

Paleointensity study on rocks from Napier Complex, Antarctica

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Abstract

Paleointensity studies on igneous and metamorphic rocks from Napier Complex by the author are reviewed with unpublished data. All the samples from Napier Complex showed the tendency of having high paleointensity in low temperature and low intensity in high temperature in Arai diagram. The reason is considered to have multi-domain mineral as the main magnetic carrier. Magneto-mineralogical analysis is required to detect multi-domain sample for rejection. High increase of both NRM and PTRM in high temperature of over 350 °C in AF demagnetized sample, suggests the mineralogical change had occurred at around 350 °C. To avoid this phenomenon, rejection of the sample with sulfide is necessary. As VRM could be added in seconds, it is also suggested that experiments have to be carried in a shielded laboratory.

Key words: paleointensity, Thelliers' method, Shaw's method, the Napier Complex, Antarctica

1. Introduction

Since 1989, granulite, mylonite, dolerite and basalt collected by Japanese Antarctic Research Expedition Party were studied to obtain the paleointensity of the geomagnetic field in the Archean. In the Napier Complex, four events of 3930, 2950, 2480 and 1000 Ma were recognized based on U-Pb dating (BLACK et al., 1986). UENO (1995) reported K-Ar age of 1.4 and 1.22 Ga on basalt and granulite samples, and of 4.6, 3.5, 2.8, 2.13 and 1.2 Ga on thermally altered samples or samples contained altered minerals. Paleointensity study on these rocks with more than 1.2 Ga in age could reveal the history of the ancient geomagnetic field of the earth. Through the experiments, a lot of difficulty was recognized. In this study, summarizing the paleointensity study carried by the author, suggestions for the further study of paleointensity on Napier Complex would be reported.

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2. Review of the Experiments with Additional Data

Samples were collected near Mt. Riiser Larsen except one from Amundsen Bay. Eight samples collected by H. MAKIMOTO of Geological Survey of Japan and one from Amundsen Bay collected by M. FUNAKI of NIPR were used. In addition, nine samples collected by M. FUNAKI and N. ISHIKAWA of Kyoto Univ. were used for the study of the secondary magnetization. Result from the sample of Amundsen Bay was reported in UENO (1990), and that from near Mt. Riiser Larsen was reported in UENO and FUNAKI (1991). On the Arai diagrams in these reports, two lines with different slopes, high slope line in low temperature under 350 °C and low slope line in high temperature above 400 °C, could be drawn. Slope in low temperature varied in multiple experiments on specimens from one sample. In Fig.1, the example of the variation of slope on the sample No.1907A with the same applied laboratory field is shown. To minimize the variation of slope within multiple experiments, various kinds of trials were carried as below.

One was the trial to delete VRM chemically. Samples were soaked in 6N HCl from 30 hours to 24 days (UENO,1990) before applied to Thelliers' method, but nothing had changed in the slope of Arai diagram.

Second, one specimen (NP2102B) was tried to Thelliers' method after AF demagnetization. Arai diagram of this trial showed the great increase of both NRM and PTRM with temperature, especially over 350 °C (Fig.2). In the case without AF demagnetization, increase of both NRM and PTRM could be seen also. In both cases of with and without AF treatment, magnetic mineral with poor NRM would be changed to magnetite at around 350 °C, and would get stable NRM. For example, the specimen(NP2102B) without AF demagnetization, had PTRM of 11.6E-03emu/g in the laboratory field of 100 μ T. Specimen after AF demagnetization with 80 mT field had PTRM of 5.0E-03emu/g at about 350 °C in the laboratory field of 50 μ T. AF demagnetization curve for MAKIMOTO sample is shown in Fig.3. The curve for FUNAKI and ISHIKAWA sample was shown in ISHIKAWA and FUNAKI (1997). Quick decay of AF demagnetization curve shows to have low coercive force in all the samples.

Third, after TRM was applied in laboratory of 50 μ T at 600 °C, Thelliers' method was carried to detect if the 50 μ T could be produced as paleointensity (Fig.4). In this experiment, most of the PTRM was blocked in the higher temperature than 500 °C, and proper paleointensity can be calculated using all the points in Arai diagram. In the original natural state of sample, three quarters of NRM was thermally deleted before 500 °C in Thelliers' experiment (cf. Fig.5). On the contrary, newly created magnetite during heating of 600 °C must have accounted for the great part of TRM. It is also notable the higher paleointensity than the applied field can be calculated in the low temperature.

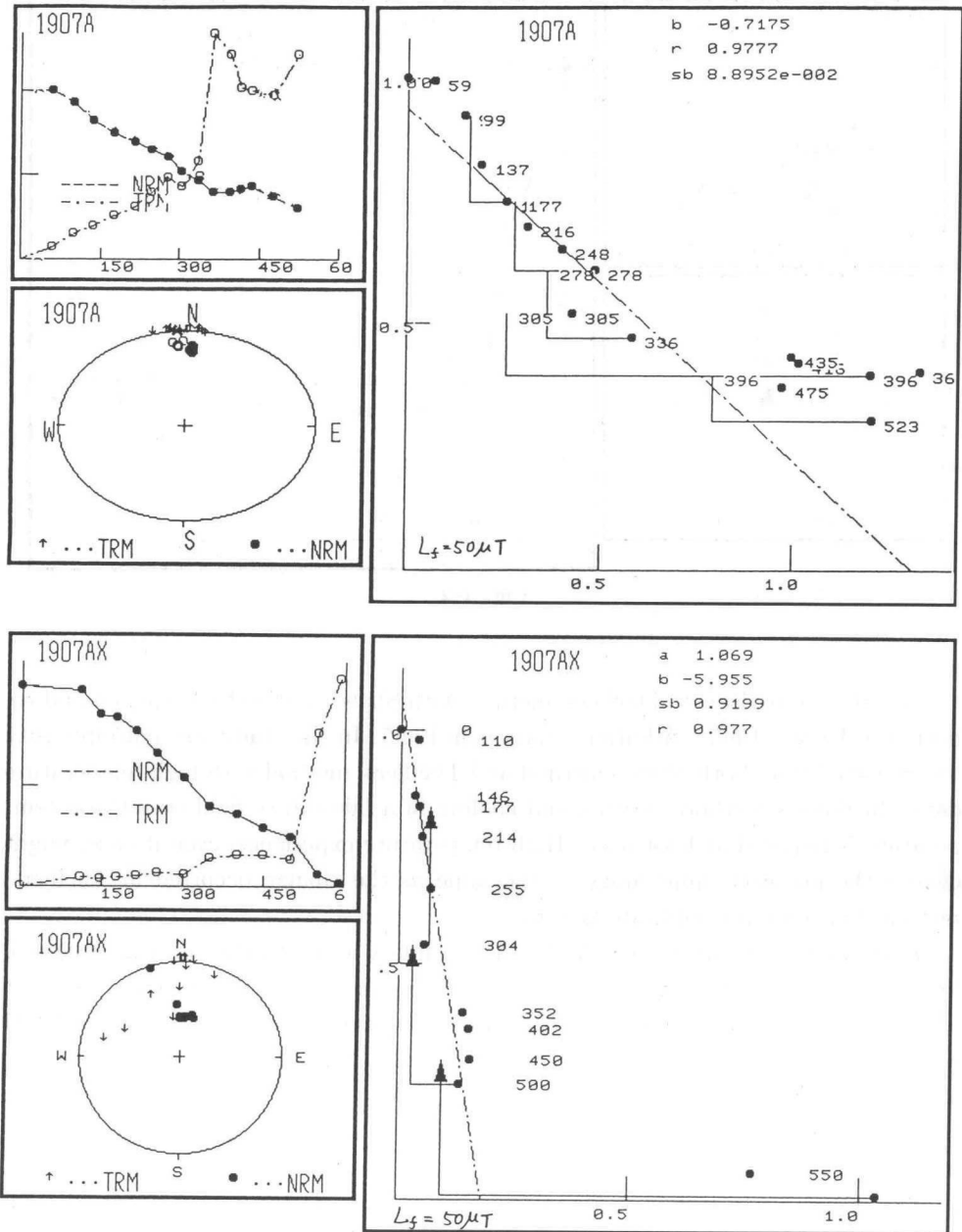


Fig. 1-1

Fig. 1 Example of the variation of slope in multiple experiments with the same applied laboratory field (No.1907A).

