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Provenance of Permian–Triassic Gondwana Sequence units accreted to the Banda Arc in the Timor region: Constraints from zircon U–Pb and Hf isotopes

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ABSTRACT

Analysis of zircons from Australian affinity Permian–Triassic units of the Timor region yield age distributions with large age peaks at 230–400 Ma and 1750–1900 Ma, which are similar to zircon age spectra found in rocks from NE Australia and crustal fragments now found in Tibet and SE Asia. It is likely that these terranes, which are now widely separated, were once part of the northern edge of Gondwana near what is now the northern margin of Australia. The Cimmerian Block rifted from Gondwana in the Early Permian during the initial formation of the Neo-Tethys Ocean. The zircon age spectra of the Gondwana Sequence of NE Australia and in the Timor region are most similar to the terranes of northern Tibet and Malaysia, further substantiating a similar tectonic affinity. A large 1750–1900 Ma zircon peak is also very common in other terranes in SE Asia.

Hf analysis of zircon from the Aileu Complex in Timor and Kisar Islands shows a bimodal distribution (both radiogenically enriched and depleted) in the Gondwana Sequence at ~300 Ma. The magmatic event from which these zircons were derived was likely bimodal (i.e. mafic and felsic). This is substantiated by the presence of Permian mafic and felsic rocks interlayered with the sandstone used in this study. Similar rock types and isotopic signatures are also found in Permian–Triassic igneous units throughout the Cimmerian continental block. The Permian–Triassic rocks of the Timor region fill syn-rift intra-cratonic basins that successfully rifted in the Jurassic to form the NW margin of Australia. This passive continental margin first entered the Sunda Trench in the Timor region at around 7–8 Ma causing the Permo-Triassic rocks to accrete to the edge of the Asian Plate and emerge as a series of mountainous islands in the young Banda collision zone. Eventually, the Australian continental margin will collide with the southern edge of the Asian plate and these Gondwanan terranes will rejoin.

1. Introduction

Asia is an evolving supercontinent built mostly of continental fragments rifted from the former supercontinent of Gondwana (e.g. Metcalfe, 2013). Some of these fragments were rifted from what is now the passive margin of northern Australia. Petrographic and paleocurrent studies of the Gondwanan affinity sedimentary rocks of northern Australia indicate they were derived mostly from the north where continental fragments of Gondwana were subsequently rifted away (Bird, 1987; Bird and Cook, 1991; Zobell, 2007; Harris, 2011). Various paleogeographic reconstructions attach the Lhasa, Sibumasu (*Si*am–*Bu*rma–*Ma*laysia–*Su*matra), East Java and Borneo terranes to NW Australia at various times (Metcalfe, 2002; Ferrari et al., 2008; Metcalfe, 2011; Gibbons et al., 2015). This paper aims to test the veracity of these reconstructions by combining the methods of sandstone petrography and U–Pb analysis of detrital zircons to address the question of what rifted away from the NW margin of Australia.

Large sections of the strata making up the NW passive margin of Australia are accreted to the Banda Arc via Late Miocene to present arc-continent collision (i.e. Carter et al., 1976). We have analyzed petrological relations and U–Pb ages of detrital zircons from Gondwana affinity sandstones and metamorphic rocks in the Banda Arc in order to determine a provenance and age fingerprint to compare with various terranes in Asia.

2. Description of the Gondwana Sequence

Three major tectono-lithic units make up the Banda Arc collision, viz. the Banda Terrane and two sedimentary successions separated by a Late Jurassic breakup unconformity, known together as the Gondwana Sequence. The Banda Terrane consists of mostly forearc basement units of Asian affinity that form the upper plate of the collision. It occupies the highest structural level in the Banda Arc collision (Harris, 2006; Standley and Harris, 2009). Subcreted beneath the Banda Terrane is the Gondwana Sequence, which makes up the Australian passive margin

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lower plate of the arc-continent collision (Fig. 2). Pre- and syn-breakup strata below the unconformity formed during the Pennsylvanian to Jurassic while Australia was part of Gondwana and are known as the Gondwana Mega-sequence (Audley-Charles, 1968; Harris et al., 2000; Haig et al., 2008). The Australian Passive Margin Mega-sequence overlies the unconformity.

The recent subduction of the Australian passive margin beneath the Banda Terrane caused the two mega-sequences that comprise the passive margin to detach and accrete to the upper plate. The detachment zone more or less follows the thick Wai Luli Shale immediately beneath the Jurassic breakup unconformity. The passive margin mega-sequence above the unconformity detaches at deformation front to form a classic imbricate stack (Charlton et al., 1991; Harris, 1991, 2011). The underlying Gondwana mega-sequence is carried further down the subduction zone where it eventually detaches to form a duplex system under the Banda Terrane (Harris, 1991; Harris et al., 1998).

The stratigraphy and sedimentology of Gondwana mega-sequence units in the Banda Arc are described by many previous studies dating back to early Dutch expeditions of late 19th and early 20th centuries (Rothpletz, 1891; Wanner, 1913, 1956). Other studies of these rocks include: Simons (1939), Gageonnet and Lemoine (1958), Audley-Charles (1968), Gianni (1971), Grady and Berry (1977), Charlton (1989), Bird and Cook (1991), Hunter (1993), Barkham (1993), Sawyer et al. (1993), Prasetyadi and Harris (1996), Harris et al. (1998, 2000, 2009), Charlton (2002), Charlton et al. (2009), Vorkink (2004), McCartain and Backhouse (2006), Kaneko et al. (2007), Zobell (2007), Haig et al. (2008), and Major (2011). From these studies it is evident that Gondwana Mega-sequence units exposed in the Banda Collision and drilled offshore on the Australian margin are best divided into two series, the Permian–Triassic Aileu-Maubisse Series, and the Permian–Jurassic Kekneno Series (Lemoine, 1959; Audley-Charles, 1968; Rosidi et al., 1981; Sawyer et al., 1993). The stratigraphic relationship between the two series is ambiguous due to the fact that in most places the Aileu-Maubisse series is thrust over the Kekneno Series.

