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Remanent Magnetization of the Tanzawa Tonalite Complex

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Abstract

The main part of the tonalite complex are mostly reversely magnetized and normally magnetized in part. It is therefore concluded that the complex encountered with a polarity transition of the geomagnetic field during a cooling process after the intrusion. However, paleomagnetic results from the complex did not provide a continuous record of the field reversal. Only part of transitional pole positions is obtained from the data. The positions of virtual north pole fall in a region between Africa and the Antarctic Continent such as those from the Japanese rocks of various types and ages. The timing of intrusions of each rock body was also estimated by examining directions of the remanent magnetization from the intrusive rocks measured.

1) Geological setting

The tonalite complex is exposed in the Tanzawa mountainland, Kanagawa Prefecture, Japan. Apparent size of the complex is 20 km long along east-west direction and 5 km wide. According to Takita (1974), this complex is composed of at least thirteen quartz-diorite intrusive bodies and four intrusive stages are recognized in the complex. The main part of the complex is mostly occupied by the Yushin and Azegamaru types which are characterized by tonalite rocks. Gabbroic rock bodies are likely to have been already emplaced before the intrusion of tonalite masses.

Of the four intrusive stages, the intrusion of the first stage is the Ōtakizawa type sampled. The second stage is characterized by the intrusions of the Yushin and Azegamaru types, which occupy the main part of the complex. The Ishiwariyama mass exposed to the west side of the complex appears to be formed at the same time as the Yushin type (Sugiyama, 1976). A samll body of the Yōkizawa type is distributed along the Shiraishizawa road and the body is likely to have intruded at the third stage (Takita, 1974).

On the other hand, results of the K–Ar age determination by Kawano and Ueda (1966) are 4.3 m.y. for a sample of the Azegamaru type, 5.2 m.y. for the Yushin type and 7.6 m.y. for the Ishiwariyama mass. However, according to Research Group for the Tanzawa Region (1975, 1977), there is a possibility that the tonalite complex was emplaced at the upper Miocene.

2) Samples and measurements

Oriented rock samples were collected at thirty five sites from five rock masses of the gabbroic rock, Ōtakizawa, Yushin, Azegamaru and Yōkizawa types as shown in Fig. 1 and also collected at a site of the Ishiwariyama mass. The gabbroic rock mass was sampled at three sites on a small road along the Sagase creek being a tributary stream of the Doshi river. The Ōtakizawa type was sampled at two sites on the Higashizawa road near the Inukoeji lodge. Samples of the Azegamaru type were

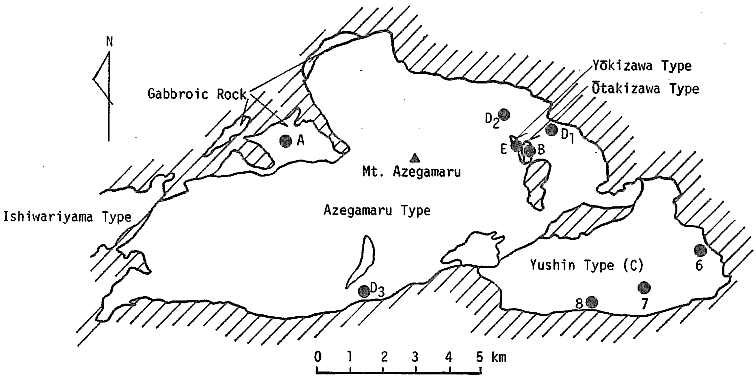

Fig. 1. Tanzawa tonalite complex (after Takita, 1974) and sampling sites.

