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Supporting Information for

Effects of provenance, transport processes and chemical weathering on heavy mineral composition: A case study from the Songhua River drainage, NE China

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Introduction

This document contains details on (1) Heavy mineral analysis for the fluvial sediments (Text S1), (2) TIMA automatic mineral analysis for the fluvial sediments (Text S2), (3) Backscatter images, scanning electron microscopy images and mineral phase maps of representative samples (Figure S1), (4) Heavy mineral abundance of the Songhua River at 63-250 μm fraction (Figure S2), (5) The heavy mineral composition of the 63-125 μm fraction in fluvial sediments in the Songhua River drainage (Table S1), (6) The heavy mineral composition of the 125-250 μm fraction in fluvial sediments in the Songhua River drainage (Table S2), (7) Heavy mineral composition of the 63-250 μm fraction in fluvial sediments in the Songhua River drainage based on the traditional optical and TIMA methods (Table S3), (8) Heavy mineral abundances in the different-sized fractions in the Balan River (Table S4), and (9) Comparison of dominant mineral assemblages between wide window and multi-window in river sediments of Songhua River (Table S5).

Text S1: Heavy mineral analysis for the fluvial sediments

The procedures for the heavy mineral analysis in this study include size separation, preliminary elutriation, elaborate elutriation, separation and identification, which is referred to as follows:

1) Size separation. The samples were dry-sieved to separate the 63-125 and 125-250 μm fraction.

2) Preliminary elutriation. First, the subsamples were weighed after drying in the oven with a temperature lower than 60 ℃, and then were elutriated with clear water repeatedly to eventually collect heavy components, light components and mud components, respectively.

3) Elaborate elutriation. The heavy components taken after preliminary elutriation were placed into the separate setting container filled with bromoform (density: 2.88), and remained stable for some time after being well stirred, with a aim to separate light minerals adhering to the heavy components and to further extract heavy and light minerals. The heavy and light minerals were collected from the container after several hours. These two batches of samples were lightly washed with ethanol 2-3 times and were dried for weighing again, whereby getting the percentage of heavy minerals.

4) Further separation of heavy minerals into different species. ferrimagnetic minerals, like ilmenite and magnetite, were obtained from the collected heavy mineral grains with a piece of glassine-wrapped magnet. This process was repeated several times until ferrimagnetic minerals were separated completely. Paramagnetic minerals (such as epidote, tourmaline, pyroxene, amphibole and garnet) were selected with an electromagnetometer (current: 10 A). The remainders were collected as diamagnetic heavy minerals, which were elutriated again with ethanol to further concentrate zircon. The separated heavy mineral species (ferrimagnetic, paramagnetic and diamagnetic) were weighed respectively.

5) Microscope identification. The separated heavy mineral species were identified under stereomicroscopy and polarized microscope by smearing on a slide. Mineral identification of each specie proceeded along the grid lines on the slide, with each species totaling up to 1000 grains. Weathering detritus minerals were counted as other category.

The percentage of each heavy mineral type was calculated based on the weight, which is regarded as the concentration of each heavy mineral.

Text S2: TIMA automatic mineral analysis for the fluvial sediments

The TIMA operating system comprises a scanning electron microscope (SEM) with four silicon drift energy dispersive (EDS) detectors arranged at ~ 90° intervals around the chamber. The four EDS detectors ensure the simultaneous reception of the characteristic electronic information from the sample surface sputtered by the electron beam in four vertical directions. On the one hand, the simultaneous operation of the four receiving channels can quickly obtain more and more reliable counts in a very short time, ensuring the quality and reproducibility of the data; on the other hand, it can ensure that sufficient energy spectrum counts can be obtained to identify minerals when the sample surface is uneven or irregular during automatic testing, which helps to analyze samples of thin slice size in a single focus (Chen et al., 2021).

The operation steps are summarized as follows: (1) Sample prepared as a thin section; (2) Area of interest, field size, pixel spacing and analysis mode selected; (3) Energy Dispersive x-rays collected for every pixel in each field and a BSE image; (4) Grain boundaries are determined using BSE image and spectroscopic data. EDS data from each pixel summed together within each grain; (5) Spectroscopic data compared to mineral definition files within the TIMA classification scheme (Ward et al., 2018).

