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Radiometric age of lava flows of the Enrei formations in central Japan (1).

By

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Abstract

Two samples from lava flows of the upper member of the Lower Enrei formations exposed at the top of Utsukushi-ga-hara volcano are dated approximately at 1.3×10^6 K-A years. The dates of these lava flows which are magnetized reversely and eastward are placed in the middle part of the "Matuyama reversed epoch". The Ina formations equivalent of the Lower member of the Lower Enrei formations suggest that during this period climatic deterioration had already taken place, so that most parts of the Enrei formations should be younger than the base of the Pleistocene.

1 Introductory Remarks

Since our earlier palaeomagnetic studies carried for lavas of the Enrei formations in central Japan, our attention has long been called to the geologic age of these lavas in relation to the questionable last epoch of palaeomagnetic reversal. In those early days of our research, we had no definite way of correlation of the Pliocene-Pleistocene boundary in Japan nor reliable evidences for the age identification of the Enrei formations (NAGATA et al., 1954 ; MOMOSE et al., 1959).

This notable boundary problem seemed to have settled in 1948 when the Italian type section was recommended by the Session of the XVIII International Geological Congress. Recent studies, however, show that the problem is more complex than it appeared in 1948 (GRICHUK et al., 1965), and controversial discussions have been raised from many countries of the world. Meanwhile, the base of the Pleistocene has been removed down from the horizon formerly accepted as this boundary in many sections of the Late Cenozoic sequence. In contrast to appreciate the significance of the change in evolution of mammalian fauna, some are to employ the first indication of climatic deterioration as a more universal criterion to mark this boundary (FLINT, 1965).

Before 1960, we had only a few evidences for inferring the age of the Enrei formation which contains only a fossil flora comrising *Metasequoia disticha* in the basal part (MOMOSE et al., 1959). Another plant bed is known from the lower part of the formation near the town of Suwa, however, the fossils, are so ill-preserved that identification has been difficult. *Metasequoia* is said to have widely been distributed throughout Tertiary time but disappeared within the early part of the Pleistocene in Japan (ITIHARA, 1960). In this connection, the Enrei formation was tentatively assigned by some of us to the latest Pliocene.

2 Stratigraphy, Palaeomagnetism and Flora of the Enrei Formations

The Enrei formations consisting of lava flows and pyroclastic materials form, as a whole, a region of flat strato-volcanoes around Lake Suwa in central part of Japan. Palaeomagnetic variation through the period of their activity was already discussed by MOMOSE and others (NAGATA et al., 1954; MOMOSE et al., 1959).

Further study since made by one of the authors, however, shows that the Enrei formations should be dismembered into two parts which geologically and magnetically be separated from each other. After the deposition of the Lower Enrei formations, a crustal subsidence may have taken place on the southwestern border with consequent strong tilting of the basal part of the Lower formations immediately south of Mt. Yosawa. The depression thus having formed was covered by lava flows and pyroclastic materials petrographically indicating the similar character to those of the Lower Enrei formations. Remarkably, the Lower Enrei lava flows are palaeomagnetically reversed, whereas the Upper Enrei lavas occupying the environs of Shiojiri Pass are normally magnetized.

Palaeomagnetic survey of the Upper formations along with the stratigraphic relation to the Lower formations will be detailed in another paper. However, with respect to their magnetic direction, the whole succession of the Enrei formations is expressed as in Table 1.

Table 1 Division and allied palaeomagnetic polarity epoch of the Enrei formations.*

Subdivision	Palaeomagnetic polarity
Upper Enrei formations	normally magnetized
~~ Unconformity ~~~~	~~~~
Upper member of Lower Enrei formations	reversed and eastward
Lower member of Lower Enrei formations	reversed and westward

*Several more samples from the Upper and Lower Enrei formations are now deposited for dating assay.

In so far as we are to assuming the age of the Enrei formations to be the palaeomagnetically reversed epoch of the latest Pliocene (ROCH, 1951, 1956; COX et al., 1964; DOELL, et al., 1966 a and b), it was difficult to give an account for that no reversed polarity epoch were detected within sections which are believed to postdate the Enrei formations.

Our recent study, however, indicates that most parts of the Enrei formations would be expected to be of the early Pleistocene in age. A part of the Lower member of the formations from which lava flows are known to be magnetically reversed and westward, is directly traced by a volcanic mud flow along the Tenryu river, to a part of the Ina formations 60 km south of this volcanic region. From above and below the volcanic mud flow embedded within the Ina formations are found several layers characterized by cool-temperate flora comprising *Picea bicolor*, *Menyanthes trifoliata* and others. The layers containing this type of flora alternate with layers characterized by warm-temperate flora containing, for instance, *Metasequoia disticha* and others. Detailed stratigraphic sequence comprising these layers of plant fossils will later be given in another paper, but a brief note may suffice for the present discussion.

