PETROLOGY, GEOCHEMISTRY AND TECTONICAL ENVIRONMENT OF THE SHALAIR METAMORPHIC ROCK GROUP AND KATAR RASH VOLCANIC GROUP, SHALAIR VALLY AREA, NORTHEASTERN IRAQ

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Abstract

The Shalair Metamorphic Rock Group (SMRG) is northern exposure of variety lithological units in Iraq, and forms part of the western margin of the active Iranian plate. The SMRG consists of metasedimentary sequences, whereas the Katar Rash Volcanic Group (KRVG) consists of basic to acidic metaigneous rocks. The petrological and geochemical studies showed that the SMRG is characterized by three lithological units, these are metapelite, metacarbonate, metaarenite, and KRVG is characterized by metaigneous series including metabasalt, metaandesite, and metarhyolitic dacite. All these rocks are regionally metamorphosed into low grade metamorphism of green schist facies – chlorite zone. Thermal conditions of metamorphism are suggested about 340±20° C at pressure conditions ranged between 2.5 – 3 Kb approximately. Data is not completely enough to interpret the tectonical environment, but the field aspects and geochemical evidences indicate that the SMRG were evolved under tectonic environment of island arc situation, so the (KRVG) are characterized by calc – alkaline nature.

الخلاصة

تعد مجموعة شلير المتحولة المكشف الشمالي الذي تتنوع فيه الوحدات الصخارية, ويكون جزءاً من الحافة الغربية للصفيحة الايرانية النشطة. تتكون هذه المجموعة من تتابعات رسوبية متحولة, بينما تتألف مجموعة كتاراش البركانية من صخور نارية متحولة تتراوح من الحامضية الى القاعدية.

بينت الدراستان الصخارية والجيوكيميائية بأن صخور مجموعة شلير المتحولة تتصف بثلاث وحدات صخارية هي الصخور المتحولة طينية الاصل, والصخور المتحولة جيرية الاصل, والصخور المتحولة رملية الاصل, فيما تتصف صخور مجموعة كتاراش البركانية بسلسلة من الصخور النارية المتحولة, تتضمن البازلت المتحول والانديسايت المتحول والداسايت الرايولايتي المتحول. ان جميع هذه الانواع الصخرية تحولت اقليمياً ضمن مدى التحول الواطئ من سحنة النضيد الاخضر – نطاق الكلورايت. تم تقدير الظروف الحرارية للتحول على انها 340 ±20 ْم تحت ظروف ضغطية تراوحت من 2.5 الى 3 كيلو بار تقريباً, رغم عدم كفاية المعلومات لتفسير البيئة التكتونية, لكن الدلائل الحقلية والشواهد الجيوكيميائية تدل على ان صخور مجموعة شلير المتحولة نشأت ضمن بيئة تكتونية تعود الى نظام الجزر القوسية. اما صخور مجموعة كتاراش البركانية فانها نشأت في بيئة الجزر الخلفية وهي ذات طبيعة قلوية كلسية.

Introduction

The metamorphic rocks in Iraq are confined to a narrow strip within the Thrust Fault Zone, The Shalair Valley area is part of this strip (Figure-1). The SMRG (Aptian – Cenomanian)) is the largest stratigraphic unit within the Thrust Fault Zone. Its thickness about 4500 m [1], and it is mostly sedimentary origin contains volcanogenic Kater Rash Group. In the Shalair Valley rocks were originally described by

DeVilliers [2] who divided these rocks into Penjween series and Shalair phyllite series. These series were later included into the Qandil Group [3]. Samirnov and Neldov [1] attributed these rocks to the Qandil group too, but Buday [4] described metamorphosed rock
of the Shalair valley and Penjween areas independently from the Qandil Group. KRVG was introducd by DeVilliers in 1975 [2]. Then due to the similar composition included into Walash Volcanic Group [3] and [1], but Buday [4] treated with them as KRVG and Walash Volcanic Group separately. Later, in the Shalair valley area, the Qandil Group and Walash volcanogenic named Shalair Metamorphic Rock Group (SMRG) and Kater Rash Volacanic Group (KRVG) respectively [4]. No authors have studied the metamorphism in the SMRG. Al-Rubaie [5] has mentioned the granitic intrusions on both limbs of Shalair anticline, and she suggested they are trondhjmetics differentiation of the ophiolite. Aswad and Elias [7] have studied the Mawat ophiolite complex which is located to the east of the SMRG. The geochemistry, mineral chemistry and petrogenesis presented by Aswad and Elias [7] showed the Mawat ophiolite complex as a mid oceanic ridge basalt, so they mentioned that the complex is characterized by low grade amphibolite facies, and they determined the age of metamorphism to be Alpian – Cenomanian.

General Geology

The terrain of the Shalair valley is generally rugged and highly thrusted fault have moved from northeast toward southeast along low angle thrust plane [8]. Ghalib [9] suggested that the overthrusting is due to tectonic compression in the later phases of folding. The Shalair Valley is an eroded asymmetrical large anticline with a general east – west trend, and gently plunging toward the east [1]. It extends about 30 km and with a width of more than 20 km. The value of the dip ranges from 30° to 70° for the southern limb and from 20° to 40° for the northern limb [1]. Within the major anticline there are many minor anticlines especially at the core where the plastic rocks of Qandil Formation are present. Those minor folds are higly stressed with intense fracturing and jointing [1]. In the core of the Shalair anticline the SMRG are exposed, whereas the KRVG is exposed at the limbs (Figure-1). The SMRG consists of phyllite, schist, slate, limestone and siltstone and it unconformably overlies by the KRVG which generally consists of massive volcanic rocks.

