Are Neoproterozoic glacial deposits preserved on the margins of Laurentia related to the fragmentation of two supercontinents?

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ABSTRACT

Remarkably similar deposits representing two Neoproterozoic glaciations are present on the west and east sides of Laurentia. Although now located near the margins of Laurentia, these glaciogenic successions were formed within supercontinents. The older glaciogenic succession (Rapitan-Sturtian, ~700 Ma) is preserved in a series of pull-apart basins formed when the supercontinent Kanatia fragmented to produce the proto–Pacific ocean. The younger Varangerian glaciogenic rocks (~600 Ma) are now scattered throughout the North Atlantic region, but formed in basins that reflect the demise of a second Neoproterozoic supercontinent (Rodinia) and heralded the formation of the Iapetus ocean.

INTRODUCTION

This paper is concerned with possible relation between preserved glaciogenic rocks and the development and fragmentation of Neoproterozoic supercontinents. Since Stewart (1972) proposed that the Neoproterozoic succession of the North American Cordillera records a rift episode, there have been several suggestions of candidates for the region that formed the other side of the western North American rifted margin (Rowlands, 1973; Sears and Price, 1978; Young, 1981, 1984; Eisbacher, 1985; Bell and Jefferson, 1987). Most of these studies emphasized the remarkable stratigraphic similarities between the Cordilleran and South Australian Neoproterozoic successions. Following publication of the so-called SWEAT hypothesis (southwest U.S.–East Antarctic connection) by Moores (1991), Dalziel (1991), and Hoffman (1991), many explored the idea that during the Neoproterozoic a large continental mass, comprising present-day Australia, Antarctica, and India, was located off what is now the western margin of North America (Ross, 1991; Hartnady, 1991; Young, 1992; Brookfield, 1993; Borg and DePaolo, 1994).

The timing of the breakup of the proposed supercontinent (Dalziel, 1992) has been debated. Stratigraphic arguments were used to suggest breakup during the Neoproterozoic at ~700 Ma. By using backstripping techniques and rates of thermal subsidence, Bond et al. (1984) and Levy and Christie-Blick (1991) argued that breakup may not have occurred until close to the beginning of the Cambrian. Ross (1991), Hoffman (1991), and Dalziel et al. (1994) favored the earlier breakup. Bond and Kominz (1984) and Ross (1991) invoked a second rift event near the Precambrian-Cambrian boundary.

CORDILLERAN REGION

Neoproterozoic glacial deposits are widespread along the length of the North American Cordillera. Until recently, all of these rocks were ascribed to a single glacial episode at about 750 Ma (Evenchick et al., 1984; Aitken, 1993; Jefferson and Parrish, 1989). The first definitive evidence of a younger glacial episode in the Cordillera was published by Aitken (1991). These younger glacial deposits (part of the Ice Brook Formation) are not well represented in the Cordilleran region.

Glaciogenic deposits of the Rapitan Group rest with unconformable to conformable contacts on a thick, carbonate-rich platformal succession known as the Mackenzie Mountains Supergroup and the recently named Coates Lake Group (Jefferson and Ruelle, 1986; Gabrielse and Campbell, 1991; Aitken, 1993). This unconformity was ascribed by Young et al. (1979) to the Hayhook "orogeny," which was considered to be related to a rift episode. The Rapitan Group (as used here) consists of two diamictite-rich units, separated by a purple turbiditic succession containing dropstones (Yeo, 1981; Eisbacher, 1985). Red coloration in the Sayunei and Shezal Formations is due to hematite which, near the Sayunei-Shezal boundary, forms a significant iron formation (Yeo, 1981; 1984; Eisbacher, 1985; Klein and Beukes, 1993). The upper diamictite is overlain by a thick unit of gray shale (Twitya Formation) and minor carbonates and sandstones, representing a major postglacial transgression (Young, 1984; Eisbacher, 1985).

A remarkably similar glaciogenic succession of similar age (Young, 1992) is preserved in the Sturtian of the Adelaide geosyncline in South Australia (Preiss, 1987). In several places along the length of the Cordillera, and also in the Adelaide geosyncline, the Neoproterozoic glaciogenic rocks are rich in iron (Yeo, 1984; Graff, 1985; Preiss, 1987; Neale, 1993). Both in the Cordilleran region (Stewart, 1972; Young et al., 1979; Yeo, 1981; Eisbacher, 1985) and in South Australia (Preiss, 1987) the glaciogenic rocks have been ascribed to a rift setting. On a map of the hypothetical Neoproterozoic supercontinent (Fig. 1A), many of these glacial deposits are concentrated along the ~700 Ma breakup zone of Stewart (1972), Moores (1991), Dalziel (1991), and Hoffman (1991).

