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Heavy Mineral Distribution of Gercus Formation in Shaqlawa and Dokan Area in Northern Iraq

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Abstract

From the Gercus Formation, eight samples were taken, ranging from fine grain sandstone to extremely fine grain sandstone. In comparison to other heavy metals, In the heavy metals examination, the opaque mineral had the highest percentage. Transparent minerals, such as metastable and unstable minerals, such as Amphibole, including Hornblend and Glaucophane (Epidote, staurolite, Garnet, Kyanite), reveal metamorphic sources. Mica group minerals, ultrastable minerals (Zircon, Rutile, Tourmaline) (Chiorite,Biotite and Muscovite), Mafic igneous and metamorphic rocks, as well as acidic igneous and reworked sediments, are frequently used to create heavy minerals , according to these accumulations. The ternary diagram of heavy metal stability showed that they are relatively stable because of the impact of the opaque mineral that draws the greatest attention. Both types of sandstone are used in construction.

Keyword: Gercus Formation, heavy minerals, provenance, opaque mineral, Transparent minerals, sandstone.

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توزيع المعادن الثقيلة لتشكيل الجركس في منطقة منطقة شقلاوة ودوكان في شمال العراق

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الخلاصة

تم جمع ثماني عينات من تكوين الجركس، تمثل الحجر الرملي الناعم إلى الحجر الرملي الناعم جدا. تشير دراسة المعادن الثقيلة أن المعادن المعتمة سجلت أعلى نسبة مقارنة بالمعادن الثقيلة الأخرى. بينما، المعادن الشفافة، تتمثل بلمعادن غير المستقرة (أمفيبول يتضمن الهورنبلند والكلاكوفين) و (البياروكسين يتضمن اورثوبايروكسين وكلاينوبايروكسين)، المعادن شبه المستقرة تتضمن (ابيدوت،شتورولايت، كارنت،كيانايت) المشار إليها مصدر متحولة، معادن فائقة الاستقرار (الزركون، روتايل، التورمالين)، مجموعة الميكا تتضمن (كلورايت وبايوتايت ومسكوفايت). تشير هذه التجمعات إلى أن المعادن الثقيلة مشتقة من الصخور النارية القاعدية والمتحولة في الغالب، بالاضافة الرواسب الحمضية النارية الرسوبية القديمة. يوضح المخطط الثلاثي لاستقرار المعادن الثقيلة أن المعادن الثقيلة مستقرة إلى حد ما بسبب تأثير المعادن المعتمة الذي تملك نسبة اعلى من بقية المعادن. كل من الحجر الرملي لتكوين الجركس مشتق من الحواف القارية النشطة.

الكلمات المفتاحية: تكوين الجركس، المعادن الثقيلة، المعادن المعتمة، المعادن الشفافة، الحجر الرملي، مصدر.

Introduction

Maxon initially described the Gercus Formation in the Gercus region of SE Turkey [1]. Wetzel from the Duhok area of northern Iraq described a supplemental type section for Iraq (originally referred to as Duhok Red Beds). Red and purple shale, mudstone, sandy and gritty marls, pebbly sandstones, and conglomerates cover 850 meters. In the Demir Dagh area, it is made up of brown clastics and limestone [2]. The formation is forming in the Unstable Shelf's High Folded zones. The formation is overthrust along the N Thrust Zone in northern Iraq; the initial depositional limit was farther north [3]. The formation's thickness reduces as it moves to the southeast; towards the Iranian border, along the Sirwan (Diyala) River, it is usually less than 100 meters thick. Gercus Formation is found in the Taq Taq (66 m thick) and Demir Dagh (117 m thick) wells [3], where fossils are extremely scarce and most likely reworked [3,4]. [5] was dated the Gercus Formation as Late Lower Eocene using palynological data.

[6] looked into the origins of red pigment and found that the Gercus Formation in northwestern Iraq is made up of a river sequence of connected red and drab beds that were formed in an arid to semi-arid climate. [7] investigated the geochemistry of northeast Iraq's Gercus red beds Formation. [8] investigated the geochemical importance of Ni and Co distribution in clayey-siltstone linked with northern Iraq's Gercus Formation. This study involves petrography and mineralogy, sandstone categorization, sandstone stability, sandstone maturity determination, and tectonic setting provenance.

