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Detrital zircon signatures of the Baltoscandian margin along the Arctic Circle Caledonides in Sweden: The Sveconorwegian connection

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ABSTRACT

New evidence is presented here that the Sveconorwegian Orogen continued northwards from type areas in southwestern Scandinavia along the Baltoscandian outer margin into the high Arctic. The Silver Road (Silvervägen) profile through the Scandinavian Caledonides, located in Sweden along the Arctic Circle at 66–67° N, provides a full section through the tectonostratigraphy of the Baltoscandian margin from the Autochthon, via the Lower Allochthon to the upperment parts of the Middle Allochthon. Metamorphic grade increases upwards through the nappes, being low greenschist facies at lowest levels and increasing to eclogite grade in the highest parts of the Seve Nappe Complex, the latter being related to early Ordovician subduction of the Baltoscandian outermost margin. The sedimentary rocks range in age from Neoproterozoic to Ordovician and provide evidence of the changes of environment from the Baltoscandian platform, westwards out over the Cryogenian rifted margin to the continent-ocean transition zone; also the Ordovician foreland basin. Twelve samples of psammites from the different tectonostratigraphic levels have yielded U/Pb detrital zircon age-signatures that reflect the changing character of their provenance. Autochthonous sandstones are derived from late Paleoproterozoic (1800–1950 Ma) crystalline rocks in the vicinity to the east of the thrust front. Ediacaran-early Cambrian quartzites of the Lower Allochthon also yield mainly late Paleoproterozoic zircon signatures, but with subordinate Mesoproterozoic and late Archaean populations, whilst mid Ordovician, W-derived foreland basin turbidites are dominated by Sveconorwegian (950–1100 Ma) signatures, with subordinate older Mesoproterozoic to latest Paleoproterozoic populations. All samples from the lower parts of the Middle Allochthon (lacking dolerite dykes) have signatures that are dominated by latest Paleoproterozoic and early Mesoproterozoic ages, with subordinate populations down to Sveconorwegian ages; the latter dominate the overlying Särv nappes and also the Seve Nappe Complex, where c. 945 Ma rhyodacites have been previously reported. This evidence of Sveconorwegian source rocks in the hinterland, taken together with previously published detrital zircon data farther south and north of the Arctic Circle, clearly favours the interpretation that the Sveconorwegian Orogen, during the Neoproterozoic, extended along the entire Baltoscandian outer margin into the high Arctic.

1. Introduction

A key question for the understanding of both Grenville-Sveconorwegian and Caledonian orogeny concerns the relationship between the Grenville and Sveconorwegian segments of this c. 1000 Ma orogen. Many authors (Li et al., 2008) favour an interpretation that, from their type areas in eastern Canada and southern Scandinavia, the deformation fronts of the two segments of this orogen converge and unite beneath the shallow continental shelves of the North Atlantic Ocean at c. 63–64° N, implying that the Grenville-Sveconorwegian Orogen (GSO) never reached into what is now the Arctic. Yet, for at least the last twenty years it has been clear that in the Caledonides of both northeastern Greenland (Strachan et al., 1995; Leslie and Nutman, 2003) and Svalbard (Gee et al., 1995; Johansson et al., 2004) there is substantial evidence of late Grenville-age (earliest Neoproterozoic, mid Tonian) orogeny.

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There is also ample evidence of late Sveconorwegian (early-mid Tonian) orogeny in the type area of this orogen (Bingen et al., 2008; Roberts and Slagstad, in press). Cawood et al. (2010) suggested that the late Grenvillian orogeny along the Laurentian margin of northeastern Greenland and on Svalbard was related to an "external" orogen – a branch of the Grenville-Sveconorwegian Orogen, oriented perpendicular to the main orogenic belt. This, so-called Valhalla Orogen was inferred, on the basis of somewhat limited paleomagnetic data, to result from the rotation of Baltica in relation to Laurentia and the closure of a marginal sea. A simpler hypothesis is preferred here: that the Grenville-Sveconorwegian Orogen continued from c. 63° N far into the high Arctic (Lorenz et al., 2012, 2013), an interpretation with profound implications for the subsequent history of Iapetus Ocean opening and closing, culminating in Laurentia-Baltica collision during Caledonian (Scandian) orogeny. It also has significance for the understanding of the influence of lithospheric inheritance on crustal deformation.

The Caledonides around the North Atlantic are extensively developed beneath the wide, shallow continental shelves of the region and also outcrop in four main areas: Svalbard, northeastern Greenland, western Scandinavia (in the Scandian mountains, "Caledonides Orientalis" of Roman cartography) and the British Isles ("Caledonides Occidentalis"). A branch of the orogen extends southeastwards from the North Sea into eastern Germany and western Poland. The Scandinavian Caledonides comprise the largest and most coherent segment of the orogen. This 1800 km long, up to 300 km wide exposure is particularly important because it includes a variety of allochthons that have been derived not only from the Baltoscandian margin of Baltica, but also from the Iapetus Ocean and uppermost, the Laurentian margin. The other part of the Caledonides of comparable dimensions, occurring along the eastern edge of the Greenland ice dome, comprises an important complement to the orogen in the Scandes, providing comprehensive evidence of the Laurentian platform and margin (Higgins et al., 2008). In the northeast Greenland Caledonides, late Grenville (Renlandian) orogeny is confined to the uppermost allocthon (the Hager Berg thrust sheets), emplaced at least a couple of hundred kilometres onto the Laurentian platform; it is this complex that has some features in common with the uppermost tectonic units in the Scandes. Other exposed parts of the North Atlantic Caledonides are disrupted by major, orogen-parallel faults and provide only subordinate fragments of the old mountain belt; they can best be understood in the context of the orogen as a whole (Leslie et al., 2008).

