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Pre-rifting Evidence of Paleotethys in the Southwest of Shahrood, Northeastern Iran

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Abstract: Vast alkaline basalt lavas mainly submarine in nature and with the age of Silurian have been identified in both north and northeast of Iran. These include Soltan meydan submarine basalts in the Abr, Abarsedje and Mayghane valleys in basal basalts of Khosh yeilagh Formation, in the northeast Shahrood and were formed during rifting. Their petrological properties are indications of extensional forces of Paleotethys rifting. In the other hand the signs of preliminary inflammations for Paleotethys rifting in this region must began in Upper-ordovician whose relicts can be observed mainly in the form of tholeiitic basaltic lavas. Within the Ordovician sediments of Ghelli formation, in southwest Shahrood, Iran, there are a number of igneous rock units, which are exception in a sense that they are the only igneous rocks within a sedimentary rock dominated terrain. Field observations and laboratory studies show that these rocks are tholeiitic basalt submarine lavas. These lavas erupted simultaneous with the precipitation of Ghelli sediments. In the other hand, preliminary inflammations for Paleotethys and its began relicts in Upper-Ordovician, whose can be observed near the ocean creation in the form of tholeiitic basaltic lavas. Considering all above, both extensional forces and asthenosphere ascend are the cause of preliminary inflammations and fracturing commencement for pre-rifting of Paleotethys.

Key word: Evidences . paleotethys . pre-rifting . shahrood . Iran

INTRODUCTION

The subject of paleothethys and timing of its creation have always attracted the attention of geologists. A number of different geological periods have been suggested as the time of initial inflammations and pre-rifting fracturing commencements. In this research, by using stratigraphic and petrologic evidences, geological time interval of inflammation, rifting and formation of paleotethys have been determined. On the basis of these investigations, the initiation of inflammations and fracturing commencements with volcanic activities during Upper-Ordovician while the rifting for oceanic creation during Middle-Upper Devonian.

The study area is situated approximately 20 Km southwest of Shahrood, in northeastern Iran. It is called Kuh-e-Kharbash and is located to the north of Deh-molla Village, near the Mine (Fig. 1) which is an abandoned mine currently in use for educational purposes. Geologically, the study area is a sedimentary rock complex whose age ranges from Cambrian to Jurassic. It is a part of the central Alborz mountain range, lying close to the western boundary of these mountains. In this area, Paleozoic rock units display major changes towards eastern and western Alborz ranges [1]; Upper Ordovician and Silurian deposits are progressively disappeared toward the central Alborz range and in the western Alborz range the entire Ordovician and Silurian deposits are completely absent. However, toward eastern Alborz (Kopeh-Dagh region), Upper Ordovician and Silurian outcrops are extensively distributed.

There is no metamorphic rock present in the above mentioned Formations. Igneous activities in the form of volcanic eruption were extensive in the region especially during Silurian. These lavas are generally submarine basalts [2]. Silurian igneous activities known as Soltan meydan formation are not seen in the study area. However, in Ordovician deposits, known as Ghelli Formation, there are a number of igneous rock bodies (Fig. 1), which have not yet been studied in detail. The objective of the current paper is to report on the geochemistry, petrogenesis and the relationship of these rocks to the creation of Paleotethys.

Sratigraphy: In the study area, there are a number of formations with varying ages and lithology. Southward, these formations are generally of Paleozoic age. The Paleozoic strata, well exposed in Kuh-e-Kharbash, consist of Mila, Lashkarak, Ghelli and Geirud Formations in ascending stratigraphic order (Fig. 2).

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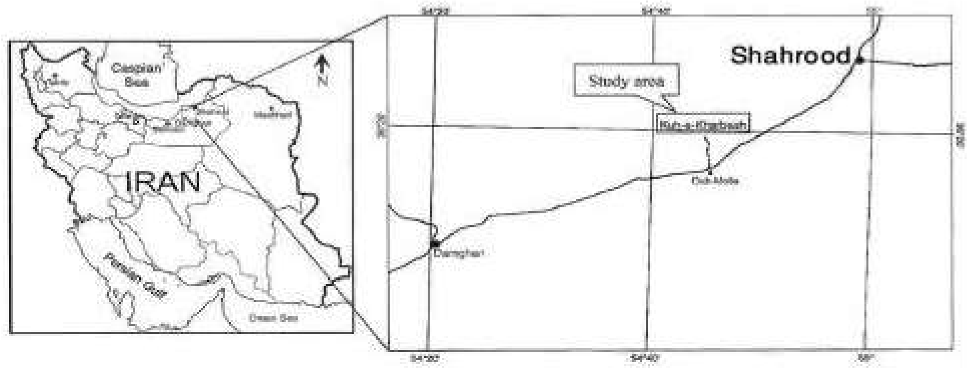


