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Geochemistry and Provenance of Sandstone Unit in Tanjero Formation in Sulimania Area, NE-Iraq.

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Abstract

Sandstone rocks occurring in the Tanjero Formation in the Sulimania and Pera-Magron areas, which crops out within the Imbricated and High Folded Zones in Northeastern Iraq, are lithic arenites with high proportions of sedimentary rock fragments. The presence of quartz, chert, carbonates and igneous and metamorphic lithic grains and fossils in the Tanjero sandstone clastic rocks indicates that the southern Neotethys Ocean was a shallow seaway during their deposition. Geochemical classification of the an Upper Cretaceous Tanjero sandstone clastic rocks are lithic arenites to Fe-Sand and indicates that they were mainly derived from Albian-Cenomanian Gimo–Qandil sequence ophiolite-bearing terrane and Hemipelagic sediments (Parautochthonous Qulqula rocks).

Keywords: Geochemistry, Provenance, Tanjero, High folded zone, Iraq.

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جيوكيميائية و مصدرية الطبقة الرملية في تكوين تانجيرو في منطقة السليمانية, شمال العراق

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الملخص

ينكشف تكوين تانجيرو ذات العمر الكريتاسي الاعلى في نطاق الطيات المتراكبة ونطاق الطيات العالية، وهو من النوع الليثيك ارينايت مع تواجد نسب عالية من القطع الصخرية الرسوبية. تواجد الكوارتز والجيرت والقطع الصخرية النارية والمتحولة والمتحجرات في الصخور الرملية تكوين تانجبرو يدل على ان بحر النيوتيثز (Neotethys) كان ضحل اثناء عمليات الترسيب. دل التصنيف الجيوكيميائي للصخور الرملية في تكوين تانجيرو ذات العمر الكريتاسي الاعلى انها من النوع اليث ارينايت للصخور الرملية في منطقة السليمانية وليث ارينايت الى الصخور الرملية الغنية بالحديد لصخور الرملية لمنطقة بيرمكرون وان الصخور الرملية لتكوين تانجيرو في منطقتي الدراسة الحالية مشتقة بشكل رئيسي من الصخور العائدة لمعقدات الاوفيولايت والصخور الرسوبية العائدة لسلسلة قولقولة.

الكلمات الدالة: الجيوكيميائية، المصدرية، تانجيرو، نطاق الطيات العالية، العراق.

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1. Introduction:

Tanjero Formation is an Upper Cretaceous unit, which crops out within the Imbricated and High Folded Zones in Northeastern Iraq [1]. It extends as narrow northwest-southeast belt near and parallel to the Iraqi- Iranian border Fig. 1. The formation mainly consists of alternation of clastic rocks of sandstone, marl and calcareous shale with occurrence of thick conglomerate and limestone [2,3] is divided the formation into three parts (lower, middle and upper parts) depend on main lithological distribution, sedimentary structures, lithology, and environment of the formation. The upper part is mainly consisting of 50-200 m thick mixed carbonate-siliciclastic successions. While, the middle part is composed of 100-300 m of bluish white marl and marly limestone on the slope and basin plain whereas it changes to calcareous shale on the shelf and to 20-50 m thick of red clay stone inside incised valleys at the area of coastal area. The lower part is generally composed, on the lower slope and basin, of thick aggradation of sandstone (100-400 m), whereas on the shelf it is dominated by 500m thick succession of conglomerate [4]. The purpose of this paper is to assess the source and depositional setting of the sandstone unit in the Tanjero Formation, based on their petrology, and geochemistr

