Provenance characteristics of Scandinavian basement terrains: Constraints from detrital zircon ages in modern river sediments

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ABSTRACT

A study of modern river sediments from northern Scandinavia has shown that detrital zircon populations derived from the Fennoscandian Shield are fundamentally different to those derived from the Caledonian Nappe Domain. The zircon age spectra derived from the Fennoscandian Shield are essentially unimodal or bimodal, whereas the Caledonian Nappe Domain spectra are much more diverse, showing multiple peaks and a wider range of ages. The greater diversity of the Caledonian Domain zircon populations compared with those from the Fennoscandian Shield reflects the fundamentally different nature of the source regions. The Caledonian Nappe Domain largely comprises metasedimentary rocks, which were themselves derived from the variety of precursor sources available at the time, mainly situated in Baltica but with Laurentian influences in the Uppermost Allochthon. By contrast, the Fennoscandian Shield zircons were largely derived from granitoid rocks formed during specific crust-forming events. Thus, the Fennoscandian Shield spectra are typical of first-cycle, basement-derived detritus, whereas the Caledonian Nappe Domain spectra are typical of a multicyclic source. The study suggests that zircon age spectra, when combined with mineralogical or petrographic data, can help to distinguish first-cycle from polycyclic sediment, with complex zircon age spectra being likely to diagnose polycyclic sources, and simple spectra more likely to indicate first-cycle sediment. Comparison between the zircons in Scandinavian rivers and Cretaceous sandstones in the Norwegian Sea support previous interpretations of provenance data that indicate a non-Scandinavian source (East Greenland) for some of the Cretaceous sandstones.

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1. Introduction

In recent years, sediment provenance studies have been revolutionised by technological developments that enable single-grain radiometric dating of some components of detrital grain populations, for example U–Pb dating of zircon (e.g. Ireland, 1992) and monazite (e.g. Evans et al., 2001), or Ar–Ar dating of hornblende (Hemming et al., 2000) and mica (e.g. Von Eynatten et al., 1996). Radiometric data provide constraints on the geological history of sediment source regions. These supplement lithological and mineralogical information acquired by more traditional methods, such as petrography, heavy mineral analysis or whole-rock geochemistry, and a combined approach that integrates radiometric, mineralogical and geochemical data provides a more

complete and accurate characterisation of sediment provenance (e.g. Von Eynatten and Gaupp, 1999; Morton et al., 2005a).

Single-grain U–Pb dating of detrital zircon, either by sensitive high-resolution ion microprobe (SHRIMP: Williams, 1998) or laser ablation inductively-coupled mass spectrometry (LA-ICPMS: Kosler and Sylvester, 2003) has proved especially useful in provenance studies, largely because of the stability of zircon in both weathering and diagenetic regimes (Fedo et al., 2003). Thus, zircon is not liable to destruction during the sedimentary cycle unless it has become metamict. Zircon forms predominantly in felsic-intermediate igneous rocks and high-grade (granulite facies) metamorphic rocks, thereby providing a record of major crust-forming events in the hinterland. Owing to its chemical and mechanical stability, zircon is readily recycled through successive sedimentary cycles. By establishing a direct link between sediment and source, detrital zircon geochronology has major applications in paleogeographic studies, for example establishing the source-lands for ancient continental margin successions (Cawood et al., 2003), resolving tectonic problems of terrane translation (Mahoney et al., 1999), or constraining intrabasinal sand distribution by identifying sediment input from different entry points (Morton et al., 2005a).

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Most previous detrital zircon studies have been carried out by characterising detrital zircon age spectra, and linking the main peaks in these spectra with known crust-forming events in the hinterland. This approach is valid providing the ages of the zircons in the hinterland are well known through previous radiometric studies. This is generally true, to a greater or lesser extent, for first cycle zircons directly derived from their igneous or metamorphic source, although in more remote areas of the world, ages of basement rocks may be relatively poorly constrained. However, it is generally more difficult to establish the detrital zircon age spectra supplied by terrains dominated by pre-existing sedimentary or metasedimentary rocks, since there are comparatively few datasets available from such lithologies. Even when datasets are available, they are generally

based on analysis of a relatively small number of individual samples. Given the likelihood of complex heterogeneity in provenance within pre-existing sedimentary or metasedimentary successions, such data are unlikely to give a balanced view of the zircon age spectra provided by such terrains.

This paper takes an alternative approach to detrital zircon provenance studies, by analysing zircons in modern river sediments from locations between 62°–69°N in Norway and Sweden. This region comprises two contrasting crustal domains, the Fennoscandian Shield in the east and the Caledonian Nappe Domain in the west (Fig. 1). The main aim of the study was to compare and contrast the nature of the zircon age populations supplied from these two domains. Subsidiary aims were to establish whether the age

Fig. 1. Generalised geological map of central and northern Scandinavia, showing major rivers and the location of the eight sample sites discussed in this paper.

structures of the detrital zircon populations can be reconciled with the known ages of the Fennoscandian Shield parent rocks, and to provide broad constraints on the basement rocks that supplied the metasediments of the Caledonian Nappe Domain. The study also provides constraints concerning provenance of hydrocarbon-bearing Cretaceous–Paleocene sandstones in the Norwegian Sea. Some of these sandstones have zircon age populations that suggest derivation from the conjugate East Greenland margin (Fonneland et al., 2004; Morton et al., 2005a,b). However, it is not possible to entirely rule out provenance from Scandinavia, because the zircon age spectra from Caledonian metasediments are poorly known, and because of possible sourcing from the Fennoscandian Shield east of the Caledonian front (Morton et al., 2005a,b). This possibility can be tested directly by comparing Cretaceous–Paleocene zircon ages from sediments offshore mid-Norway with those from the Scandinavian rivers.

2. Geological setting and sampling strategy

The Fennoscandian Shield dominantly consists of crystalline rocks that originated in a series of major crust-forming events, with relatively limited metasedimentary cover (Gaal and Gorbatshev, 1987; Koistinen et al., 2001). In northern Sweden, the Fennoscandian Shield largely comprises granitoids and coeval volcanic rocks that formed during Svecokarelian phase 1 (1.90–1.88 Ga) and Svecokarelian phase 2 (1.86–1.75 Ga), together with metasedimentary units (Koistinen et al., 2001). In the northwest of the study area, there is an outcrop of Archaean basement rocks (mainly granitoids, migmatites and grey gneisses, formed between 2.75–2.50 Ga), overlain by the Lapponian volcanic succession, which consists predominantly of mafic or ultramafic rocks with an upper age limit of c. 2.3 Ga (Gaal and Gorbatshev, 1987; Koistinen et al., 2001). The Trans-Scandinavian Igneous Belt, which is a late-stage component of the Fennoscandian Shield that outcrops in the south of the region (Fig. 1), consists of three magmatic episodes in the Trans-Scandinavian Igneous Belt, TIB1 at 1.81–1.77 Ga, TIB2 at 1.7 Ga, and TIB3 at 1.68–1.65 Ga (Larson and Berglund, 1992).

By contrast, the Caledonian Nappe Domain, which comprises a series of thrust sheets (successively, the Lower, Middle, Upper and Uppermost Allochthons) emplaced onto the Fennoscandian Shield during the Early Paleozoic, consists largely of metasedimentary rocks of varying metamorphic grades (Roberts and Gee, 1985), although a wide variety of subordinate lithologies, including granites, ophiolites and basic gneisses, are also present. The rocks comprising the Lower and Middle Allochthons represent shelf and continental rise deposits on the Baltoscandian margin of Baltica, whereas the Upper Allochthon comprises ophiolites of oceanic origin, igneous rocks of magmatic arc affinity, and marginal basin successions within or peripheral to the Iapetus Ocean (Roberts, 2003). The Uppermost Allochthon, which is largely metasedimentary, is believed to have had a Laurentian ancestry (Roberts, 2003; Kirkland et al., 2007). In addition to the thrust sheets, there are outcrops of basement windows within the Caledonian Nappe Domain. These basement windows correlate with Svecokarelian phase 2 granitoids and the oldest Trans-Scandinavian event, TIB1 (Skår, 2002; Rehnström and Corfu, 2004).

The rationale adopted in this paper is to characterise the zircon age spectra supplied by these two strongly contrasting types of sediment source terrain. The geological history of the Fennoscandian Shield is well known, with a long history of geochronological investigations (Gaal and Gorbatshev, 1987; Koistinen et al., 2001). By contrast, comparatively little is known of the ages of detrital zircons in the metasediments of the Caledonian Nappe Domain. The only data in the study area are from the Seve Nappes (Williams and Claesson, 1987), although there are also data from the Kalak Nappe Complex (Kirkland et al., 2007), which lies in northern Norway, outside the area currently under investigation.

Table 1

Location of samples discussed in this study

river	draining	latitude	longitude
Byskeälven	Fennoscandian shield	64 57.460	21 08.905
Raneälven	Fennoscandian shield	66 18.445	21 22.012
Lainioälven	Archaean	68 05.386	21 40.957
Ljusnan	Trans Scandinavian Igneous Belt	62 02.691	14 49.557
Saltelva	Norwegian Caledonides	66 50.286	15 20.579
Vefsna	Norwegian Caledonides	65 36.703	13 18.401
Vindelälven	Swedish Caledonides	65 54.480	16 18.853
Ljungan	Swedish Caledonides	62 41.010	13 58.222

Zircon age data have been acquired from eight samples between 62–69°N in Norway and Sweden (Fig. 1; Table 1). Four of the samples are from rivers draining the Fennoscandian Shield. One of these (Lainioälven) taps the outcrop of Archaean rocks in the northern part of the area, and two (Byskeälven and Raneälven) drain basement rocks formed in Svecokarelian phases 1 and 2 (Koistinen et al., 2001). The other sample is from the river Ljusnan, which drains the northern part (Dalarna province) of the Trans-Scandinavian Igneous Belt (Larson and Berglund, 1992). The other four samples are from river sediments draining the Caledonian Nappe Domain. One river (Ljungan) drains the Middle and Lower Allochthons, one (Vindelälven) drains the Upper Allochthon, and two (Vefsna and Saltelva) drain the Upper and Uppermost Allochthons. The catchments of Vindelälven, Saltelva and Vefsna either include, or are closely adjacent to, basement windows within the Caledonian Nappe Domain.

3. Analytical methods

Zircon concentrates were obtained using standard density and magnetic separation techniques. Arbitrary, and presumed representative, fractions for each sample were poured onto double sided tape, cast into an epoxy resin disk, sectioned and polished. Transmitted and reflected light photomicrographs, together with cathodoluminescence (CL) images, were prepared for all grains. The U–Pb analyses were undertaken using SHRIMP I and SHRIMP RG at The Australian National University in Canberra. The procedures employed for zircon U–Pb dating followed Williams (1998) and references therein. The number of scans through the mass stations was limited to four, thereby achieving rapid data acquisition at the expense of some counting precision per analysis. In the first instance, an arbitrary group of 60 zircons were analysed from each sample. Subjectivity in zircon dating was avoided by analysing all zircons encountered during the traverse of the mount, unless the grain showed evidence of being metamict or otherwise structurally compromised as determined from examination of the reflected and transmitted light photomicrographs and CL images. Normalisation of Pb/U isotopic ratios was achieved by reference to analyses of the FC1 reference zircon (1099 Ma: $^{206}\text{Pb}/^{238}\text{U}=0.1589$; Paces and Miller, 1993). The raw SHRIMP data were processed using SQUID (Ludwig, 2001), with plots generated using Isoplot/Ex (Ludwig, 1999). For zircon areas that are older than approximately 800 Ma, the measured $^{206}\text{Pb}/^{204}\text{Pb}$ ratios have been used to correct for common Pb and the radiogenic $^{207}\text{Pb}/^{206}\text{Pb}$ ratio used to calculate the preferred age. For zircon areas that are younger than approximately 800 Ma, correction for common Pb was made using the measured $^{207}\text{Pb}/^{206}\text{Pb}$ and ratios $^{238}\text{U}/^{206}\text{Pb}$ ratios, giving a radiogenic $^{206}\text{Pb}/^{238}\text{U}$ ratio and age following Tera and Wasserburg (1972) as described by Williams (1998). For Neoproterozoic and older zircons, when an analysis is more than 20% discordant it has been excluded from the relative probability plots. For the younger zircons, the validity of the radiogenic $^{206}\text{Pb}/^{238}\text{U}$ age has been determined on the basis of a number of factors, including the amount of common Pb (that is, if the total $^{207}\text{Pb}/^{206}\text{Pb}$ ratio deviates significantly from

Table 2
Summary of SHRIMP U–Pb zircon results for Byskeälven river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total Ratios				Radiogenic Ratios						r	Age (Ma)				% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	
1.1	103	70	0.68	23.3	0.000017	0.03	3.787	0.054	0.0942	0.0010	0.2640	0.0038	3.419	0.062	0.0939	0.0010	0.788	1510	19	1507	21	0
2.1	137	31	0.23	38.4	0.000032	0.05	3.063	0.040	0.1086	0.0009	0.3264	0.0043	4.868	0.075	0.1082	0.0009	0.847	1821	21	1769	15	−3
3.1	190	56	0.29	54.1	0.000056	0.09	3.023	0.038	0.1085	0.0008	0.3305	0.0041	4.910	0.070	0.1077	0.0008	0.869	1841	21	1762	13	−4
4.1	132	47	0.35	19.9	–	<0.01	5.701	0.077	0.0763	0.0013	0.1752	0.0024	1.819	0.040	0.0753	0.0013	0.623	1041	14	1077	34	3
5.1	266	57	0.22	46.7	0.000011	0.02	4.898	0.058	0.0836	0.0007	0.2038	0.0024	2.304	0.034	0.0820	0.0007	0.809	1196	13	1246	17	4
6.1	57	38	0.68	7.8	0.000000	<0.01	6.251	0.112	0.0768	0.0016	0.1588	0.0028	1.544	0.048	0.0705	0.0018	0.573	950	18	943	52	−1
7.1	445	120	0.27	131.3	0.000028	0.04	2.913	0.032	0.1090	0.0005	0.3431	0.0038	5.137	0.063	0.1086	0.0005	0.913	1902	18	1776	9	−7
8.1	53	37	0.70	11.2	–	<0.01	4.058	0.071	0.0897	0.0015	0.2469	0.0043	3.108	0.084	0.0913	0.0019	0.647	1422	22	1453	39	2
9.1	147	41	0.28	23.3	0.000027	0.05	5.421	0.072	0.0777	0.0009	0.1844	0.0024	1.965	0.035	0.0773	0.0009	0.737	1091	13	1129	24	3
10.1	133	29	0.22	41.9	0.000000	<0.01	2.735	0.037	0.1147	0.0010	0.3657	0.0050	5.781	0.092	0.1147	0.0010	0.854	2009	23	1875	15	−7
11.1	473	140	0.30	126.3	0.000035	0.05	3.219	0.035	0.1134	0.0005	0.3105	0.0034	4.836	0.057	0.1129	0.0005	0.920	1743	17	1847	8	6
12.1	584	140	0.24	145.4	0.000014	0.02	3.453	0.037	0.1097	0.0004	0.2896	0.0031	4.373	0.051	0.1095	0.0005	0.929	1639	16	1792	8	8
13.1	94	63	0.66	16.9	0.000074	0.12	4.798	0.069	0.0848	0.0013	0.2082	0.0030	2.403	0.053	0.0837	0.0014	0.658	1219	16	1286	32	5
14.1	625	149	0.24	179.3	0.000133	0.21	2.995	0.032	0.1162	0.0004	0.3332	0.0036	5.255	0.062	0.1144	0.0006	0.907	1854	17	1870	9	1
15.1	268	117	0.44	75.0	–	<0.01	3.073	0.036	0.1098	0.0006	0.3255	0.0038	4.932	0.064	0.1099	0.0006	0.898	1816	18	1798	10	−1
16.1	474	166	0.35	131.1	0.000002	<0.01	3.107	0.034	0.1107	0.0005	0.3219	0.0035	4.913	0.058	0.1107	0.0005	0.932	1799	17	1811	8	1
17.1	524	189	0.36	141.1	–	<0.01	3.191	0.035	0.1103	0.0005	0.3134	0.0034	4.770	0.056	0.1104	0.0005	0.932	1757	17	1806	8	3
18.1	32	21	0.65	5.0	0.000641	1.10	5.628	0.114	0.0784	0.0020	0.1765	0.0036	1.778	0.062	0.0731	0.0021	0.582	1048	22	1016	57	−3
19.1	181	90	0.50	43.5	–	<0.01	3.566	0.044	0.0982	0.0008	0.2805	0.0035	3.797	0.055	0.0982	0.0008	0.850	1594	17	1590	14	0
20.1	287	65	0.23	79.2	0.000015	0.02	3.115	0.036	0.1101	0.0006	0.3209	0.0037	4.863	0.062	0.1099	0.0006	0.900	1794	18	1798	10	0
21.1	186	35	0.19	48.5	0.000036	0.06	3.286	0.040	0.1126	0.0008	0.3041	0.0037	4.702	0.068	0.1121	0.0008	0.855	1712	18	1834	14	7
22.1	184	152	0.83	43.3	0.000197	0.31	3.645	0.045	0.1123	0.0008	0.2735	0.0034	4.135	0.069	0.1096	0.0012	0.748	1559	17	1794	20	13
23.1	123	73	0.59	16.6	0.000062	0.11	6.363	0.090	0.0730	0.0011	0.1570	0.0022	1.561	0.033	0.0721	0.0012	0.657	940	12	989	33	5
24.1	174	31	0.18	38.6	0.000031	0.05	3.879	0.054	0.0919	0.0008	0.2577	0.0036	3.251	0.055	0.0915	0.0008	0.834	1478	19	1457	18	−1
25.1	1192	214	0.18	302.5	0.000202	0.31	3.386	0.035	0.1147	0.0003	0.2944	0.0031	4.546	0.053	0.1120	0.0006	0.894	1663	15	1832	9	9
26.1	62	17	0.28	17.3	0.000064	0.10	3.098	0.047	0.1143	0.0013	0.3225	0.0049	5.046	0.097	0.1135	0.0013	0.792	1802	24	1856	21	3
27.1	204	63	0.31	56.2	0.000030	0.05	3.120	0.038	0.1101	0.0007	0.3204	0.0039	4.844	0.068	0.1097	0.0008	0.860	1792	19	1794	13	0
28.1	404	136	0.34	94.7	0.000042	0.07	3.669	0.041	0.1098	0.0006	0.2724	0.0030	4.104	0.051	0.1093	0.0006	0.895	1553	15	1787	10	13
29.1	229	50	0.22	60.7	0.000026	0.04	3.239	0.039	0.1110	0.0007	0.3086	0.0037	4.706	0.064	0.1106	0.0007	0.881	1734	18	1809	12	4
30.1	381	85	0.22	106.5	–	<0.01	3.075	0.034	0.1146	0.0005	0.3253	0.0036	5.143	0.063	0.1147	0.0005	0.920	1815	18	1875	9	3
31.1	168	46	0.28	46.9	0.000098	0.15	3.081	0.042	0.1108	0.0009	0.3240	0.0045	4.890	0.085	0.1094	0.0012	0.789	1809	22	1790	19	−1

