Age of the Hamningberg dolerite dyke, Varanger Peninsula, Finnmark: Devonian rather than Vendian – a revised interpretation

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In an earlier geochronology paper in this same journal, discordant U–Pb ages on zircons from a dolerite dyke near Hamningberg, Varanger Peninsula, Finnmark, were interpreted to favour a Vendian (Ediacaran) age of intrusion for this dyke. A re-assessment of this interpretation, and further consideration of the field, geochemical and $^{40}Ar/^{39}Ar$ or K/Ar age characteristics that this dyke shares with other, unmetamorphosed, Devonian-age dolerite dykes in this same region of NE Norway and NW Russia, leads to the conclusion that the Hamningberg dolerite dyke is also most likely of Late Devonian age.

Introduction

In an attempt to date a prominent, 13.5 m-thick, mafic dyke located close to the former fishing settlement of Hamningberg in northeastern Varanger Peninsula, Finnmark, northern Norway (Figure 1), Roberts and Walker (1997) interpreted the U–Pb analyses on three discordant zircon fractions in favour of the given upper intercept age of 567.1 $^{+30}/_{-23}$ Ma and thus argued for a Late Vendian (Late Ediacaran)[1] age of emplacement for this particular dolerite dyke. The lower intercept of 392 $^{+25}/_{-36}$ Ma, on the other hand, was then considered to most likely represent a Late Devonian thermal overprint event.

Subsequently, in a geochemical study of dolerites and metadolerites from different areas in northernmost Finnmark, Rice et al. (2004) presented arguments that strongly favoured a Devonian age for the Hamningberg dyke, and concluded by asserting that *"the interpretation of the U–Pb age data [...] given by Roberts & Walker (1997) is rejected"*.

More recently, Herrevold et al. (2009) were sufficiently influenced both by the results of a $^{40}Ar/^{39}Ar$ study of mafic dykes on Varanger Peninsula (Guise and Roberts 2002) and by incisive comments raised by Dr. A.H.N. Rice in a manuscript review, to have followed Rice et al. (2004) in accepting the view that the Hamningberg dyke is likely to be of Late Devonian age.

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The rebuttal of a Vendian (Ediacaran) age for this dyke, either directly or indirectly, by two different sources thus calls for a formal reply by the authors of the original U–Pb zircon investigation (Roberts and Walker 1997), and in the same NGU Bulletin journal. This is the main purpose of this short note, contributed in this case just by the first author as Dr. Walker unfortunately disappeared from the geoscience community in the USA almost ten years ago and has not been traced since.

