Kuwait J. Sci. **47 (4)** pp. 106-117, 2020

تأريخ زركون نظائر اليورانيوم – الرصاص في صخور السيليكا في العصر الطباشيري العلوي داخل تكوين تانجرو فليش بشمال شرق العراق: تحديدات جديدة بخصوص منشأهم والتطور اليتكتوني

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الملخص

يشير البحث إلى أنه تم استخدام علم التقويم الجيولوجي لتأريخ الرسوبيات الحُتاتية (الفُتاثية) لزركون (DZ) نظائر اليورانيوم- الرصاص لوصف صخور السيليكا في العصر الطباشيري العلوي في تانجرو فليش Tanjero flysch ، شمال شرق العراق. استخدمنا في هذا البحث أيضاً هذه البيانات لتحديد مصدر وأصل الفُتات الحجري وتقييم التطور التكتوني لحزام الأوروجينية في زاجروس الشمالية. يقع حوض تانجرو فليش في السطح الخارجي لارتفاع قلقلة Qulqula "تضاريس معقدة تراكمية" في الجزء العراقي لمنطقة الدّسر شمال زاجروس، والتي ترسم علامة فترة انتقال من الحافة السلبية إلى التضاريس المعقدة التراكمية- موضع أحواض أرض المقدمة المنحنية. أظهر البحث أنه بالاستناد إلى QFL (رسم بياني ثلاثي يوضح الكوارتز، فليسبار، شظايا حجرية)، تم تصنيف فُتات تانجرو على أنها أرينيتات حجرية وليترنيت فلسبارية. تتكون الشظايا الحجرية عادة من رسوبيات [أي حجر جيري وتشرت (ظِرّان)]، بركاني وبلوتي (حوفي)، وصخور متحولة منخفضة الدرجة. يُظهر التوصيف المعدني لتانجرو فليش بشكل واضح أن الرواسب الحُتاتية تشتمل على كمية كبيرة من الشظايا الحجرية مما يشير إلى تضمنها كمية كبيرة من الفتات (الحُتات) عبارة عن رواسب بحرية أوروجينية متقدمة (على سبيل المثال راديولاريت قلقلة ومزيج السربنتينيت). أوضح البحث أن استخدام بيانات جديدة لرسوبيات زركون حُتاتية لنظائر اليورانيوم- الرصاص (DZ) من العصر الطباشيري العلوي في حوض تانجرو فليش يسمح بإعادة تشكيل الصخور التي يرجع مصدرها لفترة فيما قبل الأوروجينية. كشفت قياسات حبيبات اليورانيوم- الرصاص بشكل واضح إمكانية إعادة تدوير فُتات تانجرو فليش عدة مرات من خلال أنظمة رسوبية مع الاحتفاظ بنظائر اليورانيوم- الرصاص الصلبة في عصور التبلور أثناء التجوية، والتعرية، والنقل، والترسيب، والتكون، والتحول منخفض الدرجة. أسفر العمر الأصغر لزركون في تانجرو فليش عن عمر Ma 94-93 والذي يتزامن إلى حد بعيد مع المرحلة السادسة من العصر الطباشيري الذي يقع فيها حدث انصهاري قوسي الشكل (بمعنى MA106-92). علاوة على ذلك، أظهرت نظائر اليورانيوم- الرصاص بشكل قوي توزيع عمر عَرَض 398–448، 511–570، 646–690، 779، 878–880، 910–996 و1045–1181 MA مما يشير إلى اشتقاق متعدد الحلقات ترجع غالباً لقاعدة حقبة Neoproterozoic (وحدة عصر جيولوجي يترواح عمره من 1000 سنة إلى 541 مليون سنة) للدرع العربي–النوبي والذي تكونت فيه في وقت ما حوض قلقلة الراديولاريت في العصر Pliensbachian–Turonian المبكر والذي كان موجوداً على طول حافة القارية العربية الخامدة.

U-Pb Zircon dating of upper cretaceous siliciclastic rocks from the Tanjero Flysch, NE Iraq: New constraints on their provenance and tectonic evolution

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Abstract

Detrital zircon (DZ) U-Pb geochronology was used to characterise Upper Cretaceous siliciclastic rocks from the Tanjero Flysch, NE Iraq. These data were also used to constrain the source and origin of lithified clasts and to evaluate the tectonic evolution of the Northern Zagros Orogenic Belt. The Tanjero Flysch Basin is located in the periphery of Qulqula Rise "accretionary complex terrane" of the Iraqi segment of the North Zagros Thrust Zone, marking the transition from passive margin to the accretionary complex terrane– flexural foreland basins setting. Based on the QFL plot, the Tanjero clastics were classified as lithic arenites and feldspathic litharenites. The lithic fragments commonly consist of sedimentary (i.e. limestone and chert), volcanic and plutonic, and low-grade metamorphic rocks. The mineralogical characterization of Tanjero Flysch clearly illustrates that the clastic sediments contain a substantial amount of lithic fragments, suggesting a significant contribution of detritus from advancing orogenic wedges (e.g. Qulqula Radiolarite and serpentinite mélange). Using new U-Pb detrital zircon (DZ) geochronological data from the Upper Cretaceous Tanjero Flysch permitted the reconstruction of pre-orogenic source rocks. The U-Pb measurements of representative DZ grains clearly revealed that the Tanjero Flysch clastics can be recycled many times in sedimentary systems whilst retaining robust U-Pb crystallisation ages during weathering, erosion, transport, deposition, diagenesis and low-grade metamorphism. The youngest zircon age population in the Tanjero Flysch yielded an age of 93-94 Ma which coincides closely with an Albian-Cenomanian arc-dominated magmatic event (i.e. 106–92 Ma). In addition the DZ U-Pb showed a strongly episodic age distribution 398- 448, 511-570, 646-690, 779, 878-880, 910-996 and 1045-1181 Ma that suggests multi-cycled derivation mostly from the Neoproterozoic basement of the Arabian-Nubian Shield that were at some point hosted by the Early Pliensbachian-Turonian Qulqula Radiolarite Basin which was located along the Arabian passive margin.

