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Revised tectono-stratigraphic scheme for the Scandinavian Caledonides and its implications for our understanding of the Scandian orogeny

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ABSTRACT

The Scandinavian Caledonides formed during the continental collision between Baltica and Laurentia. During the collision, a complex nappe stack was thrust over the Baltican continental margin. The orogen can be subdivided into segments based on architectural differences within the Scandian nappes. The southern and central segments of the orogen link up in the Gudbrandsdalen area in south-central Norway. Alpine-type metaperidotite-bearing metasedimentary complexes occur in the southern and central segments and can be traced continuously along the strike of the orogen from one into the other segment. Traditionally, these units have been assigned to different tectono-stratigraphic levels, one below the Middle Allochthon and one above the Middle Allochthon. Here, we trace the Alpine-type metaperidotite-bearing units from Bergen to Esandsjøen and show that these units exhibit a common geologic and metamorphic history, consistent with the metaperidotite-bearing units representing a single tectonic unit. We suggest that the metaperidotite-bearing units can be used as a "marker level" to revise the tectono-stratigraphy of the Gudbrandsdalen and adjacent areas. The tectono-stratigraphic revisions imply that the Scandian nappe stack consists of seven tectono-stratigraphic levels that can be traced throughout the southern

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and central segments of the Scandinavian Caledonides. Moreover, the revision of the tectono-stratigraphy and new U-Pb geochronology data also suggest a revision of the timing of the succession of tectonic events leading up to the Scandian continental collision. The available evidence indicates that Baltica-derived tectonic units collided with the Iapetan/Laurentian subduction complexes as early as ca. 450 Ma. The initial collision was followed by in-sequence nappe formation of Baltican-derived units, which occurred contemporaneously with the opening of a marginal basin in the upper plate. After the arrival of thick, buoyant, unthinned Baltican crust at the trench, the main zone of convergence stepped outboard, the marginal basins closed, and those basins were thrust out-of-sequence over the previously assembled nappe stack.

INTRODUCTION

The Scandinavian Caledonides are an archetypal Himalayan-type orogen that was assembled during the continental collision between Laurentia and Baltica during the Silurian–Devonian, i.e., the Scandian orogeny. The collision was preceded by protracted subcretion/accretion of terranes to the front of the Laurentian plate during the initial stages of Cambrian–Silurian closure of the Iapetus Ocean and shortening of the Baltican rifted margin. During the Scandian collision, the margin of Baltica was deeply buried beneath the leading edge of Laurentia, which in turn, together with the accreted terranes, was thrust onto Baltica. The remnants of these tectonic units were thrust over the Baltican margin to form the nappe stack of the Scandinavian Caledonides.

It is commonly accepted that the nappes were stacked and transported toward the east/southeast over the margin of Baltica (e.g., Fossen, 1993) and that units in tectono-stratigraphically higher levels originated further outboard (with respect to Baltica) than units in tectono-stratigraphically lower levels. Traditionally, the nappe stack is divided into four belt-long allochthonous levels, i.e., the Lower, Middle, Upper, and Uppermost Allochthons (Roberts and Gee, 1985). The allochthonous levels were originally used for correlating numerous lithotectonic units along strike of the orogen, but the scheme was later also used to indicate their paleogeographic origins (Stephens and Gee, 1989). The Lower and Middle Allochthons were interpreted to have Baltican ancestries, whereas the Upper Allochthon was assumed to have been derived from the Iapetus Ocean, and the Uppermost Allochthon was interpreted to have Laurentian origins.

The integration of a lithotectonic unit into one of the allochthonous levels is commonly based on the regional tectono-stratigraphic succession, lithologic composition, biostratigraphic/geochronologic affinities, age, and metamorphic grade. Oceanic assemblages commonly occur in higher tectono-stratigraphic levels and locally may contain geochronologic or paleontologic evidence for an exotic origin with respect to Baltica (e.g., Bruton and Bockelie, 1980; Pedersen and Dunning, 1997; Ryan et al., 1980; Wilson, 1966). Continentally derived units, such as thick sedimentary successions or continental orthogneisses at low tectono-stratigraphic levels, frequently show stratigraphic or geochronologic similarities with the Baltican (par)autochthon and are commonly assigned to the Middle or Lower Allochthon.

Locally, however, the traditional allochthon scheme appears to be too rigid, and the assignment of all lithotectonic units into just four allochthonous levels does not reflect the complexity of the Scandinavian Caledonides. The limitations of the fourfold allochthon scheme are exemplified in the Gudbrandsdalen area, where lithologically similar units of presumed different allochthonous levels are juxtaposed (Fig. 1). The Gudbrandsdalen area links the southern and central segments of the Scandinavian Caledonides and is therefore a key area for the understanding of the architecture and evolution of the orogen. The architecture of the nappe stack in the southern and south-central segment is characterized from top to bottom by (1) ophiolite, volcanic-arc, and marginal basin assemblages (e.g., Meråker, Gula, Støren Nappes); (2) continental, predominantly crystalline, nappe units of Baltican affinity (e.g., the Jotun, Lindås, and Dalsfjord nappe complexes); (3) Alpine-type metaperidotite-bearing units (e.g., the Fortun Nappe); and (4) Neoproterozoic and younger continentally derived metasediments (Lower and lower Middle Allochthons). Other Alpine-type metaperidotite-bearing units also occur in the south-central segment of the Scandinavian Caledonides, but these have been included into nappes interpreted to be in a structural level above the Jotun Nappe, e.g., the Blåhøa, Esandsjøen, or Meråker Nappe. In Gudbrandsdalen, the metaperidotite-bearing assemblages of the southern and central segments converge and are in contact with each other (Fig. 1). The Jotun Nappe Complex terminates in northern Gudbrandsdalen, and the metaperidotite-bearing assemblages further north (Blåhøa, Esandsjøen, Meråker Nappes) are structurally overlain by volcanic-arc, ophiolite, and marginal basin assemblages of the Trondheim Nappe Complex. Traditionally, the metaperidotite-bearing units structurally below the Trondheim Nappe Complex are included in the Upper Allochthon (or upper Middle Allochthon). However, those structurally below the Jotun Nappe are traditionally included in a structural level below the Middle Allochthon (Fig. 1).

Elsewhere in the Caledonides, the Upper and Lower Allochthons are locally juxtaposed along major NE-trending structures such as late to post-Scandian extensional detachments and normal faults like the Hardangerfjord shear zone or along detachments that developed along the margins of the basement windows (e.g., Wiest et al., 2020). However, the contact between the Upper and Lower Allochthons in Gudbrandsdalen strikes NW, which is normal to the nearby NE-striking contact of the nappes with the Western Gneiss Region. Moreover, the juxtaposition of the Upper and Lower Allochthons in Gudbrandsdalen would suggest a normal displacement of several kilometers. However, no evidence has been mapped for a large-scale shear zone or normal fault along this contact. Despite the problematic juxtaposition of the Lower and Upper Allochthons, it is commonly suggested that two (or more) metaperidotite-bearing assemblages from the Lower and Upper Allochthons are in close proximity in the Gudbrandsdalen area (Fig. 1; e.g., Corfu and Heim, 2020).

Attempts to include the metaperidotite-bearing units below the Jotun Nappe Complex within the Upper Allochthon are commonly centered around two tectonic models: In the first model, the metaperidotite-bearing unit below the Jotun Nappe Complex represents a tectonic mélange and was formed during Scandian thrusting (e.g., Slagstad and Kirkland, 2018). In the second model, the continental units may have been thrust back over originally structurally higher tectonic units during the orogenic collapse and back-sliding of the nappes to the west (present-day coordinates); see, e.g., discussion in Corfu and Heim (2020). However, both models require the addition of complex Scandian tectonic movements to eventually place the continental basement/cover units structurally above the metaperidotite-bearing unit, for which field evidence is lacking.

Although diverging from the traditional allochthon scheme, the simplest possible tectonic model suggests a paleogeographic position of the Jotun, Lindås, and Dalsfjord Nappes outboard of the metaperidotite-bearing units before onset of Scandian thrusting (Andersen et al., 2012, 1991; Jakob et al., 2019, 2017). A tectonic model in which the continental units were outboard of the metaperidotite-bearing units implies that the metaperidotite-bearing assemblages represent one tectonic unit that can be traced continuously structurally below the Lindås and Jotun Nappe Complexes, across the Gudbrandsdalen area, and structurally below the Trondheim Nappe Complex.

In this study, we investigated whether there is evidence for the presence of two or more metaperidotite-bearing units between Bergen and Esandsjøen (Fig. 2) that are juxtaposed in the Gudbrandsdalen area or whether the metaperidotite-bearing units are better interpreted to represent one single continuous tectonic unit. To test whether the metaperidotite-bearing assemblages represent

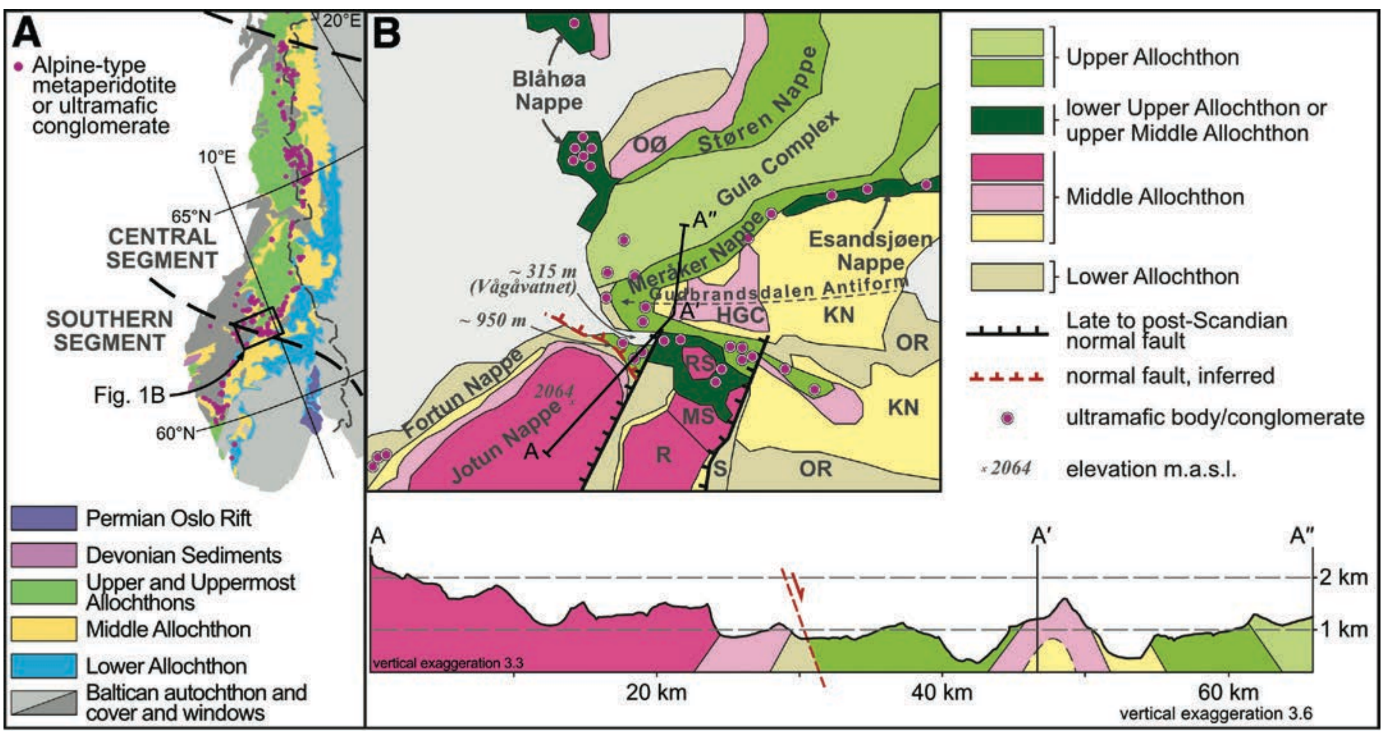

Figure 1. Tectono-stratigraphic sketch maps of (A) the south and central Scandinavian Caledonides and (B) northern Gudbrandsdalen. Note the change in the architecture of the nappe stack from the southern into the central segment in A. Note also the distribution of solitary metaperidotites within mica schists between the Middle and Upper Allochthons. In the Gudbrandsdalen area (B), the traditional allochthonous levels are indicated in greater detail. Note the juxtaposition of the Lower Allochthon with the Upper Allochthon along a NW-striking contact, which implies the excision of several structural levels. The tectonic contact is here inferred to be a late/post-Scandian normal fault. Note also that the Middle Allochthon in the southwest is more than 1 km higher in elevation than the Upper Allochthon. HGC—Høvringen Gneiss Complex; KN—Kvitvola Nappe Complex; MS—Mukampen Suite; OR—Osen-Røa Nappe Complex; R—Refjellet; S—Synnfjell Nappe; RS—Rudihø Suite; OØ—Oppdal Øyegneiss; m.a.s.l.—meters above sea level.

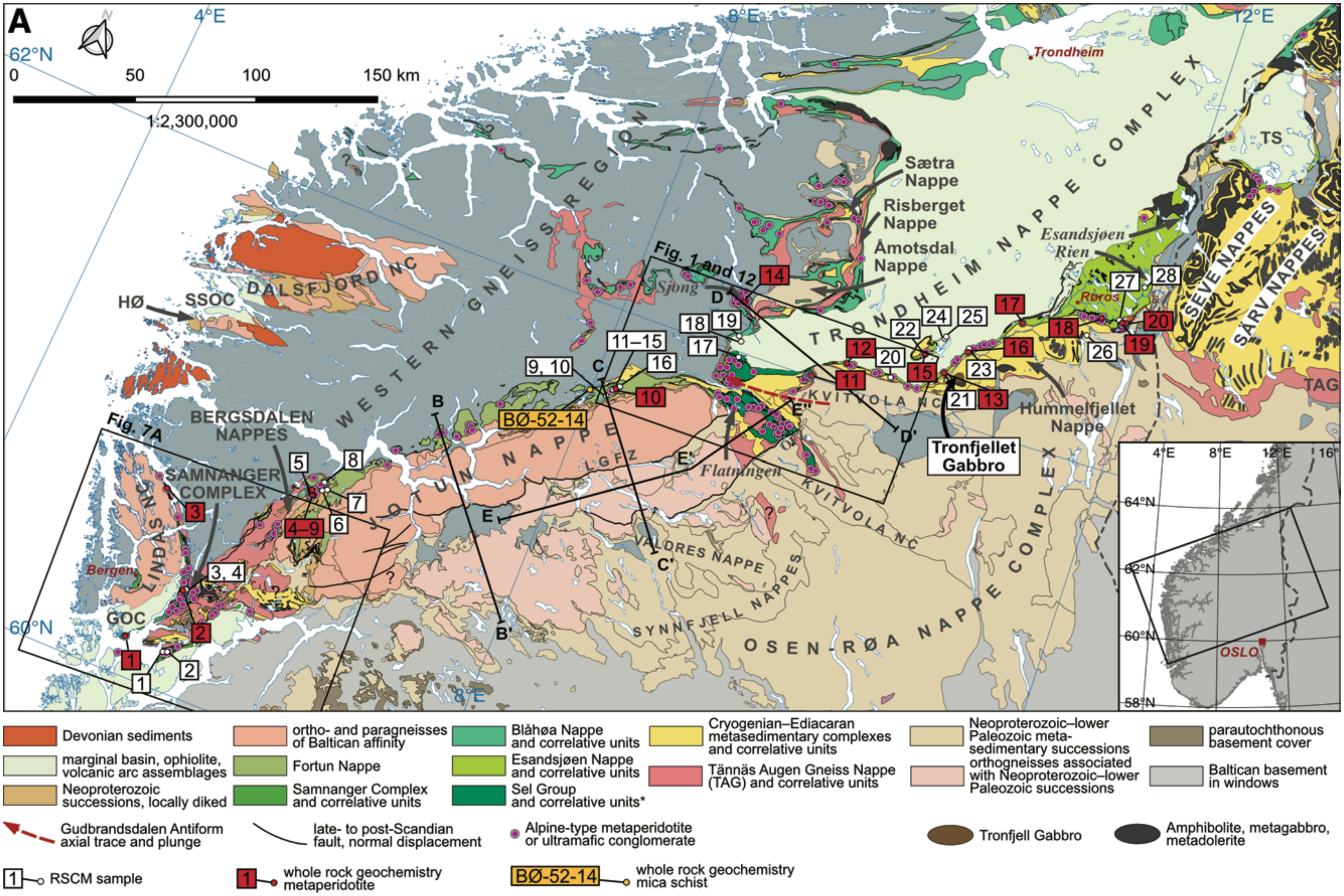

Figure 2. (A) Geologic map of the southern and south-central segments of the Scandinavian Caledonides between Bergen and Trondheim and sample locations for Raman spectra of carbonaceous material (RSCM) analyses (white), thermodynamic modeling (yellow), and whole-rock geochemistry of the metaperidotites (red). (*Continued on facing page.*)

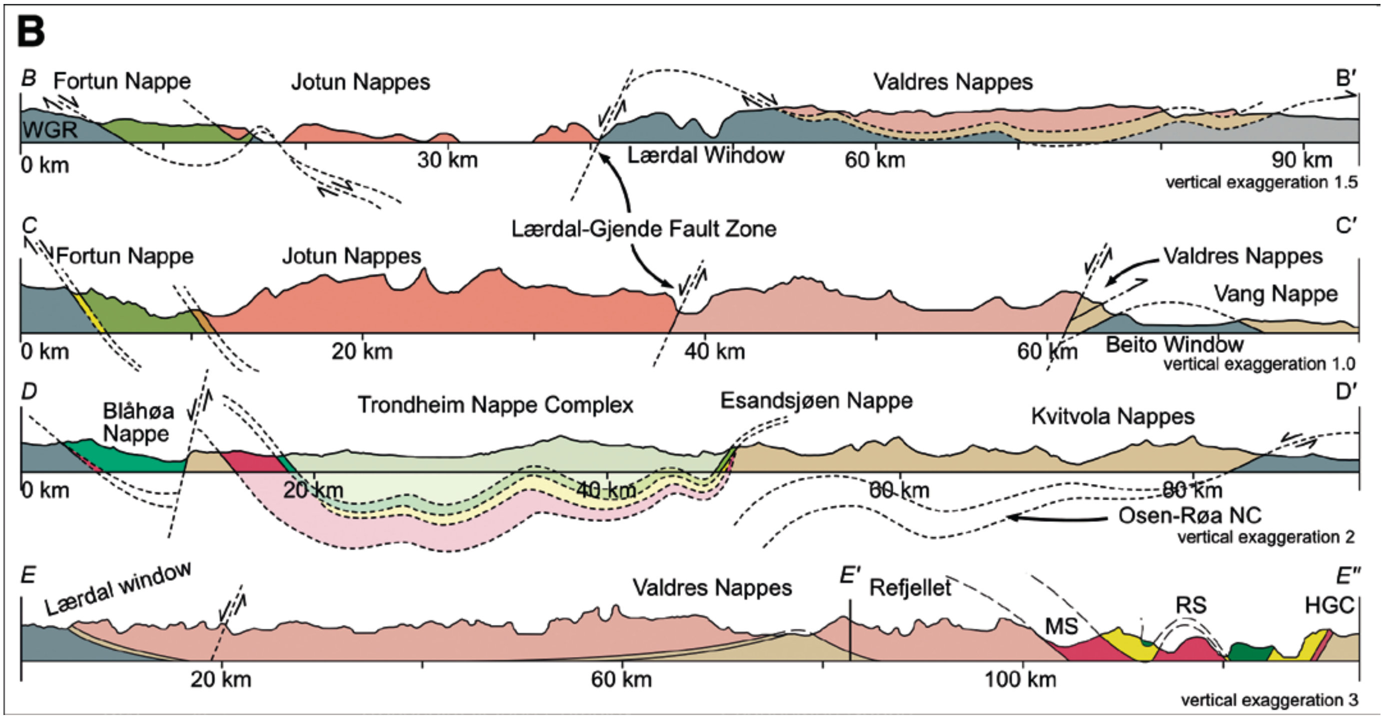

Figure 2 (*Continued*). (B) Simplified geologic profiles across the Faltungsgraben (profiles A, B, C) and parallel to and in the footwall of the Lærdal-Gjende fault zone (profile D). GOC—Gullfjellet ophiolite complex; HGC—Høvringen Gneiss Complex; HØ—Høyvik Group; LGFZ—Lærdal-Gjende fault zone; MS—Mukampen Suite; NC—Nappe Complex; OFZ—Olestøl fault zone; RS—Rudihø Suite; SSOC—Solund-Stavfjord ophiolite complex; TAG—Tännäs Augen Gneiss; TS—Tännforsen synform; WGR—Western Gneiss Region.

a single tectonic unit, we present a review of the published literature, new field observations, whole-rock geochemical data from the metaperidotite bodies, and peak metamorphic temperature estimates from the surrounding mica schists.

The available evidence presented below suggests that the metaperidotite-bearing units represent a single tectonic unit. Because this interpretation conflicts with the traditional presumed structural positions of the metaperidotite-bearing units, a revision of the Lower, Middle and Upper Allochthons is also presented. Following the revision of the tectono-stratigraphy in the Gudbrandsdalen and adjacent areas, we discuss a continuation of the newly defined tectonic levels throughout the central segment of the Scandinavian Caledonides. Furthermore, we discuss the implications of the revised tectono-stratigraphy on the timing of nappe formation and the succession of tectonic events that occurred during the Scandian orogeny. The tectonic model for the formation of the Scandian nappe stack is further refined by new U-Pb geochronology data from mafic intrusive units within the metaperidotite-bearing unit and from structurally lower Neoproterozoic successions.

Note on Terminology—Alpine-Type Metaperidotite-Bearing Units in the Scandinavian Caledonides

Ultramafic rocks occur in almost all tectono-stratigraphic levels in the Scandinavian Caledonides and have been categorized based on their geochemical composition, petrography, and textural setting (Qvale and Stigh, 1985). With reference to Qvale and Stigh (1985) sensu lato, we categorized the ultramafic rocks into four groups:

(1) Basal ultramafic zones of ophiolite–island-arc units of the Iapetus Ocean (Færseth et al., 1977; Furnes et al., 1990, 1980; Gale and Roberts, 1974, 1972; Kvassnes et al., 2004; Munday, 1974; Prestvik, 1980; Slagstad et al., 2014; Sturt and Thon, 1978).

(2) Ultramafic bodies and xenoliths associated with mafic/ultramafic magmatism other than the crystallization of oceanic crust. Ultramafic magmatism and xenoliths have been reported, for example, from the Seiland igneous province (Bennett et al., 1986; Grant et al., 2016; Griffin et al., 2013; Larsen et al., 2018; Robins, 2013). Ultramafic xenoliths have also been reported from layered mafic complexes elsewhere in the Caledonides, including the Halti igneous complex and the Tronfjell, Fongen-Hyllingen, and Råna layered mafic complexes (Andréasson et al., 2003; Boyd and Mathiesen, 1979; Nilsen et al., 2007; Wellings, 1996; Wellings and Sturt, 1998; Zwaan, 1988).

(3) Ultramafic bodies suggested to have a mantle-wedge origin. Ultramafites of this category have been proposed to occur in the Western Gneiss Region and in the Seve Nappe Complex (Andersen et al., 1991; Brueckner, 2018; Gilio et al., 2015). These ultramafic bodies experienced (ultra)high-pressure [(U)HP] metamorphism, are commonly associated with eclogite-facies rocks, and typically occur along major shear zones.

(4) Alpine-type ultramafic bodies and associated pre-Scandian metasediments of ultramafic composition. These are solitary, ultramafic, lens-shaped metaperidotite bodies that lie concordantly within metasedimentary complexes. Evidence for contact aureoles around the ultramafics is lacking. The margins of the ultramafic bodies are commonly developed as blocky serpentinite sensu Hirauchi and Yamaguchi (2007) and soapstone. The metaperidotite bodies and the surrounding metasediments are isofacial; that is, they experienced a common Scandian metamorphic overprint. Some solitary ultramafic bodies occur in association with (near-)monomict, locally fossiliferous, pre-Scandian (approximately lower Middle Ordovician) ultramafic metasediments. Local monomict meta-conglomerates of ultramafic composition that are assumed to be of Devonian age (Røragen area) and that were deposited during or after the orogenic collapse of the Scandian orogen are not included in this group.

In the Scandinavian Caledonides, the Alpine-type ultramafites are commonly poor in Al_2O_3 (<3.8 wt%) and CaO (<1.38 wt%) and characterized by SiO_2/MgO ratios of ~1 and MgO/FeO ratios of >5 (e.g., Enger, 2016; Stigh, 1979; this study). These ultramafites have been referred to as primitive ultramafites and appear to be genetically unrelated to mafic rocks locally associated with the ultramafites or their host rocks (Stigh, 1979). Other pre-Scandian metaperidotites and ultramafic conglomerates occur in nappe complexes in structurally higher tectono-stratigraphic levels (e.g., the Gula, Helgeland, and Rødingsfjell Nappe Complexes). Most of those ultramafic bodies and ultramafic metasediments, however, can be distinguished from the primitive ultramafites by higher Al_2O_3 (>4.5 wt%) and CaO (>4.7 wt%) contents as well as SiO_2/MgO ratios of ~2 and MgO/FeO ratios of <5 (commonly ~2.5; Stigh, 1979). Stigh (1979) referred to these ultramafic rocks as nonprimitive and regarded them as restites after differentiation of basaltic magmas.

PRECAMBRIAN–LOWER PALEOZOIC UNITS

Autochthonous Basement and Cover

The Baltican (para-)autochthonous basement occurs to the east of the Scandian nappes and in tectonic or erosional windows. Its principal Precambrian components include an Archean core, which is surrounded by the Paleoproterozoic and Mesoproterozoic Svecofennian and Sveconorwegian domains. In the southern segment, the basement is mostly Mesoproterozoic–Neoproterozoic in age; in the central segment, the basement is mostly Mesoproterozoic to Paleoproterozoic in age; and in the northern segment, the basement gneisses are as old as Archean (Bergh et al., 2007; Bingen et al., 2015, 2011, 2008; Bingen and Solli, 2013; Corfu et al., 2003a; Corfu and Andersen, 2016; Krill et al., 1985; Kullerud et al., 2006; Levchenkov et al., 1993; Melezhik et al., 2015; Myhre et al., 2013; Zozulya et al., 2009).

The Baltican basement is unconformably covered by Neoproterozoic–Lower Paleozoic metasedimentary successions. In the southern segment, these successions (Fig. 3) begin with a glacial deposit at the base (Moelv Formation), which belongs to the Neoproterozoic Hedmark Group (Nystuen et al., 2008). The age of the glacial deposits is uncertain, and a Marinoan (ca. 635 Ma; e.g., Hoffmann et al., 2004) or Gaskiers (ca. 580 Ma; e.g., Pu et al., 2016) age is discussed in the literature (Bingen et al., 2005; Halverson et al., 2005; Lamminen et al., 2015; Nystuen et al., 2008; Nystuen and Lamminen, 2011). The Moelv Formation is covered by a conformable and transgressive marine shale (Ekre Shale), which in turn is overlain by shallow-marine sandstones of the Vangsås Formation. The latter contains the Ediacaran-Cambrian boundary.

In the central segment and southern part of the northern segment, the Precambrian basement cover successions are referred to as the Dividalen Group (e.g., Andresen et al., 2014; Kirkland et al., 2011; Nystuen et al., 2008). These successions occur along and below the erosional front of the Scandian nappes as well as in basement windows (Andresen et al., 2014; Føyn and Glaessner, 1979; Nystuen et al., 2008). It preserves a transgressive sequence that is believed to have been deposited after the Marinoan/Gaskiers glaciations (Torneträsk Formation; Fig. 3). The sedimentary successions of the Dividalen Group (Andresen et al., 2014; Axheimer et al., 2007; Banks, 1973; Jensen and Grant, 1998; Kirkland et al., 2011; Thelander, 1982; Thickpenny, 1984) begin with unfossiliferous fluvial sandstones and alluvial

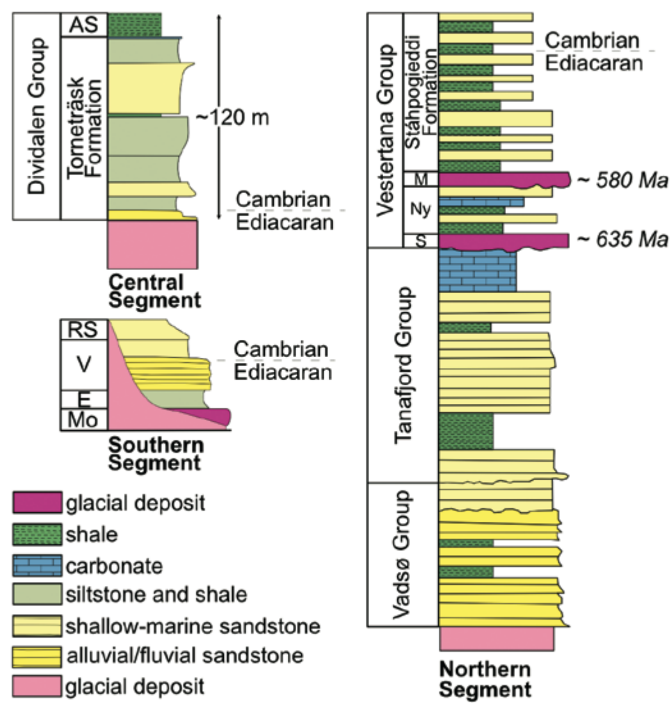

Figure 3. Stratigraphic columns of the autochthonous sedimentary successions in the southern segment, in the northern part of the central segment, and in the Varanger-Tanafjord region in the northern segment, modified after Axheimer et al. (2007) and Nystuen et al. (2008). Mo—Moelv Formation; E—Ekre Shale; V—Vangsås Formation; RS—Ringstrand Formation; AS—Alum Shale Formation; S—Smalfjord Formation; Ny—Nyborg Formation; M—Mortensnes Formation.

conglomerates at the base that are suspected to be Ediacaran in age. Higher in the successions, there occur fossiliferous coastal and shelfal deposits of Cambrian age, which in turn are overlain by the Middle Cambrian Alum Shale Formation. Locally, the transgressive successions are underlain by discontinuous remnants of tillite (Føyn, 1967; Winchester, 1988). The Dividalen Group can be traced over large distances along the erosional front of the Scandinavian Caledonides, and it is suggested that the Dividalen Group links up with the postglacial autochthonous successions of the southern segment (e.g., Winchester, 1988).

Elsewhere in the northern segment, the parautochthonous cover preserves relatively intact sequences from the (Tonian–?) Cryogenian into the middle Cambrian. In the Tanafjord-Varangerfjord region, these parautochthonous sedimentary successions include the Vadsø, Tanafjord, and Vestertana Groups (Fig. 3; Banks et al., 1974; Högström et al., 2013; Hybertsen, 2017; Reading, 1965; Rice et al., 2011; Rice and Townsend, 1996; Roberts and Siedlecka, 2012; Siedlecka and Siedlecki, 1971; Stodt et al., 2011). The Vadsø Group consists of several formations of ~600–800 m of alternating sandstone and siltstone, thought to be deposited in the Tonian or Cryogenian. The sandstones are interpreted to be largely of fluvial origin. At the base of the Vadsø Group, however, shallow-marine sandstone also occurs. The siltstones are interpreted to represent deltaic marine deposits, although some may be of lacustrine origin (Banks et al., 1974). Unconformably overlying the Vadsø Group, there are successions of the Tanafjord Group. The metasediments of the Tanafjord Group consist of ~1500 m of sandstone and shale formations that are locally intercalated with conglomeratic layers. At the top of the Tanafjord Group, there is a carbonate unit. The sedimentary successions of the Tanafjord Group are interpreted to represent shallow-marine deposits that were deposited in the Tonian(?) and Cryogenian.

The Vestertana Group, which includes Cryogenian–Cambrian sedimentary successions of glaciogenic and shallow-marine origin, overlies the Tanafjord Group with an angular unconformity (Högström et al., 2013; Reading, 1965; Siedlecka and Siedlecki, 1971). At the base of the Vestertana Group, there is a diamictite commonly interpreted to be of glaciogenic origin (Halverson et al., 2005), the Smalfjord Formation. However, Arnaud and Eyles (2004) also suggested a rift-infill setting for the deposition of these sediments because of the lack of unequivocal evidence of the influence of glacial ice during deposition. The Smalfjord Formation is overlain by ~400 m of fluvial and marine sediments of the Nyborg Formation (Reading, 1965). Carbonates from the Nyborg Formation have been suggested to represent cap carbonates deposited at the end of the Marinoan glaciation, which is corroborated by negative $\delta^{13}C$ anomalies in the sediments above and below the Smalfjord Formation (Halverson et al., 2005; Rice et al., 2011). Above the Nyborg Formation, there is another glaciogenic sediment, the Mortensnes Formation, which has been suggested to be related to the Gaskiers glaciation (e.g., Halverson et al., 2005; Rice et al., 2011). Stratigraphically overlying the Mortensnes Formation, there are shallow-marine deposits of the Stáhpogieddi Formation, which are interpreted to represent a foreland basin that developed ahead of the deformation front of the Timanian orogen (Gorokhov et al., 2001; Nielsen and Schovsbo, 2011; Roberts and Siedlecka, 2002). The Ediacaran-Cambrian boundary is preserved within the upper part of the Stáhpogieddi Formation (Högström et al., 2013).

