Continental Depositional Environments

Simplified Classification

Primary Depositional Setting	Major Environment	Subenvironment
Continental	*Fluvial	*Alluvial fan *Braided stream *Meandering stream
	*Desert	
	Lacustrine	
	*Glacial	
Marginal-marine	*Deltaic	*Delta plain *Delta front *Prodelta
	*Beach/barrier island	
	*Estaurine/lagoonal	
	Tidal flat	
Marine	Neritic	Continental shelf **Organic reef
	Oceanic	Continental slope Deep-ocean floor

*Dominantly siliciclastic deposition

**Dominantly carbonate deposition

Environments not marked by an asterisk(s) may be sites of siliciclastic, carbonate, evaporite, or mixed sediment deposition depending upon conditions.

Boggs (2006), p.243

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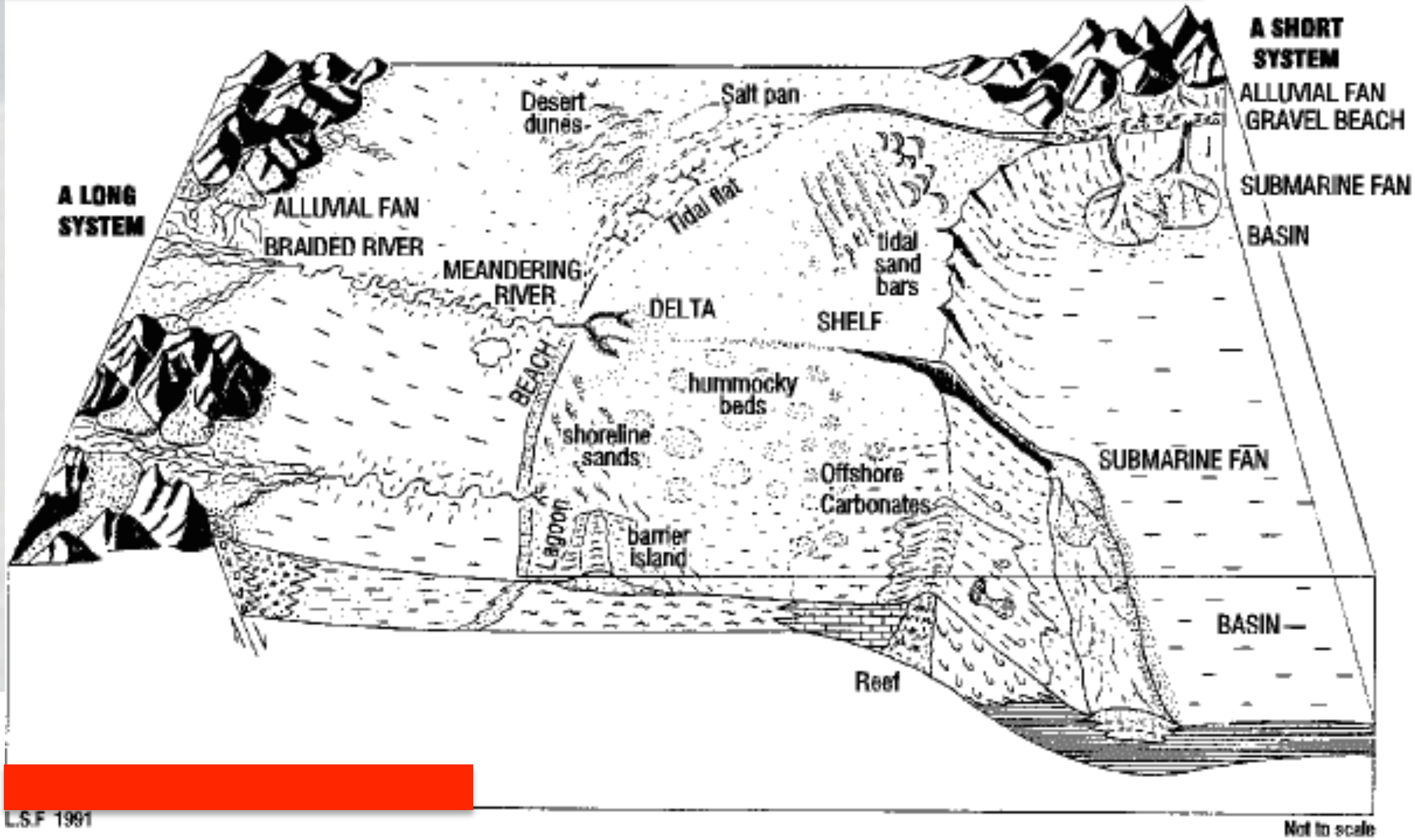
Continental Environment



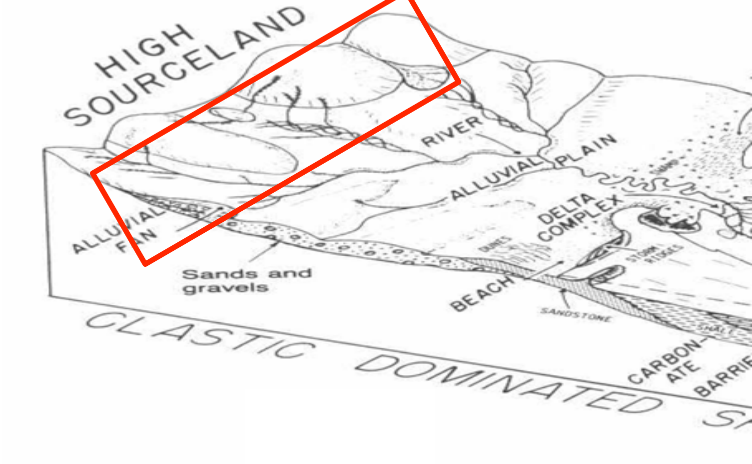
In the **continental environment**, most sediment transport is accomplished by flows that move in response to the gravity field from positions of greater to lesser potential energy except wind-blown sediment. Where the flow paths of wind flows are determined by the local barometric gradient rather than the earth's gravity field.

ALLUVIAL SYSTEMS

Alluvial environment is characterized by a wide variety of depositional settings, associated to different availability of water, fed from a more or less developed drainage basin.

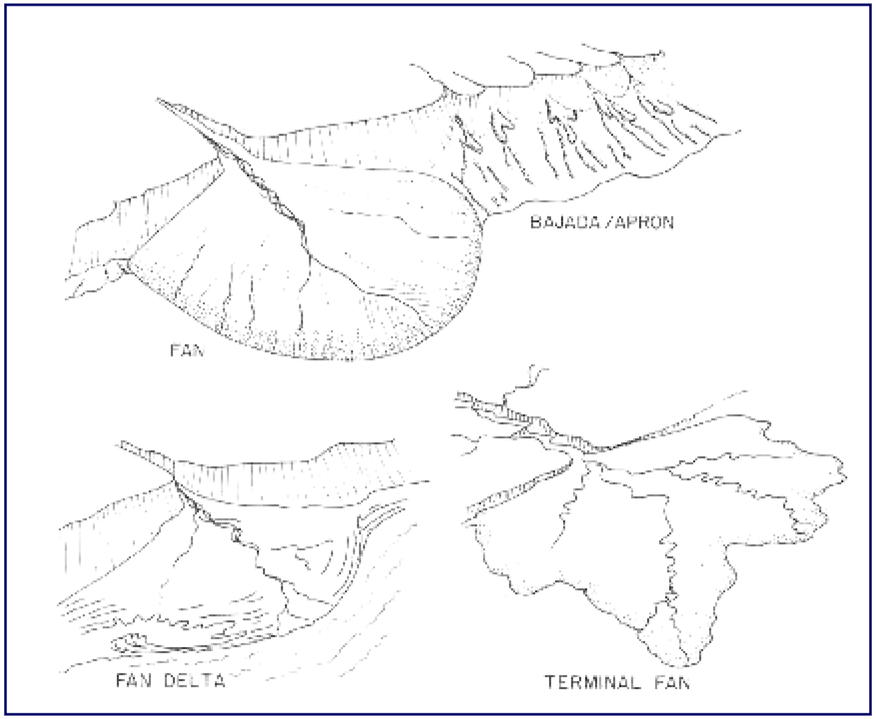
Sediment accumulation in alluvial setting is characterized by alternating phases of erosion and deposition, with a sedimentation rate significantly changing in time and space.

Alluvial deposits represent a significant component of alluvial successions, and although they can be accumulated in different alluvial and climatic settings, two main environments can be distinguished: **ALLUVIAL PLAINS** and **ALLUVIAL FANS**.



