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Palaeomagnetic Data from the Andesitic and Lamprophyric Dikes of the Sesia-Lanzo Zone (Western Alps)

By *Roberto Lanza*, Turin *)

Abstract

Natural remanent magnetization was measured using samples from 16 andesitic, lamprophyric and microdioritic dikes intruding the metamorphic rocks of the Sesia-Lanzo Zone (Western Alps). All specimens were demagnetized stepwise in AC fields and the best clusters of directions were chosen as valid. Two different mean directions of magnetization were found. The first direction (D = 143.6, I = −7.2) belongs to the dikes outcropping in the south-eastern, inner part of the Sesia-Lanzo Zone and is aligned parallel to the mean direction of the andesites from the cover of the Sesia-Lanzo Zone. The second direction (D = 157.2, I = −39.3) is characteristic of dikes from the north-western, outer part of the Sesia-Lanzo Zone and is close to that of the Bregaglia Massif. The results suggest either that the two groups of dikes may be of different ages, or that the inner part of the Sesia-Lanzo Zone may have been displaced with respect to the outer part, by having been folded about a subhorizontal axis striking north to north-east. On the basis of the geological evidence, the second hypothesis is the most reliable.

INTRODUCTION

The Sesia-Lanzo Zone is the innermost structural unit of the Western Alps and mainly consists of polymetamorphic rocks, that lastly underwent the Alpine metamorphism (COMPAGNONI et al. with references, in press). Some postmetamorphic igneous rocks occur within the Sesia-Lanzo Zone. They may be distinguished as:

1. Stocks, of Biella and Traversella.
2. Dikes, mostly andesites and lamprophyres.
3. Flows of andesites and trachyandesites, with agglomerates and tuffites, forming the stratigraphic cover of the Sesia-Lanzo Zone.

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The igneous rocks are of post-alpine Oligocene age. Geochronological investigations (KRUMMENACHER and EVERNDEN, 1960; SCHEURING et al., 1974; HUNZIKER, 1974; ZINGG et al., 1976) have yielded ages of 30 my for the