Allochthonous Neoproterozoic–Lower Paleozoic Metasedimentary Complexes in the Southern and Central Segments

Neoproterozoic–Lower Paleozoic metasedimentary successions occur in several of the major thrust nappes that were stacked on top of each other during the Scandian orogeny, and they are traditionally assigned to the Lower and Middle Allochthons. The metasedimentary complexes in the Lower Allochthon include, e.g., the Osen-Røa Nappe Complex. In the Middle Allochthon, these successions include the Valdres and Kvitvola Nappe Complexes (e.g., Gee and Stephens, 2020a; Heim et al., 1977; Kumpulainen and Nystuen, 1985; Milnes and Koestler, 1985; Nickelsen et al., 1985; Nystuen, 1980, 1983, 1987; see Fig. 2).

The lower thrust sheets in the southern segment, such as the Osen-Røa Nappe Complex, preserve the sedimentary successions of the Hedmark Basin, which can be subdivided into western and eastern facies (Fig. 4). The lower part of the western Hedmark Basin is dominated by >4-km-thick successions of deep-marine turbiditic sandstone and shale (Brøttum Formation; Fig. 4). In the eastern part of the Hedmark Basin, the lower successions are dominated by >4-km-thick successions of red-colored, coarse-grained, arkosic fluvial-alluvial sandstones and conglomerates (Fig. 4), referred to as the Rendalen Formation. These and similar coarse-clastic Neoproterozoic successions in southern Norway and Sweden are commonly referred to as sparagmites (Esmark, 1829). Individual detrital zircon grains with U-Pb ages of ca. 630–610 Ma have been reported from the Brøttum and Rendalen Formations (Bingen et al., 2005; Lamminen et al., 2015). However, because no zircon-bearing magmatic rocks of that age range have so far been reported from the Baltican basement below these nappes, the source of these detrital zircons remains uncertain, and whether or not they can be used to indicate a maximum depositional age has been questioned (Lamminen et al., 2015).

In the western Hedmark Basin, the deep-marine sediments of the Brøttum Formation are locally overlain by organic-rich shales and carbonates of the Biri Formation (Fig. 4). In the eastern Hedmark Basin, the arkosic sediments of the Rendalen Formation are overlain by quartz-arenitic, shallow-marine sandstones of the Atna Formation as well as by rocks of the Biri Formation (Fig. 4). Locally, the Neoproterozoic siliciclastic successions are associated with subordinate volumes of undated mafic igneous rocks, described as continental tholeiites and referred to as "Sparagmite Basalts" (Andresen and Gabrielsen, 1979; Furnes et al., 1983). The Sparagmite Basalts include intrusive rocks as well as a basaltic lava flow overlying the Atna Formation (Sæther and Nystuen, 1981).

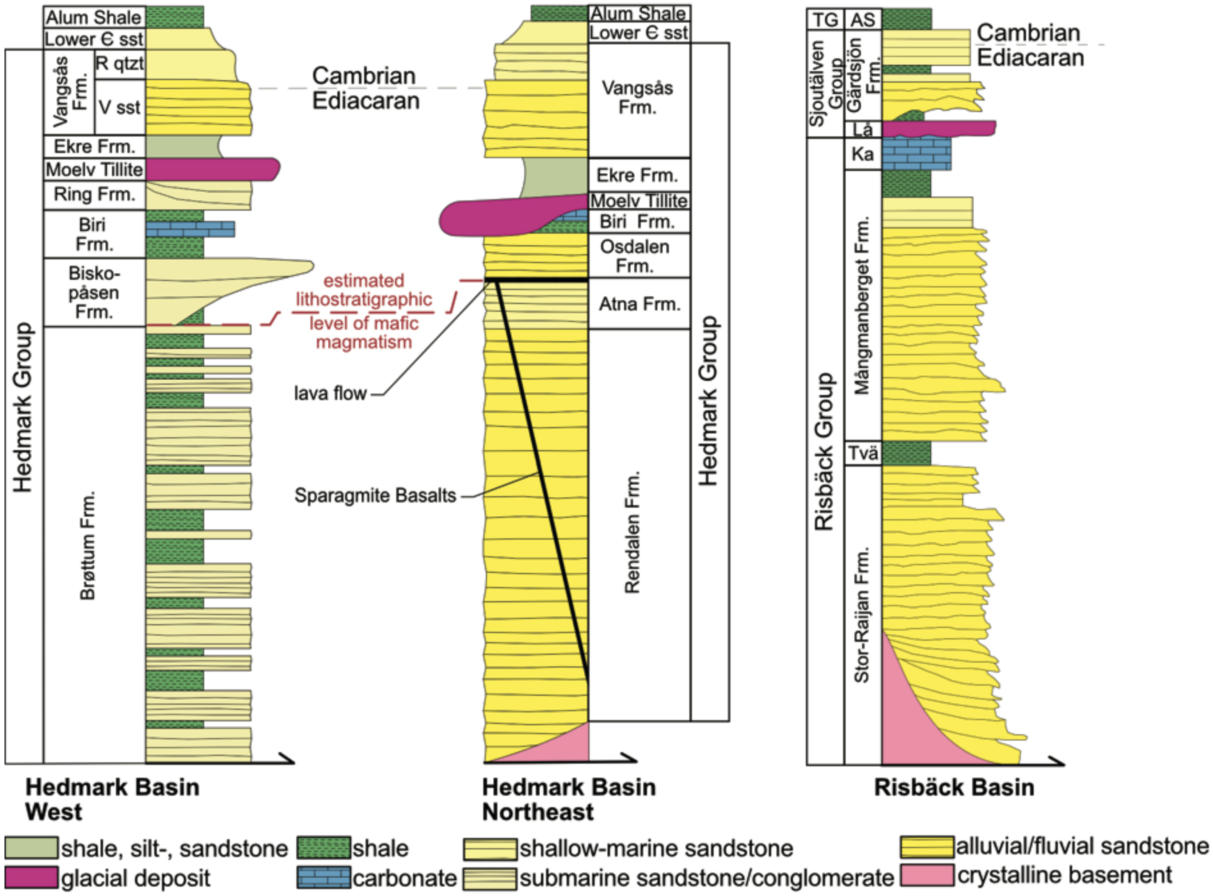

Figure 4. Stratigraphic columns of the Precambrian–Cambrian successions in the Hedmark and Risbäck basins, modified after Nystuen (2008) and Nystuen et al. (2008). R qtzt—Ringsaker Quartzite; V sst—Vardal Sandstone; lower Є sst—Lower Cambrian sandstone; TG—Tåsjön Group; AS—Alum Shale Formation; Lå—Långmarkberg Formation; Ka—Kalvberget Formation; Tvä—Tvärselet Formation; Frm—Formation.

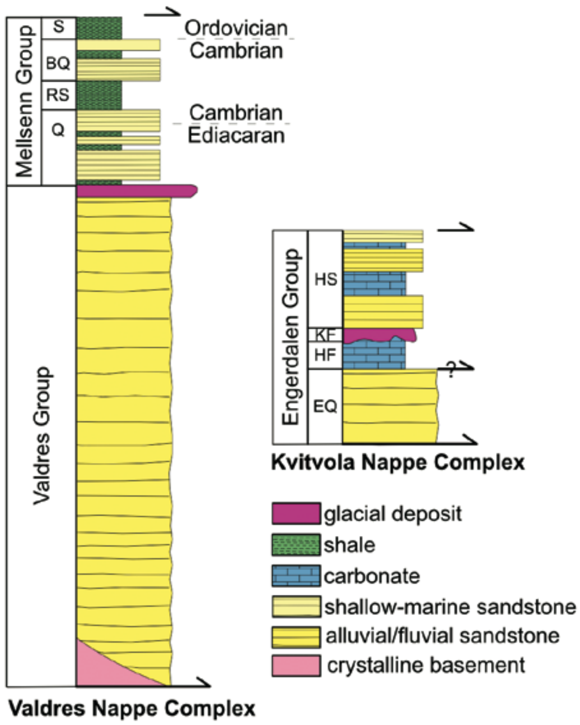

Figure 5. Stratigraphic columns of the Neoproterozoic–Lower Paleozoic successions in the Valdres and Kvitvola Nappe Complexes, modified after Nickelsen et al. (1985) and Nystuen (1980). S—Slate; BQ—Blue Quartz; RS—Roofing Slate; Q—quartzite; EQ—Engerdalen Quartzite; HF—Hylleråsen Formation; KF—Koppang Formation; HS—Høyberget Sandstone.

During early sedimentation of the Biri Formation, prograding conglomeratic submarine fans were deposited in the basin and are referred to as the Biskopåsen Formation. These conglomerates are composed of reworked material from the lower units of the Hedmark Group and include clasts of the Biri Formation as well as mafic rocks akin to the Sparagmite Basalts. The Biskopåsen Formation may be correlated with the conglomerates of the Osdalen Formation above the Atna Formation in the eastern Hedmark Basin. The Biri and Biskopåsen Formations contain a diverse assemblage of acanthomorphic acritarchs that show great similarities to the acritarch faunal assemblage zones of, for example, the Ediacaran Doushantou Formation in South China (Adamson, 2016).

In the western Hedmark Basin, the Biri Formation is overlain by stacked, coarse-clastic marine channel and lobe infill successions (several meters thick) of the Ring Formation (Fig. 4). Unconformably overlying the Biri and Ring Formations, there are glacial deposits of the Moelv Formation, which in turn are overlain by fan-deltaic shales, siltstones, fluvial sediments, and shallow-marine sandstones of the Ekre and Vangsås Formations. The Ediacaran-Cambrian boundary is preserved in the upper parts of the Vangsås Formation (Fig. 4). Overlying the Hedmark Group, there are Lower Cambrian sandstones and siltstones as well as the Middle Cambrian Alum Shale.

In the central segment, sedimentary successions comparable to those of the Hedmark Group are preserved in the Jämtlandian nappes. The 1.2–4-km-thick Precambrian–Cambrian successions there include the Risbäck and Sjoutälven Groups (Fig. 4; e.g., Gee and Stephens, 2020a). The Risbäck Group is dominated by alluvial, red-colored, arkosic sandstones and conglomerates. At the top of the succession, there is an ~150-m-thick dolomite (Kalvberget Formation) that is unconformably overlain by glacial deposits a few tens of meters thick (Långmarkberg Formation). The latter constitute the base of the Sjoutälven Group. The glacial deposits have been correlated with those in the Hedmark Basin (e.g., Kumpulainen and Nystuen, 1985). Above the glacial deposits, there is the ~300-m-thick Gärdsjön Formation, which consists of quartz-rich sandstone, siltstone, shale, and conglomerate. The lower unfossiliferous part of the Gärdsjön Formation is interpreted to be Ediacaran in age, whereas its upper part is early Cambrian. The Cambrian members of the Sjoutälven Group are overlain by the Tåsjön Group, the lowest part of which is composed of black shales of the Cambrian Alum Shale. Stratigraphically higher, Cambrian–Silurian units of the Jämtlandian successions are not discussed further here.

The Sparagmite nappes of the Lower Allochthon are structurally overlain by other sparagmite-bearing thrust nappes that are traditionally assigned to the Middle Allochthon. In the southern segment, these include the Valdres and Kvitvola Nappe Complexes (Fig. 2). The lithostratigraphic successions of the Valdres Nappe Complex and correlated thrust nappes east of the Lærdal-Gjende fault zone, e.g., Synnfjell Nappe (Nickelsen et al., 1985), include slivers of Precambrian basement, Neoproterozoic coarse-clastic sedimentary successions (Valdres Group), glacial deposits, and Cambrian–Ordovician metapsammites and metapelites (Mellsenn Group; Fig. 5; Hossack et al., 1985; Loeschke, 1967; Nickelsen, 1974; Nickelsen et al., 1985). Locally, the basement slivers are unconformably overlain by the Valdres Sparagmites or the glacial deposits. The Valdres Sparagmites vary greatly in thickness from 14 m to over 4000 m and are composed of conglomerates and arkosic arenites and wackes. Due to the immaturity of the Neoproterozoic successions, as well as their lithologic diversity and variable thickness, a fluvial depositional model in fault-controlled basins near a continental margin has been proposed (Nickelsen et al., 1985). The glacial deposits are at the top of the Neoproterozoic Valdres Sparagmites and have been correlated with the glacial deposits of the Moelv Formation. The Cambrian–Ordovician successions of the ~240-m-thick Mellsenn Group conformably overlie the glacial deposits and Valdres Sparagmites. At their base, there is a slate that has been correlated with the Ekre Formation (Nickelsen et al., 1985). The slates are overlain by feldspathic arenites, quartz arenites, slates (Roofing Slate), and quartzites (Blue Quartz). The Ediacaran-Cambrian boundary is estimated to lie within the quartzitic unit between the felspathic arenites and the "Roofing Slate" of Nickelsen et al. (1985) (Fig. 5). The highest units in the Mellsenn Group are Ordovician metapelites.

The Kvitvola Nappe Complex comprises several thrust nappes that lie structurally between the Osen-Røa Nappe Complex (below) and orthogneisses (above) of the Tännäs Augen Gneiss Nappe and other correlated orthogneisses (Fig. 2). The upper thrust unit of the Kvitvola Nappe Complex consists of several-kilometer-thick Neoproterozoic coarse-clastic successions (Rondslottet Formation), which have been thrust over the structurally lower units of the Kvitvola Nappe Complex, including the Engerdalen Group (Fig. 5; Nystuen, 1980). The Engerdalen Group consists of quartzites and arkosic sandstones of the Engerdalen quartzite, which are overlain by dolomites, phyllites, and sandstones of the Hylleråsen Formation. The contact between the Engerdalen quartzite and the Hylleråsen Formation is not exposed and may be tectonic (Nystuen, 1980). A diamictite (Koppang Formation) unconformably overlies the Hylleråsen Formation. This unit is interpreted to represent a glacial deposit and has been correlated with the Moelv Formation as well as the glacial deposits in the Valdres Nappe Complex (Holmsen, 1954; Nystuen, 1980). The Høyberget Formation stratigraphically overlies the diamictite with a transitional contact. It consists of more than 800 m of sandstones associated with red mudstone, conglomerates, and carbonate. Locally, calcareous sandstone members also occur within the Høyberget Formation. The sandstones are interpreted to be of fluvial origin, and the calcareous sandstones are thought to have been deposited in a shallow-marine environment (Nystuen, 1980).

Tännäs Augen Gneiss Nappe, Offerdal Nappe, and Correlated Units

Structurally overlying the nappes that carry the Neoproterozoic–Lower Paleozoic sedimentary successions, there are nappes composed primarily of orthogneisses that are traditionally assigned to the Middle Allochthon. This orthogneiss level can be traced over large distances and is locally referred to as the Tännäs Augen Gneiss Nappe (e.g., Gee et al., 2020; Röshoff, 1978). From the type locality of the Tännäs Augen Gneiss in Sweden, this unit can be traced into the Gudbrandsdalen area, where it includes the Høvringen Gneiss Complex and the Oppdal augen gneiss of the Risberget Nappe (e.g., Jakob et al., 2019; Nilsen, 1988). Orthogneisses at this structural level may locally be associated with feldspathic sandstones but are commonly characterized by strong deformation along their structural bases and tops, which are interpreted as thrust contacts.

The protolith age of the Tännäs Augen Gneiss in Sweden was estimated to range from 1685 ± 20 Ma (U-Pb zircon) to 1610 ± 85 Ma (Rb-Sr) (Claesson, 1980). The protolith age of the Høvringen Gneiss Complex is estimated at 1620 and 1183 Ma (U-Pb zircon; Lamminen et al., 2011). From elsewhere in the Gudbrandsdalen area, a granulite-facies metamorphic overprint from an orthogneiss was dated at ca. 909 Ma (Corfu, 2019). The orthogneisses are free of Ediacaran mafic magmatic rocks.

Locally, the orthogneisses are structurally overlain by nappes composed of Neoproterozoic sedimentary successions, i.e., the Offerdal Nappe in Sweden and correlative units. The Offerdal Nappe is composed of Neoproterozoic, tectonically imbricated, mostly marine sediments that include ~300 m of conglomerates at the base that are overlain by ~1200 m of turbidite sequences (Plink-Björklund et al., 2005). Dropstones are reported from the Offerdal Nappe (Plink-Björklund et al., 2005), and a depositional age contemporaneous with the Marinoan or Gaskiers glaciation is inferred. Notably, Ediacaran igneous rocks have not been reported from these Neoproterozoic successions.

Cryogenian–Ediacaran Metasedimentary Complexes

Cryogenian–Ediacaran metasedimentary complexes abound in the central segment and include metasedimentary complexes in the Särv, Seve, Remsklepp, Hummelfjellet, and Sætra Nappes (Fig. 2) as well as other correlative tectonic units in the Middle Allochthon (Gee et al., 1985a, 1985b, 2020; Jakob et al., 2019; Kjøll, 2020; Nilsen, 1988; Svenningsen, 1995, 1994; Törnebom, 1896).

The Cryogenian–Ediacaran metasedimentary complexes, for example, in the Särv, Sarek, and Corrovarre Nappes (Fig. 6), mainly consist of siliciclastic successions that were intruded by mafic dikes. The sedimentary successions are composed of shallow-marine deposits, quartzites, meta-arkoses, and meta-conglomerates. Locally, the siliciclastic successions are

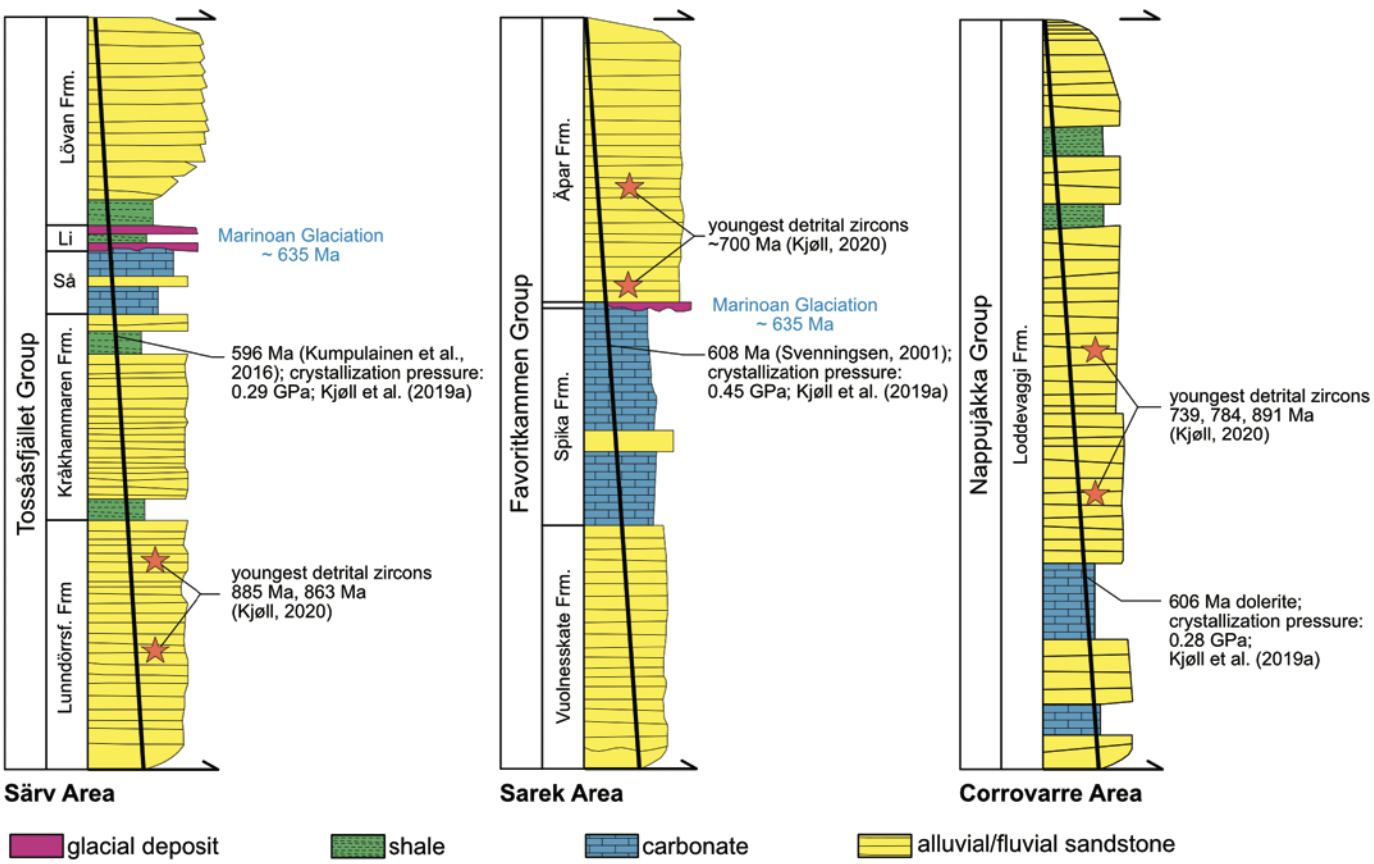

Figure 6. Stratigraphic columns of the diked Neoproterozoic succession in the Särv, Sarek, and Corrovarre areas, modified after Kjøll (2020). Frm.—Formation; Så—Ståran Formation; Li—Lillfjället Formation.

associated with carbonates and glacial deposits. Single detrital zircon grains as young as 750–700 Ma have been reported from the siliciclastic successions (Kjøll, 2020). All the sedimentary successions in the Särv, Seve, and Corrovarre Nappes are cut by mafic dike swarms, referred to as the Scandinavian Dike Complex (Kjøll, 2020; Kjøll et al., 2019a, 2019b; Tegner et al., 2019) or the Baltoscandian dike swarm (Andréasson, 1994). Locally, the mafic additions to the sedimentary successions make up as much as 50–100 vol% of the metasedimentary complexes (Kjøll et al., 2019a). The emplacement of the Scandinavian Dike Complex is dated at 608–596 Ma (Baird et al., 2014; Gee et al., 2017; Kjøll et al., 2019a; Kumpulainen et al., 2016; Svenningsen, 2001) and has been linked to the arrival of a mantle plume and the formation of the Central Iapetus magmatic province, which may have aided the continental breakup and opening of the Iapetus Ocean (Kjøll et al., 2019b, 2019a; Tegner et al., 2019). The crosscutting relationship of the Scandinavian Dike Complex with the glacial deposits suggests deposition of the glaciogenic sediments during the Marinoan glaciation at ca. 635 Ma (Hoffmann et al., 2004; Nystuen et al., 2016).

The Hummelfjellet and Sætra Nappes occur on the eastern and western sides of the Trondheim Nappe Complex in Norway, respectively (Fig. 2), and are interpreted to be correlative units (e.g., Nilsen, 1988). Furthermore, the Hummelfjellet and Sætra Nappes are commonly correlated with the Särv Nappe (or Seve nappes) in Sweden (Gee et al., 1985a; Nilsen, 1988; Stephens and Gee, 1989). The metasediments of the Hummelfjellet and Sætra Nappes are arkosic metasandstones and quartzites, as well as slate and phyllite in their upper sections (Holmsen, 1943; Nilsen and Wolff, 1989). Locally, the metasediments are associated with bodies of amphibolite and subordinate carbonates. The amphibolite bodies are undated but may correlate with the mafic dikes in the Särv and Seve Nappes. It is important to note that from the Swedish border near lake Esandsjøen toward the southwest and into the Gudbrandsdalen area (lower Heidal Group), the metasedimentary complexes show a progressive decrease in the abundance and volume of the mafic intrusions, which may indicate the presence of an Ediacaran magma-rich to magma-poor transition zone (Jakob et al., 2019). The Neoproterozoic metasediments of the Hummelfjellet Group can be traced into northern Gudbrandsdalen. There, the metasediments are exposed within the Gudbrandsdalen antiform (Fig. 2) and are referred to as the Heidal Group.

The Heidal Group (sensu Gjelsvik, 1946) is composed of a sequence of deformed and metamorphosed sediments on the southern flank of the Gudbrandsdalen antiform. The term has subsequently been used to also include meta-arkoses, quartzites, and argillaceous metasediments elsewhere in the area (Strand, 1951; Sturt et al., 1999). The contact of the metasediments with the underlying orthogneisses has been suggested to be depositional (Strand, 1951; Sturt and Ramsay, 1999) but is likely to be tectonic (Corfu and Heim, 2020).

Gjelsvik (1946) described that the sediments of the Heidal Group begin with flaggy arkosic metasandstones at the base. Further up section, the metasandstones are separated by a sharp contact from a garnet–mica schist unit as well as gray to greenish, finer-grained schist and phyllites. Our mapping shows that foliation-parallel, strongly deformed, garnetiferous amphibolite bodies occur locally at the base of the garnet–mica schist unit. Moreover, locally, the upper finer-grained parts of the Heidal Group contain leucocratic granitoid dikes. Notably, the mafic and granitoid bodies appear to be absent in the thick successions of quartzites and meta-arkoses that are well exposed in the center of the Gudbrandsdalen antiform. The absence of these intrusive rocks in the quartzitic–meta-arkosic sections of the Heidal Group, as well as the differences in grain size and composition of the protoliths, may indicate the presence of two distinct (tectonic) units. Corfu and Heim (2020) referred to rocks of the Heidal Group on the southern limb of the Gudbrandsdalen antiform as the Steinhø Complex. Corfu and Heim (2020) also described subordinate tonalite dikes from the Steinhø Group and dated those to ca. 431–427 Ma (U-Pb zircon, rutile, titanite) and further presented evidence for an amphibolite-facies metamorphic event affecting rocks of the Steinhø Group at ca. 474 Ma.

Elsewhere in the Seve Nappe Complex, there is evidence that the Cryogenian–Ediacaran metasedimentary complexes experienced a pre-Scandian (U)HP metamorphic event ca. 480 Ma (Barnes et al., 2019, 2020; Klonowska et al., 2017; Majka et al., 2014; Root and Corfu, 2012). Other metamorphic events in the Seve Nappe Complex have been dated at ca. 460 and 446–435 Ma (Barnes et al., 2020; Brueckner and Van Roermund, 2007; Fassmer et al., 2017; Klonowska et al., 2016; Li et al., 2020; Majka et al., 2015; Root and Corfu, 2012). A migmatization event in the Cryogenian–Ediacaran units has locally been dated to ca. 448–440 Ma (Bender et al., 2019; Klonowska et al., 2017; Ladenberger et al., 2014; Li et al., 2020). In Jämtland, Sweden, the timing of Scandian thrusting of these units is estimated at ca. 430 Ma (Bender et al., 2019).

Ultramafic bodies are common in the Seve Nappe Complex. These ultramafites are primitive as well as nonprimitive (sensu Stigh, 1979). Garnet peridotites that formed at (U)HP conditions and also subsequently experienced (U)HP metamorphism are proposed to have been derived from the mantle wedge during deep burial of the Seve Nappe Complex (Brueckner et al., 2004; Gilio et al., 2015; van Roermund, 1989) either in the Ordovician or Silurian. Occurrences of pre-Scandian ultramafic sediments, however, have not been reported from the Seve nappes and correlative Cryogenian–Ediacaran metasedimentary complexes elsewhere.

Alpine-Type Metaperidotite-Bearing Units between Bergen and Esandsjøen

Alpine-type metaperidotite-bearing metasedimentary complexes occur in nappes between Bergen and lake Esandsjøen (Fig. 2). These nappes are typically composed of deformed metasedimentary complexes that were metamorphosed at upper-greenschist-facies to lower-amphibolite-facies conditions and that are locally intimately associated with rootless, lens-shaped metaperidotite bodies and ultramafic metasediments. From Bergen to northern Gudbrandsdalen, these include the Samnanger Complex (Færseth et al., 1977; Kvale, 1945; Ragnhildsveit et al., 1998) and the Fortun Nappe (Lutro, 1988). In northern Gudbrandsdalen, several units have been suggested to host the metaperidotite-bearing complexes, and these units include the Otta Nappe (Bøe et al., 1993; Strand, 1951), Meråker Nappe (Corfu and Heim, 2020; Gee et al., 1985a), and Esandsjøen Nappe (Nilsen, 1988; Wolff, 1979). For simplicity, these units are collectively referred to as the Sel Group in Figure 2 (compare also with Fig. 1). The Esandsjøen Nappe continues to the northeast toward Røros and lake Esandsjøen. North of the Gudbrandsdalen area, metaperidotite-bearing units can also be traced along the eastern margin of the Western Gneiss Region, where these units are included in the Blåhøa Nappe (Fig. 2; Krill, 1980).

Samnanger Complex

The Samnanger Complex sensu stricto lies within the Major Bergen arc (Fig. 7) and was mapped in detail by Færseth et al. (1977), Ingdahl (1985), Kolderup and Kolderup (1940), and Ragnhildstveit (2003). Note that the terms Major and Minor Bergen arcs refer to a series of lithotectonic units that are arcuate-shaped in map view and not to arc magmatic complexes. The Bergen arcs wrap around an east-plunging late to post-Scandian fold/core complex exposing basement gneisses (Wiest, 2020; Wiest et al., 2019). The Major Bergen arc is bordered by the Bjørnafjorden antiform to the south and east, which in turn is cut by the Hardangerfjord shear zone. The Hardangerfjord shear zone is a late to post-Scandian shear zone juxtaposing a Baltican autochthon in its footwall with the Scandian nappe complexes in its hanging wall. The Samnanger Complex in the Major Bergen arc is structurally overlain by Baltican-type orthogneisses of the Lindås Nappe (Ragnhilstveit and Helliksen, 1997) and ophiolite/island-arc assemblages, e.g., the Gullfjellet Ophiolite Complex. The metaperidotite-bearing units east of the Bjørnafjorden antiform are structurally overlain by supracrustal units of the Upper Bergsdalen Nappe that are interpreted to be Proterozoic in age and to be of Baltican origin (Fossen, 1993; Kvale, 1945).