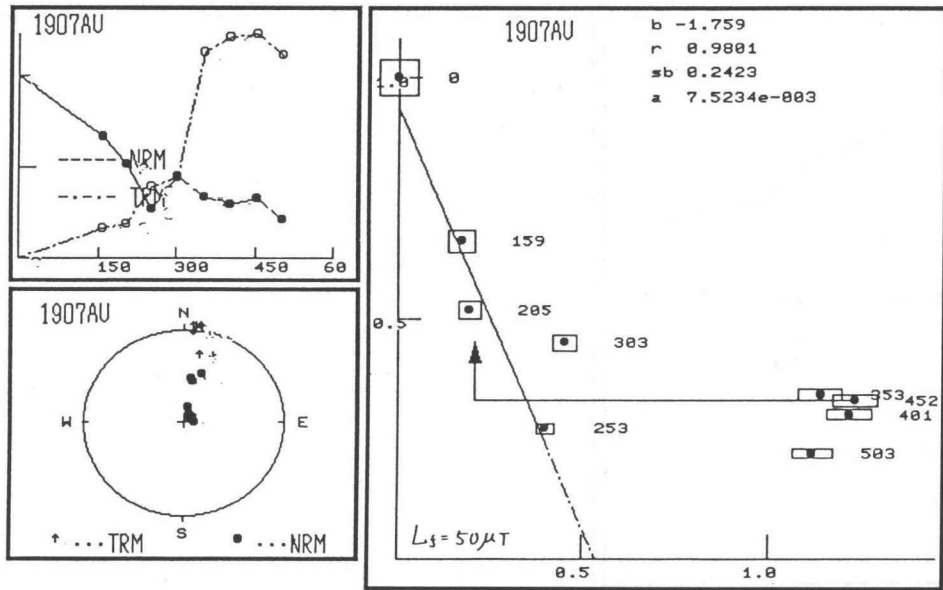


Fig. 1-2

Fourth, comparison of Thelliers' method with Shaw's method was carried and reported in UENO (1995). Additional data is in Fig.5. In the study, low paleointensity was reported from both Shaw's method and Thelliers' method with high temperature data. In Shaw's method, heating and cooling in a laboratory field over Curie temperature is required at least once. High temperature experience, even if once, might change the magnetic mineralogy to the same as the change occurred in Thelliers' method that requires duplicate heating.

Fifth, to find out the origin of VSM, the secondary magnetization during successive heating was discussed comparing the experiments in air with in vacuum (UENO et al., 1998; UENO and OGISHIMA, 1999). In some samples both the secondary NRM and PTRM were maximum between 300°C and 400°C. It was also recognized that while all the specimens in air had linear lines in Arai diagram, specimens in vacuum rarely had. In air, all specimens might be oxidized to have a linear portion even in low temperature.

The missing experiment is the experiment in the shielded laboratory. The all experiments described above were carried with care about the magnetic field of the earth. For instance, specimens were quickly transferred to a shield case and kept in it after step heating and measuring. However, even in few seconds of exposure, VSM of the earth must have been attached.

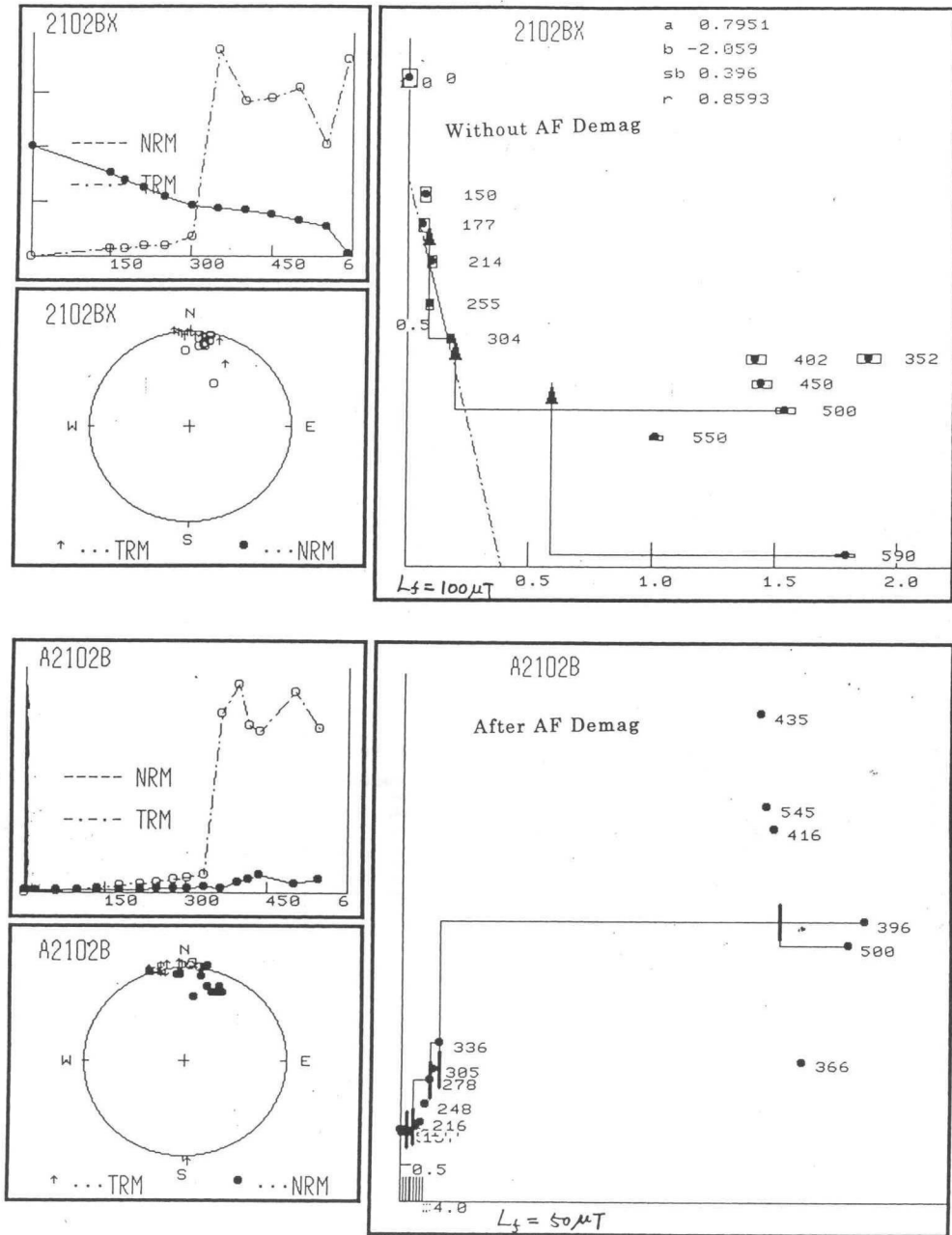


Fig. 2 Arai diagram of Thelliers' method after AF demagnetization and without AF demagnetization(NP2102B).