32.1	214	63	0.30	61.9	–	<0.01	2.965	0.038	0.1099	0.0008	0.3377	0.0044	5.169	0.085	0.1110	0.0011	0.785	1876	21	1816	19	–3
33.1	508	122	0.24	146.4	0.002040	3.20	2.979	0.036	0.1343	0.0006	0.3249	0.0040	4.771	0.194	0.1065	0.0041	0.305	1814	20	1740	71	–4
34.1	578	125	0.22	174.6	0.000007	0.01	2.844	0.032	0.1149	0.0005	0.3516	0.0040	5.568	0.068	0.1149	0.0005	0.932	1942	19	1878	8	–3
35.1	53	25	0.47	13.8	–	<0.01	3.279	0.067	0.1018	0.0016	0.3057	0.0063	4.387	0.125	0.1041	0.0021	0.718	1720	31	1698	37	–1
36.1	435	211	0.49	104.8	0.000947	1.49	3.562	0.043	0.1194	0.0007	0.2766	0.0034	4.059	0.103	0.1064	0.0024	0.481	1574	17	1739	41	9
37.1	1205	264	0.22	183.1	0.000179	0.29	5.652	0.062	0.1008	0.0005	0.1764	0.0019	2.392	0.032	0.0983	0.0007	0.830	1047	11	1593	14	34
38.1	135	31	0.23	38.0	–	<0.01	3.050	0.046	0.1104	0.0011	0.3280	0.0050	5.005	0.090	0.1107	0.0011	0.839	1829	24	1811	18	–1
39.1	84	21	0.24	24.5	0.000136	0.21	2.960	0.052	0.1097	0.0013	0.3380	0.0059	5.137	0.109	0.1102	0.0013	0.822	1877	29	1803	22	–4
40.1	639	131	0.20	189.5	0.000039	0.06	2.900	0.033	0.1138	0.0005	0.3451	0.0040	5.435	0.067	0.1142	0.0005	0.933	1911	20	1868	8	–2
41.1	306	96	0.31	84.5	0.000094	0.15	3.109	0.040	0.1110	0.0008	0.3212	0.0041	4.860	0.076	0.1098	0.0010	0.822	1795	20	1795	16	0
42.1	2172	1045	0.48	483.3	0.005814	9.16	3.860	0.041	0.1842	0.0005	0.2353	0.0029	3.399	0.381	0.1048	0.0117	0.112	1362	15	1710	205	20
43.1	194	47	0.24	49.3	0.000098	0.15	3.373	0.049	0.1117	0.0010	0.2960	0.0043	4.503	0.084	0.1103	0.0013	0.779	1672	21	1805	21	7
44.1	334	260	0.78	69.4	0.000024	0.04	4.127	0.054	0.0900	0.0008	0.2422	0.0032	2.995	0.050	0.0897	0.0009	0.791	1398	17	1419	20	1
45.1	132	101	0.76	32.7	0.000163	0.26	3.473	0.057	0.1028	0.0015	0.2872	0.0047	3.982	0.098	0.1006	0.0018	0.666	1628	23	1635	34	0
46.1	129	21	0.16	35.8	–	<0.01	3.086	0.050	0.1093	0.0012	0.3243	0.0053	4.919	0.113	0.1100	0.0018	0.713	1811	26	1800	29	–1
47.1	364	120	0.33	81.3	0.000042	0.07	3.845	0.049	0.0996	0.0008	0.2599	0.0033	3.548	0.057	0.0990	0.0010	0.797	1489	17	1606	18	7
48.1	81	74	0.91	19.8	0.000152	0.24	3.525	0.068	0.1020	0.0015	0.2830	0.0055	3.898	0.105	0.0999	0.0019	0.718	1607	27	1622	35	1
49.1	605	135	0.22	175.1	0.000012	0.02	2.971	0.035	0.1142	0.0005	0.3366	0.0039	5.292	0.067	0.1140	0.0006	0.920	1870	19	1865	9	0
50.1	211	74	0.35	58.5	0.000023	0.04	3.097	0.044	0.1091	0.0009	0.3236	0.0046	4.944	0.082	0.1108	0.0009	0.858	1807	23	1813	15	0
51.1	167	125	0.75	22.9	0.000013	0.02	6.274	0.099	0.0715	0.0012	0.1594	0.0025	1.568	0.036	0.0714	0.0012	0.681	953	14	968	35	1
52.1	359	108	0.30	85.4	0.000032	0.05	3.613	0.046	0.1006	0.0008	0.2767	0.0035	3.821	0.061	0.1002	0.0010	0.793	1575	18	1627	18	3
53.1	173	86	0.50	38.8	0.000095	0.15	3.836	0.064	0.0936	0.0013	0.2607	0.0043	3.358	0.072	0.0934	0.0013	0.776	1493	24	1497	26	0
54.1	256	64	0.25	69.7	0.000070	0.11	3.161	0.045	0.1117	0.0010	0.3160	0.0045	4.826	0.087	0.1108	0.0012	0.793	1770	22	1812	20	2
55.1	837	287	0.34	221.5	0.000038	0.06	3.244	0.037	0.1094	0.0006	0.3081	0.0035	4.627	0.059	0.1089	0.0006	0.895	1731	17	1782	10	3
56.1	68	13	0.20	15.8	–	<0.01	3.664	0.089	0.1112	0.0017	0.2730	0.0066	4.194	0.121	0.1114	0.0017	0.840	1556	34	1823	28	15
58.1	164	44	0.27	45.5	0.000085	0.13	3.093	0.049	0.1099	0.0011	0.3237	0.0052	4.947	0.094	0.1108	0.0011	0.839	1808	26	1813	19	0
59.1	278	90	0.32	54.7	–	<0.01	4.373	0.063	0.0874	0.0010	0.2289	0.0033	2.783	0.064	0.0882	0.0016	0.634	1329	18	1387	34	4
60.1	19	19	0.99	4.5	0.000058	0.09	3.567	0.131	0.1048	0.0035	0.2787	0.0102	3.840	0.196	0.0999	0.0035	0.720	1585	61	1623	66	2

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.81% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Table 3
Summary of SHRIMP U–Pb zircon results for Raneälven river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	F ₂₀₆ %	Total ratios				Radiogenic ratios						r	Age (Ma)					% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	192	53	0.27	51.8	0.000072	0.11	3.181	0.047	0.1104	0.0010	0.3140	0.0047	4.738	0.087	0.1094	0.0012	0.809	1760	23	1790	20	2	
2.1	298	149	0.50	82.5	0.000022	0.03	3.101	0.041	0.1149	0.0008	0.3223	0.0043	5.093	0.078	0.1146	0.0009	0.871	1801	21	1874	14	4	
3.1	615	183	0.30	141.1	0.000203	0.31	3.742	0.045	0.1148	0.0007	0.2664	0.0032	4.115	0.061	0.1120	0.0010	0.802	1523	16	1832	16	17	
4.1	88	37	0.42	24.7	–	<0.01	3.045	0.059	0.1171	0.0016	0.3292	0.0064	5.412	0.138	0.1192	0.0020	0.759	1834	31	1945	30	6	
5.1	122	61	0.50	35.1	–	<0.01	2.980	0.051	0.1123	0.0013	0.3368	0.0057	5.343	0.110	0.1151	0.0013	0.824	1871	29	1881	21	1	
6.1	220	101	0.46	57.4	0.000034	0.05	3.293	0.048	0.1171	0.0011	0.3035	0.0044	4.881	0.086	0.1166	0.0012	0.826	1709	22	1905	18	10	
7.1	335	155	0.46	93.8	0.000018	0.03	3.072	0.041	0.1154	0.0008	0.3255	0.0043	5.167	0.078	0.1151	0.0008	0.878	1816	21	1882	13	3	
8.1	220	70	0.32	62.1	0.000109	0.17	3.045	0.044	0.1174	0.0010	0.3278	0.0048	5.239	0.106	0.1159	0.0016	0.724	1828	23	1894	25	3	
9.1	520	470	0.90	123.3	0.000009	0.01	3.620	0.044	0.1028	0.0007	0.2762	0.0034	3.909	0.055	0.1026	0.0007	0.862	1572	17	1672	13	6	
10.1	158	64	0.40	41.9	–	<0.01	3.238	0.053	0.1116	0.0016	0.3089	0.0051	4.769	0.105	0.1120	0.0017	0.742	1736	25	1831	27	5	
11.1	225	219	0.97	64.0	0.000044	0.07	3.019	0.050	0.1164	0.0010	0.3310	0.0055	5.286	0.114	0.1158	0.0016	0.763	1843	26	1893	25	3	
12.1	142	84	0.59	40.3	0.000049	0.08	3.034	0.050	0.1158	0.0013	0.3294	0.0055	5.231	0.115	0.1152	0.0016	0.758	1835	27	1883	26	3	
13.1	129	107	0.83	37.6	0.000094	0.15	2.938	0.059	0.1138	0.0014	0.3413	0.0069	5.466	0.128	0.1161	0.0014	0.860	1893	37	1898	21	0	
14.1	80	34	0.43	22.7	–	<0.01	3.027	0.063	0.1163	0.0018	0.3316	0.0070	5.470	0.184	0.1196	0.0031	0.624	1846	34	1951	47	5	
15.1	115	60	0.52	35.5	–	<0.01	2.794	0.044	0.1141	0.0012	0.3580	0.0056	5.654	0.109	0.1145	0.0013	0.818	1973	27	1873	20	–5	
16.1	156	84	0.54	46.8	–	<0.01	2.852	0.043	0.1112	0.0011	0.3513	0.0053	5.469	0.098	0.1129	0.0011	0.845	1941	27	1847	17	–5	
17.1	131	44	0.34	39.6	0.000285	0.44	2.830	0.044	0.1154	0.0012	0.3522	0.0054	5.468	0.104	0.1126	0.0012	0.812	1945	27	1842	20	–6	
18.1	174	69	0.40	49.8	0.000009	0.01	2.996	0.050	0.1160	0.0011	0.3337	0.0056	5.333	0.104	0.1159	0.0011	0.862	1856	27	1894	18	2	
19.1	158	200	1.26	50.4	–	<0.01	2.700	0.040	0.1162	0.0010	0.3709	0.0055	6.001	0.104	0.1173	0.0010	0.859	2034	31	1916	16	–6	
20.1	158	77	0.49	51.8	–	<0.01	2.616	0.041	0.1153	0.0011	0.3824	0.0060	6.092	0.112	0.1155	0.0011	0.850	2088	28	1888	17	–11	
21.1	294	487	1.66	71.6	–	<0.01	3.527	0.052	0.0821	0.0008	0.2861	0.0043	3.536	0.071	0.0896	0.0012	0.745	1622	32	1418	25	–14	
22.1	65	89	1.36	10.4	–	<0.01	5.415	0.118	0.0756	0.0018	0.1858	0.0041	2.069	0.101	0.0808	0.0035	0.449	1099	22	1216	86	10	
23.1	101	13	0.13	31.5	0.000050	0.08	2.753	0.049	0.1157	0.0014	0.3640	0.0065	5.888	0.127	0.1173	0.0014	0.823	2001	31	1916	22	–4	
24.1	85	57	0.67	24.5	0.000156	0.25	2.982	0.059	0.1078	0.0016	0.3357	0.0066	5.028	0.123	0.1086	0.0016	0.810	1866	35	1777	26	–5	
25.1	345	262	0.76	100.4	0.000080	0.12	2.953	0.039	0.1159	0.0008	0.3382	0.0045	5.355	0.087	0.1148	0.0011	0.817	1878	22	1877	17	0	
26.1	355	123	0.35	102.2	–	<0.01	2.985	0.040	0.1139	0.0009	0.3351	0.0045	5.274	0.082	0.1142	0.0009	0.862	1863	22	1867	14	0	
27.1	268	96	0.36	75.0	0.000021	0.03	3.071	0.043	0.1114	0.0009	0.3255	0.0046	4.987	0.083	0.1111	0.0010	0.852	1817	22	1817	16	0	
28.1	170	87	0.51	50.4	–	<0.01	2.901	0.046	0.1165	0.0013	0.3449	0.0055	5.563	0.109	0.1170	0.0013	0.817	1910	26	1911	20	0	
29.1	171	119	0.70	46.1	0.000319	0.49	3.180	0.051	0.1159	0.0013	0.3129	0.0050	4.815	0.102	0.1116	0.0016	0.751	1755	24	1826	25	4	