Keywords: Flysch; provenance; Tanjero; Zagros Suture Zone; zircon geochronology.

1. Introduction

The Zagros Suture Zone is located in the Kurdistan region of Iraq, along the Iraq-Iran-Turkey border (Figure 1). It is part of the Zagros Fold-Thrust Belt. This mega-structure, approximately 5000 km^2, shows evidence of subduction, accretion, uplifting and formation mixture (Aswad *et al*. 2011; Aziz *et al*. 2011; Dercourt *et al*. 1986; Falcon, 1974; Hessami, 2002; Koshnaw *et al*. 2017). The Zagros Suture Zone encroached southwards toward a rapidly subsiding Neogene foreland basin which was filled with flysch-type clasts in front of the Arabian Plate margin (Aswad *et al*. 2011; Koshnaw *et al*. 2017). The Upper Cretaceous Tanjero Formation is a typical flysch facies of the Neogene Kurdistan Foreland Basin. The provenance of the foreland basin clasts (Tanjero Flysch) is controversial due to lacking any research concerning DZ geochronology. A number of authors have proposed that the main source terranes for the Tanjero Flysch were the Late-Cretaceous ophiolite massifs and the Late Paleogene island-arc volcanic rocks of the Zagros Suture Zone. In the present study, we propose new evidence for the first time based on detrital zircon age as indices of provenance and source area tectonics of the Tanjero formation.

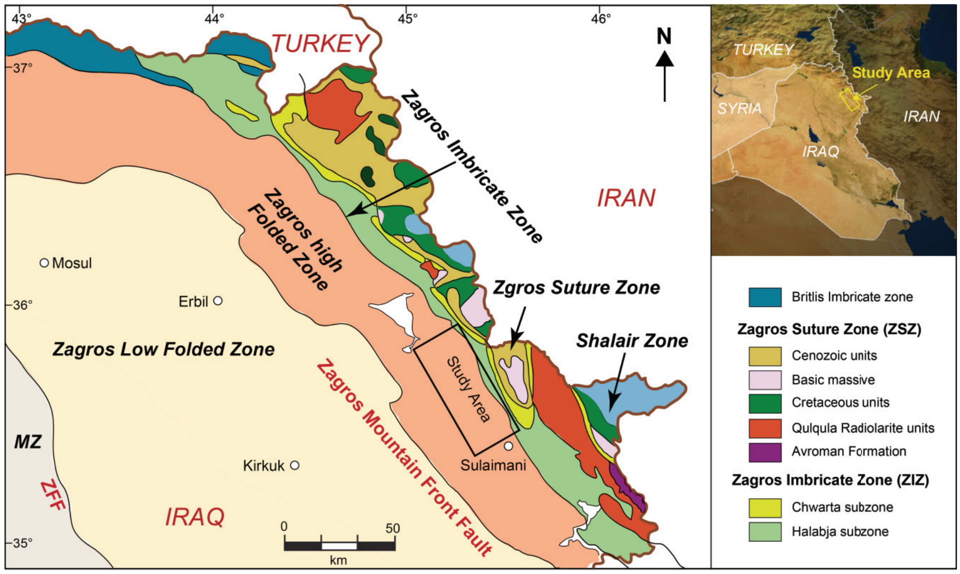

Fig. 1. Regional tectono-stratigraphic map for the NW Zagros belt across Iraq, showing the Study Area.

2. Geological Setting

The Tanjero Flysch Basin is located on the periphery of the Qulqula Rise "accretionary complex terrane" of the Iraqi segment of the Northern Zagros Thrust Zone, marking the transition from passive margin to an accretionary complex terrane–flexural foreland basin setting. This formation has been studied by many researchers, in terms of its sedimentology (Abdul-Kireem, 1986; Al-Mehaidi, 1975; Al-Rawi, 1981; Bellen *et al.* 1959; Dunnington, 1952; Karim, 2004; Karim & Surdashy 2005; Minas, 1997), and biostratigraphy (Kassab, 1972, 1975; Sharbazheri, 2008). Bellen *et al*. (1959) first defined the Tanjero Formation (as the Tanjero Clastic Formation) in the Sirwan Valley, 1 km south of Kani Karweshkan village, near Halabja town. Dunnington (1952, in Bellen *et al.* 1959) divided the formation into lower and upper parts, based on lithology in the type section. The upper part is 1532m thick and consists of silty marls, siltstone, sandstone, conglomerate, and sandy biogenic detrital limestone. The lower part is 484 m thick and composed of pelagic marl with some siltstones and rare marly limestones (Figure 2). The sub-divisions are based only on the lithological variation in the type section and are not necessarily applicable to other areas.

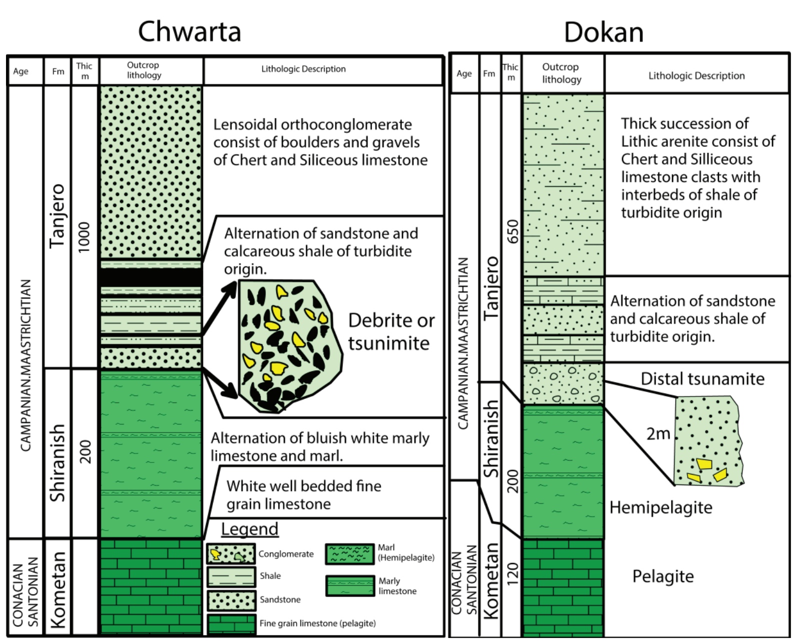

Fig. 2. Lithological section of the Tanjero Formation A: Chwarta section, B: Dokan section. Fm-formation, Thic-thickness

