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# Holocene Development of the Indus Mega-Delta

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The Indus mega-delta is the largest river delta in the world that has never been studied with modern coring/drilling and dating techniques, although it is a rich archive of paleoenvironmental information in a critical region of the Earth. Indeed, studies based on cores from the continental slope and the deep Arabian Sea have been used extensively to reconstruct the evolution of the Asian monsoon system. However, records from deltaic coastal settings are just now being added to the high resolution information available from marine, lacustrine, and ice cores. Monsoon climate and sea-level have both influenced the evolution of the Indus mega-delta; we will present the results of the first scientific study in this arid delta. In addition, we will present the recent effects on delta development of the human intervention in the Indus drainage basin. Extensive damming of the Indus since the 1950's have drastically reduced water and sediment delivery to the coast. Bathymetric comparisons of detailed early charts by the British Admiralty and the Pakistan government was combined with digital analysis of satellite imagery to provide the first comprehensive study of modern morphological changes on the coast and shelf of the Indus River delta. The subaerial morphology of the delta suggests wave and tide influences west of the active river channel, whereas it is tide-dominated to the east of the river mouth. Deltaic evolution under natural conditions between 1855 and 1954 was characterized by active sediment accumulation in two major depocenters: the nearshore zone along the entire delta coast and the western shelf between $\sim$25 and 40 m water depth. Until 1954, the shoreline advanced or was stable along most of the delta coast. The progradation rate at the active mouth

surpassed 100 m/year. The clinoform at the mouth has directly built into the head of a major submarine canyon that dissects the shelf. Major sediment bypassing of the shelf by sand from the river is supported by Nd isotope data from the area, showing different sources for the sandy river and fan sediments compared with shelf clays. Nd isotopes also show a gradually increasing Himalayan, as opposed to Karakoram influence on provenance since the last glacial maximum. The whole river is more Himalayan in character than was the case prior to 5 Ma, probably due to major drainage capture of the Punjabi tributaries away from the Ganges. Deposition patterns on the shelf suggest that the Indus delta has produced a compound clinoform on the western shelf, probably as a result of extremely active sediment transport under an energetic mixed wave-tide regime. After the reduction in discharge in the late 1950's, the deltaic shoreline along most of the western coast started to recede at rates of $\sim$50 m/year; surprisingly, the eastern tide-dominated coast remained stable or even prograded. This differential shoreline behavior suggests an active role for sediment transfer processes in the reworking of abandoned deltaic coast.