A Case Study of Unzen Volcanic Rocks by Using Zheng's Method for Paleointensity Determination

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Abstract

A new method developed by Zheng for paleointensity determination was applied for Unzen volcanic rocks. Under the dominant presence of grain interaction, TRM (cooled from given temperature (T_n) to room temperature) can be written generally in three terms in the order of its apparent unblocking T_{ub} : TRM (T_n) = CR_TRM (T_m) + PR_TRM (T_m, T_n) + Tail (T_n), (T_m lower than T_n) ; and the unblocking spectra of CR_TRM is identical to that of Full TRM (cooled from Currie temperature to room temperature) when the temperature is lower than T_m. Here CR_TRM is short for the completely reset TRM and PR_TRM for partially reset TRM (Zheng & Zhao 2006). The premise of Zheng's method is that, if the unblocking spectra of CR_TRM can be obtained before significant laboratory physicochemical alteration occurs, a reliable paleointensity can be extracted from samples, even for those samples that contain PSD and MD grains.

Key words : Paleointensity, Thellier method, Zheng method

1. Introduction

The traditional Thellier method requires the additivity law and independence of partial TRM (pTRM), however these strict conditions are seldom satisfied in the natural igneous rocks, which usually contain pseudo-single domain (PSD) and multi-domain (MD) particles. A new method for paleointensity determination was developed by comparing thermal demagnetization of the original Full TRM of natural remanent

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magnetization (NRM) with that of CR_TRM part of an artificial thermoremanent magnetization (TRM). By using this new method we successfully extracted the reliable paleointensity data from Unzen volcanic rocks.

2. General methodology

In Zheng's method, the following terms are defined for various thermal remanent magnetization.

Full TRM = TRM (T_c, T_0, H_{lab}), T_c : Curie point, T_0 : room temperature.
TRM = TRM (T_n, T_0, H_{lab}) = TRM (T_n) for short, $T_n < T_c$
pTRM = TRM (T_{i+1}, T_i, H_{lab}), $T_i < T_{i+1}$
pTRM tail = pTRM {(T_j, T_i, H_{lab}), T_j} , $T_i < T_j$;
the remaining of TRM {(T_j, T_i, H_{lab}) after thermal demagnetization at T_j.
pTRM head = pTRM (T_j, T_i, H_{lab}) − pTRM {(T_j, T_i, H_{lab}), T_i} ;
the removed magnetization after thermal demagnetization at T_i

In the case of the dominant magnetostatic interaction is appeared between grains, the TRM (cooled from given temperature (T_n) to room temperature (T_0)) can be written in three terms in the order of its apparent unblocking temperature (T_{ub}) :

$$\mathrm{TRM}(T_n, T_0) = \mathrm{CR\_TRM}(T_m, T_0) + \mathrm{PR\_TRM}(T_n, T_m) + \mathrm{Tail}(T_n),\ T_m < T_n \qquad (1)$$

and

$$\delta\mathrm{TRM}(T_i, T_{i-1}) = \delta\mathrm{CR\_TRM}(T_i, T_{i-1}) = \delta\mathrm{Full\_TRM}(T_i, T_{i-1}),\ T_i < T_m \qquad (2)$$

SD-like, PSD-like and MD-like are also defined in the following.

SD-like grains are composed from the assemblage of those SD or PSD grains of (1) spatially well isolated without magnetostatic interaction, (2) similar genuine T_{ub0} even in existence of magnetostatic interaction, (3) similar apparent T_{ub} because of the very strong magnetostatic interaction between the grains. In SD-like grains, CR_TRM is dominant and almost equal to TRM.

MD-like grains are composed from the assemblage of either MD grains or SD or PSD grains of variant apparent T_{ub} with magnetostatic interaction, that result dominant PR_TRM and tail parts. CR_TRM part can't be distinctly obtained unless being heating beyond Curie point.

PSD-like grains are composed from the assemblage of SD or PSD grains with dominant magnetostatic interaction, and there is slight difference in the apparent T_{ub}. A distinct CR_TRM part can be obtained under the temperature lower than Curie point.

Equality of the unblocking temperature spectra of CR_TRM to that of Full TRM is the crucial point of Zhneg's new experimental method for paleointensity determination. We compare the unblocking temperature spectra of the CR_TRM part of a TRM_{lab} with that of natural remanent magnetization (NRM) for estimation of paleointensity. While in the traditional Thellier-Coe method, the unblocking spectra of NRM is compared with blocking spectra of progressive TRM_{lab}. The premise of our new method is that, if the unblocking spectra of CR_TRM of a TRM_{lab} can be obtained before significant laboratory physicochemical alteration occurs, a reliable paleointensity can be extracted from samples, even for those samples that contain PSD and MD grains. It is essencially important in Zheng's method to find a safeguard maximum heating temperature T_n under which a TRM can be obtained without significant thermal alteration in magnetic properties.

In Zheng method the 1st RUN (pick-up run) is a differentiated Thellier method :

For every temperature intervals (T_{i+1}, T_i), we measure the following two terms :

$pTRM1\ (T_{i+1}, T_i, H_{lab})$ and
$\delta NRM\ (T_{i+1}, T_i) = NRM\ (T_i)_{remaining} - NRM\ (T_{i+1})_{remaining}$

Then, an apparent paleointsnsity H_{an} can be estimated (Differentiated Thellier method)

$$H_{an} = \delta NRM\ (T_{i+1}, T_i) / pTRM1\ (T_{i+1}, T_i, H_{lab}) * H_{lab} \quad (3)$$

The 2nd RUN (correction run) is carried using the same specimen to acquire a TRM_{lab} for TRM test and to correct the interaction effect.

TRM_{lab} is acquired in cooling condition from thermal alteration safeguard maximum temperature T_n to room temperature in an artificial field H_{lab} as close as possible to ancient magnetic field intensity (H_{an}) at a given low cooling rate 1℃/min. And the artificial field is applied to the sample in the same direction of NRM.

In this way, the obtained TRM_{lab} is the TRM of property nearest that of Full_TRM.

$$TRM_{lab} = TRM\ (T_n, T_0, H_{lab}) + NRM\ (T_n)_{remaining} \quad (4)$$

In the second run, TRM_{lab} is used instead of NRM, the same process as 1st RUN, to get $pTRM2\ (T_{i+1}, T_i)$ and $\delta TRM_{lab}\ (T_{i+1}, T_i)$. If no thermal alteration occur during the experiment, $pTRM2\ (T_{i+1}, T_i)$ will be almost equal to $pTRM1\ (T_{i+1}, T_i)$. The proportional part of $\delta TRM\_{lab}\ (T_{i+1}, T_i)$ and $\delta NRM\ (T_{i+1}, T_i)$ will be used to estimate genuine paleointensity (Corrected H_{an}).

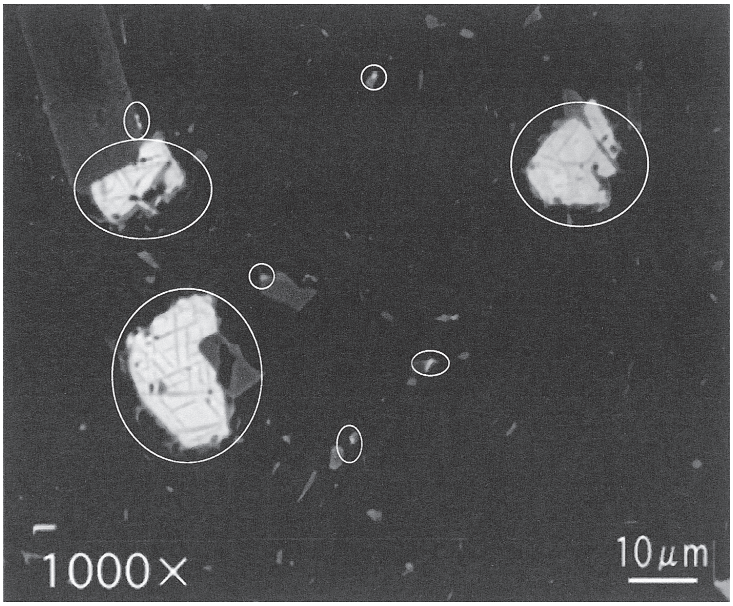

Fig.1 Back scatter electronic image of E202

$$\text{Corrected } H_{an} = H_{an} / \{\delta TRM_{lab}\ (T_{i+1}, T_i) / pTRM2\ (T_{i+1}, T_i, H_{lab})\} \quad (5)$$

3. Unzen E202 sample

E202 is the reddish dacite of dome lava erupted in 1993 at Unzen, (32° 45'N, 130° 20' E).

(1) Magnetic grains distribution

The titanomagenetite with ilmenite lamellae of grain sizes 10～30 mm are dominant in groudmass, a few small grains of size about 1 mm were also observed near the surface of plagioclase crystals. Ilmenite lathes are well developed within the host titanomagenetite gains, that show a typical lamellae structure of deuteric oxidation (high-temperature oxidation). Because of the exsolution of ilmenite lamellae, the host titanomagenetite becomes enriched in Fe and is divided into much smaller pieces. The smallest dimension of isolated Fe-rich pieces (rod-shape particles ?) is generally slight larger than 1 mm. We are interested in what kind of NRM are carried by those grains : thermochemical remanent magnetization (TCRM) or pure TRM ? In Fig.1, backscatter electronic image of E202 is shown.

(2) Unblocking temperature spectra of NRM

A small chip was conducted thermal demagnetization to obtain the unblocking tem-

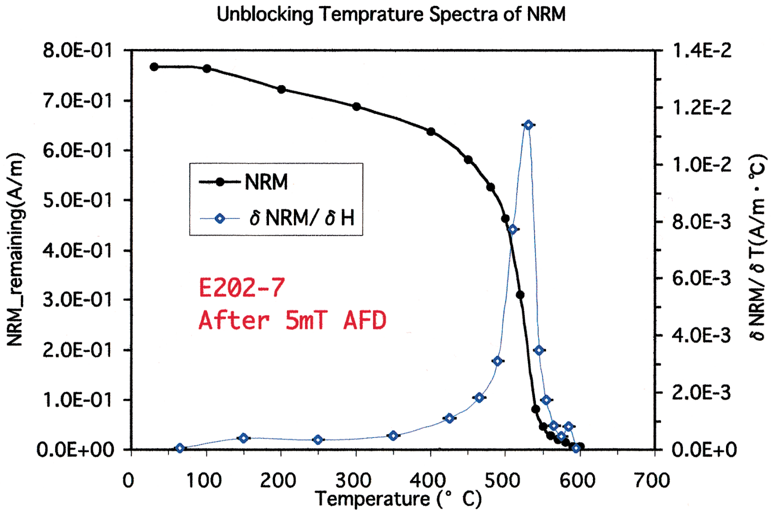

Fig.2 Unblocking temperature spectra of NRM of E202

perature spectra of NRM. The preliminary information was obtained for us to understand the thermal remanent characters and help us to arrange proper temperature steps in successive paleointensity determination experiment. As showed in following graph, the unblocking temperature spectra distribute in a very narrow temperature interval 450～550℃. And the maximum unblocking temperature is near 560℃ : after 560℃ thermal demagnetization 96% of NRM was removed. A pretreatment 5mT AF demagnetization was carried to remove the secondary viscous remanent magnetization. In Fig.2, unblocking temperature spectra of E202 is shown.

According to the unblocking temperature spectra, following steps were selected. (200℃, 300℃) ; (300℃, 400℃) ; (400℃, 450℃) ; (450℃, 480℃) ; (480℃, 500℃) ; (500℃, 520℃) ; (520℃, 540℃) ; (540°, 560℃).

(3) How to find a thermal alteration safeguard maximum temperature T_m

It is of key importance in Zheng's method to find a safeguard maximum heating temperature T_m under which a TRM is obtained without significant thermal alteration in magnetic properties. Heating in the laboratory often results higher temperature oxidation, which almost always occurs and profoundly affects magnetic properties. However, if the temperature T_n is not high enough to obtain a dominant CR_TRM part of remanent magnetization, Zheng's method will fail in getting the estimate of paleointensity.

Stepwise thermal analysis of susceptibility, IRM or ARM acquisition curves will help us to detect the laboratory thermal alteration, although these magnetic parameters other than thermal remanent magnetization (TRM) are not enough. The sensitivity of

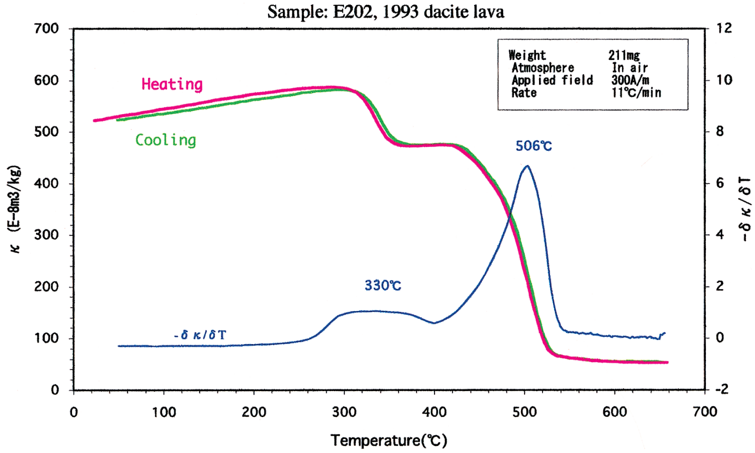

Fig.3 Thermal analysis curve of susceptibility of E202

monitor is in following ascendant order : Susceptibility - ARM - IRM - pTRM. Both of the samples E202 and E206 show us good illustrations.

Susceptibility : The thermal analysis curves of susceptibility suggests even after being heated as higher as 650℃ little alteration can be detected, a good reversible susceptibility curves were observed. The Curie point is estimated to be near 520℃. Because about 4% of NRM has unblocking temperature more than 560℃, the carriers of those high unblocking temperature part must have much higher Curie point than 560℃. Our KLY-3S thermal sensor was well calibrated and the temperature error was less than 10℃. It seems the susceptibility reflected only those of low coercivity grains. Fig.3 shows the thermal analysis curve of susceptibility of E202.