3. Materials and Methods

The study area is located in the NE part of Sulaimani city, Iraq (Figure 3). Two representative sections (Dokan and Chwarta) were sampled (Table 1). Ten highly polished thin sections of representative samples were prepared at Original Analytical Ltd in Welshpool, UK. Detail study of petrography is employed using an optical polarized microscope at the petrographic laboratory, Department of Geology, University of Sulaimani. Model analysis of the Tanjero samples is obtained at Original Analytical Ltd using a high-resolution petrographic approach, in which all of the particles were carefully and forensically classified. The analysis included full descriptions, and the determination of mineralogical abundances based on traditional or Gazzi-Dickinson's point-counting approaches as described in Ingersoll and Suczek, (1979). This involved counting 300 points per slide (300 points at 0.04 mm intervals in each sample). This method places fine-grained lithic fragments that do not have individual crystals larger than 0.0625 mm in the lithic fragment pole. The results are presented in Table 2. The detrital zircon was separated and dated at Original Analytical Ltd in Welshpool, UK. Detrital zircon U-Pb geochronological data of individual zircon was conducted using a high-sensitivity quadrupole ICP-MS instrument (Analytik Jena PQ Elite), coupled with a 193 nm ArF excimer laser (ASI resolution-SE), which allows for rapid small volume geochronology of minerals including zircon. The Plesovice and Temora reference age standards were used for the dating. Inheritance and lead loss are common in zircon and can lead to measured dates that are older or younger than the crystallization age of the zircon. Therefore, in some grains isotope ratios jumped to different values during the analysis, presumably due to age zoning. The results are presented in Table 3.

Table 1. Latitude, longitude and location of the selected Tanjero sections

Sample	Section	Locality	Latitude	longitude
T1- T10	Dokan (D-D′)	Sara Anticline Qashqoli River	N 35° 55′ 45″ - N 35° 56′ 45″	E 44° 57′ 28″ - E 44° 55′ 10″
T11-T20	Mawat-Chwarta (A-A′)	Kuna Masi-Tagaran villages	N 35° 46′ 33″- N 35° 59′ 19″-	E 45° 26’ 44”- E 44° 52’ 49”-

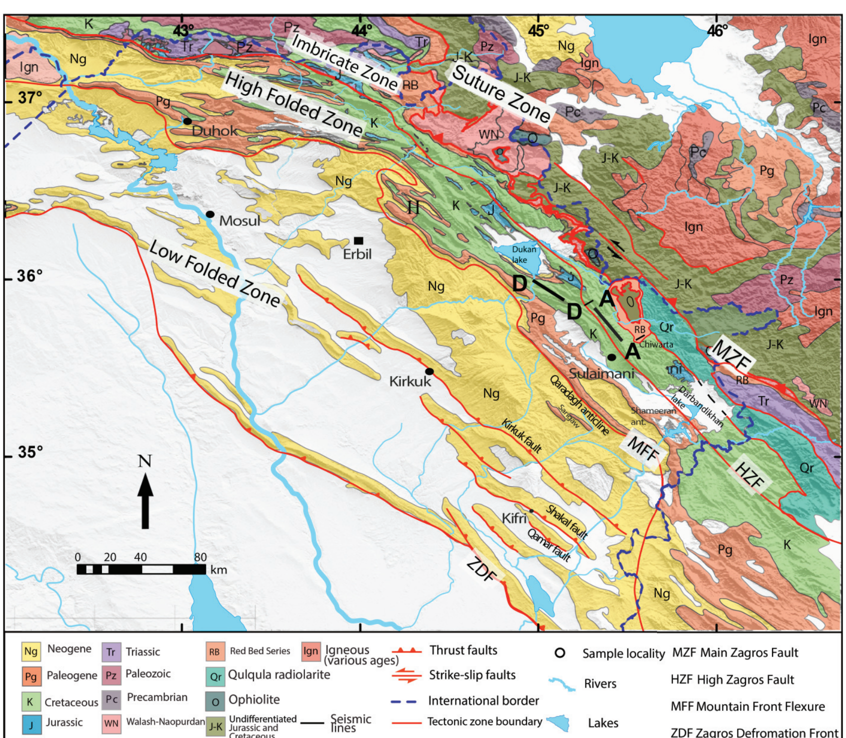

Fig. 3. Regional tectonostratigraphic map for the NW Zagros belt across Iraq shows the studied sections. After Koshnaw *et al.*, 2017.

3. Results

3.1 Petrography

Ten thin sections were selected for detailed petrographic study. Based on point-counting results (Table 2), the samples are classified into lithic arenites and feldspathic litharenites (Folk, 1980; Pettijohn, 1975; Figure 4). The sandstones of Tanjero Formation vary from fine to coarse grained (Figure 5 a, b). The average quartz content was 9.53 % in the 10 Tanjero samples with minor monocrystalline (angular to sub-rounded) and poly-crystalline (sub-angular to sub-rounded) quartz grains contents (Figure 6a). The accessory grains were mostly represented by very common benthic foraminifera, mostly larger forms that were possibly reworked/recycled (Figure 5b). The sedimentary rock fragments are carbonate (limestone) and chert (Figure 6 c, d). Plutonic rocks fragments are represented by plagioclase, phyllosilicate grains with lesser chlorite grains. Metamorphic lithic grains are common and represented by serpentine minerals. Cement content is commonly non-ferroan calcite, chert, and iron oxides. Rare siderite, hematite, and pyrite minerals are disseminated locally.