Geology of the study area

The Stable Shelf, the Unstable Shelf, and the Zagros Suture are the three tectonically distinct sections of Iraq. From west to east, the Stable Shelf is separated into three primary tectonic zones: the Rutba-Jazeera, Salman, and Mesopotamian Zones, the Unstable Shelf is divided in to four zones: the Foothill Zone, the High Folded Zone (in which the studied area included) and the imbricated Northern (Ora) and Balambo-Tanjero Zones. The Mid-Late Eocene sequence was deposited to the southwest of an emergent uplift during the final phase of subduction and closure of the remnant Neo-Tethys ocean. Red beds were deposited in a narrow intermountain basin between the raised area in the northeast and a ridge running from Amadiya in the northwest through Ranya, Sulaimaniya, and Halabja in the southeast [3], as well as in the basin to the northeast of the uplifted area.

Southwest of the Balambo-Tanjero Zone ridge, a strongly sinking depression occurred, in which the materials of the Gercus Red Beds were deposited. The clastic sediment supply from the uplifted land to the northeast halted around the end of the Mid Eocene, and the basin was filled with lagoonal carbonates of the Pila-Spi Formation [3].

Location of the study area

The area of the study is located north east of Iraq (Kurdistan region) from two sections (Shaqlawa and Dokan) between latitude, (36^{0},26^{0},01^{0}, and,35^{0},92^{0},43^{0} N), while longitude,(44^{0},19^{0},51^{0}, and 44^{0},90^{0},74^{0} E).as shown in (Fig 1).

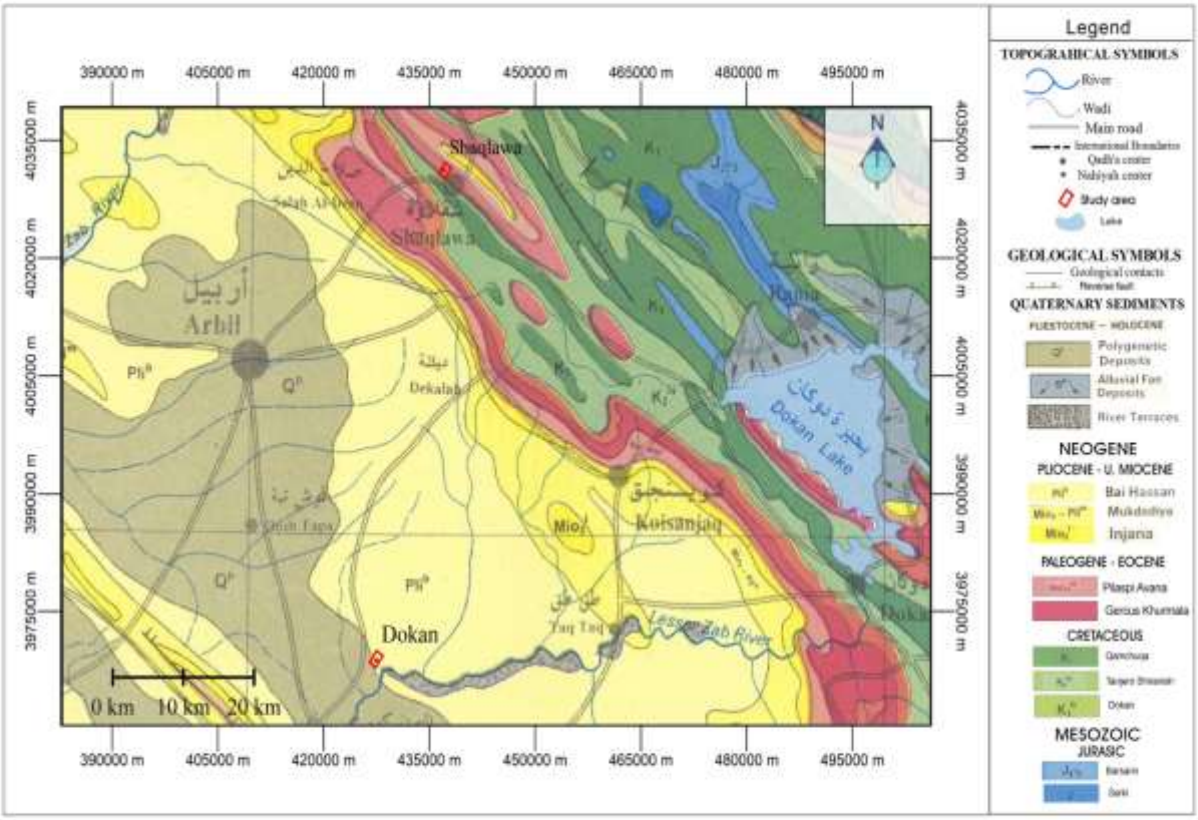

Figure 1: Location map of the Gercus Formation of the studied area.

