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RESEARCH ARTICLE

FIRST EVIDENCE OF MAFIC ROCKS IN THE PRERIF SUB-DOMAIN (EXTERNAL RIF, MOROCCO): CARTOGRAPHY AND PETROGRAPHY.

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Abstract

The Rif belt accretionary wedge built mainly during Middle Miocene had closed foredeep-basins and transported various thrust-top basin south- and westward. During Paleogene, early inversion and building of the nappe stack, various upper mantellic and ancient oceanic slices were scraped from a buried old oceanic crust. Then, they were incorporated into the External Rif accretionary prism during subduction processes. The External Domain of the Rif belt has undergone a main shortening, resulting in internal sheet deformations, and subsequent nappe stack. The recent studies cover the Mesorif suture zone and related "oceanic rocks", outcropping in the central and eastern Mesorif-Prerif units, highlighted their petrography and preliminary geochemistry. The aim of this paper is to shed light on the mafic rocks that occur in the western part of the Prerif sub-domain. We describe here for the first time geological and petrographical framework of gabbros slivers, basalt and pillow lavas that appear in Ouazzane region. These fine to medium grain sized gabbros display a subophitic to ophitic texture made up of abundant euhedral to subhedral plagioclase, clinopyroxene crystals are subhedral to anhedral that can be very altered and totally replaced by chlorite and opaques, olivine is less abundant with minor biotite. Alteration phases include serpentine-group minerals, chlorite and low-T hydrous Ca-aluminosilicates such as tremolites. The pillow basalts thin sections show a microlitic texture mainly formed of plagioclase laths and some clinopyroxene totally replaced with secondary minerals.

Introduction:-

The Rif-Betic Cordillera is a tightly arcuate, oroclinal mountain belt along the western edge of the Alpine Peri-Mediterranean Orogen (Fig. 1a). It developed as a result of the convergence and collision between the Eurasian and African plates during the Miocene (Durand-Delga 1980a, Durand-Delga & Fontbonte 1980).

Classically, the complex structure of the External Domain of the Rif belt has been interpreted as nappes stack with a radial pattern related to the Rif belt arched shape (Fig. 1b) (Durand-Delga et al. 1960-1962, Suter 1965, Faure-Muret & Choubert 1971, Andrieux 1971, Leblanc 1975-1979, Suter 1980 a,b; Michard et al, 2002, Zaghloul et al., 2005). However Vidal (1983) Indicated the presence of a huge exhumed upper mantle peridotites in the Beni Malek zone

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and gabbros slivers within the Mesorif corridor. Vidal's conclusions together with the occurrence of MP/LT metamorphism with Mg-chloritoid reported by Negro et al., 2007- promoted researches in the external zones of the Rif belt and led to the interpretation that parts of the Mesorif and prerif sub-domains can include ophiolitic units that may represent allochthonous remnants of the Tethyan oceanic floor (Benzaggagh et al., 2011; Michard et al., 2014). In fact, the development of the Mesorif suture zone (MSZ) was probably promoted by the occurrence of strongly thinned lithosphere since late Jurassic (Asebry,1994). The "ophiolitic slivers" that appear southward in the MSZ were defined by the occurrence of massive gabbro topped by thin mafic rocks; volcano-sedimentry sandstones; limestones and breccias (Michard et al., 2014). While, northward the latter are mainly clastic marbles on the top of the serpentinite of Beni Malek-Skifate Aït Amrâne (Michard et al.,1992). Since, the western part of the Mesorif suture zone still presents a lot of challenging questions about the development of these "oceanic rocks". We present in this paper the first stratigraphical and petrographical descriptions of some mafic outcrops that occur in the Western part of the Prerif Sub-domain.

Geological setting:-

The Rif chain was built during Miocene by the superposition of several thrust sheets clustered into three main tectonic complexes piled up from the bottom to the top and presently cropping out from the foreland to the hinterland as follows; (Fig. 1b) : i) External Units (Leblanc 1979; Sutter 1980).ii) Maghrebian Flysch Units (Durand-Delga,1980a) iii) Internal Units.

The Internal Domain of the Rif Chain, also called the Alboran domain, is organized into three superimposed structural complexes, from the bottom to top: Sebtides (Durand Delga & Kornprobst 1963), Ghomarides (Durand Delga et al. 1960-62, Durand Delga & Kornprobst, 1963; Michard & Chalouan 1990) and "Dorsale Calcaire" (Fallot 1937). This latter includes several stacked tectonic slices forming the highest units of the Rif Internal Domain, defining the boundary between Internal and Flysch Basin Domain in the Rif-Betic orocline (Durand Delga & Fontboté 1980).

The Flysch Basin Domain (FBD) (Durand Delga, 1980; 2006; Durand Delga & Fontboté, 1980; Wildi, 1983, Guerrera et al., 2005) sets on the southern and western paleomargin of the "Mesomediteranean terrane" (*sensu* Guererra et al., 1993, 2005) and consists in Jurassic-Early Miocene sedimentary succession which ensure Mesozoic paleogeographic transition between the external part of the internal Domain (i.e. "Dorsale Calcaire") and the External Domain. The FBD is subdivided into two main palinspastic realms classically known as Massylian and Mauritanian sub-Domains (Bouillin et al., 1970, Dercourt et al., 1986) and mainly made of upper Jurassic-early Miocene turbiditic successions located on the northern African and southern Mesomediteranean microplate paleomargins, respectively. The oceanic floor crust below the Flysch Basin deposits was accreted as narrow hiatus along the Açore-Gibraltar left lateral transfer fault since upper Jurassic between the central Atlantic Ocean (Atlantic Tethys) and Lucanian-Ligurian ocean (south Alpine Tethys) (e.g. Lemoine, 1983; Bouillin, 1986; Dercourt et al., 1986). The remnants of oceanic Flysch Basin seafloor exclusively crops out as pillow lavas basalt with E-MORB signature (Durand Delga et al., 2001). Eastward, in Tell and Sicilian Maghrebian belt, some gabbros, serpentinized peridotites and basalt flows were described in the Rekkada-Meltine area and in Troina-tusa Flysch nappe, respectively (Bouillin; 1986, Durand Delga et al., 2001).

