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A Review and Evaluation of K. H. Karim and M. Al-Bidry's 2020 Study "Zagros Metamorphic Core Complex: Example from Bulfat Mountain, Qala Diza Area, Kurdistan Region, Northeast Iraq" (Jordan Journal of Earth and Environmental Sciences, 11 (2): 113-125).

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Abstract

The attention of the present authors is drawn to what looks like odd or even erroneous evidence presented by a paper recently published by Karim and Al-Bidry (2020), focusing on the Zagros Metamorphic Core Complex and providing an example from Bulfat Mountain, Qala Diza area, Kurdistan Region, northeast Iraq. For instance, the ophiolite at Mawat is of the Cretaceous age (105 ±5 Ma; Mohammad and Qaradaghi (2016), the plagiogranites are also of the Cretaceous age, but are slightly younger (92.6 ±1.2 Ma - Mohammad and Qaradaghi (2016), 96.0 ±2.0 Ma - Ismael et al. (2017) and the Hasanbag ophiolite is 106-92 Ma (Ali et al., 2012). On the other hand, 40Ar–^{39}Ar dates on the magmatic feldspar separates from the Walash and Naopurdan volcanic rocks indicate an Eocene–Oligocene age (43.01 ± 0.15 to 24.31 ± 0.60 Ma; Ali, 2012; Ali et al., 2013).

Many studies of the Zagros region have been undertaken on structure, origin of the ophiolites and the related igneous rocks, as well as on the geodynamic evolution (Ghazal, 1980; Alavi, 1980, 1994, 2004, 2007; Agard et al., 2005; Ali, 2012, Ali et al., 2012, 2013, 2014, 2017, 2019; Ali,2017; Aswad et al., 2011, 2013; Aziz et al., 2011; Mohammad et al., 2014; Mohammad and Qaradaghi, 2016; Mohammad and Cornell, 2017; Ali, 2017; Lawa, 2018). Therefore, the following points will be addressed:

(1) Possible Metamorphic Core Complex.

(2) Absence of volcanic rocks in the "Bulfat Complex" and absence of dykes and bosses.

(3) The origins of the sedimentary rocks in the "Bulfat Complex" that were originally transported to the Bulfat area from the Urumeh-Dokhtar Magmatic (basaltic) Arc (UDMA) by turbidity currents during Paleocene-Early Eocene.

(4) the paleogeographic and tectonic model of the deposition of mafic and felsic volcaniclastic sandstones (and other sediments) by turbidity currents sourced mainly from the Urumieh-Dokhtar Magmatic Arc and transported to the Iraqi side of the Sanandaj-Sirjan Zone (SSZ) in the Bulfat and Mawat areas.

Keywords: Bulfat, Igneous Complex, Bulfat Mountain, Zagros Suture Zone, Walash-Naopurdan Groups, Kurdistan region, Iraq.

(1) Possible Metamorphic Core Complex

Karim and Al-Bidry (2020) avoid including any geological background or data on the regional geology of the studied area. This is an important part in any study to show readers some established knowledge about the studied area. Plentiful information about the geological background can be found in papers by Pshdari (1983), Aziz (1986, 2008), Buda (1993), Aswad et al. (2013, 2016), Ali (2017) and Karo et al. (2018). Unfortunately, the idea of a possible Metamorphic Core Complex (MCC) presented by Karim and Al-Badry (2020) is based on work of Ring (2014), Coney (1980), Lister and Davis (1989) and Huet et al. (2011). For example, the section on "MCC is defined by Lister and Davis (1989) as a crust structure which resulted from major continental extension, when the middle and lower continental crust is dragged out from beneath the fracturing, extending the upper crust. Deformed rocks in the footwall are uplifted through a progression of different metamorphic and deformational environments, producing a characteristic sequence of (overprinted) meso- and microstructures," an idea taken entirely from the abstract by Lister and Davis

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(1989) even without any paraphrasing.

