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A study of the tectonic origin and the source of the clastic sediments of the Miankuhi formation in the Tarik Dareh region (Torbat Jam, NE Iran)

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Abstract

The study area is located in the northeast of Iran. Miankuhi Formation is 500m thick and comprises homogeneous shales, brown granular sandstone and siltstone. In this study, 45 samples were taken from Miankuhi shales and sandstones in order to determine their tectonic origin by using a polarizing microscope. Samples were analysed by X-Ray Fluorescence (XRF) method to determine their chemical compositions and tectonic origin. Twelve shale and siltstone samples were also analysed by the X-Ray Diffraction method with the aim of identifying their mineral composition. According to the investigations conducted, the type of sandstone is greywackes. Based on XRD results, quartz, albite, orthoclase, calcite, kaolinite, and illite have existed in shales and siltstones. Chemical analysis of the rocks indicated the source of these clastic rocks as oceanic arc areas and active peripheries of a landmass. The corrosive rocks of this formation are believed to originate from intermediate felsic igneous rocks and to a lesser extent from clastic quartz-containing rocks in the region.

Keywords: *Clastic rocks, Kopet-Dagh, Tectonic origin, Triassic*

1. Introduction

Aghanabati (2004) presented the clastic rocks of the Kopeht-Dagh sedimentary basin in northeast Iran as an exceptional Iranian Triassic facies. He believed that the Early and Middle Triassic rocks of two regions of Agh-Darband in (Kopeht-Dagh) and Nakhlak in (Central Iran) contain special biological facies that are dissimilar to the other regions of Iran. One of the most obvious geological differences of the area is the occurrence of Triassic rocks by 20 km in length and between 2 and 4 km width by west-northwest direction exposed in an imbricated zone (Fig. 1). Because of this, the lower parts of the Triassic sequences in this region are not so clear.

Ruttner (1983) renamed Agh-Darband Triassic as Agh-Darband Formation, which contained four members. In the subsequent rethinking in Ruttner et al. (1991), they changed the name of the Agh-Darband Formation to the Agh-Darband Group, comprising limestones at the bottom (Sefidkooh and Nazarkardeh Formations). Sina Formation is a volcanoclastic strata, and Miankuhi Formation a silisiclastic strata at the top. The Sefidkooh, Nazarkardeh in particular, and Sina are unique in Iran, while shaley deposits (Norian) of the Miankuhi Formation resemble the coal-bearing deposits of the upper Triassic deposits of Alborz and Central Iran, both in terms of age and in rock facies.

The exclusivity of the lower and middle Triassic rocks can be an indicator of the independence of the Kopeh Dagh region while the similarity of the upper Triassic rocks of this region is indicative of the integration of the Iranian and Turan plates, which joined in the pre-Norian stage. Eftekharnezhad and Behroozi (1991) proceeded to produce a geological map of the tectonic window of Agh-Darband and thus differentiate its Miankuhi Formation. The GSI (1993) endeavoured to produce and publish the geological map of Torbat Jam in the scale of 1:250,000. Alavi et al. (1997) compared the Agh-Darband complex with the deposits from the Nakhlak Triassic in Central Iran and declared these complexes as almost identical and as being the residue of the perimeter of an active landmass on the southern edge of the Turanplate. Ghaemi (2003) and Ghaemi (2009) investigated and analysed the formation and the relationship between sedimentation and tectonics of the Agh-Darband region. Torshizian (2010) investigated the economic potential of the Miankuhi Formation in the North of Torbat Jam (South of Agh Darband), which formed the basis of the investigation of the source of the Triassic clastic facies of this region.