ALLUVIAL FAN SYSTEMS

Alluvial fans generate where a confined river with a large amount of transported sediments enter a low-gradient area. The depositional surface of alluvial fans is typically inclined at 1°-15°, depending on the sediment grain-size and depositional processes. The areal extension of alluvial fans is highly variable, ranging from few hundreds of meters to hundreds of kilometers. Alluvial fan deposits are relatively common in the stratigraphic record, locally attaining a high thickness (e.g. The Devonian Hornelen Basin, Norway, about 8000 m thick).



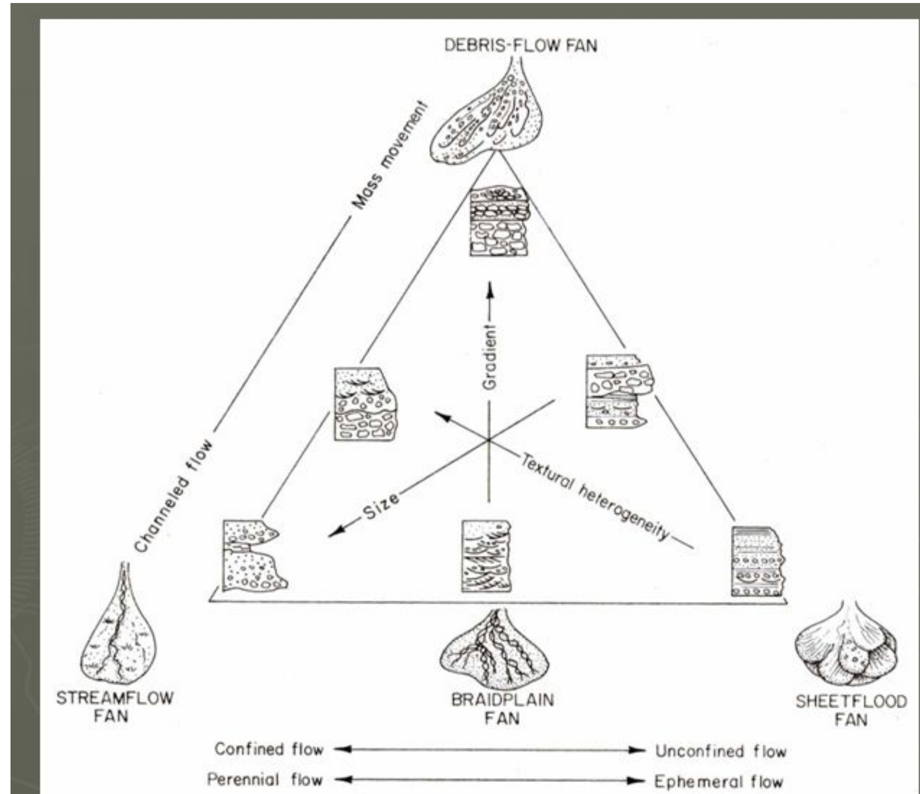
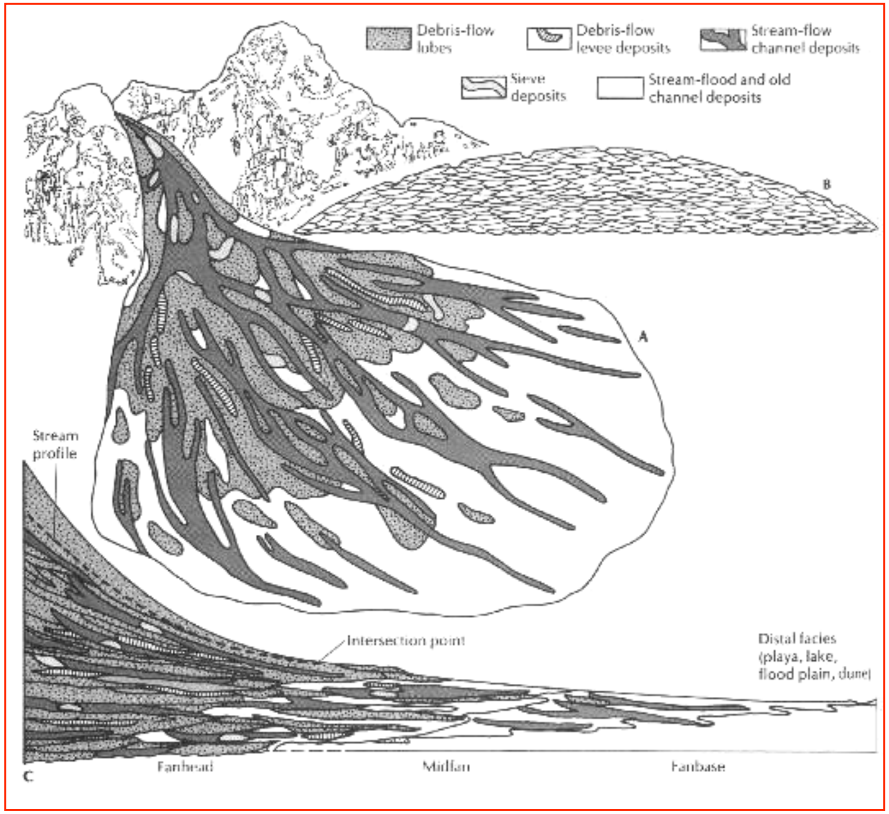


Fig. 3.4. Classification of alluvial fan systems

After Galloway and Hobday, 1996

Classical alluvial fan systems typically develop at the toe of a mountain, although the interaction with nearby depositional systems (e.g. fluvial, eolian and marine settings) within particular climatic and tectonic regimes can substantially modify their features (fan delta, terminal fans). Indeed, significantly different alluvial fans, mainly in terms of depositional processes, will result from specific combinations of climate, tectonics and grain-size of the available sediments.



After Spearing, 1974

Both in an axial section (along the alluvial fan simmetry axis) and in a transversal section, the alluvial fan body is characterized by a lens-shape geometry, well recognizable by field mapping. From the proximal to the distal part a progressive decrease in grain-size occurs.

This change is typically associated to the transition among mass flows-dominated to selective-flows-dominated areas.

