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# AMS, A Method for Determining Magma Flow in Dykes (Case Study: Andesite Dyke)

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**Abstract:** Relying on the magnetic fabrics study, Anisotropy of Magnetic Susceptibility (AMS) enjoys a special status in determining the mechanism and model of emplacement of intrusive rocks. Parameters resulted from AMS study is based on behaviors of magnetic minerals. The most important function of magnetic anisotropy measurement is to analyze rocks' petrofabric which will be possible through identification of mineral stones and their magnetic anisotropic characteristics. One of such dykes, located at the Southwestern wing of Sabzevar City was studied using magnetic Anisotropic Method. Studies showed that the Km value (in terms of μSI) ranges between 33334 and 96836 and represent the clear presence of magnetite in the studied rocks. Lineation and foliation gradients represent magma flow in a roughly longitudinal plane. The magnetic anisotropy values vary between 0.38 and 1.76. With regard to the achieved values for the (T) shape parameter, most magnetic ellipsoidal figures were prolate form.

**Key words:** AMS Method, dyke, petrofabric, fabrics, Iran

## INTRODUCTION

To perform AMS Method, initially oriented cores (including two cores in each sampling station with 5-10 m distance) are supplied by core drilling machine. Then cores are cut to pieces with 22 mm length and after renaming any piece is washed with chloridric acid 0.2 N in order to remove impurities caused by cutting or drilling procedures. In this phase, initially the rock is placed in a magnetic field in which a certain magnetic strength (H) is induced. A certain Magnetization (M) is developed in the rock sample as the result of placement in this magnetic field. The ratio of magnetization amount and the magnetic field strength induced on it (H/M) is defined as parameter K with the magnetic susceptibility factor in 3-dimnesional space of the studied rock sample. A magnetic ellipsoidal figure can be defined whose biggest vector ($K_1$) is proper with magnetic lineation, while its smallest vector ($K_3$) is proper with the magnetic foliation pole (Bouchez, 1997). The vector located between $K_1$ and $K_3$ is shown with $K_2$. Km (average magnetic susceptibility), P% (anisotropy percent) and T (shape parameter) are measured in terms of $K_1K_2K_3$ and according to the equations defined among them (Hrouda, 1991) (Fig. 1).

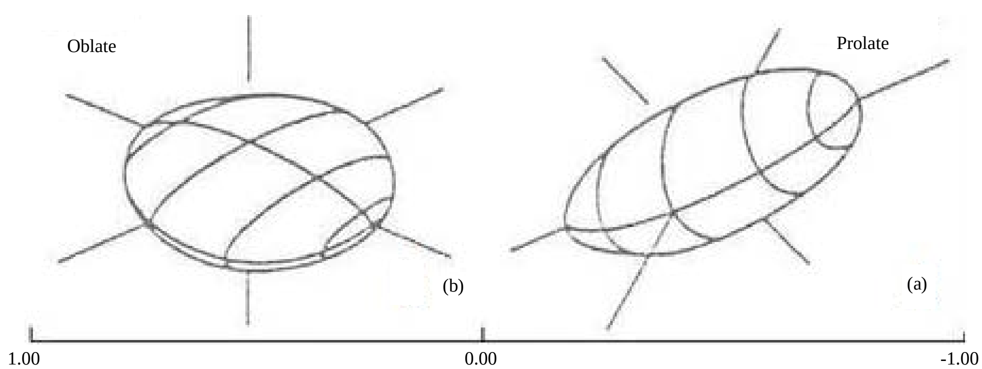


Fig. 1: a) oblate magnetic ellipsoidal figure and b) prolate magnetic ellipsoidal figure

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- Km (average magnetic susceptibility) = $K_1+K_2+K_3/3$
- P (magnetic anisotropy = $K_1/K_3$
- T (shape parameter) = (2ln ($K_2/K_3$)/ln ($K_1/K_3$))-1Top = 3 cm

In the same direction a dyke, located in the northwestern side of Sabzevar City was measured in 13 stations. After cutting cores, a number of 50 samples with the length of 22 mm were achieved. The magnetic parameters of these samples were measured with a magnetic sensitometer, Model FA-MFK1, made by AGICO Company, Czech Republic (Table 1).

