Notes on Ordovician graptolites, nautiloids and trace fossils from Lånke, Central Norwegian Caledonides

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Graptolites and trace fossils typical of deep-water environments are found on phyllitic roofing slates kept in the collections of the Stjørdal Museum Værnes, Trøndelag. The slates probably come from abandoned local quarries in the Stjørdal and Lånke districts. The fossils from Lånke also include some graptolites and poorly preserved nautiloids stored at the NTNU Vitenskapsmuseet, Trondheim. The graptolites indicate a Katian age, while the trace fossil assemblages compare to similar assemblages reported from the Middle–Late Ordovician Vuddudalen and Lower Hovin groups and the mostly Silurian Ekne Group of the Central Norwegian Caledonides.

Introduction

There are several records of fossils in the metasedimentary rocks of the Caledonian nappes in Trøndelag, but compared with the more shallow-marine and the less tectonically disturbed marine sedimentary strata in the Lower Palaeozoic of the Oslo Region, the recoveries of in situ body fossils have been limited (cf., overview in Spjeldnæs, 1985; Bruton & Harper, 1988, and subsequent publications: Neuman & Bruton, 1989; Neuman et al., 1997; Tolmacheva & Roberts, 2007). The present note provides new information on material collected from the Lånke area (Fig. 1). The Caledonian nappes in the Upper Allochthon in Mid Norway comprise ophiolites, followed by back-arc volcano-sedimentary deposits; mainly thick successions of coarse-grained, conglomeratic and argillaceous deep-water sediments and minor tuffs (Wolff, 1979; Henriksen et al., 2018) (Figs. 1 & 2). Fossil assemblages have to some extent been used for biostratigraphic age determinations and correlations of the various metasedimentary groups and formations, but in general the correlations rely on the lithostratigraphy. The graptolites in the present material are here...
tentatively correlated to Baltic graptolite zones (Fig. 3). U–Pb analyses of detrital zircons from low-grade metasandstones of the Ekne Group in the Ekne–Åsenfjord area published by Roberts et al. (2019) suggest that the succession in this area is largely of Silurian age. Assemblages of trace fossils typical of deep-water environments are more common and have been reported from the Ordovician Lower Hovin and Vuddudalen groups and the mostly Silurian Ekne Group at several localities (Torske, 1965; Roberts, 1969, 1984; Uchman et al., 2005). These ichnofossils have proved useful for interpretations of depositional environments, whereas they are of limited value for stratigraphic correlation.

In his review on biostratigraphy of the Scandinavian Caledonides, Spjeldnaes (1985) noted: “At Lånke, south of Hell, some fossils have been found in calcareous and quartzitic mica-schists. These were nautiloids and other shelly fossils which are taxonomic indeterminable, and a few graptolites which are relatively well preserved”. There are no descriptions of the localities from where the fossils were collected. The only reference given is “Spjeldnaes in Wolff 1979”. In Wolff (1979), however, there are no locations given; it is only mentioned that the graptolites and nautiloids are from a quarry in Lånke (Fig. 1). Also, there is no published information on where the fossils are stored. In a search for these fossils we found out that some of the graptolites and nautiloids are kept in the collections of the NTNU Vitenskapsmuseet in Trondheim (Fig. 4).
During previous examinations of roofing slates curated and stored at the Stjørdal Museum Værnes, we had also recognised other fossils that resemble the descriptions of the fossils reported by Spjeldnæs (1985) (Fig. 5). In the present note, we discuss possible sample locations and biostratigraphic ages of the fossils kept at the NTNU Vitenskapsmuseet (sample numbers abbreviated F), where illustrations are provided of some of the graptolites and nautiloids. We also discuss the possible origin of the fossil-bearing roofing slates stored at the Stjørdal Museum Værnes.
Graptolites

