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Key Points:
- Petrography, heavy mineral, and Sr-Nd isotopic data were used to trace sediment provenance for a tectonically stable mountainous river
- Provenance data indicates rapid sediment delivery in response to hydrological changes over seasonal timescales
- Climate variability exerts a major control on sediment compositions, revealing a third type of sediment transport regime in East Asia

Supporting Information:
- Supporting Information S1
- Table S1

Correspondence to:
X. Jian,
xjian@xmu.edu.cn

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Climate-Dependent Sediment Composition and Transport of Mountainous Rivers in Tectonically Stable, Subtropical East Asia

Xing Jian[1], Wei Zhang[1], Shouye Yang[2], and Shuh-Ji Kao[1]

[1]State Key Laboratory of Marine Environmental Science, College of Ocean and Earth Sciences, Xiamen University, Xiamen, China, [2]State Key Laboratory of Marine Geology, Tongji University, Shanghai, China

Abstract While mountainous rivers in subtropical East Asia deliver a disproportionately large amount of sediments to the global ocean, the controlling mechanisms for sediment supply and transport remain understudied. Here we target a mesoscale tectonically stable mountainous river, the Minjiang River, in southeast China. We present petrography, heavy minerals, and Sr-Nd isotopic data from suspended particulate matter (SPM) and riverbed sediments to characterize sediment-climate feedback processes. Results show Sr-Nd isotopic compositions of the SPM vary seasonally, corresponding well with the spatiotemporal variations of precipitation. River sands display low compositional and textural maturity and represent first cycle-dominated and fast-transported detritus. Provenance analysis suggests prominent contributions of upstream Proterozoic-Paleozoic rocks to downstream SPM and riverbed sediments. We propose that climate-induced hydrological variations exert a major control on sediment supply, transport, and compositions. Our study highlights the crucial role of climate in driving physical erosion of mountains in tectonically stable, subtropical East Asia.

Plain Language Summary The subtropical-tropical rivers in East and South Asia, particularly those draining mountains, account for a significant proportion of global sediment and nutrient exports. Based on tectonic settings, river basin morphology, climatic conditions, and extents of anthropogenic impacts, two distinct types of sediment supply and transport regimes in the low-middle latitudes of East Asia have been identified. Type 1 rivers are large rivers on the tectonically stable continent with slow, multicycled sediment transport, modulated by widespread flood plains, lakes, and human activities. Type 2 rivers are small mountainous rivers on tectonically active plate boundaries with rapid sediment transport, which are commonly triggered by extreme tectonic and climatic events. However, sediment transport mechanisms of the mountainous rivers in the tectonically stable, subtropical regions remain highly enigmatic. We combined petrology and geochemistry methods to track sediment sources of the Minjiang River (southeast China) and to characterize river sediment transfer processes. We find that hydroclimate changes, rather than anthropogenic forcings, exhibit the major control on discharged sediment compositions. We suggest that the mesoscale, tectonically stable, mountainous rivers have similar rapid sediment transport behavior to those small mountainous river systems, unlike other large river systems in subtropical East Asia.

1. Introduction

Rivers supply fresh water, solutes, sediments, and organic matter to the oceans, providing the most significant link between terrestrial and marine systems (Ludwig et al., 1996; Milliman & Meade, 1983). Erosion, transport, and deposition of river sediments shape the Earth's surface, affect the dynamics of ecosystems and human society (Syvitski, 2003; Walling, 2009), and play important roles in understanding of land-ocean interactions, chemical cycles, and global change (Martin & Meybeck, 1979; Gaillardet, Dupré, Louvat, et al., 1999).

The low-middle latitude, exorheic rivers in East and South Asia, particularly those draining subtropical-tropical mountains, are thought to account for the largest proportion of sediment and nutrient discharges on the global scale (Milliman & Farnsworth, 2011). The supply and transport of river sediments is influenced by a variety of internal and external factors such as tectonics, climate, morphology, and bedrock lithology over different timescales (Ludwig & Probst, 1998; Meybeck et al., 2003; Milliman & Syvitski, 1992; Walling & Fang, 2003). Human activities such as construction of dams and reservoirs, sand mining, and land use also control the supply and transport of sediments to their final depositional location (Dai et al., 2009; Syvitski et al., 2005).

Previous studies have identified two distinct river sediment transport regimes in the low-middle latitudes of East Asia. Type 1 river systems consist of large rivers (such as Yangtze and Mekong Rivers, Figure 1a, basin areas greater than 500,000 km^2) on the tectonically stable continental substrate. These rivers exhibit slow, multicycled sediment transport which is generally modulated by abundant lakes and widespread flood plains (Figure 1b) and increasing anthropogenic forcings. Type 2 river systems consist of small mountainous rivers (such as the rivers in Taiwan, Figure 1b, basin areas smaller than 10,000 km^2) on tectonically active plate boundaries. Rapid sediment transport by these rivers is commonly triggered by extreme events such as volcanos, earthquakes, and typhoons (Bi et al., 2015; He et al., 2014; Kao & Milliman, 2008; Li et al., 2016; Yang et al., 2014). A potential third type of river systems consist of mesoscale, exorheic mountainous rivers in subtropical southeast China (e.g., Oujiang, Minjiang, and Jiulongjiang Rivers). These rivers are commonly referred to as Zhe-Min rivers (Figure 1b) and serve as an important component in the land-ocean system of East Asia (Bi et al., 2017; Liu et al., 2008, 2014; Xu et al., 2012).

