U–Pb zircon ages of felsic rocks in the Forbordfjell ophiolite fragment, Støren Nappe, Mid-Norwegian Caledonides

L. Peter Gromet¹ & David Roberts²

¹Department of Earth, Environmental and Planetary Sciences, Brown University, Providence, RI 02912, USA.

²Geological Survey of Norway, P.O. Box 6315 Sluppen, NO–7491 Trondheim, Norway.

E-mail corresponding author (L. Peter Gromet): l_gromet@brown.edu

New U–Pb isotopic ages for multiple fractions of zircons from two felsic igneous rocks contained within the tectonically dismembered Forbordfjell ophiolite, Trondheim Region, Norway, provide likely magmatic crystallisation ages of 485.6 ± 0.6 Ma and 488 ± 4 Ma ($^{206}\text{Pb}/^{238}\text{U}$ ages, 95% conf. limit). These ages are within the range of those reported for several other mafic/ultramafic complexes of the Upper Allochthon in the central Norwegian segment of the Scandinavian Caledonides. The geochemical characteristics of these felsic rocks indicate they were derived by differentiation from mafic precursors originally sourced from depleted mantle. These observations are consistent with the idea that the Forbordfjell and related ophiolites represent Late Cambrian to Tremadocian ocean floor and primitive oceanic arc assemblages involved in an Early Ordovician tectonothermal event, which was quickly superceded by uplift, erosion, and deposition of overlying Ordovician to likely Early Silurian volcanosedimentary successions. These assemblages were eventually subjected to strong tectonic lensing and dissection during the Scandian collisional orogeny.

Keywords: Upper Allochthon, Trøndelag, Cambrian, Early Palaeozoic, Iapetus Ocean, Scandinavian Caledonides

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Introduction

Magmatic units traditionally termed ‘greenstones’ in Scandinavia occur widely in thrust sheets of the Caledonian Upper Allochthon in central Norway and Sweden. Detailed mapping and geochemical studies over the past four decades in the twin Trøndelag counties of Mid Norway have revealed that the greenstones are predominantly tholeiitic metabasalts, in many cases associated with lesser gabbros, felsic rocks, sheeted mafic dykes and less commonly ultramafic cumulates. These magmatic complexes have been interpreted as fragmented and dismembered ophiolites (Gale & Roberts, 1974; Grenne et al., 1980; Prestvik, 1980; Furnes et al., 1985, 1988; Heim et al., 1987; Grenne, 1989; Slagstad, 2003; Nilsson et al., 2005; Nilsson & Roberts, 2014; Slagstad et al., 2014).

U–Pb isotopic ages of zircons extracted from plagiogranite dykes and sheets or rhyodacite flows in some of these ophiolites range from c. 497 to 480 Ma, corresponding to Late Cambrian (Paibian) to Early Ordovician (Late Tremadocian) on the current International Chronostratigraphic Chart (Cohen et al., 2015). A recent summary of ages from isotopically dated fragmented ophiolites has been presented in Slagstad et al. (2014, table 1). Several other predominantly metabasaltic greenstone units of interpreted ophiolite origin have yet to be dated radiometrically. In the present contribution we report on the U–Pb zircon isotopic dating of two separate samplings of felsic rocks from the Forbordfjell ophiolite body, located some 30 km northeast of Trondheim (Fig. 1).

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Figure 1. (A) Simplified geological map of the Trondheimsfjord region in the Central Norwegian Caledonides, showing key geological units. The black rectangle marks the region covered in the more detailed geological map of the Forbordsfjellet area shown in Fig. 1B. The red rectangle in the inset map of Norway marks the region of Fig. 1A. Abbreviation: F – Forbordsfjellet. (B) Geological map of the region around Forbordsfjellet and the Frosta peninsula. Locations are indicated for samples Forb 3 and Forb 1/14. Forb 3 – 59460 704520; Forb 1/14 – 59865 704930. Coordinates apply to UTM Zone 32V, WGS84. Both localities are on 1:50,000 map-sheet 'Frosta' 1622–2.