The metaperidotite-bearing unit in the Samnanger Complex is composed mostly of originally fine-grained metasediments

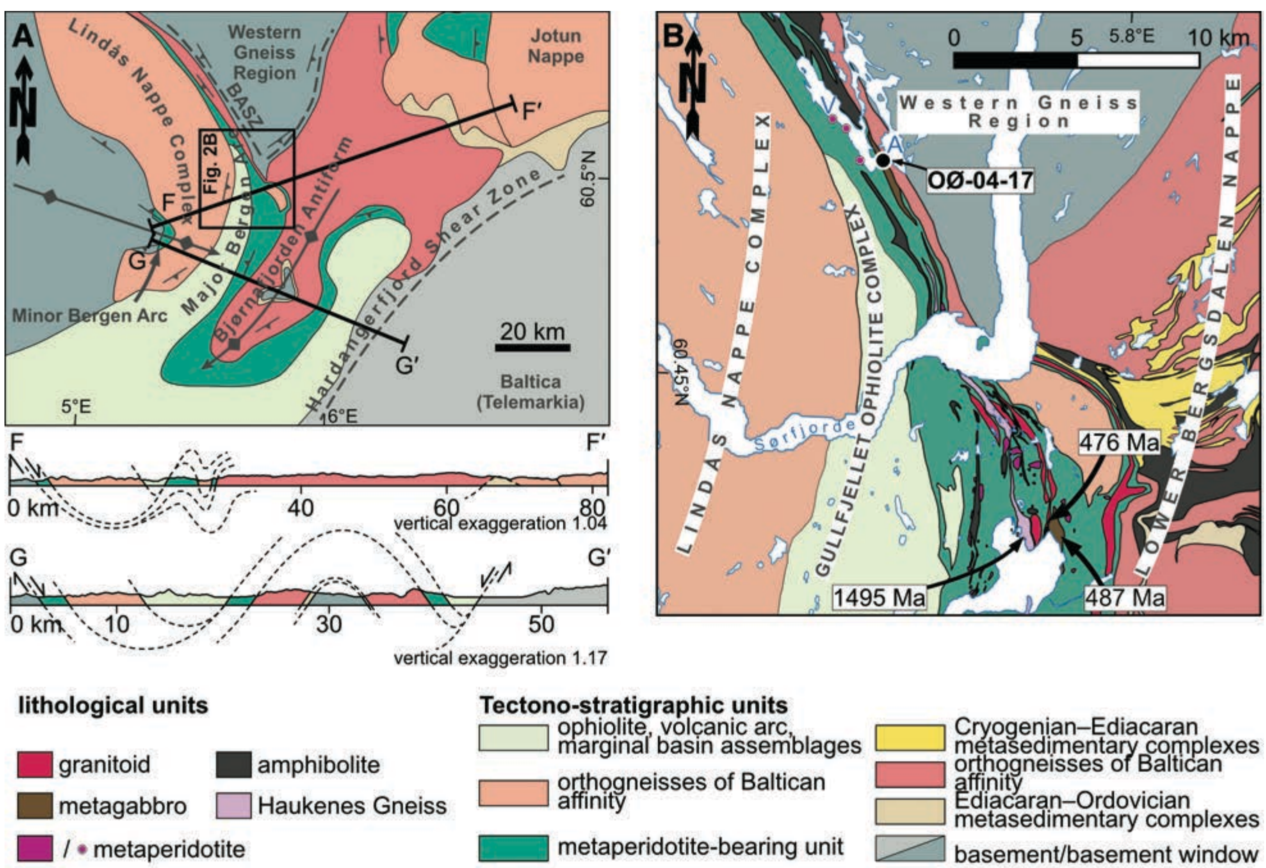

Figure 7. (A) Simplified cross sections and tectono-stratigraphic sketch map emphasizing the main late Scandian regional structures of western Hordaland. BASZ—Bergen Arc shear zone. (B) Simplified geologic map of the Samnanger Complex on Osterøy and in Samnanger, north and south of Sørfjorden, respectively. Radiometric ages are from Jakob et al. (2017). A—Austrevatnet; V—Vestrevatnet. OØ-04-17 marks the sample location for the U-Pb isotope dilution–thermal ionization mass spectrometry (ID-TIMS) sample from a mafic sheet near the base of the Samnanger Complex.

with subordinate coarse-grained siliciclastic deposits, including quartzites, quartz-pebble conglomerates, and carbonate rocks. The depositional age of the metasediments is poorly constrained, but sedimentation in the Cambrian–Ordovician has been suggested (Færseth et al., 1977; Kolderup and Kolderup, 1940). The metasediments host solitary metaperidotite bodies and, locally, monomict ultramafic conglomerates. The metaperidotites are to various degrees serpentinized and talcified, recording a metasomatic history of pre-Scandian hydration, Scandian dehydration, and rehydration (Jakob et al., 2018). The metaperidotite bodies typically exhibit oblate shapes with their short axes oriented normal to the regional fabrics. Angular breccias and blocky serpentinites (sensu Hirauchi and Yamaguchi, 2007) are characteristically developed both internally within the metaperidotite bodies and more commonly along the margins of the bodies.

The sedimentary complexes of the Samnanger Complex contain several discontinuous slivers of metamorphosed mafic and granitoid orthogneisses. These gneiss slivers commonly have a high aspect ratio, follow the regional strike of the Major Bergen arc (Fig. 7), and are commonly some tens to several hundreds of meters thick and up to 40 km long. The most extensive of these slivers of orthogneisses is referred to as the Haukenes Gneiss. Its protolith age was dated to 1495 Ma (Jakob et al., 2017), which is similar in age to Telemarkian gneisses to the east of the Hardangerfjord shear zone. Meta-anorthosites and mangerites with relict granulites that overlie the metaperidotite-bearing units in the northeastern part of the Samnanger Complex are interpreted as a klippe of the Lindås Nappe (Færseth et al., 1977). A metagabbro and a mylonitic granitoid structurally below the Haukenes Gneiss were dated to 487 and 476 Ma, respectively (Jakob et al., 2017). The youngest intrusives in the Samnanger Complex are ca. 421 Ma synorogenic granitoids that locally contain magmatic epidote (Jakob et al., 2017; Wennberg et al., 2001), which indicates crystallization at pressures >4 kbar (Naney, 1983; Schmidt and Poli, 2004; Zen and Hammarstrom, 1984). Several dominantly coarse-grained, commonly deformed, locally garnetiferous amphibolite and greenstone bodies are intercalated with the other lithostratigraphic units of the Samnanger Complex.

Bergsdalen and Fortun Nappes

To the northeast of the Samnanger Complex, metaperidotite-bearing units can be traced along the eastern margin of the Western Gneiss Region, where these units are included in the Bergsdalen Nappes, and further to the northwest in the Fortun Nappe (Figs. 2 and 7). The metaperidotite-bearing units in the eastern limb of the Bjørnafjorden antiform have been correlated with those in the Samnanger Complex (e.g., Kvale, 1945). Note that in other tectono-stratigraphic interpretations, the metaperidotite-bearing units in the Major Bergen arc are included in the Upper Allochthon, whereas those in the Bergsdalen and Fortun Nappes are commonly included in either the Lower or Middle Allochthon (e.g., Gee et al., 1985a, 1985b; Gee and Stephens, 2020b).

The metasediments in the Bergsdalen and Fortun Nappes are garnetiferous amphibole-bearing metapelites that are locally intercalated with metasandstones, meta-conglomerates, and carbonaceous metasediments. Amphibolitic bodies and granitoids are locally associated with the metasediments. Like in the Samnanger Complex, the metaperidotite bodies in the Bergsdalen and Fortun Nappes occur as lens-shaped solitary metaperidotite bodies tens to hundreds of meters and in a few cases kilometers in size. The metaperidotites are to various degrees serpentinized and talcified. Blocky serpentinite is commonly well developed, and monomict ultramafic conglomerates and sandstones occur within the sedimentary complexes near the ultramafic bodies.

Detrital zircon ages from the metasediments from the Fortun Nappe are as young as ca. 468 Ma (Slama and Pedersen, 2015). A sheet of metadiorite within the metasedimentary complexes hosting the metaperidotites in the Fortun Nappe was dated to 471 Ma (U-Pb zircon; Jakob et al., 2017), which indicates deposition of the metasediments penecontemporaneous with the crystallization of the metadiorite. Other discontinuous sheets of orthogneisses from further north in the Fortun Nappe were dated to ca. 1495 Ma as well as ca. 1229 Ma and were interpreted to be of Baltican origin (Jakob et al., 2017).

Northern Gudbrandsdalen

The Fortun Nappe can be traced continuously structurally between the Western Gneiss Region (below) and the Jotun Nappe Complex (above) into the Gudbrandsdalen area. There, it links up with metaperidotite-bearing units that have been included within the Otta Nappe (Bøe et al., 1993; Strand, 1951; Sturt et al., 1995), the Esandsjøen and Sjoa Nappes (Siedlecka et al., 1987; Wolff, 1979), the Meråker Nappe (Corfu and Heim, 2020), or the Gula Nappe (collectively referred as the Sel Group of the Otta Nappe in Fig. 2). The region is structurally complex, and the thrust-related structures are overprinted by late to post-Scandian extensional tectonics. The dominating late to post-Scandian structural elements in the region (Fig. 2) include the northeastern trailing ends of the Lærdal-Gjende and Olestøl fault zones and the west-plunging Gudbrandsdalen antiform (Sturt and Ramsay, 1997). The Gudbrandsdalen antiform folds all units from the Lower to the Upper Allochthon, and foliations commonly dip steeply to the NW and SW in the northern and southern limbs of the Gudbrandsdalen antiform, respectively (Fig. 2).

The metasediments in these nappes include locally garnetiferous and amphibole-bearing metapelites, metapsammites, carbonaceous metasediments, and metaconglomerates. Locally, the metasediments are associated with amphibolitic and metagabbroic bodies. Ultramafic rocks occur chiefly as monomict ultramafic conglomerates that locally contain a Dapingian–Darriwilian, island-type fauna (Bruton and Harper, 1981; Harper et al., 2009). At one locality, a talc-ophicarbonate body is directly overlain by a monomict serpentinite conglomerate. Carbonates associated with the ultramafic conglomerates as well as from fossil fragments preserved in an ultramafic conglomerate exhibit carbon and oxygen stable isotope compositions that are similar to those from carbonates associated with the metaperidotites in the Samnanger Complex and Fortun Nappe (Jakob et al., 2018).

Esandsjøen Nappe

The Esandsjøen Nappe (Nilsen, 1988; Wolff, 1979) occurs in the northern limb of the Gudbrandsdalen antiform structurally below the Meråker Nappe of the Trondheim Nappe Complex and structurally above Neoproterozoic metasediments of the Heidal Group (sensu Sturt et al., 1999). To the northeast, it can be continuously traced as a thin tectonic unit structurally above Neoproterozoic metasedimentary complexes of the Hummelfjellet Nappe into the Røros area and toward lake Esandsjøen.

The lithologies in the Esandsjøen Nappe include garnetiferous, amphibole-bearing, calcareous metapelites and metagraywackes. In the Røros area, these assemblages are referred to as the Aursunden Group (also referred to as Røros schists). Within the Aursunden Group, the garnetiferous units are well developed in the northeast, whereas around Røros (Fig. 2), the metasediments are dominantly muscovite-biotite-chlorite schists (Nilsen, 1988). In the western part, rocks of the Esandsjøen Nappe are referred to as Røsjø Formation and are structurally between the Aursunden Group (below) and the Trondheim Nappe Complex (above). The Røsjø Formation includes greenish to gray metagraywackes, tuffitic layers, and mafic metavolcanites (Nilsen, 1988). Metaperidotites occur as lens-shaped bodies, conglomerates, and sheets within the Esandsjøen Nappe between Vågåmo and lake Esandsjøen. In the Røros area, the metaperidotites occur near or at the base of the Esandsjøen Nappe.

Blåhøa Nappe

The Blåhøa Nappe occurs on the western side of the Faltungsgraben (sensu Goldschmidt, 1912) and locally is in tectonic contact with gneisses of the Western Gneiss Region, Neoproterozoic metasediments of the Åmotsdal and Sætra Nappes, as well as augen gneisses of the Risberget Nappe (Fig. 2). The Blåhøa Nappe includes locally anatectic, kyanite-, amphibole-, and garnet-bearing, originally fine- to coarse-grained metasediments, boudinaged mafic dikes and bodies, and leucocratic granitoid dikes.

Ultramafic bodies are common in the Blåhøa Nappe (Fig. 2; Bakke and Korneliussen, 1986; Guezou, 1978). At Sjong (Fig. 2), the metasedimentary successions of the Blåhøa Nappe are intercalated with ultramafic sediments, now preserved as monomict conglomerate bodies and subordinate talc and antigorite layers. The intercalation of these metasediments demonstrates that the ultramafic and siliciclastic metasediments were deposited contemporaneously. At the base of the metasedimentary succession, there are metaperidotite bodies that are cut by mafic dikes, which are now preserved as chlorite schists. The lack of obvious tectonic contacts between the metaperidotite sheets at the base and the overlying sedimentary successions further suggests that the sediments were directly deposited on the ultramafic substratum.

The ultramafic rocks, particularly the conglomerates, experienced extensive dehydration during Scandian metamorphism and are now preserved as jackstraw-textured olivine-talc rocks (Bakke and Korneliussen, 1986). Large olivine crystals overgrowing the sedimentary structures demonstrate pre-Scandian hydration and deposition of the ultramafic sediments and isofacial metamorphism of the ultramafic and siliciclastic rocks. Deposition of the metasedimentary succession was followed by near-complete dehydration of the ultramafic rocks during prograde metamorphism and development of the olivine-talc assemblage. A subsequent phase of retrograde rehydration is shown by the occurrence of serpentine minerals that locally replace the prograde metamorphic mineral assemblages in the ultramafic rocks. The prograde and retrograde metamorphism is here interpreted to be of Scandian age.

Jotun, Lindås, and Dalsfjord Nappe Complexes

Baltican-type orthogneisses, locally associated with Precambrian–Silurian metasediments, occur structurally above the Alpine-type metaperidotite-bearing metasedimentary complexes in the southern segment of the Scandinavian Caledonides (Fig. 2). To the east and south of the Western Gneiss Region, these orthogneisses and paragneisses include the Jotun Nappe Complex and the Lindås Nappe, respectively. West of the Western Gneiss Region, orthogneisses and paragneisses that have been correlated with those in the Jotun and Lindås Nappes are included in the Dalsfjord Nappe Complex. The Lindås and Dalsfjord Nappe Complexes are structurally overlain by ophiolite and volcanic-arc assemblages of the Gullfjellet and Solund-Stavfjord ophiolite complexes, respectively.

The Baltican-type orthogneisses of these nappe complexes belong to the anorthosite-mangerite-charnockite-granite (AMCG) suite and are dominantly Mesoproterozoic in age. The oldest crystalline rocks of the Jotun and Dalsfjord Nappe Complex (here including also the Eikefjord Nappe Complexes) have protolith ages of ca. 1660–1630 Ma (U-Pb zircon, monazite, and titanite; Corfu and Andersen, 2016, 2002; Lundmark et al., 2007). Protolith ages of other Precambrian crystalline rocks in the Dalsfjord Nappe Complex have been dated to ca. 1507, 1464, and 1191 Ma (U-Pb zircon and titanite; Austrheim and Corfu, 2009; Corfu and Andersen, 2016, 2002). The oldest crystalline rocks of the Lindås Nappe have been dated to ca. 1237 Ma; however, upper intercepts and initial Sr ratios indicate protolith ages of up to ca. 1600 Ma (Bingen et al., 2001). Rocks of similar protolith ages (ca. 1257 Ma) to those in the Lindås Nappe Complex have also been dated in the Jotun Nappe Complex (Lundmark et al., 2007).

The crystalline basement rocks of the Jotun, Lindås, and Dalsfjord Nappe Complexes record Proterozoic granulite-facies metamorphism and widespread granitic and subordinate mafic magmatism during the Sveconorwegian orogeny between ca. 1000 and 900 Ma (Bingen et al., 2008; Corfu, 2019; Corfu and Andersen, 2016; Lundmark et al., 2007; Lundmark and Corfu, 2008; Roffeis et al., 2012). Locally, the crystalline rocks of both the Jotun and Lindås Nappe Complexes were intruded by ca. 427–420 Ma granitoids (Kühn et al., 2002; Lundmark and Corfu, 2007).

Precambrian metasediments are locally associated with the crystalline rocks of the Jotun and Dalsfjord Nappe Complexes. In the Dalsfjord Nappe Complex, the Precambrian metasediments are sandstones, meta-arkoses, and subordinate conglomerates that were deposited nonconformably on the Proterozoic basement in the Cryogenian (Brekke and Solberg, 1987; Johnston et al., 2007; Slama, 2016). Locally, these continental metasediments also contain as-yet-undated mafic dike swarms and locally preserved metabasalt and pillow lava, e.g., in the Høyvik Group (HØ in Fig. 2). Because the Precambrian geologic history of these units was very similar to that of the autochthon, a Baltican origin for these nappe complexes is commonly accepted (e.g., Corfu and Andersen, 2016).

Middle Ordovician cooling ages from phengitic mica from the Høyvik Group in the Dalsfjord Nappe Complex indicate that these rocks were deformed and metamorphosed ≥450–447 Ma (Andersen et al., 1998; Eide et al., 1999). Eclogite-facies metamorphism at 440–430 Ma has been documented from the Lindås Nappe Complex (Austrheim, 1987; Boundy et al., 1996; Fossen et al., 1998; Glodny et al., 2008; Jamtveit et al., 2018). Note that the originally published ages of HP metamorphism reported by Glodny et al. (2008) of ca. 430 Ma have here been recalculated to ca. 440 Ma using the Rb decay constant recommended by Villa et al. (2015).

ANALYSES AND RESULTS

Whole-Rock Geochemical Analyses of the Ultramafites

Ultramafites were sampled between Bergen and Røros to test (1) whether the ultramafic rocks differ in their geochemistry, which could indicate that the ultramafites originated from different geodynamic settings, and (2) whether their whole-rock composition is primitive, sensu Stigh (1979), i.e., (a) low Al_2O_3 and CaO, (b) SiO_2/MgO ratios ~1, and (c) MgO/FeO ratios >5.

The whole-rock geochemical compositions of 20 samples collected from 17 Alpine-type metaperidotite bodies are presented in Table 1; sample locations are shown in Figure 2 (in red). The samples were collected from massive parts of solitary metaperidotite bodies and away from their margins or strongly carbonated and talcified domains. The analyses show that the sampled metaperidotite bodies geochemically match the definition of primitive ultramafites sensu Stigh (1979). The samples in Table 1 are arranged from the south (sample 1) to the north (sample 20). A regional trend in the whole-rock geochemistry cannot be recognized, and the metaperidotites are essentially geochemically indistinguishable. Slightly higher CaO values of samples 1, 7, 13, and 20 are likely due to partial carbonation of the sampled metaperidotites, which reflects Scandian metasomatism after peak metamorphism rather than the original geochemical composition. Other samples collected from the same localities as these outliers support the primitive geochemical signature.

Raman Spectroscopy of Carbonaceous Material (RSCM) in Metasediments

RSCM—Methodology and Sampling Strategy

During regional metamorphism, carbonaceous material, which is a common component in sedimentary protoliths, is progressively transformed into graphite (Buseck and Beyssac, 2014). The degree of graphitization of this carbonaceous material can be quantified by Raman spectroscopy and depends on temperature (Beyssac et al., 2002). Graphitization is an irreversible process, and so the degree of graphitization of carbonaceous material is not affected by retrogression and consequently reflects the maximum temperature of metamorphism (Beyssac et al., 2002). Beyssac et al. (2002) showed that the relative area of the defect band of the carbonaceous material Raman spectra (R2 parameter) is controlled by temperature following the relation T (°C) = –445R2 + 641. This relation was calibrated for temperatures between 330 °C and 640 °C. The accuracy on the obtained temperature is ±50 °C due to uncertainties in the petrologic data used for calibration, but the relative uncertainties are lower, around 10–15 °C (Beyssac et al., 2004).

The Raman spectra of carbonaceous material (RSCM) in this study were obtained with a Renishaw InVIA Reflex microspectrometer with a 514.5 nm argon laser at Université Pierre et Marie Curie, Paris (UPMC). The laser power at the surface was set to <1 mW and was focused on the sample using a DMLM Leica microscope with a 100× magnification objective (numerical aperture [NA] = 0.85). The Rayleigh diffusion was eliminated by edge filters and dispersed using an 1800 gr/mm grating to be analyzed by a Peltier-cooled RENCAM charge-coupled device (CCD) detector. The Raman spectrometer was calibrated with a silicon standard. Spectra were processed following the procedure of Beyssac et al. (2003) using the PeakFit© software. Measurements were done following the procedure of Beyssac et al. (2002, 2003) on polished thin sections, and carbonaceous material was analyzed behind a transparent mineral (e.g., quartz) to avoid possible structural damages induced by thin-section polishing. Because the studied samples were metasediments, it was important to ensure that the analyzed carbonaceous material did not have a detrital origin. Therefore, ~20 spectra were acquired for each sample to test the within-sample heterogeneity.

For the RSCM analyses, carbon-rich metapelites were collected (Fig. 2) from the metaperidotite-bearing unit (samples 1–17, 21, 22, 24, 27, 28). We also collected carbon-rich fine-grained metasandstones from the Hummelfjellet Nappe structurally below the metaperidotite-bearing unit (samples 20 and 26) and from carbon-rich metapelites from the Trondheim Nappe Complex structurally above the metaperidotite-bearing unit (samples 18, 19, 23, 25).

RSCM Results

RSCM temperature estimates from samples south of the Gudbrandsdalen antiform (samples 1–16) yielded temperature estimates of 461–542 °C (average of 508 °C, σ = 24 °C; Table 2). A slight increase in the peak metamorphic temperatures from the south (samples 1–8) to the north (samples 9–16) can be noted. The peak metamorphic temperature estimates for the samples north of the Gudbrandsdalen antiform (samples 17–28) ranged from 488 °C to 562 °C. Sample 23 (FÅ-07-17) yielded the highest temperature estimate of 562 °C. The sample was collected proximal to an undeformed, medium-crystalline, igneous rock of

TABLE 1. WHOLE-ROCK GEOCHEMISTRY OF ALPINE-TYPE METAPERIDOTITE BODIES BETWEEN BERGEN AND RØROS

No.	Sample	Locality	Lat. (°N)	Long. (°E)	Reference	SiO_2	Al_2O_3	Fe_2O_3(T)	MnO	MgO	CaO	Na_2O	K_2O	TiO_2	LOI	Total	SiO_2/MgO	MgO/FeO*
1	OS-08-14	Halhjem, Os	60.14937	5.43993	This study	34.36	0.21	6.74	0.103	36.66	4.93	0.02	<0.01	0.003	17.1	100.10	0.94	6.04
2	RP-JJ-04	Raunekleiv, Samnanger	60.39356	5.69794	This study	37.5	0.42	7.76	0.105	43.39	0.01	<0.01	<0.01	0.002	9.45	98.64	0.86	6.21
3	LIN-04-17	Sævrås, Lindås	60.73212	5.27537	This study	37.16	0.57	9.22	0.143	43.79	0.19	0.05	0.02	0.016	8.39	99.55	0.85	5.28
4	VIK-13-14	Vettle Rauberget, Stølsh.	60.91609	6.32090	This study	38.5	0.55	7.43	0.109	42.67	0.02	<0.01	<0.01	0.002	9.9	99.18	0.90	6.38
5	A-SEL-40-14	Vettle Rauberget, Stølsh.	60.91702	6.31737	Enger (2016)	48.83	0.49	7.96	0.067	32.83	0.06	0.02	<0.01	0.005	8.86	99.12	1.49	4.58
6	A-SEL-02-14	Rauberget, Stølsh.	60.92703	6.29600	Enger (2016)	40.45	0.6	7.05	0.109	43.19	0.02	0.02	0.01	0.003	8.61	100.06	0.94	6.81
7	A-SEL-11-14	Rauberget, Stølsh.	60.92968	6.28268	Enger (2016)	41.01	1.53	9.12	0.073	33.26	4.98	0.05	0.02	0.004	8.55	98.60	1.23	4.05
8	A-SEL-20-14	Rauberget, Stølsh.	60.93057	6.29590	Enger (2016)	33.45	0.33	9.93	0.137	37.71	0.04	0.02	<0.01	0.003	16.9	98.56	0.89	4.22
9	A-SEL-56-14	Rauberget, Stølsh.	60.93487	6.29588	Enger (2016)	37.83	0.34	8.56	0.137	42.69	0.09	0.02	<0.01	0.001	9.49	99.16	0.89	5.54
10	BØ-48-14	Bøverdalen, Lom	61.70763	8.17768	This study	39.06	0.36	5.78	0.074	43.64	0.03	0.01	<0.01	0.001	9.46	98.42	0.90	8.39
11	HSHØ-02-17	Hornsjøhøe, Dovre	62.00544	9.58424	This study	36.49	0.59	6.93	0.047	34.55	0.09	0.01	<0.01	0.01	21	99.72	1.06	5.54
12	TH-02-17	Tollevshaugen, Grimsdalen	62.09255	9.81378	This study	37.26	0.26	6.3	0.093	47.57	0.06	0.02	<0.01	0.006	7.54	99.11	0.78	8.39
13	BB-SRP-17	Brekkbekken, Alvdal	62.17538	10.56693	This study	37.12	0.66	9.16	0.118	35.45	2.83	0.01	<0.01	0.013	13.4	98.74	1.05	4.30
14	LES-51-17	Sjong, Lesja	62.18682	8.87967	This study	44.52	1.68	6.94	0.052	40.69	0.03	0.01	<0.01	0.016	4.74	98.68	1.09	6.51
15	SV-02-17	Savalen, Tynset	62.22223	10.37312	This study	31.68	0.26	5.8	0.065	36.37	0.11	<0.01	<0.01	0.003	25.3	99.63	0.87	6.97
16	Fåsten-SRP-17	Fåsteinen, Tynset	62.27928	10.69500	This study	35.77	0.23	6.39	0.091	43.79	0.05	0.01	<0.01	0.004	12.8	99.14	0.82	7.61
17	STEN-01-17	Stenkletten, Tolga	62.44802	11.03064	This study	35.67	0.6	6.91	0.093	40.69	0.37	<0.01	<0.01	0.005	14.1	98.45	0.88	6.54
18	RØ-21-17	Raudhåmmåren, Røros	62.55684	11.62158	This study	34.65	0.13	5.95	0.087	46.6	0.04	0.01	<0.01	0.003	12	99.48	0.74	8.70
19	RØ-09-17	Wessel, Feragsfjellet	62.56216	11.78949	This study	36.69	0.25	7.89	0.11	48.36	0.04	<0.01	<0.01	0.003	6.09	99.43	0.76	6.81
20	RØ-08-17	Lergruva, Feragsfjellet	62.56583	11.81953	This study	38.05	1.1	7.43	0.114	42.19	1.25	0.04	0.02	0.009	8.88	99.08	0.90	6.31

Note: The samples are numbered from south to north; see Figure 2 for sample locations on the map. Samples 1–10 were collected south of the Gudbrandsdalen antiform, and samples 11–20 were collected north of the antiform. Oxides are given in wt%. Stølsh.—Stølsheimen; LOI—loss on ignition.

*FeO calculated from Fe_2O_3.

mafic to intermediate composition. Because the rock was virtually undeformed, we interpreted it to be late orogenic, and the high temperature yielded by the RSCM analyses might be due to a late Scandian contact metamorphic overprint of the regional metamorphic signature; however, no clear boundaries for a contact aureole could be mapped. The average temperature of all samples north of the Gudbrandsdalen antiform (samples 17–28) was 535 °C (σ = 22 °C). Exclusion of both the highest and lowest values yielded an average peak metamorphic temperature of 538 °C (σ = 15 °C). For simplicity, we estimate the peak metamorphic temperatures of samples north of the Gudbrandsdalen antiform at 535 °C.

The peak metamorphic temperature estimates conform with earlier studies (Bergman, 1987; Fauconnier et al., 2014; McClellan, 2004) and are interpreted to represent the peak temperature during Scandian metamorphism. Note that the temperatures from samples north of the Gudbrandsdalen antiform continue the trend of slightly increasing peak metamorphic temperatures toward the northeast compared to the samples from south of the Gudbrandsdalen antiform. Note also that the data do not indicate a metamorphic jump across the Gudbrandsdalen antiform and that the slight increase in metamorphic temperatures rather indicates that the units strike subparallel to the Scandian isograds. Furthermore, post-thrusting normal displacement of tectonic units across the Gudbrandsdalen antiform would suggest a decrease in peak metamorphic temperatures from south to north—opposite to the slight increase in peak metamorphic temperatures reported here.

Thermodynamic Modeling

The RSCM results give good control on the peak metamorphic temperatures, which can be used to refine and test thermodynamic models based on the whole-rock geochemical composition of the metapelites, which in turn can be used to estimate pressures during the formation of the peak metamorphic mineral assemblage. One mica-schist sample (BØ-52-14) was collected

TABLE 2. RAMAN SPECTROSCOPY OF CARBONACEOUS MATERIAL (RSCM) DATA AND RESULTS

No.	Sample	Latitude (°N)	Longitude (°E)	Sp.	R2		*T* (°C)	
					Mean	SD	Mean	SE
1	BA-02-14	60.14737	5.74376	19	0.294	0.07	507	1.15
2	BA-01-14	60.15338	5.77439	18	0.301	0.06	506	1.41
3	SAM-7-14	60.40117	5.71632	20	0.029	0.05	511	1.12
4	SAM-10-14	60.40394	5.72243	20	0.353	0.04	484	0.89
5	VIK-05-14	60.91787	6.30566	19	0.295	0.06	512	1.38
6	VIK-14-14	60.94685	6.37026	19	0.307	0.06	494	1.38
7	VIK-15-14	60.95661	6.40261	26	0.331	0.06	504	1.18
8	VIK-18-14	60.97894	6.36090	20	0.404	0.04	461	0.89
9	BØ-41-14	61.67023	8.12970	19	0.385	0.05	470	1.15
10	BØ-42-14	61.67064	8.12778	20	0.240	0.07	534	1.57
11	BØ-38-14	61.70134	8.16087	16	0.240	0.07	540	1.50
12	BØ-34-14	61.70348	8.16870	19	0.222	0.06	542	1.38
13	BØ-16-14	61.70485	8.17210	20	0.249	0.03	530	0.67
14	BØ-21-14	61.70702	8.17959	20	0.333	0.05	493	1.12
15	BØ-23-14	61.70736	8.18015	20	0.270	0.04	521	0.89
16	BØ-53-14	61.72108	8.20292	20	0.276	0.07	518	1.57
17	LES-41-17	61.92253	8.98649	20	0.186	0.05	558	1.09
18	LES-54-17	62.04044	0.96715	21	0.187	0.08	551	1.16
19	LES-53-17	62.05807	8.93806	19	0.299	0.06	508	1.40
20	RK-01-17	62.09496	10.17797	18	0.201	0.06	548	1.23
21	BB-01-17	62.17585	10.56821	19	0.241	0.05	534	1.10
22	SV-01-17	62.22000	10.37030	24	0.253	0.04	529	0.83
23	FÅ-07-17	62.29339	10.69180	20	0.177	0.06	562	1.45
24	SV-04-17	62.30059	10.48285	19	0.220	0.05	543	1.25
25	SV-05-17	62.31002	10.48863	22	0.244	0.07	533	1.40
26	RØ-04-17	62.47754	11.55023	18	0.200	0.08	549	1.83
27	RØ-11-17	62.57010	11.76040	23	0.343	0.06	488	1.18
28	RØ-13-17	62.71772	11.87505	13	0.255	0.08	522	2.59

Note: The uncertainty of the temperature (*T*) estimates is ±50 °C. R2—R2-ratio of Beyssac et al. (2002); Sp.—number of spectra; SD—standard deviation; SE—standard error. Samples 1–16 were collected south of the Gudbrandsdalen antiform, and samples 17–28 were collected north of the antiform.

for analysis of its whole-rock composition. The analysis was conducted by Actlabs, Ontario, Canada.

The peak metamorphic mineral assemblage of sample BØ-52-14 includes white mica, biotite, chlorite, garnet, and albite. During greenschist-facies retrogression, the garnet was partially replaced by biotite and chlorite; the biotite is partially chloritized. The whole-rock composition and calculated stable phases are presented in Figure 8A. Fields in the pseudosection that yield the same metamorphic mineral assemblage that was observed in thin section are marked in yellow.

More constraints on the peak metamorphic pressure and temperature can be estimated by including the end-member composition of the garnets as well as the silica per formula unit (SIPFU) in white mica. The compositions of the garnet and white mica were measured with the electron microprobe at the Department of Geosciences, University of Oslo, Oslo, Norway. Garnet end-member composition and silica per formula unit were calculated from the whole-rock composition and are plotted as isopleths over the modeled metamorphic mineral assemblages in Figure 8B.