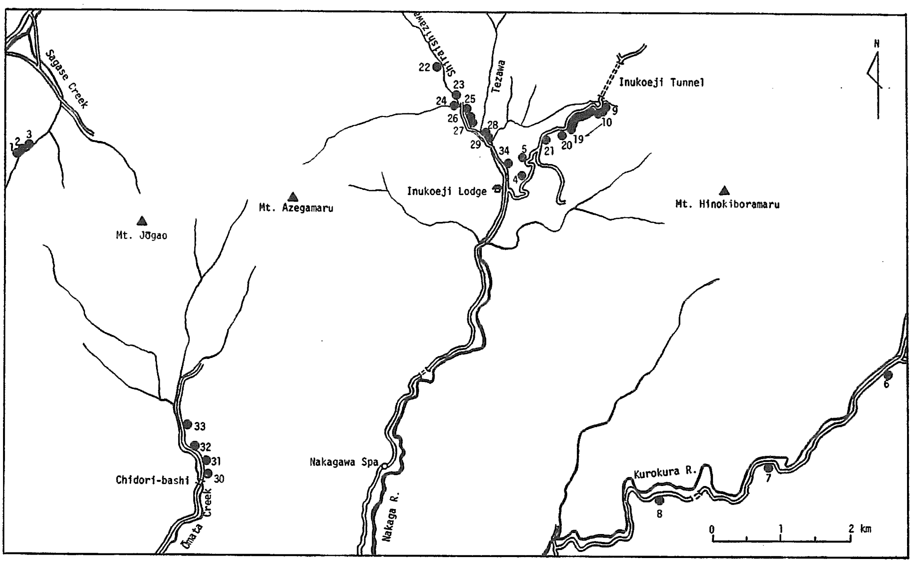

Fig. 2. Detailed map of sampling sites.

taken from thirteen sites on new successive outcrops along the Inukoeji road that intersects the contact zone, from six sites on new road cutting along the Shiraishizawa, and from four sites on road cutting from Chidori-bashi to upstream along the Ōmata creek. Samples of the Yōkizawa type were collected at an outcrop between the Tezawa and the Inukoeji lodge. Detailed map of the sampling sites are shown in Fig. 2, except for the Ishiwariyama mass. One or two core samples of 1.6 cm in diameter and 2.2 cm in length were drilled from each hand sample in the laboratory.

The natural remanent magnetization (NRM) of all hand samples was preliminarly measured with an astatic magnetometer. Then the NRM of core samples was measured with a SCT cryogenic magnetometer at the University of California, Santa Barbara. Systematic magnetic cleaning by AF technique was applied to all core samples measured. The optimum peak field of 300 oe was chosen for the samples of these intrusive rocks. Curie point determination of the Azegamaru type demonstrated that the dominant magnetic phase was an iron-rich titanomagnetite in samples investigated as shown in Fig. 3.

