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Chemical Th-U-total Pb isochron age of zircon from the Mereb Granite in northern Ethiopia

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ABSTRACT

The chemical Th-U-total Pb isochron age was determined for zircon grains from the post-tectonic Mereb Granite in northern Ethiopia. Twenty-seven analyses from five zircon grains yield a well defined isochron of 545 ± 24 Ma. One of the analyzed grains is chronologically zoned with a core having age range of 732−828 Ma. The core is interpreted as a xenocryst. The 545 ± 24 CHIME zircon age, slightly younger than the previously reported Rb-Sr whole-rock isochron age of 633 ± 62 Ma, dates emplacement of the Mereb Granite, and agrees well with the 541+10/−16 Ma U-Pb zircon age for the post-tectonic Mao granite in western Ethiopia.

INTRODUCTION

The Precambrian geology of northern Ethiopia is characterized by the widespread occurrence of low-grade, volcanic and volcano-sedimentary rock assemblage (Kazmin, 1972; Tadesse, 1997). This assemblage belongs to the upper Proterozoic Red Sea Fold Belt of Ethiopia (Kazmin et al., 1978) or more broadly to the neo-Proterozoic Pan-African Arabian-Nubian Shield (De Wit and Chaweka, 1981), and is intruded by syn-tectonic composite granitoids and post tectonic pink granites.

Although gross lithological similarities are pointed out between the low-grade rocks of northern Ethiopia and those of the Arabian-Nubian shield in Arabia, Egypt and the Sudan, the lack of chronological data has prevented the correlation of the sequence of geological events and the geodynamic setup of the region. Recently, Alemu (1997) obtained an Ar-Ar age of 792 ± 2 Ma for the syn-tectonic Chila intrusion and an Ar-Ar age of 745 ± 4 Ma for the syn-tectonic Rama intrusion (Fig. 1). These ages are nearly equal to the 780−760 Ma ages for the low-grade Pan-African metamorphism in western Ethiopia (Ayalew et al., 1990) and the Tokar area in eastern Sudan (Kröner et al., 1991). For the post-tectonic Mereb granite, Alemu (1997) reported a Rb-Sr whole-rock isochron age of 633 ± 62 Ma with an initial ratio of 0.7034 ± 9. The Rb-Sr isotopic data which yield this age, however, are highly scattered. Further, our detailed petrographic observation revealed that the Mereb granite contains

