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Late Vendian U-Pb zircon age of a dolerite dyke from near Hamningberg, Varanger Peninsula - a preliminary report.

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REPORT

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Late Vendian U-Pb zircon age of a dolerite dyke from near Hamningberg, Varanger Peninsula - a preliminary report.

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Summary:
A dolerite dyke cutting very low-grade metasandstones of the Løkvikfjellet Group near Hamningberg, NE Varanger Peninsula, has yielded a U-Pb zircon age (upper intercept) of $554^{+20}/_{-14}$ Ma; and a lower intercept of c.375 Ma. This dyke is one of several in this area that have previously given K-Ar dates of c.360 Ma. These dykes are similar in field appearance, petrography and chemistry to dolerite dykes cutting Baikalian (Late Vendian) NW-SE-trending folds and cleavage on the Rybachi Peninsula, NW Russia; and all trend between NE-SW and c.N-S. It is suggested that the Hamningberg dyke, and the other, comparable dykes with published Late Devonian K-Ar 'ages', probably intruded along 'ac' extensional, master fractures either during the terminal stages of, or shortly after the Baikalian deformation in Late Vendian time. The lower intercept date of c.375 Ma is interpreted as reflecting a Mid Devonian isotopic disturbance related to a Caledonide (Scandian) tectonothermal event.

(Keyword: Neoproterozoic, dolerite dykes, U-Pb zircon dating, Varanger Peninsula, Finnmark.)

Keywords: Senproterozoikum	Dolerittganger	Aldersbestemmelse

CONTENTS

FIGURES

TABLES

1. INTRODUCTION AND REGIONAL SETTING

Varanger Peninsula, Finnmark, is underlain by weakly metamorphosed sedimentary rocks of Neoproterozoic to Early Cambrian age. A complex, NW-SE-trending fault zone, the Trollfjorden-Komagelva Fault Zone (TKFZ), effectively divides the peninsula into two halves -- the Tanafjorden-Varangerfjorden Region (TVR) to the southwest, and the Barents Sea Region (BSR) to the northeast (Siedlecka & Siedlecki 1967) (Fig.1). The geology of the peninsula has been described in many publications over the past 20 years. Reviews or accounts of various kinds include those of Siedlecka (1985), Rice et al. (1989), Siedlecka & Roberts (1992) and Karpuz et al. (1993). Correlations with areas in nearby NW Russia can be found in Siedlecka (1975) and Siedlecka et al. (1995a,b).

The only manifestation of magmatism on Varanger Peninsula is that of mafic dykes. These occur as spectacular swarms in parts of the western BSR, where they are clearly metamorphosed and schistose or cleaved; and in consequence have been termed **metadolerites** (Roberts 1975). The metadolerites generally trend ENE-WSW. In contrast, comparatively unaltered, sporadic mafic dykes occur in the eastern BST, and also in just 2-3 localities in the southeastern TVR, south of the TKFZ. These relatively fresh dykes have been termed **dolerites** (Roberts (1975). They generally trend between NE-SW and N-S. Differences in geochemical signature are also apparent between the metadolerites and the dolerites (Roberts 1975).

A K-Ar dating investigation of these mafic dykes by Beckinsale et al. (1975) produced three age groups: (1) A group of ages ranging from 945 to 1945 Ma, from schistose metadolerites in the Kongsfjorden area; (2) Ages of c.650 Ma for less strongly cleaved metadolerites from the Båtsfjorden area; (3) Ages of c.360 Ma for the comparatively fresh dolerite dykes, from the eastern parts of Varanger Peninsula, in both the BSR and the TVR. The ages given here are recalculated according to Dalrymple (1979). An initial attempt at $^{40}Ar/^{39}Ar$ dating of pyroxenes from group 3 dykes in the southeastern TVR produced inconclusive results (Roberts et al. 1995). A palaeomagnetic study of one of these same dykes yielded data which suggested a probable Vendian to Cambrian age (Torsvik et al. 1995), rather than the Late Devonian age indicated by the K-Ar analyses of Beckinsale et al.(1975). Results of a similar study on dolerite dykes from the BSR were not definitive, but also tended to favour a latest Neoproterozoic to Early Palaeozoic age (Knutsen 1995).