30.1	139	36	0.26	42.7	–	<0.01	2.805	0.050	0.1123	0.0014	0.3567	0.0064	5.546	0.130	0.1128	0.0017	0.767	1967	30	1844	27	–7
31.1	172	59	0.35	25.8	0.000644	1.02	5.711	0.102	0.1111	0.0018	0.1692	0.0030	1.938	0.098	0.0831	0.0039	0.353	1008	19	1271	93	21
32.1	447	234	0.52	120.7	0.000019	0.03	3.180	0.044	0.1080	0.0009	0.3144	0.0043	4.670	0.077	0.1078	0.0010	0.839	1762	21	1762	16	0
33.1	275	81	0.30	81.5	0.000043	0.07	2.903	0.044	0.1099	0.0010	0.3460	0.0053	5.413	0.098	0.1135	0.0011	0.842	1915	26	1856	18	–3
34.1	184	153	0.83	49.9	0.000084	0.13	3.169	0.055	0.1095	0.0014	0.3151	0.0055	4.707	0.111	0.1083	0.0017	0.735	1766	27	1771	29	0
35.1	216	129	0.60	66.2	–	<0.01	2.811	0.046	0.1130	0.0014	0.3562	0.0058	5.602	0.118	0.1141	0.0015	0.774	1964	28	1865	24	–5
36.1	223	119	0.54	68.3	–	<0.01	2.803	0.050	0.1165	0.0012	0.3574	0.0063	5.801	0.119	0.1177	0.0012	0.865	1970	32	1922	18	–2
37.1	106	53	0.49	30.7	0.000131	0.21	2.976	0.059	0.1096	0.0016	0.3356	0.0067	5.028	0.125	0.1087	0.0016	0.803	1866	35	1777	27	–5
38.1	102	38	0.37	32.2	0.000021	0.03	2.722	0.055	0.1148	0.0016	0.3682	0.0075	5.921	0.147	0.1166	0.0017	0.818	2021	37	1905	26	–6
39.1	89	80	0.90	25.8	–	<0.01	2.962	0.066	0.1150	0.0018	0.3386	0.0075	5.487	0.160	0.1175	0.0022	0.759	1880	36	1919	34	2
40.1	357	7864	22.0	88.3	0.001648	2.55	3.478	0.048	0.1357	0.0016	0.2802	0.0041	4.383	0.200	0.1135	0.0049	0.320	1592	21	1855	78	14
41.1	235	111	0.47	65.3	0.000066	0.10	3.093	0.048	0.1159	0.0011	0.3230	0.0050	5.121	0.096	0.1150	0.0012	0.820	1804	24	1880	19	4
42.1	24	14	0.58	4.7	–	<0.01	4.291	0.168	0.0864	0.0037	0.2348	0.0098	3.009	0.442	0.0929	0.0131	0.285	1360	51	1487	266	9
43.1	278	147	0.53	80.8	0.000037	0.06	2.953	0.043	0.1155	0.0010	0.3385	0.0049	5.367	0.097	0.1150	0.0012	0.804	1879	24	1880	19	0
44.1	369	240	0.65	108.1	0.000005	0.01	2.932	0.039	0.1161	0.0008	0.3410	0.0046	5.457	0.083	0.1161	0.0008	0.878	1892	22	1896	13	0
45.1	104	88	0.84	31.5	0.000160	0.25	2.839	0.060	0.1124	0.0016	0.3546	0.0075	5.759	0.149	0.1178	0.0018	0.815	1957	40	1923	27	–2
46.1	235	119	0.51	69.4	0.000154	0.24	2.904	0.043	0.1157	0.0010	0.3454	0.0051	5.622	0.098	0.1181	0.0011	0.855	1913	26	1927	16	1
47.1	263	87	0.33	77.1	0.000070	0.11	2.930	0.042	0.1138	0.0010	0.3410	0.0049	5.307	0.089	0.1129	0.0010	0.848	1891	23	1846	16	–2
48.1	476	104	0.22	138.4	0.024495	28.74	2.958	0.382	0.5565	0.0201	0.2409	0.0362	10.498	3.111	0.3160	0.0807	0.507	1392	188	3551	393	61
49.1	75	36	0.48	21.0	–	<0.01	3.081	0.069	0.1107	0.0019	0.3251	0.0073	5.024	0.151	0.1121	0.0022	0.746	1815	35	1834	36	1
50.1	157	63	0.40	45.9	–	<0.01	2.944	0.049	0.1094	0.0013	0.3400	0.0057	5.166	0.111	0.1102	0.0015	0.786	1887	28	1802	24	–5
51.1	170	58	0.34	49.9	0.000054	0.08	2.932	0.048	0.1141	0.0013	0.3407	0.0055	5.325	0.109	0.1133	0.0014	0.795	1890	27	1854	22	–2
52.1	300	162	0.54	90.7	0.000063	0.10	2.845	0.040	0.1156	0.0009	0.3511	0.0049	5.557	0.093	0.1148	0.0011	0.831	1940	23	1876	17	–3
53.1	171	76	0.45	54.8	–	<0.01	2.688	0.051	0.1166	0.0012	0.3726	0.0071	6.058	0.148	0.1179	0.0018	0.774	2041	33	1925	28	–6
54.1	331	235	0.71	93.9	0.000044	0.07	3.029	0.052	0.1155	0.0013	0.3299	0.0057	5.227	0.108	0.1149	0.0013	0.833	1838	27	1879	21	2
55.1	172	76	0.44	51.8	0.000160	0.25	2.847	0.047	0.1153	0.0013	0.3503	0.0057	5.463	0.119	0.1131	0.0016	0.751	1936	27	1850	26	–5
56.1	349	248	0.71	97.8	–	<0.01	3.064	0.046	0.1167	0.0009	0.3265	0.0049	5.270	0.090	0.1171	0.0009	0.882	1821	24	1912	14	5
57.1	798	500	0.63	264.9	0.000572	0.88	2.588	0.031	0.1226	0.0006	0.3836	0.0046	6.175	0.088	0.1168	0.0009	0.831	2093	23	1907	14	–10
58.1	151	56	0.37	45.4	–	<0.01	2.852	0.049	0.1158	0.0013	0.3518	0.0060	5.749	0.118	0.1185	0.0013	0.832	1943	30	1934	20	0
59.1	181	45	0.25	79.9	0.000086	0.13	1.944	0.037	0.1146	0.0011	0.5164	0.0098	8.383	0.180	0.1177	0.0012	0.882	2684	43	1922	18	–40
60.1	263	136	0.51	78.9	–	<0.01	2.866	0.046	0.1149	0.0010	0.3491	0.0056	5.551	0.102	0.1153	0.0010	0.874	1930	27	1885	16	–2

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.50% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Table 4
Summary of SHRIMP U–Pb zircon results for Lainioälven river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios					r	Age (Ma)					
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb		±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	% Disc
1.1	63	60	0.96	17.1	0.000081	0.13	3.154	0.062	0.1150	0.0020	0.3166	0.0062	4.973	0.142	0.1139	0.0024	0.686	1773	30	1863	37	5
2.1	145	92	0.64	38.7	0.000086	0.14	3.210	0.047	0.1084	0.0012	0.3111	0.0046	4.599	0.092	0.1072	0.0014	0.735	1746	22	1752	25	0
3.1	45	79	1.77	13.1	0.000325	0.51	2.955	0.067	0.1146	0.0022	0.3417	0.0077	5.769	0.171	0.1224	0.0023	0.764	1895	49	1992	34	5
4.1	119	129	1.09	31.5	0.000079	0.12	3.232	0.055	0.1125	0.0013	0.3090	0.0052	4.749	0.104	0.1115	0.0016	0.770	1736	26	1823	25	5
5.1	30	39	1.31	8.1	0.000166	0.26	3.140	0.133	0.1140	0.0029	0.3177	0.0135	4.895	0.323	0.1118	0.0056	0.646	1778	66	1828	91	3
6.1	116	101	0.87	48.4	0.000126	0.17	2.056	0.048	0.1924	0.0015	0.4856	0.0112	12.777	0.318	0.1908	0.0017	0.930	2552	49	2749	15	7
7.1	134	94	0.70	36.9	0.000049	0.08	3.112	0.050	0.1107	0.0011	0.3211	0.0052	4.870	0.105	0.1100	0.0016	0.748	1795	25	1799	26	0
8.1	1083	168	0.16	179.4	0.000245	0.36	5.183	0.057	0.1391	0.0013	0.1922	0.0021	3.601	0.056	0.1359	0.0015	0.711	1133	12	2175	19	48
9.1	313	163	0.52	87.6	0.000049	0.08	3.072	0.040	0.1142	0.0008	0.3252	0.0043	5.091	0.078	0.1135	0.0009	0.859	1815	21	1857	14	2
10.1	481	207	0.43	116.7	0.000025	0.04	3.537	0.042	0.1121	0.0007	0.2826	0.0034	4.356	0.060	0.1118	0.0008	0.871	1604	17	1829	12	12
11.1	45	52	1.16	11.9	0.000058	0.09	3.241	0.074	0.1113	0.0024	0.3083	0.0070	4.698	0.150	0.1105	0.0025	0.713	1732	35	1808	41	4
12.1	28	32	1.13	8.0	0.000305	0.47	3.047	0.089	0.1138	0.0026	0.3267	0.0095	4.940	0.200	0.1097	0.0031	0.719	1822	46	1794	51	-2
13.1	50	67	1.34	13.5	0.000139	0.22	3.157	0.064	0.1105	0.0019	0.3161	0.0065	4.733	0.186	0.1086	0.0036	0.524	1771	32	1776	61	0
14.1	63	44	0.70	17.5	0.000117	0.18	3.080	0.067	0.1118	0.0019	0.3241	0.0071	4.924	0.168	0.1102	0.0029	0.640	1810	35	1803	48	0
15.1	89	76	0.85	24.5	0.000057	0.09	3.139	0.051	0.1087	0.0014	0.3193	0.0052	4.871	0.101	0.1106	0.0014	0.787	1786	29	1810	23	1
16.1	25	20	0.81	6.8	-	<0.01	3.137	0.083	0.1119	0.0028	0.3205	0.0086	5.153	0.215	0.1166	0.0037	0.642	1792	42	1905	57	6
17.1	44	38	0.86	12.1	0.000058	0.09	3.120	0.066	0.1125	0.0021	0.3202	0.0068	4.932	0.157	0.1117	0.0027	0.665	1791	33	1828	43	2
18.1	144	116	0.81	38.9	0.000022	0.03	3.170	0.047	0.1096	0.0012	0.3154	0.0047	4.753	0.091	0.1093	0.0013	0.781	1767	23	1788	22	1
19.1	117	131	1.12	32.7	0.000146	0.22	3.065	0.048	0.1165	0.0013	0.3255	0.0051	5.139	0.115	0.1145	0.0018	0.696	1817	25	1872	29	3
20.1	83	75	0.91	23.2	0.000100	0.16	3.063	0.053	0.1113	0.0015	0.3268	0.0057	5.046	0.112	0.1120	0.0015	0.782	1823	31	1832	25	1
21.1	53	41	0.77	22.6	0.000092	0.12	2.007	0.045	0.1922	0.0023	0.4978	0.0111	13.117	0.334	0.1911	0.0024	0.872	2604	48	2752	20	5
22.1	36	43	1.21	10.1	0.000095	0.15	3.064	0.075	0.1139	0.0025	0.3259	0.0081	5.062	0.239	0.1126	0.0045	0.528	1819	39	1842	73	1
23.1	239	16	0.07	112.8	0.000036	0.05	1.818	0.024	0.1946	0.0011	0.5496	0.0073	14.712	0.215	0.1941	0.0011	0.915	2824	31	2778	10	-2
24.1	1728	9	0.01	525.3	0.000148	0.20	2.825	0.031	0.1796	0.0005	0.3532	0.0038	8.660	0.098	0.1778	0.0006	0.957	1950	18	2632	5	26
25.1	54	75	1.40	21.8	0.000173	0.24	2.111	0.042	0.1859	0.0022	0.4727	0.0095	11.979	0.284	0.1838	0.0023	0.846	2495	41	2688	21	7
26.1	105	86	0.82	29.4	0.000128	0.20	3.063	0.049	0.1114	0.0014	0.3258	0.0053	4.925	0.140	0.1096	0.0026	0.574	1818	26	1793	42	-1
27.1	604	216	0.36	241.5	-	<0.01	2.150	0.028	0.1840	0.0010	0.4651	0.0061	11.807	0.166	0.1841	0.0010	0.926	2462	27	2690	9	8
28.1	61	98	1.61	14.9	0.000704	1.11	3.493	0.071	0.1134	0.0020	0.2831	0.0059	4.051	0.180	0.1038	0.0041	0.465	1607	29	1693	73	5
29.1	183	372	2.03	31.7	0.000398	0.62	4.969	0.083	0.1123	0.0016	0.2000	0.0034	2.947	0.085	0.1069	0.0025	0.580	1175	18	1747	43	33
30.1	73	82	1.11	20.4	-	<0.01	3.087	0.059	0.1149	0.0018	0.3239	0.0061	5.134	0.125	0.1149	0.0018	0.779	1809	30	1879	28	4

31.1	31	22	0.69	13.1	–	<0.01	2.059	0.054	0.1797	0.0031	0.4859	0.0127	12.063	0.381	0.1801	0.0032	0.831	2553	55	2654	29	4
32.1	90	171	1.90	40.2	0.000147	0.20	1.929	0.034	0.1864	0.0017	0.5175	0.0092	13.174	0.292	0.1846	0.0025	0.801	2688	39	2695	22	0
33.1	59	18	0.30	20.3	–	<0.01	2.503	0.059	0.1880	0.0034	0.3996	0.0095	10.371	0.309	0.1882	0.0034	0.795	2167	44	2727	30	21
34.1	130	49	0.38	58.4	–	<0.01	1.908	0.030	0.1889	0.0015	0.5242	0.0082	13.658	0.239	0.1890	0.0015	0.894	2717	35	2733	13	1
34.2	61	36	0.60	14.2	–	<0.01	3.667	0.163	0.1241	0.0098	0.2727	0.0121	4.668	0.423	0.1241	0.0098	0.492	1555	62	2017	140	23
35.2	504	505	1.00	95.1	0.001359	2.09	4.559	0.066	0.1345	0.0036	0.2148	0.0032	3.441	0.174	0.1162	0.0056	0.298	1254	17	1899	87	34
36.1	133	99	0.74	56.2	0.000000	0.00	2.027	0.056	0.1853	0.0043	0.4933	0.0137	12.601	0.455	0.1853	0.0043	0.769	2585	59	2701	38	4
37.1	53	53	0.99	13.3	0.000310	0.48	3.436	0.102	0.1125	0.0030	0.2896	0.0088	4.324	0.275	0.1083	0.0060	0.478	1640	44	1770	102	7
38.1	72	45	0.63	27.9	0.002583	3.61	2.219	0.061	0.2016	0.0049	0.4344	0.0122	10.147	0.584	0.1694	0.0085	0.490	2326	55	2552	84	9
39.1	75	37	0.49	23.6	0.000307	0.50	2.739	0.070	0.0904	0.0176	0.3633	0.0093	4.312	0.897	0.0861	0.0178	0.123	1998	44	1340	399	–49
40.1	172	101	0.59	73.9	0.000134	0.18	2.003	0.040	0.1846	0.0020	0.4984	0.0100	12.575	0.290	0.1830	0.0021	0.871	2607	43	2680	19	3
41.1	125	122	1.00	54.4	0.000442	0.60	1.977	0.042	0.1943	0.0029	0.5028	0.0106	13.101	0.353	0.1890	0.0032	0.785	2626	46	2733	28	4
42.1	68	45	0.66	21.6	0.000673	1.06	2.728	0.061	0.1143	0.0024	0.3626	0.0083	5.254	0.287	0.1051	0.0052	0.419	1995	39	1716	91	–16
43.1	86	63	0.74	23.9	–	<0.01	3.087	0.066	0.1156	0.0019	0.3243	0.0070	5.220	0.144	0.1167	0.0020	0.780	1811	34	1907	31	5
44.1	37	38	1.00	10.1	0.000595	0.93	3.182	0.085	0.1163	0.0028	0.3114	0.0084	4.645	0.221	0.1082	0.0042	0.569	1747	41	1769	72	1
45.1	141	278	1.97	40.3	0.000178	0.28	3.010	0.048	0.1152	0.0017	0.3313	0.0053	5.155	0.118	0.1128	0.0019	0.697	1845	26	1845	30	0
46.1	73	62	0.85	21.2	0.000721	1.14	2.949	0.073	0.1137	0.0021	0.3398	0.0085	5.396	0.167	0.1152	0.0021	0.806	1886	46	1883	33	0
48.1	56	63	1.12	14.9	0.000243	0.38	3.235	0.075	0.1095	0.0020	0.3079	0.0071	4.509	0.152	0.1062	0.0026	0.686	1730	35	1735	45	0
49.1	136	268	1.96	37.5	0.000073	0.11	3.125	0.051	0.1106	0.0013	0.3196	0.0052	4.832	0.115	0.1096	0.0019	0.691	1788	26	1794	31	0
50.1	641	143	0.22	139.6	0.000424	0.66	3.945	0.047	0.1146	0.0007	0.2518	0.0030	3.780	0.065	0.1089	0.0014	0.688	1448	15	1781	23	19
51.1	93	89	0.95	26.5	0.000071	0.11	3.025	0.054	0.1093	0.0013	0.3310	0.0059	5.025	0.108	0.1101	0.0013	0.825	1843	33	1801	22	–2
52.1	267	179	0.67	93.9	0.000137	0.19	2.443	0.032	0.1816	0.0010	0.4086	0.0054	10.140	0.152	0.1800	0.0013	0.885	2209	25	2653	12	17
53.1	49	52	1.05	13.9	0.000302	0.48	3.054	0.072	0.1100	0.0021	0.3280	0.0077	5.043	0.153	0.1115	0.0021	0.776	1829	44	1824	35	0
54.1	35	53	1.53	9.8	0.000415	0.66	3.041	0.085	0.1068	0.0023	0.3314	0.0092	5.162	0.182	0.1130	0.0025	0.788	1845	56	1848	39	0
55.1	41	47	1.15	11.1	0.000064	0.10	3.139	0.077	0.1143	0.0022	0.3183	0.0078	4.980	0.167	0.1135	0.0026	0.732	1781	38	1856	41	4
56.1	178	64	0.36	82.3	0.000002	0.00	1.856	0.027	0.1874	0.0012	0.5389	0.0079	13.921	0.221	0.1874	0.0012	0.918	2779	33	2719	10	–2
57.1	26	31	1.21	7.1	0.001608	2.54	3.096	0.108	0.1245	0.0037	0.3205	0.0112	5.231	0.249	0.1184	0.0038	0.733	1792	67	1932	58	7
58.1	16	14	0.88	4.6	0.001824	2.95	2.888	0.116	0.1180	0.0038	0.3484	0.0140	5.900	0.299	0.1228	0.0038	0.794	1927	76	1998	55	4
59.1	96	78	0.81	40.2	0.000319	0.44	2.048	0.040	0.1823	0.0032	0.4862	0.0094	11.959	0.338	0.1784	0.0037	0.686	2554	41	2638	34	3
60.1	69	98	1.41	19.0	0.000461	0.73	3.133	0.067	0.1095	0.0018	0.3272	0.0070	5.829	0.186	0.1292	0.0030	0.675	1825	42	2087	41	13

