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Yangtze Sediment Decline Partly From Three Gorges Dam

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It could be argued that nowhere has the impact of dams on rivers been more important than in China, where since 1950 almost half of the world's large dams (higher than 15 meters) have been built [*Fuggle and Smith,* 2000]. China's Yangtze River (Changjiang)—the largest river in south Asia (1.8 million square kilometers) and whose basin is home to more than 400 million inhabitants—alone has more than 50,000 dams within its watershed, including the world's largest, the Three Gorges Dam (TGD) (Figure 1a).

Water and sediment began being impounded behind the TGD in June 2003, and two years after impoundment, river sediment discharge downstream (at Datong Station) had decreased by nearly half of its 2002 load (Figure 1c). However, the decrease in Yangtze sediment load did not begin with TGD impoundment. Rather, the sediment load at Datong has declined continually since 1987 despite a slight increase in river discharge (Figure 1c). The change in pre-TGD loads at Yichang, just downstream from the TGD, has been even more extreme, decreasing by approximately 300 million tons in 1986–2002, before declining another 130 million tons after 2002 (Figure 1b). All of this suggests that collective changes on the Yangtze upstream (above Yichang) have been more important in decreasing the river's sediment load than the TGD.

Seven stations present the temporal and spatial variations in sediment transport throughout the Yangtze (Figure 2a). (Most data come from the *Bulletin of Yangtze River Sediment* (BYRS), 2000–2004, and from the Changjiang Water Resources Commission in China.) Between 1950 and 1986, the sediment discharge increased sharply downstream, reaching maximum levels at Yichang, downstream of which sediment trapping in Dongting Lake (Figure 1a), floodplain deposition, and channel aggradation decreased the sediment by approximately 100 million tons per year at Hankou and Datong (Figure 2a).

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Changes in Yangtze Sediment Transport

The first dramatic decline in sediment load occurred in 1987, the result of a sharp decrease (~100 million tons per year) in sediment load of the Jialing River, which enters the Yangtze at Beibei Station (Figures 1a and 2c). Low precipitation (60% below normal) and approximately 4500 dams decreased the Beibei sediment load by approximately 68 million tons per year [*Mao and Pei*, 2002]. The Project of Yangtze Upstream Water and Soil Conservation, begun in 1988, trapped an additional 30 million tons per year in the Jialing. At the same time, however, increased deforestation upstream led to a marked increase in mean annual suspended sediment concentrations at Pingshan (Figure 2b). The sharp decrease in sediment concentrations at Pingshan after 1997 was presumably related to increased reforestation.

By 2001, a number of small- and medium-sized tributary dams and reforestation efforts, particularly along the steep slopes above Pingshan (Figure 1a), had resulted in a second decrease, leading to declines of 46 and 137 million tons in sediment loads at Pingshan and Yichang, respectively, and further declines of 56 and 71 million tons in 2002 (Figure 2a).

The TGD impoundment in 2003 initiated the third severe decrease along the middle and lower reaches. In 2003–2004, sediment loads at Yichang declined by 164 million tons relative to 2002. At Datong, the 2003–2004 decline was less dramatic (128 million tons), and for the first time sediment loads were actually greater than at Yichang. By 2004, at Yichang and Datong, the Yangtze transported only 12 percent and 33 percent, respectively, of its 1950–1986 loads. More than half of this decrease (65% and 60%) occurred prior to the TGD impoundment.

Prior to 2000, the middle and lower reaches were primarily depositional. By 2001, however, sediment loads downstream of Yichang increased, first gradually and then markedly after 2002, suggesting active erosion (Figure