On the northwestern part of Rybachi Peninsula, on the Kola Peninsula in Russia, just 60 km southeast of Varanger Peninsula, dolerite dykes comparable in many ways to those of group 3 on Varanger, and also trending NE-SW, have yielded Ordo-Silurian model ages and a Late Devonian overprint based on $^{40}Ar/^{39}Ar$ laser microprobe analysis of pyroxenes and feldspars (Roberts & Onstott 1985). Palaeomagnetic data on these same dykes, on the other hand, have suggested a Vendian to Cambrian age (Torsvik et al. 1995).

Clearly, there is a need for a more precise isotopic dating of many of these mafic dykes, both on Varanger and on Rybachi. With this need in mind, one of us (DR) delivered a 3 kg sample of dolerite from near Hamningberg, NE Varanger (Fig.1), to NGU's mineral separation laboratory, in the hope that some few zircons could be recovered. A limited number of zircons were, in fact, found. In this brief, preliminary report we present the results of U-Pb analyses of zircon fractions from this dyke.

2. THE HAMNINGBERG DOLERITE DYKE

The sample is from a 13 m-thick dyke located just southeast of the former fishing settlement and whaling station of Hamningberg, in the northeastern part of the BSR on Varanger Peninsula (grid.ref. 113 268, 1:50,000 map-sheet Syltefjord 2436-2). The dolerite dyke trends between NE-SW and ENE-WSW and dips at c.70° to the NW. It cuts very low-grade, thick-bedded sandstones of the Sandfjorden Formation of the Løkvikfjellet Group, of assumed Vendian age. The sandstones dip at c.40° to the SE. Thin, silty pelite intercalations carry a weakly developed, steep, SE-dipping, spaced cleavage.

The dark brown to almost black, medium- to coarse-grained dolerite shows orange-brown colours on weathered surfaces. A feature of the dyke, best seen along its margins, is that it displays well developed, pseudohexagonal, columnar jointing (see fig.27 in Siedlecka & Roberts 1992). The mineralogy of the dyke is dominated by plagioclase (An_{44-60}) and clinopyroxene (pigeonite, with some augite in outer marginal zones). Lath-shaped plagioclase exhibits minor sericitisation, and the cpx is typically twinned. There are minor amounts (<1%) of a primary yellow-green amphibole and secondary chlorite; and magnetite is the opaque phase. A sub-ophitic texture prevails, but there are also glomerophyric clots of plag+cpx and just cpx.

3. ANALYTICAL METHODS AND RESULTS

3.1 U-Pb zircon analytical methods

Relatively pure zircon separates (split according to magnetic character and size) were received from NGU. The separates were, however, re-combined to form a single bulk sample and cleaned in successive solutions of 2N HNO_3, 3N HCl and distilled H_2O to remove contaminant sulphides and surface impurities. Zircon concentrates thus treated were then handpicked into three 3- to 4-grain fractions on the basis of morphological similarity, employing visual discriminants such as size, form, colour, clarity and aspect ratio. In each case the zircon grains appeared to be magmatic in origin (as judged by aspect ratio and preservation of crystal terminations and crystal edges) with no macroscopic evidence of magmatic resorption as might be observed if these zircons were xenocrystic.

The handpicked fractions were air abraded in a device similar to that described by Krogh (1982). Zircon dissolution and ion-exchange procedures were comparable to those described by Krogh (1973) and Parrish et al. (1987). A mixed ^{205}Pb-^{233}U-^{235}U tracer was employed. Pb and U were loaded on W or Re filaments and analysed on the Finnigan MAT 261 multicollector mass spectrometer at Brown University. Pb was analysed in static multicollector mode employing Faraday cup collection of masses 208, 207, 206 and 205, while simultaneously collecting mass 204 in a secondary electron multiplier. Uranium was analysed in static multicollector mode employing Faraday collectors only. Additional analytical details are given in the footnotes to Table 1.