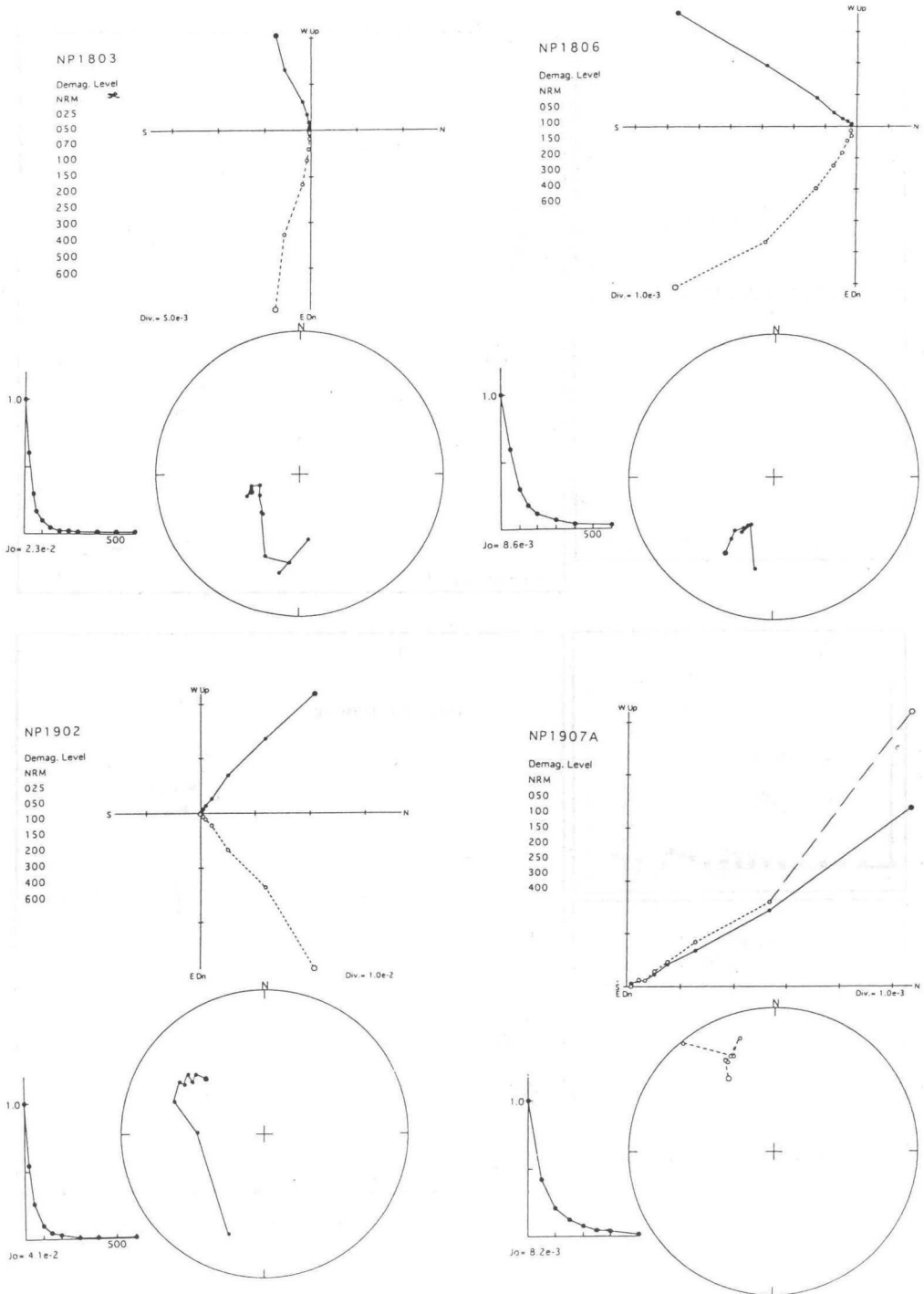


Fig. 3-1

Fig. 3 AF demagnetization curves on MAKIMOTO samples.

