Megafans in younger orogens

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Abstract. Fluvial megafans are unusually large fan-shaped bodies of sediment, whose formation is primarily restricted to 15°–35° latitude in Northern and Southern Hemispheres. Recent megafan-formation seems to be dependent on large rivers, that undergo seasonal fluctuations in discharge, resulting in instability of its channels. The global distribution of fluvial megafans, fringing the tropical climatic zone, is correlating with seasonal precipitation and may thus provide paleoclimatic information for ancient stratigraphic successions where megafan deposits are recognized.

Introduction

The volumetrically largest known accumulations of coarse sediment in foreland basin systems are fluvial megafans (DeCelles and Cavazza 1999; Fig.1). Their formation is connected to rivers exiting the topographic front of a mountain range, entering an adjacent basin, allowing the river to migrate laterally and to deposit huge fan-shaped bodies of sediment (Gohain and Parkash 1990). Although fluvial megafans have in common some characteristics with alluvial fans, they differ in the size of the area they occupy and in their gradients. Fluvial megafans cover areas of 10^3–10^5 km^2 whereas alluvial fans generally take up less than 100 km^2 and compared to a gradient of about 1°–4° for alluvial fans, fluvial megafans possess an extreme low slope of 0.01°–0.1°.

The morphology of a megafan results like other fan-shaped sediment bodies from a fixed upstream portion of the main feeder channel and the freedom to migrate laterally in the direction further downstream over an angle of ~180°. But because adjacent megafans constrict each other in their lateral growth the actual arc typically is less than 180° (DeCelles and Cavazza 1999).

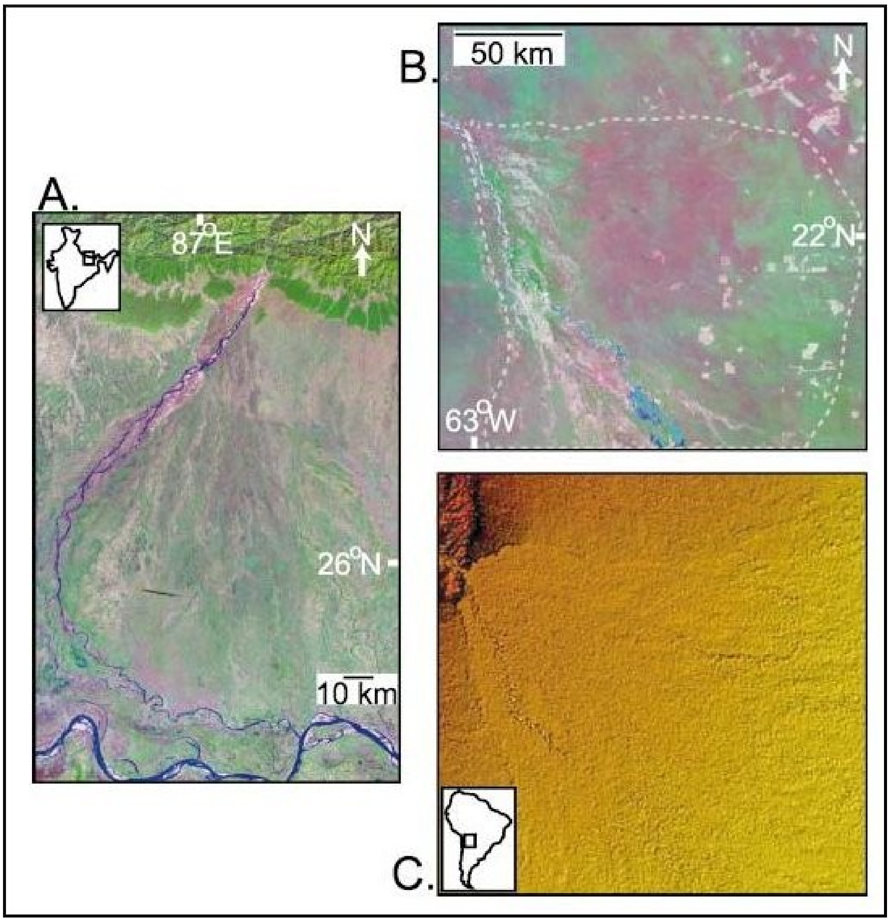

Fig. 1. Images of modern fluvial megafans. A: Kosi fluvial megafan south to the Himalayan front. B: Pilcomayo fluvial megafan (outlined by dashes) forming as Pilcomayo river exits Andes. C: DEM of Pilcomayo megafan with 100 times vertical exaggeration (taken from Leier et al. 2005).