Materials and Methods

Eight heavy mineral samples were selected for polarized microscopy identification.Mineral separation was carried out according to prior processes [9-10]. Utilizing sieves with size fractions of 2mm, 1mm, 0.5mm, 0.25mm, 0.125mm, and 0.063mm, different sand fractions were separated. Dry sieving was used to obtain the 3 (0.125 mm) fine grain (F) and 4 (0.063

mm) very fine grain (VF). Mineral separation was accomplished using five grams of both sizes of grains and a Bromoform with a density of 2.89, according to Fleet [10], before mounting on glass slides with 300–500 grains per slide.

Results

Two sets of heavy metals were identified and described in the samples used for the current study (Tables 1 and 2).

Opaque Minerals

There are two forms of opaque iron oxide minerals: opaque black and dark brown these minerals often have subangular to angular grains, while some have subrounded to rounded grains as well. Shaqlawa sandstone had a percentage of opaque minerals ranging from 36.4 to 40.1 percent, with an average of 39.45 percent. In Dokan sandstone, the proportion ranged from 37.1 to 45.3 percent, with an average of 40.37 percent (Figure- 2-A, B and C).

Hematite was found in some Shaqlawa and Dokan sandstone samples. Hematite grains are angular, high-relief in shape, and have a rich red color. Hematite content in Shaqlawa sandstone ranged from 12.4 to 16.3 percent, with an average of 14.05. The percentage ranged from 10.6-12.1 percent in Dokan sandstone, with an average of 11.33 percent (Figure- 2-D). Chromian spinel was identified in sandstone samples from Shaqlawa and Dokan. Chromian spinel grains have a subrounded to rounded form, a high relife, and a rich brown color. The spine of the Chromian is isotropic. In the Shaqlawa sandstone, the percentage of chromian spinel ranged from 4.6 to 6.3 percent, with an average of 5.5 percent. The proportion ranged from 4.1 to 6.2 percent in Dokan sandstone, with an average of 4.93 percent (Figure- 2-E).

Table 1: Mineral components in sandstone samples from the Shaqlawa portion of the Gercus Formation (percentage, range, and average).

Shaqlawa section						
Sample No	Sh1%	Sh10%	Sh12%	Sh13%	Range	Average
Opaques	40.1	36.4	39.1	42.2	36.4-40.1	39.45
Hematite	16.3	12.4	13.2	14.3	12.4-16.3	14.05
Chromian spinel	4.6	5.7	6.3	5.4	4.6-6.3	5.5
Chlorite	2.4	3.3	4.5	4.2	2.4-4.5	3.6
Orthopyroxene	2.4	2.2	2.4	2.3	2.2-2.4	2.33
CliniPyroxene	1.7	5.1	4.5	2.1	1.7-5.1	3.35
Hornblende	2.4	2.2	2.3	3.4	2.2-3.4	2.58
Glaucophane	1.5	2.1	0.9	1.2	0.9-2.1	1.43
Actinolite	0.6	1.5	2.4	2.6	0.6-2.6	1.78
Biotite	1.3	1.3	2.9	1.1	1.1-2.9	1.65
Muscovite	1.5	3.4	1.4	1.7	1.4-3.4	2.0
Clinozoisite	2.2	4.8	1.3	2.0	1.3-4.8	2.58
Zoisate	1.3	1.4	1.2	1.5	1.2-1.5	1.35
Gernet	5.4	3.7	4.6	3.4	3.4-5.7	4.28
Zircon	4.9	5.4	6.4	3.7	3.7-6.4	5.1
Tourmaline	3.6	4.2	1.7	2.8	1.7-4.2	3.08
Rutile	3.6	1.6	1.7	2.6	1.6-3.6	2.38
Staurolite	2.2	0.5	1.6	1.2	0.5-2.2	1.38
Kyanite	1.4	1.7	1.3	1.7	1.3-1.7	1.53
Others	0.6	1.1	0.3	0.6	0.3-1.1	0.65

Table 2: Mineral components in sandstone samples from the Dokan portion of the Gercus Formation (percentage, range, and average).

