Problems of the Zagros Ophiolites and Basaltic Bodies, Examples from Kurdistan Region, Northern Iraq

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Abstract

In the Iraqi Zagros, there are ten ophiolites and basaltic bodies, the famous ones are Penjween, Mawat, Bulfat and Peshashan Ophiolite complexes in addition to basaltic bodies such as Kata Rash, Avroman, Gercus, Chalki, and Hamrin basaltic bodies. The present study describes more than 12 significant problems concerning the previous assigning of the bodies as igneous rocks. These problems are observable in the field, laboratory, and in most previous works of literature that oppose the magmatic origin of these bodies. Our study explicated all aspects of each problem and clarified how the problems contradict magmatic crystallization and aid the sedimentary origin of these claimed igneous bodies. Finally, the interpretations of all the problems were collected as conjugate pieces of evidence for appraisal of the new origin of all igneous bodies in the Iraqi and Iranian Zagros belt. The outcomes consider the ophiolitic and basaltic rocks metamorphosed volcaniclastic sandstones (greywackes or mafic sandstone). These sandstones belong to fresh or metamorphosed greywackes of stratigraphic units of the Paleocene-Eocene Walash Formation (as distal facies) and Kata Rash Conglomerate (as proximal facies) which were previously considered volcanic rocks. These sediments are sourced originally from Urumeiah-Dokhtur Magmatic Arc (ADMA) and deposited inside Neo-Tethys, present Sanandaji-Sirjan Zone (SSZ), during the Jurassic-Early Cretaceous. Later, the sediments were metamorphosed and uplifted during the Paleocene and deposited inside the Iraqi Zagros belt by turbidity currents inside the Zagros Foreland basin. These ideas are shown in detail by tectonic and paleogeographic models.

Keywords: ophiolites, basaltic bodies, Kurdistan region, Northern Iraq

Introduction

Gass (1968) [1] documented ophiolite during works on the Troodos Complex as segments of an oceanic crust and upper mantle thrusted on the continental margins yet its origin is still controversial and problematic. The problems of the ophiolites are treated by many authors such as Belostotskiy and Kolbantsev (1970) [2], Coleman (1972) [3], Moores (1986) [4], Dewey et al. (2009) [5], Wakabayashi and Dilek (2003) [6], Casey and Dewey (2009) [7]. The most serious problem is the shifting of the geochemical affinity of the ophiolites toward the island arc such as those of Zagros (see Desmons and Beccaluva,1983[8]). The above authors solved many problems in their view, however, there are many unsolved ones since there are 40 questions about ophiolite on the ResearchGate (https://www.researchgate.net/topic/Ophiolite).

The Zagros ophiolitic and basaltic rocks are more problematic than other regions which is the focus of the present study. Previous studies investigated more than 10 claimed mafic igneous bodies (Ophiolite and basaltic bodies) and nearly the same number of felsic dykes in Northern Iraq. One of the serious problems in these studies is ignoring boundary data such as similarities, dissimilarity, and the correlation between igneous bodies in different areas in addition to concordant and discordant relations with host rocks. Another ignored issue is no attempts are tried to investigate the relation of these claimed igneous rocks with surrounding fresh or metamorphosed sedimentary rocks. In this context, this study arises and explains many problems that are associated with these bodies and elucidated in-depth the consequences of these problems on their origins. The first problem is the occurrence of all ophiolites and basalts inside siliciclastic sedimentary rocks (table1), and from the 10 bodies, no one of them is located inside marl, limestone, dolomite, gypsum, and shale. A second is an absence of contact metamorphism around all the claimed dykes, ophiolites and basaltic bodies in northern Iraq. A third problem is the lack of cross-cutting between claimed dykes and basaltic bodies and bodies extending parallel to the layers of the hosting, rocks. The fourth is the barrenness of all the basaltic bodies of volcanic vents (necks), cones, flows, calderas, volcanic bombs, and peperite. A fifth property is wide-spread of beddings and laminations in all the bodies with occasional cross-bedding, graded bedding, and erosional surfaces. The sixth is a resemblance of the claimed ophiolites to the Tanjero and Kolosh formations in terms of architecture, bedding, topography, lamination, and depositional models. The seventh problem is an absence of enclaves and xenoliths clasts in the basalts of the High Folded zone (Arabian platform) while those of the thrust Zone Sanandaj-Sirjan Zone (SSZ) claimed to contain these clasts. The eighth problem is the high tectonic tilt angle (mostly 30- 90 degrees) of both ophiolite layers and surrounding sedimentary beds. The ninth problem is the contrasting result of age determinations by previous studies even for the same bodies and same sample. A tenth is an absence of relevant deep marine sediments (pelagic limestone, hemipelagic marl) at the top of the claimed ophiolite, conversely, they are topped by reefal limestones (Naopurdan Formation or its metamorphosed equivalent). The Eleventh Problem is why all ophiolites and basaltic rocks do have the properties of strati-bound rocks. The twelfth one is why there is no ophiolite obduction at present. The thirteenth is a similarity between the olivine of Mawat and Penjween ophiolites with that of the Arabian platform (e.g. Jabal Sanam). For solving these problems, the present study displays many new pieces of evidence with the aid of previously published articles. The main previously described ophiolite and basaltic bodies are listed and defined below. In Iraq, ophiolite rocks are introduced for the for the first time in the Mawat area by Masek and Etabi (1972) [9] and Al-Mehaidi (1975) [10] which is expanding of the previous idea of Horn and Lees (1943) [11] about the nape emplacement as an origin of the Mawat Igneous rocks.

Mawat Ophiolite Complex

This complex is located 35 km north of Sulaimani city directly to the south of the Iranian border (Fig. 1). Al-Mehaidi (1975) [11] considered the Mawat ophiolite as ultrabasic rocks, gabbros, biabases, metadiabase basalts, and metabasalts. While Buda and Al-Hashimi (1977) [12] recorded rocks such as ultramafics, pyroxenite, layered and coarse gabbros, diorites, dolerite dykes, and late-stage plagiogranite differentiates. Buday (1980) [13], Jassim et al. (1983) [14], characterized the complex as massif and nape bodies, which consisted of two parts, the first is metabasalts and diabases located at the boundary of the complex, and the second is mafic and ultramafic rocks that exposed in the core of the complex. The rocks of this complex, similar to Penjween Ophiolite, underwent regional metamorphism to greenschist facies.

Penjween Ophiolite and Basalts

Penjween area is the outer part of the SSZ and contains Shalair valley which extends northeastward inside Iran for about 40km. Its igneous rocks were under extensive studies by Jassim and Al-Hassan (1977) [15], Owesis (1984) [16], Buday (1980) [13], Jassim et al. (1983) [14], Buday and Jassim, (1987) [17], Mohammad et al. (2007) [18], Ali et al. (2016) [19], Abdulzahra et al. (2016) [20] and others. according to these authors, its ophiolite and volcanic rocks are comprised of tens of rocks such as basalts, basic dykes, andesite, dacite, rhyodacites, lithic tuffs, calc-alkaline basalt, arc tholeiite, rhyolite, sub-alkali basalt, pyroxenite, layered gabbro, dunite, serpentinite, pegmatitic gabbro, banded gabbro, diorite, boninite, microdiorites sills, granodiorite, granite, albitite, dolerite, diabase, olivine tholeiite, trondhjemite, granite porphyry, phyllite, and plagiogranite. These rocks are metamorphosed regionally to greenschist facies. Ali et al. (2016) [19] determined the basaltic rocks of the Penjween area in Shalair valley as ophiolite–an arc complex.

Bulfat Ophiolite Complex

According to available literature, Jassim and Goff (2006) [21] applied, for the first time, the name of ophiolite complex to the igneous and metamorphic rocks of Bulfat Mountain (area). Earlier, Buda (1993) [22] and Buday and Jassim (1987) [16] studied it under the name of Bulfat Igneous Complex and identified many igneous rocks such as olivine-pyroxene gabbro, synite, nepheline synite, amphibolite, diorite, dyke rocks, serpentinite. Despite the above studies, Karim and Al-Bidry (2020) [23] and Karim and Ghafur (2021) [24] presented more than ten pieces of evidence to substantiate the sedimentary origin of claimed Bulfat Ophiolite Complex. They reconsidered the above-mentioned rocks as different types of metamorphosed greywackes, felsic and mafic arenites.

Pushtashan Ophiolite

This ophiolitic terrain is located 20 km north of Ranyia town on the Iraq-Iran border and is named after Pushtashan village. It is called ophiolite by Ismail et al. (2016) [25] and attributed its origin to two types of tectonic settings which are MORB and island arc tholeiite to boninitic geochemical characteristics. Previously, Buday and Jassim (1987) [17] studied it under the name of Pushtashan Intrusive Complex in which they found basalt, norite, gabbro, granodiorite, peridotite and serpentinite, and trondhjemite rocks.

Basaltic Bodies

Despite the association of basalts rocks with the aforementioned ophiolite complexes, yet there are several separate and independent basaltic bodies, and their definitions come below.

Avroman Basaltic Bodies

These bodies are more than nine separated small outcrops exposed on the southwestern side of Avroman Mountain in the Halabja area at the boundary between Avroman and Qulqula Formations. These bodies consist of olivine basalt, some of which were studied by Buday and Jassim (1987) [17] aged them Triassic-Cretaceous while Sasvari et al. (2015) [26] considered them as ophiolite fragments of oceanic origin. Conversely, Karim and Abioui (2006) [27] discussed in detail their tectonics and origins through which they proved their sedimentary origins which belong to volcaniclastic sandstone (greywackes) and conglomerates. They aged them as a Paleocene turbidite deposition and considered them part of the Walash Formation (Group).

Gercus (Duhok) Basalts

This body is located inside the middle part of the Gercus Formation (Middle Eocene), 18 km northwest of Duhok City, in the eroded core of the Bekhair Anticline (Figure1). Kettanah and Bamarni (2019) [28] found and studied it geochemically and petrographically, describing it as an Eocene basaltic intrusive body or sill, which has 16 m thickness and 4 km width). These authors named it “Gercus Basalt” and concluded that the sill was originally a dyke, which had penetrated the continental crust of the Arabian Plate, then extruded on the basin floor of the Gercus Formation during the Eocene as a sill. Karim et al. (2020) [29] restudied this body and presented ten testimonies for proving its sedimentary origins. They added that its sediments were transported from remote a volcanic arc inside Iran and deposited as volcaniclastic sandstone (greywackes) inside Gercus Formation.

Hamrin (Baquba) Basalt

This basalt is first found by Abdulrahman (2016) [30 and consists of six small bodies, each one occupying a top of a hill on the Hamrin Mountain between Kirkuk and Baquba towns. Kettanah et al. (2021) [31] studied in detail the petrology, geochemistry, and tectonics of this basalt. They concluded that it penetrated the Arabian continental plate as dyke and extruded on the surface on the top of the Injana Formation during the Quaternary.

Materials and Methods

The materials of the study are all the ophiolite and volcanic bodies in northern Iraq where the main concerns are focused on the interior and exterior properties of these bodies (Fig. 1). The study not only examined the properties of the bodies but also looked into the boundary condition on the scale of millimeters to several tens of kilometers around the basaltic and ophiolitic bodies. For presenting new and accepted ideas about previously claimed igneous bodies, the stratigraphy of northern Iraq is encountered in the evaluation of the problems of the Zagros ophiolites in Iraq. The methodology includes inverse modeling achieved by extensive field studies in northern Iraq and part of Iran for the inspection of hundreds of outcrops and succession profiles using hand lenses for the correlation and documentation of complexes' internal and exterior (boundary condition) characteristics. The tectonic, textural, structural and depositional features are considered for deduction of their causes and related processes that generated the above four attributes. When the cause and processes are inferred the tectonic and paleogeographic models are drawn for depicting the idea of the present study to show the sedimentary origin of the claimed igneous bodies. The methodology includes the collection of necessary and appropriate samples for petrographic microscopy. Many crystalloclasts of the claimed basaltic and ophiolitic rocks are inspected under SEM microscope for investigation of grain surface textures to differentiate detrital grains from the crystallization ones. After reverse modeling, our study reviewed all the previous geochemical and petrological studies objectively for differentiating the positive and negative properties that agree or disagree with the results of the our modeling and conclusions.