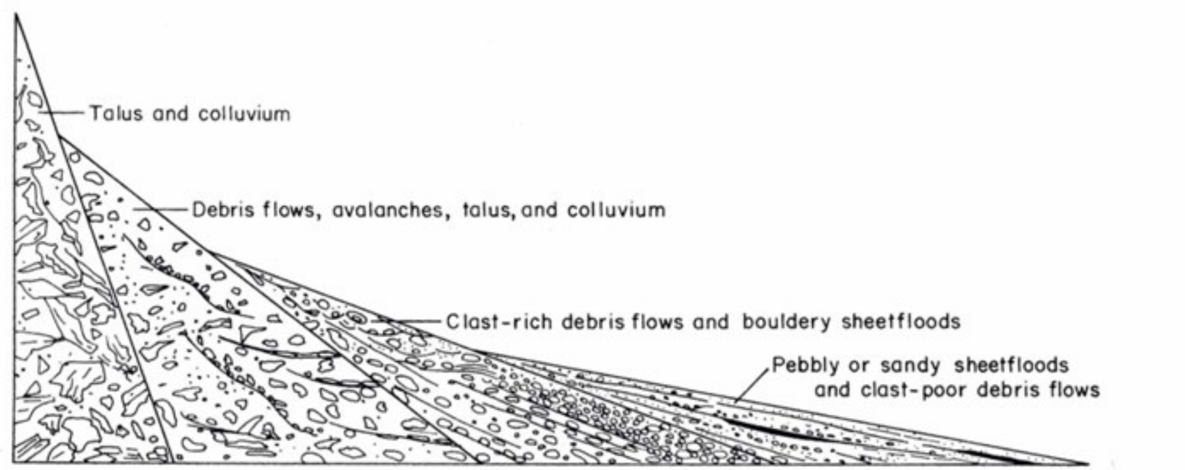
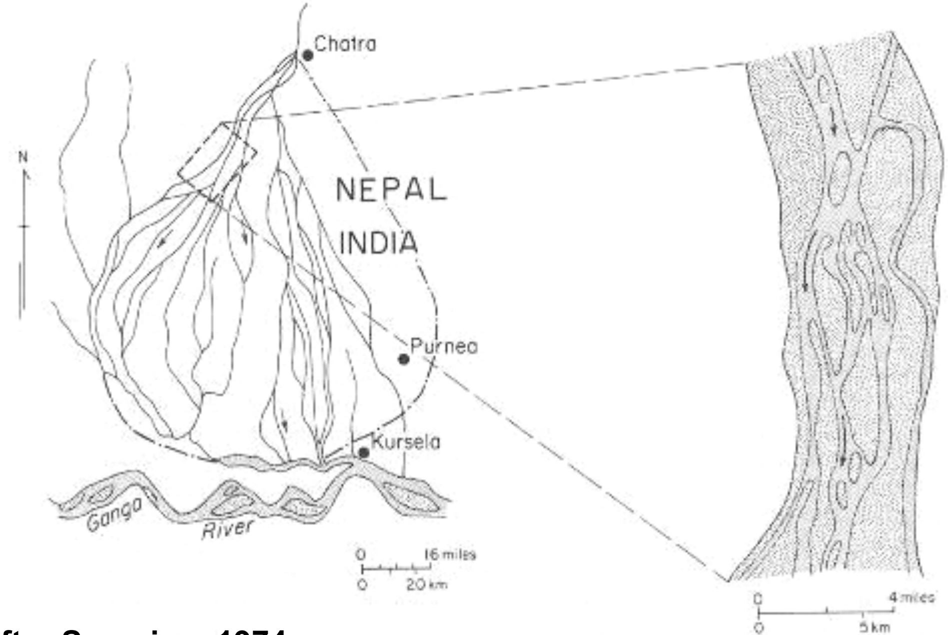
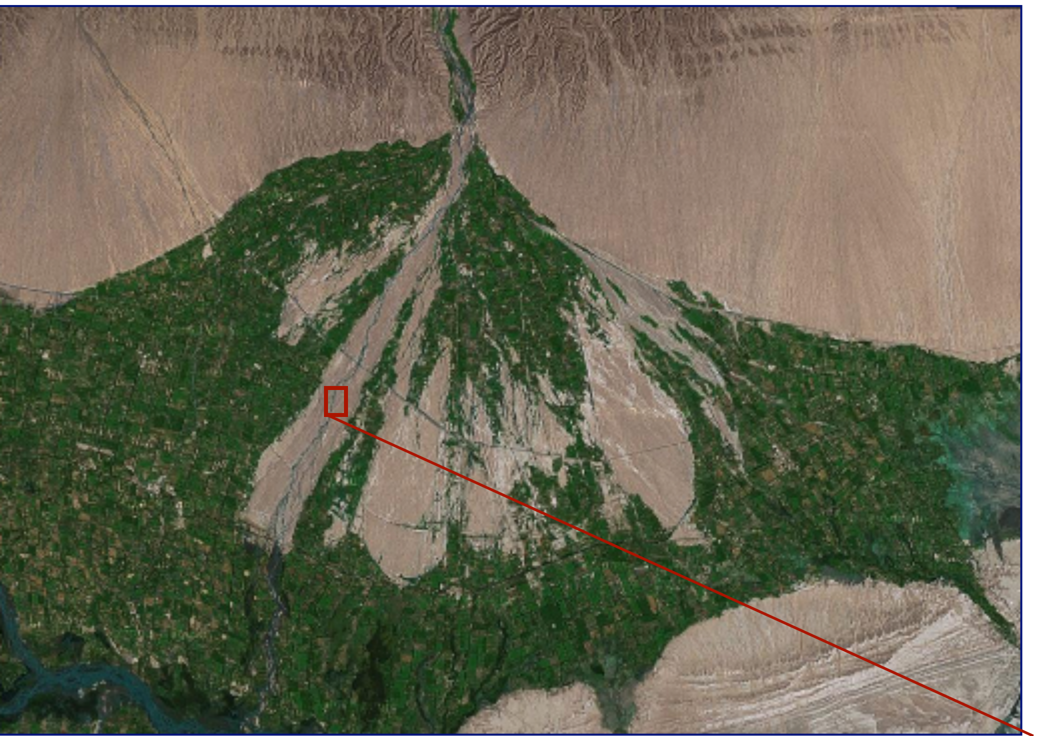


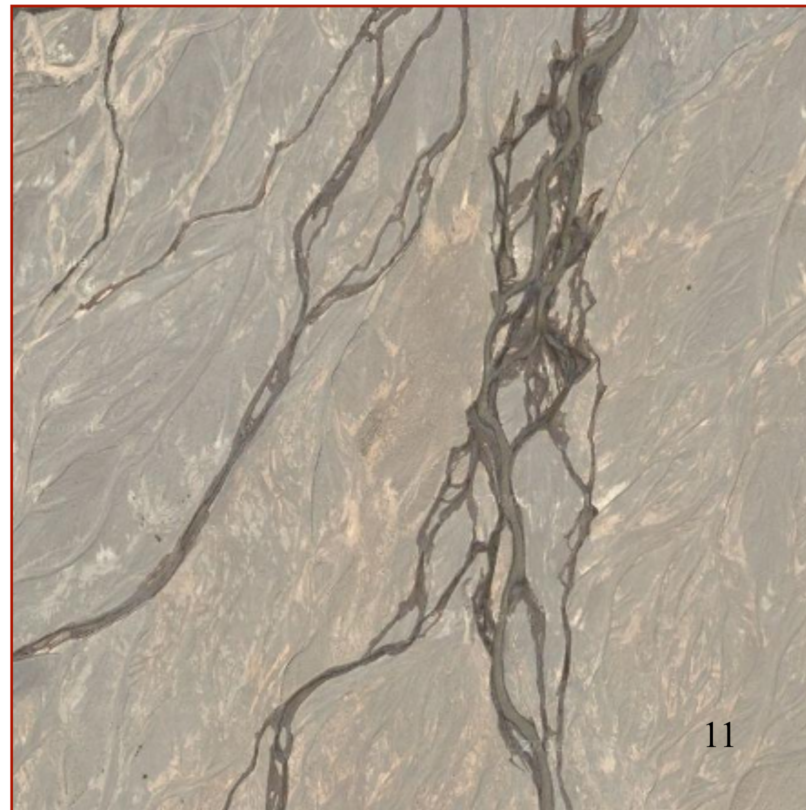
Fig. 3.7. Internal facies partitioning within debris-flow fans. Note decreasing clast size, improved sorting, and development of stratification downflow. (Derived from Blair and McPherson 1993)



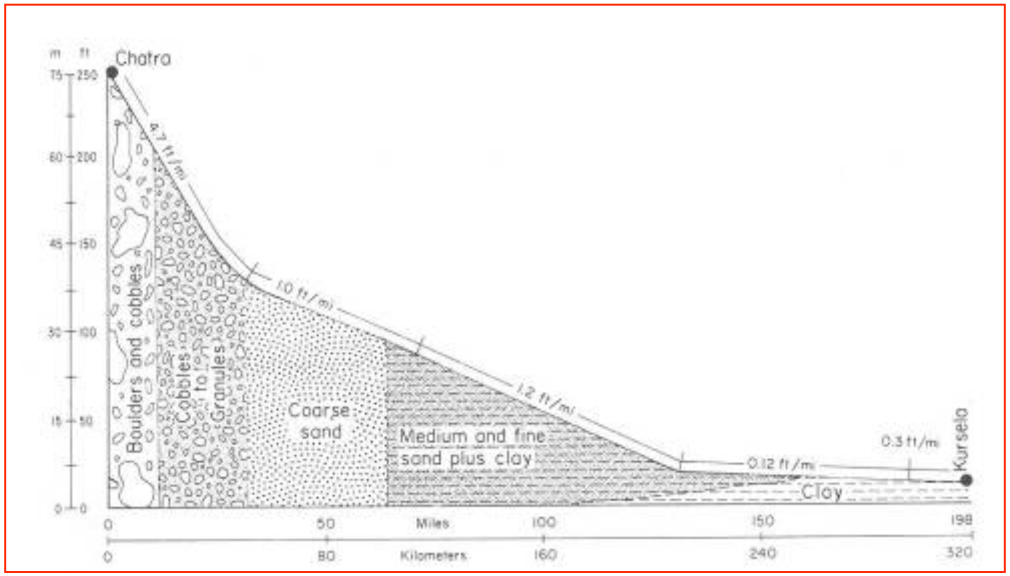
After Spearing, 1974

Notwithstanding the distinction between alluvial fan and fluvial systems is quite obvious from a morphological point of view, it should be kept in mind that alluvial fans are commonly depositional settings crossed by channels. It follows that at a small scale (and from an outcrop perspective) alluvial fans may resemble fluvial systems.