From many countries, this type of floral alternation recorded within the Cenozoic sequence is accepted as marking the basal part of the Pleistocene (Venzo, 1965; Flint, 1965). Also the floral change indicated within the Ina formation is obviously assignable to the so-called "period of disappearing *Metasequoia*" in Japan, which was named by Itihara (1960) from the lower part of the Osaka group and being referred to the early part of the Pleistocene.

The samples for the K-A radiometry, which dates are presented in this paper, were taken from lava flow close to the top of Utsukushi-ga-hara volcano 10 km east of the town of Matsumoto, and being reversed and eastward in magnetic direction. The lava is believed to belong to the Upper member of the Lower Enrei formations. The radiometry was undertaken in the Laboratory of Geophysics in the University of Tokyo.

Our opinion mentioned above is compatible with the dates which are placed within the middle part of the "Matuyama reversed epoch" of Cox, Doell and Dalrymple (1964). If the whole range of the Pleistocene would approximate 2.0×10^6 years in time-length, these facts and dates may be very important, because the K-A dates presented here imply an approach to this geologically debatable problem about the Pliocene-Pleistocene boundary.

3 K-A Radiometric Ages (Table 2)

(*1*) *Argon analysis*. About 10 grams of total rock sample were used for argon extraction. Samples were preheated at 200°C overnight in a high vacuum pyrex line. Radiogenic argon was extracted by heating samples at 1300°C for one hour and then purified by CuO at 350°C and titanium sponge at 950°C. Quantitative determinations of radiogenic A^{40} were made by an isotope dilution method using 99.99 % pure A^{38} spike of about 5×10^{-6} cc STP with 60 degree, 15 cm radius, Reynolds type mass spectrometer. Isotopic analyses were made statically. In most of cases the isotopic ratio A^{36}/A^{40} and A^{38}/A^{40} were determined by extrapolating the ratios to zero time when the sample was introduced into the spectrometer. Mass discrimination was occasionally checked by analyzing purified air argon. A^{36}/A^{40} was usually within 1 % of the value given by Nier and no attempt was made to correct for discrimination in radiogenic A^{40} determination. For each sample thin sections were examined and samples which show any indication of

Table 2 Analytical data for Potassium – Argon age determinations

Samples (**)	Material	A^{40} (moles/gr.)	$(A^{40})_{rad}/(A^{40})_{total}$	K(%)	K^{40} (moles/gr.)	A^{40}/K^{40}	t(*)
1-a-3(1)	Andesite	4.014×10^{-12}	22 %				
//	//	3.987×10^{-12}	10.9 %	1.852	5.636×10^{-8}	7.098×10^{-5}	1.20my
3-2(2)	Andesite	3.880×10^{-12}	9.7 %	1.474	4.485×10^{-8}	8.651×10^{-5}	1.47my
3-4(3)	//	4.024×10^{-12}	12 %	1.563	4.756×10^{-8}	8.461×10^{-5}	1.44my

(*) $\lambda e=0.585\times10^{-10}$y R=0.124 $K^{40}/K=1.19\times10^{-4}$ moles/mole
(**) See MOMOSE's paper of 1963.
(1) : (Ut-Ib), Magnetic direction : 157°E, −27°, (2)-(3) : (Ut-IV), Magnetic direction : 158°E, −20°.

alteration other than alteration of olivine were rejected.

(2) *Potassium analysis.* All K-analyses were made by an isotope dilution method using 60 degree, 22 cm radius, single filament mass spectrometer with an electron multiplier. After specimens were crushed to −150 mesh, about 0.03-0.06 grams of samples were dissolved by HF and $HClO_4$ and evaporated to dryness. The precipitates were dissolved by 2.5 N HCl and mounted on a tantalum filament for isotopic analyses. Mass discrimination was occasionally checked by analysing KCl shelf solution.

When $\sqrt{m_1/m_2}$ correction was made, K^{39}/K^{41} ratios were usually found within 1 % of the value given by NIER. Hence, all isotopic ratios measured were corrected for the discrimination by multiplying by $\sqrt{m_1/m_2}$.

(3) *Estimation of errors in* K *and* A *analyses and in calculated ages.* K analyses are believed to be reproducible to about 3 % and A analyses to about 1 %. We believe that overall precision in the ages thus obtained is about 5 %.

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