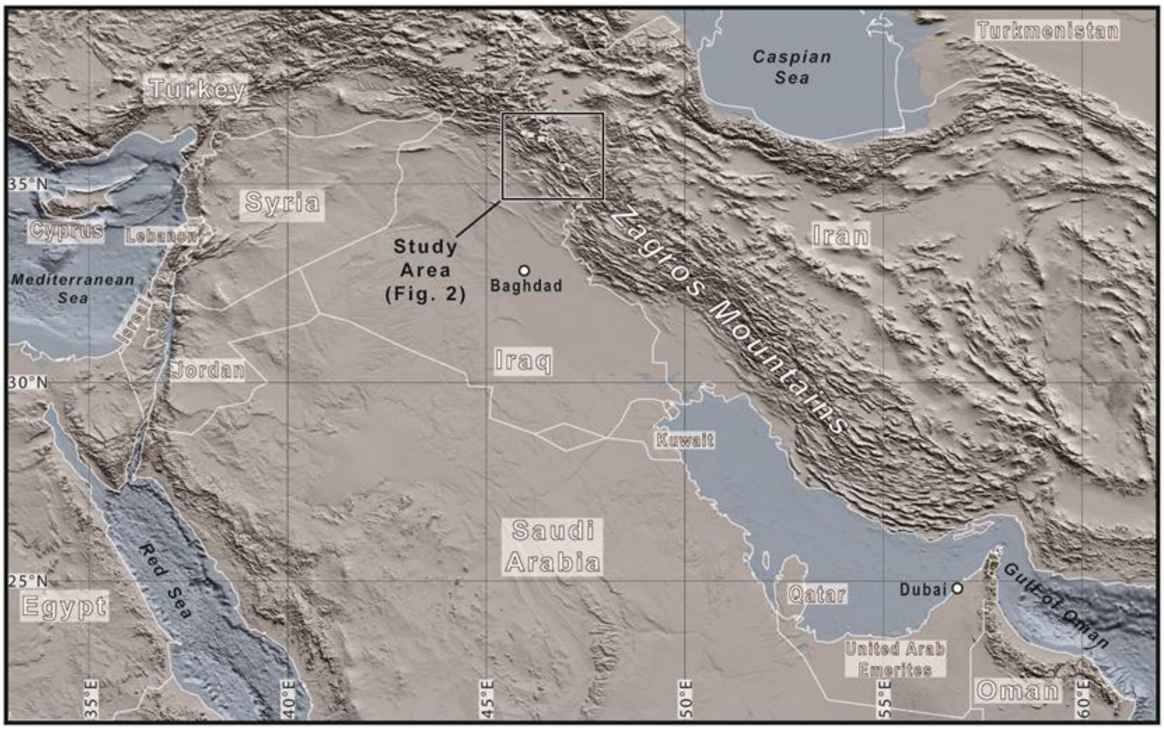

Fig. 1: Location of the study areas within the Zagros Suture Zone [5].

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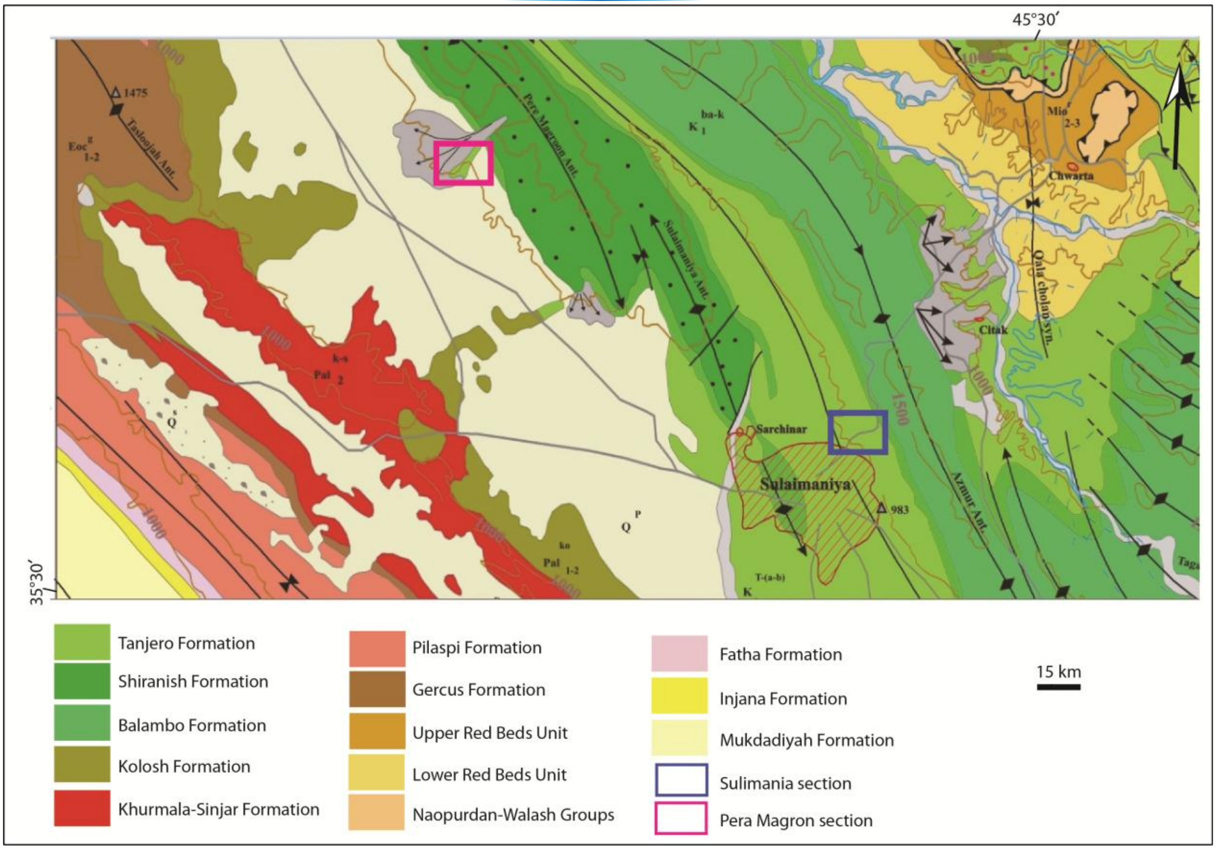