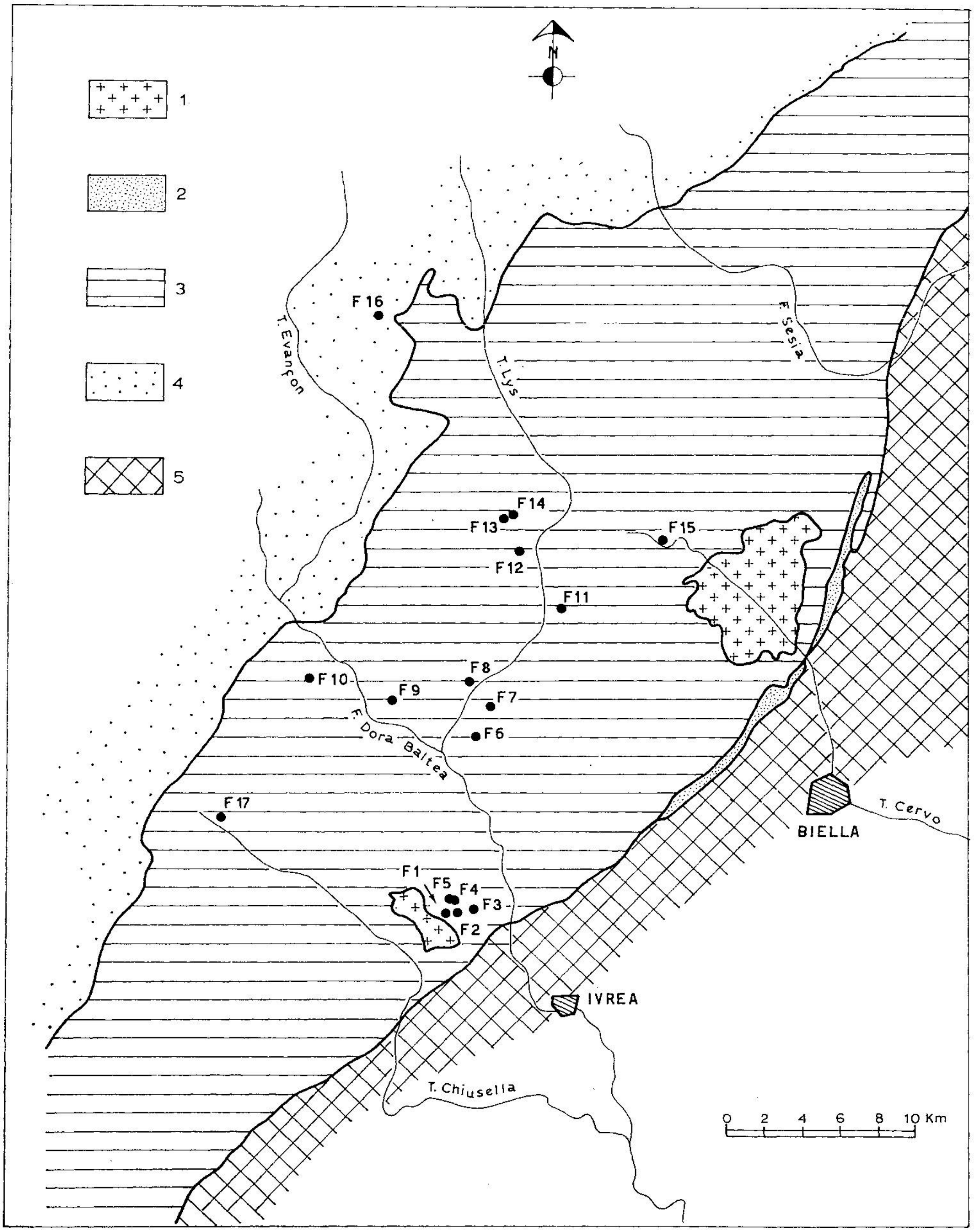

Fig. 1. Geological sketch map and locations of dikes. 1) Biella and Traversella stocks; 2) Andesitic cover of the Sesia-Lanzo Zone; 3) Sesia-Lanzo Zone; 4) "Calcescisti" complex; 5) Southern Alps.

plutons and between 30 and 33 my for the effusive rocks. The dikes are generally held to be of the same age of the plutons (e.g., NOVARESE, 1943). A value of 31 my has been found by DAL PIAZ et al. (1973) for a similar lamprophyric dike intruding the Mesozoic "Calcescisti" of the Piemonte Zone, quite close to the contact with the Sesia-Lanzo Zone. Palaeomagnetic investigations so far have been confined to the effusive rocks (HELLER and SCHMID, 1974; LANZA, in press).

The present paper gives the results of remanent magnetization studies of samples from 16 andesitic, lamprophyric and microdioritic dikes intruding the Sesia-Lanzo metamorphics, as well as from the dated lamprophyric dike from the "Calcescisti" complex. Locations are shown in the geological sketch map of Fig. 1.

MEASUREMENTS AND RESULTS

Samples have been cored at each site and oriented by both solar and magnetic compasses. The values of the declinational correction range from 2° W to 7° W. The highest values occur near the Traversella stock and are due to magnetite mineralizations in its metamorphic aureole.

The measurements and demagnetization tests have been carried out by means of a SCHONSTEDT SSM-1A spinner magnetometer and the AF demagnetization coil of the Laboratorio di Geologia Marina, CNR, in Bologna.

Two or three pilot specimens from each dike have been demagnetized in alternating magnetic fields with maximum H_{peak} values from 50 to 2000 Oe. The intensities of the natural remanent magnetization (NRM) vary initially from 10^{-4} to 10^{-6} Gauss and decrease in much the same regular manner for all dikes during magnetic cleaning. The NRM directions, on the other hand, vary considerably from one dike to another and in several cases even from specimen to specimen from the same dike. Some demagnetization diagrams are shown in Fig. 2. Fig. 2A illustrates the pattern for a specimen from one of the two dikes (F9, F11) whose NRM directions are virtually constant during cleaning: there is a single, stable magnetization component. Fig. 2B shows the most common behavior: some specimens with a prevailing stable component and other specimens from the same dike with considerably strong unstable components that are gradually erased, leaving stable components whose directions are closely grouped. Fig. 2C gives an example of a highly irregular curve from which no stable component, if any, can readily be detected.