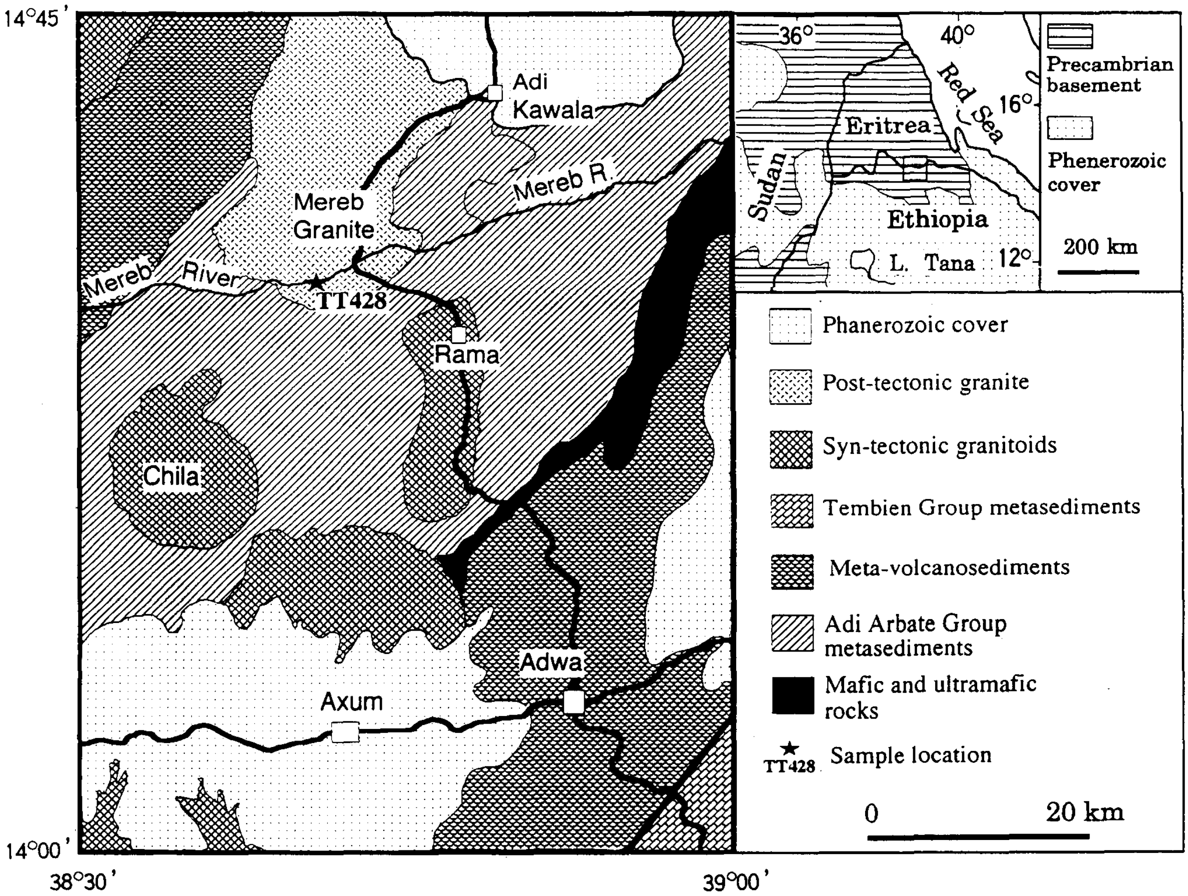

Fig. 1. Geological map of the area around the Mereb Granite in northern Etiopia (modified after Tadesse, 1997).

core-mantle zircon grains. This, coupled with the high age error and apparently high MSWD (not reported), leads us to a suspicion that the 633 ± 62 Ma isochron is a pseudoisochron. Therefore, the upper limit of plutonism in northern Ethiopia still remains unclear. In order to shed more light on the tectonic evolutuon in northern Ethiopia, we dated the post-tectonic Mereb Granite (Fig. 1) using chemical Th-U-total Pb isochron method (CHIME; Suzuki and Adachi, 1991a,b, 1994) on zircons. This paper reports on the preliminary finding.

GEOLOGICAL SETTING AND SAMPLE DESCRIPTION

The Mereb Granite is located in the northernmost tip of Ethiopia (Fig. 1). It is batholithic in size, but the major part of the intrusion occurs in Eritrea across the Mereb River. The granite has intruded into low grade metasedimentary unit in the south and appears to have intruded into biotite-rich tonalitic to granodioritic rock which is exposed in the northern side around Adi Kawala (Fig. 1). The northern end of the pluton is overlain with a Phanerozoic cover.

The metasedimentary unit comprises phyllitic and carbonaceous schist, graywacke, quartzite and minor marble layers. This unit was previously included within the Tembien Group (Beyth, 1971; Kazmin, 1972), but recently redefined as a distinct tectono-stratigraphic unit, Adi Abun Group (Tadesse, 1997). The Mereb Granite, like other post-tectonic granitoids in the Arabian-Nubian Shield, deflects and/or cuts the metamorphic layering of the country rock, and yields a narrow (less than 200 m wide) but distinct contact aureole. The biotite-rich tonalitic to granodioritic rock in the northern side of the Mereb granite is clearly deformed and are very similar to those of the syn-tectonic Rama and Chila Granitoids situated south of the Mereb River (Fig. 1; Tadesse, 1997; Alemu, 1997).

The typical Mereb Granite is pink and has porphyritic appearance owing to the presence of randomly oriented K-feldspar phenocrysts. A fresh sample (Sample No. TT428) for the present CHIME dating was collected from an outcrop along the Mereb River in southern part of the intrusion (Fig. 1). It consists mainly of 42% K-feldspar, 19% plagioclase (albite-oligoclase), 23% quartz, 11% biotite and 5% hornblende. Accessory minerals include sphene, zircon, trace of epidote, allanite, apatite and iron oxide. K-feldspar is mainly microperthitic microcline. Most of plagioclase grains show zoning. The core of zoned plagioclase grains are severely affected by secondary alteration and hence have cloudy appearance. Biotite is generally brownish and rarely altered into chlorite along the margins and cleavages. Zircon grains form short prism of 0.06 to 0.29 mm in length. Euhedral crystals with concentric growth zoning dominate in the sample. Some zircon grains show a core-mantle structure in which unzoned cores are overgrown by zoned rim. The core is generally anhedral and corroded.

ANALYTICAL METHOD

We analyzed zircon grains in a polished thin section prepared for the conventional electron microprobe analyses. Four unzoned and one zoned zircon grains were analyzed on JEOL JXA-733 electron microprobe equipped with three wavelength dispersive-type spectrometers at Department of Earth and Planetary Sciences, Nagoya University. The analysis was carried out under the following instrument operating conditions; a 15 kv accelerating voltage, 0.02−0.15 μA current and 5 μm probe diameter. X-ray intensities were integrated 300s for the line and 150s for backgrounds at two optimum positions on both sides of the lines. The measurement was repeated twice or three times, and the arithmetic average was taken as true intensities. Under the condition, the detection limits of ThO_2, UO_2 and PbO at 2σ confidence level were 0.012, 0.007 and 0.004 wt.%, respectively. The possible maximum errors in the determination of ThO_2, UO_2 and PbO are about 14% for 0.1 wt.% of the concentrations. The details of analytical procedure and CHIME age calculation were described by Suzuki and Adachi (1991a,b, 1994).

