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## Supplemental Material

**Figure S1.** Magmatic provenance diagrams (Grimes et al., 2007; Grimes et al., 2015) for zircons from sites U1431 and U1432. Samples are grouped according to their stratigraphic positions and zircon age signatures.

**Table S1.** Geographic location, stratigraphic context, and lithology of the samples from sites U1431 and U1432 for heavy mineral analysis and detrital zircon U-Pb dating. The depositional ages of samples are estimated assuming a constant sedimentation rate for each stratigraphic unit (Fig. 2). mbsf—meters below seafloor.

**Table S2.** Relative abundances of non-opaque detrital heavy minerals of the Upper Miocene to Pleistocene samples from sites U1431 and U1432.

**Table S3.** U-Pb geochronological results, elemental concentrations, grain size and shape measurements of detrital zircons from sites U1431 and U1432. Only ages with  $\leq 10\%$  discordance and  $\leq 10\%$  uncertainty ( $1\sigma$ ) are shown here. Discordance tests for zircons older and younger than 1000 Ma are calculated by  $[1 - (^{206}\text{Pb}/^{238}\text{U} \text{ age} / ^{207}\text{Pb}/^{206}\text{Pb} \text{ age})] * 100$  and  $[1 - (^{206}\text{Pb}/^{238}\text{U} \text{ age} / ^{207}\text{Pb}/^{235}\text{U} \text{ age})] * 100$ , respectively. Aspect Ratio = Major axis/Minor axis. Circularity =  $4\pi * \text{Area} / (\text{Perimeter})^2$ . Roundness =  $4 * \text{Area} / [\pi * (\text{Major axis})^2]$ . Effective diameter =  $2 * (\text{Area} / \pi)^{1/2}$ . Nominal diameter =  $(\text{Major axis} * \text{Intermediate axis} * \text{Minor axis})^{1/3}$ , assuming Intermediate axis equal to Minor axis (Garzanti et al., 2008; Lawrence et al., 2011).

**Table S4.** Compilation of published detrital zircon U-Pb ages along with sampling information and references from the Upper Miocene to Pleistocene samples in the South China Sea region. Samples are grouped according to their geographic locations, including the Western Foothills and Hengchun Peninsula of Taiwan (Chen et al., 2017; Kirstein et al., 2010; Lan et al., 2016; Zhang et al., 2014; Zhang et al., 2017), the Central Depression of the Qiongdongnan Basin (Cao et al., 2015; Chen et al., 2015; Li et al., 2019; Shao et al., 2018), the Central Depression of the Yinggehai Basin (Cao et al., 2015; Jiang et al., 2015; Wang et al., 2018; Wang et al., 2014; Xie et al., 2016; Yan et al., 2011), the Da Lat Zone of Southeast Vietnam (Hennig et al., 2018), South Palawan (Cao et al., 2020; Suggate et al., 2014; Yan et al., 2018b), and the Miri Zone of Northwest Borneo (Hennig-Breitfeld et al., 2019). Published age data, if available, are filtered with a cutoff criterion of  $\leq 10\%$  discordance and  $\leq 10\%$  uncertainty ( $1\sigma$ ). The filtered age data set of each sample group with a relatively limited number of analyses (e.g., Upper Miocene of Pearl River Mouth Basin; Yan et al., 2018a) is omitted.

**Table S5.** Pearson correlation results of age, elemental concentration and ratio, grain size and shape of zircons from sites U1431 and U1432. Samples are grouped according to their stratigraphic positions and zircon age signatures. The correlation coefficient (r) and probability (p) values are shown at the bottom left and top right of each matrix, respectively. Coefficient

values with  $|r| > 0.7$  at the significance level of 0.01 (dark yellow) and 0.05 (light yellow) on two-tailed test are indicated in bold font.

**Table S6.** Compilation of published detrital zircon U-Pb ages along with sampling information and references from drainage sediments and bedrocks of modern potential provenances surrounding the South China Sea. Samples are grouped into 11 source areas, including West Taiwan (Chen et al., 2019; Deng et al., 2017), Coastal Southeast China (Chen et al., 2019; Xu et al., 2014b; Zhang et al., 2017), Pearl River (He et al., 2020; Liu et al., 2017; Xu et al., 2007; Zhao et al., 2015), Hainan (Cao et al., 2015; Wang et al., 2015; Xu et al., 2014a), Red River (Bodet and Schärer, 2000; Clift et al., 2006; Fyhn et al., 2019; Hoang et al., 2009; Wang et al., 2018), North Palawan (Cao et al., 2020; Padrones et al., 2017; Shao et al., 2017; Suggate et al., 2014; Walia et al., 2012), East Vietnam (Fyhn et al., 2019; Jonell et al., 2017; Usuki et al., 2013; Wang et al., 2018), Mekong River (Bodet and Schärer, 2000; Clift et al., 2006), Northwest Borneo (Breitfeld and Hall, 2018; Breitfeld et al., 2017; Breitfeld et al., 2020; Galin et al., 2017; Hennig-Breitfeld et al., 2019), Malay Peninsula (Sevastjanova et al., 2011), Southeast Sumatra (Zhang et al., 2019). Published age data, if available, are filtered with a cutoff criterion of  $\leq 10\%$  discordance and  $\leq 10\%$  uncertainty ( $1\sigma$ ). Age data are preferentially compiled from drainage sediments that discharge into the South China Sea instead of bedrocks unless the former are unavailable (i.e., in North Palawan and Northwest Borneo). The two tectonic units along the eastern Indochina margin, Truong Son Belt and Kontum Massif, are together defined as the East Vietnam Provenance (Nagy et al., 2001; Ngoc Nam, 1998) because their zircon age distribution patterns are largely comparable albeit with a certain degree of variation among different mountainous rivers. Likewise, the tectonic units of Miri, Sibul, and Kuching zones of Borneo are grouped as the Northwest Borneo provenance.

**Table S7.** Summary of the inverse Monte Carlo mixture model results of detrital zircon U-Pb age data of the upper Upper Miocene to Pleistocene samples from sites U1431 and U1432. Potential provenances with blank values of relative contribution and standard deviation ( $1\sigma$ ) are those not included in the modeling. The goodness-of-fit metric of the model is calculated by the cross-correlation coefficient of KDE spectra between observed and modeled data (10,000 trials).

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Figure S1