Because of these patterns of the demagnetization curves, it was deemed appropriate to examine all specimens after different values of cleaning: NRM, 50, 100, 200, 400, 600 Oe, not exceeding an upper limit of 600 Oe because at this point the magnetization of most dikes is destroyed. The results of the

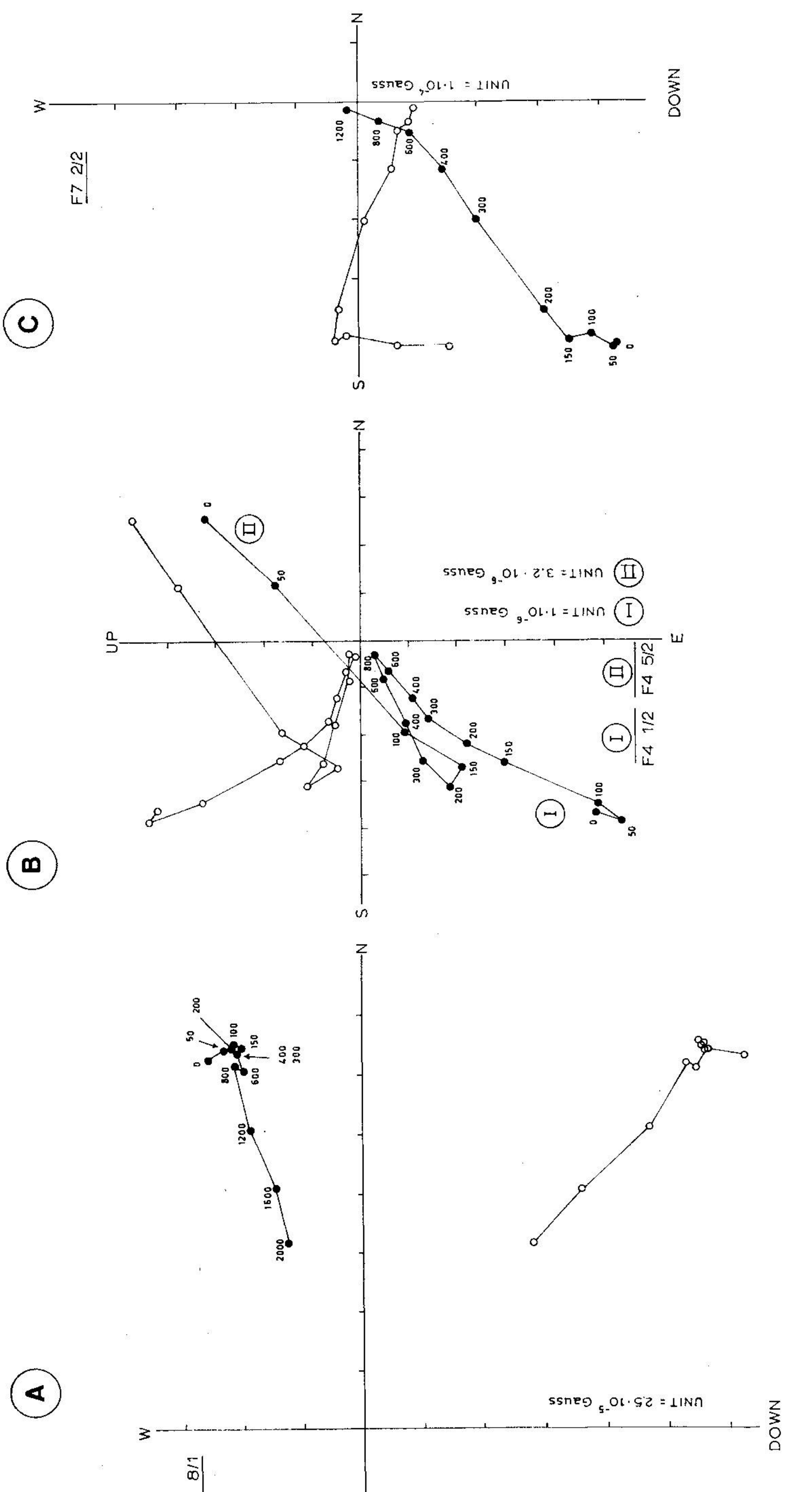

Fig. 2. Progressive demagnetization diagrams: orthogonal projections of the vector path of the NRM during AF cleaning (Zijderveld, 1967). Solid circles: projections on the horizontal plane; open circles: projections on the vertical N–S plane. Figures: H_{peak} values in Oe.