In this study, the 63-250 μm river sand samples were mounted in epoxy and polished. A conductive coating is then applied to the sample surface in order to reduce the charge generated during observation and to enhance the secondary electron or backscattered electron signal to obtain a better signal-to-noise ratio. The operating conditions were conducted at 25 keV using a spot size of 69.61 nm, a working distance of 15 mm and a field size set at 1500 μm. The image and grain resolution is determined by the pixel spacing, here set at 2 μm pixel size. The TIMA analysis using high-resolution liberation analysis mode. The area of the sample to be analyzed is framed (containing as many particles as possible), and the selected test area is then cut equally into a number of square fields. The analysis is performed in fields, the sample stage is automatically shifted, and the scan is completed in one field before moving to the next field to start scanning; within the field, BSE photographs and EDS tests are analyzed point by point with pre-set pixel parameters (Hrstka et al., 2018; Chen et al., 2021).

After the tests are completed, the TIMA offline processing software is used to obtain the test point spectra. Element identification is automatically performed and the content of the identified elements is calculated based on the characteristic energy values of the test point spectra. The spectral lines and the elemental content of the test point are then compared with the spectral lines and composition of standard or existing minerals in the database to determine the mineral type and name of the test point (Hrstka et al., 2018; Chen et al., 2021). Finally, various data analysis reports are exported as needed.

References

Chen, Q., Song, W.K., Yang, J.K., Hu, Y., Huang, J., Zhang, T., Zheng, G.S., 2021. Principle of automated mineral quantitative analysis system and its application in petrology and mineralogy: An example from TESCAN TIMA. Mineral Deposits 40 (2): 245-368 (in Chinese with English abstract).

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Ward, I., Merigot, K., Mcinnes, B.I.A., 2018. Application of Quantitative Mineralogical Analysis in Archaeological Micromorphology: a Case Study from Barrow Is., Western Australia. J. Archaeol. Method Theory 25: 45-68.