Fig. 2: Geological map of study area modified from [6].

2. Geological Background:

The study area is located in the north and northeast part of the Sulimania city of Iraq. Two representative sections were sampled, the first one occurs between longitudes 45° 27′ 11.3″E and latitudes 35° 35′ 26.2″ N while the second section is located between longitudes 45° 14′ 0.4″ E and latitudes 35° 43′ 55.17″ N Fig.2. The Tanjero Formation is one of the formations that were deposited in Mesopotamian Foreland Basin in the western Zagros Belt, in Kurdistan region of northeast Iraq, near the Iraqi-Iranian border Fig. 1. The Zagros Orogen consists of rugged mountains with an irregular steep dendritic drainage pattern superimposed on a structurally complex area are dominated by folding and thrusting [1]. The Zagros Orogen can be subdivided into four subparallel tectonic zones: the Ueumich-Dokhtar Magmatic Arc, the Sanandaj-Sirjan Zone. The Zagros Fold and Thrust Belt and the Mesopotamian Foreland Basin [7, 8, 9]. The study area forms part of the Mesopotamian Foreland Basin, which developed as a response to the ongoing collision between the Arabian and Iranian plates with the consumption of Neotethys [5, 10, 11].

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3. Analytical Methods:

Extensive fieldwork and associated structural investigations have determined the occurrence and spatial distribution of sandstone rocks in the Tanjero Formation Fig.2. Sandstone samples were studied under a standard petrographic microscope at Applied Geology department at Kirkuk University. Modal analysis was performed by point-counting 300–350 points in each sample for thin sections from sandstone unit of Tanjero Formation Tables 1 and 2. Major and trace (including Rare Earth) elements of the sandstone rocks of Tanjero Formation were analyzed using ICP-ES and ICP-MS at ACME Analytical Laboratories Ltd, Canada, following fusion with lithium metaborate/tetraborate and digestion by nitric acid Major element analysis of the studied rocks were performed at ACME lab (Canada). Total volatile contents or "Loss on Ignition" (LOI) was determinate in Acme laboratory.

4. Results:

A study of clastic rocks through petrography and heavy mineral analysis can provide palaeo environmental analysis and sandstone provenance [12].

4.1 Sandstone petrography:

The sandstones of Tanjero Formation vary from fine to coarse grained. Coarse-grained sandstones from Sulimania section are moderately sorted, while fine-grained sandstones from Pera-Magron section are poorly sorted. Grains are mostly sub rounded and range from sub-angular to well rounded. The average quartz content is 17.4% in the Pera-Magron samples and 13% in the Sulimania samples Table 1, Fig. 3 a and d. Feldspar content in the Sulimania samples (average of 4%) is similar to Pera-Magron samples (average of 3.9%) that are mostly plagioclase Table 1 most of feldspars have a slightly dusty appearance due to partial alteration to clay minerals Fig. 3c. Rock fragments are the most abundant constituents (average 62% in Sulimania samples and 57.3% in Pera-Magron samples; Table 2). The high content chert in both sections may be from radiolarian chert in the Cretaceous Qulqula series Fig. 3 a and b.

The matrix mostly consists of carbonate and is generally greater in the Pera-Magron samples than Sulimania samples. Cement content is commonly chert in Sulimania samples while most of Pera-Magron samples are cemented by iron oxides Table 1 and 2, Fig. 3d). According to [13] classification both the Sulimania and Pera-Magron samples are lithic arenites Fig. 4a.