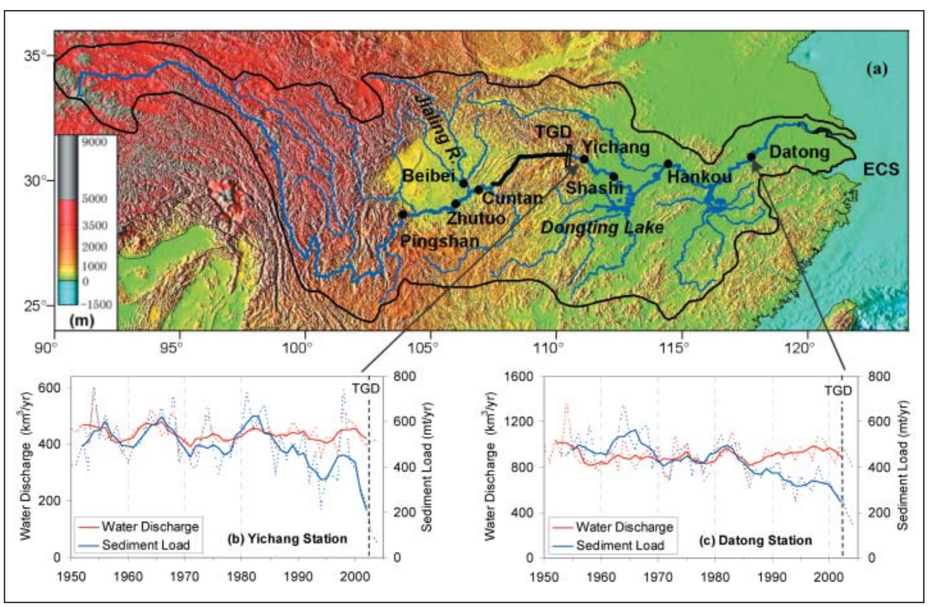

Fig. 1. (a) Yangtze River drainage basin. (b and c) Water discharge and sediment load at Yichang and Datong stations, respectively. TGD indicates Three Gorges Dam, ECS is East China Sea, and mt/yr represents million tons per year. In Figure 1a, bold black curve upstream of the TGD is the impounded river channel with a length of 500 kilometers; topographic base map is modified from http://www.ngdc.noaa.gov/mgg/image/2minrelief.html; left color bar corresponds to elevation (in meters).

2a). This marked change can be assumed to have been due to both decreased sediment storage in Dongting Lake [*Du et al.*, 2001] and channel erosion downstream of Yichang (Figure 3). Erosion along a 55-kilometer stretch between Yichang and Zhicheng (a station downstream of Yichang), for instance, amounted to 30 million cubic meters from September 2002 to October 2003 and 18 million cubic meters from October 2003 to November 2004. Assuming a bulk density of 1.3 tons per cubic meter, the eroded sediment would have been 39 and 23 million tons, representing approximately 30–35 percent of the increased sediment load noted between Yichang and Datong.

Between 1988 and 2000, the Project of Yangtze Upstream Water and Soil Conservation had reforested 63,000 square kilometers of the watershed [*BYRS*, 2000] and reduced the sediment yield extensively, especially in two high-yield regions: the Jialing River and the steep slopes above Pingshan. Moreover, a subsequent 1999–2003 conservation effort has reforested an additional 13,100 square kilometers, leading to increasing forest cover and a significant reduction (60 million tons per year) in sediment load [*BYRS*, 2004].

