

Text S1. Supplementary Methods

Sample preparation

Apatite is present in varying but always very low abundances in detrital sediment samples from Prydz Bay. Accurate characterization of all sources in a detrital sample requires complete sampling of the mineral; incomplete sampling will bias the results toward sources that produce larger, more archetypal, or more abundant apatite grains. In order to achieve near-complete recovery of apatite, several steps were taken prior to manual picking of grains to ensure that a minimum of other minerals were present in the final separate and that each sample was treated as similarly as possible. Because sample recovery was extremely low (ODP sediment samples yielded fewer than 10 apatites), we chose to double-date each individual grain in order to most completely explore the time-temperature history of the sediments.

First, sediment samples are disaggregated in deionized water and sieved at 63 μm , the traditional boundary between sand and silt on the Wentworth scale. Grains smaller than this are extremely difficult to isolate consistently and are of limited use for mineral dating. The coarse fraction from this step is dried and dry-sieved at 600 μm to remove clastic particles. Further separations were performed in the range on some samples in order to isolate minerals for other related studies; apatite was never observed in size fractions greater than 250 μm . After sieving, the 63-600 μm fraction (or fractions if other separations were performed) was separated by density using lithium heteropolytungstate (LST) heavy liquid ($\rho = 2.85 \text{ g/mL}$) to isolate the heavier fraction ($\rho_{\text{apatite}} = 3.2 \text{ g/cm}^3$). This fraction, which comprised no more than 10% of the volume of the 63-600 μm size fraction, was further separated using a hand magnet and a Frantz isodynamic separator. The apatite remains in the non-magnetic fraction after passing through a Frantz on the highest power setting, but a hand magnet must be used first even if no further separation of the magnetic fraction is desired in order to remove ferromagnetic minerals that would otherwise stick to the magnets of the Frantz, reducing sample recovery and increasing the difficulty of equipment cleaning significantly. After magnetic separation, a further round of density separation was performed using methylene iodide (MI) heavy liquid ($\rho = 3.3 \text{ g/mL}$). Apatite remains in the light fraction after this separation, which is also useful to isolate zircon ($\rho = 4.65 \text{ g/cm}^3$), which can be dated using the same techniques as apatite. After this final density separation, apatite grains were picked manually under a stereomicroscope from the 63-600 μm , 2.85-3.3 g/cm^3 , nonmagnetic fraction.

Apatite (U-Th)/He and fission-track age measurement

For fission-track dating, which must precede (U-Th)/He dating since currently reliable methods of (U-Th)/He dating are destructive, apatite grains are mounted in epoxy and then polished to produce the extremely flat surfaces necessary for the external detector method and for later measurement of fission tracks.

Fission-track dating methodology follows that outlined in Thomson and Ring (2006). IRMM540R glass was used to monitor neutron fluence during irradiation at the Oregon State University Triga Reactor, Corvallis, OR, USA. A zeta calibration factor (Hurford and Green, 1983) of 352.4 ± 12.1 (IRMM540R apatite) was used in age calculation. Central ages (Galbraith and Laslett, 1993), quoted with 1σ errors, were calculated using the IUGS recommended zeta calibration approach of Hurford & Green (1983), which allows for non-Poissonian variation within a population of single-grain ages belonging to an individual sample. Owing to the low spontaneous track counts in several of the grains, ages are also presented with 95% confidence intervals for a binomial parameter (Galbraith, 2005).

After fission track dating, apatites were manually removed from the epoxy mounts and then individually wrapped in niobium tubes under a stereomicroscope. The protective tubes (or comparable foil packets) are necessary to ensure coupling with the laser and complete degassing during helium measurement and to ensure that no material is ablated during helium measurement prior to uranium and thorium measurement. Platinum has been used rather than niobium in the past, but there are concerns about the uranium blank in the currently available platinum.

Helium was measured by laser degassing, isotope dilution, cryogenic purification, and quadrupole mass spectrometry. U, Th, and Sm were measured by isotope dilution, using high-pressure-HF-dissolution methods (same as those for routine zircon measurements) to recover U-Th in small inclusions, and inductively-coupled plasma mass spectrometry. Detailed methods are in Reiners (2005). Ages of euhedral or subhedral grains were corrected for the effects of alpha-ejection (Farley, 2002) using a modified calculation appropriate for polished grains plucked from fission-track mounts (Reiners et al., 2007); uncertainties on these grains are two-sigma analytical uncertainties, not including the effects of alpha-ejection. Highly rounded or fragmented morphologies were not corrected for alpha-ejection effects, following the assumption that relatively recent abrasion or breakage removed the majority of the alpha-ejection-affected volume of the grain. However, to allow for the possibility that this removal occurred at an age close to the cooling age of the grain, or that removal did not remove most of the ejection-affected volume, positive uncertainties on these grains are taken to be the fully-corrected (Reiners et al., 2003) age

minus the raw uncorrected age; negative uncertainties are two-sigma analytical precision on the uncorrected age.