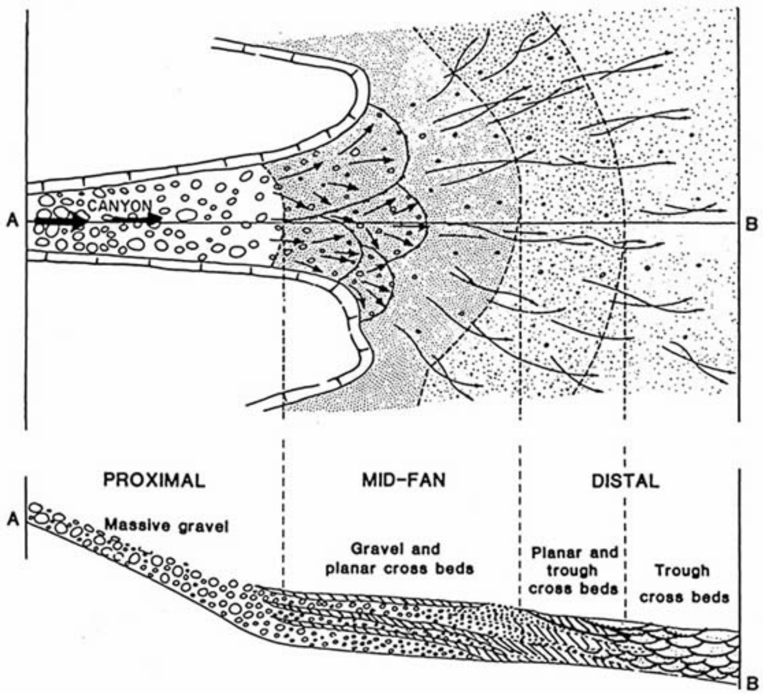




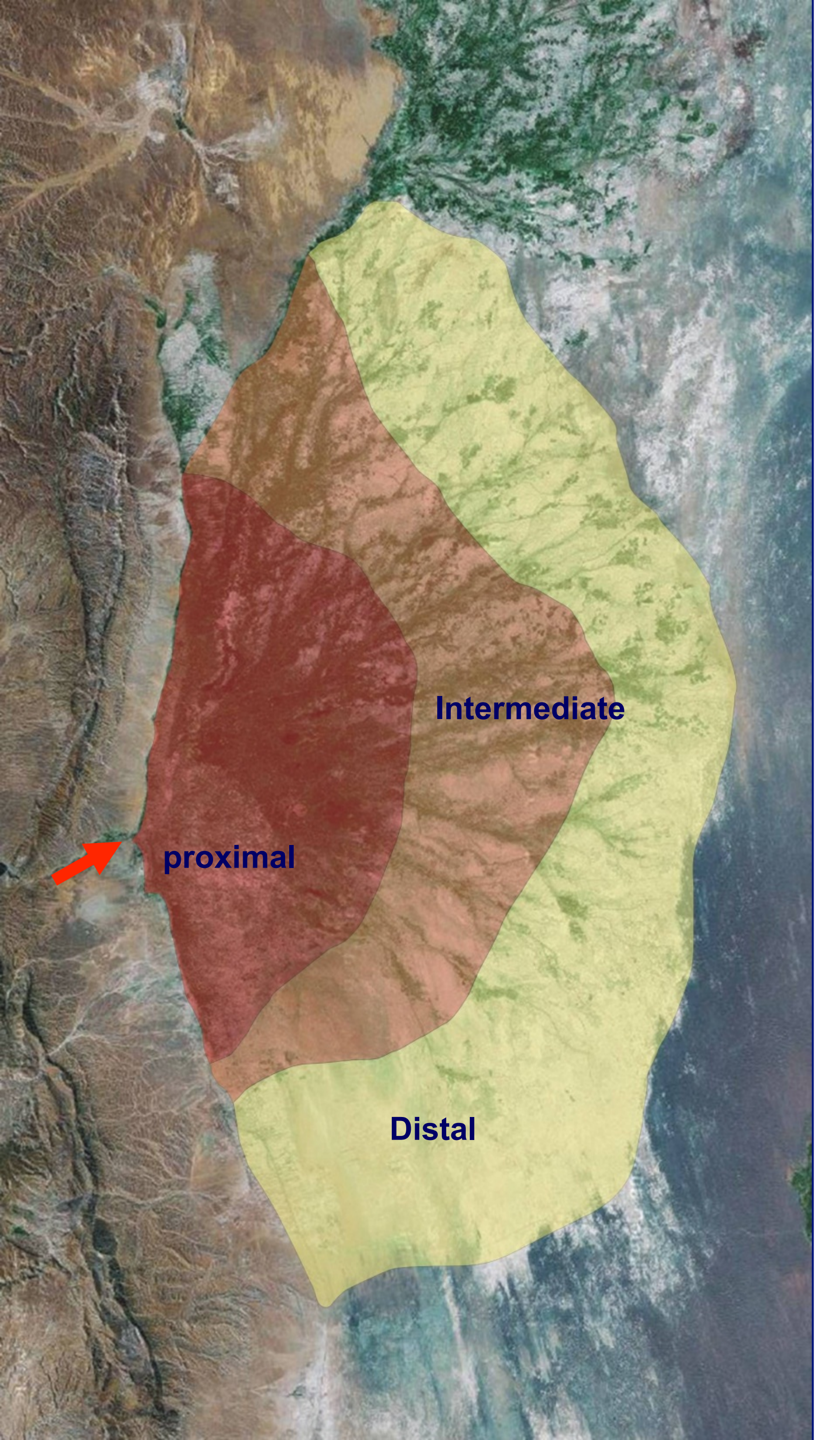
In plan view, an alluvial fan shows a peculiar fan shape with the apex pointing to the source area. The fan amplitude varies according to local phisiography and sedimentary processes. From a general point of view, and depending on the grain-size of sediment and depositional processes, an alluvial fan can be subdivided into proximal, intermediate and distal areas. In the stratigraphic record such an architecture is not always recognizable from an outcrop perspective. To this purpose, paleocurrents distribution and channels axes orientation are diagnostic features for recognizing ancient alluvial fans.



After Galloway and Hobday, 1996



After McGowen and Broat, 1971

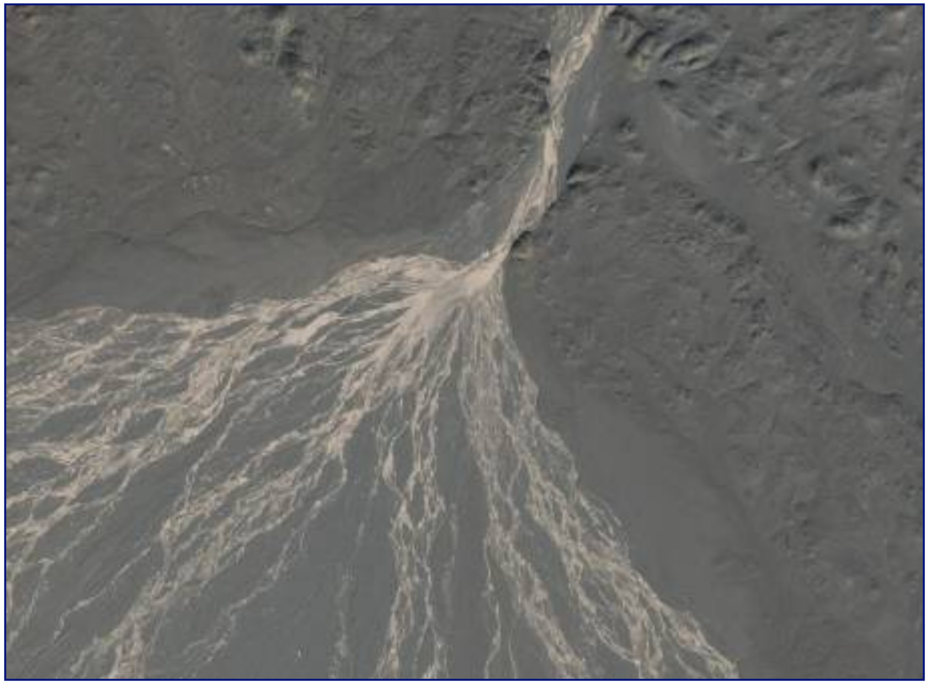


A further feature changing in a proximal to distal direction is the channels depth/width ratio.