2.1. Aileu Complex

The Aileu Complex is the metamorphosed part of the Aileu-Maubisse Series. It is found in several places along the north coast of Timor as far east as Manatutu (Fig. 1). It is also exposed on the island of Kisar (Richardson and Blundell, 1996; Harris, 2006; Major et al., 2013) and likely on other outer-arc islands to the east based on lithological similarities (Kaneko et al., 2007). The Aileu Complex consists of a protolith of Permian–Triassic, and possibly Jurassic, psammite and limestone, and basalt, rhyolite, tuffaceous material and gabbroic and dioritic plutons (Berry and McDougall, 1986; Prasetyadi and Harris, 1996; Harris, 2011). These units are metamorphosed into pelitic schist and gneiss, marble, phyllite and amphibolite. Metamorphic grade varies between lower greenschist to upper amphibolite facies (Berry and Grady, 1981). Some high temperature metamorphism may have occurred during the rifting event that formed the edge of the Australian continental margin. This event is overprinted by medium to high-pressure metamorphism during Late Miocene onset of collision in central Timor (Berry and McDougall, 1986; Harris, 1991; Harris et al., 2000).

2.2. Maubisse Formation

The Maubisse Formation consists of a distinct red, crinoidal limestone, shale and volcanic rocks that were deposited mostly during the Permian with ages ranging from latest Pennsylvanian to Triassic, and represents the oldest rocks exposed in the Banda Orogen (de Roever, 1940; Audley-Charles, 1968; Davydov et al., 2013). Pillow lavas found within the Maubisse Formation have geochemical signatures of within-plate and ocean-ridge basalt, which is interpreted as representing the onset of rifting (Berry and Jenner, 1982). Clastic sedimentary units found in the Maubisse Formation show fining in grain size toward the south (Carter et al., 1976). Rocks similar to the Maubisse Formation are documented on the Sahul Shoals of the undeformed Australian continental margin (Grady and Berry, 1977).

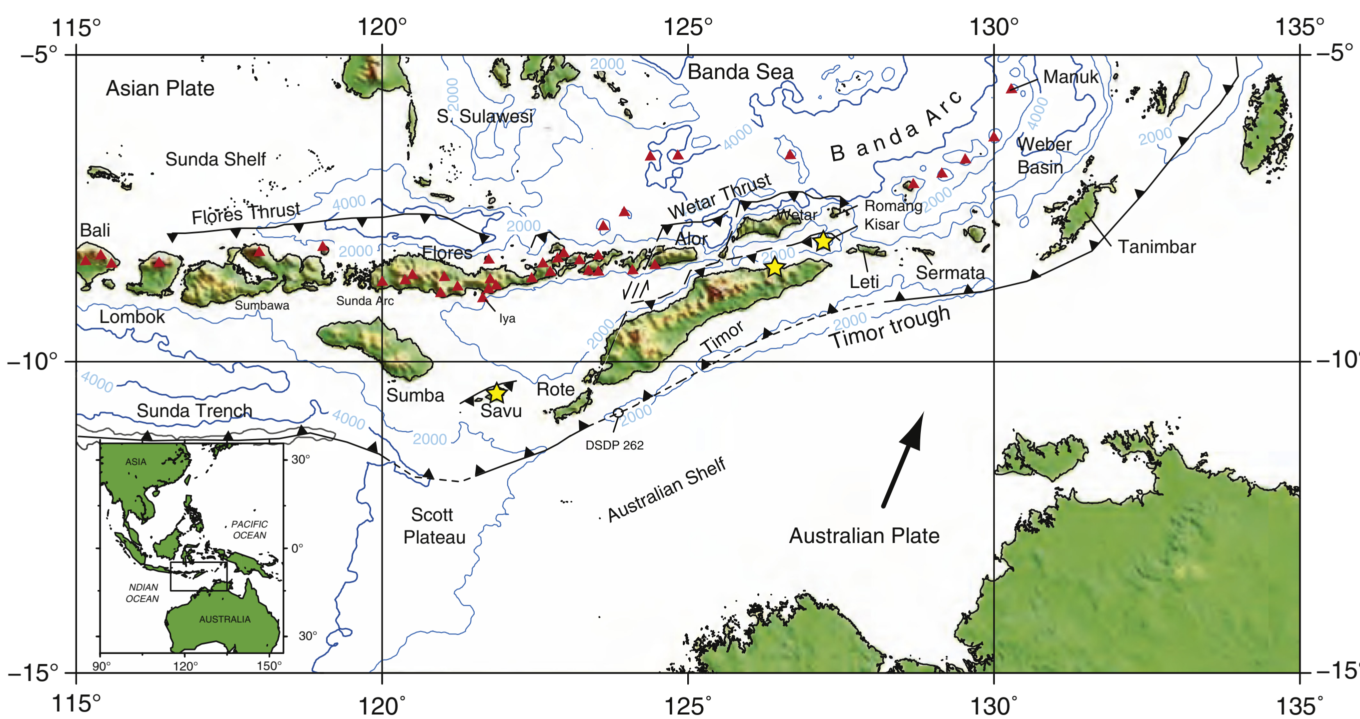

Fig. 1. Regional tectonic map of the Banda Arc region showing active faults (black, dashed if poorly defined) and active volcanoes (red triangles) (from Harris, 2011). Stars represent localities from which samples were taken. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

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