NORTH ATLANTIC REGION

Neoproterozoic glaciogenic rocks are widespread in the North Atlantic region. They extend from western Ireland and Scotland through Sweden and Norway, East Greenland, Spitsbergen, and northwestern Russia. Spencer (1975) and Hambrey (1983) proposed relations among the Neoproterozoic rocks of this region. These rocks are much younger than the Rapitan-Sturtian successions of the Cordilleran region of North America and South Australia. They are of Vendian age (~650 Ma–base of the Cambrian) (Chumakov and Semikhatov, 1981).

The stratigraphy and tectonic setting of the Varangerian glacial deposits are remarkably similar to those of the older Rapi-

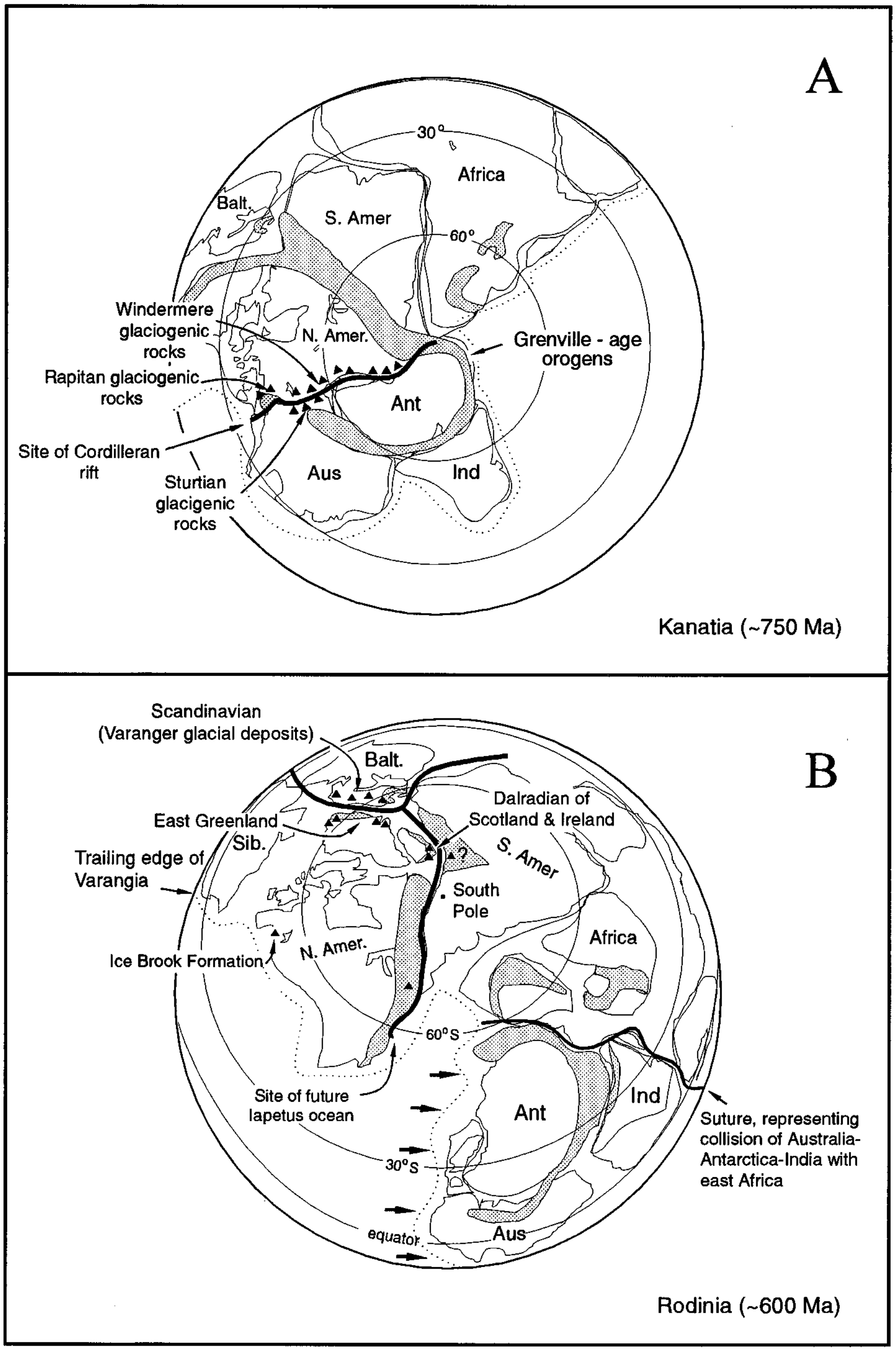

Figure 1. A: Reconstruction of Neoproterozoic supercontinent Kanatia at ~750 Ma (after Moores, 1991; Dalziel, 1991; Hoffman, 1991; Dalla Salda et al., 1992). Circles at 30° and 60° are for scale only and are not meant to denote location of continents. Ind—India; Aus—Australia; N. Amer.—North America; S. Amer—South America; Balt.—Baltica; Ant—Antarctica. Note that Sturtian-Rapitan glacial rocks (shown schematically by triangles) are concentrated along site of future breakup of supercontinent. B: Reconstruction of second Neoproterozoic supercontinent, Rodinia, at ~600 Ma (after Dalziel et al., 1994). Sib.—Siberia. See text for discussion and explanation of terminology for supercontinents.

tan-Sturtian succession (Fig. 2). Throughout much of the North Atlantic region these glaciogenic deposits rest unconformably on older carbonate-rich shallow-marine platformal successions such as the Eleonore Bay Group and Islay Limestone, which are similar to those beneath the Rapitan-Sturtian succession. Other similarities include the presence, in most regions, of two distinct diamictite-rich units separated by mudstones and sandstones, and a red color (hematite) in the upper diamictite.