Even though there currently is a great number of rivers with suitable dimensions and premises for the formation of megafans only a few actually develop them today. The work of Leier et al. 2005 showed that factors concerning large fluctuations in discharge of the rivers resulting from seasonal or monsoonal precipitation enables rivers to form fluvial megafans and thus restricts their occurrence. They further argue that the same association between seasonal precipitation and fluvial megafans is existing in ancient stratigraphic successions and therefore propose that fluvial megafan deposits may come in handy as paleoclimate indicators (Leier et al. 2005).

Methods

To determine whether the deposits of a river can be classified as fluvial megafan deposits a range of different data has to be evaluated and combined. Landsat-5 satellite imagery, topographic maps and digital elevation models (DEMs) are useful for a first recognition of potential megafans (Leier et al. 2005). Because of the peculiarities that lead to the formation of fluvial megafans monthly and annual stream-discharge records as well as precipitation records have to be used.

Fluvial megafans are identified by using the satellite images to discover distinguishable fan-shaped sedimentary bodies. Because their size is important, recognized fan-shaped bodies need to be distinctly larger than adjacent alluvial fans to be considered as megafans. Leier at al. 2005 proposed that sediment bodies smaller than 30 km from apex to toe should not be designated fluvial megafans. Another criterion for identification are the rivers associated with the megafan. They must maintain the discharge levels in the main channel (i.e., once it exits the topographic front no tributaries join the megafan river) and abandoned channels must be present trending to deposit in a divergent or arcuate manner, because nonmegafan rivers tend to form prevailingly linear channel belts (Leier et al. 2005).

Using facies analysis fluvial megafan deposits can be separated into four zones (Shukla et al. 2001; Fig. 2): Zone I – Gravelly braided streams; Zone II – Sandy braid plain; Zone III – Anastomosing channel plain and Zone IV – Meandering channels with interfluve areas.

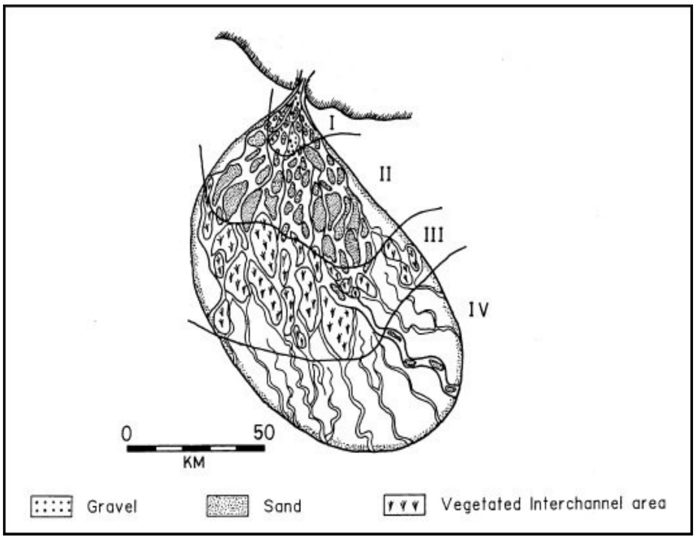

Fig. 2. Schematic diagram of a fluvial megafan with four identified zones: Zone I – Gravelly braided zone, Zone II – Sandy braid plain, Zone III – Anastomosing channel plain, Zone IV – Meandering channels with broad interfluve areas (modified after Shukla et al. 2001).

Ancient megafans

Because fluvial megafans present such large bodies of sediment, they remain poorly known for ancient times. Only little attempt has been made to identify possible megafans and to compare modern and ancient megafan deposits (DeCelles and Cavazza 1999). Table 1 lists a number of ancient and modern fluvial megafans, showing that the basis of information remains thin for ancient ones.

