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World-Class Example of an Ancient Deep-Marine Passive-Margin Turbidite System, Neoproterozoic Windermere Supergroup in the Southern Canadian Cordillera

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Summary

Originally termed the Windermere System by Walker (1926) from exposures in the Windermere valley of southeastern B.C., the now stratigraphically elevated Neoproterozoic Windermere Supergroup (WSG) has been subsequently shown to form an extensive outcrop belt from northern Mexico to the Yukon-Alaska border – a strike length of over 4000 km. In addition to its significant areal distribution, deposition of the Neoproterozoic WSG coincided with a truly dynamic time in Earth's evolution, which included the break-up of the supercontinent Rodinia, potentially global-scale glaciations and changes in geochemical cycles, and most notably, the rise of metazoan life. This report highlights an important part of the WSG – a large, well exposed, turbidite system in the context of the western Laurentian margin rift-drift sequence.

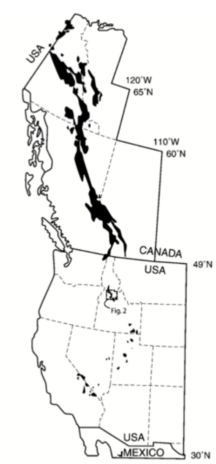

Fig. 1. Distribution of exposed Windermere Supergroup strata in western North America (modified from Ross, 1991).

Although extensively exposed throughout western North America, internal correlations from one area to another have been controversial in the absence of clearly synchronous markers, and here we offer an interpretation that appears to provide a simple solution. The WSG is particularly well exposed in the southern Canadian Cordillera (SCC) where alpine exposures of recently deglaciated strata provide an unparalleled opportunity for detailed geological study. Here the WSG forms an outcrop belt that extends across 35,000 km^2 (palinspastically unrestored) that in its lower and middle part consists mostly of deep-marine siliciclastic strata overlain by predominantly shallow-marine carbonate rocks in the upper part. In this area the WSG is of the order of 7-9 km thick and is interpreted to consist of two parts related to the rift and then drift of Laurentia (ancestral North America) from the Rodinia supercontinent (Stewart, 1972; Ross, 1991). The lower rift part consists of a few-kilometer-thick assemblage of intercalated coarse clastic sedimentary and mafic extrusive igneous rocks. This, then, is overlain by post-rift to drift strata consisting of a several-kilometer-thick succession of mostly siliciclastic upward to carbonate sedimentary rocks representing a deep- to shallow-marine succession deposited on the margins of an expanding oceanic basin.

In outcrop the most proximal part of the WSG in the SCC consists of mudstone interstratified with fine-grained, upper division turbidites incised locally by >100 m deep scours filled with coarse, typically granule and pebble conglomerate, siliciclastic strata interpreted to be the fill of submarine canyons incised into continental slope mudrocks (Arnott and Hein, 1986). Basinward the succession comprises locally developed channel complexes, some that range up to 250 m in thickness, within a succession dominated by thin-bedded turbidites. Channels are typically filled with medium- and coarse-grained sandstone flanked on their margins by well-developed, finer-grained deposits commonly consisting of distinctive multi-set ripple cross-stratified turbidites. Collectively these strata are interpreted to represent levee bounded slope channels that formed downflow of the upslope canyons (Navarro et al., 2007). In turn, these strata are succeeded and transition further basinward into a few-kilometer-thick succession of laterally extensive, several meter- to decameter-thick stratal packages composed of either sandstone-rich, lower division turbidites or mudstone-rich upper division turbidites interpreted to represent deposition by unconfined sand-rich and sand-poor turbulent suspensions on the basin floor (Terlaky et al., 2016; Navarro and Arnott in press).

