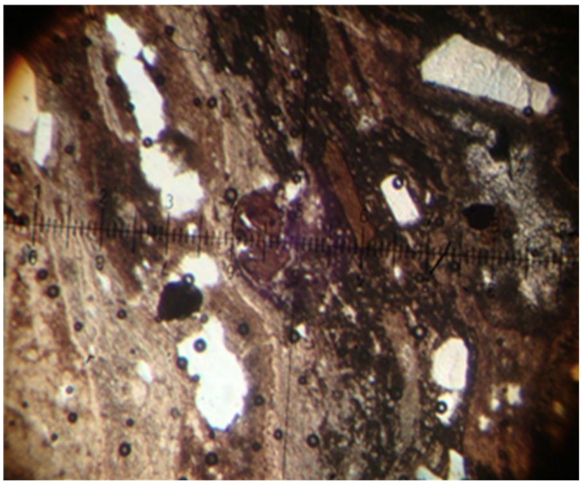


Fig. 5 (d): Quartz phenocrysts embedded in a glassy matrix with a zeolite minerals and containing bubbles of gas (PP-40X).

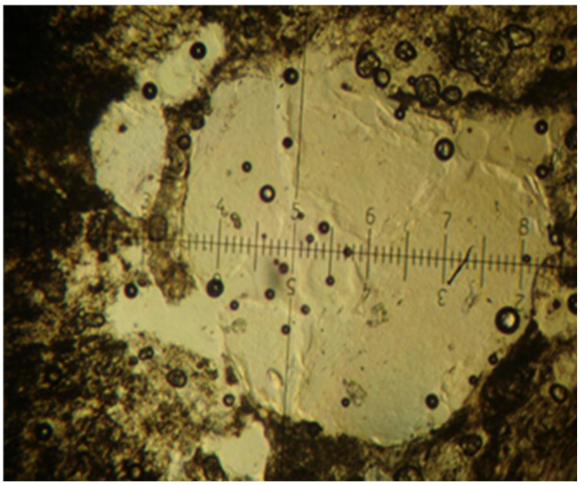


Fig. 5 (e): Photomicrograph of zeolited tuff: quartz pheno-cryst, embedded in a matrix of zeolite minerals (PP-40 X).

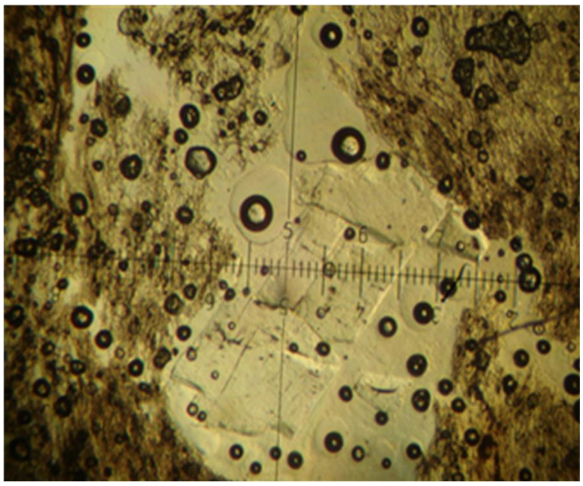


Fig. 5 (f): Quartz phenoccryst embedded in a matrix, composed of zeolite and clay minerals (PP-40X).

Texture

Petrographical studies showed that the tuffs and zeolitic tuffs rocks are characterized by porphyritic and glassy were recognized in the studied thin sections, and they are briefly discussed in the followings:

Porphyritic texture:

The porphyritic texture is present in all of the studied rock samples this texture comprises large crystals of corroded quartz and sanidine minerals embedded in the groundmass (Figs.4a, b, c and 5a, d, e)

Glassy texture:

The glassy texture comprises the amorphous silica groundmass.

Mineralogy of zeolitic tuffs

X-Ray Diffraction

XRD is the most reliable and widely used method for identifying zeolite minerals and providing a semi-quantitative estimate of the percent present in the sample (Papke, 1972). This method has high degree accuracy and can readily be used to identify individual minerals in mixtures of zeolite and nonzeolite minerals. A skilled technician is required to operate the XRD equipment, which many be automated and able to run multiple determinations unattended, and to interpret the results, XRD analysis is a nondestructive method, and the powder used for the analysis can be further tested. The method is least reliable in mixtures of minerals; the lower detection limit for an individual zeolite is about 1%. An experienced mineralogist is needed to interpret the diffraction trace (Flanigen and Mumpton, 1981; Altaner and Teague, 1993). The mineralogical assemblages of Mareya zeolitized tuff were investigated using X-Ray diffraction. Selected X-ray traces for zeolitized tuff are given in table (1) respectively, Clinoptilolite, Mordienit and Quartz contents seem to be the highest in the zeolitized tuff. XRD sheets are shown in (Figs.6 a, b, c). This was inferred from their high peaks intensity in the XRD charts.

