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A History of Crockerland – The Little Arctic Terrane that Could

Ashton Embry, Geological Survey of Canada, Calgary, aembry@nrcan.gc.ca
Owen Anfinson, University of Texas at Austin, anfinson@jsg.utexas.edu

Introduction

Crockerland is the name given by Embry (1993) to an interpreted land area which lay north of the Canadian Arctic Islands from earliest Devonian to early Middle Jurassic. The interpretation of the existence of such a land area came from two sets of observations. Firstly, the deformation of the Neoproterozoic to Devonian succession of the Franklinian Basin (Ellesmerian Orogeny) was the result of the collision of the northern margin of Laurentia with an allochthonous terrane (Embry, 1988). The impacting terrane, which lay to the north of the present Arctic Archipelago, was a substantial source area for the Franklinian foreland basin in the Late Devonian. Secondly, the facies distributions and thicknesses of Permian and Triassic strata of the Sverdrup Basin indicate that a large amount of siliciclastic sediment was derived from a relatively extensive and low lying land area to the north of the basin (Embry, 1991, 1993). The amount of sediment greatly declined in the latest Triassic with the last notable input occurring in Aalenian (early Middle Jurassic).

Thus Crockerland is currently conceived as an allochthonous terrane which accreted to the northern Laurentian margin in the Devonian and which remained an important source area for terrigenous clastics until the latest Triassic. The history of Crockerland has been interpreted from a variety of data sets including tectonic analyses, facies analyses and sediment composition. The ages of detrital zircons in Devonian to Jurassic sandstones have been especially instructive for deciphering the nature of Crockerland, its place of origin, and the timing of its eventual demise by rift fragmentation and subsequent sea floor spreading. The detrital zircon data have also provided insight into the present location of Crockerland fragments within the modern arctic realm

Origin and Arrival of Crockerland

The origin of Crockerland has been inferred mainly on the basis of the ages of the detrital zircons from the Late Devonian foreland basin deposits which were derived from the north. As detailed in Anfinson et al. (2012a, b) the zircons in these deposits exhibit populations of 900-2150 MA, 500-700 MA and 370-450 MA. The 500-700 MA zircons do not have a Laurentian source and are characteristic of the Timanide Orogen which occurred along the north-northeastern margin of Baltica. Thus it appears that the Crockerland terrane originated to the east as a fragment of either Baltica or the Caledonide Orogenic Belt which consisted of fused Baltica and Laurentia crust. The latter interpretation is preferred on the basis of the large number of Silurian (440-420 MA, Caledonide) zircons in some Late Devonian sandstones. Such a Caledonide-derivation of Crockerland fits well with the concept of “escape tectonics” and the westward migration of numerous terranes in response to continent-continent collision of Laurentia and Baltica in the Silurian (Ohta, 1994; Gee and Page, 1994; Colpron and Nelson, 2011).

The first notable and well documented tectonic deformation of the Franklinian succession occurred in earliest Devonian on northern Axel Heiberg Island (Trettin, 1989). We interpret this tectonic episode to record the initial docking of Crockerland to the north. Subsequent times of tectonic activity, widespread emergence and sedimentary regime change in the Devonian strata of the Franklinian Basin include Late Pragian, Early Eifelian, Late Givetian and Late Frasnian (Embry, 1988). Each of these times is interpreted to record the episodic southward migration of Crockerland onto the Laurentian margin. The final convergence of Crockerland and Laurentia occurred near the Devonian-Carboniferous boundary and is recognized as the climax of the Ellesmerian Orogeny. This tectonic episode was characterized by widespread deformation and substantial shortening of the Franklinian succession (Trettin, 1989).

Carboniferous to Triassic

In Early Carboniferous, the highly deformed portion of the Franklinian succession was affected by extension. This resulted in the formation of the Sverdrup Basin and the post-Devonian history of Crockerland is recorded in the sediments of that basin. The Carboniferous strata along the northern flank of the Sverdrup Basin (southern margin of Crockerland) consist mainly of carbonate strata and the lack of siliciclastic input from Crockerland at this time was likely due to a combination of the presence of Carboniferous rifts along the northern Sverdrup margin and a hot, dry climate (Embry and Beauchamp, 2008). In the Early Permian, rifting ceased and the climate became cooler and more humid (Embry and Beauchamp, 2008). Substantial amounts of siliciclastic sediment were derived from Crockerland during the Permian and thick, fine to medium grained sandstone units occur along the northern flank of the Sverdrup Basin (Embry, 1993).

