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NOTE

The elemental composition of suspended particles from the Yellow and Yangtze Rivers

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Abstract—The elemental composition of suspended particles from the Yellow River is similar to those of the loess terraces and the world's average soils. The contents of Zn, Cu, Ni, Co and Pb in the suspended particles are higher in the Yangtze River than in the Yellow River, indicating pollution inputs or the high-side of natural variability.

THE LACK OF dissolved chemical composition data of the major rivers of China in western literature has been partly rectified by the recent work of HU *et al.* (1982). We present here a few complementary data on the elemental composition of suspended particles from the two largest rivers in China. The river suspended particle samples were obtained near river mouths using a metal-free water sampler between 1980 to 1981. For comparison one Malang loess sample from the Kansu Province (5.5 m below soil surface) was also analyzed. The samples were ignited at 450°C to estimate roughly the organic matter content (loss weight on ignition). The ashes were analyzed, for 22 elements, by an emission spectrographic method (TERAOKA, 1982). The average reproductibility is about 10% (see the loess in Table 1). We used USGS standards PCC-1, GSP-1 and BCR-1 as references. The results are summarized in Table 1, along with the composition data for the world's average river suspended particles (MARTIN and MEYBECK, 1979) and soils (BOWEN, 1979). Sn and Ag are below detection limits (<16 and <1.3 ppm respectively).

Since most of the suspended particles downstream of the Yellow River are supplied by the intensive erosion of the loess terraces (rough geographic distribution of the loess terraces is enclosed by dotted lines in Fig. 1a), it is not surprising to find a close resemblance between the elemental compositions of the Yellow River suspended particles and the Malan loess (Table 1). The high Ca and Sr contents in both samples represent the occurrence of $CaCO_3$ minerals. As shown by LIU (1966), the average content of $CaCO_3$ in the Malan loess is 13.7%. The high Na content indicates the existence of evaporites in the loess terraces as also shown by the high Na^+, Cl^-, SO_4^{-2} concentration in the Yellow River during and after flowing through the loess terraces (LEH and WANG, 1963; HU *et al.*, 1982). The concentrations of trace metals Zn, Cu, Ni, Co and Pb in the Yellow River suspended particles (as well as the Malan loess) are much closer to those of the world's average soils (BOWEN, 1979) then those of the world's average river suspended particles (MARTIN and MEYBECK, 1979). The implication is that the pollution input of these trace metals in the Yellow River is minor as compared with the natural inputs. As discussed by LI (1981), the high concentrations of these

Table 1. Elemental compositions of suspended particles (s.p.) from rivers, loess and soils. (ppm)

	Yangtze (6/14/80)	Yangtze (8/5/81)	Yellow (9/15/81)	Loess	Average+ s.p.	Average++ soils
Si	270k*	270k	270k	260k±20k	285k	330k
Al	97k	97k	80k	80k± 8k	94k	71k
Fe	57k	54k	32k	32k± 4k	48k	40k
Ca	26k	30k	60k	90k± 8k	21.5k	15k
Mg	14k	13k	13k	13k± 1k	11.8k	5k
Na	5k	6.5k	9k	10k± 1k	7.1k	5k
Ti	5.1k	6.3k	4k	4k± 0.4k	5.6k	5k
Mn	1150	960	800	850 ±80	1050	1000
Ba	540	580	600	580 ±90	600	500
Sr	130	170	220	250 ±20	150	250
Zr	160	160	140	160 ±20	-	400
V	150	170	110	120 ±10	170	100
Zn	100	115	75	75 ± 7	350	90
Cr	90	76	72	74 ± 6	100	70
Cu	68	71	33	38 ± 4	100	30
Ni	84	72	38	46 ± 3	90	50
Co	24	25	12	14 ± 1	20	8
Pb	42	87	<35	<35	150	12
Be	2.0	2.1	1.6	1.6±0.2	-	0.3
P	1200	1100	1100	1100 ±200	1150	800
LOI**	5.9%	10%	3.5%	3.5%	-	-

* $k = 10^3$, ** LOI = Lost weight on ignition.
+ Martin and Maybeck (1979), ++ Bowen (1979).