Fig. 1: Location of the study area in southwest Shahrood, Northeastern Iran

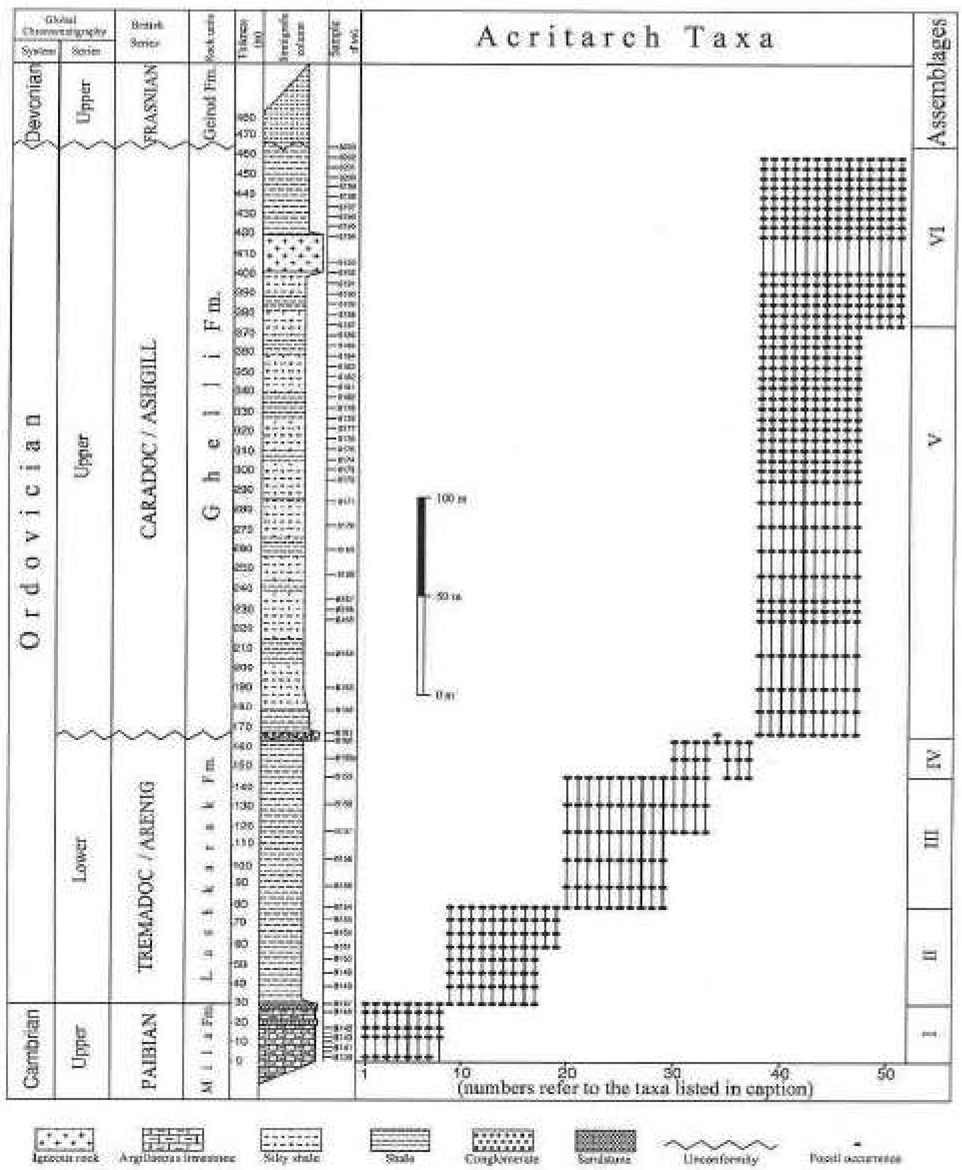


Fig. 2: Simple stratigraphic column of Ghelli Formation and its overlying and underlying formations [4]