IRM acquisition curves : IRM acquisition curves also could not detect any thermal alteration even after 550℃ heating. However, later pTRM measurements has detected thermal alteration in the TRM properties after a maximum 560℃ heating. Fig. 4 shows the IRM acquisition curve of E202.

PSD-like grains dominant : The behavior of pTRM during thermal demagnetization shows the difference between unblocking temperature (T_{ub}) and blocking temperature (T_b). One specimen was used to acquire a pTRM (T_{i+1}, T_i, H_{lab}) (cooling from T_{i+1} to T_i in an artificial field H_{lab}=500uT, then in zero field when $T<T_i$). Afterwards, thermal demagnetization was performed to obtain its unblocking temperature (T_{ub}) distribution. The blocking temperature (T_b) is equal to given temperature interval (T_{i+1},T_i). Following two intervals were applied, (480℃, 450℃) and (550℃, 530℃). The signifi-

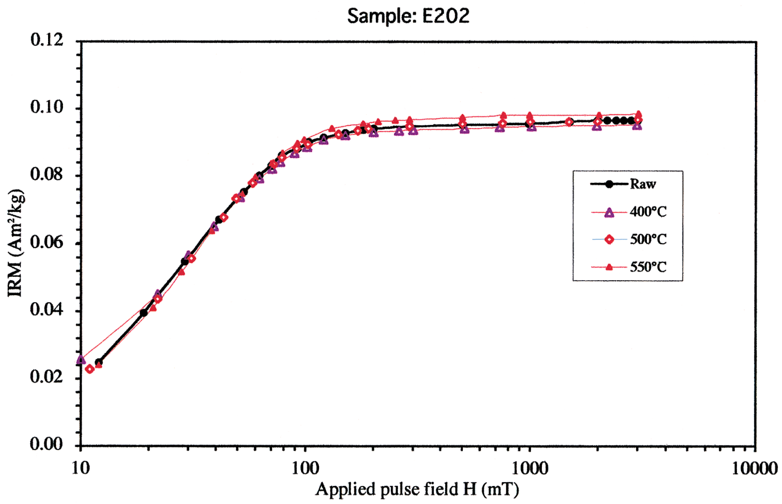

Fig.4 IRM acquisition curve of E202

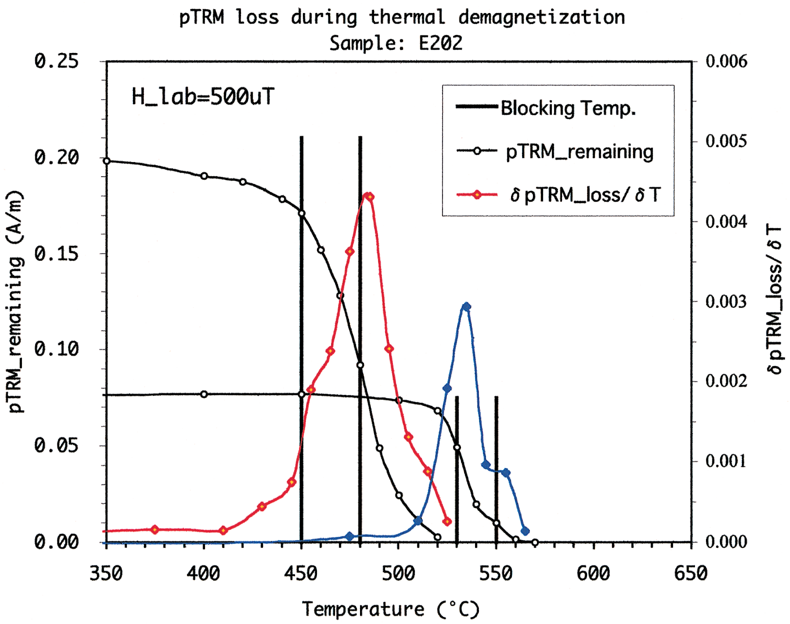

Fig.5 PTRM loss during thermal demagnetization of E202

cant difference between T_{ub} and T_b (~40℃) suggests dominant existence of pseudo-single domain (PSD) -like grains. In Fig.5, pTRM during thermal demagnetization of E202 is shown.

In the present case of sample E202, 560℃ was taken as T_n. Because the maximum

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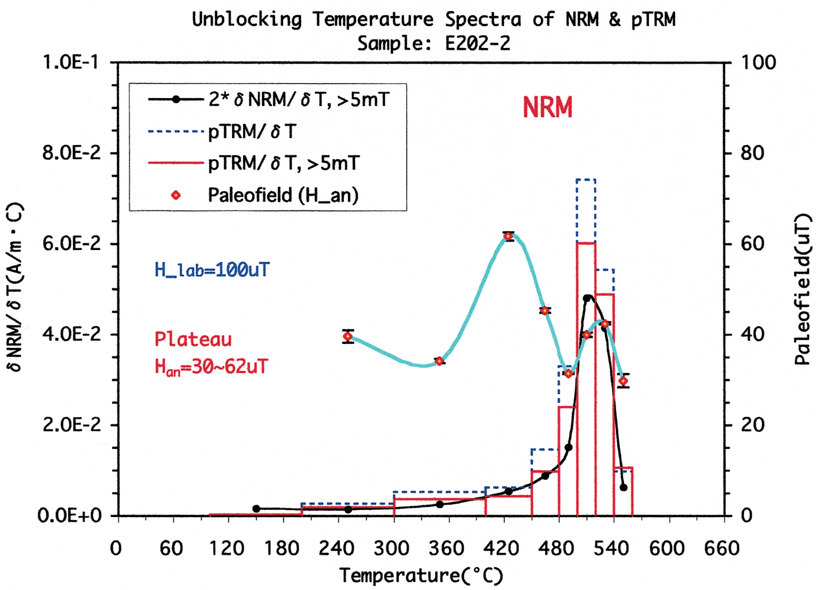


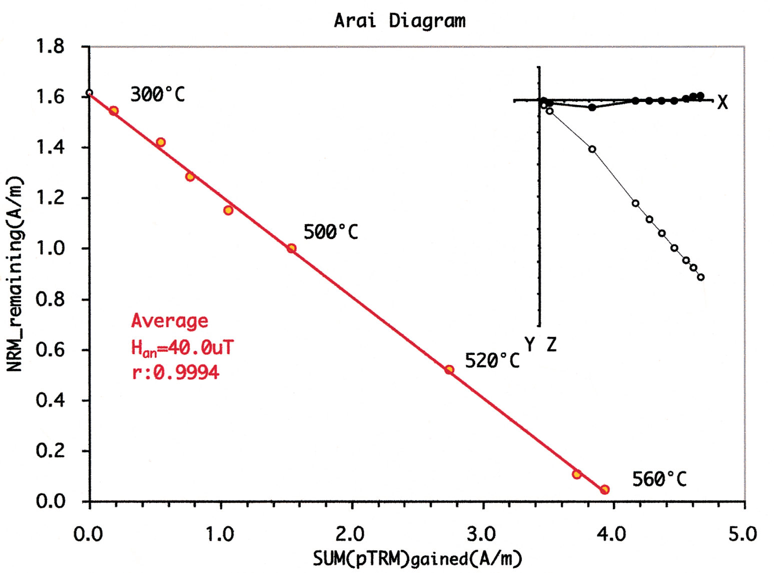
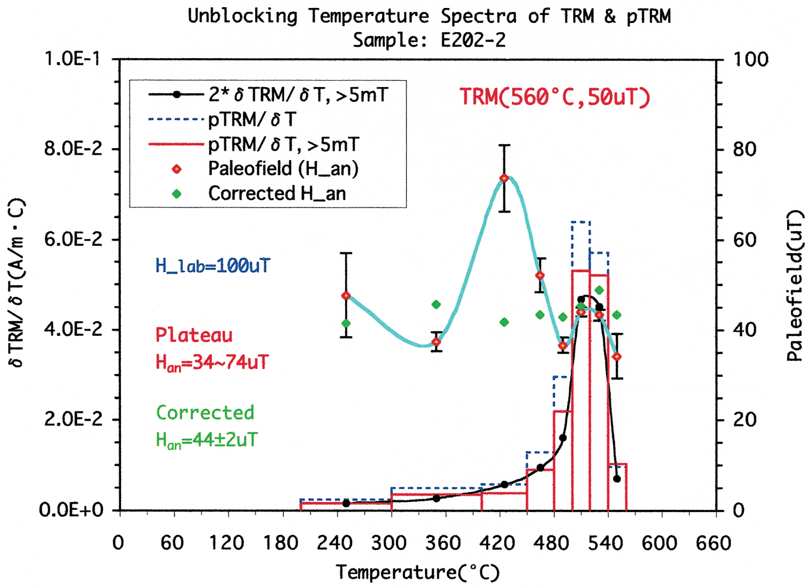


Fig.6-1 E202-2 1st RUN (Pick-up)



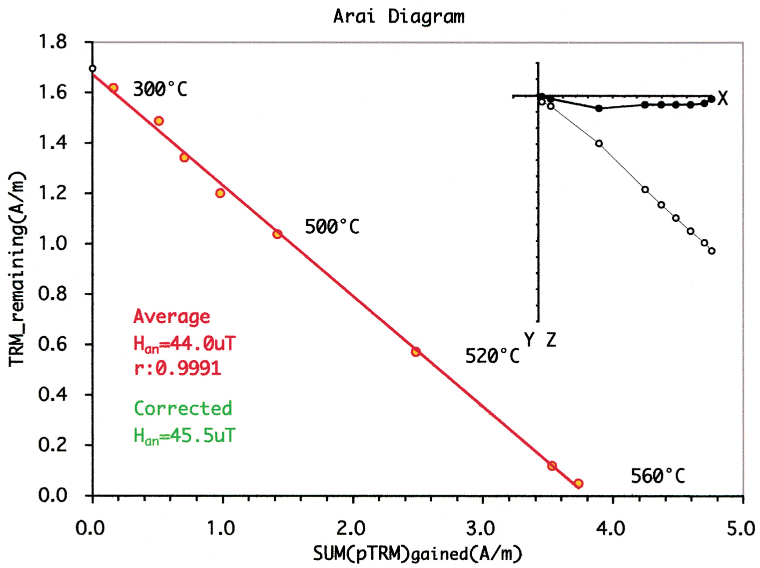
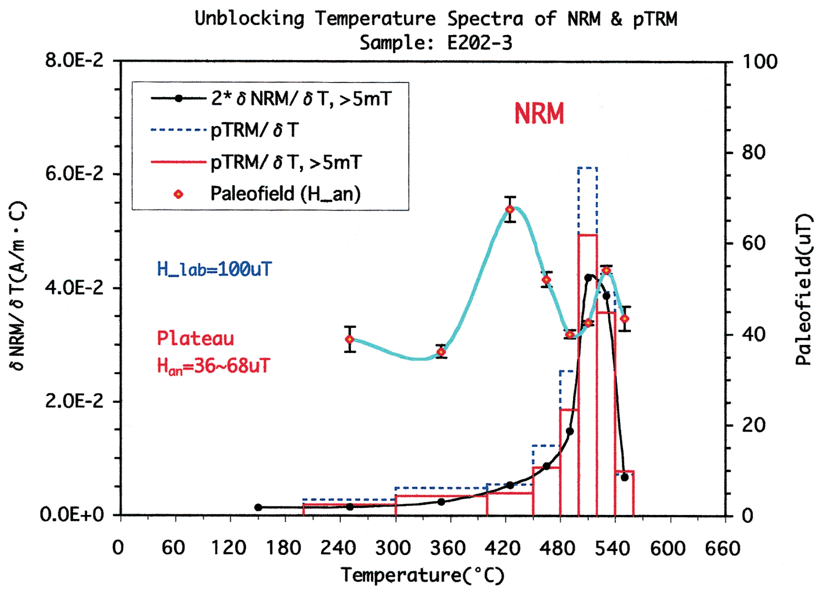


Fig.6-2 E202-2 2nd RUN (Correction)



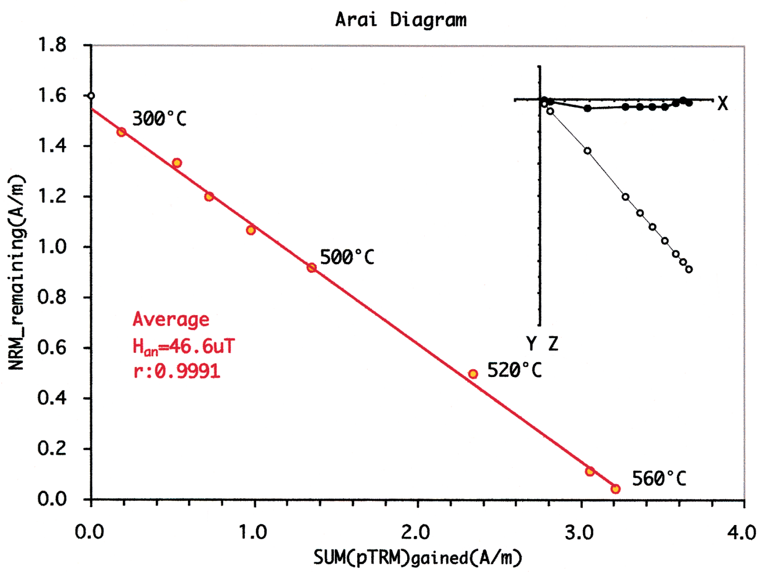


Fig.7-1 E202-3 1st RUN (Pick-up)

