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Kappameter KT-3 and its Application for Some Volcanic Rocks in Japan

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Abstract: Kappameter KT-3 is very useful for field work of opaque oxides problems. The use with distance stick makes distinguishable the magnetite-series and ilmenite-series granitoids and thus recommendable. The measurement shown in SI unit gives a good correspondance with the results of Bison Model 3101 on powdered samples. χ-value ($\times 10^{-6}$ emu/g) = 1.2 $\times$ SI unit ($\times 10^{-3}$).

Magnetic susceptibility of typical tholeiite suite lavas of Quaternary age is less than that of typical low-K_2O magnetite-series granitoids of Miocene age and calc-alkaline suite lavas of Quaternary age, which occur in the inner side of the volcanic front. However, calc-alkaline suite of Sanukite group of Miocene age has lower magnetic susceptibility than the above-mentioned, inner calc-alkaline suite. Magnetic susceptibility of late Mesozoic to early Cenozoic volcanic rocks in the Inner Zone of Southwest Japan is high in the north and low in the south. Thus northward increase of magnetic susceptibility is expected on these Mesozoic to Cenozoic volcanic terranes. Ratio of the magnetite-series/ilmenite-series volcanic rocks increases drastically from the late Mesozoic to recent.

Introduction

Kappameter KT-3 is a magnetic susceptibility measuring device designed by the Institute of Applied Geophysics (UGF), Czechoslovakia. It is light weighing only 1.25 kg and is handy having demensions of 6.5 $\times$ 8.5 $\times$ 25.5 cm. Thus the device is very useful for field work.

Magnetite content of common granitoids has important bearing on both petrogenesis and metallogenesis (ISHIHARA, 1977; SASAKI and ISHIHARA, 1979). The content is easily determined by magnetic susceptibility measurement (KANAYA and ISHIHARA, 1973; KANAYA, 1974). In these earlier works, we measured magnetic susceptibility on powdered samples by the Bison Model 3101. Recently, however, we have been also using the Kappameter KT-3 (Fig. 1).

This paper concerns with comparison of the data obtained by the two devices and application of the Kappameter for some volcanic rocks in Japan.

The Kappameter KT-3 and its Application

All necessary information about the Kappameter KT-3 is available in the attached manual of the device, which is distributed by ABEM, Box 20086, S-161 20, Bromma 20, Sweden (IAG, 1971). Thus only few comments are given below from the writer's experience.

On its application for granitoid study, sensitivity is most important, because granitoids consist of magnetite-bearing magnetite-series and magnetite-free ilmenite-series (ISHIHARA, 1977), and the

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Fig. 1 Kappameter KT-3 (After IAG, 1971).

latter has very low magnetic susceptibility. The Kappameter has excellent sensitivity of 0.02×10^{-3} SI unit (1.5×10^{-6} cgs unit). The two series of granitoids are divided by $n \times 10^{-5}$ cgs unit (ISHIHARA, 1979). This device has enough sensitivity for the granitoid study.

On common outcrop, surface of exposure is not smooth. Thus correction factor is given in the manual (IAG, 1971, p. 20–23) depending upon uneveness of the surface. In the writer's experience, however, it is recommendable to use the device with distance stick which separates the measuring face from surface of outcrop about 14 mm. With this stick, no correction for the surface uneveness is needed. The sensitivity is slightly lowered but is still enough to identify the ilmenite-series granitoids and to find out meaningful amount of magnetite for the petrological study.

Fig. 2 illustrates relationship between magnetic susceptibility by the Bison Model 3101 (χ, emu/g) and Kappameter KT-3 (SI unit). The magnetic susceptibility was measured at first at outcrop by the Kappameter, and hand specimen was taken out from closest place to the measured portion and powdered in laboratory for about 500 g; then the magnetic susceptibility was measured by the Bison's device. Thus the measured materials by the two devices may not represent the same portion. In other words, this test was aimed at practical purpose in combining the earlier and recent works of the writer. Agreement of the two measurement is good in general, which is shown by solid line in Fig. 2. Their relationship can be expressed as χ-value $(\times 10^{-6}) = 1.2 \times$ SI unit $(\times 10^{-3})$.

