**Appendix A**

Twenty-nine samples were selected for the analysis of major- and trace elements. The concentrations were determined at the commercial ACME laboratories Ltd., Vancouver, Canada. Major elements were analysed using ICP-AES (0.2 g of pulp sample by LiBO2 fusion). The detection limits are approximately 0.001-0.04%. For trace elements, 0.2 g of sample powder and 1.5 g of LiBO2 flux were mixed in a graphite crucible and heated to 1050 oC for 15 min in a muffle furnace. The molten sample was then dissolved in 100ml of 5% HNO3. The sample solutions were shaken for 2h, and then an aliquot was poured into a polypropylene test tube and aspirated into a Perkin-Elmer Elan 600 ICP mass spectrometer. Calibration and verification standards together with reagent blanks were added to the sample sequence. The elemental concentrations of the samples were obtained using GS311-1, GS910-4, SO-18 and SO-19 as internal standards. The detection limits ranged from 0.01 to 0.5 ppm for most of the trace elements. Major and trace elements concentrations of the analyzed samples and standards are presented in Tables S1 and S2, respectively.

Radiogenic isotope ratios of Sr (87Sr/86Sr), Nd (143Nd/144Nd) and Pb (206Pb/204Pb, 207Pb/204Pb, 208Pb/204Pb) were measured at the Department of Earth Sciences, University of Geneva (Switzerland). The method is described in detail in ([Beguelin et al. 2015](#_ENREF_3)). Between 100 and 120 mg of whole rock powder were dissolved during 7 days in Savillex® Teflon vials using 4 ml of concentrated HF and 1 ml of HNO3 14M, at a temperature of 140 °C and with the help of ultrasonication for 30 minutes twice a day. Subsequently, samples were dried and re-dissolved for 3 days (also with 30 minutes ultrasonication twice a day) in 3 ml of HNO3 14M and dried again. Sr, Nd and Pb were then separated using cascade columns with Sr-Spec, TRU-Spec and Ln-Spec resins according to a protocol modified from ([Pin et al. 1994](#_ENREF_12)). Finally, the material was redissolved in 2% HNO3 solutions and ratios were measured using a Thermo Neptune PLUS Multi-Collector ICP-MS in static mode. Ratios used to monitor internal fractionation were: 88Sr/86Sr = 8.375209 for the 87Sr/86Sr ratio, 146Nd/144Nd = 0.7219 for the 143Nd/144Nd ratio and 203Tl/205Tl **=** 0.418922 for the three Pb ratios (a Tl standard was added to the solution). Used external standards were SRM987 (87Sr/86Sr = 0.710248, long-term external reproducibility: 10 ppm, 1SD), JNdi-1 (143Nd/144Nd = 0.512115; ([Tanaka et al. 2000](#_ENREF_15)); long-term external reproducibility: 10 ppm, 1SD), and SRM981 ([Baker et al. 2004](#_ENREF_2)) for Pb (long-term 1SD external reproducibility of 0.0048% for 206Pb/204Pb, 0.0049% for 207Pb/204Pb and 0.0062% for 208Pb/204Pb). 87Sr/86Sr, 143Nd/144Nd and Pb isotope ratios were further corrected for external fractionation (due to a systematic difference between measured and accepted standard ratios) by a value of -0.021‰, +0.051‰ and +0.36‰ amu respectively. Interferences at masses 84 (84Kr), 86 (86Kr) and 87 (87Rb) were corrected by monitoring 83Kr and 85Rb, 144Sm interference on 144Nd was monitored on the mass 147Sm and corrected by using a 144Sm/147Sm value of 0.206700 and 204Hg interference on 204Pb was corrected by monitoring 202Hg. Total procedural blanks were <500 pg for Pb and <100 pg for Sr and Nd which are insignificant compared to the amounts of these elements purified from the whole rock samples investigated. Whole-rock Sr-Nd-Pb isotope data are presented in Table S3.

For LA-ICPMS U-Pb geochronology, zircon crystals from two- to three-kg rock samples were randomly handpicked after concentration by conventional heavy liquid and magnetic techniques. Zircon grains were mounted in epoxy resin and then polished to expose their internal surfaces. We have used the Cathodoluminescence (CL) images to identify the internal structures of zircons to find the suitable points for U-Pb analysis. The CL images helped us to avoid dating of inclusion-bearing and/or cracked segments of zircons which would affect our resulting ages. Zircon LA-ICPMS U-Pb dating was performed using an Agilent 7500a Q-ICP-MS equipped with a 193-nm excimer Ar Flaser ablation system (Geolas Plus) at Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS), following methods described in ([Wu et al. 2010](#_ENREF_17)). GLITTER 4.4 software ([Griffin et al. 2008](#_ENREF_4)) was used for calculating the 207Pb/206Pb and 206Pb/238U ratios. The isotope ratios were then corrected using the Harvard zircon 91500 ([Wiedenbeck et al. 1995](#_ENREF_16)) as an external standard. Common Pb has been corrected following ([Andersen 2002](#_ENREF_1)). Isoplot 4.0 ([Ludwig 2011](#_ENREF_9)) was used for Concordia diagram plots and age calculations. Zircon LA-ICPMS U-Pb isotopic data are presented in Table S4.

