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Microstructural approaches to tectonic reconstructions of the Balcooma Metamorphic Group, Greenvale Province, north-eastern Australia

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Eastern Australia has been affected by the Ross - Delamerian (520-500 Ma), an Early Ordovician (475-450 Ma), Benambran (440-420 Ma), Tabberabberan (410-370 Ma), Kanimblan (360-320 Ma) and Hunter-Bowen (Permian) Orogenies. A succession of five foliation intersection/inflection axes preserved in porphyroblasts (FIAs), sequential growth of metamorphic index minerals, spectacular inclusion trails and in-situ dating of monazite grains within porphyroblasts show that the Balcooma Metamorphic Group has been affected by 5 orogenic cycles of different intensities from ~476±5 to 408.8±8.9 Ma. The E-W trending FIA set 1 in garnet porphyroblasts indicates N-S shortening and the beginning of the amphibolite facies metamorphism around ~476±5 Ma across the Greenvale Province. The Early Ordovician N-S shortening was followed by staurolite, kyanite and plagioclase growth in a clockwise P-T-t-D path during an Early Silurian continuous crustal thickening event. The NNW-SSE trending FIA set 2 in staurolite and NNE-SSW trending FIA set 3 in staurolite, kyanite and plagioclase porphyroblasts suggest rotation of the direction of bulk shortening to ENE-WSW and ESE-WNW between 443.2±3.8 Ma and 425.4±3.7 Ma respectively. Localized E-W trending FIA set 4 in staurolite porphyroblasts indicates N-S bulk shortening by 408.8±8.9 Ma. FIA set 5 trends NE-SW and is only present in andalusite. It suggests subsequent rotation of the bulk shortening direction to NW-SE. The Balcooma Metamorphic Group is unconformably overlain by the uncleaved Emsian age (400-392 Ma) Conjuboy Formation. Constraints from FIAs, textural relationship, Emsian age unconformity and absolute monazite plus SHRIMP U-Pb ages indicate that the Delamerian, Kanimblan and Hunter Bowen Orogenies did not affect this region. FIA 1 (~476±5 Ma), FIA 2 (443.2±3.8 Ma), FIA 3 (425.4±3.7 Ma), FIA 4 (408.8±8.9 Ma) and FIA 5 (<408.8±8.9 Ma) indicate that this region was initially affected by an Early Ordovician Orogeny but was later overprinted by the Benambran (440-420 Ma) and Tabberabberan (410-370 Ma) Orogenies.