The Caledonide Orogen in Scandinavia (Fig. 1) has been described extensively elsewhere, in some detail in Gee and Sturt (1985) and, more recently, in Corfu et al. (2014). The tectonostratigraphic framework (Gee et al., 1985) is similar to that used in the Swedish part of the Caledonides by Kulling, in Strand and Kulling (1972); it has been variously interpreted in terms of palaeogeography and tectonic evolution by many authors. Subsequent geological mapping, summarized in Solli and Nordgulen (2006), has revised some aspects of the correlation of the allochthons; for example, substantial areas of southeastern Tröndelag, regarded in 1985 as parts of the Seve Nappe Complex, are typical of the Särv Nappes, being dominated by greenschist facies metamorphosed sandstones and dolerite dyke swarms. The 1985 framework tectonostratigraphy has been used for the last thirty years, with minor modifications (Andréasson and Gee, 2008; Gee et al., 2008; Robinson et al., 2008), and involves subdivision of the allochthons into four major categories: Lower, Middle, Upper and Uppermost. Late Neoproterozoic and Early Paleozoic successions of the Lower Allochthon have unambiguous stratigraphic and faunal affinities with the Baltoscandian platform of western Baltica and provide key evidence concerning foreland basin evolution (Thorslund, 1960; Karis, in Karis and Strömberg, 1998; Greiling and Garfunkel, 2007). The overthrust Middle Allochthon is dominated in lower parts by long-transported, basement-derived thrust sheets and Neoproterozoic sandstone successions. In upper parts, dolerite dyke-swarms become an increasingly important component, intruding Cryogenian and Ediacaran successions (Kumpulainen, 1980, 2011). Metamorphic grade increases upwards throughout the Lower and Middle allochthons and, in the uppermost parts (Seve Nappe Complex), amphibolite, granulite, HP and UHP assemblages provide evidence of Ordovician to early Silurian subduction systems along the continental margin. The overlying thrust sheets of the Upper Allochthon (Köli Nappe Complex) comprise Iapetus ocean-related terranes, including ophiolites and volcanic arc assemblages derived from positions proximal to both Baltica and Laurentia. The contact between the Upper and Middle allochthons is, in many places, dominated by extensional faulting.

Probably the best part of the Scandinavian Caledonides for obtaining a comprehensive overview of the orogen is located in central parts of the Scandian mountains between 62° and 65° N; farther north, the orogen narrows and much of the foreland has been removed by Cenozoic uplift and erosion. This central segment of the orogen includes the classical areas for our understanding of thrust tectonics (Törnebohm, 1888, 1896; Högbom, 1894, 1910; Asklund, 1938, 1960). The Swedish part of the central Scandes, in western Jämtland, includes the spectacular exposures of the dolerite-intruded Särv Nappes (Strömberg, 1961) of the Middle Allochthon, from Funäsdalen in the south to Ottfjället in the north, an area of about 5000 km^2. These dyke-swarms, occurring in both the Särv and overlying Seve nappes, dominated the outer margin of Baltica, and have been mapped from southeastern Trøndelag to northernmost Norway; they are also probably present on Atlöy (near Bergen) and in the Egersund area of southernmost Norway; i.e. along the whole length of the mountain-belt. In central parts (Jämtland-Tröndelag) their outcrop area reaches westwards as far as Trondheimsfjord, a W–E distance of 200 km. Their absence in the underlying basement-derived thrust-sheets of the Lower Allochthon and deeper "parautochthonous" basement, leaves little doubt that thrusting in the Scandes is of similar dimensions (several hundreds of kilometres, at least) to that in the Himalayas.

Farther north, in Norrbotten (66–69° N), profiles through the Scandes, though shorter than in the central parts of the orogen, with much of the foreland basin and other units of the Lower Allochthon removed by erosion, provide particularly interesting information about the outermost parts (continent-ocean transition-zone, COT) of the Baltoscandian margin. The Särv and Seve nappes at 66–67° N, are comparable with their correlatives in northern Jämtland; they pass northwards into thrust sheets with more than 80% dykes (Sarektjåkkå Nappe, SA in Fig. 1; Andréasson, 1986; Svenningsen, 1994; Andréasson et al., 1998) and in the area around Sweden's highest mountain, Kebnekaise (K in Fig. 1; Andréasson and Gee, 1989; Baird et al., 2014). In the latter area, the dykes also cut 850 Ma granites (Paulsson and Andréasson, 2002). These compare well to granites of the Kalak Nappe Complex farther north (Daly et al., 1991; Kirkland et al., 2006) and perhaps signal a change in derivation of the Middle Allochthon northwards to regions that also include the pre-Caledonian, Timanian margin of Baltica (Gee et al., submitted for publication). Whereas some of the Seve Nappes have been subducted and educted, others were not. And one particular unit, including pillow basalts, provides evidence of LT/HP metamorphism, with glaucophane in association with eclogites (Kullerud et al., 1990).

In order to better understand the depositional environments, age and provenance of the sedimentary rocks associated with these outer margin dyke-swarms and compare them with those in the underlying tectonic units, a selection of samples from different tectonic units were collected along and in the vicinity of Silvervägen (the Silver Road) in 2010; zircons have been separated and their