Stractural and Tectonic Setting

The Cretaceous and Tertiary orogenic phases are the two major orogenic phases within the Alpine Orogenic Belt in the North and Norheastern Iraq. In the foreland and quasiplatform basin (Figure-1), these two major orogenic phases are separated by angular unconformity marking the Cretaceous – Tertiary boundary [10]. In the subduction tectonical zone, the ophiolites and flysch deposits that belonging to the Cretaceous and Tertiary are thrown into two major thrusted sheets. The upper sheet are the Qulqula Group, Mawat Group and the khwakurk series, while the lower sheet are Naopurdan , Walash and Gimo-Qandil Groups (Tertiary) [10]. Three major episodes took place through the Cretaceous and Tertiary phases [11], these are:

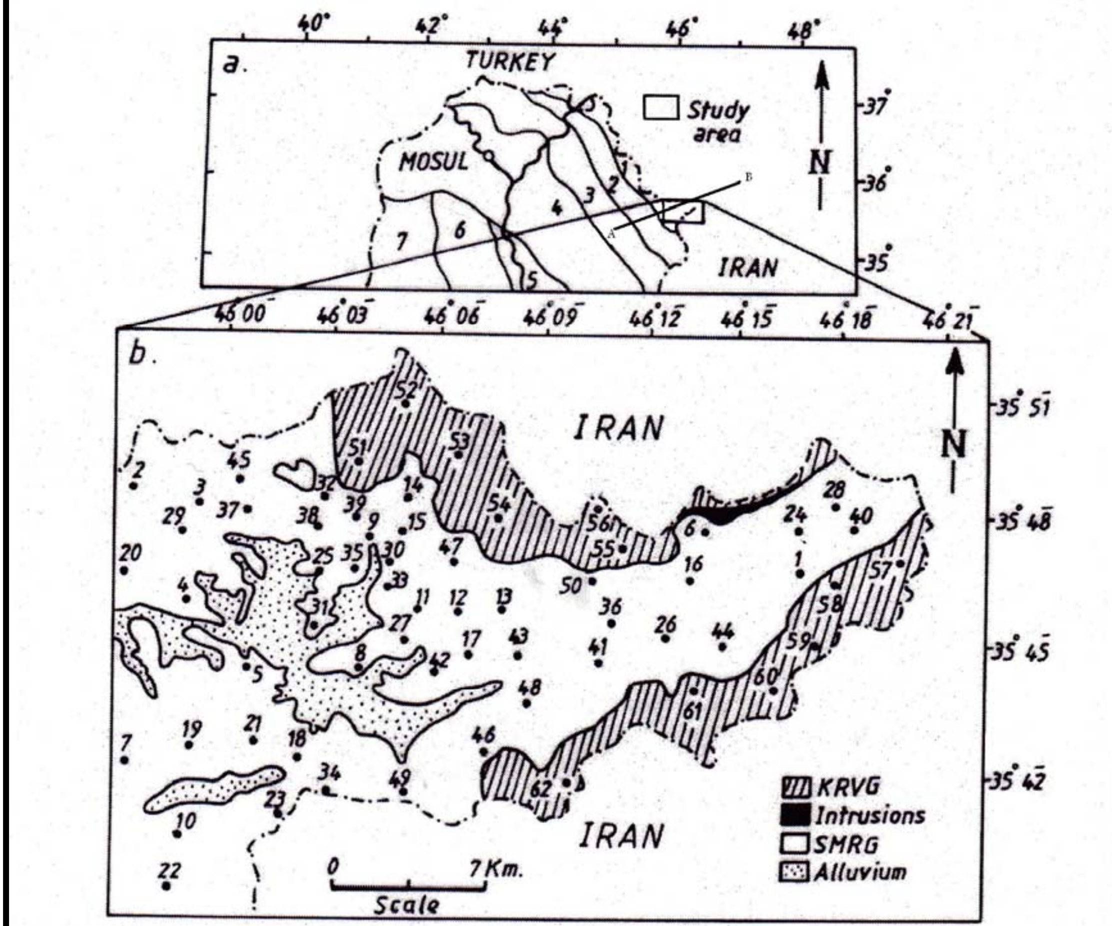
1- Late Jurassic- Early Cretaceous: The oceanic crust of the Neo Tythian subducted beneath the active margin of Iranian plate. The Nucleus of Shalair Metamorphic Rock Group formed from the continuing of the deposition processors in the oceanic floor.

2- Late Cretaceous: Because of the continuance subduction of the Arabian plate passive margin beneath the Iranian plate active margin, the oceanic crust has been faulted and some parts have locally moved upward forming the ophiolite that lies between the foreland basin and the subduction tectonic facies. The uplifted area is generally weathered forming submarine flysch. The actual witness of the uplifting is submarine facies in addition to the upper part of Qulqula conglomerate.

3- Paleocene – Miocene: In the Miocene the direct collision happened between the Arabian plate and the Iranian plate. This collision marks the final closure of the Tythian Sea in northeastern Iraq. The Shalair Metamorphic Rock Group and Katar Rash Group have been thrown overriding the Mawat complex ophiolite as a result of that collision.