Table 1. *AF cleaning for specimens from dike F 4*

F 4/A, F 4/B, F 4/C: groups of specimens (see text). N, number of specimens; D, declination; I, inclination; H_{peak}, peak field during AF demagnetization; α_{95}, angle of confidence.

	F 4/A N = 6		F 4/B N = 5		F 4/C N = 6		All specimens N = 17		
H_{peak}	D	I	D	I	D	I	D	I	α_{95}
0	130.8	−29.4	298.0	−37.8	204.7	−25.8	194.1	−51.6	28.5
50	127.7	−27.9	275.2	−58.2	187.3	−23.5	173.3	−47.4	22.5
100	124.0	−22.3	158.2	−27.7	158.8	−5.9	146.5	−18.9	9.8
200	124.3	−18.8	152.3	−14.6	149.6	−2.1	141.8	−12.0	8.0
400	136.9	−7.6	154.3	−13.4	150.4	−2.3	146.8	−7.5	6.7
600	137.7	−3.5	156.6	−14.4	149.4	−4.5	147.4	−7.2	7.3

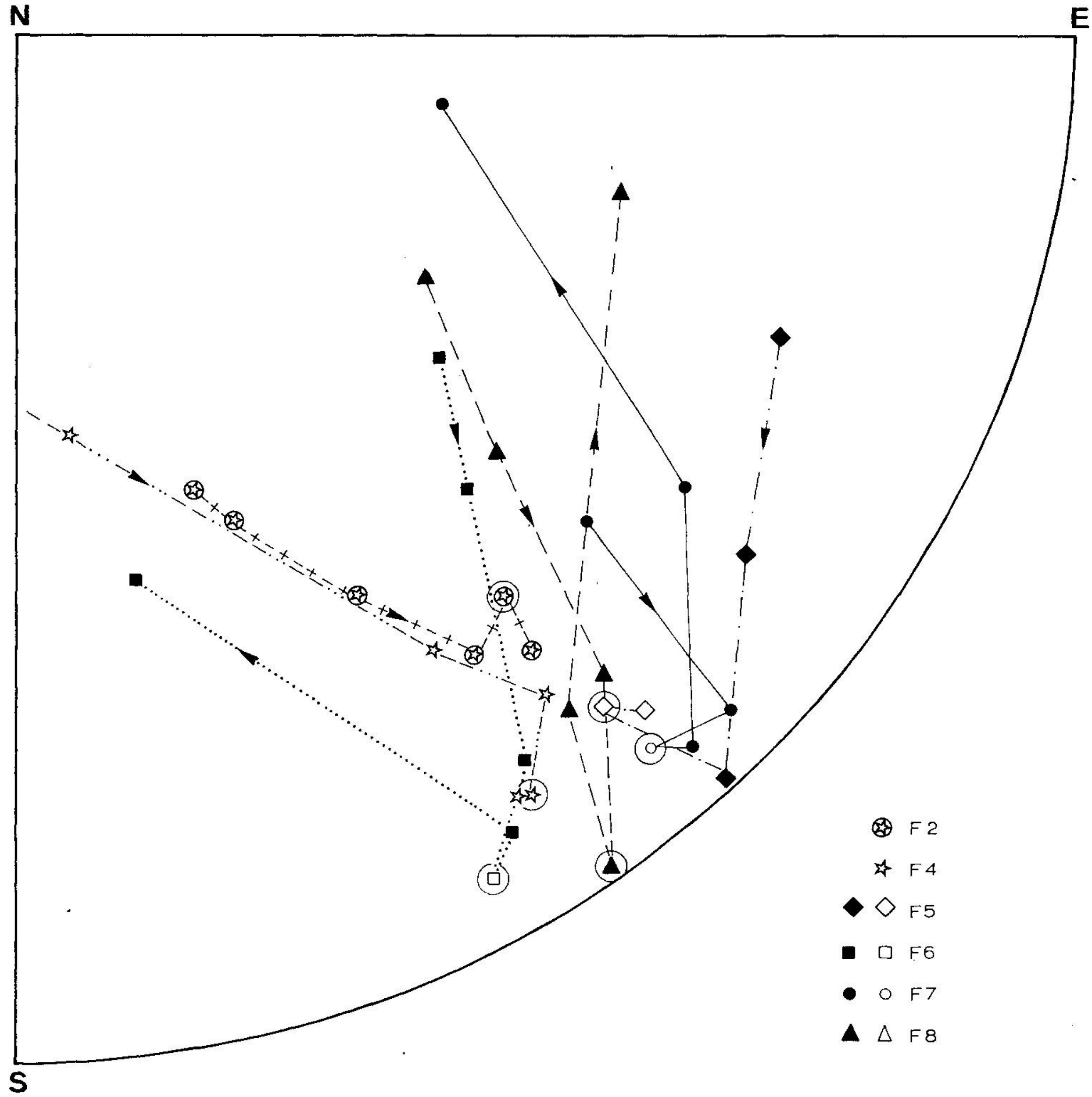

Fig. 3. Stereographic projection of magnetization directions for six dikes during AF cleaning. Solid symbols: lower hemisphere; open symbols: upper hemisphere. The arrows point to increasing H_{peak} field of demagnetization. The large circles enclose the best clustered mean directions.

Table 2. *Directions of magnetization after cleaning at H_{peak} field for which best clusters have been obtained*

First column: dike number and location. Lithologies: A, andesite; L, lamprophyre; MD, microdiorite. Coordinates: latitude and longitude (E of Greenwich) in degrees, minutes and seconds. N, number of specimens; H_{peak}, peak field during AF demagnetization; D, declination; I, inclination; R, length of the resultant vector; α_{95}, angle of confidence.

Dike	Lithologies	Coordinates	N	H_{peak}	D	I	R	α_{95}
F 1 Grange Verna	MD	45.3028 7.4737	10	0	94.1	−59.9	9.84	6.5
