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## ***Interactive comment on “Extreme extension across Seram and Ambon, eastern Indonesia: Evidence for Banda slab rollback” by J. M. Pownall et al.***

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The high grade metamorphic rocks on Seram have puzzled geologists for many years and Pownall et al. (2013) should be congratulated on providing a masterful and well-argued insight into these unusual and hard-to-reach sections. I participated in the 1975 University of London expedition to Seram (Audley-Charles et al., 1979) and was involved with the Wai Tuh traverse through the Kobipoto Complex under the leadership of A.J. Barber. My recollections (and photographs) of the migmatites, granites and serpentinites tally very closely with those of Pownall et al. However, there are three issues that are worth raising.

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The first comment concerns the Wai Tuh section. In addition to the lithologies described by Pownall et al., there were several large blocks of pillow basalt (Figure 1). The largest block was more than 4m across and showed very well developed pillow structures that were clearly in an inverted position. At the time we assumed that this occurrence was not in-situ, but either displaced from nearby outcrop or from the Salas Block Clay. In either case, the authors can add it to their catalogue of pillow lavas in the Seram region.

It is difficult to be sure of the exact location of the pillow lava seen in 1975 in the Wai Tuh. The 1975 visit was at the end of a two week foot traverse from Wahai to Kanikeh, returning via the Wai Tuh, without the benefit of maps, airphotos, Landsat imagery (these came later) or of course GPS. We knew it was the Wai Tuh because our local guides said so, and in any case, the other very distinctive rock types were as described by Pownall et al.

The second issue concerns the structure of the Kobipoto Mountains. Having been involved with the Wai Tuh traverse, it is worth recording that there was continued disagreement among the authors of Audley-Charles et al. (1979) about the origin and structural position of the Kobipoto Complex that was never fully resolved. It is therefore interesting that Pownall et al. interpret the present day structure of the Kobipoto Mountains as a partly rotated dextral strike-slip pop-up. In 1975 I thought, with very limited evidence, that the high grade metamorphic rocks were probably Australian Precambrian basement, and that the presence of large, more-or-less vertical crush zones and abrupt changes in lithologies in Wai Tuh and elsewhere in Seram were indicative of major strike-slip fault movement. Prior to my visit to Seram, I had been engaged in mapping a very large dextral transpressional strike-slip fault zone in the Bewani-Torricelli Mountains of northern Papua New Guinea, which contained kilometer-wide fault breccia zones, rotated flank anticlines and fault splays (Hutchison and Norvick, 1978; Norvick and Hutchison, 1980). The fault zones continue westwards into West Papua and ultimately exit northeast of Seram as the Sorong fault zone. To me in 1975, the northern New Guinea faulting pattern appeared quite similar to the structures seen

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in central Seram. However my coauthors were of the opinion that the Kobipoto Complex was an allochthonous unit, thrust from Sundaland. The question remains: could the Kobipoto Mountains represent a pop-up of basement from the Australian plate (Sula Spur or Greater Birds Head) in a major strike-slip zone, without the need to invoke significant crustal thinning?

The third comment is of a more philosophical nature and concerns the comparison of extremely extended continental margins. According to the model of Pownall et al., Seram contains continental crust extended into a series of giant boudins, which have been heated and metamorphosed at very high temperatures by asthenospheric flow during slab rollback. Pownall et al. say that a similar mechanism may have operated in the Betic-Rif arc in the western Mediterranean. However, extremely extended continental crust also appears to have formed under relatively low temperature conditions in certain magma-poor passive margins, notably on the Galician margin of Iberia (Perez-Gussigye and Reston, 2001; Reston and Perez-Gussignye, 2007 and references therein) and adjacent to the Bight Basin, offshore southern Australia (Sayers et al., 1996; Direen et al., 2011).

In purely extensional, magma-poor, deep-water settings, continental crust has been thinned by rotational normal faults running from the mantle to the sea floor. In these situations, fault plane dip increases with extension until the beta factor reaches about 3. According to the models of Perez-Gussignye and Reston (2001), seawater then penetrates to the mantle, which becomes serpentinised, and the serpentinites provide additional lubrication for extension, until the extended continental crust is thinned to less than 10 kms and oceanic crust begins to form. Features that occur at these margins include highly rotated fault blocks cored with granites, metamorphics, gabbros and ultimately mantle peridotites at the sea floor. Some of these structures bear a superficial resemblance to the boudins proposed in Seram. Most of these magma-poor extended margins remained in deep water, but Manatschal et al. (2007 and references therein) described examples that had been exhumed by thrusting in the European Alps.

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However, in none of these examples are there any indications of the presence of the type of extremely high temperature migmatites seen in the Kobipoto Complex.

The significant compositional and structural distinctions between these two highly extended terrain types, formed either by passive extension or rollback, therefore raise the very interesting question of what controls their differences. Were the differences caused purely by higher heat flow during rollback, were the passive margin crustal fault blocks thermally insulated by the serpentinite layer, or was there some other reason? Having made such an excellent start on describing the anatomy of rollback-induced extended margins, I would like to invite the authors to comment on why these other extended terrains are so different.

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**Fig. 1.** Block of pillow basalt in the Wai Tuh, Kobipoto Mountains. The pillow structures are clearly upside down, but the block is likely to have been displaced. Photo by M. Norvick, 1975.

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