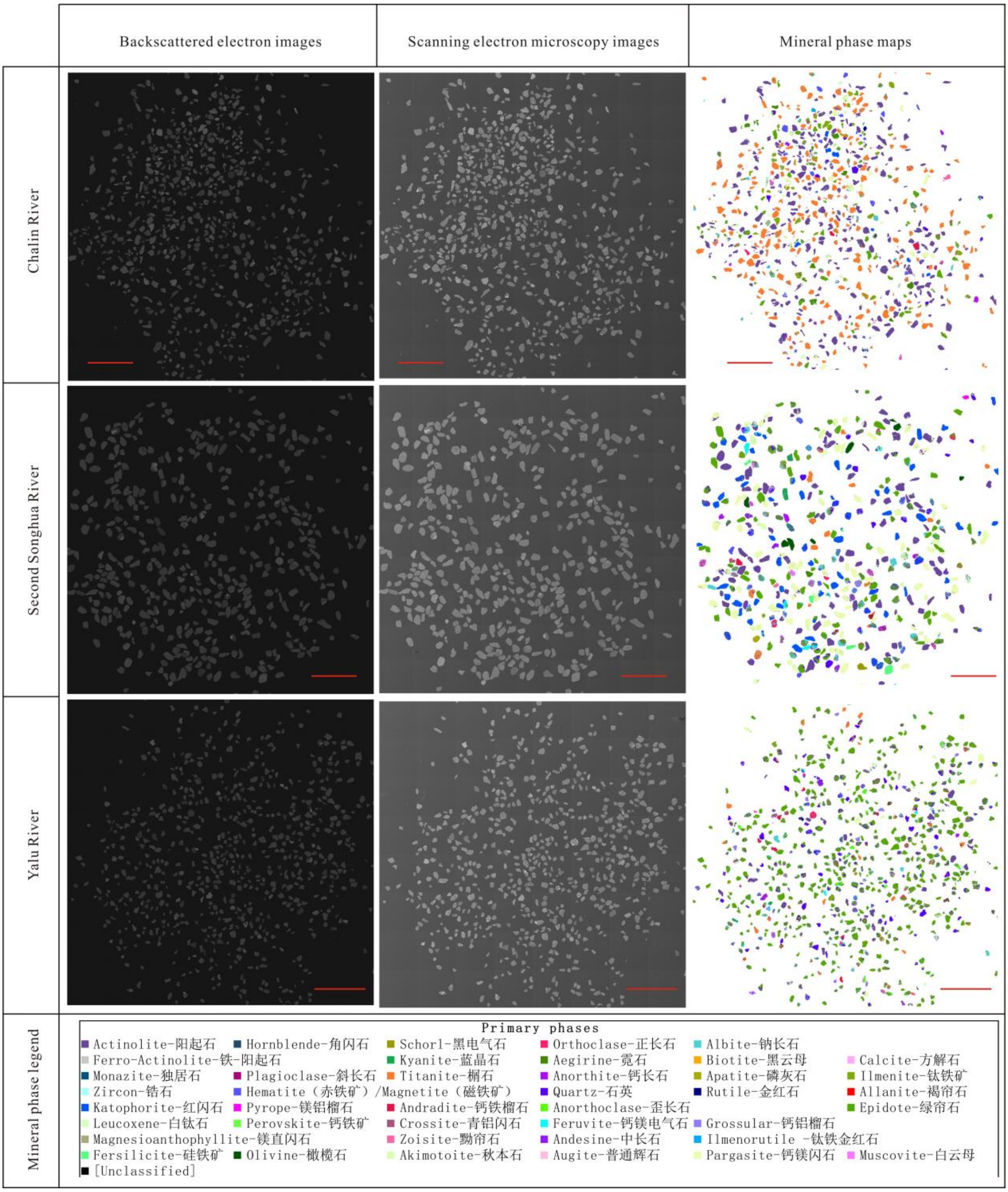

Fig. S1 Backscatter images, scanning electron microscopy images and mineral phase maps of representative samples from the Songhua River. Scale bar = 2 mm.

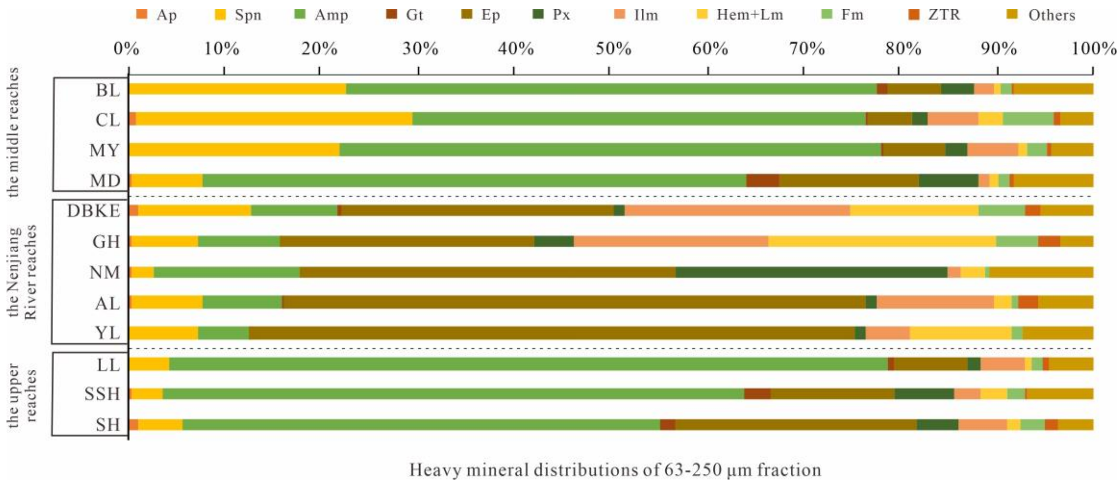

Fig. S2 Heavy mineral abundance of the Songhua River at 63-250 μm fraction, expressed as relative weight percentage (wt%). Systematic mineral abbreviation list: Ap = apatite, Spn = sphene, Amp = amphibole, Gt = garnet, Ep = epidote, Px = pyroxene, Ilm = ilmenite, Hem = hematite, Lm = limonite, Fm = ferromagnetic minerals, ZTR = zircon + tourmaline + rutile. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

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Table S1 Heavy mineral composition of the 63-125 μm fraction in fluvial sediments in the Songhua River drainage, expressed as relative weight percentage (wt.%).