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.53% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Table 5
Summary of SHRIMP U–Pb zircon results for Ljusnan river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios					r	Age (Ma)					% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb		±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	
1.1	158	103	0.65	40.4	0.000060	0.09	3.356	0.041	0.1038	0.0007	0.2977	0.0036	4.227	0.061	0.1030	0.0008	0.843	1680	18	1678	14	0
2.1	226	178	0.79	59.2	0.000025	0.04	3.281	0.038	0.1039	0.0006	0.3046	0.0035	4.349	0.058	0.1035	0.0007	0.873	1714	17	1688	12	-2
3.1	215	132	0.61	56.4	0.000028	0.04	3.274	0.041	0.1035	0.0006	0.3053	0.0038	4.340	0.062	0.1031	0.0007	0.872	1718	19	1680	13	-2
4.1	24	15	0.63	6.1	-	<0.01	3.351	0.069	0.1018	0.0019	0.2995	0.0062	4.328	0.145	0.1048	0.0027	0.622	1689	31	1711	48	1
5.1	105	67	0.64	28.2	0.000055	0.09	3.195	0.042	0.1024	0.0009	0.3127	0.0041	4.383	0.069	0.1016	0.0009	0.831	1754	20	1654	16	-6
6.1	226	112	0.49	54.0	0.000024	0.04	3.594	0.042	0.1026	0.0009	0.2782	0.0033	3.924	0.058	0.1023	0.0009	0.797	1582	16	1666	16	5
7.1	108	75	0.69	26.3	-	<0.01	3.532	0.047	0.1037	0.0009	0.2833	0.0038	4.070	0.073	0.1042	0.0012	0.747	1608	19	1700	22	5
8.1	944	314	0.33	154.7	0.001162	1.93	5.243	0.055	0.0983	0.0007	0.1870	0.0020	2.112	0.068	0.0819	0.0025	0.331	1105	11	1243	59	11
9.1	385	193	0.50	79.0	-	<0.01	4.190	0.047	0.1050	0.0006	0.2387	0.0027	3.460	0.044	0.1051	0.0006	0.892	1380	14	1716	10	20
10.1	144	81	0.56	28.8	0.000072	0.11	4.303	0.055	0.1036	0.0009	0.2321	0.0030	3.285	0.052	0.1026	0.0010	0.801	1346	15	1672	18	20
11.1	411	152	0.37	83.4	0.000218	0.35	4.229	0.046	0.1044	0.0005	0.2357	0.0026	3.296	0.046	0.1014	0.0009	0.785	1364	13	1650	16	17
12.1	608	301	0.49	150.8	0.000022	0.04	3.460	0.037	0.1036	0.0004	0.2889	0.0031	4.114	0.047	0.1033	0.0004	0.938	1636	15	1684	7	3
13.1	109	67	0.62	31.6	0.000003	0.00	2.956	0.041	0.1047	0.0009	0.3383	0.0046	4.881	0.081	0.1046	0.0010	0.830	1879	22	1708	17	-10
14.1	194	175	0.90	53.4	0.000021	0.03	3.123	0.037	0.1044	0.0007	0.3201	0.0038	4.594	0.063	0.1041	0.0007	0.877	1790	19	1698	12	-5
15.1	111	93	0.84	26.8	-	<0.01	3.573	0.047	0.1054	0.0009	0.2800	0.0037	4.077	0.066	0.1056	0.0010	0.818	1591	19	1725	17	8
16.1	92	58	0.63	23.8	0.000160	0.25	3.340	0.045	0.1049	0.0010	0.2987	0.0041	4.230	0.080	0.1027	0.0013	0.718	1685	20	1674	24	-1
17.1	50	29	0.58	13.7	-	<0.01	3.144	0.051	0.1057	0.0013	0.3184	0.0051	4.673	0.099	0.1065	0.0014	0.766	1782	25	1740	25	-2
18.1	193	119	0.62	49.9	0.000020	0.03	3.331	0.040	0.1057	0.0007	0.3001	0.0036	4.363	0.059	0.1054	0.0007	0.879	1692	18	1722	12	2
19.1	230	89	0.39	53.2	0.000011	0.02	3.707	0.043	0.1039	0.0007	0.2697	0.0031	3.859	0.052	0.1038	0.0007	0.866	1539	16	1692	12	9
20.1	97	61	0.63	19.6	0.000104	0.17	4.259	0.058	0.0906	0.0010	0.2344	0.0032	2.881	0.054	0.0891	0.0011	0.727	1358	17	1407	24	4
21.1	150	77	0.51	21.4	0.000003	0.01	6.005	0.070	0.0775	0.0009	0.1665	0.0020	1.779	0.030	0.0775	0.0009	0.697	993	11	1134	24	12
22.1	417	247	0.59	100.4	0.000012	0.02	3.570	0.039	0.1030	0.0005	0.2800	0.0030	3.970	0.047	0.1028	0.0005	0.920	1592	15	1676	9	5
23.1	350	192	0.55	89.6	0.000018	0.03	3.352	0.037	0.1028	0.0005	0.2983	0.0033	4.219	0.051	0.1026	0.0005	0.914	1683	16	1671	9	-1
24.1	137	69	0.51	23.6	0.000010	0.02	4.968	0.064	0.0768	0.0010	0.2012	0.0026	2.126	0.041	0.0766	0.0011	0.671	1182	14	1111	28	-6
25.1	161	74	0.46	29.8	0.000047	0.08	4.641	0.057	0.0791	0.0007	0.2153	0.0027	2.329	0.038	0.0784	0.0008	0.763	1257	14	1158	21	-9
26.1	436	136	0.31	105.2	0.000018	0.03	3.556	0.039	0.0935	0.0004	0.2811	0.0031	3.613	0.043	0.0932	0.0004	0.917	1597	15	1492	9	-7
27.1	243	187	0.77	70.2	0.000028	0.04	2.976	0.035	0.1041	0.0006	0.3359	0.0040	4.802	0.064	0.1037	0.0006	0.885	1867	19	1691	12	-10
28.1	130	77	0.59	35.7	-	<0.01	3.129	0.047	0.1043	0.0012	0.3197	0.0048	4.609	0.089	0.1046	0.0013	0.777	1788	23	1707	22	-5
29.1	79	47	0.59	21.4	0.000013	0.02	3.172	0.049	0.0986	0.0012	0.3152	0.0049	4.278	0.084	0.0984	0.0012	0.784	1766	24	1595	23	-11

30.1	58	83	1.44	13.2	0.000024	0.04	3.759	0.059	0.0925	0.0013	0.2659	0.0042	3.381	0.073	0.0922	0.0014	0.732	1520	21	1472	28	-3
31.1	317	168	0.53	76.9	0.000015	0.02	3.547	0.040	0.1004	0.0006	0.2819	0.0032	3.896	0.050	0.1002	0.0006	0.894	1601	16	1629	11	2
32.1	133	111	0.84	16.4	0.000071	0.12	6.958	0.100	0.0758	0.0020	0.1436	0.0021	1.480	0.050	0.0748	0.0023	0.428	865	12	1062	61	19
33.1	405	243	0.60	94.7	-	<0.01	3.675	0.040	0.1043	0.0005	0.2721	0.0030	3.916	0.047	0.1044	0.0005	0.915	1551	15	1703	9	9
34.1	60	16	0.26	15.2	-	<0.01	3.384	0.052	0.1008	0.0013	0.2955	0.0045	4.105	0.082	0.1008	0.0013	0.759	1669	22	1638	24	-2
35.1	76	26	0.35	10.3	0.000159	0.27	6.307	0.099	0.0743	0.0013	0.1581	0.0025	1.571	0.051	0.0720	0.0021	0.482	946	14	987	58	4
36.1	176	79	0.45	47.2	0.000576	0.91	3.202	0.039	0.1113	0.0007	0.3095	0.0038	4.415	0.089	0.1035	0.0017	0.607	1738	19	1687	30	-3
37.1	483	357	0.74	137.5	0.000026	0.04	3.019	0.033	0.1044	0.0005	0.3311	0.0037	4.748	0.057	0.1040	0.0005	0.916	1844	18	1697	9	-9
38.1	57	40	0.70	15.5	-	<0.01	3.157	0.049	0.1063	0.0013	0.3175	0.0050	4.744	0.106	0.1084	0.0017	0.699	1777	24	1772	29	0
39.1	779	369	0.47	191.1	0.000038	0.06	3.503	0.037	0.1032	0.0004	0.2853	0.0030	4.040	0.046	0.1027	0.0004	0.929	1618	15	1674	8	3
40.1	271	294	1.09	46.4	0.000017	0.03	5.013	0.062	0.0929	0.0008	0.1994	0.0025	2.548	0.039	0.0927	0.0009	0.795	1172	13	1481	18	21
41.1	213	135	0.63	47.9	0.000008	0.01	3.825	0.045	0.1045	0.0007	0.2614	0.0031	3.763	0.052	0.1044	0.0007	0.859	1497	16	1704	13	12
42.1	222	53	0.24	103.6	0.000042	0.06	1.844	0.021	0.1981	0.0007	0.5420	0.0062	14.763	0.177	0.1976	0.0007	0.952	2792	26	2806	6	1
43.1	209	128	0.61	58.1	0.000024	0.04	3.092	0.038	0.1045	0.0007	0.3233	0.0040	4.642	0.066	0.1041	0.0007	0.877	1806	20	1699	13	-6
44.1	154	105	0.68	43.0	0.000019	0.03	3.080	0.038	0.1048	0.0008	0.3246	0.0040	4.678	0.067	0.1045	0.0008	0.858	1812	20	1706	14	-6
45.1	257	174	0.68	73.5	0.000028	0.04	3.007	0.035	0.1051	0.0006	0.3324	0.0039	4.799	0.063	0.1047	0.0006	0.883	1850	19	1709	11	-8
46.1	358	255	0.71	86.9	0.000142	0.22	3.539	0.040	0.1058	0.0005	0.2819	0.0032	4.037	0.060	0.1038	0.0010	0.753	1601	16	1694	18	5
47.1	143	95	0.66	41.1	0.000020	0.03	3.001	0.038	0.1038	0.0008	0.3331	0.0042	4.755	0.072	0.1035	0.0009	0.830	1853	20	1688	16	-10
48.1	295	171	0.58	66.1	0.000175	0.28	3.832	0.042	0.1049	0.0005	0.2602	0.0029	3.678	0.050	0.1025	0.0008	0.810	1491	15	1670	15	11
49.1	258	250	0.97	67.7	0.000010	0.02	3.274	0.039	0.1047	0.0006	0.3053	0.0036	4.404	0.059	0.1046	0.0006	0.885	1718	18	1707	11	-1
50.1	303	208	0.69	77.1	0.000041	0.07	3.374	0.038	0.1038	0.0006	0.2961	0.0034	4.215	0.054	0.1032	0.0006	0.886	1672	17	1683	11	1
51.1	81	26	0.32	11.3	-	<0.01	6.100	0.096	0.0685	0.0012	0.1642	0.0026	1.575	0.043	0.0696	0.0015	0.581	980	14	917	45	-7
52.1	293	185	0.63	75.2	-	<0.01	3.344	0.039	0.1041	0.0006	0.2991	0.0034	4.297	0.056	0.1042	0.0006	0.891	1687	17	1700	11	1
53.1	177	123	0.69	47.3	0.000014	0.02	3.211	0.040	0.1076	0.0008	0.3114	0.0039	4.610	0.068	0.1074	0.0008	0.852	1748	19	1755	14	0
54.1	504	276	0.55	128.2	0.000037	0.06	3.376	0.038	0.1045	0.0004	0.2961	0.0033	4.245	0.051	0.1040	0.0005	0.920	1672	16	1696	9	1
55.1	411	103	0.25	91.1	0.000019	0.03	3.882	0.043	0.0946	0.0005	0.2575	0.0028	3.349	0.041	0.0943	0.0005	0.899	1477	15	1514	10	2
56.1	175	107	0.61	44.5	-	<0.01	3.371	0.041	0.1041	0.0010	0.2968	0.0036	4.275	0.069	0.1045	0.0011	0.763	1675	18	1705	19	2
57.1	197	175	0.89	49.7	0.000001	<0.01	3.405	0.041	0.1031	0.0007	0.2937	0.0035	4.173	0.058	0.1031	0.0007	0.863	1660	18	1680	13	1
58.1	61	23	0.37	7.1	0.000174	0.30	7.364	0.128	0.0676	0.0015	0.1358	0.0024	1.265	0.036	0.0676	0.0015	0.605	821	14	855	48	4
59.1	334	175	0.52	86.5	0.000001	<0.01	3.317	0.038	0.1045	0.0006	0.3015	0.0035	4.342	0.056	0.1044	0.0006	0.893	1699	17	1705	11	0
60.1	91	65	0.71	24.6	-	<0.01	3.191	0.046	0.1056	0.0011	0.3134	0.0045	4.562	0.080	0.1056	0.0011	0.816	1758	22	1724	19	-2
61.1	464	364	0.78	120.7	0.000037	0.06	3.300	0.036	0.1044	0.0005	0.3029	0.0033	4.337	0.053	0.1039	0.0006	0.898	1706	17	1694	10	-1