2. Method

Forty-five samples from shale and sandstone were collected and investigated, using the polarization

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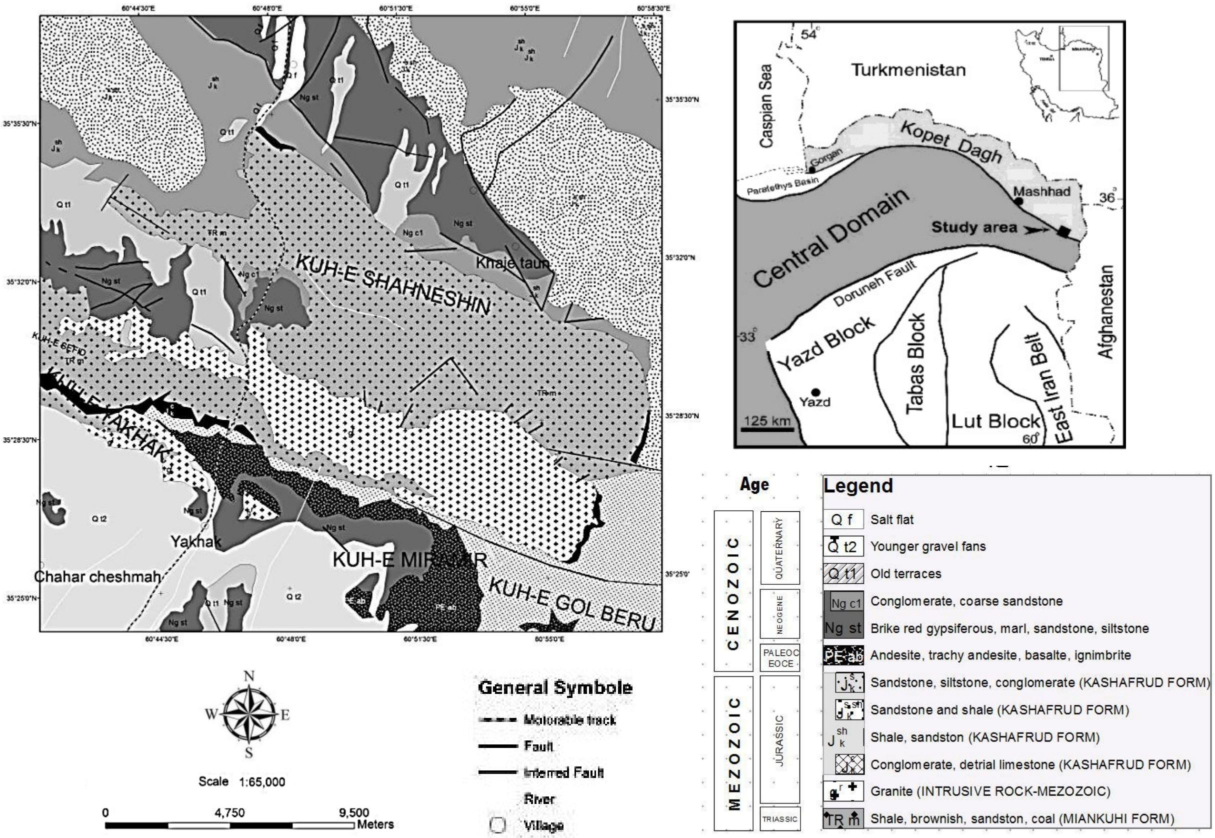

Fig. 1: Geographical location of the Miankuhi Formation at Tarik Dareh region (NE Iran)

microscope and the Dickinson and Suczek (1979); Dickinson (1985) diagrams in order to determine their tectonic origin. Twelve shale and siltstone samples were also analysed by the X-Ray Diffraction method with the aim of identifying their mineral composition. In addition, thirty samples were analysed by the X-Ray Fluorescence (XRF) method at Amitis Shargh Laboratories so as to determine their chemical compositions and type. Diagrams produced by Pettijohn et al. (2012) and Herron (1988) were implemented in order to classify the regional sedimentary rocks. Diagrams provided by Roser and Roser and Korsch (1986); Roser and Korsch (1988) and Bhatia (1983) as well as Bhatia and Crook (1986) were utilized in order to determine the tectonic provenance and position of sedimentary facies of the region. The Roser and Korsch (1988) method was also used to determine the origin and source of the sedimentary rocks of the Miankuhi Formation.