## DISCUSSION

The location chosen for this study is located geologically in the Northern edge of the central Iran Zone and Sabzevar Zone (Alavi, 1976) (Fig. 2). The volcanic and volcanic-sedimentary rocks of Eocene epoch Northwest of Sabzevar are cut off by a number of dikes with trachyandesite composition that were formed in middle and upper Eocene in the domain of the volcanic arc of the active continental margin related to the subduction. With the subduction and the dehydration of the subducting continental crust, the partial melt of the

Table 1: The measured magnetic parameters from the studied dyke

| Stations | L | Km | F | T | P | $K_3$ | $K_1$ | Y | X |
|---|---|---|---|---|---|---|---|---|---|
| DA | 257.5-45.3 | 33333.96333 | 207.5 | 0.409 | 1.007 | 117.5-37.3 | 45.3-257.5 | 4031224 | 495089 |
| DB | 180.6-8.6 | 41039.3 | 6 | 0.0283 | 1.008 | 275.6-31.8 | 180.6-8.6 | 4031224 | 495090 |
| DC | 343.6-9.5 | 57085.2 | 180.6 | -0.128 | 1.011 | 89.7-58.7 | 343.6-9.5 | 4031206 | 495083 |
| DD | 338.2-49.8 | 66448.85 | 182 | 0.3007 | 1.010 | 92-19 | 338.2-49.8 | 4031336 | 495088 |
| DE | 106.7-28.1 | 50703.79667 | 38.6 | 0.6403 | 1.014 | 308.7-59.4 | 106.7-28.1 | 4031336 | 495088 |
| DF | 355.6-12.2 | 70799.12333 | 191.1 | -0.345 | 1.005 | 101.3-54 | 355.6-12.2 | 4031354 | 495084 |
| DG | 339.6-2.1 | 62587.29667 | 170.2 | 0.1057 | 1.012 | 79.9-80.3 | 339.6-2.1 | 4031354 | 495084 |
| DH | 338.3-4.6 | 96836.06 | 160.8 | -0.154 | 1.011 | 71.31-6 | 338.3-4.6 | 4031372 | 495103 |
| DI | 169.7-9.9 | 72073.27333 | 163.6 | -0.247 | 1.008 | 73.8-30.1 | 169.7-9.9 | 4031372 | 495103 |
| DJ | 332-18.7 | 66924.11667 | 165.8 | 0.175 | 1.009 | 75.8-29.1 | 332-18.7 | 4031389 | 495103 |
| DK | 209.9-18 | 56974.83333 | 191.4 | 0.628 | 1.005 | 101.6-34.4 | 209.9-18 | 4031389 | 495103 |
| DL | 314.5-12.7 | 62769.98333 | 148.5 | 0.029 | 1.009 | 58.5-32.7 | 314.5-12.7 | 4031385 | 495091 |
| DM | 145.2-13 | 73556.20333 | 136.7 | 0.133 | 1/01 | 46.7-41 | 145.3-13 | 4031358 | 495097 |