Similar to Type 1 river systems, the Zhe-Min rivers are located in tectonically stable settings and are influenced by human activities. Dams and reservoirs along the Zhe-Min rivers (Figure S1 in the supporting information) are presumed to block upstream sediment transfer to the river mouth and are suggested as a principal cause for the decline of sediment flux over the past few decades (Dai et al., 2009; Ministry of Water Resources, the People's Republic of China, 2016). However, these mountainous rivers have different basin morphologies and climatic conditions (rainfall dominated by summer monsoon and tropical cyclone) from Type 1 river systems (Chang et al., 2012; Su et al., 2018; Yin et al., 2010). Thus, there remains a question of whether the Zhe-Min rivers exhibit a similar sediment transfer regime as Type 1 river systems as previously inferred (Bi et al., 2015) or represent a separate, unique river system type.

We target the Minjiang River Basin because it is characterized by bedrock lithologic and geochemical, as well as climatic heterogeneity (Figures 1 and 2; Chen & Jahn, 1998). This diverse natural laboratory allows for a short-timescale sediment source-to-sink study. We present petrographic, heavy mineral, and Sr-Nd isotopic data from suspended particulate matter (SPM) and riverbed sediments. The objective of this study is to track sediment provenance and to evaluate short-term sediment supply and transport by this mesoscale, tectonically stable subtropical mountainous river.

2. The Minjiang River Basin

The Minjiang River basin is characterized by a forested, highland watershed landscape, with a drainage area of approximately 61,000 km^2. It originates in the Wuyi Mountains which are 700–2,200 m above sea level (Figure 1b). The Minjiang River historically discharges approximately 54 billion m^3 of water and 6 million tons of sediment annually (Ministry of Water Resources, the People's Republic of China, 2016). The upstream river basin consists of Precambrian basement metasedimentary rocks of the Cathysia block, Paleozoic sedimentary strata, as well as Mesozoic igneous rocks. The downstream basin is dominated by Jurassic-Cretaceous igneous rocks and volcano-sedimentary strata (Figure 2; Chen & Jahn, 1998; Li et al., 2014). The Precambrian and Paleozoic rocks have higher $^{87}Sr/^{86}Sr$ and lower $^{143}Nd/^{144}Nd$ ratios than the Mesozoic rocks (Chen & Jahn, 1998; Li et al., 2014; Yu et al., 2012; Wang et al., 2013, 2014, 2015; Zhao et al., 1995). Annual precipitation in the river basin ranges from approximately 1,500 to 2,000 mm and displays high spatiotemporal heterogeneity (Figures 1c and d). Most rainfall in the upstream regions occurs in March–June, whereas the downstream regions undergo March–June rains and heavy rains triggered by tropical cyclones in July–September (Figure 1c; Yin et al., 2010).

3. Samples and Methods

Sediment samples were collected from exposed, accessible riverbeds below dams and reservoirs where sediment was deposited during high water levels. To collect SPM samples, river water was collected from the middle of channels using a clean polyethylene water sampler by standing on bridges. Samples covered the mainstream of the Minjiang River and its associated tributaries (except the inaccessible Gutianxi tributary) (Figure 2a). Twenty-five water-SPM samples were collected from October 2016 to October 2017 (a hydrologic