The best overlap of the thermodynamic model with the sample is presented by field "A" in Figure 8B. Note the good correlation of the estimated peak metamorphic temperature from the thermodynamic modeling (~525 °C) with the RSCM result (519 °C ± 50 °C) from the same area. The peak metamorphic

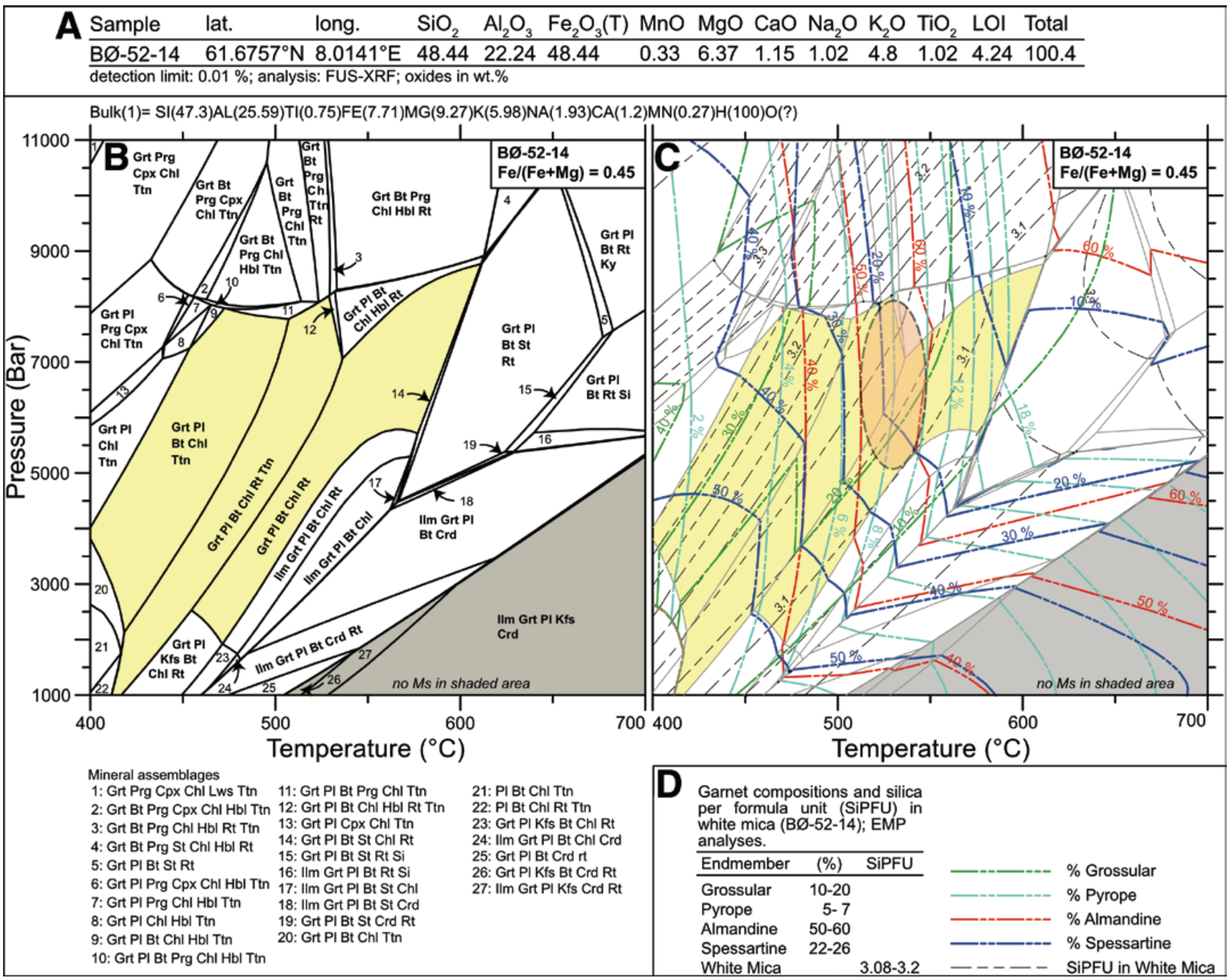

Figure 8. (A) Whole-rock geochemistry of metapelite from the Fortun Nappe. LOI—loss on ignition. FUS-XRF—fusion x-ray spectroscopy after Norrish and Hutton (1969). (B) Pressure-temperature (*P-T*) pseudosection of metapelite from the Fortun Nappe, showing equilibrium assemblages for the bulk-rock composition of sample BØ-52-14. Yellow fields mark the mineral assemblage observed in thin section. Mineral abbreviations after Siivola and Schmid (2007). (C) Garnet end-member composition and silica per formula unit (Si PFU) of white mica. Red shaded area shows the best fit of garnet end-member composition and Si (PFU) compared to the measured values of the sample. (D) Electron microprobe measurements of sample BØ-52-14.

pressures can be estimated at 5.25–7.25 kbar for these mica schists. Similar pressures of 6–8.1 kbar and peak metamorphic temperatures of 510–525 °C were estimated for garnet mica schists in Stølsheimen (near RSCM samples 5–8) by Kjelberg (2015) using the same method. The presence of magmatic epidote (Naney, 1983; Zen and Hammarstrom, 1984) in synorogenic granitoids in the Samnanger Complex (ca. 420 Ma) and south of lake Rien (near RSCM sample 28 in Fig. 2) further corroborates the interpretation that the metaperidotite-bearing units between Bergen and Røros experienced peak metamorphic pressures of ~6–8 kbar. Earlier studies from metaperidotite-bearing metasedimentary complexes of the lower Köli Nappe in Sweden, which have been correlated with the Aursunden Group, reported peak metamorphic pressure and temperature of 6.3 kbar and 500–540 °C, respectively (Bergman, 1987; Ghent and Stout, 1981; Sjöström, 1983).

U-Pb Geochronology

U-Pb Zircon Dating of Mafic Rocks in the Samnanger Complex

The U-Pb analyses were carried out by isotope dilution–thermal ionization mass spectrometry (ID-TIMS) following the general procedure of Krogh (1973). The method applied in this laboratory is summarized in Corfu (2004). A mixed ^{202}Pb-^{205}Pb-^{235}U spike was used, and zircons were abraded using the chemical abrasion procedure of Mattinson (2005). The data were calculated using the decay constants and compositions of Jaffey et al. (1971) and plotted and calculated using the add-in Isoplot for Excel by Ludwig (2003). The U-Pb ID-TIMS results are presented in Table 3.

In the northern part of the Samnanger Complex on Osterøy, a sample (OØ-04-17) from one amphibolitic sheet between the southern terminations of Vestrevatnet and Austrevatnet was collected for ID-TIMS geochronology (Fig. 7B). The metamorphic mineral assemblage included amphibole + plagioclase + carbonate ± zoisite ± titanite ± rutile ± zircon. The carbonate occurs in veins cutting the foliation, in pressure shadows around porphyroblasts of amphibole, and as aggregates. Aggregates of titanite overgrow aggregates of rutile or have rutile cores. The protolith of this amphibolitic rock is here interpreted to have been a dolerite or a gabbro.

In total, 23 zircons were separated from the heavy fraction after mineral separation. Those zircons were euhedral, prismatic, inclusion-free, transparent crystals or broken tips with crystal habits typical for magmatic zircons (Corfu et al., 2003b). Four transparent and prismatic zircons were selected for chemical abrasion and ID-TIMS analyses. The results are presented in Figure 9A and Table 3. The four analyses are concordant and partly overlap within error. The mean $^{206}Pb/^{238}U$ age of all four analyses is 436.3 ± 1.3 Ma, which we interpret to be a good estimation of the protolith's crystallization age.

U-Pb Zircon Dating of the Tronfjell Gabbro Massif

The Tronfjell Gabbro Massif is a layered cumulate gabbro interpreted to have intruded the Neoproterozoic metasediments of the Hummelfjellet Nappe (Fig. 10; Dreyer, 1975; Wellings, 1996). The gabbro can be divided into four domains (Dreyer, 1975): a zone of strongly deformed and altered rocks in the western part of the Tronfjell; an outer zone of fine- to medium-grained gabbro and gabbronorite that is commonly found at the base of the intrusion; a transitional zone with medium- to coarse-grained olivine gabbro; and a core zone that contains coarse-grained olivine gabbro and troctolite. Dunitic ultramafic cumulates occur in all zones.

Most of the gabbro displays only minor alteration. This alteration (serpentinization along cracks in olivine) affects only isolated grains in otherwise pristine rocks in the outer, transitional, and core zones and is related to normal postmagmatic processes within the gabbro (Wellings, 1996). Intense alteration of the gabbro occurs in the altered zone, along the edges of the intrusion, and locally along discrete zones in the other domains, e.g., shear zones. In these zones, the igneous mineral assemblage completely recrystallized during metamorphism, including the formation of amphibole at the expense of pyroxene, the formation of zoisite and albite at the expense of plagioclase, and the formation of chrome-rich sodium-mica (Dreyer, 1975; Wellings, 1996).

The metasediments of the Hummelfjellet Nappe comprise well-recrystallized quartzites and meta-arkoses that have been proposed to grade structurally upward into metapelites (Holmsen, 1943). The coarse-grained continental metasediments host mafic dikes, whereas remnants of pillow basalts have been reported from its finer-grained upper parts (Holmsen, 1943). Structurally below the northern flank of the gabbro massif, the metasediments of the Hummelfjellet Nappe contain some mafic sheets that have been suggested to have intruded the metasediments during the emplacement of the gabbro massif (Wellings, 1996). Other large mafic bodies can locally be found elsewhere, e.g., greenstones south and southwest of the gabbro massif (e.g., Lunsæter, 2016) and a large gabbroic body at Storkletten (Fig. 10). These mafic rocks as well as meta-dolerites elsewhere in the Hummelfjellet Nappe are geochemically distinct from the gabbro massif and the related mafic intrusive rocks at its northern flank (Lunsæter, 2016; Wellings, 1996). Moreover, these rocks are recrystallized to amphibolite and display a pervasive foliation parallel to that in the surrounding metasediments. The mafic rocks unrelated to the gabbro massif are similar to tholeiitic ocean-floor basalt and are suggested to have been emplaced during the opening of the Iapetus Ocean and to be correlated with the mafic dike swarms (Scandinavian Dike Complex) in the Särv and Seve Nappes (Dreyer, 1975; Gee et al., 1985a; Holmsen, 1943; Jakob et al., 2019; Lunsæter, 2016; Nilsen, 1988; Törnebom, 1896; Wellings, 1996).

Samples C-13-7 and C-13-8 were collected from the core zone of the gabbro massif. The sampled rock is a little-deformed or altered, coarse-grained olivine gabbro. Five clear euhedral zircons were optically selected for chemical abrasion and ID-TIMS analyses. The results are presented in Figure 9B and Table 3. Two of the five analyses are concordant, and the other three fall slightly below the concordia line. The results are partly overlapping within error. Including all five analyses, the mean $^{206}Pb/^{238}U$

TABLE 3. U-Pb ISOTOPE DILUTION–THERMAL IONIZATION MASS SPECTROMETRY (ID-TIMS) DATA FOR SAMPLES FROM OSTERØY, TRONFJELL, AND THE MÅRMA IGNEOUS COMPLEX

Mineral characteristics*	Weight† (µg)	U† (ppm)	Th/U§	Pb_i# (ppm)	Pb_c# (pg)	$^{206}Pb/^{204}Pb$**	$^{207}Pb/^{235}U$††	±2σ (abs)	$^{206}Pb/^{238}U$††	±2σ (abs)	rho	$^{207}Pb/^{206}Pb$	±2σ	$^{206}Pb/^{238}U$ (Ma)	±2σ	$^{207}Pb/^{235}U$ (Ma)	±2σ	$^{207}Pb/^{206}Pb$ (Ma)	±2σ	Disc.§§ (%)
Garnetiferous amphibolite, Osterøy, sample OØ-04-17 (60.531765°N, 5.618731°E)																				
Z eu CA [1]	1	48	0.50	0.00	2.8	91	0.505	0.030	0.0703	0.0005	0.33	0.0521	0.0030	437.6	2.8	415.0	19.7	291.1	124.4	–52.1
Z eu CA [1]	1	15	0.58	0.00	1.2	73	0.523	0.049	0.0701	0.0007	0.47	0.0541	0.0048	436.5	4.4	426.9	31.8	375.7	187.5	–16.7
Z eu m CA [1]	1	51	0.28	0.00	0.8	297	0.534	0.010	0.0700	0.0003	0.40	0.0553	0.0010	436.1	1.6	434.4	6.5	425.3	38.1	–2.6
Z eu CA [1]	1	33	0.32	0.00	2.9	66	0.558	0.108	0.0691	0.0013	0.81	0.0585	0.0105	431.0	7.7	450.1	67.9	549.0	348.5	22.2
Gabbro, Tronfjell, sample C-13-7 (62.170805°N, 10.673304°E)																				
Z an CA [1]	17	196	0.59	0.00	1.8	7960	0.539	0.001	0.0702	0.0001	0.88	0.0557	0.0001	437.3	0.9	438.0	0.9	441.7	2.8	1.0
Z eu CA [1]	2	1190	0.57	0.51	3.0	3455	0.538	0.002	0.0701	0.0002	0.84	0.0556	0.0001	436.6	0.0	436.8	1.0	438.1	3.6	0.4
Gabbro, Tronfjell, sample C-13-8 (62.170805°N, 10.673304°E)																				
Z fr CA [1]	2	584	0.63	0.00	2.0	2597	0.540	0.002	0.0701	0.0001	0.68	0.0559	0.0002	437.0	0.9	438.7	1.3	447.8	6.0	2.5
Z lp fr CA [6]	9	357	0.62	0.26	4.4	3220	0.537	0.002	0.0699	0.0001	0.75	0.0558	0.0001	435.2	0.8	436.7	1.1	444.3	4.7	2.1
Z lp fr CA [1]	1	622	0.61	0.00	1.1	2423	0.535	0.002	0.0698	0.0002	0.74	0.0555	0.0002	435.2	1.1	434.9	1.6	433.1	6.8	–0.5
Mafic sheet in Hummelfjell quartzites, Tronfjell, sample TRON-06-17 (62.19599°N, 10.719916°E)																				
Z eu CA [1]	2	191	0.77	0.00	1.2	1424	0.539	0.002	0.0701	0.0002	0.73	0.0558	0.0002	436.6	1.1	437.9	1.4	445.1	5.8	2.0
Z eu CA [1]	23	46	0.74	0.00	0.6	7729	0.538	0.002	0.0702	0.0002	0.86	0.0556	0.0001	437.1	1.0	437.1	1.1	437.1	3.5	0.0
Z eu CA [1]	4	96	0.77	0.00	1.0	1751	0.540	0.002	0.0703	0.0002	0.66	0.0556	0.0002	438.1	1.0	438.1	1.5	438.1	7.0	0.0
Z eu CA [1]	11	56	0.75	0.00	2.2	1204	0.538	0.003	0.0701	0.0002	0.56	0.0557	0.0002	436.6	1.0	437.1	1.8	439.8	9.6	0.7
Gabbro, Mårma, sample HJK_2070 (68.081258°N, 18.735681°E)																				
Z		374	0.348		1.04	3029	1.268329	0.297	0.137239	0.222	0.80			829.03	1.72			835.96	3.70	
Z		158	0.385		1.07	1251	1.2699	0.479	0.136925	0.245	0.53			827.25	1.90			843.30	8.43	
Z		357	0.325		0.88	3419	1.264946	0.274	0.137341	0.204	0.99			829.61	1.59			828.85	3.34	
Z		1724	0.231		1.20	12142	1.273693	0.261	0.137790	0.234	0.96			832.15	1.82			836.40	1.59	
Gabbro, Mårma, sample HJK_2091 (68.010711°N, 18.8992°E)																				
Z		634	0.313		1.08	4973	1.272640	0.257	0.137935	0.209	0.89			832.98	1.64			832.49	2.50	
Z		1355	0.314		1.84	6214	1.282365	0.308	0.138066	0.275	0.94			833.72	2.15			846.36	2.25	
Z		1687	0.211		1.82	7822	1.277646	0.262	0.137683	0.230	0.94			831.55	1.79			844.46	1.90	
Gabbro, Mårma, sample HJK_2093 (68.0241°N, 18.915561°E)																				
Z		225	0.767		1.45	1337	1.289328	0.504	0.138519	0.327	0.66			836.28	2.56			850.80	7.83	
Granite, Mårma, sample HJK_2064 (68.082215°N, 18.743935°E)																				
Z		495	0.105		1.22	3421	1.25913795	0.277	0.13710187	0.205	0.82			828.25	1.59			822.89	3.37	
Z		209	0.091		0.51	3410	1.23296621	0.286	0.13509486	0.215	0.99			816.87	1.65			809.83	3.41	
Z		351	0.134		1.43	2055	1.24117766	0.346	0.13588673	0.210	0.68			821.36	1.62			811.49	5.34	

*Z—zircon; eu—euhedral; an—anhedral; fr—fragment; lp—long prismatic (l/w > 5); m—milky; CA—chemical abrasion; [1] number of grains.
†Weight and concentrations are known to better than 10%, except for those near and below the ~1 µg limit of the resolution balance.
§Th/U model ratio inferred from $^{208}U/^{206}U$ ratio and age of sample.
#Pb_i is initial common Pb (corrected for blank); Pb_c is total common Pb in sample (initial + blank).
**Raw data corrected for fractionation.
††Data corrected for fractionation, spike, blank, and initial common Pb; error was calculated by propagating the main sources of uncertainty. Initial common Pb was corrected with compositions calculated with model of Stacey and Kramers (1975). Spike ($^{202}Pb/^{205}Pb/^{235}U$) was calibrated relative to ET100 solution.
§§Disc.—discordance.

age is 436 ± 1.2 Ma. The mean $^{206}Pb/^{238}U$ of only the three oldest points yields an age of 437.0 ± 0.5 Ma, which we consider to be a good estimate of the crystallization age.

Sample TRON-06-17 was collected from a mafic body within the metasediments of the Hummelfjellet Nappe at the northern flank of the gabbro massif (Fig. 10). The country rocks are well-recrystallized quartzites and meta-arkoses. The foliation in the metasediments dips toward the gabbro massif and forms a bowl-shaped structure with the Tronfjell Gabbro Massif in its center (Wellings, 1996; Wellings and Sturt, 1998). However, locally, the foliation is gently folded along outcrop-scale, NE-SW–trending, open folds, and the foliation at the sample location dips 30°–50° toward the SSW or WSW. The mafic bodies are subparallel to the foliation of the country rock and probably exploited preexisting fabrics during their emplacement (Wellings, 1996).

The mafic rock is partly amphibolitized and foliated and was sampled to test whether these rocks and the Tronfjell Gabbro are consanguineous. In total, 42 zircons were recovered from the heavy fraction after mineral separation. The zircons are mostly euhedral, prismatic, clear, inclusion-free crystals or broken tips. The crystal habit is typical for magmatic zircons. Some zircons are pale brown tinted, and yet others contain some inclusions or

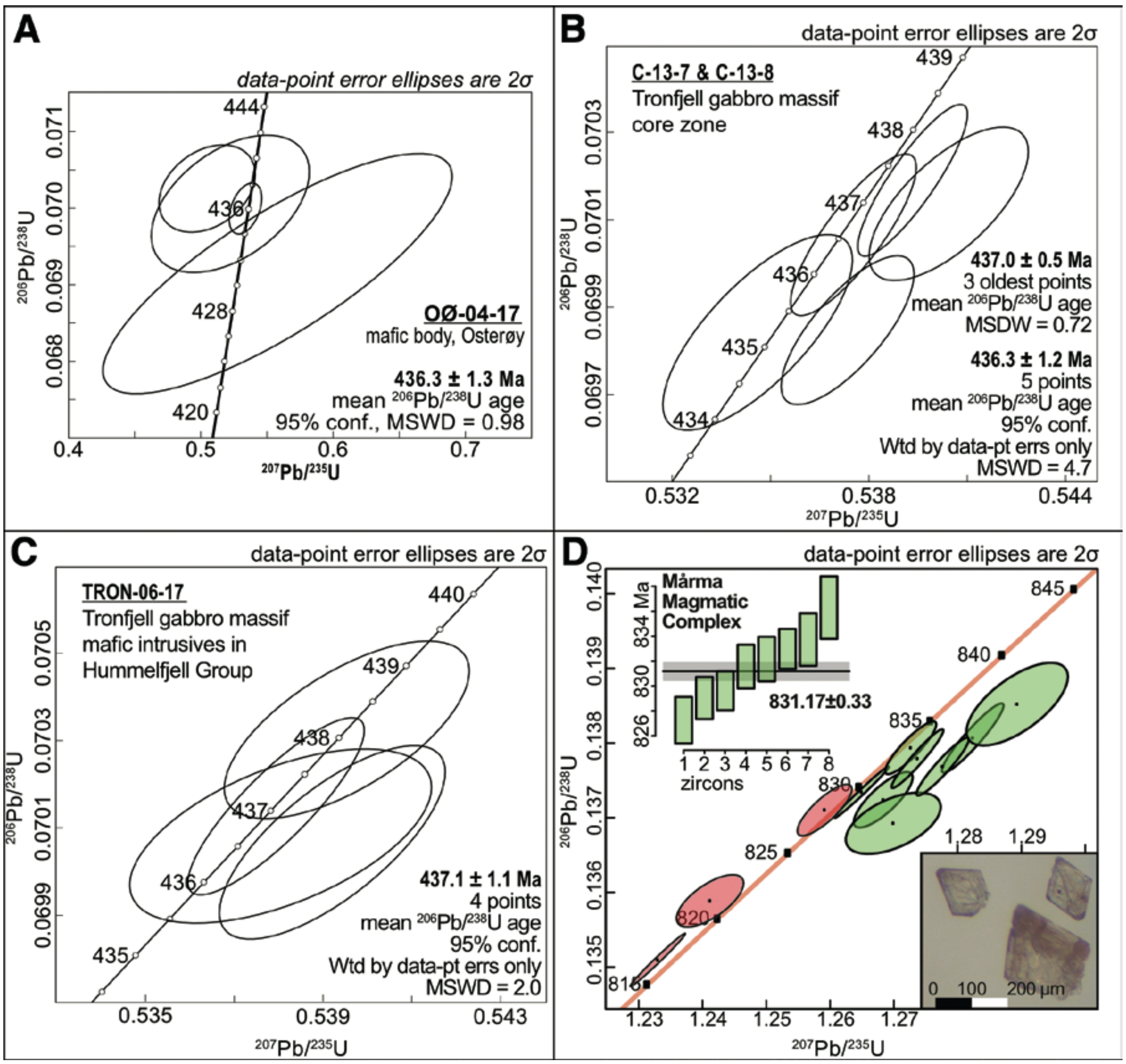

Figure 9. Results of the geochronological analyses. (A) Concordia plot of sample OØ-04-17 from the Samnanger Complex. (B–C) Concordia plots of samples from the Tronfjellet Gabbro and mafic intrusives in the Hummelfjellet Nappe, respectively. (D) Concordia diagram with inset picture of the analyzed zircons. Reverse discordant analyses are shown with red error ellipses. Other analyses are shown with green error ellipses and were used for calculating the age; see inset. Inset graph shows the age of the analyzed zircons in ascending order, as well as the mean age. MSWD—mean square of weighted deviates.

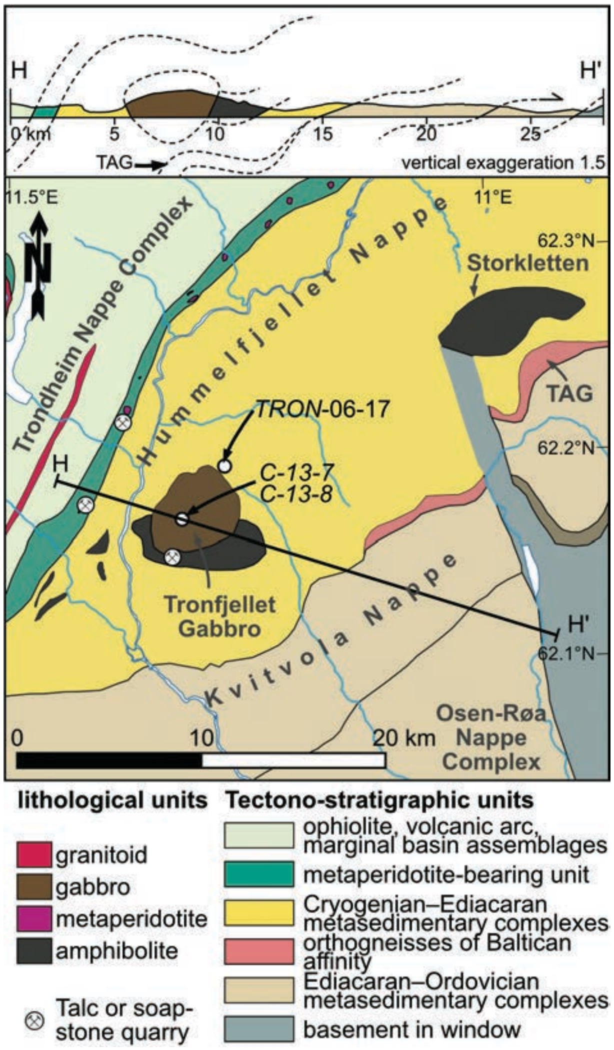

Figure 10. Tectono-stratigraphic map and cross section in the Tronfjellet area. TAG—Tännäs Augen Gneiss.

are fractured. Of those 42 zircons, four zircons free of inclusions, fractures, and cores were optically selected for chemical abrasion and ID-TIMS analyses. The results are presented in Figure 9C and Table 3. Three of the analyses are concordant, and the fourth plots below the concordia line. All analyses overlap within error, and the mean $^{206}Pb/^{238}U$ age of all four points is 437.1 ± 1.1 Ma, which we interpret to represent a good estimate of the crystallization age.

Mårma Magmatic Complex and Surrounding Basement

The Mårma magmatic complex is a bimodal magmatic complex preserved within the Seve Nappe Complex in the Kebnekaise area in the central segment (Fig. 11). The complex measures ~10 × 5 × 1 km and sits within a mixture of orthogneisses and paragneisses. Both the felsic and mafic components of the Mårma magmatic complex as well as the host rock basement gneisses are cut by fine-grained mafic dikes with chilled margins toward the host rock. Locally, chilled margins have dendritic garnet growth. The geochemistry of these dikes is similar to that of the Scandinavian Dike Complex, and it is therefore interpreted to be related to the Scandinavian Dike Complex (Andréasson et al., 2018; Tegner et al., 2019). The felsic component of the Mårma magmatic complex, referred to as the Vistas granite by Paulsson and Andréasson (2002) and the Vassacorru igneous complex by Andréasson et al. (2018), constitutes a porphyritic granite with large phenocrysts of K-feldspar. Locally, rims of finer-grained albite can be observed, giving the rock a conspicuous rapakivi texture. Other common minerals within the granite are muscovite, biotite, quartz, and plagioclase with accessory minerals such as zircon, magnetite, and apatite. Toward the edge of the well-preserved lens, the granite becomes strained into an augen gneiss. Here, zoisite, titanite/rutile, and zoned garnet become abundant. The mafic component is a medium-grained gabbro with plagioclase, orthopyroxene, and clinopyroxene. A static corona texture has developed between orthopyroxene and plagioclase and consists of garnet, clinopyroxene, and quartz. This metamorphic reaction has not been dated, and its timing is yet unconstrained.

The felsic and mafic components were intruded contemporaneously, as is shown by abundant back veining of both components and magma mingling and hybridization textures (Fig. 11). The mixing of the two components can also be observed in geochemistry (Andréasson et al., 2018).

Some dating efforts have been conducted using secondary ion mass spectrometry (SIMS) on various overgrowth textures on zircons. Several long, prismatic zircons with a high aspect ratio, likely representing typical magmatic zircons, provided an age of 845 ± 14 Ma (Paulsson and Andréasson, 2002) for the felsic component. This age is, however, based on five SIMS analyses, of which four overlap within error. No age dating of the mafic component has been attempted. The following paragraphs present new, precise, ID-TIMS U-Pb zircon ages for both the granite and the gabbro of the Mårma magmatic complex.

Samples HJK_2070, HJK_2091, and HJK_2093 (Fig. 11) are all medium-grained gabbroic rocks consisting primarily of pyroxene and feldspar. They are unstrained but show corona textures as described above. The zircon crystals were relatively large (~100 µm), brown, and often skeletal. Two overlapping concordant analyses yielded a concordia age of 833 ± 054 Ma. Most of the remaining analyses were slightly below the concordia line (Fig. 9D; Table 3). The weighted average $^{206}Pb/^{238}U$ age for all the zircon analyses is 831 ± 0.33 Ma.

Sample HJK_2064 is an augen gneiss with a strong L-tectonite fabric defined by the stretched K-feldspar porphyroclasts. It is coarse grained and, in addition to the K-feldspar augen, also contains biotite, quartz, and plagioclase as main phases. To avoid issues with inheritance, clear, prismatic zircon crystals with a high aspect ratio were chosen for the subsequent dating. One of the analyses was concordant and gave a concordia age of 828 ± 0.75 Ma. The other three near-concordant analyses were slightly younger, and all the analyses gave a weighted average $^{206}Pb/^{238}U$ age of 822 ± 0.47 Ma (Fig. 9D; Table 3).

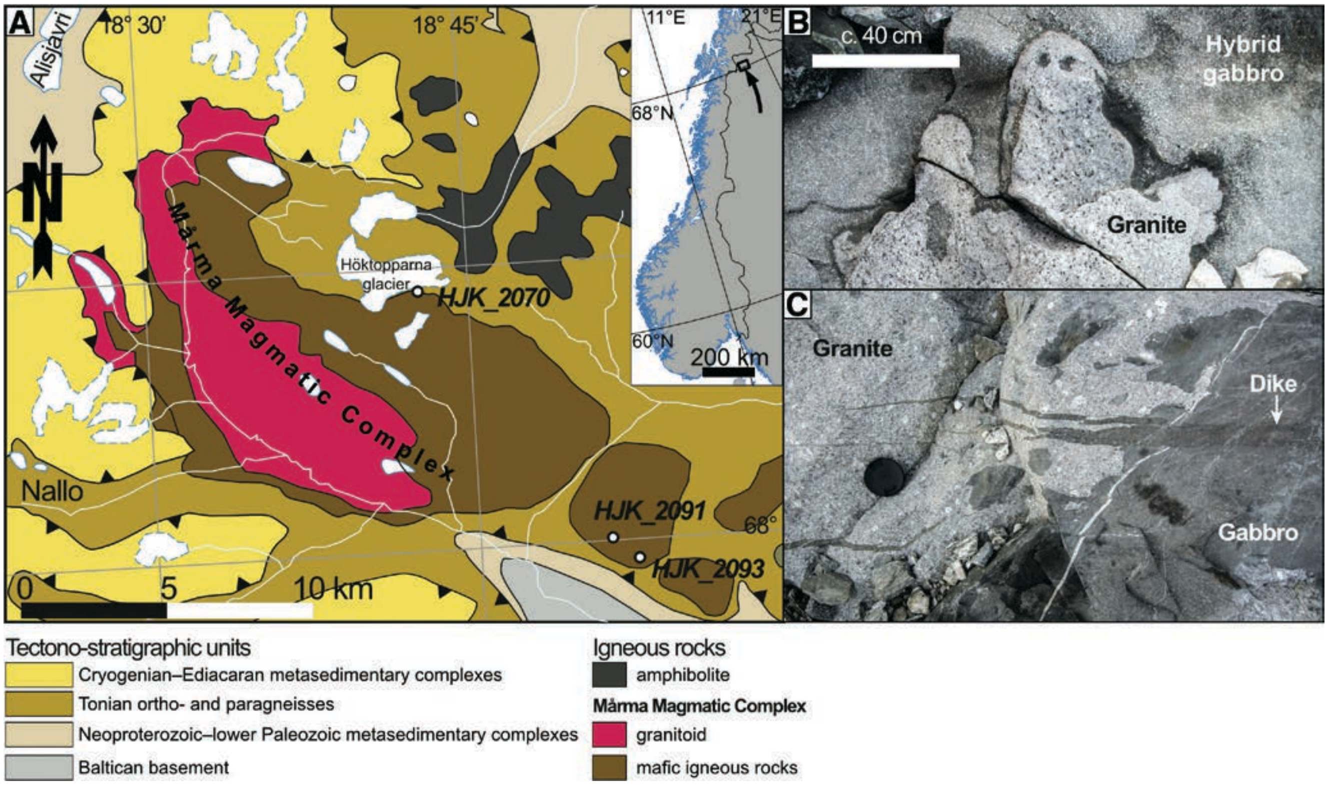

Figure 11. (A) Geologic map of the Mårma area based on maps from Paulsson and Andréasson (2002) and Andréasson et al. (2018). Sample locations for geochronological analyses are indicated. (B–C) Mingling and mixing between the felsic and mafic components. Note the late mafic dikes cutting the Mårma igneous complex in C.

DISCUSSION

Alpine-Type Metaperidotite-Bearing Units—A Marker Level within the Tectono-Stratigraphy of the South and South-Central Scandinavian Caledonides

The Alpine-type metaperidotite-bearing metasedimentary complexes between Bergen and Esandsjøen share several characteristics. First and foremost, the metasedimentary units are composed of similar lithological assemblages consisting of a mix of fine- and coarse-grained, locally calcareous metasediments that are intimately associated with lens-shaped solitary ultramafic bodies and monomict ultramafic metasediments. The metasedimentary host rocks of the Samnanger Complex, the Fortun Nappe, and the metaperidotite-bearing units in Gudbrandsdalen are estimated to have been deposited in the Cambrian–Ordovician. More precise estimates for the depositional ages can be derived from the youngest detrital zircons (ca. 468 Ma; e.g., Slama and Pedersen, 2015) and estimates for the age of the Dapingian–Darriwilian Otta conglomerate fauna (470–458 Ma). Because of the occurrences of monomict ultramafic conglomerates and ultramafic bodies and the similar composition of the metasedimentary complexes hosting the ultramafic rocks in the Blåhøa and Esandsjøen Nappes, a correlation with the metaperidotite-bearing units in the Vågåmo-Otta area is suggested. Earlier correlations with, e.g., the Särv and Seve Nappes, are difficult because no occurrences of pre-Scandian monomict ultramafic conglomerates have been reported from these units. Locally, the metasediments are associated with slivers of Precambrian gneisses of Baltican affinity, Cambrian–Ordovician intermediate to felsic meta-igneous rocks, mafic magmatic rocks of unknown age, as well as ca. 437 Ma and 427–420 Ma granitoids.