Sampling sites		Sample number	Zr	Ap	Rt	Ant	Lcx	Spn	Mnz	Tr	Amp	Tur	Gt	Ep	Px	Ilm	Hem+Lm	Sd	Fm	Cr-Spl	ZTR index	Other
The middle reaches	Balan River	BLH1	4.29	0.64	0.08	0.06	0.17	16.35	0.00	0.00	22.12	0.13	3.79	4.19	0.92	18.32	3.40	0.00	22.16	0.00	4.50	3.40
	Balan River	BLH2	3.45	0.92	0.04	0.07	0.18	10.09	0.00	0.00	43.67	0.54	3.23	7.19	1.98	6.65	1.80	3.05	12.40	0.00	4.03	4.74
	Chalin River	TH1	1.64	0.55	0.00	0.03	0.08	11.52	0.00	0.00	34.44	0.00	0.00	4.90	0.00	22.28	1.74	0.00	18.02	0.00	1.64	4.81
	Mayan River	TH3	1.22	0.80	0.00	0.03	0.12	12.32	0.00	0.00	64.23	0.00	0.17	5.71	0.00	4.33	2.08	0.00	3.10	0.00	1.22	5.86
	Mayan River	MYH1	4.33	0.06	0.04	0.04	0.02	10.28	0.00	0.00	35.35	0.00	1.04	2.24	1.19	23.72	2.83	0.00	15.98	0.00	4.37	2.87
	Mudan River	MDJ1	0.62	1.96	0.21	0.03	0.24	9.17	0.00	0.00	31.69	2.53	10.69	21.00	0.00	7.19	2.14	0.00	4.67	0.00	3.36	6.26
	Mudan River	MDJ3	1.52	0.74	0.03	0.01	0.03	3.66	0.00	0.04	44.79	0.00	4.23	12.87	0.81	11.24	0.49	0.00	14.90	0.00	1.55	4.65
	Mudan River	MDJ2	4.33	0.00	0.00	0.00	0.03	18.69	0.19	0.00	37.45	0.00	2.66	3.04	0.76	18.44	3.61	0.00	1.29	0.00	4.33	9.51
	Tonghe T3 terrace	YL1	9.55	2.68	0.51	0.94	4.92	0.65	0.00	0.00	0.00	1.26	2.05	10.09	0.00	32.32	3.78	0.00	5.98	16.87	11.32	8.32
	Tonghe T3 terrace	YL2	4.86	0.40	0.07	0.18	2.31	0.00	0.00	0.00	0.00	0.76	9.56	6.00	0.00	53.46	3.19	0.00	10.35	0.00	5.69	8.84
Nenjiang River reaches	Duobukuer River	DBKE1	2.19	0.53	0.03	0.22	0.17	15.54	0.00	0.00	15.30	0.00	0.40	25.96	1.21	27.77	2.21	0.00	5.02	0.00	2.22	3.45
	Ganhe River	GH1	2.36	0.32	0.01	0.14	0.30	5.37	0.00	0.00	8.47	0.00	0.79	28.77	2.17	27.58	13.40	0.00	3.68	0.00	2.37	6.63
	Nuomin River	NMH1	0.60	1.31	0.03	0.03	0.47	3.66	0.00	0.00	2.98	0.00	0.19	25.16	34.29	15.28	4.85	0.00	4.22	0.00	0.63	6.94
	Alun River	ALH1	1.64	0.95	0.31	0.10	1.06	8.87	0.00	0.00	6.46	0.19	1.71	35.88	3.23	14.05	11.39	0.00	4.75	0.00	2.14	9.41
	Nenjiang River	NJ1	3.84	0.40	0.25	0.11	0.56	5.89	0.00	0.00	12.19	0.19	3.00	33.94	6.00	23.44	4.13	0.00	3.46	0.00	4.27	2.60
	Nenjiang River	NJ10	2.95	0.51	0.21	0.00	0.31	5.17	0.00	0.00	24.59	0.00	1.91	32.01	3.18	16.54	3.61	0.00	3.52	0.00	3.16	5.41
	Nenjiang River	SN40a	2.13	1.74	0.36	0.03	1.40	5.59	0.00	0.00	30.78	0.19	1.51	38.52	0.00	8.31	2.64	0.00	0.40	0.00	2.69	6.39
	Yalu River	SN62	1.16	0.34	0.12	0.03	0.82	4.75	0.18	0.00	1.14	0.00	0.32	33.77	0.00	10.55	31.98	0.00	8.66	0.00	1.28	6.17
	Kule River	SN73	1.26	0.72	0.15	0.03	0.77	5.94	0.03	0.00	6.23	0.18	0.73	35.00	0.00	5.68	23.83	0.00	14.25	0.00	1.60	5.18
The upper reaches	Lalin River	Ha22	1.92	0.19	0.09	0.07	0.34	4.02	0.00	0.00	65.42	0.00	1.43	5.18	6.44	5.72	2.86	0.00	2.39	0.00	2.01	3.74
	Second Songhua River	JL44	1.50	2.00	0.07	0.02	0.24	3.76	0.00	0.00	37.63	0.00	0.39	25.87	0.00	6.08	3.92	0.00	11.88	0.00	1.57	6.64
	Songhua River	Ha16	2.20	1.16	0.11	0.03	0.17	4.17	0.00	0.00	38.63	0.00	1.55	19.74	4.12	16.14	1.03	0.00	8.41	0.00	2.31	2.56
	Songhua River T2terrace	Ha17	2.39	0.51	0.22	0.06	0.13	5.56	0.00	0.00	34.89	0.00	3.06	25.54	4.14	11.69	1.44	0.00	5.07	0.00	2.61	5.28