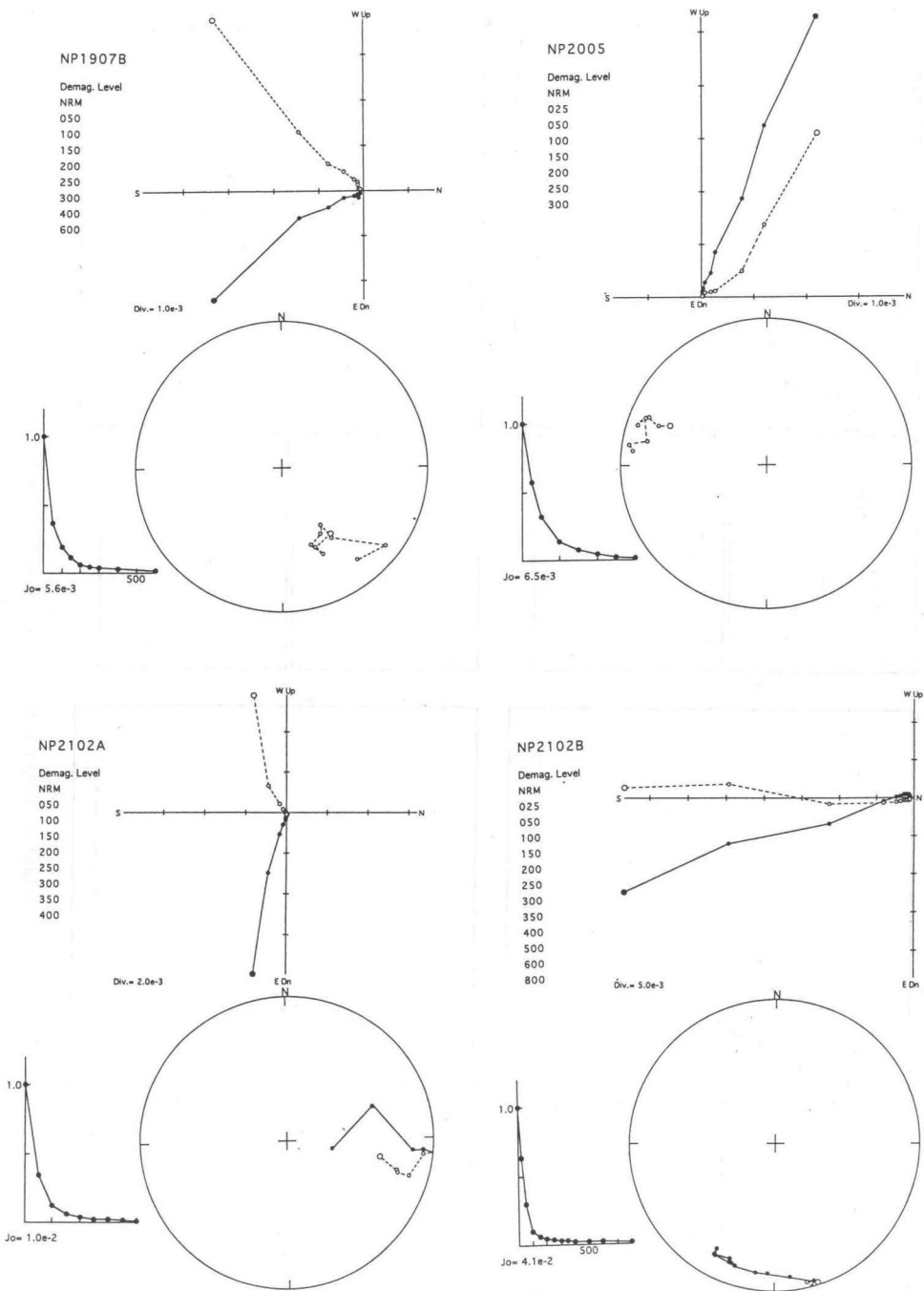


Fig. 3-2

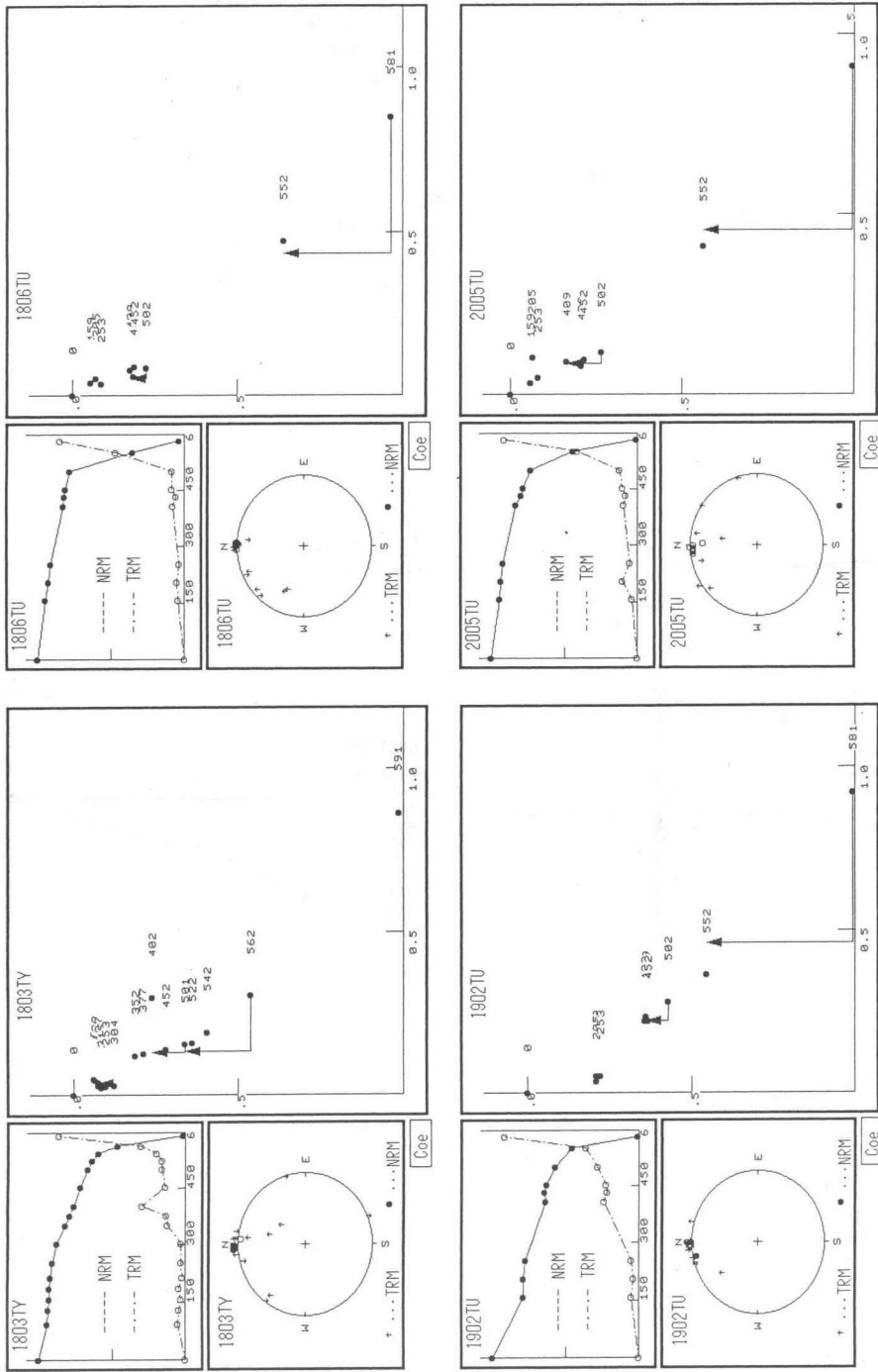


Fig. 4 Thelliers' method to detect if the 50 μ T could be produced as paleointensity.

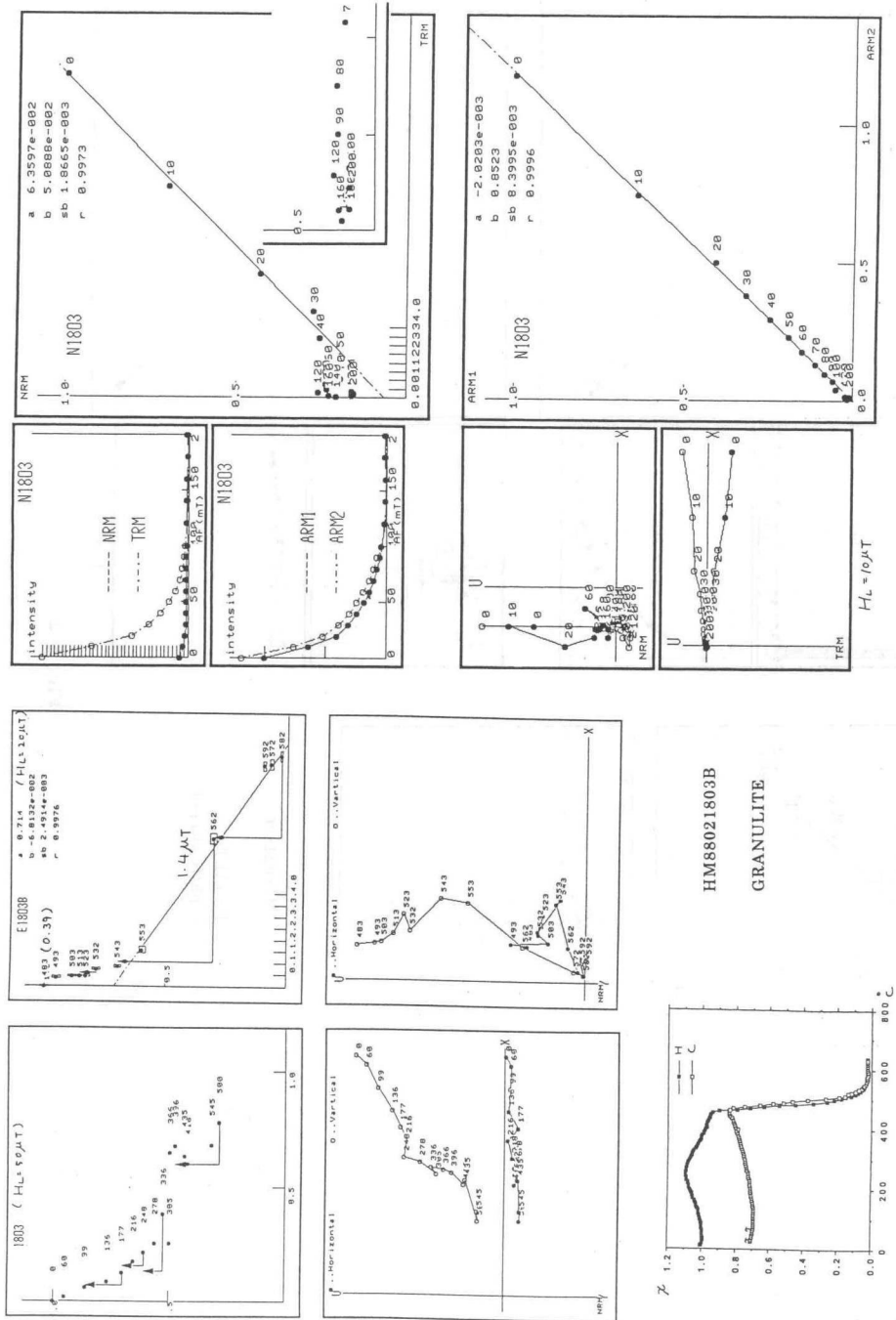


Fig. 5 Comparison between Thelliers' method and Shaw's method.