Only two species of graptolites from Lånke were mentioned by Spjeldnæs (1985); a doubly twisted one resembling *Dicellograptus caduceus* and a very large one (35 cm-long branches) resembling *Dicellograptus forchammeri* or *D. morrisi*. Based on these, an age of the upper part of the *Dicranograptus clingani* zone or in the *Pleurograptus linearis* zone was indicated (Spjeldnæs, 1985), corresponding to the Katian Stage (Upper Caradoc–lowermost Ashgill). The collection at the NTNU Vitenskapsmuseet includes a graptolite labelled *Dicellograptus* sp. A (Fig. 4C, E) and a specimen labelled *Glossograptus* sp. (Fig. 4B). The first one, *Dicellograptus* sp. A was apparently collected by Nils Spjeldnæs in 1960 (i.e., labelled N. Spjldnæs (sic) 1960) and could possibly be the specimen mentioned to resemble *Dicellograptus forchammeri* or *D. morrisi* by Spjeldnæs (1985). According to Henry Williams (pers. comm.), *D. forchammeri* has more openly divergent and straight or gently flexed stipes than *D. morrisi*, and the specimen labelled *Dicellograptus* sp. A is probably *D. morrisi*, which occurs in both the Katian *D. clingani* and...
Figure 5. Graptolites and trace fossils present on roofing slates stored at the Stjørdal Museum Værnes (SNT.17499 (Primus). (A) A possible graptolite specimen, most likely Dicranograptus or Dicellograptus marked D, and Protovirgularia isp. marked P; (B) Protovirgularia isp.; (C) Protovirgularia isp. marked P, and Nereites isp. marked N; (D) Protovirgularia isp. marked P, and Nereites isp. marked N.

P. linearis zones in Scotland. The specimen labelled Glossograptus sp. is possibly a graptolite but has none of the characters typical of this genus (H. Williams pers. comm.).

Poorly preserved graptolites have also been found on some slates at the Stjørdal Museum Værnes. One of the slates contains a poorly preserved specimen that in overall character resembles Dicranograptus (Fig. 5A), but Dicellograptus is an alternative interpretation, since the proximal end of the specimen may be erratic. The overall poor preservation hampers further identifications of possible graptolites.
Nautiloids

Several nautiloids from Lånke are kept in the collection of the NTNU Vitenskapsmuseet (Fig. 4A, C, D). They are, however, mostly poorly preserved. Spjeldnaes (1985) notes that “The nautiloids are (according to communication from Professor Walter C. Sweet) indeterminable both taxonomically and as to province”. Some of the roofing slates examined at the Stjørdal Museum Værnes also contain poorly preserved fossils resembling orthoceratid nautiloids.

Ichnofossils

Chevron-like (stacked V) trace fossils assigned to Protovirgularia are quite common on several of the examined slates at the Stjørdal Museum Værnes (Fig. 5). Similar forms have been described under different ichnogenera, including Uchrites Macsotay, Walcottia Miller and Dyer, Rhabdoglyphus Vossoevich, Sutergichnus Chamberlain, Imbrichnus Hallam, Biformites Linck and Chevronichnus Hakes (Uchman et al., 2005). Notably, Protovirgularia has previously been interpreted as an octocoral (McCoy, 1850) and a graptolite (Richter, 1853). Moreover, this enigmatic ichnofossil has also been described as a structure produced by crabs (Gümbel, 1879), arthropods (Richter, 1941; Volk, 1961) and annelids (Richter, 1941; Claus, 1965). As pointed out by Kim et al. (2000), it was not until 1958 that Protovirgularia was convincingly established as an ichnofossil by Häntzschel (1958).

Seilacher & Seilacher (1994) have demonstrated that Protovirgularia probably was produced by burrowing bivalves in, or crawling on, soft substrates. According to Nara & Ikari (2011), Protovirgularia is now widely regarded as a locomotive trace of the protobranchs or scaphopods that have a bilobate foot. The ichnogenus is found in deep-marine to shallow-marine, and even glacio-marine and non-marine environments (Kim et al., 2000; Ekdal & Bromley, 2001; Gibert & Domènech, 2008; Nara & Ikari, 2011; Luo & Shi, 2017).

