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Sediment load of Indian rivers

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The annual sediment load of Indian rivers is a little more than 1.2 billion tonnes which is roughly 10% of the global sediment flux to the world oceans. Indian rivers show pronounced seasonal and spatial variability in their sediment discharge. Further, lithological contributions and anthropogenic impacts are pronounced on the sediment load of several Indian rivers.

Introduction

THE greatest sediment yields are generally associated with rivers draining areas of intensive tectonic activity. The loess areas of China have likewise a very high sediment yield[1]. The Himalayan rivers draining the tectonically active belts, show a very high yield. The present estimates of sediment yield of the Ganga and Brahmaputra together is about a billion tonnes/yr[2] compared to the global annual sediment flux of about 15 billion tonnes/yr[3]. Table 1 summarizes the sediment erosion values for the rivers draining the Indian Sub-continent.

Spatial variability

Spatial variability of sediment load is evident in large river basins, primarily in response to lithological and geomorphological variations. This is illustrated in Figures 1*a* and *b* for the Godavari and the Mahanadi rivers, respectively. Obviously, the sedimentary rocks and easily weatherable igneous rocks (such as the Deccan Trap) contribute the bulk of the sediments to the river systems though they may not occupy vast areas of the drainage basins. The time-lag between erosion and sediment transported by large rivers today may represent episodes of erosion back in time, often a few decades, centuries or even millinia ago. Further, not all sediments eroded reach the oceans: This is very well illustrated for the Krishna River–the Krishna has a sediment load of $67,000 \times 10^3$ t/yr at Morvakonda but damming of the river and other human activities have reduced the load to $4,100 \times 10^3$ t/yr at its mouth at Vijayawada just a hundred km downstream[4].

All rivers show pronounced spatial variations primarily in response to the river-bed slope and also the gradual build-up of the urban areas. For example, the sediment load of the Ganga at Haridwar is 16 million tonnes/yr, whereas 1500 km downstream at Farakka, it is 800 million tonnes/yr[5]. Of course within such a large stretch of a river, sediment contributions from individual tributaries vary from a low 7 million tonnes/yr for the Gomti River at Lucknow to a high of 140 million tonnes/yr for the Yamuna River at Allahabad. Similarly for the Krishna River, a small upstream

Table 1. Sediment yield of rivers in the Indian sub-continent.

River	Basin area (km^2)	Run-off (10^6 m^3/yr)	Sediment load (10^6 t/yr)
Ganga[2]	7,50,000	4,93,000	329
Brahmaputra[2]	5,80,000	5,10,000	597
Indus[3]	9,70,000	2,38,000	100
Irrawady[3]	4,30,000	4,22,000	265
Narmada[8]	87,900	46,700	70
Tapi[8]	49,000	18,000	25
Godavari[9]	3,13,000	92,200	170
Krishna[4]	2,51,400	32,400	4
Mahanadi[7]	41,000	54,500	15.7
Mahi[6]	25,500	11,000	9.7
Brahmani[6]	28,200	16,300	20.4
Kaveri[6]	66,300	21,500	1.5