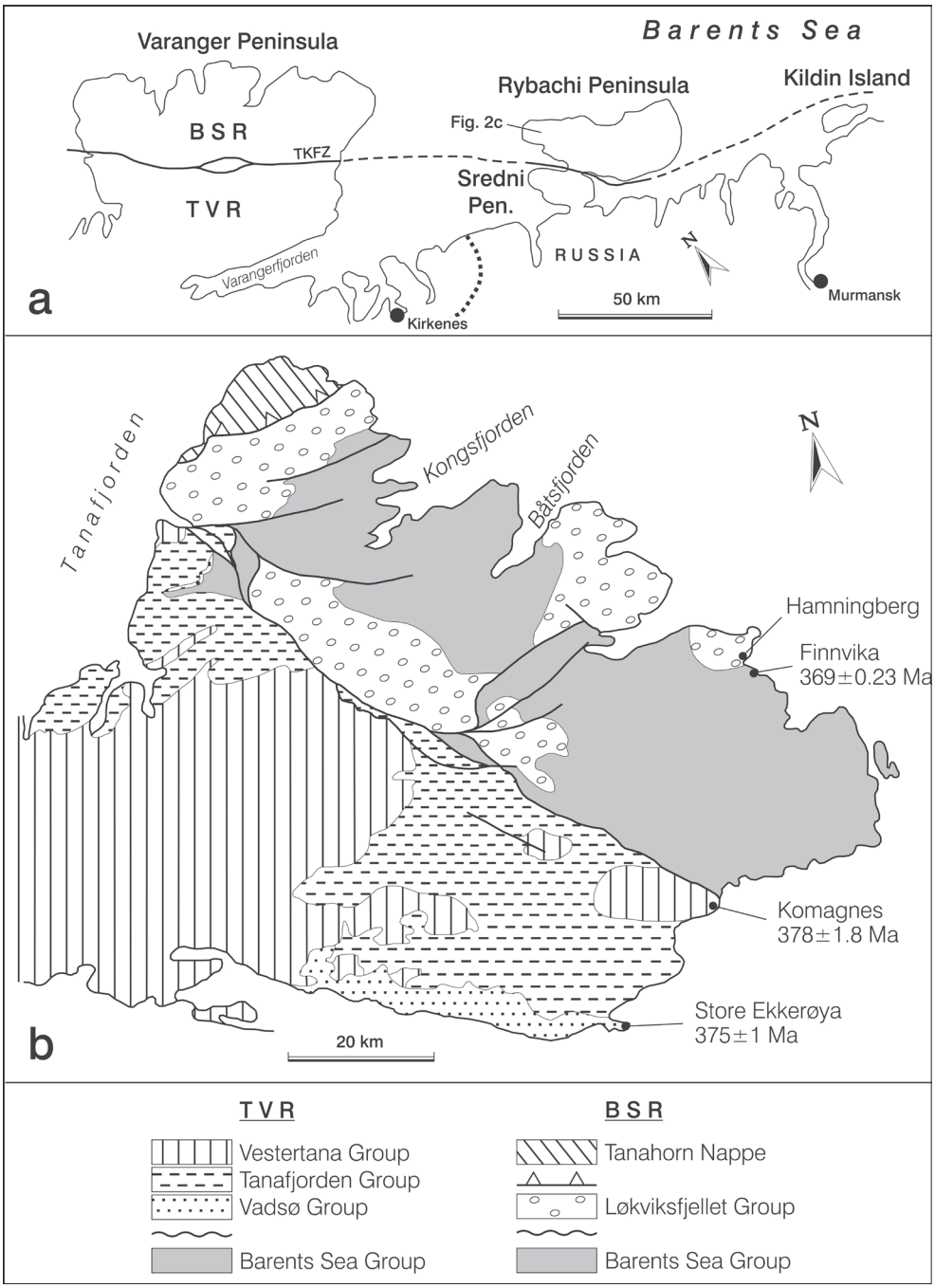

Figure 1. Simplified geological map of Varanger Peninsula (b) showing the location of the Hamningberg dolerite dyke. The locations of the Devonian dolerite dykes studied by Guise and Roberts (2002), at Finnvika, Komagnes and Store Ekkerøya, are also indicated. The outline map (a) shows the location of Rybachi Peninsula, Northwest Russia, and the dyke featured in Figure 2c. BSR–Barents Sea Region; TVR–Tanafjorden-Varangerfjorden Region; TKFZ–Trollfjorden-Komagelva Fault Zone.

[1] The term **Vendian**, introduced by Sokolov (1952) for the youngest period of the Neoproterozoic, has been, and still is, used in Russian and Nordic geological literature. In 2004, the IUGS International Commission on Stratigraphy decreed that the name Vendian should be replaced formally by **Ediacaran**, named after the Ediacara Hills in Australia where the soft-bodied Ediacara fossils were first discovered. However, the time ranges of the Vendian and Ediacaran are not identical. Whilst both terminate upwards at the base of the Cambrian, the base of the Vendian is taken at the base of the Smalfjord (Marinoan) tillite whereas the base of the Ediacaran is placed at the top of the Smalfjord Formation, just below a carbonate layer that caps the glacial deposit. Thus, the Ediacaran period is of shorter duration than the Vendian. In spite of losing its formality, the term Vendian is not invalid and can still be used as a legitimate chronostratigraphic unit.

Discussion

The ca NE–SW-trending, Hamningberg dolerite dyke cuts very low-grade sandstones of the Sandfjorden Formation of the Løkviksfjellet Group (Figures 1 and 2a), a siliciclastic succession of inferred Vendian/Ediacaran age which has been shown by Siedlecki and Levell (1978) to lie unconformably upon the Riphean to Lower Vendian Barents Sea Group (Vidal and Siedlecka 1983). Thin intercalations of shale in the sandstones carry a steep cleavage axial planar to regional N–S to NNW–SSE-trending folds. This cleavage, which is also cut by the dyke, has not yet been dated successfully, but work is in progress. Earlier, Taylor and Pickering (1981) produced an imprecise, Rb–Sr whole-rock, isochron age of 520 ± 47 Ma from cleaved mudstones near Hamningberg. Assessment of the regional geology, however, including neighbouring areas of NW Russia, has favoured a Late Vendian, Timanian age for the cleavage (Roberts 1995, Herrevold et al. 2009).

In their discussion, Roberts and Walker (1997) noted the moderate to strong discordance and scatter of the three fractions along the discordia line, and the fact that the large intercept uncertainties appear to relate to a combination of Pb loss and variable amounts of inheritance. Nevertheless, the authors chose to interpret the upper discordia intercept as indicating the approximate age of crystallisation of the dyke, i.e., ca. 567 Ma. Earlier, Beckinsale et al. (1975) had reported a K–Ar whole-rock age of 361 ± 10 Ma for the Hamningberg dyke; and a comparable, ca. NE–SW-trending, dolerite dyke near Finnvika (Figure 2b), just 3.5 km farther south, had yielded a K–Ar age of 363 ± 10 Ma. Both dykes had been reported to have almost identical geochemical signatures of continental within-plate type (Roberts 1975), a fact subsequently confirmed and elaborated upon by Rice et al. (2004).