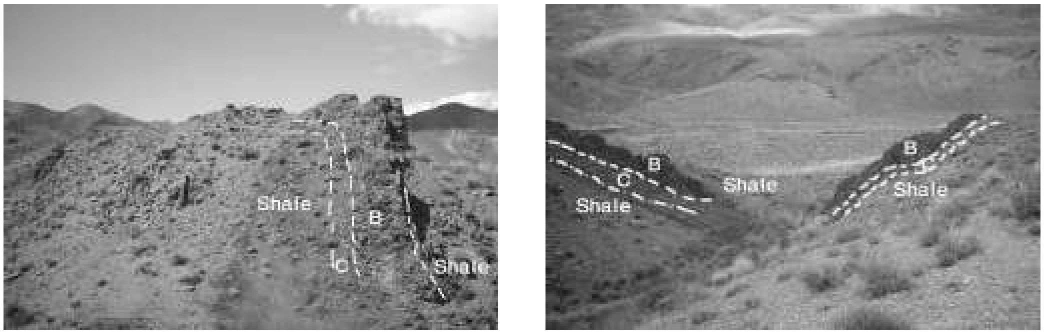


Fig. 3-4: Lavas (B) and baking effects (C) in its basal layer are illustrated

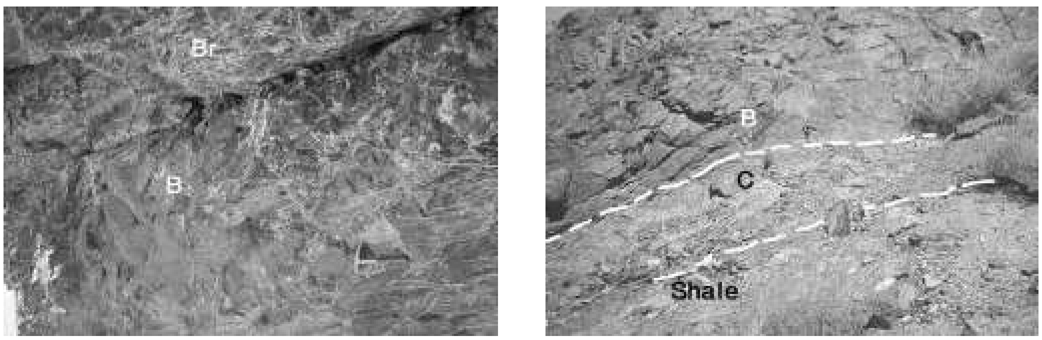


Fig. 5-6: Baking of shale underlying lava is illustrated (C), B = lava and breccial surface (Br) of lava

These formations are located close to the northern side of a west-east anticline [3], which plunges toward west.

Mila Formation mainly comprises of limestone with abundant trace of fossils (trails, tracks and burrows) especially at its upper parts. Dominant fossils are Trilobites and Brachiopods. Based on Trilobite fauna, this Formation-at its type section-has been assigned to Middle and Upper Cambrian [5]. Due to faulting, the lower boundary of Mila Formation is not clear, though its upper boundary with Lashkarake Formation is conformable.

Lashkarake Formation, 135 meter in thickness, consists mostly of gray-olive shale. Based on acritarch fossils present in the other parts of the Alborz range, its age has been assigned to Lower Ordovician [6-8]. Its upper and lower contact surfaces with overlying and underlying Formations are conformable.

Ghelli Formation, 299 m thick, is located in the study area and consists mainly of olive-grey, silty shale and dark gray shales. The lower and upper contacts of this Formation are disconformable with the underlying Lashkarak Formation and the overlying Geirud Formation. Ghelli Formation lacks macro fauna, but there are trace fossils in some parts of it. On the basis of palynological cross sections, its age has been determined as Middle-Upper Ordovician [6-10].