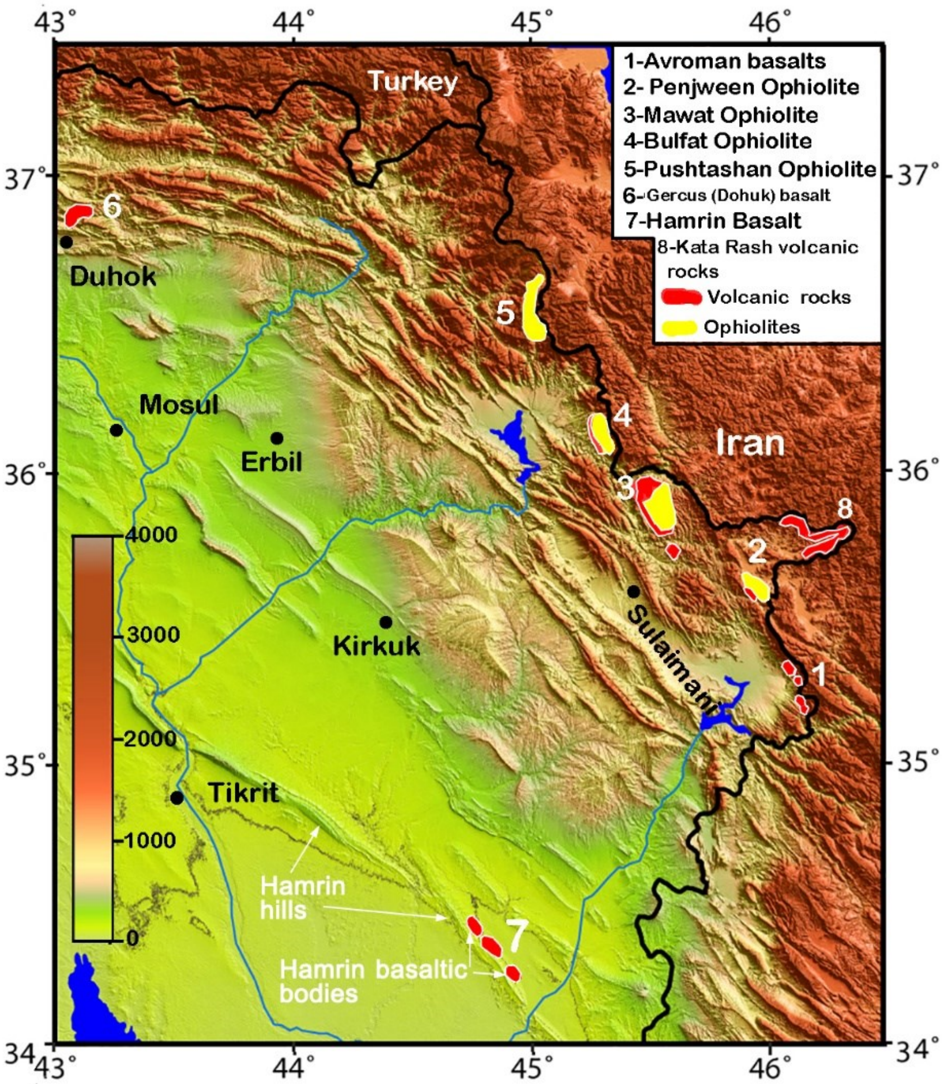

Fig. 1. Location of the Iraqi igneous bodies on the digital elevation map of northern Iraq

Results and Discussion

The problem of the Boundary Conditions

In geology, the boundary conditions include testing all the geological variables around the geological materials of the study on small and large scales and their correlations in vast geographic spread. After that connecting the boundary condition setting with the internal properties of the materials. When a geologist reviews the previous studies of the ophiolites and basaltic bodies, he realizes ignorance of the boundary conditions during their studies. Most of these studies looked after collecting consensus ideas about the problems and avoided the discussion of contrasting results. These studies are more than twenty, which are not been mentioned here, nevertheless, they can be found in Karim and Abioui (2021) [27]; Karim and Al-Bidry (2020) [23] and Karim and Ghafur (2021) [24] whereas discussed objectively. Conversely, the present study investigated the boundary conditions (on a scale) of millimeters to several tens of kilometers which substantiated that all the 10 igneous bodies (claimed ophiolite complexes and basaltic bodies) are hosted in siliciclastic sedimentary rocks as shown in table (1) below. The main hosting sedimentary rock is Red Bed Series (mainly sandstone, and conglomerate) which according to Hassan et al. (2015) [32] are sediments derived from volcanic arcs.

No one of these 10 bodies is located on marl, shale, or limestone, this condition points to the sedimentary origin of these claimed igneous bodies. Moreover, there are no thermal (contact) metamorphisms between the igneous rocks and the sedimentary host rocks even on the scale of millimeters except for some discoloration and shearing. This is true for the mineralization of the host rocks and the digitation of the guest rocks into host rocks. All the claimed igneous bodies in Table (1) have the same boundary condition shown in Fig. (2) which are barren of contact metamorphism and mineralization. These properties of the boundary condition of the bodies contradict the previous igneous origin and they have properties of sedimentary stratigraphic successions such as relations the Walash with Naoperdan, Kolosh with Sinjar and Aqra with Tanjero Formations (Fig. 3).

Fig. 2. The contact between Gercus (Duhok) Basalt and Gercus Formation is sharp and barren of contact metamorphism, chilled border, and mineralization. This indicates cold emplacement of claim basalt (present greywackes). This condition is true for all igneous bodies and dykes in the Mawat, Bulfat and Penjween claimed Ophiolite Complexes.

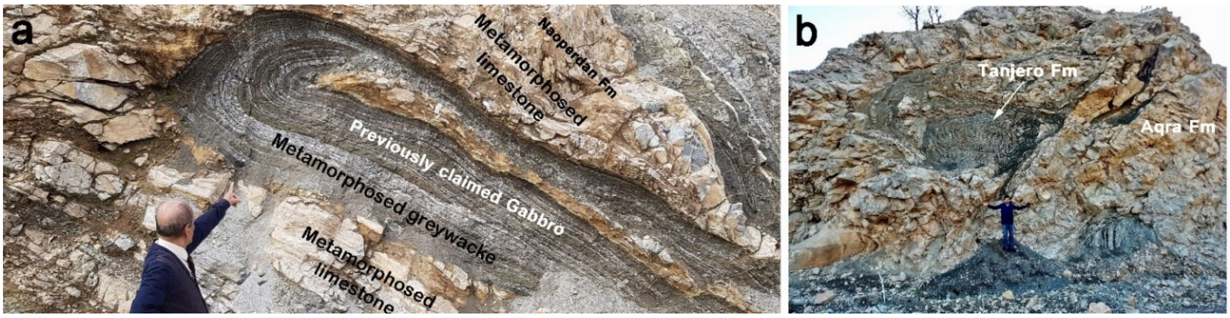

Fig. 3. a) The boundary condition (deformation relation and contact types) between claimed gabbro (as part of the Bulfat Ophiolite) and marble (regionally metamorphosed Naopurdan Fm) on the Bulfat Mountain. The intercalations, lamination, and absence of contact metamorphism are observable. The present study considers these two rocks as metamorphosed greywacke (volcaniclastic or basaltic sandstone) of Walash Formation and metamorphosed limestone of the Naopurdan Formation which are deposited as carbonate-siliciclastic succession during Paleocene-Eocene. **b**) The same features between Tanjero Formation and Aqra Fm in Shahidan valley Qandil area, between Bardgerkan and Gojar villages.

Tab. 1. All the claimed igneous bodies are located inside siliciclastic sedimentary rocks without contact metamorphism, chilled border, and mineralization. So, all of them are sedimentary rocks

No.	Name of Igneous rocks	Location	Petrology	Hosting rocks	Authors
1	Chalki volcanics	Duhok area, Khabour Vall	Basalt	Perispiki Red Bed (sandstone and claystone)	Bellen et al. 1959) [33], Ali et al. (2016) [19]
2	Gercus Basalt	10 km northwest of Dohuk area	Basalt	Gercus Fm (sandstone and red claystone)	Karim et al. (2020) [29], Kettanah and Bamarni (2019) [28]
3	Hamrin Basalt	Hamrin mountain,	Basalt	Upper Fars Formation of sandstone and claystone	Kettanah et al. (2021) [31]
4	Mawat Ophiolite	Mawat area	Gabbro, Peridotite and basalt etc.	Red Bed Series (sandstone, conglomerate & red claystone	Buday & Jassim, (1987) [17], Al-Mehaidi,(1975) [11]
5	Bulfat Ophiolite	Qaladiza area and Bulfat mountain	Gabbro, peridotite	Red Bed Series (sandstone, conglomerate & red claystone	Buday & Jassim, (1987) [17]
6	Penjween Ophiolite	Penjween area	Gabbro, Peridotite and basalt etc.	Red Bed Series (sandstone, conglomerate & red claystone	Buday and Jassim (1987) [17], Ali et al. (2014) [34]
7	Peshtashan Ophiolite	Qandil mountain	Gabbro, Peridotite and basalt etc.	Red Bed Series (sandstone, conglomerate & red claystone	Buday and Jassim,1987) [17], Ali et al. (2019) [35]
8	Hassan Bag Ophiolite	Soran Area	Gabbro, Peridotite and basalt etc.	Red Bed Series (sandstone, conglomerate & red claystone	Ali et al. (2012[36] and 2019) [35]
9	Avroman basaltic bodies	Avroman mountain	Basalt	conglomerate of Tanjero Fm and shale of Qulqula Fm	Sasvari et al. (2015) [26], Karim and Abioui (2020[27])
10	Kata Rash volcanics	Shalair valley	Basalt, andesite,	Phyllite (Metamorphosed shale and sandstone)	Bud ay and Jassim, (1987) [17]

Lack of Cross-cutting and Contact Metamorphism Between Claimed Dykes and Host Rocks

In northern Iraq, previous studies investigated more than 13 felsic and basaltic dykes. Despite this high number of the claimed intrusive igneous bodies, there is no published single photo to show evidence of cross-cutting, contact metamorphism, and mineralization. When the present study tested them in the field, extracted the coming two facts. The first is the sedimentary origin of the claimed felsic dykes since they are neither cutting the host rocks nor showing contact (thermal) metamorphosis and mineralization. The second is their extending parallel to the layers of host rocks and both have the same attitudes (dip angles and strikes) (Fig. 4). They consist mainly of metamorphosed plagioclase-quartz arenites (Arkose) deposited among the hosted layers of mafic sediments of greywackes sandstones. In some cases, thousands of these two types of sediment, alternate in one outcrop such as 1 km north of Dauzhan village (Fig. 4) at the northeast of Esewa town. The associated interbed shales and surrounding rocks show that they are neither diorite nor gneiss (as claimed previously) due to the absence of only low-grade metamorphic rocks and the absence of contact metamorphism. Buda (1993) [22] called this alternation “Pyroxene-amphibole gabbro and diorite” and mentioned the presence of two types of plagioclases, granulated and rather high Ca content plagioclases.

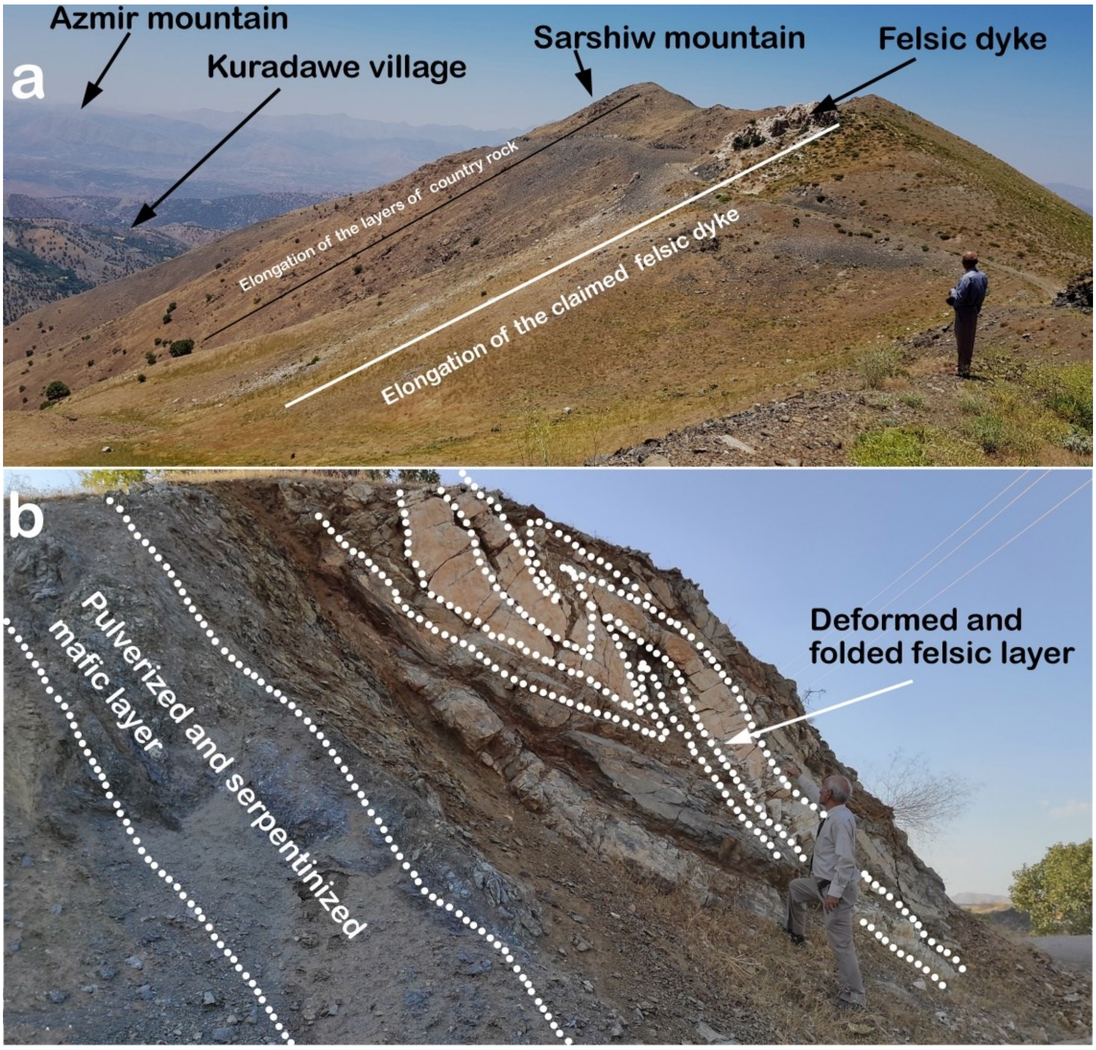

Fig. 4. All the claimed Zagros dykes have no requirements of dykes due to their parallelism to the layers of the hosting rocks and the absence of cross-cutting relations. **a**) Claimed Kuradawe (Daraban) dyke 1km east of Daraban village, Mawat Ophiolite Complex, **b**) Amadin Dyke (folded) 1km west of Daraban village, Mawat Ophiolite Complex, at 35° 50' 36.50'' N and 45° 27' 46.28'' E.