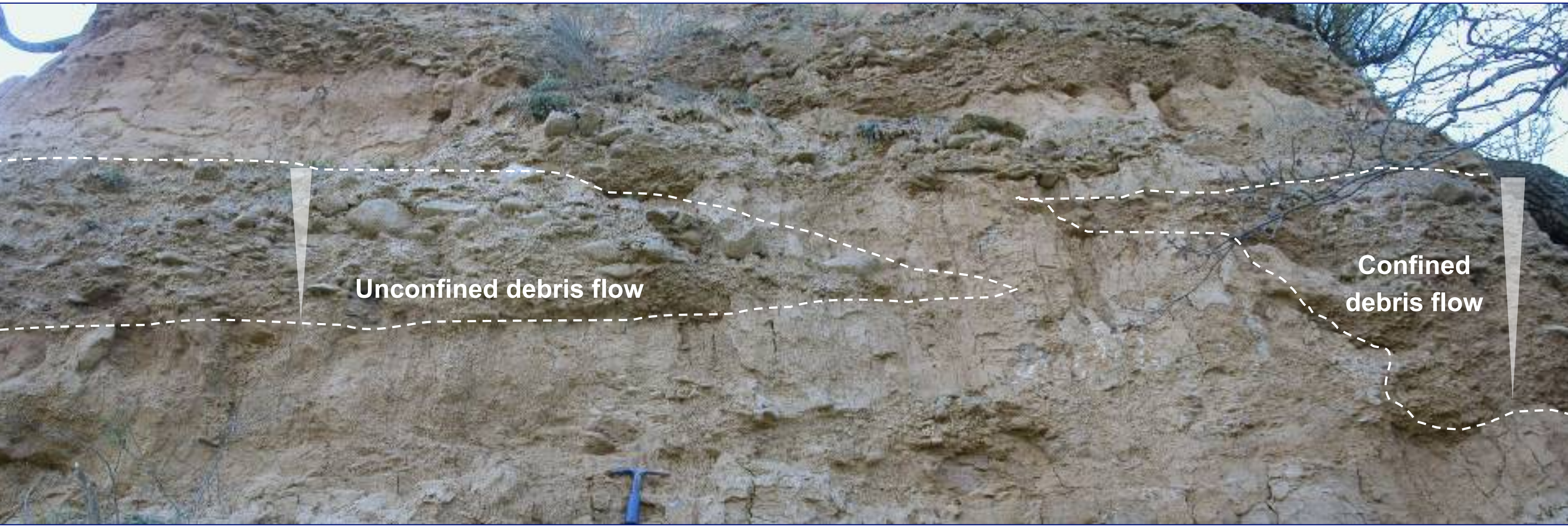
In the proximal part of an alluvial fan (~15°), one or more distributary channels are commonly present and active (typically entrenched), whereas overbank deposits are rare and with a low degree of preservation.

The proximal portion of an alluvial fan systems is adjacent to high-relief areas and thus it is characterized by mass-flows rapresented by debris flows and hyperconcentrated flows, although the finer sediments are transported and deposited under tractional conditions.

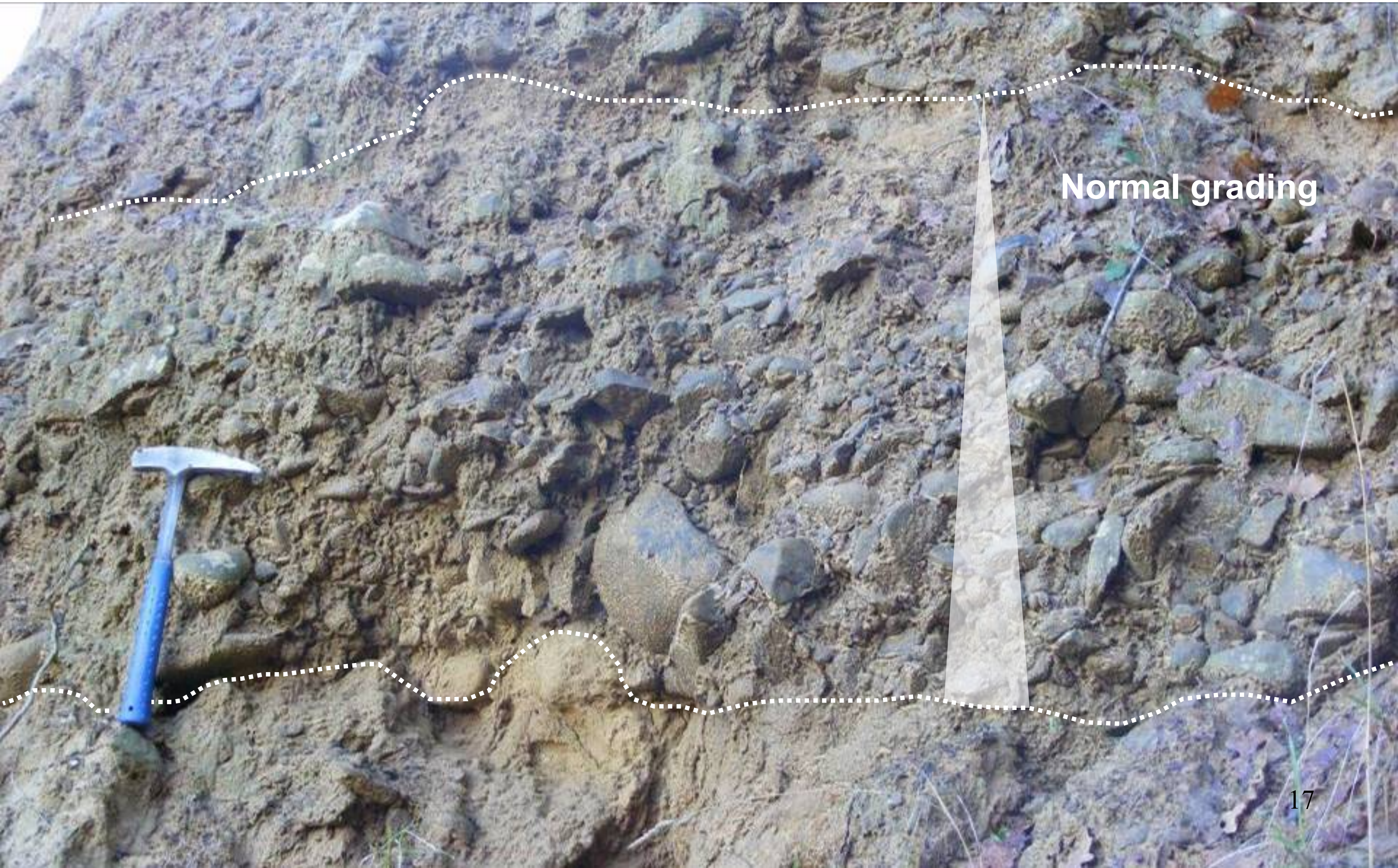
Proximal alluvial-fan deposits are typically disorganized (chaotic) and amalgamated



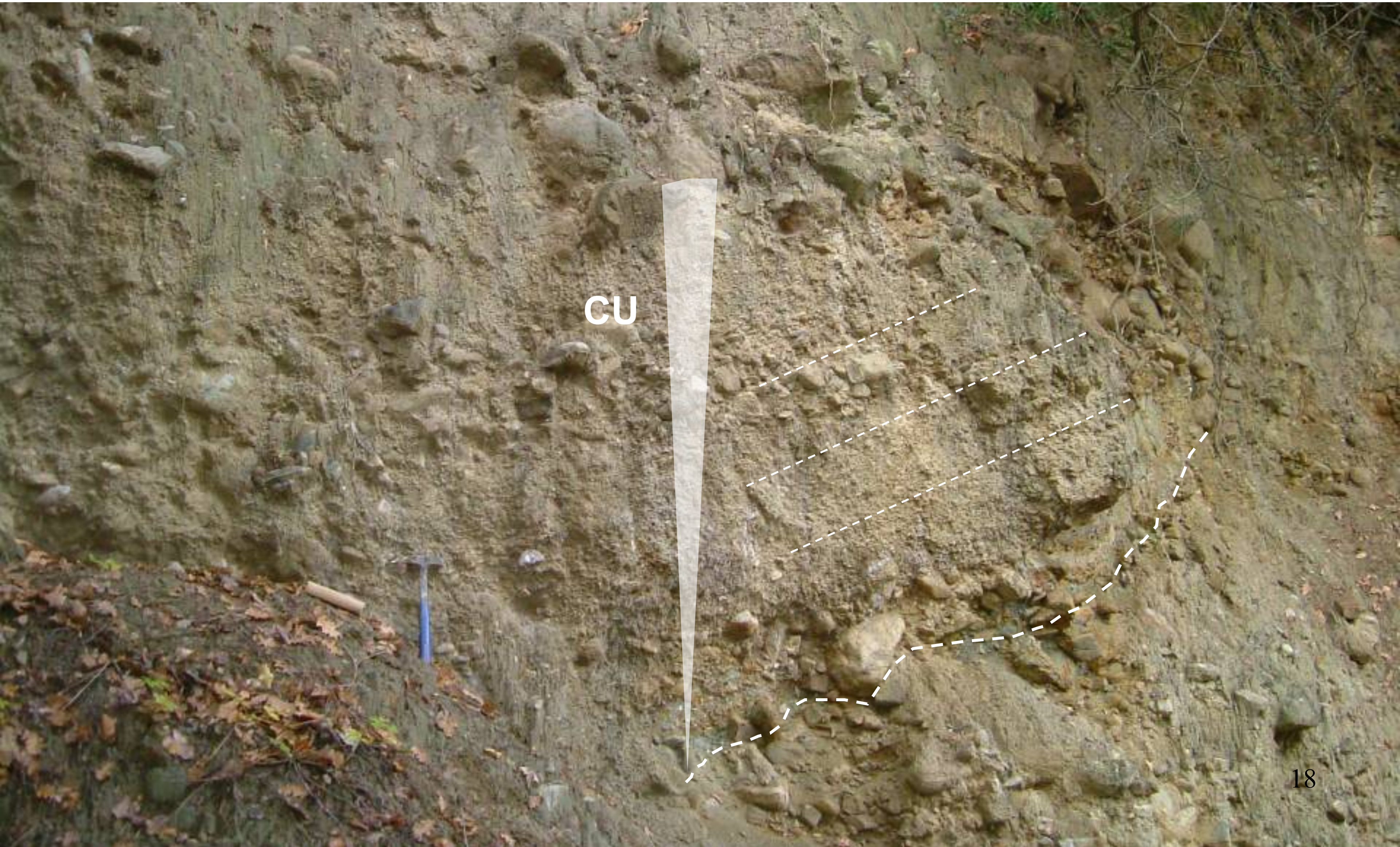
Debris flows deposits are generally amalgamated, although sometimes they can occur as isolated bodies within fines. Debris flow deposits are typically unconfined and characterized by a lens-shaped geometry with plane bases and convex upper surfaces, although locally they can represent the infill of former channels cut by turbulent flows.