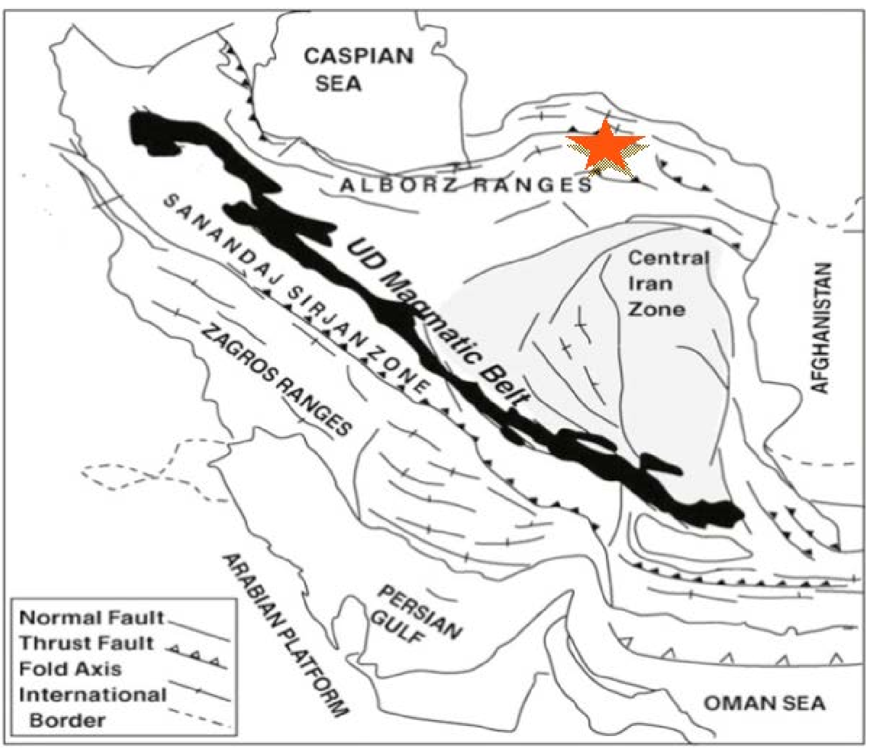


Fig. 2: Location of the studied area in the central Iran zone (Gilg *et al.*, 2006)


Fig. 3: Infiltration of the basaltic rachyandesite dike into the Eosine pyroclastic and volcanic rock sequence

mantle wedge below the subcontinental lithosphere caused the formation of enriched mafic magmas with a dominant alkaline nature. In the grab samples of these trachyandesites, there are large phenocrysts of hornblende with preferred orientation that can be recognized with the naked eye. One of these dikes was studied using the anisotropy of magnetic susceptibility (ASM analysis). The studied dyke has a width of 1.5-2 m and about 1 km length (Fig. 3). This dyke has crossed a range of basaltic lava, shale, tuff and sandstone of Eocene age.

## PETROGRAPHY

Trachyandesites are andesitic rocks containing alkaline minerals. Among phenocrysts visible in trachyandesites, mention can be made of orthoclase, plagioclase and one or more mafic minerals such as hornblende and pyroxene which are among the major minerals present in rocks. Their main microscopic textures vary from glomeroporphyritic to porphyritic textures with microlithic matrix and trachytic textures. Among the manifest properties of these rocks is the presence of euhedral hornblendes with burnt margins, embayments and sieve textures. There are inclusions of opaque and apatite minerals inside these crystals. Hornblendes have also undergone dissolution and chemical corrosion. This corrosion is visible in the central parts and margins of these crystals.

Growth of hornblendes then restarted. Formation of magnetic rings represents provision of environmental conditions for the growth of magnetite (Fig. 4 and 5). Magnetite was able to quickly nucleate and form simultaneously with the growth of hornblendes. Moreover, continuation of the faces in the same direction and on both sides of the ring indicates the growth of the crystal practically stopped during these stages. Magnetite and titanium magnetite are among the most frequently observed opaque minerals in trachyandesites. These minerals are often present in the form of inclusions inside other minerals which indicates the almost simultaneous crystallization of bright and opaque minerals. The mutual effects of rapid cooling, rate of nucleation and growth of various minerals in the melt caused some of the minerals such as magnetite and olivine to remain small inside the rocks. That is, small sizes of opaque and olivine minerals will accompany the high rate of nucleation and the low rate of growth. Ferromagnetic particles including magnetite of the greatest dimensions orient themselves parallel to the magma flow and find magnetic lineation parallel to the flow direction (Bouchez, 1997).

