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My Geological Connection between Minnesota and Western Australia

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"I would rather have bowel surgery in the woods with a stick. If you are not stung or pronged to death in some unexpected manner, you may be fatally chomped by sharks or crocodiles, or carried helplessly out to sea by irresistible currents, or left to stagger to an unhappy death in the baking outback."

— Bill Bryson, ***In a Sunburned Country***

Bill Bryson paints a rather scary picture of Australia, at least if you are going to spend time in 'the bush'. Much of Bryson's description of the 'sunburned country' is done in his typical 'tongue in cheek' manner, but an Australian traveler does need to be alert and aware. In truth, Bryson's description of Australia is not quite as bad as it seems, but I would encourage any new visitor to Australia to read *In a Sunburned Country*. If, during the reading, you don't grin and giggle between some serious contemplation, then I would suggest you change your plans and visit Austria (P.S. If you do visit Austria, a country in central Europe, Austrians would prefer you don't ask, "where are the kangaroos?").

In terms of humans, Australia is the most urban country on Earth. The vast majority of Australians live in towns and cities, which means there is a great deal of wide, open space to explore. This is my 9th trip to Australia and I'm amazed with each visit. I've been asked on numerous occasions, "if you love Australia so much, why don't you just move?" My response is always, "it's a great place to visit, but I certainly wouldn't want to live there!" I have been fortunate in having had the opportunity to have seen a significant portion of the continent and according to my Aussie friends, I have seen more of Australia than most Australians, which is an interesting compliment. So, here I am in Western Australia, 17,125 kilometres (10,641 miles) from home, surrounded by a flora and fauna dramatically different from central Minnesota. However, as a geologist, I feel a certain geological connection to my home state of Minnesota when I look at Australian rocks.

Australia is a great place to do field work, if for no other reason than the weather is nearly always 'fine'. I'm serious! Evening news on the TV does the weather for the entire continent in 5-minutes – *it is fine in Perth, it's hot and humid in Darwin, it's fine in Brisbane, it's fine in Sydney, it's fine in Adelaide, it's fine in Melbourne, and it's raining in Hobart. Across the nation, the weather is*

fine. Aussies can't understand why American's are obsessed with the weather! Well, crickey the weather in America changes every 20-minutes and every 20-miles! When going into the field in Australia, do keep in mind you have to drive on the left side of the road, you need to have plenty of water, and always carry a jar of vegemite. For the uninformed, Vegemite is an axial-grease-like substance chock-a-block full of vitamins, which Aussies smear on their morning toast. As an American, having Vegemite as part of your 'kit' will endear you to your Aussie colleagues, even if you don't actually eat the stuff.

Apart from meteorites, Australian rocks contain the oldest materials dated in the Earth's crust (at least to this point). The Narryer gneissic terrane in the Yilgarn Craton of Western Australia is composed of highly deformed granites, mafic intrusions, and meta-sedimentary rocks and dated at 3.6 Ga. Immediately, readers should balk at the above reference to the oldest dated rocks on Earth because the Isua Greenstone Belt in Greenland is dated at ~3.7, but zircons from the Jack Hills Meta-conglomerate at Mt Narryer (Fig. 1) are dated at 4,404 ± 8Ma (Wilde, *et al.*, 2001). The conglomerate has been interpreted as being deposited in an alluvial fan-deltaic system. The zircons provide evidence that the Hadean Earth might have been wetter than originally thought and the existence of liquid water 4.4 billion years ago could have important implications for the evolution of life (Wilde, *et al.*, 2001). Although not quite as old, Minnesota does boast the Morton gneissic terrane (3.6 Ga) (Fig. 2). And, that is my first geological connection.

Figure 1. Jack Hills Meta-conglomerate at Mt. Narryer in the Narryer gneissic terrane of Western Australia. Photo from: http://earthobservatory.nasa.gov/Features/Zircon/.