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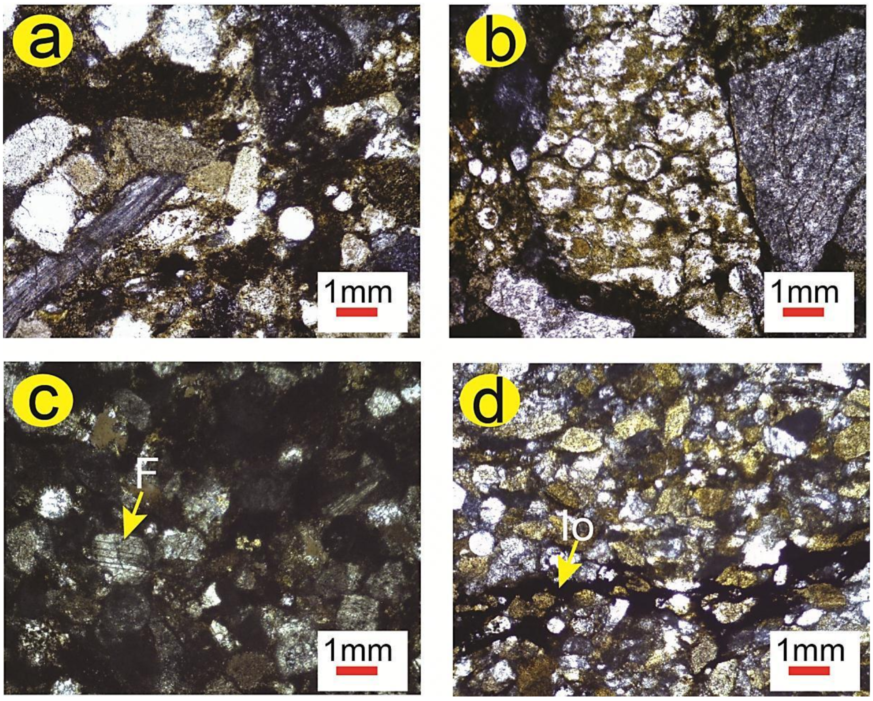

Fig. 3: Photomicrographs of the Tanjero sandstones (A) Sulimania sample S2 coarse lithic; (B) Sulimania sample S11 coarse lithic with radiolarian chert (under XPL); (C) Pera-Magron sample sample P14 showing feldspar(under XPL); (D) Pera-Magron sample sample P14 showing iron oxides cement (under XPL). F= feldspar, Io=iron oxides.

Table 1: Modal analyses of sandstone of Tanjero Formation in the Sulimania area, Ig R.F= Igneous Rock Fragments, Sed R.F= Sedimentary rock Fragments, Mt R.F=Metamorphic Rock Fragments

Sample	Total Quartz	Feldspar	Ig.R.F	Sed.R.F	Mt R.F	Total	Matrix	Cement
S1	18	4		56		56	4	18
S2	13	2		63		63	7	15
S4	15	4	2	56	2	60	9	13
S5	15	6		60		60	7	11
S7	12	2		61		61	6	18
S8	11	4		68		68	4	13
S9	13	5		65		65	6	11
S10	13	7		60		60	7	13
S11	13	3		63		63	7	14
S13	8	5		65		65	8	15

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Table 2: Modal analyses of sandstone of Tanjero Formation in the Pera-Magron area.

Sample	Total Quartz	Feldspar	Ig R.F	Sed R.F	Mt RF	Total	Matrix	Cement
P1	18	3	5	45	8	58	15	6
P5	16	4	2	54	2	58	8	14
P8	20	6	6	42	4	52	12	10
P11	19	4	3	52	3	58	13	6
P14	24	3	1	54		55	10	8
P15	17	4	2	54	2	58	12	9
P16	16	4	3	52	2	57	13	10
P17	15	4	2	55	2	59	10	12
P20	14	4	1	58	1	60	10	12
P27	15	3	2	54	2	58	10	14