The lens-shaped ultramafic bodies that were collected from the metaperidotite-bearing units presented above and that were analyzed for whole-rock geochemistry all exhibited a primitive composition sensu Stigh (1979). Moreover, the O and C stable isotope compositions of carbonates associated with the metaperidotites and ultramafic conglomerates indicate that the metaperidotite bodies experienced a common metamorphic/metasomatic history at similar peak metamorphic temperatures (Jakob et al., 2018). The metasomatic history of these ultramafics is consistent with pre-orogenic exhumation to Earth's surface and hydration (serpentinization), which likely occurred in the early Middle Ordovician. The hydration was followed by prograde (partial) dehydration and crystallization of olivine and talc due to the breakdown of the other hydrated phases that were stable at lower temperatures. Dehydration (the breakdown of serpentine minerals) is a common reaction within the metaperidotites in these units and can be observed in the metaperidotite bodies and conglomerates between Bergen and Esandsjøen. Dehydration is largely temperature dependent and occurs at temperatures of ~500–550 °C (e.g., Trommsdorff and Connolly, 1996), which is in excellent agreement with the peak metamorphic temperatures derived from the RSCM analyses and thermodynamic calculations.

The ultramafic rocks and metasediments experienced common metamorphism that is here interpreted to be of Scandian age. The available evidence suggests that juxtaposition of the metaperidotite-bearing units between Bergen and Esandsjøen occurred prior to the metamorphism at the recorded peak temperatures. Furthermore, there is no evidence to suggest that the metaperidotite-bearing units originated in two (or more) different geodynamic settings or paleogeographic realms, as there is no documented variation in the whole-rock geochemistry of the ultramafic rocks or different depositional ages of the sedimentary successions.

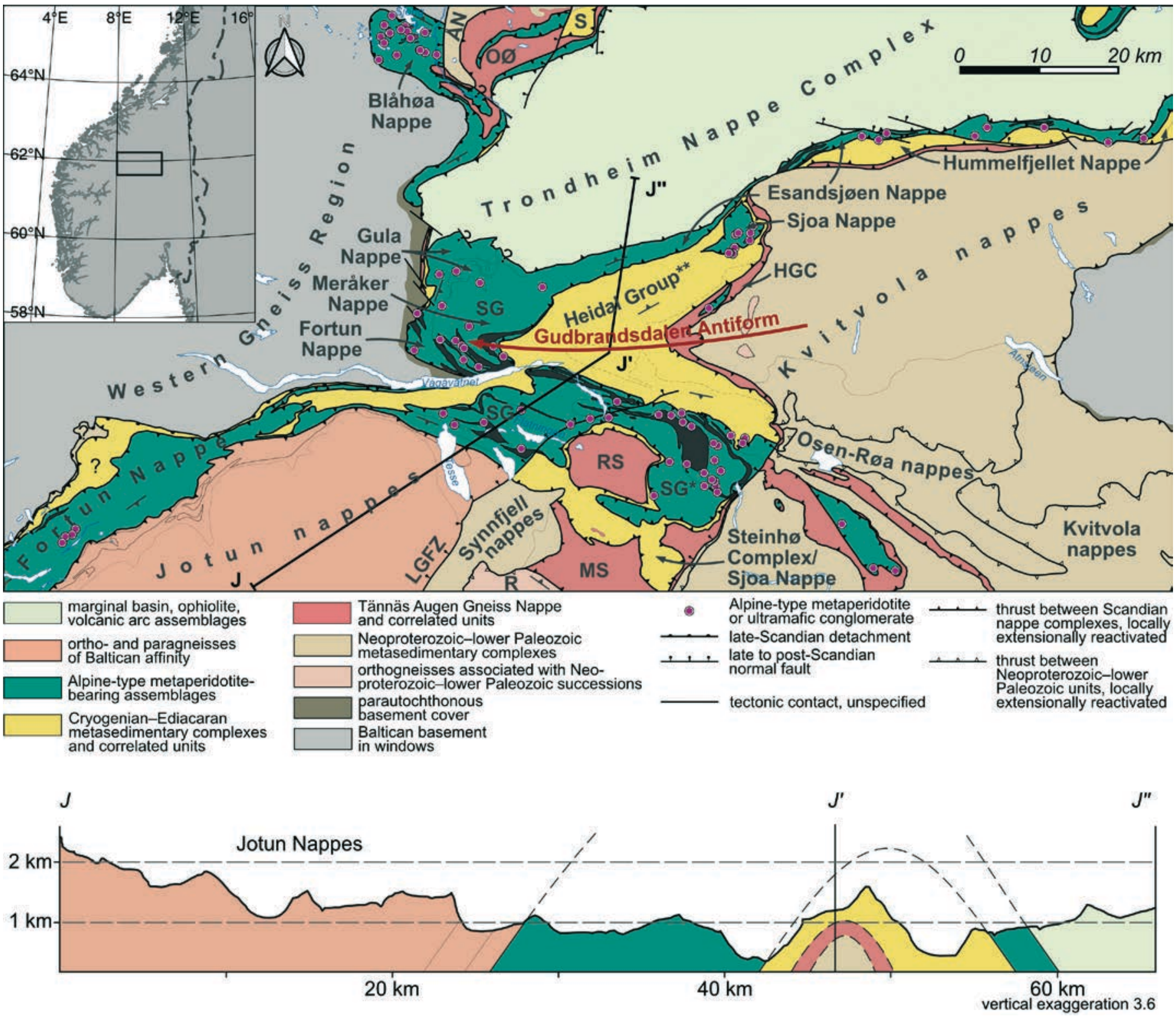

Figure 12. Geologic map of northern Gudbrandsdalen. Note that all metaperidotite-bearing units are displayed in the same color, but that the names that have been used in the literature for various sections of the metaperidotite-bearing unit in Gudbrandsdalen are indicated. ÅN—Åmotsdal Nappe; HGC—Høvringen Gneiss Complex; LGFZ—Lærdal-Gjende fault zone; MS—Mukampen Suite; OØ—Oppdal Øyegneiss; R—Refjellet; RS—Rudihø Suite; S—Sætra Nappe; SG—Sel Group. Note that the Sel Group to the east of the Lærdal-Gjende fault zone is also referred to as Svartkampen Group (SG*) and has been suggested to belong to the Otta or Meråker nappes. **In some tectono-stratigraphic compilations, the Heidal Group in the center of the Gudbrandsdalen antiform is also included in the Kvitvola nappes (e.g., Siedlecka et al., 1987).

It is important to note that the data presented above do not enable us to establish whether there are two (or more) tectonic units present with virtually identical characteristics, or, alternatively, there is only one tectonic unit. However, the lack of distinguishable characteristics and the almost seamless continuity of the metaperidotite-bearing units at the same tectono-stratigraphic level from one region into the next suggest that—with the principle of parsimony in mind—the metaperidotite-bearing assemblages represent one single tectonic unit, as suggested previously (Andersen et al., 2012; Jakob et al., 2019).

Revision of the Tectono-Stratigraphy in the Gudbrandsdalen and Adjacent Areas

Assigning the metaperidotite-bearing units to a single tectonic unit greatly simplifies the structural geology in northern Gudbrandsdalen (Fig. 12) as it resolves the structurally problematic juxtaposition of the Lower and Upper Allochthons (Fig. 1). In Figure 13, the traditional allochthon scheme for the south and south-central Scandinavian Caledonides is compared with the revised tectono-stratigraphic scheme (Jakob et al., 2019; this study). Note that in the traditional tectono-stratigraphic scheme, at minimum, two structural levels are characterized by the occurrence of metaperidotite-bearing assemblages (Figs. 1 and 13). In the revised scheme, all metaperidotite-bearing units are combined into a single tectono-stratigraphic unit based on the shared characteristics presented above (Figs. 12 and 13). Note also that the metaperidotite-bearing units include tectonic units that traditionally were assigned to the Lower, Middle, and Upper Allochthons. Moreover, whereas the metaperidotite-bearing units north of the Gudbrandsdalen antiform are structurally overlain by tectonic units traditionally included in the Upper Allochthon, i.e., the Trondheim Nappe Complex, south of the Gudbrandsdalen antiform, these units are structurally overlain by units traditionally included in the Middle Allochthon, i.e., the Jotun, Lindås, and Dalsfjord Nappes (Figs. 12 and 13). The interpretation that the metaperidotite-bearing units belong to one tectonic unit implies that the traditional tectono-stratigraphic scheme needs to be revised. For example, on the southern limb of the Gudbrandsdalen antiform and near the northeastern termination of the Jotun Nappe, metaperidotite-bearing assemblages occur west and east of the trailing end of the Lærdal-Gjende fault zone (Fig. 12). West of the Lærdal-Gjende fault zone, the metaperidotite-bearing units dip below the gneisses of the Jotun Nappe. East of the Lærdal-Gjende fault zone, the metaperidotite-bearing units structurally overlie paragneisses and orthogneisses that

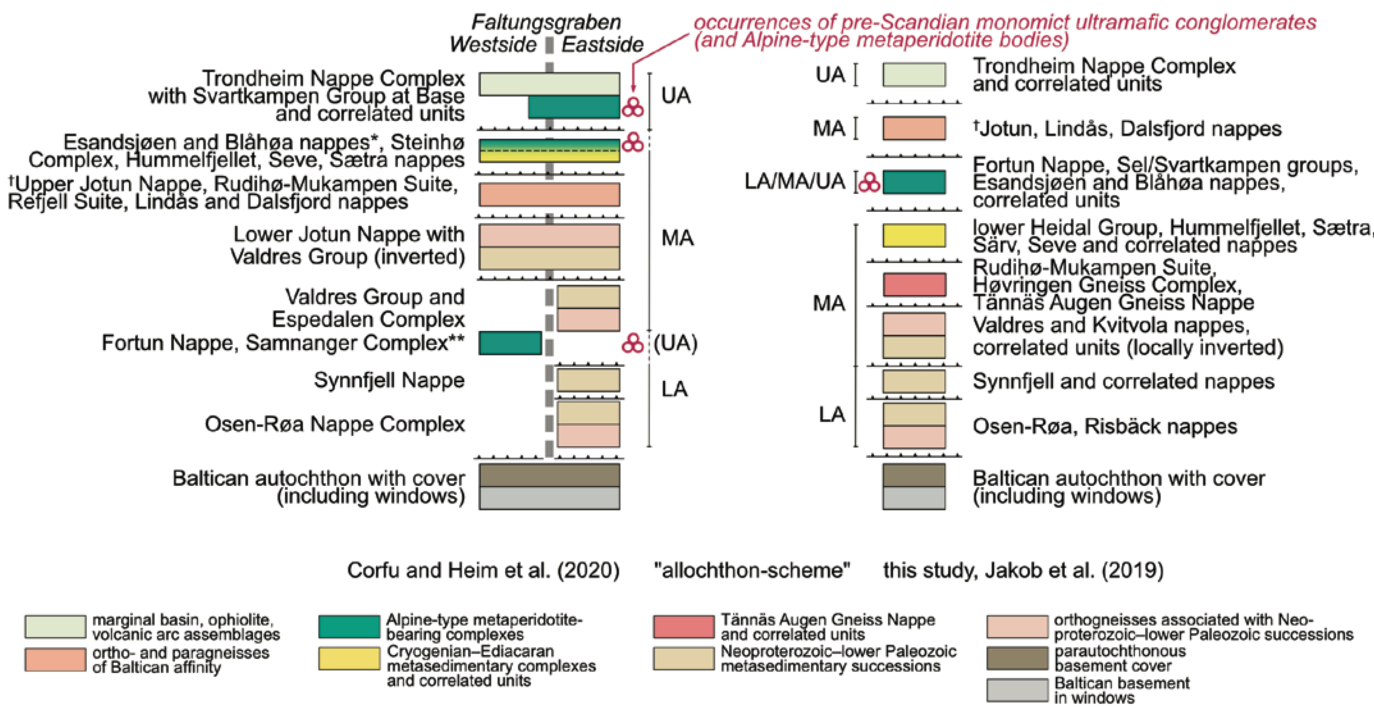

Figure 13. Summary chart of selected tectono-stratigraphic schemes used in northern Gudbrandsdalen. The distribution of ultramafic conglomerates and Alpine-type metaperidotite bodies within the tectonic units between Bergen and northern Gudbrandsdalen is shown. Note that in the revised tectono-stratigraphic scheme (see also Jakob et al., 2019), occurrences of ultramafic conglomerates are restricted to one tectono-stratigraphic level. By following this approach, it is difficult to interpret the structural position of these tectonic units within the framework of the traditional tectono-stratigraphic scheme, that is, the Lower, Middle, and Upper Allochthons (LA, MA, and UA). *The Esandsjøen and Blåhøa nappes are in some tectono-stratigraphic interpretations included in the Upper Allochthon. **The Samnanger Complex is either interpreted to be part of the Lower or Middle Allochthon (in the Bergsdalen Nappes) or to be part of the Upper Allochthon (in the Major Bergen arc). †Tectono-stratigraphic level restricted to the southern segment of the Scandinavian Caledonides.

traditionally are correlated with those to the west of the Lærdal-Gjende fault zone—together commonly referred to as the Jotun-Valdres Nappe Complex. A correlation of the gneisses west and east of the Lærdal-Gjende fault zone, however, is only possible if there are at least two metaperidotite-bearing units (see discussion in Corfu and Heim, 2020; see also Figs. 1 and 13)—one below the Middle Allochthon and one above the Middle Allochthon. The suggestion of a single metaperidotite-bearing unit, however, implies that the paragneisses and orthogneisses west and east of the Lærdal-Gjende fault zone, respectively, were juxtaposed by normal displacement along the Lærdal-Gjende fault zone during late and post-Scandian extensional tectonics (see profiles in Fig. 2). The juxtaposition of the units west and east of the Lærdal-Gjende fault zone after the tectono-stratigraphy was established is also indicated by the common occurrences of metaperidotite bodies and ultramafic conglomerates in the Fortun Nappe to the west of the Lærdal-Gjende fault zone and the distinct lack of these lithologies in the Cambrian–Ordovician sedimentary successions to the east of the Lærdal-Gjende fault zone. Another indication for the juxtaposition of these units after the formation of the nappe stack is the prominent occurrence of the younger than 430 Ma granitoid Årdal Dike Complex in orthogneisses west of the Lærdal-Gjende fault zone, which only occurs subordinately in the orthogneisses to the east of the Lærdal-Gjende fault zone (Corfu and Heim, 2020; Lundmark and Corfu, 2007).

A profile parallel to and in the footwall of the Lærdal-Gjende fault zone from Gudbrandsdalen to Lærdal shows a southwestward progressive exposure of lower structural units (profile E in Fig. 2). The progressive occurrence of lower structural units is due to the increased footwall uplift toward the Lærdal Window, where offsets of the Lærdal-Gjende fault zone (along the profile line) are largest. Note that the thickness of the nappe stack west of the Lærdal-Gjende fault zone is in places estimated to be in the order of ~10–15 km (Smithson et al., 1974). Note also that basement gneisses in the Lærdal Window have a higher elevation than the orthogneisses of the Jotun Nappe west of the Lærdal-Gjende fault zone (Fig. 2), which implies large, late to post-Scandian normal displacements along the Lærdal-Gjende fault zone, making correlations between units west and east of the Lærdal-Gjende fault zone difficult.

A position of the Jotun Nappe Complex above the metaperidotite-bearing units (west of the Lærdal-Gjende fault zone) implies that the Jotun Nappe Complex (and the Lindås and Dalsfjord Nappes) occupies a higher structural position than traditionally envisaged. Moreover, because the Lindås and Dalsfjord Nappes are structurally overlain by marginal basin, ophiolite, and volcanic-arc assemblages, the Jotun, Lindås, and Dalsfjord Nappes occupy a structural level between the metaperidotite-bearing units (below) and the ophiolite, island-arc, and marginal basin assemblages (above). Because these ophiolite, island-arc, and marginal basin assemblages can be correlated with those in the central segment, such as the Trondheim Nappe Complex, this implies that the metaperidotite-bearing units in the central Scandinavian Caledonides are separated from the structurally overlying units by a major tectonic contact, which also implies that the metaperidotite-bearing units are genetically unrelated to the structurally overlying tectonic units.

The reinterpretations presented above also suggest critical scrutiny of the tectonic position of the other units of the Middle Allochthon structurally below the metaperidotite-bearing metasedimentary complexes. Moreover, the revisions of the tectono-stratigraphic units to the west and east of the Lærdal-Gjende fault zone may also suggest a revision of other tectono-stratigraphic correlations along strike of the orogen. For example, earlier correlations of the Jotun and Valdres Nappes with the Tännäs Augen Gneiss Nappe or of the Blåhøa and Esandsjøen Nappes with the Seve Nappe (e.g., Gee et al., 1985a, 1985b) need to be reassessed.

In the following, we define the Scandian nappe complexes from base to top from the characteristics of the lithotectonic units within each of the proposed structural levels. The lowest Scandian nappe complex is here defined to include all nappes containing metasedimentary successions of Neoproterozoic, coarse-grained successions associated with minor amounts of mafic meta-igneous rocks and Ediacaran–Lower Paleozoic glacial and marine deposits as well as slivers of Baltican affinity. The lowest Scandian nappe complex as defined above includes the Osen-Røa, Risbäck, Valdres, and Kvitvola Nappes and correlative units. These sequences are commonly interpreted to represent synrift successions, deposits of the rift-drift transition, and postrift sediments. Younger than 635 Ma detrital zircons in the coarse-grained sparagmite successions, the lack of cap carbonates above the glacial deposits, the occurrence of the Ediacaran-Cambrian boundary above the glacial deposits, and the presence of Ediacaran acanthomorphic acritarchs in the sediments below the glacial deposits strongly suggest that these successions are Ediacaran in age. The glacial deposits overlying the sparagmite successions can, therefore, most likely be correlated with the Mortensnes Formation (Figs. 3 and 4) in the parautochthon of the northern segment and are interpreted to be of Gaskiers age (ca. 580 Ma; e.g., Pu et al., 2016).

The next higher structural level is occupied by orthogneisses, including the Tännäs Augen Gneiss Nappe and other correlative orthogneiss units, as well as overlying Neoproterozoic metasedimentary successions such as the Fuda and Offerdal Nappes. These orthogneisses and sedimentary successions lack mafic intrusive rocks of Ediacaran age. The nappes in this structural level can be traced over large distances and structurally overlie the nappe assemblages of the Neoproterozoic–Lower Paleozoic metasedimentary complexes. Because of the occurrence of dropstones within the turbidite successions and the lack of Ediacaran mafic magmatism, these sediments are here interpreted to be of similar age as the alluvial-fluvial successions in the Neoproterozoic–Lower Paleozoic metasedimentary complexes, and likely of Ediacaran age. However, a Cryogenian depositional age cannot be excluded.

Structurally above the orthogneisses are nappes composed of Cryogenian–Ediacaran metasedimentary complexes intruded by mafic dike swarms between 608 and 596 Ma. Between Røros and Gudbrandsdalen, mafic magmatic rocks within these metasedimentary complexes at this structural level progressively decrease (Fig. 2; Jakob et al., 2019), but the units can, nevertheless, be traced into the Gudbrandsdalen area, where they link up with the Heidal Group. Locally, glacial deposits are cut by the Scandinavian Dike Complex and, therefore, are older than 608 Ma. Because of this age constraint, a correlation with the glacial deposits within the metasedimentary complexes at the base of the nappe stack (e.g., Osen-Røa, Risbäck, Valdres, Kvitvola Nappes) is implausible. However, a temporal correlation of the Scandinavian Dike Complex in the Cryogenian–Ediacaran successions with the mafic magmatic rocks in the sparagmite successions (Sparagmite Basalts) is possible.

We suggest a rigorous separation of the Neoproterozoic–Lower Paleozoic and Cryogenian–Ediacaran metasedimentary complexes into different Scandian nappe complexes. Dislodging those from the Middle Allochthon and placing them in separate structural levels will emphasize the differences and ease further discussions about the age of glaciations in Baltica (e.g., Bingen et al., 2005; Lamminen et al., 2015; Nystuen et al., 2008) and about the possible non-Baltican origins of the Cryogenian–Ediacaran metasedimentary complexes, e.g., the Seve Nappe Complex (e.g., Corfu et al., 2007; Kirkland et al., 2011). Please note that, although not discussed in detail in this contribution, we also suggest a rigorous tectono-stratigraphic separation of the Tonian metasedimentary complexes in the Kalak Nappe Complex (Kirkland et al., 2007, 2006) from the Cryogenian–Ediacaran successions. In addition to the different depositional and magmatic histories compared to the Cryogenian–Ediacaran metasedimentary complexes, the Tonian metasedimentary complexes are structurally below the Cryogenian–Ediacaran units within the Scandian nappe stack, e.g., at Mårma and Corrovarre. Moreover, the Tonian units were at lower-crustal levels in the Cryogenian and during Ediacaran magmatism (e.g., Gasser et al., 2015; Larsen et al., 2018), whereas the Cryogenian–Ediacaran units were at mid-crustal levels during Ediacaran magmatism (Kjøll et al., 2019a). Note also that an Ediacaran age for the sparagmite successions in the Neoproterozoic–Lower Paleozoic metasedimentary complexes and a correlation of the mafic intrusive and extrusive rocks within the Sparagmite basins with the 608–596 Ma magmatism in the structurally higher nappes imply an upper-crustal level and even a position at Earth's surface for the Sparagmite basin deposits during Ediacaran magmatism. The available evidence strongly suggests that the early–late Neoproterozoic successions in the Scandinavian Caledonides, although related, are not genetically equivalent and were at different crustal levels during the Ediacaran magmatism, which further highlights the importance of separating these metasedimentary successions into different tectono-stratigraphic units and levels.

Structurally above the Cryogenian–Ediacaran metasedimentary complexes, there are the Alpine-type metaperidotite-bearing units. The available data suggest that the metaperidotite-bearing units represent a single tectonic unit, which is defined by the characteristics discussed above, and which can be traced continuously within the Scandian nappe stack over large distances from the southern segment into the central segment (Fig. 12). This structural level is overlain by different tectonic units in the southern and central segments. In the southern segment, the metaperidotite-bearing units are overlain by the Jotun, Lindås, Dalsfjord, and upper Bergsdalen Nappe Complexes, whereas in the central segment, the metaperidotite-bearing units are structurally overlain by the Trondheim Nappe Complex (Figs. 2 and 13).

Northward Continuation of the Revised Tectono-Stratigraphic Units

The revisions of the tectono-stratigraphy in the Gudbrandsdalen area show that, although many of the tectonic units can be traced over large distances, some units are discontinuous, such as the orthogneisses of the Jotun, Lindås, and Dalsfjord Nappes. However, other tectonic units can be traced along the strike of the orogen and can be used to test tectono-stratigraphic correlations. As shown above, the metaperidotite-bearing unit is a key level in the tectono-stratigraphy that can be used to link tectono-stratigraphic units between the south and south-central segments. The defining criteria for the Alpine-type metaperidotite-bearing unit may help to trace it along side the other tectonic units further to the north and beyond the Røros-Esandsjøen area.

Northeast of Esandsjøen, metaperidotite-bearing units occur at the base of the metasedimentary successions in the Tännforsen synform (Fig. 2). In Sweden, these sediments are commonly included in the Köli Nappe Complex. In the Tännforsen area, the metaperidotite-bearing metasedimentary complexes have been studied by Beckholmen (1984, 1978) and Bergman (1993, 1987). These units also contain pre-Scandian ultramafic pebble conglomerates akin to those in the Gudbrandsdalen area. Notably, the ultramafic rocks there have been described as tectonically emplaced ultramafic bodies and are primitive ultramafites sensu Stigh (1979) (Bergman, 1993, 1987). The timing of thrusting of the lower Köli Nappe over the structurally lower rocks of Cryogenian metasedimentary complexes is estimated at ca. 430–423 Ma (Bender et al., 2019). Evidence for another deformation event at ca. 415 Ma was presented by Bender et al. (2019), which is here interpreted as an extensional reactivation of the Scandian thrust.

During the Scandian orogeny, most of the rocks in the Tännforsen synform experienced amphibolite-facies metamorphism and are now amphibole + garnet + biotite garbenschists. Although the depositional age is poorly constrained, these metasediments are believed to have been deposited in the Cambrian–Ordovician (e.g., Siveter, 1977). The western part of the area, however, is composed of greenschist-facies biotite-bearing metasediments without amphibole and garnet that were deposited in the Hirnantian or Llandovery (Boucot and Johnson, 1964; Dahlqvist et al., 2010). It is important to reiterate that the tectono-stratigraphy of southern Norway suggests a major shear zone between the metaperidotite-bearing units and the structurally overlying tectonic units. Beckholmen (1982) mapped out series of pseudotachylite-bearing mylonite zones in the Tännforsen area that separate the Cambrian–Ordovician garbenschists from the biotite-grade Llandovery metasediments. Thus, the latter are probably correlative with Llandovery metasediments in the Meråker Nappe in Norway (e.g., Kjølhaugen Group). It appears that the metaperidotite-bearing unit correlates with the lower Köli Nappe but may also include units that are traditionally assigned to other structural levels of the Köli nappes. However, detailed investigations of the different lithologies within these units are needed to facilitate the comparisons with the Alpine-type metaperidotite-bearing units as defined here in the south and south-central segments.

To trace the Scandian nappes further north, we used existing correlations of tectonic units with, for example, the lower Köli Nappe, Seve Nappe, or Tännäs Augen Gneiss Nappe. The Scandian nappes can be traced continuously along the eastern margin of the Faltungsgraben. It is important to note that the succession of nappes is consistent and can be traced from one region into the next; i.e., Neoproterozoic–Lower Paleozoic units are structurally overlain by the orthogneisses of the Tännäs Augen Gneiss and correlated units, which in turn are overlain by Cryogenian–Ediacaran metasedimentary complexes. Metaperidotite-bearing units consistently overlie the Cryogenian–Ediacaran metasedimentary complexes (Fig. 14). In basement windows, some of the lower structural units are locally excised, but the preserved successions are consistent with and repeat parts of the less disturbed tectono-stratigraphic successions along the eastern margin of the Faltungsgraben.

Although locally strongly metasomatized, serpentinites at Linnajavri are primitive ultramafites sensu Stigh (1979) (see supplemental material in Beinlich et al., 2012) (Fig. 14). Carbonates associated with the metaperidotites exhibit O and C isotopic signatures that are virtually indistinguishable from those of carbonates associated with the metaperidotite bodies in the southern segment (Beinlich et al., 2012; Jakob et al., 2018). The geochemistry of the metaperidotites and the O and C isotope signatures of the carbonates indicate similar protoliths for the ultramafic bodies in the southern and central segments as well as a similar metasomatic/metamorphic history.

The ultramafites in the central segment are associated with amphibolite-facies metasediments that are locally garnet-bearing garbenschist and ultramafic pebble conglomerates, as well as mafic magmatic rocks, partly pillow basalts (e.g., Lindahl et al., 2008). At one locality, an ultramafic pebble conglomerate is interlayered with a fossiliferous carbonate near its top. The latter contains gastropods of the genus *Maclurites* (Holmqvist, 1982, 1980), which have been compared to the fossils in the metaperidotite conglomerates at Gudbrandsdalen. The comparison with the Otta fauna, however, has been criticized due to the poor preservation quality of the few fossils found at the locality in the lower Köli Nappe (Bruton and Harper, 1982). Elsewhere, the development of blocky serpentinite has been reported from some of the metaperidotite bodies in the central segment (Stølen, 1985). An albite trondhjemite intruding rocks of the volcanic Ankerede Formation, which is structurally in-between two metaperidotite-bearing formations, was dated at 488 Ma (Claesson et al., 1983). Therefore, the depositional and magmatic ages of the metasediments and magmatic rocks associated with the metaperidotites in the central segment are comparable with those in the southern segment.

Further toward the north, metaperidotite is abundant at this structural level until the Narvik area (Fig. 14). Metaperidotite bodies are scarce within the Narvik and lower Köli Nappes of the northern segment (Karlsen and Nilsson, 2000). Augland et al. (2014b) correlated the Narvik Nappe with the Nordmannvik Nappe in the northern segment, which does contain several solitary metaperidotite bodies that have been metasomatized to sagvandites (Zwaan et al., 1998). The metasediments of the Narvik Nappe are amphibolite-facies garbenschists, and they contain a 437 Ma layered gabbroic intrusion (Tucker et al., 1990) as well as 437 Ma granitoid dikes (Northrup, 1997). However, the depositional age of the metasediments of the Nordmannvik Nappe is unknown. Moreover, the Nordmannvik Nappe structurally overlies Ordovician–Silurian metasediments of the Tamokdal Nappe, and, therefore, a correlation with the metaperidotite-bearing units of the southern segment remains speculative. Locally, Alpine-type metaperidotite-bearing mica schist units also occur intercalated with the Kalak Nappe Complex. However, neither the age of these mica schists nor the geochemistry of these metaperidotites is known, and a genetic relationship with the Ordovician metaperidotite-bearing units of the southern segment also remains speculative. Therefore, these units are not included further here in the discussion.

Scandian Orogeny in View of a Revised Tectonic Framework

The succession of tectonic units presented above warrants a revision of the succession of the tectonic events leading up to the Scandian orogeny in the context of the revised tectono-stratigraphy. The tectono-stratigraphic framework is paramount for the understanding of the evolution of an orogen, because paleogeographic reconstructions and the succession of metamorphic events that formed the nappe stack are derived from the tectono-stratigraphy. The simplest possible tectonic model suggests that the highest tectono-stratigraphic units were incorporated into the nappe stack first and, therefore, were lying further outboard (with respect to the lower/subducting plate) than structurally lower units. The paleogeographic positions derived from this "unstacking" of the nappes imply that metamorphic events, related to the shortening leading up to the Scandian orogeny, occurred in sequence and become younger from the top to the base of the nappe stack. In the traditional tectono-stratigraphic scheme, some tectonic events, e.g., the ca. 450 Ma metamorphism in the Dalsfjord Nappe Complex, were not easily explained, because those events were older than expected with respect to their presumed paleogeographic position. Within the revised tectono-stratigraphic framework, the Jotun, Lindås, and Dalsfjord nappe complexes occupied the highest tectono-stratigraphic position of the continentally derived units interpreted to be of Baltican origin before the onset of Scandian thrusting, which naturally implies that these units were the first to experience metamorphism and deformation during the collision of Baltica with the Iapetan subduction complexes.