F 2 q. 1170	MD	45.3028 7.4753	14	400	139.9	−18.3	13.69	6.2
F 3 la Serra	A	45.3021 7.4838	8	0	86.3	31.5	7.37	17.4
F 4 Grange Piani	A	45.3040 7.4746	17	400	146.8	−7.5	16.46	6.7
F 5 Grange Piani	A	45.3040 7.4746	7	400	139.6	−8.7	6.67	14.4
F 6 Ivery	L	45.3541 7.4833	15	200	151.0	−4.2	14.43	7.9
F 7 Rechantez	L	45.3633 7.4929	13	200	139.0	−5.1	11.70	14.4
F 8 Marine	A	45.3721 7.4846	19	200	145.4	0.8	17.95	8.3
F 9 Albard	L	45.3637 7.4529	19	400	339.5	37.1	18.97	1.4
F 10 Col Courtil	A	45.3726 7.4159	8	500	151.4	−49.7	7.53	14.9
F 11 Farettaz	L	45.3916 7.5210	18	400	149.5	−34.3	17.40	6.6
F 12 Issime	L	45.4054 7.5043	22		Unstable magnetization			
F 13 Alpe Stolen	A	45.4155 7.5007	8	100	17.2	76.1	7.87	7.5
F 14 Bourrine	A	45.4155 7.5033	8	200	164.6	−28.2	7.81	9.3
F 15 Rosei	A	45.4118 7.5268	13		Unstable magnetization			
F 16 Palasina	L	45.4745 7.4530	6	200	203.5	−59.1	5.99	2.1
F 17 Alpe Carnera	A	45.3328 7.3818	9	200	339.6	46.6	8.98	2.6

progressive magnetic cleaning are very similar for all dikes. Table 1 illustrates the cleaning for specimens from dike F 4. The measured NRM directions are scattered around three significantly different mean directions, so that three groups of specimens (F 4/A, F 4/B, F 4/C) can be recognized. During cleaning, directions from F 4/A do not change, whereas those from F 4/B and F 4/C change in varying degrees with a trend toward the directions of group F 4/A. Ac-

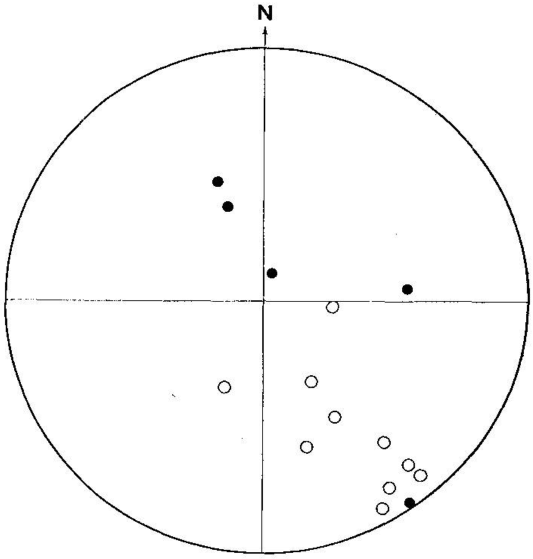

Fig. 4. Stereographic projection of the optimum magnetization directions of dikes. Solid symbols: lower hemisphere; open symbols: upper hemisphere.