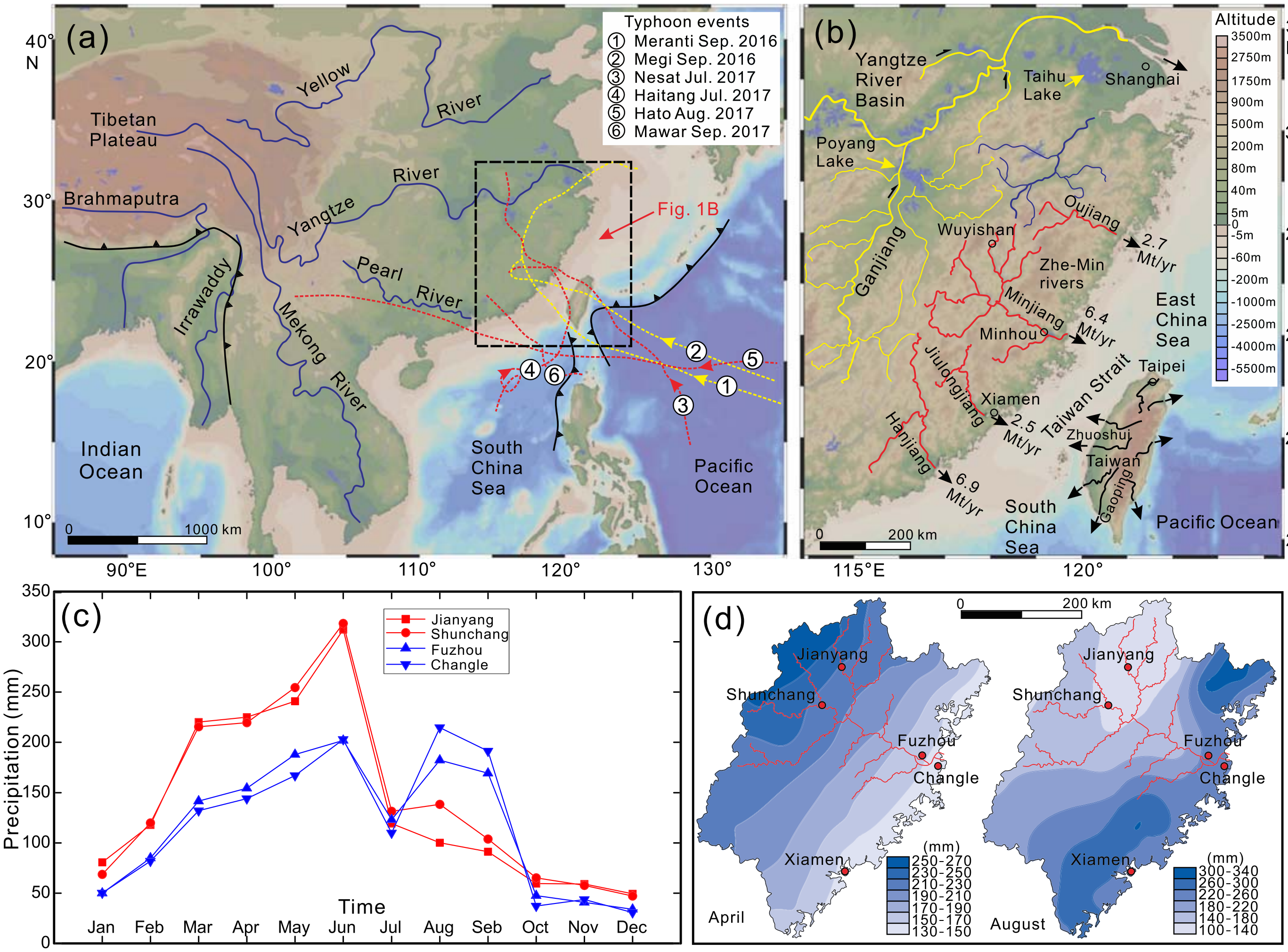

Figure 1. (a) Overview map of major rivers in East Asia. Representative typhoon events associated with sampling seasons and corresponding trajectories (red and yellow dash lines) are shown. (b) Major subtropical mountainous river systems in southeast China, delineated by box in Figure 1a. Most areas of the Minjiang River Basin sit about 0.5–2 km above sea level. (c) Monthly precipitation of representative areas (Jianyang and Shunchang are upstream weather stations and Fuzhou and Changle are downstream weather stations) in the Minjiang River basin. (d) April and August precipitation of the Fujian Province, southeast China. The data and paths of the typhoons were collected from http://typhoon.weather.com.cn website. All the rainfall data are average values during 1981–2010, collected from http://data.cma.cn website.

cycle) at Station S04 in the lower reach of the Minjiang River, approximately 50-km landward from the river mouth (Figure 2a). These water-SPM samples were collected nearly semimonthly, with slightly lower frequencies in dry seasons (e.g., January–February 2017). We collected one sample at a time during falling tide to avoid the influence of signals from the ocean. Each SPM sample was filtered from 25 L of river water through 0.45-μm membranes. To minimize the hydraulic sorting bias on provenance analysis, fractions of 63–500, 63–250, and <63 μm of the riverbed samples were sieved for framework petrography, heavy mineral analysis, and Nd isotope geochemistry, respectively. Information and descriptions of the samples are in Table S1.

Samarium and Nd are chemically similar rare earth elements that experience negligible fractionation during processes such as weathering, sediment transport, and deposition of fine-grained clastic material (Taylor & McLennan, 1985). Therefore, Nd isotopic ratios are powerful tracers of sediment provenance and mean crustal age of source terrains (Goldstein & Jacobsen, 1988; Hemming et al., 2007; Taylor & McLennan, 1985). Although Sr is quite mobile during chemical weathering and sediment Sr isotopic ratios have been widely used to evaluate continental weathering regimes (Blum & Erel, 2003), Sr isotopes can be useful when