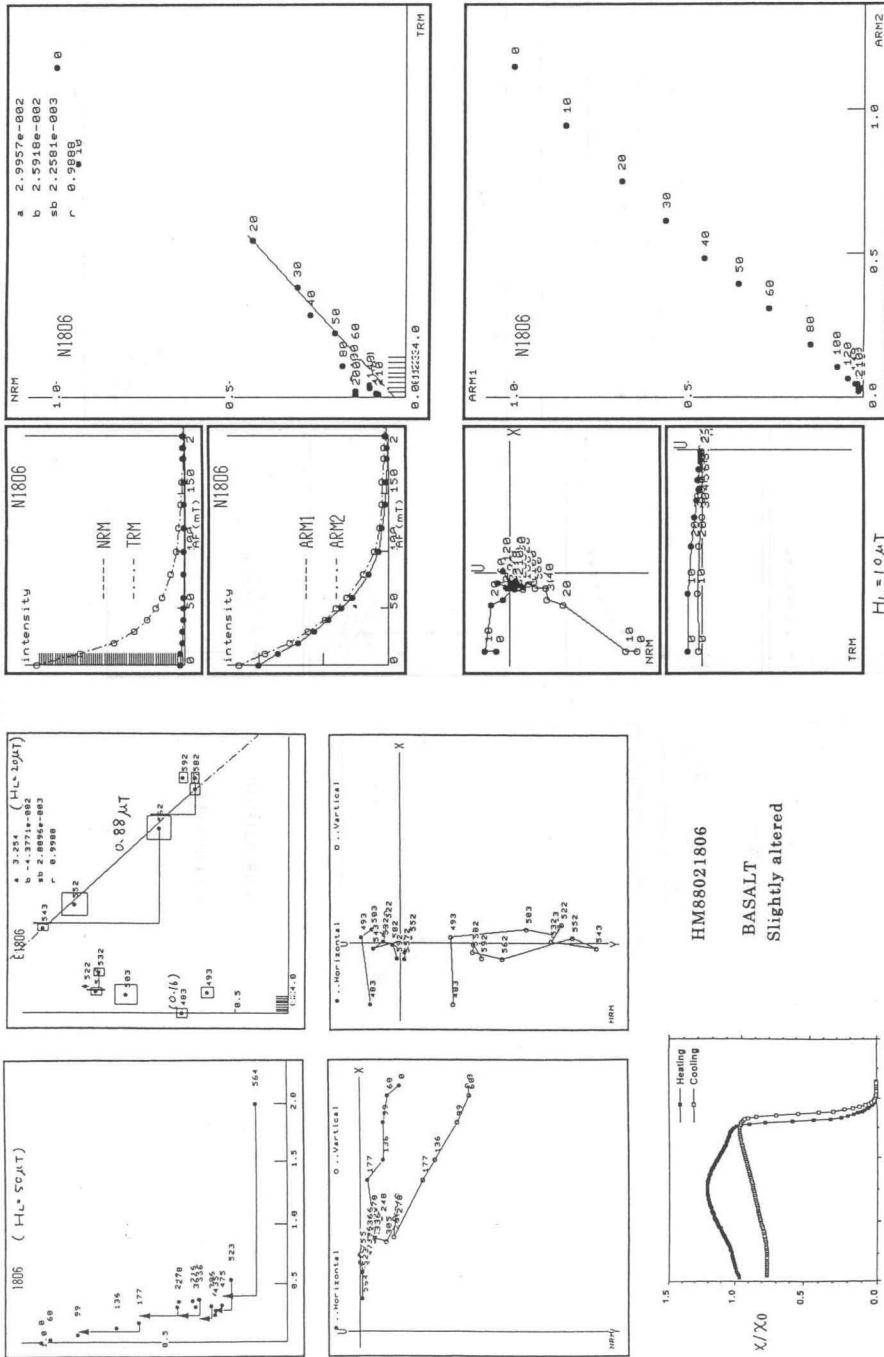


Fig. 5-2

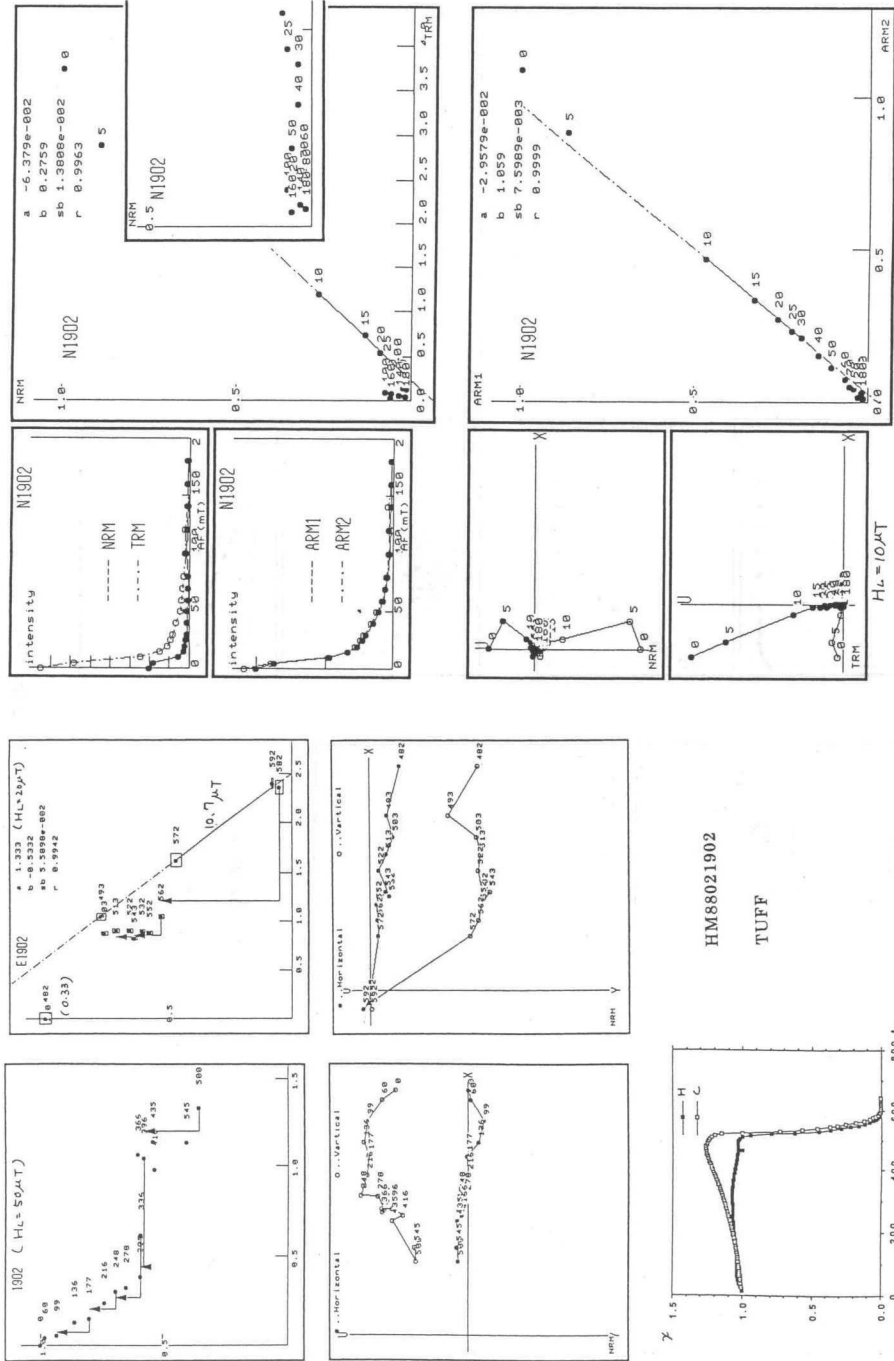