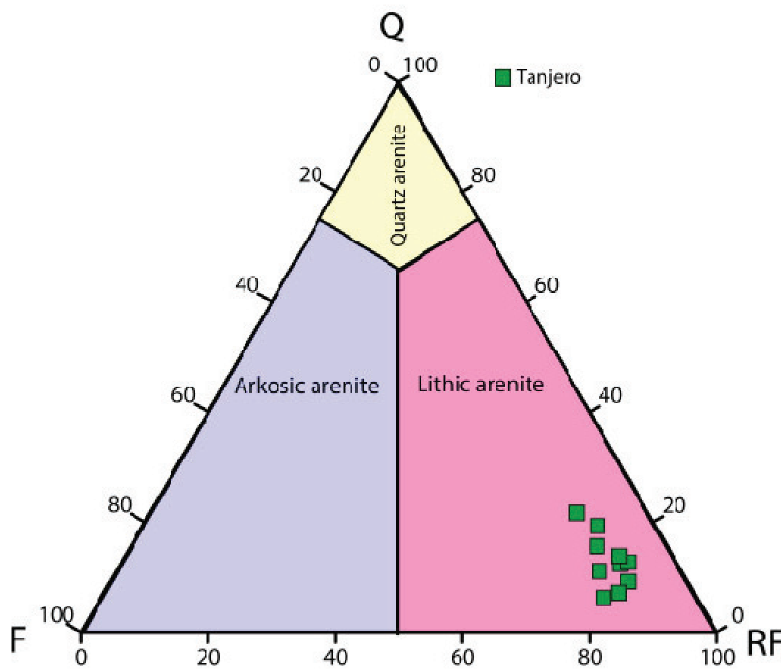

Fig. 4. Mineralogical classification of the clastic rocks in the Tanjero Formation (Pettijohn, 1975). Q: total quartz, F: total feldspar, RF: total rock fragments

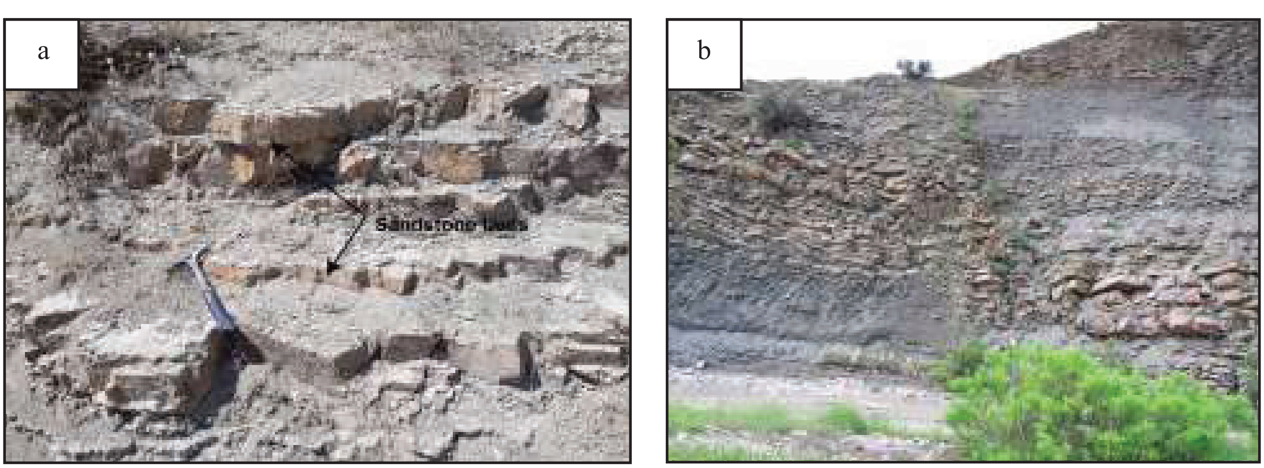

Fig. 5. (a) Field photograph of sandstone beds of Tanjero Formation in Chwarta section 2 km west of Mokaba village. (b) Coarse sandstone parasequence about 10m thick, 2 km west of Dokan town.