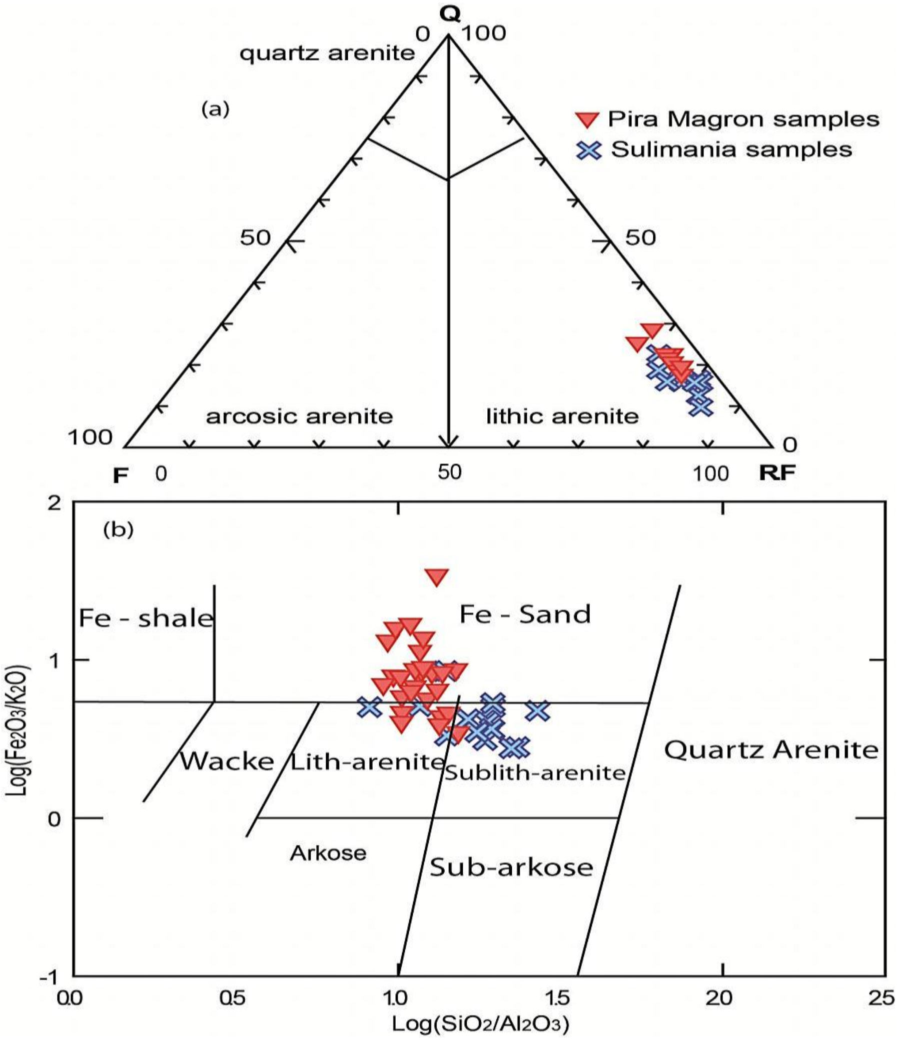

Fig. 4: (A) Mineralogical classification of the sandstone rocks within the Tanjero Formation after [13], Q: total quartz, F: total feldspar, RF: total rock fragments. (B) SiO_2/Al_2O_3 vs Na_2O/K_2O geochemical classification after [14].

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5. Geochemistry:

The geochemical composition of the clastic sedimentary rocks was shown by [15] to reflect provenance, transport, weathering and depositional setting. The composition of the clastic sediments is controlled mainly by the original composition of source rocks; consequently, the major and trace elements in sediments provide information about their origin as well as the weathering conditions in the source area [16]. The 42 clastic rock samples were analysed for major, trace and rare earth elements Tables 3 and 4. The purpose of this chemical study of the Tanjero clastic rocks is to extend our petrogenetic interpretations and determine the tectonic environments [15, 17]. Geochemical results for major and trace elements were analysed to show their chemical behavior and characteristics in the studied Tanjero sandstone samples. The relative concentrations of three major oxide groups – silica (SiO_2), alumina (Al_2O_3), alkali oxides (K_2O) and iron oxide (Fe_2O_3) - have been used to classify the sandstones.

Silica contents in the Tanjero sandstone samples are low with an average 49% in Pera-Magron samples and 53% in Sulimania samples. This may reflects the high content of carbonate rock fragments and ferromagnesian minerals and low content of quartz. Silica is positively correlated with Al_2O_3, TiO_2, Fe_2O_3, and MgO and negatively with CaO Fig.5a. Alumina is highly negatively correlated with CaO, and strongly positively correlated with Fe_2O_{3t} Fig.5b, probably reflecting the content of chlorite in the matrix and rock fragments.