Petrology

Rock - forming minerals and their textures interpret the origin of the metamorphic rocks and show where those rocks are derived. On this basis and according to their origin, in the Shalair valley area four major types of rocks can clearly be distinguished as:



1 = Subdictional tectonic facies of the Zagros Thrust (Qulqula group).
2 = Zone of imbrication of the foreland basin.
3 = High folded zone of the foreland basin.
2+3= Foreland basin.
4 = Suspended basins, Foothill zone of the quasiplatform foreland.
5 = Sagged basins of the Mesopotamian zone of the quasiplatform.
4+5= Quasiplatform foreland.
2+3+4+5= Foreland belt of the Arabian plate.
6 = Salman zone
7 = Rutba – Jezera zone.
6+7= Stable platform deposition.
• = Location of sample.
A-B= Cross section drown in the figure -9. and 10.

Figure (1): a) Major tectonic divisions in Iraq (after 3, 6 and 10).
b) Geological map of the Shalair valley area shows samples locations.

1- Metapelites: These rocks are slate and phyllite as derivative of aluminous sedimentary rocks like shale and mudstone. Because of their high alumina content, they are characterized by abundance of micaceous minerals like sericite, muscovite and chlorite. Mineralogically slates appear to be as same as phyllites, but the texture of phyllites is more schistose and has clossy sheen as consequence of coarse grains of that platy minerals. Obviously, the direct pressure causes development of the foliation where mineral grains are well arranged into alignment and layres. Illite and kaolinite are coexistent with equant fine grains of quartz. The groundmass of kaolinite contains a little quantity of fine grain of potash feldspar and muscovite that may coincide with the following reaction:

$$\underset{\text{(kaolinite)}}{Al_2Si_2O_5(OH)_4} + \underset{\text{(K-feldspar)}}{KAlSi_3O_8} \rightarrow \underset{\text{(muscovite)}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\text{(quartz)}}{2SiO_2} + \underset{\text{(water)}}{H_2O}$$

This reaction indicates low grade metamorphism [12]. Schistose cleavages in the phyllites are developed to the strain slip cleavage forming S_1 surface which seem to be semi perpendicular to the original schistose S_0 surface (Fiqure-2).

2-Metacarbonates: These rocks are divided according to their purity into two groups:

A) Marble: They essentially consist of recrystallized calcite that exhibits deformed lamellae twining, and commonly with two sets of not perpendicular cleavages. Some of calcite grains contain fine grains of quartz showing a thermodynamic equilibrium state. Beside calcite grains, dolomite also appeared but in little quantity. In addition to marbles some limestones have not highly metamorphosed and the sedimentary texture still kept pronounced, therefore named metamorphosed limestone.

B) Calc schist: These rocks are calcium - rich essentially derivative of limestone and dolostone. Calcite seems to be anequant subidioblastic grains characterized by helicitic texture. Dolomite grains display parallel extinction of the short diameter. Mostly quartz grains have angular edges and some of the fractured grains tend to display undulose extinction (Fiqure-3). Other quartz tends to have rounded grains displaying undulatory extinction. Micacouse minerals such as chlorite, muscovite and sericite also being exist as well as calcite and dolomite. Despite of that these rocks are simply characterized by distinct foliation, they have undergone slight metamorphism and the original sedimentary texture is still observed.

3- Metaarenites: These rocks are originally contained mostly quartz that is stable over a wide range of temperature. Two types of quartz are distinguished, the first is of sedimentary origin quartz and the second one is volcanogenic which is characterized by the hypidomorphic texture. Metaarenitic rocke include quartzite and greywacke, In the quartzite the mosaic interlocking texture due to the recrystallization and growth the quartz grains are the dominant texture, but graywake (impure quartzite) generally are characterized by blastoarenitic texture which is a suboriented mosaic texture. The impurity of quartzite comes from cement materials represented by micaceouse minerals (phingite, sericite and chlorite) yielded from the metamorphism of clay [13]. graywake composed of elongated subidoblastic grains of quartz, fine grained siricite and secondary chlorite. The sericite and chlorite occur as flaky grains. Quartz grains in graywake form a porpheroblasts scattered in the groundmass of sericite and secondry chlorite. In addition, they also contain a little quantities of feldspar, hematite , magnetite and ilmenite. Generally those constitutes are semi arranged into parallel alignment as response to pressure.

4-Metaigneous rocks: According their geochemistry and mineral composition, these rocks are metabasalt, metaandesite and metarhyolitic dacite. Metabasalt appears to have limited occurrance on the two limbs of the anticline. Plagioclase and pyroxene altered to the chlorite sericite, epidote and iron oxide. The metaandesite rocks occur as large thick sheets of lava associated with pyroclastic rocks. Despite of the appearance the schistosic texture in these rocks, the porphyric texture is still kept and characterized by large grains of albite. Most of the major minerals that composed the metarhyolotic dacite rocks have been altered to the chlorite, sericite, muscovite forming clearly schistosic texture with s-shape due to the porphyroblast of oligoclase. These rocks are resulteded from acidic magma differentiation forming a small flow on two limbs of the anticline. The metapelites, metacarbonates, metaarenites are belong to SMRG, whereas the metaigneouse rocks are belong to KRVG.

