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ON THE NATURE OF REMANENCE IN THE 1985 ANDESITIC PUMICE WITH SELF-REVERSED MAGNETIZATION FROM THE NEVADO DEL RUIZ, COLOMBIA

by

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(with 5 text-figkres and 4 tables)

Abstract

The magnetic remanence of the andesitic pumice of the Nevado del Ruiz 1985 eruption has the multi-component nature. The major normal component behavior is due to the titanomagnetite phase with variable chemistry. The major reverse component has a peak demagnetization and acquisition range between 200°-225℃ but no such mineral phase could be detected. The titanomagentite phase contributes to the major normal component and has probably no relation to the reverse magnetization.

Introduction

Self reversal properties in rock magnetism were first found in the dacitic pumice of Mt. Haruna, Honshu, Japan and were well discussed by Nagata et al. (1952), Uyeda (1958), Ishikawa and Akimoto (1957) and Ishikawa and Syono (1963). These authors used the interaction model proposed by Neel (1951) for interpretation. The occurrence of self-reversal of remanent magnetization found in the 1985 pumice of Nevado del Ruiz, Colombia has been described by Heller et al. (1986). In their study, they demonstrated the reverse nature of the natural remanent magnetization (NRM) in the pumice and showed that the NRM suddenly changes its polarity from reverse to normal at 120℃, with complete demagnetization of the reverse component around 150℃-160℃. The remaining normal component disappeared at temperatures from 350° to 400℃ on further heating. They observed that the self-reversibility of the remanence in the laboratory conditions was very sensitive to the maximum demagnetization temperatures of 160°-190℃ during which the higher the temperature raised the more suppressed was the reverse component. The two opaque oxide phases of titanomagnetite and hemoilmenite observed were attributed to correspond to the major and minor phases of

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saturation magnetization with Curie temperatures of 370-410℃ and 180-200℃, respectively. The titanomagnetite was considered solely to be responsible for the normal component whereas the reverse component was attributed to be the effect of exchange interaction between two intimately mixed phases of hemoilmenite within the lower Curie temperature range. The exact mechanism controlling the self-reversal, however, was not made clear.

The present study was initiated with an aim of better understanding of the nature of the remanence in the 1985 pyroclastics of Nevado del Ruiz. We report here some of the preliminary findings concerning the multi-component nature of the remanence. An elaborate discussion is believed to be possible in future as the work progresses further.

Geologic background of the 1985 Nevado del Ruiz pumice.

The main object of this study is the 1985 Nevado del Ruiz pumice, sampled during the field survey of Ruiz Volcano as a part of the Natural Disaster Scientific Research Expedition organized by one of us (Y. K.). The pumice samples were collected from the pyroclastic fall deposit distributed around the summit area and north-northeastern foot of Ruiz Volcano. The pumice is hornblende-titaniferous phlogopite-orthopyroxene-clinopyroxene andesite in composition and occurs as mostly white(SiO_2 63%) but partly gray (SiO_2 60%) varieties. Both white and gray pumices occur as banded pumices and, in places, the gray one includes the white one. This mutual relation probably suggests magma mixing (Katsui et al., 1986).

Cylindrical specimens (2.54 cm in diameter and 2.5 cm in length) were drilled from two 1985 pumice samples (R5 and R15) and also from a prehistoric andesitic lava (R4) for comparable magnetic measurements. Measurements of magnetization were made by using Schonstedt SSM-1A spinner magnetometer.

Experimental procedures and results

Magnetic measurements include: a) Measurements of NRM of the standard specimens b) Stepwise thermal demagnetization of specimens with heating in air with steps ranging from 5 to 50℃ from room temperature up to 500-600℃ and partial thermo-remanent magnetization (PTRM) acquisition experiments at the ambient geomagnetic field in the laboratory c) Thermomagnetic analysis of whole rock samples, magnetic fractions and heavy fractions (obtained by heavy-liquid separation using Bromoform). In addition (d), the sample R5 was examined in a polished thin section by using reflective light microscope and electron probe micro analyzer (EPMA).