The External Zones derive from the North-African paleomargin inverted during the Early Miocene collision of the Internal Zones. It consists of Mesozoic–Cenozoic successions mainly made of pelagic sediments and of siliciclastic turbidites, which were deposited onto thinned and partially oceanized continental crust of the African margin (Durand-Delga et al., 1960; Guerrera et al., 1993). The external Rif Domain is characterized by Triassic evaporitic deposits of Germanic facies, followed by a lower Jurassic carbonate mega-sequence and by an Upper Jurassic turbiditic sucessions. This margin has undergone different stages of subsidence mainly during the Cretaceous, characterized by sequences with olistostromes and very important lateral thickness variations Ciszak, 1986 ;Lespinasse, 1975; Asebriy et al., 1987; Ciszak, 1987). In the External Rif we may distinguish three structural zones, the Prerif, Mesorif and Intrarif, each of these zones has undergone a main shortening and related deformations and nappe stacking mainly during Middle Miocene (Serravallian-Tortonian) and propagated to the south and southwest during the Late Miocene to the Quaternary (Morel, 1989; Ait Brahim, 1991).

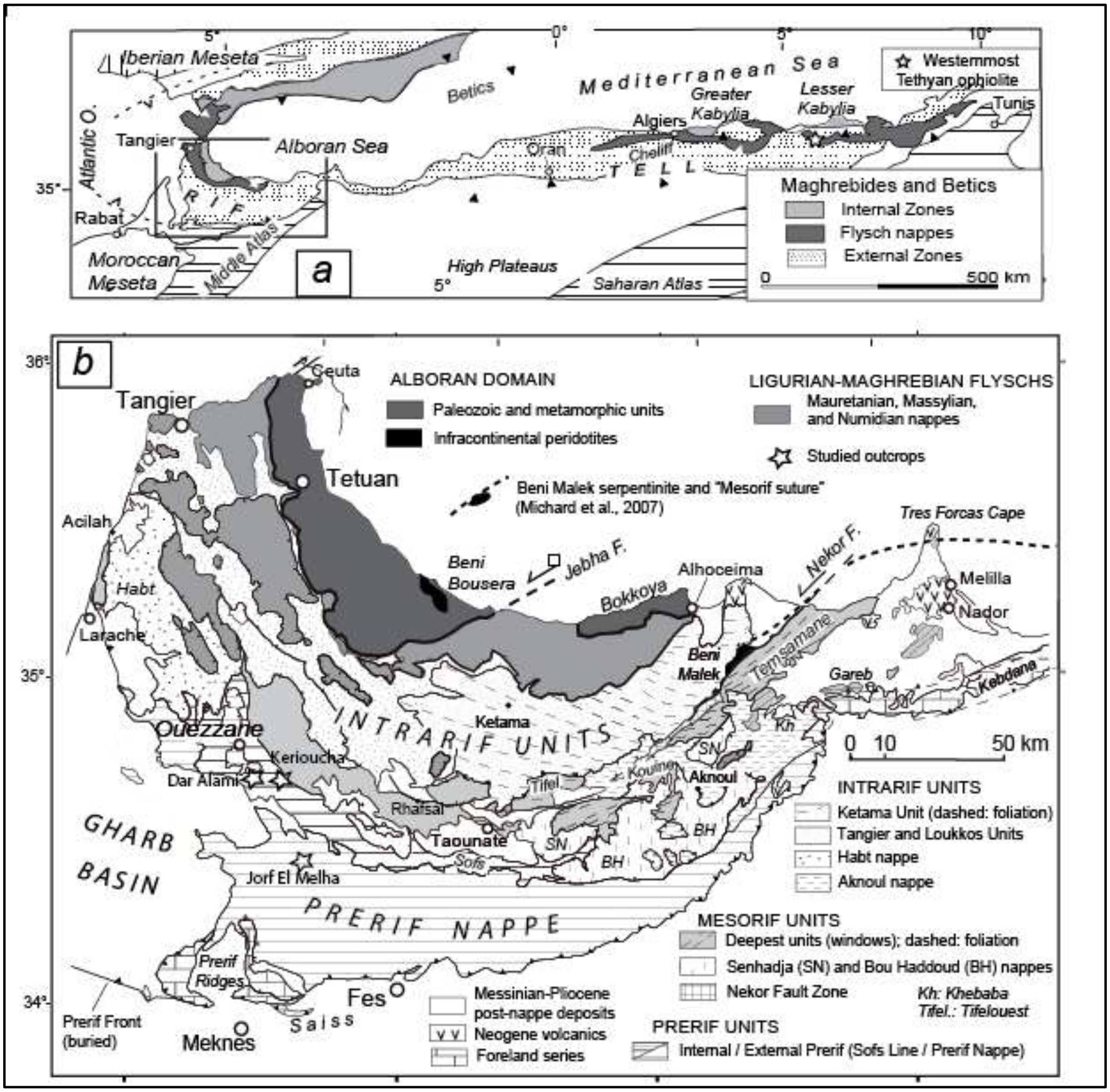


Figure 1:- (a) : Location of the study area in the Maghrebide Belt of North-Africa; (b) : Structural map of the Rif Belt modified after Suter (1980b) and Chalouan et al. (2008)

