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PALAEOMAGNETIC STUDIES OF THE BASIC BOCKS IN SOUTH PATAGONIA, CHILE.*

by

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(with 11 Text-figures)

(Contributions from the Department of Geology and Mineralogy, Faculty of Science, Hokkaido University. No. 1072)

Inroduction

Three of the authors of the present note, S. ANMA, T. ENDO and T. NISHIMURA who participated in the expedition in Patagonia as members of the Patagonia Resarch Group of the Hokkaido University in 1965, tried to collect well oriented rock samples with desiring to make a palaeomagnetic study on certain rocks there. Sampling was made at two localities in the course of their field work in the southern part of Patagonia, Chile. One of them is located at Sillon del Diablo (50°50′S, 72°20′W) where they collected samples from doleritic rocks and basalt flows. The geological articles about these rocks will be given below. The specimens were numbered by the collectors as A-330 (dolerite), G-330 (olivine basalt) and E-330 (andesitic baslt) respectively.

Another locality is situated at Cerro Guido, also suthern Patagonia (50°54′S, 72°27′W) where they collected samples from dolerite only. These specimens were numbered by them as A-331, E-331 and G-331.

All of these rock specimens were disposed for measurement under Y. FUJIWARA and S. OHTA, the palaeomagnetic laboratory of the Geological and Mineralogical Department of the Hokkaido University, after the paticipator's comming back to Japan.

According to ANMA, ENDO and NISHIMURA, in the area where the samples now in concern were collected, metamorphic rocks composed of phyllite, sericite schist, biotite schist and so on is widely exposed as the oldest complex there which is covered by the fossiliferous Jurassic or Cretaceous formations. These Messozoic formations are chiefly consisting in tuffaceous shales, siltstones and sandstones, besides basic rocks including sheets and dykes of dolerites. The samples for the

* Contribution from the Patagonia Research Group of the Hokkaido University.

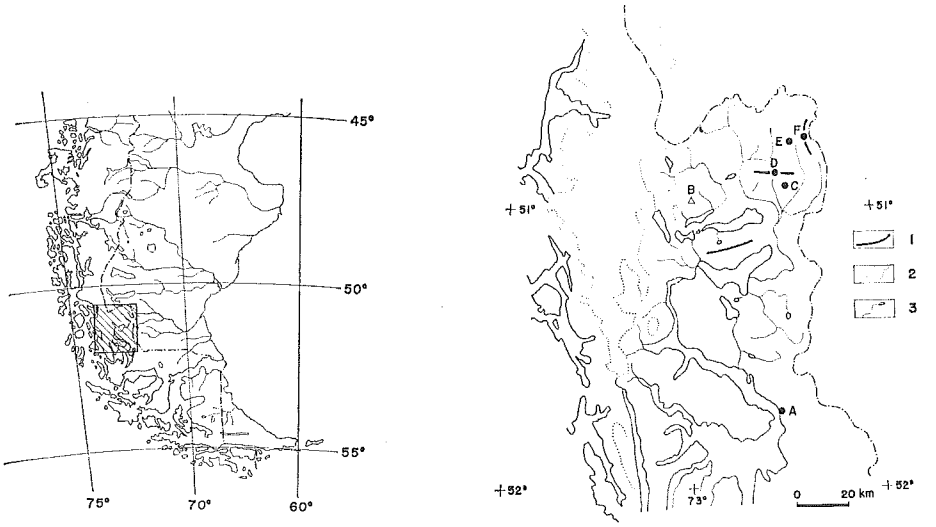

Fig. 1
Sketch map of the southern part of Patagonia, showing sampling locality.
1 : mountains, 2 : glacier, 3 : river, A : Puerto Natales, B : Cerro Paine, C : Estancia Cerro Guido, D : Cerro Guido, E : Estancia Leones, F : Sillon del Diablo.

thesis of the present study were chosen from these doleritic sheets, which were observed in field to have intrude into the Cerro Toro formation, upper Cretaceous in age. The exact stratigraphical position of the dolerite could not accordingly be settled yet, except for the lower limit of the age is post Cerro Toro formation.

