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UHP metamorphism recorded by kyanite-bearing eclogite in the Seve Nappe Complex of northern Jämtland, Swedish Caledonides

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ABSTRACT

The first evidence for ultrahigh-pressure (UHP) metamorphism in the Seve Nappe Complex of the Scandinavian Caledonides is recorded by kyanite-bearing eclogite, found in a basic dyke within a garnet peridotite body exposed close to the lake Friningen in northern Jämtland (central Sweden). UHP metamorphic conditions of ~3 GPa and 800 °C, within the stability field of coesite, are constrained from geothermobarometry and calculated phase equilibria for the peak-pressure assemblage garnet + omphacite + kyanite + phengite. A prograde metamorphic evolution from a lower P–T (1.5–1.7 GPa and 700–750 °C) stage during subduction is inferred from inclusions of pargasitic amphibole, zoisite and kyanite in garnet cores. The post-UHP evolution is constrained from breakdown textures, such as exsolutions of kyanite and silica from the Ca-Eskola clinopyroxene. Near isothermal decompression of eclogite to lower crustal levels (~0.8–1.0 GPa) led to formation of sapphirine, spinel, orthopyroxene and diopside at granulite facies conditions. Published age data suggest a Late Ordovician (460–445 Ma) age of the UHP metamorphism, interpreted to be related to subduction of Baltoscandian continental margin underneath an outboard terrane, possibly outermost Laurentia, during the final stages of closure of the Iapetus Ocean. The UHP rocks were emplaced from the hinterland collision zone during Scandian thrusting of the nappes onto the Baltoscandian foreland basin and platform. The record of P–T conditions and geochonological data from UHP rocks occurring within the allochthonous units of the Scandinavian Caledonides indicate that Ordovician UHP events may have affected much wider parts of the orogen than previously thought, involving deep subduction of the continental crust prior to final Scandian collision between Baltica and Laurentia.

1. Introduction

Eclogites play an important role in reconstructions of global orogenic processes. This is because their mineralogy reflects physical and chemical transformations that have taken place under high (HP) and ultrahigh-pressure (UHP) metamorphic conditions, during collision between continent–continent or continent–oceanic plates. In addition, a wide range of exhumation processes post-dating (U)HP metamorphism, can bring eclogites (and their surrounding country rocks) back to the surface of the earth. In some cases, eclogites show their (U)HP assemblages well preserved, and can be used to reconstruct the physical–chemical conditions during collisional processes in orogenic belts (e.g., Faryad et al., 2012; Sajeev et al., 2012). In the following, we will present an example of this approach leading to the first recognition of UHP metamorphism within the Seve Nappe Complex of the Scandinavian Caledonides in central Sweden.

The Scandinavian Caledonides (Fig. 1) offer one of the best opportunities to study the role of UHP metamorphism during orogenesis. Already many years ago, occurrences of eclogites were described by Eskola (1921) from southwestern Norway, now called the Western Gneiss Region (WGR, e.g. Cuthbert et al., 2000). Subsequently, compelling evidence for their metamorphic origin and widespread occurrence was found throughout much of the WGR (e.g. Gjelsvik, 1952; Griffin and Råheim, 1973; Bryhni et al., 1977; Krogh, 1977; Griffin et al., 1985; Griffin, 1987). Discovery of coesite in the WGR (Smith, 1984; Wain, 1997) followed by that of micro-diamond (Dobrzhinetskaya et al., 1995; Van Roermund et al., 2002) and majoritic garnet (Van Roermund and Drury, 1998; Scambelluri et al., 2010) provided unequivocal evidence for UHP metamorphism within the hinterland of the Scandinavian Caledonides. For more details concerning this topic the reader is referred to recent reviews by Carswell and Cuthbert (2003) and Hacker et al. (2010). Eclogites were also discovered in the Caledonian nappes belonging to the Seve Nappe Complex (SNC), exposed in the Swedish Caledonides of northern Jämtland (Zwart, 1974). In