a) Remanence and polarity

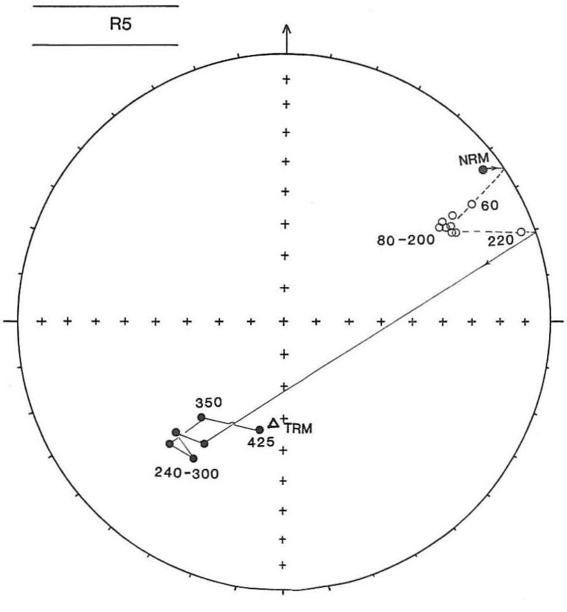
Table 1 shows the initial NRM and the total laboratory induced thermo-

Table 1 Samples and magnetization intensity data.

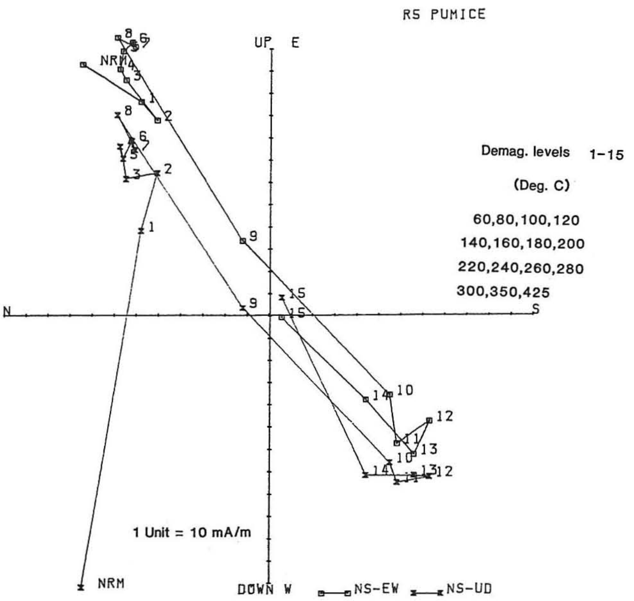
Sample	Description	NRM Intensity (x10-3 Am-1)	TRM Intensity (x10-3 Am-1)	Polarity
R5	Andesite pumice, white	141	167	Reverse
R15-W	Andesite pumice, dominantly white	150	42	Reverse
R15-G	Andesite pumice, dominatly gray	617	617	Reverse
R4	Prehistoric Lava	642	3100	Normal

remanent magnetization (TRM) intensities with the polarities for the representative specimens. It is evident that the gray pumice has NRM intensity comparable to that of the lava whereas it is about 5 times higher compared to that of the white pumice. The total TRM intensity is surprisingly the same to that of NRM for the gray pumice, implying that the original NRM was also a TRM.

All pumice specimens acquired TRM in a direction antiparallel to the applied filed showing their reverse nature by which it was inferred that the NRM directions were of reverse nature as well. The sample were not field-oriented so that judging from the direct measurements was not possible. The lava, in contrast, was magnetized parallel to the applied field.



Text-fig. 1 Result of progressive thermal demagnetization of the Nevado de Ruiz 1985 pumice (Sample R5). Temperatures in ℃. Open(solid) symbols are projections on upper(lower) hemisphere.



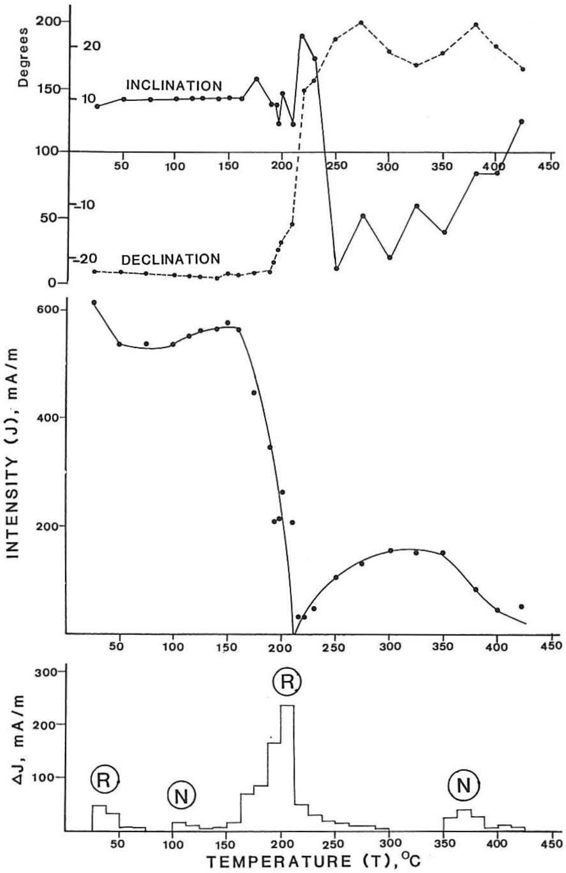
Text-fig. 2 Representative Zijderveld(1967) demagnetograms of the pumice. Demagnetization level 1-15 isolates to temperatures illustrated in Text-figure 1.