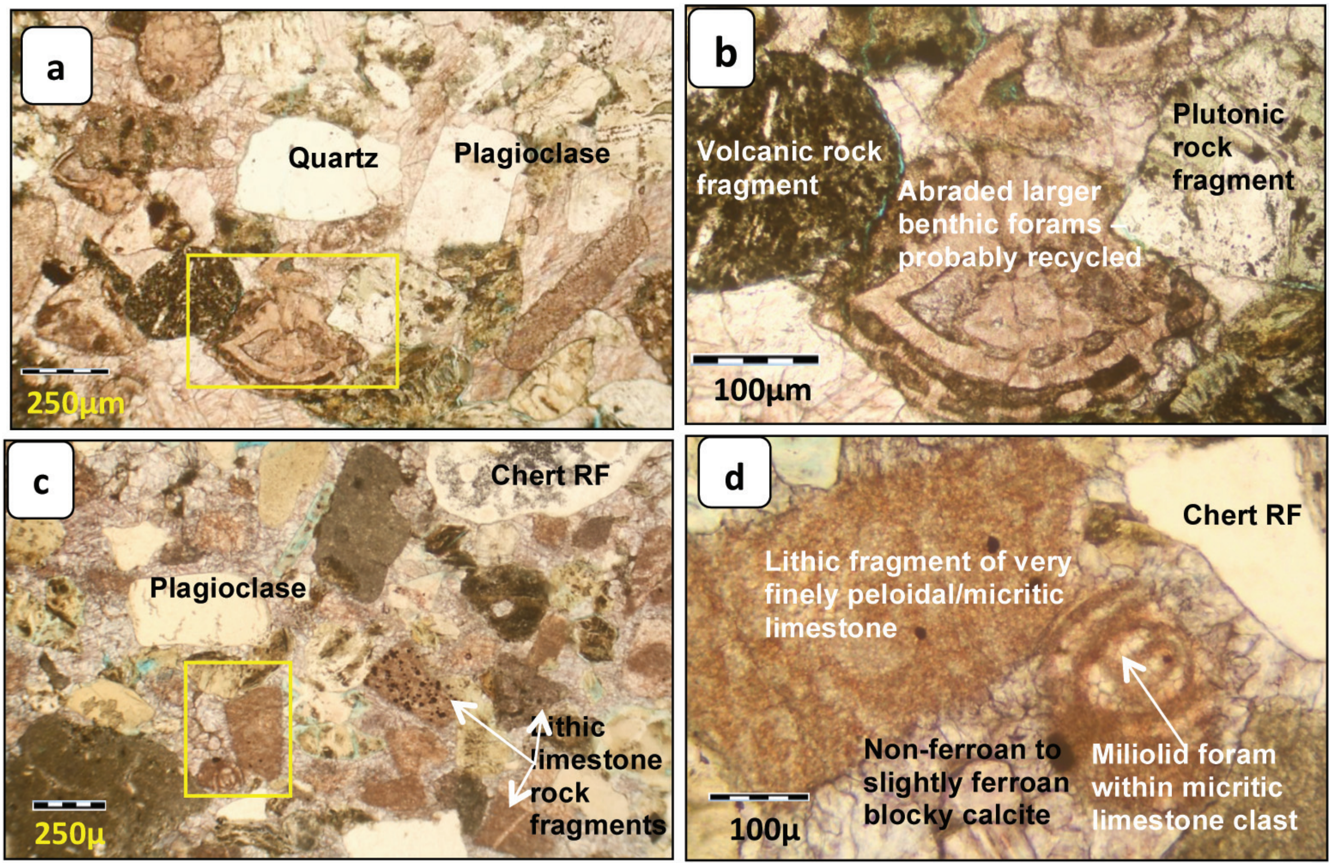

Fig. 6. Photomicrographs of Tanjero clastic rocks. a-b: coarse lithic sand with fossil debris. c-d: lithic arenite with plagioclase and chert rock fragment.

Table 2. Modal analyses of the Tanjero siliciclastic rocks

Sample ID	Quartz%		Feldspar	Rock fragment					Phyllosilicate & Accessories	Matrix	Cement	Clays	Porosity
	Mono	Poly		Sed	Meta	Ign	Chert	Total RF					
T2	2.6	3.43	6.19	29.66	2.95	6.25	14.7	53.56	4.62	6.29	19.82	0.95	2.54
T3	3	1.42	10.5	36.4	2.5	7.3	10.2	56.4	6.08	6.1	13.1	0.9	2.5
T4	6	2.9	6.5	35.5	3.3	8.1	9.7	56.6	1.15	5.5	18.2	0.82	2.33
T6	5	3.3	9.7	34.9	2.7	9.2	10.2	57	5.28	6.8	10.2	0.31	2.41
T8	7.9	4	8.4	32.7	2.4	9.5	11.38	55.98	3.59	7.2	10.5	0.43	2
T10	10	4	6.6	30.5	3.2	7.55	10.8	52.05	7.43	5.5	11.4	0.93	2.1
T11	7.1	2.2	5.6	35.7	2.5	7.4	12.8	58.4	2.26	6.9	13.9	0.64	3
T13	11	5.8	8.7	29.5	4.8	7.1	10.8	52.2	1.87	7.3	10.5	0.51	2.12
T16	4	1	8.3	37.8	2	6.7	10.3	56.8	4.59	7.4	14.7	0.55	2.66
T19	7.3	3.3	6.5	37.3	2.6	9.9	9.9	59.7	1.45	6.1	12.6	0.95	2.1
Av.	6.39	3.14	7.699	33.996	3.3	8.31	11.078		4.74	6.75	14.54	0.68	2.54

3.2 Heavy Minerals

The importance of heavy minerals in sedimentary studies, despite their low abundances (<1.0%), is that they allow an assess of the source and environmental conditions of deposition of the sediment (Garzanti, *et al.* 2013; Pettijohn *et al.* 1987). Each heavy mineral grain is a unique messenger of coded data, carrying the details of its ancestry and the vicissitudes of its sedimentary history (Mange & Wright, 2007). Thus the analysis of heavy minerals in foreland basin sequences can prove valuable in constraining the structural histories of both extra-basin and intra-basin (e.g., hydraulic) processes that influenced the formation of clastic rocks (Dill, 1998). Sub-rounded to sub-angular opaque minerals were identified in all the samples, forming 79.83-87.04 % of the heavy mineral suite. These minerals included magnetite, Cr-spinel, and ilmenite which are usually derived from mafic igneous rocks (Pettijohn, 1975). Ultra-stable non-opaque minerals include zircon (0.11%), in a few samples with more widespread rutile (0.11 - 0.16 %) and a relatively high content of titanite (0.22 -0.32 %) with angular to subhedral tourmaline grains and euhedral apatite grains (Figure 6 a-d). Metastable non-opaque minerals included garnet (rare) which is usually derived from dynamothermal metamorphic and igneous rocks (Folk, 1980; Pettijohn, 1975). Epidote was a dominant non-opaque component, being sub-rounded and pitted (Figure 6f). The unstable heavy minerals were pyroxene, hornblende, chlorite, and biotite. The pyroxene (hypersthene) grains with visible cleavages were sub-rounded (Figure 6e) and probably sorted from nearby mafic igneous rocks. Chlorite, with yellowish-green lamellae, was common. Accordingly, the heavy minerals suites from the Tanjero clastic samples were dominated by opaque grains, epidote, pyroxene, amphibole and chlorite all of which were derived from ultrabasic to basic igneous successions. However, the presence of zircon, rutile, tourmaline, and garnet suggest derivation from earlier igneous and metamorphic sources.