DOKAN SECTION						
Sample No	D5%	D12%	D13%	D15%	Range	Average
Opaques	45.3	37.3	43.2	37.1	37.1-45.3	40.73
Hematite	11.2	12.1	11.4	10.6	10.6-12.1	11.33
Chromian spinel	4.3	5.1	6.2	4.1	4.1-6.2	4.93
Chlorite	2.1	3.5	4.1	4.2	2.1-4.2	3.48
Orthopyroxene	2.3	2.3	2.4	2.3	2.3-2.4	2.33
CliniPyroxene	2.4	2.4	2.8	3.4	2.4-3.4	2.12
Hornblende	2.4	2.4	3.3	2.7	2.4-3.3	2.7
Glaucophane	1.2	1.2	1.1	1.5	1.1-1.5	1.25
Actinolite	2.4	2.4	1.6	1.8	1.6-2.4	2.05
Biotite	1.1	1.1	1.2	2.3	1.1-2.3	1.43
Muscovite	2.7	2.7	2.8	2.1	2.1-2.8	2.58
Clinozoisite	2.4	2.4	1.1	4.6	1.1-4.6	2.63
Zoisate	2.1	2.1	2.2	0.3	0.3-2.2	1.68
Gernet	4.4	5.7	5.7	4.5	4.4-5.7	5.08
Zircon	2.2	7.5	4.4	5.4	2.2-7.5	4.88
Tourmaline	1.4	4.4	1.4	3.5	1.4-4.4	2.68
Rutile	2.3	3.2	1.8	4.8	1.8-4.8	3.03
Staurolite	2.2	1.6	1.4	2.5	1.4-2.5	1.93
Kyanite	2.3	1.2	1.3	1.1	1.1-2.3	1.48
Others	0.6	0.3	0.6	1.2	0.3-1.2	0.68

ChIorite

Chlorite grains were found in the majority of the Shaqlawa and Dokan sandstone samples analyzed. Common fresh chlorite ranges in color from a strong bluish green to a green. The grains of chlorite are flaky, irregularly shaped, and have subrounded to rounded edges.Inclusions of opaque minerals (iron oxides) can be seen in chlorite grains. Chlorite percentages in Shaqlawa sandstone ranged from 2.4 to 4.5 percent, with an average of 3.6 percent. The amount of chlorite in Dokan sandstone ranged from 2.1 to 4.2 percent, with an average of 3.48 percent) (Figure- 2-F).

Orthopyroxene

Orthopyroxene is found in all of the Shaqlawa and Dokan sandstone samples analyzed. Typically colorless to light green in appearance, orthopyroxene granules exhibit a prismatic pattern. In Shaqlawa sandstone, the proportion ranged from 2.2 to 2.4 percent, with an average of 2.33 percent. The percentage varied from 2.3 to 2.4 percent in Dokan sandstone, with an average of 2.33 percent (Figure- 2-G).

Clinopyroxene

Clinopyroxene was found in all of the Shaqlawa and Dokan sandstone samples studied. Clinopyroxene grains were found to be prismatic, subhedral, and irregular in shape, with a high relief. They were either colorless or pale green or green. The proportion ranged from 1.7 to 5.1 percent in Shaqlawa sandstone, with an average of 3.35 percent). The amount ranged from 2.4 to 3.4 percent in Dokan sandstone, with an average of 2.12 percent (Figure- 2-H).

Hornblende

Hornblende can be detected in all Shaqlawa and Dokan sandstone samples. Its grains are mainly fresh green, tabular, prismatic, and cleaved, with some showing euhedral to subhedral alteration. Hornblende content in Shaqlawa sandstone ranges from 2.2 to 3.4 percent, with an average of 2.58 percent. The proportion ranges from 2.4 to 3.3 percent in Dokan sandstone, with an average of 2.7 percent (Figure- 2-I).

Glaucophane

Glaucophane is discovered in some Shaqlawa and Dokan sandstone samples. Pleochroic grains are normally fresh and range in hue from deep blue to violet.They have an asymmetrical subhedral form. The proportion in Shaqlawa sandstone ranged from 0.9 to 2.1 percent, with an average of 1.43 percent, whereas the percentage in Dokan sandstone ranged from 1.1 to 1.5 percent, with an average of 1.25 percent (Figure- 2-J).