3. Geographical Location

The area is located in the northeast of Iran and 40 km northeast of Torbat Jam in Khorasan Razavi Province and between 60.45° to 61.00°E and 35.21° to 35.30°N. This area is situated in the southern frontier of Kopeht-Dagh and Central Iran (Fig. 1).

4. Discussion

4.1. Lithology and Geography:

The Miankuhi Formation is 200m thick at the type section Aghanabati (2004). This thickness has increased to 500m in the region because of the activities of the existing faults. This formation comprises homogenous shales containing brown granular sandstone and siltstone inter-layers (Fig. 2). Generally, the Miankuhi Formation is made up of three units in the study area. The lowest unit is a coal-bearing layer adjacent to the Torbat Jam granitoid mass and assumed horn felsic (Akrami 1999). Sandstone layers containing greywacke feldspathic, lithic greywacke and, to a lesser extent, poorly sorted fine sub-arkose to fine sublitarenites and rock alongside siltstone lay on top of the aforementioned layer. Greywacke feldspar sandstones contain 70 to 80% quartz and these consist of more feldspar than lithics (Fig 3A). These rocks contain 10% feldspar, mainly of the plagioclase type, though some orthoclase feldspar is also apparent. They also are made up of fine to medium grains of sizes of 0.625 to 0.25 millimetres. This facies also contains 20% clay matrix. The lithic greywacke sandstones comprise 80 to 85 per cent quartz and contain a higher quantity of lithic fragments than feldspar. The lithic fragments are mainly sedimentary rock fragments of chert type. Grain components are fine to medium sand size. This facies has poor sorting and 18% clay matrix is detectable in it. The frequency of lithic fragments fluctuates between 5 and 8 per cent in these rocks (Fig. 3B).

Brownish to grey, homogeneous without layering, shales are situated on top of the sandstones (Fig. 2). These shales are fossil-free, which had suggested a non-marine origin (Ruttner 1983). However, Eftekharnezhad and Behroozi (1991) reported benthic foraminifers of *Ammodiscus sp., Reophax sp., Nodlelum sp., Saccaminidaie sp., Textulariidae, Hypermmina sp., Ammobaculites sp., cf. Endothyra sp., cf. Heterohelix sp.* in this unit, which, according to the investigations of Oberhauser (1991), have *Equisetophyta sp., Neocalamites sp., Taeniopteris sp.,* and *Sphenobaiera sp.* of Norian age inside the coal-bearing layers. According to petrographic and geochemical analysis, the minerals are mainly comprised of quartz, albite and orthoclase with calcite, kaolinite, and illite.

Fig 2: A view of the grey-brown shales containing sandstone and siltstone interlayers of the Miankuhi Formation

4.2. Sedimentary facies and geochemistry:

Thirty samples were, in addition, analysed by the X-Ray Fluorescence (XRF) method so as to determine their chemical composition and tectonic and sedimentary origins (Table 1).

Pettijohn et al. (2012) used a chemical maturity profile and the ratio Na_2O/K_2O to propose a classification for clastic sandstones. It is determined by plotting (Na_2O/K_2O) against (SiO_2/Al_2O_3). This graph was also corrected by Herron (1988). According to this study, the sedimentary rocks in the study area are geochemicaly classified under greywackes (Fig. 4).

Herron (1988) corrected the Pettijohn et al. (2012) graph by replacing log (Na_2O/K_2O) by log (Fe_2O_3/K_2O) on the Y-axis. The total ratio of Fe_2O_3/K_2O facilitates the successful classification of arkoses. This ratio can also be used as a measurement for the stability of the minerals as ferromagnesian minerals are less resistant during weathering (Rollinson 1993). Sedimentary rocks are classified under shale, ferrous shale, and wackes, according to Heron's graph (1988) (Fig. 5).

4.3. Plate tectonics of the Miankuhi Formation:

Plate tectonics transfer special geochemical characteristics to the sediments in two ways. Firstly, various tectonic environments possess special resource features and, secondly, these environments are identified by specified sedimentary procedures. Sedimentary basins may be related to the tectonic settings (Bhatia and Crook 1986).