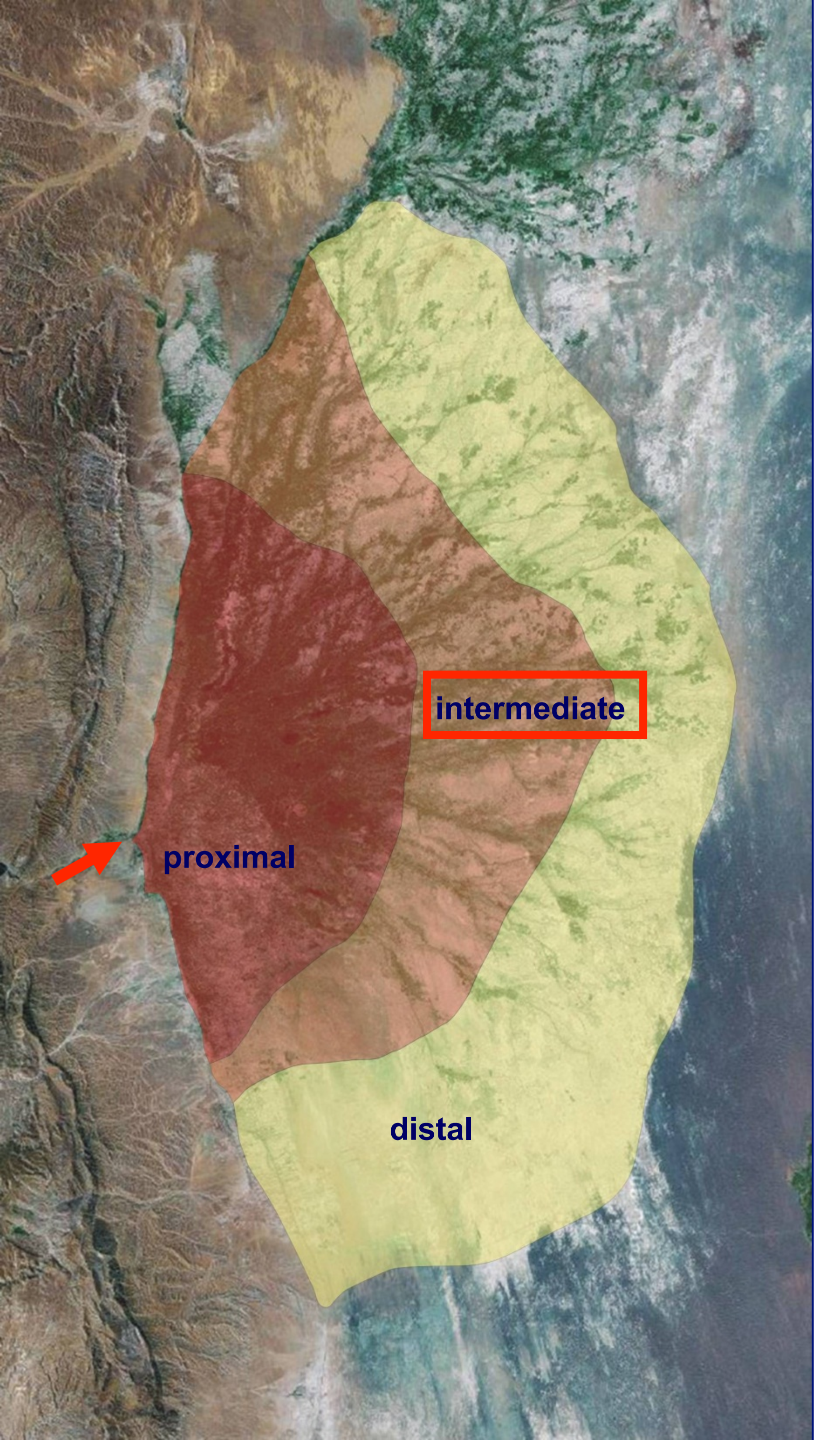


Hyperconcentrated flow deposits are typically confined within steep-sided channels, although not easily recognizable due to amalgamation. Such channels are often incised and filled during the same event (cut and fill). Erosive base and normal grading are typical features of hyperconcentrated deposits.



When selective transport is common, channels often shows longitudinal bars and occasional side bars, the latter evidence of lateral accretion processes.