CaO contents in the Sulimania samples ranges between 17.08 and 32.3% (av. 20.88%) while in the Pera-Magron samples ranges between 12.68 and 29% and averages 19.05%. In addition to the high content of carbonate rock fragment in the studied samples, CaO is also present in silicate minerals such as plagioclase and epidote and as carbonate cement. The alkali (Na_2O and K_2O) contents (both about 0.6%) mainly reflect the presence of detrital feldspar but also occur in clays. The Tanjero sandstone rocks are classified geochemically using several discrimination diagrams that depend on immobile elements. SiO_2/ Al_2O_3 vs. Fe_2O_3/K_2O diagram by [14] have been used here to classify Tanjero sandstone rocks. All of the Sulimania samples show litharenites to sublitharenites except one sample plotted in Fe-sand, whereas, Pera-Magron samples are plotted in both litharenites and Fe-sand Fig. 4.b.

Zirconium is a high field strength element that is largely immobile during alteration and metamorphic processes [18]. Average Zr contents are 23 ppm in Sulimania and 34 ppm in Pera-Magron samples reflecting its low concentrations in mafic and ultramafic rocks [19]. It

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shows a strong positive correlation with most major oxides and Hf, Nb,Rb, Ga and Th and negative correlation with CaO and Sr in both sets of samples Fig. 5c and d.

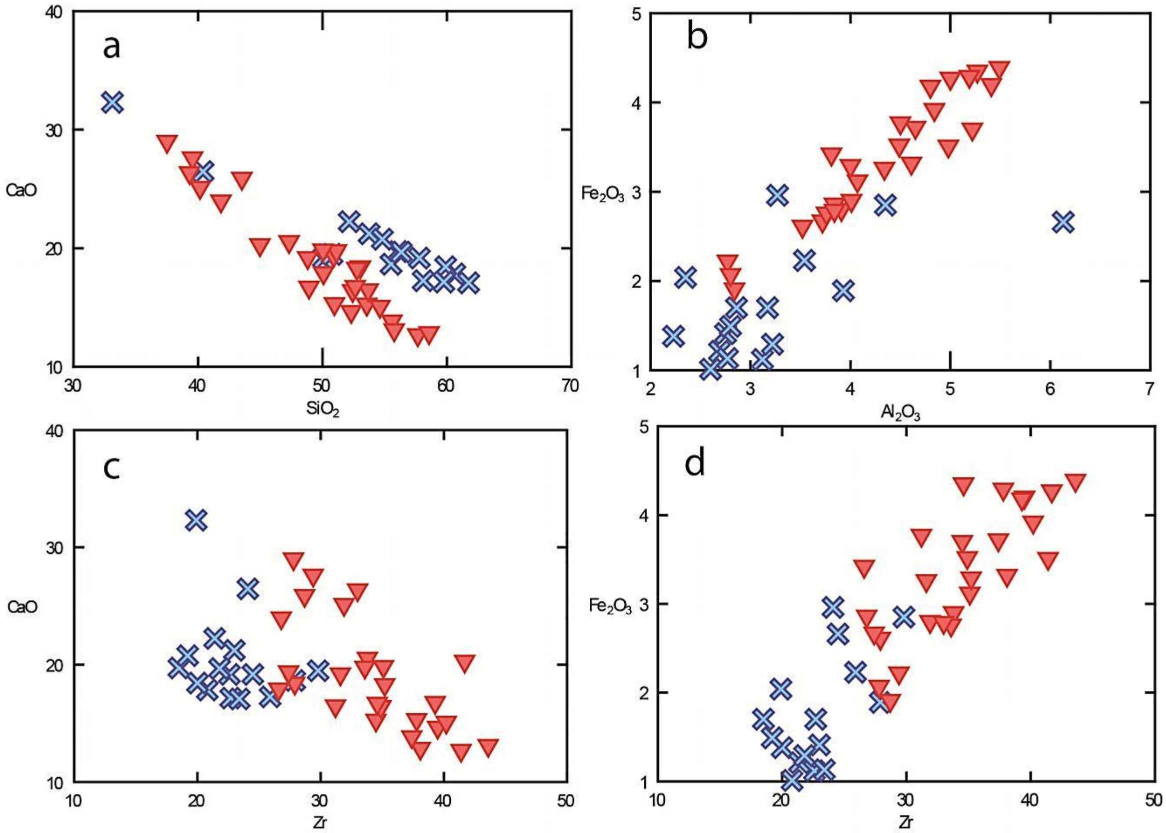

Fig. 5: Selected binary diagrams showing major and trace elements variation of both Sulimania and Pera-Magron rocks. Symbols are as in Fig. 4.

Table 3: Major oxide analyses (%) of Sulimania (S) and Pera-Magron (P).