The second is an absence of features of volcanic intrusion and extrusion such as lava flow, pillows, cones, bombs, volcanic necks, volcanic edifices, and channels in the areas of claimed basaltic bodies. The dolerite dykes (diabase) of the Mawat and Penjween Ophiolite complexes (Ali et al. 2019) [35] are supposed to be part of Cretaceous mid-oceanic ridges that obducted on the Arabian northeastern platform during the Late Cretaceous. The present study surveyed both Penjween and Mawat for finding the claimed dolerites dykes, however, what has been found are metamorphosed bedded successions of alternation of plagioclase-rich felsic layers (lecosome) and mafic crystaloclasts-rich layers (greywackes or melanosome or volcanic sandstone of Sigurdsson et al.,1980) [37] with tilting angles of 20- 80 degrees that considered as the dolerite, diabase or sheeted dykes in previous studies (Figures 4 and 5). Johannes and Gupta (1982) [38] attributed similar alternation of these layers in genesis and migmatite to parent rocks greywackes. The metamorphosed volcanic sandstones (previous gabbro and diorite) in northern Iraq, are consisting of thousands of layers, each one with a thickness of 5-40 cm. These layers exhibit lamination, sharp-planner contacts, and bedding surfaces and their pattern and shapes resemble those of well-known sedimentary stratigraphic units of Kolosh and Tanjero Formations (Figures 5 and 6). Their texture shows granulation, graded bedding, and high content of Ca and alkalis (see Buda, 1993 [22]; Al-Saffi et al. 2012 [39]). These latter authors attributed these characteristics to magmatic processes yet our conjugate pieces of evidence indicate their sedimentary origins.

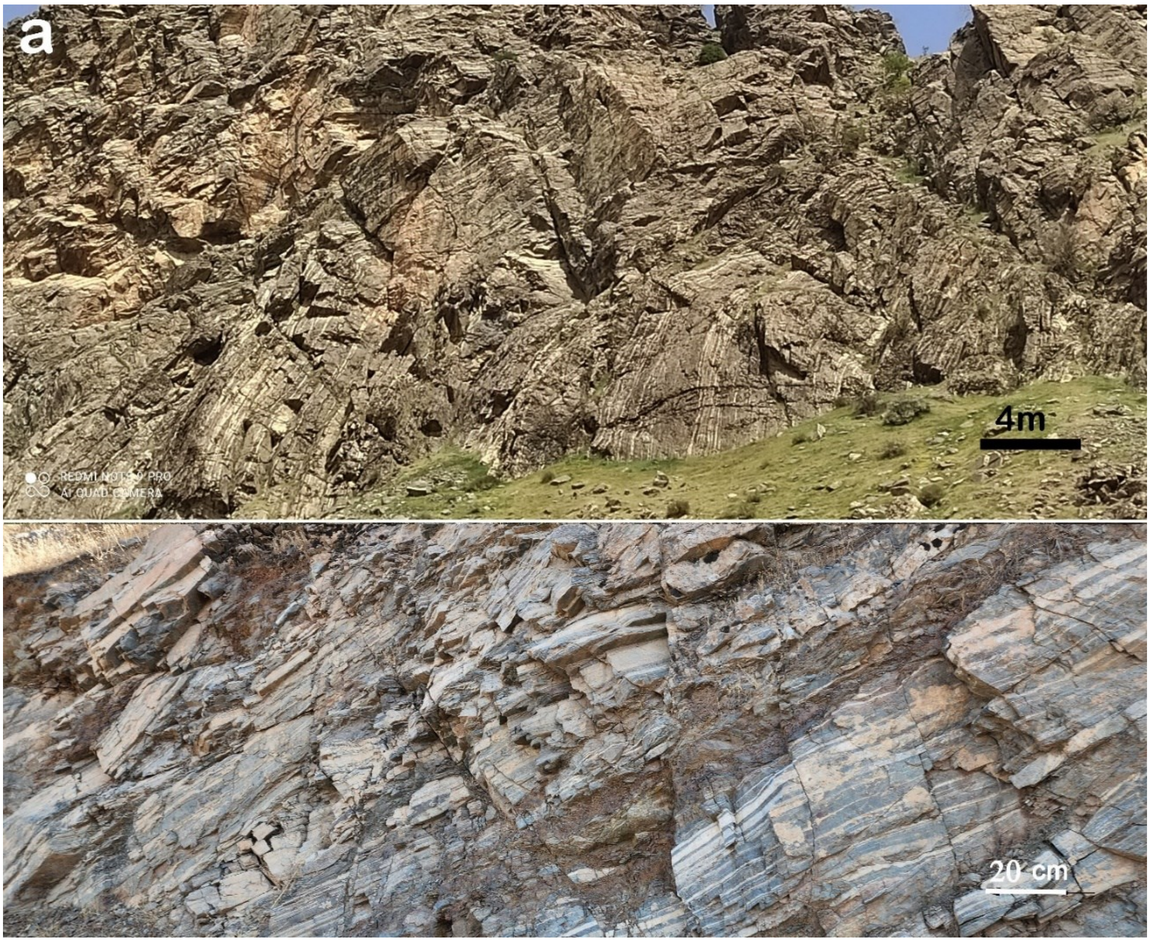

Fig. 5. a) A part of the eastern claimed Bulfat Ophiolite Complex at 1 km north of Dauzhwan village, manifests a very thick alternation of arkosic (felsic) arenite and dark greywackes (all regionally metamorphosed to low-grade greenschist facies) about 200 thick which were previously considered as gabbro and diorite by Buda (1993). **b**) A close-up view of part of the alternation shows the planner bedding surfaces which is direct evidence of its sedimentary origin, at 36° 03' 15.35" N and 45° 21' 03.21" E.

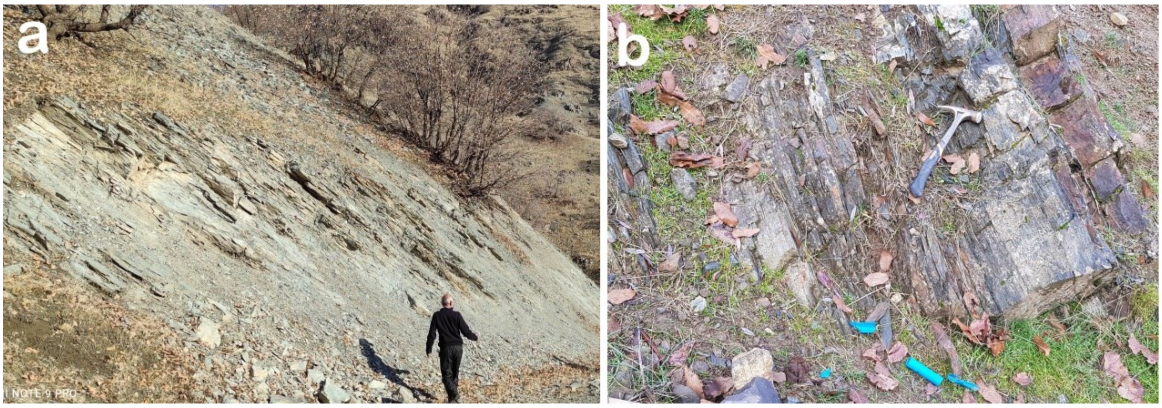

Fig. 6. a) A thick succession of greywackes (basaltic sandstones) in the central part of the Penjween Ophiolite Complex on the Kani Shawqat mountain, which was previously considered as dolerite or layered gabbro at 35° 34' 50.94" N and 45° 57' 24.83" E. **b**) Close view of the claimed dolerite (present metamorphosed greywackes and volcanic detritus) at 35° 37' 16.99" N and 45° 55' 56.72" E.

Problem of an Enclave in Volcanic Rocks

Previous studies found abundant enclaves in the claimed volcanic rocks and granitoid dykes and can be observed from the Avroman mountain to the Hakari area at the extreme northwest. On both sides of the Shalair valley, these claimed enclaves occur as extensive outcrops and discontinuous massive beds about 5- 30 m thick which were previously called Kata Rash Volcanic rocks. The abundance and size calibers of enclave clasts (or igneous xenoliths) increase toward the northeast where the sizes of the enclaves at the end of Shalair valley inside the SSZ generally reach more than 10 cm in diameter (Fig. 7). While at 35 km to the southwest of the valley decreased to granule size (1-3 cm in diameter) (Fig. 8a) near Penjween and Mawat towns. More southeastward in the High Folded and Mesopotamian Zones, the claimed basaltic rocks in Duhok and Hamrin areas are barren of any enclaves. According to

Mohammad et al. (2014) [40], these enclaves are associated with negative Eu and high corundum (40%) in a leucogranite dyke in the Mawat ophiolite while Abdulzahra et al. (2018) [41] recorded many of them in the Shalair valley.

These characteristics of the claimed enclaves and their grain sizes decrease toward the southwest indicated their sedimentary origins since their abundancy must be more in the latter two areas than Shalair valley because they cut more sialic crust than the valley. These enclaves do not have appendices of digestion and signals of contact metamorphisms (metamorphic zoning). Therefore, the present study considers these enclaves as clasts of gravel conglomerates or pebbly sandstones that are regionally metamorphosed to low-grade facies (Figures 7 and 8) and rest on the Shalair phyllite as progradation of facies. These conglomerates are coarser in the Sanandaj-Sirjan Zones (Shalair valley) which is close to the source areas of the Paleocene-Eocene Foreland basin. While their grain sizes decrease southeastward and change to carse sandstone (coarse greywackes and basaltic sandstones) in Bulfat, Mawat and Penjween areas. In these areas, the sandstones are metamorphosed and called Ophiolites in previous studies while their fresh ones are designated as the Walash Formation. These Paleocene sediments change to fine grain sandstone and shale in the High Folded Zones (coincides with the basin plain of the Foreland Basin) where they are called Kolosh Formation. Karim and Hamza (2021) [42] connected the relation between these different sediments along the Foreland basin paleodip in one model during Paleocene (Fig. 9).

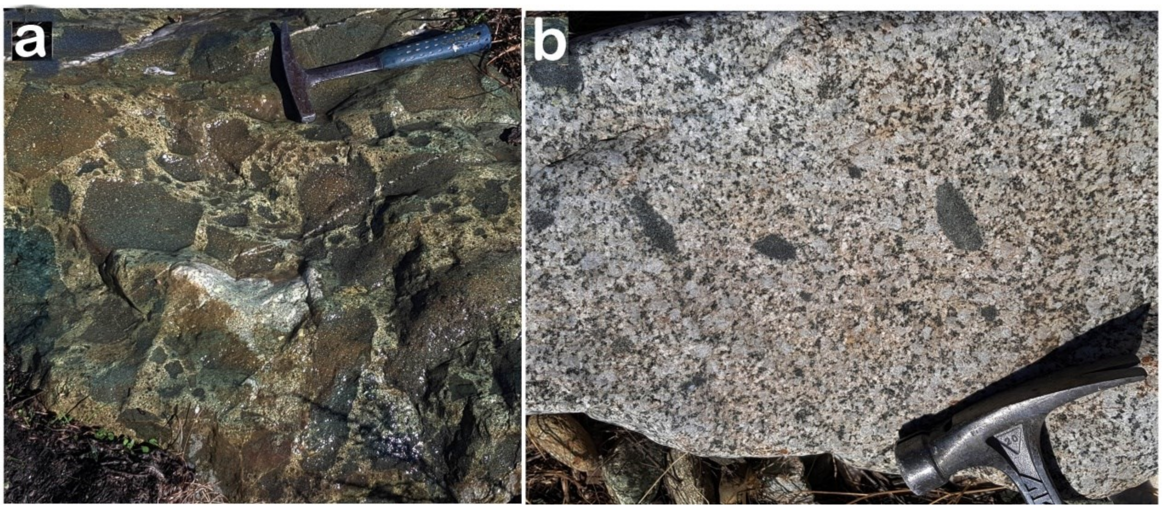

Fig. 7. Occurrence of the extensive and thick succession of regionally metamorphosed mafic and felsic conglomerates and pebbly sandstone in the Shaliar valley that is considered volcanic rocks with enclaves previously. **a**) Gravels conglomerate whereas its clasts derived from volcanic source areas, **b**) felsic gravely sandstone with basaltic pebbles (previous enclaves)

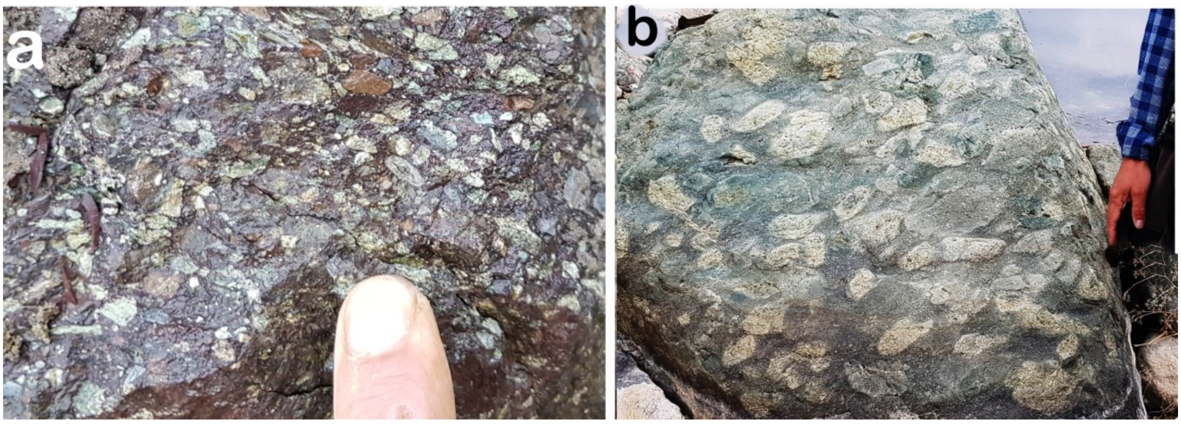

Fig. 8. The caliber of the clasts of the conglomerate generally decreases southwestward, **a**) granule conglomerate in Satur Gorge, 4km west of Mawat town, **c**) the same conglomerate (metamorphosed) near Penjween Town. Both photos show lineation (parallel arrangement of elongate clasts).