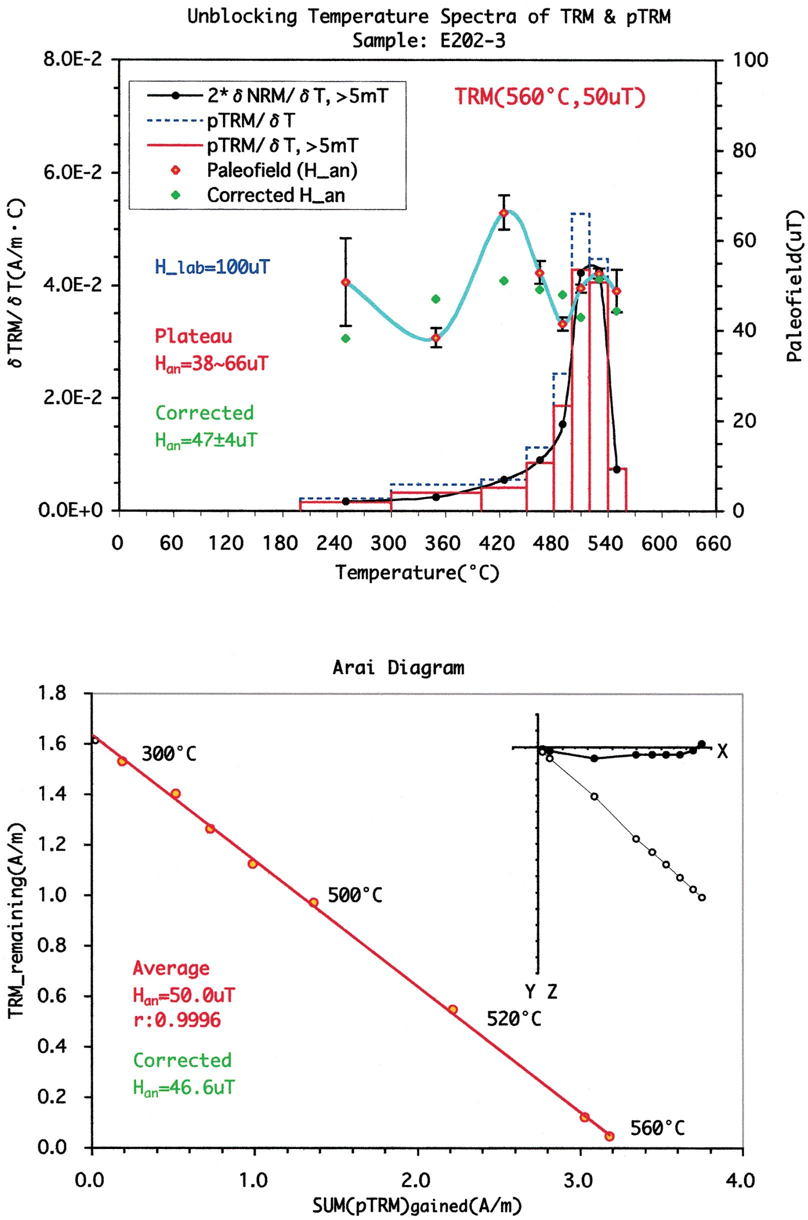
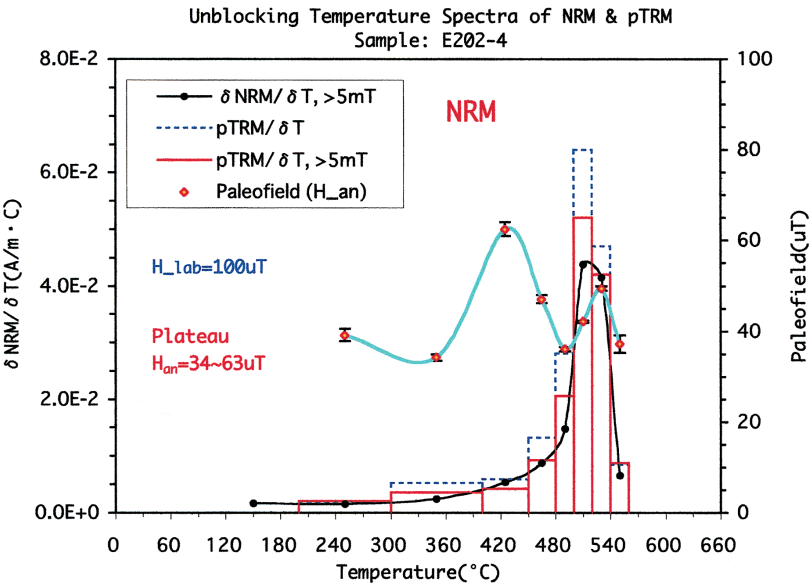


Fig.7-2 E202-3 2nd RUN (Correction)



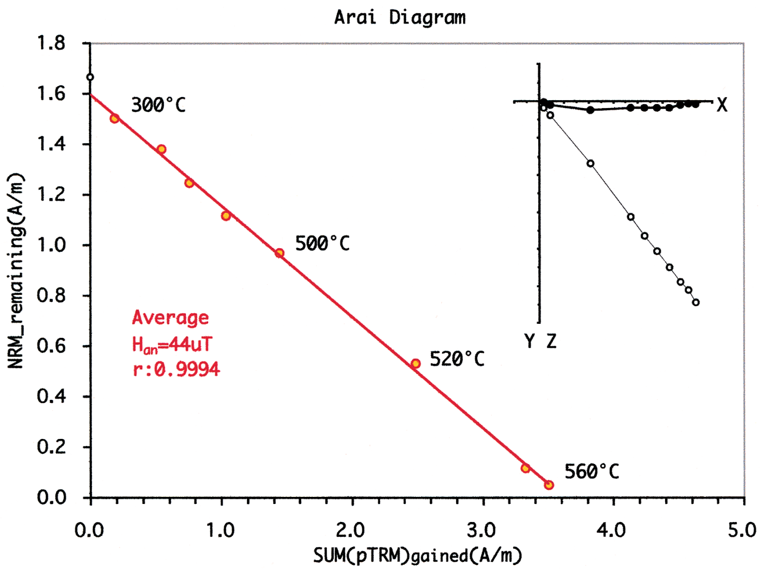
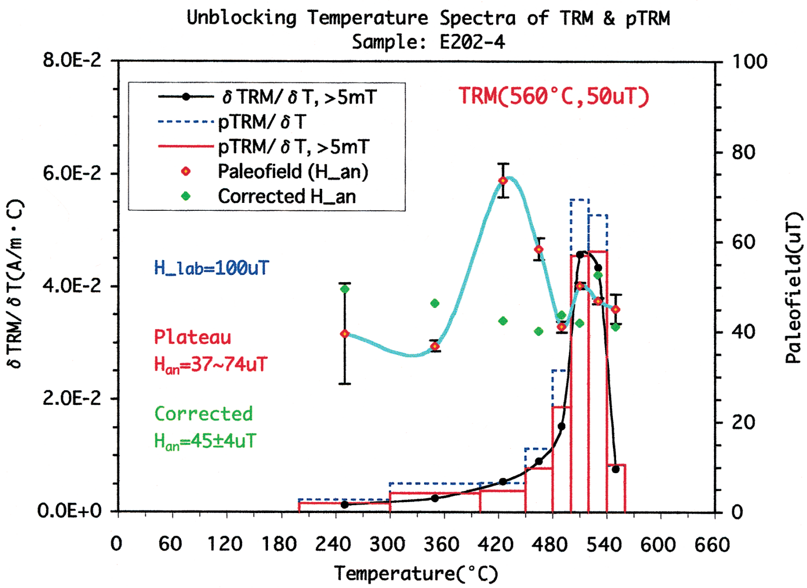


Fig.8-1 E202-4 1st RUN (Pick-up)



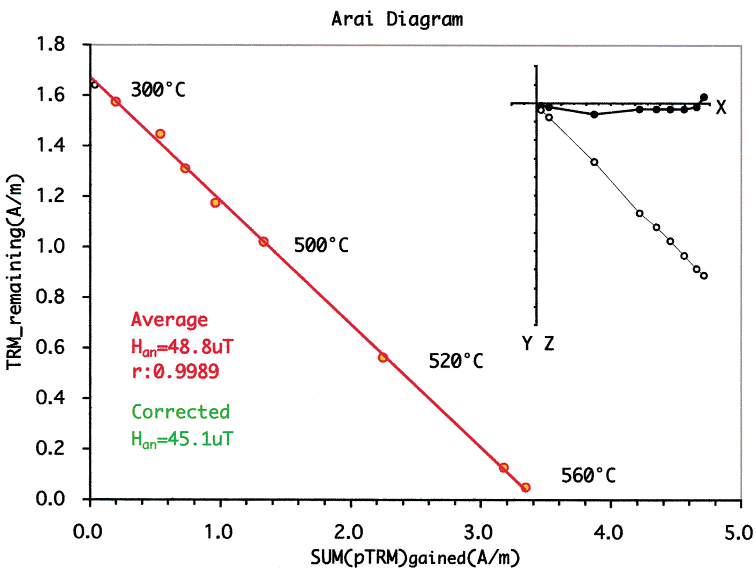


Fig.8-2 E202-4 2nd RUN (Correction)

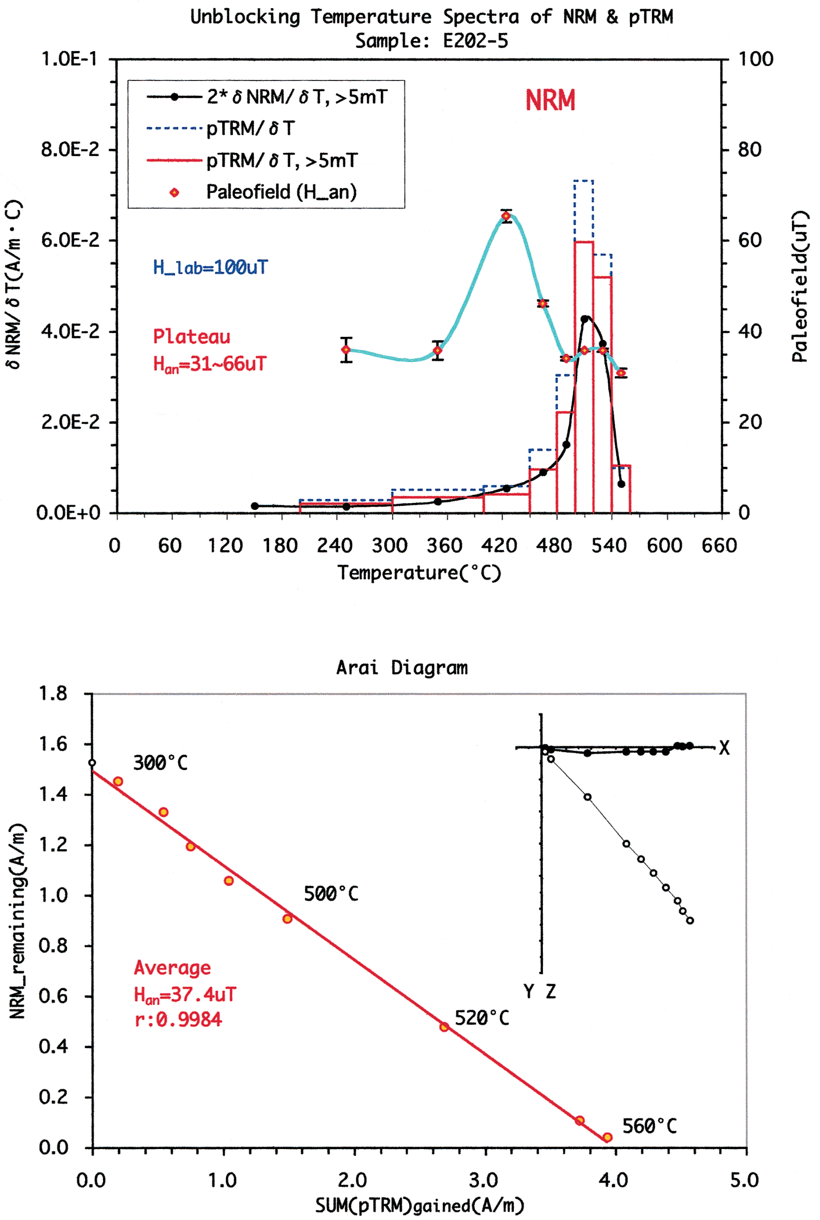
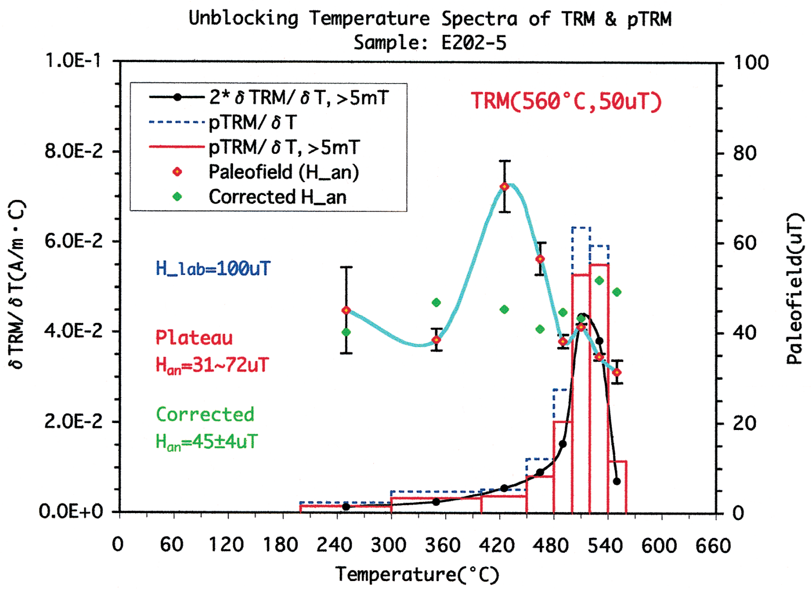


Fig.9-1 E202-5 1st RUN (Pick-up)