In a $^{40}Ar/^{39}Ar$ study of plagioclase from three, geochemically similar, dolerite dykes from eastern Varanger Peninsula, Guise and Roberts (2002) reported comparable age spectra indicative of dyke emplacement at around 370 Ma, in latest Devonian (Famennian) time (Figure 1). These same dykes had earlier featured in the K–Ar work of Beckinsale et al. (1975), then also favouring a Late Devonian age of intrusion. Importantly, one of the three dykes investigated by Guise and Roberts (2002) was the Finnvika dyke. Thus, both the $^{40}Ar/^{39}Ar$ plagioclase and the K–Ar whole-rock dating studies had reached the same conclusion, which gave reason to question the interpreted Vendian, upper-intercept age for the nearby Hamningberg dyke.

As noted above, the analytical data presented by Roberts and Walker (1997) spread considerably along the discordia line and are not precisely colinear, a fact which led the authors to consider that there might be variable amounts of inherited zircon present in the zircon fractions. In such a case, the upper intercept age could represent an inheritance signature instead of a crystallisation age, and the lower intercept age of 392 $^{+25}/_{-36}$ Ma would then reflect the approximate age of dyke intrusion. Inheritance would most likely occur via magma contamination with assimilated country rocks – a suggestion forwarded by Rice et al. (2004). Thus, although the discordant zircon age results were originally interpreted as indicating a Vendian crystallisation age, the zircon data are also compatible with a Late Devonian age of intrusion for the dyke.

In the light of the accumulated body of evidence for other Devonian-age mafic dykes in the Varanger Peninsula and in other, adjacent areas of the Fennoscandian Shield, the Hamningberg dyke is now also considered to be Devonian. A feature of the few dolerite dykes in eastern Varanger Peninsula which are now reliably dated as Late Devonian is that they are unmetamorphosed, display pseudohexagonal to reticulate, columnar jointing and show distinctive orange-brown colours on weathered surfaces. In this regard, the Hamningberg dyke is no exception (Figure 2a). This 'trademark' for the Devonian dykes contrasts with the greenish-grey, schistose, metadolerite dykes (Figure 2e) of northwestern Varanger Peninsula (Roberts 1975) which have provided K–Ar and, in one case, Sm–Nd dating evidence of a Vendian/Ediacaran age (Beckinsale et al. 1975, Andersen and Sundvoll 1995, Rice et al. 2004). These metadolerites were clearly involved in Early Ordovician and later, less penetrative, Silurian orogenesis (Rice and Frank 2003).

Dolerite dykes occurring on Rybachi Peninsula in Russia (Figure 2c), some 60 km to the southeast of Varanger, trend NE–SW, and transect NW–SE-trending, Timanian (Vendian) folds and cleavage. They also show reticulate to pseudohexagonal jointing and display an orange-brown weathering crust (Roberts and Onstott 1995). In their $^{40}Ar/^{39}Ar$ study, Roberts and Onstott (1995) reported that isochron ages for three dykes range from ca. 402 to 376 Ma, but older model ages down to 450 Ma led them to cautiously interpret the dykes as being of possible Vendian to Cambrian age with a pervasive thermal overprint in Late Devonian time. In view of the field character of the unmetamorphosed Rybachi dykes, and their close resemblance to the Devonian dolerite dykes on Varanger Peninsula, also in terms of geochemistry, it is here considered more likely that they, too, are of Late Devonian age. In this same area of western Kola Peninsula, Pb–Zn vein mineralisations of Late Devonian age are commonly found in association with NE–SW- to N–S-trending dolerite dykes (Juve et al. 1995). The dolerite dykes were emplaced during a major episode of Mid to Late Devonian rifting, sedimentation and basaltic magmatism, associated with the Kontozero graben in this northern part of the Kola Peninsula and adjacent Barents Sea (Ziegler 1988, Bugge et al. 1995, Nikishin et al. 1996, Gudlaugsson et al. 1998, Drachev et al. 2010), a scenario which is also discussed in Guise and Roberts (2002). Many of the mafic dykes on Rybachi and other parts of Kola Peninsula were probably feeders to the basaltic lavas. Mafic dykes of comparable geochemistry occur farther southeast in the Devonian rift basins of the Timans where there are also thick accumulations of columnar-jointed basalts (Figure 2d).