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.81% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Table 6
Summary of SHRIMP U–Pb zircon results for Saltelva river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios				r	Age (Ma)				% Disc		
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±		²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±		²⁰⁷ Pb/ ²⁰⁶ Pb	±
1.1	328	6	0.02	47.1	–	<0.01	5.974	0.079	0.0736	0.0009	0.1674	0.0022	1.700	0.030	0.0736	0.0009	0.744	998	12	1032	24	3
2.1	333	88	0.27	57.1	0.000025	0.04	5.013	0.065	0.0781	0.0008	0.1994	0.0026	2.138	0.037	0.0778	0.0009	0.759	1172	14	1141	22	–3
3.1	298	118	0.40	83.0	0.000009	0.01	3.084	0.040	0.1099	0.0008	0.3242	0.0042	4.908	0.075	0.1098	0.0009	0.860	1810	21	1796	14	–1
4.1	97	27	0.28	16.6	0.000086	0.15	5.017	0.095	0.0786	0.0016	0.1990	0.0038	2.124	0.059	0.0774	0.0016	0.679	1170	20	1131	41	–3
5.1	357	84	0.24	58.9	0.000189	0.30	5.208	0.081	0.0985	0.0011	0.1914	0.0030	2.530	0.064	0.0958	0.0019	0.615	1129	16	1545	38	27
6.1	621	345	0.56	127.7	0.000292	0.47	4.180	0.057	0.0957	0.0009	0.2372	0.0033	2.896	0.057	0.0886	0.0012	0.699	1372	19	1394	27	2
7.1	1474	189	0.13	225.9	0.000019	0.03	5.606	0.061	0.0748	0.0004	0.1783	0.0019	1.831	0.023	0.0745	0.0004	0.875	1058	11	1054	12	0
8.1	416	181	0.44	71.0	–	<0.01	5.025	0.064	0.0778	0.0007	0.1993	0.0025	2.169	0.042	0.0790	0.0012	0.657	1171	14	1171	29	0
9.1	257	94	0.37	52.7	0.000039	0.06	4.183	0.058	0.0870	0.0009	0.2389	0.0033	2.846	0.053	0.0864	0.0011	0.745	1381	17	1347	24	–2
10.1	202	24	0.12	51.4	0.000076	0.12	3.367	0.058	0.1038	0.0011	0.2966	0.0051	4.202	0.094	0.1028	0.0015	0.764	1674	25	1675	27	0
11.1	336	172	0.51	142.1	0.000034	0.05	2.033	0.026	0.1902	0.0009	0.4916	0.0062	12.866	0.173	0.1898	0.0009	0.938	2578	27	2740	8	6
12.1	59	41	0.69	12.8	0.000565	0.93	3.963	0.090	0.0930	0.0020	0.2522	0.0057	3.219	0.101	0.0926	0.0020	0.722	1450	33	1479	41	2
13.1	171	104	0.61	44.7	0.000104	0.17	3.290	0.049	0.1009	0.0010	0.3035	0.0045	4.164	0.078	0.0995	0.0011	0.795	1709	22	1615	21	–6
15.1	42	36	0.87	10.4	0.000917	1.46	3.414	0.100	0.1138	0.0030	0.2887	0.0087	4.027	0.311	0.1012	0.0072	0.389	1635	43	1646	132	1
16.1	931	276	0.30	250.0	0.000023	0.03	3.200	0.038	0.1494	0.0006	0.3124	0.0038	6.421	0.082	0.1491	0.0006	0.941	1753	18	2335	7	25
17.1	47	18	0.37	8.1	–	<0.01	4.981	0.133	0.0841	0.0026	0.1995	0.0053	2.167	0.095	0.0788	0.0027	0.612	1173	31	1167	68	–1
18.1	95	56	0.59	22.7	–	<0.01	3.579	0.066	0.0961	0.0015	0.2800	0.0053	3.774	0.141	0.0978	0.0032	0.503	1591	27	1582	61	–1
19.1	483	124	0.26	87.7	0.000623	1.02	4.730	0.059	0.0948	0.0011	0.2086	0.0026	2.406	0.059	0.0836	0.0018	0.509	1221	15	1284	41	5
20.1	122	37	0.30	17.7	0.000299	0.51	5.904	0.102	0.0752	0.0014	0.1694	0.0029	1.763	0.045	0.0755	0.0014	0.677	1009	17	1081	38	7
21.1	168	78	0.47	46.2	0.000024	0.04	3.123	0.047	0.1093	0.0010	0.3201	0.0048	4.810	0.087	0.1090	0.0011	0.835	1790	24	1783	18	0
22.1	109	33	0.31	31.8	0.000103	0.16	2.944	0.051	0.1122	0.0013	0.3399	0.0059	5.282	0.111	0.1127	0.0013	0.832	1886	30	1843	21	–2
23.1	55	55	1.00	8.6	0.000136	0.23	5.475	0.129	0.0784	0.0048	0.1822	0.0046	1.921	0.224	0.0765	0.0087	0.215	1079	25	1107	227	3
24.1	147	72	0.49	29.9	–	<0.01	4.218	0.066	0.0932	0.0012	0.2374	0.0037	3.089	0.062	0.0944	0.0012	0.781	1373	19	1516	24	9
25.1	1214	324	0.27	293.8	0.000051	0.08	3.550	0.040	0.0988	0.0004	0.2815	0.0032	3.808	0.047	0.0981	0.0005	0.915	1599	16	1589	9	–1
26.1	330	124	0.37	87.5	0.000007	0.01	3.239	0.041	0.1097	0.0008	0.3087	0.0039	4.663	0.071	0.1096	0.0009	0.842	1734	19	1792	15	3
27.1	383	196	0.51	84.5	0.000025	0.04	3.893	0.049	0.0935	0.0007	0.2568	0.0032	3.297	0.049	0.0931	0.0007	0.847	1473	16	1490	15	1
29.1	74	53	0.71	17.9	0.000331	0.54	3.578	0.075	0.0965	0.0016	0.2807	0.0058	3.863	0.103	0.0998	0.0017	0.778	1595	33	1621	31	2
30.1	103	41	0.40	15.6	0.000214	0.37	5.667	0.103	0.0750	0.0014	0.1758	0.0032	1.745	0.063	0.0720	0.0022	0.506	1044	18	985	64	–6
31.1	145	35	0.24	18.1	0.006774	12.00	6.863	0.104	0.1585	0.0019	0.1282	0.0026	1.066	0.313	0.0603	0.0177	0.069	778	15	615	633	–27
32.1	173	47	0.27	27.0	0.000072	0.12	5.519	0.078	0.0760	0.0010	0.1810	0.0026	1.870	0.041	0.0749	0.0012	0.652	1072	14	1067	33	–1
33.1	209	109	0.52	27.6	0.000212	0.35	6.526	0.103	0.0927	0.0060	0.1527	0.0024	1.889	0.132	0.0897	0.0061	0.225	916	13	1420	130	35
34.1	187	70	0.37	40.9	0.000162	0.27	3.925	0.052	0.0891	0.0009	0.2550	0.0034	3.155	0.052	0.0897	0.0009	0.814	1464	18	1420	18	–3
35.1	593	194	0.33	122.4	0.000064	0.10	4.162	0.047	0.1050	0.0005	0.2401	0.0027	3.447	0.045	0.1041	0.0007	0.864	1387	14	1699	12	18

36.1	257	186	0.72	74.1	0.000020	0.03	2.981	0.039	0.1114	0.0008	0.3354	0.0044	5.137	0.081	0.1111	0.0010	0.823	1864	21	1817	16	−3
37.1	185	61	0.33	32.2	0.000258	0.44	4.917	0.071	0.0777	0.0010	0.2035	0.0029	2.198	0.042	0.0783	0.0010	0.761	1194	16	1155	24	−3
38.1	605	139	0.23	160.0	0.000011	0.02	3.247	0.037	0.1009	0.0005	0.3079	0.0035	4.278	0.052	0.1008	0.0005	0.920	1730	17	1638	9	−6
39.1	159	78	0.49	41.6	0.000044	0.07	3.293	0.047	0.1034	0.0010	0.3035	0.0043	4.303	0.078	0.1028	0.0012	0.782	1709	21	1676	21	−2
40.1	142	60	0.42	25.9	0.000130	0.22	4.717	0.069	0.0832	0.0011	0.2115	0.0031	2.373	0.070	0.0814	0.0021	0.499	1237	17	1230	50	−1
41.1	95	111	1.16	13.5	0.000311	0.54	6.045	0.119	0.0704	0.0015	0.1660	0.0033	1.684	0.049	0.0735	0.0016	0.675	990	22	1029	44	4
42.1	39	17	0.45	6.9	0.001645	2.81	4.829	0.311	0.0953	0.0049	0.2067	0.0133	2.664	0.221	0.0935	0.0049	0.777	1211	76	1498	99	19
43.1	180	75	0.42	34.7	0.000373	0.61	4.463	0.062	0.0960	0.0010	0.2227	0.0031	2.789	0.066	0.0908	0.0017	0.586	1296	16	1443	37	10
44.1	133	46	0.30	36.6	0.000129	0.20	3.126	0.045	0.1112	0.0010	0.3193	0.0046	4.817	0.098	0.1094	0.0016	0.715	1786	23	1790	26	0
45.1	90	44	0.49	16.8	0.000112	0.18	4.581	0.073	0.0903	0.0013	0.2179	0.0035	2.666	0.087	0.0887	0.0025	0.490	1271	19	1399	55	9
46.1	101	35	0.35	18.4	0.000460	0.79	4.719	0.075	0.0790	0.0012	0.2118	0.0034	2.290	0.050	0.0784	0.0012	0.728	1238	19	1158	30	−7
47.1	189	140	0.74	25.9	0.000054	0.09	6.251	0.086	0.0725	0.0009	0.1598	0.0022	1.582	0.041	0.0718	0.0016	0.537	956	12	979	44	2
48.1	147	54	0.37	32.6	0.000075	0.12	3.862	0.054	0.0966	0.0010	0.2586	0.0036	3.409	0.067	0.0956	0.0013	0.715	1483	19	1540	26	4
49.1	49	31	0.63	14.6	0.000410	0.64	2.898	0.055	0.1125	0.0016	0.3451	0.0066	5.356	0.127	0.1126	0.0016	0.806	1911	35	1841	25	−4
50.1	235	90	0.38	38.7	0.000003	0.00	5.221	0.067	0.0759	0.0008	0.1915	0.0025	2.004	0.034	0.0759	0.0009	0.751	1130	13	1092	23	−3
51.1	407	180	0.44	110.5	–	<0.01	3.162	0.037	0.1099	0.0006	0.3163	0.0037	4.797	0.063	0.1100	0.0007	0.887	1772	18	1799	11	2
52.1	228	88	0.39	34.7	0.000034	0.06	5.641	0.073	0.0746	0.0008	0.1773	0.0023	1.832	0.030	0.0749	0.0008	0.773	1052	13	1066	21	1
53.1	1315	225	0.17	294.8	0.000015	0.02	3.832	0.041	0.0926	0.0003	0.2609	0.0028	3.323	0.038	0.0924	0.0004	0.940	1494	14	1475	7	−1
54.1	62	42	0.68	10.4	0.000373	0.63	5.155	0.095	0.0791	0.0016	0.1940	0.0036	2.119	0.057	0.0792	0.0016	0.684	1143	22	1177	39	3
55.1	299	121	0.40	48.0	0.000081	0.14	5.352	0.067	0.0760	0.0007	0.1870	0.0023	1.979	0.031	0.0767	0.0007	0.799	1105	13	1114	19	1
56.1	745	20	0.03	52.8	0.000000	0.00	12.104	0.136	0.0578	0.0006	0.0826	0.0009	0.658	0.010	0.0578	0.0006	0.743	512	6	521	22	2
57.1	53	60	1.12	14.4	0.000468	0.75	3.192	0.059	0.1034	0.0015	0.3131	0.0058	4.449	0.105	0.1030	0.0015	0.783	1756	34	1680	27	−5
58.1	12	8	0.67	5.2	0.001118	1.54	1.910	0.062	0.1927	0.0037	0.5179	0.0167	13.193	0.510	0.1848	0.0039	0.837	2690	78	2696	35	0
59.1	155	38	0.25	43.0	–	<0.01	3.101	0.042	0.1080	0.0009	0.3226	0.0043	4.820	0.081	0.1083	0.0011	0.802	1803	21	1772	18	−2
60.1	63	52	0.82	10.0	0.000002	0.00	5.464	0.098	0.0746	0.0015	0.1830	0.0033	1.883	0.055	0.0746	0.0017	0.611	1083	18	1058	47	−2

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.88% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb^* is the proportion of Pb that is radiogenic.

Table 7
Summary of SHRIMP U–Pb zircon results for Vefsna river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios					r	Age (Ma)					% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb		±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	
1.1	190	238	1.25	60.1	0.000060	0.09	3.399	0.045	0.1037	0.0009	0.2939	0.0039	4.170	0.068	0.1029	0.0010	0.821	1661	20	1677	17	1
2.1	67	209	3.10	36.4	0.000036	0.06	4.927	0.069	0.0764	0.0009	0.2030	0.0028	2.147	0.039	0.0767	0.0009	0.766	1192	16	1113	23	-7
3.1	26	42	1.62	5.9	0.001040	1.84	6.129	0.159	0.0759	0.0025	0.1624	0.0042	1.613	0.071	0.0720	0.0026	0.590	970	26	987	72	2
4.1	34	34	1.00	14.0	0.000147	0.21	2.073	0.053	0.1649	0.0024	0.4820	0.0122	10.924	0.321	0.1644	0.0024	0.863	2536	60	2501	25	-1
5.1	749	2445	3.27	141.5	0.000934	1.67	14.842	0.156	0.0708	0.0004	0.0662	0.0007	0.523	0.021	0.0572	0.0022	0.267	414	4	500	84	17
6.1	151	624	4.13	113.6	0.000335	0.53	4.717	0.054	0.1063	0.0006	0.2109	0.0024	2.956	0.047	0.1017	0.0011	0.718	1233	13	1655	21	25
7.1	56	121	2.17	18.7	0.000235	0.40	5.549	0.091	0.0751	0.0013	0.1795	0.0030	1.774	0.078	0.0717	0.0029	0.379	1064	16	977	83	-9
8.1	50	192	3.86	52.7	0.000063	0.10	3.122	0.043	0.1078	0.0009	0.3200	0.0044	4.717	0.080	0.1069	0.0011	0.812	1789	22	1748	18	-2
9.1	176	716	4.06	96.2	0.000690	1.11	6.393	0.074	0.1044	0.0007	0.1547	0.0018	2.024	0.050	0.0949	0.0020	0.476	927	10	1526	41	39
10.1	21	81	3.85	15.2	0.000806	1.32	4.587	0.083	0.1001	0.0017	0.2151	0.0040	2.636	0.132	0.0889	0.0041	0.372	1256	21	1401	89	10
11.1	18	34	1.92	10.2	-	<0.01	2.866	0.071	0.1151	0.0023	0.3489	0.0087	5.539	0.178	0.1151	0.0023	0.773	1929	41	1882	37	-3
12.1	83	249	3.00	38.2	0.000074	0.13	5.589	0.075	0.0745	0.0009	0.1787	0.0024	1.809	0.043	0.0734	0.0014	0.571	1060	13	1025	39	-3
13.1	49	123	2.51	22.1	0.000307	0.52	4.762	0.075	0.0793	0.0012	0.2101	0.0033	2.312	0.050	0.0798	0.0012	0.733	1229	19	1192	29	-3
14.1	86	118	1.36	19.3	0.000050	0.08	5.234	0.087	0.0780	0.0014	0.1909	0.0032	2.035	0.069	0.0773	0.0023	0.492	1126	17	1129	59	0
15.1	128	307	2.39	53.5	0.000165	0.28	4.940	0.068	0.0783	0.0007	0.2025	0.0028	2.197	0.037	0.0787	0.0007	0.829	1189	16	1164	18	-2
16.1	82	104	1.28	23.7	-	<0.01	3.780	0.066	0.0948	0.0014	0.2645	0.0046	3.453	0.080	0.0947	0.0014	0.751	1513	26	1522	29	1
17.1	138	216	1.57	57.7	0.000064	0.10	3.220	0.043	0.1024	0.0009	0.3103	0.0041	4.342	0.074	0.1015	0.0011	0.788	1742	20	1652	19	-5
18.1	283	640	2.26	134.8	0.000039	0.06	4.076	0.046	0.1067	0.0006	0.2452	0.0028	3.588	0.046	0.1061	0.0006	0.883	1414	14	1734	11	18
19.1	51	73	1.45	9.2	0.000252	0.42	6.801	0.131	0.0820	0.0018	0.1464	0.0029	1.582	0.085	0.0784	0.0039	0.366	881	16	1157	99	24
20.1	254	385	1.51	25.8	-	<0.01	12.807	0.183	0.0556	0.0009	0.0782	0.0011	0.617	0.017	0.0572	0.0014	0.516	486	7	499	53	3
21.1	148	334	2.26	99.3	0.000027	0.04	2.885	0.035	0.1101	0.0006	0.3465	0.0042	5.242	0.073	0.1097	0.0007	0.879	1918	20	1795	12	-7
22.1	303	367	1.21	25.2	0.000073	0.13	12.521	0.165	0.0573	0.0009	0.0798	0.0011	0.626	0.013	0.0569	0.0009	0.629	495	7	486	36	-2
23.1	105	168	1.60	46.4	0.000097	0.16	3.114	0.051	0.0881	0.0009	0.3228	0.0053	4.112	0.082	0.0924	0.0010	0.822	1804	29	1475	21	-22
24.1	148	506	3.43	130.7	0.000043	0.07	3.330	0.039	0.1101	0.0006	0.3001	0.0035	4.531	0.060	0.1095	0.0007	0.888	1692	17	1791	11	6
25.1	21	40	1.93	6.9	0.003969	7.42	5.017	0.263	0.0971	0.0064	0.1966	0.0103	2.322	0.217	0.0857	0.0066	0.560	1157	62	1331	150	13
26.1	263	268	1.02	18.0	0.000293	0.53	12.788	0.179	0.0577	0.0010	0.0784	0.0011	0.641	0.014	0.0593	0.0011	0.620	486	8	580	39	16
27.1	104	398	3.81	58.5	0.000074	0.13	5.838	0.073	0.0772	0.0008	0.1706	0.0021	1.742	0.030	0.0741	0.0009	0.711	1016	12	1043	25	3
28.1	413	1399	3.39	86.4	0.000074	0.13	13.911	0.157	0.0565	0.0005	0.0719	0.0008	0.556	0.008	0.0561	0.0005	0.813	447	5	455	18	2
29.1	83	211	2.55	48.1	0.000311	0.50	3.772	0.050	0.1025	0.0009	0.2638	0.0035	3.571	0.077	0.0982	0.0017	0.621	1509	18	1590	32	5
30.1	101	316	3.12	50.5	0.000060	0.10	5.368	0.067	0.0771	0.0007	0.1861	0.0023	1.956	0.036	0.0762	0.0010	0.672	1100	13	1102	27	0
31.1	21	39	1.85	5.5	-	<0.01	6.073	0.148	0.0659	0.0022	0.1662	0.0042	1.693	0.142	0.0739	0.0059	0.301	991	23	1038	162	4
32.1	291	569	1.95	48.3	0.001326	2.38	10.130	0.116	0.0760	0.0007	0.0967	0.0011	0.785	0.030	0.0588	0.0022	0.298	595	7	561	80	-6