cordingly, the mean magnetization direction for the dike F 4 varies considerably during demagnetization, while its directional scatter (represented by the 95% confidence angle α_{95}) is reduced gradually. Since a similar behavior was found for other dikes, the cleaned mean directions with the lowest scatter have been chosen as significant. This criterion is often adopted in palaeomagnetic studies, although it is grounded on empirical basis only. Fig. 3 gives the demagnetization patterns of mean directions for dikes F 2, F 4, F 5, F 6, F 7, F 8. The directions of each dike vary considerably, but all the statistically optimum mean directions fall within a small area. A similar pattern (in another area of the stereonet) is found for the dikes F 9, F 10, F 11, F 14, F 17.

Table 2 gives the optimum mean directions and their statistical parameters for all dikes, with the exception of F 12 and F 15, whose magnetization is totally unstable. Fig. 4 is a stereographic projection of the optimum directions, which can be separated into three groups:

Group 1 (F 2, F 4, F 5, F 6, F 7, F 8). Here the optimum directions fall within the SE quadrant with low inclinations. The mean direction for these six dikes (each dike having unit weight) is: D = 143.6, I = −7.2, with α_{95} = 6.6.

Group 2 (F 9, F 10, F 11, F 14, F 17). These directions of magnetization also fall in the SE quadrant, with higher inclinations. The directions of dikes F 9 and F 17 fall actually in the NW quadrant because they have normal polarity, whereas dikes F 10, F 11, F 14 have reversed polarity. The mean direction of the five dikes (all taken with reverse polarity) is: D = 157.2, I = −39.3, with α_{95} = 9.7.

Group 3 (F 13, F 1, F 3). This group includes dikes with scattered magnetization directions. F 13 has a direction close to that of the present field and its demagnetization curve drops rapidly to very low intensities with low demagnetizing fields. F 1 and F 3 do not change their scatter with the progressive cleaning, although there is a migration of the directions of magnetization towards the mean direction of Group 1. Therefore, following the best cluster criterion, directions before cleaning, although scattered, must be taken as the representative ones.

Lastly the magnetization direction of dike F 16 should not be related to the others on geological grounds, because this dike is intruded in a different structural unit, that is the "Calcescisti" complex.

DISCUSSION AND CONCLUSIONS

The optimum magnetization directions neither are affected by the varying mineral assemblages nor by the varying attitudes of the dikes. Directions of Group 1 belong to the dikes lying in the inner, south-eastern part of the Sesia-Lanzo Zone, whereas directions of Group 2 belong to the dikes of the north-western, outer part. Therefore Group 1 can be referred as the inner group and Group 2 as the outer group. Two explanations for the existence of these two groups can be proposed:

1. Magmatic events of different ages are responsible for the intrusions of each of the two groups.
2. All dikes were intruded synchronously and with the same original direction of magnetization. Later, the inner part of the Sesia-Lanzo Zone was displaced with respect to the outer, leading to the present discordance of directions.

The first hypotesis is not supported by geological evidence, which points rather to a close relationship between the dikes and the nearest stocks of Biella and Traversella, both with ages of about 30 my. The dikes must also be younger than 38 my, this being the age of the thermal peak of the second Alpine metamorphic event (the Lepontine phase), which affected the rocks of the Sesia-Lanzo Zone and not the dikes (Compagnoni et al., in press). The second hypotesis, on the other hand, is in agreement with the finding that the mean direction of magnetization of the inner group ($D = 143.6$, $I = -7.2$) is quite close to that of the andesitic cover of the Sesia-Lanzo Zone ($D = 135.9$, $I = -2.9$) (Lanza, in press). The cover must have originally been subhorizontal. It dips now of about 60°–70° toward to SE, with its horizontal axis lying presumably between the N and NE directions (see also Heller and Schmid,