In Deh-molla region, there are multiple igneous bodies in Ghelli Formation (midelle and near the top) which are the subject of this research. These rocks have sill like appearance, but more precise evaluation have shown that they are lava in origin and contain baked shale (red color) in their basal part (Fig. 3-5). Lack of baking sign in their upper contact, presence of breccial surfaces (Fig. 6) and presence of small lava fragments within the overlying shale are all evidences that suggest that these bodies are lava and not sills. Lassemi [11] also showed that submarine lavas are present in Ghelli Formation and its origin and occurrence was simultaneous with the occurrence of syn-rift.

Geirud Formation is typically represented by red shale and white sandstone, changing to an alternation of shale and fossiliferous limestone toward the top. This Formation contains both marine macrofauna and palynomorph entities and based on this combined biostratigraphical data, its age has been assigned to Upper Devonian [6, 12].

MATERIALS AND METHODS

Visual inspection of a few outcrop of the igneous bodies in the Ghelli Formation in the study area raised some questions such as: Are these sill shaped lithologies can be considered lava flows? What kind of

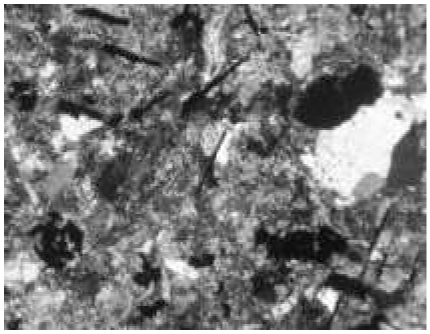


Fig. 7-8: Vesicules filled with secondary minerals in microscopic and macroscopic samples

rocks are these from the petrological and geochemistry point of view? What was their environmental and effusive process and what is the age and relationship between their effusion and geological processes at the effusion time?

In order to answer these questions, further field as well as laboratory studies were deemed necessary. A number of field visits were therefore arranged and 38 rock samples were collected for detail analysis. After preparation of thin sections at Shahrood University of Technology laboratories and follow up petrographical studies, six fresh samples were sent to the Geological Survey of Iran (GSI) laboratories for XRF analysis. The results of the analysis were assessed and interpreted using GDC.Kit, IGPET and Excel soft wares. Data of field evidences and laboratory analysis are presented in the following sections.

Petrography: Sampling from submarine basalts of Ghelli Formation, with dark color and diabasic appearance, is a difficult task. No mineral can be seen with naked eye, but the filled vesicules minerals (calcite and quartz microcrystal) are visible (Fig. 7 and 8) which demonstrate their effusive environment. In the thin sections, minerals show high alteration. These minerals consist of plagioclase, ferromagnesian minerals and opaque minerals which accompany some secondary minerals such as calcite and quartz. Damourittization and Saussoritization in Plagioclases are common and easily recognizable, but ferro-magnesium minerals have been altered to chlorite and are not identifiable (Fig. 8). Opaque minerals are mainly automorphes and unaltered. Calcites, which are present in some rocks, have originated from the alteration of main minerals such as plagioclase and clyno-pyroxene and are scattered and amorphous. Some of them fill vesicules and have entered rock from outside (ex-situ origin). Withn the mesostase of these rocks (not vesiculaires), somes free SiO_2 is present in the form of both quartz as well as amorphous, which quartz are resaults of amorphous free SiO_2 re-crystallization.

The age of lavas: Potassium-Argon dating method is not the best to date the absolute age of igneous rocks in this study. However, this method was the only one which has been in access. Therefore, a lot of efforts and co-ordination were made and a number of samples were sent to C.N.R.S institute in Montpellier, France in a number of occasions. However, due to sever alteration of the samples and the complexity of the analysis, it is not possible to determine the age of samples. We have, however, one fact and that is these rocks are lava. Consequently, it is possible that these rocks (guests) have erupted at the same time as host sediments precipitated. These sediments in Deh-molla region consist of alternation of shale, gray mica siltstone and gray-olive shale with the traces of fossils and a large number of sedimentary structures. As a result, these sediments are assigned to late-Ordovician [1]. Recently, paleontological studies [5] have also reinstated the same age for the deposits in question.

Magma petrogenesis and geochemical: Due to severe alteration, sampling for chemical analysis of igneous rocks in this area has been very difficult. For this, there may be some limitations in the accuracy and precision of the chemical analyses which are presented in Table 1.