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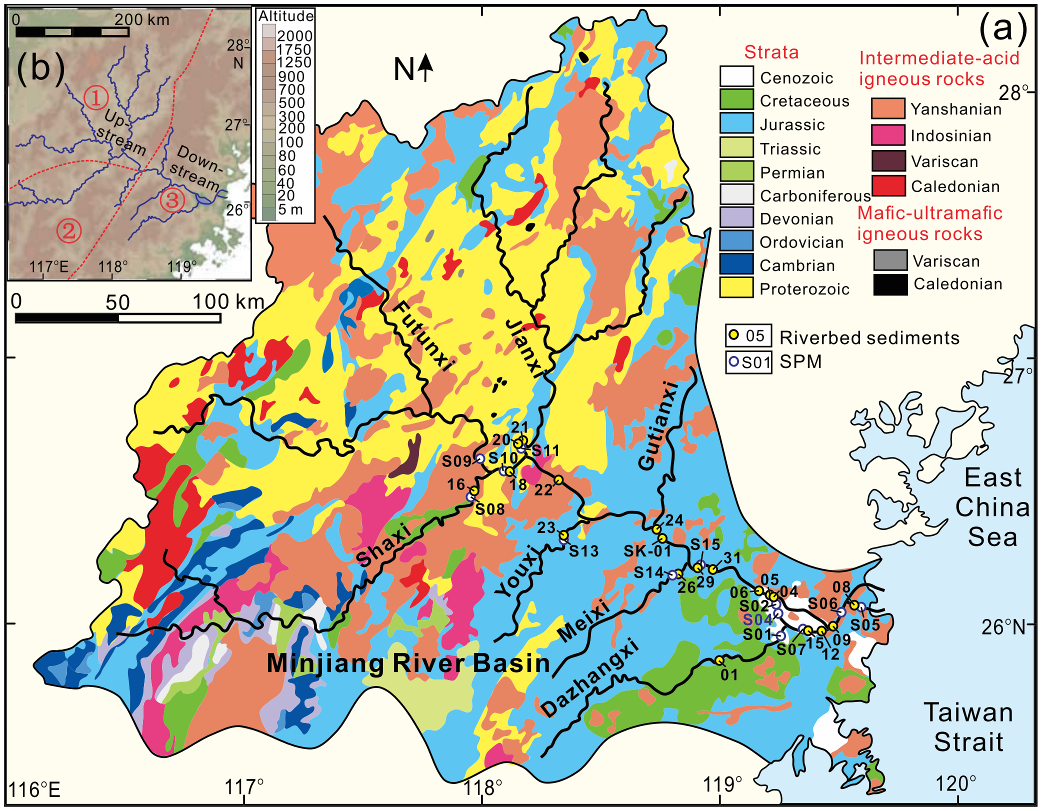

Figure 2. (a) Geological map of the Minjiang River Basin and sample locations. (b) Stratigraphic divisions of the river basin: (1): Proterozoic; (2): Paleozoic; (3): Jurassic–Cretaceous.

coupled with Nd isotopes to trace the combined Sr-Nd characteristics of sediment sources (Goldstein & Hemming, 2003). For the pretreatment of Sr-Nd isotope analysis, SPM samples and <63-μm fractions of the riverbed sediments were powdered with an agate mortar. Carbonate components were removed from the powder samples by soaking in 1 N acetic acid for 24 hr. The residues were burned in a muffle furnace at 600 °C for 2 hr to remove organic matter. Each pretreated sample was accurately weighed (~50 mg) and completely digested with a mixture of concentrated HF and HNO_3 in high-pressure Teflon bombs at 190 °C for 48 hr. Strontium and Nd were separated following standard ion exchange techniques and their isotopes were determined using a Neptune plus MC-ICP-MS at the State Key Laboratory of Marine Geology, Tongji University. Ratios of $^{87}Sr/^{86}Sr$ and $^{143}Nd/^{144}Nd$ ratios were corrected for mass fractionation by normalizing to $^{86}Sr/^{88}Sr = 0.1194$ and $^{146}Nd/^{144}Nd = 0.7219$, respectively. The NBS 987 ($^{87}Sr/^{86}Sr = 0.710241$) and JNdi ($^{143}Nd/^{144}Nd = 0.512115$) standard solutions were employed to monitor the quality of Sr and Nd isotopic measurements, respectively. The standard NBS 987 gave an average value of measured $^{87}Sr/^{86}Sr = 0.710242 \pm 0.000011$ (2σ, $N = 8$) and the JNdi standard gave an average value of measured $^{143}Nd/^{144}Nd = 0.512116 \pm 0.000003$ (2σ, $N = 10$), well within the recommended values. Neodymium isotopic results are reported as $^{143}Nd/^{144}Nd$ and as εNd ($\varepsilon Nd = ((^{143}Nd/^{144}Nd)_{measured}/(^{143}Nd/^{144}Nd)_{CHUR}-1) \times 10^4$) using the "Chondritic Uniform Reservoir" value of 0.512638 (Jacobsen & Wasserburg, 1980).

The 63- to 500-μm fractions of riverbed sediments were impregnated with araldite, cut into standard thin sections, and analyzed by counting approximately 400 points under a polarizing microscope, using the Gazzi-Dickinson method (Dickinson, 1985). Major framework grains, including quartz, plagioclase, K-feldspar, and various lithic fragments, were identified as well as sedimentary textures. Heavy minerals were separated by heavy liquid tribromomethane (2.89 g/cm^3) from the 63- to 250-μm fractions and subsequently weighted and mounted on glass slides with Canada balsam. About 200 transparent heavy mineral grains were identified and point-counted at suitable regular spacing under a polarizing microscope (Mange & Maurer, 1992).

4. Results

4.1. Sr-Nd Isotopes of SPM and Riverbed Sediments

The $^{87}Sr/^{86}Sr$ ratios of the middle to lower tributaries and the mainstream SPM samples vary between 0.714792 ± 0.000025 and 0.729398 ± 0.000016. The εNd values of these samples have a range of −12.6 ± 0.1 to -10.2 ± 0.2 (Figures 3a and Table S2). In contrast, the SPM samples from upstream tributaries have much higher $^{87}Sr/^{86}Sr$ ratios and more negative εNd values, ranging from 0.729896 ± 0.000021 to 0.743911 ± 0.000021 and from −13.8 ± 0.2 to −12.2 ± 0.2 (Figure 3a), respectively. Similarly, downstream riverbed sediment samples (e.g., samples 16MJ-09 and 16MJ-15) have relatively higher Nd isotope ratios than those upstream riverbed samples (Table S2).