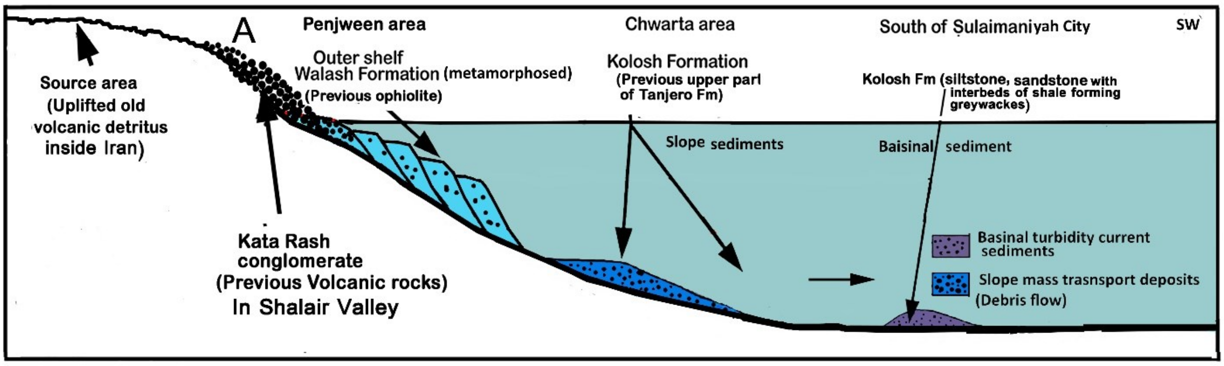

Fig. 9. The distribution and tectonic setting of the claimed ophiolite and igneous rocks (Kata Rash conglomerate, claimed ophiolite, Walash and Kolosh Formations) agree with sedimentary and sequence stratigraphy models in addition to sharing the same foreland basin.

The Problem of the Close Similarity Between the Topography of the Sedimentary and Ophiolite Terrains

The walking on the surface of the well-known sedimentary terrains and the claimed ophiolites shows the clear and close similarity between the two types of topographies. The non-disputable sedimentary topographies of Tanjero, Shiranish, Balambo, Sarmord Formations have a resemblance to those of the claimed Ophiolite and basaltic rocks of northern Iraq. The correlative similarity of the ophiolite terrains is only applicable to thinly and well-bedded sedimentary rocks such as above mentioned four formations. This correlative similarity is due to common features of terrains that are represented by mountains with nearly the same roughness, relief, v-shape valleys, dendritic drainage patterns, and badlands (Figures 10 and 11). They are generally barren of high cliffs and narrow gorges when present they are formed by metamorphosed limestones such as Gimo and Keley peaks in the Mawat and Bulfat complexes. This type of topography is different from those of the massive (reefal) limestone of the Naopurdan and Avroman Formations, which formed high cliffs and sharp peaks near ophiolites. From the topographic features, it is clear that the competency of the claimed ophiolites is less than the massive limestones while the features of ophiolite are nearly equal to bedded (relatively thinly layered) sedimentary rocks and both contain thousands of planner bedding surfaces which are unequivocal evidence of sedimentary origin (Fig. 5b). Although the layering may be present in igneous rocks but must be massive and at least must be similar to the Qamchuqa Formation which is layered but it is massive and resistive to weathering and mass wasting (Fig. 12). This is manifesting another evidence of the sedimentary origin of the igneous rocks of northern Iraq.

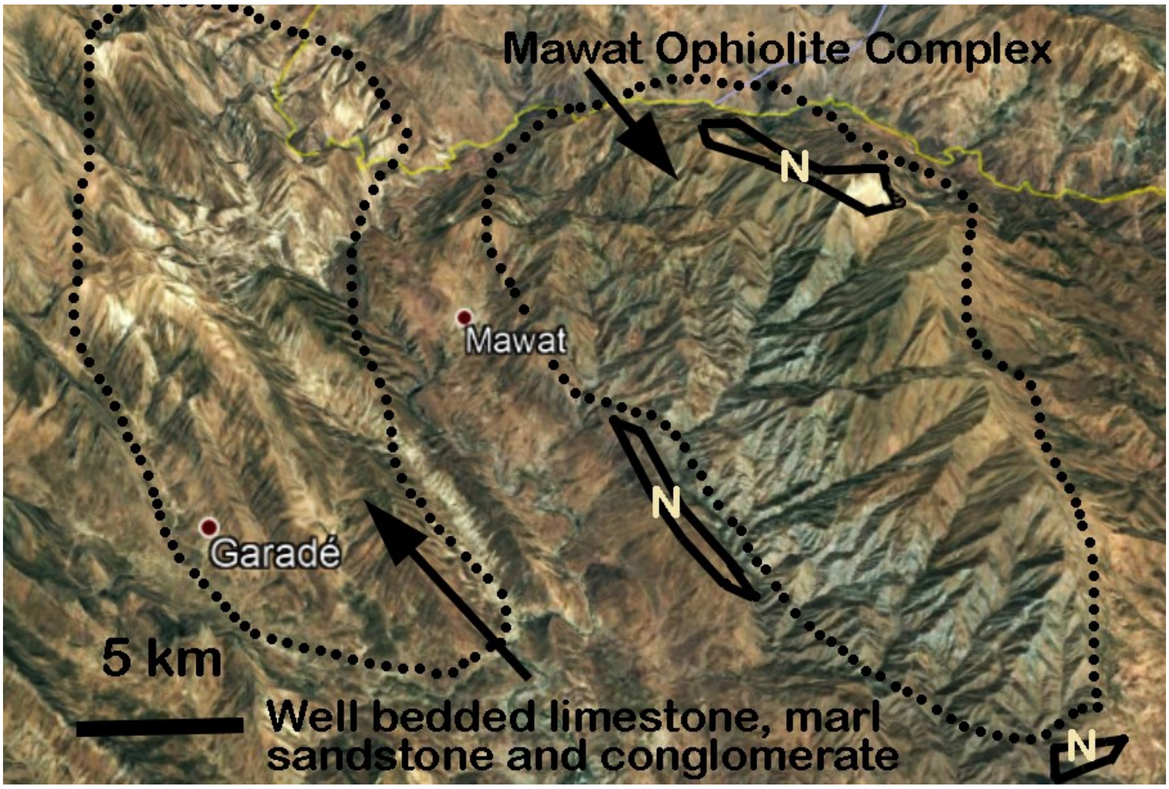

Fig. 10. Topography of the claimed Mawat ophiolite Complex (claimed gabbro, basalt and peridotite) is nearly similar to sedimentary-layered sedimentary rocks, N) reefal limestone of the Naoperdan Formation at the tops of Mawat Ophiolite

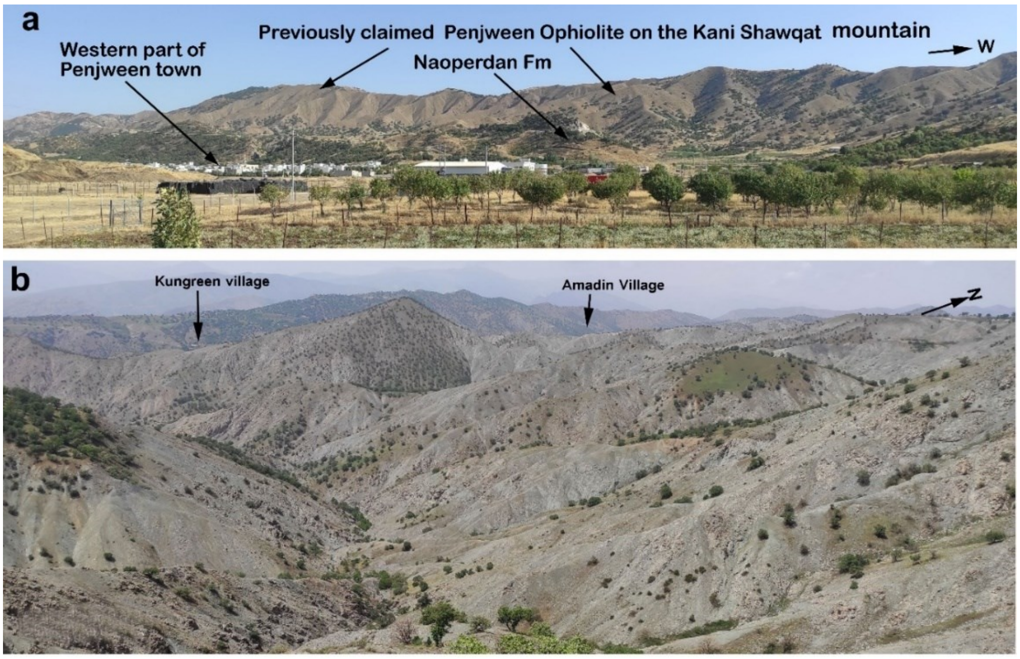

Fig. 11. Topography of the claimed ophiolite Complexes of Northern Iraq are very similar to the topography of thinly bedded sedimentary successions and forming badlands, **a**) claimed Penjween Ophiolite Complex (the photo look south) and, b) Central part of Mawat Ophiolite complex (the photo looks west).

Fig. 12. Put crops of the Qamchuqa Formation in the form of massive and high topography with v-shape vallyes, At least the topography of ophiolite rocks must have similar features

Wide Range of the Ophiolite Ages of the Iraq Zagros Igeous Rocks

There are wide ranges of age recordings by zircon grains in the Mawat Ophiolite Complex. The previously calculated ages of the felsic and gabbroic rocks of the complex by Al Humadi et al. (2019) [43] are 222, 94, 81, 40 and 38 Ma. The aging of the same authors concluded that a felsic dykes 10 ma is older than the host gabbroic rock. They added that one of their samples contained zircons of different ages. Most recently Nutman et al. (2022) [44] recorded 48 and 39 ma in one sample of a vein of trondhjemite in gabbro of Bulfat Ophiolite complex. In the sample, they aged 16 voided and corroded (spongy) grains of zircon and each grain yielded different ages. They justified the wide range of ages and corrosion to different stages of crystallization and to the effect of NaCl-rich hydrothermal influx. These wide age differences, the oldness of dykes relative to host rocks, and different ages of corroded zircons of the same samples prove the sedimentary origin of the claimed Mawat ophiolite, especially the dyke boundaries do not show contact metamorphism, forceful emplacement, or cross-cutting relation. This study attributes this wide age ranges to sedimentary mixed and reworked zircons from erosion of different dissected depths and source areas. The source areas were volcanic arcs and were located inside Iran that most possibly consisted of the UDMA which was dissected by shallow, deep, new, and old erosions. The same age controversy is true for the Kata Rash Volcanic Group since Buday (1980) [13] attributed the group to the Turonian-Senonian age while Ali et al. (2016) [19] determined this group as of late Cretaceous ophiolite–arc complex and aged it 108 Ma. They interpreted this age as the time of igneous crystallization. They mentioned the presence of dioritic and granitic dykes that crosscut rhyodacite-rhyolite, andesite, and basaltic-andesite. In the Kata Rash group, Abdulzahra, et al. (2016) [41] studied a granitic dyke (they called it dyke-like body) inside the above group in the Shaliar valley near Damamna village and obtained the age of 372 ma while Ali et al. (2016) [19] determined the age of the nearby Harbar dyke (5 km far from the former dyke) to be 108 Ma.

From these ages, the present study concludes two facts; the first is the oldness of the age of some dykes relative to their host rocks in the Kata Rash volcanic rocks. The second is the ages of the two nearby dykes have very big age differences of about 250 Ma. The above facts in Penjween and Mawat ophiolite complexes indicate the sedimentary origin of these claimed ophiolites since the ages indicate the mixing of old and new zircons that are used for dating. Another evidence for the sedimentary origin of the claimed igneous rock in northern Iraq is general decrease in their ages toward the southwest from the SSZ to the Low Zone of Iraq. In this context, the age of the interior of the latter Zone (including Shalair valley) is Triassic-Jurassic, while its southwestern boundary is Cretaceous. Toward the southwest, the age becomes younger whereas in High folded and Low Folded Zones, the ignous bodies become Middle Eocene and Quaternary in age (see Kettanah and Bamarni, 2019[28], Kettanah et al. 2021[31]).

Absence of Contact Metamorphism Between Igneous and Host Rocks (Carbonate or Siliciclastic Sediments

In the Belfat, Mawat and Penjween claimed Ophiolite Complexes, there are distributions of marble (metamorphosed limestone) among and around claimed gabbro, peridotite, diorite and felsic dykes. Their contacts with the above igneous rocks reach more than ten kilometers collectively, however, no contact metamorphism was recorded in the present study despite investigating tens of contacts between claimed igneous rocks with limestone and shales. In the Bulfat and Penjween ophiolite complexes, Jassim e al. (1982) [14], Buday, and Jassim (1987) [17] mentioned contact (thermal) metamorphisms while there are no details about the degree and location of the contact metamorphism. We think that the regional metamorphism affected the rocks of the latter three complexes and changed the Penjween, Mawat and Bulfat to amphibolite and greenschist facies. Karim and Al-Bidry (2020) [23] and Karim and Abioui (2021) [27] and Karim (2021) [45] discussed tens of signals of sedimentary origins of these claimed ophiolite complexes. The rocks of these complexes consist of alternations of thousands of layers of different rocks such as pure limestone, clayey limestone, sandy limestone, marls, shales, calcareous shales, volcanic detritus, greywackes, arkose, arenites (plagioclase, olivine, amphibole or pyroxene arenites). Therefore, regional metamorphism results in the crystallization of different minerals responding to the chemical composition of the rocks and the grade of metamorphism. When a succession of pyroxene-rich sandstone or marlstone (calcareous shale) metamorphosed regionally, they look like gabbro (see Bucher et al.2011) [46] while it will be similar to basalt if the sandstone was badly sorted and contained crystalloclasts of the pyroxene embedded in fine volcanic mud (Fig. 13). Due to depositional laminations and layering, in most cases, the mineralogy is changing from a centimeter to another in the Bulfat, Mawat, and Penjween claimed ophiolites (Figures 5, 6, and 14). These lamination and layers (beds) are not magmatic segregation or deposition since they have sharp boundaries between mafic and felsic layers in addition to the richness in cross-bedding, channel fills, erosional surfaces and bedding surfaces.