The Rouser and Korsch graph (1986)

This graph was designed on the basis of the ratio SiO_2 to log (Na_2O/K_2O). The three tectonic settings of passive margins (PM), active continental margins (ACM), and oceanic island arc (OIA) are identified on this graph. The clastic rocks of the Miankuhi Formation are attributed to oceanic arc environment and active continental margins (Fig. 6).

The Bhatia Graph (1983)

This graph is designed on the basis of the following discriminant functions:

The first discriminant function =

$-0.044\ SiO_2 – 0.972TiO_2 + 0.008Al_2O_3 – 0.267Fe_2O_3 – 0.208FeO – 3.092MnO + 0.14MgO + 0.195CaO + 0.719Na_2O – 0.032\ K_2O + 7.51P_2O_5 + 0.303$

The second discriminant function =

$-0.421\ SiO_2 + 1.988TiO_2 – 0.526Al_2O_3 – 0.551Fe_2O_3 – 1.61FeO + 2.72MnO + 0.881MgO + 0.907CaO + 0.117Na_2O – 1.840\ K_2O + 7.244P_2O_5 + 43.57$

Bhatia (1983) plotted a graph based on the abovementioned functions and classified sandstones that originated from various tectonic settings. As can be seen in Figure 7, the sandstones of Miankuhi Formation originated from active continental margins.

The Bhatia Bivariate Graphs (1983)

The present-day sandstones, related to continental arcs, oceanic arcs and active and passive environments, are made up of different quantities, especially of MgO+Total FeO, $Al_2O_3/Na_2O/K_2O$, and $Al_2O_3(CaO + Na_2O)$. Bhatia (1983) used this diversity in the chemical composition to determine the tectonic settings in a set of bivariate graphs, as shown below. These diagrams indicate the continental arcs and active margins for Miankuhi Formation (Fig. 8).

4.4. The origin of the sedimentary facies of the Miankuhi Formation, based on the main elements

In order to determine the origin of the clastic rocks of the Miankuhi Formation, the Roser and Korsch (1988) graphs were used and discriminant functions used the following plotted, as in Figure 7.

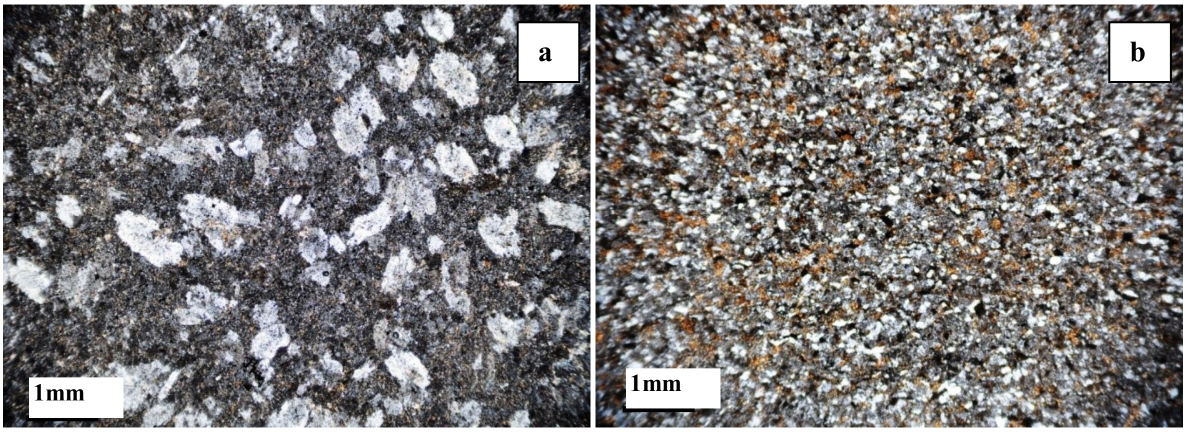

Fig 3: Miankuhi sandstones: a) a greywacke feldspar sandstone b) a lithic greywacke feldspar sandstone