Geological setting

In the tectonostratigraphic framework of the Scandinavian Caledonides, the Upper Allochthon is one of four principal subdivisions of the package of nappes and thrust sheets that constitutes the Caledonian orogen (Roberts & Gee, 1985). Below this level are the Lower and Middle allochthons, comprising mostly metasedimentary and subordinate magmatic rocks that are generally considered as indigenous to Baltica, the former representing platformal or shelf sequences and the latter regarded as having once formed the continental rise prism of the Baltoscandian margin of the Baltican plate (Stephens & Gee, 1989). The Upper Allochthon embraces the diverse ocean-floor and marginal basin assemblages and volcanic arc complexes, considered to have originated within the exotic offshore realm of the Iapetus Ocean, and traditionally referred to in Scandinavia as the 'Köli nappes'. Above this is the Uppermost Allochthon which consists largely of magmatic and metasedimentary rocks considered to have originally formed parts of the continental margin of Laurentia (Stephens & Gee, 1989;

Roberts et al., 2002a, 2007; Barnes et al., 2007). Some modifications have been made to the original four-fold subdivision (e.g., Andréasson & Gee, 2008) and questions have been raised about the scheme in general (Corfu et al., 2014), but it continues to provide a very convenient and useful framework in which to categorise the rocks in the many individual nappes and thrust sheets.

In the Trondheim Region of Mid Norway, the Köli nappes of the Upper Allochthon are represented by the Trondheim Nappe Complex, comprising the low-grade Støren Nappe (in the west) and Meråker Nappe (in the east), and a central, generally higher-grade and structurally more complex Gula Nappe (Wolff, 1979; Grenne et al., 1999; Roberts & Stephens, 2000). Most of the fragmented ophiolites appear to occur at the base of the Støren Nappe and have generally been ascribed to what Vogt (1945) termed the Støren Group – really a misnomer in view of today's strict rules of stratigraphic nomenclature. Earlier, Carstens (1920) had used the name Bymark Group for the full complement of 'greenstones' in the western Trondheim Region, but since the mid 20th century the name Støren Group has

gained precedence (Vogt, 1945; Wolff, 1967, 1979; Gale & Roberts, 1974).

In recent years, the fragmented ophiolites have been interpreted as suprasubduction-zone ocean-floor rocks obducted (possibly as one large ophiolite originally) on to the rocks of the Gula Complex in what is now the Gula Nappe (Roberts et al., 1984, 2002b; Sturt & Roberts, 1991; Hollocher et al., 2012). In this interpretation the ophiolite was metamorphosed, uplifted and eroded, and then received deposition of the Lower Hovin, Upper Hovin and Horg groups, mostly low-grade metasedimentary successions with sparse incursions of both mafic and felsic igneous rocks. The basal unit in the Lower Hovin Group is a polymict conglomerate with a green silty matrix, composed mostly of debris from the ophiolite. This carries the name Venna Conglomerate from the Hølanda area SW of Trondheim, but other names are used elsewhere in central Norway. In the Forbordsfjellet district, the Stokkvola conglomerate is considered to represent this same basal formation of the Lower Hovin Group (Fig. 1B), and an equivalent polymict conglomerate on the

Frosta peninsula (Fig. 1B) is the Helsinglassen conglomerate (Lippard & Roberts, 2010).

In the type area southwest of Trondheim, the Lower Hovin Group is well known for its diverse fauna which is largely of North American affinity (Bergström, 1979, 1997; Bruton & Bockelie, 1980; Ryan et al., 1980; Neuman & Bruton, 1989) with the oldest genera of Mid Arenig (Dapingian) age. Thus, palaeotectonic reconstructions have favoured ophiolite obduction during the time interval 480–475 Ma. Although the Upper Hovin and Horg groups are not directly relevant to our current isotopic study, Vogt (1945) had maintained that the Horg Group probably extended into the Early Silurian. Northwest of Forbordsfjellet in the Åsenfjorden district, the basal unit of the Upper Hovin Group (known as the Ekne Group in this area; Fig. 1B), the Hopla conglomerate, is situated not far above fossiliferous rocks of Mid Katian age (Tolmacheva & Roberts, 2007), and is followed by a c. 2800 m-thick succession of barren, partly tuffaceous sandstones and phyllitic shales which, thus, most likely, extends up well into the Llandovery epoch of the Silurian period (Henriksen