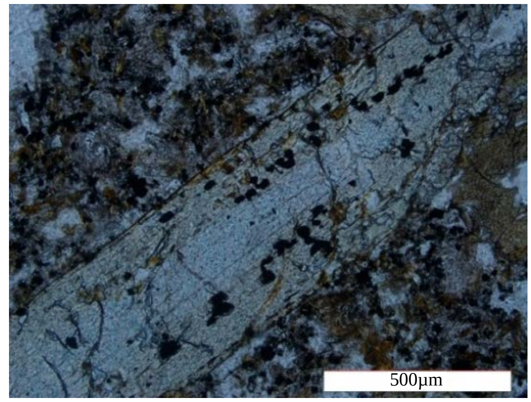


Fig. 4: Magnetite crystallization in the direction of pyroxene cleavage and the subsequent regrowth of pyroxene. This phenomenon represents the simultaneous crystallizaton of pyroxene (augite) and magnetite

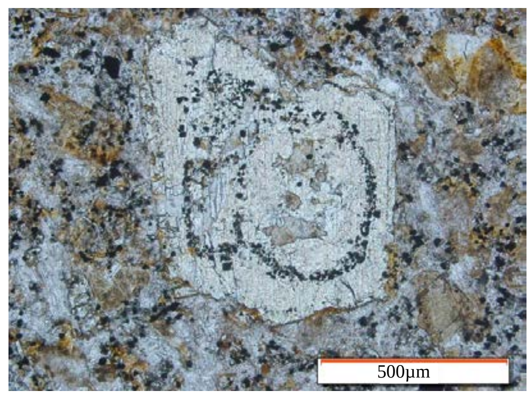


Fig. 5: Microscopic image of the magnetite ring that formed simultaneously with the growth of hornblende (PPL)

In basic rocks, the quantity of magnetite is usually >0.1% and controls the magnetic fabric of the rock. The magnetic susceptibility in basic igneous rocks ranges from 1500-90000 μ (SI units) which is because they contain more magnetite. The higher the volumetric percentages of the ferromagnetic minerals including magnetite are in a rock, the higher the magnetic susceptibility of the rock will be.

In the diagrams of the geochemical classification (Le Bas *et al.*, 1986; Winchester and Floyed, 1977), the studied samples are placed in the combined ranges of trachyandesites and andesites (Fig. 6a and b). This conforms to petrographic studies too.

**Anisotropy of Magnetic Susceptibility (AMS):** Magnetic parameters of these samples have been measured in the magnetic lab and by MFK1-FA kappabridge machine. Km value in terms of μSI, varies between 33334 and 96836 (Table 1); very high Km values are due presence of magnetite in samples (Fig. 7 and 8). The value of K only