b) Demagnetization behavior

Results of the thermal demagnetization studies for specimens are presented in Text-figures. 1, 2 and 3. It can be observed that the region from room temperature to about 225℃ is reverse dominated whereas the region above it is dominated by normal polarity. The difference curve clearly indicated the presence of four regions during which either reverse or normal components are being removed. These regions are: 1) reverse, poorly definded (20 to 50℃), 2) normal (100 to 125℃), 3) reverse (150 to 275℃). The white pumice specimens (R5 and R15-W) also exhibited similar component-regions with the only difference that the proportion of intensities carried out by each of these components varied. TRM acquisition curves showed clearly the presence of three regions corresponding approximately to the last three component regions derived from the difference curves.

c) Thermomagnetic analysis

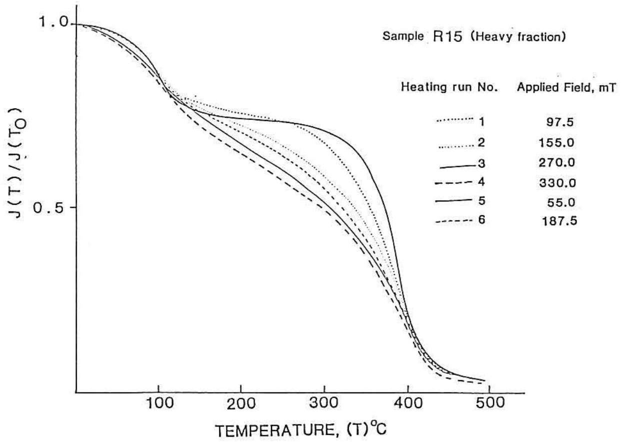
Text-figure. 4 shows a set of thermomagnetic curves (analysis in vacuum close to 0.26 Pa., heating rate at 10℃/min.) for the heavy fraction constituting sample R15. Whole rock analysis showed only sigle Curie-point curves as opposed to the clear double Curie point character for magnetic and heavy fractions. Repeated runs for the same sample with varying applied field values showed the clear field-dependence especially well expressed for the right part of the curve. The repeated heating in the same applied field yielded completely reversible curve.



Text-fig. 3 Results of stepwise thermal demagnetization of the pumice (sample R15-2).
Top: Change in declination, inclination of the remanent vector.
Middle: Variation in intensity of remanent magnetization.
Bottom: Difference intensity curve deduced from the intensity response curve (middle) to show the amount of the intensity removed during successive temperature interval. Only absolute value is plotted. R and N enclosed by circles denote reverse and normal polarity regions, respectively.

d) Microscopic and EPMA analyses

Optical examination of sample R5 revealed the presence of two types of opaques with contrasting reflectivity occurring mostly in isolation to each other but very rarely as twins. Representative EPMA data and relevant information on grains with results of recalculated analyses applying the scheme by Charmichael (1964) are given in Tables 2 and 3. Chemical composition of analyzed grains is shown in the ternary diagram (Text-fig. 5). These data suggest the mineralogical phases to be titanomagnetite (X ulvospinel range: 0.216 to 0.251) and hemoilmenite (X ilmenite range: 0.704 to 0.731).



Text-fig. 4 Doule Curie-point thermomagnetic curves showing dependence of the shape and the applied field(mT).

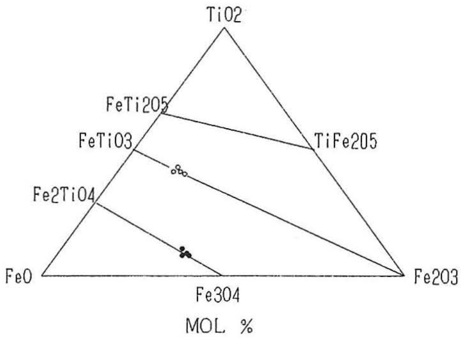
Table 2 Representative Electron Probe Microanalysis data for titanomagnetite and hemoilmenite from sample R5.