Systematic mineral abbreviation list: Zr=zircon, Ap=apatite, Rt=rutile, Ant=Anatase, Lcx=leucoxene, Spn=sphene, Mnz=monazite, Tr=tremolite, Amp=amphibole, Tur=tourmaline, Gt=garnet, Ep=epidote, Px=pyroxene, Ilm=ilmenite, Hem+Lm=hematite+limonite, Sd=siderite, Fm=ferromagnetic minerals, Cr-Spl=chrome-spinel, ZTR index=Zircon+Tourmaline+Rutile. The samples of YL1 and YL2 were sampled from the Songhua River T3 river terrace in Tonghe county.

Table S2 Heavy mineral composition of the 125-250 μm fraction in fluvial sediments in the Songhua River drainage, expressed as relative weight percentage (wt.%). Abbreviation definitions see Table S1.

Sampling sites		Sample number	Zr	Ap	Rt	Ant	Lcx	Spn	Mnz	Tr	Amp	Tur	Gt	Ep	Px	Ilm	Hem+Lm	Sd	Fm	Cr-Spl	ZTR index	Other
The middle reaches	Balan River	BLH1	1.21	0.11	0.02	0.02	0.10	26.99	0.00	0.00	36.21	0.34	2.01	2.68	0.50	14.25	3.52	0.00	7.26	0.00	1.57	4.78
	Balan River	BLH2	0.16	0.44	0.02	0.02	0.12	35.97	0.00	0.00	38.78	0.37	2.62	3.00	0.75	7.87	1.87	1.50	3.51	0.00	0.56	2.94
	Chalin River	TH1	0.08	0.06	0.00	0.00	0.14	37.13	0.00	0.00	48.63	0.00	0.00	1.93	0.00	4.15	1.11	0.00	2.54	0.00	0.08	4.24
	Mayan River	TH3	0.00	1.00	0.00	0.00	0.00	19.97	0.00	0.00	55.07	0.00	4.99	6.99	1.00	1.00	3.00	0.00	0.00	0.00	0.00	6.99
	Mayan River	MYH1	1.17	0.05	0.00	0.00	0.23	28.32	0.00	0.00	34.45	0.00	1.63	7.43	0.89	19.45	0.59	0.00	2.75	0.00	4.37	2.87
	Mudan River	MDJ1	0.20	2.62	0.00	0.00	4.52	8.63	0.00	0.00	35.07	0.00	10.72	2.61	7.25	1.74	9.85	0.00	0.00	0.00	0.20	12.45
	Mudan River	MDJ3	1.43	0.53	0.00	0.00	0.16	9.15	0.00	0.02	51.53	0.00	2.61	9.42	1.40	8.22	1.40	0.00	4.74	0.00	1.43	9.18
	Mudan River	MDJ2	0.64	0.00	0.02	0.02	0.08	34.28	0.00	0.00	31.27	0.00	4.36	5.45	1.27	14.00	5.09	0.00	0.37	0.00	0.66	2.73
	Tonghe T3 terrace	YL1	1.43	0.00	0.51	0.00	11.89	0.00	0.00	0.00	0.00	1.40	2.60	3.01	0.00	53.08	3.61	0.00	1.76	0.00	3.34	6.29