The 1-year hydrological cycle (different season samples from the Station S04) SPM samples have $^{87}Sr/^{86}Sr$ ratios and εNd values between 0.714792 ± 0.000025 and 0.725939 ± 0.000018 and between −12.1 ± 0.2 and −10.2 ± 0.2 (Figure 3d), respectively. The highest $^{87}Sr/^{86}Sr$ ratios and most negative εNd values were recorded from late June to early July 2017 (Figure 3d). All the Sr-Nd isotope data of the analyzed samples are shown in Table S2.

4.2. Framework Petrography and Heavy Minerals of River Sands

Framework grains of the river sands are dominated by quartz (42%–76%) and feldspar (14%–44%). Lithic fragments show low abundances (3%–22%) in most analyzed samples (Figures 4a and 4b). Four upstream samples (16MJ-16, 16MJ-19, 16MJ-22, and 16MJ-23) have relatively high metamorphic lithic fragment proportions (>10%) (Table S3). Transparent heavy minerals in the samples mainly consist of hornblende, garnet, augite, epidote, tourmaline, and zircon (Figure 4c). Most of the framework grains and heavy minerals are angular to subangular (Figures 4b and 4d). The ZTR index (ZTR index = (zircon + tourmaline + rutile)/all transparent heavy minerals × 100) values, which represent the degrees of sediment maturity, are relatively low (averaging 25.8) and quite invariable for upstream and downstream sands (Figure S3). The petrographic and heavy mineral data are shown in Tables S3 and S4.

5. Discussion

5.1. Provenance Analysis

Comparison of Sr-Nd isotopic data between the catchment bedrock and the analyzed river SPM samples indicates that the SPM is derived from both Mesozoic and pre-Mesozoic rocks (Figures 3b and 3c). By assigning Mesozoic and pre-Mesozoic rocks in the river basin as the two sediment-source end-members (Figure 3b), the upstream tributary suspended-load sediments (five samples) are supplied by 30%–55% Mesozoic rocks and 45%–70% pre-Mesozoic rocks. The downstream and discharged suspended-load sediments are from a mixing of 55%–85% Mesozoic rocks and 15%–45% pre-Mesozoic rocks. The modeled parent-rock compositions of the discharged sediments are broadly consistent with previous detrital zircon dating results of two samples from the Minjiang River mouth which indicate that detrital zircons therein consist of approximately 45% Mesozoic and approximately 55% pre-Mesozoic populations (Xu et al., 2014, 2016).

The Sr-Nd isotopes of the SPM samples at the downstream Station S04 display clear seasonal variations (Figure 3d). The $^{87}Sr/^{86}Sr$ ratios during the wet season show successively increasing trends from March to middle April and from May to June, suggesting an increased contribution of the upstream pre-Mesozoic bedrock. The $^{87}Sr/^{86}Sr$ ratios also show a decreasing trend from July to September 2017, suggesting either a decreased contribution of pre-Mesozoic bedrock or an increased contribution of Mesozoic bedrock. The εNd values indicate reverse relations to the $^{87}Sr/^{86}Sr$ ratios (Figure 3d). These seasonal provenance variations of the discharged SPM correspond well with the spatiotemporal variations of precipitation in the catchment, which show relatively higher rainfall in the upstream regions in March and May–June periods and much higher rainfall in the downstream regions during the late summer to autumn typhoon seasons (Figures 3d and S4; Yin et al., 2010). The changes in SPM Sr-Nd isotopic variation trends in April 2017