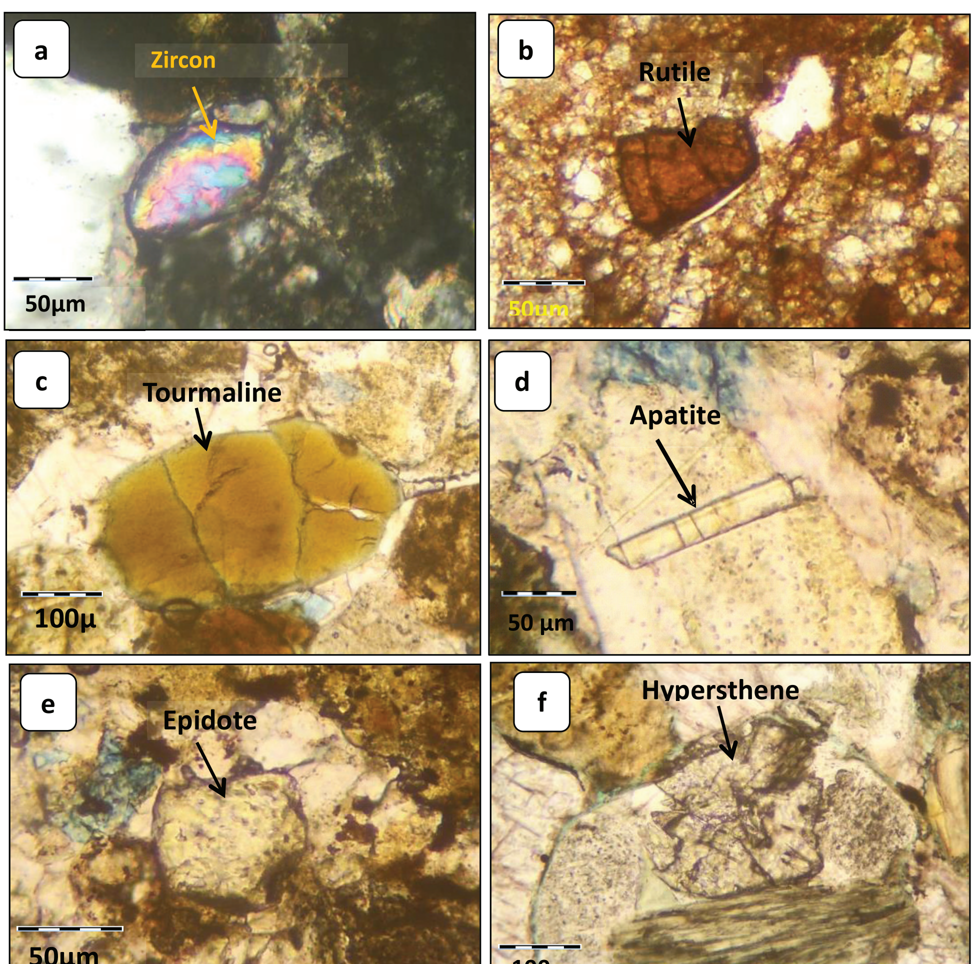

Fig. 7. Photomicrographs of selected heavy minerals in the Tanjero Formation

3.3 U-Pb Dating

Detrital zircon (DZ) U-Pb geochronology is a popular and powerful technique that has been used in many studies (e.g., Fedo *et al.* 2003) to identify provenance components in sedimentary units (Haas *et al*. 1999). It has been successfully employed in siliciclastic sediments to map reservoirs in the basins, tracing sedimentary pathways, recording denudation histories and dating volcano-magmatic events (Andersen, 2005). Recently, there have been detrital zircon geochronological studies of the post-collisional Neogene foreland basin in the Kirkuk Embayment (Koshnaw *et al*. 2017). No attempt has been made to apply the detrital zircon U–Pb geochronology to assess the Late Cretaceous age active syn-orogenic sedimentation records within foreland basins. In this study, we analysed DZ U-Pb isotope data of the Tanjero Flysch for the first time (Table 3). Thirty zircon grains were extracted and analysed. Their probability density plots (PDP) and concordia diagrams are shown in Figure 8 and 9, respectively. The U–Pb age spectra preserved in the Tanjero Flysch are complex (i.e., having multiple age components). These complex DZ age spectra are attributed to tectonically active terranes occurring in the east of the studied flysch outcrops, and has pronounced 93-94, 398- 448, 511-570, 646-690, 779, 878-880, 910-996 and 1045-1181 Ma ages, highlighting Albian-Cenomanian active magmatic arc and a cratonic influence during both the Neoproterozoic and Mesoproterozoic. Therefore, the zircon age populations of the flysch units studied here can easily be correlated with those of the source-rock of Qulqula Rise (accretionary complex terrane), and erodible Arabian Craton sources. The accretionary complex which is inferred to have accommodated a zircon-bearing detrital supply may be seen as an infinite reservoir of detrital zircons for its adjacent foreland basin systems, resulting in an invariant detrital zircon provenance trend through time.