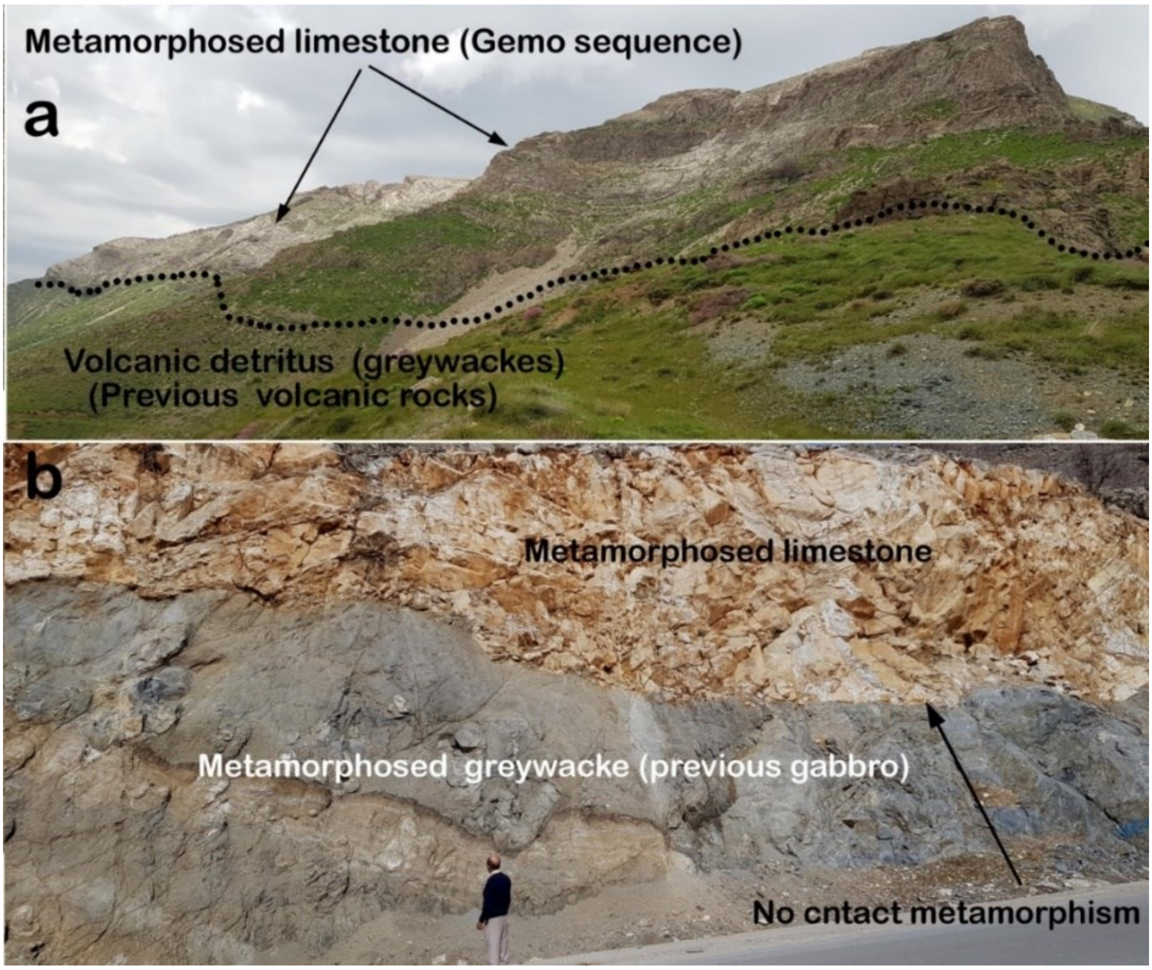

Fig. 13. There is no contact metamorphism at the boundary between claimed volcanic or plutonic igneous rocks with carbonate and siliciclastic rocks, **a**) the contact on Gimo mountain, Mawat ophiolite, **b**) the same contact on the Kele mountain, Bulfat ophiolite complex, the arrow shows contact without contact metamorphism

Fig. 14. **a**) cross-bedding and erosional surfaces between mafic and felsic volcanic detritus near Duzhwan village Bulfat ophiolite Complex). **b**) an outcrop along roadcut show alternation of metamorphosed arkose (white) and greywacke (grey) as volcaniclastic sandstone 1km north of Dauzhan village, Bulfat complex.

Absence of the Deep Marine Sediments and Pillow Basalt at the Top of the Ophiolites

The ophiolite, as an oceanic crust and upper mantle section, must be topped by pillow basalt and deep marine sediments (Coleman, 1977) [47]. Unfortunitly, there are no deep marine sediments and pillow basalts at the top of the claimed Bulfat, Mawat, and Penjween Ophiolite complexes. Conversely, they are associated with the reefal limestone of the Eocene (Naopurdan Formation). This formation overlies the claimed gabbro and peridotite with gradational contact and without contact metamorphism (Figures. 3a, 13 and 15). According to Karim and Ghafur (2021) [24] the metamorphosed equivalent of Naopurdan is previously called Gimo Sequence) (Fig. 13). The most near deep marine sediments are Qulqula Radiolarian and Balambo Formations that belong to Jurassic and Early Cretaceous while the ophiolites claimed to have upper Cretaceous ages of Cenomanian -Turonian. Therefore, the overlying ophiolites by reefal limestone with gradational contacts contradict the nature of the oceanic crust and activate the re-thinking of the origin of the claimed three Ophiolite complexes. The tectonic locations of the Naopurdan Formation and ophiolites are in the Thrust Zone which is called Crusted Zone by Stocklin, 1968) [48] and Wells (1969) [49].

Although previous studies recorded hundreds of kilometers of claimed basaltic outcrops in northern Iraq (Table 1), yet they did not report true pillow basalts, especially at the top of the Ophiolites sections. The present author visited all the localities of the claimed pillows and their inspection manifested four facts. The first is the occurrence of pillow-like bodies, only in small areas whose surface areas are not more than a few tens of square meters. The second is the occurrence of all the claimed pillows in the granular rocks, which are considered in the present study as sandstones of greywacke types whose clasts are derived from remote volcanic source areas. Pettijohn et al. (1987, p114 [50]) confirmed the role of sandstone (granular rocks) in the development of pillow-like structures. The third is the development of pillow-like structures in undisputable sedimentary formations such as Tanjero and Kolosh, Kometan, and Qamchuqa formations (Figures. 16 and 17). In the first two formations, Karim, (2005) [51] documented, in detail, the development of these structures in the latter two formations. The fourth is photos of claimed pillow basalts of the previous studies of the Bulfat, Mawat Penjween ophiolites Complexes. A rechecking of the locations of these photos unproved the presence of pillow basalts since their form and shape and boundary condition indicated their development by shearing and subsquent weathering as indicated by Ogawa (1982) [52] (Fig. 17d). Many photos are published aimed to show pillow basalts, the best one is the one shown in the 3rd Geokurdistan Conference field excursion in the Mawat Ophiolite Complex (Fig. 18). The latter photo shows a compartment of the section of pillows into several parts by diagonal lines of the shearing stress. In literature, Okay et al. (2011, p.5) [53] recorded similar shear structures in the greywackes of Karakaya Complex, Northwest Turkey.

All the claimed pillow basalt is located at the base of the Ophiolite section while dunite is located at the top which contradicts the nature of true ophiolites. This location is documented by previous studies and indicated the basalts at the base of the ophiolite sequences in northern Iraq. These studies are such as Ali et al. (2019) [35], Mohammad et al. (2020) [54], Mohammad (2020) [55], Mohammad and Cornell, (2017) [56] (Fig. 8). The latter two articles attributed this abnormal stratigraphic feature of the basalt to the overturning of the ophiolite sections. However, these studies did not give any tectonic or depositional pieces of evidence to justify their claims of ophiolite overturning which is impossible due to the nature of ophiolite which consists of a huge and thick sheet of heavy rocks relative to sedimentary host rocks. The present study does not aid this reversal of stratigraphy since there are no field pieces of evidence for this process, all sedimentary structures such as graded bedding, channel shapes and paleocurrents refer to upright stratigraphy of Mawat area including claimed ophiolites.

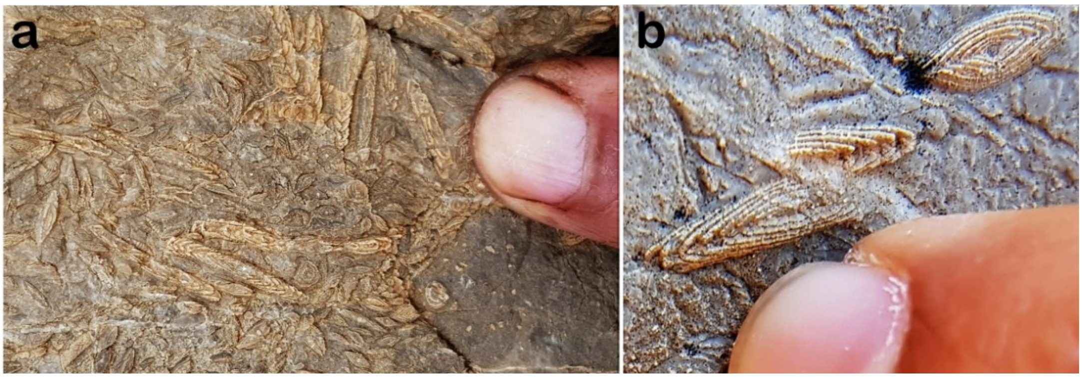

Fig. 15. Forereef limestone of the Naopurdan Formation at the top of the claimed Mawat Ophiolite, at 1km south of Amadin village, **a**) accumulation of nummulites, **b**) faulted nummulite

Fig. 16. Ball-like bodies, in northern Iraq, are common in all types of granular and well-bedded rocks, such as sandstone and detrital limestone, **a**) ball-like bodies in sandstone of the Tanjero Formation near Zarda Bee village, 7 km south of Chwarta town, **b**) in sandstone of Kolosh Formation near.

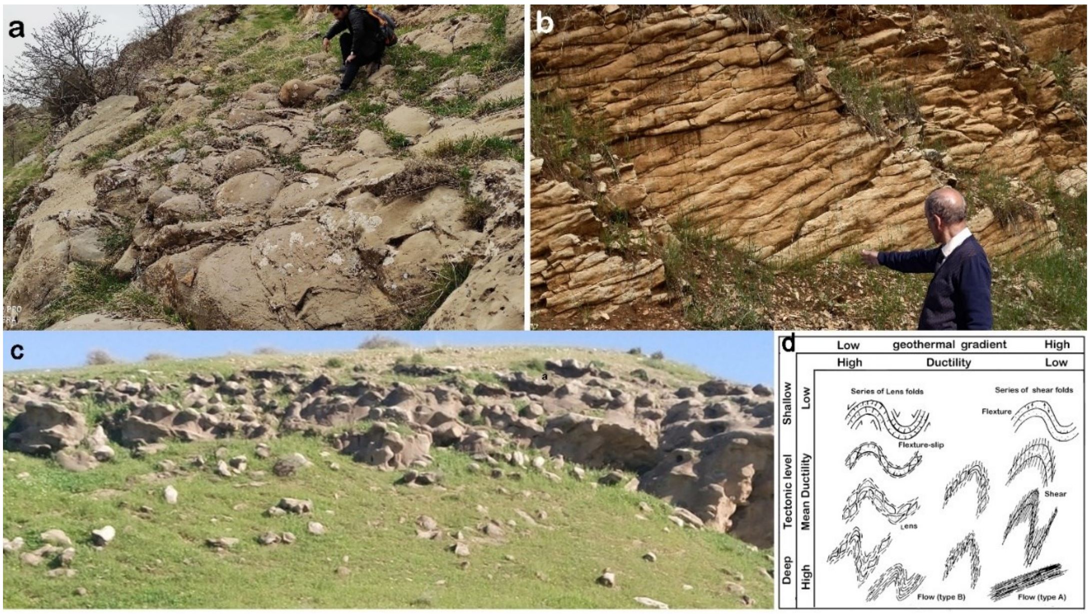

Fig. 17. Pillow-like bodies can be developed in any type of rock such as, **a**) Reefal limestone of the Qamchuqa Formation, on Babo mountain at 4 km southwest of Sargelu village, **b**) Pelagic limestone of the Kometan Formation, 4 km southeast of Halanja town, near Chawg village, **c**) sandstone of the Upper Fars Formation, Chiman village, Kirkuk, d) Pillow -like bodies are more common in the high tectonic area where they formed by shear stress (Ogawa, 1982) [52].