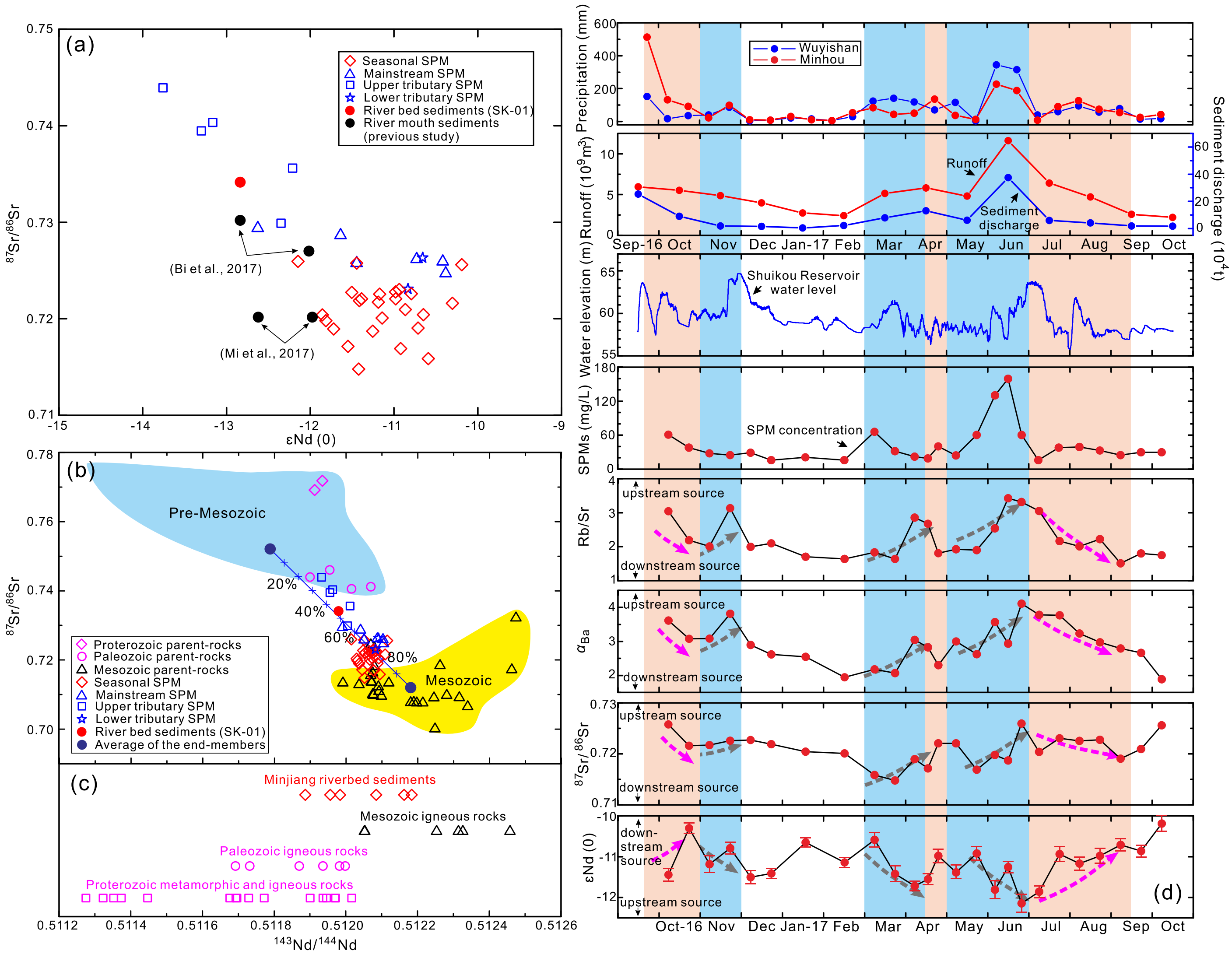

Figure 3. (a) Sr-Nd isotopic ratios of the samples and river mouth sediments from previous studies (Bi et al., 2017; Mi et al., 2017). (b) Mixed sediment-source compositions modeling by using published Sr-Nd isotopic data of potential parent-rocks in the Minjiang River catchment. Mesozoic and pre-Mesozoic crystalline rocks were assigned as two parent-rock end-members (blue solid dots indicate their average compositions) to quantitatively model mixed source compositions for the sediment samples. Mixing curves are divided into 10% increments. Data of the parent-rocks are from Zhao et al. (1995), Chen and Jahn (1998), Yu et al. (2012), Wang et al. (2013, 2014, 2015), and Li et al. (2014). (c) Comparison of Nd isotope ratios of the catchment parent-rocks and the analyzed riverbed sediments. (d) Seasonal variations in precipitation, runoff, sediment discharge of the Minjiang River, Shuikou reservoir water levels, discharged SPM concentrations, representative trace element ratios (trace element data are from Jian et al. (2020)), and Sr-Nd isotopes. Blue and red vertical bands indicate greater and less precipitation periods in the upstream regions, respectively. Grey and pink dashed lines with arrows show the variation trends of the element and Sr-Nd isotopic ratios, revealing increasing and decreasing supply of upstream materials, respectively. $\alpha_{Ba} = [Th/Ba]_{sed}/[Th/Ba]_{UCC}$ (Gaillardet, Dupré & Allègre, 1999). The error bars of Rb/Sr, α_{Ba}, and $^{87}Sr/^{86}Sr$ ratios are smaller than the size of the symbols. Note that the upstream tributary sediments have relatively higher Rb/Sr, α_{Ba}, and $^{87}Sr/^{86}Sr$ ratios and lower εNd values than the downstream tributary sediments (Figures 3a and S2).

can also be associated with precipitation variations because the downstream regions (e.g., Minhou) had relatively higher rainfall than the upstream regions (e.g., Wuyishan) during this time (Figure 3d).

As mentioned above, the upstream river basin exposes widespread Proterozoic basement metamorphic rocks and Paleozoic (meta)sedimentary rocks of the Cathysia block (Figure 2). The occurrence of metamorphic lithic fragments and high abundances of garnet and epidote in heavy minerals in the downstream riverbed samples (Figure 4) implies that the discharged river sands do not only primarily originate from the downstream Mesozoic igneous rocks but are also supplied by the upstream tributaries draining dominant pre-