Fig. 5-3

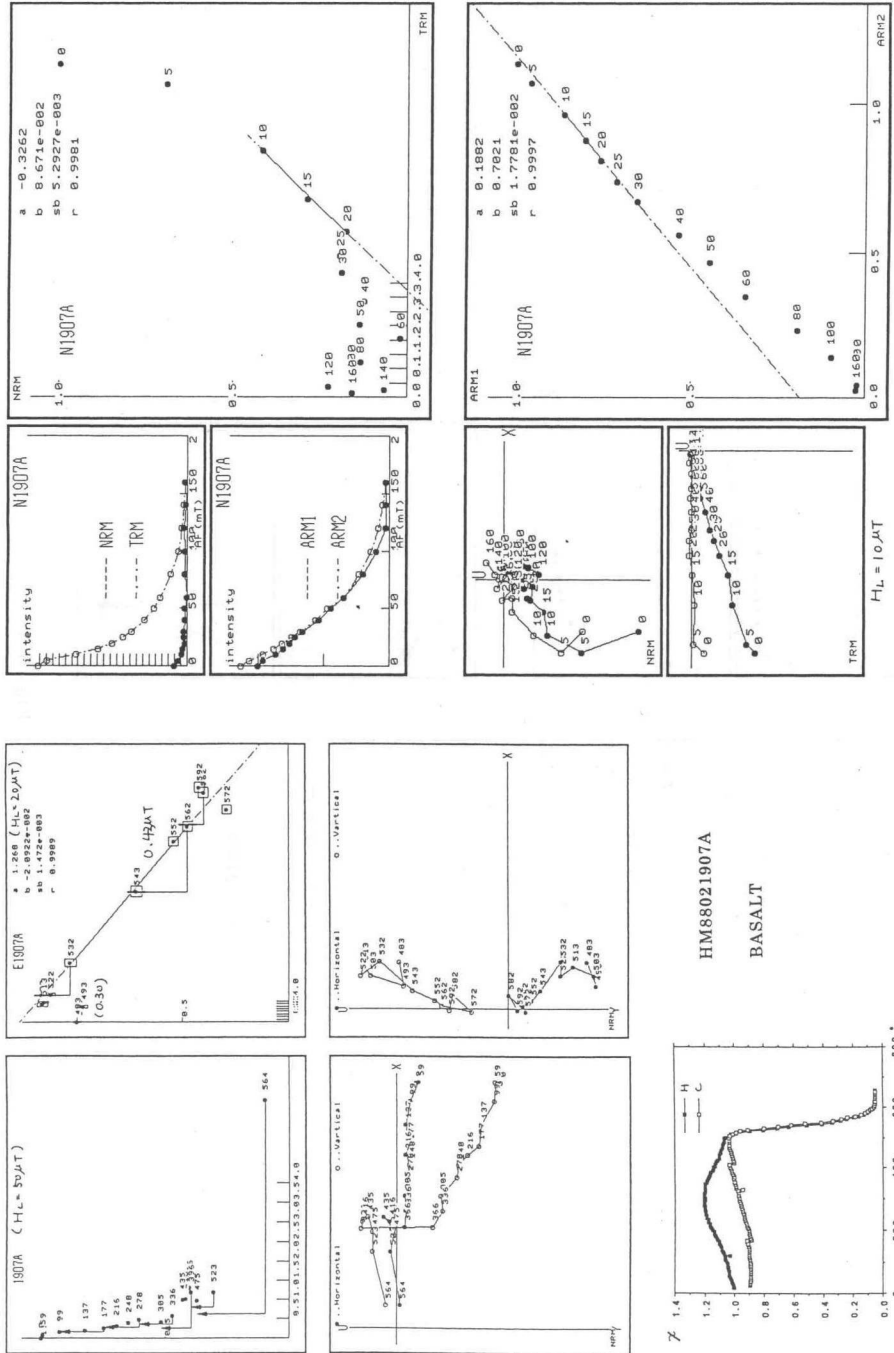


Fig. 5-4

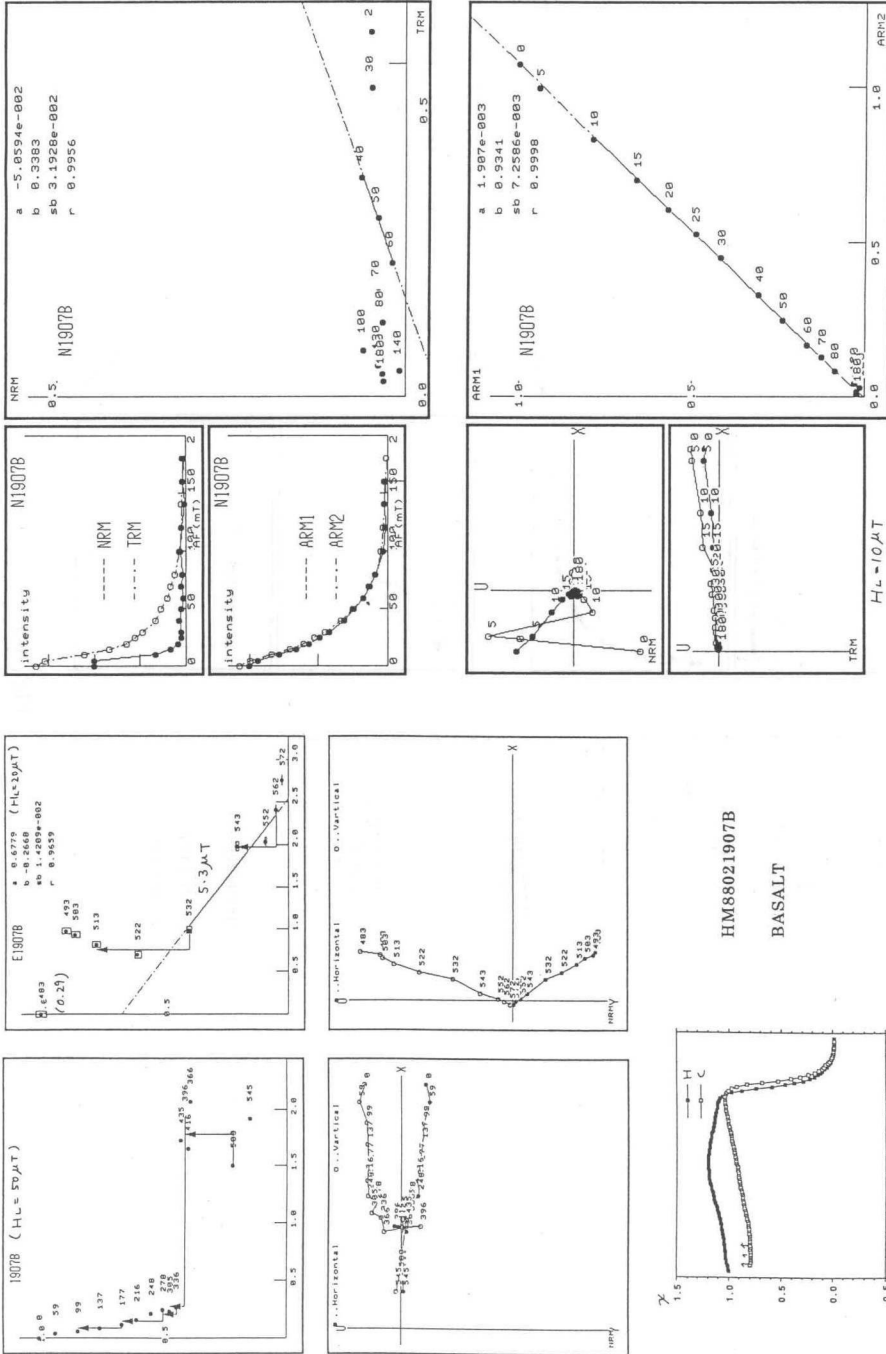