Table 1. List of selected modern and ancient fluvial megafans in foreland basin systems (after DeCelles and Cavazza 1999 and references therein)

River-Megafan	Location	Catchment (10^3 km^2)	Megafan area (10^3 km^2)	Slope
Modern				
Kosi	Nepal, India (Himalaya)	59	~16.5	0.06°
Gandak	Nepal, India (Himalaya)	45	~17.5	0.03°
Karnali	Nepal, India (Himalaya)	44	~1.0	0.18°
Tista	Nepal, India (Himalaya)	~12	~16	0.04°
Pastaza-Marañon	Peru, Brazil (Andes [north])	?	60	?
Jachal	Argentina (Andes [south])	27.7	~1.4	?
Huaco	Argentina (Andes [south])	7.1	~0.7	?
Ancient				
Hams Fork (Cretaceous-Paleocene)	Utah (Sevier belt)	?	>2.5	?
Harebell-Pinyon (Cretaceous-Paleocene)	Wyoming (Sevier belt)	?	>10	?
Central Utah (Cretaceous-Paleocene)	Utah (Sevier belt)	?	>3.6	?
Southern Utah (Cretaceous-Paleocene)	Utah (Sevier belt)	?	>4.0	?
Luna (Miocene)	Spain (Pyrenees)	?	~2.5	?

Modern megafans

The work of Leier et al. 2005 discovered nearly 30 modern fluvial megafans throughout the world dispersed from the Andes over the Himalaya, the Mid East, the Russo-Sino and southern Mongolia to sub-Saharan Africa (Fig. 3; GSA Data Repository item 2005049).

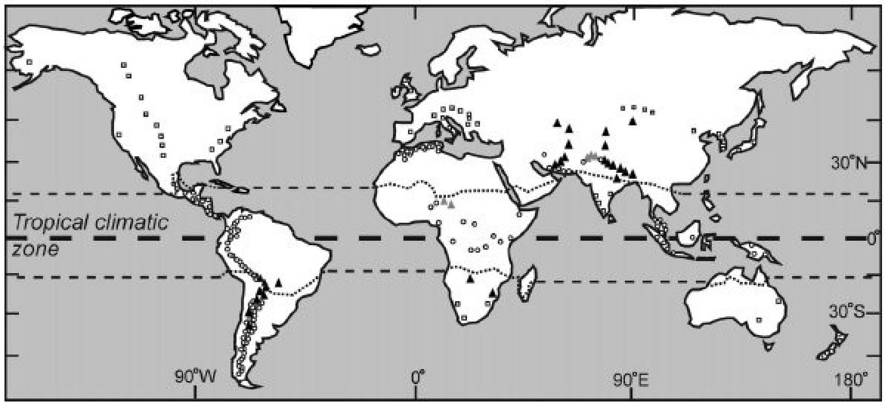

Fig. 3. Location of megafan rivers (black triangles) and the tropical climatic zone according to Köppen's classification. Fluvial megafans are prevalent in latitudinal belts fringing the tropical climate zone, corresponding to regions with seasonal precipitation (after Leier et al. 2005).

Their study revealed that fluvial megafans form predominantly in regions fringing the tropical climate zone and are restricted to latitudes from 15° to 35° in both hemispheres. This correlates with the prerequisite of rivers to undergo large seasonal fluctuations in discharge, resulting from seasonal to monsoonal precipitation in the rivers' drainage basins, in order to lead to the formation of a megafan.

The reason why rivers with seasonal fluctuations in discharge tend to form fluvial megafans lies within the dynamic of its channels. The fan-shaped sediment lobes that account for the appearance of a fluvial megafan are the result of the lateral instability of the river (Leier et al. 2005). This instability favors rapid channel migration and frequent avulsion.

A good analyzed example is the Kosi River (e.g. Willis 1993, DeCelles et al. 1998), which drains a large part of the Himalaya in northeast India and Nepal. Satellite images of the over-bank areas of this region are replete with abandoned channels (Leier et al. 2005) and the river has migrated westward more than 113 km in the past 228 years, averaging 0.5 km/yr (Fig. 4; Wells and Dorr 1987b).

