Geochemistry of Gabbroic and Diabasic sills in the Central Alborz

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1. Geological Setting

There are several gabbroic and diabasic sills, in the central Alborz, which represent about 150 meter thickness. These intrusive rocks are overlaid by Khosh-Yeylagh formation (Devonian period) and underlain by Mobarak formation (Carboniferous period). So their stratigraphic positions indicate an epoch between late Devonian and early Mississippian. These intrusive sills spread through the Alborz structure zone between two main Iranian geological sedimentary formations as a key bed and may imply an extensional zone in Iranian Paleozoic platform. These extension movements were reflected by Hercynian orogenic movement in Europe.

2. Petrography

These intrusive rocks represent range of variety of gabbroic compositions including Olivine-gabbro, Hornblende-gabbro, Hornblende pyroxene-gabbro, and Pyroxene-gabbro. Rock textures in these sills gradually vary from center to margin, so that coarse grain gabbros slowly convert to fine grain diabase. Because of Paleozoic age, these rocks experienced deeply alterations; hence Fe-Mg minerals and plagioclase change to chlorite, epidote, uralite, calcite, and zoisite. Olivine in olivine-gabbros altered to reticulated serpentine minerals, antigorite/lizardite. Their major minerals are plagioclase, clinopyroxene and olivine plus accessory minerals such as apatite, ilmenite, and spinel. Random orientations of plagioclase create intergranular texture especially in diabase. Ilmenite with lamellar twins and fairly large crystals present in most thin sections. Some hornblendes have been converted to biotite by potasic alteration. Porous spaces have been filled by radial epidote, chlorite, calcite and quartz as secondary minerals.

3. Analytical method

From sill cross section 9 rock samples that show least alteration in thin sections, and contain low LOI were selected to analyze for major and trace elements plus REEs. Each sample was crushed by jaw crusher to obtain grains size with 2-3 mm diameters then 100 gr grains were mill to obtain at least 95 gram powder with 75 µ sizes. Finally, from each rock sample, 10gr powder which was generated by alumina ball-mill, have been analyzed by ICP-MS at the SGS laboratory.

4. Geochemistry

Samples on the TAS diagram (Middlemost, 1985) (fig. 1), plot in sub alkaline field. Due to high alteration, they plot on Y vs. Zr diagram (Le Maitre et al, 1989) as immobile trace elements and they show transitional series (fig 2).

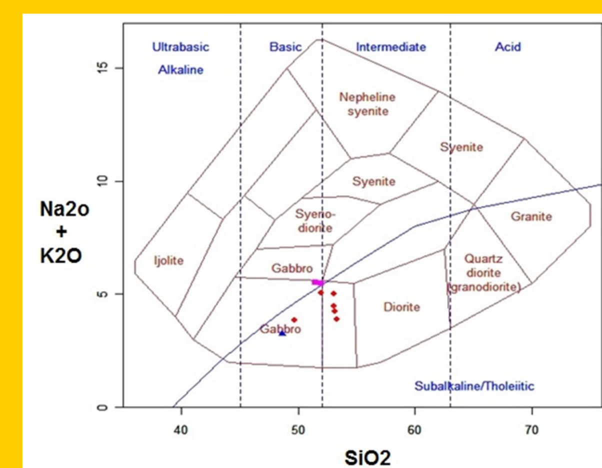

Fig.1. *Total alkaline vs. SiO2 (TAS) (Middlemost, 1985) diagram, sill samples fall into the gabbro field.*

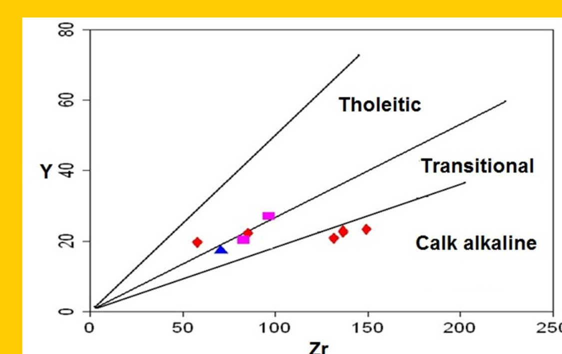

Fig.2. *Y vs. Zr plot (Le Maitre, 1989) diagram, rock samples tendency to transitional zone.*

On chondrite normalized pattern LREE and HREE reveal enrichment by factor of 30-80 and 10 respectively. Although HFS elements Ti, Zr, Ta, and Nb, don't show any negative anomalies ,but LIL elements, Ba, Rb,Th, and K, reveal zigzag pattern indicate crustal contamination or/and post-magmatism alterations (fig.3a-b). Depletion of HREE probably reflect residual garnet in the mantle source; also these trends are seen in the within plate basalts (Wilson, 1989). All of samples display intra-plate rift gabbro on Biermannes (1996) diagram (fig.4).