Geochemistry of the Metasedimentry Rocks

The geochemical analyses results (Table-1) are graphically plotted on the ACF diagram (Figure-4) according to their end members. The slate and phyllite samples are plotted along AF line, and they are more adjacent to the A vertex (Figure-4a and b). This case indicates that they are of pelitic origin [14]. Calcareous rocks distributed into three groups. The first group represents marble and the second group is metamorphosed limestone. Both of these groups plotted near the C vertex (Figure-4c) due to their high content of calcite. The chemical composition of the second group has not highly different from the marble, but the essential differences appearing in their texture show that the second group is a metamorphosed limestone, therefore they are distributed closer the C component too. The third group of calcareous origin is the calc schist rocks that are distributed from C component toward AF line (Fiqure-4d). This reflects associated of micaceous mineral beside calcite. The arenitic origin rocks such as quartzite and graywacke are represented by Fiqure-4e and f, Quartzites occupies the middle of triangle (Fiqure-4e), while the graywackes tend to extend near AF side line (Fiqure- 4f).

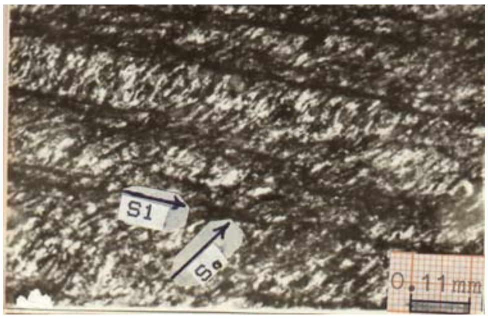


Figure (2): S_0-S_1 surfaces in phyllites.

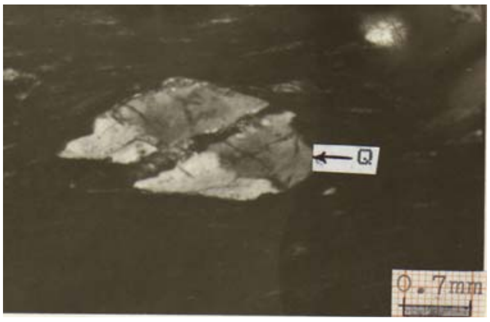


Figure (3): angular grain of qrtaz displays undulose extinction in the calc schist.

Geochemistry of the Metaigneous Rocks

In addition to petrological aspects, the geochemistry shows that the KRVG consists of basic volcanic to acidic volcanic series represented by basalt, andesite and rhyolitic dacite (Figure-5). Major groups are defined by Pearce and Cann [15]. These are oceanic floor basalts (divergent plate margins), volcanic arc basalts (converging plate margins), oceanic island basalts (within plate-oceanic crust) and continental basalts (within plate – continental crust) (Figure-6).

According to the classification above The KVRG considered as calc alkaline basalt of volcanic arc formed in the western edge of Iranian plate margin (Figure- 6 and 9). The alkali oxides (Na_2O and K_2O) versus silica diagram (Figure-7) exhibits that KRVG is occupied the calc alkalic and tholeitic field, therefore the AFM diagramhs been designed by Irvin and Bargar [16] is useful to use for discreminating between them as in Figure-8 that shows samples distribution within the calc alkaline field.

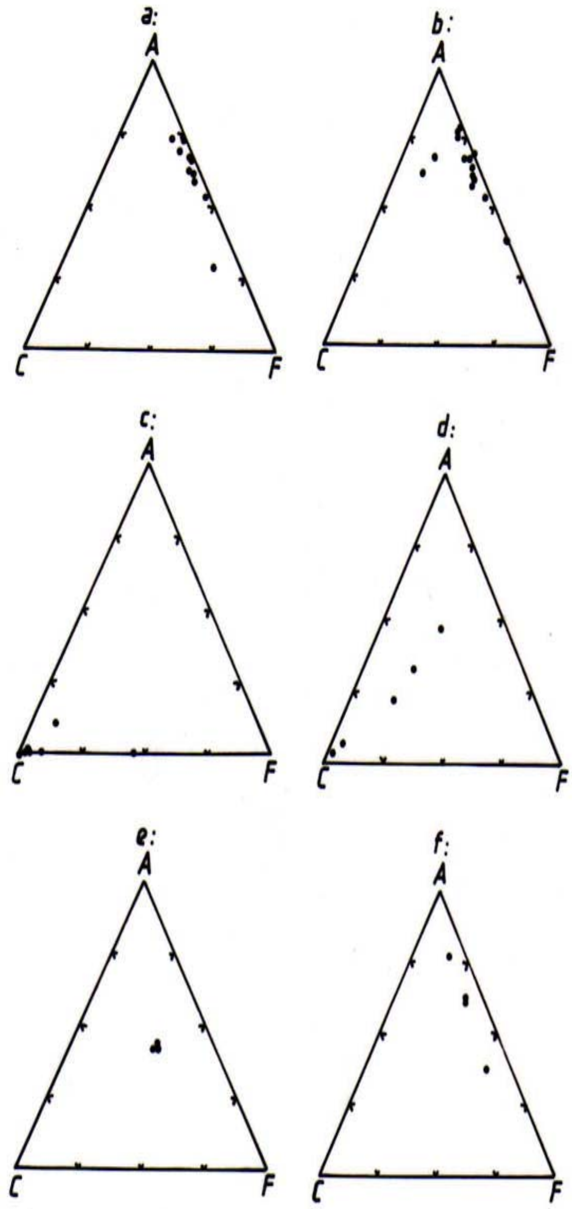


Figure (4): ACF diagram shows the origin of the metasedimentary rocks. The a and b are the metapelitic rocks, whereas a is the slate and b is phyllite, c and d are the calcareous origin, whereas c is marble and metamorphosed limestone, d exhibits calc schist. c and d represent the arenitic origin, whereas e exhibits quartzite, the d shows the greywacke location.