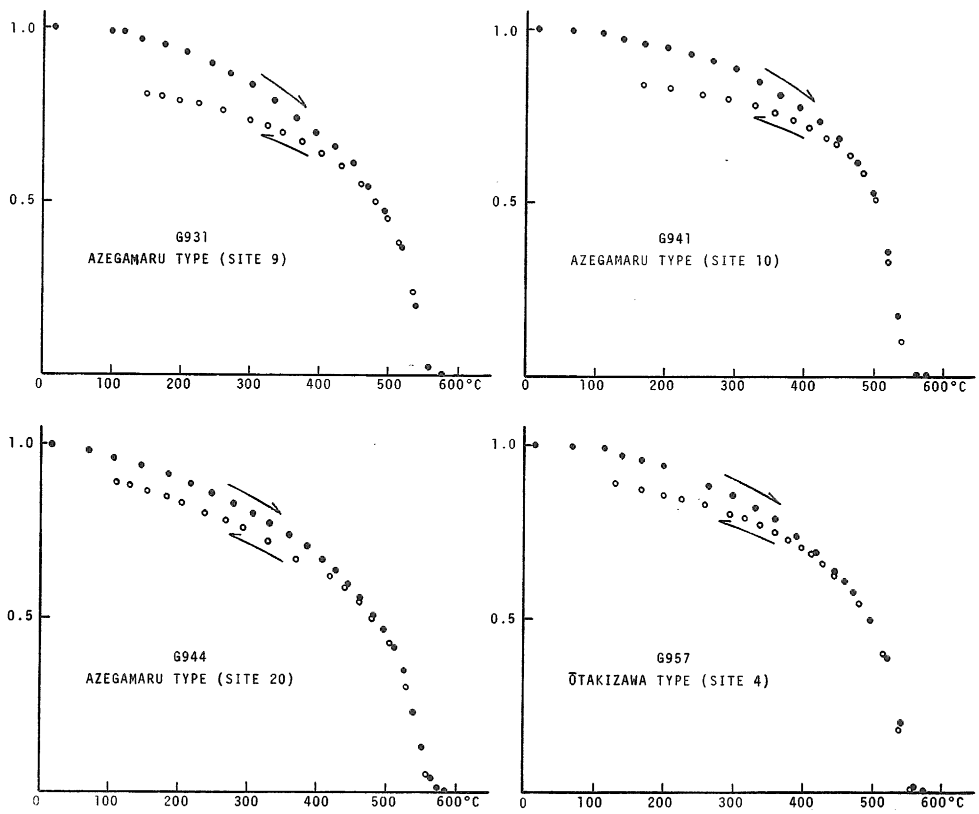

Fig. 3. Thermomagnetic curves for typical samples.

3) Directions of NRM

The core samples of the gabbroic rock, Yushin and Azegamaru types are reversely magnetized except for several sites near the center of the Azegamaru mass. Site-mean directions of the NRM at each sampling site of the complex are shown in Fig. 4 and the results of measurements are tabulated in Table 1. Area-mean directions of the NRM for each rock type or sampling area are shown in Fig. 5 and Table 2.

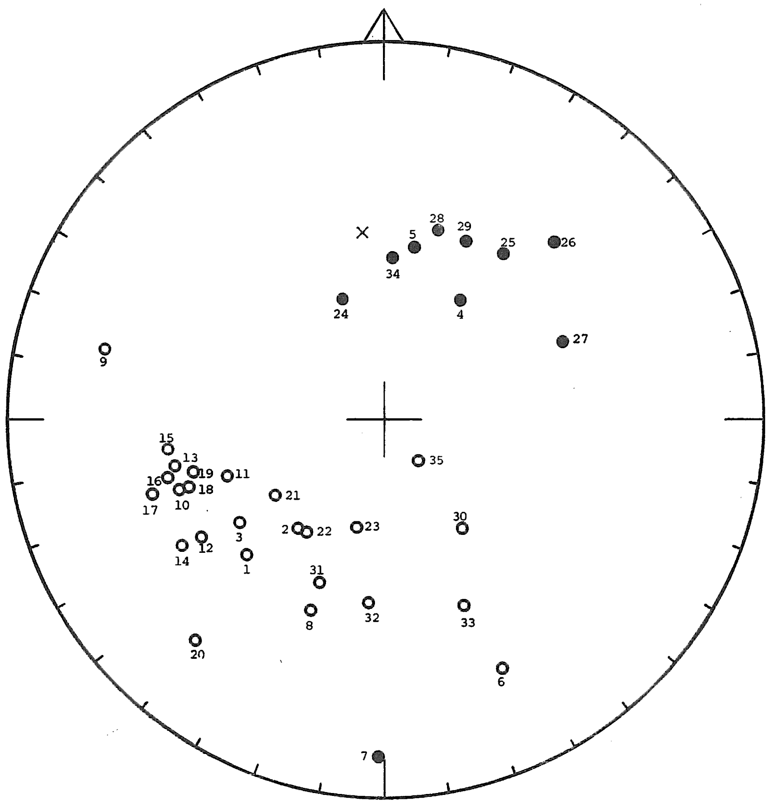

Fig. 4. Site-mean directions of NRM after demagnetization of 300 oe. Dots show to be in the lower hemisphere and open circles show to be in the upper hemisphere. The cross represents the present geomagnetic field direction.

The area-mean direction of the gabbroic rock is 227° in declination and $-53°$ in inclination and it is significantly close to that of the Azegamaru type (D_1) taken from the Inukoeji road. The Azegamaru type (D_2–R and D_2–N) from the Shira-ishizawa road is reversely magnetized near the margin of the mass and normally

Table 1. Paleomagnetic data for the Tanzawa tonalite complex.