1-1 The Intrarif Sub-Domain:

The Intrarif zone includes the most distal units derived from the african paleomargin. The Intrarif nappes display a simple internal structure characterized by open folds and locally, by a pre-nappe cleavage. They overthrust the mesorif and Prerif zones, and they are tectonically overlain by the Numidian Nappe (Leblanc 1979). These units crop out immediately beneath the Maghrebian Flyschs and Dorsale units. This domain consisting of both the Tanger and Ketama Units, mainly formed by Mesozoic-Tertiary successions, is locally well marked by a Paleogene sedimentation hiatus in the Internal Tanger Unit (Durand-Delga & Mattauer, 1959b; Lespinasse, 1975). Lower Miocene conglomerates unconformably are overlying the Jurassic-Neocomian successions located in the more external areas of the Ketama Unit and belonging to the Mesorif Units (Favre 1992).

1-2 The Mesorif Sub-Domain:

The Mesorif is a narrow and disrupted zone of imbricated Mesozoic rocks. It shows allochthonous units (nappes) including Triassic to Lower Miocene formations. They are thrust over parautochthonous Intrarif units observed in tectonic windows and whose series end with Middle-Upper Miocene turbidites and olistostromes (Wildi, 1983;

Michard et al., 2014). This zone displays different from western-central Rif to eastern Rif. The recent studies covering the Mesorif suture zone and related *"oceanic"* rocks that crop out in the central and eastern Mesorif-Prerif units, highlighted the presence of serpentinites and gabbros at the stratigraphic base of the eastern and central Mesorif sequences and Mg-chloritoid-bearing MP/LT metamorphic rocks ~~occur~~ in the eastern Mesorif sequences indicating their involvement in subduction zone metamorphism (Negro et al., 2007; Benzegagh et al., 2011; Michard et al., 2014).

1-3 The Prerif Sub-Domain:

The Prerif is the most external zone of the Rif belt. It was defined on the base of its marly Cretaceous sequence with a large number of stratigraphical gaps due to erosion and resedimentation into the Mesorif (Marçais and Suter in Durand-Delga et al. 1962). It is classically divided into Internal and External Prerif.

The Internal Prerif is formed by a fold-and-thrust belt involving Jurassic and Lower Cretaceous rocks detached from the Paleozoic basement. It is made up of thin and discontinuous thrust-sheets emplaced over the External Prerif (Michard, 1976; Ben Yaïch, 1991; Favre, 1992). The Internal Prerif sequence starts with Triassic redbeds and evaporites with reworked altered ophites followed by Sinumerian-Carixian massive and calcareous breccias. Middle Jurassic is mainly made of marly limestones and marls, while late Jurassic is characterized by a siliciclastic "ferrysch" turbiditic sucession which outcrop as extrusive slices. The Kimmeredgian-Portlandian is characterized by external plateform/slope carbonates with nodular, thickbeded lenticular and *amonitico-rosso* limestones (Suter, 1985). The plateform deposits passe to Cretaceous-lower Miocene marly, marly limestone and siliciclastic turbidiic successions, and later to the fine-grained foredeep deposits middle to early-late Miocene in age. The latter rework huge olistholiths of greenschist metapelites/metarenites slivers and rare E-MORB and N-MORB basalt rocks (Benzeggagh et al., 2011).

The external Prerif or "melange zone" of Vidal, (1983a and b) is mainly formed by Jurassic to Miocene units, surrounded by a Triassic redbeds and evaporites that was extruded transported to the SW and deposited in the foreland basin during the Middle and Late Miocene (Feinberg, 1986; Ben Yaich 1991; Frizon de Lamotte et al. 1991; Kerzazi, 1994; Chalouan et al. 2001; Michard et al., 2008).This unit shows, in many cases, Cretaceous- lower Miocene stratigraphic successions similar to those of the Internal Prerif. The main fold and thrust contacts of the whole External zones are sealed by the transgression of Upper Tortonian conglomerates and sandy marls (molasses) recording the southward collapse of the tectonic prism (Samaka et al., 1997). These youngest marine deposits of the area were folded during the Messinian-Pliocene and are preserved now within large "post-nappe" synclines. Triassic diapirs are scattered in the whole area, frequently associated with salt ponds and gypsum quarries (Chalouan et al., 2011).

1- Stratigraphy of the outcrops:

This is the first work that aimed the study and sampling of Dar Alami, Jorf El Melha and Kerioucha outcrops, belonging to the prerif unit, to give an overview of their stratigraphic and petrographic characteristics.

2-1 Dar Alami Outcrop:

The outcrop is named based on the huge exotic Paleozoic rock called "Alami Rock" (Plate I Photo 1), it is located on the road Ouazzane-Fes at about 22Km from Ouazzane city (Fig. 1b). It is made of highly sheared metapelites and metarenites greenshist facies.