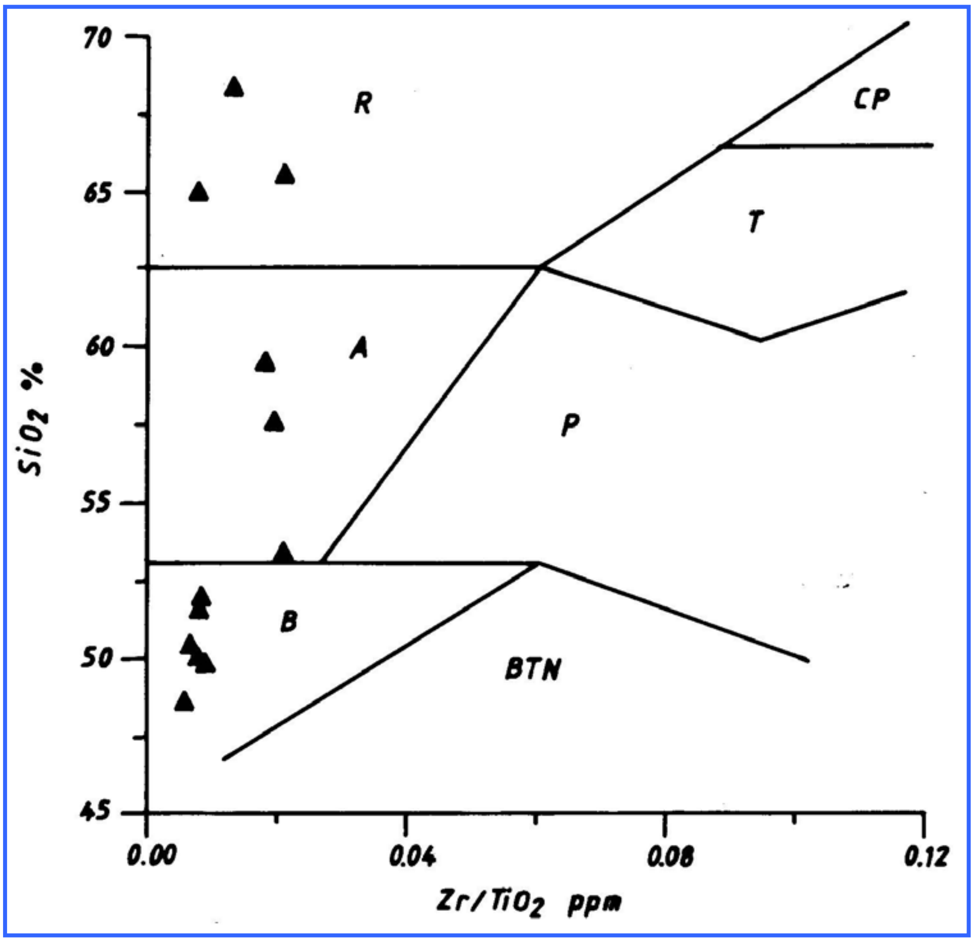


Figure (5): chemical classification of the igneous rocks (after Hughes,1982). B=basalt, A=andesite, R=rhyoliticandesite, BTN=basanite, trachybasanite, nephilinite, p=phonolite, T= trachyte, CP=comendite, pantelierite.

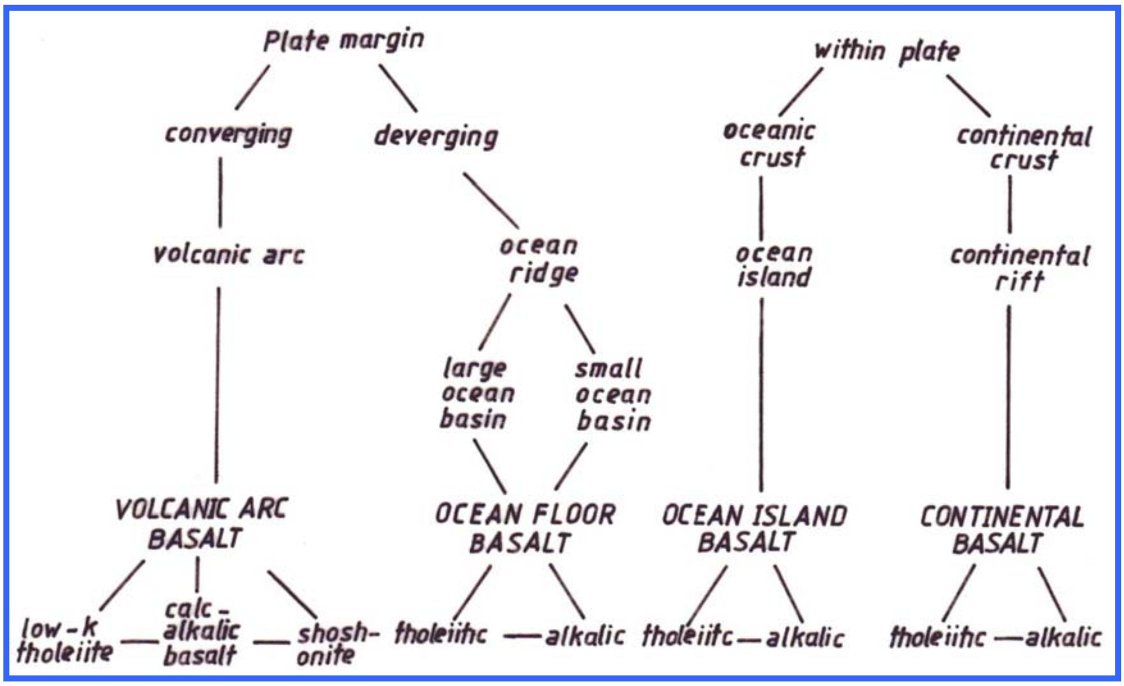


Figure (6): classification scheme for basic volcanic rocks based on tectonic setting (after Pearce and Cann, 1973).