According to petrogenesis and geochemical diagrams, these lavas show some relationship to basaltic rocks and tholeiitic and toleiitic-calcalkaline series. On the basis of tectonic environments, they belong to extensions and rifts settings. The value of some oxides such as SiO_2 (42.45-50.66%) and total FeO (>12) are high whilst some others such as MgO, P_2O_5, K_2O, Na_2O, Al_2O_3 are low. This shows their association to tholeiitic series.

AFM, Al_2O_3-An and Al_2O_3-FeO_t/ FeO_t + MgO diagrams also show that these volcanic rocks belong to tholeiitic series (Fig. 9). In Le Bass diagram [13],

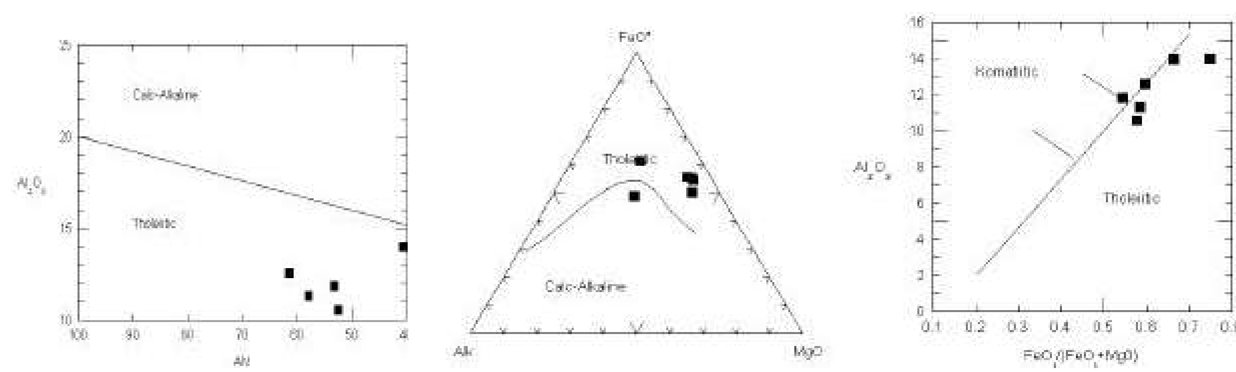
Table 1: Chemicals analysis of samples and norm calculations

Samples	SiO_2	Al_2O_3	FeO	MgO	CaO	Na_2O	K_2O	MnO	TiO_2	P_2O_5
HD1	46.44	13.99	16.60	5.58	8.75	3.22	1.70	0.23	2.70	0.79
HD2	51.67	13.96	12.23	6.21	6.42	3.28	3.21	0.11	2.04	0.87
HDS1	43.98	10.57	20.09	14.67	5.47	1.97	0.17	0.08	2.81	0.20
HDS2	44.01	11.84	16.36	13.63	7.26	2.07	0.63	0.24	3.61	0.35
HDS4	45.37	12.58	17.93	12.08	5.99	1.75	0.47	0.04	3.57	0.22
HDS6	44.20	11.31	19.58	13.88	5.65	1.80	0.21	0.07	2.98	0.33

Samples	%AN	or	ab	an	ne	di	hy	ol	mt	il	Ap
HD1	41.34	10.22	27.13	19.12	1.41	15.97	0.00	16.12	4.51	3.83	1.68
HD2	31.99	19.10	29.67	13.96	0.00	9.90	12.26	6.69	3.75	2.86	1.82
HDS1	52.47	0.99	17.78	19.63	0.00	5.10	20.73	26.83	4.59	3.93	0.41
HDS2	53.18	3.70	18.65	21.19	0.00	10.08	13.08	22.11	5.41	5.03	0.74
HDS4	61.42	2.83	15.96	25.41	0.00	2.59	33.33	9.58	4.79	5.04	0.47
HDS6	57.86	1.23	16.30	22.38	0.00	3.01	27.22	20.20	4.77	4.19	0.69