Fig. 18. a) Road cut section shows, according to previous studies, the best pillow lava in the Ophiolite complexes of Northern Iraq (the photo taken during field excursions of 3th GeoKurdistan conference), b) in this study does not aid pillow lava and they are referred to as shear zones inside greywackes. The arrows pointing in direction of dextral shear sense. c) more wide view of the same section of the present study shows two shear surfaces among several ones.

The Problem of Ignorance of volcanic detritus (Greywackes Volcanic Sandstone) in the Development of the Zagros Collisional Belt

Although Dickinson and Suczek (1979) [57], discussed sediment dispersal from active magmatic arcs into the trenches, forearc, and foreland basins while Dickinson and Valloni (1980) [58] referred to sands in the modern Oceanic basin including detritus from island arcs. Unfortunately, the previous studies ignored the role of the arcs sediments in the development of the Zagros belts. These sediments were accumulated in the Neo-Tethys Ocean (present Sanandaj-Sirjan Zone) and studied in detail by (Karim and Abioui, 2021) [27]. although the previous studies modeled the arcs and continental blocks inside and around the Neo-Tethys ocean from Permian to Oligocene. These studies previously drew and discussed tens of models in which imagined the development of the Zagros belt from the ophiolite obductons by the pushing huge blocks of oceanic crust and upper mantle by the Sanandaj-Sirjan Zone (as a continental block) during the converging of Arabian and Iranian plates. According to these studies, the pushing resulted in the thrusting of the blocks (as ophiolite complexes) on the Arabian Plate Passive Margin during the late Cretaceous. In these models, the role of the volcanic detritus (as lithic clasts and crystalloclasts) was ignored and erosion products of these arcs are not considered.

We are sure that the presence of these arcs, as high-contrast topographies, supplied voluminous quantities of volcanic detritus in the form of greywackes, arkose, arenites, shales, and volcaniclastic conglomerates of felsic and mafic compositions (Fig. 19). According to the previous models, these arcs last for more than a hundred million years and Farhoudi (1978) [59] concluded that the Zagros includes island arcs, in different stages of development. The models of Omar, et al. (2015) [60], Mohammad and Cornel (2017) [56] and Ali et al (2019) [35], include arcs aged from Triassic to Eocene while they ignored the role of metamorphosed sediments of these arcs. On the contrary, the present study envisages their role and considers that claimed ophiolites and volcanic rocks in Iraq are accumulations of volcanic detritus of one type or a mixture of several crystalloclasts and lithic detritus that are deposited by turbidity current (Figures. 9, 13 and 14). Karim and Abiuoi (2020) [27] and Karim (2020) [61] discussed in detail how these sediments were transported from Urumieh-Dokhtar magmatic arc to northern Iraq during two phases of transportation, deposition, uplift, and redeposition. The latter article substantiated their deposition during Paleocene-Eocene, which stratigraphically, geologists called these deposits Walash Formation (Group). Another problem of all the previous studies is that their models of the Zagros belt and Neo- Tethys Sea considered the SSZ as a continental block and island arc which does not agree with the geology of the zone.

Conversely, the Zone was part of the Neo- Tethys Sea in which volcaniclastic sediments (greywacke and arkose), limestone and radiolarites were accumulated during the Jurassic and Early Cretaceous. During the converging of the two plates, these sediments converted to the accretionary prism, compressed, metamorphosed and later during Campanian-Maastrichtian, limestone and radiolarians were uplifted and their erosion products were deposited in the foreland basin as Tanjero and Shiranish Formations. As a result of more converging during the paleocene, the volcaniclastic sediments uplifted in the Iranian SSZ and their erosion products reached Mawat and Bulfat and Penjween areas. These processes are shown in three models (Fig. 19) whose drawings are based on our studies of the Iraqi and Iranian SSZ where we did not find any direct evidence of igneous activities. Moreover, ~~than that~~, the geophysical studies aid our models since they show the occurrence of moho at a very deep level below the surface relative to that of the Zagros Fold-Thrust belt (Fig. 19d). In these geophysical models, the Moho is located at a depth of 60 km below the former zone while it is located at 40km below the latter zone (Shomali et al. 2011) [62]. These latter authors attributed this high depth of the SSZ to the overriding Iranian Plate over the Arabian one which is impossible for the Arabian plate to reach the UDMA.

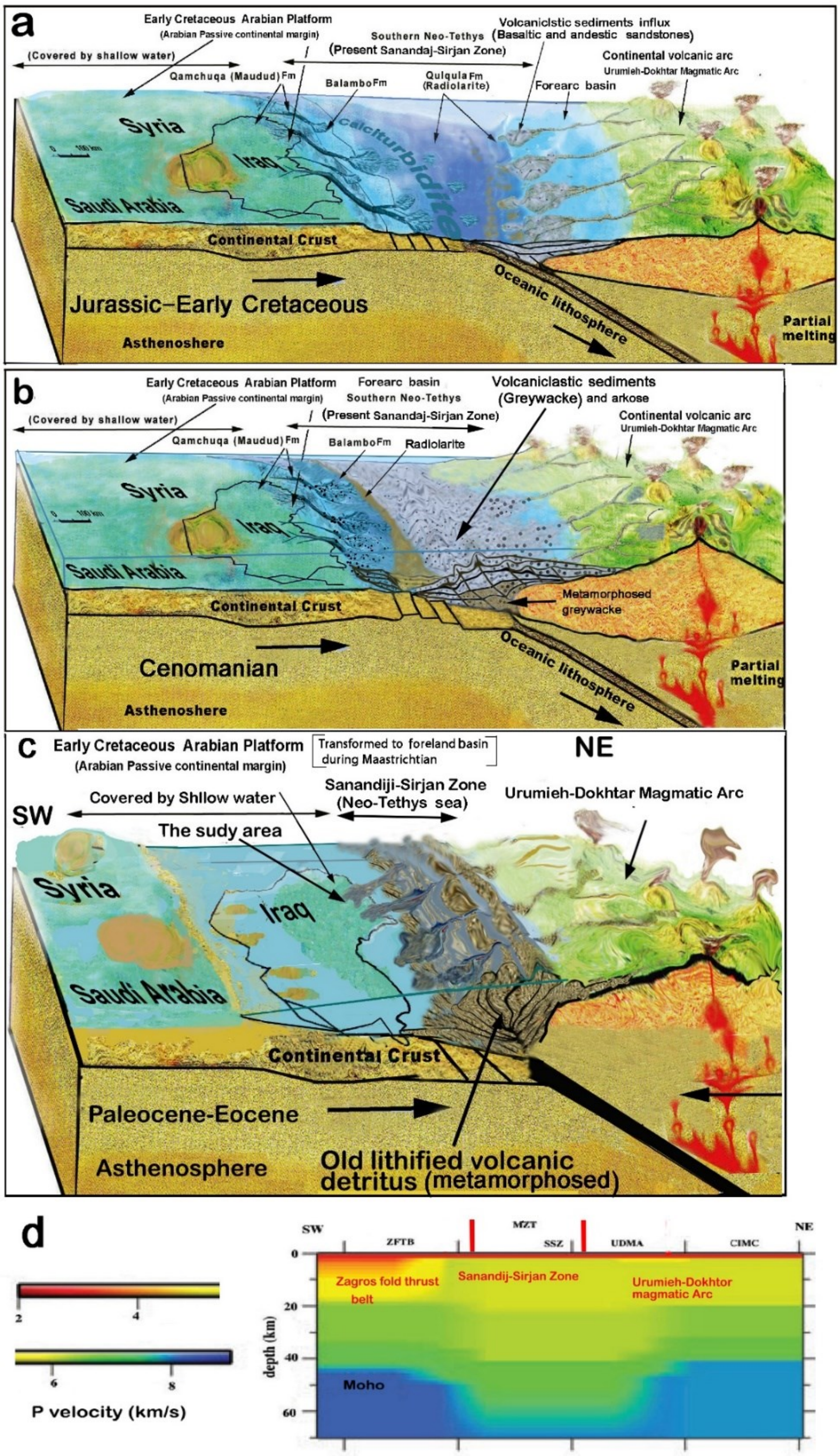

Fig. 19. Three tectonic and paleogeographic models show the development of the Zagros Collisional Belt, **a**) filling of the Neo-Tethys Sea (present SSZ) by volcaniclastic sediments (felsic and mafic sediments) during Jurassic and Early Cretaceous (modified from Karim, 2020) [61], **b**) deformation and metamorphism of the sediments as an accretionary prism during the Late Cretaceous in the SSZ (Karim and abioui, 2021 [27], **c**) Uplifting and erosion of old sediments during Campanian-Paleocene and rewording into the Mawat, Bulfat, and Penjween areas. **d**) The geophysical model by Shomali, et al. (2011) [62] aids the basin nature of the Sanadaj-Sirjan Zone and refutes being a continental block

The problem of pervasive lineation, foliation, and inclusions in the ophiolite crystalloclasts

Despite visible prevalent laminations and beddings, planner bedding surfaces on the outcrop of Iraqi ophiolite rocks (Figures 5b, and 20), they are characterized by pervasive lineations and foliations in thin sections. During the thin section inspection under a petrographic microscope, rarely one can find a view without either lineation or foliation (Fig. 7). Moreover, the grains (crystaloclasts and lithic ckasts) are all unheral, relatively cloudy, crucked, show roundness and their boundaries exibit wearing by trasportation. These views are clear also in the previous studies, on condition; they had cut the slides normal to the thickness. These metamorphic textures are very clear in the Bulfat, Mawat, and Penjween claimed ophiolites and their associated volcanic rocks and felsic dykes. Other ductile properties of the ophiolites are sutured grain boundaries, wavy extinction and kink bands of the platy minerals have been well documented in previous studies by Al Humaidi (2019) [43] and Mohammad and Cornel, (2017) [56]. -

We assume that these textures are common in the metamorphism of the sedimentary successions; therefore, the pervasive textures of low-grade greenschist facies of regional metamorphism are not relevant to igneous rocks of ophiolites since the ophiolite rock are massive, stiff and cannot transfer stress to the whole body of the rocks pervasively and to all its grains. Conversely, in the sedimentary rocks, each grain and bedding surface act as discontinuity which can be deformed, or metamorphosed pervasively with aid of the bearing water and muds. These textures and foliation are inherited from laminations of the sedimentary rocks, especially the long and platy lithic clasts and crystalloclasts deposited parallel to the sediment and water interface. These claimed ophiolites are very heavy, thick and stiff masses developed in an extension tectonic setting, therefore, their uplift and obduction on the continental margins is suspicious. conversely, the sediments derived from volcanic arcs are soft, porous, relatively light, and rich in reactive materials including clays, limes, alkalis, and brines solutions. Therefore, these rocks are more prone to obduction (uplifting), and metamorphism at lower pressure and temperature than igneous rocks.

Fig. 20. Faulted and laminated outcrop section of the Bulfat ophiolite complex, 2km north of Dauzhan village. The dark and white laminae are metamorphosed greywacke and arkose sandstones. This rock was considered diorite previously and now the dark and white laminae are transformed to hornbelnde and plagioclase by regional metamorphism

The Problem of the Absence of the Present-Day Ophiolite Obduction

This problem is not only related to Zagros Ophiolite but also to its global occurrences. Although there are several thousand kilometers of present-day subduction zones and millions of square kilometers of the oceanic floor (Fig. 21), yet there is no record of ophiolite obduction globally at the present and even there is no prediction of the obduction occurrence in the future. Along these zones, heavy and coherent oceanic crust diverts under overriding plates due to gravitational downward pulling. In contrast, the subduction zones and their trenches are loci of turbidite deposition derived from nearby volcanic arcs (Moore et al.1982) [63], Thornburg and Kulm (1987) [64], Lomize, and Luchitskaya (2012) [65]. We speculated that the light and the relatively soft arc sediments (as accretionary prisms) are more prone to uplifting and obduction than the heavy and coherent oceanic crust and upper mantle rocks. The surfaces of each grain of the trench sediment act as a zone of weakness for deformation and they are normally surrounded by clays, limes mud, or empty spaces which act as lubricants. Nowadays, in the trenches, several kilometers of sediment are accumulated and there is the actual accretionary prism in southern Iran in the Makran area which is predicted to be obducted in the future. Another example of sediment accumulation is the occurrence of 20 kilometers thick and deformed sediment on the oceanic floor of the Caspian Sea accumulated during 18 million years (Brunet et al. 2003) [66]. According to Abdullayev et al. (2017) [67], the thickest accumulation is located in the southwest where there is a thrust zone (similar to a subduction zone). Therefore, in these vast sedimentary basins, the priorities of uplift are more for arc sediments (Figures 19c and 21) than gabbroic and basaltic rocks. The present authors are confident that what is called ophiolites and basaltic rocks previously are metamorphosed volcaniclastic sandstones (greywackes and arenites). According to Moore et al. (1982) [63], in the Sonda trench, for example, the sediments consist of quartzose detritus and volcaniclastic sediments.