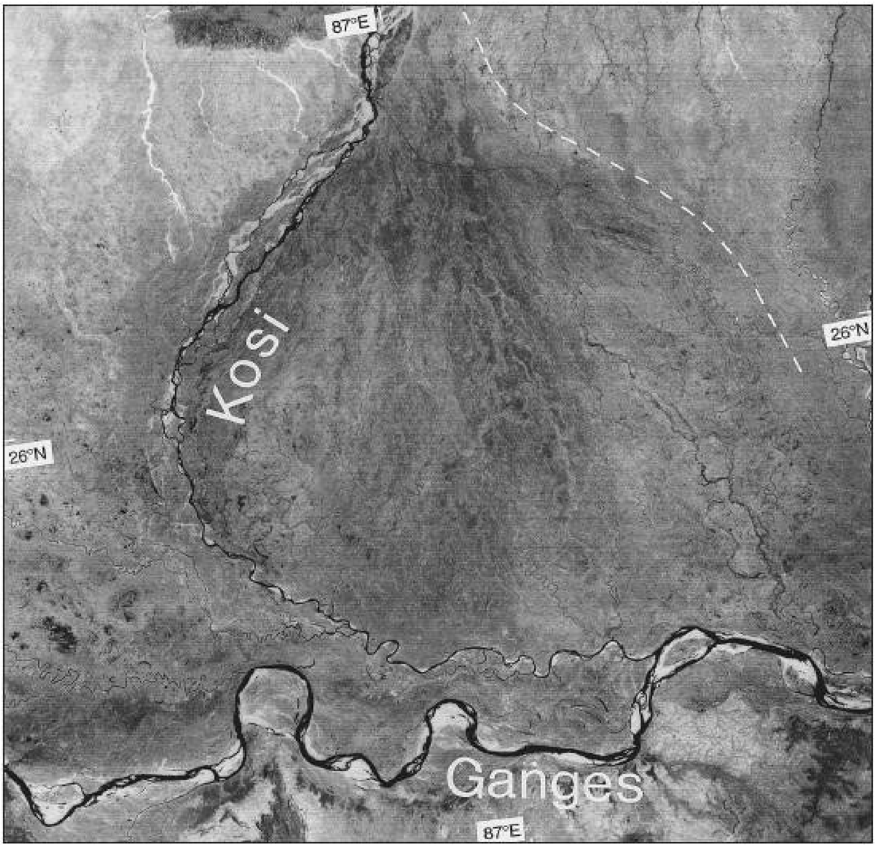

Fig. 4. Landsat MSS image of the Kosi River megafan. The eastern boundary is presented by the dashed line and the western boundary is just west of the present Kosi River (from DeCelles and Cavazza 1999).

Acting as a trigger for the frequently recurring avulsion events in megafan rivers are the annual floods, which are associated with the wet season. Peak annual discharges may also be responsible for periods of increased channel migration, leading to the erosion of river banks by the elevated stream power (Ritter et al. 2002).

The river's transport capacity may at times be exceeded due to the relatively high sediment yields from basins that alternate between dry and wet seasons. Those high sediment yields can lead to massive channel aggradation and cause rapid channel movement or avulsion (Wells and Dorr 1987a).

Discussion and conclusion

Fluvial megafans are always formed by large rivers that undergo great fluctuations in discharge, even though not all rivers experiencing large fluctuations in discharge are forming fluvial megafans. Additional factors need to be met for the development of a megafan. The river must enter a basin that allows it to migrate laterally, otherwise the river will be unable to construct fan-shaped sediment lobes. Spacing between river outlets can also be of crucial importance. If the outlets of rivers are to closely spaced the formation of a fluvial megafan is forestalled because channel migration then is confined by the deposits of the adjacent river.

Megafan forming rivers that undergo large seasonal fluctuations in discharge are tied to seasonal or monsoonal precipitation in their catchment areas. Especially monsoonal floods are the trigger for abandonment or avulsion of channels that lead to the migration of the river and consequently to the establishment of large fan-shaped sediment bodies.

Because of its peculiarities regarding climatic conditions, e.g. seasonal to monsoonal precipitation, the formation of fluvial megafans is restricted to the fringing zone of the tropic climate belt. All known modern fluvial megafans are distributed from 15° to 35° in both Northern and Southern Hemispheres.

Since seasonal precipitation and the occurrence of modern fluvial megafans are strongly correlated, stratigraphic successions identified as fluvial megafan deposits can provide important information for paleoclimate reconstructions. But due to the fact that only little information is available on the subject of ancient fluvial megafans, more research has to be done. Nevertheless, the few megafan deposits already recognized, e.g. the Hams Fork Conglomerate in northeastern Utah and southwestern Wyoming (DeCelles and Cavazza 1999; Table 1), provide crucial information for the approach to discover and identify more ancient megafans.

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