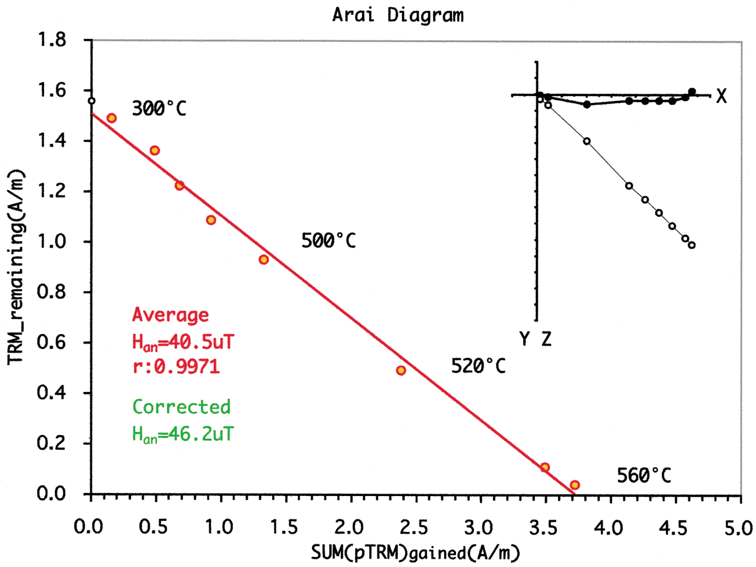
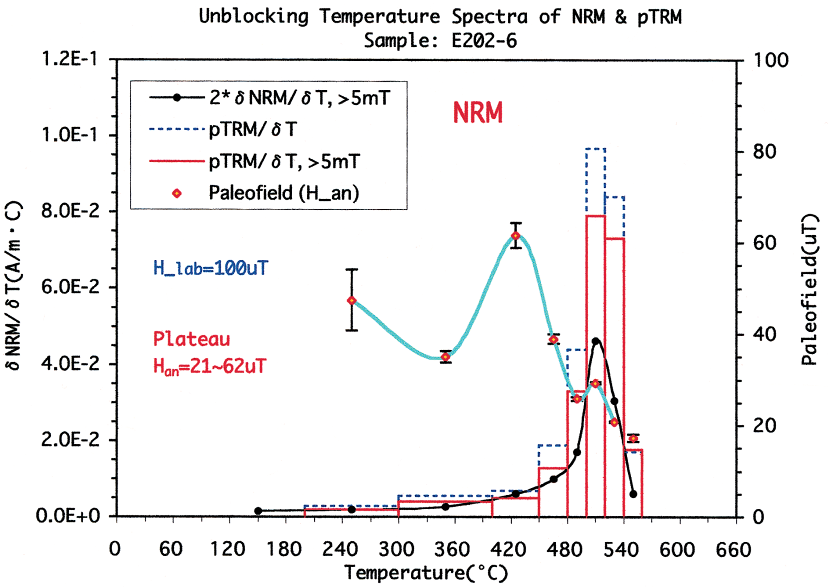


Fig.9-2 E202-5 2nd RUN (Correction)



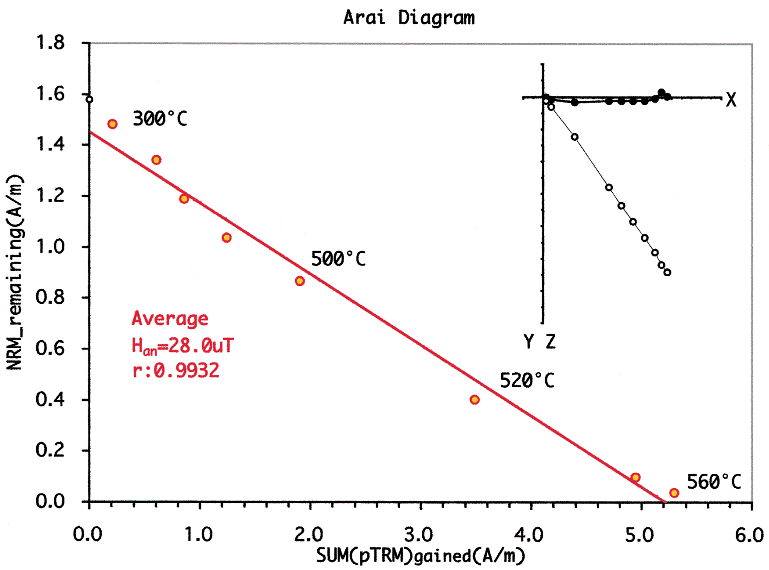
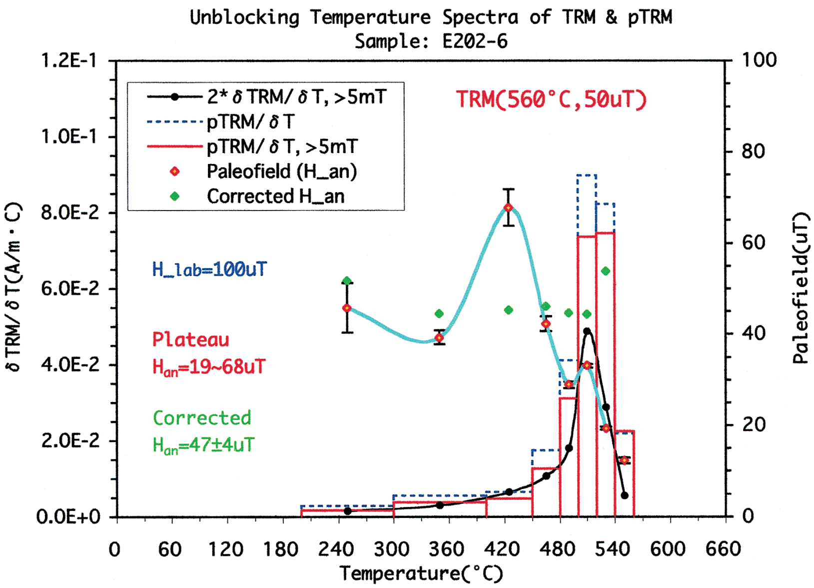


Fig.10-1 E202-6 1st RUN (Pick-up)



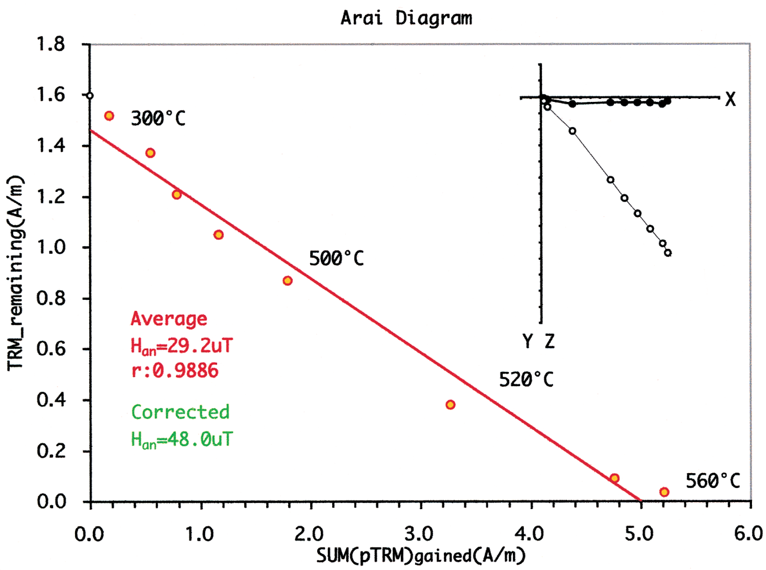


Fig.10-2 E202-6 2nd RUN (Correction)

unblocking temperature of E202 is near 560℃, the TRM acquired cooling from 560℃ to room temperature in artificial field $H_{lab.}$ is CR_TRM dominant, and is quite close to the Full TRM.

Results of paleointensity experiment：Six specimens were used. AF demagnetization of 5 mT was carried as a pretreatment to remove the secondary viscous remanent magnetization. The results of both samples E202 and E 206 were summarized in histogram (Fig. 23). Total 47 plateau data were obtained. The Thellier method induced averaged apparent paleointensity with the greater variance：$40.2 \pm 12.0\,\mu T$, while Zheng's method induced a paleointensity data in a quite small variance $45 \pm 4\,\mu T$ for 47 plateau data, and $45 \pm 1\,\mu T$ for 6 specimen data averaged.

During the experiment, only slight thermal alteration in pTRM was observed. By comparing the pTRM1 acquired 1^{st} RUN and pTRM2 in 2^{nd} RUN, one may easy to find the pTRM2 became slight smaller, especially in temperature intervals 500℃～540℃. The averaged SUM (pTRM2)/SUM (pTRM1) is 0.958. However, Zheng's method still gave good paleointensity estimates data even from those temperature intervals of slight thermal alteration. It seems Zheng's method sensitively detect the thermal alteration, and as well as complete a good alteration correction for slight alteration

In Fig. 6 to Fig.10, unblocking temperature spectra of 1^{st} run (pick-up) and 2^{nd} run (correction) for 5 specimens of sample E202 are shown.

4. Unzen E206 sample

E206 is the black dacite bomb of the Unzen eruption in 1991 (32° 45'N, 130° 20'E).

(1) Magnetic grains distribution

The titanomagnetite grains were scattered in matrix or within plagioclase crystals with variant sizes from less than 1 um to 20 mm in maximum. To our experience the grains of size larger than 10 mm usually are more Ti-rich and have little contribution to remanent magnetization but act as noises both as more MD-like behavior in Thellier experiment and also of the property easily to be thermally altered during laboratory heating. A pretreatment of medium alterative field demagnetization was considered in trying to remove the effect of those large grains with low coercivity. Due to the well spatially scattered distribution of grains, the "trap" effect of magnetostatic interaction field was supposed to be "loosen". A "loosen" interaction resulting the offset of apparent paleointensity from genuine one is supposed to be relative small. Fig.11 is the backscatter electronic image of E206.

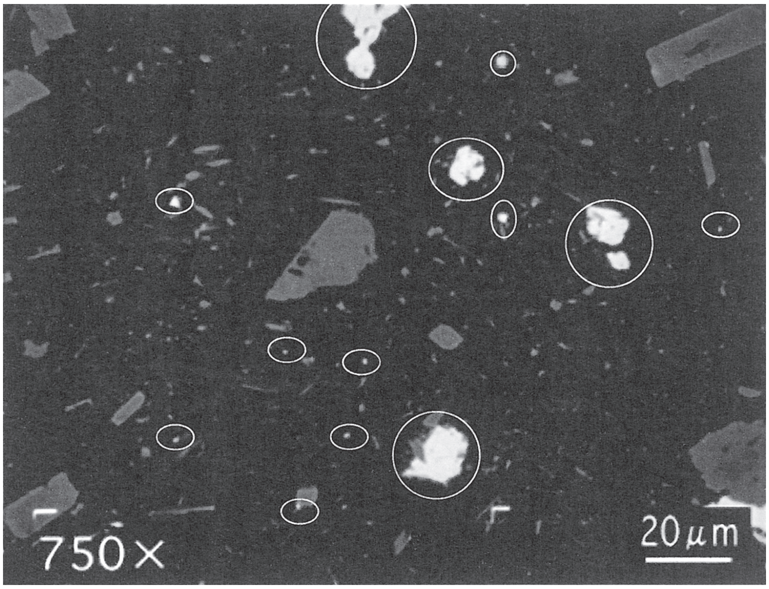


Fig.11 Back scatter electronic image of E206

(2) Unblocking temperature spectra of NRM

A small chip was conducted thermal demagnetization to obtain the unblocking temperature spectra of NRM. As showed in following graph, the unblocking temperature spectra distribute in a relative broad temperature interval 150～400℃. And the maximum unblocking temperature is near 400℃ : after 400℃ thermal demagnetization 93 % of NRM was removed. As a pretreatment 5 mT AF demagnetization was carried to remove the secondary soft viscous remanent magnetization, which has a slight difference direction. In Fig.12, unblocking temperature spectra of NRM of E206 is shown.

According to the unblocking temperature spectra, following steps were selected. (150 ℃, 210℃) ; (210℃, 240℃) ; (240℃, 270℃) ; (270℃, 300℃) ; (300℃, 350℃) ; (350℃, 400℃).

(3) How to find a thermal safeguard maximum temperature T_m

The same procedures were carried as E202.

<u>**Susceptibility**</u> : Following thermal analysis curves of susceptibility suggests even after being heated as higher as 650℃ littler alteration can be detected : a good reversible susceptibility curves were observed. Two phases exist with Curie point one is near 370℃ and another 500℃, which are consistent with distinct two peaks (150～350℃ & 300～500℃) in unblocking temperature spectra. Thermal analysis curve of susceptibility of E206 is illustrated in Fig.13.

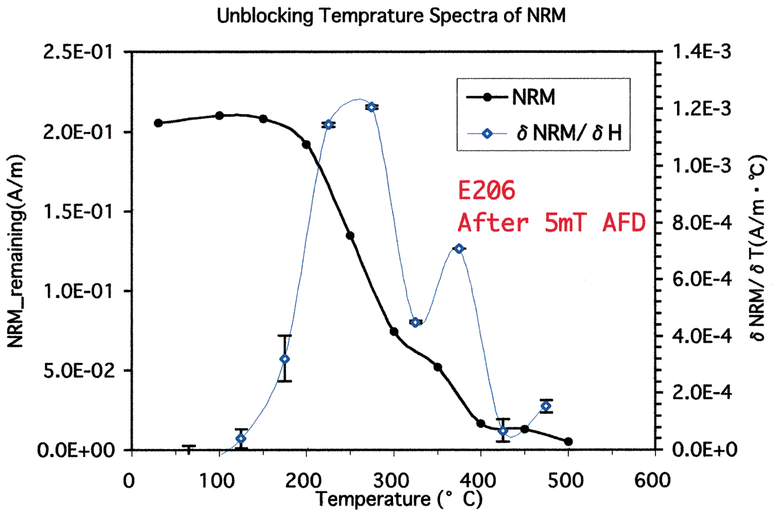


Fig.12 Unblocking temperature spectra of NRM of E206

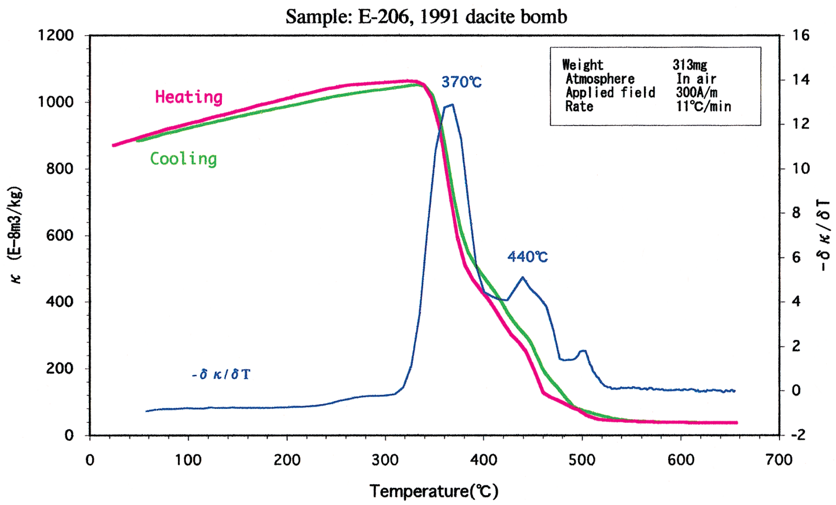


Fig.13 Thermal analysis curve of susceptibility of E206

IRM acquisition curves : IRM acquisition curves did not detected any thermal alteration until 400℃ heating. A slight change can be observed at 500℃ curve. It seems a lower temperature less than 400° is the maximum safeguard temperature. In Fig.14, IRM acquisition curve of E206 is shown.