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.88% for the analytical session (not included in above errors but required when comparing ²⁰⁶Pb/²³⁸U data from different mounts). f₂₀₆% denotes the percentage of ²⁰⁶Pb that is common Pb. Correction for common Pb made using the measured ²⁰⁴Pb/²⁰⁶Pb ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

concordance on the Tera and Wasserburg plot), the relative concentrations of U and Th, the nature of the area analysed when examined post analysis, and the abundance of a particular age grouping. Zircon age data from the samples are presented in Tables 2–9, and are shown on combined histogram-relative probability plots in Figs. 2 and 3.

4. Zircon age data and provenance implications

4.1. Fennoscandian Shield

The age spectra from two samples of river sediment derived from the northern part of the Fennoscandian domain in Sweden (Byskeälven and Raneälven) are relatively simple. The spectrum from Byskeälven has a bimodal pattern, with a main peak at 1.80 Ga and a subordinate peak at 1.87 Ga (Fig. 2). By contrast, the Raneälven spectrum has a single main peak at 1.89 Ga, although there is a small secondary group comprising five zircons dated between c. 1.76 and 1.79 Ga (Fig. 2). Both samples have a small number of younger Proterozoic zircons ranging down to c. 940 Ma, the Byskeälven sample containing more of these than the Raneälven sample. Neither sample contains any unambiguous Archaean or pre-1.95 Ga zircons, apart from grain 48.1 in the Raneälven sample, which has an apparent age of c. 3.5 Ga but is markedly discordant (Table 3).

The main peaks in the Raneälven and Byskeälven zircon age spectra can be directly matched with Svecokarelian phase 1 and Svecokarelian phase 2. The group peaking at 1.89 Ga in the Raneälven sample directly correlates with the age range of the Svecokarelian phase 1, and the small number of zircons between c. 1.76–1.79 Ga correlate with the end of Svecokarelian phase 2. The main peak in the Byskeälven sample (1.80 Ga) corresponds to Svecokarelian phase 2, and the subordinate peak at c. 1.87 Ga is close to the range of Svecokarelian phase 1. The origin of the small number of younger grains is more speculative. Those between c. 1.70 and 1.54 Ga may represent erosional products of post-orogenic granites, which are found sporadically within the Svecofennian Domain (Gaal and Gorbatschev, 1987; Koistinen et al., 2001). The small number of younger zircons, especially those between c. 940 Ma and 1130 Ma, presumably diagnose minor input from the Caledonian Nappe Domain further to the west, although neither river appears to drain this region at present.

The absence of proven Archaean or pre-1.95 Ga zircons in the two samples indicates that very little detritus was supplied by the metasedimentary units within the Fennoscandian Shield area. The metasediments from the Svecofennian Domain contain two main groups of zircon, Archaean (mostly 2.97–2.60 Ga) and early Proterozoic (2.12–1.88 Ga), the latter being the predominant group (Claesson et al., 1993; Skiöld and Rutland, 2006; Bergman et al., 2008). The absence of such zircons in the two samples is interpreted as reflecting the biased nature of the zircon population, since it implies that most of the zircons were derived from the granitoid rocks and comparatively few from the metasediments.

4.2. Archaean

Lainioälven almost exclusively drains the Archaean domain in northern Sweden (Fig. 1). The age spectrum (Fig. 2) has a bimodal pattern, with a well-defined peak at c. 1.80 Ga and a broader group between 2.65 and 2.78 Ga. The latter group corresponds to the age of the granitoids, migmatites and grey gneisses that form the Archaean basement in the Lainioälven drainage basin, which are considered to have formed between 2.75–2.50 Ga (Koistinen et al., 2001). The 1.80 Ga peak directly matches the main peak in the sample from Byskeälven, indicating that the main phase of metamorphic reworking of the Archaean took place during Svecokarelian phase 2. There is no evidence for zircons derived from the Lapponian volcanic succession,

which has an upper age limit of c. 2.3 Ga (Gaal and Gorbatschev, 1987). This probably reflects the composition of the Lapponian volcanic succession, which consists predominantly of mafic or ultramafic rocks, lithologies that are generally zircon-poor. There is also no evidence for derivation from Saamian basement rocks (3.1–2.9 Ga), consistent with regional data that suggest basement of this age is confined to Finland and the Kola Peninsula (Koistinen et al., 2001).

4.3. Trans-Scandinavian igneous belt

The zircon population from the Ljusnan river, which drains the Dalarna province of the Trans-Scandinavian Igneous Belt (Fig. 1) comprises a single main group peaking at 1.70 Ga (Fig. 2), corresponding precisely to TIB2 as defined by (Larson and Berglund, 1992). Curiously, although both TIB1 (which correlates with the late Svecofennian granitoid intrusion phase) and TIB2 events are recorded in the Dalarna province (Larson and Berglund, 1992), the river sample only identifies the younger of the two episodes. This either indicates significant regional differences in age of the granitoid rocks in the Dalarna province, or that TIB1 granitoids are volumetrically minor in the Ljusnan river catchment. There are scattered younger zircons in the Ljusnan river sample, ranging down to c. 0.80 Ga. These zircons probably represent minor supply from the Caledonian Nappe Domain, since the Ljusnan catchment extends into a region comprising the Lower/Middle Allochthon.

4.4. Caledonian Nappe Domain

The four zircon age spectra from modern river sediments derived from the Caledonian Nappe Domain are broadly similar, being composed almost exclusively of Proterozoic zircons between c. 0.80 Ga and c. 1.85 Ga (Fig. 3). This compares well with the only other available data from metasediments of the Caledonian Nappe Domain, since the 15 detrital zircons analysed by Williams and Claesson (1987) from the Seve Nappes fall into the same age range. In addition, the Vefsna sample contains a significant number of Early Paleozoic zircons, which form c. 15% (5 out of 32 grains) of the population, and a single late Neoproterozoic grain (595 ± 7 Ma). The Saltelva and Vefsna samples also contain a small number of Archaean grains, two being present in the Saltelva sample and one in the Vefsna sample.

The four spectra share several common elements within the Proterozoic part of the spectra (Fig. 4). Vefsna, Saltelva and Vindelälven all show a major peak at c.1.79–1.80 Ga, an event that is poorly represented in the Ljungan sample. All samples have major group at c.1.64–1.67 Ga, together with younger zircons ranging down to c. 1.55 Ga. Saltelva, Vindelälven and Ljungan contain significant clusters of zircons between c. 1.45 Ma and 1.50 Ga. There is relatively little representation between 1.40 Ga and 1.20 Ga. All four samples have broadly bimodal patterns within the 0.90–1.22 Ga range, with peaks between c. 1.15 Ga and 1.22 Ga and between c. 0.95 Ga and 1.06 Ga. In addition, the Vefsna sample has minor peaks at c. 1.74 Ga and c. 1.10 Ga that are not represented in the other samples.

These peaks can be directly related to events in Baltica. The peak at c. 1.79–1.80 Ga group is the same age as the basement windows and allochthonous granites within the Caledonian Nappe Domain (Skär, 2002; Rehnström and Corfu, 2004), which correlate with Svecokarelian phase 2 granitoids and the oldest Trans-Scandinavian event, TIB1 (Gaal and Gorbatschev, 1987; Larson and Berglund, 1992; Koistinen et al., 2001). The minor peak at c. 1.74 Ga in the Vefsna sample corresponds to the ages of granitoids in the Rombak–Sjangeli basement window (Rehnström and Corfu, 2004). The 1.64–1.67 Ga peak corresponds to the Gothian/Kongsbergian orogeny, which is the main crust-forming event in southwest Scandinavia and the Western Gneiss Region (Gaal and Gorbatschev, 1987; Gower et al., 1991; Tucker et al.,

Table 8
Summary of SHRIMP U–Pb zircon results for Vindelälven river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios				r	Age (Ma)						
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±		²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	% Disc
1.1	139	93	0.67	34.2	0.000048	0.08	3.486	0.075	0.1003	0.0012	0.2866	0.0062	3.938	0.101	0.0996	0.0014	0.845	1625	31	1617	25	0
2.1	83	51	0.61	12.5	0.000908	1.57	5.726	0.100	0.0805	0.0016	0.1723	0.0030	1.646	0.058	0.0693	0.0021	0.492	1025	19	907	64	−13
3.1	530	141	0.27	98.0	0.000010	0.02	4.647	0.054	0.0806	0.0006	0.2152	0.0025	2.388	0.034	0.0805	0.0007	0.808	1256	13	1209	17	−4
4.1	184	68	0.37	51.6	−	<0.01	3.060	0.041	0.1115	0.0010	0.3272	0.0044	5.084	0.087	0.1127	0.0012	0.786	1825	21	1843	19	1
5.1	64	31	0.48	8.6	−	<0.01	6.421	0.121	0.0734	0.0018	0.1560	0.0030	1.612	0.062	0.0749	0.0025	0.496	935	16	1066	67	12
6.1	29	27	0.91	4.7	0.000496	0.82	5.349	0.135	0.0936	0.0029	0.1854	0.0048	2.215	0.171	0.0867	0.0063	0.338	1097	26	1353	140	19
7.1	459	207	0.45	123.9	−	<0.01	3.183	0.037	0.1070	0.0006	0.3144	0.0037	4.665	0.061	0.1076	0.0006	0.901	1762	19	1760	10	0
8.1	723	110	0.15	108.1	0.000015	0.03	5.743	0.065	0.0735	0.0005	0.1741	0.0020	1.759	0.024	0.0733	0.0005	0.848	1035	11	1021	14	−1
9.1	222	94	0.42	31.2	0.000488	0.79	6.110	0.089	0.1006	0.0012	0.1624	0.0024	2.101	0.072	0.0939	0.0029	0.430	970	13	1505	59	36
10.1	276	67	0.24	74.6	0.000080	0.13	3.182	0.040	0.1107	0.0008	0.3138	0.0040	4.742	0.074	0.1096	0.0010	0.807	1760	19	1792	17	2
11.1	618	203	0.33	164.0	0.000025	0.04	3.237	0.039	0.1100	0.0006	0.3088	0.0037	4.671	0.063	0.1097	0.0007	0.890	1735	18	1794	11	3
12.1	199	128	0.65	46.4	0.000028	0.05	3.681	0.049	0.0988	0.0010	0.2715	0.0036	3.683	0.063	0.0984	0.0010	0.784	1548	18	1594	20	3
13.1	180	72	0.40	29.0	0.000156	0.26	5.311	0.079	0.0794	0.0013	0.1878	0.0028	1.998	0.061	0.0772	0.0020	0.494	1109	15	1126	53	1
14.1	531	116	0.22	115.3	0.000027	0.04	3.956	0.047	0.0999	0.0006	0.2527	0.0030	3.468	0.047	0.0995	0.0007	0.865	1452	15	1616	13	10
15.1	417	239	0.57	82.7	0.000046	0.07	4.331	0.054	0.0917	0.0009	0.2307	0.0029	2.898	0.049	0.0911	0.0010	0.740	1338	15	1448	22	8
16.1	298	204	0.68	72.8	0.000146	0.23	3.523	0.044	0.1032	0.0008	0.2832	0.0036	3.952	0.067	0.1012	0.0011	0.746	1608	18	1646	21	2
17.1	679	347	0.51	96.4	0.000164	0.27	6.049	0.071	0.0887	0.0007	0.1649	0.0020	1.963	0.039	0.0864	0.0014	0.598	984	11	1347	31	27
18.1	1191	421	0.35	261.7	0.000130	0.21	3.909	0.044	0.0928	0.0004	0.2553	0.0029	3.204	0.041	0.0910	0.0006	0.878	1466	15	1447	12	−1
19.1	505	248	0.49	124.8	−	<0.01	3.476	0.041	0.1012	0.0006	0.2877	0.0034	4.016	0.054	0.1012	0.0006	0.880	1630	17	1647	12	1
20.1	448	783	1.75	102.4	0.000050	0.08	3.762	0.045	0.0937	0.0007	0.2656	0.0032	3.406	0.051	0.0930	0.0008	0.801	1518	16	1488	17	−2
21.1	91	47	0.52	19.0	0.000072	0.12	4.105	0.124	0.0918	0.0018	0.2433	0.0074	3.047	0.113	0.0908	0.0020	0.813	1404	38	1443	41	3
22.1	209	92	0.44	46.2	0.000375	0.59	3.877	0.052	0.1091	0.0011	0.2564	0.0035	3.675	0.083	0.1039	0.0019	0.592	1471	18	1696	34	13
23.1	684	529	0.77	162.8	0.000002	<0.01	3.611	0.042	0.1013	0.0006	0.2769	0.0032	3.868	0.051	0.1013	0.0006	0.883	1576	16	1648	11	4
24.1	467	87	0.19	118.8	0.000006	0.01	3.378	0.041	0.1099	0.0007	0.2960	0.0036	4.483	0.063	0.1098	0.0008	0.864	1671	18	1797	13	7
25.1	271	78	0.29	64.9	0.000105	0.17	3.591	0.047	0.1020	0.0009	0.2780	0.0037	3.855	0.065	0.1006	0.0011	0.775	1581	18	1635	20	3
26.1	477	116	0.24	129.4	0.000022	0.03	3.167	0.037	0.1089	0.0007	0.3156	0.0037	4.726	0.064	0.1086	0.0007	0.868	1768	18	1776	12	0
27.1	43	17	0.38	7.5	0.000649	1.11	4.980	0.117	0.0802	0.0027	0.2013	0.0047	2.285	0.092	0.0823	0.0027	0.586	1182	27	1253	64	6
28.1	209	211	1.01	26.2	0.000178	0.31	6.837	0.097	0.0715	0.0011	0.1458	0.0021	1.386	0.037	0.0689	0.0016	0.532	877	12	896	47	2
29.1	86	43	0.50	12.1	−	<0.01	6.074	0.110	0.0757	0.0018	0.1653	0.0030	1.797	0.071	0.0789	0.0028	0.465	986	17	1169	69	16