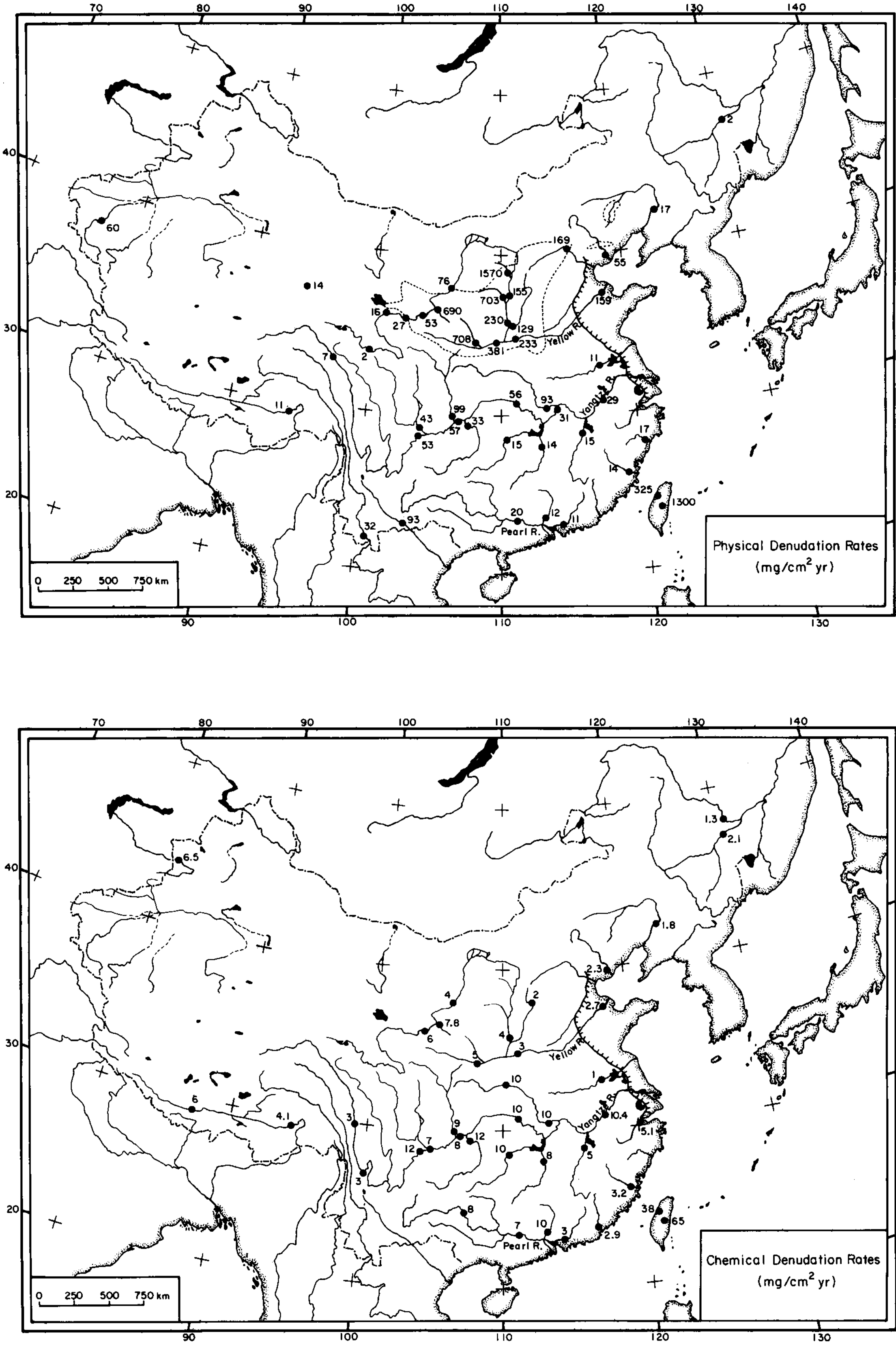

FIG. 1. The physical and chemical denudation rates of drainage areas above each station (solid circles). The areas enclosed by dotted lines are the loess terraces.

trace elements in the world average river suspended particles are of pollution origin.