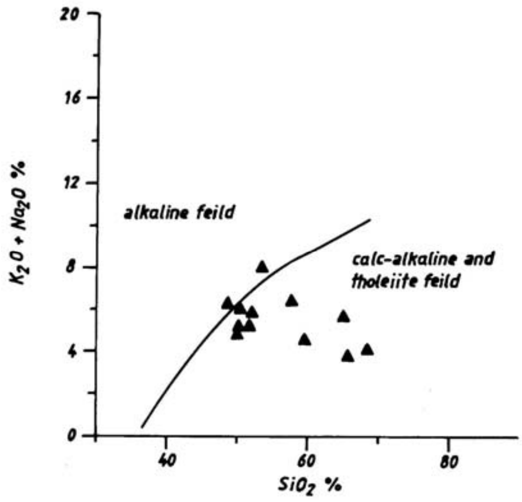


Figure (7): The relationship between silica and alkalis shows calc- alkalic and tholeiitic nature of KRVG.

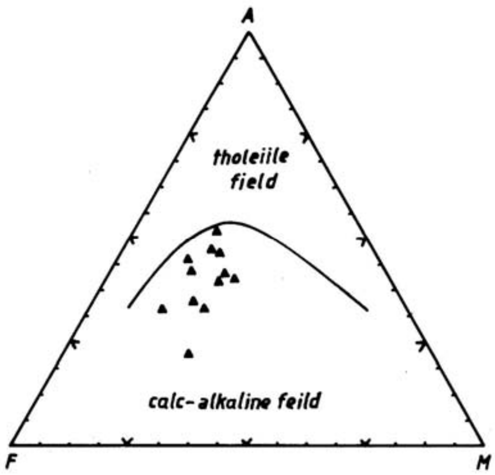


Figure (8): AFM diagram shows the calc-alkalic nature of KRVG.

Discussion and Conclusion

The appearance of new minerals and disappearance of others marks the boundary of the metamorphic facies [17]. The lower limit of metamorphism is marked by the mineral assemblages (muscovite- orthoclase- kaolinite- quartz) in phyllite. These mineral assemblages may probably indicates that the following reaction is to be expected:

$$\underset{\text{(Kaolinite)}}{Al_2Si_2O_5(OH)_4} + \underset{\text{(K-feldspar)}}{KAlSi_3O_8} \longrightarrow \underset{\text{(muscovite)}}{KAl_3Si_3O_{10}(OH)_2} + \underset{\text{(quartz)}}{2SiO_2} + \underset{\text{(water)}}{H_2O}$$

Hans [12] and Winkler [13] deduced that this reaction happens at about 320°C and 2.5kb .Such paragenesis is restrictive to the low grade metamorphism. In the calc schist the coexistence of epidote with calcite and kaolinite leads to suggest the following reaction:

Calcite + kaolinite $\longrightarrow$ epidote + water + CO_2

The equilibrium data of such reaction have been determined Winkler [12] and considered as 340±20°C at 2.5 - 3 kb.

The mineral assemblage of muscovite, chlorite and quartz in phyllite leads to estimate that the temperature did not exceed 410°C at 3kb.Winkler [13] has mentioned such paragenesis under same physical conditions and he also pointed out to the appearance of garnet. All studied samples devoid garnet despite existence of the parent materials.

Winkler [13] also discussed formation of pyrophyllite by reaction of kaolinite with quartz at 360°C and 3kb. In the pilitic rocks, the disappearance of pyrophyllite in spite of association the kaolinite and quartz marked the upper limit of the metamorphic facies that does not exceed 360°C at 3kb. However the metamorphic conditions are characterized by green schist facies – chlorite zone that were regionally metamorphosed under 340° C + 20 °C at approximately 2.3 to 3 kb. All studied samples have not affected by contact metamorphism. The accumulative graywacke, mixture of quartzite with graywacke and redeposited volcanites that come from the adjacent areas like Penjaween and KRVG indicate that the SMRG deposited in high tectonic environment. The angular grains of the volcanogenic quartz that occurred in all type of rocks are marked and supported nearness to the supplying source, and also indicate to the close association between metamorphism and the tectonical events. KRVG are formed by fractional melting processes of the subducted oceanic crust. The AFM diagram (Figure-8) exhibits the calc alkaline nature of the igneous rocks that deposited in the back island arc (Figure-9). The Arabian plate eventually got dragged down along with the subduction oceanic crust, and as they got dragged down they undergone metamorphim. SMRG controlled by the length of subduction plate boundary and the rate of plate motion. The melted materials in the zone of fractional melting are ascended upward forming KRVG in the back arc due to the convection cell that was formed eastward of subduction zone within the active margin of the Iranian plate (Figure-9). KVRG produced due to the subduction. When the subduction happened, the molten materials generated. This magma has a different composition from the material they derived from because of the assimilation processes. This case leads to generation many types of rock like basalt andesite and rhyolitic dacite. The existing of these volcanic series indicates the oceanic crust and Arabian plate are subducted beneath the Iranian plate along a distance that may range from at least 100 to 300 km. Closing of Tythian Sea in Northeastern Iraq in Miocene is result of the direct collision between Arabian plate and Iranian plate. After this collision SMRG and KVRG have been thrown overridden ophiolite and still developed until Recent (Figure-10).