Figure 2. Field photos of the outcrops from where the samples were taken (coordinates given in the caption to Fig. 1B). (A) **Forb 3.** Transgressive felsite sill in metabasalts of the ophiolite, close to the top of Forbordsfjellet. The sample was taken adjacent to the hammer in the centre of the photo. (B) **Forb 1/14.** Disrupted felsite dyke with a subjacent minor shear zone, in a new long road-cut exposing mostly metabasalts on the minor road to Skei. The felsite contains several small xenoliths of the basalt.

Table 1. Major and trace element analyses of felsic rock samples, Forbordfjell ophiolite.

	Forb3	Forb1/14		Forb3	Forb1/14		Forb3	Forb1/14
SiO ₂	65.23	61.8	Zr	349	250	La	21.83	19.7
Al ₂ O ₃	19.24	18.9	Y	60	59.6	Ce	51.59	52.6
Fe ₂ O ₃	2.42	2.38	Sr	233	94.4	Pr	6.65	6.81
TiO ₂	0.19	0.28	Rb	<5	<5	Nd	28.84	33.1
MgO	0.24	1.02	Zn	<5	21.2	Sm	7.15	9.81
CaO	3.59	3.48	Cu	6	<5	Eu	1.88	1.26
Na ₂ O	9.39	9.61	Ni	8	11.8	Gd	7.77	9.08
K ₂ O	0.07	0.05	Cr	<5	29.3	Tb	1.33	1.84
MnO	0.02	0.05	Ba	10	6.47	Dy	8.59	12.2
P ₂ O ₅	0.01	0.04	Nb	2.4	6.23	Er	5.79	8.16
LOI	0.64	1.36	V	15	<5	Tm	0.83	1.4
Sum	101.06	98.9	Ga	17	18.5	Yb	5.58	8.69
			Th	0.95	4.64	Lu	0.83	1.27
			U	--	1.41	Hf	8.96	8.4
						Ta	0.16	0.45

Major elements in wt.%, trace and other elements in ppm.

et al., in review). In this regard, a provenance study of the Ekne Group, currently in progress, should help to resolve this issue.

The Forbordfjell ophiolite

Originally known as the Forbordfjell greenstone, geological mapping has shown that the ophiolite fragment consists principally of a medium-grained foliated metabasalt with pillow structure present in many parts of the succession (Grenne & Roberts, 1980). Breccias consisting of broken pillows are also recorded in some places. In addition, there are massive flow units ranging in thickness from 3 to 25 m, some of which attain exceptionally coarse-grained gabbroic textures in their central parts. There are also subconcordant gabbro sheets that transect the lava stratigraphy, and a prominent leucogabbro body located close to the summit of Forbordsfjellet. Several mafic dykes have been recorded in parts of the succession, but none of the swarm proportions observed in other dismembered ophiolites in the Trondheim Region. Less common rock types include thin layers of felsic volcanites (traditionally termed quartz keratophyres), dykes or transgressive sills of fine-grained plagiogranite/trondjemite, and thin layers of chert or jasper. The metabasalts show a wide textural range from aphyric to porphyritic and consist mainly of actinolite, albite, epidote, chlorite and some biotite and stilpnomelane, with secondary titanite, leucoxene, calcite, quartz and iron oxides. The felsic extrusive or sill-like rocks (Fig. 2A, B) are composed principally of microcrystalline albite and some quartz, and correspond to sodic trachytes on a total alkali oxide vs. silica diagram, whereas the plagiogranite

dykes consist of quartz and albitic plagioclase with minor biotite and epidote. Other felsic rocks analysed fall in the rhyolite field; one such rhyolite was sampled for radiometric dating but proved to be devoid of zircons.