A basic feature of metamorphic core complexes are the exposures of deep crustal rocks exhumed in association with a largely magmatic extension. Metamorphic core complexes are exciting examples of large-scale continental extension, usually juxtaposing metamorphic lower crust against upper crustal rocks (Coney, 1980). Detachment faulting is associated with large-scale extensional tectonics. Detachment faults often have very large displacements and juxtapose unmetamorphosed hanging walls against medium to high-grade metamorphic footwalls forming the metamorphic core complexes (Singleton, 2013). It is not necessary for all metamorphic core complexes to contain only metamorphosed sedimentary rocks. Many metamorphic core complexes consist of plutonic rocks in addition to the metamorphosed sedimentary rocks. The best example is the Shuswap Complex in Canada, which is the largest and longest recognized metamorphic core complex and is considered a typical example (Coney 1980; for more information see Reesor, 1965, 1970; Reesor and Moore, 1971; Simony et al., 1980; Banks, 1980; Davis, 1983; Lister and Davis, 1989). Therefore, on the basis of the new evidence in sections 2, 3, and 4, the authors of the present work completely reject a new Metamorphic Core Complex tectonic model for the Bulfat igneous complex.

(2) Absence of Volcanic Rocks in the "Bulfat Complex" and Absence of Dykes and Bosses.

The present work argues that most of the observations in Karim and Al-Bidr (2020) do not support the idea that volcanic rocks, dykes, and bosses are absent in the Bulfat Igneous Complex as mentioned in the introduction. Most of their field photographs and petrographic thin section descriptions leave doubts about their mineral and texture identifications since they are not accompanied by illustrations. Therefore, this work provides data on some of the volcanic and dyke thin sections as well as field photographs taken from publications on the Bulfat Igneous Complex. The publication discussed here is a good example of duly documented misidentifications (see figures 1, 2, 3; for more see Aswad and Pshdari, 1984; Aziz, 1986; Aqrawi and Sofy, 2007; Aswad et al., 2013; Ali, 2017; Karo et al., 2018; Zrary, 2019).

Below are a few examples of misidentifications with some revised identifications:

a. Karim and Al-Bidry (2020) state that the pyroxenite facies is a regional metamorphic one. This is quite incorrect as facies refers to the set of predictable mineral assemblages and the P-T conditions they represent. The three common types of facies series are: High P/T facies series: (zeolite) – (prehnite-pumpellyite) – blueschist - eclogite; Medium P/T series: (zeolite) – (prehnite-pumpellyite) – greenschist – amphibolite – (granulite); Low P/T series: (zeolite) – (prehnite-pumpellyite) – albite-epidote hornfels – hornblende hornfels – (pyroxene hornfels) – (sanidinite). It is clear from the above-mentioned information that the pyroxenite facies is related to the Low P/T series, and it is formed in high geothermal orogenic settings or contact metamorphism (Winter, 2001).

b. Karim and Al-Bidry (2020) state that during a traverse from the southern boundary to the core of the "Bulfat Complex," the signature of gradation is clear; woefully this is supported by only two thin-section photomicrographs which do not validate their claim about the boundary conditions of the Bulfat Igneous Complex. Instead, they should have supported their observed gradation with field photographs of rock units.

c. Karim and Al-Bidry's (2020) reinterpretation of previously published figures is completely wrong as they do not give the exact location of the thin-sections. It seems they never examined those thin-sections under a microscope; instead they should produce new thin-sections to support their interpretations.

d. Karim and Al-Bidry's (2020) interpretation of Figures 7 and 16 is completely wrong, as they consider fresh typical gabbro to be mafic granulite, and for the first time in the literature they claim irregular intergranular hornblende as a cement matrix, which has never been mentioned even in principle petrographic books. Karim and Al-Bidry (2020) state that no contact metamorphism was seen in the field, yet Figure 10b in the Karim and Al-Bidry (2020) shows hornfels. Hornfelsic rocks are the product of contact metamorphism (Aswad and Pshdari, 1984). This means their postulated channel in Figure 10b is actually an igneous intrusion that metamorphosed the country rocks. In addition, Figures 7a, 7b, 16, and 17a in Karim and Al-Bidry (2020) clearly show typically igneous textures and not a sandstone or conglomerate protolith. Moreover, Figure 7a is definitely igneous amphibole and this was documented by Ali (2015) using electron microprobe mineral analyses (for more information see Ali, 2012; Ali et. al., 2013; Ali, 2015).

e. A sign of misleading is obvious in Figure 9, as they criticize other unnamed authors who consider this view to be a mafic igneous rock.