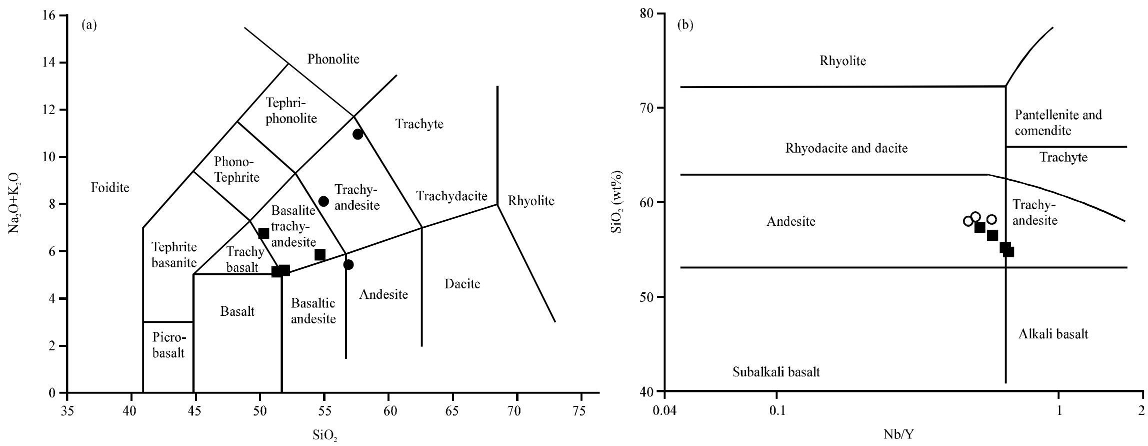


Fig. 6: a) Position of the studied samples in the region in the classification diagram by Le Bas *et al.* (1986) and b) the Nb/Y diagram against $SiO_2$ (Winchester and Floyed, 1977); ■: Basaltic trachyandesite; ●: Trachyandesite

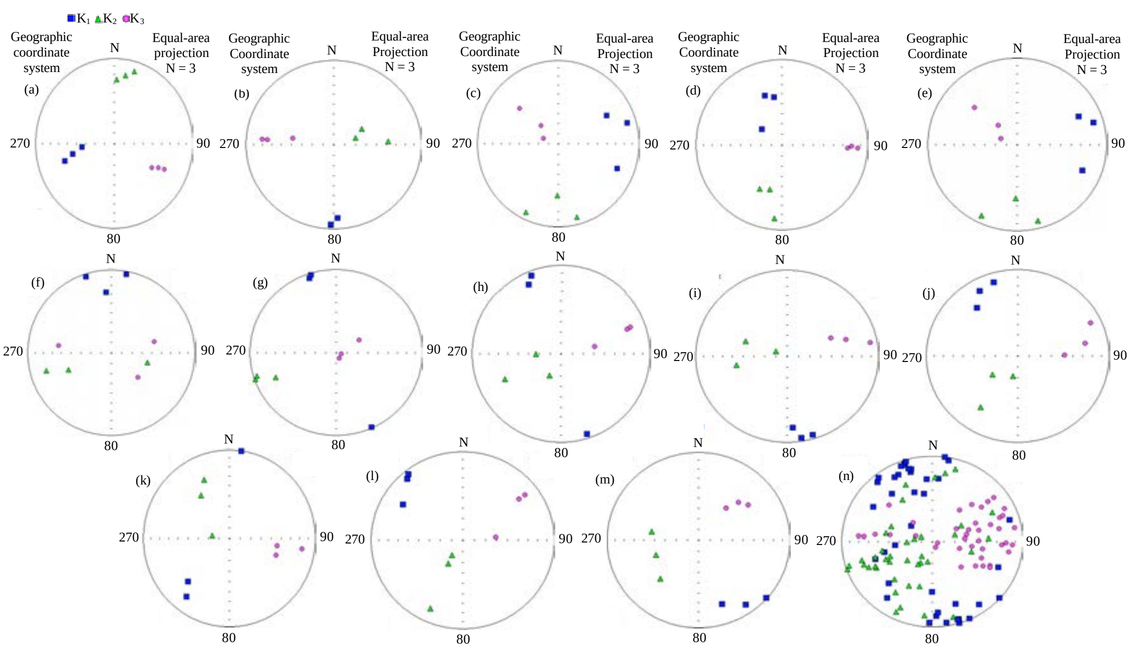


Fig. 7: Stereograms showing the status of magnetic lineation's of cores resulted from the average amounts of $K_1$, $K_2$, $K_3$ in the studied dyke: a) DA; b) DB; c) DC; d) DD; e) DE; f) DF; g) DG; h) DH; i) DI; j) DJ; k) DK; l) DL; m) DM and n) DTota