Inboard of the Jotun, Lindås, and Dalsfjord nappe complexes (i.e., closer to Baltica), there were the metaperidotite-bearing units, and even further inboard, there were the Cryogenian–Ediacaran metasedimentary complexes. Whereas the Scandian thrust distances for the Cryogenian–Ediacaran metasedimentary complexes structurally below the metaperidotite-bearing units have been estimated to be up to 600–1000 km (Gee, 1978; Kumpulainen and Nystuen, 1985; Nystuen et al., 2008), the Scandian displacement of the Jotun, Lindås, and Dalsfjord nappe complexes was traditionally envisaged to be much less—similar to that of the Neoproterozoic–Lower Paleozoic units, e.g., thrust distance of ~300 km (e.g., Hossack et al., 1985; Kumpulainen and Nystuen, 1985). The revised tectono-stratigraphy, however, also implies a much-increased displacement for the Jotun, Lindås, and Dalsfjord nappe complexes (Andersen et al., 2012; Jakob et al., 2019, 2017). A paleogeographic position of these units comparable to that of Cryogenian–Ediacaran units in the central segment is corroborated by the contemporaneity of the ca. 450–445 Ma HP metamorphism and the unconformable deposition of post-Ashgillian sediments onto both units (e.g., in the

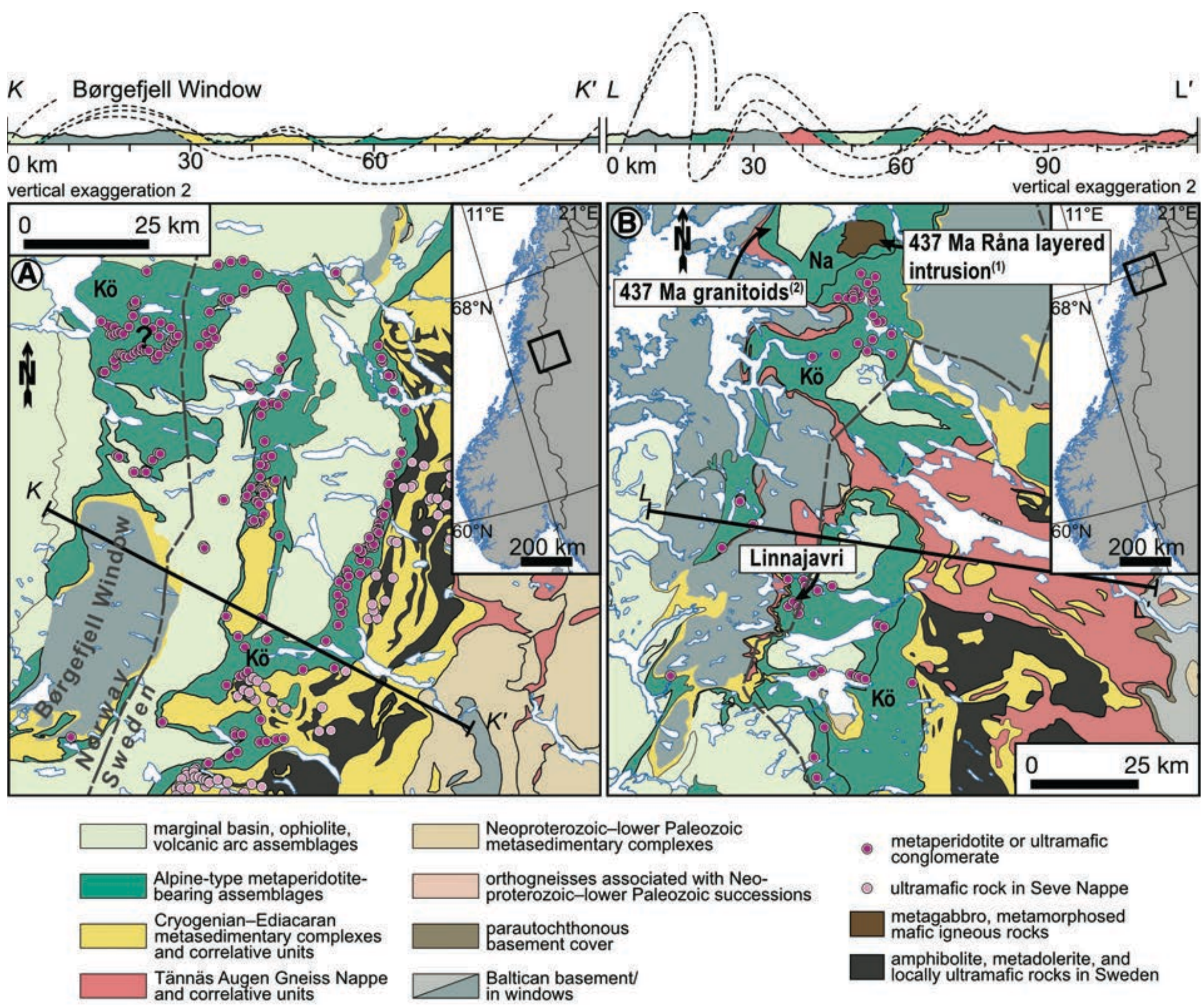

Figure 14. Tectono-stratigraphic maps and profiles in the central segment of the Scandinavian Caledonides of (A) the area east and north of the Børgefjell Window and (B) northern Nordland. 1—Tucker et al. (1990); 2—Northrup (1997). Note the consistent tectono-stratigraphic succession of Alpine-type metaperidotite-bearing units structurally overlying the Cryogenian–Ediacaran succession, which is also repeated within basement windows. Note also that tectonic units of the Köli Nappe Complex that are free of metaperidotite-bearing assemblages are here included within the marginal basin, ophiolite, and volcanic arc assemblages. Other tectonic units of the Köli Nappe Complex, which are characterized by the presence of solitary ultramafic bodies but are commonly considered to be in the middle or upper Köli nappes, e.g., at Hatfjelldal (question mark in A), are here tentatively included in the metaperidotite-bearing unit. Kö—Köli Nappe Complex; Na—Narvik Nappe.

Dalsfjord and Váddás nappe complexes). Further support for a far outboard position is indicated by the paleomagnetic data from the Magerøy Nappe in northern Norway (Corfu et al., 2006), as well as by the exotic island-type nature of the Otta fauna (Bruton and Harper, 1981). It is here suggested that all units that experienced a ca. 450 Ma HP metamorphic event were in comparable paleogeographic positions, i.e., at similar distance to the present-day Caledonian erosional front.

In the context of the revisions suggested here, the 437 Ma mafic magmatism in the metaperidotite-bearing unit (Osterøy) and in the Cryogenian–Ediacaran units (Tronfjell Gabbro) is of particular interest with respect to the ca. 450–440 Ma HP metamorphism. High-pressure, low-temperature and eclogite-facies metamorphism typically occurs in the lower plate in a subduction zone, whereas magmatism and granulite-facies metamorphism occur in the upper plate. The sequence of HP metamorphism and subsequent magmatism suggests that these units were first in a lower-plate position but were subsequently accreted to the upper plate within a period of ~10 m.y.

Models presenting the sequence of tectonic events, i.e., the accretion of tectonic units from the lower to the upper plate, formation of the nappe stack, and its thrusting over the Baltican margin for the southern and central segments, are presented in Figures 15 and 16. In these models, HP and eclogite-facies metamorphism in the nappes is interpreted to indicate a position in the lower plate at the time of metamorphism, whereas sedimentation and contemporaneous magmatism and lower-pressure and higher-temperature metamorphism are interpreted to indicate a position in the upper plate. For simplicity, a displacement of ~300 km for each of the tectonic units has been indicated, in agreement with displacement estimates previously suggested in the literature (Gee, 1978; Kumpulainen and Nystuen, 1985; Nystuen et al., 2008; Rice, 1998).

Because of the evidence for HP metamorphism in the Lindås, Dalsfjord (Fig. 15), and Seve Nappes (Fig. 16) at ca. 450 Ma, a lower-plate position at this time, i.e., on the Baltican plate, is suggested for these tectonic units. This implies that Baltican continental units were ≥900 km outboard of the present-day Caledonian erosional front and collided with a subduction complex well before the cessation of arc magmatism at ca. 430 Ma (Corfu et al., 2006). The termination of the arc magmatism is here interpreted to mark the onset of collision between the little- to nonthinned components of the rifted margins of Baltica and Laurentia, leading to the burial of the future Western Gneiss Region. The large thrust distances and the protracted nappe formation until the collision of the little- to nonthinned cratonic margins suggest that there was a wide rifted margin composed of thinned continental crust outboard of the Baltican necking domain. Comparable wide present-day margins may be represented by, for example, the Atlantic margin offshore the UK and Ireland (Andersen et al., 2012), the Iberia-Newfoundland margin, and other wide rifted margins in the southern Atlantic (Mohn et al., 2014; e.g., Péron-Pinvidic et al., 2013; Péron-Pinvidic and Manatschal, 2010). The width of the Baltican margin is here interpreted to be the result of protracted Tonian–Ediacaran thinning of the continental crust and the subsequent successful rifting and seafloor spreading.

Before the Ashgillian (ca. 460 Ma), Iapetus oceanic crust was subducted beneath a complex magmatic arc system along the leading edge of the Laurentian plate, referred to as pre-Ashgillian oceanic assemblages in Figures 15 and 16. This subduction complex developed on earlier ophiolite/arc and marginal basin assemblages that were accreted to and formed at the leading edge of the Laurentian margin before, during, and after the Taconian orogeny (e.g., Slagstad et al., 2014; van Staal et al., 2013; Waldron and van Staal, 2001).

The time of the entry of originally Baltican continental crust into subduction systems in the Late Ordovician can roughly be estimated by the ≤450 Ma amphibolite-facies to HP metamorphism in the Cryogenian–Ediacaran units and the Lindas and Dalsfjord Nappes. Note that these metamorphic ages are older than crystallization and depositional ages of the units that structurally overlie the Lindås, Dalsfjord, and Seve Nappes. It is here suggested that the entry of continental crust stalled the subduction, which resulted in a reduction of the convergence speed between Laurentia and Baltica, which in turn led to extension in the upper plate and the opening of marginal basins, e.g., the Solund-Stavfjord and Sulitjelma marginal basin ophiolites. We further suggest that the collision of the continental units with the trench and opening of the marginal basins were associated with the formation of pre-Ashgillian unconformities and the deposition of the Late Ordovician–early Silurian sedimentary successions.

During and after HP metamorphism of the Dalsfjord and Lindås Nappes, as well as of the Cryogenian–Ediacaran metasedimentary complexes, these continental units were sheared off the lower plate, sensu Tetreault and Buiter (2012), and accreted/subcreted to the upper plate (Figs. 15 and 16). The timing of these pre-Scandian nappe-forming events is constrained by the age of the HP metamorphism and local migmatization, i.e., 450–440 Ma (Andersen et al., 1998; Bender et al., 2019; Glodny et al., 2008; Ladenberger et al., 2014; Root and Corfu, 2012). Moreover, the Jotun, Lindås, and Dalsfjord nappe complexes, the metaperidotite-bearing units, and the Cryogenian–Ediacaran units must have been accreted to the upper plate before the emplacement of the 437 Ma igneous rocks in the metaperidotite-bearing units structurally below the Lindås and Jotun Nappes and those in the Hummelfjellet Nappe (Figs. 15 and 16).

Nappe formation occurred in sequence, and the structurally lower nappes composed of the Neoproterozoic–Lower Paleozoic units formed between 438 and 432 Ma (Bender et al., 2019; Faber et al., 2019). The age estimates for the timing of the formation of these nappes shows that in-sequence shortening, nappe formation, and thrusting toward Baltica continued contemporaneously with the opening of the marginal basins in the upper plate in the southern and central segments (Figs. 15 and 16). Nappe formation and arc magmatism continued until subduction was thwarted by the entry of thick continental lithosphere into the trench, i.e., the burial of the proto–Western Gneiss Region. Due to the blocking of the subduction zone, the main zone of convergence migrated outboard (with respect to Baltica), resulting in the closure and out-of-sequence thrusting of the marginal basins over the already assembled nappe stack (Figs. 15 and 16). The timing of the out-of-sequence thrusting and the development of the final thrust-related architecture of the nappe stack can be estimated to have lasted until after the emplacement of the ca. 430–420 Ma synorogenic granitoids that occur, for example, in the Jotun Nappe and the metaperidotite-bearing units in the southern segment, but not in the Neoproterozoic–Lower Paleozoic metasedimentary complexes (Andersen and Jamtveit, 1990; Augland et al., 2014b; Bender et al., 2019; Corfu et al., 2006, 2003a; Jakob et al., 2017; Lundmark and Corfu, 2007). After the closure of the

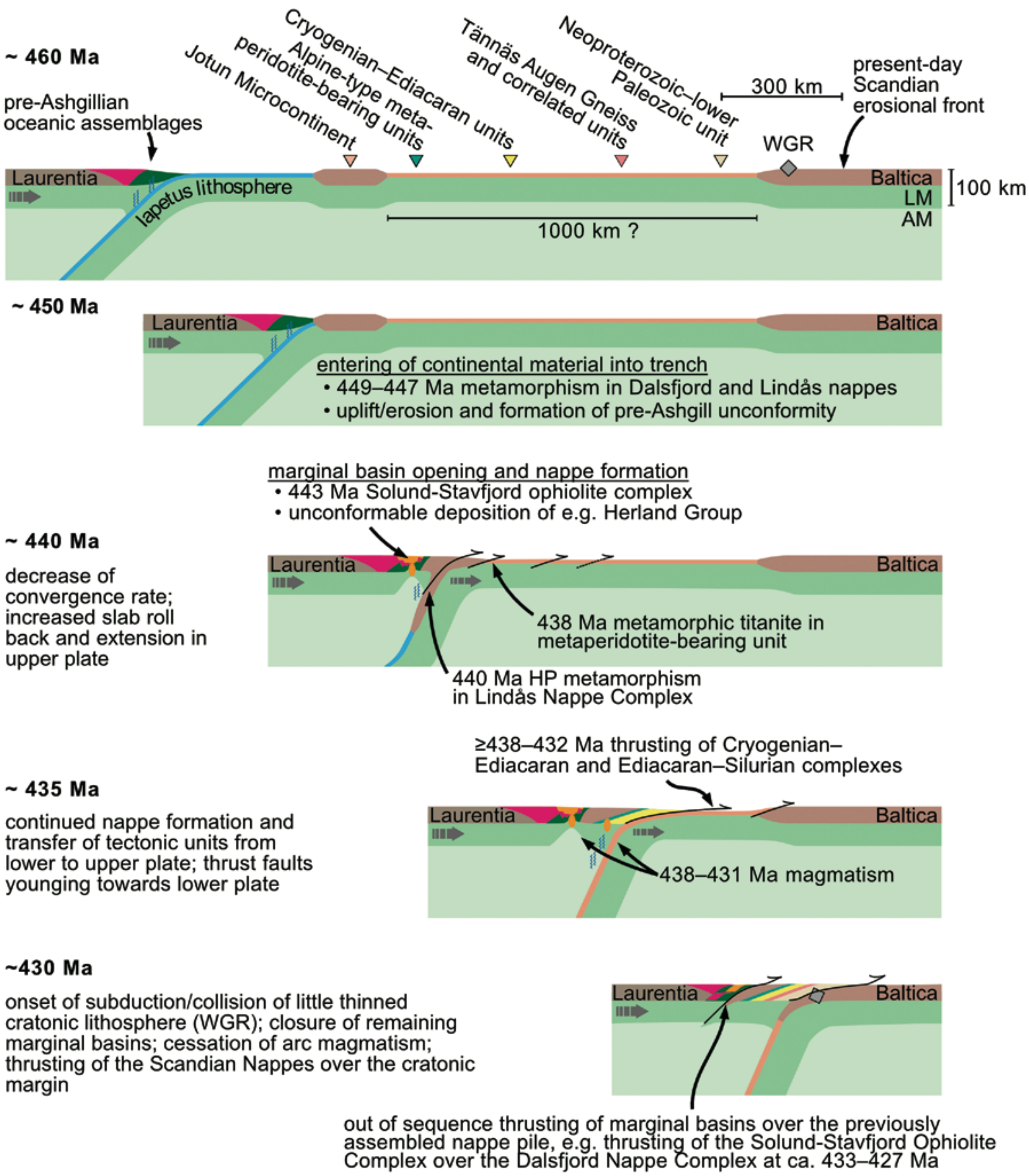

Figure 15. Sequence of tectonic events between 460 and 430 Ma in the southern and south-central segments of the Scandinavian Caledonides. Triangles indicate the paleogeographic distance of the main tectonic units with respect to the present-day Scandian erosional front before the onset of shortening at ca. 450 Ma. The Jotun microcontinent includes the Jotun, Lindås, and Dalsfjord nappes. AM—asthenospheric mantle; LM—lithospheric mantle; WGR—future Western Gneiss Region; HP—high pressure.

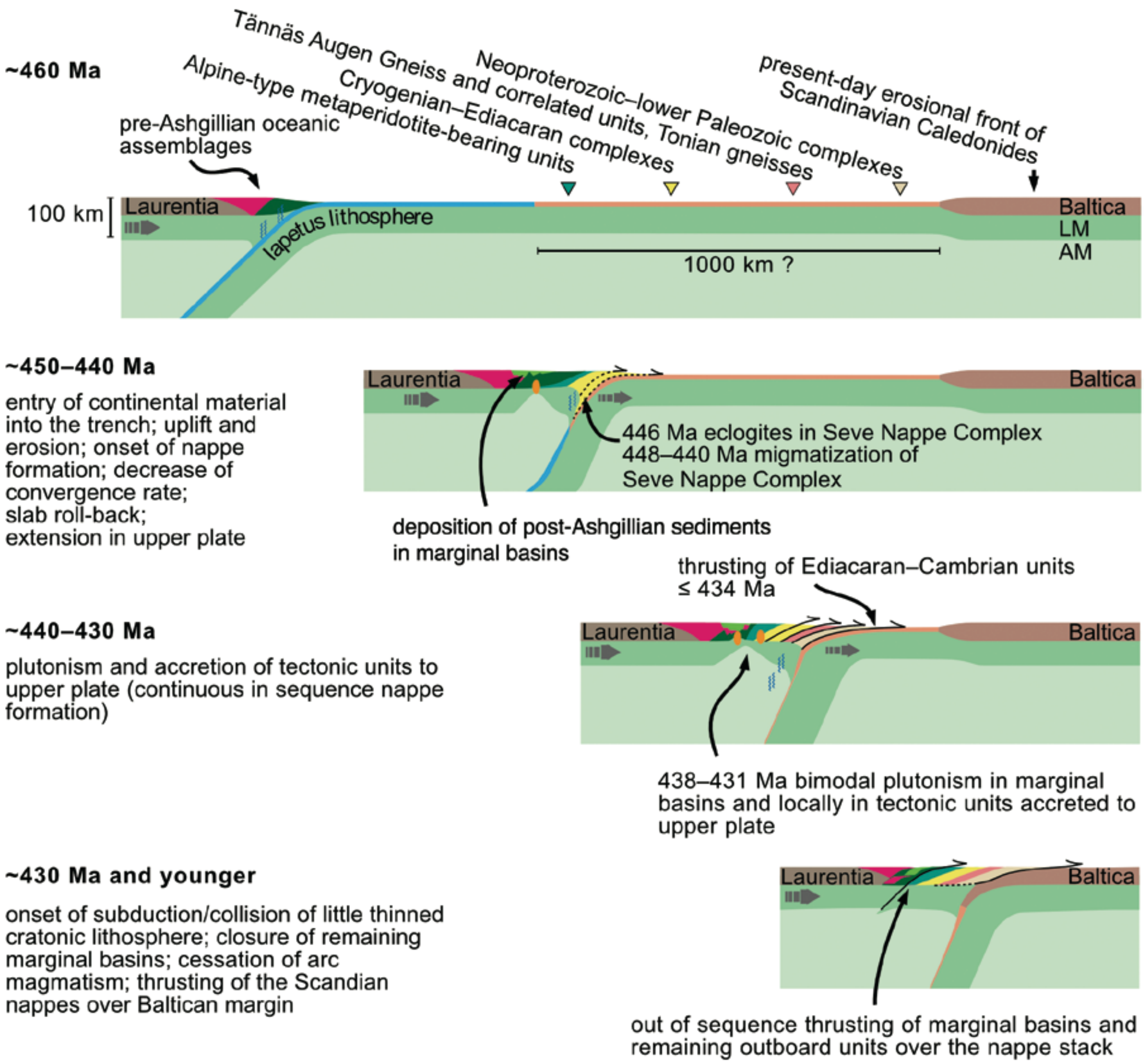

Figure 16. Sequence of tectonic events between ca. 460 and 430 Ma in the central segment of the Scandinavian Caledonides. Triangles indicate the paleogeographic distance of the main tectonic units with respect to the present-day Scandian erosional front before the onset of shortening ca. 450 Ma. Note that the orthogneisses of the Jotun, Lindås, and Dalsfjord nappes do not occur in the central segment but that the Cryogenian–Ediacaran successions are affected by high-pressure (HP) metamorphism at about the same time as the rocks of the Dalsfjord Nappe Complex (compare with Fig. 15). AM—asthenospheric mantle; LM—lithospheric mantle.

marginal basins and final development of the nappe stack, convergence was accommodated by continued thrusting of the Scandian nappes over the Baltican margin and the deeply buried rocks of the Western Gneiss Region until slab break-off, eduction, and the onset of orogenic collapse after ca. 410 ± 5 Ma (Hacker et al., 2010; Hacker and Gans, 2005).

The revised tectono-stratigraphy and resulting changes in the framework of the timing of tectonic events suggest that nappes were forming as early as 450 Ma and were transported over large distances until the onset of the orogenic collapse. Displacement of the highest Baltican-derived tectono-stratigraphic nappes (Jotun and Seve Nappes) for a duration of ~30–40 m.y. at conservatively estimated convergence rates between 2 and 3 cm/yr suggests thrusting over 600–1200 km. These estimates correlate well with the estimates of the thrust distances of ~600–900 km that have been proposed in the literature (Gee, 1978; Kumpulainen and Nystuen, 1985; Nystuen et al., 2008; Rice, 1998). For comparison, present-day convergence rates between India and south Tibet are ~2 cm/yr (e.g., Ader et al., 2012). Similar displacement distances and convergence rates are suggested by paleomagnetic studies of the 438 Ma Honningsvåg igneous complex, which was displaced ~1350 km southward between its crystallization and final emplacement onto Baltica (Corfu et al., 2006). Note that the Honningsvåg igneous complex is structurally at a higher level than the Seve or Jotun Nappe and that only latitudinal changes during the displacement can be estimated from the paleomagnetic studies.

Therefore, the SE-directed thrust distances were likely smaller. Nevertheless, 600–900 km of displacement of the Honningsvåg igneous complex over Baltica may be estimated between 440 and 410 Ma at convergence rates between 2 and 3 cm/yr.

CONCLUSIONS

The new observations and interpretations presented here show that the Scandinavian Caledonides comprise at least seven tectono-stratigraphic units that were finally emplaced onto the Baltican margin during the Scandian orogeny. In structurally ascending order, these include the following:

(1) Anchizone to low-grade metasedimentary complexes of mostly Neoproterozoic–Lower Paleozoic age that only locally are associated with mafic magmatic rocks, and that commonly contain the Ediacaran-Cambrian boundary;

(2) Proterozoic orthogneisses (e.g., Tännäs Augen Gneiss Nappe and correlated units) and locally other nondiked Neoproterozoic sedimentary successions (Offerdal Nappe) that structurally overlie the orthogneisses;

(3) Tonian metasedimentary and Archean basement complexes that predominantly occur in the northern segment of the Scandinavian Caledonides and occupy a similar structural position within the nappe stack as the orthogneisses (item 2), i.e., these complexes are structurally between Neoproterozoic–Lower Paleozoic metasedimentary complexes (below) and the Cryogenian–Ediacaran metasedimentary complexes (above);

(4) Cryogenian–Ediacaran metasedimentary complexes with large volumes of mafic dike complexes;

(5) Cambrian to Ordovician metasedimentary complexes that host a large number of Alpine-type, primitive (sensu Stigh, 1979) metaperidotite bodies and ultramafic metasediments;

(6) Orthogneisses and paragneisses of the Jotun, Lindås, and Dalsfjord nappe complexes, and associated cover metasediments (only in the southern segment of the Scandinavian Caledonides); and

(7) Ophiolites, island arcs, and marginal basin assemblages.

The revised tectono-stratigraphy highlights that some of the tectono-stratigraphic levels cannot be traced throughout the length of the orogen and that traditional tectono-stratigraphic correlations along strike of the orogen, for example, within the Middle and lower Upper Allochthons, are difficult to uphold.

A simple tectonic model derived from the top-to-the-west "unstacking" of the revised succession of Scandian nappes suggests that the Lindås, Dalsfjord, and Seve nappe complexes collided with the subduction complexes of the Iapetus Ocean as early as ca. 450 Ma. The temporal relationship between ca. 450 Ma HP metamorphism in these nappes and the emplacement of ca. 437 Ma magmatic rocks in the Cryogenian–Ediacaran successions and the metaperidotite-bearing units below the Lindås Nappe Complex shows that these units were accreted to the upper plate within ~10 m.y. after the collision with the trench and onset of nappe formation. Following the collision of these continental units with the trench, marginal basins opened in the upper plate. The early collision with the trench and the opening of the marginal basins were associated with the formation of the pre-Ashgillian unconformities, the deposition of post-Ashgillian sedimentary successions, and ca. 437–431 Ma magmatism in the upper plate. Nappe formation continued in sequence and contemporaneously with the opening of the marginal basin in the upper plate. The arrival of the buoyant, little- to nonthinned continental crust of the proto–Western Gneiss Region between 430 and 420 Ma terminated subduction and led to the closure of the marginal basins in the upper plate, which was followed by out-of-sequence thrusting of these units and the leading edge of the Laurentian margin over the previously assembled nappe stack. Deep burial of the Baltican margin and final emplacement of the nappe stack continued until slab break-off and the onset of the orogenic collapse at ca. 410 ± 5 Ma. The nappe stack was reworked during the orogenic collapse and the prolonged formation of the Faltungsgraben in the Paleozoic and Mesozoic.

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REFERENCES CITED

Adamson, P.W., 2016, Palaeobiology of the Ediacaran Biskopås Formation [Ph.D. thesis]: Cambridge, UK, Girton College, University of Cambridge, 224 p

Ader, T., Avouac, J.P., Liu-Zeng, J., Lyon-Caen, H., Bollinger, L., Galetzka, J., Genrich, J., Thomas, M., Chanard, K., Sapkota, S.N., Rajaure, S., Shrestha, P., Ding, L., and Flouzat, M., 2012, Convergence rate across the Nepal Himalaya and interseismic coupling on the Main Himalayan thrust: Implications for seismic hazard: Journal of Geophysical Research–Solid Earth, v. 117, B04403, https://doi.org/10.1029/2011JB009071.

Andersen, T.B., and Jamtveit, B., 1990, Uplift of deep crust during extensional orogenic collapse: A model based on field studies in the Sogn-Sunnfjord region of western Norway: Tectonics, v. 9, p. 1097–1111, https://doi.org/10.1029/TC009i005p01097.

Andersen, T.B., Jamtveit, B., Dewey, J.F., and Swensson, E., 1991, Subduction and eduction of continental crust: Major mechanisms during continent-continent collision and orogenic collapse, a model based on the south Norwegian Caledonides: Terra (Helsinki, Finland), v. 3, p. 303–310.

Andersen, T.B., Berry, H.N., Lux, D.R., and Andresen, A., 1998, The tectonic significance of pre-Scandian $^{40}Ar/^{39}Ar$ phengite cooling ages in the Caledonides of western Norway: Journal of the Geological Society, v. 155, p. 297–309, https://doi.org/10.1144/gsjgs.155.2.0297.

Andersen, T.B., Corfu, F., Labrousse, L., and Osmundsen, P.T., 2012, Evidence for hyperextension along the pre-Caledonian margin of Baltica: Journal of the Geological Society, v. 169, p. 601–612, https://doi.org/10.1144/0016-76492012-011.

Andréasson, P.G., 1994, The Baltoscandian margin in Neoproterozoic–early Palaeozoic times: Some constraints on terrane derivation and accretion in the Arctic Scandinavian Caledonides: Tectonophysics, v. 231, p. 1–32, https://doi.org/10.1016/0040-1951(94)90118-X.

Andréasson, P.G., Gee, D.G., Whitehouse, M.J., and Schöberg, H., 2003, Subduction-flip during Iapetus Ocean closure and Baltica-Laurentia collision, Scandinavian Caledonides: Terra (Helsinki, Finland), v. 15, p. 362–369, https://doi.org/10.1046/j.1365-3121.2003.00486.x.

Andréasson, P.G., Allen, A., Aurell, O., Boman, D., Ekestubbe, J., Goerke, U., Lundgren, A., Nilsson, P., and Sandelin, S., 2018, Seve terranes of the Kebnekaise Mts., Swedish Caledonides, and their amalgamation, accretion and affinity: Geologiska Föreningen i Stockholm Förhandlingar (GFF), v. 140, p. 264–291, https://doi.org/10.1080/11035897.2018.1470200.

Andresen, A., and Gabrielsen, R.H., 1979, Major element chemistry of metavolcanic rocks and tectonic setting of the Precambrian Dyrskard Group, Hardangervidda, south Norway: Norsk Geologisk Tidsskrift, v. 59, p. 47–57.

Andresen, A., Agyei-Dwarko, N.Y., Kristoffersen, M., and Hanken, N.-M., 2014, A Timanian foreland basin setting for the late Neoproterozoic–early Palaeozoic cover sequences (Dividal Group) of northeastern Baltica, *in* Corfu, F., Gasser, D., and Chew, D.M., eds., New Perspectives on the Caledonides of Scandinavia and Related Areas: Geological Society, London, Special Publication 390, p. 157–175, https://doi.org/10.1144/SP390.29.

Arnaud, E., and Eyles, C.H., 2004, Glacial influence on Neoproterozoic sedimentation: The Smalfjord Formation, northern Norway—Reply: Sedimentology, v. 51, p. 1423–1430, https://doi.org/10.1111/j.1365-3091.2004.00675.x.

Augland, L.E., Andresen, A., Corfu, F., Agyei-Dwarko, N.Y., and Larionov, A.N., 2014a, The Bratten-Landegode gneiss complex: A fragment of Laurentian continental crust in the Uppermost Allochthon of the Scandinavian Caledonides, *in* Corfu, F., Gasser, D., and Chew, D.M., eds., New Perspectives on the Caledonides of Scandinavia and Related Areas: Geological Society, London, Special Publication 390, p. 633–654, https://doi.org/10.1144/SP390.1.

Augland, L.E., Andresen, A., Gasser, D., and Steltenpohl, M.G., 2014b, Early Ordovician to Silurian evolution of exotic terranes in the Scandinavian Caledonides of the Ofoten-Troms area—Terrane characterization and correlation based on new U-Pb zircon ages and Lu-Hf isotopic data, *in* Corfu, F., Gasser, D., and Chew, D.M., eds., New Perspectives on the Caledonides of Scandinavia and Related Areas: Geological Society, London, Special Publication 390, p. 655–678, https://doi.org/10.1144/SP390.19.

Austrheim, H., 1987, Eclogitization of lower crustal granulites by fluid migration through shear zones: Earth and Planetary Science Letters, v. 81, p. 221–232, https://doi.org/10.1016/0012-821X(87)90158-0.

Austrheim, H., and Corfu, F., 2009, Formation of planar deformation features (PDFs) in zircon during coseismic faulting and an evaluation of potential effects on U-Pb systematics: Chemical Geology, v. 261, p. 25–31, https://doi.org/10.1016/j.chemgeo.2008.09.012.

Axheimer, N., Ahlberg, P., and Cederström, P., 2007, A new Lower Cambrian eodiscoid trilobite fauna from Swedish Lapland and its implications for intercontinental correlation: Geological Magazine, v. 144, p. 953–961, https://doi.org/10.1017/S0016756807003597.

Baird, G.B., Figg, S.A., and Chamberlain, K.R., 2014, Intrusive age and geochemistry of the Kebne Dyke Complex in the Seve Nappe Complex, Kebnekaise Massif, Arctic Sweden Caledonides: GFF, v. 136, p. 556–570, https://doi.org/10.1080/11035897.2014.924553.

Bakke, S., and Korneliussen, A., 1986, Jack-straw-textured olivines in some Norwegian metaperidotites: Norsk Geologisk Tidsskrift, v. 4, p. 271–276.

Banks, N.L., 1973, Trace Fossils in the Halkkavarre Section of the Dividal Group (? late Precambrian Lower Cambrian), Finnmark: Norges Geologiske Undersøkelse Bulletin, v. 288, p. 1–6

Banks, N.L., Hobday, D.K., Reading, H.G., and Taylor, P.N., 1974, Stratigraphy of the late Precambrian “Older Sandstone Series” of the Varangerfjord area, Finnmark: Norges Geologiske Undersøkelse Bulletin, v. 303, p. 1–16.

Barnes, C., Majka, J., Schneider, D., Walczak, K., Bukała, M., Kośmińska, K., Tokarski, T., and Karlsson, A., 2019, High-spatial resolution dating of monazite and zircon reveals the timing of subduction-exhumation of the Vaimok Lens in the Seve Nappe Complex (Scandinavian Caledonides): Contributions to Mineralogy and Petrology, v. 174, p. 5, https://doi.org/10.1007/s00410-018-1539-1.

Barnes, C.J., Jeanneret, P., Kullerud, K., Majka, J., Schneider, D., Bukala, M., and Klonowska, I., 2020, Exhumation of the high-pressure Tsäkkok Lens, Swedish Caledonides: Insight from the structural and white mica ^{40}Ar/^{39}Ar geochronological record: Tectonics, v. 39, e2020TC006242, https://doi.org/10.1029/2020TC006242.

Beckholmen, M., 1978, Geology of the Nordhallen–Duved–Greningen area in Jämtland, central Swedish Caledonides: Geologiska Föreningens i Stockholm Förhandlingar, v. 100, p. 335–347, https://doi.org/10.1080/11035897809454471.

Beckholmen, M., 1982, Mylonites and pseudotachylites associated with thrusting of the Köli nappes, Tännforsfältet, central Swedish Caledonides: GFF, v. 104, p. 23–32, https://doi.org/10.1080/11035898209454532.

Beckholmen, M., 1984, The Köli Nappe Complex in Tännforsfeltet western Jämtland, Swedish Caledonides [Ph.D. thesis]: Stockholm, Sweden, Stockholm University, 82 p.

Beinlich, A., Plümper, O., Hövelmann, J., Austrheim, H., and Jamtveit, B., 2012, Massive serpentinite carbonation at Linnajavri, N-Norway: Terra (Helsinki, Finland), v. 24, p. 446–455, https://doi.org/10.1111/j.1365-3121.2012.01083.x.

Bender, H., Glodny, J., Ring, U., and Stephens, M.B., 2019, Absolute timing of Caledonidan orogenic wedge assembly, central Sweden, constrained by Rb-Sr multi-mineral isochron data: Lithos, v. 344–345, p. 339–359, https://doi.org/10.1016/j.lithos.2019.06.033.