Actinolite

Actinolite is found in all samples of shaqlawe and Dokan sandstone.It was found as colorless to pale green colored grains. Actinolite percentage in sandstone shaqlawe is ranging between (0.6-2.6%) with an average 1.78%. While the Dokan section has 1.6 -2.4 % with an average 2.05 %. (Figure- 2-K).

Biotite

Biotite was found in all of the shaqlawe and Dokan sandstone samples analyzed. A flaky type of biotite with an angular to irregular shape and reddish and brown pleochroic colors was found. Biotite content in Shaqlawa sandstone ranged from 1.1 to 2.9 percent, with an average of 1.65 percent. The amount ranged from 1.1 to 2.3 percent in Dokan sandstone, with an average of 1.43 percent (Figure-2-L).

Muscovite

Muscovite was found in all of the shaqlawe and Dokan sandstone samples analyzed. Muscovite is a flaky mineral with a subangular to irregular shape, is transparent and colorless, and has little relief. Muscovite percentages in shaqlawe sandstone varied from 1.4 to 3.4 percent, with an average of 2 percent. The amount ranged from 2.1 to 2.8 percent in Dokan sandstone, with an average of 2.58 percent (Figure- 2-M).

Clinozoisite

Clinozoisite was found in all of the shaqlawe and Dokan sandstone samples analyzed. Clinozoisite percentages in the Shaqlawe sandstone range from 1.3 to 4.8 percent, with an average of 2.58 percent, whereas the Dokan sandstone has a range of 1.1 to 4.6 percent, with an average of 2.63 percent (Figure2-N).

Zoisate

Zoisate was found in all of the shaqlawe and Dokan sandstone samples analyzed, Zoisate is colorless and usually occure shape rounded to subrounded, and crystallographic system orthorhombic.The percentage of zoisat in shaqlawe sandstone ranging between 1.2-1.5% with an average 1.35%, while the Dokan sandston 0.3-2.2%, with an average 1.68%,(Figure2-O).

Garnet

Garnet can be found in all of the shaqlawe and Dokan sandstone samples tested. Garnet was found in angular to subrounded high relief, usually in the form of fresh grains, colorless to light brown in tint and equant to subequant in shape. The proportion ranges from 3.4 to 5.7 percent in Shsqlawa sandstone, with an average of 4.28 percent). The percentage of garnet in Dokan sandstone ranges from 4.4 to 5.7 percent, with an average of 5.08 percent (Figure- 2-P).

Zircon

Zircon grains were found in all of the sandstone samples studied, including shaqlawe and Dokan. Prismatic zircon and euhedral to subhedral zircon grains were found, together with rounded and subrounded grains. Typically, zircon grain is transparent and white, and it has a high relief. In Shaqlawa sandstone, the proportion ranged from 3.7 to 6.4 percent, with an average of 5.1 percent. The amount ranged from 2.2 to 7.5 percent in Dokan sandstone, with an average of 4.88 percent (Figure- 2-Q).

Tourmaline

Tourmaline was found in all of the shaqlawe and Dokan sandstone samples analyzed. Honey-colored tourmaline grains with pleochroism and great relief. They are typically fresh and have a subrounded to rounded shape. Subhedral grains have been detected in few samples. Tourmaline content in Shaqlawa sandstone ranges from 1.7 to 4.2 percent, with an average of 3.08 percent. Its percentage ranges from 1.4 to 4.4 percent in Dokan sandstone, with an average of 2.68 percent (Figure- 2-R).

Rutile

Every sample of shaqlawe and Dokan sandstone contains rutile, which appears as elongated, subhedral, and irregular grains with a deep red color and noticeable relief. Rutile content in Shaqlawa sandstone ranges from 1.6 to 3.6 percent, with an average of 2.38 percent. The proportion ranges from 1.8 to 4.8 percent in Dokan sandstone, with an average of 3.03 percent (Figure- 2-S).

Staurolite

Staurolite is present in every sample of Dokan and Shaqlawe sandstone. High relief, pleochroism, a yellowish to golden tint, and a subhedral to subrounded morphology are all characteristics of saurolite grains. Staurolite content in Shaqlawa sandstone ranges from 0.5 to 2.2 percent, with an average of 1.38 percent. The proportion ranges from 1.4 to 2.5 percent in Dokan sandstone, with an average of 1.93 percent (Figure- 2-T).

