New Perspectives on Geomorphic Processes: Megafans in Terrestrial and Planetary Environments

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The mesoscale sedimentary environment known as the megafan is a low-angle, partial cone of fluvial sediment generated where a river enters an unconfined basin and begins the process of avulsing over wide areas. The significance of megafans as a new feature was first revealed by astronaut handheld imagery. Our research, based on the first global study of megafans, has resulted in new perspectives in both terrestrial and planetary environments.

Planetary megafans: A new explanation for the martian landscapes of Sinus Meridiani

Explanations for the enigmatic geology of Sinus Meridiani, on which the NASA rover "Opportunity" still operates, are dominated by the common, but restricted, view that river channels only form in hilly country; i.e., channels are always confined within valley walls. The features of numerous megafans around the world closely parallel Meridiani landscapes, including: (1) networks of stream channels that (2) occupy vast plains, with (3) the channels forming more resistant elements in the landscape, thereby resulting in the classic sinuous "inverted" ridges of the terrestrial and martian landscapes. The Libyan landscapes on Earth even show a detail of sinuous ridges interacting with circular craters, which provides our most persuasive analog yet for the Meridiani Planum (figure 1).

Terrestrial megafans: A new explanation for the Kalahari Desert landscapes of south-central Africa

Maps of a series of megafans of the Kalahari basin provide a fundamental shift in our understanding of the landscape evolution, biological evolution, and water resources of the arid central Kalahari basin. A newly identified megafan shows that the large Okavango River once flowed alternately southward, into a basin in northern Namibia, and eastward, to the modern downstream megafan of the Okavango delta of northern Botswana. Paleontological data confirm that this alternative flow operated until approximately 6 Ma, at which point the Okavango River incised into the new fan, causing the drying up of the paleo-lake Etosha. This drying-up has been ascribed to climate change, but likely relates to activity on the faults of the Okavango Rift. Three geological publications have incorporated these new perspectives.

Tropical terrestrial megafans: A new explanation for the evolution of modern Amazon landscapes

We generated maps based on Mars topographic roughness algorithms for South America. These maps reveal that (1) the very widespread megafan plains of Argentina likely extended far to the north, explaining much of modern Amazonia in the later Neogene Period of the Cenozoic Era; and (2) megafans can act as species pumps for

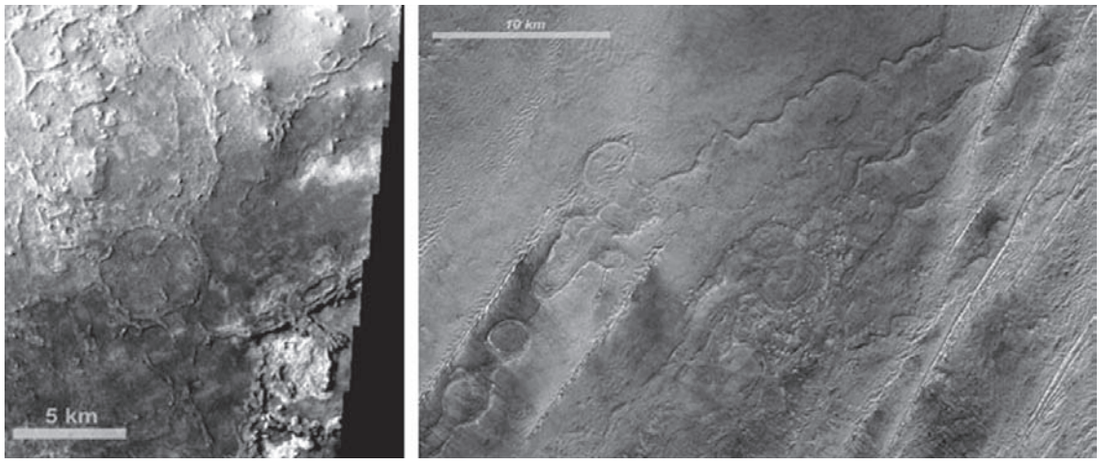

Fig. 1. *Sinuous and partly circular (crater) features, Sinus Meridiani (left). Craters with indurated rims and numerous stream channels (flow direction is NE, towards top right), Libyan Sahara (right).*

aquatic fauna, as argued by earlier work. Applying these arguments to Amazonia, we contend that paleo-megafans could well explain some of the fish biodiversity of the western Amazonia, where many species occupy the "megafan zone" against the Andes Mountains (figure 2).

Fig. 2. *Roughness map of South America. Darkest areas are lowest slope and smoothest landscapes, all dominated by megafans.*

Other new perspectives: A new biogeographic boundary coinciding with a tectonic plate boundary

This study portrays one of the few known Latin-American plate boundaries that coincides with the clear-cut distributional limits separating major biogeographic provinces. The Costa Rica Grande de Tárcoles River occupies the fault zone that defines the Costa Rica-Panama microplate boundary. The Tárcoles River also marks an unusually clear biogeographic frontier between the Pacific dry forest (the Mexican Pacific Coast Province) and the Pacific rain forest (the Western Panamanian Isthmus Province).

Species richness and endemicity maps for scarab beetles, which are probably representative of most insects, allow definition of four priority levels of conservation area. The single most critical zone of land use overlap is in the Central Valley of Costa Rica. This zone lies mostly outside of the protected zones, in which commercial agriculture land use is dominant. This analysis has significant policy implications for a country in which the protection of biodiversity is a key tourist attraction (figure 3).

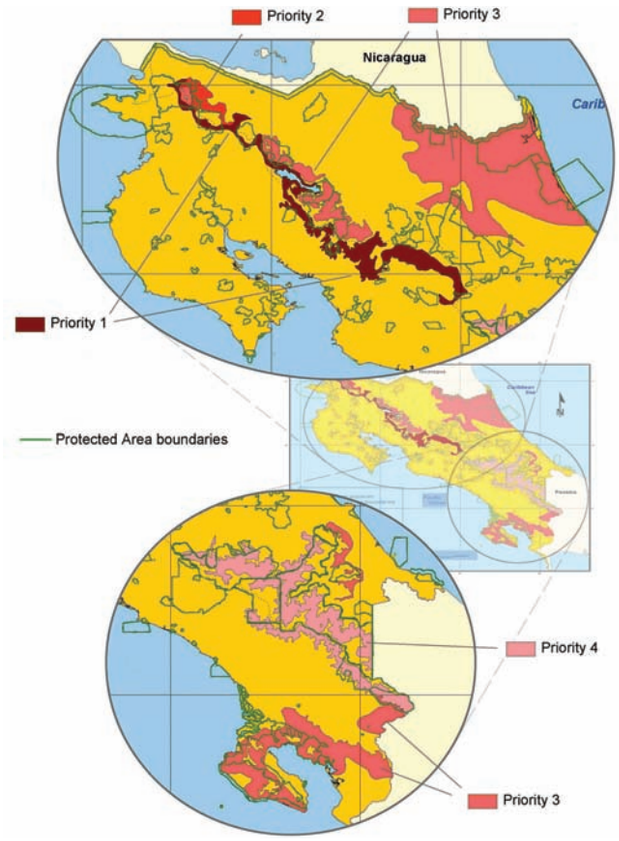

Fig. 3. *Central Valley of Costa Rica biodiversity zones.*

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