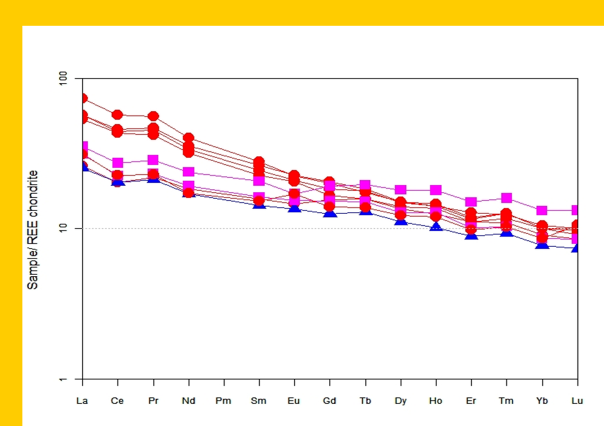

Fig.3a. *Chondrite (Nakamura, 1974) normalized pattern for gabbroic sill.*

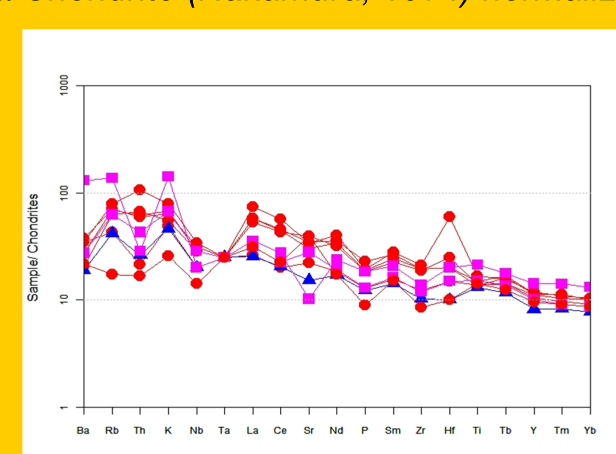

Fig.3b. *Chondrite (McDonough and Sun, 1995) multi-element diagram for rock samples.*

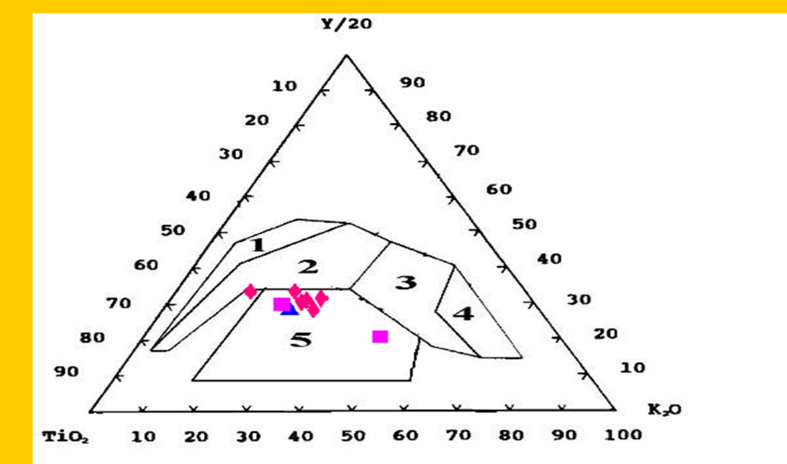

Fig.4. *Tectono-magmatic setting of gabbros based on TiO2-K2O-Y/20 triangle diagram (Biermanns, 1996); 1= immature island arc gabbros; 2=mature island arc gabbros; 3=Arc gabbros; 4= continent-continent collision gabbros; 5= intra-plate rift gabbros; gabbroic sill samples represent intra-plate gabbros.*

5. Discussion and Conclusion

It seems the magma source of this sill was developed from enriched mantle. Increasing Zr as decreasing Y in Y- Zr diagram (Abuhamatteh, 2005) (fig. 5a), as well as positive liner trend of samples on the Nb-Zr diagram (fig. 5b) may indicate enriched mantle source.