Table 1: Chemical analysis of the sandstone samples of Miankuhi Formation

Sample	SiO_2	Al_2O_3	Na_2O	MgO	K_2O	TiO_2	MnO	CaO	P_2O_5	Fe_2O_3	LOI
TD.1	64.12	16.85	2.44	1.05	3.16	0.59	0.04	2.41	0.12	4.95	3.99
TD.2	65.73	15.32	3.78	1.9	3.97	0.48	0.09	1.66	0.11	4.19	2.42
TD.3	67.05	14.74	3.54	1.68	4.61	0.41	0.08	1.32	0.09	4.16	1.96
TD.4	63.16	17.82	2.17	1.25	4.66	0.95	0.07	0.76	0.12	4.85	3.8
TD.5	71.1	12.95	3.19	1.99	1.12	0.64	0.08	1.54	0.13	5.02	1.99
TD.6	73.66	12.07	2.85	1.84	0.8	0.46	0.07	0.72	0.11	5.04	2.19
TD.7	67.39	14.75	3.02	1.36	4.47	0.37	0.09	2.31	0.09	4.09	1.73
TD.8	69.06	14.54	2.99	1.17	4.63	0.34	0.06	1.48	0.09	3.59	1.71
TD.9	69.1	14.33	3.08	1.46	4.96	0.33	0.06	1.21	0.09	3.46	1.63
TD.10	68.3	14.72	2.75	1.39	4.05	0.37	0.06	2.76	0.09	3.77	1.38
TD.11	68.84	14.8	3.32	1.15	4.59	0.35	0.06	1.58	0.09	3.35	1.55
TD.12	67.22	14.42	2.87	1.31	4.22	0.46	0.09	3.18	0.17	4.32	1.43
TD.13	65.86	14.19	2.89	1.32	4.33	0.37	0.08	4.05	0.11	3.71	2.79
TD.14	69.45	14.53	2.83	1.31	4.75	0.33	0.06	1.22	0.09	3.28	1.88
TD.15	68.57	14.64	2.99	1.71	4.38	0.34	0.06	1.7	0.09	3.44	1.77
TD.16	66.69	13.38	3.29	1.35	4.17	0.35	0.07	3.41	0.09	3.32	3.59
TD.17	61.74	13.09	3.13	0.63	3.9	0.34	0.11	8.36	0.08	2.53	5.82
TD.18	71.29	13.86	2.89	0.75	4.82	0.28	0.05	2.03	0.08	2.76	0.91
TD.19	70.25	14.13	3.14	1.13	5.02	0.29	0.05	1.15	0.08	2.89	1.62
TD.20	66.68	14.34	3.11	2	3.96	0.52	0.09	2.28	0.15	4.65	1.87
TD.21	65.23	14.89	3.07	1.91	4.09	0.51	0.08	2.54	0.16	4.42	2.73
TD.22	66.12	14.67	2.8	1.81	3.66	0.56	0.08	3.27	0.18	4.68	1.84
TD.23	68.6	14.93	2.84	1.32	4.82	0.33	0.05	1.88	0.09	3.18	1.66
TD.24	66.07	15.04	3.18	1.79	3.75	0.5	0.09	2.11	0.16	5.13	1.89
TD.25	68.03	14	2.68	1.55	4.41	0.46	0.08	2.51	0.15	4.25	1.59
TD.26	64.82	15.15	3.96	1.68	4.03	0.49	0.09	2.05	0.16	4.63	2.64
TD.27	67.21	14.89	3.4	1.93	4.2	0.45	0.08	1.41	0.14	4.1	1.9
TD.28	75.86	13.18	2.54	0.03	6.59	0.03	0.02	0.31	0.01	1.04	0.22
TD.29	67.78	14.6	3.51	1.53	4.52	0.4	0.08	1.6	0.12	3.89	1.66
TD.30	71.92	13.42	3.22	0.43	4.33	0.19	0.06	1.07	0.04	3.22	1.87