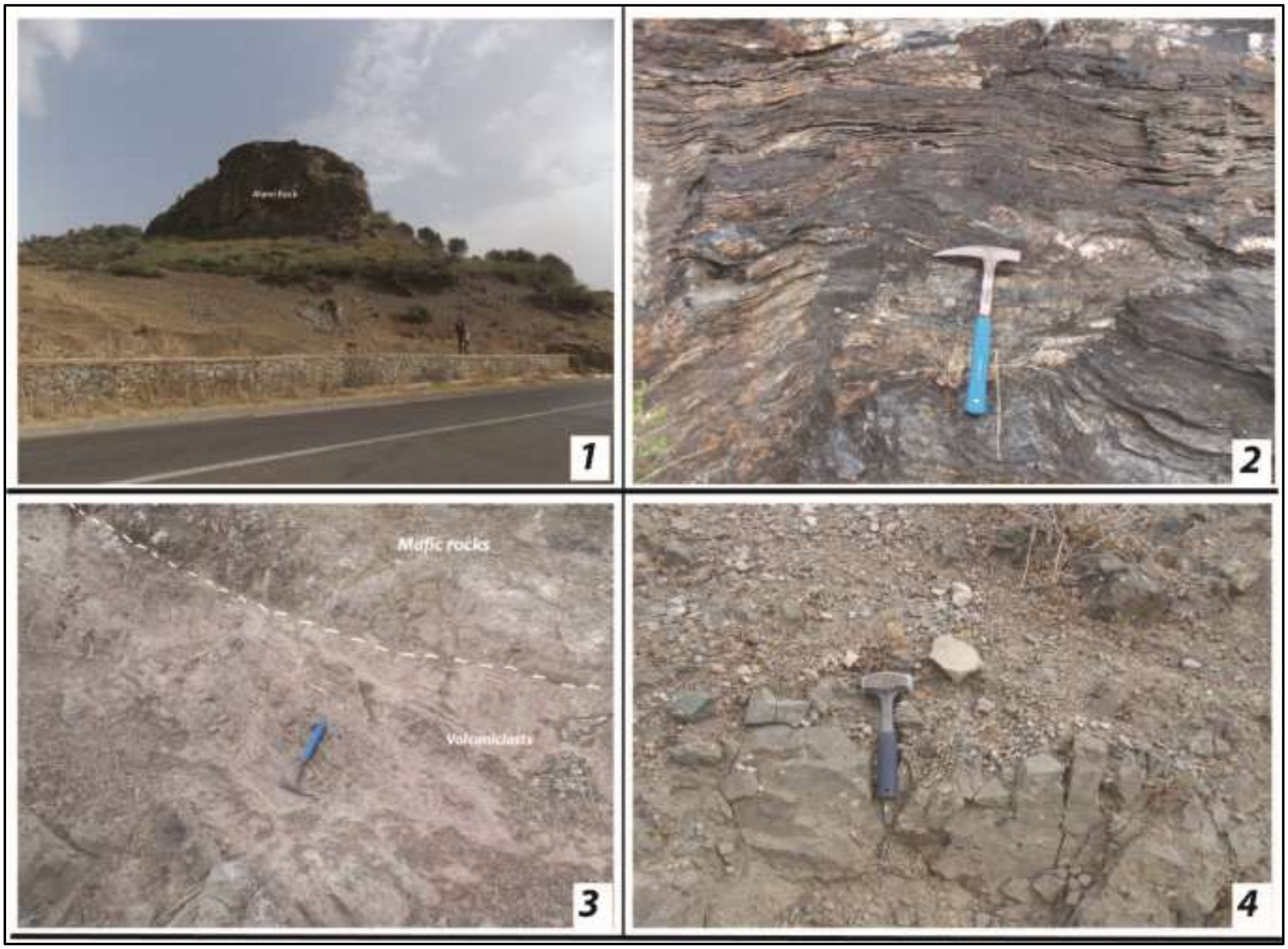


Plate I : Photo (1) :- panoramic vue showing Alami Rock, Photo (2) ductile deformation affecting the metapelites and metarenites greenshist facies, Photo (3) : the contact between the mafic rocks and the volcaniclastic level, Photo (4) : the gabbro

This outcrop shows two main coaxial ductile deformations (Plate I Photo 2).

- Near the rock a vertical succession displaying from the base to the top (Fig. 3):
- about 1m of thin-bedded reddish stratified volcaniclastic deposit reworking some pillow lavas (RE-4) (Plate I Photo 3)
-about 2m of doleritic dyke (Plate I Photo 3) (RE-5),
-about 10m of decimeter thick grey and stratified crystalline limestones
- Around 50 m of light colored marls
- A gabbroic body of about 2m (Plate I Photo 4) (PS-4, RE-06).
- Around 150m of weathered light-colored marls reworking a metric olistolith 2 to 3m thick of stratified crystalline limestones and gypsum breccias.
- And about nearly 150 m of turbiditic sandstones intercalation with light-colored marls.