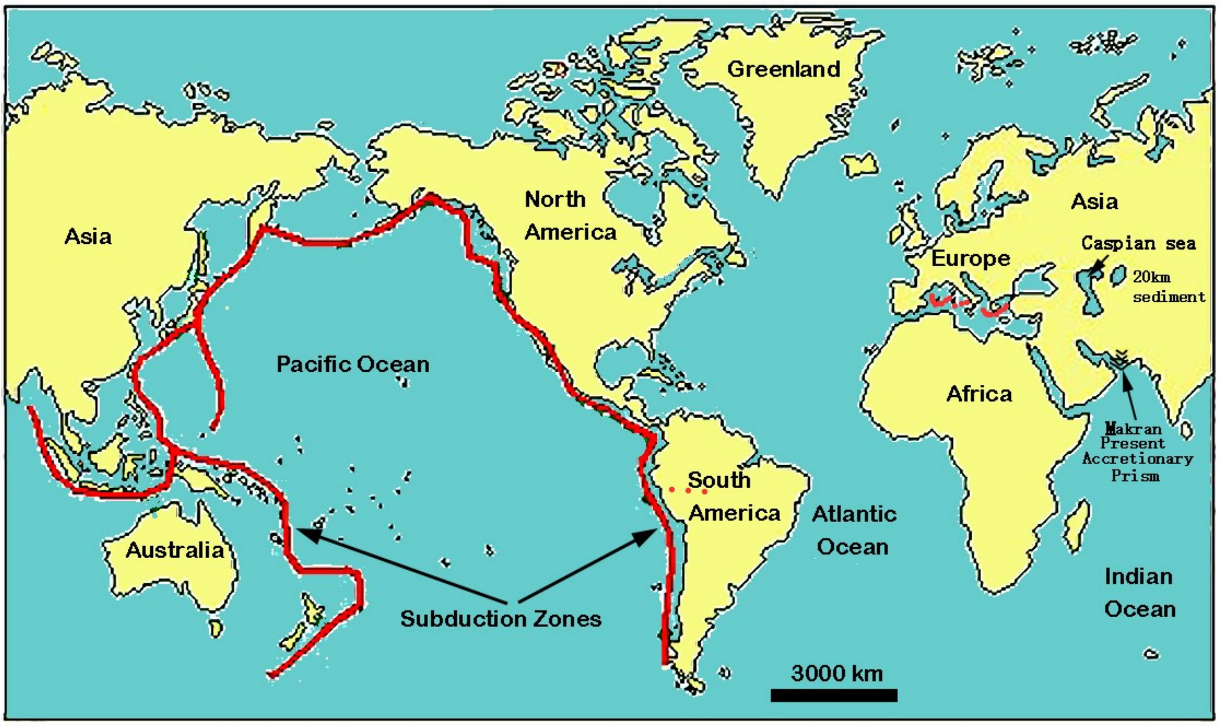

Fig. 21. Subduction Zones, indicated by red lines (modified from Lomize and Luchitskaya, 2012) [65], where there is no present-day oceanic crust (ophiolite) obduction

The Problem of Geochemical study of the Zagros Ophiolite and Basaltic Bodies

Another problem is the dependence of the previous studies on petrography and geochemistry for proving the magmatic origins of the claimed igneous bodies, however, these methods can offer only circumstances evidence not unique (direct) ones. This is because the poorly (badly) sorted textures of sandstone (Folk et al.1970) [68] highly resemble the porphyritic and amygdaloidal textures of basalt. In this context, the porphyrocrysts of volcanic rock are similar to porphyroclasts of sedimentary rocks (Figures.7 and 8). The geochemistry cannot prove if the rock constituents are in situ crystallization or transported from remote source areas espicially when they are metamorphosed. As an example: a rock sample is very difficult to be proved as a meteorite by the geochemical analysis while boundary conditions and outline features can be more decisive. Therefore, if the sample was strange in its area of occurrence and has signs of burnt outlines, they reveal most possibly a meteorite

Karim et al. (2020) [29], Karim (2021) [45] and Karim and Abioui, (2021) [27] clarified the inability of textures and geochemistry to indicate the origin of rocks. These latter three articles presented more than ten pieces of evidence for refuting the magmatic origin of the Mawat Ophiolite, Avroman and Gercus basaltic bodies in northern Iraq. Kattnanah and Bamarni (2019[28]) depending on thin section and geochemistry considered the greywackes (volcanic detritus) deposited in Dohuk and Harmin hills as basaltic intrusion and extrusion. These bodies are located inside Iraqi oil fields and cannot be considered Island Arc since they have properties of sedimentary successions and geophysical surveys did not find any dykes and volcanic necks (steams) in these areas.

The Most Serious Challenge to This Study

The most serious criticism (challenge) against this study is the occurrence of small and localized bodies of magnetite iron ore, Chromium Spinel, and relatively pure dunite. These bodies constituted less than 1% of the surface area of the Mawat and Penjween Ophiolite Complexes while Bulfat complex is barren of these bodies. Most of these bodies have lenticular shapes, their mineral grains are anhedral, and with irregular outlines and abrasion, surface textures are observable. These properties fit well into two probable origins, the first is metamorphism of detrital lithic clasts and crystalloclasts of iron, Chromium and olivine (Figures 22 and 23) that were accumulated in samall concentration as placer deposits. The placer deposits (or placer sediments) (Komar, 2005[69]) were deposited by hydraulic sorting in a submarine or subaerial channel in metamorphosed Walash Formation and occure as small iron, chromite, and dunite bodies in the Mawat and Penjween Complexes. The second possible orgin is replacement of limestone (marble) of Naopurdan Formation by hydrothermal solution rich in Fe, Mg or Cr. In this conection Moinevaziri and Mirza (2021) [70] concluded that the Sanandaj-Sirjan iron mineralzations are not crytallized in veins from magma but from solution of high-temperature.

On the Jabal Sanam, near the Iraq-Kuwait border, there is an igneous rock called dolerite by Al-Bassam, (2011) [71], while his thin section photos show dunite since it consists totally of forsterite (Fo 90-92). This mineralogy and texture are exactly similar to dunites of the Mawat and Penjween claimed Ophiolite complexes (Fig. 24) that are studied by Mohammad, 2013 [72]and 2020) [55]. In the three localities, the dunites have coarse textures with granular, anhedral and cracked crystalloclasts. We must ask a question: why the mineralogy and texture of the dunites are similar in the two different areas of different tectonics and petrographic composition? Previously, it is known that the Mawat and Penjween areas are located on the suture zone of the Zagros belt and the dunite was considered previously by tens of authors as part of the Ophiolite (oceanic crust) that crystalized on the Midoceanic ridge. While Jabal Sanam is located on the Arabian platform interior as the continental sialic crust. This similarity is not a coincidence but there is a relation between them, the relationship is well documented by Karim et al (2020) [29] Karim and Hamza (2021) [42], Karim and Ghafur (2021) [24], Karim and Abioui, (2021) [27]. In these articles, the long-distance transportations of different crystalloclasts of igneous rocks are shown and they refuted the presence of Ophiolite rocks in Iraqi Zagros. According to Al-Bassam, (2011) [71] the age of Jabal Sanam igneous rocks is 575 -580 Ma by K/Ar method. We strongly think that the igneous rock is sedimentary and deposited during Paleocene -Eocene because the stratigraphy around the Jabal contains a sedimentary succession of Paleocene-Miocene such as limestone, dolomite and gypsum and anhydrite without salt. The claimed igneous rock located between these rocks and its age is not the age of deposition but the age of crystallization on the source area which was most possible Urumieh-Dokhtar Magmatic arc.

Another criticism that may arise against this article is extending the volcanic activity in the Urumieh-Dokhtar Magmatic arc (UDMA) to Jurassic -Lower Cretaceous; while its exposed rocks not older than Paleocene in Iran. My justification is shown in three facts: the first is the recent conclusion of Chaharlang and Ghorbani (2020) [73] that a volcanic activity occurred on UDMA during the Cretaceous (106 m.y.). The second is the extensive erosion of the rocks of the UDMA during the Jurassic-Early Cretaceous due to the availability of large accommodation space for sediments transport to the deep basin (Fig. 19a). This accommodation was a result of two contrasting topographies which were high terrestrial land (continental arc of UDMA) and nearby deep oceanic basin of Neo-Tethys basin (present SSZ) in which the sediment accumulations were preserved. The third is the covering of the UDMA by Tertiary extrusive and intrusive rocks due to a decrease in the accommodation and topographic contrasts as a result closing (filling) of the latter zone (Fig. 19b) as an ocean which is the ancestor of the present Zagros Belt including SSZ.

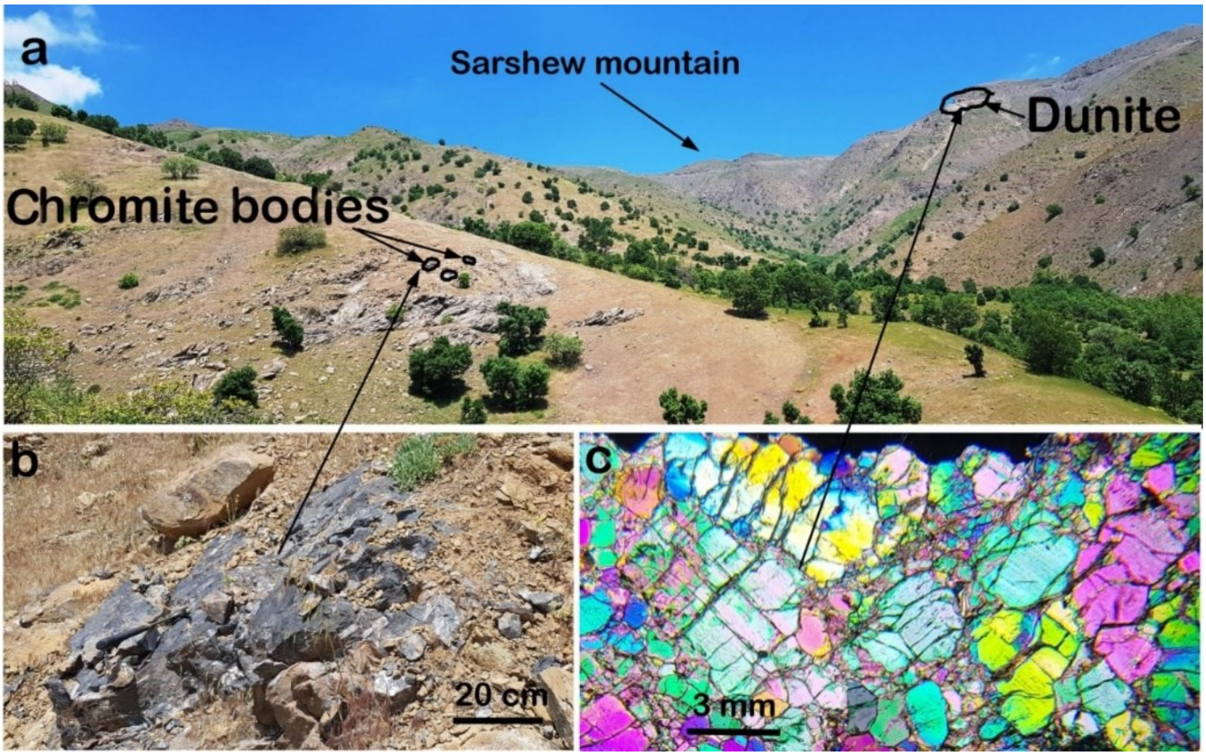

Fig. 22. a) location of the three chromite and one dunite bodies in the central part of the Mawat Ophiolite Complex, **b**) a close-up photo of one of the three chromite bodies, **c**) granular and anheral texture (grains) of the claimed dunite body.

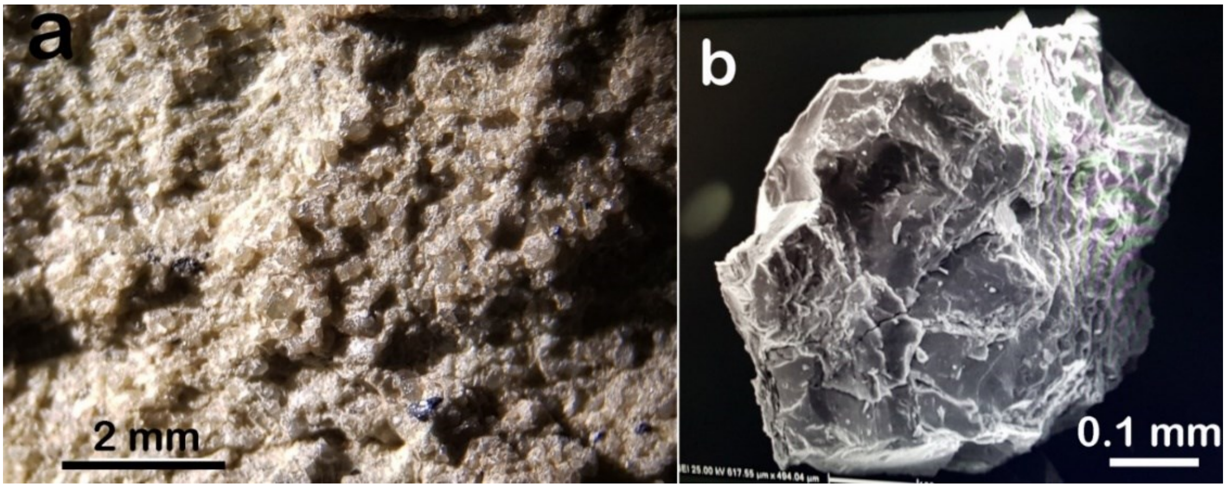

Fig. 23. a) sandy appearance of the olivine grains of the previously claimed dunite on the Mawat Ophiolite Complex, **a**) A grain of olivine under SEM microscope shows mechanical wearing (breakage) on its surface and edges