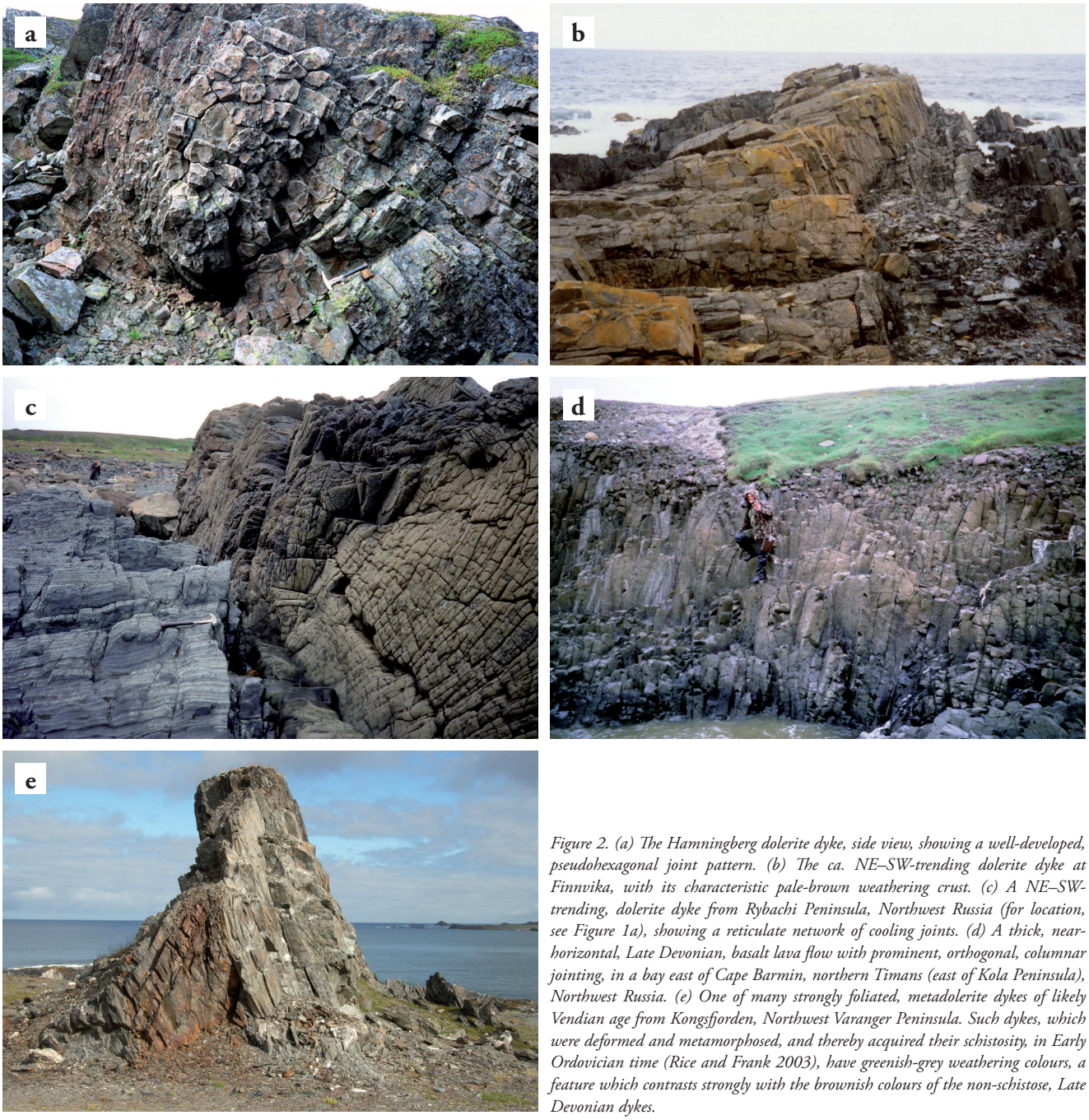

Figure 2. (a) The Hamningberg dolerite dyke, side view, showing a well-developed, pseudohexagonal joint pattern. (b) The ca. NE–SW-trending dolerite dyke at Finnvika, with its characteristic pale-brown weathering crust. (c) A NE–SW-trending, dolerite dyke from Rybachi Peninsula, Northwest Russia (for location, see Figure 1a), showing a reticulate network of cooling joints. (d) A thick, near-horizontal, Late Devonian, basalt lava flow with prominent, orthogonal, columnar jointing, in a bay east of Cape Barmin, northern Timans (east of Kola Peninsula), Northwest Russia. (e) One of many strongly foliated, metadolerite dykes of likely Vendian age from Kongsfjorden, Northwest Varanger Peninsula. Such dykes, which were deformed and metamorphosed, and thereby acquired their schistosity, in Early Ordovician time (Rice and Frank 2003), have greenish-grey weathering colours, a feature which contrasts strongly with the brownish colours of the non-schistose, Late Devonian dykes.

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