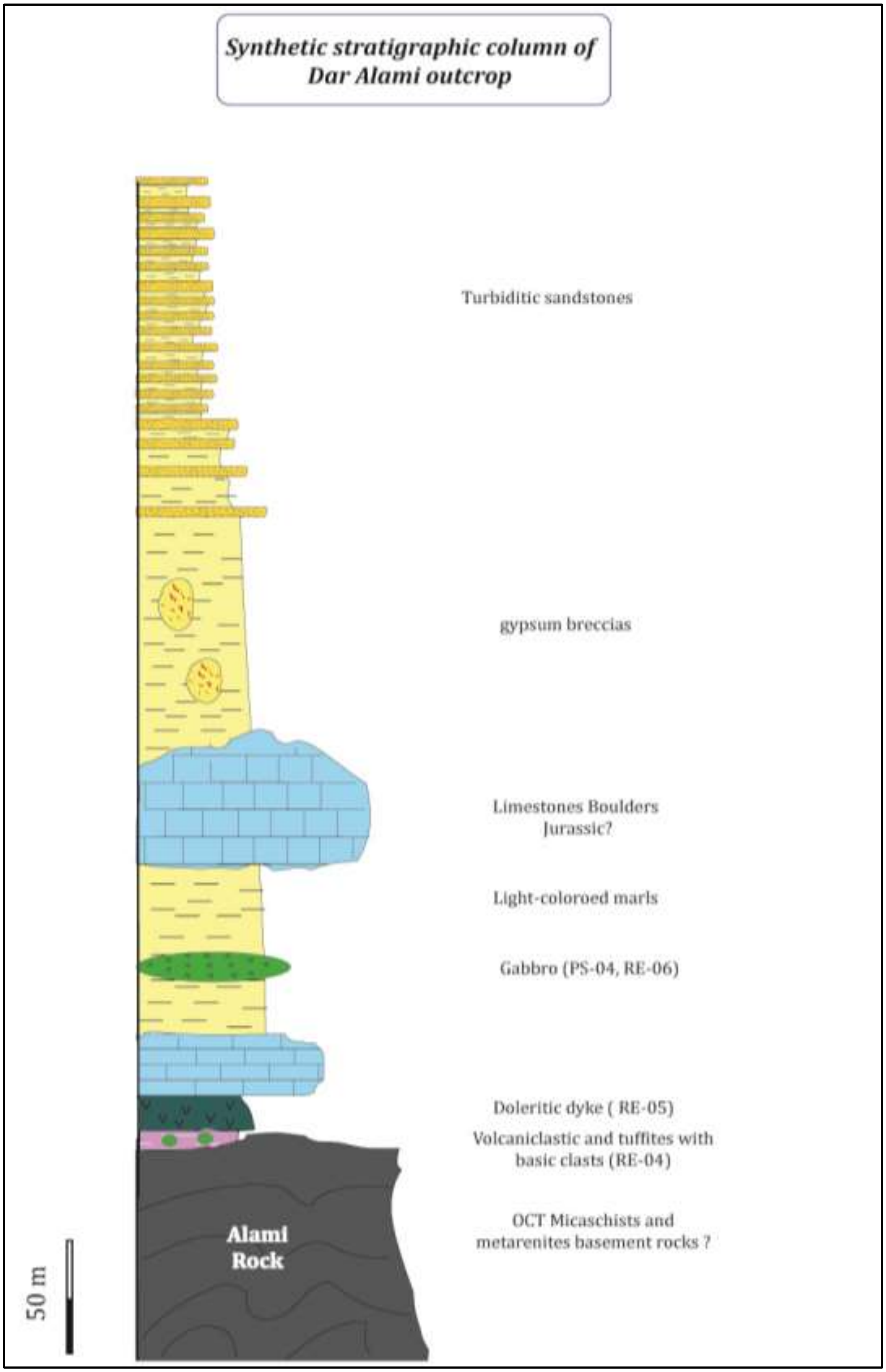


Figure 3:- Synthetic stratigraphic column of Dar Alami section

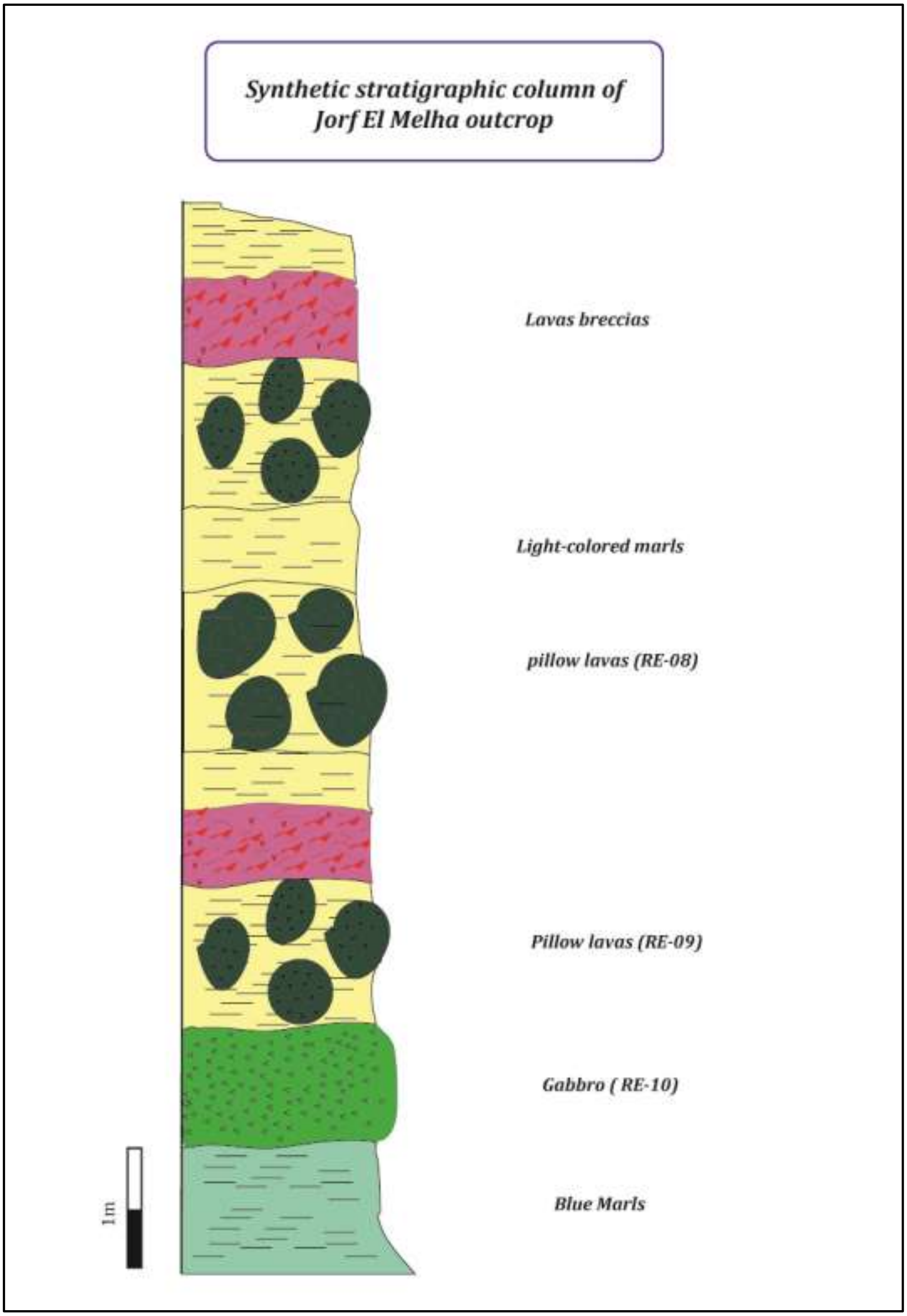
2-2 Jorf El Melha Outcrop:
Jorf El Melha outcrop is located at about 43Km South of Ouazzane city (Fig. 1b) on the road Ouazzane-Fes. It starts from the bottom with about 1m blue marls succeeded by a gabbroic body of nearly 1m wide (RE-10), then well-developed decameter pillow-lava basalt (about 10m wide) (Plate II Photo 1).