The entire ophiolite assemblage lies in a structurally inverted position in the core of a tight synform (*Forbordfjell Synform*; Roberts, 1968), a structure which is ascribed to the second main Caledonian (Scandian) deformation phase, as it refolds earlier synmetamorphic, isoclinal folds recognisable in the Hovin and Ekne metasedimentary successions (Roberts, 1968). The ophiolite is also delimited by tectonic slides (shear zones that developed during folding; Fleuty, 1964; Hutton, 1981) with the more prominent structurally lower one (Fig. 1B) passing up to the stratigraphic top of the Stokkvola conglomerate, where it is responsible for excision of most of the shallow-marine strata that characterise this level of the Lower Hovin Group in other parts of the region (Henriksen et al., in review).

Geochemistry

A geochemical study of the metabasalts of the Forbordfjell ophiolite (Grenne & Roberts, 1980) showed that the bulk of these mafic lavas have signatures akin to those of LREE-depleted, 'normal', mid-ocean ridge tholeiites. Samples from greenstone layers in the lowest and highest members of the pseudostratigraphy revealed a slightly more transitional, within-plate character. The LREE-depleted patterns are similar to those shown by metabasaltic greenstones of the bimodal Fånes complex on Frosta peninsula (Lippard & Roberts, 2010).

The felsic rocks of our present isotopic dating study (Table 1) both show chondrite-normalised, REE patterns with moderately enriched LREEs, flat HREEs and marked negative Eu anomalies (Fig. 3). These rare-earth element signatures are almost identical to those displayed by the comagmatic felsic rocks in the Fånes complex (Lippard & Roberts, 2010) which have features indicative of generation in a primitive island-arc, suprasubduction zone setting. The REE patterns (Fig. 3) are also comparable to those of the c. 481 Ma Fagervika arc-type granitoid in the Bymarka ophiolite near Trondheim (Slagstad, 2003; Slagstad et al., 2014).

Geochronology

Two samples of fine-grained felsic igneous rocks were taken from small bodies contained within metabasalts of the Forbørdfjell ophiolite (Fig. 2A, B) at locations Forb 3 and Forb 1/14 (Fig. 1B; grid coordinates are given in the figure caption). Zircon concentrates were prepared at NGU, and zircon grains were hand picked from these materials at Brown University for U–Pb isotopic analysis. The Forb 3 sample yielded an abundance of zircons, characteristically as small prisms of 75 to 150 μm length and 2:1 to 3:1 aspect ratio. Four analysed fractions of 7 to 14 grains each were selected so as to minimise the presence of inclusions, cracks, and cloudiness. The Forb 1/14 sample yielded fewer zircons which were more stubby (2:1 aspect ratio or less). Five fractions of 11 to 17 grains each were analysed.

The fractions were processed through HF–HNO₃ dissolution and chemical separation, largely following

analytical procedures given by Krogh (1973). Pb and U were analysed on a Finnigan MAT 261 mass spectrometer, using either combined Faraday–SEM multi-collection, or by peak hopping into the SEM in those cases where signal intensity was low. Results are reported in Table 2 and plotted on concordia (Fig. 4).

All zircon fractions analysed have low U contents and therefore developed relatively low amounts of radiogenic Pb since their crystallisation, and yielded uncorrected $^{206}\text{Pb}/^{204}\text{Pb}$ ratios of 565 to 1519. The four fractions from Forb 3 ran with strong signal intensities and gave relatively low uncertainties in their calculated ages. The five fractions of Forb 1/14 ran with lower signal intensities, leading to larger errors in their calculated ages, especially the $^{207}\text{Pb}/^{235}\text{U}$ ages.

On the concordia diagram, error ellipses for 4 of the 5 fractions from Forb 1/14 overlap the concordia curve between c. 475 and 500 Ma, indicating they are concordant within their errors; the remaining fraction is very slightly displaced to the right of the concordia curve. The error ellipses from the Forb 3 fractions are smaller and more tightly grouped at a location that is very slightly displaced to the right of the concordia curve. Note that the error ellipses for the 4 tightly grouped fractions from Forb 3 are centred in the field defined by the larger error ellipses of the 5 fractions from Forb 1/14, indicating that the U–Pb ages for both samples are indistinguishable within their errors.