Figure 1. Typical felsic dyke intruded into an older gabbroic rock unit of the Bulfat Igneous Complex northwest of Hero.

Karim and Al-Bidry (2020) state that "the Walash-Naopurdan Series occurs around the Bulfat and Mawat Complexes (at least, to the south, southwest and southeast) apparently below the Red Bed Series, and consists (as previously indicated) of a mixture of volcanic rocks, sedimentary rocks, and carbonate sediments. But the present study inferred that the series does not contain volcanic rocks; instead, it consists of volcaniclastic sandstone, shale and greywacke (Figure 17) that was derived mainly from the volcanic (basaltic arc) source areas. These sediments can produce the gabbro or diorite-like rocks after metamorphism and crystallization". The present authors completely disagree with these three unusual results. First, in all Iraqi geological databases the Walash-Naopurdan Groups represent the lower allochthon, which is thrust over the Red Bed Series in all parts of the Iraqi Zagros Thrust Zone. Secondly, the igneous rocks in the Walash-Naopurdan Groups are genuine igneous rocks in terms of texture, mineralogy, and field occurrence, which is documented in all previously published papers about the Walash-Naopurdan Groups (for more information see Aziz, 1986, Aziz, 1993; Aziz et al., 1993a; Aziz et al., 1993b; Ali, 2002; Aziz and Ali, 2005; Ali, 2012; Ali et al., 2013, 2014, 2017, 2019; Aswad et al., 2013). Thirdly, one asks if it is possible for sediments to produce the gabbro or diorite-like rocks after metamorphism and recrystallization? It is impossible to generate ultrabasic or basic rocks from clastic sediments by metamorphism. In studying metamorphic rocks, the first thing to be considered is their protolith and thermodynamics. The metamorphic products depend on the prevailing temperature, the type of pressure whether it is directed (deviatoric stress) or confined pressure (non-directed pressure), and the protolith rocks (Winter, 2001). Additionally, a geochemical and petrological study of twelve closely-spaced rock samples from the Bulfat Igneous Complex at Wadi Rashid, which consists of gabbro and granitic composite intrusions, show that the gabbro or diorite-like rocks preserve igneous textures with domains of ferromagnesian igneous minerals showing minimal replacement by secondary tremolitic green amphibole and chlorite (Aswad et al., 2013). Another example from Bulfat Igneous Complex is the Shaki-Rash gabbro which contains olivine, plagioclase and clinopyroxene, with lesser orthopyroxene, biotite, brown hornblende and alkali feldspar (Figure 2) which is intruded by Eocene arc-related magmatic rocks (Ali, 2017). From all the above-mentioned evidence, it is clear that Karim and Al-Bidry (2020) failed to distinguish between the different kinds of igneous rocks, serpentinite and other sedimentary rocks in the field (Figure 3).

