147Sm–143Nd and 87Rb–87Sr ages of the eucrite Piplia Kalan

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Abstract—Prompted by the finding that the eucrite Piplia Kalan could have retained Pu fission Xe earlier than the eucrites so far studied and hence be very ancient, we have measured a precise internal 147Sm–143Nd isochron for this meteorite. The age and initial Nd ratio relative to CHUR are 4.570 ± 0.023 Ga and −1.3 ± 0.7 eu, respectively. A Rb–Sr whole rock (clast) isochron for this meteorite corresponds to an age of 3.963 ± 0.119 Ga and initial 87Sr/86Sr ratio of 0.69902 ± 3. But initial 87Sr/86Sr ratio calculated for an age of 4.57 Ga is 0.698956 ± 25, which is indistinguishable from 0.698970 ± 15 reported for the angrites LEW and ADOR dated at 4.5578 ± 0.0005 Ga. These results indicating that Piplia Kalan could have formed within only a few million years of the earliest condensates in the Solar System are strongly supported by the recent discovery of live 26Al in it.

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1. INTRODUCTION

Eucrites, a subgroup of achondritic meteorites, are relics of the earliest known basaltic magmatism in protoplanetary/asteroidal crusts. They therefore have been investigated extensively over the last 20 years with a variety of radioactive parent–daughter systems (40Ar–39Ar, 87Rb–87Sr, 207Pb–206Pb, 147Sm–143Nd, 146Sm–142Nd, 244Pu–Xe, 53Mn–53Cr, 26Al–26Mg) to determine the timing of partial melting and differentiation of meteorite parent bodies in the early Solar System (Birck and Allegre, 1978, Prinzhofer et al., 1992; Bogard, 1995; Allegre et al., 1995; Wadhwa and Lugmair, 1995, 96; Shukolyukov and Begemann, 1996; Hsu and Crozaz, 1996; Nyquist et al., 1997; Tera et al., 1997; Miura et al., 1998). Since precise Pb–Pb model and Sm–Nd isochron ages for several eucrites are within errors very close to the time of the earliest condensates in the Solar System, the most likely heat source for such an early melting and differentiation is the decay of the short-lived 26Al (half-life 0.72 Ma). Of the various eucrites studied for evidence of live 26Al, the most promising one was the eucrite Ibitira. Ibitira has the oldest Pb–Pb age among the eucrites at 4.530 ± 0.030 Ga (Unruh et al., 1977). Pu–Xe retention prior to Angra dos Reis (Shukolyukov and Begemann, 1996) but less equilibrated than Ibitira. Pasamonte also did not show any evidence for 26Al (Hsu and Crozaz, 1996).

Fresh hope for search of 26Al in eucrites has come from the eucrite Piplia Kalan, which fell in India on 20 June, 1996 (Vaya et al., 1996). By using the refined procedure used by Shukolyukov and Begemann (1996) for calculating Pu–Xe ages of eucrites, Bhandari et al. (1998) have shown that Piplia Kalan could have started retaining Pu–Xe as early as 42 Ma before ADOR. As it is hence even more promising than Ibitira for evidence of 26Al, we have taken up a Sm–Nd and Rb–Sr study of the Piplia Kalan eucrite to see if it is really as old as indicated by its Pu–Xe age.

Texture, mineralogy, and bulk composition indicate that Piplia Kalan is an equilibrated, monomict, noncumulate intermediate in composition between the main group (such as Juvinas) and the Nuevo Laredo trend eucrites (Shukla et al., 1998). It consists mainly of lithic clasts of variable size and shape (60–80 vol%) in a subordinate brecciated matrix. Lithic clasts show a large range in grain size and texture (Vaya et al., 1996; Shukla et al., 1998), the latter varying from granular to ophitic/subophitic. These clasts are classified broadly into coarse and fine-grained varieties. Despite the textual differences, the bulk compositions of individual lithic clasts and brecciated matrix are similar (Shukla et al., 1998), suggesting that they were derived as fragments from a single lava flow or a shallow intrusive body. Major phases are pyroxene (55–60 wt%) and plagioclase (25–45 wt%) in a subordinate brecciated matrix. Lithic clasts show a large range in grain size and texture (Vaya et al., 1996; Shukla et al., 1998), the latter varying from granular to ophitic/subophitic. These clasts are classified broadly into coarse and fine-grained varieties. Despite the textual differences, the bulk compositions of individual lithic clasts and brecciated matrix are similar (Shukla et al., 1998), suggesting that they were derived as fragments from a single lava flow or a shallow intrusive body. Major phases are pyroxene (55–65%) and plagioclase (25–45%) with chromite, ilmenite, and troilite as minor or rare phases. Phosphate minerals have not yet been petrographically identified. Piplia Kalan shows evidence of shock and brecciation. Very thin veins of brown glass transect both lithic clasts and matrix and are possibly related to a late stage impact event that ejected this meteorite from its parent body.

2. EXPERIMENTAL PROCEDURES

From a 5-g bulk sample of Piplia Kalan, ~1.1 g of a medium grained (0.5 mm) clast was extracted, gently crushed in a clean agate mortar to...