PSD-like grains dominant : According to the same method in the case of E202 sample the following 2 intervals were applied (230℃, 200℃), (400℃, 380℃) for E206. The difference between T_{ub} and T_b (~90℃) suggests dominant existence of pseudo-single

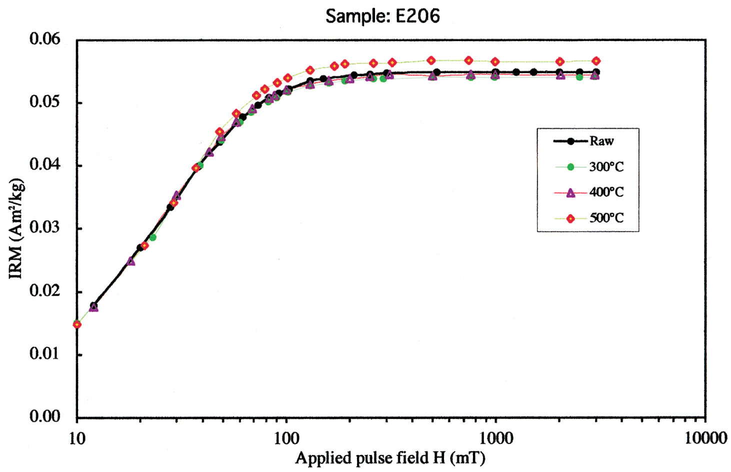


Fig.14 IRM acquisition curve of E206

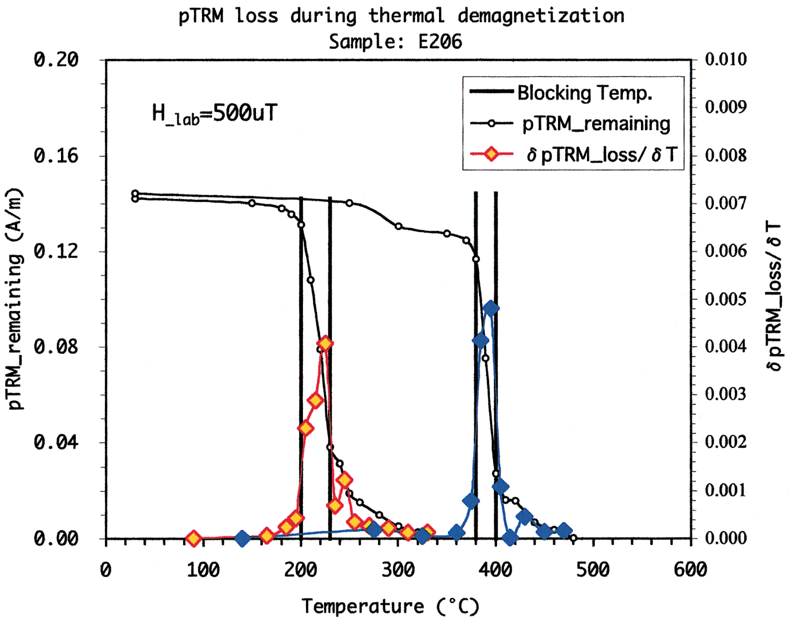


Fig.15 PTRM loss during thermal demagnetization of E206

domain (PSD) -like grains. It also suggests that for a TRM (400℃), the part of low T_{ub} less than 300℃ is CR_TRM dominant. Fig.15 is the illustration of pTRM loss during thermal demagnetization of E206.

In the study of E206, for comparison two T_m were tried, at first 400 ℃, then 350℃. **TRM (400℃) $_{lab}$ RUN results** : Four specimens were conducted paleointensity experiment under a maximum temperature T_n (400℃). As a pretreatment, 5mT AF demagnetization was carried at every step to remove the secondary viscous remanent magnetization. Specimen E206-2 presents a typical result. As we mentioned earlier, there are two phases of titanomagnetite existing in sample : (1) phase A corresponds to unblocking temperature spectra (δNRM/dT) between temperature interval 150～360℃ ; and (2) phase B 300～500℃. It seems there was no thermal alteration occurred in phase B grains during 2nd RUN experiment because there are almost no any changes in its blocking temperature spectra (pTRM/δT). However for the unblocking temperature spectra, δTRM/δT curve went much steeply toward high temperature than that of δNRM/dT suggesting a significant high-temperature oxidation had occurred and some new grains of B phase were produced during 1st RUN experiment. Phase A seem is composed by Ti-rich titanomagnetite with Curie point 370℃ and phase B to Ti-rich titanomagnetite with Curie point 500℃. Because of the thermal alteration, phase B was rejected for further paleointensity correction. For phase A, small change between pTRM1 (1st RUN) and pTRM2 (2nd RUN) suggests occurrence of slight thermal alteration. Except for week magnetization temperature interval 150～210℃, consistent corrected paleointensity data (39.3±0.6μT) were obtained from slight alteration affected three temperature intervals between 210～300℃. According to this analysis, only the data from temperature between 210～300℃ were used to obtain estimate of paleointensity except specimen E206-1, from which we failed to got a consistent data.

Total 9 data were obtained. The Thellier method induced an averaged apparent paleointensity with a greater variance : 40.2±6.4μT from 12 plateau data, while Zheng's method induced a paleointensity with a much smaller variance : 39.4±3.5μT from 9 plateau data and 39.3±0.6μT when 3 specimen data were averaged.

TRM (350℃) $_{lab}$ RUN results : Under a maximum temperature 350℃ four another specimens were conducted for paleointensity experiment again as same as 400℃ run. Specimen E206-7 presents a typical result (Ueno et.al, 2008). The thermal alteration effect became much smaller : Not only both spectra of unblocking & blocking temperature obtained in 2nd run are similar to that in 1st run, thus resulting similar apparent paleointensity curves in all temperature intervals (150～300°), but also the rate of total pTRM {(SUM (pTRM1) /SUMP (pTRM2))} became much nearer 1 than that in 400℃ run (0.884 vs.0.818). A well consistent corrected paleointensity data (42.1±3.4μT) were obtained from whole temperature intervals between 150～350℃. For the other 3 specimens, similar to the present case of E206-7, we accepted the data from the temperature intervals with similar apparent paleointensity curves between 1st & 2nd runs.

Total 16 plateau data were obtained. The Thellier method induced an averaged apparent paleointensity with a greater variance : 46.3±8.8μT for plateau data, while

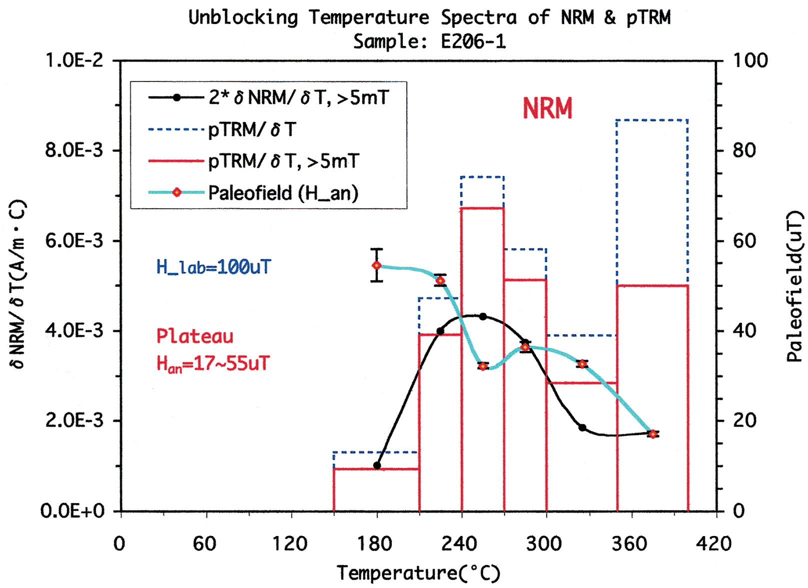
Zheng's method induced a paleointensity with a much smaller variance : 42.1 ± 3.4 μT from 16 plateau data and 42 ± 1 μT when 4 specimen data were averaged. It is slight bigger than that of 400℃ run (42 μT vs.39 μT). Combining both data of 350℃ run and 400℃ run, we reached total 28 plateau data average 44 ± 8 μT by Thellier method and 41 ± 4 μT by Zheng's method. Though the difference is very slight, we prefer the more precisely estimated paleointensity of 350℃ run because of less thermal alteration effect.

The effect of PR_TRM seems have been small in this 350℃ run. Two reasons can be considered : (1) Because of well spatially scattered distribution of grains the effect of PR_TRM itself was small. (2) TRM_{lab} was obtained in the way to have the property nearest that of Full_TRM, TRM_{lab} = TRM (350℃, H_{lab}) + NRM (350 ℃)$_{remaining}$, H_{lab} was chosen very near the ancient field intensity (40 μT vs. 42 ± 3 μT).

5. Discussion and Conclusion

The geomagnetic field intensity of Unzen area is following : the reference field calculated from models IGRF85, 90, 95 to be 47 μT, and the local measurement filed at Mayuyama dam Unzen vocano is 48uT. The field obtained from E202 from this study is 45.3 ± 3.7 μT, and that from E206 is 42 ± 3 μT. A slight difference is presented between geomagnetic field intensity and intensity obtained from this study. The difference may be due to rock magnetic contribution on magnetic field. The field obtained from sample is very sampling site (outcrop) magnetic field. It is composed of (1) reference geomagnetic field, (2) local field, (3) local rock magnetic field contributed by averaged whole rock maintain and (4) very near rock field contributed by underlain rock. Following evidences support our conclusion. The remanent magnetization of Uzen underlain 1792 erupted dacite is about 8A/m (Ueno, 2000), on the very surface of dacite, it will results about maximum 5uT negative additional magnetic field based on a simple calculation. The handle sample E202, which was collected from the top of dacite dome about 2 m apart from ground rock, seem was affected little by underlain rock magnetization, however, the sample E206 may have been affected greatly because of the small bomb of size of 20 cm in diameter, which was very closed to underlain ground rock.

In conclusion, (1) Zheng's method seems sensitively detects the thermal alteration of magnetic properties, and as well perform a good alteration correction when the magnetic properties are not changed significantly. (2) The contribution of underlain ground rock magnetization to magnetic field may be significant when the sample is located close enough to it.



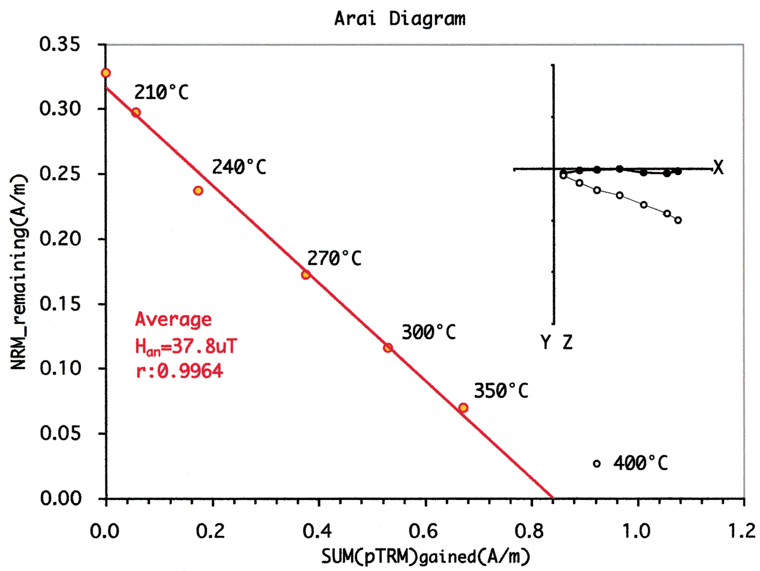
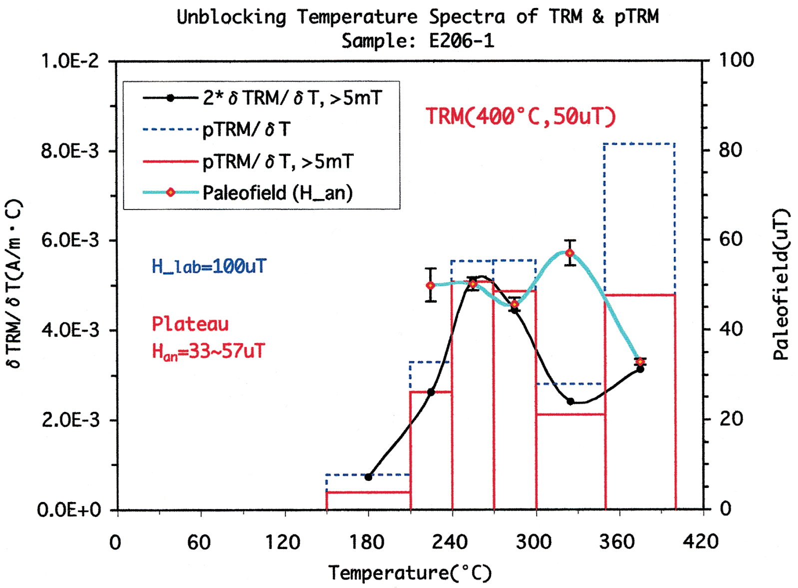


