Supplementary File 2. Analytical methods and approaches

U-Pb detrital zircon dating

Zircons were extracted using standard crushing, density and magnetic separations. Zircon grains ranged from ~50μm to ~240μm in length. The zircons were mounted in epoxy and polished them for sensitive high-resolution ion microprobe (SHRIMP-II) analyses. SEM and/or cathodoluminescent (CL) imaging guided analytical locations and helped decipher the internal structures of the sectioned grains.

Zircon grains were mounted together with chips of the TEMORA (Middledale Gabbroic Diorite, New South Wales, Australia) and 91500 (Geostandart zircon) reference zircons. The grains were sectioned approximately in half and polished.

The U-Pb analyses of the zircons were made using SHRIMP-II ion microprobe (Center of Isotopic Research, VSEGEI, St. Petersburg, Russia). Each analysis consisted of 5 scans through the mass range, diameter of spot was about 18 mkm, primary beam intensity was about 4 nA. The data have been reduced in a manner similar to that described by Williams (1998, and references therein), using the SQUID Excel Macro of Ludwig (2000). The Pb/U ratios have been normalized relative to a value of 0.0668 for the $^{206}Pb/^{238}U$ ratio of the TEMORA reference zircons, equivalent to an age of 416.75 Ma (Black & Kamo, 2003). Uncertainties given for individual analyses (ratios and ages) are at the 1σ level; however the uncertainties in calculated concordia ages are reported at 2σ level.

Sm-Nd whole-rock isotopic study

Nd isotopes were analyzed on a TRITON TI mass spectrometer in static mode (Center of Isotopic Research, VSEGEI, St. Petersburg, Russia). Total blanks of the laboratory are 30 pg for Sm and 70 pg for Nd. Analytical uncertainty of the measurements of Sm and Nd contents and $^{147}Sm/^{144}Nd$ ratio are 0.5%, and 0.005% for $^{143}Nd/^{144}Nd$ ratio. $^{143}Nd/^{144}Nd$ ratios were corrected for mass fractionation using a $^{148}Nd/^{144}Nd$ ratio of 0.241578 and a value of 0.511860 for the La Jolla standard. The $\varepsilon_{Nd}(t)$ values were calculated using the present-day chondritic uniform reservoir (CHUR) values of $^{143}Nd/^{144}Nd = 0.512638$ and $^{147}Sm/^{144}Nd = 0.1967$ (Jacobsen & Wasserburg, 1984). Uncertainty of ε_{Nd} calculation is ±0.5. Average of 10 measurements of BCR-1 standard are Sm 6.45 ppm, Nd 28.4 ppm, $^{147}Sm/^{144}Nd = 0.1383 \pm 3$, $^{143}Nd/^{144}Nd = 0.512654 \pm 8$. In order to account for the possible fractionation of Sm and Nd in crustal processes for sedimentary rocks, two-stage T_{Nd}(DM-2st) model ages were calculated (Keto & Jacobsen, 1987), using the mean crustal ratio of $^{147}Sm/^{144}Nd = 0.12$ (Taylor and McLennan, 1985).

Chemical analyses

Whole-rock chemical study was done at the Central Laboratory, VSEGEI, St. Petersburg. Major element concentrations were determined by XRF using ARL 9800 spectrometer. Trace and rare earth elements (REE) were determined by Inductively Coupled Plasma–Mass Spectrometry (ICP–MS) using an Optima 4300DV emission spectrometer and an

ELAN 6100 DRC mass spectrometer. All measured concentrations typically are far above detection limits, with analytical uncertainties of less than 3% for major elements and 4-10% for trace and rare earth elements, except for Ni, which has an uncertainty of about 15%.

Notes regarding U-Pb detrital zircon data interpretation

40 to 67 zircon grains (893 grains in total) were dated by SHRIMP in each sample. At the 95% confidence level, analysis of 60 grains would fail to sample a grain from a component that constituted approximately 5% of the overall grain population, whereas analysis of 40 grains would fail to sample a grain from a component that constituted approximately 9% of the overall grain population (McLennan et al. 2003). This component of loss from the overall grain population is considered suitable for a reconnaissance study with the aim of identifying major provenance areas, but may omit or obscure minor secondary provenance regions that sourced clastic sediments constituting less than 5% to 9% of the overall zircon population.