In the meantime, the lava flows composed of olivine basalt or andesitic basalt were also sampled by the same members as before mentioned. These rocks are widely outcroped on the top of the moutains Sillon del Diablo, Cerro Pagoda. These lava flows unconformably cover the Augua Fresca formation widely developed in these mountanious region and the age of which is believed to be Eocene (KATZ 1961). The same kind of lava flows with the same lithology have been however also observed to cover the upper Tertiary deposits in the eastern region from these mountains (PIATNITZKY 1938). Further, the lave flows are observed to have been subjected to the glacial erossion during the Late Pleistocene in the mountains Sillon del Diablo, Cerro Pagoda, where the sampling for these rocks were made. Accordingly, the age of these basaltic flows may be eventually concluded to be after the Pliocene but prior to the Late Pleistocene.

Result of measurements

The directions and intensities of N. R. M. of the sampled rocks were measured

by means of an astatic magnetometer. However, the dolerite specimens collected from the locality of Cerro Guido, could not be measured by the aparatus available for us. These specimens have less than 10^{-8} emu/gr. in intensity, although the petrographic nature of which do not show any remarkable difference to the other specimens of dolerite collected from another locality, Sillon del Diablo. It may be very interesting problem why the dolerite samples at the locality, Cerro Guido do show such weak intensity, for which there may be plausible explanation. However, the authors wish to merely describe the result on the magnetic determination in this paper about the specimens collected from the Sillon del Diablo amongst doleritic rocks.

The inclinations and declinations of magnetization of the dolerites are plotted on Schimidt's net, which show the reversed magnetization. Further, the result of laboratory works on lava flows both of olivine basalt and andesitic basalt will be

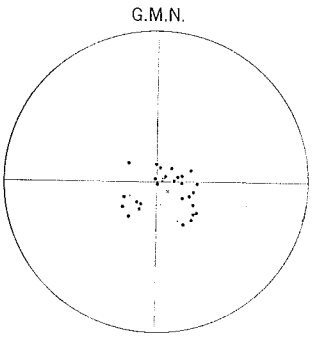

Fig. 2
Direction of magnetization of the specimens collected from doleritic sheets (A-330).

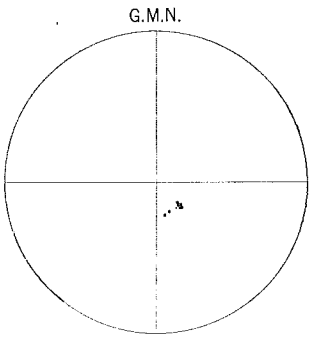

Fig. 3
Direction of magnetization of the specimens collected from olivine basalt lava flow (E-330).

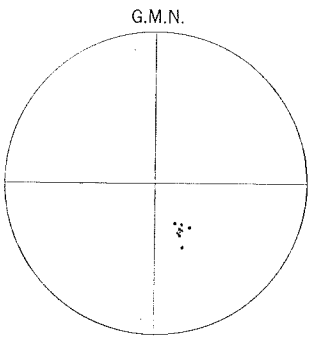

Fig. 4
Direction of magnetization of the specimens collected from andesitic basalt lava flow (G-330).

described below, which also show the reversed magnetization, and especially high inclination as is shown in text figures 2–4.

Table 1. Result of palaeomagnetic determinations

Sample No.	Declination	Inclination	α_{95}	Intensity (emu/gr.)	Jn/J_T	Pole position	δ_p	δ_m	Rock	Geological age
A-330	151°	82°	5°	9.4×10^{-4}	0.1	63°S, 55°W	11°	10°	dolerite	Post Cerro Toro form.
E-330	160°	73°	3°	3.6×10^{-3}	0.5	76°S, 22°W	5°	4°	olivine basalt	Lower to Middle Pleist.
G-330	170°	60°	3°	1.2×10^{-3}	0.3	78°S, 80°W	5°	4°	andesitic basalt	Lower to Middle Pleist.