30.1	35	21	0.60	6.4	–	<0.01	4.716	0.116	0.0930	0.0027	0.2104	0.0052	2.503	0.103	0.0863	0.0029	0.595	1231	30	1345	64	8
31.1	108	82	0.76	26.5	0.000210	0.34	3.494	0.057	0.1002	0.0014	0.2875	0.0047	4.114	0.088	0.1038	0.0014	0.762	1629	26	1693	25	4
32.1	80	64	0.80	11.3	0.000387	0.65	6.097	0.124	0.0834	0.0020	0.1629	0.0034	1.750	0.123	0.0779	0.0052	0.301	973	19	1144	133	15
33.1	145	41	0.28	21.3	0.000094	0.16	5.825	0.083	0.0734	0.0011	0.1714	0.0025	1.703	0.063	0.0721	0.0024	0.395	1020	14	988	69	–3
34.1	247	91	0.37	56.7	0.000056	0.09	3.747	0.047	0.0920	0.0008	0.2667	0.0034	3.353	0.055	0.0912	0.0009	0.770	1524	17	1451	20	–5
34.2	189	81	0.43	48.2	0.000048	0.08	3.371	0.047	0.1035	0.0010	0.2965	0.0041	4.206	0.074	0.1029	0.0011	0.789	1674	21	1677	20	0
35.2	106	31	0.29	23.6	0.000124	0.20	3.842	0.059	0.0927	0.0013	0.2599	0.0040	3.274	0.069	0.0914	0.0013	0.731	1489	21	1455	27	–2
36.1	117	5	0.04	21.9	–	<0.01	4.577	0.084	0.0876	0.0014	0.2185	0.0040	2.639	0.064	0.0876	0.0014	0.759	1274	21	1374	30	7
37.1	186	98	0.53	46.8	0.000120	0.19	3.420	0.045	0.1055	0.0009	0.2919	0.0039	4.181	0.090	0.1039	0.0018	0.617	1651	19	1695	31	3
38.1	73	32	0.44	16.8	0.000115	0.19	3.720	0.063	0.0916	0.0014	0.2683	0.0046	3.330	0.077	0.0900	0.0014	0.730	1532	25	1426	30	–7
39.1	576	236	0.41	142.2	0.000018	0.03	3.481	0.040	0.1016	0.0005	0.2872	0.0033	4.014	0.052	0.1014	0.0006	0.885	1627	16	1650	11	1
40.1	138	31	0.23	37.3	0.000090	0.14	3.188	0.048	0.1078	0.0011	0.3135	0.0048	4.643	0.085	0.1074	0.0011	0.825	1758	24	1756	19	0
41.1	827	285	0.30	190.3	0.000028	0.04	3.733	0.041	0.0999	0.0004	0.2678	0.0029	3.674	0.044	0.0995	0.0005	0.921	1530	15	1615	9	5
42.1	507	202	0.40	142.7	0.000076	0.12	3.052	0.035	0.1069	0.0006	0.3283	0.0038	4.905	0.063	0.1084	0.0006	0.904	1830	19	1772	10	–3
43.1	269	44	0.16	38.6	0.000066	0.11	5.984	0.086	0.0759	0.0042	0.1669	0.0024	1.726	0.103	0.0750	0.0043	0.242	995	13	1069	116	7
44.1	128	86	0.67	33.4	0.000134	0.21	3.305	0.048	0.1034	0.0011	0.3038	0.0044	4.461	0.082	0.1065	0.0012	0.797	1710	24	1741	20	2
45.1	47	18	0.38	8.2	0.000176	0.29	4.916	0.102	0.0819	0.0024	0.2028	0.0044	2.221	0.178	0.0794	0.0061	0.272	1190	24	1183	152	–1
46.1	369	246	0.67	86.2	–	<0.01	3.679	0.044	0.0977	0.0007	0.2718	0.0033	3.671	0.051	0.0980	0.0007	0.861	1550	17	1586	13	2
47.1	326	104	0.32	87.0	0.000004	0.01	3.225	0.039	0.1091	0.0007	0.3100	0.0038	4.660	0.065	0.1090	0.0008	0.863	1741	18	1783	13	2
48.1	202	41	0.20	54.5	0.000107	0.17	3.191	0.042	0.1085	0.0009	0.3129	0.0042	4.617	0.079	0.1070	0.0012	0.775	1755	20	1750	20	0
49.1	210	85	0.41	52.5	0.000055	0.09	3.434	0.050	0.1037	0.0010	0.2910	0.0042	4.129	0.077	0.1029	0.0012	0.778	1646	21	1678	22	2
50.1	80	77	0.96	20.9	0.000040	0.06	3.274	0.055	0.1016	0.0014	0.3062	0.0051	4.374	0.095	0.1036	0.0014	0.775	1722	29	1690	25	–2
51.1	214	100	0.47	57.0	–	<0.01	3.222	0.042	0.1106	0.0009	0.3104	0.0041	4.745	0.074	0.1109	0.0009	0.840	1743	20	1814	15	4
52.1	611	157	0.26	159.9	0.000065	0.10	3.283	0.039	0.1100	0.0006	0.3043	0.0036	4.576	0.062	0.1091	0.0007	0.880	1713	18	1784	12	4
53.1	32	12	0.38	8.5	0.000643	1.02	3.249	0.081	0.1092	0.0025	0.3066	0.0077	4.485	0.156	0.1061	0.0026	0.718	1724	40	1733	44	1
54.1	493	203	0.41	118.7	–	<0.01	3.570	0.042	0.1021	0.0006	0.2801	0.0033	3.943	0.052	0.1021	0.0006	0.893	1592	17	1662	11	4
55.1	511	297	0.58	69.7	0.000034	0.06	6.300	0.074	0.0712	0.0006	0.1586	0.0019	1.548	0.023	0.0708	0.0006	0.791	949	10	951	19	0
56.1	421	311	0.74	111.8	0.000058	0.09	3.236	0.040	0.1078	0.0013	0.3088	0.0038	4.556	0.079	0.1070	0.0013	0.715	1735	19	1749	22	1
57.1	220	93	0.42	49.4	0.000115	0.19	3.817	0.050	0.0938	0.0009	0.2622	0.0034	3.418	0.055	0.0945	0.0009	0.810	1501	19	1519	18	1
58.1	338	83	0.24	95.5	0.000033	0.05	3.044	0.039	0.1088	0.0007	0.3289	0.0042	4.972	0.071	0.1096	0.0007	0.897	1833	21	1793	12	–2
59.1	66	64	0.97	16.2	0.000222	0.35	3.477	0.063	0.1036	0.0017	0.2866	0.0052	3.973	0.128	0.1006	0.0027	0.563	1624	26	1634	50	1
60.1	707	244	0.34	192.5	0.000043	0.07	3.158	0.036	0.1118	0.0005	0.3165	0.0036	4.855	0.061	0.1113	0.0006	0.910	1773	18	1820	9	3

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.53% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206}\%$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Fig. 2. Combined histogram-relative probability plots of zircon ages in rivers draining the Fennoscandian Shield and Trans-Scandinavian Igneous Belt.

1991; Skår and Pedersen, 2003). The 1.45–1.50 Ga peak corresponds to felsic magmatism in various parts of southern Scandinavia (Gower et al., 1991). The 1.15–1.22 Ga range is coincident with the onset of the Sveconorwegian orogeny, the effects of which continued until c. 0.90 Ga (Gower et al., 1991; Starmer, 1996).

The 1.79–1.80 Ga peak in the Vefsna, Saltelva and Vindelälven samples is found only in sediments from rivers with catchments that include, or are closely adjacent to, the basement windows. It is there-

fore likely that this peak reflects first-cycle derivation from the basement window exposures, rather than recycling from Caledonian Nappe metasediments. This view is given further credence by the poor representation of the 1.79–1.80 Ga event in the Ljusnan sample, whose catchment does not include basement windows.

Although the zircon age spectra in the rivers draining the Caledonian Nappe Domain can be reconciled with ultimate derivation from Baltica, Laurentia cannot be ruled out, since Laurentian and Baltican zircon age signatures are closely comparable (Cawood et al., 2007). Hence, some

Fig. 3. Combined histogram-relative probability plots of zircon ages in rivers draining the Caledonian Nappe Domain.

of the zircons in the Saltelva and Vefsna samples, which were derived from the Upper and Uppermost Allochthon, could be ultimately of Laurentian origin, since the metasediments of the Uppermost Allochthon are believed to have had a Laurentian ancestry (Roberts, 2003; Kirkland et al., 2007).

The relatively large number of Early Paleozoic zircons in the Vefsna sample (Fig. 3, Table 7) reflects the widespread occurrence of Caledonian granitoids in the catchment of this river, represented by

diorite–granite plutons within the Western Helgeland nappes. These granitoids have been dated as 443–447 Ma and 469–477 Ma (Bingen et al., 2002; Yoshinobu et al., 2002). The former of these two groups is represented by grain 28.1 (447 ± 5 Ma), and the latter corresponds reasonably closely with grains 20.1, 22.1 and 26.1 (486 ± 7 , 495 ± 7 and 486 ± 8 Ma respectively). Derivation from high-grade Caledonian metamorphic rocks can be ruled out because the zircons have relatively high Th/U ratios (Table 7). The late Neoproterozoic grain in the Vefsna

Fig. 4. Relative probability plots comparing zircon ages from rivers draining the Fennoscandian Shield and Caledonian Nappe Domain in central-northern Scandinavia, and a typical MN2 sandstone (Well 6607/5-2, 4172.0 m depth) from the Norwegian Sea.

sample corresponds to the major igneous pulse related to the opening of Iapetus. This is well represented in Baltica by the presence of mafic dykes dated as 616 ± 3 Ma (Bingen et al., 1998), although these are likely to be zircon-poor. There was also igneous activity of this age on the Laurentian margin (Cawood et al., 2001), in this case including felsic bodies that are more likely to supply zircons.

4.5. Comparison with the Cretaceous of the Norwegian Sea

A combined heavy mineral, mineral chemical and zircon age study of Cretaceous–Paleocene sandstones of the Norwegian Sea (Morton et al., 2005a,b) identified three different sand types in the basin, termed MN1, MN2 and MN3. Sand types MN1 and MN3 can be

confidently tied back to source areas on the Norwegian margin, MN1 being derived from the northern Nordland area and MN3 to western Norway, including the Western Gneiss Region (Fig. 5). MN2 sandstones, by contrast, have a complex provenance involving Archaean and Early Proterozoic basement, Proterozoic metasedimentary rocks, Caledonian granites and Permo–Triassic and Early Cretaceous felsic igneous rocks, all of which occur, or can be inferred to occur, on the East Greenland margin. MN2 sandstones have therefore been interpreted as having an East Greenland source (Fonneland et al., 2004; Morton et al., 2005a,b). However, a source from the Scandinavian margin cannot be entirely ruled out because of the scarcity of data on detrital zircons in the metasediments of the Caledonian Nappe Domain. These metasediments could include

Archaean and Early Proterozoic zircons absent from Norwegian basement rocks, by analogy with Dalradian metasedimentary rocks in Scotland. The Dalradian succession is broadly equivalent to the metasediments of the Caledonian Nappe Domain and is known to contain a significant proportion of Archaean zircons (Cawood et al., 2003). Another possibility is that the Archaean and Early Proterozoic zircons in the MN2 sandstones were supplied from the Fennoscandian Shield to the east of the Caledonides.

A comparison of the MN2 zircon age spectrum with those found in Scandinavian river sediments (Fig. 4) shows that the MN2 spectrum could not have been generated by recycling of Caledonian Nappe metasediments similar to those sampled by the modern rivers. The Caledonian Nappe metasediments are scarce in zircons older than c. 1.8 Ga, whereas such zircons are abundant in MN2 sandstones. The pre-1.8 Ga population in MN2 sandstones includes both Early Proterozoic and Archaean zircons. Only three of the 217 zircons analysed from the rivers draining the Caledonian Nappe Domain are Archaean, in contrast to the MN2 spectrum (Fig. 5), where c. 10% of the zircon population is Archaean. Furthermore, the main peak in MN2 is at c. 1.90 Ga, significantly older than the oldest Proterozoic zircons in the rivers draining the Caledonian Nappe Domain.

The MN2 spectrum can also not be reconciled with a proposed origin through combined recycling of the Caledonian Nappe metasediments plus first-cycle derivation from the Fennoscandian Shield. It would be possible to supply the requisite number of Archaean zircons through this mechanism, providing derivation was from the Archaean realm of the Fennoscandian Shield in the northern part of Sweden, which supplied the sediment in Lainioälven, as discussed above. However, the Archaean in this region is heavily intruded by Late Svecofennian granitoids dated at c. 1.80 Ga, as demonstrated by the Lainioälven spectrum (Fig. 4). Since the MN2 spectrum lacks a significant peak at c. 1.80 Ga, derivation from this part of the Fennoscandian Shield can be discounted. Furthermore, the MN2 spectrum contains a small but significant number of pre-1.95 Ga zircons, which are almost entirely absent in sediments derived from either the Fennoscandian Shield or the Caledonian Nappe Domain. Involvement of sediment derived from the Fennoscandian Shield can therefore be ruled out. The c. 1.90 Ga peak that is a characteristic feature of the MN2 spectrum is also found in Devonian and Cretaceous sandstones of northern East Greenland, and is evidently of local origin (Knudsen et al., 2001; Morton et al., 2005b). Derivation from Lofoten–Vesterålen can be ruled out, since although there are exposures of Archaean rocks dated as c. 2600 Ma by Jacobsen and Wasserburg (1978), these are not spatially associated with a potential source of abundant pre-1800 Ma Proterozoic zircons, the Early Proterozoic of Lofoten–Vesterålen and the adjacent basement windows in the Nordland region being dated as c. 1770–1800 Ma (Skår, 2002; Corfu, 2004). There can therefore be little doubt that MN2 sandstones were not derived from Scandinavia, leaving East Greenland as the only viable source area.

5. Conclusions

The zircon age spectra in river sediments derived from the Caledonian Nappe Domain are fundamentally different to those derived from the Fennoscandian Shield. Whereas the Fennoscandian Shield spectra are comparatively simple, with one or two sharp and well-defined peaks, the Caledonian Nappe Domain spectra are much more diverse, with a wider range of ages and multiple peaks being present. The greater diversity largely reflects the nature of the sediment source, since most of the zircons from the Caledonian domain have been derived from metasedimentary rocks, which were themselves derived from the variety of precursor sources available at the time. For the most part, these precursor sources lay on the Baltican margin, although the Uppermost Allochthon may include sediment derived from Laurentia (Roberts, 2003). By contrast, the Fennoscan-

dian Shield zircons were largely derived from granitoid rocks formed during specific crust-forming events. Thus, the Fennoscandian Shield spectra are typical of first-cycle, basement-derived detritus, whereas the Caledonian Nappe Domain spectra are typical of a multicyclic source.

The results from the river sediment study highlight a problem concerning the definition of polycyclic sediment. In lithological and mineralogical terms, the sediments derived from the Caledonian Nappe Domain would be classified as first-cycle, being predominantly sourced from metasedimentary rocks of varying metamorphic grades. However, the zircon population is predominantly recycled, the range of ages largely reflecting the variety of precursor sources that supplied the Caledonian metasedimentary successions. Integration of petrographic or mineralogical data with detrital zircon age data should clarify whether sediments are first-cycle or polycyclic.

Zircon age data from river sediment draining the Fennoscandian Shield faithfully reflect the ages of major phases of granitoid intrusion in these areas. The main peaks recognised in the Fennoscandian river sediments are (i) between 2.65 and 2.78 Ga, which corresponds to the age of the granitoids, migmatites and grey gneisses that form the Archaean basement of northern Sweden: (ii) 1.89 Ga and 1.80 Ga, which represent Svecokarelian phases 1 and 2, and; (iii) 1.70 Ga, corresponding to the second phase of granitoid intrusion within the Trans-Scandinavian Igneous Belt (TIB2). The Fennoscandian zircon spectra show virtually no representation of Lapponian volcanics or Early Proterozoic metasediments, despite the presence of both lithologies within the drainage basins of the rivers concerned. The lack of Lapponian-age zircons is unsurprising given the mafic/ultramafic nature of the volcanic succession, but the scarcity of zircons reworked from the metasediments is more enigmatic. The biased nature of the zircon populations is most likely to reflect a difference in relative abundance of zircons in the granitoids compared with the metasediments.