Figure 2. Outcrop of the Morton Gneiss in southeastern Minnesota, near Morton, MN.

My next geological connection is associated with the Brockman and Marra Mamba Iron Formations in the Hamersley Range of the Pilbara region of Western Australia (Fig. 3), which are equivalent in age to the Biwabik Iron Formation of the Mesabi Iron Range in northern Minnesota (Fig. 3). The banded iron formations of Western Australia are noted for their occurrence of 'tiger iron', which is the pseudomorphic substitution of silica 'tiger-eye' following low-grade metamorphism that creates veins of crocidolite asbestos. It should be noted that Heaney and Fisher (2003) disagree with the idea of pseudomorphic substitution but rather are in favour of synchronous mineral growth through a crack seal, vein-filling process. Since I am not a mineralogist, I'll let others do the arguing.

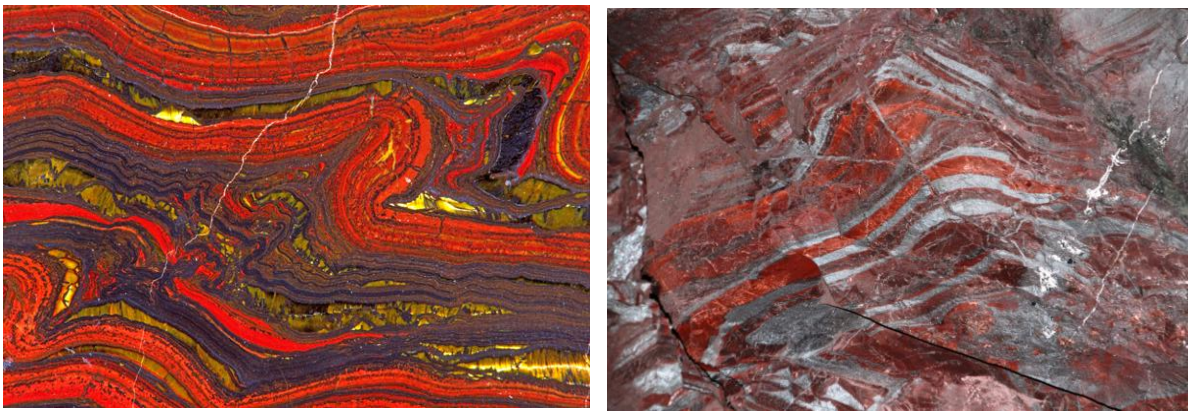

Figure 3. Polished slab of banded iron from the Brockman Iron Formation (left). Note the 'tiger iron' or tiger-eye in the sample. Biwabik Band Iron Formation (right) exposed in the Soudan Mine, Tower, MN.

My favourite geological connection between Minnesota and Western Australia are the stromatolites. In northern Minnesota, beautiful stromatolites are preserved in the 1.8 Ga Biwabik Iron Formation (Fig. 4), and large, puscular domal stromatolites are well exposed in the Willow River Member of the Lower Ordovician Shakopee Formation in southeastern Minnesota (Fig. 5) (May, *et al.*, 2012).

Figure 4. Digitate stromatolites in the Biwabik Iron Formation of the Mary Ellen Mine. Photo by Ms. Deborah Rausch, Duluth, MN.