Bennett, M.C., Emblin, S.R., Robins, B., and Yeo, W.J.A., 1986, High-temperature ultramafic complexes in the north Norwegian Caledonides: I—Regional setting and field relationships: Norges Geologiske Undersøkelse Bulletin, v. 405, p. 1–40.

Bergh, S.G., Kullerud, K., Corfu, F., Armitage, P.E.B., Davidsen, B., Johansen, H.W., Pettersen, T., and Knudsen, S., 2007, Low-grade sedimentary rocks on Vanna, north Norway: A new occurrence of a Palaeoproterozoic (2.4–2.2 Ga) cover succession in northern Fennoscandia: Norsk Geologisk Tidsskrift, v. 87, p. 301–318.

Bergman, S., 1987, A possible ophiolite at Handöl, Swedish Caledonides: GFF, v. 109, p. 340–343, https://doi.org/10.1080/11035898709453102.

Bergman, S., 1993, Geology and geochemistry of mafic-ultramafic rocks (Koli) in the Handöl area, central Scandinavian Caledonides: Norsk Geologisk Tidsskrift, v. 73, p. 21–42.

Beyssac, O., Goffé, B., Chopin, C., and Rouzaud, J.N., 2002, Raman spectra of carbonaceous material in metasediments: A new geothermometer: Journal of Metamorphic Geology, v. 20, p. 859–871, https://doi.org/10.1046/j.1525-1314.2002.00408.x.

Beyssac, O., Goffé, B., Petitet, J.P., Froigneux, E., Moreau, M., and Rouzaud, J.N., 2003, On the characterization of disordered and heterogeneous carbonaceous materials by Raman spectroscopy: Spectrochimica Acta Part A: Molecular and Biomolecular Spectroscopy, v. 59, p. 2267–2276, https://doi.org/10.1016/S1386-1425(03)00070-2.

Beyssac, O., Bollinger, L., Avouac, J.-P., and Goffé, B., 2004, Thermal metamorphism in the lesser Himalaya of Nepal determined from Raman spectroscopy of carbonaceous material: Earth and Planetary Science Letters, v. 225, p. 233–241, https://doi.org/10.1016/j.epsl.2004.05.023.

Bingen, B., and Solli, A., 2013, Geochronological database of magmatic events in Norway and related areas: Update 2012: Geological Survey of Norway, Report No. 2013.028.

Bingen, B., Davis, W.J., and Austrheim, H., 2001, Zircon U-Pb geochronology in the Bergen arc eclogites and their Proterozoic protoliths, and implications for the pre-Scandian evolution of the Caledonides in western Norway: Geological Society of America Bulletin, v. 113, p. 640–649, https://doi.org/10.1130/0016-7606(2001)113<0640:ZUPGIT>2.0.CO;2.

Bingen, B., Griffin, W.L., Torsvik, T.H., and Saeed, A., 2005, Timing of late Neoproterozoic glaciation in Baltica constrained by detrital zircon geochronology in the Hedmark Group, south-east Norway: Terra (Helsinki, Finland), v. 17, p. 250–258, https://doi.org/10.1111/j.1365-3121.2005.00609.x.

Bingen, B., Andersson, J., Soderlund, U., Moller, C., Söderlund, U., and Möller, C., 2008, The Mesoproterozoic in the Nordic countries: Episodes, v. 31, p. 29–34, https://doi.org/10.18814/epiiugs/2008/v31i1/005.

Bingen, B., Belousova, E.A., and Griffin, W.L., 2011, Neoproterozoic recycling of the Sveconorwegian orogenic belt: Detrital-zircon data from the Sparagmite basins in the Scandinavian Caledonides: Precambrian Research, v. 189, p. 347–367, https://doi.org/10.1016/j.precamres.2011.07.005.

Bingen, B., Solli, A., Viola, G., Torgersen, E., Sandstad, J.S., Whitehouse, M.J., Røhr, T.S., Ganerød, M., and Nasuti, A., 2015, Geochronology of the Palaeoproterozoic Kautokeino greenstone belt, Finnmark, Norway: Tectonic implications in a Fennoscandia context: Norsk Geologisk Tidsskrift, v. 95, p. 365–396, https://doi.org/10.17850/njg95-3-09.

Bøe, R.L.V., Sturt, B.A., and Ramsay, D.M., 1993, The conglomerates of the Sel Group, Otta-Vaga area, central Norway: An example of a terrane-linking succession: Norges Geologiske Undersøkelse Bulletin, v. 425, p. 1–23.

Boucot, A.J., and Johnson, J.G., 1964, Brachiopods of the Ede Quartzite (Lower Llandovery) of Norderon, Jämtland: Bulletin of the Geological Institutions of the University of Uppsala, v. 42, p. 1–11.

Boundy, T.M., Essene, E.J., Austrheim, H., and Halliday, A.N., 1996, Rapid exhumation of lower crust during continent-continent collision and late extension: Evidence from ^{40}Ar/^{39}Ar incremental heating of hornblendes and muscovites, Caledonian orogen, western Norway: Geological Society of America Bulletin, v. 108, p. 1425–1437, https://doi.org/10.1130/0016-7606(1996)108<1425:REOLCD>2.3.CO;2.

Boyd, R., and Mathiesen, C.O., 1979, The nickel mineralization of the Rana mafic intrusion, Nordland, Norway: Canadian Mineralogist, v. 17, p. 287–298.

Brekke, H., and Solberg, P.O., 1987, The geology of Atløy, Sunnfjord, western Norway: Norges Geologiske Undersøkelse Bulletin, v. 410, p. 73–94.

Brueckner, H.K., 2018, The great eclogite debate of the Western Gneiss Region, Norwegian Caledonides: The in situ crustal v. exotic mantle origin controversy: Journal of Metamorphic Geology, v. 36, p. 517–527, https://doi.org/10.1111/jmg.12314.

Brueckner, H.K., and Van Roermund, H.L.M., 2007, Concurrent HP metamorphism on both margins of Iapetus: Ordovician ages for eclogites and garnet pyroxenites from the Seve Nappe Complex, Swedish Caledonides: Journal of the Geological Society, v. 164, p. 117–128, https://doi.org/10.1144/0016-76492005-139.

Brueckner, H.K., van Roermund, H.L.M., and Pearson, N.J., 2004, An Archean (?) to Paleozoic evolution for a garnet peridotite lens with sub-Baltic Shield affinity within the Seve Nappe Complex of Jämtland, Sweden, central Scandinavian Caledonides: Journal of Petrology, v. 45, p. 415–437, https://doi.org/10.1093/petrology/egg088.

Bruton, D.L., and Bockelie, J.F., 1980, Geology and paleontology of the Hølonda area, western Norway—A fragment of North America?, *in* Wones, D.R., ed., The Caledonides in the USA: Blacksburg, Virginia, Department of Geological Sciences, Virginia Polytechnic Institute and State University Memoir 2, p. 41–55.

Bruton, D.L., and Harper, D.A.T., 1981, Brachiopods and trilobites of the Early Ordovician serpentine Otta Conglomerate, south central Norway: Norsk Geologisk Tidsskrift, v. 61, p. 153–181.

Bruton, D.L., and Harper, D.A.T., 1982, Ordovician gastropods from Vardofjallet, Swedish Lapland, and the dating of Caledonian serpentinite conglomerates: A discussion: GFF, v. 105, p. 189–190, https://doi.org/10.1080/11035898209455251.

Buseck, P.R., and Beyssac, O., 2014, From organic matter to graphite: Graphitization: Elements, v. 10, p. 421–426, https://doi.org/10.2113/gselements.10.6.421.

Claesson, S., 1980, A Rb-Sr isotope study of granitoids and related mylonites in the Tännäs Augen Gneiss Nappe, southern Swedish Caledonides: GFF, v. 102, p. 403–420, https://doi.org/10.1080/11035898009454497.

Claesson, S., Klingspor, I., and Stephens, M.B., 1983, U-Pb and Rb-Sr isotopic data on an Ordovician volcanic-subvolcanic complex from the Tjopasi Group, Köli nappes, Swedish Caledonides: GFF, v. 105, p. 9–15, https://doi.org/10.1080/11035898309455285.

Corfu, F., 2004, U-Pb age, setting and tectonic significance of the anorthosite-mangerite-charnockite-granite suite, Lofoten-Vesterålen, Norway: Journal of Petrology, v. 45, p. 1799–1819, https://doi.org/10.1093/petrology/egh034.

Corfu, F., 2019, The Sognefjell volcanic-subvolcanic complex—A late Sveconorwegian arc imbricated in the central Norwegian Caledonides: Precambrian Research, v. 331, 105353, https://doi.org/10.1016/j.precamres.2019.105353.

Corfu, F., and Andersen, T.B., 2002, U-Pb ages of the Dalsfjord complex, SW Norway, and their bearing on the correlation of allochthonous crystalline segments of the Scandinavian Caledonides: International Journal of Earth Sciences, v. 91, p. 955–963, https://doi.org/10.1007/s00531-002-0298-3.

Corfu, F., and Andersen, T.B., 2016, Proterozoic magmatism in the southern Scandinavian Caledonides, with special reference to the occurrences in the Eikefjord Nappe: GFF, v. 138, p. 102–114, https://doi.org/10.1080/11035897.2015.1077886.

Corfu, F., and Heim, M., 2020, Geochronology of Caledonian metamorphic allochthons in the Otta–Heidal region, south Norway; Tectonostratigraphic and palaeogeographical implications: Journal of the Geological Society, v. 177, p. 66–81, https://doi.org/10.1144/jgs2019-010.

Corfu, F., Armitage, P.E.B., Kullerud, K., and Bergh, S.G., 2003a, Preliminary U-Pb geochronology in the West Troms basement complex, north Norway: Archaean and Palaeoproterozoic events and younger overprints: Norges Geologiske Undersøkelse Bulletin, v. 441, p. 61–72.

Corfu, F., Hanchar, J.M., Hoskin, P.W.O., and Kinny, P., 2003b, Atlas of zircon textures: Reviews in Mineralogy and Geochemistry, v. 53, p. 469–500, https://doi.org/10.2113/0530469.

Corfu, F., Torsvik, T.H., Andersen, T.B., Ashwal, L.D., Ramsay, D.M., and Roberts, R.J., 2006, Early Silurian mafic-ultramafic and granitic plutonism in contemporaneous flysch, Magerøy, northern Norway: U-Pb ages and regional significance: Journal of the Geological Society, v. 163, p. 291–301, https://doi.org/10.1144/0016-764905-014.

Corfu, F., Roberts, R.J., Torsvik, T.H., Ashwal, L.D., and Ramsay, D.M., 2007, Peri-Gondwanan elements in the Caledonian nappes of Finnmark, northern Norway: Implications for the paleogeographic framework of the Scandinavian Caledonides: American Journal of Science, v. 307, p. 434–458, https://doi.org/10.2475/02.2007.05.

Dahlqvist, P., Harper, D.A.T., and Wickström, L., 2010, Late Ordovician shelly faunas from Jämtland: Palaeocommunity development along the margin of the Swedish Caledonides: Bulletin of Geosciences, v. 85, p. 505–512, https://doi.org/10.3140/bull.geosci.1175.

Dreyer, G., 1975, Die Geologie des Tronfjell-massivs bei Alvdal/Hedmark in Südöstlichen Trondheim-Gebiet [Ph.D. thesis]: Mainz, Germany, University of Mainz, 247 p.

Eide, E.A., Torsvik, T.H., Andersen, T.B., and Arnaud, N.O., 1999, Early Carboniferous unroofing in western Norway: A tale of alkali feldspar thermochronology: The Journal of Geology, v. 107, p. 353–374, https://doi.org/10.1086/314351.

Enger, A.S., 2016, Solitary Mantle Peridotites in Stølsheimen, Central South Norway [Master's thesis]: Oslo, Norway, Department of Geosciences, University of Oslo, 147 p.

Esmark, J., 1829, Reise fra Christiania til Trondhjem: Christiania (Oslo), Norway, Dahl, 81 p.

Faber, C., Stünitz, H., Gasser, D., Jeřábek, P., Kraus, K., Corfu, F., Ravna, E.K., Konopásek, J., Jeřábek, P., Kraus, K., Corfu, F., Ravna, E.K., and Konopásek, J., 2019, Anticlockwise metamorphic pressure-temperature paths and nappe stacking in the Reisa Nappe Complex in the Scandinavian Caledonides, northern Norway: Evidence for weakening of lower continental crust before and during continental collision: Solid Earth, v. 10, p. 117–148, https://doi.org/10.5194/se-10-117-2019.

Færseth, R.B., Thon, A., Larsen, S.G., Sivertsen, A., and Elvestad, L., 1977, Geology of the Lower Palaeozoic rocks in the Samnanger-Osterøy area, Major Bergen arc, western Norway: Norges Geologiske Undersøkelse Bulletin, v. 344, p. 19–58.

Fassmer, K., Klonowska, I., Walczak, K., Andersson, B., Froitzheim, N., Majka, J., Fonseca, R.O.C., Münker, C., Janák, M., and Whitehouse, M., 2017, Middle Ordovician subduction of continental crust in the Scandinavian Caledonides: An example from Tjeliken, Seve Nappe Complex, Sweden: Contributions to Mineralogy and Petrology, v. 172, p. 103, https://doi.org/10.1007/s00410-017-1420-7.

Fauconnier, J., Labrousse, L., Andersen, T.B., Beyssac, O., Duprat-Oualid, S., and Yamato, P., 2014, Thermal structure of a major crustal shear zone, the basal thrust in the Scandinavian Caledonides: Earth and Planetary Science Letters, v. 385, p. 162–171, https://doi.org/10.1016/j.epsl.2013.10.038.

Fossen, H., 1993, Structural evolution of the Bergsdalen nappes, southwest Norway: Norges Geologiske Undersøkelse Bulletin, v. 424, p. 23–49.

Fossen, H., Dunlap, J.W., and Dunlap, W.J., 1998, Timing and kinematics of Caledonian thrusting and extensional collapse, southern Norway: Evidence from ^{40}Ar/^{39}Ar thermochronology: Journal of Structural Geology, v. 20, p. 765–781, https://doi.org/10.1016/S0191-8141(98)00007-8.

Føyn, S., 1967, Dividal-gruppen (Hyolithus-sonen) i Finnmark og dens forhold til de eokambriske-kambriske formasjoner: Norges Geologiske Undersøkelse Bulletin, v. 249, p. 1–84.

Føyn, S., and Glaessner, M.F., 1979, Platysolenites, other animal fossils, and the Precambrian–Cambrian transition in Norway: Norsk Geologisk Tidsskrift, v. 59, p. 25–46.

Furnes, H., Sturt, B.A., and Griffin, W.L., 1980, Trace element geochemistry of metabasalts from the Karmøy ophiolite, southwest Norwegian Caledonides: Earth and Planetary Science Letters, v. 50, p. 75–91, https://doi.org/10.1016/0012-821X(80)90120-X.

Furnes, H., Nystuen, J.P., Brunfelt, A.O., and Solheim, S., 1983, Geochemistry of Upper Riphean–Vendian basalts associated with the "sparagmites" of south Norway: Geological Magazine, v. 120, p. 349–361, https://doi.org/10.1017/S0016756800027266.

Furnes, H., Skjerlie, K.P., Pedersen, R.-B., Andersen, T.B., Stillmann, C.J., Suthren, R.J., Tysseland, M., and Garmann, L.B., 1990, The Solund-Stavfjord ophiolite complex and associated rocks, west Norwegian Caledonides: Geology, geochemistry and tectonic environment: Geological Magazine, v. 127, p. 209–224, https://doi.org/10.1017/S0016756800014497.

Gale, G.H., and Roberts, D., 1972, Palaeogeographical implications of greenstone petrochemistry in the southern Norwegian Caledonides: Nature Physical Science, v. 238, p. 60–61, https://doi.org/10.1038/physci238060a0.

Gale, G.H., and Roberts, D., 1974, Trace element geochemistry of Norwegian Lower Palaeozoic basic volcanics and its tectonic implications: Earth and Planetary Science Letters, v. 22, p. 380–390, https://doi.org/10.1016/0012-821X(74)90148-4.

Gasser, D., Jeřábek, P., Faber, C., Stünitz, H., Menegon, L., Corfu, F., Erambert, M., and Whitehouse, M.J., 2015, Behaviour of geochronometers and timing of metamorphic reactions during deformation at lower crustal conditions: Phase equilibrium modelling and U-Pb dating of zircon, monazite, rutile and titanite from the Kalak Nappe Complex, northern Norway: Journal of Metamorphic Geology, v. 33, p. 513–534, https://doi.org/10.1111/jmg.12131.

Gee, D.G., 1978, Nappe displacement in the Scandinavian Caledonides: Tectonophysics, v. 47, p. 393–399, 401–419, https://doi.org/10.1016/0040-1951(78)90040-9.

Gee, D.G., and Stephens, M.B., 2020a, Lower thrust sheets in the Caledonide orogen, Sweden: Cryogenian–Silurian sedimentary successions and underlying, imbricated, crystalline basement, *in* Stephens, M.B., and Bergman Weihed, J., eds., Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources: Geological Society, London, Memoir 50, p. 495–515, https://doi.org/10.1144/M50-2018-7.

Gee, D.G., and Stephens, M.B., 2020b, Regional context and tectonostratigraphic framework of the early–middle Paleozoic Caledonide orogen, northwestern Sweden, *in* Stephens, M.B., and Bergman Weihed, J., eds., Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources: Geological Society, London, Memoir 50, p. 481–494, https://doi.org/10.1144/M50-2017-21.

Gee, D.G., Guezou, J.-C., Roberts, D., and Wolff, F.C., 1985a, The central-southern part of the Scandinavian Caledonides, *in* Gee, D.G., and Sturt, B.A., eds., The Caledonide Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley, p. 109–133.

Gee, D.G., Kumpulainen, R., Roberts, D., Stephens, M.B., Thon, A., and Zachrisson, E., 1985b, Scandinavian Caledonides Tectonostratigraphic Map: Sveriges Geologiska Undersökning Ba 35 (and in Swedish, Ba 36), scale 1:2,000,000.

Gee, D.G., Andréasson, P.G., Li, Y., and Krill, A., 2017, Baltoscandian margin, Sveconorwegian crust lost by subduction during Caledonian collisional orogeny: GFF, v. 139, p. 36–51, https://doi.org/10.1080/11035897.2016.1200667.

Gee, D.G., Klonowska, I., Andréasson, P.G., and Stephens, M.B., 2020, Middle thrust sheets in the Caledonide orogen, Sweden: The outer margin of Baltica, the continent-ocean transition zone and late Cambrian–Ordovician subduction-accretion, *in* Stephens, M.B., and Bergman Weihed, J., eds., Sweden: Lithotectonic Framework, Tectonic Evolution and Mineral Resources: Geological Society, London, Memoir 50, p. 517–548, https://doi.org/10.1144/M50-2018-73.

Ghent, E.D., and Stout, M.Z., 1981, Geobarometry and geothermometry of plagioclase-biotite-garnet-muscovite assemblages: Contributions to Mineralogy and Petrology, v. 76, p. 92–97, https://doi.org/10.1007/BF00373688.

Gilio, M., Clos, F., and van Roermund, H.L.M., 2015, The Friningen Garnet Peridotite (central Swedish Caledonides): A good example of the characteristic *PTt* path of a cold mantle wedge garnet peridotite: Lithos, v. 230, p. 1–16, https://doi.org/10.1016/j.lithos.2015.05.003.

Gjelsvik, T., 1946, Anorthosittkolpekset i Heidal: Norsk Geologisk Tidsskrift, v. 26, p. 58.

Glodny, J., Kühn, A., and Austrheim, H., 2008, Geochronology of fluid-induced eclogite and amphibolite facies metamorphic reactions in a subduction-collision system, Bergen arcs, Norway: Contributions to Mineralogy and Petrology, v. 156, p. 27–48, https://doi.org/10.1007/s00410-007-0272-y.

Goldschmidt, V.M., 1912, Geologisch-petrographische Studien im Hochgebirge des südlichen Norwegens. II. Die kaledonische Deformation der südnorwegischen Urgebirgstafel: Skrifter Videnskapsselskappet i Kristiania, v. 19, p. 11.

Gorokhov, I.M., Siedlecka, A., Roberts, D., Melezhik, V.A., and Turchenko, T.L., 2001, Rb-Sr dating of diagenetic illite in Neoproterozoic shales, Varanger Peninsula, northern Norway: Geological Magazine, v. 138, p. 541–562, https://doi.org/10.1017/S001675680100574X.

Grant, T.B., Larsen, R.B., Anker-Rasch, L., Grannes, K.R., Iljina, M., McEnroe, S., Nikolaisen, E., Schanche, M., and Øen, E., 2016, Anatomy of a deep crustal volcanic conduit system: The Reinfjord ultramafic complex, Seiland igneous province, northern Norway: Lithos, v. 252–253, p. 200–215, https://doi.org/10.1016/j.lithos.2016.02.020.

Griffin, W.L., Sturt, B.A., O'Neill, C.J., Kirkland, C.L., and O'Reilly, S.Y., 2013, Intrusion and contamination of high-temperature dunitic magma: The Nordre Bumandsfjord pluton, Seiland, Arctic Norway: Contributions to Mineralogy and Petrology, v. 165, p. 903–930, https://doi.org/10.1007/s00410-012-0841-6.

Guezou, J.-C., 1978, Geology and structure of the Dombås-Jesja area, southern Trondheim region, south-central Norway: Norges Geologiske Undersøkelse Bulletin, v. 340,0 p. 1–34.

Hacker, B.R., and Gans, P.B., 2005, Continental collisions and the creation of ultrahigh-pressure terranes: Petrology and thermochronology of nappes in the central Scandinavian Caledonides: Geological Society of America Bulletin, v. 117, p. 117–134, https://doi.org/10.1130/B25549.1.

Hacker, B.R., Andersen, T.B., Johnston, S.M., Kylander-Clark, A.R.C., Peterman, E.M., Walsh, E.O., and Young, D., 2010, High-temperature deformation during continental-margin subduction & exhumation: The ultrahigh-pressure Western Gneiss Region of Norway: Tectonophysics, v. 480, p. 149–171, https://doi.org/10.1016/j.tecto.2009.08.012.

Halverson, G.P., Hoffman, P.F., Schrag, D.P., Maloof, A.C., and Rice, A.H.N., 2005, Toward a Neoproterozoic composite carbon-isotope record: Geological Society of America Bulletin, v. 117, p. 1181–1207, https://doi.org/10.1130/B25630.1.

Harper, D.A.T., Owen, A.W., and Bruton, D.L., 2009, Ordovician life around the Celtic fringes: Diversifications, extinctions and migrations of brachiopod and trilobite faunas at middle latitudes, *in* Bassett, M.G., ed., Early Palaeozoic Peri-Gondwana Terranes: New Insights from Tectonics and Biogeography: Geological Society, London, Special Publication 325, p. 157–170, https://doi.org/10.1144/SP325.8.

Heim, M., Scharer, U.R.S., and Milnes, A.G., 1977, The nappe complex in the Tyin-Bygdin-Vang region, central southern Norway: Norsk Geologisk Tidsskrift, v. 57, p. 171–178.

Hirauchi, K., and Yamaguchi, H., 2007, Unique deformation processes involving the recrystallization of chrysotile within serpentinite: Implications for aseismic slip events within subduction zones: Terra (Helsinki, Finland), v. 19, p. 454–461, https://doi.org/10.1111/j.1365-3121.2007.00771.x.

Hoffmann, K.H., Condon, D.J., Bowring, S.A., and Crowley, J.L., 2004, U-Pb zircon date from the Neoproterozoic Ghaub Formation Namibia: Constraints on Marinoan glaciation: Geology, v. 32, p. 817–820, https://doi.org/10.1130/G20519.1.

Högström, A.E.S., Jensen, S., Palacios, T., and Ebbestad, J.O.R., 2013, New information on the Ediacaran-Cambrian transition in the Vestertana Group, Finnmark, northern Norway, from trace fossils and organic-walled microfossils: Norsk Geologisk Tidsskrift, v. 93, p. 95–106.

Holmqvist, A., 1980, Ordovician gastropods from Vardofjället, Swedish Lapland, and the dating of Caledonian serpentinite conglomerates: GFF, v. 102, p. 493–497, https://doi.org/10.1080/11035898009454502.

Holmqvist, A., 1982, Ordovician gastropods from Vardofjället, Swedish Lapland, and the dating of Caledonian serpentinite conglomerates: A reply: GFF, v. 104, p. 191–192, https://doi.org/10.1080/11035898209455251.

Holmsen, P., 1943, Geologiske og petrografiske undersøkelser i området Tynset-Femunden: Norges Geologiske Undersøkelse Bulletin, v. 158, p. 65.

Holmsen, P., 1954, Om morenekonglomeratet i sparagmittformasjonen i det sydlige Norge: GFF, v. 76, p. 105–121.

Hossack, J.R., Garton, M.R., and Nickelsen, R.P., 1985, The geological section from the foreland up to the Jotun thrust sheet in the Valdres area, south Norway, *in* Gee, D., and Sturt, B.A., eds., The Caledonian Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley & Sons Ltd, p. 443–456.

Hybertsen, D., 2017, Distribution of *Sabellidites* (*Annelida*?) in the Basal Cambrian of the Digermulen Peninsula, Arctic Norway [Master's thesis]: Uppsala, Sweden, Institute for Geosciences, Uppsala University, 38 p.

Ingdahl, S.E., 1985, Stratigraphy, Structural Geology and Metamorphism in the Os Area, Major Bergen Arc [Cand. Real thesis]: Bergen, Norway, University of Bergen, 666 p.

Jaffey, A.H., Flynn, K.F., Glendenin, L.E., Bentley, W.C., and Essling, A.M., 1971, Precision measurement of half-lives and specific activities of ^{235}U and ^{238}U: Physical Review C: Nuclear Physics, v. 4, p. 1889–1906, https://doi.org/10.1103/PhysRevC.4.1889.

Jakob, J., Alsaif, M., Corfu, F., and Andersen, T.B., 2017, Age and origin of thin discontinuous gneiss sheets in the distal domain of the magma-poor hyperextended pre-Caledonian margin of Baltica, southern Norway: Journal of the Geological Society, v. 174, p. 557–571, https://doi.org/10.1144/jgs2016-049.

Jakob, J., Andersen, T.B., Boulvais, P., and Andersen, T.B., 2018, Oxygen and carbon isotope compositions of carbonates in a prominent lithologically mixed unit in the central south Norwegian Caledonides: International Journal of Earth Sciences, v. 107, p. 1445–1463, https://doi.org/10.1007/s00531-017-1551-0.

Jakob, J., Andersen, T.B., and Kjøll, H.J., 2019, A review and reinterpretation of the architecture of the south and south-central Scandinavian Caledonides—A magma-poor to magma-rich transition and the significance of the reactivation of rift inherited structures: Earth-Science Reviews, v. 192, p. 513–528, https://doi.org/10.1016/j.earscirev.2019.01.004.

Jamtveit, B., Moulas, E., Andersen, T.B., Austrheim, H., Corfu, F., Petley-Ragan, A., and Schmalholz, S.M., 2018, High pressure metamorphism caused by fluid induced weakening of deep continental crust: Scientific Reports, v. 8, 17011, https://doi.org/10.1038/s41598-018-35200-1.

Jensen, S., and Grant, S.W.F., 1998, Trace fossils from the Dividalen Group, northern Sweden: Implications for early Cambrian biostratigraphy of Baltica: Norsk Geologisk Tidsskrift, v. 78, p. 305–317.

Johnston, S.M., Hacker, B.R., Andersen, T.B., and Ducea, M.N., 2007, Exhuming Norwegian ultrahigh-pressure rocks: Overprinting extensional structures and the role of the Nordfjord-Sogn detachment zone: Geological Society of America Bulletin, v. 119, p. 1232–1248, https://doi.org/10.1130/B26172.1.

Karlsen, T.A., and Nilsson, L.-P., 2000, Talc Deposits in Norway: Geological Survey of Norway Report 99.135: Trondheim, Geological Survey of Norway, 146 p.

Kirkland, C.L., Daly, J.S., and Whitehouse, M.J., 2006, Granitic magmatism of Grenvillian and late Neoproterozoic age in Finnmark, Arctic Norway—Constraining pre-Scandian deformation in the Kalak Nappe Complex: Precambrian Research, v. 145, p. 24–52, https://doi.org/10.1016/j.precamres.2005.11.012.

Kirkland, C.L., Daly, J.S., and Whitehouse, M.J., 2007, Provenance and terrane evolution of the Kalak Nappe Complex, Norwegian Caledonides: Implications for Neoproterozoic paleogeography and tectonics: The Journal of Geology, v. 115, p. 21–41, https://doi.org/10.1086/509247.

Kirkland, C.L., Bingen, B., Whitehouse, M.J., Beyer, E., and Griffin, W.L., 2011, Neoproterozoic palaeogeography in the North Atlantic region: Inferences from the Akkajaure and Seve Nappes of the Scandinavian Caledonides: Precambrian Research, v. 186, p. 127–146, https://doi.org/10.1016/j.precamres.2011.01.010.

Kjelberg, Ø., 2015, Petrography, Structure and Metamorphism of the Melange Rocks below the Jotun Nappe in Stølsheimen, Central South Norway [Master's thesis]: Oslo, Norway, University of Oslo, 113 p.

Kjøll, H.J., 2020, Late Neoproterozoic basin evolution of the magma-rich Iapetus margin of Baltica: Norsk Geologisk Tidsskrift, v. 100, p. 1–32, https://doi.org/10.17850/njg100-1-6.

Kjøll, H.J., Andersen, T.B., Corfu, F., Labrousse, L., Tegner, C., Abdelmalak, M.M., and Planke, S., 2019a, Timing of breakup and thermal evolution of a pre-Caledonian Neoproterozoic exhumed magma-rich rifted margin: Tectonics, v. 38, p. 1843–1862, https://doi.org/10.1029/2018TC005375.

Kjøll, H.J., Galland, O., Labrousse, L., and Andersen, T.B., 2019b, Emplacement mechanisms of a dyke swarm across the brittle-ductile transition and the geodynamic implications for magma-rich margins: Earth and Planetary Science Letters, v. 518, p. 223–235, https://doi.org/10.1016/j.epsl.2019.04.016.

Klonowska, I., Janák, M., Majka, J., Froitzheim, N., and Kośmińska, K., 2016, Eclogite and garnet pyroxenite from Stor Jougdan, Seve Nappe Complex, Sweden: Implications for UHP metamorphism of allochthons in the Scandinavian Caledonides: Journal of Metamorphic Geology, v. 34, p. 103–119, https://doi.org/10.1111/jmg.12173.

Klonowska, I., Janák, M., Majka, J., Petrík, I., Froitzheim, N., Gee, D.G., and Sasinková, V., 2017, Microdiamond on Åreskutan confirms regional UHP metamorphism in the Seve Nappe Complex of the Scandinavian Caledonides: Journal of Metamorphic Geology, v. 35, p. 541–564, https://doi.org/10.1111/jmg.12244.

Kolderup, C.F., and Kolderup, N.-H., 1940, Geology of the Bergen Arc system: Bergens Museum Skrifter, v. 20, p. 137.

Krill, A.G., Bergh, S.G., Lindahl, I., Mearns, E.W., Often, M., Olerud, S., Sandstad, J.S., Siedlecka, A., and Solli, A., 1985, Rb-Sr, U-Pb and Sm-Nd isotopic dates from Precambrian rocks of Finnmark: Norges Geologiske Undersøkelse Bulletin, v. 403, p. 37–54.

Krill, A.G., 1980, Tectonics of the Oppdal area, central Norway: GFF, v. 102, p. 523–530, https://doi.org/10.1080/11035898009454505.

Krogh, T.E., 1973, A low-contamination method for hydrothermal decomposition of zircon and extraction of U and Pb for isotopic age determinations: Geochimica et Cosmochimica Acta, v. 37, p. 485–494, https://doi.org/10.1016/0016-7037(73)90213-5.

Kühn, A., Glodny, J., Austrheim, H., and Råheim, A., 2002, The Caledonian tectono-metamorphic evolution of the Lindås Nappe: Constraints from U-Pb, Sm-Nd and Rb-Sr ages of granitoid dykes: Norsk Geologisk Tidsskrift, v. 82, p. 45–57.

Kullerud, K., Skjerlie, K.P., Corfu, F., and de la Rosa, J.D., 2006, The 2.40 Ga Ringvassøy mafic dykes, West Troms basement complex, Norway: The concluding act of early Palaeoproterozoic continental breakup: Precambrian Research, v. 150, p. 183–200, https://doi.org/10.1016/j.precamres.2006.08.003.

Kumpulainen, R.A., and Nystuen, J.P., 1985, Late Proterozoic basin evolution and sedimentation in the westernmost part of Baltica, *in* Gee, D.G., and Sturt, B.A., eds., The Caledonide Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley, p. 213–232.