Fig.16-1 E206-1 1st RUN (Pick-up)



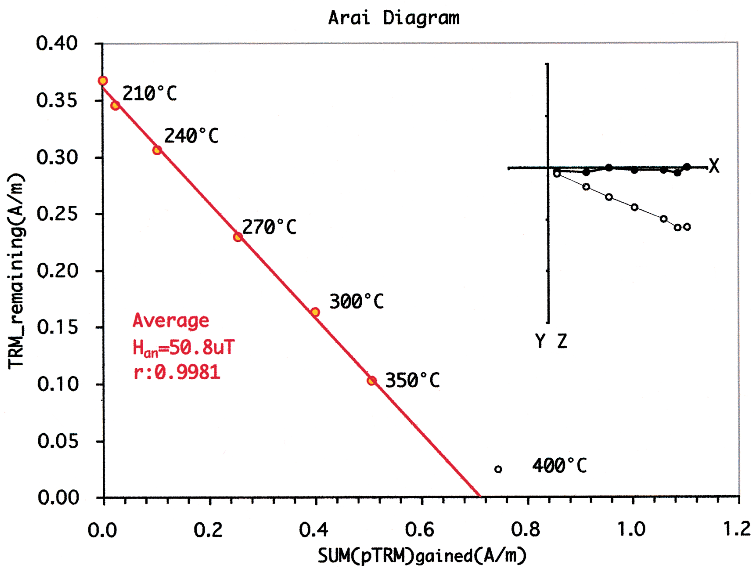
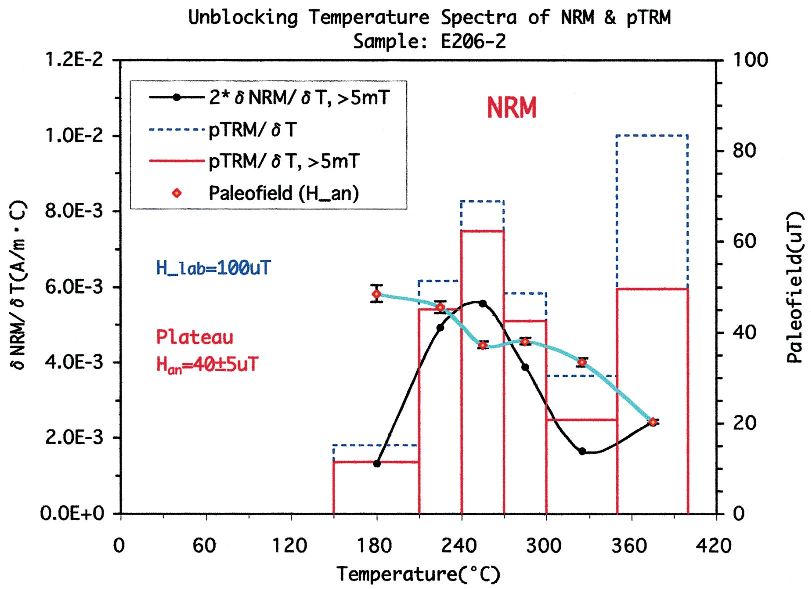


Fig.16-2 E206-1 2nd RUN (Correction)



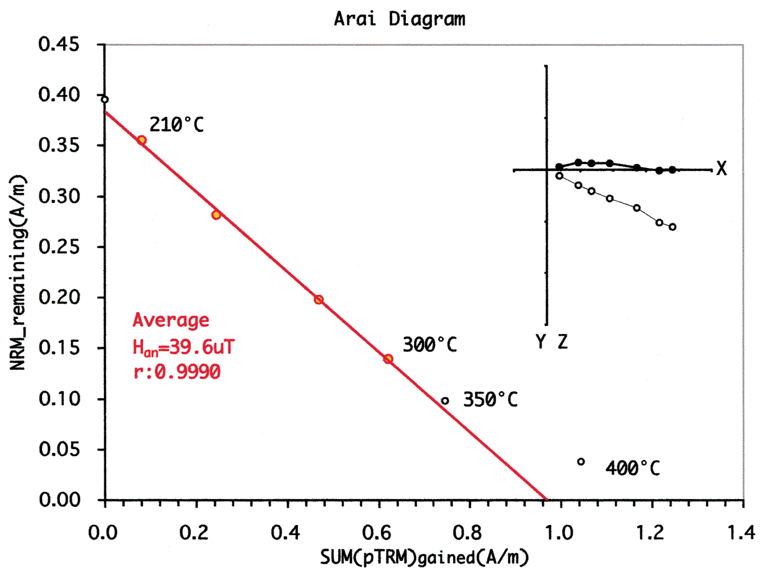
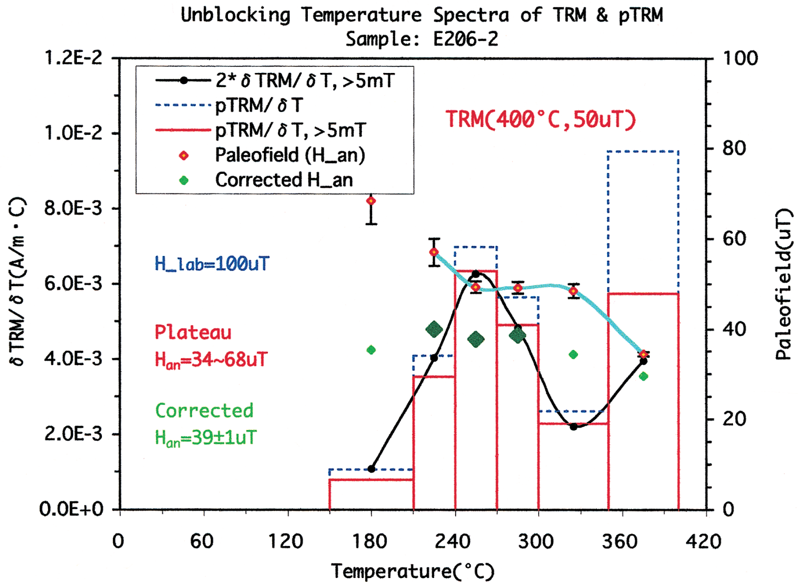


Fig.17-1 E206-2 1st RUN (Pick-up)



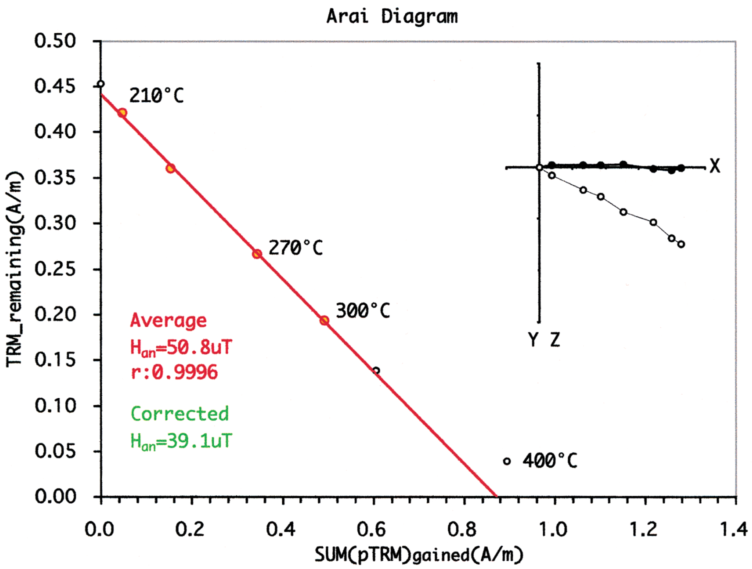
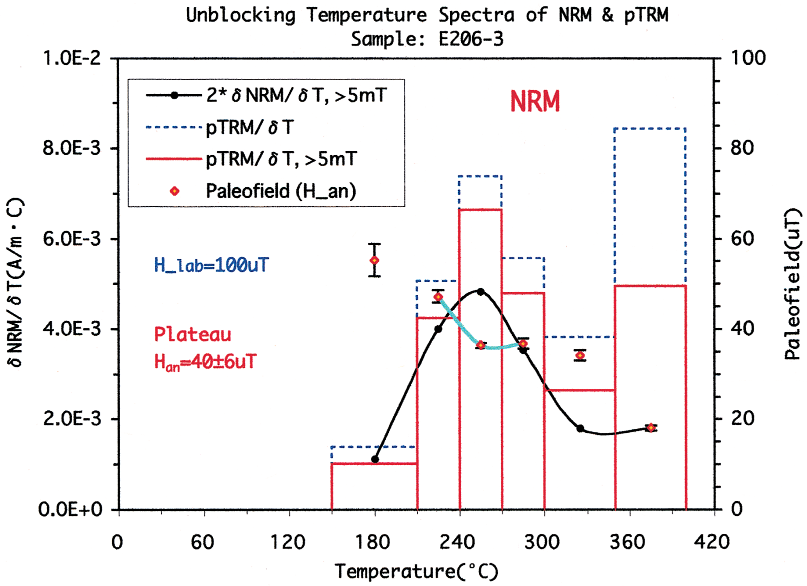


Fig.17-2 E206-2 2nd RUN (Correction)



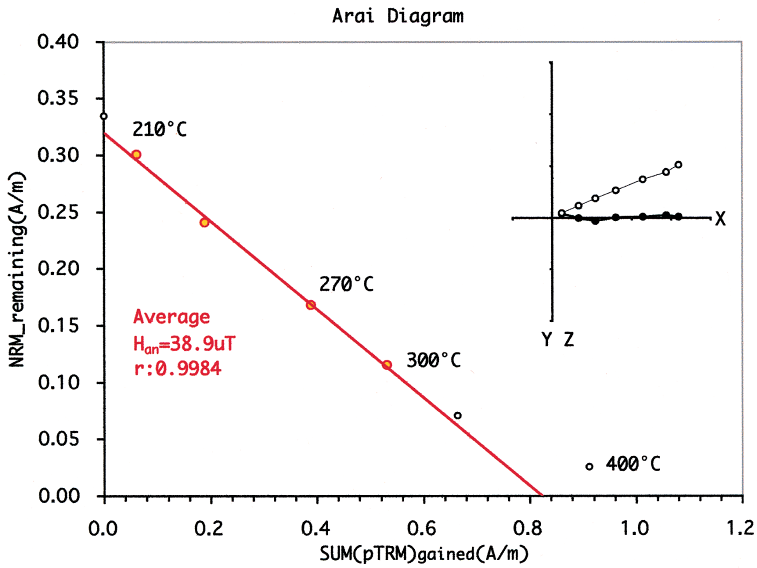
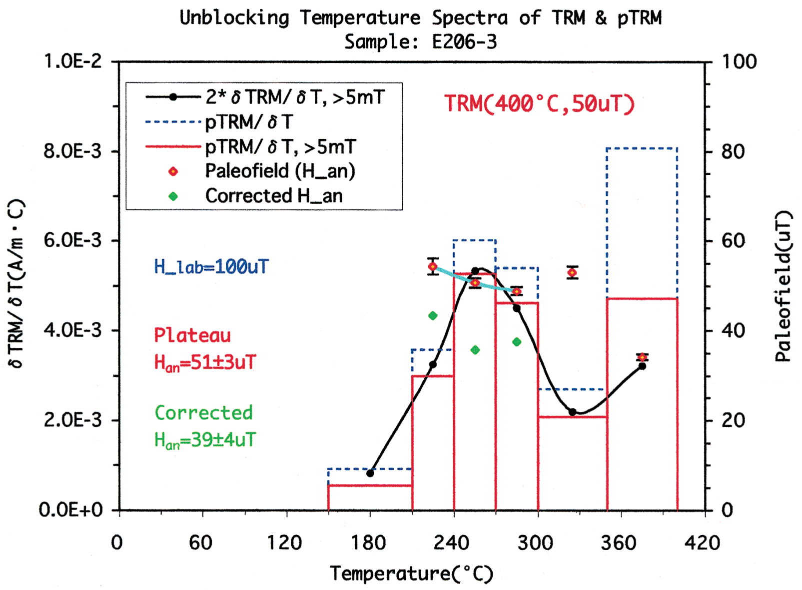


Fig.18-1 E206-3 1st RUN (Pick-up)



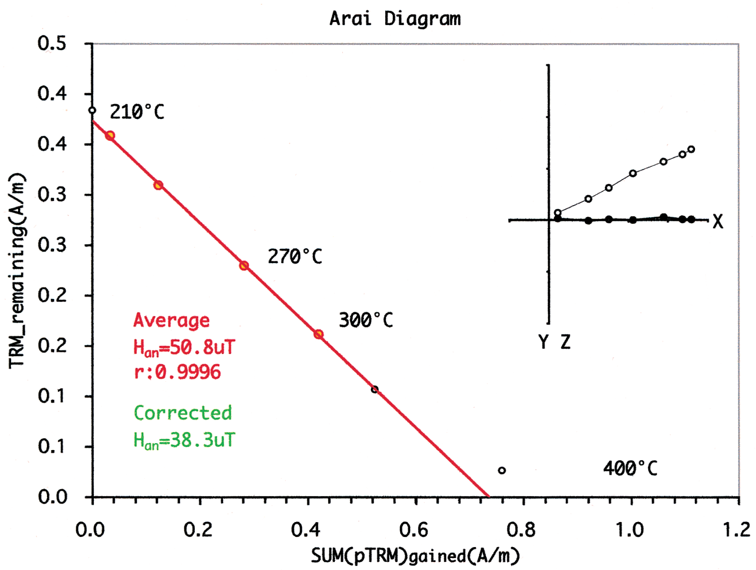
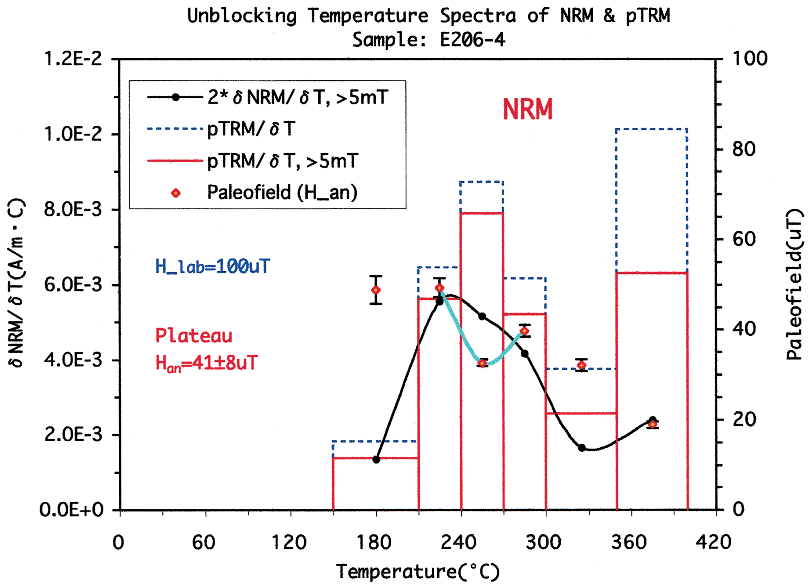