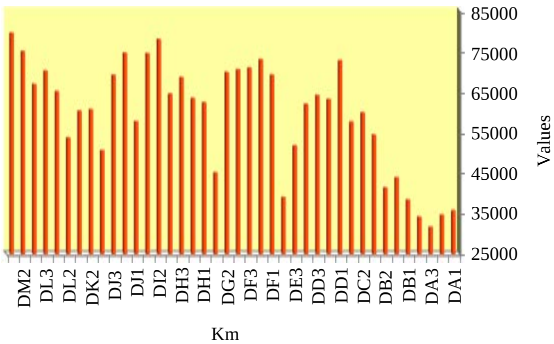


Fig. 8: Km alterations in the studied samples

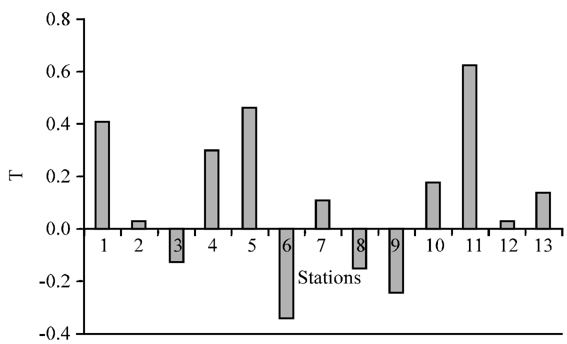


Fig. 9: T shape parameter versus the supplied cores which mostly have positive T and represent prolate form of magnetic ellipsoidal figures

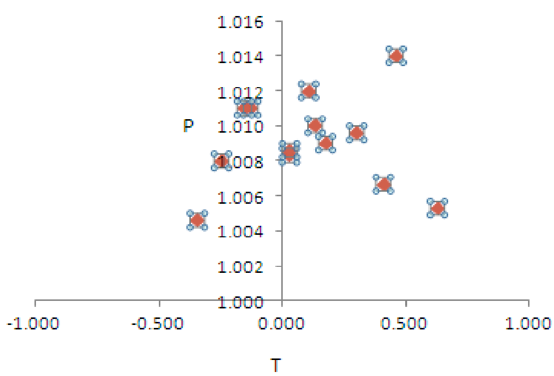


Fig. 10: p-values versus t-values

depends in the material's type (Robinson and Coruh, 1988). Dips of magnetic lineations and foliations correspond to movement of magma forming dike in a nearly horizontal level, along the dike strike. The state of magnetic lineation and foliation in the studied dyke has been shown through transferring foliation and lineation features into the core drilling stations map (Fig. 9-11). Stereograms drawn, indicating that the lava in an almost horizontal level and has expanded to the North West. The

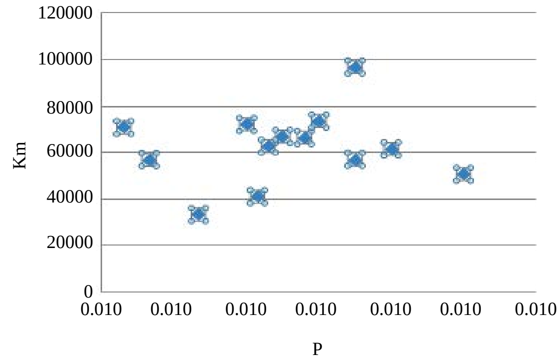


Fig. 11: Km values verses P, magnitude of Km value represent presence of magnetit in samples

position of the $K_1$ and $K_2$ are simultaneously representing the magmatic foliation page are average. Foliation average slope of about 70 degrees with a general dip of the study correspond dyke.

## CONCLUSION

The result indicate that the average magnetic foliation and lineation (N11 W/52 SW and 346.2, respectively) are compatible with the general trend of the dyke (N 10-15). The magma's magnetic foliation gradients have flown northward in a roughly longitudinal plane with the average gradient of 2.3 degree (the current location of the dyke) and the magnetic ellipsoidal figures are prolate form. Thus, the results gained from magnetic fabric method can provide us with valuable information about how magma is flown in dykes and presence of magnetite mineral will increase Km value in rocks.

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