Kaynite

All studied samples of shaqlawe and Dokan sandstone contain kyanite. Colorless, high relief, subhedral kyanite grains have an elongated or prismatic form. Kyanite content in Shaqlawa sandstone ranges from 1.3 to 1.7 percent, with an average of 1.53 percent. Its percentage ranges from 1.1 to 2.3 percent in Dokan sandstone, with an average of 1.48 percent (Figure- 2-U).

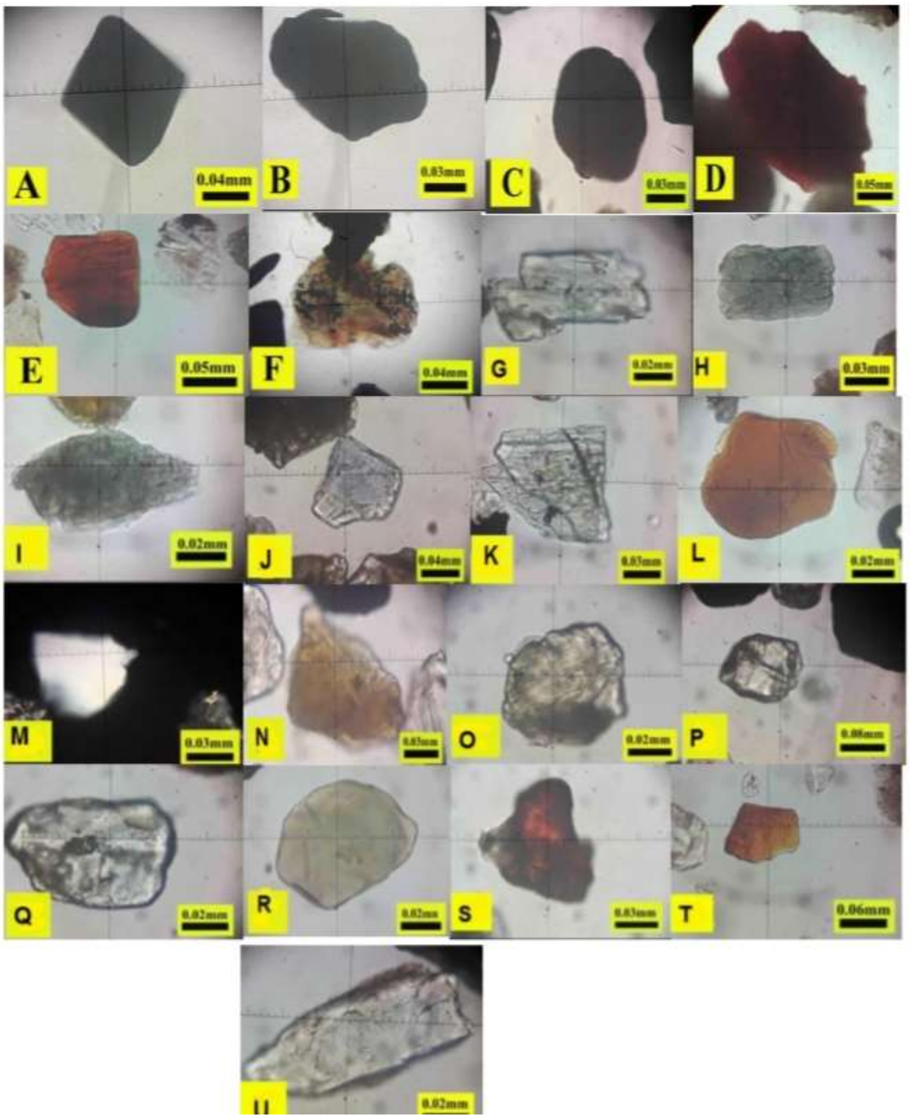

Figure 2: Photomicrograph of Shaqlawa and Dokan sandstone heavy minerals: A, B, C Opaque mineral ,D- Hematite ,E- Chromian spinel ,F- Chlorite ,G- Orthopyroxe ,H- Clinopyroxene , I- Hornblende ,J- Glaucophane ,K- Actinolite amphibole ,L- Biotite ,M- Muscovite ,N- Clinozoisate epidote ,O- Zoisate epidote ,P- Garnet ,Q- Zircon ,R- Tourmaline ,S- Rutile, T- Staurolite, U- Kyanite.