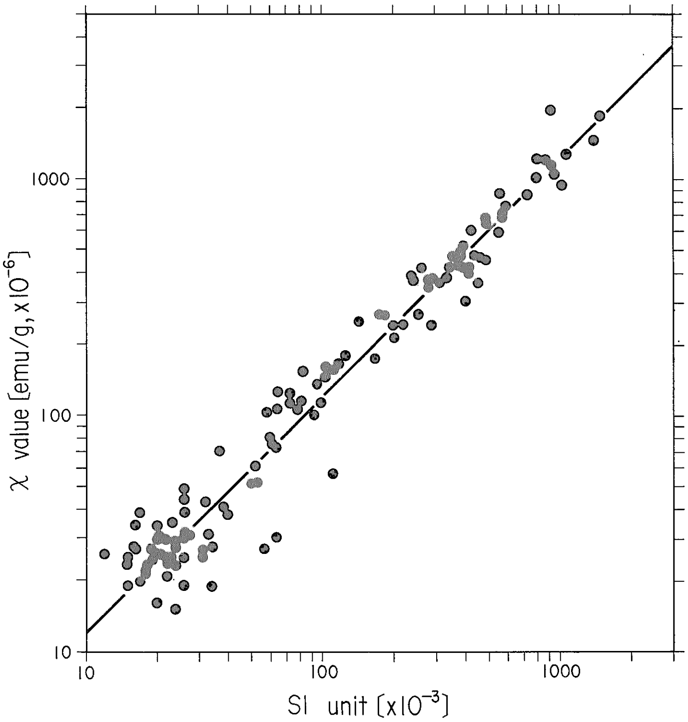

Fig. 2 Magnetic susceptibility of granitoids from the Chugoku district measured by the Kappameter (SI unit) and Bison Model 3101(emu/g). Solid line is general trend of the plots.

Late Cenozoic Volcanic Rocks

Since volcano-plutonic concept has been widely accepted on magmatism of the Japanese islands, regional variation of magnetic susceptibility found on the granitoids is expected to be seen on the volcanic rocks. Fig. 3 shows magnetic susceptibility of tholeiite-suite lavas of Quaternary age from Hachijo-jima. All have values of magnetite bearing, which are above 50×10^{-6} emu/g (ISHIHARA, 1979). Two relatively low values obtained at high SiO_2 percentage are ferroaugite-ferrohortonalite quartz andesite which is a bread-crust bomb in pumice flow deposit (No.11 of ISSHIKI, 1963, p. 122) and ferroaugite-fayalite dacite (No. 12) which is obsidian in pumice flow deposit.

The volcanic rocks from Hachijo-jima give lower magnetic susceptibility than the Tanzawa-type low-K_2O tonalite of Miocene age (Fig. 3), which may be plutonic equivalent of low-K_2O tholeiite. Calc-alkaline suite lavas were studied on samples from Mt. Kuju-Aso area and other Quaternary volcanoes along the Japan Sea coast. These lavas have higher magnetic susceptibility than the tholeiite suite. Most of the Quaternary and Miocene volcanic rocks occurring along and in the inner side of the volcanic front (Green Tuff belt) give magnetite-bearing values.

On the contrary, calc-alkaline suite volcanic rocks (Sanukite group) of Miocene age of the Setouchi terrane may be different, because these rocks are distributed in area between the magnetite-bearing Miocene volcanic rocks of the Sanin Green Tuff belt and the magnetite-free igneous rocks of the Outer Zone of Southwest Japan. There is indeed evidence that some of the rocks may be magnetite-free as indicated by very low bulk Fe^{+3}/Fe^{+2} ratios on volcanic rocks from Shidara area (ONO, 1962), which is the eastern extension of the Setouchi volcanic field. Thus the volcanic rocks were studied in the main part of Kagawa Prefecture.

Most of the studied rocks have magnetic susceptibility of weakly magnetite bearing (Fig. 3). Magnetite-free values are commonly found on andesite from Hiyama and Washinoyama. These rocks are said to contain abundant xenoliths from the basement (O. UJIKE, personal communication); the phenomenon common in the ilmenite-series granitoids (ISHIHARA, 1977). Miocene granitoids of the Outer Zone of Southwest Japan are of the ilmenite-series and thus have low magnetic susceptibility below 50×10^{-6} emu/g (ISHIHARA, 1979). The Okueyama pluton is shown in Fig. 3 as an example. Volcanic rocks of the same zone were studied at few places and found to be mostly magnetite-free. Throughout the Miocene plutonic and volcanic rocks in Southwest Japan, magnetic susceptibility seems to increase toward the Japan Sea side, which is the same tendency as that seen on the Cretaceous to Paleogene granitoids of the Inner Zone (ISHIHARA, 1979).