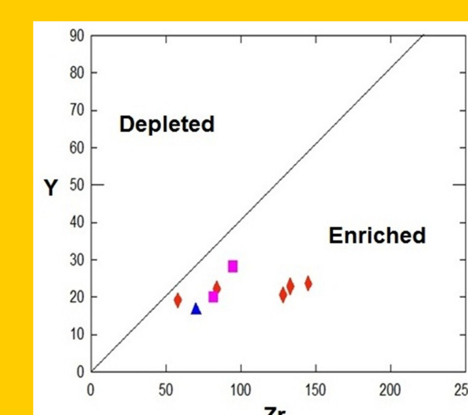

Fig.5a. *Y vs. Zr diagram reveals enriched source for gabbroic sill, discrimination line is from Abuhamatteh (2005) based on Sun and McDonough (1989) data.*

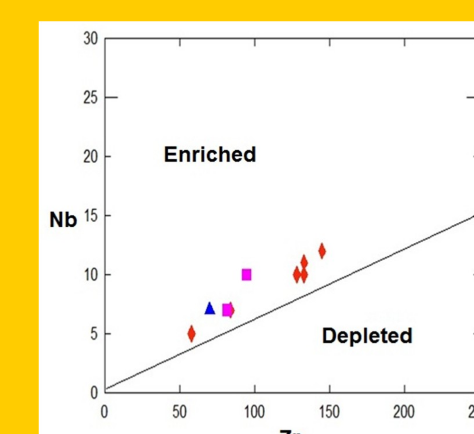

Fig.5b. *Nb vs. Zr diagram shows enriched source for intrusive rocks. Discrimination line is from Abuhamatteh (2005) based on Sun and McDonough*

This sill can be formed by 15-20% of partial melting of a garnet peridotite (fig. 6) which its Gt/(Gt+Sp) ratio is range of 0.3 to 0.5 (fig. 7). Based on Yb, Sm, and Ce, concentrations, Depth of segregation melt may take place at 70-90 km (fig.8).

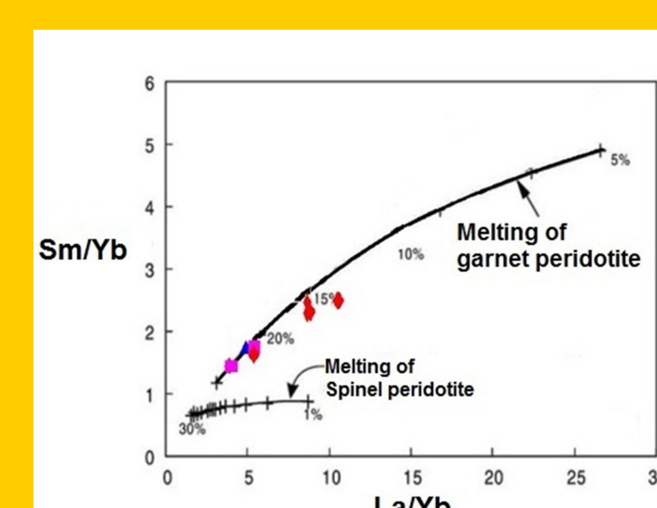

Fig.6. *Sm/Yb vs. La/Yb diagram exhibit about 15% to more than 20% partial melting of a garnet- peridotite may generate primary magma of these intrusive rocks. Numbers on trajectories are percentage of source rock partial melting, and represented by Johnson et al (1990).*

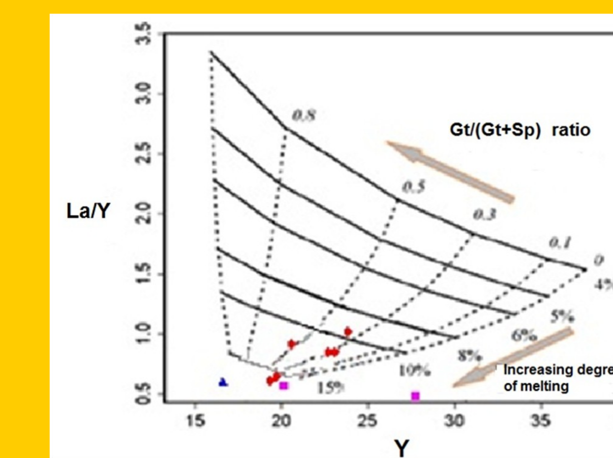

Fig.7. *La/Y vs. Y diagram illustrate a range of partial melting degrees of mantle peridotite with different Gt/(Gt+Sp) ratio; Studied samples present more than 15% melting of a garnet-spinel peridotite with Gt/(Gt+Sp) ratio around 0.3-0.5. Trajectories were calculated by Lustrino et al (2006).*