Rock type	Site No.	N	D (°E)	I (°)	I_r (emu/cc)	K	α_{95}	Pole position Lat.	Long.
Cabbroic rock	1	3	226	−48	24.07×10^{-5}	51.0	17.5	51.0°S	45.0°E
	2	3	216	−60	12.63	79.0	13.9	59.7°S	27.0°E
	3	5	235	−51	18.57	17.9	18.6	44.0°S	37.3°E
Ōtakizawa type	4	5	33	+59	16.00	56.8	10.2		
	5	5	10	+51	18.50	47.5	11.2		
Yushin type	6	5	155	−28	6.32	60.9	9.9	59.6°S	167.0°W
	7	5	181	+11	1.86	10.7	24.4	49.0°S	137.6°E
	8	5	201	−45	9.21	104.3	7.5	70.0°S	69.6°E
Azegamaru type (D_1)	9	5	284	−24	2.31	11.4	23.6	3.8°N	31.0°E
	10	5	251	−42	5.26	65.4	9.5	29.0°S	38.8°E
	11	5	250	−53	7.28	120.0	7.0	33.4°S	28.4°E
	12	5	238	−42	3.56	32.0	13.7	39.1°S	45.2°E
	13	5	257	−42	4.20	10.4	24.9	23.9°S	35.0°E
	14	5	239	−37	4.85	49.0	11.0	36.4°S	48.2°E
	15	3	262	−42	3.91	22.5	26.6	19.3°S	33.5°E
	16	3	255	−40	3.25	53.7	17.0	25.1°S	38.2°E
	17	2	252	−35	4.13	—	—	25.0°S	42.7°E
	18	3	251	−43	5.02	32.9	21.9	29.2°S	38.0°E
	19	3	255	−46	4.33	64.0	15.5	27.1°S	33.1°E
	20	3	221	−24	2.42	16.0	31.9	46.8°S	70.4°E
	21	2	236	−61	2.92	—	—	46.8°S	23.0°E
Azegamaru type (D_2)	22	5	217	−60	7.08	8.5	27.9		
	23	4	194	−66	3.84	9.7	31.0		
	24	5	341	+62	5.64	31.0	14.0		
	25	3	36	+44	3.27	14.3	33.9		
	26	5	44	+34	3.12	15.1	20.3		
	27	4	67	+47	5.10	10.7	29.4		
	28	5	16	+46	2.58	9.5	26.1		
Azegamaru type (D_3)	29	5	25	+46	3.00	6.0	33.9		
	30	3	144	−61	2.76	10.6	39.9		
	31	5	202	−52	21.99	16.6	19.3		
	32	3	195	−50	13.63	720.9	4.6		
	33	4	157	−45	21.52	10.6	29.6		
Yōkizawa type	34	5	3	+54	4.12	1200.0	2.2	87.4°N	115.6°W
Ishiwariyama type	35	4	138	−79	3.70	39.5	14.8	49.5°S	63.0°W

N=number of samples measured.
D, I=site-mean declination and inclination of NRM.
K=Fisher's precision parameter.
α_{95}=semi-angle of cone of 95% confidence for the site-mean direction.

magnetized near the center of the mass. The area-mean direction of reversed samples is 207° in declination and −63° in inclination, and that of normal samples is 34° and 48° respectively. Although the Yushin type is evidently reversely magnetized, the NRM directions appear to be different from site to site. Therefore, we could not obtain

Table 2. Area-mean directions of NRM and corresponding virtual pole positions.

Rock type	N	D (°E)	I (°)	K	α_{95}	Pole position Lat.	Pole position Long.	dp	dm
Gabbroic rock (A)	11	227	−53	28.3	8.7	51.6°S	37.9°E	8.3	12.0
Ōtakizawa type (B)	10	21	+55	37.6	8.0	73.0°N	136.4°W	8.1	11.4
Azegamaru type (D_1)	49	251	−42	16.0	5.2	28.7°S	38.5°E	3.9	6.4
Azegamaru type (D_2–R)	9	207	−63	11.9	16.7	67.6°S	17.2°E	20.6	26.2
Azegamaru type (D_2–N)	27	34	+48	9.7	9.4	60.7°N	128.0°W	8.0	12.3
Azegamaru type (D_3)	15	186	−54	11.5	11.8	85.0°S	139.7°W	11.6	16.5
Yōkizawa type (E)	5	3	+54	1200.0	2.2	87.4°N	115.6°W	2.2	3.1

N=number of samples measured.
D=area-mean declination of NRM.
I=area-mean inclination of NRM.
K=Fisher's precision parameter.
α_{95}=semi-angle of cone of 95% confidence for the area-mean direction.
dp, dm=semi-angle of ovals of 95% confidence.