Heavy Mineral Stability

Heavy minerals are divided into groups based on their relative stability, and there are numerous classifications for them. Heavy minerals were categorized into four classes in a prior study [11]. Another study [12] proposed a ternary diagram for determining the stability of heavy mineral concentration, which considers unstable, moderately stable, and ultra-stable groups. The stability factor was applied to the sandstone of the Gercus Formations, and all samples were found to be reasonably stable (Figure -3,4).

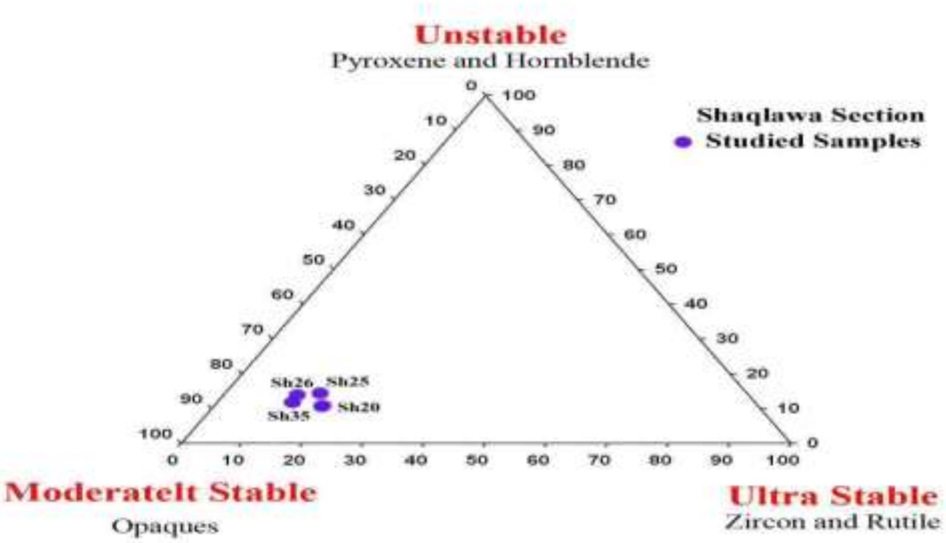

Figure 3: Ternary diagram of Shaqlawa sandstone heavy mineral stability after [12].

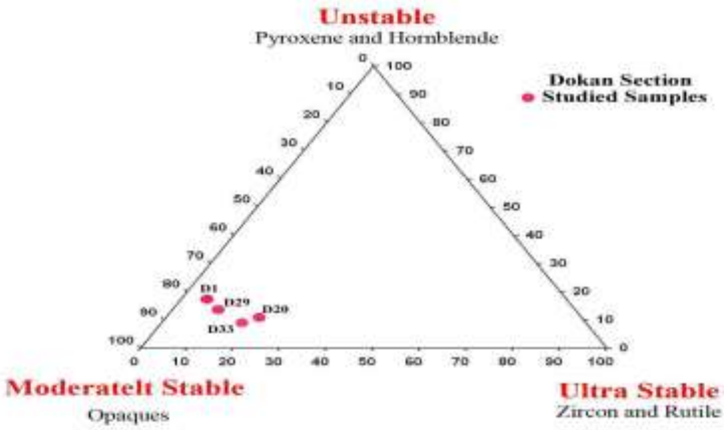

Figure 4: Ternary diagram showing heavy mineral stability in Dokan sandstone after [12].

Continental Margin Activity and Heavy Mineral Assemblage

For a long time, scientists have recognized that tectonics and sediment composition are linked [13] Nechoev and Isophroding [14] presented a plate tectonic analysis of heavy mineral data by contrasting the assemblage with potential sources of clastic material from various phases of the plate tectonic cycle. They created a triangular graphic (MF, GM, and MT) to show the link between plate tectonics and heavy mineral assemblages:

MF: Mafic magmatic rocks' common components

MT: fundamental metamorphic rocks' shared components

GM: Granite and sialic metamorphic rock accessory minerals.

The data for the MF, GM, and MT rocks were completely revised. When the investigated Gercus Formation samples were plotted on a ternary diagram, they were found to be all part of the active continental borders, which are identified by a high percentage of minerals originating from basic rocks (Figure -5,6). Two active continental edges produced these sandstones. Taurus and Zagros Mountains may represent these source rocks.