The main spectra in the river sediments derived from the Caledonian Nappe Domain also reflect major crust-forming events in Baltica, notably the Gothian/Kongsbergian and Sveconorwegian orogenies, plus intervening phases of anorogenic granitoid intrusion. Three of the four zircon populations also contain a peak at c. 1.80 Ga, the age of basement windows and allochthonous granites within the Caledonian Nappe Domain. These zircons are interpreted as being of first-cycle origin, rather than recycled from the Caledonian metasediments, since the catchments of the rivers containing these zircons include, or are closely adjacent to, the basement windows. One sample contains a high proportion of Early Paleozoic zircons derived from Caledonian granites, which are widespread in the catchment of this river. It is not possible to rule out ultimate derivation from Laurentia, since the zircon signature of Laurentian and Baltican detritus contain many common elements (Cawood et al., 2007), and the catchments of two of the rivers (Saltelva and Vefsna) include Laurentian-derived metasediments in the Uppermost Allochthon.

Comparison between the zircons in the Scandinavian rivers and Cretaceous sandstones in the Norwegian Sea demonstrate that recycling of Caledonian metasediments cannot account for the presence of Early Proterozoic and Archaean zircons in the MN2 group, as defined by Morton et al. (2005a). It is also difficult to reconcile the MN2 spectra with a combined provenance involving recycling of Caledonian metasediments and first-cycle sourcing from the Fennoscandian Shield. The most likely source of this sand type is therefore East Greenland, supporting previous interpretations of provenance data (Fonneland et al., 2004; Morton et al., 2005a,b).

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Table 9
Summary of SHRIMP U–Pb zircon results for Ljungan river sand

Grain. spot	U (ppm)	Th (ppm)	Th/U	Pb* (ppm)	²⁰⁴ Pb/ ²⁰⁶ Pb	f ₂₀₆ %	Total ratios				Radiogenic ratios						r	Age (Ma)					% Disc
							²³⁸ U/ ²⁰⁶ Pb	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±	²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²³⁵ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		²⁰⁶ Pb/ ²³⁸ U	±	²⁰⁷ Pb/ ²⁰⁶ Pb	±		
1.1	260	70	0.27	46.0	–	<0.01	4.859	0.059	0.0781	0.0008	0.2062	0.0026	2.263	0.051	0.0796	0.0012	0.793	1208	14	1187	29	–2	
2.1	117	80	0.69	26.4	–	<0.01	3.799	0.050	0.0924	0.0011	0.2632	0.0035	3.355	0.060	0.2632	0.0035	0.733	1506	18	1476	23	–2	
3.1	55	20	0.37	9.5	0.000093	0.16	4.947	0.080	0.0788	0.0016	0.2020	0.0035	2.177	0.095	0.0782	0.0027	0.681	1186	19	1151	68	–3	
4.1	50	55	1.10	9.5	–	<0.01	4.492	0.073	0.0800	0.0016	0.2231	0.0036	2.512	0.080	0.2231	0.0036	0.514	1298	19	1238	53	–5	
5.1	256	80	0.31	35.1	0.000062	0.11	6.272	0.073	0.0712	0.0008	0.1595	0.0019	1.571	0.040	0.0714	0.0013	0.759	954	11	970	37	2	
6.1	114	94	0.83	25.4	0.000100	0.16	3.853	0.050	0.0939	0.0011	0.2591	0.0033	3.304	0.064	0.2591	0.0033	0.660	1485	17	1477	28	–1	
7.1	306	137	0.45	74.2	0.000011	0.02	3.547	0.041	0.0972	0.0007	0.2819	0.0033	3.774	0.051	0.2819	0.0033	0.858	1601	16	1569	13	–2	
8.1	64	40	0.63	16.5	–	<0.01	3.325	0.049	0.1043	0.0015	0.3008	0.0044	4.325	0.087	0.3008	0.0044	0.722	1695	22	1702	26	0	
9.1	213	135	0.64	55.1	0.000040	0.06	3.316	0.039	0.1032	0.0008	0.3014	0.0035	4.268	0.061	0.3014	0.0035	0.813	1698	17	1673	15	–1	
10.1	89	33	0.37	20.5	–	<0.01	3.745	0.051	0.0975	0.0013	0.2670	0.0037	3.590	0.068	0.2670	0.0037	0.727	1526	19	1577	24	3	
11.1	206	70	0.34	35.0	–	<0.01	5.050	0.061	0.0787	0.0009	0.1980	0.0024	2.150	0.036	0.1980	0.0024	0.722	1165	13	1166	23	0	
12.1	592	191	0.32	81.4	0.000012	0.02	6.246	0.069	0.0714	0.0005	0.1601	0.0018	1.571	0.021	0.1601	0.0018	0.836	957	10	963	15	1	
13.1	126	35	0.28	19.7	0.000040	0.07	5.497	0.072	0.0721	0.0011	0.1821	0.0025	1.831	0.055	0.0729	0.0017	0.701	1078	14	1012	46	–7	
14.1	204	100	0.49	46.9	–	<0.01	3.729	0.044	0.0949	0.0008	0.2682	0.0032	3.513	0.051	0.2682	0.0032	0.806	1532	16	1528	16	0	
15.1	291	155	0.53	80.5	0.000109	0.17	3.108	0.035	0.1030	0.0007	0.3212	0.0036	4.493	0.065	0.3212	0.0036	0.786	1795	18	1651	17	–9	
16.1	113	39	0.34	19.4	0.000081	0.14	5.028	0.068	0.0781	0.0011	0.1988	0.0028	2.136	0.069	0.0779	0.0019	0.723	1169	15	1145	48	–2	
17.1	365	191	0.52	90.8	0.000028	0.05	3.453	0.038	0.1020	0.0006	0.2895	0.0032	4.054	0.053	0.2895	0.0032	0.859	1639	16	1653	12	1	
18.1	47	34	0.73	7.3	–	<0.01	5.503	0.097	0.0758	0.0019	0.1817	0.0032	1.899	0.058	0.1817	0.0032	0.577	1076	17	1090	50	1	
19.1	116	44	0.38	16.5	–	<0.01	6.062	0.083	0.0709	0.0012	0.1650	0.0023	1.613	0.036	0.1650	0.0023	0.623	984	13	955	35	–3	
20.1	306	108	0.35	74.5	0.000064	0.10	3.530	0.042	0.1034	0.0008	0.2830	0.0033	3.998	0.059	0.2830	0.0033	0.805	1606	17	1669	16	4	
21.1	114	31	0.28	17.3	–	<0.01	5.655	0.078	0.0727	0.0012	0.1768	0.0025	1.773	0.038	0.1768	0.0025	0.640	1050	13	1006	34	–4	
22.1	146	99	0.68	38.0	0.000048	0.08	3.292	0.041	0.1022	0.0010	0.3039	0.0042	4.293	0.135	0.1025	0.0022	0.818	1711	21	1669	40	–2	
23.1	83	30	0.36	11.2	0.000079	0.14	6.321	0.096	0.0701	0.0015	0.1583	0.0026	1.537	0.068	0.0704	0.0025	0.660	947	14	941	73	–1	
24.1	65	44	0.68	14.7	0.000117	0.19	3.830	0.059	0.0922	0.0015	0.2609	0.0045	3.299	0.157	0.0917	0.0033	0.758	1495	23	1461	69	–2	
25.1	1268	138	0.11	324.8	0.000013	0.02	3.354	0.035	0.1026	0.0004	0.2985	0.0031	4.253	0.052	0.1033	0.0004	0.947	1684	16	1685	8	0	
26.1	20	9	0.44	3.7	–	<0.01	4.672	0.111	0.0794	0.0027	0.2140	0.0051	2.343	0.097	0.2140	0.0051	0.571	1250	27	1182	67	–6	
27.1	323	130	0.40	72.7	–	<0.01	3.817	0.043	0.0956	0.0007	0.2620	0.0030	3.454	0.046	0.2620	0.0030	0.846	1500	15	1540	13	3	
28.1	207	41	0.20	30.4	–	<0.01	5.853	0.071	0.0736	0.0009	0.1709	0.0021	1.733	0.030	0.1709	0.0021	0.699	1017	11	1030	25	1	
29.1	88	0	0.00	14.3	–	<0.01	5.270	0.076	0.0760	0.0013	0.1898	0.0027	1.989	0.045	0.1898	0.0027	0.633	1120	15	1096	35	–2	
30.1	620	287	0.46	86.5	–	<0.01	6.158	0.067	0.0708	0.0005	0.1624	0.0018	1.585	0.021	0.1624	0.0018	0.819	970	10	951	16	–2	
31.1	386	291	0.75	88.8	0.001064	1.69	3.738	0.041	0.1145	0.0008	0.2630	0.0030	3.622	0.071	0.2630	0.0030	0.574	1505	15	1622	30	7	

32.1	134	209	1.56	32.3	0.000025	0.04	3.558	0.045	0.1009	0.0010	0.2809	0.0036	3.896	0.064	0.2809	0.0036	0.772	1596	18	1635	20	2
33.1	171	119	0.70	43.0	0.000030	0.05	3.410	0.042	0.0981	0.0009	0.2937	0.0040	4.025	0.127	0.0994	0.0022	0.820	1660	20	1613	41	-3
34.1	41	30	0.72	11.4	0.000291	0.46	3.075	0.058	0.1110	0.0019	0.3243	0.0069	4.856	0.252	0.1086	0.0041	0.791	1811	33	1776	68	-2
35.1	278	89	0.32	40.0	-	<0.01	5.973	0.070	0.0727	0.0008	0.1674	0.0019	1.678	0.026	0.1674	0.0019	0.738	998	11	1006	22	1
36.1	71	65	0.91	18.8	0.000320	0.51	3.259	0.048	0.1057	0.0015	0.3053	0.0046	4.266	0.126	0.3053	0.0046	0.504	1718	23	1649	47	-4
37.1	100	40	0.40	13.4	0.000086	0.15	6.370	0.091	0.0708	0.0013	0.1568	0.0023	1.504	0.040	0.1568	0.0023	0.540	939	13	916	46	-3
38.1	171	119	0.70	43.6	0.000034	0.05	3.371	0.041	0.0994	0.0013	0.2964	0.0036	4.042	0.074	0.2964	0.0036	0.673	1674	18	1603	25	-4
39.1	36	50	1.41	9.2	0.000045	0.07	3.304	0.060	0.1047	0.0020	0.3024	0.0055	4.340	0.119	0.3024	0.0055	0.663	1703	27	1698	38	0
40.1	100	64	0.64	22.9	0.001101	1.77	3.743	0.056	0.1097	0.0014	0.2625	0.0042	3.418	0.193	0.2625	0.0042	0.285	1502	22	1517	102	1
41.1	227	78	0.34	55.6	0.000016	0.02	3.508	0.041	0.0984	0.0008	0.2852	0.0035	3.894	0.083	0.0990	0.0013	0.827	1618	18	1606	24	-1
42.1	640	167	0.26	94.2	0.000016	0.03	5.836	0.063	0.0728	0.0005	0.1713	0.0019	1.713	0.023	0.1713	0.0019	0.817	1019	10	1001	15	-2
43.1	87	28	0.32	15.3	0.000178	0.30	4.897	0.071	0.0794	0.0014	0.2045	0.0031	2.275	0.078	0.0807	0.0021	0.698	1200	17	1214	51	1
44.1	151	58	0.38	20.8	-	<0.01	6.234	0.082	0.0709	0.0011	0.1604	0.0021	1.569	0.032	0.1604	0.0021	0.645	959	12	955	32	0
45.1	167	66	0.40	24.2	0.000368	0.64	5.927	0.077	0.0712	0.0011	0.1689	0.0023	1.683	0.060	0.0722	0.0020	0.707	1006	13	993	56	-1
46.1	111	89	0.80	24.4	-	<0.01	3.899	0.052	0.0932	0.0012	0.2565	0.0034	3.307	0.063	0.2565	0.0034	0.710	1472	18	1498	25	2
47.1	221	117	0.53	58.5	0.000017	0.03	3.247	0.038	0.1038	0.0008	0.3081	0.0039	4.428	0.110	0.1042	0.0016	0.837	1731	19	1701	29	-2
48.1	91	65	0.72	23.6	0.001061	1.69	3.305	0.047	0.1140	0.0014	0.2976	0.0048	4.095	0.194	0.0998	0.0036	0.769	1680	24	1620	68	-4
49.1	21	18	0.88	3.1	0.000855	1.51	5.630	0.138	0.0735	0.0029	0.1749	0.0046	1.473	0.194	0.1749	0.0046	0.199	1039	25	642	277	-62
50.1	284	111	0.39	49.8	-	<0.01	4.894	0.059	0.0787	0.0008	0.2046	0.0026	2.249	0.059	0.0797	0.0014	0.801	1200	14	1191	35	-1
51.1	434	131	0.30	61.5	-	<0.01	6.066	0.068	0.0705	0.0007	0.1649	0.0019	1.604	0.023	0.1649	0.0019	0.771	984	10	944	19	-4
52.1	451	203	0.45	103.3	0.000009	0.01	3.748	0.041	0.0933	0.0006	0.2669	0.0031	3.451	0.075	0.0938	0.0012	0.858	1525	16	1503	25	-1
53.1	96	63	0.66	22.7	-	<0.01	3.610	0.051	0.0978	0.0013	0.2770	0.0039	3.734	0.073	0.2770	0.0039	0.724	1576	20	1582	25	0
54.1	528	87	0.17	134.7	-	<0.01	3.369	0.037	0.1011	0.0006	0.2969	0.0033	4.148	0.062	0.1013	0.0007	0.886	1676	16	1648	13	-2
55.1	72	44	0.61	16.7	-	<0.01	3.688	0.056	0.0909	0.0015	0.2720	0.0046	3.510	0.149	0.0936	0.0030	0.750	1551	23	1500	60	-3
56.1	41	17	0.41	6.1	0.000240	0.42	5.764	0.128	0.0644	0.0021	0.1735	0.0041	1.543	0.113	0.0645	0.0039	0.656	1031	23	758	127	-36
57.1	218	117	0.53	60.7	0.000033	0.05	3.089	0.037	0.1096	0.0009	0.3235	0.0039	4.871	0.072	0.3235	0.0039	0.815	1807	19	1786	16	-1
58.1	39	21	0.54	6.5	0.000143	0.24	5.131	0.100	0.0801	0.0022	0.1944	0.0038	2.092	0.078	0.1944	0.0038	0.520	1145	20	1148	64	0
59.1	78	24	0.31	10.5	-	<0.01	6.400	0.101	0.0731	0.0016	0.1563	0.0025	1.575	0.043	0.1563	0.0025	0.578	936	14	1017	45	8
60.1	130	109	0.84	20.8	0.000053	0.09	5.355	0.073	0.0761	0.0012	0.1866	0.0025	1.938	0.042	0.1866	0.0025	0.626	1103	14	1077	34	-2
61.1	236	148	0.63	59.3	-	<0.01	3.422	0.041	0.0990	0.0008	0.2926	0.0038	4.039	0.113	0.1001	0.0019	0.830	1654	19	1626	35	-2
62.1	81	27	0.33	11.5	-	<0.01	6.045	0.094	0.0721	0.0016	0.1655	0.0026	1.659	0.046	0.1655	0.0026	0.564	987	14	1005	46	2
63.1	226	205	0.91	61.0	0.000036	0.06	3.182	0.039	0.1023	0.0008	0.3149	0.0044	4.525	0.158	0.1042	0.0025	0.848	1765	22	1700	44	-4
64.1	114	78	0.68	16.8	0.000985	1.69	5.864	0.082	0.0853	0.0014	0.1683	0.0027	1.730	0.099	0.0745	0.0035	0.736	1003	15	1056	94	5
65.1	408	112	0.27	99.9	0.000038	0.06	3.509	0.039	0.0967	0.0006	0.2856	0.0033	3.883	0.068	0.0986	0.0010	0.860	1619	16	1598	18	-1

Uncertainties given at the one σ level. Error in FC1 Reference zircon calibration was 0.40% for the analytical session (not included in above errors but required when comparing $^{206}\text{Pb}/^{238}\text{U}$ data from different mounts). $f_{206\%}$ denotes the percentage of ^{206}Pb that is common Pb. Correction for common Pb made using the measured $^{204}\text{Pb}/^{206}\text{Pb}$ ratio. For % Disc, 0% denotes a concordant analysis. Pb* is the proportion of Pb that is radiogenic.

Fig. 5. Regional distribution and inferred sources of Cretaceous–Paleocene sand types MN1, MN2 and MN3 in the Norwegian Sea. Adapted from Morton et al. (2005a).

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