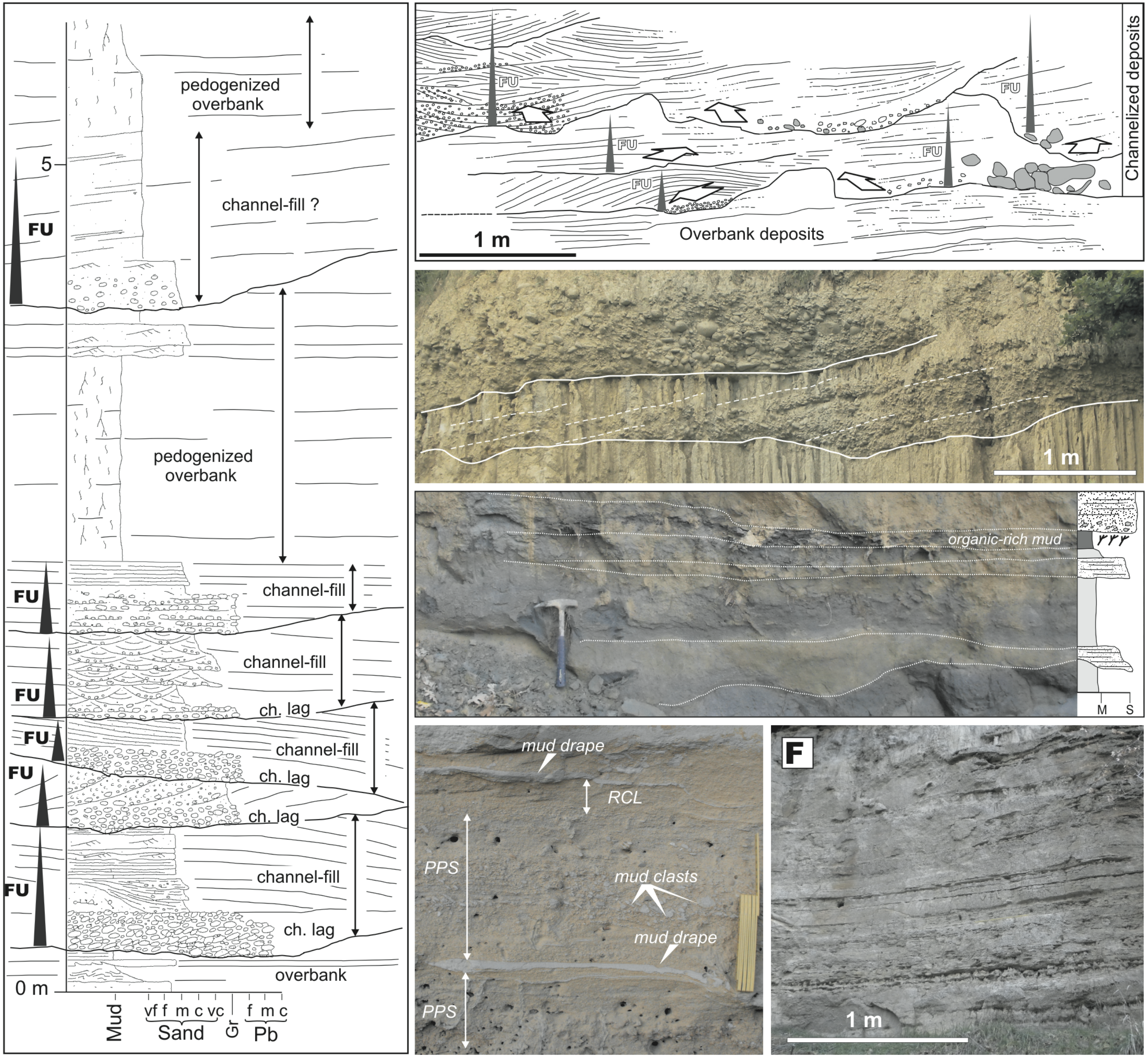




Moving towards the intermediate portion (~5°) of the alluvial fan system, sediment average grain-size decreses and sediment flows show a higher water content (hyperconcentrated flows and selective transport).

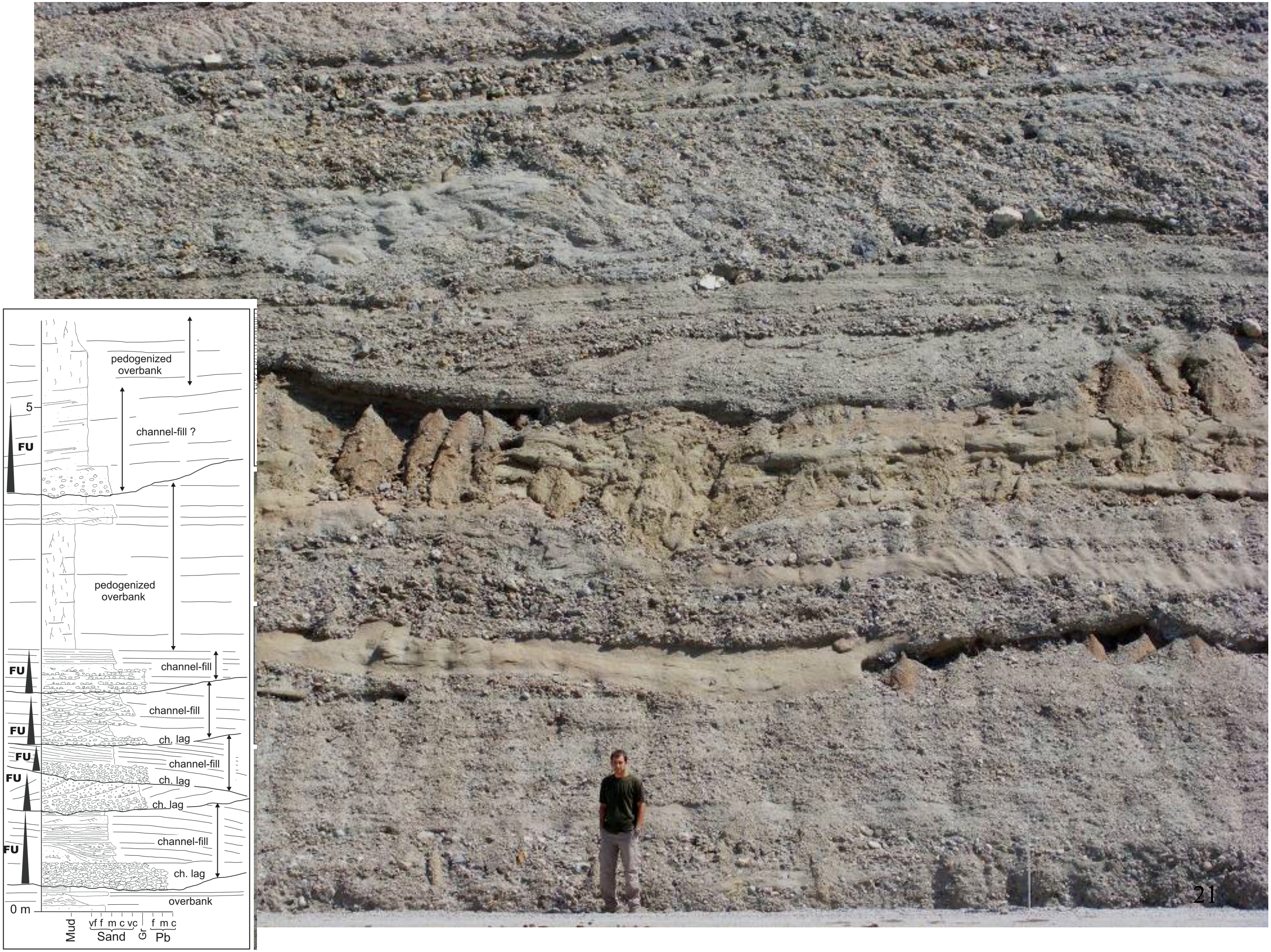
The distributary channels show minor depths (channels depth/width ratio decreases) although usually not all are active at the same time

Overbank deposits are better represented, quite widespread and with a higher degree of preservation



After Fidolini et al., 2013

In these areas, channels show a braided style, since the gradient is too high for high-sinuosity channel development. As a whole, these deposits are better organized compared to the proximal ones (see next slide).