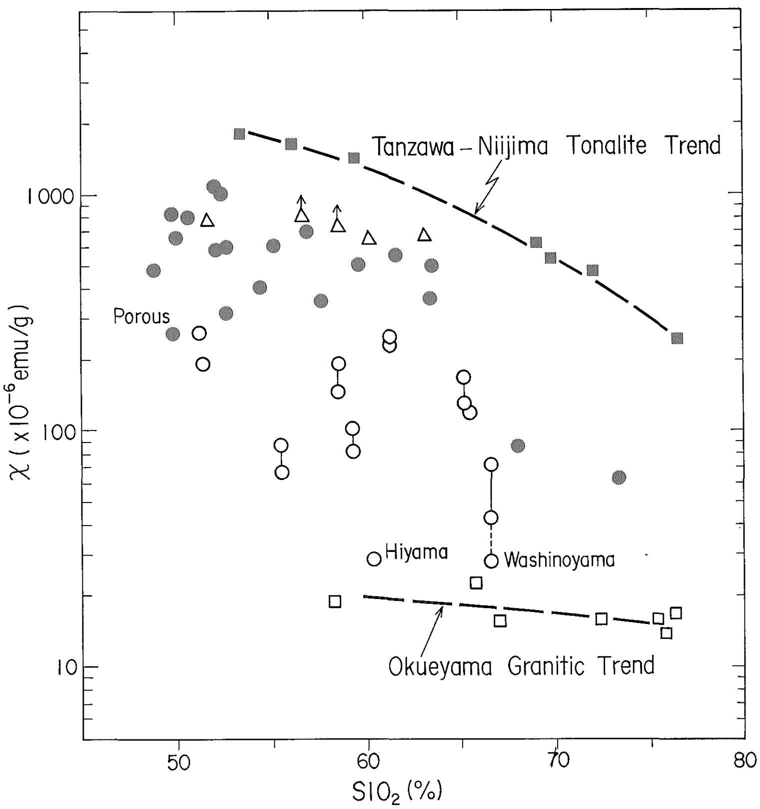

Fig. 3 Magnetic susceptibility and silica diagram of the late Cenozoic volcanic and plutonic rocks. Solid circle, tholeiite suite lavas from Hachijo-jima (SiO_2 % from ISSHIKI, 1963); Open circle, Sanukite group lavas and neck from Kagawa Pref. (SiO_2 % from UJIKE, 1972; UJIKE and ONUKI, 1976). Circle connected with bar implies variation at one outcrop. Open triangle, calc-alkaline suite lavas from Mt. Kuju (SiO_2 % from ONO, 1963). Triangle with arrow indicates minimum value. The volcanic rocks were measured by the Kappameter KT-3, then the values converted to emu/g. The plutonic rocks by the Bison Model 3101.

Late Mesozoic to Early Cenozoic Volcanic Rocks

Vast volume of mainly pyroclastic flow deposits are known in the Chugoku district. The late Mesozoic to early Cenozoic volcanic rocks are generally considered effusive facies of underlying granitic rocks. Magnetic susceptibility was measured by the Kappameter on outcrops of such rocks in several areas. Since structure of these rocks is poorly seen, the measurement was performed randomly at 10 meters interval along road-cut of continuous exposure. Wherever possible, the outcrop was selected at distance from granitic plutons. The results are summarized in Table 1.

Table 1 Magnetic susceptibility of the late Mesozoic to early Cenozoic volcanic rocks in the Chugoku district shown by number of the measurement.

		Magnetic susceptibility ($\times 10^{-6}$ emu/g)			
		10–50	50–100	100–500	500 and more
Rhyo-dacitic tuff					
Sanin district	Western Shimane Pref.	11	12	7	0
	Central Shimane Pref.	5	2	17	0
	Western Tottori Pref.	8	0	11	2
	Total measurement	24	14	35	2
Sanyo district	Mihara, Hiroshima Pref.	49	3	2	0
	Takehara, ditto	19	8	18	1
	Mitsu, ditto	9	11	8	0
	Eastern Yamaguchi Pref.	66	0	0	0
	Total measurement	143	22	28	1
Andesitic lava and tuff					
Sanin district	Western Shimane Pref. Lava	0	0	6	17
	Tuff	0	2	7	0
	Central Shimane Pref.	0	0	3	8
	Total measurement	0	2	16	25
Sanyo district	Kisa, Hiroshima Pref.	47	7	6	1

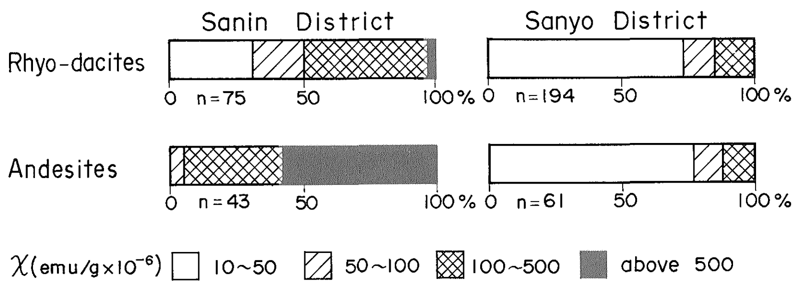

Fig. 4 Relative abundance of the late Mesozoic to early Cenozoic volcanic rocks of the Inner Zone of Southwest Japan on the basis of their magnetic susceptibility.