The first discriminant function =
$-1.773TiO_2 + 0.607Al_2O_3 + 0.76\ Fe_2O_3 - 1.5MgO + 0.616CaO + 0.509Na_2O - 1.224\ K_2O - 9.09$

The second discriminant function =
$0.445TiO_2 + 0.07Al_2O_3 + 0.25Fe_2O_3 - 1.142MgO + 0.438CaO + 1.475Na_2O + 1.426\ K_2O - 6.861$

The origin of the clastic rocks of the Miankuhi Formation is associated with the intermediate to felsic igneous rocks, and also with clastic quartz-rich rocks.

Roser and Korsch (1988) also used a different graph to determine the origin of clastic rocks, which incorporates the following discriminant functions:

The first discriminant function =
$30.638\ TiO_2 / Al_2O_3 - 12.541\ Fe_2O_3 / Al_2O_3 + 7.329MgO/Al_2O_3 + 12.031Na_2O/Al_2O_3 + 35.402\ K_2O/Al_2O_3 - 6.382$

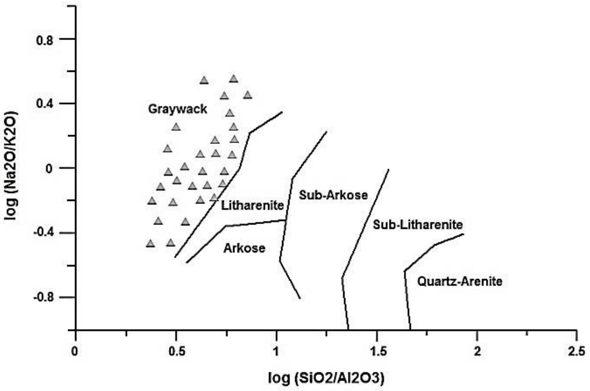

Fig. 4: Geochemical classification of Miankuhi rocks, according to Pettijohn et al. (1972)

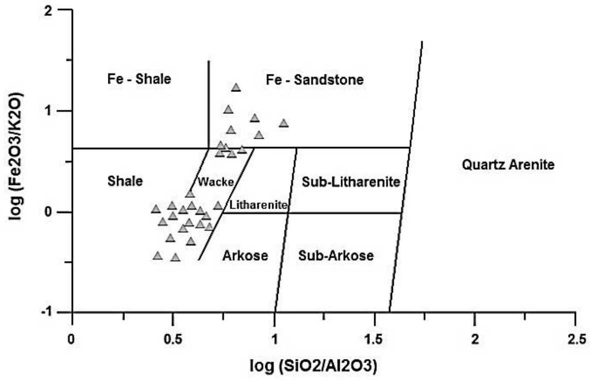

Fig. 5: Classification of Miankuhi rocks, according to Heron (1988)

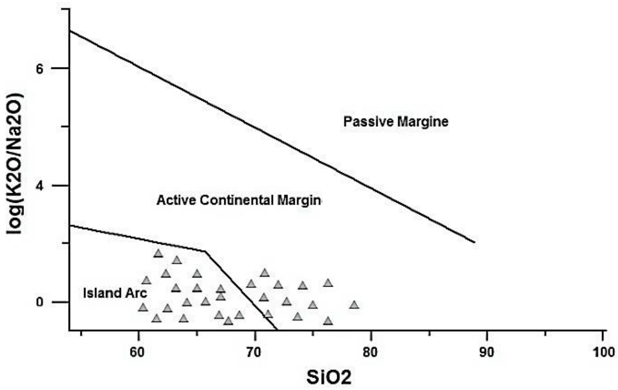

Fig. 6: Determination of the tectonic setting of the Miankuhi Formation, according to Rouser and Korsch (1988)