Stability of N.R.M.

In order to reduce the effect of soft component of magnetization and check the reliability of specimens for the palaeomagnetic determination, the authors tried to make the following four trials in the stability of rock magnetism. Namely, alternating current magentic field demagnetization method, thermo demagnetization method, thermomagnetic analysis and X-ray analysis were applied.

1) *A-C demagnetization*

The results of this test are shown in text figures 5–7. During the course of this experiment, the N.R.M. of specimens, both in basalt and dolerits, do not decay in intensity less than 1/3 by increasing alternating magnetic field up to 400 Oe. So, the authors regard those specimens to be almost stable.

2) *Thermo demagnetization*

Then, the authors try to measure the thermal variations of N.R.M. and T.R.M. of some purposely chosen specimens. Set of curves of N.R.M. and T.R.M. for each sample fairly coincide as are shown in the text figures 5–7. It may accordingly concluded that the N.R.M. of the sampled rocks has been preserved in the form of thermoremanent magnetization. The ratio between N.R.M. and T.R.M. (Jn/J_T) of some dolerites specimens, however falls less than 0.1. This suggests us the reliability of N.R.M. of these rocks to be somewhat suspicious. Nevertheless, the examination for the stability of N.R.M. shows rather stable, as above stated. Therefore, the authors believe that the intensity of geomagnetic field in those days when these rocks intruded, was possibly far weaker than the present.

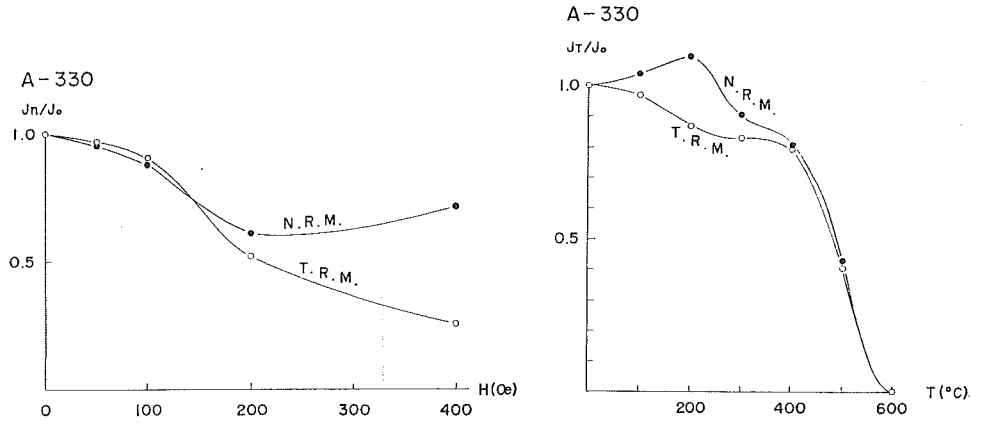

Fig. 5
Value of relative intensity of N. R. M. and T. R. M. of dolerite after A-C demagnetization and thermo-demagnetization.

