Occurrence of I-type granitoid in the Paleo-Tethys ophiolite and associated metaflysch (Mashhad, NE Iran)

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The Dehnow igneous body is a part of the NW-SE trending granitoid-metamorphic complexes along with Binaloud structural zone which is cropped out at the west to south of Mashhad city (NE Iran) and it forms an individual intrusive body intruded into the metamorphic rocks and flysch in the west of Dehnow [1].

This part of Iran is regarded as the suture zone (SZ) of Paleo-Tethys ocean closures. In the Paleozoic, the Tethys Ocean was separating Eurasia in the north from Gondwana in the south. The Iranian plate, as a part of Gondwana, was located at the southern margin of Tethys Ocean and Turan plate in the north. The northward subduction and closure of the Paleo-Tethys and subsequent collision between the Iranian Cimmerian Microcontinent and the Turan plate resulted in the obduction of ophiolite complexes and generation of metamorphic rocks and granitic batholith in Mashhad area [2, 3] and the granitoid-metamorphic complexes intruded into the remnant of Paleo-Tethys meta-ophiolite and associated metaflysch [2, 3, 4]. [2] related the obduction of the accretionary assemblage over the Iranian microcontinent to the prior of Late Triassic time. [4] suggested that Paleo-Tethys Ocean opened during Silurian time and subduction under Turan plate was started in Late Devonian and then Turan plate obducted over Iran Plate by Late Triassic (225 Ma). Then, in Triassic to Cretaceous, the Paleo-Tethys remnants (meta-ophiolite and meta-flysch) were intruded by granitic rocks. The obducted remnants of the Paleo-Tethys Ocean in Binaloud range include several rock assemblages including ophiolite complexes, meta-flysch and some submarine pyroclastics. [5] compared the meta-flysch with similar less metamorphosed, fossil-bearing rock exposed 150 Km southeast of Mashhad and given a Devonian-Carboniferous age for them. The ophiolite complexes and metamorphic rocks with a NW-SE trending belt are in the northern flank of Binaloud, and in the northern part Mashhad granitoids are located.

The pale grey tonalite of Dehnow is a xenolith free igneous body. It is mineralogically include of quartz (~20-30 vol. %), plagioclase (~45-50 vol. %), ferro-hornblende (~10 vol. %), and secondary and accessory minerals of annite-siderophyllite (~10-15 vol. %), almandine (-pyrope), muscovite, chlorite, epidote, calcite and ilmenite. The microscopical texture is granular and the mineralogy show a tonalite (-granodiorite) composition. Lack of sedimentary or metamorphic enclaves or minerals (i. e. cordierite, sillimanite, etc.), in neither macro- nor micro scale, is the most significant characteristics in this studied tonalite.

A quantitative chemical analysis of minerals was carried out by wavelength-dispersive EPMA, model JEOL JXA-8500F and JXA-8800 (XDS), at Institute for Research on Earth Evolution (Japanese Agency for Marine-Earth Science and Technology, Yokosuka, Japan). The analysis was performed under an accelerating voltage of 15 kV and a beam current of 15 nA. The standard ZAF data corrections were performed. Natural and synthetic minerals of known composition are used as standards. Whole rock chemical analyses were conducted by X-ray fluorescence spectrometry at Geological Survey of Iran.

Petrography and mineral chemistry reveals that quartz occurred as xenomorphic interstitial grain, show wavy extinction, and rarely contains inclusions of plagioclase. Plagioclases show zonation and polysynthetic twining and suffered saussuritization to some extent. They are andesine to labradorite in composition. Amphiboles that are mostly replaced with biotite and chlorite in the rims, are mostly ferrohornblende to ferro-tschermakite. The biotites which are formed at the expense of amphiboles are annite to siderophyllite in composition. Phenocrystic garnet reported by [1] with almandine composition.

According to geochemical data set it is tonalite (to granodiorite) in composition with SiO_2 ~ 62.2-66.5 wt%. It is metaluminous (A/CNK = 0.93-1.00) and according to the mineralogy, geochemistry, and the isotopic data of [4], they are calcalkaline I-type granitoid formed in an oceanic - continental subduction setting [6, 7]. SiO2, Fe2O3t and Rb/Ba are higher in sample from centre of the tonalitic body while Al_2O_3, MgO, Na_2O/K_2O and Sr/Y content are progressively enriched toward the marginal samples.

Sr/Y ratio (~18-61-23.68) and Y (~17-31 ppm) indicate an island arc affinity rather than adakitic for the studied tonalitic magma. Low content of Sr/Y suggests low content or lack of garnet in the residual phases of tonalitic parental magma.

The more immobile trace elements of Zr and Zn against SiO_2 content (on plot by [8]) display I–type magma origin. [4] performed an isotopic research on the intrusive rocks of Dehnow and they obtained $^{87}Sr/^{86}Sr$ = 0.707949 to 0.708589, $^{143}Nd/^{144}Nd$ = 0.512059 to 0.512019, and εNd = -6.63 to -5.90 for them. These values on the diagram of εNd versus $^{87}Sr/^{86}Sr$ by [9] clearly are plotted within the I-types field.

The isotopic data of zircon [4] show the mean age of ~215±4Ma (Late Triassic) and [5] suggested the age of Devonian-Carboniferous for the area metaflysch. Therefore, absence of sedimentary aged zircons (from Devonian-Carboniferous meta-

Sample No.	2.1	2.2	1.1	1.2	TD- 1	TD- 3	TD- 4
SiO_2	66.50	65.98	66.25	66.60	63.12	64.18	65.37
Al_2O_3	14.54	14.74	15.02	14.32	15.18	14.25	13.21
Fe_2O_3	5.09	5.21	4.68	4.98	7.07	7.07	7.37
CaO	4.52	4.62	4.81	4.80	5.86	5.29	4.61
Na_2O	2.09	2.22	2.29	2.03	1.85	1.71	1.62
MgO	2.28	2.28	2.12	2.29	2.14	2.52	2.56
K_2O	2.71	2.63	2.65	2.62	2.35	2.54	2.93
TiO_2	0.49	0.50	0.43	0.46	0.69	0.69	0.72
MnO	0.10	0.11	0.11	0.12	0.13	0.13	0.14
P_2O_5	0.14	0.16	0.16	0.16	0.23	0.23	0.21
LOI	1.08	0.96	1.25	1.09	1.22	1.19	1.15
Total	99.54	99.41	99.77	99.47	98.61	98.61	98.72

Table. Major elements of tonalite from Dehnow.

sediments of the area) in tonalite points out that the tonalitic magma source confidently could not be not connected to the melting of sourronding Paleozoic flysch and sediments in the area.

Dehnow igneous tonalite (- granodiorite) is a metaluminous I-type granitoids formed in an oceanic - continental subduction setting. Our conclusion is based on:

(1) Lack of sedimentary enclaves or nonmagmatic minerals (like cordierite, sillimanite and etc.) in the studied rocks simply describe that magma origin may not be related to the adjacent metasedimentary rocks.

(2) Based on geochemical data, we figure out that enigmatic nature of the Dehnow tonalite is definitely an I-type granitoid developed in a more deep magma origin or an extensional tectonic setting. It is metaluminous (A/CNK = 0.93-1.00) and I- type amphibole-bearing calcalkaline granitoids (ACG) formed in an oceanic - continental subduction setting. The tonalitic melt may experienced little contaminatation by the lower crust material and then undergone nearly shallow alterations.

(3) The isotopic data of zircon and whole rock as mentioned in previous paragraphs.

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