3.2 Data and age interpretation

Three zircon fractions from sample HMBG were analysed. The data are shown in Table 1 and graphically displayed in Fig.2. U-Pb systematics are relatively simple and normally discordant for the three fractions. A best-fit discordia trajectory through these data defines an upper intercept of 554 $^{+20}/_{-14}$ Ma with a lower intercept of approximately 375 Ma. The relatively high uncertainty results, in part, from the low angle of intersection of the discordia trajectory with concordia. Assuming that none of these zircon fractions contains components of inherited radiogenic Pb, the simplest interpretation is that the upper intercept of 554 Ma is the crystallisation age of the dyke. The lower intercept of c.375 Ma might reflect Mid Devonian isotopic disturbance related to Caledonide tectonothermal events.

4. DISCUSSION

The U-Pb zircon crystallisation age for the Hamningberg dyke differs appreciably from the latest Devonian (c.360 Ma) K-Ar dates of Beckinsale et al. (1975). On most modern time-scales an age of 554 Ma falls in the Late Vendian, taking the base of the Cambrian at 540 Ma. As a consequence of this, it is necessary to reassess certain aspects of the geological history of the region. In this short preliminary report, however, we purposely restrict discussion to just one or two of the more relevant points.

A micropalaeontological study of the Løkvikfjellet Group produced inconclusive results (Vidal & Siedlecka 1983), although these authors speculated that the age could be as young as Late Vendian. Our U-Pb zircon age for the dyke, which cuts the oldest formation in the Løkvikfjellet Group, does not directly negate this possibility. On the other hand, it may suggest that the Group could be slightly older; perhaps Mid or even Early Vendian, though presumably younger than the Varangerian glaciation.

Although in general appearance the dated dyke seems to be unmetamorphosed, and as such should postdate the spaced cleavage seen in silty pelite interbeds, a definitive mutual relationship has not been observed at this locality. Some 2 km to the southeast, however, near Finvik, a similar NE-SW trending, unmetamorphosed dolerite dyke with a comparable K-Ar age cuts an ESE-dipping cleavage. The indications are, therefore, that the earliest cleavage and very low-grade metamorphism in this area of Varanger Peninsula are pre-554 Ma, i.e. pre-Caledonian.

On the Rybachi Peninsula in NW Russia, the turbiditic Upper Riphean succession is quite pervasively folded and cleaved along a consistent NW-SE trend (Roberts 1995). This is the so-called **Baikalian** deformation, recognised also southeast of Kola in the Timans. Biostratigraphic and radiometric dating evidence on Rybachi, and on the nearby Sredni Peninsula, have constrained this deformation and low-grade metamorphic event to c.580-560 Ma. As noted earlier, there are NE-SW trending dolerite dykes on Rybachi which clearly cut across, and are therefore younger than the NW-SE folds and cleavage. These dykes are comparable in field appearance, petrography and chemistry to the dolerites of eastern Varanger Peninsula. Palaeomagnetic data are also pointing to a likely similar age (cf. Torsvik et al.1995); and favouring Vendian to Cambrian rather than Late Devonian emplacement.

It has been argued that the Baikalian structures occurring on Rybachi and Sredni can also be recognised in the eastern parts of Varanger Peninsula, especially in the eastern BSR (Roberts 1995, 1996). This is, in fact, an idea first presented almost a century ago (Ramsay 1899, Tchernyschev 1901), i.e., that the 'Timanian mountain chain' could be followed from the

Timans along the northern coastline of the Kola Peninsula, and possibly into the Varanger Peninsula in northeastern Norway.

As the arguments for an extension of Baikalian folds and cleavage into NE Varanger are quite strong, then the U-Pb zircon age presented here should be seen in a more regional context. As noted earlier, the group 3 dolerites with Late Devonian K-Ar dates occur almost exclusively in NE Varanger Peninsula, and they trend between NE-SW and c.N-S. The dolerites occurring in NW Rybachi also fall into this same category. If the 554 Ma zircon age can also be applied generally to this group of mafic dykes (but they need not all be of *precisely* the same age), then it is tempting to interpret these particular dykes as having intruded either in the terminal stages of, or shortly after the Baikalian tectonothermal event. As the dykes strike at high angles to, and clearly transect the Baikalian folds and cleavage, they can be readily envisaged as having been emplaced along major 'ac' fractures or faults which developed in association with the regional folds. It is in such an extensional situation, antithetic to the cleavage- and fold-generating compressive stress, that one would expect rising mafic magma to have met least resistance to penetration of the uppermost crust.