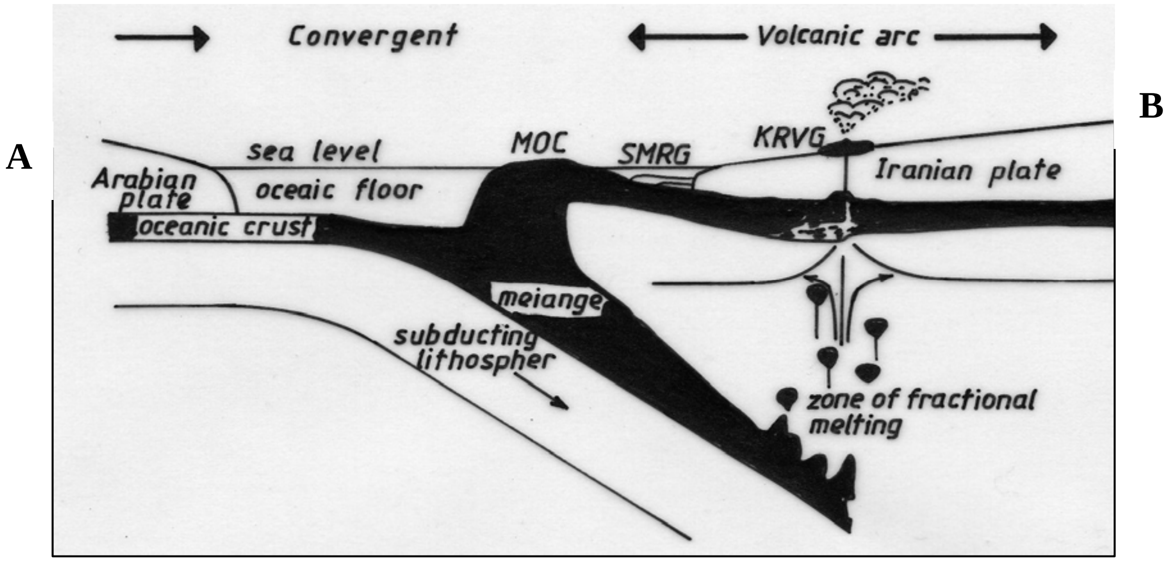


Figure (9): Plate tectonic scheme of the Arabian and Iranian plates during Upper Cretaceous.

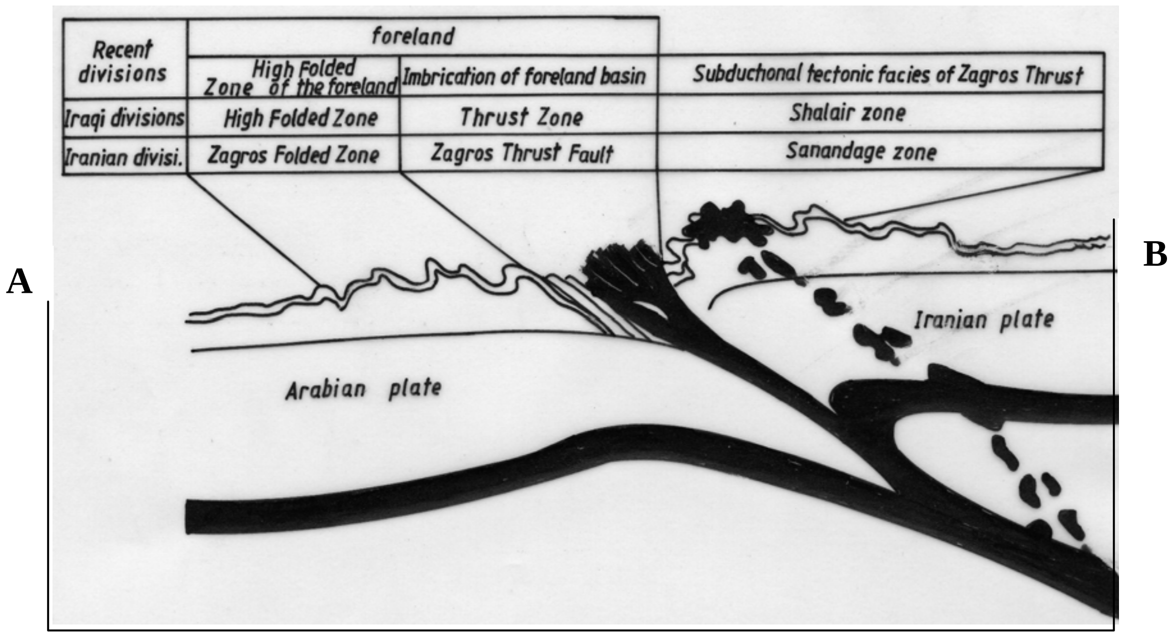


Figure (10): Collision between the Arabian and Iranian plates (Paleocene to Recent).