In many papers, analyses with discordance above 10% are often excluded from further interpretation. However, there is no uniform discordance criteria and an appropriate discordance filter needs to be determined for each data set in light of the goals of the study (Nemchin & Cawood 2005; Gehrels 2012). For example, Mackey et al. (2012) used a 60% discordance filter for analyses younger than 350 Ma, whereas Link et al. (2012) did not exclude any samples based on discordance criteria for analyses with Phanerozoic ages. No discordance filter was applied by Bue & Andresen (2014) to produce age probability density plots. In our data set (Electronic Supplementary Data File 3), 224 analyses have the best age older than 1000 Ma, only 4 out of 224 analyses have discordance above 30%, and 29 out of 224 analyses have discordance above 10%. However, younger grains are characterized by a progressively higher discordance, therefore the use of any uniform discordance criteria would introduce an unwanted bias in the data interpretation. A comparison of the probability density plots for the whole zircon population when applying a discordance filter to exclude zircons with more than 10% discordance, more than 30% discordance, and with no discordance filter applied (Fig. S1), reveals the occurrence of similar age peaks, but with a selective decrease in the number of young ages when a strong discordance filter is used. To avoid this bias, no discordance filter was used but, on the other hand, we do not refer in the following discussion to the ages of individual peaks on the probability density plots, as related ages are likely to be associated with high uncertainty due to the inclusion of highly discordant grains.

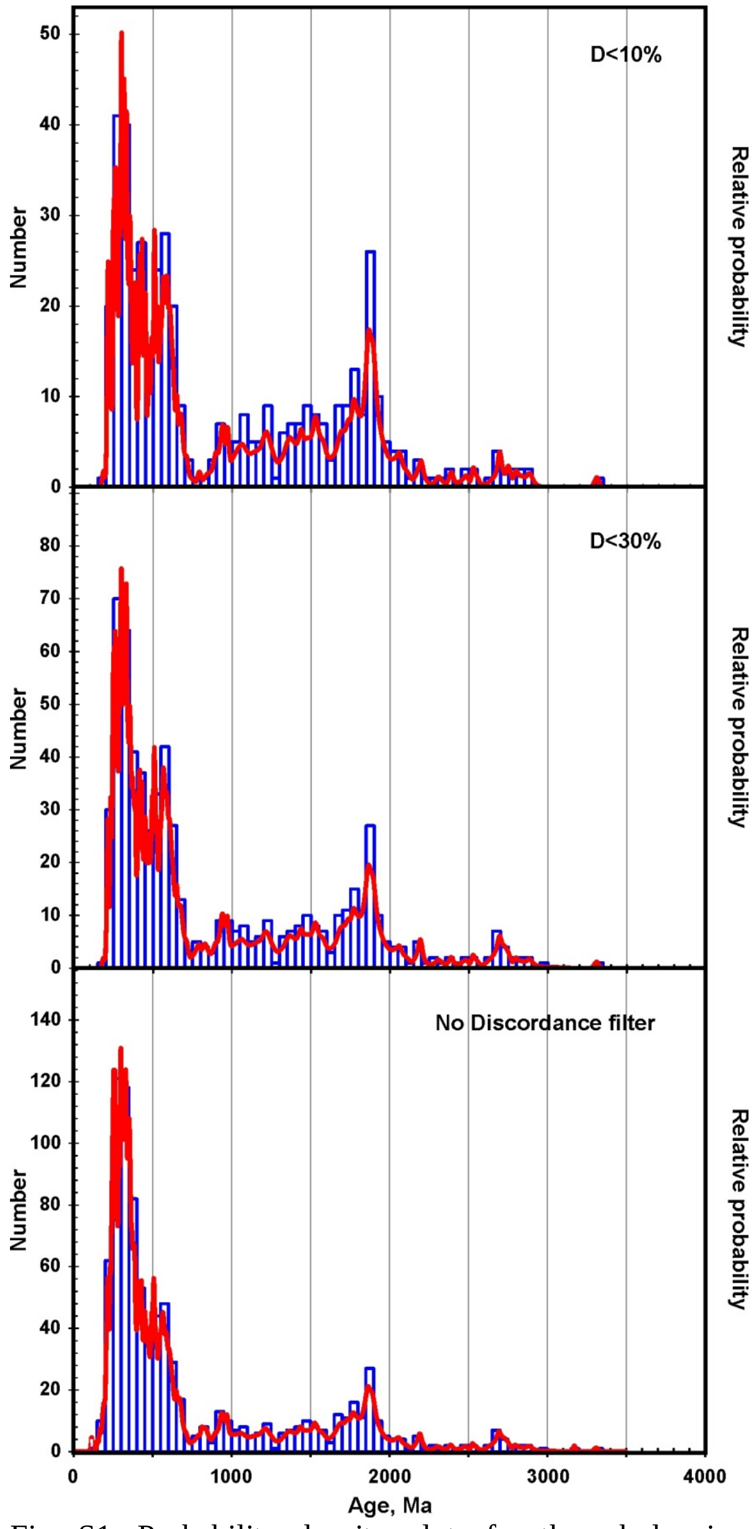

Fig. S1. Probability density plots for the whole zircon population after applying a different discordance (D) filter.