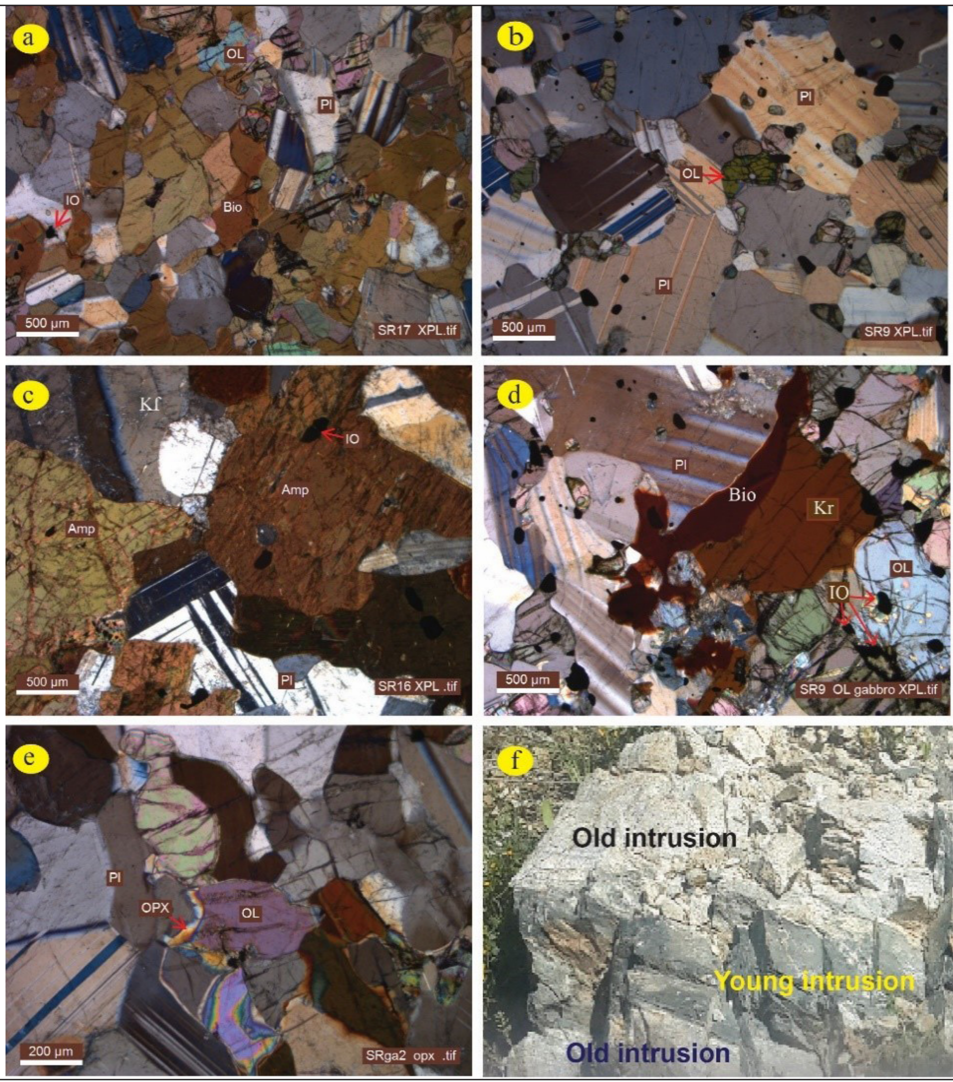

Figure 2. Photomicrographs of Shaki-Rash gabbro rocks showing typical igneous minerals and textures (for more details see Ali, 2017).

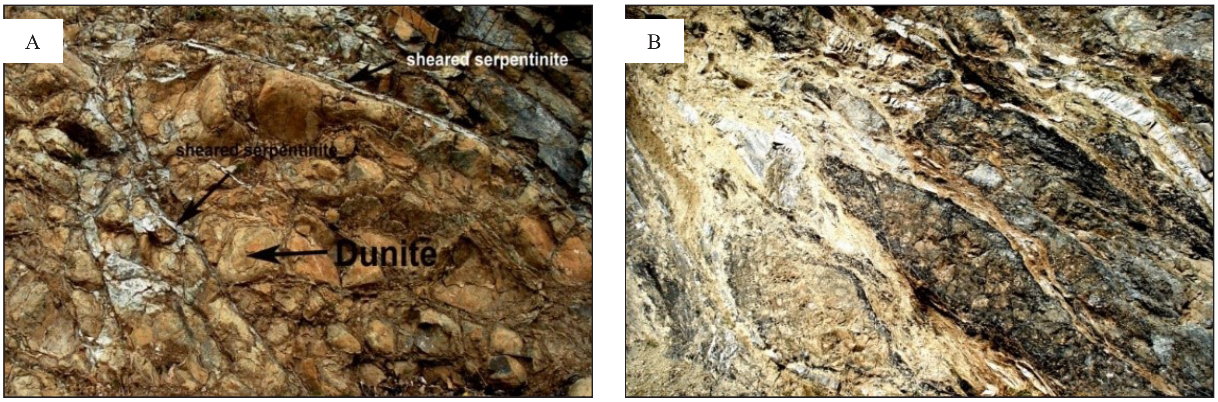

Figure 3. Field photograph of sheared serpentinite (A), and massive serpentinite (B) in the Pauza area of the Bulfat Igneous Complex (after Aziz, 2008).