The 554 Ma age for the Hamningberg dyke thus fits quite neatly into this general story, whereby the dyke emplacement is seen as a very late-stage, Baikalian event. The U-Pb age also falls within the 'age range' for these group 3 dolerite dykes indicated by palaeomagnetic data, some of which are yet unpublished (e.g., the thesis of Knutsen 1995). The U-Pb dating also questions the validity, or rather the precision of the K-Ar ages of c.640 Ma for the group 2 dykes (Beckinsale et al. 1975). It is possible that the true age, or ages, of these particular dykes could be slightly younger than their K-Ar age; but on the other hand, the group 2 dykes may belong to a genuinely older swarm which was increasingly affected by Caledonian deformation in western areas of the Varanger Peninsula.

The lower intercept date of c.375 Ma is interpreted as reflecting a resetting of the isotopic system during a Caledonide (Scandian) tectonothermal event. This Mid Devonian date is quite close to the K-Ar ages recorded by Beckinsale et al.(1975) for their group 3 dykes. It is also comparable to the 376 Ma minimum age for a thermal overprint event registered in the dolerite dykes on the Rybachi Peninsula (Roberts & Onstott 1995).

5. CONCLUSIONS

A 13 m-thick dolerite dyke cutting the Løkvikfjellet Group near Hamningberg in NE Varanger Peninsula, has yielded a U-Pb zircon crystallisation age of 554 Ma. It is argued that dykes of comparable field character, petrography and chemistry occurring in this northeastern part of Varanger Peninsula and in northwestern Rybachi Peninsula, NW Russia, which have previously given K-Ar or ^{40}Ar-^{39}Ar Mid to Late Devonian dates, may be of broadly the same age, i.e. Late Vendian.

Taking into account the regional geological development, which involves a Late Vendian, *Baikalian* deformation and low-grade metamorphic event on Rybachi and Sredni, and probably also in NE Varanger, then the 554 Ma dyke age can be seen as relating either to a very late-stage Baikalian event, or an immediately post-Baikalian emplacement. Following the regional development of NW-SE trending folds and cleavage, mafic magma is envisaged as having penetrated along extensional master fractures and faults trending c.NE-SW, i.e., at high angles to the Baikalian fold axes.