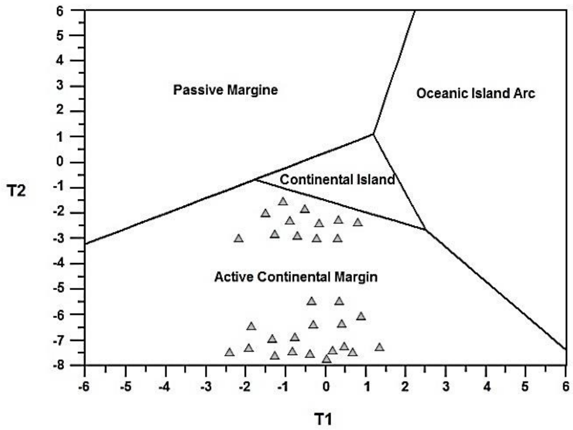

Fig. 7: Determination of the tectonic setting of Miankuhi Formation, according to Bhatia (1983)

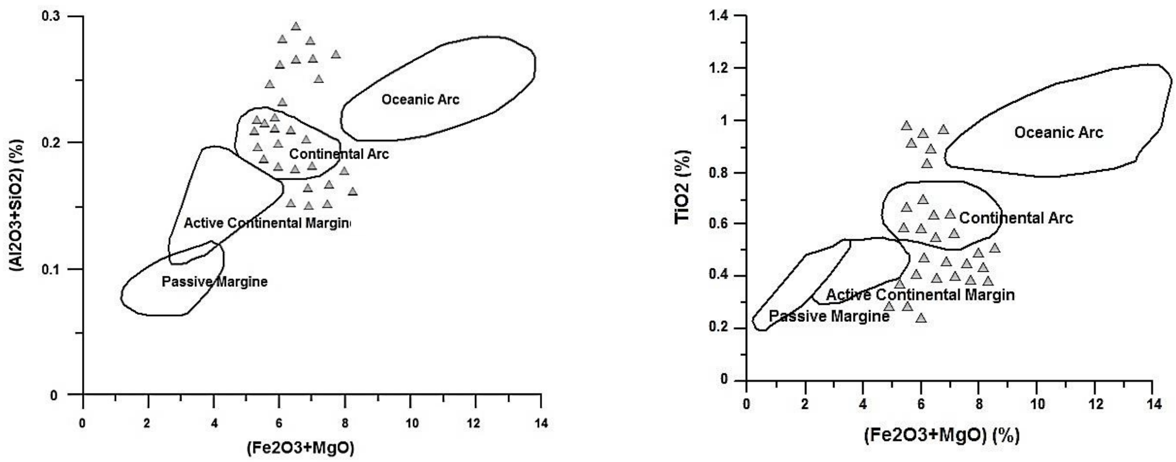

Fig. 8: Determination of the tectonic setting of the Miankuhi Formation, according to the Bivariate Graphs of Bhatia (1983)

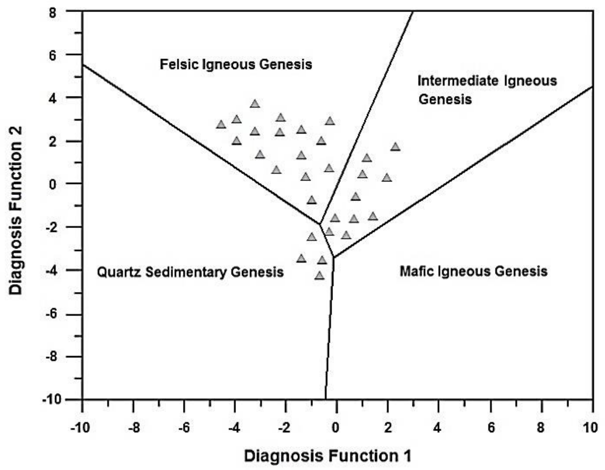

Fig. 9: Determination of the origin of the clastic rocks of the Miankuhi Formation, based on the main elements (Roser and Cruise, 1988)