(3) The origins of the rocks in the "Bulfat Complex" are sediments that were originally transported to the Bulfat area from the Urumeh-Dokhtar Magmatic (basaltic) Arc by turbidity currents during Paleocene -Early Eocene.

The Iraq (Kurdish) section of the Zagros Suture Zone is marked by numerous allochthons of Neotethyan ophiolitic and volcanic arc assemblages that were obducted onto the Arabian margin (Ali et al., 2012, 2013, 2014, 2017, 2019). New geochronological data, including SHRIMP U-Pb zircon, combined with whole rock geochemistry, indicate that both Cretaceous (˜96 Ma) and Cenozoic (˜40 Ma) assemblages are present (Ali et al., 2019). An increase of $^{40}Ar/^{39}Ar$ mineral and U–Pb zircon geochronology has revealed two important periods of arc magmatism: in the Cretaceous (Albian–Cenomanian) and the Paleogene (Eocene–Oligocene; Aswad et al., 2011, 2013; Ali et al., 2013, 2016, 2019). Aswad et al. (2016) discovered unrelated but essentially coeval Paleogene arc magmatism in two separate allochthons which points to the complex tectonic episodes in the final stages of Neotethys consumption. It is well-known that ophiolites are of an oceanic crust protolith, composed dominantly of basic rocks. No one has ever, even in international works, suggested the protolith of ophiolites to be arenites, greywacke or pyroclastic rocks. Karim and Al-Bidry (2020) are claiming that the source of sediment in the "Bulfat Complex" was derived from the Urumieh-Dokhtar Magmatic Arc and was transported 90 km by turbidity currents to a basin of deposition in the Qaladiza and Bulfat area (as a part of the SSZ) during the Paleocene-Eocene. This is a completely incorrect statement as the rocks in the SSZ are much older than the Cenozoic Urumieh-Dokhtar Magmatic Arc (Figure 4; for more information see Chiu et al., 2013). From this point, it is very clear that the Karim and Al-Bidry have no sufficient knowledge of the tectonic evolution of the Zagros Orogenic Belt. Moreover, their perplexing model shows that the SSZ is represented by a gigantic fan of about 115 km extending from Penjween to Bulfat fed by a submarine channel without any hydraulic sorting of the sediments and no record of a submarine canyon along the entire Zagros.