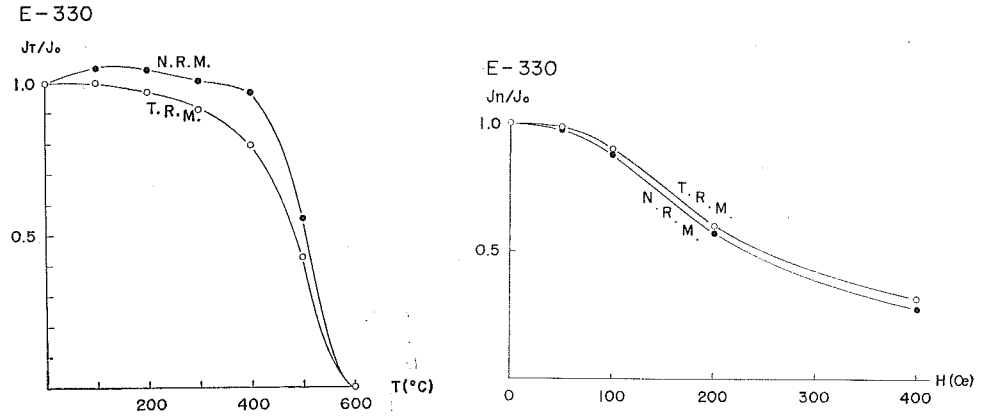

Fig. 6
Value of relative intensity of N. R. M. and T. R. M. of olivine basalt after A-C demagnetization and thermo-demagnetization.

3) *Thermomagnetic analysis*

By means of thermomagnetic balance, the authors undertook a thermomagnetic analysis to obtain the Curie temperature of the ferromagnetic minerals in the sampled rocks and the thermal variation of the the saturation magnetization. The results of these experiments are shown in the text figures 8–10.

As shown in the text figures, in respect of the most specimens, reversible heating and cooling curve indicates the Curie temperature to have been ranging from

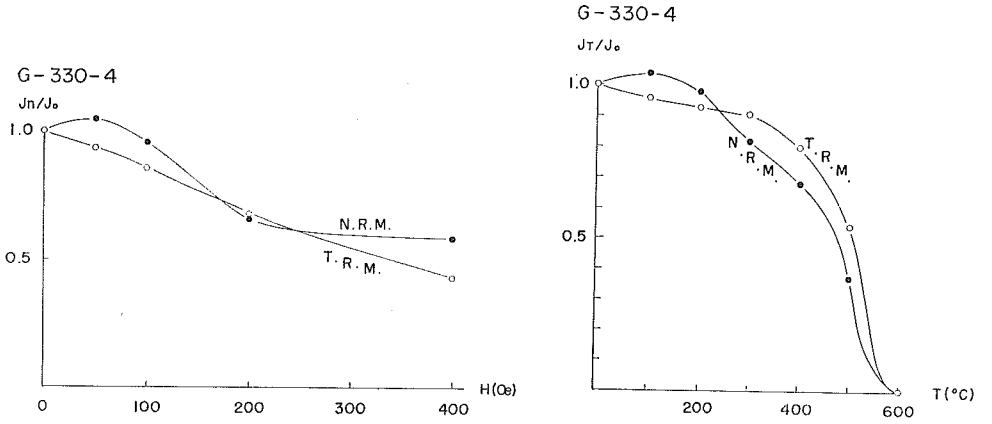

Fig. 7
Value of relative intensity of N. R. M. and T. R. M. of andesitic basalt after A-C demagnetization and thermo-demagnetization.

560° to 570°C. This denotes that the ferromagnetic minerals of the rocks treated in the present study, may mainly composed of pure magnetite or titanomagnetite which contain few $TiFe_2O_4$. In the same experiments, the heating curve shows to have a transition point between 230° and 260°C at least in certain specimens both in the lava flow of basalt and in the dolerite sheet. During the course of thermo demagnetization, the direction of magnetization was observed to show only minor change by increasing temperature up to 600°C, and the decay in intensity was also observed less then 1/10 by increasing temperature up to 300°C. (text fig. 6, 7) It may be

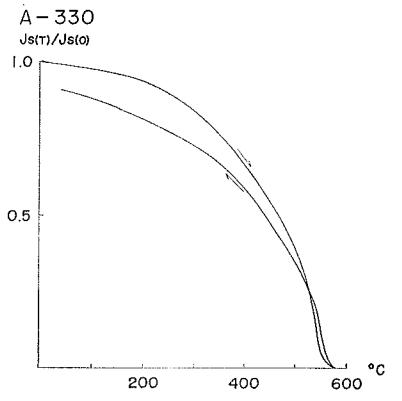

Fig. 8
Thermo-magnetic curves of the specimens collected from doleritic sheets.

