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## DISCUSSION AND REPLY

### Discussion on 'Implications of cross-bedding data from the upper part of the Cambrian succession, Arrowie Basin, South Australia' by J. B. Jago, C. G. Gatehouse, C. McA Powell and T. Casey

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Jago *et al.* (2013) have published an account of paleocurrents in Cambrian rocks of South Australia flawed by unsubstantiated claims of early Middle Cambrian geological age and mainly marine environments for the upper Lake Frome Group. In this and previous publications, Jago *et al.* (2006, 2010, 2012) dismiss all fossil evidence for age or environment of the Pantapinna Formation or Grindstone Range Sandstone and so have no basis for their claims.

Following Stock (1974) and Moore (1990), my own research confirmed the absence of marine fossils and ubiquity of trough cross-bedding, paleochannels and other features of fluvial facies in the Pantapinna Formation and Grindstone Range Sandstone, but also demonstrated that both formations have common paleosols (Retallack 2008, 2009a, b). Paleosols have been confirmed with petrographic and geochemical studies revealing a pattern of clay production and alkali and alkaline earth depletion unique to soils. Furthermore, they have a variety of field and thin-section features, such as sepic plasmic fabrics and micritic nodules, characteristic of soils (Retallack 2008, 2011). Fossils from the Grindstone Range Sandstone include no definitively marine forms (Retallack 2009b), and support evidence from elsewhere for varied Cambrian non-marine life (Havlíček 1971; Mikuláš 1995; MacNaughton *et al.* 2002; Hagadorn *et al.* 2011).

Stratigraphic diagrams of Jago *et al.* (2006, 2010, 2013) designed to show the age of the upper Lake Frome Group lack any numerical axis. They show Pantapinna and Grindstone Range Formations (combined thickness 2010 m) at the same thickness as the Balcoracana and Moodlatana Formations (combined thickness 682 m as measured by Mawson 1939). Jago *et al.* (2006, 2010, 2012, 2013) further explain that no age diagnostic fossils have been found in either formation, and probably not in the underlying Balcoracana Formation either. This is a

situation unlikely to be remedied if the rocks are non-marine (Stock 1974; Moore 1990; Retallack 2008), but there are other ways of estimating age. Daily & Forbes (1969) and Moore (1990) considered the great thickness of the Pantapinna and Grindstone Range Sandstone evidence of possible Late Cambrian to Early Ordovician age. This estimate was confirmed by Retallack (2008) using an age model that passed two independent tests.

Test one is graphic correlation of age versus stratigraphic level, giving a relationship with a very high coefficient of variation ( $R^2 = 0.99$ ) and low t-test probability ( $p = 0.0015$ ), predicting that the base of the Grindstone Range Formation is close to the Ordovician–Cambrian boundary (Retallack 2008, figure 1). Erosional hiatuses or slowing of regional subsidence rate would create anomalous points on such a graph: none were seen in the original 5 points used. If as recommended by Jago *et al.* (2006, 2010) a doubtful trilobite occurrence is abandoned, the relationship persists in the other 4 points ( $R^2 = 0.99$ , t test  $p = 0.008$ ).

Test two is prediction of the position of synorogenic conglomerates, which stand out in these sandy red-bed sequences. A significant correlation of present latitude with geological age of granites and volcanics along the Delamerian Orogen (Retallack 2008, figure 2) confirms the 514 to 490 Ma progression of igneous activity from south to north (Foden *et al.* 2006), beginning with Early Cambrian activity near Kangaroo Island and ending with Ordovician activity near Mt Painter (Elburg *et al.* 2003). Using regression relationships of Retallack (2009a, figure 2), volcanic and granitic cooling ages of 524 and 500 Ma, respectively, are predicted at the latitude of Kangaroo Island. Ages of 517 and 492 Ma are predicted at Stansbury, and 483 and 451 Ma at Ten Mile Creek, where the Upper Frome Lake Group is best known. Predicted volcanic ages are close to those of the only syntectonic conglomerates known in each of these locations: the

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White Point Conglomerate of Kangaroo Island (Daily *et al.* 1980), the Mindlayton Conglomerate of the Stansbury town bore (Stock 1974) and the Dawson Arkose Member of the uppermost Grindstone Range Sandstone in Ten Mile Creek (Jago *et al.* 2010). This is confirmation that volcanic activity coincides with deposition of local synorogenic conglomerates, and of the age model of Retallack (2008).

Other ways of estimating the geological age of these rocks using paleomagnetic stratigraphy and detrital zircons also could be applied to testing this age model, but

it remains unfalsified. Educated guesses are heuristically useful in exploratory geological mapping, but should eventually yield to reasoned testing. Until evidence is forthcoming to the contrary, entirely non-marine paleoenvironments and ages of Late Cambrian to Early Ordovician are likely for the Pantapinna Formation and Grindstone Range Sandstone.

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