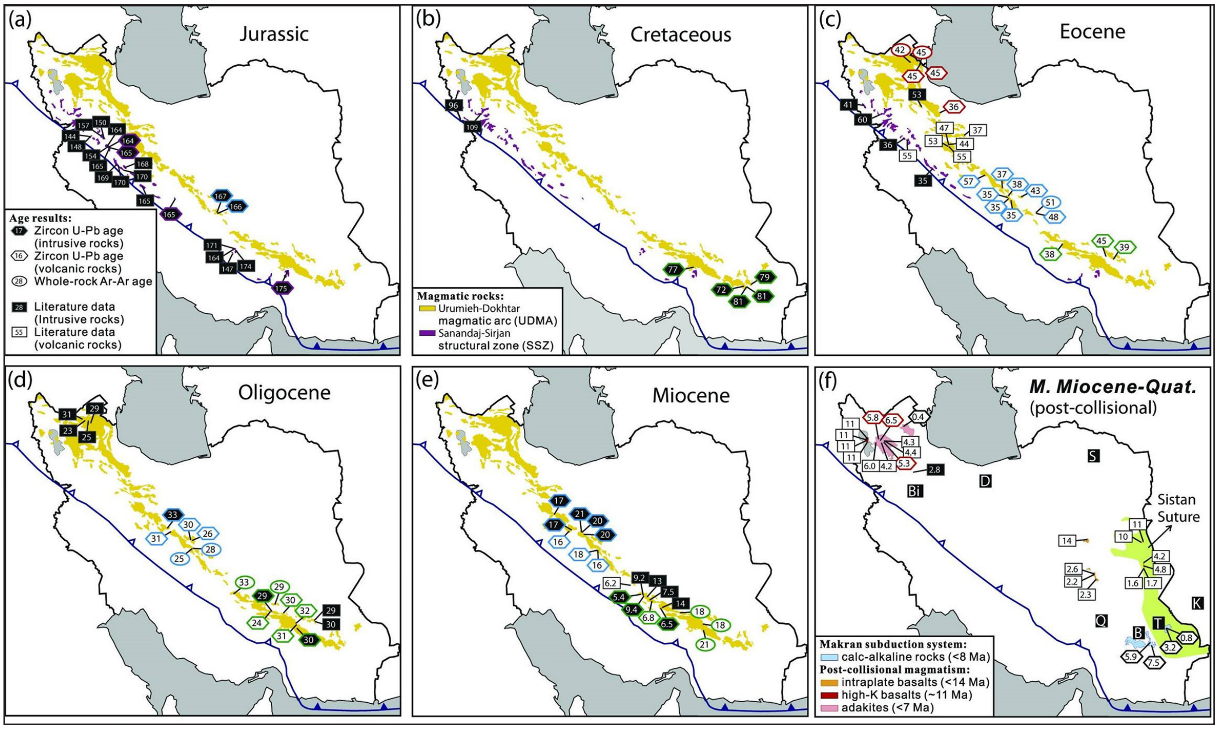

Figure 4. Magmatic distribution in the UDMA and SSZ plotted in age spans from Jurassic to Quaternary along Zagros Orogenic Belt (after Chi et al., 2013), clearly indicate that the younger UDMA cannot be a sediment source of older SSZ rocks.

(4) Paleogeographic and tectonic model of the deposition of mafic and felsic volcaniclastic sandstones (and other sediments) by turbidity currents sourced mainly from the Urumieh-Dokhtar Magmatic Arc and transported to the Iraqi part of the Sanandij-Sirjan Zone (Bulfat and Mawat areas).

The new tectonic model of a "Metamorphic Core Complex" proposed by Karim and Al-Bidry (2020) for the Bulfat Igneous Complex depended mostly on literature reviews (e.g. Ring, 2014; Coney, 1980; Lister and Davis, 1989; Huet et al., 2011) and on field photos, using twenty thin sections for such a large area. However, the model cannot be accepted on the basis of a similarity of some of the features between Bulfat and those mentioned in the above literature reviews without doing a detailed structural study of the Bulfat area. Karim and Al-Bidry (2020) state that 'the Bulfat MCC is associated with extension and normal faulting both locally and regionally. On a local scale, many normal faults can be seen which occurred after metamorphism (during uplifting).'' They use no references to support their tectonic model hypothesis; in fact there is no structural study or any publication done on the Bulfat Igneous complex preceding this study. Therefore, the authors of the current work completely reject the new Metamorphic Core Complex tectonic model for the Bulfat Igneous Complex.

It is important to mention that the Urumieh-Dokhtar Magmatic Arc lies several hundred kilometers from the Bulfat area, and it is separated from Bulfat Igneous Complex by the Sanandaj-Sirjan Zone igneous and metamorphic complex. The transportation of huge deposits by rivers from the Urumieh-Dokhtar Magmatic Arc to the Bulfat area during Paleocene-Eocene has not been recorded or recognized in any geological work in Iraq and Iran for more than a century (Alavi, 1980, 2004, 2007; Pshdari, 1983; Agard et al., 2005; Jassim and Goff , 2006, Aziz et al., 2011; Aswad et al., 2011, 2013; Ali, 2017; Ali et al., 2012, 2013, 2014, 2016, 2017, 2019; Mohammad et al., 2014; Mohammad and Qaradaghi, 2016; Mohammad et al., 2016; Ali, 2017; Mohammad and Cornell, 2017; Lawa, 2018). Furthermore, there are neither erosional, nor depositional features of those rivers in Iraq or Iran. There are no incised valley deposits of those rivers, no fresh water deposits have been recorded, and no fresh water fossils. The submarine fan as part of a major foreland basin should contain fossils (fauna or flora) or other bio-markers. The proposed submarine fan model contains no mentioning of fossils as in the Neotethys basin, such as planktic foraminifera in the shale or Nummulites in the Bulfat carbonates, or any record of reworked fossils or even any trace fossils. Karim and Al-Bidry (2020) mentioned that, after erosion, these sediments were transported and deposited by turbidity currents in the Zagros Foreland basin during the Paleocene-Eocene. Actually, the rocks show no turbidite sedimentary structures, and there are no field data or laboratory indications for the presence of submarine canyon, gullies, channels, levees, and lobate surfaces. Also, there are no field or laboratory indications for any arenite deposits in channels. The lobe and levee dirty sandstone (greywackes) oppose the argument that these sediment have been transported for a very long distance from the source to the Bulfat area.