Plate II : Photo (1) a vue of the contact between lavas breccias and pillow lavas body from Jorf El Melha outcrop, Photo (2) and (3) the pillow lavas , Photo (4) and (5) the olistholists of gabbro and gypsum reworked in light colored marls.

These basaltic pillow-lavas (samples RE-08, RE-09) are capped by 1m to 2m thick breccias level with subangular basalt with seldom red basinal clays matrix in-between (Plate II Photo 2)(Fig. 4). Both, pillow-lava and overlying breccias are presently embedded as huge olistholitostrome within late Miocene? yellow light-colored marls (Plate II Photo 2 and 3).

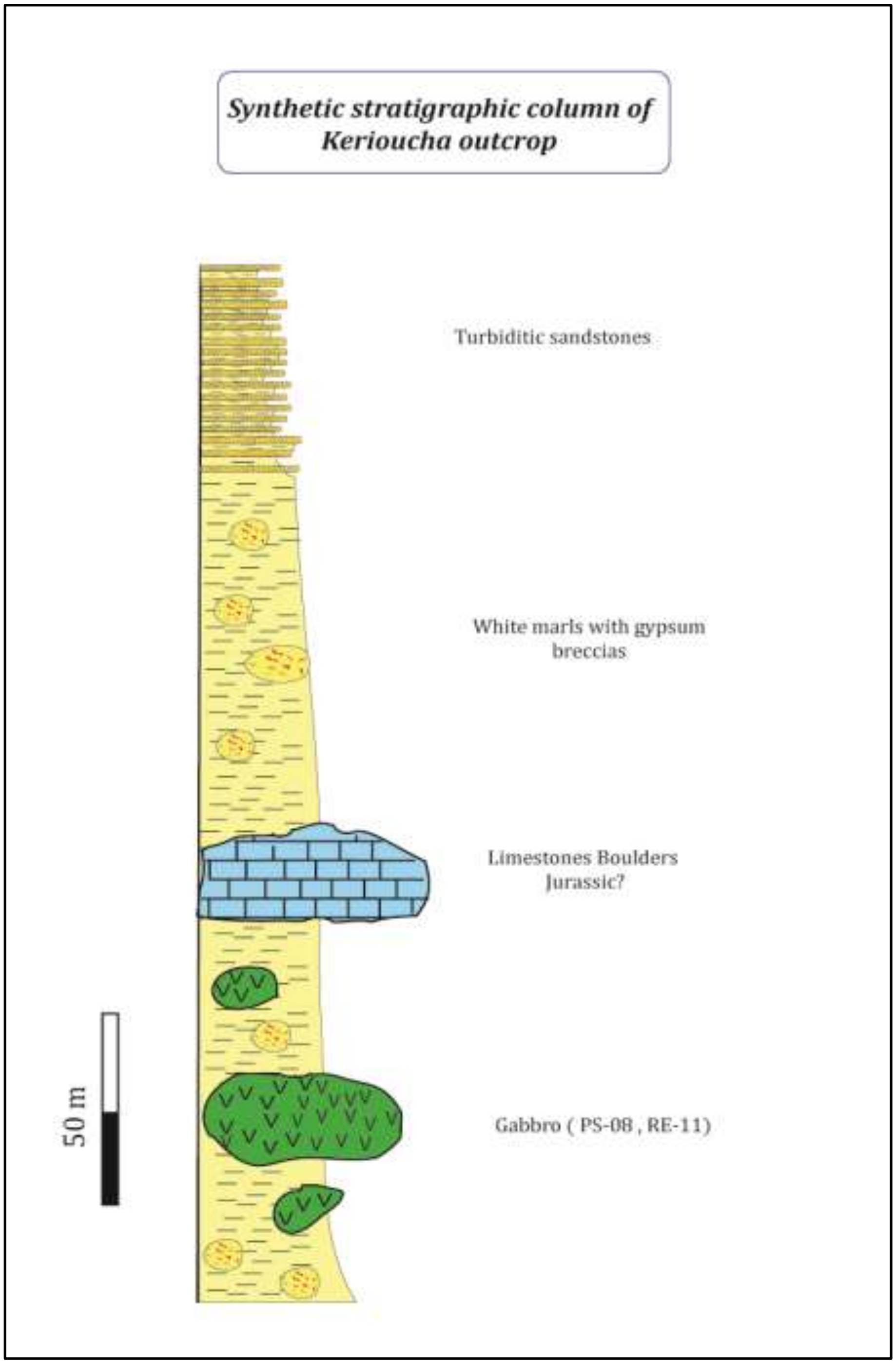
Figure 4 : Synthetic stratigraphic column of Jorf EL Melha ouctrop

Figure 4:- Synthetic stratigraphic column of Jorf EL Melha ouctrop



2-3 Kerioucha Outcrop:
The outcrop is located in the Krioucha near Dar Alami rock (Fig. 1b); it is represented by light colored marls, probably Miocene, reworking meter to plurimeter-sized heterogeneous calcareous boulder limestone, gypsum breccias and a huge gabbro olistholith (PS-08 and RE-11) (Plate II Photo 4 and 5) as reported in the stratigraphic log of Krioucha (Fig.5).