Even though two suspended particle samples from Yangtze River were collected one year apart, the elemental compositions are about identical (within the analytical uncertainty). The concentrations of Zn, Cu, Ni, Co and Pb are definitively higher than those from the Yellow River, indicating either a natural variability or some pollution inputs. Certainly we need more data to find out the natural variability in both rivers. The Zr concentration of the suspended particles from the Yellow River and Yangtze Rivers (150 ± 10 ppm) is much lower than that of the world's soil average (400 ppm) but is comparable to those of the Japanese (150 ± 83 ppm, TERAOKA and KOBAYASHI, 1980), and Russian rivers (200 ± 40 ppm, GORDEYEV and LISITSYN, 1980). The Be concentration of our samples ranges from 1.6 to 2.1 ppm which are much higher than the world's soil average (0.3 ppm) given by Bowen. The major trace element concentrations of the soil sample SO-4 of Canadian Certified Reference Materials Projects (BOWMAN *et al.*, 1979) are very similar to the world's soil averages (BOWEN, 1979), but the Be concentration of SO-4 is 1.7 ppm which is much closer to our values. The x-ray diffraction analysis showed that the major clay minerals of the loess and the suspended particles from the Yellow River are illite (65 ± 3%), smectite (14 ± 2%), kaolinite (9 ± 1%) and chlorite (12 ± 2%). As expected, a strong calcite signal was also detected. The clay minerals from the Yangtze River suspended particles are illite (53 ± 7%) smectite-illite mixed peaks (19 ± 6%), kaolinite (18 ± 1%) and chlorite (10 ± 2%).

Chinese scientists have done extensive work on the major ion chemistry and suspended particle transport in about 500 rivers with more than 900 stations since 1956 (LEH and WANG, 1963; Committee on the Natural Geography of China, Academia Sinica, 1981). Unfortunately, the comprehensive results have never been published except for some descriptive summary, contour maps and some average numbers. Figure 1 summarizes the average physical and chemical denudation rates of river drainage areas above each station. Those data are obtained from the above mentioned two references and some recent calculations on chemical denudation rates (CHEN *et al.*, 1983). The above mentioned two references also provide many useful data on the annual discharge rates of water, suspended particles and dissolved salts for many hydrologic stations. The data from Taiwan are given by LI (1975). Rivers which pass through the loess terraces always give high physical denudation rates. The highest one is 1570 mg/cm^2 yr. The areas of relatively high chemical denudation rates (>8 mg/cm^2 yr) in the midstream of the Yangtze River and the Pearl River coincide with the areas of carbonaceous rock types and high rainfall. The ratios of physical and chemical denudation rates of Chinese rivers lie mostly between 2 to 10 excluding the loess areas where the ratio is as

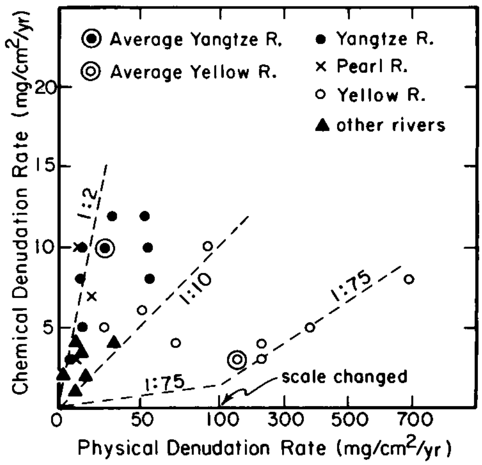

FIG. 2. The plot of the physical *versus* chemical denudation rates for Chinese rivers.

high as 90 (Fig. 2). The average physical denudation rates of the Yellow and Yangtze drainage areas are 159 and 29 mg/cm^2 yr respectively. The average chemical denudation rates are 2.7 and 10.4 mg/cm^2 yr respectively. The later two numbers agree quite well with the estimates by HU *et al.* (1982) (even though Hu *et al.* based the estimation on a few data). The total annual discharge of suspended solids and dissolved salts are respectively about 1200 × 10^{12} g and 20 × 10^{12} g for the Yellow River, and 490 × 10^{12} g and 180 × 10^{12} g for the Yangtze River. Adding the two rivers together, the total discharge of solids and salts is comparable to that of the Amazon River (HU *et al.*, 1982; MILLIMAN and MEADE, 1982).

Besides the mountainous oceanic islands (*e.g.* Taiwan, New Guinea, Indonesia, Philippines), the Yellow River, Yangtze River and the loess terraces of China are the major sources of salts, sediments and dusts for the North Pacific Ocean (MILLIMAN and MEADE, 1983). Their chemical and mineralogical characterizations are an important tool for linking the land and the sea systems. Our data are still too few to be representative. We hope, however, this work will stimulate further investigations especially on various analysis of stable and unstable isotopes.

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