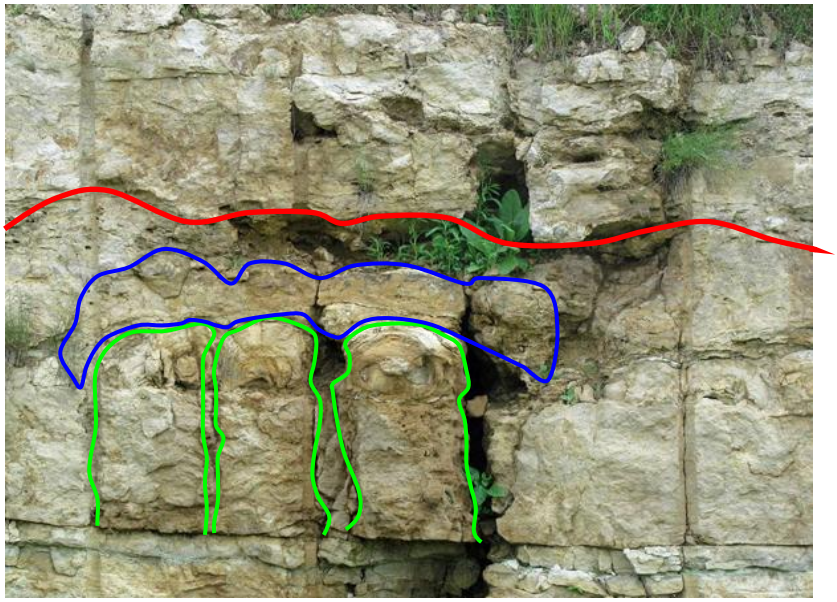

Figure 5. Stromatolites in the Willow River Member of the Lower Ordovician Shakopee Formation in southeastern Minnesota. Individual algal structures are outlined in green; overlapping algal growth is outlined in blue; and the entire stromatolitic structure is outlined in red. Photo from May *et al.*, 2012.

Western Australia boasts some of the oldest and youngest stromatolites on Earth. Fine examples of ancient stromatolites can be found in the ~3.4 Ga Strelley Pool Formation in the East Pilbara Terrane (Fig. 6) (Wacey, 2010) and the ~3.49 Ga Dresser Formation in the Warrawoona Group of the Pilbara near North Pole, Western Australia (Fig. 7) (Walter, *et al.*, 1980). Of course, it is in Western Australia that one can find the very best examples of modern stromatolites – the famous Hamelin Pool of Shark Bay (Fig. 8). Additionally, Western Australia contains modern examples of thrombolites (Fig. 9), which are similar to stromatolites, but consist of 'clotted' algal structures formed by the precipitation of CaCO3, rather than layered accretions of trapped sediment by cyanobacteria.

Figure 6. Stromatolitic structures in the 3.49 Ga Dresser Formation of the Warrawoona Group in the North Pole Dome area of the East Pilbara of Western Australia.

Figure 7. Stromatolitic structure in the 3.430 Ga Strelley Pool Chert of the Warrawoona Group in the East Pilbara of Western Australia.

Figure 8. Approximately 6,000 year old 'living' stromatolites in the Hamblin Pool, Shark Bay, Western Australia.

Figure 9. 'Living' thrombolites along the shore of Lake Clifton approximately 100 km south of Perth, Western Australia.

Most recently, I visited the Boya Quarry (also called Government Quarry) near Perth, Western Australia and was immediately reminded of the granite quarries only a few miles from my home in St. Cloud, MN. The granites exposed in the Boya Quarry (Fig. 10) along the 1000 km long Darling Scarp are part of the Yilgarn Craton and dated at 2.69-2.626 Ga (Nemchin and Pidgeon, 1997). The granite has been intruded by a number of dacite (dolerite in Australian useage) dikes of Late Proterozoic (590-560 Ma) age (Wilde and Low, 1978). The granites are associated with the accretion and assembly of Proterozoic proto-Australia. The Archean Yilgarn and Pilbara cratons were assembled into the West Australian Craton during the late Paleoproterozoic (2000 Ma) Glenburgh Orogeny (Cawood, P.A. & Korsch, R.J. (2008). Exposure of the granites along the Darling Scarp occurred in the early Cretaceous when India rotated away from Australia along the proto-Indian Ocean rift (Cannon, *et al*, 1981 and Powell, *et al.*, 1988).

Figure 10. Two north-south trending dacite (dolerite) dikes intruding granites at Boya Quarry along the Darling Scarp just east of Perth, Western Australia.