Fig. 5-5

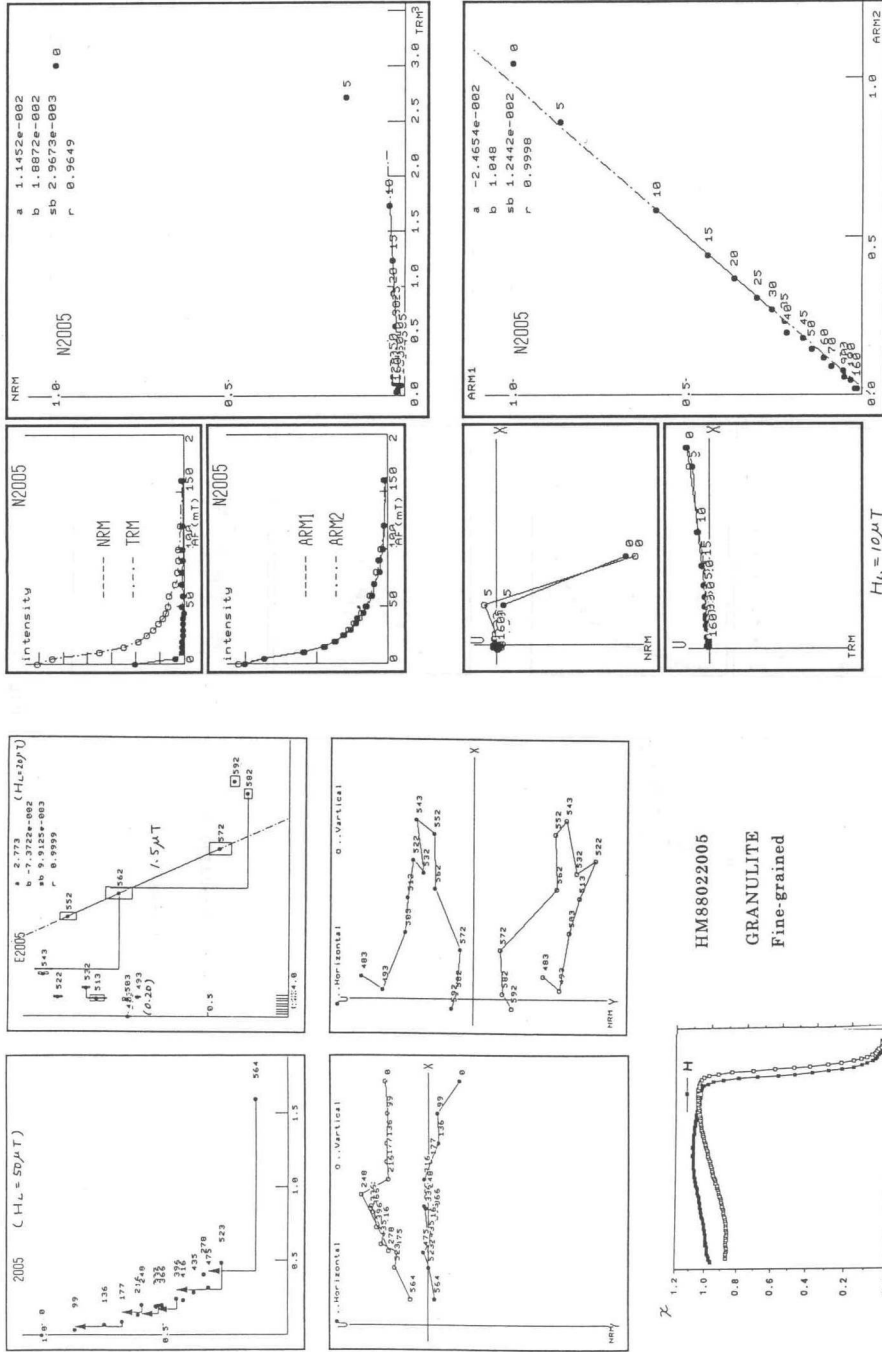
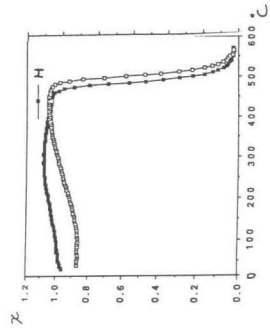