Karim and Al-Bidry (2020) mis-identified the rock types and the sedimentary structures as follows:

a. Figures 4, 5, and 6 are used as a proof of bedding or lamination; they use the terms sandstone, shale and marl. Actually there is no bedding or lamination, or any sandstone or shale. The rocks are schist and phyllite with clear schistosity and foliations. In addition, a marl should include planktonic foraminifera (like Morozvella and Subbottina spp., Lawa, 2004), nanofossils and/or palynomorphs to support the age determination and submarine fan model.

b. Figure (7) was used to indicate sorting and roundness; actually it shows angular crystals without any roundness, sphericity or porosity.

c. Figure (10a) is explained as an erosional surface below a small channel with laminations in the metamorphosed volcaniclastic sandstone. In reality, it is gabbro (Aswad et al., 2013, 2016) that was subjected to intense deformation with folding, and faulting (note two minor sets), without any erosional surface or any type of channel.

e. Figure (11b) showed the contact between Kolosh and Sinjar Formations. This boundary between the two formations had been recorded by Lawa et al. (2013) who determined the gap age between the Paleocene and Eocene, which is not mentioned by the authors.

Karim and Al-Bidry (2020) mention that the foreland basin occupied part of the Sanandaj-Sirjan Zone of Iran and the whole of Iraq, without using any reference. Again it is a big mistake, because the foreland basin simply does not cover the whole of Iraq, as mentioned by Lawa (2018). On the same page, they also state that during the Paleocene-Eocene, a thick succession of volcaniclastic sandstones and shales was deposited in the rapidly subsiding foreland basin. Stratigraphically in Iraq, they were called the "Walash-Naopurdan Series," which consists of clastic and carbonate sediments without volcanic rocks. Such a statement points (without adding references and without being studied) to the fact that they were not able to differentiate between two different tectonic thrust sheets, the Iraqi Zagros Thrust Zone contains two thrust sheets; the Upper and Lower Allochthons (see Figure 2b in Ali et al., 2019). The Upper Allochthon ophiolite bearing terrane is part of the Outer Zagros Ophiolite Belt. The Bulfat Igneous Complex is located in the Upper Allochthon ophiolite-bearing terrane, while the Walash-Naopurdan Groups are located in the Lower Allochthon, and these two allochthons represent two different tectonic domains (Ali, 2012; Ali et al., 2012; 2013; 2014; 2016; 2019; Aswad et al., 2016). Consequently, there are no original sedimentary structures and textures such as the planar bedding, laminations, cross-bedding, folding or erosional surfaces in the granular textures in Bulfat Igneous Complex. Also without any fossils (neither as flora nor as fauna, and even no trace fossils). However, The presence of quasi-sedimentary structures in igneous rocks, such as cross bedding, layering, graded bedding, and channeling are quite common in igneous intrusions such as those found in the Skeargard Massif. The origins of the rocks of the Bulfat Igneous Complex are not sediments that were originally transported to the Bulfat area from the Urumeh-Dokhtar Magmatic (basaltic) Arc by turbidity currents during the Paleocene -Early Eocene. The present authors believe that, today, the Iraqi geological Wikipedia, that has long benefited from the pioneer geological investigations, should contribute to helping fill this huge scientific gap made by some researches including Karim and Al-Bidry (2020) in supporting new modern igneous and metamorphic investigations.

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