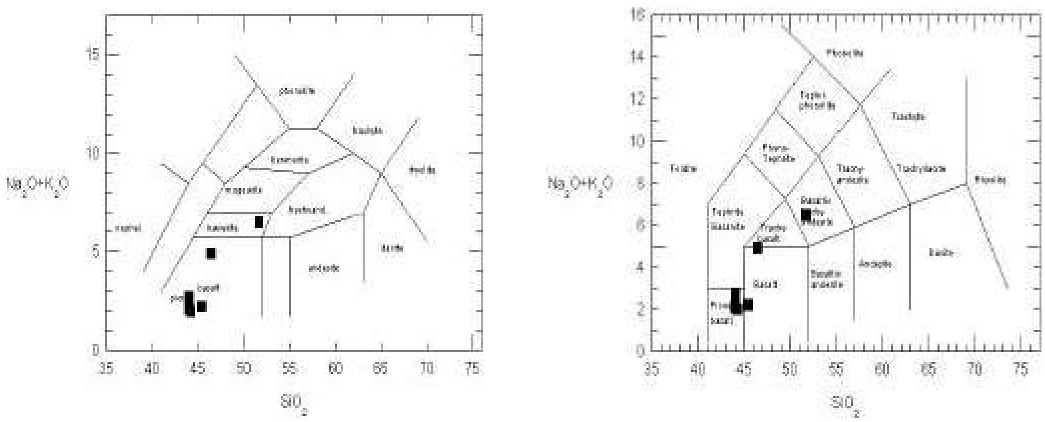
Samples	Ni	Rb	Sr	Y	Cr	Zr	Tb	Yb	Eu
HD1	34.90	29.60	518.10	40.20	37.30	174.7	2.10	2.50	2.10
HD2	85.90	82.60	720.10	37.20	81.60	258.1	0.00	2.70	1.30
HDS1	225.50	5.10	297.40	19.00	211.90	213.9	2.10	3.10	1.00
HDS2	124.00	13.80	224.00	34.90	166.30	177.2	1.30	4.10	1.30
HDS4	200.00	6.50	207.50	23.50	208.40	167.6	1.30	4.00	1.03
HDS6	134.50	8.50	290.10	25.50	154.20	210.3	1.20	3.00	1.10

Samples	Sc	Cu	Co	Zn	Cs	Ga	Mo	Sn	Th
HD1	38.20	60.00	48.10	163.60	8.80	24.90	3.50	3.40	8.80
HD2	20.80	29.40	37.40	119.20	9.20	28.60	2.70	3.20	10.50
HDS1	27.40	19.20	53.40	233.90	0.00	32.70	2.00	3.50	3.70
HDS2	34.40	81.40	52.00	269.30	5.70	25.50	2.80	3.60	4.50
HDS4	25.30	65.40	51.20	243.20	4.50	30.40	1.98	3.70	4.10
HDS6	26.20	20.50	53.00	250.00	6.50	31.20	2.20	4.10	4.00



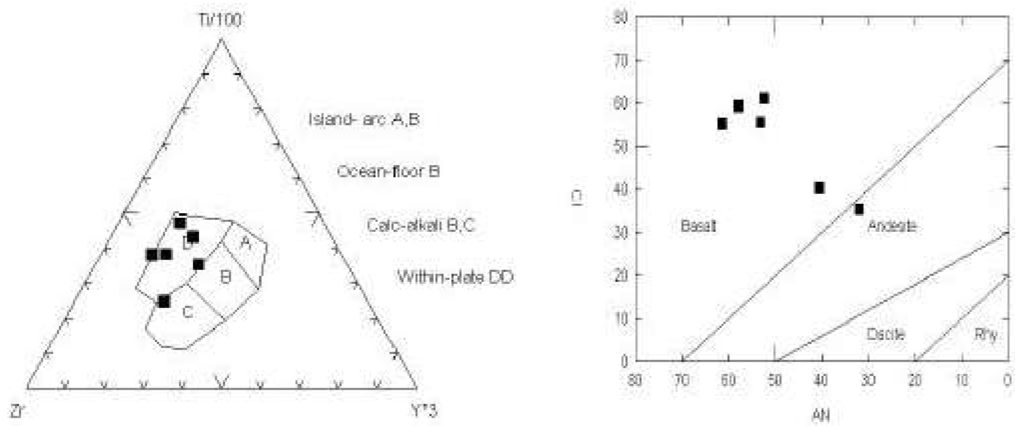
A B C

Fig. 9: Location of samples in (A)?AFM, (B) Al_2O_3-An, (C) Al_2O_3-FeO_t/FeO_t+MgO diagrams show that they are tholeitic