In several areas of the North Atlantic region the tectonic setting of the Varangerian glaciations has been interpreted to be partly fault controlled (Schermerhorn, 1974, 1983; Anderton, 1982, 1985; Nystuen, 1985; Bjorlykke, 1985). The Neoproterozoic rocks in Scotland and Ireland may have been deposited in a northeast-trending (present coordinates) shallow(?) gulf that opened to the northeast (Anderton, 1982).

A recent reconstruction of the North Atlantic region during this period (Dalziel et al., 1994) places South America on the southeast side of the Iapetus suture (Fig. 1B). Although many of the Varangerian glacial deposits formed in broad stable shelf settings (Deynoux and Trompette, 1981), some (e.g., in Scandinavia) are concentrated in rift zones marking the breakup of a second Neoproterozoic supercontinent (Fig. 1B). Bond et al. (1984), Murphy and Nance (1991), Dalziel et al. (1992, 1994), and Dalziel (1992) proposed the existence of two supercontinents during the Neoproterozoic. Purportedly following McMenamin and Schulte McMenamin (1990), the name "Rodinia" has been applied to the older supercontinent. However, the original Rodinia as defined by McMenamin and Schulte McMenamin (1990, p. 95–96) is more closely akin, in definition, age, and configuration, to Dalziel's (1992) younger supercontinent. For reasons of precedence, the name "Rodinia" is here used to refer to the younger supercontinent, and the name "Kanatia" is proposed for the older one. The name "Kanatia" derives from the Huron-Iroquois word "kanata," meaning a collection of huts or a settlement, and is supposed to be the word from which "Canada" is derived. This name is considered an appropriate designation for the older supercontinent for two reasons: (1) Kanata refers to a collection or "coming together" (as in amalgamation of a supercontinent), and (2) the original proposal for the configuration of this supercontinent was made by Canadian geologists (Bell and Jefferson, 1987) and was largely based on stratigraphic correlations between Canada and Australia.