	Tonghe T3 terrace	YL2	3.85	1.06	0.43	0.07	0.78	1.97	0.00	0.00	0.00	4.68	2.71	0.00	0.00	74.42	2.71	0.00	0.00	0.00	8.96	7.25
Nenjiang River reaches	Duobukuer River	DBKE1	0.58	0.72	0.00	0.02	0.58	17.36	0.00	0.00	16.64	0.00	0.42	33.92	4.42	14.54	1.47	0.00	1.88	0.00	0.58	7.44
	Ganhe River	GH1	1.16	0.29	0.00	0.00	1.00	8.09	0.00	0.00	13.35	0.00	0.40	47.84	2.19	12.76	7.18	0.00	1.24	0.00	1.16	4.50
	Nuomin River	NMH1	0.35	0.68	0.00	0.00	0.71	9.26	0.00	0.00	11.71	0.00	0.00	37.07	17.37	8.78	2.34	0.00	1.38	0.00	0.35	10.34
	Alun River	ALH1	1.10	0.03	0.00	0.00	0.55	4.40	0.00	0.00	10.66	0.00	0.23	57.82	0.68	0.00	7.48	0.00	1.04	0.00	1.10	8.98
	Nenjiang River	NJ1	3.40	0.13	0.30	0.19	0.19	10.07	0.00	0.00	18.56	0.20	1.95	39.26	3.32	13.09	3.32	0.00	2.48	0.00	3.89	3.47
	Nenjiang River	NJ10	0.06	0.00	0.00	0.00	1.62	1.83	0.00	0.00	15.63	0.20	6.53	35.62	11.08	6.93	2.57	0.00	0.86	0.00	0.26	12.02
	Nenjiang River	SN40a	0.73	0.91	0.22	0.00	2.78	4.32	0.00	0.00	21.40	0.00	0.58	56.97	0.00	0.00	5.21	0.00	0.00	0.00	0.95	6.90
	Yalu River	SN62	0.25	0.07	0.02	0.04	1.32	4.82	0.00	0.00	4.55	0.00	0.24	41.70	0.00	9.35	23.01	0.00	2.58	0.00	0.27	12.05
	Kule River	SN73	0.16	0.15	0.05	0.00	1.57	5.61	0.00	0.00	19.81	0.00	0.00	50.58	0.00	7.78	8.67	0.00	1.12	0.00	0.22	4.50
The upper reaches	Lalin River	Ha22	0.50	0.05	0.00	0.00	0.91	7.99	0.00	0.00	73.95	0.78	0.47	6.54	0.78	2.96	0.47	0.00	0.61	0.00	1.28	3.39
	Second Songhua River	JL44	0.03	1.22	0.00	0.00	0.26	4.95	0.00	0.00	52.67	0.21	0.42	28.23	0.00	1.05	0.63	0.00	3.78	0.00	0.24	6.53
	Songhua River	Ha16	0.69	0.80	0.04	0.00	0.09	4.14	0.00	0.00	43.74	0.00	5.14	23.20	2.85	12.36	0.57	0.00	2.70	0.00	0.73	3.63
	Songhua River T2terrace	Ha17	1.38	0.21	0.04	0.00	0.27	4.58	0.00	0.00	37.78	0.17	0.84	29.68	2.19	6.91	0.84	0.00	12.55	0.00	1.59	2.53