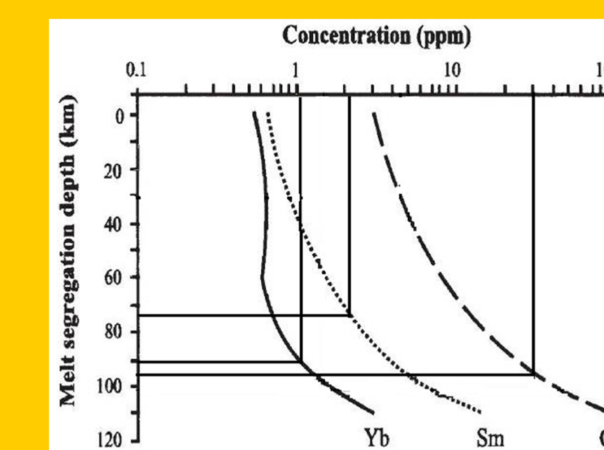

Fig.8. *Diagram displays logarithmic concentration of Yb, Sm, and Ce, as HREE, MREE, and LREE, versus melt segregation depth; trajectories are provided by Ellam and Cox (1991). Mean concentration of Yb, Sm, and Ce are plotted on trajectories and reveal approximately 70-90 km depth for*

Assessments of fractional crystallization in evolved magma indicate that it is not solely way to control of the magma chemistry. Furthermore combination of crustal contamination and fractional crystallization play main role in evolved magma (fig. 9). Continental crust are mainly depleted of Nb and enriched of LREE and LIL_E ; so low ratio of Nb/U and high ratio of La/Nb in these intrusive rocks to those of the mantle peridotite, indicate role of crustal contamination (Hofmann et al, 1988). In addition, Nb/U ratio in these intrusive rocks are about 10 to 30 and they are smilar to those of upper crust and lower crust respectively (Krienitz et al, 2006) (fig. 10).

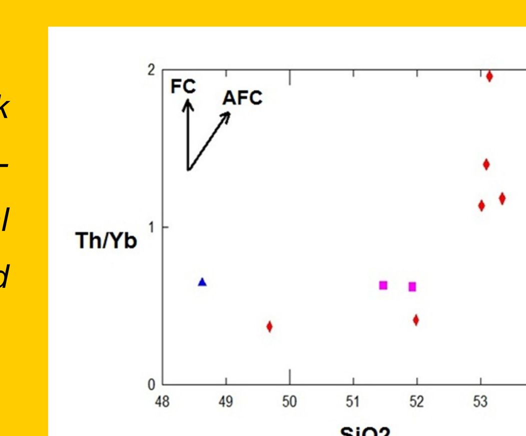

Fig.9. *Th/Yb vs. Sio2 diagram illustrate rock samples follow assimilation and fractional crystallization (AFC) trend rather than fractional crystallization (FC) one. Trajectories of FC and AFC are represented by Tchameni et al (2006).*

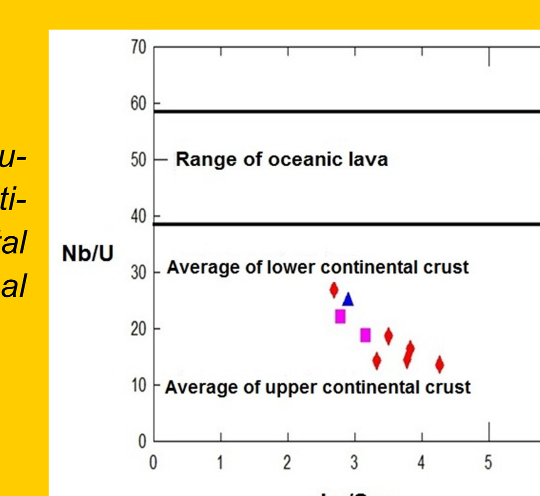

Fig.10. *Nb/U vs. La/Sm diagram shows intrusive rocks plot between average of lower continental crust and average of upper continental crust. Field discrimination from Krienitz et al (2006).*