CONCLUSIONS

Two important Neoproterozoic glaciogenic successions are preserved on opposite margins of Laurentia. The older (Sturtian-Rapitan) glacial deposits are abundant in the North American Cordillera and in the Adelaide geosyncline of South Australia. They mark a rift zone that developed during the breakup of Kanatia at ~700 Ma. The second Neoproterozoic glacial episode

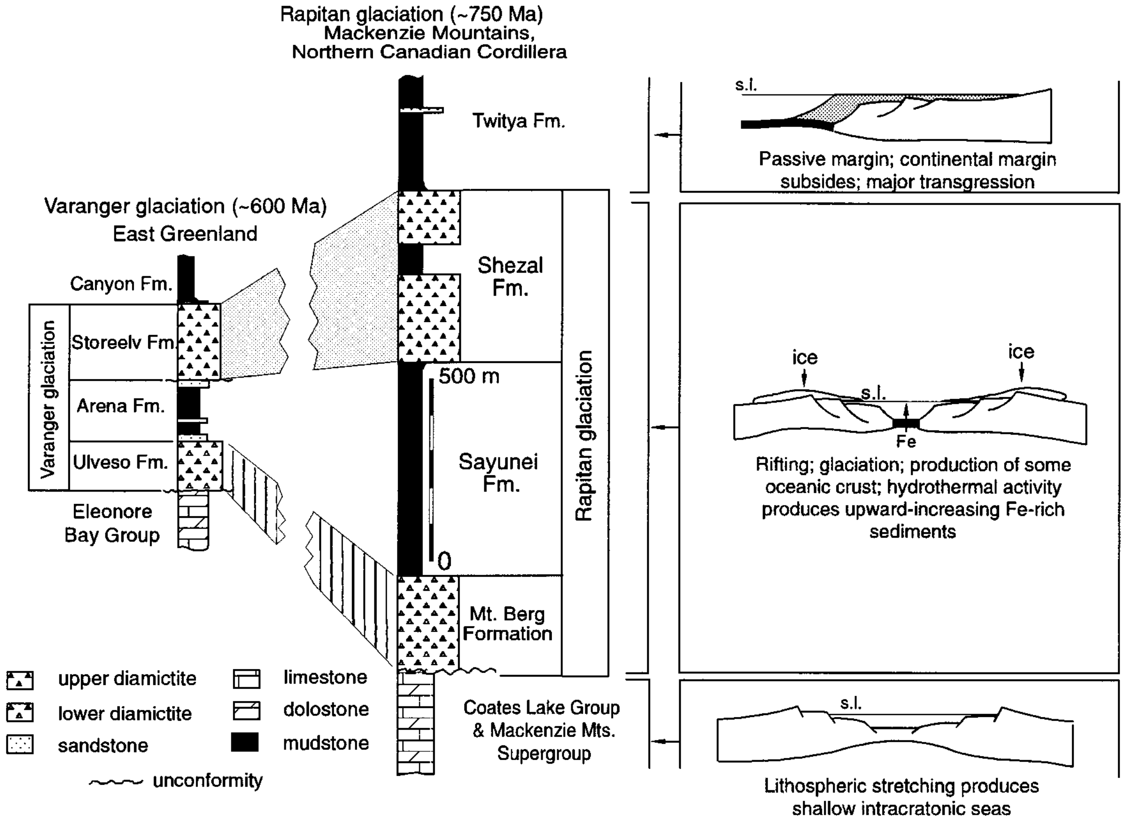

Figure 2. Comparison of representative successions from older Rapitan-Sturtian glacial succession and younger Varanger glaciation to illustrate stratigraphic similarities. Sketches at right side show inferred tectonic setting; s.l.—sea level. Vertical pattern designates lower drab diamictites; gray pattern between columns indicates upper, commonly purple to red diamictites. Breaks in patterns between columns are meant to show that time stratigraphic correlation is not implied.

(~600 Ma) is only weakly expressed in the Cordilleran zone (which was either a passive margin or the site of a second [minor?] rifting episode [Ross, 1991]), but its deposits are widespread in the North Atlantic region in the vicinity of a rift complex that preceded the breakup of a second supercontinent (Rodinia). Despite the difference in age, there are remarkable similarities between the glacial deposits of the Varangerian glaciation in the North Atlantic region and the older glaciogenic rocks of the Rapitan-Sturtian succession (Fig. 2). These similarities may reflect the tectonic setting, which in both cases involved fragmentation of a supercontinent. Whether the glaciations were initiated by drawdown of CO_2, related to weathering of a partly tropical supercontinent (Marshall et al., 1988), or were due to uplift of orogenic belts (Raymo and Ruddiman, 1992) or rift shoulders (Yeo, 1984; Schermerhorn, 1983), they appear to have formed in the interior of supercontinents and are now, in part at least, preserved near the margins of Laurentia, which broke away successively from Kanatia, Rodinia, and eventually from Pangea.

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