Uchman et al. (2005) reported that the stratigraphic range of Protovirgularia is Arenig to Miocene. A correlation to the British Arenig Series and the ICS Florian and Dapingian Stages (latest Early–Middle Ordovician) or younger Ordovician fits with the previous age assignments of the Lower Hovin and Ekne groups in the Central Norwegian Caledonides. However, according to Luo & Shi (2017), Protovirgularia is also known from Cambrian deposits.

Some simple trace fossils present on the Stjørdal Museum slates (not figured) are comparable to ?Planolites previously reported from Fættenjorden (Fig. 1), or ?Helminthopsis reported from Mała B (Fig. 1) by Uchman et al. (2005). The museum slates also contain several trace fossils assigned to Nereites (Fig. 5C, D), possibly N. missouriensis, which is reported from similar roofing slates at Tilrem in Brønnøysund, Nordland (Uchman et al. 2005) (see location inserted in Fig. 1). Some trace fossils figured as possible arthropod tracks from the Ekne Group in Fagerdalen (Fig. 1) by Roberts (1969) are similar to Nereites. This ichnogenus is characteristic in bathyal to abyssal deposits and has also been described from Fættenfjorden by Roberts (1984). Traces that can be attributed to Nereites missouriensis are present in situ at Tønsåsen, Lånke (Fig. 1), occurring in thin-bedded sandstones and shales of the Ekne Group.

Origins of the slates and fossils

In the Lånke area and the adjacent Stjørdalen there has been a considerable production of light- to medium-grey and dark grey to black roofing slates from several quarries (Fig. 1). According to Dahle et al. (2017), the first slate quarries in the region where opened in the late eighteenth century. A hundred years later 19 quarries were in operation at the same time (Helland, 1893). Square slates for roof covering
were made from approximately 1840. Everyone from large-scale producers with several employees and industrially driven quarries, to single persons working alone, put standardised slate tiles into a local and regional market (Leirfall, 1972). Due to the structure of this market and the tendency to move houses and reuse and mix stocks of slate tiles, geological knowledge and methods seem to be the best way to relate single tiles to specific geological locations. Today, very few quarries are active, and at Lånke only the Sorte Quarry is still producing, and delivering several products from rocks of different colours and textures.

The largest and thickest slates stored at the Stjørdal Museum Værnes resemble grey and greenish-grey phyllitic roofing slates from the quarries near Okkelberg and west of Skjelstad. The quarry at Hoset-kammen (Fig. 1) started production around 1830, with slates typically 1.5 to 3 cm thick. At Gjeterås-berget the year 1884 is visible etched on the quarry wall.

Large, thick and solid roofing slates, traditionally named “60 x 60 alen slates”, were quarried at the farm Børset in Skjelstadmarka. These were phyllitic shales which vary from very dark to light grey, to greenish/bluish-grey in colour. Most slates from the Børset quarry are lighter in colour than the average slates from the Stjørdal and Lånke districts. The texture and colour of the largest and solid slates with fossils at the Stjørdal Museum Værnes closely resemble typical phyllitic shales from the quarry at Børset.

However, some of the slates in the Stjørdal Museum might also have come from the quarries closer to Lånke, including Sorte and Mæla. The Mæla quarry typically contains dark grey to black phylilit. Dark grey to black slates are also typical of some of the abandoned quarries south of Elvran; such as Brennmoen, Fossmo and Kvalsås (Fig. 1). Thin and dark grey to black slates typically are found near Tyldfossen in Flora, but layers of dark shale, with common pyrite, are found in many places in the Stjørdalen–Lånke districts, and the collection at NGU also contains dark slates from the Sorte Quarry. In conclusion, the exact provenance of the unmarked roofing slates stored at the Stjørdal Museum Værnes is difficult to point out, although the small Børset quarry in northern Skjelstadmark appears to be the provenance for the fossil-bearing “60 x 60 alen slates”, referring to the traditional Norwegian measure alen, equal to 62 centimetres.