There is insufficient spread in the fractions to support calculation of a discordia array for either sample or for the samples combined, and therefore upper intercept ages are not defined for these analyses. The cause of the

Figure 3. Chondrite-normalised REE plot of samples Forb 3 and Forb 1/14 from the Forbørdfjell ophiolite. Note the strong enrichment of all trivalent REE and the pronounced negative Eu anomalies. There is only modest relative enrichment of the light REE despite the strong overall REE enrichment, a feature consistent with the derivation of these felsic rocks from more mafic rocks sourced from depleted mantle. Normalising values after Sun & McDonough (1989).

Figure 4. Concordia diagram for multiple zircon fractions from samples Forb 3 and Forb 1/14.

slight discordance of the more precise analyses from Forb 3 is unclear. Inheritance is not expected in these primitive, oceanic volcanic rocks, and discordance due to radiation damage and ensuing Pb loss is also not anticipated given the low U contents of the zircon.

Due to these factors, providing an age interpretation of the results is somewhat subjective. We consider the

$^{206}\text{Pb}/^{238}\text{U}$ ages of the fractions of each of the two samples to be the best indicator of their crystallisation age, based on (1) the lack of discordia arrays, which would be produced by variable Pb loss if such loss occurred, (2) the measured $^{206}\text{Pb}/^{204}\text{Pb}$ ratios of all the analyses indicate the presence of some common Pb, and the $^{206}\text{Pb}/^{238}\text{U}$ ages are significantly less sensitive to the common Pb correction, and (3) despite larger variations in $^{207}\text{Pb}/^{235}\text{U}$ ages, the $^{206}\text{Pb}/^{238}\text{U}$ ages for all 9 fractions from the two samples fall consistently in a tight range, which is unlikely to be coincidental. Given this, we consider the weighted mean $^{206}\text{Pb}/^{238}\text{U}$ ages of 485.6 ± 0.6 Ma (95% conf. limit) for the 4 fractions from Forb 3 and 488 ± 4 Ma (95% conf. limit) for the 5 fractions from Forb 1/14 to be the minimum and also the most likely crystallisation ages. We note that the ages for the two samples are coincident within their errors. As for maximum ages, even though we do not believe the slight observed discordance can be confidently attributed to Pb loss, assuming that it is due to modern Pb loss would permit the $^{207}\text{Pb}/^{206}\text{Pb}$ age of each fraction to be interpreted as a maximum possible age (equivalent to an upper intercept age for modern Pb loss). Therefore, our estimates of the maximum possible ages of these samples correspond to the weighted mean $^{207}\text{Pb}/^{206}\text{Pb}$ ages of 512 ± 10 Ma and 516 ± 16 Ma (95% conf. limit) for Forb 3 and Forb 1/14, respectively. Again we note these ages are coincident within their errors.

Figure 5. (A) View towards Berget, a small hill and cliff c. 1.2 km southwest of Forbordsfjellet peak, looking east, showing the tectonised contact between metabasalts of the ophiolite (upper part of the cliff) and protomylonitic limestone of the Lower Hovin Group. Highly disrupted black shales below the limestone are not visible in this photo. (B) A close-up of the extreme left part of photo (A) showing the tectonic slide contact, the mylonitic limestone, and black shale below. An isolated block of metabasalt with a sigmoidal shape (due to the shear deformation) has been tectonically incorporated in the deformed limestone.

Table 2. Zircon U–Pb isotopic analyses of felsites from the Forbordfjell ophiolite.