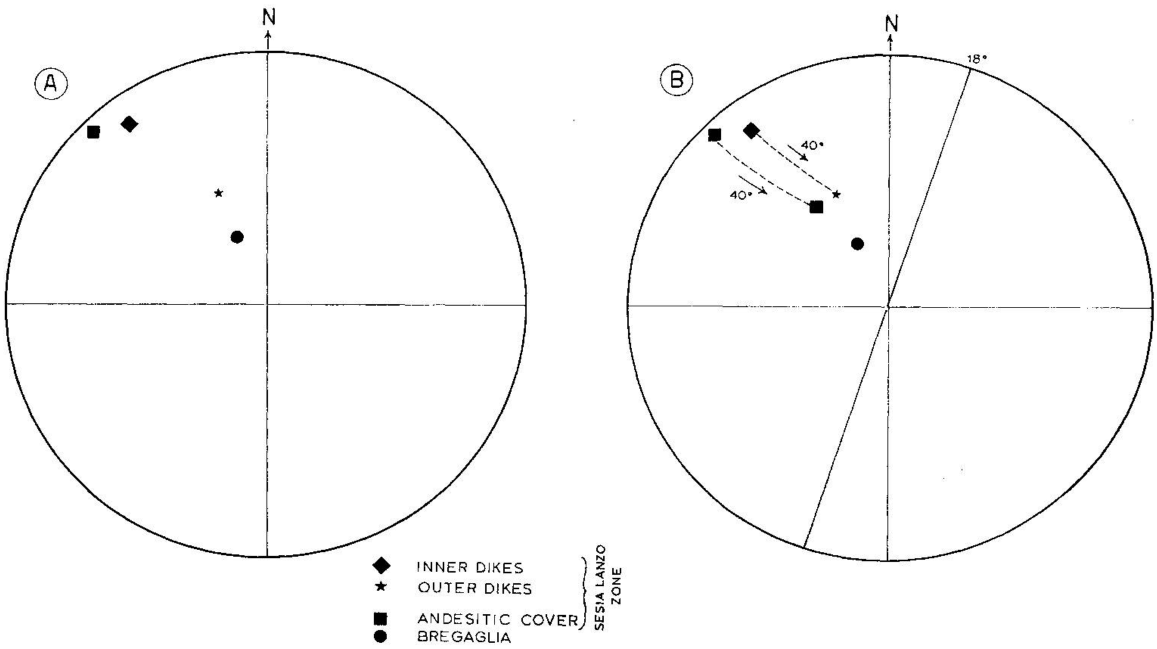

Fig. 5. Mean magnetization directions of the inner and the outer groups of dikes, of the andesitic cover and of the Bregaglia massif (all taken with normal polarity and represented on the lower hemisphere). Fig. 5A: measured directions. Fig. 5B: directions after rotation of the inner dikes and the andesitic cover.

1974). The underlying inner part of the Sesia-Lanzo Zone should obviously have been affected by the same rotational motion.

Fig. 5A is a stereographic projection of the mean magnetization directions of the dikes of the inner and the outer group from the Sesia-Lanzo Zone, of the andesites from the cover of the Zone and of the granites of the Bregaglia massif, which are so far the nearest rocks of Oligocene age whose NRM direction has been ascertained (Heller, 1973). It clearly appears that the data for this massif ($D = 337$, $I = 58$) and for the outer group ($D = 337$, $I = 39$) are fairly close. Their directions of magnetization, then, may correspond to the regional direction of the Earth's magnetic field in the Middle-Upper Oligocene. If all the dikes are of the same age, it may be supposed that the outer dikes are still lying in their original attitude, whereas those of the inner group and the andesitic cover underwent a displacement. Fig. 5B shows the minimum amount of motion required to bring the mean direction of the inner group to be aligned with that of the outer, i.e. a rotation of about 40° around a horizontal axis striking N 18°.

In conclusion, palaeomagnetic data available so far suggest that after the Middle Oligocene the Sesia-Lanzo Zone was folded about a subhorizontal axis. The movement affected the inner part and the cover, but had no appreciable effect on the outer part of the Zone. This folding is consistent with the results of structural studies in progress on the Sesia-Lanzo Zone, which point to the occurrence of folds of a late-alpine generation, with near horizontal axes striking north-east (P. F. WILLIAMS, personnal communication, 1977).

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