Figure 5:- Synthetic stratigraphic column of Kerioucha section



3 Petrography of the studied outcrops:
3-1* Dar Alami samples*:

Sample RE-04 collected from the pillow lava reworked in the volcaniclastic level represents a very weathered basalt, the rock contains very altered phenocrysts of pyroxene and randomly orientated with weathered plagioclase laths set in an aphanitic matrix. The thin section shows many bimodal vesicle structures filled with calcite or quartz with developed calcite or chlorite rims (Fig. 6a), in addition to iron oxides. In the other hand Sample RE-05 represents a holocrystalline dolerite (diabase), with an aphanitic matrix. It represents abundant altered slender laths of plagioclase (Fig. 6b) and less abundant phenocrysts of clinopyroxene transformed sometimes completely on calcite or chlorite. While Samples (PS-4 and RE-06) collected from the gabbro level represent a fine to medium grained gabbro, they show a strongly altered ophitic to subophitic texture mainly made of very altered euhedral/subhedral laths of plagioclase, large clinopyroxene crystals and small crystals of olivine, in addition to low-Temperature alteration minerals such as chlorite, some biotite and epidote with many opaques (Fig. 6 c & d).

3-2 Jorf El Melha:

the pillow lava sample RE-08 ,is a basalt where euhedral plagioclase crystals (up to 1.5-1.7 mm in size) are the most abundant phenocryst species, often forming glomeroporphyritic aggregates; the sample shows euhedral to subhedral clinpopyroxene completely replaced by chlorite and opaques, occur as isolated crystals or in bimineralic clots associated with plagioclase (Fig. 6e), while the groundmass consists mainly of altered slender laths of plagioclase clinopyroxene micrograins with some opaques and oxides. While the RE-09 collected from the uppermost pillow lavas deposit represents a basalt with a subophtic texture made manly (about 90%) of subhedral to anhedral laths of plagioclase, with very altered euhedral/subhedral clinopyroxene crystals completely replaced sometimes with opaques and oxides. The last mafic sample collected from this outcrop (RE-10) is a gabbro displaying a subophitic to ophitic texture, with abundant and altered subhedral to anhedral plagioclase laths, clinopyroxene crystals are very wheathered showing subhedral to anhedral forms (more likely augite) and replaced partially and even totally sometimes with chlorite and opaques, olivine crystals are consistently transformed to iddingsite, relatively abundant biotite crystals with low-T hydrous minerals represented by serpentines, chlorites and epidotes in addition to calcite that fills the cracks (Fig. 6f).