Magnetic susceptibility is generally high in the volcanic rocks of the Sanin district which are mainly of the Kawauchi formation of Stage V of YAMADA (1977). Within the magnetite-bearing volcanic rocks, lavas have higher magnetic susceptibility than tuffs and tuff breccia. In the Sanyo district, typical Kisa andesites in the Kisa township give generally magnetite-free values. Well known rhyo-dacitic welded tuffs of the Abu group and Takata rhyolites (Stage III of YAMADA, 1977) are largely composed of low magnetic susceptibility rocks. However weakly magnetic tuffs are rather dominant in the Takata rhyolites of the Takehara-Mitsu area, Hiroshima Prefecture. The summary is illustrated in Fig. 4.

Conclusions

Quaternary tholeiite suite lavas have lower magnetic susceptibility than the Miocene tonalites of the Tanzawa type, which may be plutonic equivalent of the tholeiite suite. Quaternary calc-alkaline suite lavas from the same tectonic unit, i.e., inner side of the volcanic front (and Green Tuff belt), may have higher magnetic susceptibility than the tholeiite suite. Intermediate magnetic susceptibility was found on the Sanukite group of volcanic rocks which occur between the Quaternary volcanic front and Miocene volcano-plutonic rocks of the Outer zone in Southwest Japan. On the late Mesozoic to early Cenozoic volcanic rocks of the Inner Zone of Southwest Japan, magnetic susceptibility is high in the north and low in the south. Thus increase of magnetic susceptibility toward the Japan Sea side, which is observed on granitoids of the same terrane, seems to be also the case for the Mesozoic and Cenozoic volcanic rocks.

The Quaternary volcanic rocks are composed almost entirely of rocks having magnetic susceptibility over 50×10^{-6} emu/g (i.e., magnetite series), which is also true in the Miocene volcanic rocks. However, magnetite-series and ilmenite-series volcanic rocks, as defined by their magnetic susceptibility, are equal amount in the late Mesozoic to early Cenozoic volcanic terranes in the Inner Zone of Southwest Japan. This would imply sudden change in the tectonic setting of the Japanese islands between the two periods of igneous activity.

Acknowledgement: Most of the Cenozoic materials were provided by the writer's colleagues: N. ISSHIKI (Hachijo-jima), K. ONO (Mt. Kuju and Aso) and O. UJIKE (Sanukite group). O. UJIKE guided the writer in field. H. KANAYA measured magnetic susceptibility by the Bison Model 3101. Discussion with the above friends and M. TAKAHASHI (Univ. Tokyo) is appreciated.

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Kappameter KT-3 帯磁率計と火山岩類への適用

石 原 舜 三

要 旨

上記の携帯用帯磁計は不透明鉱物を対象とする野外調査に有効であり，露頭表面の凹凸の影響を除くために一定距離で測定する方法によって，磁鉄鉱系とチタン鉄鉱系花崗岩類を識別することが可能である．この方法による測定値と筆者らが既に公表した粉末法による帯磁率との間には良い相関性がみられる．

第四紀の火山岩類は一般に磁鉄鉱系の帯磁率を示し，低 K_2O ソレアイト系火山岩類は同系統と思われる中新世花崗岩類および第四紀カルクアルカリ岩系火山岩類よりも若干帯磁率が低い．グリンタフ帯の中新世火山岩類も磁鉄鉱系に属するが，讃岐岩は低い帯磁率の磁鉄鉱系を主体として少量のチタン鉄鉱系とから構成される．西南日本外帯の火成岩類は主にチタン鉄鉱系の値を示すから，広域的に北方へ帯磁率が増加する傾向が西南日本について推察される．西南日本内帯の白亜紀後期-古第三紀火山岩類についても同様な傾向が得られ，日本海側へ帯磁率が増加する現象は白亜紀以後の共通する性質である．磁鉄鉱系/チタン鉄鉱系火山岩類の量比は白亜紀後期-古第三紀，中新世，第四紀の順序で増加している．

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