Oxdies(%)	Titanomagnetite		Hemoilmenite	
SiO2	0.08	0.13	0.01	0.02
TiO2	7.96	8.56	37.88	38.67
Al2O3	1.88	1.95	0.33	0.28
Cr2O3	0.38	0.04	0.07	0.11
FeO*	81.42	80.85	55.58	54.04
NnO	0.33	0.34	0.34	0.34
MgO	2.13	2.25	2.79	3.03
CaO	0.01	0.02	0.01	0.04
NiO	0.06	0.06	0.04	0.07
Sum	94.25	94.20	97.05	96.60
Recalculated analysis:				
Fe2O3	51.57	50.53	29.87	27.89
FeO	35.02	35.38	28.7	28.94
Total	99.42	99.26	100.04	99.39
	Cations on 32 Oxygen basis		Cations on 3 Oxygen basis	
Si	0.023	0.038	0.000	0.001
Ti	1.793	1.925	0.713	0.731
Al	0.663	0.689	0.010	0.008
Cr	0.091	0.009	0.001	0.002
Fe^{+++}	11.615	11.377	0.562	0.527
Fe^{++}	8.765	8.853	0.601	0.608
Mn	0.083	0.086	0.007	0.007
Mg	0.948	1.004	0.104	0.114
Ca	0.004	0.006	0.000	0.001
Ni	0.014	0.014	0.001	0.001
Total	23.999	24.001	1.999	2.000
	Molar fractions: X ulvospinel		Molar fractipons: X ilmentie	
	0.227	0.245	0.713	0.731

* Total Fe calculated as FeO

Table 3 Average composition of titanomagnetite and hemoilmenite in sample R5 (From EPMA analysis).

Classification of grains	Analyzed grains		Mineral	Molar proporition	
	Size(μm)	Number of grains		Mean value	Standard deviation
Grains with low brownish white reflection with well-developed cracks.	10-140	10	Titano-magnetite	X ulvospinel: 0.231	0.021
Grains with high yellowish white reflection with almost absence of cracks.	20-250	8	Hemo-ilmenite	X ilmentie: 0.716	0.010



Text-fig. 5 Chemical composition of the magnetic minerals in the pumice, represented on a FeO-Fe_2O_3-TiO_2 diagram in mol. %. Recalculation is based on the scheme by Carmichael (1967).

Discussion and conclusion

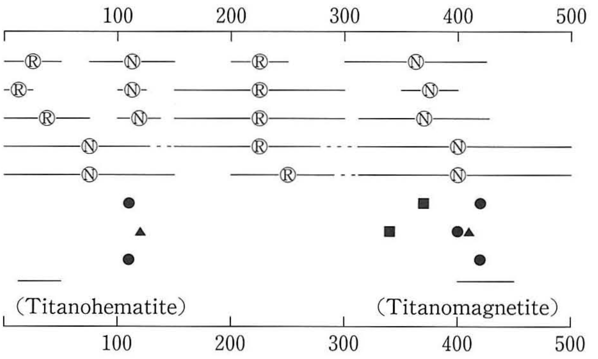
Table 4 summarizes our temperature data. Calculated Curie temperatures are based on the assumption of linear variation of the values from $-153°$ to 578℃ for titanomagnetite series and from -200℃ to 675℃ for ilmenite-hematite series (Collinson, 1983).

It can be definitely said that the major normal component is carried out by the titanomagnetite phase with variable chemistry having Curie temperatures close to 400℃. There is a definite correlation between the observed lower Curie temperature and the minor normal component demagnetization spectra. The major reverse component has a peak demagnetization and acquisition range between 200-225℃ but no such mineral phase could be detected by thermomagnetic analysis. Therefore, the exact contribution of self-reversal properties in the Nevado del Ruiz pumice could also be explained in terms of order-disorder transition of Ti and Fe ions in the hemoilmenite phase, as previously proposed by Ishikawa and Syono (1963).

In conclusion, we would like to point out that the exact nature of the remanen-

Table 4 Summary of the temperature analysis. Curie temperature range and unblocking temperature spectra.

Parameter(s)	Sample /Specimen	TEMPERATURE, (℃)
Unblocking temperature spectra	R5 R15-G R15-W	
Lab. TRM acquisition ranges	R15-G R15-W	
Curie temperatures, observed	R5 R15-G R15-W	
Curie temperature range, calculated	R5	



—Ⓝ— Normal —Ⓡ— Reverse ■ Chip ● Magnetic fraction ▲ Heavy fraction

ce and the mineral chemistry in the 1985 Nevado del Ruiz pumice seems to be rather complex. One of the clear difference in previous data (Heller et al., 1986) and ours is that the major reverse component has higher unblocking temperatures than mentioned earlier. The fact that the titanomagnetite phase contributes to the major normal component and has probably no relation to the reverse magnetization is suppoted also by our study.

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