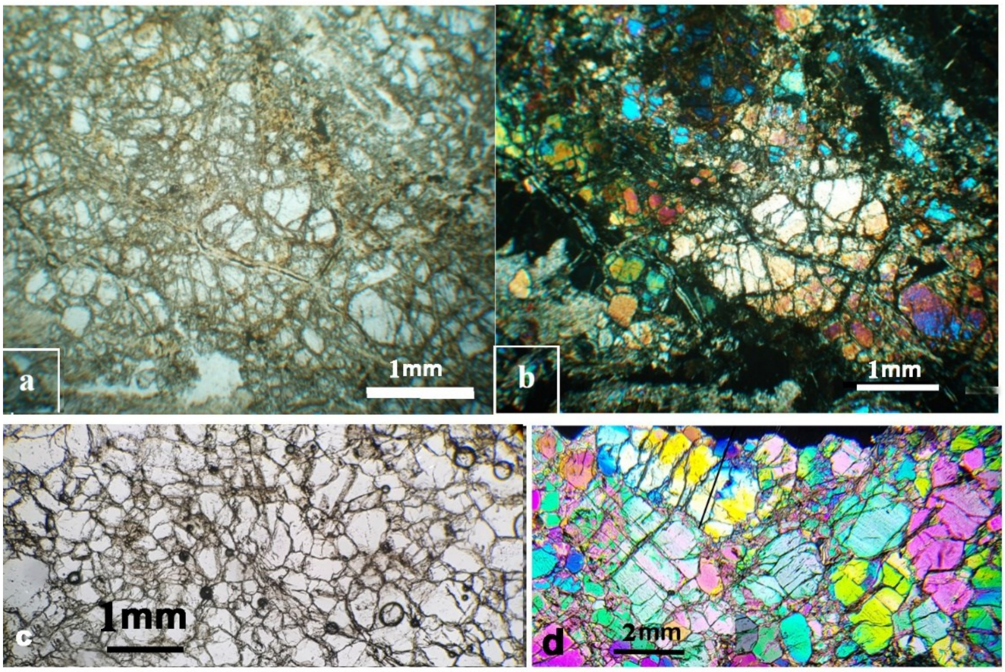

Fig. 24. a, b) Microphotograph of dunite on the Jabal Sanam (Al-Bassam, 2011) [71], near the Iraq-Kuwait border is nearly similar mineralogically and texturally to the dunite of the Mawat and Penjween claimed Ophiolite complexes (**c**, **d**). The color and black-white photos are under XP and ppl lights

Fossils Remain in the Iraqi-Claimed Ophiolites

According to previous studies the Iraqi ophiolites hosted many granitoid intrusions in the Mawat, Penjween, and Bulfat areas. All these intrusions are extending parallel to the layers of hosting gabbros or peridotites and they cut nothing, yet they are considered dykes previously. Their thicknesses range 20 cm to 10 meters while their lengths are unmeasurable due to intense brittle and ductile deformations. These felsic claimed dykes are more competent than their hosting rocks; therefore, they emerge as positive relief from the ground (Fig. 4a). Mohammad and Qaradaghi (2016) [74] confirm that Mawat granitoid (aged 92 ma) dykes are a result of anatexis of pelagic sediments during the late Cretaceous subduction in the Neo-Tethys Ocean. Ismail et al. (2020) [75] got the same result for the granitoid body (aged 46 ma) at the southern boundary of the Penjween ophiolite since mentioned the probable melting of sedimentary rocks from the downgoing Neo-Tethyan oceanic slab.

Unfortunately, these authors did not discuss how, and where this anatexis occurred since granitic magma can be generated from sandstone (quartz arenite) not from pelagic sediments and the models of Mohammad and Qaradaghi (2016) [74] for the same dykes don't aid the generation of granite by anataxis of pelagic sediments. In these claimed granitoid dykes (present felsic arenites or arkose) remains of deep marine branched coral are observable. Despite the metamorphism and mineralogical replacements, external and minute internal structures are identifiable when compared to the similar structure of recent corals (Fig. 25a and b) and of Cretaceous corals (Fig. 25c and d). The coral in Fig. 28a is previously called t "skeletal crystal of tourmaline" by Kareem (2015) [76]". Deep marine coral skeletons consist either of high Mg-calcite or Argonite (Bostock, et al 2015) [77], therefore they are replaced by secondary minerals.

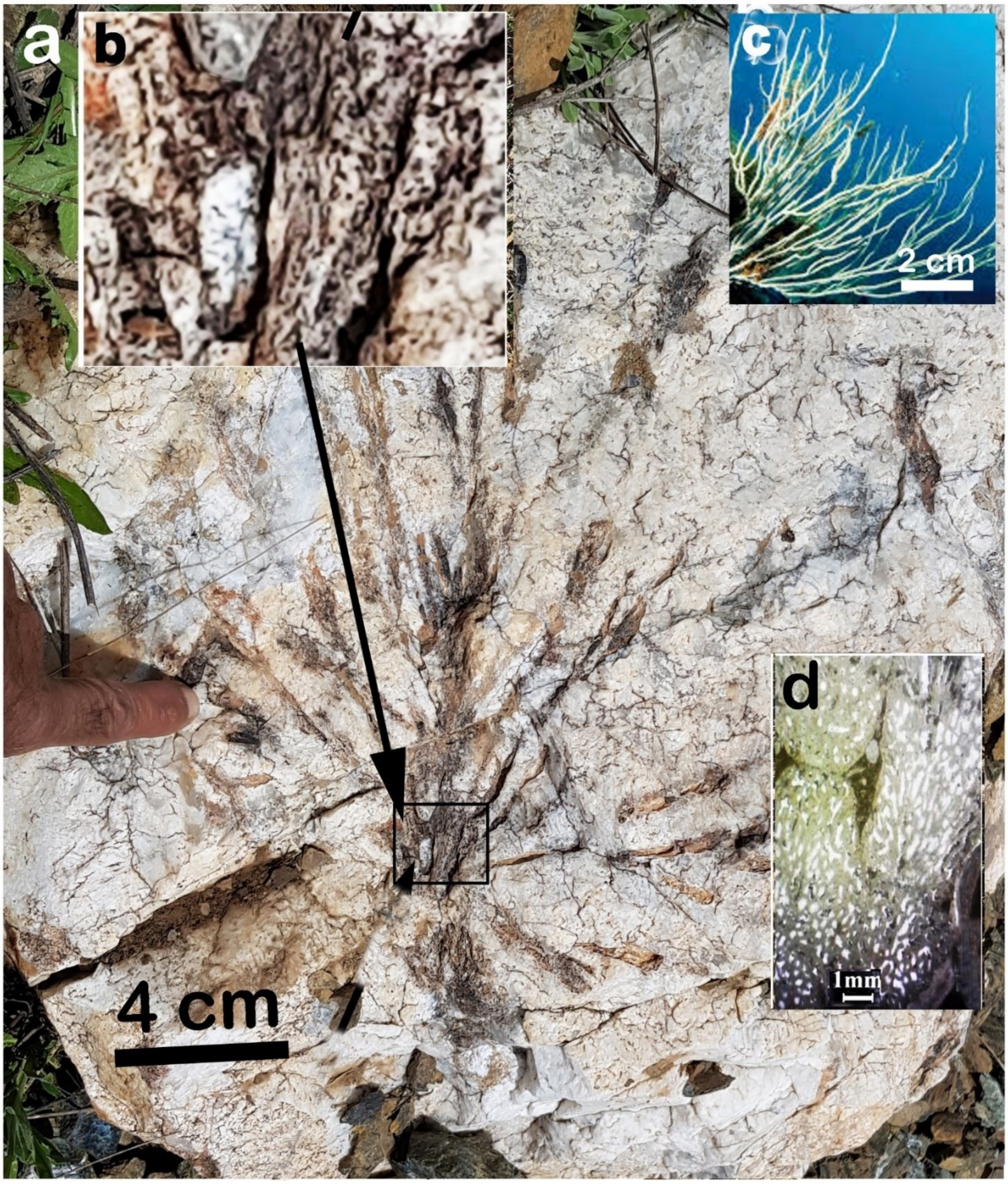

Fig. 25. a) deep marine branched coral in claimed granitoid dyke (present metamorphosed felsic arenite), **b**) enlarged part of the shows an internal structure of coral which is comparable with (**d**) which is Cretaceous coral of the Qamchuqa Formation, **c**) similar coral at present time (taken from web).

Fossil remains not only occur in claimed granitoid dykes but are also present in claimed metamorphosed basalts in the Mawat Ophiolite (present greywacke). These basalts are located 2 km north and northeast of Mawat town on the Spidara mountain at the latitude and longitude 35° 55' 21.13'' and 45° 26' 34.93''. On the Guley mountain, the layered (bedded) and regionally metamorphosed rocks occur and previously called metabasalt (Al-Mehaidi, 1975) [11] while Aswad et al., 2014) [78] stated high alteration of the metabasalts of the studied area and the recorded a porphyritic texture with occasional variolitic and amygdaloidal. They added that the mineral assemblages indicate greenschist facies (An1–An7- plagioclase, actinolite, chlorite, Zoisite, quartz, calcite). The present study found possible nummulite (Fig. 26) with the ghost of its protoconch and radiating structures. Moreover, white spherical, oblate, or irregular granule-sized bodies (grains) of plagioclase in the claimed above-mentioned basalt are found. These bodies are neither similar to amygdales nor to volcanic clasts due to their perforation (holed) and their wavy and meandering peripheries. Although metamorphism and reworking distorted their shapes and masked most of their holes, yet present study; considers these bodies as globigerina (Fig. 27 a, c, d, and e) and miliolids (Figure27 c-j) foraminiferas replaced by plagioclase during metamorphism. in some bodies, a dark matrix filled the center of the remains and their holes. The boundary of the miliolids has wavy or serrate outlines which are only related to the living organism, not volcanic rocks.

Another problem is the conclusion of Azizi et al. (2013) [79] who stated that the Mawat Ophiolite Complex does not show a typical ophiolite profile and is comprised mainly of basic rocks, which intruded into an extensional tectonic setting on the Arabian Plate passive margin. Therefore, the latter article changed the tectonic setting of the Mawat area from compression and ophiolite obduction and thrusting to extension and local magma intrusion.

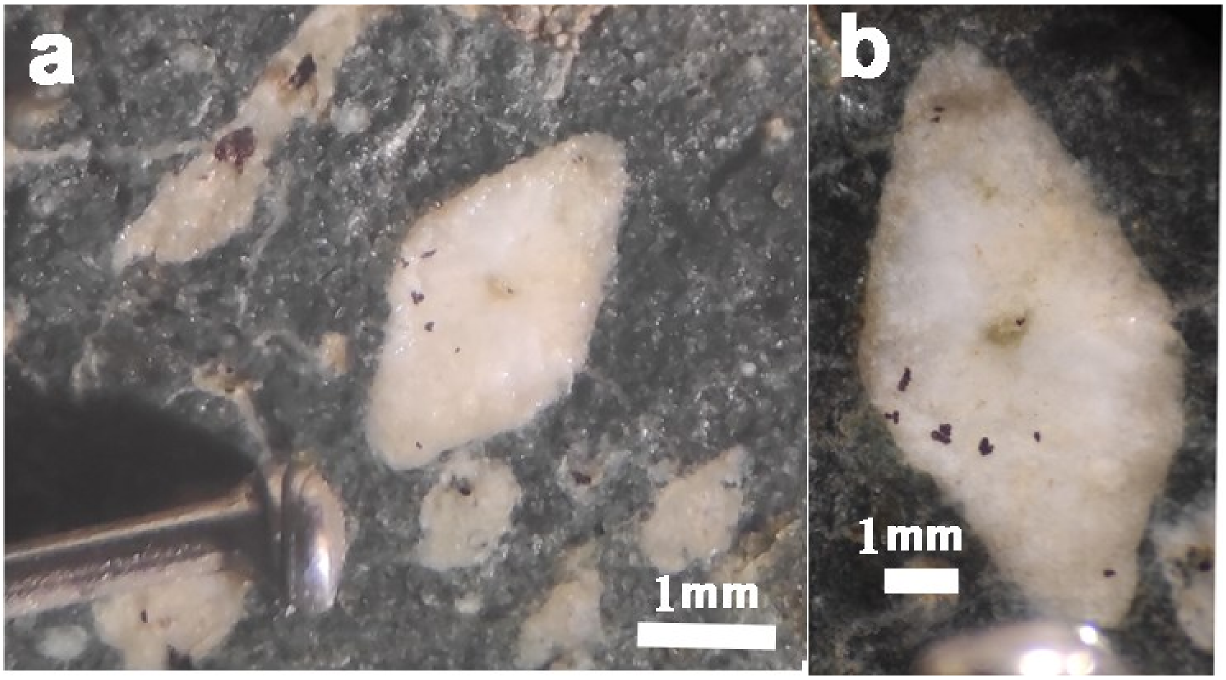

Fig. 26. a and **b**) Possible nummulite with the ghost of its protoconch and radiating structures at 35° 55’ 21.13’’ and 45° 26’ 34.93’’

Fig. 27. Possible fossils (globigerina and borealis species) in the claimed metamorphosed andesite, 2km northeast of Mawat town on the Spidara mountain. a, c, d, e) globular bodies with holes in their center and meanders in peripheries, the most possibly representing deformed globigerina test (b). f, g, h, i) A possible test of borealis with dentation of the boundary which represents holes similar to (j, taken from http://paleopolis.rediris.es/cg/14/04/images/Fig_11drag.htm). The pin point is for scale (0.4 mm).

Conclusions

More than thirteen problems of the Iraqi Zagros ophiolites and basaltic bodies are indicated and argued in the present study and previous considerations are objectively discussed. The study did not find any direct pieces of evidence for the presence of igneous rocks and ophiolites in Northern Iraq. All previous evidences are circumstances and no direct ones were published previously to confirm the latter rocks. All the circumstances evidences are re-considered and visited in addtion to boundary condition inspection in this study. Conversely, the present study found tens of sedimentary structures, textures and fossils that conclude their sedimentary origin of what are called igneous rocks and ophiolites and manifested that they are metamorphosed greywackes (volcanoclastic sandstones) of the Paleocene Walash Formation with participitation of other rocks such as older marl and limestones that are replaced by felsic and mafic minerals during metamorphism. Therefore, the tectonics, ophiolites, and basaltic bodies of Northern Iraq and Zagros must be reconsidered seriously.

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