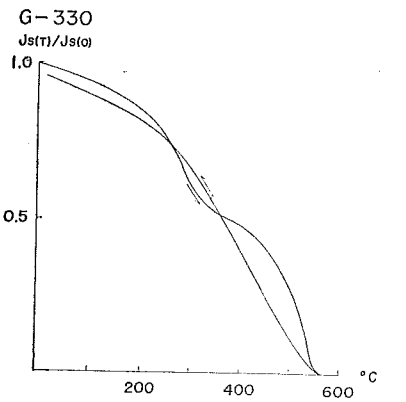

Fig. 9
Thermo-magnetic curves of the specimens collected from andesitic basalt.

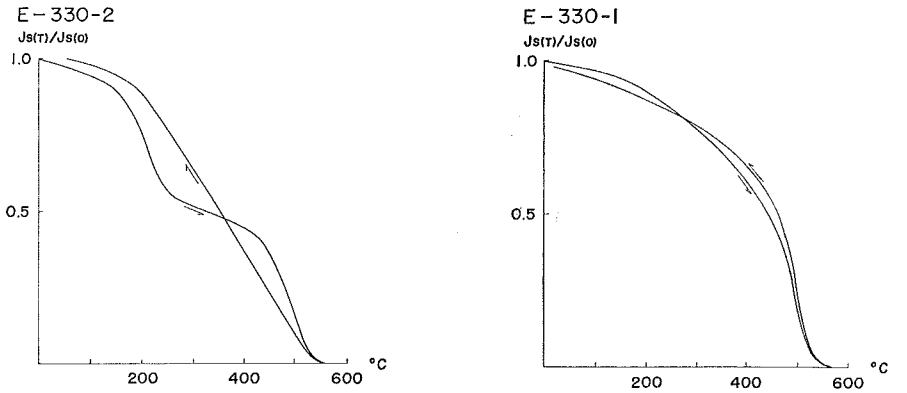

Fig. 10
Thermo-magnetic curves of the specimens collected from olivine basalt.

accordingly concluded that most remanent magnetization were depend to high temperature phase of ferromagnetic minerals. They might be either pure magnetite or titanomagnetite with less component of $TiFe_2O_4$.

4) *X-ray analysis*

The X-ray aparatus was operated at 35 KV 7 mA, with Fe-target and Mn-filter. Scanning speed was 1°/4 min. The result will be shown below;

A-330: a=8.405±0.005 Å, titanomagnetite
E-330: a=8.405−8.445±0.005 Å, titanomagnetite
G-330: a=8.405−8.438±0.005 Å, titanomagnetite

Conclusions

Based on the data in measurements, the authors tried to calculate the virtual geomagnetic pole positions (text figure 11). From the geologic point of view, the lava flows of olivine basalt and andesitic basalt can be post Pliocene but pre-Late Pleistocene as before stated. The age may be accordingly sometime in the Lower to Middle Pleistocene. The result of the present study, however shows that these lava flows Sillon del Diablo, has reversed magnetization. Therefore, it may be correlatable to the Matsuyama's reversed epoch ($0.7-2.5\times10^6$y. B.P.) (Cox et al. 1964), with high possibility.

In respect to the dolerite sheet, the virtual geomagnetic pole position was also determined by caluculation based on the result of measurement, although the age of this rock is not known beyond the fact that it may be somewhat younger than the

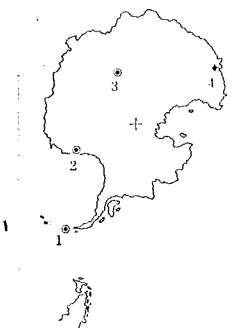

Fig. 11
Position of the virtual geomagnetic pole, based on the data from the southern Patagonia, Chile. 1; infered from doleritic sheet 2; from olivine basalt 3; from andesitic basalt 4; position of the present geomagnetic pole.

Cerro Toro fromation, upper Cretaceous in age. The rock samples also show the reversed magnetization, and very weak intensity.

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