A B

Fig. 10: Location of samples in (A). Cox, (B) Le Bass, diagrams show that they are basaltic rocks



A B

Fig. 11: Location of samples in (A) Zr-Ti/100-Y*3 and (B) Cl-An diagrams show that they are basaltic rocks

they plot at picro-basalts, basalt and basaltic trachy-andesite area. In Cox diagram [14] they plot in basalt and hawaiites area (Fig. 10) and in Cl-An diagram they plot in the basalt area. In Zr-Ti/100-Y*3diagram [4], they plot within plate basalts area (Fig. 11).

All samples are strongly enriched in LILE and LREE which is an indication of high contamination by crust, metasomatic mantel or low rhythmic partial fusion [15]. Spiders diagrams of samples normalized to MORB and mantel show the same for MREE and LREE and can prove syngenetic nature of these lavas.

Aggressive tectonic and Paleotethys formation in Iran: Various evidences show that during Ordovician-Devonian, stable platform of Iran was involved in uplifting, extension of continental crust and rifting processes. This extension happened during pre-Ordovician with normal faults and occurrence of turbidity facies commenced in deep marine environment (member 5 of Mila Formation) [16].

Submarine basalts of Ghelli Formation (Ordovician), lower section of Neyour Formation and their equivalents (Soltan Meydan basalt in Shahrood Mayghane's valley and Masuleh Basalt in southern Alborz), the lower section of basalt in Khosh yeilagh Formation and Jeirud Formation etc, created at the time of earth crust extension and creation of rift [2, 17]. Lassemi [18], on the basis of sedimentary environmental study of Ordovician rocks of Iran, also concluded that during Ordovician (in contrast to Cambrian), deep sea conditions were dominated mainly in north and northeastern parts of Gondovana. Sedimentary structures like graded bedding, slumping slide, cross bedding, groove-cast and flute cast were reported by Lassemi [18].

Presence of tholeiitic lava with vesicules filled with secondary minerals indicates not only that, lavas were formed in deep sea, but also it shows that they erupted in an extensional environment. On the other hand, we know that the presence of elementary inflammables in

Fig. 12: State of continents in Ordovician. Proto-Paleotethys and Turin rift in the North of Iran are shown [17]

the pervious period is a necessity for rifting in Silurian. Stampfli [2], suggests that rift origin of Paleotethys is at the boundary of Ordovician-Silurian. From Lassemi point of view [11], however, Ghelli Formation facies associated with deep sea basalts is a sign of pre-Paleotethys condition in the extension phases of rift creation in Ordovician (Fig. 12).

In addition to some sedimentary structures such as flute cast, tool mark and load cast, biogenic structures and graded beddings were studied in the study area who, indicate that the turbidities currents had an important role in the evolution of this sedimentary basin [19]. Therefore, on the basis of field and laboratory evidences, lavas and the associated rocks prove that an earth inflamation and fracturing in Ordovician, but tectonic aggression and initiation of rift was related to Paleotethys during post Ordovician.

CONCLUSION

In visual inspection, igneous rock units in Ghelli Formation in the Deh-molla region of Iran have sill appearance; detail field study, however, does not approve this. Field evidences and laboratory analysis have demonstrated that these 'igneous rocks' are lavas which have exited in the deep sea. Shale and sandstone of Ghelli formation also have turbidity facies which support the deep depth origin. Presence of these submarine lavas with tholeitic natures suggest that they extruded in an extensional and inflammable environment. Dating of old and highly weathered igneous rocks is a cumbersome task, but paleontological studies of shales, which precipitated at the same time, suggests the age of Ordovician for the igneous rocks in question. Ordovician in Iran, particularly in north and northeastern part of the country, was a turbulent period and from tectonic point of view it was very active.

In conclusion, all the evidences point to the inflammability of Earth at this region in Ordovician which was caused by extensional forces and Asthenosphere ascends. This can be considered as an introduction to rifting in Silurian and ultimately opening of Paleotethys in Alborz range.