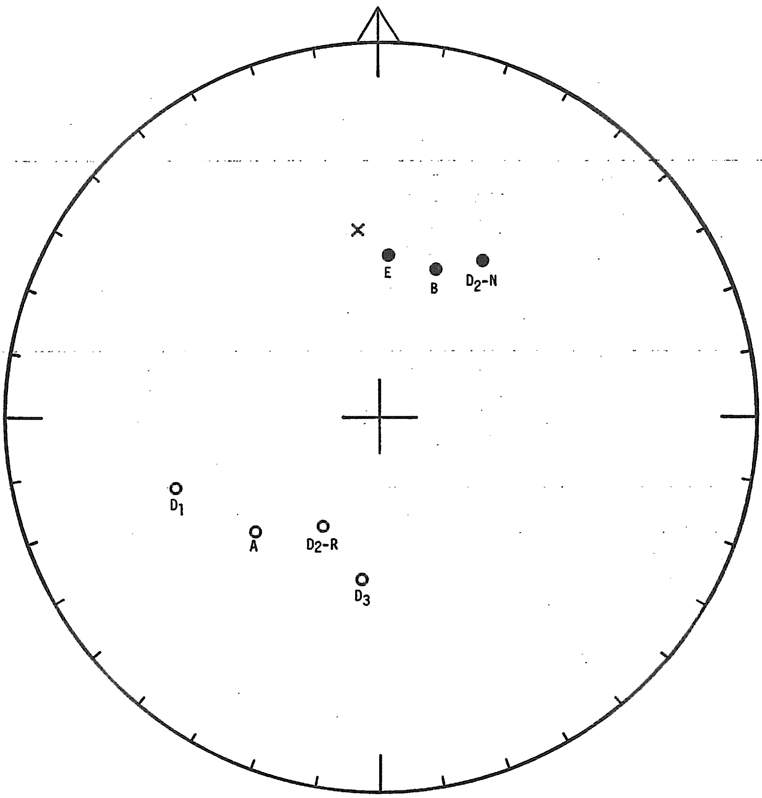

Fig. 5. Area-mean directions of NRM. Dots show to be in the lower hemisphere and open circles show to be in the upper hemisphere. The cross represents the present geomagnetic field direction.

an area-mean direction of the NRM for the Yushin type. Samples at a site of the Ishiwariyama mass is also reversely magnetized. However, the NRM directions are apparently different from those of the Yushin type which is likely to be emplaced at the same time as the Ishiwariyama mass (Sugiyama, 1976).

The Ōtakizawa type, which was formed at the first stage, are normally magnetized and the NRM directions are close to the present field direction. It means that the remanent vector is not magnetically affected by the Azegamaru type which is the intrusion of the second stage. On the other hand, the Yōkizawa type at the third stage is also normally magnetized and the NRM directions are consistent with those of the Ōtakizawa type. Therefore, if the four intrusive stage proposed by Takita (1974) are reasonable and if cooling rate of the Azegamaru type that occupies the main part of the complex was of the order of 10^4 years, there is every probability that an entire record of a geomagnetic field reversal is contained in the tonalite complex.

From paleomagnetic results described above, first there is a possibility that the gabbroic rock was formed at the same time as the intrusion of the Azegamaru type (D_1). Second it is concluded that the Azegamaru type was encountered with a polarity transition during a cooling process after the intrusion, because the reversed and normal samples are separately collected from adjacent two outcrops belonging to the Azegamaru type (D_2).

4) Virtual geomagnetic pole

Fig. 6 shows virtual geomagnetic poles obtained from the site-mean directions of the Azegamaru type (D_1) and the gabbroic rock (A). In the figure, site 9 is the oldest point near the margin of the Azegamaru mass and site 21 corresponds to the youngest place near the center of the mass. It appears to me that swings of the virtual pole along a great circle occur in the southern part of Africa. Unfortunately, because the geometry of the mass is so poorly known and also successive outcrops along the Inukoeji road are very unlikely to be oriented at right angles to the cooling front permitted the acquisition of remanent magnetization, the distance between the sites 9 and 21 is not always a linear function of the time. Therefore, detailed movements of the virtual geomagnetic pole may have no significance, but it will be recognized that the virtual pole has transiently passed by Africa.