Sample	Fraction / # grains	U ppm	Pb ppm	$^{206}\text{Pb}/^{204}\text{Pb}$ Measured ¹	$^{206}\text{Pb}/^{238}\text{U}$ $\pm$ err (abs) ²	$^{207}\text{Pb}/^{235}\text{U}$ $\pm$ err (abs) ²	$^{206}\text{Pb}/^{238}\text{U}$ age (Ma)	$^{207}\text{Pb}/^{235}\text{U}$ age (Ma)	$^{207}\text{Pb}/^{206}\text{Pb}$ age (Ma)
Forb 1/14	zir1 / 11	73.3	5.76	629.2	0.07827 $\pm$ 89	0.6316 $\pm$ 159	485.8 $\pm$ 5.5	497.1 $\pm$ 12.5	549.7 $\pm$ 46.7
	zir2 / 15	85.8	6.78	564.7	0.07880 $\pm$ 74	0.6203 $\pm$ 122	489.0 $\pm$ 4.6	490.0 $\pm$ 9.6	494.9 $\pm$ 36.4
	zir3 / 17	89.6	7.04	923.4	0.07949 $\pm$ 64	0.6344 $\pm$ 98	493.1 $\pm$ 4.0	498.8 $\pm$ 7.7	525.3 $\pm$ 27.6
	zir4 / 17	66.6	5.18	597.7	0.07845 $\pm$ 83	0.6221 $\pm$ 123	486.9 $\pm$ 5.2	491.1 $\pm$ 9.7	511.1 $\pm$ 35.2
	zir5 / 15	113.2	9.07	759.6	0.07771 $\pm$ 95	0.6124 $\pm$ 157	482.5 $\pm$ 5.9	485.1 $\pm$ 12.4	497.5 $\pm$ 47.8
Forb 3	zir1 / 14	100.5	8.18	974.3	0.07824 $\pm$ 22	0.6188 $\pm$ 26	485.6 $\pm$ 1.4	489.1 $\pm$ 2.0	505.6 $\pm$ 6.5
	zir3 / 10	145.4	11.58	1326.1	0.07851 $\pm$ 45	0.6253 $\pm$ 28	487.2 $\pm$ 2.8	493.2 $\pm$ 2.2	520.8 $\pm$ 8.2
	zir4 / 11	93.4	7.64	1519.0	0.07816 $\pm$ 16	0.6175 $\pm$ 24	485.1 $\pm$ 1.0	488.3 $\pm$ 1.9	503.0 $\pm$ 7.2
	zir5 / 11	125.0	10.19	1023.3	0.07827 $\pm$ 16	0.6229 $\pm$ 24	485.8 $\pm$ 1.0	491.7 $\pm$ 1.9	519.1 $\pm$ 7.2

All zircon fractions were dissolved in the presence of a mixed ^{205}Pb – ^{235}U spike calibrated against NBS and NBL metal standards. All Pb/U ratios are corrected for total processing blanks of 10 ± 5 pg or 20 ± 10 pg Pb (Forb 3 and Forb 1/14, respectively) and 2 ± 1 pg U, mass fractionation of $0.12 \pm .03\%$ /amu, and initial Pb values for 480 Ma from Stacey & Kramers (1975). The error calculations follow the treatments described by Ludwig (1980). Uncertainties in measured ratios and in blank and mass fractionation corrections were propagated through the error calculation; no errors were assigned to the initial Pb ratios derived from Stacey & Kramers (1975). Pb/U ratio and age errors are reported at 2 σ level. Concentrations are approximate because they are based on estimated sample weights (too small to measure).

¹Uncorrected for fractionation and blank.

²err (abs) refers to absolute errors in last decimal places.

Discussion

The U–Pb ages reported here on zircons from felsic rocks in the Forbordfjell ophiolite fall in line with those hitherto documented for the principal segments of most of the ophiolites in the Trondheim Region. Slagstad et al. (2014) provided a tabular summary of all the U–Pb zircon ages obtained on these ophiolites and noted that they mostly had formation ages in the range 487–480 Ma. In just two cases, on the islands Leka and Ytterøya, older plagiogranite ages have been reported at c. 497 Ma and c. 495 Ma, respectively (Dunning & Pedersen, 1988; Roberts & Tucker, 1998). Thus, the ocean-floor and primitive arc precursors of the now tectonically dismembered, fragmented and moderately metamorphosed ophiolites can be traced back in time to at least the earliest stage (Paibian) of the Late Cambrian, if not the latest Mid Cambrian, Guzhangian stage.