Fig.18-2 E206-3 2nd RUN (Correction)



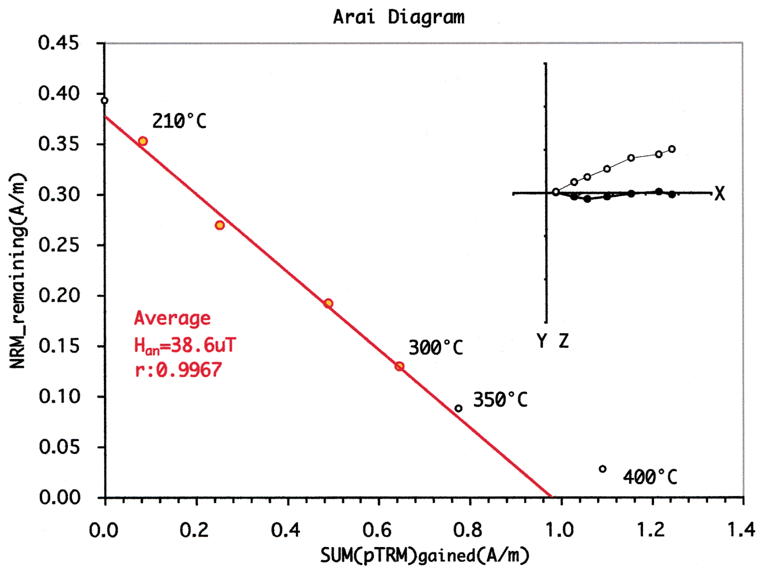
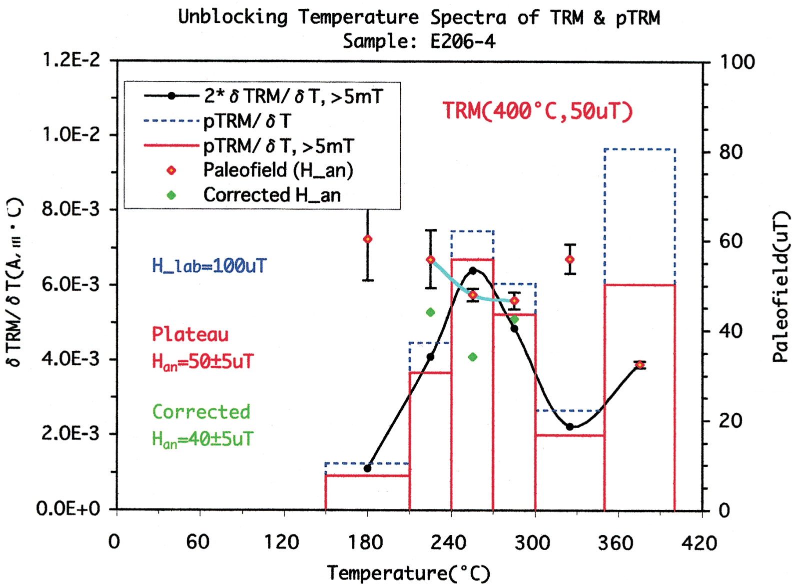


Fig.19-1 E206-4 1st RUN (Pick-up)



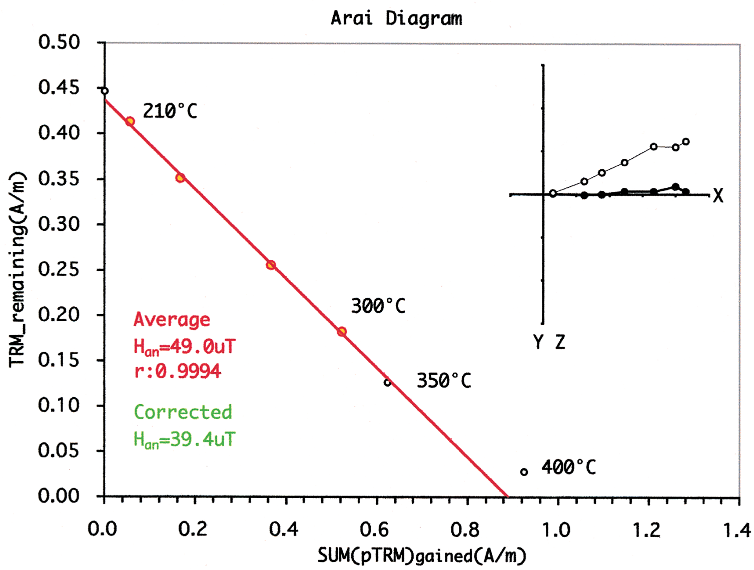
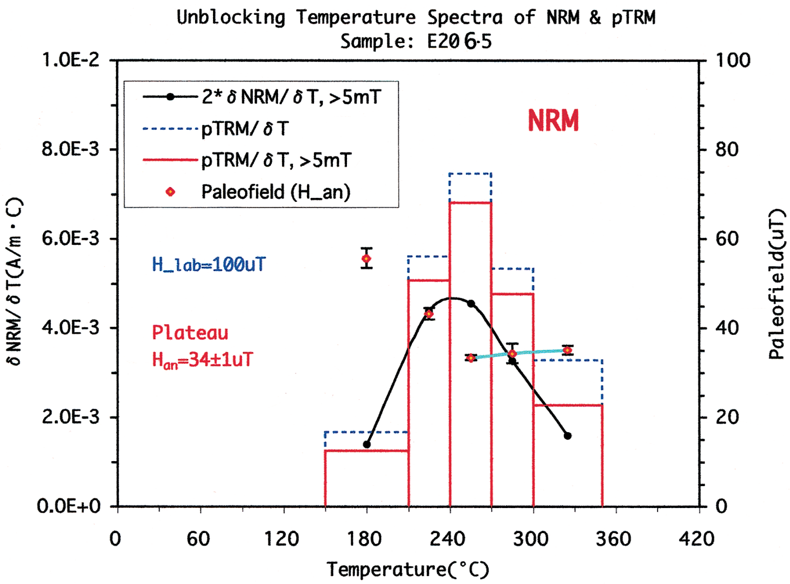


Fig.19-2 E206-4 2nd RUN (Correction)



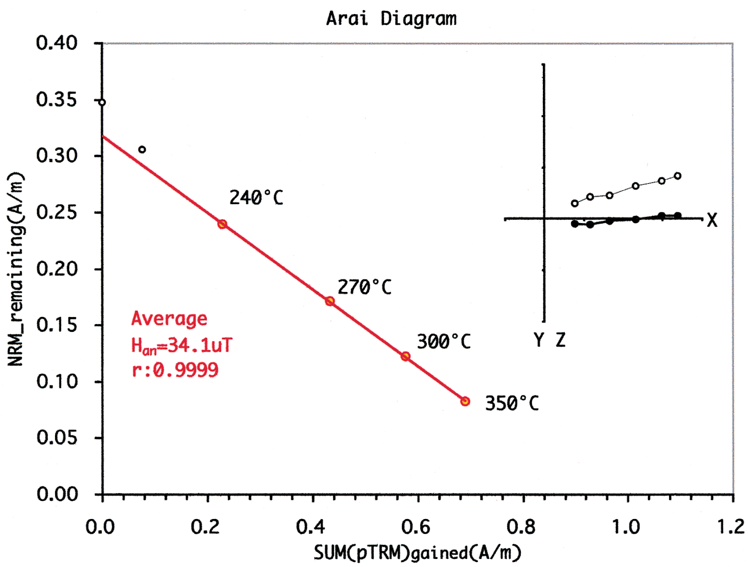
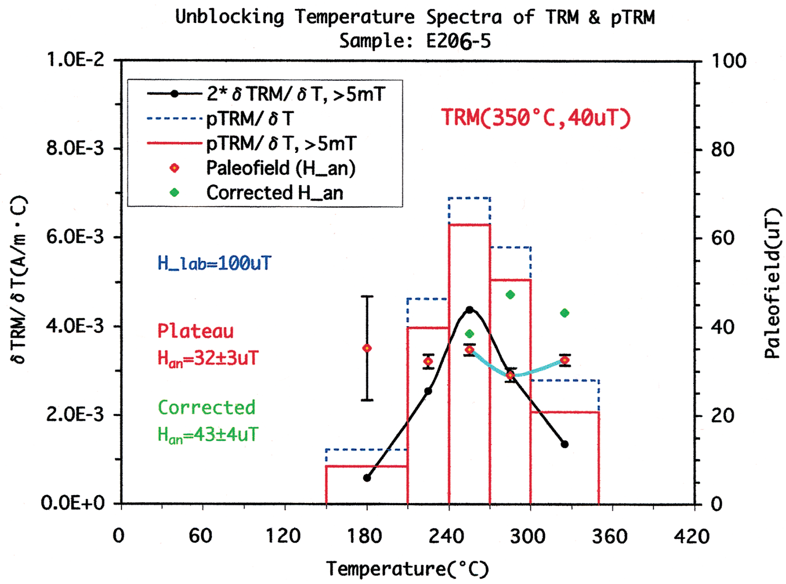


Fig.20-1 E206-5 1st RUN (Pick-up)



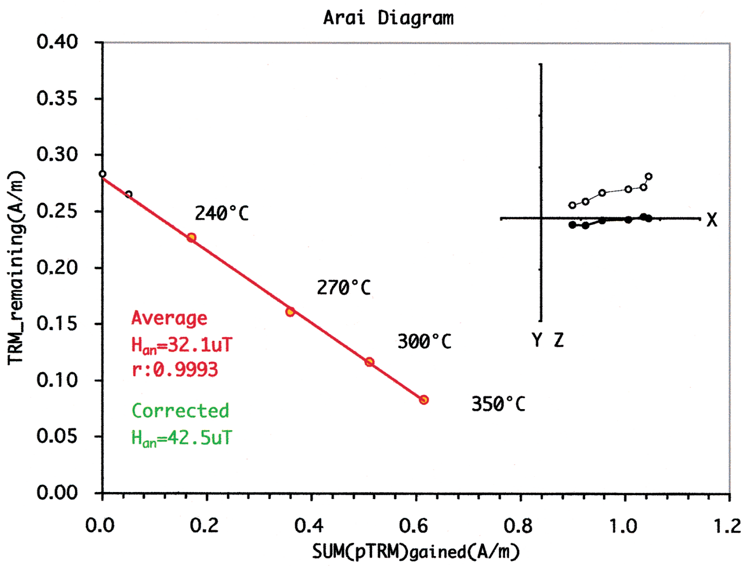
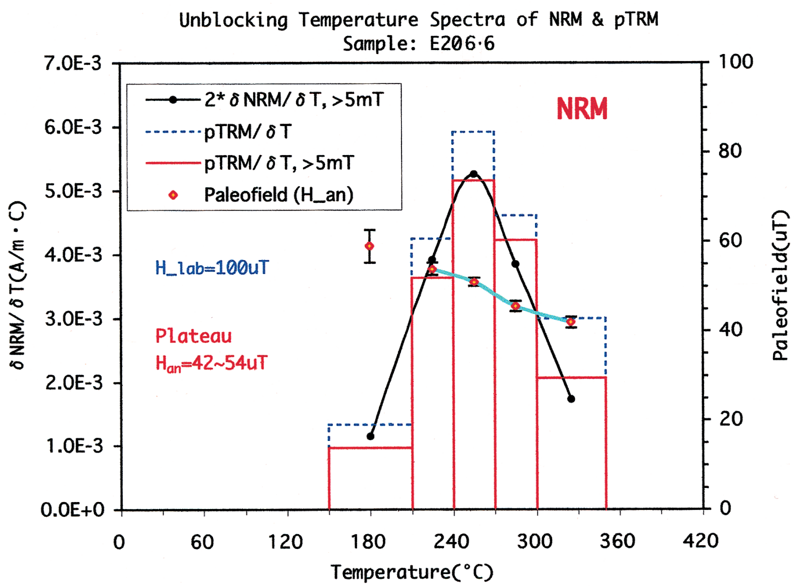


Fig.20-2 E206-5 2nd RUN (Correction)