We note that Uchman et al. (2005) illustrate Protovirgularia dichotoma on parting surfaces on roof-slates from Tilrem, a farm near Brønnøyysund (Fig. 1). The Protovirgularia shown by Uchman et al. (2005) are very similar to the ones seen on slates at the Stjørdal Museum Værnes. The slates at Tilrem were used on a vicarage roof at Vassås in Bindal, south of Brønnøyysund, dating from about 1870. The original provenance is not known, but presumably they come from an unknown, abandoned slate quarry located east of Trondheimsfjorden (Uchman et al., 2005).

The only record of a precise location for the graptolites and nautiloids stored at NTNU Vitenskapsmuseet is a single specimen labelled collected by Spjeldnæs 1960. According to the collection label, this comes from “Lånke skiferbrudd”. This is an imprecise location name, given the large number of quarries in the Lånke area. However, based on colours and texture, most of the fossil-bearing micaceous slate samples stored at the NTNU Vitenskapsmuseet possibly come from the Sorte Quarry (Fig. 1).

Ages and correlations

The probable Katian graptolite Dicellograptus morrisoni from Lånke is somewhat younger than the well-documented Llanvirn–Arenig graptolite faunas found at Bogo in the Løkken–Meldal area (Blake, 1962; Skevington, 1963; Berry, 1968; Ryan et al., 1980; Schmidt, 1984, 1987; Schmidt-Gündel, 1994). In addition to the Katian graptolites mentioned by Spjeldnæs (1985) and the one confirmed in the collection at NTNU Vitenskapsmuseet (Fig. 4E, F), corals of Sandbian to early Katian age (Caradoc) are
found in a limestone quarry at Åsen (Fig. 1), north of Stjørdal (Wolff, 1979). Limestones on the nearby Frosta peninsula have yielded conodonts of Katian age (Tolmacheva & Roberts, 2007). These are assigned to the Vuddudalen Group (Henriksen et al., 2018), which is stratigraphically below the Ekne Group but post-dates the Tremadocian–Furongian Forbordfjell ophiolite (Gromet & Roberts, 2016).

The graptolite which resembles *Dicranograptus*, found on the Stjørdal Museum Værnes slate, also indicates a Katian age (Uchman, pers. comm.). Unfortunately, the exact location of the slates with graptolite remains is presently not known, and the stratigraphic positions within the Lower Hovin Group and/or lowermost Ekne Group cannot be determined. Possibly the fossils stored at the NTNU Vitenskapsmuseet labelled “Lånke Quarry” come from the Sorte Quarry. The rocks at the Sorte Quarry are thin-banded metasandstone and alternating dark grey, thinly laminated slate and phyllite assigned to the Ekne Group. A Katian age for this part of the Ekne Group at this location, however, cannot be confirmed at present. Based on the U–Pb zircon datings on sandstone samples from the Ekne–Åsenfjorden area (Roberts et al., 2019), only the lowermost part of the group is likely to be of Katian–Hirnantian age, with the bulk of the 2.8 km-thick succession being clearly Silurian.

There is a need, and potential, for new discoveries of in situ fossils in the Caledonian rocks of the Stjørdal and Lånke areas. Records of graptolites are mentioned in several notes and literature of local history, although there are no published determinations of any taxa. A few diplograptids are reported from slates from the Fossmo Quarry (Fig. 1), but further studies are needed to confirm the unauthorised and unpublished records.

Conclusions

Research on phyllitic roofing slates stored at the Stjørdal Museum Værnes has revealed assemblages of graptolites and trace fossils typical of deep-water environments. The roof-slates probably originate from abandoned local quarries in the Stjørdal and Lånke districts, but the precise provenances of the slates are presently not known. The graptolites and nautiloids mentioned by Spjeldnæs (1985) possibly originates from the Sorte Quarry in Lånke. The graptolites stored at the NTNU Vitenskapsmuseet appear to indicate a Katian age, while the trace fossils found on the slates at Stjørdal Museum Værnes compare to trace fossil assemblages reported from the Vuddudalen and Ekne groups of this part of the Central Norwegian Caledonides. The findings suggest that rich assemblages of trace fossils, and probably also some graptolites and other body fossils, are to be found in several of the historical quarries and adjacent areas with metasedimentary rocks in the Stjørdalen – Lånke areas.

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