A statistical comparison of the distribution of detrital zircon ages between samples was assessed using the Kolmogorov–Smirnov (K–S) test, which measures the probability that two age distributions have been selected from the same original population (Gehrels 2012). The common criterion applied is that if the probability (P) is >0.05, there is a >95% confidence that the two samples are not statistically different. At least 20 analyses must be selected from each sample for the test to be statistically significant. The value of P is sensitive to the number of analyses and analytical uncertainty, therefore, P-values can be used for a comparison of different samples only if the number of analyses in each sample is similar, and if analyses with analytical uncertainty of >10% are excluded from the test (Guynn & Gehrels 2010).

References

Black, L.P., Kamo, S..L, Allen, C.M., Aleinikoff, J.N., Davis, D.W., Korsch, R.J., Foudoulis, C., 2003. TEMORA 1: a new zircon standard for U-Pb geochronology. Chemical Geology 200, 155–170

Bue, E.P., Andresen, A. 2014. Constraining depositional models in the Barents Sea region using detrital zircon U–Pb data from Mesozoic sediments in Svalbard. In: Scott, R.A., Smyth, H.R., Morton, A.C., Richardson, N. (eds.). Sediment Provenance Studies in Hydrocarbon Exploration and Production. Geological Society, London, Special Publications, 386, 261–279

Gehrels, G.E. 2012. Detrital zircon U-Pb geochronology: current methods and new opportunities. In: Busby, C., Azor, A. (eds.). Tectonics of Sedimentary Basins: Recent Advances, Chapter 2. Blackwell Publishing Ltd. 47–62

Guynn, J., Gehrels, G. 2010. Comparison of Detrital Zircon Age Distributions Using the K-S Test. University of Arizona, Arizona LaserChron Center. 16 p. https://sites.google.com/a/laserchron.org/laserchron/

Jacobsen S.B., Wasserburg G.J. Sm-Nd evolution of chondrites and a chondrites. II. Earth and Planet Science Letters, 1984, 67, 137–150.

Keto L.S., Jacobsen S.B. 1987. Nd and Sr isotopic variations of Early Paleozoic oceans. Earth and Planet Science Letters 84, 27-41.

Ludwig, K.R., 2000. SQUID 1.00, A User's Manual; Berkeley Geochronology Center Special Publication, No. 2, 2455 Ridge Road, Berkeley, CA 94709, USA.

Mackey, G.N., Horton, B.K., Milliken, K.L. 2012. Provenance of the Paleocene–Eocene Wilcox Group, western Gulf of Mexico basin: evidence for integrated drainage of the southern Laramide Rocky Mountains and Cordilleran arc. Geological Society of America Bulletin 124, 1007–1024

McLennan, S.M., Bock, B., Hemming, S.R., Hurowitz, J.A., Lev, S.M., McDaniel, D.K., 2003. The role of provenance and sedimentary processes in the geochemistry of sedimentary rocks. In: Lentz, D. (ed.). Geochemistry of Sediments and Sedimentary

Rocks: Evolutionary Considerations to Mineral Deposit-Forming Environments. St. John's, Geological Association of Canada, 7–38.

Nemchin, A.A., Cawood, P.A. 2005. Discordance of the U-Pb system in detrital zircons: implication for provenance studies of sedimentary rocks. Sedimentary Geology 182, 143–162

Link, P.K., Fanning, C.M., Beranek, L.P. 2005. Reliability and longitudinal change of detrital-zircon age spectra in the Snake River system, Idaho and Wyoming: An example of reproducing the bumpy barcode. Sedimentary Geology 182, 101–142

Taylor S.R., McLennan S.M. 1985. The continental crust: its composition and evolution. Oxford: Blackwell Scientific Publications, 312 p.

Williams, I.S., 1998. U-Th-Pb Geochronology by Ion Microprobe. In: McKibben, M.A., Shanks III, W.C. and Ridley, W.I. (eds), Applications of microanalytical techniques to understanding mineralizing processes. Reviews in Economic Geology **7**, 1–35.