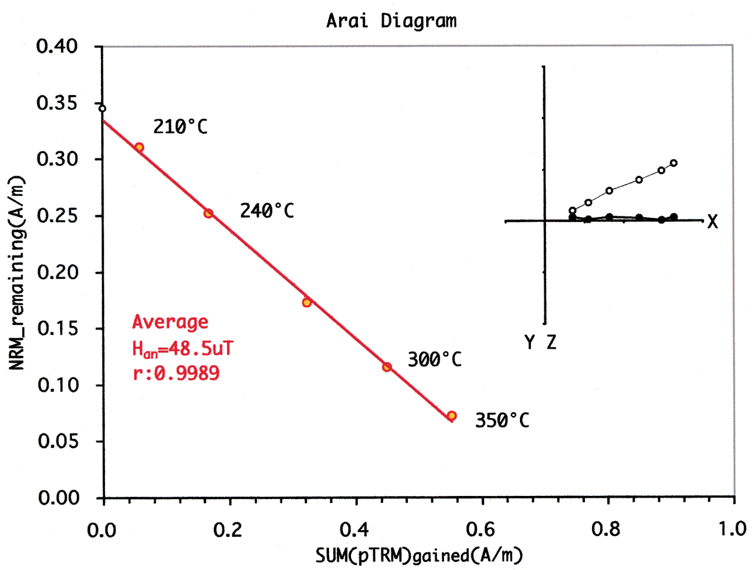
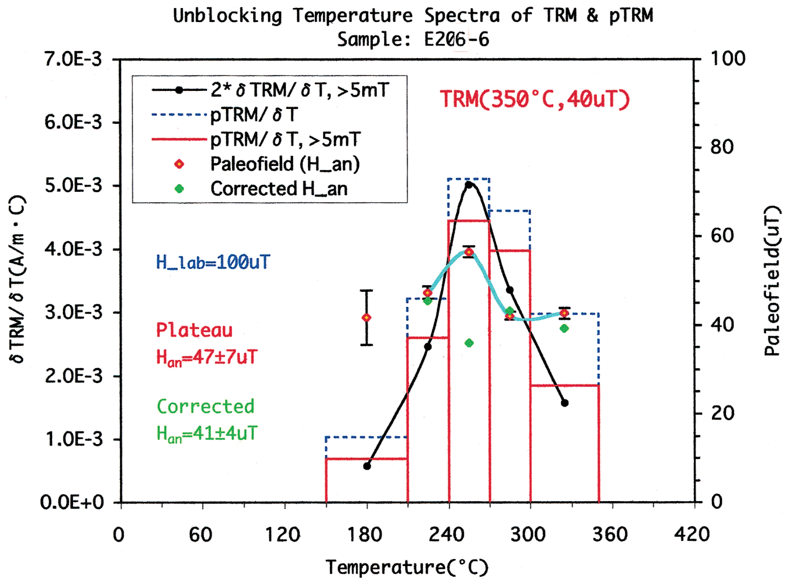
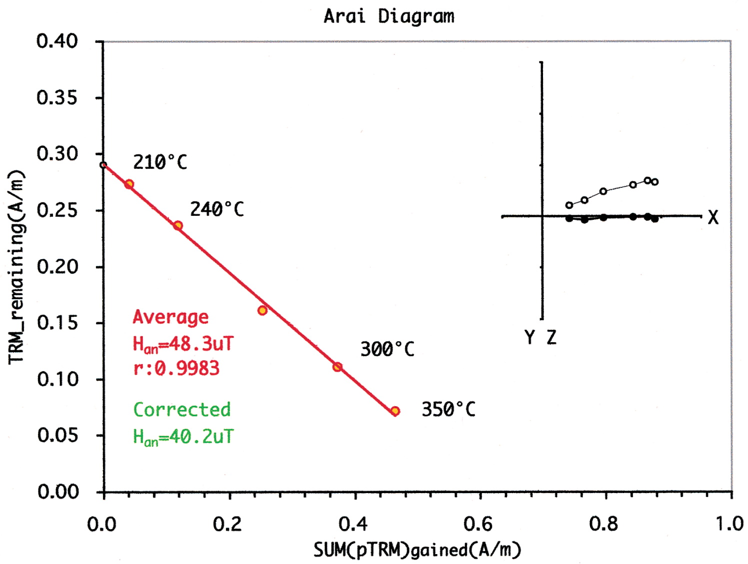


Fig.21-1 E206-6 1st RUN (Pick-up)





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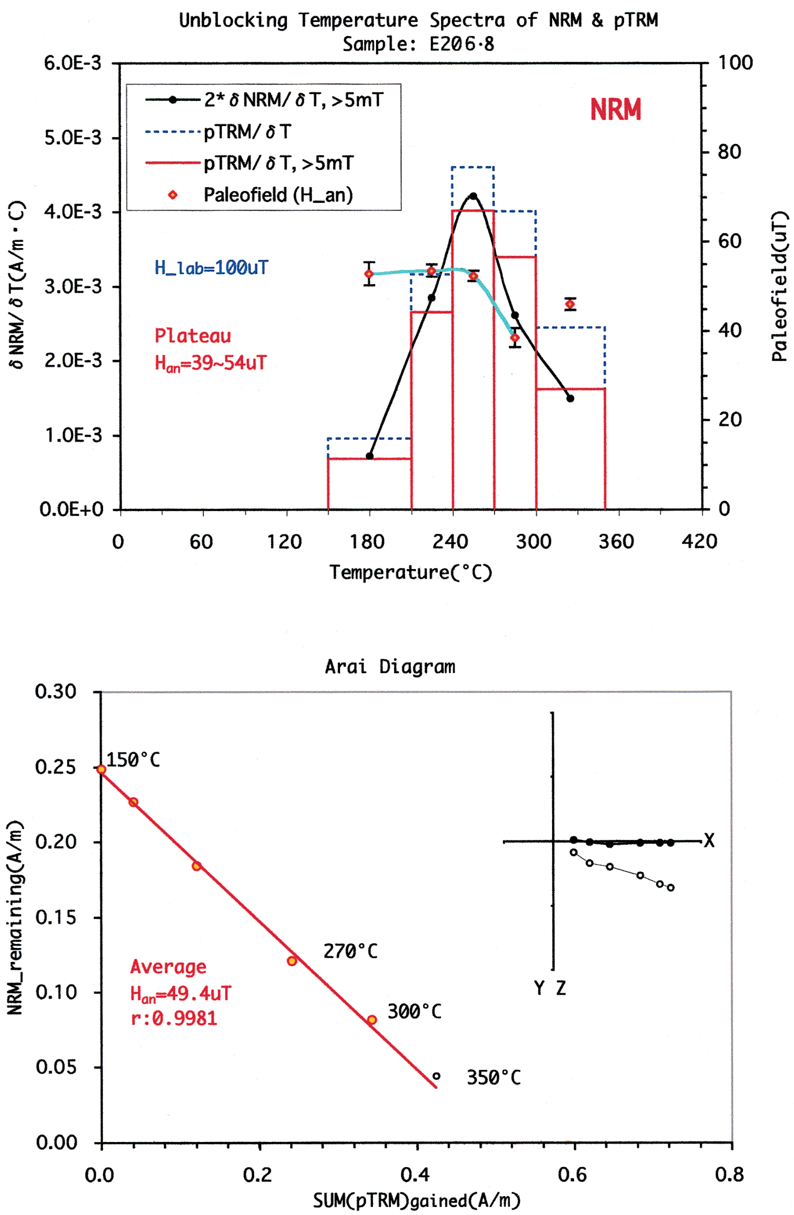
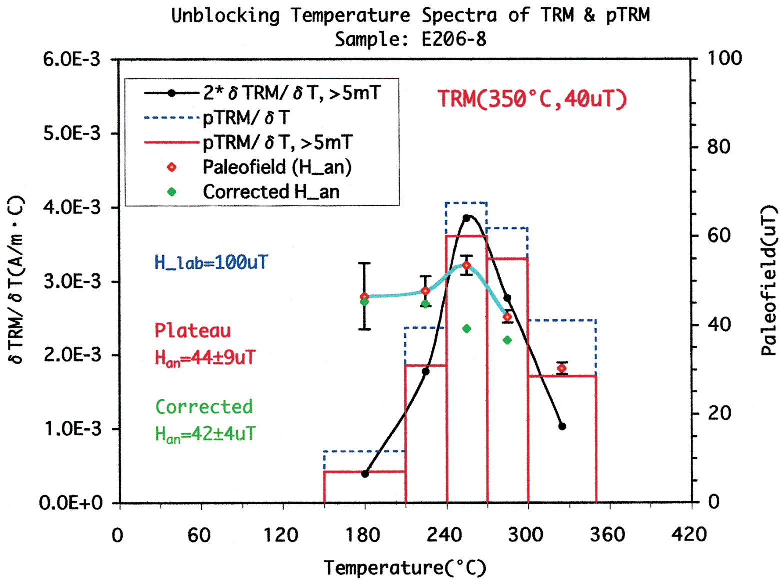
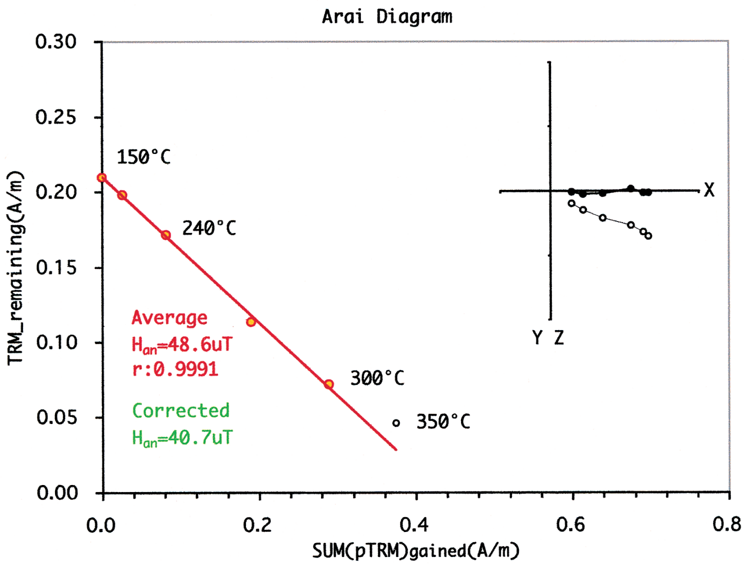


Fig.22-1 E206-8 1st RUN (Pick-up)





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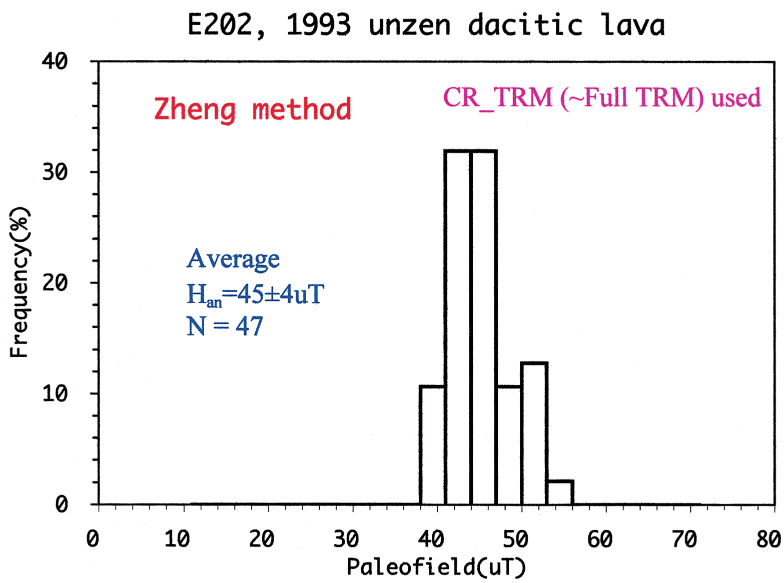

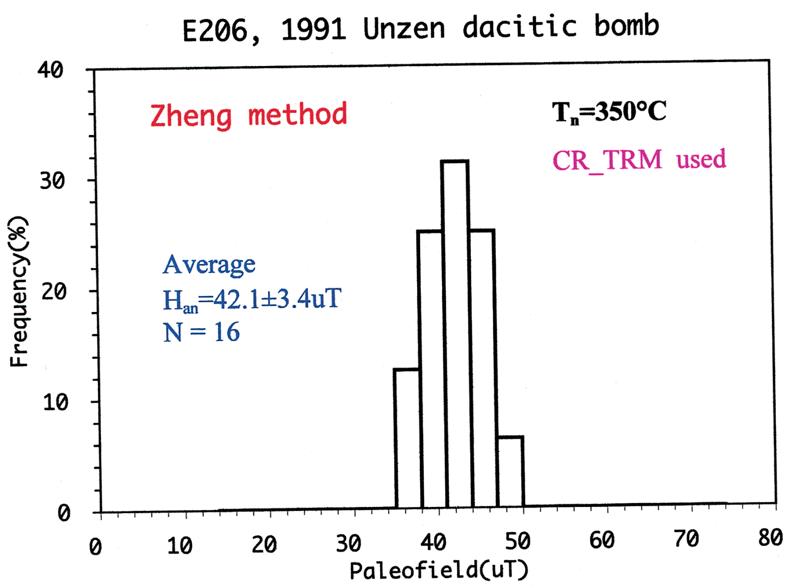

Fig.23 Histogram of the paleointensity by the Zheng's method

Acknowledgements

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要　旨

Zheng 法による古地磁気強度測定法～雲仙火山岩を例にして～

上野直子・鄭　重

鄭によって開発された古地磁気強度測定の新法について、雲仙火山岩を例にして解説した。磁性粒子間の相互作用があると、温度 T_n まで加熱後に室温まで定磁場下で冷却したときに獲得する熱残留磁化 TRM（T_n）は unblocking 温度の順に 3 項の和で成り立つ。(1) T_n より低温の T_m まで：消磁された磁化が生成時の粒子磁気状態に完全にリセットされて獲得した磁化 CR_TRM（T_m）部分、(2) T_n と T_m 間：消磁されたが T_n まで加熱された時に粒子磁気状態が完全にはリセットされず、磁化が部分的にしか獲得できていない PR_TRM（T_m,T_n）部分、(3) T_n で消磁されずに残っていた Tail（T_n）部分である。鄭法が成り立つ前提は（1）の CR_TRM 部分が物理・化学的な変化が起きない温度範囲で獲得できることである。この CR_TRM 部分が獲得できるなら、擬似単磁区（PSD）や多磁区（MD）を含む試料でも信頼できる古地球磁場強度を得ることができる。

雲仙火山岩 E202 では 560℃までの、E206 では 350℃までの残留磁化を使い、信頼できる古地球磁場強度を得ることができた。