Fig. 5-6

HM88022005
GRANULITE
Fine-grained



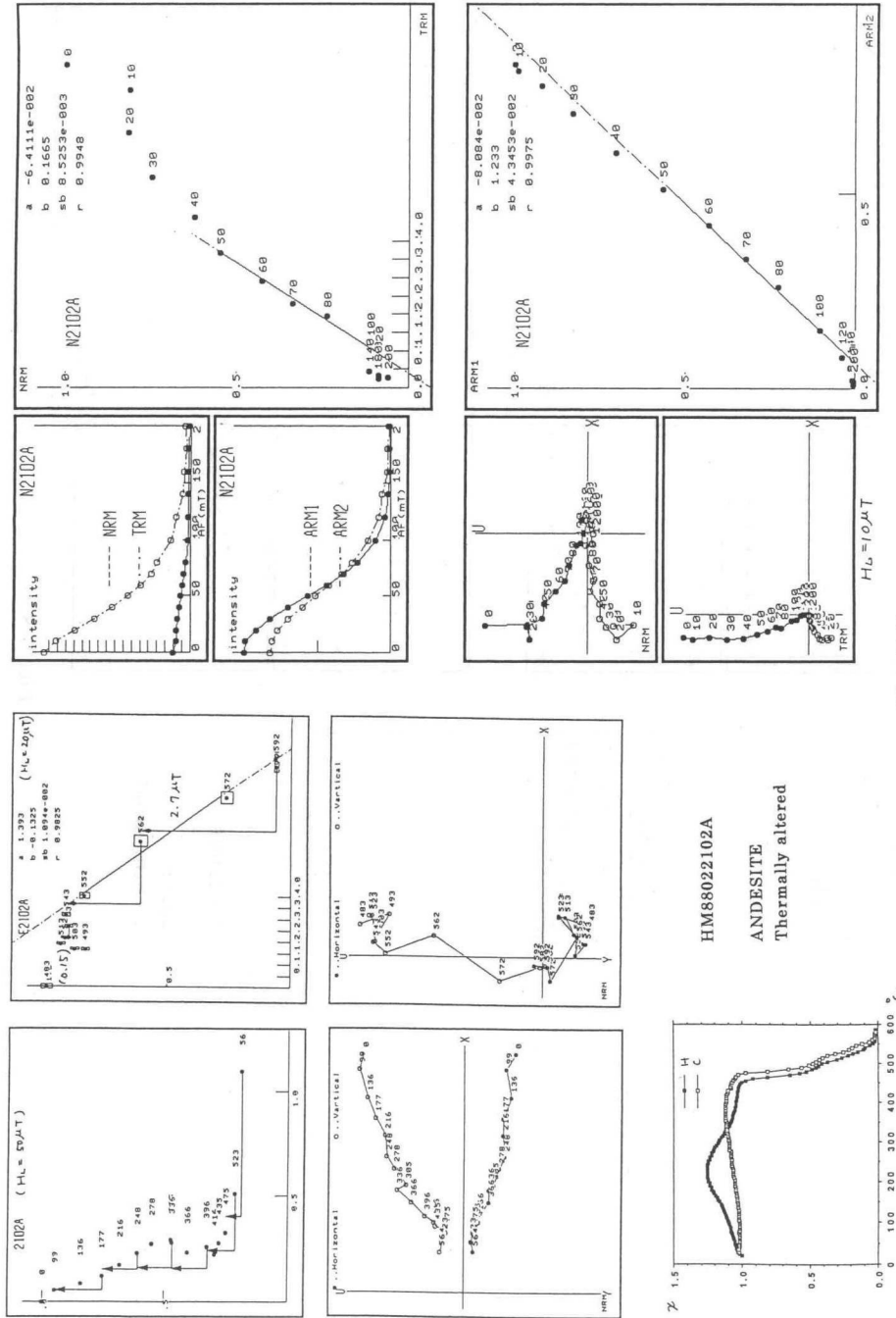


Fig. 5-7

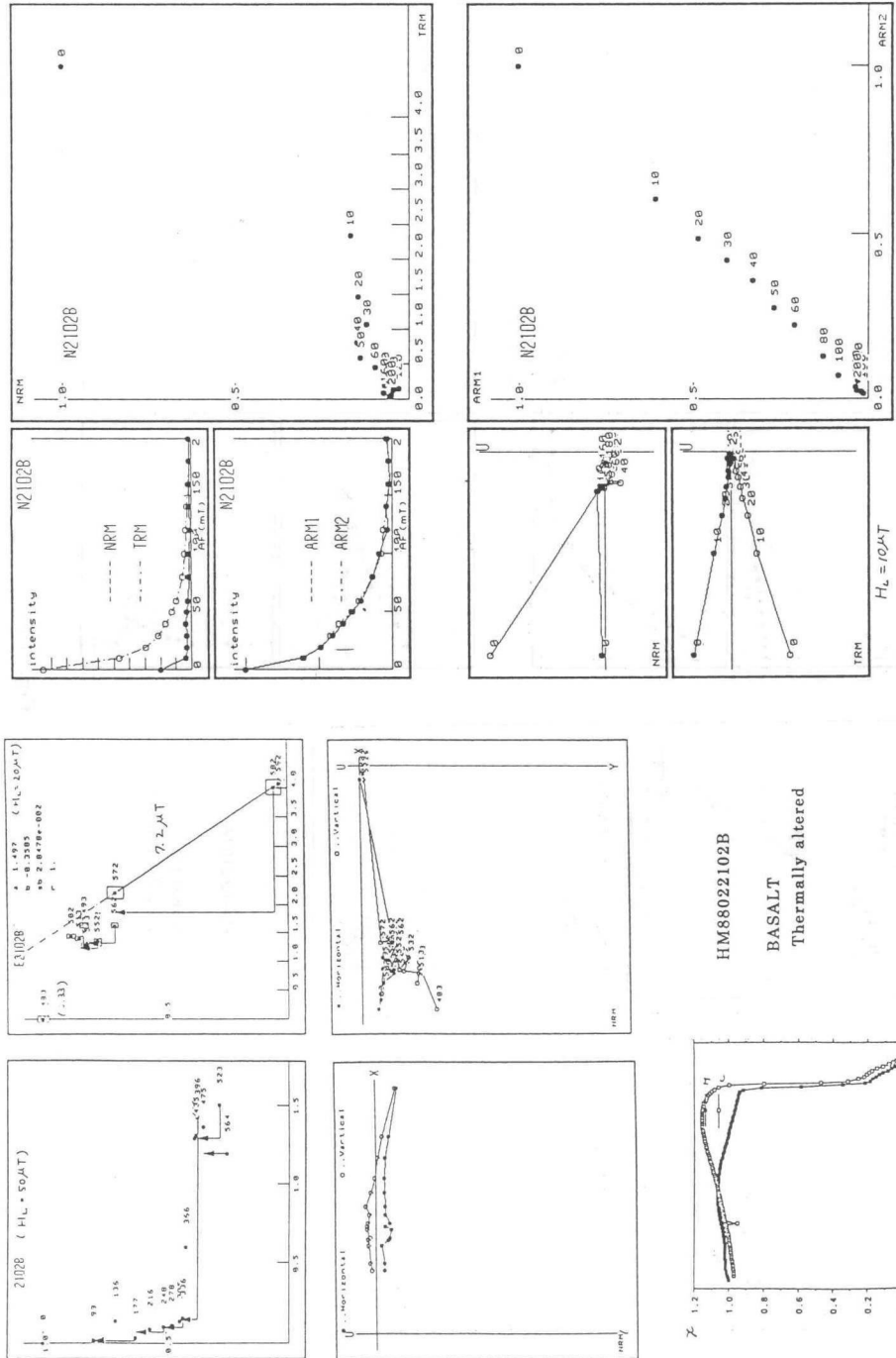


Fig. 5-8

Magneto-mineralogical study such as hysteretic properties was carried for few samples, and not enough to discuss about the relation with the paleointensity study.

3. Discussions and Conclusion

Samples of which the main magnetic mineral is multi-domain, tend to show high paleointensity in low temperature and low intensity in high temperature in Arai diagram (cf. DUNLOP and OZDEMIR, 1997). All the samples from Napier Complex show this tendency. Magneto-mineralogical study is necessary to detect multi-domain sample for rejection. At the same time, methodology to delete the effect of multi-domain and altered mineral should be developed.

Increase of both NRM and PTRM in high temperature in AF demagnetized sample over 350 °C suggests the mineralogical change has occurred at around 350 °C. In this point, rejection of the sample with sulfide is also necessary.

As VRM could be added in seconds, laboratory has to be shielded magnetically.

If we could find out the rock that has been keeping the meaningful information of geomagnetic field throughout deposition without having multi-domain and iron-sulfide, and could carry an experiment in shielded laboratory with heating in vacuum, we would get the reasonable paleointensity of early history of the earth.

Acknowledgement: The author is grateful to Dr. Minoru FUNAKI of NIPR for a lot of cooperation throughout the study. Most of the experiment before 1995 was carried in the laboratory of Tokyo Institute of Technology.

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要 旨

上野直子：南極ナピア岩体の古地球磁場強度

日本南極観測隊によって採取された12億年以上の年代をもつナピア岩体の火成岩と変成岩につき、テリエ法による古地球磁場の測定をおこなってきた。しかしアライダイアグラム上で低温部は高磁場強度を、高温部では低磁場強度を示し、その値は複数回の実験でばらつきが大きく、信頼できる結果は得られていない。その原因はマルチドメインの磁性鉱物と硫化鉱物にあると思われる。原因を探る、あるいは影響を少なくするために、さまざまな実験を試みた。

- 1) 前処理として塩酸に浸けたが変化はなかった。
- 2) 交流消磁のあと実験すると、350°C 以上で交流消磁しない場合と同じ量の NRM, PTRM になった。
- 3) 600°C で 50 μ T の定磁場中で TRM をつけて、50 μ T の古地球磁場強度が得られるか実験した。全部のデータを用いると 50 μ T に近づくが、低温部は高磁場強度を示す。また、低温から段階消磁した自然の NRM の場合よりも高温部に残留磁化が占める割合が高い。
- 4) ショウ法との比較を行った。テリエ法の高温部と同じく低い古地球磁場強度が得られた。ショウ法ではキュリー温度以上での加熱が一回は必要なので、そのせいであると思われる。
- 5) 各段階消磁温度での VRM の発生を捉えることを試みながらテリエ法を行った。300°C と 400°C の間で発生が大きいことがわかった。この実験は空気中と真空中で行ったが、真空中のほうではアライダイアグラム上で直線部がほとんど得られなかった。

地球磁場を遮蔽した実験室内での実験は行っていない。熱炉から取り出した後、すぐに遮蔽容器に保管して測定したが、数秒の内に VRM を獲得する可能性がある。遮蔽室内での実験を行い比較する必要がある。

キーワード：古地球磁場強度，テリエ法，ショウ法，ナピア岩体，南極