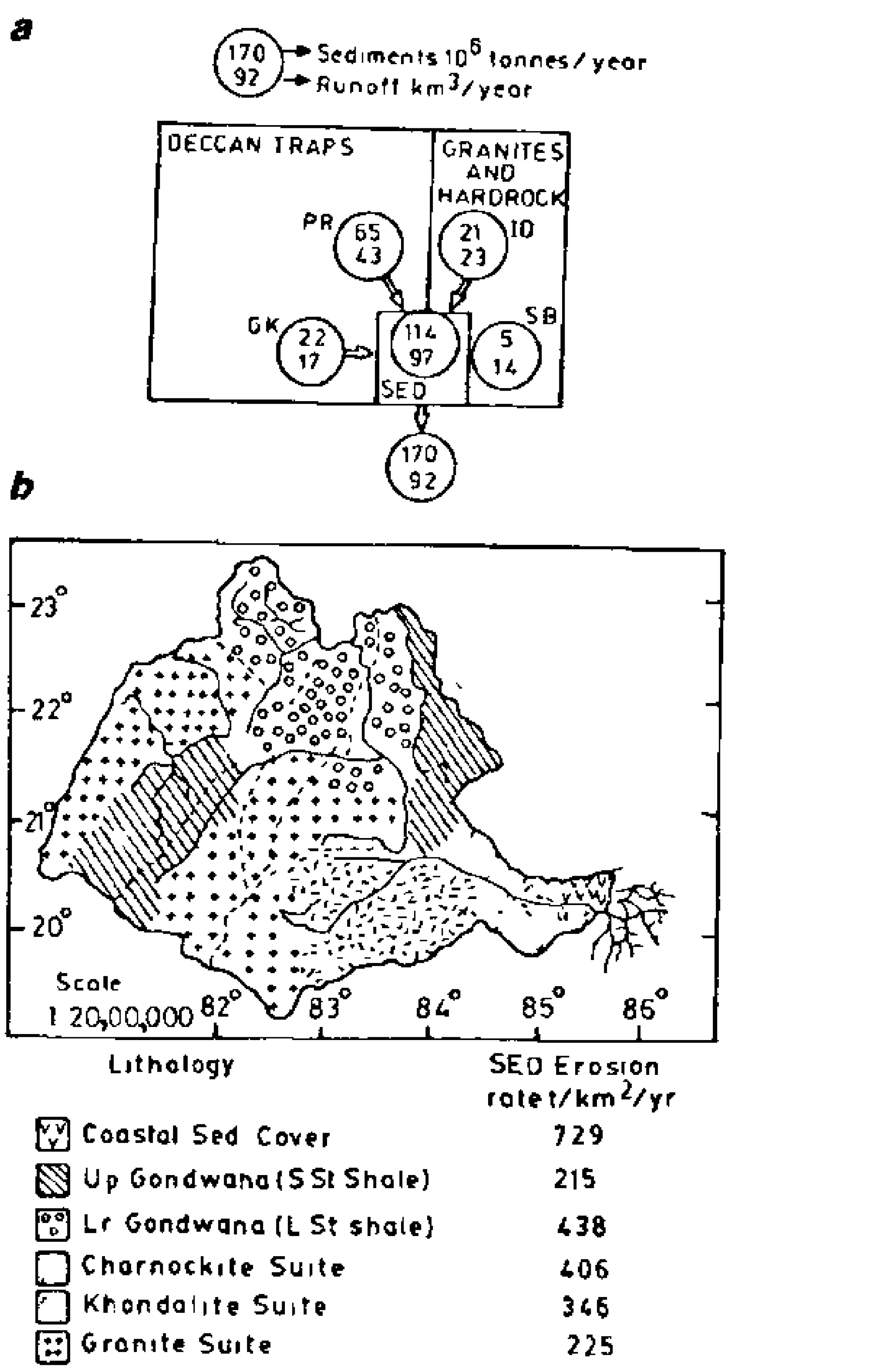

Figure 1. Lithological control of sediment load in *a*, Godavari and *b*, Mahanadi rivers.

tributary Bhima River contributes the bulk of the sediment load of the river farther downstream[4].

Seasonal variations

On a seasonal time scale, rivers generally tend to deposit sediments on their beds and along their banks at low discharges. During the monsoon months of high discharge, the Peninsular Indian rivers carry upto 95% of their annual sediment load[6]; whereas the monsoon contribution of the Himalayan rivers, though very significant, is not necessarily that high in comparison.

The sediment load of the Indian rivers show extreme variations as a function of time. For example, in the Godavari River the sediment load, at its mouth was 80 million tonnes in 1969–1970, whereas in 1974–1975, it was as low as 4 million tonnes. Similarly, in the case of the Mahanadi River, over a ten year period, the annual sediment load varied by a factor of twelve[7]. Further, on a single day (June 17, 1978) the Godavari carried 12% of the entire annual sediment load for that year. The annual variations in the sediment load of the peninsular rivers are shown in Figure 2*a*.