REFERENCES

1. Afshar-Harb, A., 1975. The Stratigraphic, tectonic and petroleum of Kopet-Dagh region, northern Iran. Ph.D. Thesis. Petrol. Sec. school of Mines, Imperial College, London, pp: 316.
2. Stampfili, G. Marcoux, J. and A. Baud, 1991. Tethyan margin in space and time. Paleogeog. Paleoecol., 87: 374-409.
3. Salehie Rad, 1979. Etude géologique de la région de Gorgan (Alborz oriental, Iran) These de docteur 3em cycle
4. Thornton C.P. Tutttle, 1960. Chemistry of igneous rocks: Part I, Differentiation on Index. Am. J. Sci., 258: 664-684.
5. Ghavidel-Syooky, M., 2006. Palinostratigraphy and Palaeogeography of the cambro-ordovician strata in the southwest of Shahrood city (kuh-e-Kharbash, near Deh-molla), central Alborz range, northern Iran, Rev. of Palaeobotany and Paleontology, 136: 81-95.
6. Ghavidel-Syooky, M., 1995. Palinostratigraphy and Palaeogeography of a Paleozoic in Hassanakdar area. Central Alborz range. Northern Iran. Rev. Palaeobot., 86 (1/2): 91-109.
7. Ghavidel-Syooky, M., 2000. Palinostratigraphy and Palaeogeography of lower Paleozoic strata in the Ghelli area, northeastern Alborz range (Kopet-dagh region). J. Sci. I.R. Iran, 11 (4): 305-318.
8. Ghavidel-Syooky, M., 2001. Palinostratigraphy and Palaeogeography of lower Paleozoic sequence in the northeastern Alborz range (Kopet-dagh region) of Iran, In: Goodman. D.K. and R.T. Clarke (Eds.). Proceedings of the IX international palynological congress Houston, Texas, USA, 1996. American Association of Stratigraphic Penologist Foundation, pp: 17-35.
9. Ghavidel-Syooki, M., 1996. Palyno-biostratigraphy and pale geography of lower Paleozoic sediments (Mila, Ghelli and Niur formations) at ghelli area in southwestern Bujnord city, Kopet-Dagh region, Estern Alborz range of Iran. National Iranian oil company, Geological Report No: 485.

10. Ghavidel-Syooky, M. and T. Winchester-seeto, 2002. Biostratigraphy and Palaeogeography of late Ordovician chitinozoans from the northeastern Alborz range Iran. Rev. Palaeobot. Palinol., 118 (1-4): 77-99.
11. Lassemi, Y., 1997. Depositional systems and sedimentary events of the early-late Ordovician syn-rift succession (Upper Sauk-lower Tippecanoe Sequence) in northern and central Iran. CSPG-SEPM joint convention, Calgary, Canada. Abstract, pp: 161.
12. Ghavidel-Syooky, M., 1994. Upper Devonian Arcritarchs and microspores from the Geirud formation in central Alborz range. Northern Iran, J.R. Iran, 5 (3): 102-122.
14. Cox, K.G., J.D. Bell and R.J. Pinehurst, 1979. The interpretation of igneous rocks, London Unwind Hyman, pp: 450.
15. Rollinson, H., 1993. Using geochemical data: Evaluation, presentation interpretation, Longman.
16. Lassemi, Y., 2000. Sedimentary environmental facies and sequences sediments Stratigraphic of Iran Upper Pre-Cambrian and Paleozoic, Book 78, Iran Igs (in Persian).
17. Berberian and King, 1981. Towards a pale geography and tectonic evolution of Iran. Can. J. Earth Sci., 18: 240-265.
18. Lassemi, Y., 2000. Sedimentary environments of Iran Ordovician rocks (Syn-Rift secretions) and Paleotethys and divergent margin creation. 18^{th} conference of earth sciences, (in Persian), pp: 158-16.
18. Le Bass, Le Maitre, Streckeisen and Zanttin, 1986. A chemical classification of volcanic rocks based on the total Alkali-silica Diagram, J. Pet., 27 (3): 745-750.
19. Vaziri, H. and A. Taheri, 2003. Ignofossils and Ignofacies of Upper-Ordovician studies in S-W of Shahrood (in Persian).