Table S3 Heavy mineral composition of the 63-250 μm fraction in fluvial sediments in the Songhua River drainage based on the traditional optical and TIMA methods, expressed as relative weight percentage (wt.%). Abbreviation definitions see Table S1.

Methods	Sampling sites	Sample number	Zr	Ap	Rt	Ant	Lcx	Spn	Tr	Amp	Tur	Gt	Ep	Px	Ilm	Fm	Ky	ZTR index	Other
Optical	Lalin River	H20c	0.82	0.23	0.00	0.03	0.54	4.14	0.00	73.97	0.05	0.58	7.63	1.21	4.52	1.84	0.01	0.87	4.43
	Songhua River	H20g	0.64	1.12	0.06	0.03	1.48	4.42	0.00	48.72	0.51	1.54	24.56	4.40	5.01	3.78	0.04	1.21	3.69
	Second Songhua River	H20h	0.05	0.45	0.00	0.00	1.53	3.20	0.00	59.16	0.00	2.76	12.65	5.96	2.76	4.60	0.05	0.05	6.83
	Alun River	ALH10	1.24	0.31	0.10	0.22	3.79	7.00	0.00	8.06	0.72	0.07	57.89	1.05	11.73	2.35	0.00	2.06	5.47
	Nuomin River	NMH10	0.01	0.29	0.00	0.00	3.94	2.29	0.00	14.59	0.00	0.00	37.22	27.10	1.36	2.80	0.00	0.01	10.4
	Ganhe River	GH1	2.11	0.38	0.06	0.23	1.82	6.67	0.00	8.34	0.11	0.06	25.86	4.00	19.63	27.40	0.00	2.28	3.33
	Duobukuer River	DBKE1	1.61	1.11	0.03	0.27	2.25	11.4	0.00	8.63	0.00	0.47	27.40	1.14	22.76	17.59	0.00	1.64	5.33
	Yalu River	YLH12	0.08	0.21	0.00	0.05	2.73	6.77	0.00	5.14	0.00	0.14	60.89	1.22	4.47	11.30	0.00	0.08	7.00
	Mudan River	MDJ10a	0.01	0.29	0.03	0.03	0.64	7.16	1.64	55.05	0.19	3.51	13.96	6.04	1.17	2.14	0.00	0.23	8.14
	Balan River	BLH11a	0.05	0.24	0.00	0.00	1.18	22.10	0.00	54.33	0.19	1.03	5.55	3.29	2.07	1.93	0.00	0.24	8.04
	Chalin River	CLH11	0.63	0.78	0.04	0.07	0.43	28.50	0.00	46.8	0.00	0.19	4.70	1.60	5.07	7.76	0.00	0.67	3.46
	Mayan River	MYH10a	0.44	0.23	0.00	0.03	1.13	21.50	0.00	55.48	0.00	0.18	6.40	2.13	5.16	2.98	0.00	0.44	4.33
TIMA	Lalin River	H20c	0.00	0.67	0.67	0.00	0.34	3.70	0.00	73.98	1.07	0.13	13.11	0.05	1.53	0.66	2.00	1.74	2.09
	Songhua River	H20g	0.16	1.39	0.57	0.00	1.06	4.37	0.00	52.99	2.14	1.14	29.56	0.04	2.84	1.39	0.21	3.69	2.15
	Second Songhua River	H20h	0.03	0.14	0.26	0.00	0.10	3.99	0.00	54.21	0.97	0.90	25.78	0.10	1.64	6.06	0.00	1.14	5.82
	Alun River	ALH10	0.05	0.31	3.12	0.00	2.55	6.92	0.00	11.64	0.36	1.71	67.71	0.01	1.24	1.49	1.79	0.72	1.10
	Nuomin River	NMH10	0.01	0.85	1.30	0.00	1.99	2.82	0.00	12.05	0.73	2.59	43.28	25.24	1.44	4.83	0.00	1.59	2.87
	Ganhe River	GH1	1.04	0.18	3.38	0.00	2.29	12.40	0.00	9.99	0.98	4.13	41.98	0.03	13.48	9.14	0.00	2.20	0.98
	Duobukuer River	DBKE1	0.68	1.27	3.50	0.00	2.91	15.52	0.00	6.72	1.06	8.48	32.59	0.09	13.37	13.07	0.20	3.02	0.53
	Yalu River	YLH12	0.14	0.14	2.22	0.00	1.90	5.01	0.00	6.57	1.11	3.16	72.38	0.04	3.58	2.87	0.37	1.39	0.52
	Mudan River	MDJ10a	0.02	0.73	0.65	0.00	0.96	7.16	0.00	48.21	3.89	4.80	23.80	0.45	0.48	3.17	2.27	4.65	3.40
	Balan River	BLH11a	0.43	0.30	0.49	0.00	0.25	19.78	0.00	37.11	4.68	3.40	22.49	0.12	2.03	1.75	1.32	5.40	5.87
	Chalin River	CLH11	0.18	0.70	1.93	0.00	2.06	32.43	0.00	35.79	0.50	0.51	8.88	0.14	9.87	4.42	0.09	1.37	2.52
	Mayan River	MYH10a	0.22	0.04	0.60	0.00	0.44	27.16	0.00	44.30	1.17	1.60	16.08	0.03	5.32	1.25	0.20	1.44	1.57

Table S4 Heavy mineral abundances (wt.%) in the different-sized fractions in the Balan River (A: < 63 μm, B: 63-125 μm, C: 125-250 μm). Systematic mineral abbreviation list: Amp=amphibole, Spn=sphene, Zr=zircon, Mgh=maghemite, Ilm=ilmenite, Mag=Magnetite, Hem=hematite, Lm=limonite, Px=pyroxene, Gt=garnet, Ep=epidote, Tur=tourmaline, Leu=leucoxene, Mnz=monazite, Rt=rutile, Ant=anatase, Ap=apatite.