Table 3. DZ U–Pb isotopes of the Tanjero Flysch

Analysis No.	U ppm	Th ppm	Th/U	$^{207}Pb/^{206}Pb$	± 2 σ, Ma	$^{206}Pb/^{238}U$	± 2 σ Ma	$^{207}Pb/^{235}U$ Age Ma	± 2 σ, Ma	$^{206}Pb/^{238}U$ Age Ma	± 2 σ Ma
T1	200	130	0.65	70	200	92	3	87	9	93	3
T 2	45	301	6.69	1100	45	1119	27	1112	20	1100	16
T 3	69	111	1.61	446	69	568	13	548	17	570	5
T 4	38	2540	66.84	738	38	516	11	560	11	511	14
T 5	49	247	5.04	1121	49	1049	28	1066	25	1121	11
T 6	60	79	1.32	1026	60	997	24	1004	23	996	9
T 7	94	400	4.26	690	94	401	43	440	35	398	5
T8	41	498	12.15	979	41	881	22	900	20	878	4
T 9	42	1200	28.57	610	42	644	22	628	15	646	3
T10	67	134	2	544	67	449	10	464	13	448	3
T11	26	1970	75.77	611	26	554	11	565	11	553	10
T 12	30	1400	46.67	440	30	401	7	406	8	400	11
T13	27	760	28.15	984	27	973	18	974	16	973	7
T 14	48	338	7.04	1010	48	787	21	846	23	779	9
T 15	290	74	0.26	950	290	960	130	905	82	916	2
T 16	258	250	0.97	0	110	93	2	92	6	93	2
T17	97	210	2.16	200	96	96	2	102	2	94	2
T 18	118	130	1.1	128	118	96	2	101	4	94	2
T19	33	313	9.48	971	34	944	18	965	16	942	18
T 20	30	496	16.53	1181	28	1224	23	1220	15	1181	28
T 21	29	307	10.58	1110	29	1150	20	1152	18	1111	29
T 22	80	110	1.37	880	82	678	19	736	22	670	17
T 23	57	392	6.87	689	57	693	27	690	222	697	30
T 24	50	390	7.8	360	41	410	4	410	4	410	4
T 25	39	308	7.89	1120	35	1150	16	1150	16	1125	20
T26	31	300	9.68	1100	45	1119	27	1112	20	1112	35
T27	35	308	8.8	1121	49	1049	28	1066	25	1045	29
T28	44	351	7.98	970	31	880	21	900	20	880	21
T29	34	315	9.26	950	29	960	30	910	16	910	16
T30	29	295	10.17	1020	30	997	24	995	21	990	20

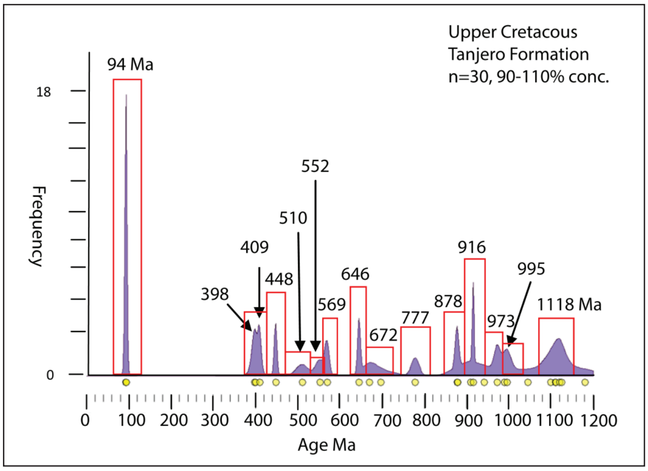

Fig. 8. Age probability distribution diagram depicting detrital zircon U-Pb ages

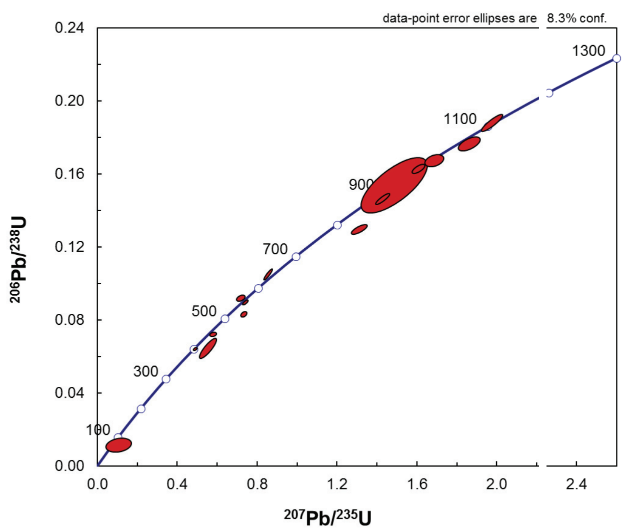

Fig. 9. Concordia diagram of dated detrital zircons from Tanjero Flysch

4. Discussions

4.1 U-Pb Zircon Geochronology and its Tectonic Implications

The discussion on the U-Pb results highlights the fact that the parautochthonous radiolarite basin hosted a significant fraction of the DZ, which was derived predominantly from cratonic source-rocks of the Arabian passive margin, as well as transported directly from the contemporaneous Albian-Cenomanian active magmatic arc. The youngest peak age of DZ (93-94 Ma) obtained from the Tanjero Formation constrains the upper age limit of the stratigraphic succession of the radiolarite formation before it was accreted onto the Arabian carbonate platform. Therefore, the DZ U-Pb data indicate that the Albian-Cenomanian marked initiation of the closure of the Neotethys, which means that slab pull appears to be the main driving force of extensional orogeny and the decreases in the slab pull latter (which was associated with ongoing mantle drag) leading to the cessation of subduction that was incipient during the Albian-Cenomanian. In other words, the pre-orogenic extensional collapsed soon after 90 Ma (Turonian) and was caused by dramatic decreases in slab pull force leading to proto-Zagros Orogeny in the middle Campanian (≥ 80 Ma) (70 Ma, Koshnaw *et al.,* 2017). The conclusion concerning the closure of the Neotethys, however, contradicts a common view held by geologists that the transition from autochthonous platform carbonates to neoautochthonous flysch sedimentation marked the proto-Zagros Orogeny that has been associated with the initiation of the closure of the Neotethys (Aswad, 1999). Furthermore, we believe that the DZ grains acquired from the Tanjero Flysch did not come from a primary cratonic source, but were recycled from a proximal sediment source of high relief, accretionary complex terrane, and had likely already experienced sedimentary recycling.