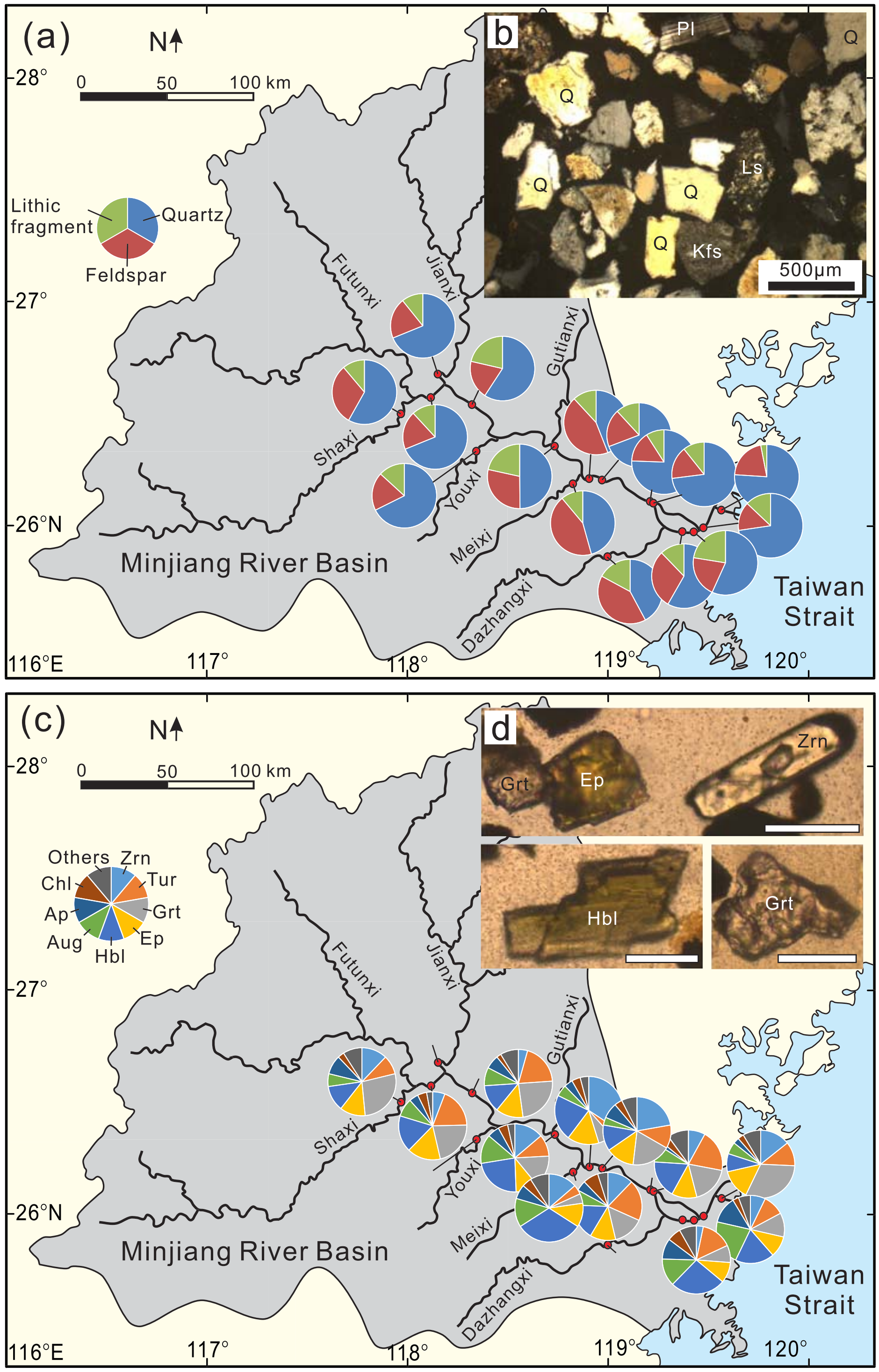

Figure 4. Framework petrography and heavy mineral analysis results of the Minjiang River sands. (a) Q-F-L (Quartz-feldspar-lithic fragment) proportions; (b) representative photomicrographs (Sample 16 MJ-05); (c) heavy mineral assemblages and abundances; and (d) representative photomicrographs of major heavy minerals (from samples 16MJ-12, 16MJ-31, and 16MJ-24, scale bar 200 μm (white horizontal lines) for all the grains). Other heavy minerals mainly include rutile, titanite, staurolite, and monazite. Q = quartz; Pl = plagioclase; Kfs = K-feldspar; Ls = sedimentary lithic fragment; Zrn = zircon; Tur = tourmaline; Grt = garnet; Ep = epidote; Hbl = hornblende; Aug = augite; Ap = apatite; Chl = chlorite.

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Mesozoic rocks. Furthermore, relatively unstable detrital grain species, such as apatite, augite, and hornblende (Morton & Hallsworth, 1999), are quite common and display considerable abundances in the river sands (Figures 4 and Tables S3 and S4). This is consistent with the low ZTR values (Figure S2). Texturally, most detrital grains in these samples are angular to subangular in shape (Figure 4). These results suggest that the Minjiang River sands probably represent first cycle-dominated detritus.