The virtual geomagnetic poles calculated from the area-mean directions of NRM of each rock type or sampling area are shown in Fig. 7. As seen in the figure, the virtual north pole from the Ōtakizawa type emplaced at the first stage is close to the present north pole. The poles from the Azegamaru type at the second stage lie in the Southern Hemisphere except for that from the normal sample (D_2–N). The pole from the Yōkizawa type at the third stage is again located near the present north pole. From a fact that the virtual pole from the normal sample of the Azegamaru type (D_2–N) deviates considerably form the present pole, it is predicted that the Yōkizawa

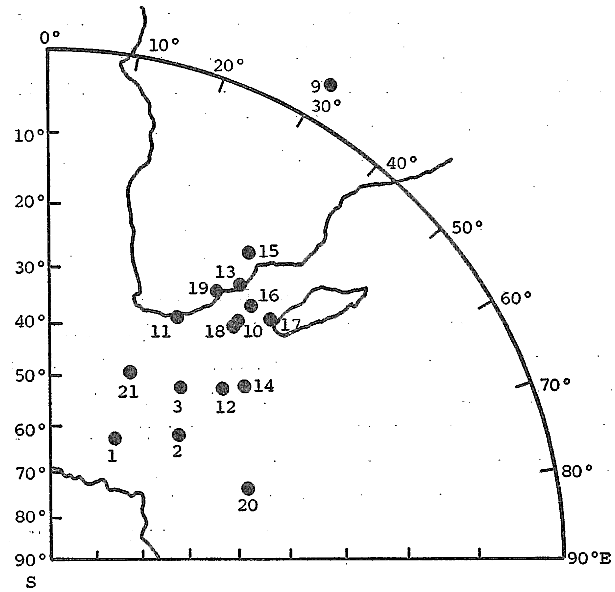

Fig. 6. Virtual geomagnetic poles from the site-mean directions of NRM of the Azegamaru type (D_1) and the gabbroic rock (A).

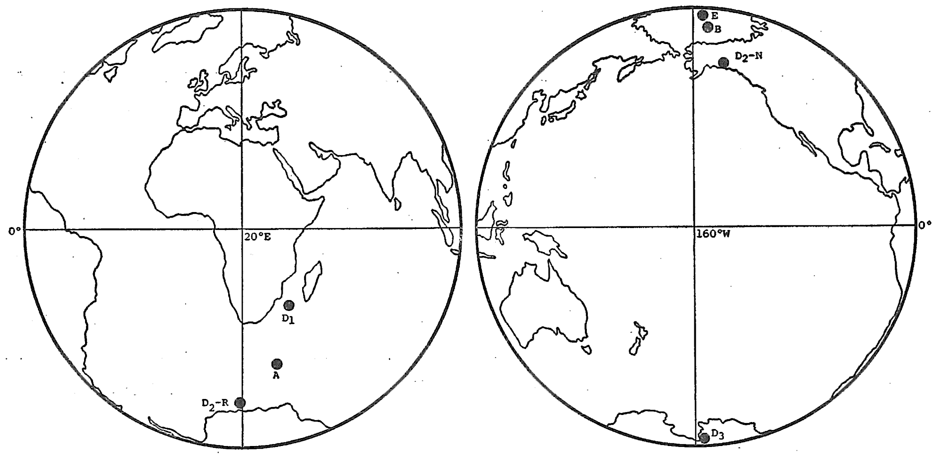

Fig. 7. Virtual geomagnetic poles from the area-mean directions of NRM.

type was shortly emplaced after cooling of the Azegamaru type (D_2–N).

The virtual geomagnetic pole from the gabbroic rock corresponding to the early plutonic activity in this region is approximately consistent with that from the Azegamaru type (D_1). If these two bodies have been emplaced at the nearly same time and if each virtual pole from the bodies represents transient positions of the geomagnetic pole during a polarity change, this short record of a field reversal should indicate that the geomagnetic pole moved northward along a great circle because of geological evidences described previously. Such results have been obtained from paleomagnetic studies on the Japanese rocks of various types and ages (Momose, 1958; Nomura, 1963; Ito, 1971; Ito and Tokieda, 1978).

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