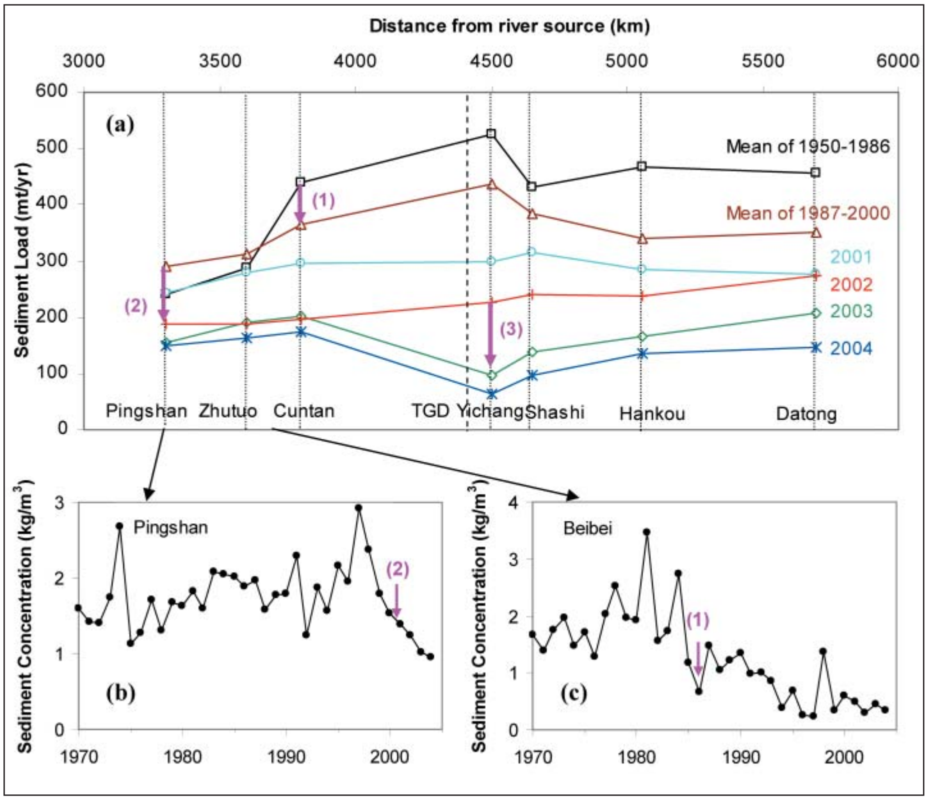

Fig. 2. (a) Sediment load at seven stations along the mainstream of the Yangtze River (locations shown in Figure 1). (b and c) Mean annual sediment concentrations at Pingshan and Beibei, respectively; mt/yr represents million tons per year. Three major sediment decreases (purple numerals 1, 2, and 3 and down arrows) correspond to the decreases at Beibei (1987), Pingshan (2001–2002), and Yichang (2003), respectively. Decreases 1, 2, and 3 are shown in greater detail in Figures 2c, 2b, and 1b, respectively. For the Pingshan, Hankou, and Datong stations, the 1950–1986 records are shorter, but longer than 31 years. Means for 1950–1986 and 1987–2000 at Zhutuo Station were calculated by deducting annual loads at Beibei from those at Cuntan. Similarly, loads for these two periods at Shashi were determined by subtracting Yichang from three passages entering Dongting Lake between Yichang and Shashi.

Future Changes to the Yangtze Watershed

The number of dams along the Yangtze upper reaches above Yichang increased from a handful in the early 1950s to approximately 12,000 by the late 1980s, and since then has increased continuously. The water storage capacity of major upstream dams totaled 27 cubic kilometers in 2000, and TGD added another 39 cubic kilometers in 2003. Ongoing or planned dams, such as Wudongde, Baihetan, Xiluodu, and Xiangjiaba, all located along the high-yield mainstream Yangtze River above Pingshan, will add another 41 cubic kilometers of total water-storage capacity. The total installed hydropower capacity of these four dams alone will be 38,500 megawatts, about double that of the TGD.

Between 1950 and 1986, sediment passing Pingshan accounted for about half of sediment passing Yichang, but in 2002 it carried about 90 percent of Yichang sediment (Figure 2a). Since these four future dams will probably trap about 70 percent of sediment passing Pingshan, sediment entering and exiting the TGD should decline quickly, leading to further decreases in the sediment loads at Yichang and Datong.

In addition to increased channel erosion and (presumably) less lateral escape of sediment-laden waters onto broad floodplains near Dongting Lake, the lower part of the Yangtze watershed should undergo increased environmental pressure. Since Datong Station is located 600 kilometers upstream from the East China Sea, very little river-borne sediment may actually reach the coastal ocean. Although the Yangtze developed slowly in its funnel-shaped estuary from 7000 to 2000 years ago, since then it has prograded eastward rapidly (>50–100 kilometers) in response to increased sediment supply due to deforestation and agriculture. With the recent dramatic sediment decline, however, accretion in the subaqueous delta has slowed and erosion has occurred on the outer side of the delta front [*Yang et al.*, 2002]. Coastal erosion may be a particu-

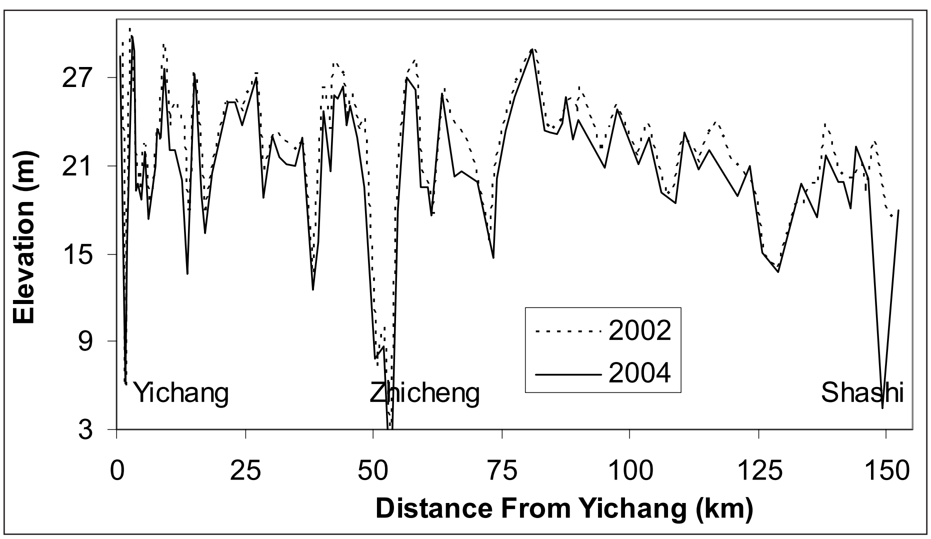

Fig. 3. Comparison of 2002 and 2004 thalweg profiles between Yichang and Shashi, connecting the lowest points of the river valley. Elevation is relative to the mean sea level. The measured dates are September 2002 and November 2004 for profiles from Yichang to Zhicheng, and October 2002 and October 2004 from Zhicheng to Shashi.

larly troubling prospect for the Shanghai region, considering that as recently as 2000 years ago it was coastal marsh. Since the Yangtze contributes about 90 percent of the fluvially derived nutrient supply to the East China Sea, a change in the ecological character and productivity in western East China Sea waters can be anticipated.

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