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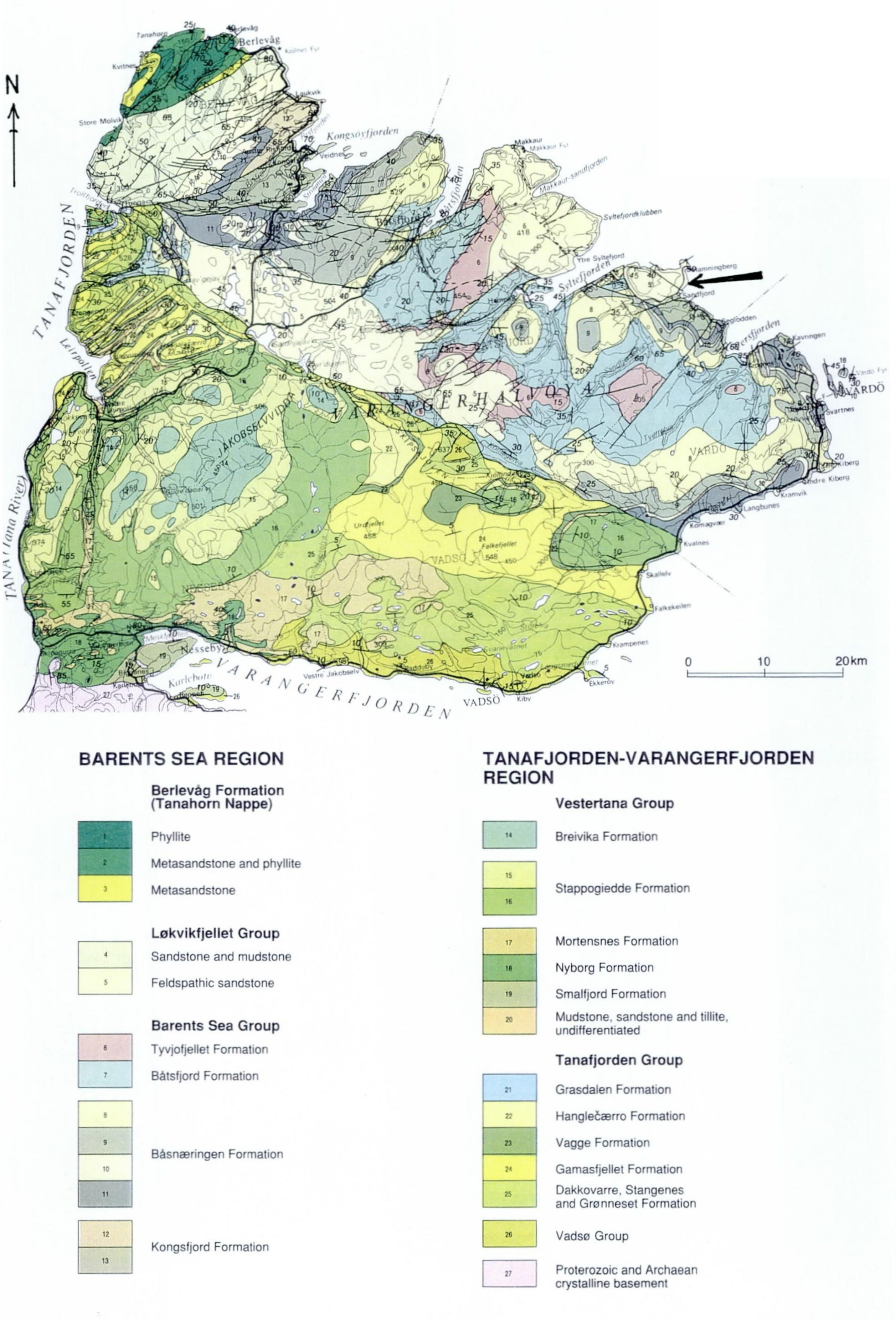

Fig.1. Bedrock geology of the Varanger Peninsula, taken from Siedlecka & Roberts (1992), showing the location of the Hamningberg dolerite dyke (arrow).