4.2 Tectonic Evolution

As a consequence of a dramatic decrease in slab pull (which was associated with ongoing mantle drag), leading to the cessation of subduction in the middle Campanian, a shift occurred from extensional to compressional settings in the region (Figure 10). The compressional settings were generated through the accretion of displaced terranes (referred to as the Qulqula Accretionary Wedge) onto the autochthonous platform carbonates. The accreted terranes were composed of blocks of different ages and lithologies (i.e. the Qulqula Radiolarite and serpentinite–matrix mélange). The load of the accretionary wedge controlled the amount of flexural subsidence in the adjacent foreland basin. In response to dynamic loading by the adjacent accretionary wedge, the Zagros Foreland Basin was partitioned into foredeep (Shiranish Formation), forebulge "peripheral bulge" (i.e., Aqra Formation), and marine flysch trough (Tanjero Formation) environments (Figure 10a). Evidently, the dynamic loading of the orogenic wedge lagged behind the initiation of subduction. An erroneous view of certain geologists is that the initial Neotethys closure was coeval with the proto-Zagros Orogeny, as shown by foreland flexural subsidence. During Albian-Cenomanian subduction, however, extensional tectonics of the Northern Zagros Orogenic Belt were in operation mainly detected by disruption of the Arabian carbonate platform. The timing of the initial closure of the Neotethys Ocean was virtually synchronous with a short-lived mid-oceanic subduction. It can be hypothesised that the episodic nature of the slab pulls geodynamics triggered short-lived extensional stresses associated with Albian–Cenomanian arc tectono-magmatism during the early stages of the closure of the Neotethys (~100 Ma; Figure 10b). Alternatively, ongoing mantle drag may have induced middle Campanian compressive deformation (~80 Ma), resulting in the formation of the Tanjero Flysch within the foreland basin.

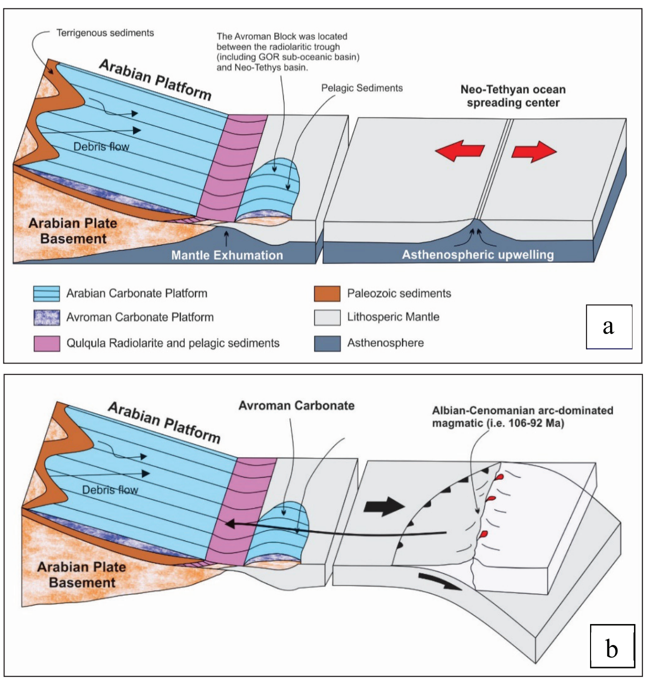

Fig. 10. (a) Model showing recycling of cratonic and terrigenous materials into intermediate sediment repository (Qulqula Radiolarite Basin). **(b)** Model illustrating recycling of magmatic arc material transported directly to the radiolarite basin (Albian-Cenomanian)

5. Conclusions

Based on the Petrographic point count data, the samples are identified as lithic arenites and feldspathic litharenites. The lithic fragments commonly consisted of sedimentary (limestone and chert), volcanic, plutonic, and low-grade metamorphic rocks, suggesting poor sorting and rapid deposition. Heavy mineral contents within Tanjero clastics indicate the presence of a relatively high percentage of detrital opaque minerals, as well as rutile, apatite, pyroxene, amphibole and high serpentine, suggesting that these minerals are derived from the heterogeneous source areas. Owing to the polymictic mafic–ultramafic rich nature of the lithic arenites, however, almost all authors erroneously tend to assume that the main source terranes for the Tanjero Flysch were the obducted Albian-Cenomanian ophiolite massifs. The tectonics of the studied region is certainly very complicated, and it does not appear amenable to adequate tectonic model without using the available U-Pb geochronologic data of detrital zircons. By using the ICP-MS method of detrital zircons of two representative stratigraphic sections (Dokan and Chwarta), the data has proved its value as a method to study the provenance of Tanjero Flysch and evolutionary processes in the foreland basin. Briefly, the complex U–Pb age spectrum had multiple age components, including: (1) the incorporation of cratonic and terrigenous material into an intermediate sediment repository (i.e., the Qulqula Radiolarite Basin) during the early Pliensbachian-Turonian; and (2) a significant fraction of contemporaneously active magmatic arc sedimentation during the Albian-Cenomanian. In other words, the DZ grains acquired from the Tanjero Flysch did not come from a primary cratonic source, but were recycled from a proximal sediment source of high relief and accretionary complex terrane, and had likely already experienced sedimentary recycling.

ACKNOWLEDGMENTS

We would like to thank Prof. Dr. Khalid Jalal Aswad, Department of Geology, University of Mosul for his critical reading of an early draft of the manuscript and his interesting discussions.

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Submitted : 02/05/2019

Revised : 30/07/2019

Accepted : 06/08/2019