Figure 2*b* shows the inverse relation between the erosion rate upstream and the deposition rate down-

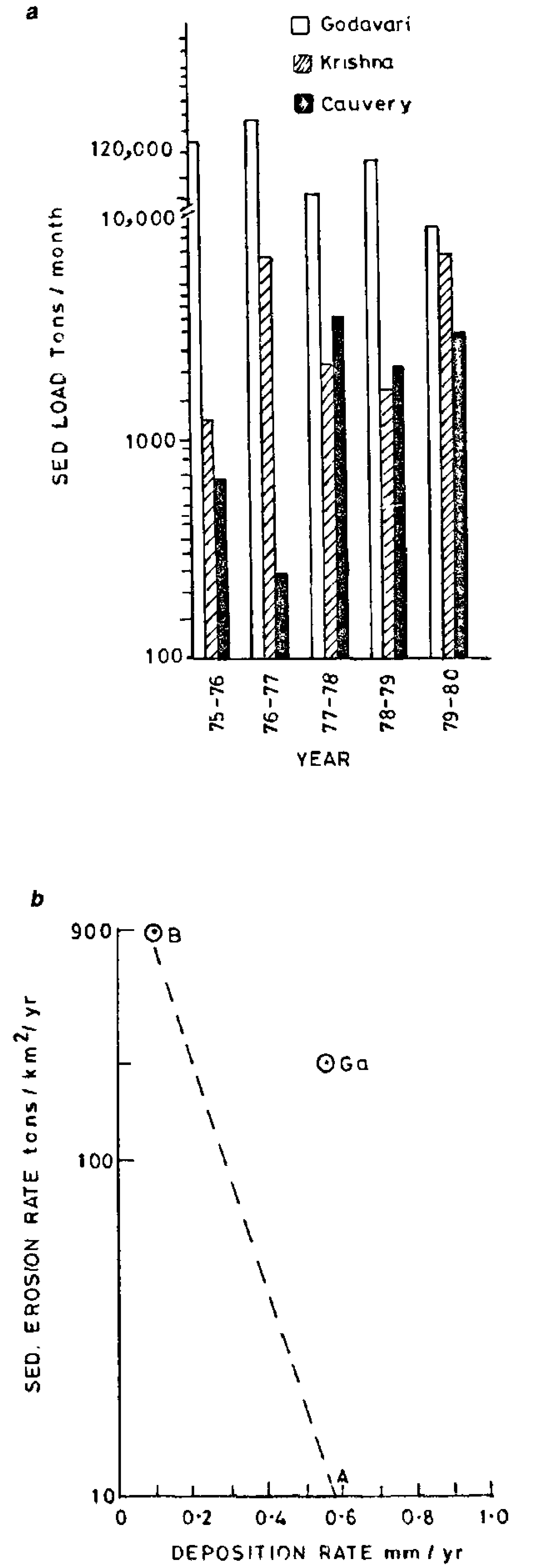

Figure 2. *a*, Annual variations in the sediment load of peninsular rivers. *b*, Relationship between sediment erosion rate and sediment deposition rate for Indian rivers.