The St. Cloud Granite exposed in the quarries at Quarry Park in Waite Park, MN has been dated at 1.77 GA (Horan, *et al.*, 1987). The St. Cloud Granite has been intruded by northeast-trending diabase dikes (Fig. 11) dated at 1.57 GA (Hanson, 1968), although some dikes indicate an older age of 1.8 Ga (Horan, *et al.*, 1978).

The St. Cloud Granite, along with closely associated Rockville Granites and Reformatory Granodiorite formed during Penokean Orogeny was a mountain-building episode that occurred in the early Proterozoic about 1.85 to 1.84 billion years ago, in the area of North America that would eventually become Minnesota, Wisconsin, Michigan and Ontario (Schulz and Cannon, 2007). Exposure of the granites in eastern Stearns County, Minnesota has been the result of long periods of erosion culminating in the Wisconsin Glacial Episode by the Laurentide ice sheet beginning about 85,000 years ago and ending about 11,000 years ago.

When walking through the bush in Australia, I may spook a kangaroo or emu rather than a deer and the grass trees and *Banksias* are vivid reminders that I am no longer in Minnesota. However, on a rocky outcrop it is easy to be mentally transported home to Minnesota and I am reminded of an Aboriginal proverb: "*We are all visitors to this time, this place. We are just passing through. Our purpose here is to observe, to learn, to grow, to love, and then we return home".*

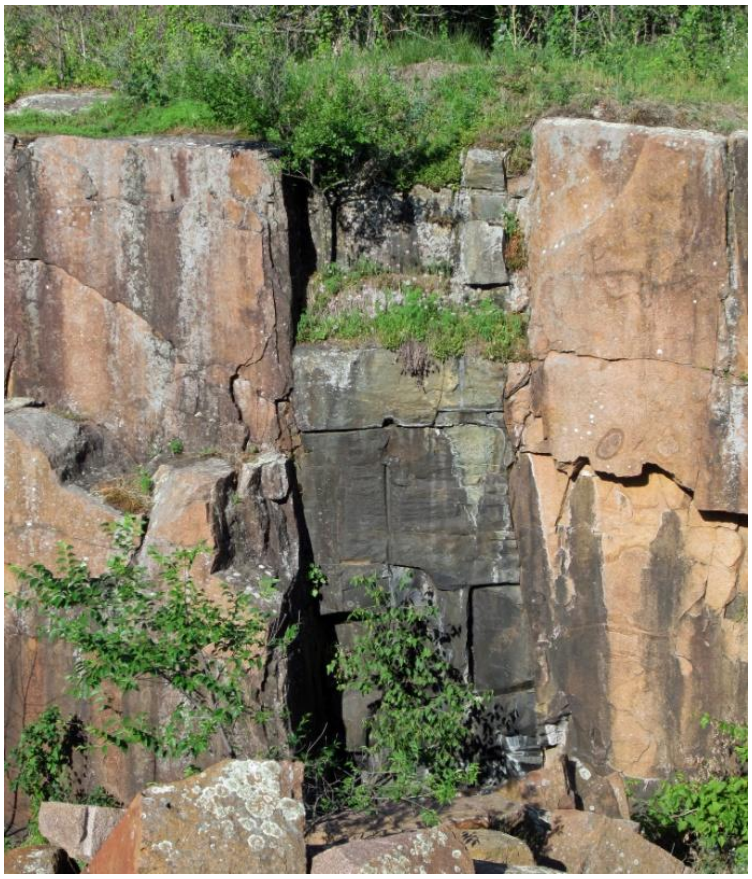

Figure 11. Northeast trending, nearly vertical dacite dike intruding the St. Cloud Granite at Quarry Park, Waite Park, Minnesota. Dacite dikes intruding the granites at Quarry Park are not nearly as large as some of the dacite dikes at Boya Quarry in Western Australia (Fig. 10). Photo taken by Dr. Michael Ross, St. Cloud, MN.

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