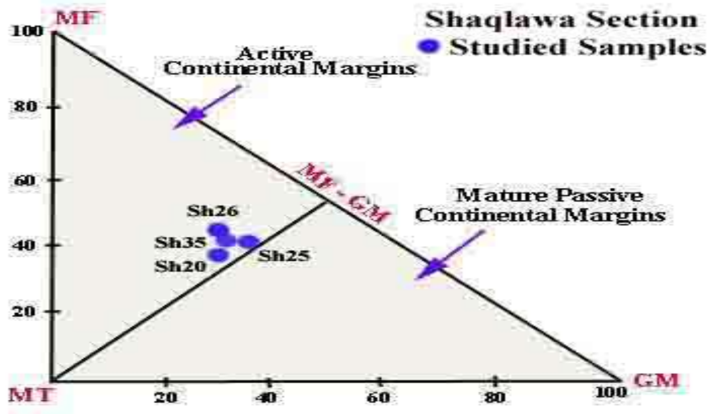

Figure 5: Interrelationship of the Shaqlawa sandstone's MF-MT-GM suites, following [14].

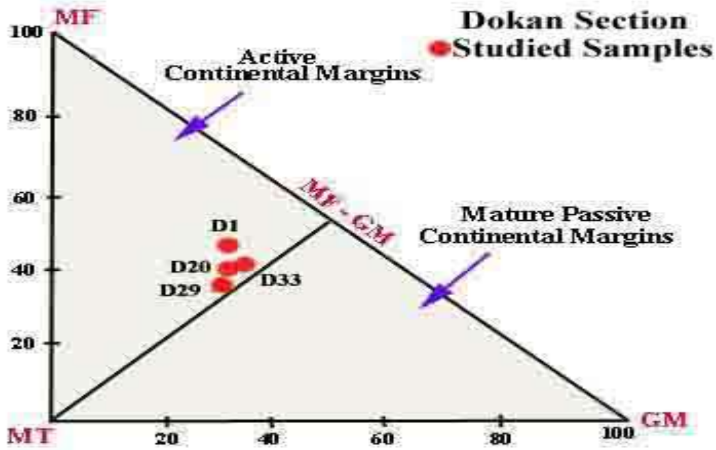

Figure 6: Interrelationship of the Dokan sandstone's MF-MT-GM suites, following [14].

Provenance from Heavy minerals

The origin and geological context of the source location are determined via heavy mineral analyses. The presence of opaques in mafic and metamorphic igneous and metamorphic rock, as well as acidic and reworked sedimentary rock, was observed in the current analysis. Pyroxene can be found in a wide range of igneous rocks [15].Glaucophene is a mineral that can be found in metamorphic rocks including schist and gneiss [7]. Both mafic and metamorphic rocks contain hornblende [16]. Epidote, garnet, chlorite, amphibole (tremolite-actinolte and glaucophane), kyanite, staurolite, and sillimanite all point to a metamorphic genesis [17]. Acidic igneous and metamorphic rocks produce biotite [18, 19]. In ultramafic igneous rocks, chroomian spinel is a common accessory mineral [20]. Zircon is found in both acid and intermediate igneous rocks, and its euhedral shape suggests that it is an acid igneous rock [17]. Rutile can be found in acidic igneous rock and metamorphosed argillaceous sediments of a high-grade schist [13]. Tourmaline is found in granitic pegmatites and acidic igneous sources [13]. Some opaques, zircon, and tourmaline have rounded to subrounded grains, indicating a reworked sedimentary provenance [21, 22]. The parent rocks of the Gercus Formations samples were found to be largely basic, ultrabasic, as well as altered sedimentary and acidic igneous rocks, and metamorphic rocks, according to heavy minerals analysis.

Conclusion

Different types of heavy minerals imply different types of parent rocks. In contrast to the other heavy minerals, which are believed to originate from sources such as acidic igneous, reworked sediments, mafic igneous, and metamorphic rocks, rutile is thought to come from mafic igneous and metamorphic sources. The opaques make up a high percentage of the heavy mineral collection. The presence of brittle heavy minerals indicates a near proximity to the source rock. The sandstone Gercus Formation's rich mineral composition and evidence of continental edge activity point to active continental margins. The stability factor was applied to the Gercus Formation sandstone and revealed that all samples are moderately stable. Basic, ultrabasic, as well as altered sedimentary and acidic igneous rocks, and metamorphic rocks , served as the source materials for the investigated samples, according to the results of heavy minerals analysis. Both of these sandstones come from active continental edges.

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