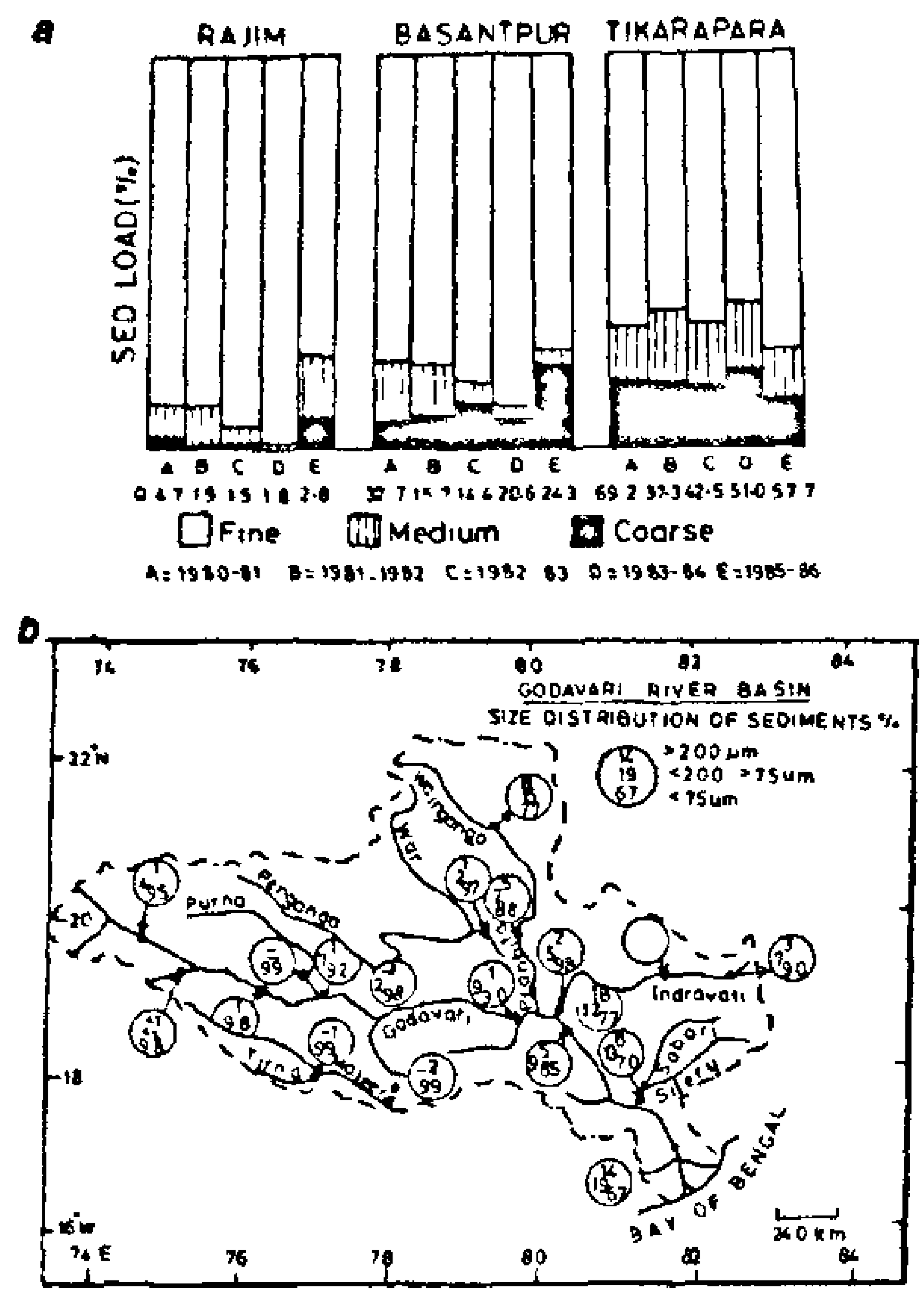

Figure 3. Control of grain size on sediment load of **a**, Mahanadi and **b**, Godavari rivers.

stream in several Indian rivers. Variations in sediment load is primarily due to variation in individual size population of sediments. Figure 3 illustrates this point for the Mahanadi and Godavari rivers. Individual size variations of sediment load are generally more pronounced in the downstream region, rather than near the catchment areas, as has been shown for a number of rivers in India[6].

Data from the Indian rivers indicate that erosion and deposition of sediments in the sub-continent is controlled by (i) basin geology and geomorphology, (ii) river discharge and its time and special variabilities (iii) type of urban activities, and (iv) intensity of physical weathering as reflected in the sediment size population. All these factors do not necessarily play the same important role for various rivers.

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Palynostratigraphy of lake deposits of Himalaya and palaeoclimate in Quaternary period

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This paper is the synoptic analysis of palynological data on Himalayan lacustrine sediments covering Kashmir, Ladakh, Himachal Pradesh, Kumaun, Nepal, Darjeeling and Sikkim. Reconstructed palaeovegetation and deduced palaeoclimatic inferences cover mainly Quaternary period, discussed separately for Western, Central, and Eastern Himalayan regions.

Introduction

PALYNOSTRATIGRAPHY provides insight into the conditions of past vegetation and its development in time and space, and thus helps in the reconstruction of palaeoclimate. For example, recovery of Larch (*Larix*) pollen[1] and some *Sphagnum*[2] taxa from Western Himalayan sedimentary profiles, which do not exist in the region today, were very much present until about 1000 years B.P. Their complete disappearance from Western Himalaya and their present distribution in the Central and Eastern Himalaya, is possibly a result of shifting or migration to better situations, attributable to the climatic change. This implies that Western Himalaya is becoming warmer and drier.

Systematic Quaternary palynological studies in the Indian subcontinent started in the mid-fifties at Birbal