RESULTS

A total of 30 spots on 5 zircon grains were analyzed. The ThO_2, UO_2 and PbO analytical data (in wt.%) together with apparent ages (Ma) and UO_2* values (sum of the measured UO_2 and UO_2 equivalent of the measured ThO_2) are listed in Table 1. The ThO_2 concentration of zircon ranges from 0.019 to 0.178 wt.%, the UO_2 concentration from 0.056 to 0.395 wt.%, and the PbO concentration from 0.0047 to 0.0307 wt.%.

Table 1. Analytical data of the five zircon (Z1-Z5) grains from sample No. TT428 (Mereb Granite). (c) core of the zoned zircon grain UO_2*: sum of the measured UO_2 and UO_2 equivalent to the measured ThO_2 of zircon.

Grain No.	ThO_2 (wt%)	UO_2 (wt%)	PbO (wt%)	apparent age (ma.)	UO_2*
Z1 (zoned)					
Z1-1	0.030	0.090	0.0075	543	0.0986
Z1-2	0.030	0.087	0.0067	501	0.095
Z1-3	0.079	0.395	0.0307	525	0.4190
Z1-4	0.075	0.146	0.0128	541	0.1691
Z1-5	0.047	0.102	0.0084	518	0.1161
Z1-6	0.056	0.201	0.0162	531	0.2183
Z1-7	0.062	0.294	0.0246	561	0.3130
Z1-8 (c)	0.053	0.101	0.0122	732	0.1167
Z1-9 (c)	0.056	0.104	0.0136	785	0.1207
Z1-10 (c)	0.063	0.122	0.0168	828	0.1406
Z2-Z5 (unzoned)					
Z2-1	0.048	0.118	0.0105	567	0.1320
Z2-2	0.049	0.155	0.0129	543	0.1697
Z2-3	0.051	0.116	0.0098	534	0.1313
Z2-4	0.062	0.116	0.0106	561	0.1348
Z2-5	0.030	0.099	0.0070	466	0.1081
Z3-1	0.019	0.065	0.0056	563	0.0710
Z3-2	0.021	0.056	0.0049	562	0.0622
Z3-3	0.045	0.102	0.0075	466	0.1160
Z3-4	0.024	0.072	0.0061	551	0.0791
Z3-5	0.031	0.080	0.0067	537	0.0892
Z3-6	0.020	0.067	0.0047	462	0.0733
Z3-7	0.053	0.071	0.0067	550	0.0870
Z3-8	0.056	0.120	0.0108	564	0.1365
Z4-1	0.073	0.126	0.0116	560	0.1478
Z4-2	0.106	0.174	0.0162	561	0.2059
Z4-3	0.146	0.135	0.0136	542	0.1795
Z4-4	0.124	0.136	0.0129	532	0.1736
Z4-5	0.093	0.108	0.0114	595	0.1362
Z4-6	0.109	0.125	0.0114	518	0.1576
Z5-1	0.178	0.317	0.0275	531	0.3703