5.2. Sediment Transport by the Mesoscale Mountainous Rivers in Subtropical East Asia

Several factors such as catchment morphology, bedrock lithology, tectonics, climate, as well as different kinds of human activities can regulate river sediment transport and, thus, impact flux and composition of sediment into the oceans (e.g., Kao & Milliman, 2008; Syvitski et al., 2005; Walling & Fang, 2003). Note that the dams and reservoirs within the Minjiang River catchment were mainly established in the upper and middle reaches (Figure S1), which are expected to hold back sediments from the upstream regions (Dai et al., 2009). However, our provenance interpretations on both SPM and riverbed sands demonstrate prominent contributions of the upstream Paleozoic and Proterozoic rocks to the Minjiang River-discharged sediments. Although all the reservoirs (e.g., the Shuikou reservoir; Figure S1) periodically release water depending on precipitation and reservoir storage conditions (Figure 3d) and other human influences (such as land use, mining, and particulate pollution) on the river sediment compositions might vary (but cannot be easily quantified) on seasonal timescales, the correlation between rainfall variability and provenance changes suggests that the anthropogenic impacts probably play a minor role in discharged sediment compositions. The rapid response of the SPM geochemical signals to rainfall variability suggests that climate-induced hydrological variation, instead, serves as the major control on discharged sediment compositions. Therefore, we propose that in this mountainous landscape that is tectonically inactive, climate (specifically rainfall) is likely the most important factor controlling season-timescale sediment transport processes. While climate variability also indicates a major control on runoff change and soil erosion of the Minjiang River during last 50 years (Guo et al., 2016; Zhang et al., 2011), variations of sediment provenance due to the human disturbances over annual and decadal timescales may deserve further attention.

Hydrological response to rainfall in a catchment depends largely on location specific factors such as water storage in the soil, antecedent soil moisture, land use, and topography and can therefore be characteristic of that catchment, but it can also be related to individual rainfall events (Latron et al., 2008). Previous studies on event-timescale material transfer by small mountainous rivers in southeast China, such as the Mulanxi and Jiulongjiang rivers, and rivers in Taiwan (Figure 1b), indicate that the flux and composition of water and SPM could quickly respond to tropical cyclone-driven heavy rains within 1 to 2 days (e.g., Goldsmith et al., 2008; Hilton et al., 2008; Milliman et al., 2017; Milliman & Kao, 2005; Su et al., 2018; Wei et al., 2016). Monitoring of SPM concentrations in the Jiulongjiang river estuary during a wet season (2009) revealed an average lag of 5 days for the estuary in response to river sediment input (Chen et al., 2018). Although the Minjiang River has a larger drainage basin than these rivers, we suggest that these geographically and climatically similar mountainous rivers should exhibit similar hydrological behaviors and sediment transport regime in response to climatic changes such as precipitation. The relatively invariable compositional and textural immaturity of sands from the Minjiang River and the rapid suspended solid delivery in response to hydroclimatic changes (Figures 3 and 4) suggests that sediment transport along these mountainous rivers is quite fast and sediments are likely less recycled than previously thought (sediments in stable tectonic settings are expected to be multicycled). This observation differs from large river sediment transport on the stable East Asia continent, such as the Yangtze River (Figure 1a), in which sediments are suggested to undergo a relatively long-term (>200 kyr based on sediment U-series isotopes) recycling and complex trapping history (Li et al., 2016).

5.3. Broader Implications

Environmental changes on the Earth's surface impact the generation and transport of river sediment mainly by means of modulating catchment erosion patterns or rates. Tectonics and climate are generally considered as major controls on continental erosion over different spatiotemporal scales (e.g., Galy & France-Lanord, 2001; Herman et al., 2013; Marshall et al., 2015; Montgomery et al., 2001; Willett, 2010). Erosion in tectonically stable catchments is usually expected to be slower than those in tectonically active catchments (Portenga & Bierman, 2011). As represented by the Zhe-Min rivers, erosion and sediment transfer (e.g., the variability of SPM concentrations and compositions; Figure 3d) in these mesoscale, igneous and metamorphic bedrock-dominated, mountainous rivers, are quite sensitive to short-term (seasonal or event timescales) precipitation changes. This reveals the crucial role of climate in driving physical erosion of tectonically stable mountainous regions in subtropical East Asia.

We propose that the exorheic, mountainous rivers in southeast China involve a third type of sediment transport regime, that is, the climate-forcing-dominated material transfer, in East Asia river systems. Our results and previously published data (Bi et al., 2017; Dou et al., 2016) demonstrate that the Zhe-Min mountainous rivers display much higher spatial variability of discharged sediment compositions than those large rivers in East Asia and small mountainous rivers in Taiwan (Figure S5), underlining the importance of these tectonically stable, mountainous rivers in the East Asia continental margin sediment source-to-sink system. Our findings are an important step towards a better understanding of East Asia land-sea interactions, terrigenous inputs to the oceans and geochemical cycles.

6. Conclusions

Our study focused on the Minjiang River, in southeast China, to better understand the sedimentary feedbacks of climate in a subtropical, tectonically stable, mountainous region. Results demonstrate that Sr-Nd isotopic and provenance variations of the SPM correspond well with spatiotemporal variations of precipitation. River sands display low compositional and textural maturity, representing less cycled detritus than expected. Therefore, we propose that the Minjiang River and presumably other tectonically stable, mountainous rivers in southeast China, comprise a third type of sediment transport regime in East Asia river systems, one dependent upon the climate-forcing-dominated material transfer over/sensitive to short-term (seasonal or event timescales) precipitation changes.

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