Petrographical and mineralogical composition of the studied zeolite tuffs and associated rocks is supported by XRD analysis. These made it possible to investigate and define the conditions that were responsible for the formation of zeolites in the study area.

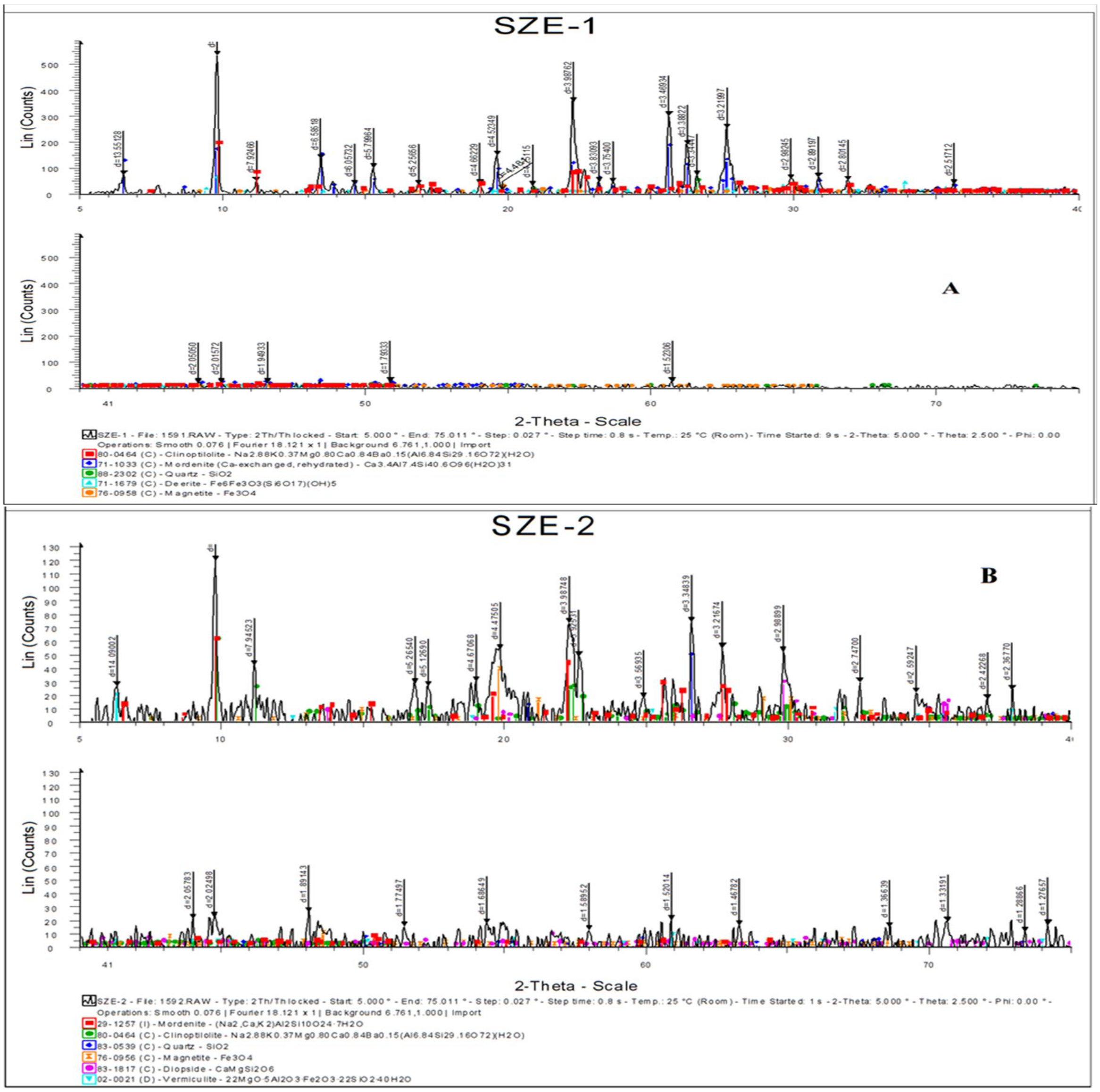
In acidic tephras of hydrothermal regions at shallow depths clinoptilolite and mordenite are formed, and with temperature increase at depth, they are substituted by analcime, laumontite and wairakite (Almner and Grim, 1990 and Tsirambides *et al.,* 1993).