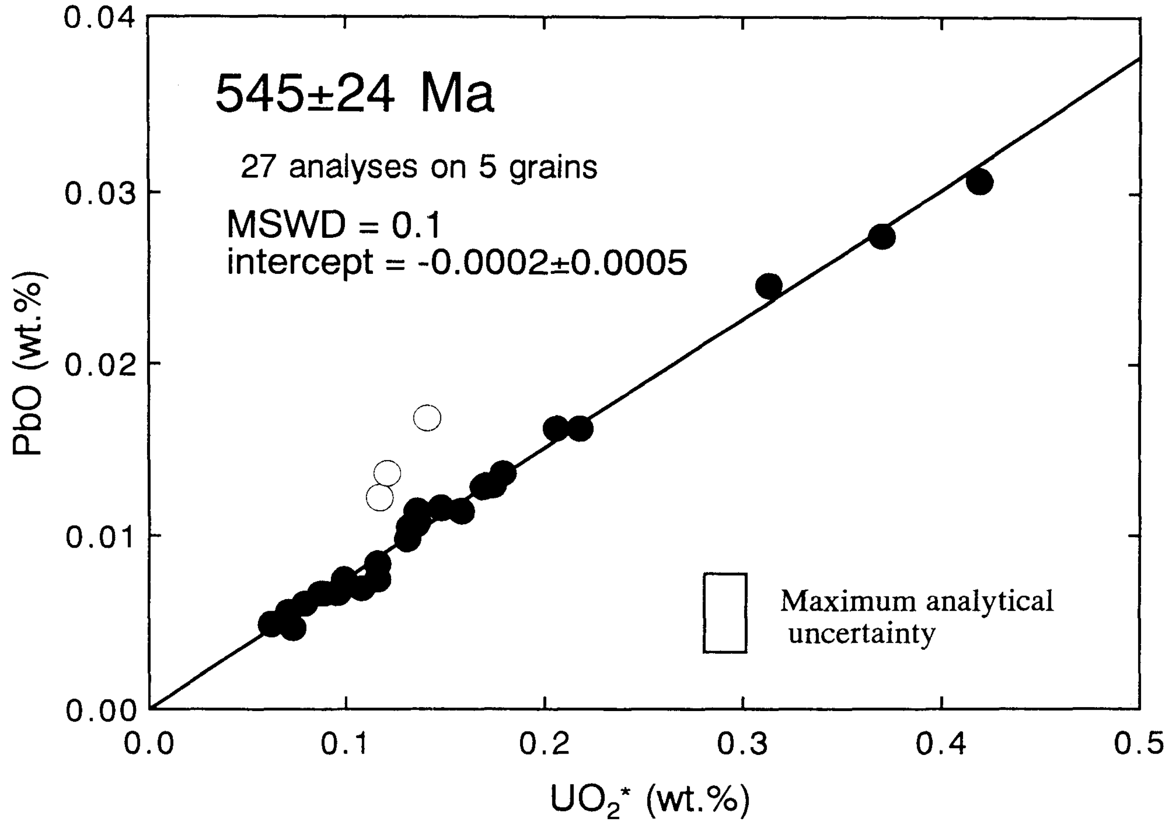

Fig. 2. Plot of PbO vs. UO_2* for zircon grains from Sample TT428 of the Mereb Granite in northen Ethiopia. Solod circle represents data points for chronologically unzoned grains and the rim of zoned Z1 grain, and open circle represents data points for the core of zoned Z1 grain.

The analytical data are plotted on the PbO-UO_2* diagram (Fig. 2). Excluding three data point for the core of Z1 grain (Table 1, Z1-8,9 and 10), all data point including those for the rim of Z1 grain are arrayed linearly on the diagram. They are regressed with an isochron of 545±24 Ma (MSWD=0.10) with an intercept value of −0.0002±0.0005 (errors quoted in this paper are of 2σ). The core of Z01 grain gives apparent ages of 732—828 Ma (Table 1).

DISCUSSION

The well defined isochron of 545±24 Ma passes through the origin of the PbO-UO_2* diagram (Fig. 2). This rules out any suspicion of partial Pb loss or heterogeneity in the distribution of initial Pb. Therefore, we consider that the 545±24 Ma CHIME zircon age is highly reliable.

The Mereb Granite has been dated by Alemu (1997) using the Rb-Sr whole-rock isochron method. The Rb-Sr age, 633±62 Ma, is inconsistent with the CHIME zircon age. This inconsistency may not be ascribed to the simple error in both the microprobe and isotopic analyses. Rather, we believe that the inconsistency is responsible to the old Rb-Sr age possibly resulted from isotopic disequilibrium in the Rb-Sr system. Inspection of the Rb-Sr isochron diagram shows that 4 data points are not strictly aligned; the scatter is beyond analytical uncertainty and resulted in large error (Alemu, 1997 Personal Comm.). This suggests that the Rb-Sr system is not in equilibrium on the whole-rock scale and therefore, Rb-Sr whole isochron age of 633 ± 62 Ma might be fortuitous. In this connection, it is important to note that the Mereb granite contains zoned zircon grains with older cores yielding apparent age upto 828 Ma (Table 1). We interprate this core as a xenocryst of older zircon surrounded by new grown in the Mereb Granite. The oldest apparent age (828 Ma) is similar to the U-Pb zircon age of Syn-tectonic granitoid in western Ethiopia (Ayalew et al., 1990). We therefore, prefer the CHIME zircon ages of 545 ± 24 Ma as dating the emplacement of the Mereb Granite. This CHIME zircon age just overlaps with the 541+10/−14 Ma U-Pb zircon age of the post-tectonic Mao granite in western Ethiopia (Ayalew et al., 1990).

Further dating works is in progress to get detailed geochronological information of the syn-tectonic and post-tectonic granitoids in northern Ethiopia using the CHIME method and Sm-Nd isotopic method.

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