# Supplementary File 2

# Sample Preparation and Methods

## Sedimentary Petrography

Nineteen samples of medium- to fine-grained sandstone were collected from the Dashtijum measured section for petrographic (point-counting) analysis. Each thin section was stained for potassium feldspar and calcium plagioclase. Framework grains (n=450) were counted on each thin-section following the Gazzi-Dickinson method (Ingersoll et al., 1984). Principal grain types identified are monocrystalline quartz (Qm), polycrystalline quartz (Qp), foliated polycrystalline quartz (Qpt), plagioclase feldspar (P), potassium feldspar (K), metamorphic lithic grains (Lm), sedimentary lithic grains (Ls; quartzite, sandstone, and siltstone), and volcanic lithic grains (Lv). Volcanic lithic grains include microlitic, trachytic, vitric, mafic and felsic varieties. Sedimentary lithic grains include dolostone, limestone, quartzite/sandstone, mudstone, siltstone, and chert. Metamorphic lithic grains include phyllite, schist, and marble. Trace minerals counted (but not included in modal calculations) consists of muscovite, biotite, chlorite, tourmaline, zircon, and Fe/Mg/Ti oxides.

## Geochronology and Thermochronology

Zircon was extracted from sandstone samples by standard separation methods for detrital zircon U-Pb geochronology. U-Th-Pb isotope ratios in zircon were measured at the University of Arizona LaserChron Center (laserchon.org) by LA-ICP-MS with a Teledyne Photon Machines G2™ solid state NeF excimer laser ablation system coupled to a Thermo Fisher Scientific ELEMENT 2™ single collector inductively coupled plasma mass spectrometer. Details of the data collection and reduction procedures are described in Gehrels et al. (2008). Each zircon separate was characterized by 75-400 single-grain analyses. Reported peak ages are weighted mean ages for age populations composed of three or more single grain analyses. Populations were identified using AgeCalc (Gehrels et al., 2008).

A subset of the sandstone samples analyzed for zircon U-Pb geochronology was also analyzed for detrital zircon fission track (ZFT) thermochronology at the University of Arizona. A “double-dating” technique was employed in which U-Pb crystallization ages and ZFT cooling ages were obtained from the same grain using a LA-ICP-MS fission track method and a modified zeta calibration (cf., Hasebe et al., 2004). Spontaneous zircon fission tracks/etch pits were counted using backscatter electron images from a scanning electron microscope and U concentrations were determined along with U-Th-Pb isotope ratios. Details of the ZFT—U-Pb double dating process, standardization, and data reduction are reported in Chapman et al. (2018). Fifty to 100 detrital zircon grains were analyzed for ZFT from each sandstone sample. The ZFT thermochronologic system has a closure temperature of 240 ± 30 °C (Bernet and Garver, 2005), which corresponds to an exhumation depth of ca. 7-10 km for 25-30 °C/km geothermal gradients. The average uncertainty (1σ) for single-grain ZFT analyses is ~25%. Single-grains with ZFT cooling ages significantly older than corresponding zircon U-Pb crystallization age (ZFT age - σ) > (U-Pb age + 2σ) were removed from the dataset. Constituent ZFT age population peaks were deconvolved using DensityPlotter (Vermeesch, 2012) and uncertainties are reported at 2σ.

## Micropaleontology

Seven samples were collected from the Dashtijum section for micropaleontological analysis. Samples were prepared as smear slides, washed and sieved residues, and thin-sections following standard procedures for the analysis of calcareous nannofossil, benthic foraminifera, and ostracod content. For calcareous nannofossils, five samples of mudstone were collected: DSH 16-18 (1340 m level), DSH 16-22 (1640 m level), DSH 16-24 (1750 m level), DSH 16-26 (1875 level), and DSH 16-28 (2110 m level).

Calcareous nannofossils were analyzed using simple smear slide preparation in order to retain original composition of nannofossil assemblages and standard light-microscope techniques. Assemblages are qualitatively estimated, observing two random traverses of the slide at 1250X magnification. Ages are assigned with reference to the biozonation of Burnett (1998). For analyses of foraminifera and ostracods, washed residues were prepared using 100-150 g of dry rock. Each sample was disaggregated, treated with H2O2 for at least 12 hours, washed and sieved through meshes of 425, 180 and 63 μm, dried in an oven at 40°C, and finally analyzed under a stereomicroscope. The samples were also prepared as thin sections (30 μm thick) and analyzed under a polarized-light microscope. The ostracod biostratigraphy follows the zonation of Keen (1978) whereas larger benthic foraminiferal biostratigraphy follows BouDagher–Fadel (2008).

## References Cited

Bernet, M. and Garver, J.I., 2005. Fission-track analysis of detrital zircon: Reviews in Mineralogy and Geochemistry, v. 58, p. 205-237.

BouDagher-Fadel, M.K., 2008. The Mesozoic larger benthic foraminifera: the Cretaceous: Developments in Palaeontology and Stratigraphy, v. 21, p. 215-544.

Burnett, J.A. 1998. Upper Cretaceous. In P.R. Bown (Ed.), Calcareous Nannofossil Biostratigraphy. British Micropaleontology Society Publications Series, Kluwer Academic Publishers, London, p. 132-199.

Chapman, J.B., Robinson, A.C., Carrapa, B., Villarreal, D., Worthington, J., DeCelles, P., Kapp, P., Gadoev, M., Oimahmadov, I., Gehrels, G., 2018, Cretaceous shortening and exhumation history of the South Pamir terrane: Lithosphere, v. 10, p. 494-511, doi: 10.1130/L691.1

Gehrels, G.E., Valencia, V.A. and Ruiz, J., 2008, Enhanced precision, accuracy, efficiency, and spatial resolution of U-Pb ages by laser ablation–multicollector–inductively coupled plasma–mass spectrometry: Geochemistry, Geophysics, Geosystems, v. 9.

Hasebe, N., Barbarand, J., Jarvis, K., Carter, A., and Hurford, A.J., 2004, Apatite fission-track chronometry using laser ablation ICP-MS: Chemical Geology, v. 207, p. 135-145.

Ingersoll, R.V., Bullard, T.F., Ford, R.L., Grimm, J.P., Pickle, J.D. and Sares, S.W., 1984. The effect of grain size on detrital modes: a test of the Gazzi-Dickinson point-counting method: Journal of Sedimentary Research, v. 54, p. 103-116.

Keen, M., 1978, The Tertiary—Palaeogene. A stratigraphical index of British Ostracoda, p. 385-449.

Vermeesch, P., 2012, On the visualisation of detrital age distributions: Chemical Geology, v.312-313, p. 190-194.