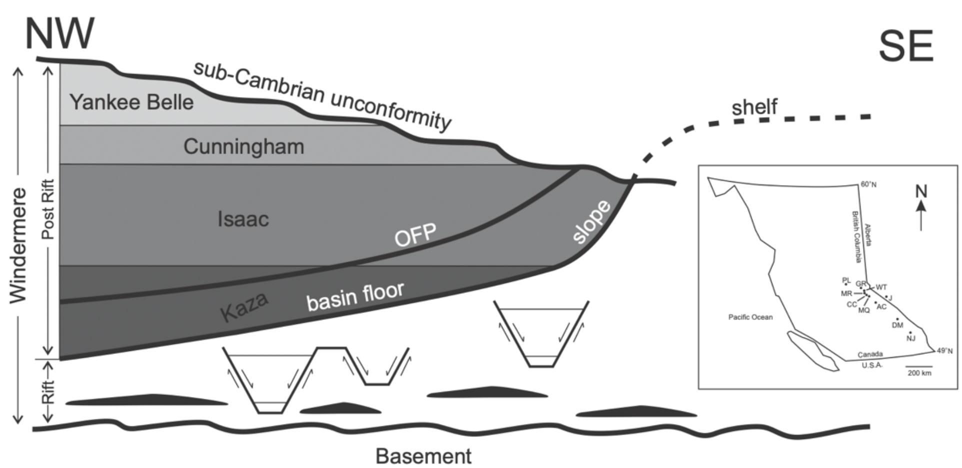

Fig. 2. Schematic of the temporal development of Windermere strata in the southern Canadian Cordillera. It overlies the unconformity at the top of the Belt-Purcell Supergroup and generally thickens toward the northwest. The lower rift succession consists of intercalated mafic extrusive igneous rocks (black lens) and coarse siliciclastic sedimentary rocks that in many places accumulated in contemporaneous fault-bounded continental basins (e.g. Root 1987). The overlying post-rift succession consists of a several km-thick, upward-shoaling succession of basin floor (Kaza) to continental slope (Isaac) to continental shelf (Yankee Belle and Cunningham deposits related to progradation of the Laurentian continent margin into the expanding Pacific miogeocline (Ross and Arnott, 2007). Note that the terms Kaza, Isaac, Cunningham and Yankee Belle refer to stratigraphic nomenclature in the Cariboo Mountains of east-central B.C. (Campbell et al. 1973), but the main characteristics of the single sequence are more widespread in our interpretation of the correlations. Inset map shows detrital zircon sample locations stretching from upper continental slope deposits in the Windermere valley of southeastern B.C. to basin floor strata just east of Prince George in central B.C.

In terms of the dimensions of its component stratal elements, for example leveed slope-channels, basin-floor depositional lobes, width and depth of submarine canyons, in addition to the areal extent of the entire outcrop belt, which with conservative palinspastic reconstruction is at least 80,000 km^2, suggests that the Windermere turbidite system in the SCC is comparable to modern passive margin systems like the deep-marine Amazon and Mississippi turbidite systems. Detrital zircon data indicate two distinct provenance assemblages related to the long-term evolution of the WSG system in the SCC (Fig. 3). The first assemblage, which consists of abundant Mesoproterozoic (1.15-1.5 Ga) zircons, occurs in rift strata at the base of the WSG sedimentary pile. Above this, the drift detrital zircon assemblage, consistent with previous authors, namely Ross and Bowring (1990) and Ross and Parrish (1991), consists of a bimodal assemblage dominated by Paleoproterozoic (1.8 Ga) and Archean (>2.0 Ga) zircon ages. The profound difference in zircon assemblages between the rift and drift parts of the Windermere sedimentary pile in the SCC suggests distinctively different sediment provenance. The diverse suite of Mesoproterozoic ages in the rift assemblage most probably reflects sediment derived from local bedrock sources, quite possibly on the raised margins of fault-bounded continental basins, whereas the bimodal assemblage of Paleoproterozoic and Archean ages in the drift succession indicates a consistent long-term supply of sediment from a stable drainage system that arose in the craton to the east/southeast. Moreover, these data complement the observed upward change in sediment texture and composition, from typically angular and coarse-grained strata, suggesting derivation from underlying or nearby older rocks (i.e. Belt-Purcell Supergroup) in the lower rift sequence, to finer, more texturally mature quartz with lesser feldspar bearing strata in the overlying drift succession.

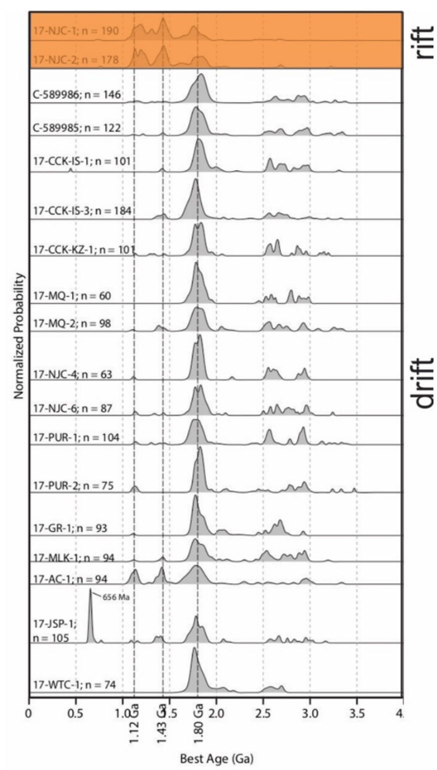

Fig. 3. Detrital zircon age distribution in WSG samples from the SCC. Note the abundant Mesoproterozoic but limited Archean ages in strata associated with rift sedimentation. In contrast, note the characteristic and areally consistent bimodal (Paleoproterozoic and Archean) zircon age distribution in the drift assemblage. Note also the prominent peak in the JSP-1 sample (Jasper, Alberta) at 656 Ma, which provides a maximum age for Windermere sedimentation in the SCC.

Conclusions

In the southern Canadian Cordillera, the Windermere Supergroup contains a single, large post-rift turbidite system deposited on the passive continental margin of Laurentia. This turbidite system, in terms of its areal extent, the dimensions of its component stratal elements, and its sediment sourced from a stable and long-lasting drainage system, is consistent with modern deep-marine systems like the economically important Amazon and Mississippi turbidite systems. This makes the Windermere turbidite system not only one of largest turbidite systems in the geological record, but also one of its rarest -- an example of an ancient passive-margin turbidite system. Furthermore, it is generally well exposed and easily accessed.

Acknowledgements

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