Sediment input gradually increased through the Triassic and Crockerland-derived sandstone units were restricted to the northern flank of the basin in Early Triassic (Embry, 1999). Detrital zircon ages from an Early Triassic sandstone include plentiful Permian zircons (265-290 MA) as well Mesoproterozoic ones (950-1500 MA) (Omma et al, 2011). The common Permian zircons suggest that the Pacific-facing side of Crockerland was an active margin with igneous activity. In early Late Triassic Crockerland-derived sandstones up to 200 m thick extended across the western Sverdrup to the SW margin (Embry, 1991, 1993). Notably, numerous detrital zircons of Middle Triassic and Carnian age were present in a Carnian sandstone from northern Axel Heiberg Island (Omma et al, 2011). This once again indicates that the Crockerland drainage systems reaching the Sverdrup Basin stretched all the way to the tectonically active Pacific margin. Another Carnian sandstone yielded detrital zircons with Silurian to Neoproterozoic ages (440-700 MA) (Miller et al, 2006) supporting the Caledonian origin of Crockerland.

Sediment influx from Crockerland reached a zenith in the Norian (Late Triassic) when Crockerland-derived siliciclastic deposits were up to a kilometre thick and extended over the entire basin (Embry, 2011). Thick, sand-rich deltaic strata dominate the eastern portion of the Sverdrup Basin and detrital zircons from these deposits once again are characterized by Late Paleozoic to Triassic ages including nearly penecontemporaneous ones. Zircons with Devonian to Neoproterozoic ages and a variety of Mesoproterozoic ages are also present. All these ages fit well with the Caledonian origin of the Crockerland terrane and the continued presence of a tectonically active, Pacific margin.

Insight into the nature of the Pacific-facing margin of Crockerland has also been gained from the Triassic sediments of Wrangel Island and mainland Chukotka (Kos'ko et al., 1993, Tuchkova et al., 2009). These sediments were derived from the Pacific-margin of Crockerland which lay to the north of the area. The sandstones contain numerous volcanic fragments as well as detrital zircons dominated by Triassic-Permian and Silurian-late Neoproterozoic ages (Miller et al., 2006), very similar to those found in the Triassic strata of the Sverdrup Basin.

Rifting and Dismemberment of Crockerland

A significant tectonic episode affected the Sverdrup Basin in latest Triassic (earliest Rhaetian) and a widespread unconformity caps the Norian deposits (Embry, 2011). Following this event, sediment input from Crockerland became very minor and all the latest Triassic-Early Jurassic siliciclastic sediment in the basin was derived from cratonic areas to the east and south. It is interpreted that Crockerland began to rift along a N-S axis in the latest Triassic resulting in a complete disruption of regional drainage patterns and a consequent huge reduction of sediment supply. Rifting of Crockerland continued throughout the Jurassic, reaching the southwestern Sverdrup Basin in Bajocian and Banks Basin in Oxfordian (Embry, 1991). From Rhaetian onward, only local streams from nearby rift shoulders would have supplied the northern margin of Sverdrup Basin. In support of this interpretation, detrital zircons from a northerly-derived, Middle Jurassic (Bajocian) sandstone are no younger than Devonian and also include characteristic late Neoproterozoic zircons (prominent peak at 700 MA).

The rift/drift transition occurred in Early Cretaceous and the Amerasia Basin opened by the counter clockwise rotation of the Arctic Alaska-Chukotka microplate from early Hauterivian to late Albian (Embry, 1990). Crockerland was completely dismembered during sea floor spreading and its fragments now form the basement of three main areas: 1) the continental shelf and slope adjacent to the northern Canadian Arctic Archipelago (Brock Island and north), 2) the Chukotka-East Siberia continental margin of Russia, and 3) the Chukchi Borderland, a continental fragment within the Amerasia Basin. For the most part, these scattered fragments of the former Crockerland terrane now lie deeply buried by Cretaceous and Cenozoic sediments.

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