Sample	SiO2	Al2O3	Fe2O3	MgO	CaO	Na2O	K2O	TiO2	P2O5	MnO	LOI
P1	50.08	3.81	3.42	5.12	17.91	0.11	0.1	0.18	0.04	0.16	18.7
P2	40.16	3.91	2.8	3.05	25.11	0.11	0.6	0.16	0.06	0.35	23.5
P3	57.66	4.98	3.51	4.69	12.68	0.16	0.43	0.23	0.07	0.14	15.2
P4	58.57	4.61	3.32	4.46	12.86	0.16	0.4	0.22	0.07	0.16	14.9
P5	53.56	5.22	3.7	4.26	15.26	0.24	0.63	0.2	0.07	0.21	16.4
P6	48.82	4.34	3.26	3.6	19.2	0.24	0.48	0.18	0.06	0.41	19.2
P7	53.05	3.52	2.61	3.19	18.41	0.18	0.3	0.17	0.06	0.33	18
P8	52.31	5.41	4.2	5.18	14.65	0.23	0.53	0.24	0.08	0.19	16.7
P9	50.91	3.72	2.67	3.38	19.38	0.26	0.32	0.18	0.06	0.4	18.5
P10	52.43	4.49	3.52	4.36	16.41	0.25	0.31	0.21	0.07	0.25	17.5
P11	48.92	5.27	4.35	5.18	16.7	0.41	0.33	0.26	0.07	0.32	17.9

P12	50.97	5.19	4.29	5.52	15.31	0.38	0.27	0.29	0.09	0.25	17.2
P13	47.32	4.01	2.9	3.75	20.54	0.35	0.34	0.22	0.07	0.36	19.9
P14	55.58	4.65	3.72	5.15	13.85	0.3	0.27	0.24	0.08	0.17	15.7
P15	41.84	3.84	2.86	3.57	23.98	0.37	0.17	0.24	0.06	0.36	22.3
P17	54.62	4.84	3.92	3.89	15.08	0.2	0.45	0.23	0.07	0.23	16.3
P18	51.12	3.76	2.76	2.33	19.77	0.15	0.63	0.16	0.06	0.32	18.8
P20	43.52	2.84	1.91	1.57	25.88	0.24	0.55	0.14	0.04	0.45	22.7
P21	53.67	4.5	3.77	3.25	16.48	0.23	0.42	0.2	0.08	0.29	16.9
P22	39.56	2.77	2.22	1.79	27.61	0.19	0.48	0.14	0.04	0.5	24.6
P23	52.77	4	3.29	2.7	18.29	0.29	0.51	0.22	0.09	0.31	17.4
P24	44.98	5	4.27	3.33	20.28	0.26	0.61	0.25	0.09	0.43	20.3
P25	39.32	3.84	2.79	1.9	26.36	0.34	0.69	0.16	0.07	0.47	23.9
P27	37.51	2.8	2.07	1.43	29	0.19	0.53	0.14	0.05	0.48	25.7
S1	58.1	3.54	2.23	1.13	17.25	0.14	0.53	0.17	0.05	0.11	16.6
S2	40.41	3.27	2.96	1.82	26.46	0.19	0.35	0.13	0.04	0.32	23.9
S3	50.08	6.13	2.66	1.74	19.16	0.12	0.53	0.2	0.05	0.14	19
S4	56.08	2.86	1.7	1.15	19.71	0.22	0.34	0.12	0.04	0.13	17.5
S5	55.51	3.93	1.89	1.36	18.65	0.08	0.57	0.18	0.04	0.13	17.5
S6	33.12	2.35	2.04	1.4	32.3	0.1	0.24	0.12	0.03	0.34	27.8
S7	60.63	2.6	1.01	0.65	17.83	0.16	0.36	0.12	0.03	0.11	16.4
S8	53.76	2.75	1.41	1.06	21.21	0.08	0.39	0.14	0.05	0.16	18.8
S9	57.79	3.12	1.12	0.76	19.16	0.07	0.36	0.13	0.04	0.12	17.2
S10	59.9	2.23	1.38	0.79	18.43	0.08	0.29	0.13	0.04	0.09	16.4
S11	59.75	3.17	1.7	1.28	17.15	0.15	0.42	0.14	0.04	0.08	15.9
S12	52.15	2.69	1.21	1.03	22.24	0.19	0.33	0.14	0.04	0.12	19.7
S13	50.77	4.35	2.85	2.17	19.48	0.09	0.56	0.2	0.05	0.12	19.2
S14	61.74	2.77	1.13	0.81	17.08	0.08	0.41	0.13	0.04	0.11	15.5
S15	56.34	3.22	1.29	0.96	19.67	0.08	0.37	0.14	0.04	0.11	17.6
S16	54.82	2.8	1.49	0.83	20.76	0.06	0.28	0.13	0.04	0.1	18.5