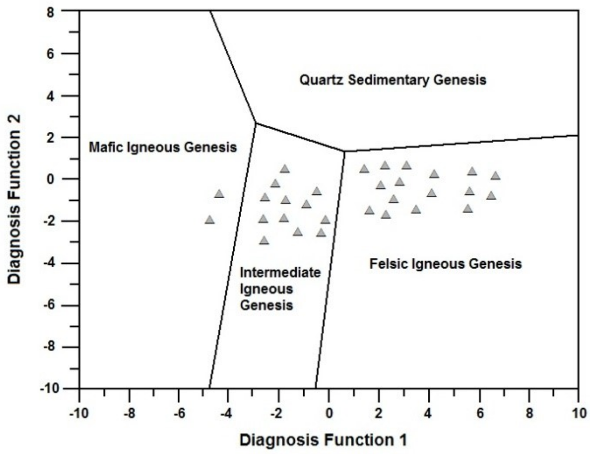

Fig 10: Determination of the origin of the clastic rocks of the Miankuhi Formation, based on the main elements (Roser and Cruise, 1988)

The second discriminant function =
$56.500\ TiO_2 / Al_2O_3 - 10.879\ Fe_2O_3 / Al_2O + 7.329\ MgO / Al_2O_3 + 5.404 Na_2O / Al_2O_3 + 11.112 K_2O / Al_2O_3 - 3.89$

Based on Fig. 10, the origin of the clastic rocks of the Miankuhi Formation is determined to be the intermediate to felsic igneous rocks.

4.5. Tectonic history of the Miankuhi Formation at Tarik Dareh

At the Upper Triassic in the NE of Iran, the flysch depositional basin developed between the two continents, while the continental margins of the Central Iran and Turan plate were approaching one another. It vanished, turning into a quite shallow and swamp-like foreland basin. Coals are formed within this basin, followed by the deposition of Miankuhi brownish grey shales containing siltstone and fine-grained sandstone inter layers (Fig. 11). Tectonic observations—along with the sedimentary characteristics of this rock unit—suggest that these rocks are deposited in a foreland basin. This basin is formed on the forehead of the uplifted regions on the southern edge of Turan during the impact with the Central Iran Plate, and simultaneously of the Cimmerian orogeny (Alavi et al. 1997). Therefore, the Miankuhi Formation and its equivalent Shemshak Formation (Latian to Lias), are formed in a single basin, but the difference is that the shales of the Miankuhi Formation are formed in the most northern parts and on the Turan basement, whereas the Shemshak Formation is deposited on the most southern areas on the Central Iran basement (Ghaemi 2003).

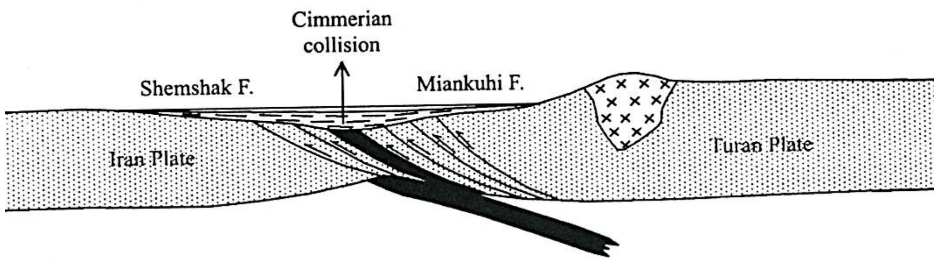

Fig 11: Diagram showing the late Triassic impact of the Central Iran and Turan plates and the establishment of the Miankuhi Formation (Ghaemi 2003)

5. Conclusion

At the Upper Triassic in the NE of Iran, the flysch depositional basin developed between the 2 continents, while the continental margins of Central Iran and Turan were approaching each other, and vanished, turning into a quite shallow and swamp-like foreland basin. Coals are formed within this basin followed by the deposition of Miankuhi brownish grey shales containing siltstone and fine-grained sandstone inter layers with a thickness of more than 500m. The sandstones of this formation include various types of greywacke, ferrous sandstone, and shale, which were formed in active continental margins and oceanic island arcs. They probably originated from the clastic rocks of intermediate to felsic igneous rocks and also from clastic quartz-rich rocks of the edge of the basin.

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