Sample	Zr	Ap	Rt	Ant	Mnz	Px	Amp	Tur	Hem Lm	Mag	Mgh	Gr	Spn	Ep	Leu
BLH1 A	7.00	0.06	0.12	0.06	0.17	2.85	50.70	0.84	3.02	4.1	0	1.68	12.41	1.18	0.42
BLH2 A	4.76	0.63	0.10	0.03	0.21	4.86	55.97	1.06	0.42	4.29	0.48	1.48	9.42	3.17	0.02
BLH3 A	6.05	1.25	0.12	0.09	0.20	2.95	48.94	0.39	1.38	1.57	2.48	0.79	15.81	4.13	0.20
BLH4 A	9.14	0.83	0.19	0.69	0.00	2.47	38.17	0.95	3.60	3.05	2.07	1.90	9.80	15.00	0.19
BLH5 A	14.11	1.00	0.56	0.83	0.00	0.00	30.75	0.00	1.61	0.56	10.42	2.42	9.14	14.28	0.72
BLH6 A	11.93	2.00	0.16	0.05	0.00	0.56	42.51	0.19	1.50	9.18	2.51	0.56	13.52	3.56	0.05
BLH7 A	11.53	2.10	0.24	0.05	0.00	1.85	44.78	0.00	1.39	12.31	3.13	0.31	8.23	7.10	0.20
BLH8 A	10.72	1.37	0.17	0.05	0.00	0.41	44.02	0.00	0.62	3.41	5.23	1.03	14.37	5.14	0.11
BLH1B	4.29	0.64	0.08	0.06	0.00	0.92	22.12	0.13	3.40	15.5	6.66	3.79	16.35	4.19	0.17
BLH2 B	3.45	0.92	0.04	0.07	0.00	1.98	43.67	0.54	1.80	3.33	9.07	3.23	10.09	7.19	0.18
BLH3 B	0.45	1.27	0.00	0.01	0.00	1.00	55.06	0.20	2.80	0.27	5.9	0.60	18.37	6.61	0.01
BLH4 B	1.10	0.25	0.00	0.11	0.00	1.56	46.22	0.00	1.33	9.16	2.74	1.33	16.30	7.78	0.29
BLH5 B	5.01	0.42	0.00	0.21	0.00	0.25	45.18	0.00	2.76	3.97	3.58	4.27	14.09	11.30	0.27
BLH6 B	2.65	0.34	0.02	0.10	0.00	0.52	40.64	0.00	3.96	2.62	17.75	1.89	15.50	1.72	0.34
BLH7 B	1.32	1.78	0.00	0.02	0.00	0.78	48.36	0.00	1.56	12.75	8.48	0.47	10.50	2.65	0.20
BLH8 B	2.16	1.29	0.00	0.01	0.00	0.49	50.50	0.00	1.80	8.21	6.39	0.33	14.29	2.46	0.18
BLH1 C	1.21	0.11	0.02	0.02	0.00	0.50	36.21	0.34	3.52	4.52	2.74	2.01	26.99	2.68	0.09
BLH2 C	0.16	0.44	0.02	0.02	0.00	0.75	38.78	0.37	1.87	1.13	2.38	2.62	35.97	3.00	0.12
BLH3 C	0.45	0.35	0.00	0.00	0.00	1.26	53.39	0.84	1.05	1.28	0	0.63	28.77	3.99	0.14
BLH4 C	0.00	1.39	0.00	0.00	0.00	1.46	39.49	0.00	2.30	1.74	1.87	1.05	30.36	7.73	4.81
BLH5 C	0.00	1.03	0.00	0.10	0.00	0.53	45.00	0.00	0.27	1.08	0	0.53	12.04	26.21	2.12
BLH6 C	0.18	0.59	0.00	0.12	0.00	0.18	42.67	0.18	2.88	0.98	4.32	2.52	26.47	3.42	0.45
BLH7 C	0.01	0.75	0.00	0.00	0.00	0.16	49.43	0.00	1.43	14.39	3.11	0.48	18.47	4.77	0.19
BLH8 C	0.22	0.29	0.00	0.00	0.00	0.17	42.40	0.00	1.02	6.02	5.87	1.19	26.45	2.71	0.22
Enrichment				Enriched in fine particles					Enriched in intermediate particle				Enriched in coarse-grained		

Table S5 Comparison of dominant mineral assemblages between wide window (63-250 μm) and multi-window (63-125 μm and 125-250 μm) in river sediments of Songhua River. Abbreviation definitions see Table S1.

Rivers\ Grain-size fraction	63-250 μm	63-125 μm	125-250 μm
The upper reaches	Amp+Ep	Amp+Ep+Ilm+Fm	Amp+Ep+Spn+Ilm/Fm
The middle reaches	Amp+Spn+Ep	Amp+Spn+Ilm+Fm	Amp+Spn+Ilm
Duobukuer River	Ep+Ilm+(Hem+Lm)	Ep+Ilm+Spn+Amp	Ep+Ilm+Amp+Ilm
Nuomin River	Ep+Px+Amp	Px+Ep+Ilm	Ep+Px+Amp
Alun River	Ep+Ilm+Amp+Spn	Ep+Ilm+(Hem+Lm)	Ep+Amp+(Hem+Lm)+Ilm
Yalu River	Ep+(Hem+Lm)+Spn	Ep+(Hem+Lm)+Fm	Ep+(Hem+Lm)+Ilm