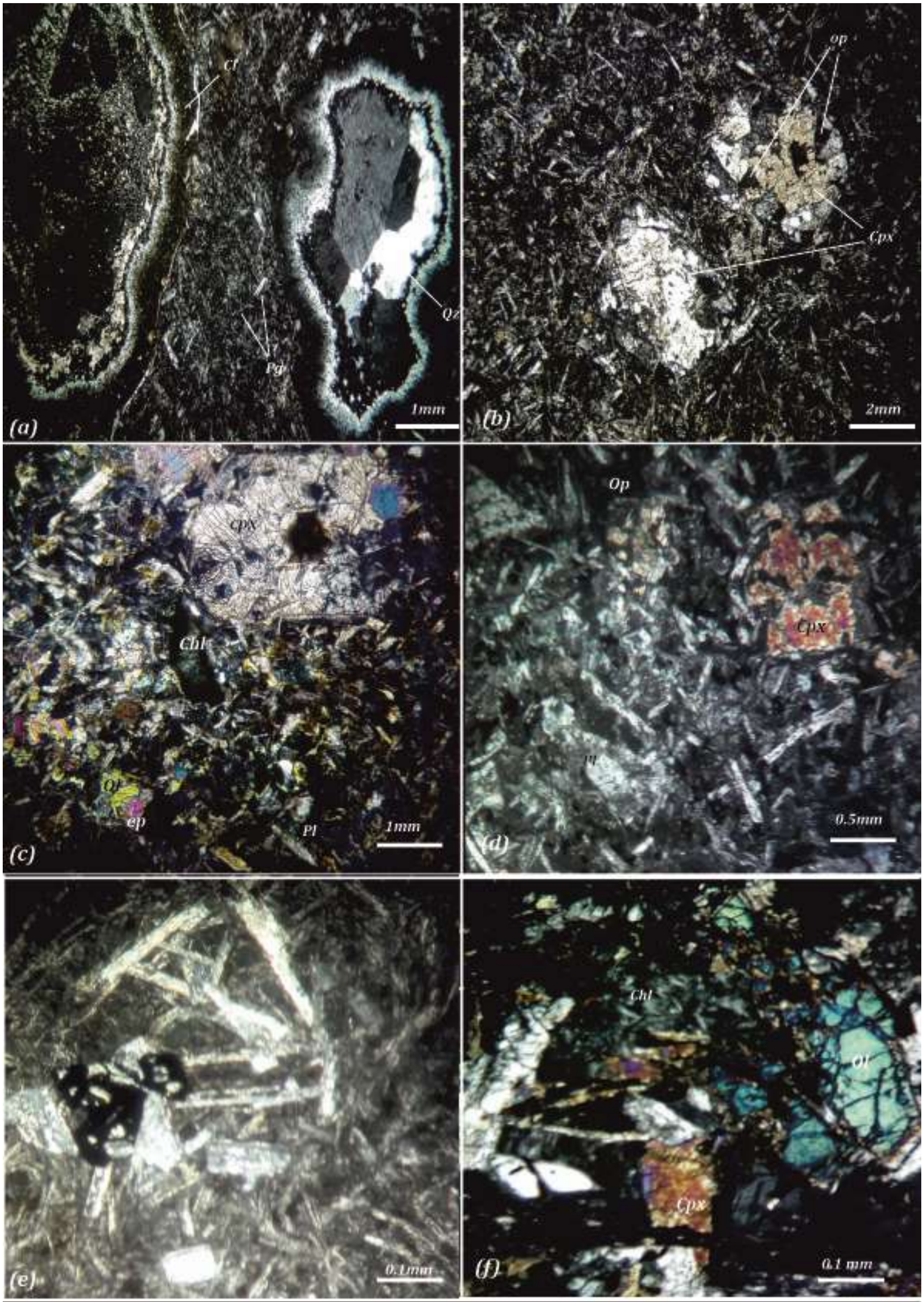


Figure 6:- (a) sample RE-04 in thin section with the vesicles filled with quartz and calcite and multiple rims, (b)

sample RE-05, (c) sample PS-04, (d) RE-06, (e) sample RE-08 showing clinopyroxene replaced by opaques and forming bimineralic clot associated with plagioclase, (f) sample RE-10

3-3 Krioucha outcrop:

The olistolith's samples PS-8 and RE-11 are medium-grained gabbros with a subophitic to ophitic texture sometimes locally intersertal, made of very weathered euhedral to subhedral plagioclase laths sometimes transformed completely to albite, with subhedral to anhedral clinopyroxene crystals more likely augite crystals (generally smaller and less abundant) some infrequent olivine (completely replaced by iddingsite in some places) and few opaque microphenocrysts/microcrysts are also present. The samples show a very similar appearance and a deeply altered status, with abundant low-T hydrous minerals represented by serpentines, chlorites, epidotes and tremolite sometimes filling the cracks (Fig. 7b).

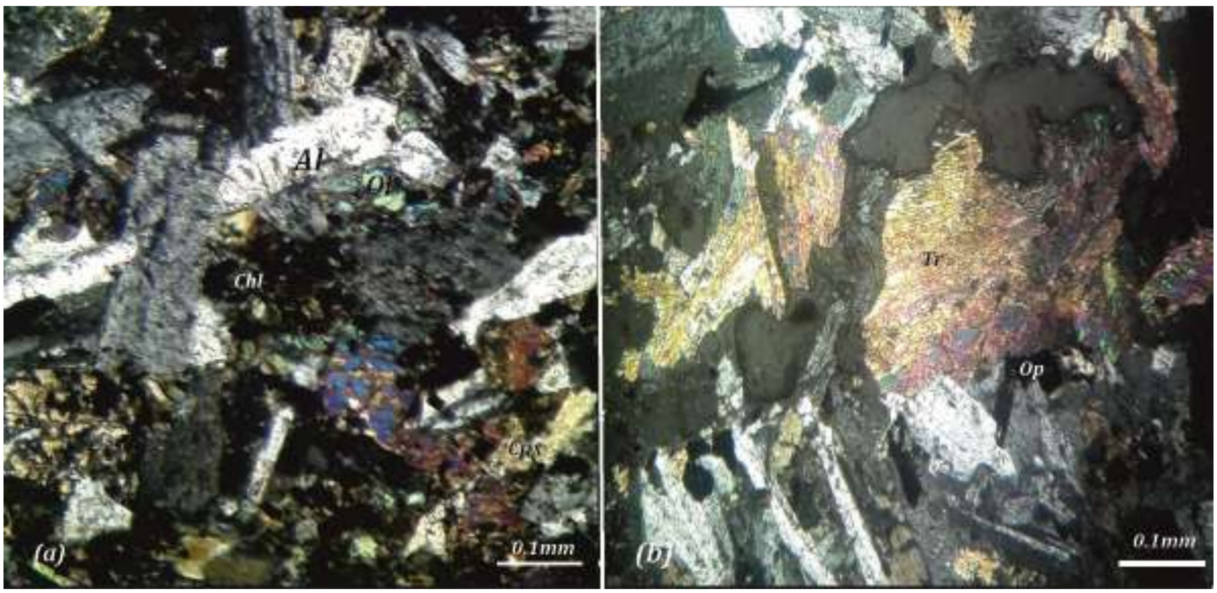


Figure 7:- (a) Sample PS-08 Thin section , (b) sample RE- 11 showing tremolite crystals

Conclusion:-

In this paper, we have presented for the first time geological and petrographical evidences of mafic rocks occurrence in the western part of the prerif sub-domain. These rocks consist of gabbro pillow lavas and other diabases, still geochemical and geochronological analyses are needed to understand first the origin of these rocks as well as the geodynamic framework. Are these sections remnants of an ophiolitic complex as it was already indicated in the western and central parts of the Mesorif suture zone by Michard et al. (2014) or in a bigger scale these rocks are slivers of a hyperextended margin?

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