For SIMS analysis, zircon concentrates were separated from crushed *ca* 3 kg rock samples using standard density and magnetic separation techniques. Zircon unknowns together with standards were mounted in epoxy mounts, which were then polished to section the crystals in half for analysis. Both optical photomicrographs and cathodoluminescence (CL) images were taken to guide analytical spot selection. The mount was vacuum-coated with high-purity gold prior to SIMS analyses. U-Pb analyses were performed on a Cameca IMS-1280/HR SIMS at Institute of Geology and Geophysics, Chinese Academy of Sciences (IGG-CAS) using standard operating conditions (7-scan duty cycle, ~8 nA primary O2− beam, 20×30 μm analytical spot size, mass resolution ~5400). U-Th-Pb ratios and absolute abundances were determined relative to the standard zircon Plešovice (337 Ma, ([Slama et al. 2008](#_ENREF_13))) and M257 (U = 840 ppm, Th/U = 0.27, ([Nasdala et al. 2008](#_ENREF_11))) respectively. Measured Pb-isotope compositions were corrected for common Pb using analyzed 204Pb values. An average Pb of present-day crustal composition ([Stacey & Kramers 1975](#_ENREF_14)) was used for the common-Pb correction. A long-term uncertainty of 1.5% (1 RSD) for 206Pb/238U measurements of the standard zircon was propagated to the unknowns ([Li et al. 2010b](#_ENREF_8)). In order to monitor the external uncertainties of SIMS U-Pb measurements, analyses of the in-house zircon standard Qinghu were interspersed with unknowns. Twenty-two analyses yield a weighted mean 206Pb/238U age of 159.4 ± 0.9 Ma (MSWD= 0.31), identical within error to the reported age of 159.5 ± 0.2 Ma ([Li et al. 2013](#_ENREF_7)). Uncertainties on individual analyses are reported at the 2σ level; mean ages for pooled U/Pb and Pb/Pb analyses are quoted with 95% confidence interval. These data were processed using the Isoplot/Ex v. 2.49 program ([Ludwig 2003](#_ENREF_10)). Zircon SIMS U- Pb isotopic data are presented in Table S5.

In situ oxygen-isotope analyses for selected samples of Paleogene rocks were conducted on zircons that were previously dated using the same Cameca IMS-1280 SIMS at IGG-CAS. After U-Pb dating, the sample mount was reground to ensure that any oxygen implanted in the zircon surface from the O2− beam used for U-Pb analysis was removed. The Cs+ primary ion beam was accelerated to 10 kV, with an intensity of ~2 nA corresponding to a beam size of ~10 μm in diameter. A normal-incidence electron flood gun was used to compensate for sample charging during analysis. Negative secondary ions were extracted with a -10 kV potential. Oxygen isotopes were measured using the multi-collection mode on two off-axis Faraday cups. One analysis consists of 16 cycles, with an internal precision generally better than 0.4‰ (2SE) on the 18O/16O ratio. The detailed analytical procedures are similar to those reported by ([Li et al. 2010a](#_ENREF_6)).

Oxygen isotope ratios are expressed as δ18O, representing deviation of measured 18O/16O values from that of the Vienna Standard Mean Ocean Water ((18O/16O)VSMOW = 0.0020052) in parts per thousand. The internal precision for each spot analysis is typically better than 0.4‰ for the 18O/16O ratio (2SE). The results are then corrected for instrumental mass fractionation factor (IMF), following the equation: δ18OCorrected = δ18OMeasured - IMF. IMF is monitored in terms of the difference between measured and recommended oxygen isotopic compositions of the Penglai zircon standard with a δ18O value of 5.31‰ ([Li et al. 2010b](#_ENREF_8)). The zircon O- isotope data are presented in Table S6.

Zircon Lu-Hf isotope compositions were acquired in IGG-CAS. The *in situ* zircon Lu-Hf isotopic analysis was carried out on a Neptune multi-collector ICP-MS equipped with a Geolas-193 laser-ablation system, and the analytical procedures were similar to those described by ([Wu et al. 2006](#_ENREF_18)). Lu-Hf isotopic analyses were obtained on the same zircon grains that were previously analyzed for U-Pb, with ablation pits of 63 μm in diameter, ablation time of 26 seconds, repetition rate of 10 Hz, and laser beam energy density of 10 J/cm2. During laser ablation analyses, the isobaric interference of 176Lu on 176Hf is negligible due to extremely low 176Lu/177Hf in zircons. Isobaric interference of 176Yb on 176Hf is corrected using independent mass bias factors for Hf and Yb for correction. During analysis, an isotopic ratio of 176Yb/172Yb = 0.5887 was applied ([Wu et al. 2006](#_ENREF_18)). Measured 176Hf/177Hf ratios were normalized to 179Hf/177Hf = 0.7325. The zircon Lu-Hf isotopic results are listed in Table S8. For calculation of initial Hf ratios, εHf (t) and TDM, we used the measured 206Pb/238U ages of each analysis point. Average crustal model ages (TDMC) were calculated by assuming that the host-rock of a zircon was originally derived from the depleted mantle and then evolved as a reservoir with 176Lu/177Hf of 0.015, similar to the average continental crust ([Griffin et al. 2002](#_ENREF_5)). Zircon Hf isotope data are presented in Table S6.

**Captions for supplementary materials**

Table S1- Bulk rock major and trace elements composition of the Paleogene rocks from oceanic tract of NW Iran.

Table S2- Geological standard values for whole rock major and trace elements analyses.

Table S3- Bulk rock Sr-Nd-Pb isotopic composition of the Paleogene rocks from oceanic tract of NW Iran.

Table S4- Zircon LA-ICPMS U-Pb ages for the magmatic rocks from SE parts of Kamyaran.

Table S5- Zircon SIMS U-Pb ages for the magmatic rocks from NW parts of Kamyaran.

Table S6- Zircon Lu-Hf and O isotope composition of the Paleogene rocks from oceanic tract of NW Iran.

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