In a geographical context, Forbordsfjellet is no more than 10 km away from the metabasalt-dominated but bimodal Fånes complex of Frosta peninsula (Fig. 1A). Zircons from a felsic sheet of rhyolitic composition in this complex yielded a U–Pb age of 488 ± 5 Ma (Gromet & Roberts, 2010). Geochemical data from metabasalts in the Fånes complex show a LREE-depleted, chondrite-normalised pattern and negative Ta anomalies which, together with other element contents and ratios, are suggestive of a suprasubduction-zone, primitive arc environment (Lippard & Roberts, 2010). Moreover, the geochemical data from the Fånes mafic rocks have clear similarities to the principal ‘middle member’ metabasalts of the Forbordfjell ophiolite (Grenne & Roberts, 1980). The felsic rocks from Forbordsfjellet and the Fånes

complex share in the LREE-enriched patterns of the Fagervika trondhjemite near Trondheim, interpreted as a primitive arc product on recently formed oceanic crust (Slagstad, 2003; Slagstad et al., 2014). These similarities in age and geochemical characteristics indicate that all three occurrences formed in a similar manner within a period lasting just several million years.

Geological mapping over the last half century has shown that the ophiolites in the western Trondheim Region have been tectonically dissected during the protracted Caledonian orogeny, and most likely at different times from Early Ordovician obduction to the poly-phase folding and thrusting associated with the terminal Mid Silurian to Early Devonian Scandian event. Some of the dissection possibly even relates to the late-Scandian extensional faulting episode associated with orogenic collapse. The 1:250,000 map-sheet ‘Trondheim’ (Wolff, 1976) shows the Støren Group greenstones in the area of Selbusjøen and Mostadmarka (Fig. 1A) extending unbroken northeastwards directly above the basal thrust of the Støren Nappe. This ophiolite unit then gradually thins and is ultimately excised, before appearing again in a structurally complicated area c. 15 km east-southeast of Levanger (Fig. 1A). More recent mapping at smaller scale has disclosed that the greenstones north and northeast of Selbusjøen are separated into several tectonic slices, which also involve repetition of the Støren/Lower Hovin lithostratigraphy (Wolff, 2005a, b). This is shown in somewhat simplified form in Fig. 1A.

The tectonic slide structurally below the Forbordfjell ophiolite (and synform; Fig. 5A, B) can be traced north-eastwards, gradually excising strata of the Lower Hovin

Group and curving around a prominent, NE-plunging, antiformal structure (*Hegra Antiform*; Fig. 1A; Roberts, 1968). Some pre-existing isoclinal folds in Upper Hovin Group rocks are also cut out along this slide, which then swings south-southwestwards to link up with a lensoid megaboudin-like mass of 'greenstone' (here termed the *Kleivan lens*) along strike from Mostadmarka (Fig. 1A). The ophiolitic rocks of the Støren Group then continue southwestwards, tectonically juxtaposed against the Gula Complex. Given the along-strike Forbordfjell–Kleivan–Mostadmarka linkage, our U–Pb zircon dating result thus also indirectly provides an approximate latest Cambrian age for the Støren Group *sensu stricto* in its type area c. 40 km south of Trondheim. As noted earlier, the Støren/Gula contact has been interpreted by some (Sturt & Roberts, 1991; Roberts et al., 2002a; Hollocher et al., 2012) as the original surface of obduction in Early Ordovician time, although this inferred relationship has been overprinted by structural and metamorphic events during the Scandian orogeny.

Exactly how the Forbordfjell–Kleivan–Mostadmarka–Støren segment of the ophiolite links up with the similarly aged Løkken–Vassfjell–Bymarka segments is still an open question. Linkage is indicated in the northwestern corner of the 1:250,000 map-sheet 'Røros og Sveg' (Nilsen & Wolff, 1989), but more detailed, small-scale mapping is required in that particular area before we can be assured of this important relationship.

Conclusions

New U–Pb isotopic zircon ages from minor felsic rocks associated with the dismembered and fragmented Forbordfjell ophiolite confirm a Late Cambrian age for this particular example of the ophiolitic complexes of the Upper Allochthon of the Central Norwegian Caledonides. The minor and trace element signatures of the Forbordfjell felsic rocks are indicative of rocks ultimately derived from depleted oceanic mantle. These Late Cambrian ocean floor and primitive ocean arc assemblages underwent Early Ordovician deformation, uplift, erosion, and ultimately tectonic dismemberment during the Silurian–Early Devonian Scandian collisional orogeny and late-Scandian extension.

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