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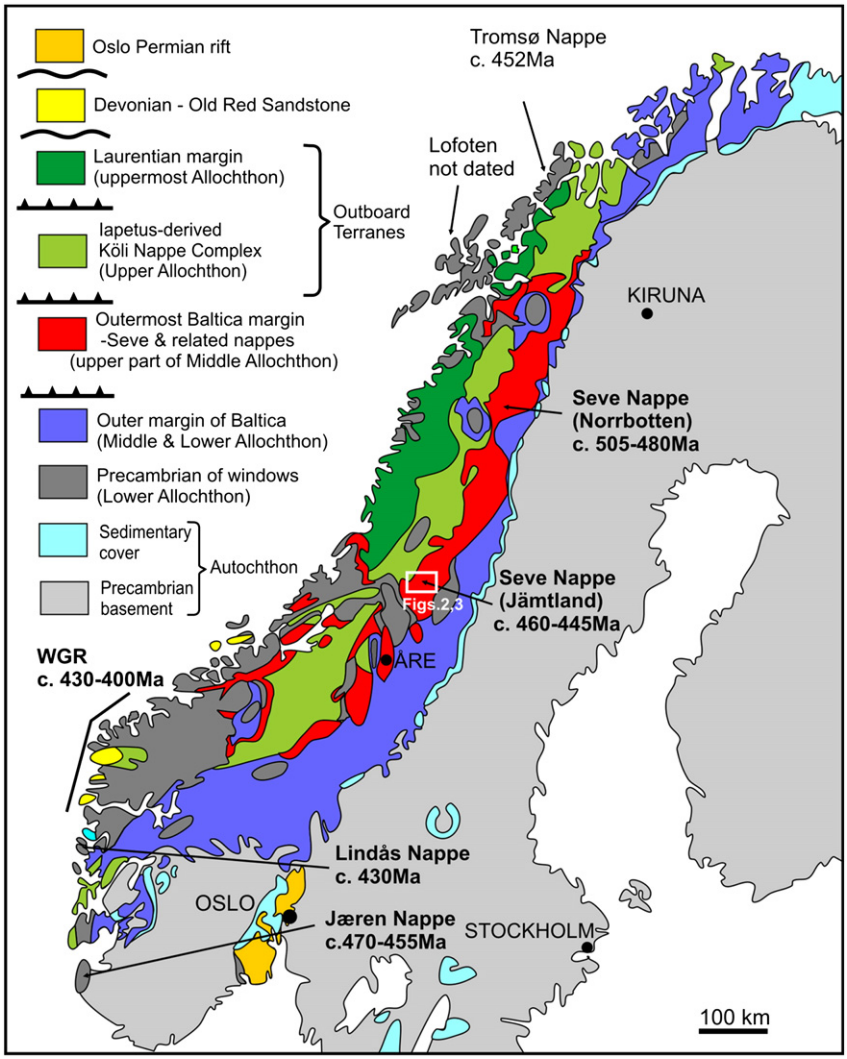

Fig. 1. Tectonic map of the Scandinavian Caledonides with eclogite occurrences, modified from Gee et al. (2008).

contrast to the Western Gneiss Complex, it has been demonstrated that the SNC has been emplaced far eastwards over the Baltoscandian margin, including the foreland basin and platform sediments that now occur in the lower nappes and underlying autochthon (Gee, 1975). These "foreland" eclogites were subsequently found to be relatively widespread in the SNC (Van Roermund, 1982; Van Roermund and Bakker, 1983; Andréasson et al., 1985; Van Roermund, 1985; Kullerud et al., 1990). It has been inferred that they were generated during Ordovician subduction of the Baltoscandian continental margin (Dallmeyer and Gee, 1986; Mørk et al., 1988; Andréasson, 1994; Brueckner and Van Roermund, 2004, 2007), i.e. prior to initial Scandian collision and the subsequent (late Scandian) generation of the WGR eclogites (Kylander-Clark et al., 2009).

This paper presents the evidence for UHP metamorphism within the SNC based on mineralogical/petrological features, thermobarometric calculations and thermodynamic modelling performed on a newly discovered kyanite-bearing eclogite (Majka and Janák, 2011), enclosed within a garnet peridotite body in northern Jämtland (Figs. 2, 3). This new identification of UHP metamorphism has profound implications for unravelling the mode of continental subduction and emplacement of UHP rocks in the Scandinavian Caledonides, from their generation in the deeply subducted outermost margin of continent Baltica, far to the west of today's WGR, to their accommodation in the allochthonous units following their transport onto the platform.

2. Geological background

The early to mid Paleozoic Scandinavian mountain belt (Fig. 1), comprising the eastern flank of the North Atlantic Caledonides, resulted from the Cambro–Ordovician closure of the Iapetus Ocean and collision between the continents Laurentia and Baltica in the Silurian, with the latter being subducted below the former. Convergence continued into the Devonian, with hinterland uplift and collapse of the mountain belt (Gee et al., 2008). Major allochthons containing HP/UHP rocks occur in both the East Greenland and the Scandinavian Caledonides, being thrust westwards in the former at least 100 km and eastwards in the latter, for substantially greater distances. In the Scandinavian Caledonides, the eclogite-bearing SNC can be followed more than 1000 km along the length of the orogen (Fig. 1). Metasedimentary units in the SNC are dominated by psammites in the lower parts, giving way upwards into more semi-pelitic to pelitic units. Amphibolitized dolerites and gabbros are abundant and the latter are sometimes associated with ultramafites. The SNC is underlain by lower grade units of the Middle and Lower Allochthons and overthrust by the Köli Nappes of the Upper Allochthon, which are Iapetus ocean-related terranes.

There are at least two areas within the SNC where eclogites occur (Fig. 1). The first one is located in the southern parts of Norrbotten where the HP rocks occur within the so-called Vaimok and Tsäkkok