6. Discussion and conclusions

The provenance of Tanjero sandstone rocks has been determined by several petrographical processes, including quartz, feldspar and rock fragments [20]. Clastic sediments derived from arcs (continental or oceanic) are typically poor in detrital quartz and rich in lithic grains [21, 22]. The presence of quartz, chert, carbonates, igneous and metamorphic lithic grains and fossils in the Tanjero sandstone clastic rocks indicates that the southern Neotethys Ocean was a shallow seaway during their deposition. The low total quartz content in the Tanjero sandstone samples together with minor quantities low grade metamorphic rock fragments and the high proportion of rock fragments confirm the principle source to be from subduction related rocks and radiolarian chert in the Cretaceous Qulqula series.

Plotting data from the modal analysis of the Sulimania and Pera-Magron sandstones on the ternary Q-F-RF diagram of [23] shows that they fall entirely in the undissected magmatic arc field and in SiO_2-(K_2O/Na_2O) diagram after [24] they mostly fall in the island arc field Fig. 6a and b. It can be concluded that the deposited sandstones in the Tanjero Formation in Sulimania and Pera-Magron areas were mainly derived from Albian-Cenomanian Gimo–Qandil sequence ophiolite-bearing terrane and Hemipelagic sediments (Parautochthonous Qulqula rocks).

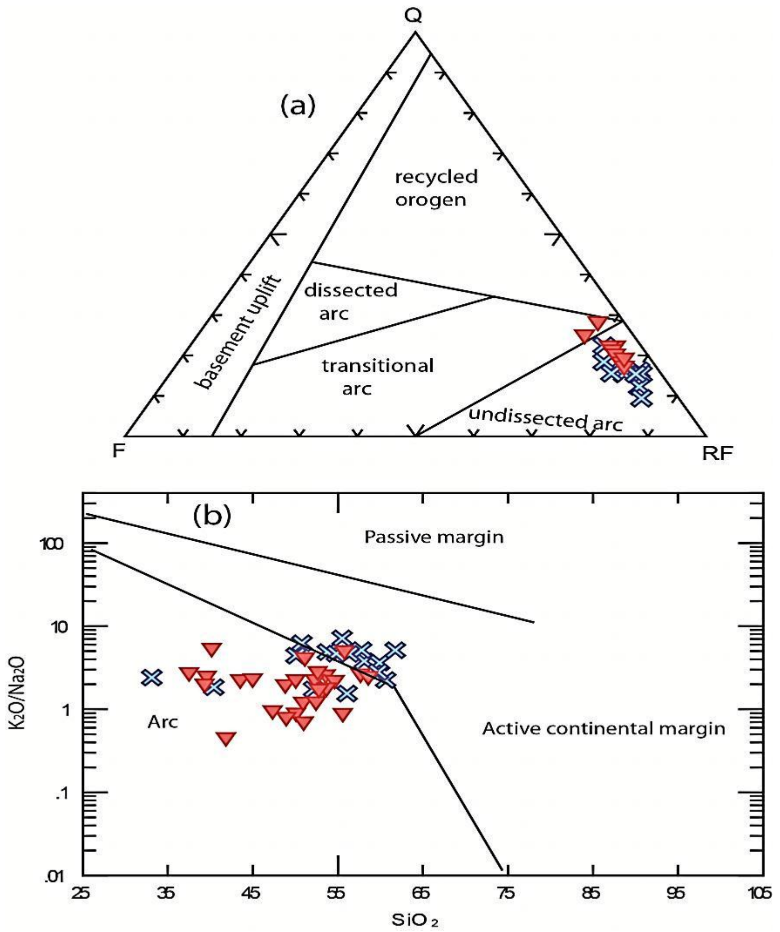

Fig. 6: Tectonic interpretation diagrams (A) Ternary plots of detrital components in the Sulimania and Pera-Magron sandstones on the tectonic provenance discrimination diagram of [23] Qt is the total quartz, F is the feldspar, and RF is the total rock fragments., (b) SiO2-log (K2O/Na2O) diagram after [24], Symbols are as in Fig. 4.

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