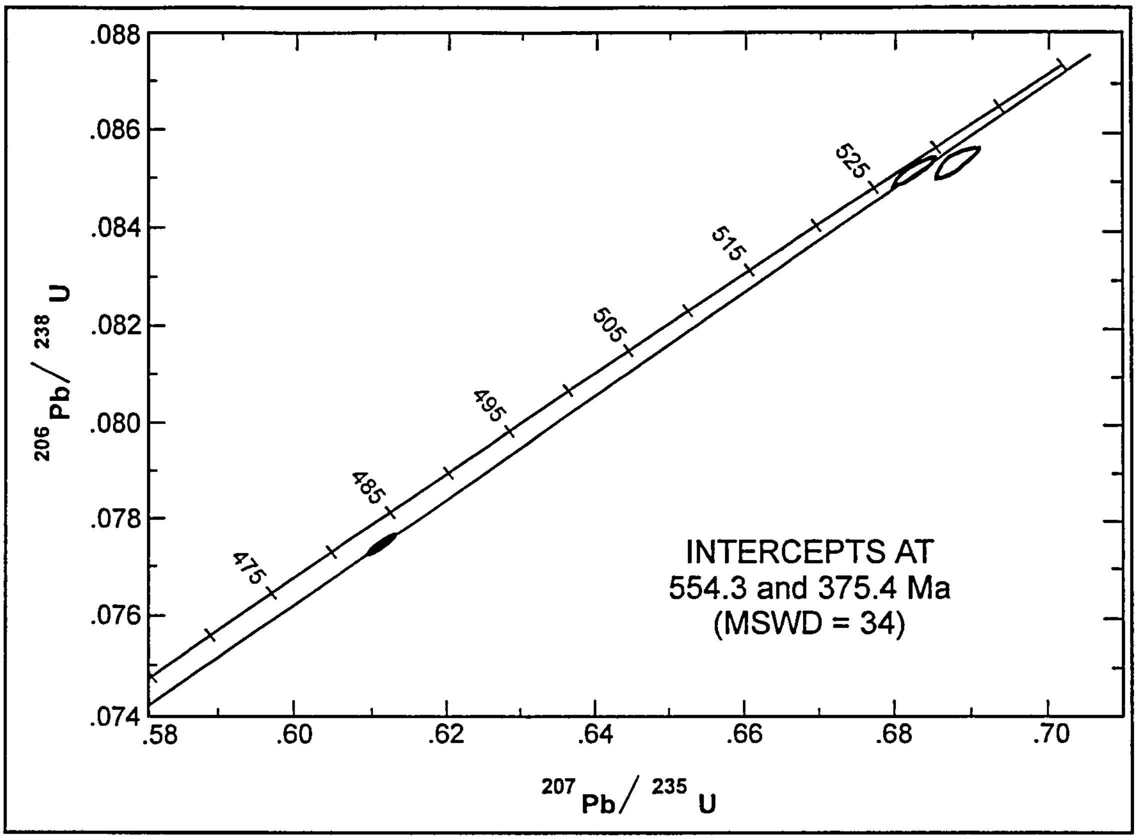

Fig.2. U-Pb concordia diagram for the 3 zircon analyses (data given in Table 1 - the three HMBG fractions).

Table 1. U-Pb zircon data from the dolerite dyke near Hamningberg (HMBG). A single zircon fraction (MG) taken from a dolerite dyke on Magerøya, West Finnmark, was also analysed (see Roberts et al.1991). This proved to be a xenocrystic entrained grain with a 207/206 age of c.1160 Ma.

Sample	Fraction properties◊	Amount analyzed (grains)	Concentration+ (ppm)		Pb isotopic composition#			Age and uncertainty ** (Ma)		
			Pb	U	206/208	206/207	206/204	206Pb*/238U	207Pb*/235U	207Pb*/206Pb*
HMBG	ar=2:1, pale yellow	3	82.3	996.9	9.266	15.930	2,940	527.1 ±1.5	528.2 ±1.8	533.2 ± 0.9
HMBG	ar=3:1, pale brown	4	73.5	835.2	7.207	15.629	2,473	528.5 ±1.5	531.7 ±1.7	545.7 ± 1.0
HMBG	ar=3:1,pale brown	3	64.3	855.3	14.43	16.350	3,515	481.1 ±1.1	484.3 ±1.3	499.5 ± 0.5
MG	ar = 3:1, pale brown	3	38.1	180.9	8.666	10.263	716.5	1140.4 ±2.3	1146.4 ±2.5	1157.8 ±3.1

◊ Zircon fractions abraded 6 to 12 hours; ar= aspect ratio

+Total Pb concentration includes blank Pb, common Pb in zircon and radiogenic Pb. Total procedural blanks are ~2 picograms for U and ~10 picograms for Pb. Because a mixed U-Pb tracer was employed, uncertainty in the weights of grains affects only concentration data, not calculated U-Pb or Pb/Pb ages.

#Measured isotopic ratios corrected for mass fractionation of ~ 0.11% per atomic mass unit based on replicate analyses of NIST SRM 981 and 982 and adjusted for small amount of 206Pb in tracer.

**Decay constants: 238U = 1.5513 E-10/yr.; 235U = 9.8485 E-10/yr. Atom ratio 238U/235U = 137.88. Uncertainty in the calculated ages is stated at the two-sigma level and estimated from combined uncertainties in calibrations of mixed 205Pb - 233U - 235U tracer, measurement of isotopic ratios of Pb and U, common and laboratory blank Pb isotopic ratios, Pb and U mass fractionation corrections, and reproducibility in measurement of NIST Pb and U standards.