The devitrification feature of the studied rocks is distinguished, which indicates that the rocks have been subjected to extensive hydrothermal alteration (Barrer, 1982; De'Gennaro *et al.,* 2000; Ted and David, 2006).

The zeolite minerals (clinoptilolite and mordenite) in Mareya area occur as a product of hydrothermal alteration of vitric tuffs.

Mineralogical studies by XRD analysis showed that the zeolitic tuffs have been subjected to a various degree of zeolitization. The lithic fragments within these pyroclastic rocks composed of glass shards, rhyolite, some of these fragments are up to 1mm in diameter, furthermore, these pyroclastic rocks are locally intensively zeolitized, silicified and opalized, probably by hydrothermal activity (Cerri, et al., 2001; As Sabri, 2003; Barker, 2003).

Petrographic studies that the zeolitic tuff is characterized by porphyritic , glassy textures, corroded quartz and sanidine are the most abundant minerals in the volcanic tuff (fresh and zeolitized).



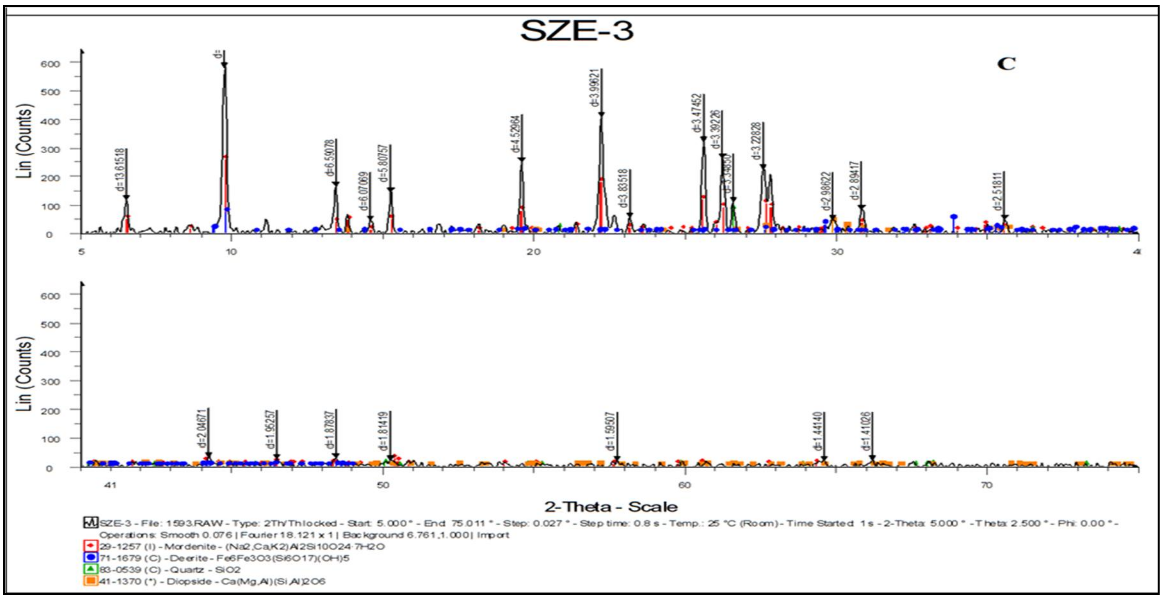


Fig. (6 a, b and c): X-ray diffraction analysis for bulk samples from Mareya Zeolitized tuff.

Mineralogical studies by XRD analysis showed that the zeolites minerals (clinoptilolite and mordenite) of the Mareya area. The zeolites minerals (clinoptilolite and mordenite) have been reported as directly associated with quartz and sanidine.

These studies indicate that the zeolites (clinoptilolite and mordenite) of the Mareya area support that they are formed by subareal hydrothermal alteration of the parent volcanic glass.

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