Kumpulainen, R.A., Hamilton, M.A., Söderlund, U., and Nystuen, J.P., 2016, A new U-Pb baddeleyite age for the Ottfjället dolerite dyke swarm in the Scandinavian Caledonides—A minimum age for late Neoproterozoic glaciation in Baltica, *in* Staboulis, S., Karvonen, T., and Kujanpaa, A., eds., Abstracts of the 32nd Nordic Geological Winter Meeting, Helsinki, 13–15 January 2016: Bulletin of the Geological Society of Finland, Special Volume 1, p. 171–172.

Kvale, A., 1945, Petrofabric analysis of quartzite from the Bergsdalen quadrangle, western Norway: Norsk Geologisk Tidsskrift, v. 25, p. 193–215.

Kvassnes, A.J.S., Strand, A.H., Moen-Eikeland, H., and Pedersen, R.B., 2004, The Lyngen Gabbro: The lower crust of an Ordovician incipient arc: Contributions to Mineralogy and Petrology, v. 148, p. 358–379, https://doi.org/10.1007/s00410-004-0609-8.

Ladenberger, A., Eri-shlevin, Y.B.E., and Claesson, S., 2014, Tectonometamorphic evolution of the Åreskutan Nappe—Caledonian history revealed by SIMS U-Pb zircon geochronology, *in* Corfu, F., Gasser, D., and Chew, D.M., eds., New Perspectives on the Caledonides of Scandinavia and Related Areas: Geological Society, London, Special Publication 390, p. 337–368, https://doi.org/10.1144/SP390.10.

Lamminen, J., Andersen, T., and Nystuen, J.P., 2011, Zircon U-Pb ages and Lu-Hf isotopes from basement rocks associated with Neoproterozoic sedimentary successions in the Sparagmite region and adjacent areas, south Norway: The crustal architecture of western Baltica: Norsk Geologisk Tidsskrift, v. 91, p. 35–55.

Lamminen, J., Andersen, T., and Nystuen, J.P., 2015, Provenance and rift basin architecture of the Neoproterozoic Hedmark Basin, south Norway, inferred from U-Pb ages and Lu-Hf isotopes of conglomerate clasts and detrital zircons: Geological Magazine, v. 152, p. 80–105, https://doi.org/10.1017/S0016756814000144.

Larsen, R.B., Grant, T., Sørensen, B.E., Tegner, C., McEnroe, S., Pastore, Z., Fichler, C., Nikolaisen, E., Grannes, K.R., Church, N., ter Maat, G.W., Michels, A., and ter Maat, G.W., 2018, Portrait of a giant deep-seated magmatic conduit system: The Seiland igneous province: Lithos, v. 296–299, p. 600–622, https://doi.org/10.1016/j.lithos.2017.11.013.

Levchenkov, O.A., Levsky, L.K., Nordgulen, O., Dobrzhinetskaya, L.F., Vetrin, V.R., Cobbing, J., Nilsson, L.P., and Sturt, B.A., 1993, U–Pb zircon ages from Sørvaranger, Norway, and the western part of the Kola Peninsula, Russia, *in* Roberts, D., and Nordgulen, Ø., eds., Geology of Eastern Finnmark–Western Kola Peninsula Region: Geological Survey of Norway Special Publication 7, p. 29–477.

Li, B., Massonne, H.-J., and Zhang, J., 2020, Evolution of a gneiss in the Seve nappe complex of central Sweden—Hints at an early Caledonian, medium-pressure metamorphism: Lithos, v. 376–377, 105746, https://doi.org/10.1016/j.lithos.2020.105746.

Lindahl, I., Nilsson, L.P., and Slagstad, T., 2008, Geology of the soapstone deposits of the Linnajavri area, Hamarøy, Nordland, north Norwegian Caledonides—Norway's largest reserves of soapstone, *in* Slagstad, T., ed., Geology for Society: Geological Survey of Norway Special Publication 11, p. 19–35.

Loeschke, J., 1967, Zur Stratigraphie und Petrographie des Valdres-Sparagmites und der Mellsenn-Gruppebei Mellane/Valdres (Süd-Norwegen): Norges Geologiske Undersøkelse Bulletin, v. 243, p. 5–66.

Ludwig, K.R., 2003, A Geochronological Toolkit for Microsoft Excel: Berkeley Geochronology Center Special Publication 4, 71 p.

Lundmark, A.M., and Corfu, F., 2007, Age and origin of the Årdal dike complex, SW Norway: False isochrons, incomplete mixing, and the origin of Caledonian granites in basement nappes: Tectonics, v. 26, TC2007, https://doi.org/10.1029/2005TC001844.

Lundmark, A.M., and Corfu, F., 2008, Late-orogenic Sveconorwegian massif anorthosite in the Jotun Nappe Complex, SW Norway, and causes of repeated AMCG magmatism along the Baltoscandian margin: Contributions to Mineralogy and Petrology, v. 155, p. 147–163, https://doi.org/10.1007/s00410-007-0233-5.

Lundmark, A.M., Corfu, F., Spürgin, S., and Selbekk, R.S., 2007, Proterozoic evolution and provenance of the high-grade Jotun Nappe Complex, SW Norway: U-Pb geochronology: Precambrian Research, v. 159, p. 133–154, https://doi.org/10.1016/j.precamres.2006.12.015.

Lunsæter, M.G., 2016, Geology and Origin of the Cu-Sulphide Ores in the Tynset-Alvdal Region, Southern Scandinavian Caledonides [Master's thesis]: Tromsø, Norway, Department of Geology, The Arctic University of Norway, 89 p.

Lutro, O., 1988, Gerggrunnsgeologisk kart Lustrafjorden 1:50,000: Norges Geologiske Undersøkelse Skrifter, v. 83, p. 1–39.

Majka, J., Rosén, Å., Janák, M., Froitzheim, N., Klonowska, I., Manecki, M., Sasinková, V., and Yoshida, K., 2014, Microdiamond discovered in the Seve Nappe (Scandinavian Caledonides) and its exhumation by the "vacuum-cleaner" mechanism: Geology, v. 42, p. 1107–1110, https://doi.org/10.1130/G36108.1.

Majka, J., Kruszewski, Ł., Rosén, Å., and Klonowska, I., 2015, Ba- and Ti-enriched dark mica from the UHP metasediments of the Seve Nappe Complex, Swedish Caledonides: Mineralogia, v. 46, p. 41–50, https://doi.org/10.1515/mipo-2017-0001.

Mattinson, J.M., 2005, Zircon U-Pb chemical abrasion ("CA-TIMS") method: Combined annealing and multi-step partial dissolution analysis for improved precision and accuracy of zircon ages: Chemical Geology, v. 220, p. 47–66, https://doi.org/10.1016/j.chemgeo.2005.03.011.

McClellan, E.A., 2004, Metamorphic conditions across the Seve-Köli Nappe boundary, southeastern Trondheim region, Norwegian Caledonides: Comparison of garnet-biotite thermometry and amphibole chemistry: Norsk Geologisk Tidsskrift, v. 84, p. 257–282.

Melezhik, V.A., Bingen, B., Sandstad, J.S., Pokrovsky, B.G., Solli, A., and Fallick, A.E., 2015, Sedimentary-volcanic successions of the Alta–Kvænangen tectonic window in the northern Norwegian Caledonides: Multiple constraints on deposition and correlation with complexes on the Fennoscandian Shield: Norsk Geologisk Tidsskrift, v. 95, p. 245–284, https://doi.org/10.17850/njg95-3-01.

Milnes, A.G., and Koestler, A.G., 1985, Geological structure of Jotunheimen, southern Norway (Sognefjell-Valdres cross-section), *in* Gee, D., and Sturt, B.A., eds., The Caledonian Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley & Sons Ltd, p. 457–474.

Mohn, G., Manatschal, G., Beltrando, M., and Haupert, I., 2014, The role of rift-inherited hyper-extension in Alpine-type orogens: Terra (Helsinki, Finland), v. 26, p. 347–353, https://doi.org/10.1111/ter.12104.

Munday, R.J.C., 1974, The geology of the northern half of the Lyngen Peninsula, Troms, Norway: Norsk Geologisk Tidsskrift, v. 54, p. 49–62.

Myhre, P.I., Corfu, F., Bergh, S.G., and Kullerud, K., 2013, U-Pb geochronology along an Archaean geotransect in the West Troms basement complex, north Norway: Norsk Geologisk Tidsskrift, v. 93, p. 1–24.

Naney, M.T., 1983, Phase equilibria of rock-forming ferromagnesian silicates in granitic systems: American Journal of Science, v. 283, p. 993–1033, https://doi.org/10.2475/ajs.283.10.993.

Nickelsen, R.P., 1974, Geology of the Røssjøkollan-Dokkvatn area: Oppland: Norges Geologiske Undersøkelse Bulletin, v. 314, p. 53–99.

Nickelsen, R.P., Hossack, J.R., Garton, M., and Repetsky, J., 1985, Late Precambrian to Ordovician stratigraphy and correlation in the Valdres and Synfjell thrust sheets of the Valdres area, southern Norwegian Caledonides; with some comments on sedimentation, *in* Gee, D.G., and Sturt, B.A., eds., The Caledonide Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley, p. 369–378.

Nielsen, A.T., and Schovsbo, N.H., 2011, The Lower Cambrian of Scandinavia: Depositional environment, sequence stratigraphy and palaeogeography: Earth-Science Reviews, v. 107, p. 207–310, https://doi.org/10.1016/j.earscirev.2010.12.004.

Nilsen, O., 1988, The tectonostratigraphic setting of stratabound sulphide deposits in the southern Trondheim region: Central Norwegian Caledonides: Norges Geologiske Undersøkelse Bulletin, v. 412, p. 55–66.

Nilsen, O., and Wolff, F.C., 1989, Geological Bedrock Map Røros og Sveg: Geological Map of Norway, Scale 1:250000: Trondheim, Norway, Geological Survey of Norway.

Nilsen, O., Corfu, F., and Roberts, D., 2007, Silurian gabbro-diorite-trondhjemite plutons in the Trondheim Nappe Complex, Caledonides, Norway: Petrology and U-Pb geochronology: Norsk Geologisk Tidsskrift, v. 87, p. 329–342.

Norrish, K., and Hutton, J.T., 1969, An accurate X-ray spectrographic method for the analysis of a wide range of geological samples: Geochimica et Cosmochimica Acta, v. 3, p. 431–453, https://doi.org/10.1016/0016-7037(69)90126-4.

Nystuen, J.P., 1980, Stratigraphy of the Upper Proterozoic Engerdalen Group, Kvitvola Nappe, southeastern Scandinavian Caledonides: GFF, v. 102, p. 551–560, https://doi.org/10.1080/11035898009454507.

Nystuen, J.P., 1983, Nappe and thrust structures in the Sparagmite region, southern Norway: Norges Geologiske Undersøkelse Bulletin, v. 380, p. 67–83.

Nystuen, J.P., 1987, Synthesis of the tectonic and sedimentological evolution of the late Proterozoic–early Cambrian Hedmark Basin, the Caledonian thrust belt, southern Norway: Norsk Geologisk Tidsskrift, v. 67, p. 395–418.

Nystuen, J.P., 2008, The north-western margin of Baltica—The Sparagmite Region in south Norway, *in* Ramberg, I.B., Bryhni, I., Nøttvedt, A., and Rangnes, K., eds., The Making of a Land: Geology of Norway: Trondheim, Norway, Norwegian Geological Association, p. 120–147.

Nystuen, J.P., and Lamminen, J.T., 2011, Neoproterozoic glaciation of south Norway: From continental interior to rift and pericratonic basins in western Baltica, *in* Arnaud, E., Halverson, G.P., and Shields-Zhou, G., eds., The Geological Record of Neoproterozoic Glaciations: Geological Society, London, Memoir 36, p. 613–622, https://doi.org/10.1144/m36.59

Nystuen, J.P., and Siedlecka, A., 1988, The "Sparagmites" of Norway, *in* Winchester, J.A., ed., Later Proterozoic Stratigraphy of the Northern Atlantic Regions: London, Blackie and Son Ltd., p. 237–252, https://doi.org/10.1007/978-1-4615-7344-9.

Nystuen, J.P., Andresen, A., Kumpulainen, R.A., and Siedlecka, A.W.G., 2008, Neoproterozoic basin evolution in Fennoscandia, East Greenland and Svalbard: Episodes, v. 31, p. 35–43, https://doi.org/10.18814/epiiugs/2008/v31i1/006.

Nystuen, J.P., Kumpulainen, R.A., Söderlund, U., and Hamilton, M.A., 2016, The Varangerian/Marinoan glaciation in Scandinavia—New age constraints, *in* Staboulis, S., Karvonen, T., and Kujanpaa, A., eds., Abstracts of the 32nd Nordic Geological Winter Meeting, Helsinki, 13–15 January 2016: Bulletin of the Geological Society of Finland, Special Volume 1, p. 172.

Paulsson, O., and Andréasson, P.G., 2002, Attempted break-up of Rodinia at 850 Ma: Geochronological evidence from the Seve-Kalak superterrane, Scandinavian Caledonides: Journal of the Geological Society, v. 159, p. 751–761, https://doi.org/10.1144/0016-764901-156.

Pedersen, R.-B.B., and Dunning, G.R., 1997, Evolution of arc crust and relations between contrasting sources: U-Pb (age), Nd and Sr isotope systematics of the ophiolitic terrain of SW Norway: Contributions to Mineralogy and Petrology, v. 128, p. 1–15, https://doi.org/10.1007/s004100050289.

Péron-Pinvidic, G., and Manatschal, G., 2010, From microcontinents to extensional allochthons: Witnesses of how continents rift and break apart?: Petroleum Geoscience, v. 16, p. 189–197, https://doi.org/10.1144/1354-079309-903.

Péron-Pinvidic, G., Manatschal, G., and Osmundsen, P.T., 2013, Structural comparison of archetypal Atlantic rifted margins: A review of observations and concepts: Marine and Petroleum Geology, v. 43, p. 21–47, https://doi.org/10.1016/j.marpetgeo.2013.02.002.

Plink-Björklund, P., Björklund, L., and Loorents, K.J., 2005, Sedimentary documentation of the break-up of Rodinia, Offerdal Nappe, Swedish Caledonides: Precambrian Research, v. 136, p. 1–26, https://doi.org/10.1016/j.precamres.2004.08.007.

Prestvik, T., 1980, The Caledonian ophiolite complex of Leka, north central Norway, *in* Panayiuotou, A., ed., Proceedings of the International Ophiolite Symposium, Cyprus 1979: Nicosia, Cyprus, Ministry of Agriculture and Natural Resources, Geological Survey Department, p. 555–566.
Pu, J.P., Bowring, S.A., Ramezani, J., Myrow, P., Raub, T.D., Landing, E., Mills, A., Hodgin, E., and Macdonald, F.A., 2016, Dodging snowballs: Geochronology of the Gaskiers glaciation and the first appearance of the Ediacaran biota: Geology, v. 44, p. 955–958, https://doi.org/10.1130/G38284.1.
Qvale, H., and Stigh, J., 1985, Ultramafic rocks in the Scandinavian Caledonides, *in* Gee, D.G., and Sturt, B.A., eds., The Caledonide Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley, p. 693–715.
Ragnhilstveit, J., 2003, Geological Bedrock Map Samnanger: Geological Map of Norway, scale 1:50000: Trondheim, Norway, Geological Survey of Trondheim.
Ragnhilstveit, J., and Helliksen, D., 1997, Geological Bedrock Map Bergen: Geological Map of Norway, scale 1:250000: Trondheim, Norway, Geological Survey of Norway.
Ragnhildsveit, J., Natersted, J., Jorde, K., and Egeland, B., 1998, Geological Bedrock Map Haugesund: Geological Map of Norway, scale 1:250000: Trondheim, Norway, Geological Survey of Norway.
Reading, H.G., 1965, Eocambrian and Lower Palaeozoic geology of the Digermul Peninsula, Tanafjord, Finnmark: Norges Geologiske Undersøkelse Bulletin, v. 234, p. 167–191.
Rice, A.H.N., 1998, Stretching lineations and structural evolution of the Kalak Nappe Complex (Middle Allochthon) in the Repparfjord-Faegfjord area, Finnmark, northern Norway: Norsk Geologisk Tidsskrift, v. 78, p. 277–289.
Rice, A.H.N., Edwards, M.B., Hansen, T.A., Arnaud, E., and Halverson, G.P., 2011, Glaciogenic rocks of the Neoproterozoic Smalfjord and Mortensnes formations, Vestertana Group, E. Finnmark, Norway, *in* Arnaud, E., Halverson, G.P., and Shields-Zhou, G., eds., The Geological Record of Neoproterozoic Glaciations: Geological Society, London, Memoir 36, p. 593–602, https://doi.org/10.1144/M36.57.
Rice, H., and Townsend, C., 1996, Correlation of the late Precambrian Ekkerøya Formation (Vadsø Group; E. Finnmark) and the Brennelvfjord Interbedded Member (Porsangerfjord Group; W. Finnmark): N. Norwegian Caledonides: Norsk Geologisk Tidsskrift, v. 76, p. 55–61.
Roberts, D., and Gee, D.G., 1985, An introduction to the structure of the Scandinavian Caledonides, *in* Gee, D.G., and Sturt, B.A., eds., The Caledonide Orogen—Scandinavia and Related Areas: Chichester, UK, Wiley, p. 55–68.
Roberts, D., and Siedlecka, A., 2002, Timanian orogenic deformation along the northeastern margin of Baltica, northwest Russia and northeast Norway, and Avalonian-Cadomian connections: Tectonophysics, v. 352, p. 169–184, https://doi.org/10.1016/S0040-1951(02)00195-6.
Roberts, D., and Siedlecka, A., 2012, Provenance and sediment routing of Neoproterozoic formations on the Varanger, Nordkinn, Rybachi and Sredni Peninsulas, north Norway and northwest Russia: A review: Norges Geologiske Undersøkelse Bulletin, v. 452, p. 1–19.
Robins, B., 2013, Dunite magma or ultramafic cumulates? A discussion of Griffin et al. "Intrusion and contamination of high-temperature dunite magma: The Nordre Bumandsfjord pluton, Seiland, Arctic Norway" Contrib. Mineral. Petrol. (2013) 165:903–930: Contributions to Mineralogy and Petrology, v. 166, p. 1539–1541, https://doi.org/10.1007/s00410-013-0924-z.
Roffeis, C., Corfu, F., and Austrheim, H., 2012, Evidence for a Caledonian amphibolite to eclogite facies pressure gradient in the Middle Allochthon Lindås Nappe, SW-Norway: Contributions to Mineralogy and Petrology, v. 164, p. 81–99, https://doi.org/10.1007/s00410-012-0727-7.
Root, D.D.B., and Corfu, F., 2012, U-Pb geochronology of two discrete Ordovician high-pressure metamorphic events in the Seve Nappe Complex, Scandinavian Caledonides: Contributions to Mineralogy and Petrology, v. 163, p. 769–788, https://doi.org/10.1007/s00410-011-0698-0.
Röshoff, K., 1978, Structures of the Tännäs Augen Gneiss Nappe and its relation to under- and overlying units in the central Scandinavian Caledonides: Sveriges Geologiska Undersökning Serie C, v. 739, p. 3–34.
Ryan, P.D., Williams, D.M., and Skevington, D., 1980, A revised interpretation of the Ordovician stratigraphy of Sør-Trøndelag, and its implications for the evolution of the Scandinavian Caledonides, *in* Wones, D.R., ed., The Caledonides in the USA: Blacksburg, Virginia, Department of Geological Sciences, Virginia Polytechnic Institute and State University Memoir 2, p. 99–105.
Sæther, T., and Nystuen, J.P., 1981, Tectonic framework, stratigraphy, sedimentation and volcanism of the late Precambrian Hedmark Group, Østerdalen, south Norway: Norsk Geologisk Tidsskrift, v. 61, p. 193–211.
Schmidt, M.W., and Poli, S., 2004, Magmatic epidote: Reviews in Mineralogy and Geochemistry, v. 56, p. 399–430, https://doi.org/10.2138/gsrmg.56.1.399.
Siedlecka, A., and Siedlecki, S., 1971, Late Precambrian sedimentary rocks of the Tanafjord-Varangerfjord region of Varanger Peninsula, northern Norway: Norges Geologiske Undersøkelse Bulletin, v. 269, p. 246–294.
Siedlecka, A., Nystuen, J.P., Englund, J.O., and Hossak, J.R., 1987, Geological Bedrock Map Lillehammer: Geological Map of Norway, scale 1:250000: Trondheim, Norway, Geological Survey of Norway.
Siivola, J., and Schmid, R., 2007, A systematic nomenclature for metamorphic rocks: 12. List of mineral abbreviations. Recommendations by the IUGS Subcommission on the Systematics of Metamorphic Rocks, *in* Recommendations, web version of 01.02.2007. IUGS, p. 14.
Siveter, D.J., 1977, Trilobites of the Family Calymenidae: Norsk Geologisk Tidsskrift, v. 56, p. 335–396.
Sjöström, H., 1983, Geothermometry, garnet chemistry and geobarometry of the Seve-Köli Nappe Complex in the Handöl-Storlien area: Uppsala, Sweden, Department of Mineralogy and Petrology, University of Uppsala, Research Report, p. 1–28.
Slagstad, T., and Kirkland, C.L., 2018, Timing of collision initiation and location of the Scandian orogenic suture in the Scandinavian Caledonides: Terra Nova, v. 30, p. 179–188, https://doi.org/10.1111/ter.12324.
Slagstad, T., Pin, C., Roberts, D., Kirkland, C.L., Grenne, T., Dunning, G., Sauer, S., and Andersen, T., 2014, Tectonomagmatic evolution of the Early Ordovician suprasubduction-zone ophiolites of the Trondheim region, mid-Norwegian Caledonides, *in* Corfu, F., Gasser, D., and Chew, D.M., eds., New Perspectives on the Caledonides of Scandinavia and Related Areas: Geological Society, London, Special Publication 390, p. 541–561, https://doi.org/10.1144/SP390.11.
Slama, J., 2016, Rare late Neoproterozoic detritus in SW Scandinavia as a response to distant tectonic processes: Terra Nova, v. 28, p. 394–401, https://doi.org/10.1111/ter.12232.
Slama, J., and Pedersen, R.B., 2015, Zircon provenance of SW Caledonian phyllites reveals a distant Timanian sediment source: Journal of the Geological Society, v. 172, p. 465–478, https://doi.org/10.1144/jgs2014-143.
Smithson, S.B., Ramberg, I.B., and Grönlie, G., 1974, Gravity interpretation of the Jotun Nappe of the Norwegian Caledonides: Tectonophysics, v. 22, p. 205–222, https://doi.org/10.1016/0040-1951(74)90082-1.
Stacey, J.S., and Kramers, J.D., 1975, Approximation of terrestrial lead isotope evolution by a 2-stage model: Earth and Planetary Science Letters v. 26, no. 2, p. 207–221, https://doi.org/10.1016/0012-821X(75)90088-6.
Stephens, M.B., and Gee, D.G., 1989, Terranes and polyphase accretionary history in the Scandinavian Caledonides, *in* Dallmeyer, R.D., ed., Terranes in the Circum-Atlantic Paleozoic Orogens: Geological Society of America Special Paper 230, p. 17–30, https://doi.org/10.1130/SPE230-p17.
Stigh, J., 1979, Ultramafites and Detrital Serpentinites in the Central and Southern Parts of the Caledonian Allochthon in Scandinavia [Ph.D. thesis]: Gothenburg, Sweden, University of Gothenburg, 222 p.
Stodt, F., Rice, A.H.N., Björklund, L., Bax, G., Halverson, G.P., and Pharaoh, T.C., 2011, Evidence of late Neoproterozoic glaciation in the Caledonides of NW Scandinavia, *in* Arnaud, E., Halverson, G.P., and Shields-Zhou, G., eds., The Geological Record of Neoproterozoic Glaciations: Geological Society, London, Memoir 36, p. 603–612, https://doi.org/10.1144/M36.58.
Stølen, L.K., 1985, Et geologisk studium av solitære ultramafiske bergarter og omkringliggende metasedimenter og metavulkanitter tilhørende kølidekkende i Krutadalsområdet, Hattfjelldal, Nordland [Master's thesis]: (Stratigrafi, deformasjon og metamorfose) Part II: Figurer og Appendix: Oslo, Norway, University of Oslo, 135 p.
Strand, T., 1951, The Sel and Vågå map areas—Geology and petrology of a part of the Caledonides of central southern Norway: Norges Geologiske Undersøkelse, v. 178, p. 117.
Sturt, B.A., and Ramsay, D.M., 1997, The Gudbrandsdalen antiform—A major late Caledonian structure: Norges Geologiske Undersøkelse Bulletin, v. 433, p. 12–13.
Sturt, B.A., and Ramsay, D.M., 1999, Early Ordovician terrane-linkages between oceanic and continental terranes in the central Scandinavian Caledonides: Terra Nova, v. 11, p. 79–85.

Sturt, B.A., and Thon, A., 1978, An ophiolite complex of probable early Caledonian age discovered on Karmøy: Nature, v. 275, p. 538–539, https://doi.org/10.1038/275538a0.

Sturt, B.A., Bøe, R., Ramsay, D.M., and Bjerkgård, T., 1995, Stratigraphy of the Otta-Vågå tract and regional stratigraphic implications: Norges Geologiske Undersøkelse Bulletin, v. 427, p. 25–28.

Sturt, B.A., Ramsay, D.M., and Lutro, O., 1999, Geological Bedrock Map Sel og Vågå Kommunar, scale 1:250000: Geological Map of Norway: Trondheim, Norway, Geological Survey of Norway, Trondheim, Norway.

Svenningsen, O.M., 1994, The Baltica-Iapetus passive margin dyke complex in the Sarektjåkkå Nappe, northern Swedish Caledonides: Geological Journal, v. 29, p. 323–354, https://doi.org/10.1002/gj.3350290403.

Svenningsen, O.M., 1995, Extensional deformation along the late Precambrian–Cambrian Baltoscandian passive margin: The Sarektjåkkå Nappe, Swedish Caledonides: Geologische Rundschau, v. 84, p. 649–664, https://doi.org/10.1007/BF00284527.

Svenningsen, O.M., 2001, Onset of seafloor spreading in the Iapetus Ocean at 608 Ma: Precise age of the Sarek Dyke Swarm, northern Swedish Caledonides: Precambrian Research, v. 110, p. 241–254, https://doi.org/10.1016/S0301-9268(01)00189-9.

Tegner, C., Andersen, T.B., Kjøll, H.J., Brown, E.L., Hagen-Peter, G., Corfu, F., Planke, S., and Torsvik, T.H., 2019, A mantle plume origin for the Scandinavian Dyke Complex: A "piercing point" for 615 Ma plate reconstruction of Baltica?: Geochemistry, Geophysics, Geosystems, v. 20, p. 1075–1094, https://doi.org/10.1029/2018GC007941.

Tetreault, J.L., and Buiter, S.J.H., 2012, Geodynamic models of terrane accretion: Testing the fate of island arcs, oceanic plateaus, and continental fragments in subduction zones: Journal of Geophysical Research, v. 117, B08403, https://doi.org/10.1029/2012JB009316.

Thelander, T., 1982, The Torneträsk Formation of the Dividal Group, northern Swedish Caledonides: Sveriges Geologiska Undersökning Serie C 789, 41 p.

Thickpenny, A., 1984, The sedimentology of the Swedish Alum Shales, *in* Stow, D.A.V., and Piper, D.J.W., eds., Fine-Grained Sediments: Deep-Water Processes and Facies: Geological Society, London, Special Publication 15, p. 511–525, https://doi.org/10.1144/GSL.SP.1984.015.01.33.

Törnebom, A.E., 1896, Grunddagen af det centrala Scandinaviens bergbyggnad (mit einem Résumé in deutscher Sprache): Kongliga Svenska Vetenskapsakademiens Handlingar, v. 28, no. 5, p. 212.

Trommsdorff, V., and Connolly, J.A.D., 1996, The ultramafic contact aureole about the Bregaglia (Bergell) tonalite: Isograds and a thermal model: Schweizerische Mineralogische und Petrographische Mitteilungen, v. 76, p. 537–547.

Tucker, R.D., Boyd, R., and Barnes, S.J., 1990, A U-Pb zircon age for the Rana intrusion, N. Norway: New evidence of basic magmatism in the Scandinavian Caledonides in early Silurian time: Norsk Geologisk Tidsskrift, v. 70, p. 229–239.

van Roermund, H.L.M., 1989, High-pressure ultramafic rocks from the Allochthonous Nappes of the Swedish Caledonides, *in* Gayer, R.A., ed., The Caledonide Geology of Scandinavia: London, Graham & Trotman, p. 205–219.

van Staal, C.R., Chew, D.M., Zagorevski, A., Hibbard, J., Castonguay, S., Escayola, M.P., and Paul, J., 2013, Evidence of late Ediacaran hyperextension of the Laurentian Iapetan margin in the Birchy Complex, Baie Verte Peninsula, northwest Newfoundland: Implications for the opening of Iapetus, formation of peri-Laurentian microcontinents and Taconic–Grampian orogenesis: Geoscience Canada, v. 40, p. 94–117, https://doi.org/10.12789/geocanj.2013.40.006.

Villa, I.M., De Bièvre, P., Holden, N.E., and Renne, P.R., 2015, IUPAC-IUGS recommendation on the half life of ^{87}Rb: Geochimica et Cosmochimica Acta, v. 164, p. 382–385, https://doi.org/10.1016/j.gca.2015.05.025.

Waldron, J.W.F., and van Staal, C.R., 2001, Taconian orogeny and the accretion of the Dashwoods block: A peri-Laurentian microcontinent in the Iapetus Ocean: Geology, v. 29, p. 811–814, https://doi.org/10.1130/0091-7613(2001)029<0811:TOATAO>2.0.CO;2.

Wellings, S.A., 1996, Geology of the Tronfjell Massif: Placing Mafic Magmatism into a Tectono-Stratigraphic Framework: Geological Survey of Norway Report 96.112: Trondheim, Geological Survey of Norway, 52 p.

Wellings, S.A., and Sturt, B.A., 1998, Tectonic setting of the Tronfjell Massif: Further evidence for pre-Scandian orogenesis in the Trondheim Nappe Complex, central Norway: Norges Geologiske Undersøkelse Bulletin, v. 434, p. 109–115.

Wennberg, O.P., Skjerlie, K.P., and Dilek, Y., 2001, Field relationships and geochemistry of the Ostereide dykes, western Norway: Implications for Caledonian tectonometamorphic evolution: Norsk Geologisk Tidsskrift, v. 81, p. 305–320.

Wiest, J.D., 2020, Exhumation of the Caledonian Orogenic Infrastructure in West Norway: Concepts–Structures–Ages–Reactivation [Ph.D. thesis]: Bergen, Norway, University of Bergen, 298 p.

Wiest, J.D., Osmundsen, P.T., Jacobs, J., and Fossen, H., 2019, Deep crustal flow within postorogenic metamorphic core complexes: Insights from the southern Western Gneiss Region of Norway: Tectonics, v. 38, p. 4267–4289, https://doi.org/10.1029/2019TC005708.

Wiest, J.D., Jacobs, J., Fossen, H., Ganerød, M., and Osmundsen, P.T., 2020, Segmentation of the Caledonian orogenic infrastructure and exhumation of the Western Gneiss Region during transtensional collapse: Journal of the Geological Society, v. 178, jgs2020-2199, https://doi.org/10.1144/jgs2020-199.

Wilson, J.T., 1966, Did the Atlantic close and then re-open?: Nature, v. 211, p. 676–681, https://doi.org/10.1038/211676a0.

Wolff, F.C., 1979, Beskrivelse til de berggrunnsgeologiske kart Trondheim og Østersund 1:250,000 (med fargetrykt kart): Skrifter, v. 353, p. 1–76.

Zen, E.A., and Hammarstrom, J.M., 1984, Magmatic epidote and its petrologic significance: Geology, v. 12, p. 515–518, https://doi.org/10.1130/0091-7613(1984)12<515:MEAIPS>2.0.CO;2.

Zozulya, D., Kullerud, K., Ravna, E.K., Corfu, F., and Savchenko, Y., 2009, Geology, age and geochemical constraints on the origin of the late Archaean Mikkelvik alkaline stock, West Troms basement complex in northern Norway: Norsk Geologisk Tidsskrift, v. 89, p. 327–340.

Zwaan, K.B., 1988, Geological Bedrock Map Nordreisa: Geological Map of Norway, scale 1:250000: Trondheim, Norway, Geological Survey of Norway.

Zwaan, K.B., Fareth, E., and Grogan, P.W., 1998, Geological Bedrock Map Tromsø: Geological Map of Norway, scale 1:250000: Trondheim, Norway, Geological Survey of Norway.

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