sample no.	rock type	rock origin	Oxides%			
			Al_2O_3	CaO	MgO	FeO
1	slate	pelitic	17.65	0.95	1.56	3.85
2	slate	pelitic	23.21	0.28	1.71	2.71
3	slate	pelitic	18.41	0.62	1.11	30.0
4	slate	pelitic	18.50	3.80	9.82	8.85
5	slate	pelitic	21.50	0.32	1.97	3.85
6	slate	pelitic	21.30	0.90	1.39	5.70
7	slate	pelitic	25.50	0.56	0.97	13.0
8	slate	pelitic	19.38	0.84	1.65	1.15
9	slate	pelitic	20.50	0.84	1.47	5.10
10	slate	pelitic	18.90	0.28	1.53	3.45
11	slate	pelitic	17.39	0.64	1.68	4.90
12	phyllite	pelitic	22.26	0.54	1.45	6.25
13	phyllite	pelitic	19.82	0.46	1.45	0.90
14	phyllite	pelitic	20.77	0.36	1.53	6.20
15	phyllite	pelitic	21.05	0.53	1.54	3.70
16	phyllite	pelitic	20.30	0.62	1.32	1.46
17	phyllite	pelitic	20.30	0.84	1.32	3.40
18	phyllite	pelitic	19.16	0.16	1.03	0.67
19	phyllite	pelitic	23.21	0.46	0.61	1.45
20	phyllite	pelitic	21.70	0.54	1.77	4.10
21	phyllite	pelitic	20.60	0.87	1.62	5.15
22	phyllite	pelitic	20.67	0.61	1.41	4.85
23	phyllite	pelitic	20.10	0.73	1.29	6.00
24	phyllite	pelitic	17.84	1.12	1.36	5.40
25	phyllite	pelitic	20.00	0.56	4.10	4.00
26	phyllite	pelitic	18.24	0.03	1.75	2.55
27	marble	calcerous	0.16	53.0	0.67	0.10
28	marble	calcerous	0.24	50.0	1.03	0.24
29	marble	calcerous	0.09	51.5	3.63	0.02
30	marble	calcerous	0.24	51.3	0.83	1.00
31	m.l.st	calcerous	0.34	52.8	1.25	0.66
32	m.l.st	calcerous	0.04	35.3	18.1	0.13
33	m.l.st	calcerous	1.70	49.3	0.62	0.60
34	m.l.st	calcerous	0.34	51.9	0.84	0.20
35	m.l.st	calcerous	0.16	52.5	0.70	0.20
36	m.l.st	calcerous	0.12	32.2	18.7	0.20
37	m.l.st	calcerous	0.10	31.1	20.7	0.05
38	m.l.st	calcerous	7.10	30.5	1.57	1.60
39	calc schist	calcerous	9.72	14.0	1.50	2.85
40	calc schist	calcerous	15.1	4.90	1.24	3.55
41	calc schist	calcerous	14.6	10.9	2.10	2.74
42	calc schist	calcerous	5.48	36.1	0.75	1.10
43	calc schist	calcerous	3.12	42.73	0.45	0.50
44	quartzite	arenitic	1.11	0.33	0.27	0.15
45	quartzite	arenitic	1.26	0.31	0.26	0.16
46	quartzite	arenitic	1.18	0.30	0.31	0.17
47	graywacke	arenitic	4.00	0.40	0.60	0.41
48	graywacke	arenitic	4.10	0.40	0.61	0.40
49	graywacke	arenitic	4.60	0.35	0.06	0.31
50	graywacke	arenitic	4.80	0.39	0.68	0.40

Table (1): Geochemical results of the metasedimentary rocks.

Table (2): Geochemical results of the metaigneous rocks.

Sample no.	**Rock type**	**rock origin**	**Oxides%**									**Zr ppm**
			SiO_2	**Al_2O_3**	**CaO**	**MgO**	**FeO**	**Fe_2O_3**	**K_2O**	**Na_2O**	**TiO_2**	
51	metabasalt	volcanic	48.5	19.02	7.28	3.77	6.3	1.7	1.3	4.9	1.00	57
52	Metabasalt	volcanic	50.3	21.0	4.10	2.73	3.4	1.8	1.0	6.0	0.90	60
62	metabasalt	volcanic	51.9	18.2	2.42	7.00	7.1	7.1	1.3	4.5	0.82	69
57	metabasalt	volcanic	50.0	19.5	3.50	2.33	2.2	1.6	1.1	4.1	0.75	60
55	metabasalt	volcanic	51.5	18.9	6.40	3.10	3.1	1.3	1.9	3.3	0.80	65
65	metabasalt	Volcanic	49.8	20.4	6.33	3.20	3.0	0.9	1.8	3.0	0.81	80
58	metaandesite	volcanic	53.4	19.8	1.7	3.26	6.1	1.9	1.2	6.8	1.12	238
59	metaandesite	volcanic	57.5	18.1	2.3	3.54	4.3	2.0	4.1	6.4	1.10	225
53	metaandesite	volcanic	59.4	17.0	6.73	2.32	1.6	4.6	2.1	2.4	1.12	205
54	metarhyoliticdacite	volcanic	62.8	17.6	4.12	2.50	0.9	3.2	2.0	2.1	0.61	80
60	metarhyoliticdacite	volcanic	64.9	14.5	2.8	1.84	0.7	4.76	2.7	2.9	0.75	57
61	metarhyoliticdacite	volcanic	65.5	14.2	3.7	1.81	3.0	2.0	2.7	1.1	0.45	95

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