pedogenized
overbank
5
channel-fill ?
FU
pedogenized
overbank
FU
channel-fill
channel-fill
FU
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FU
channel-fill
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FU
channel-fill
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overbank
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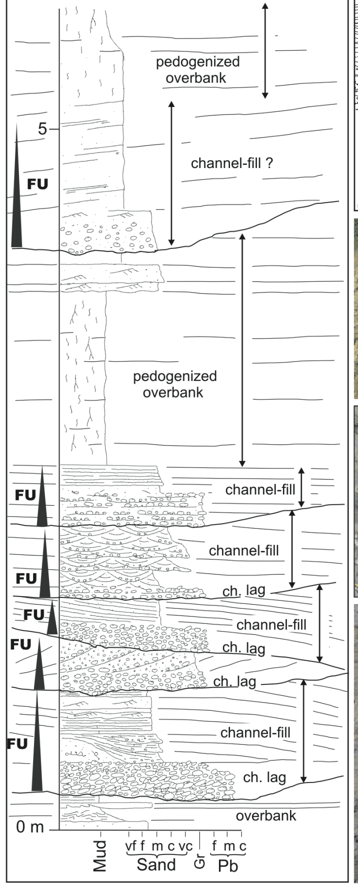
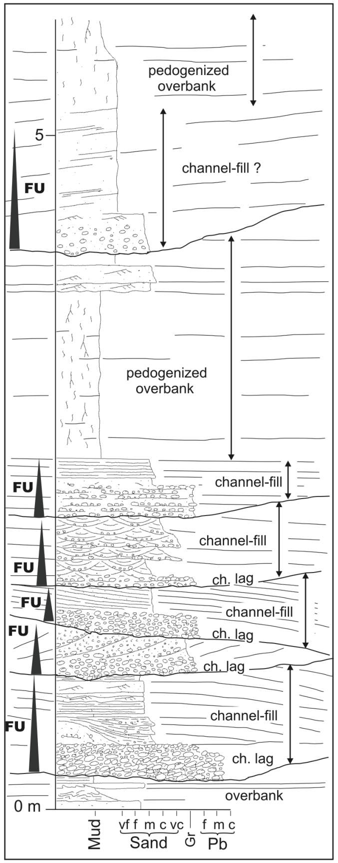
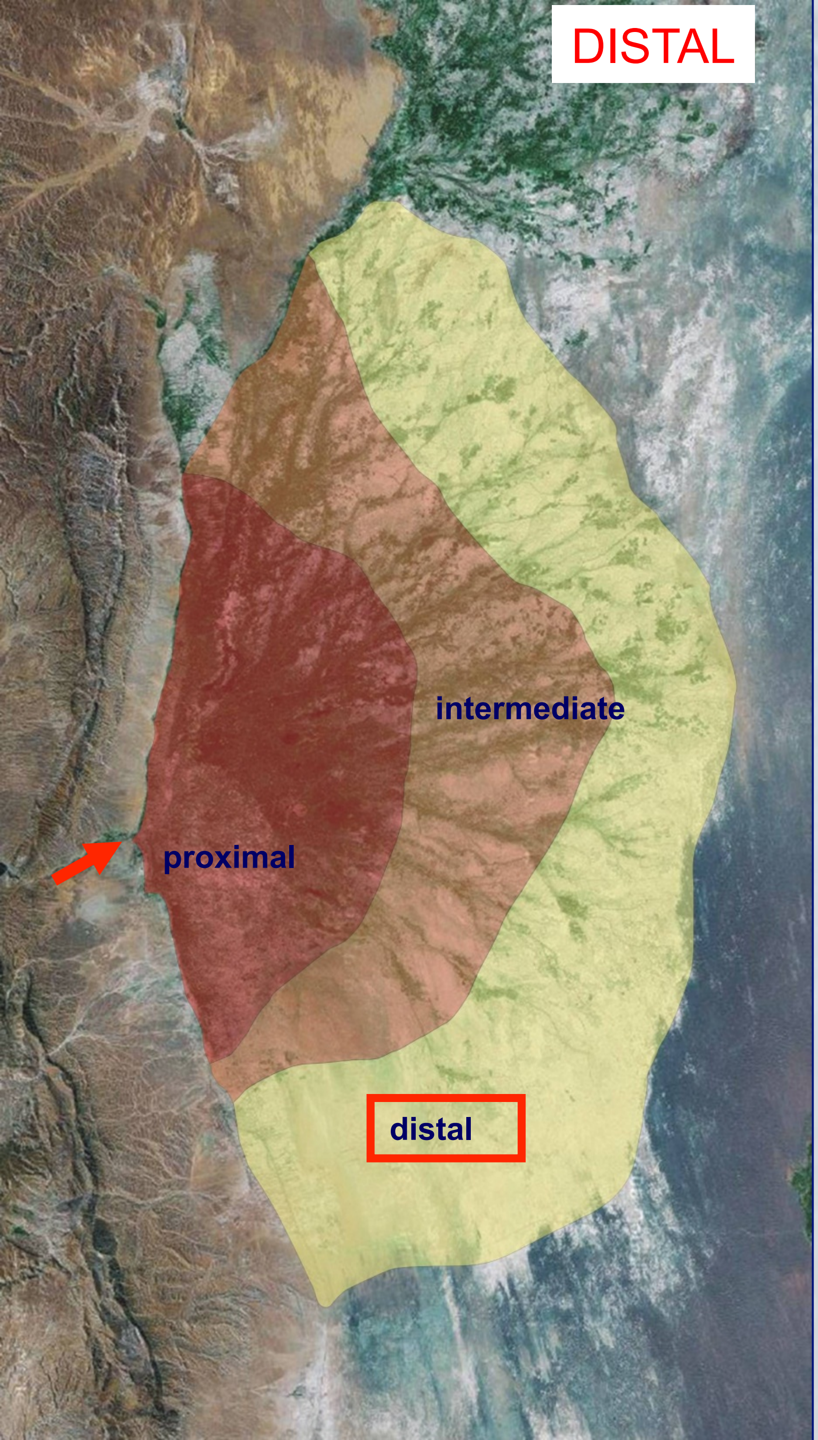
Mud
vf f m c vc
Sand
Gr
f m c
Pb



In the intermediate alluvial fan the proportion of fine deposits increases due to the minor gradient. Areas of overbank deposition often experience pedogenetic processes giving rise to occasionally well developed soil.



Overbank-prone areas are characterized by sand deposition by hyperconcentrated flows or under tractional transport, typically associated to settling of fines. Analogously to alluvial plain overbank areas, the discontinuous character of sedimentation (short-lived depositional events followed by longer non-depositional periods) allow these deposits to be homogenized by bioturbation and pedogenetic processes. During higher energy depositional events, coarse-grained deposits may be emplaced within crevasse-splay settings.



In a downcurrent direction (distal part: ~2°), average sediment grain-size furtherly decreases
Mass transport processes are poorly represented and characterized by a low efficiency.

Occasionally, debris flows may originated from hyperconcentrated flows.
Such a flow transformation is typically promoted by the increase in sediment content of an hyperconcentrated flow while crossing intermediate alluvial fan areas.

As a whole, distal alluvial fan areas are characterized by sand and mud deposition.

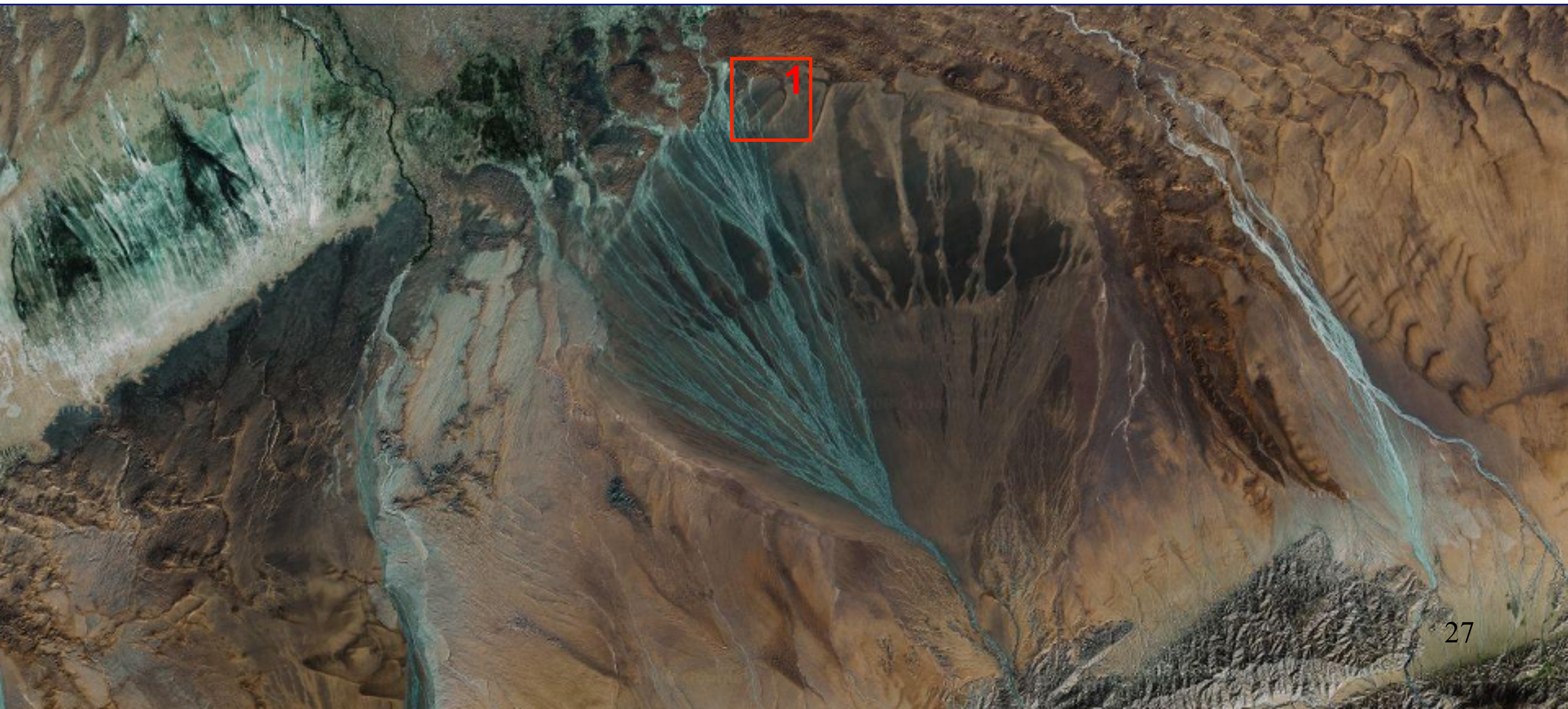
Moreover, channels are large and shallow, to the point that flows are practically unconfined and sediment bodies geometries are tabular.

Finally, in areas with a perennial drainage system, distal areas (i.e. their low gradient) favour the development of high-sinuosity channels.

Distal alluvial fan areas are characterized by relatively frequent depositional events compared to the intermediate ones. It follows that the preservation potential of sedimentary structures and primary bedding is higher. The presence of horizons of fines points to ephemeral pond deposition.

Distal areas of alluvial fans commonly interfinger with nearby depositional systems, (e.g. fields of eolian dunes).

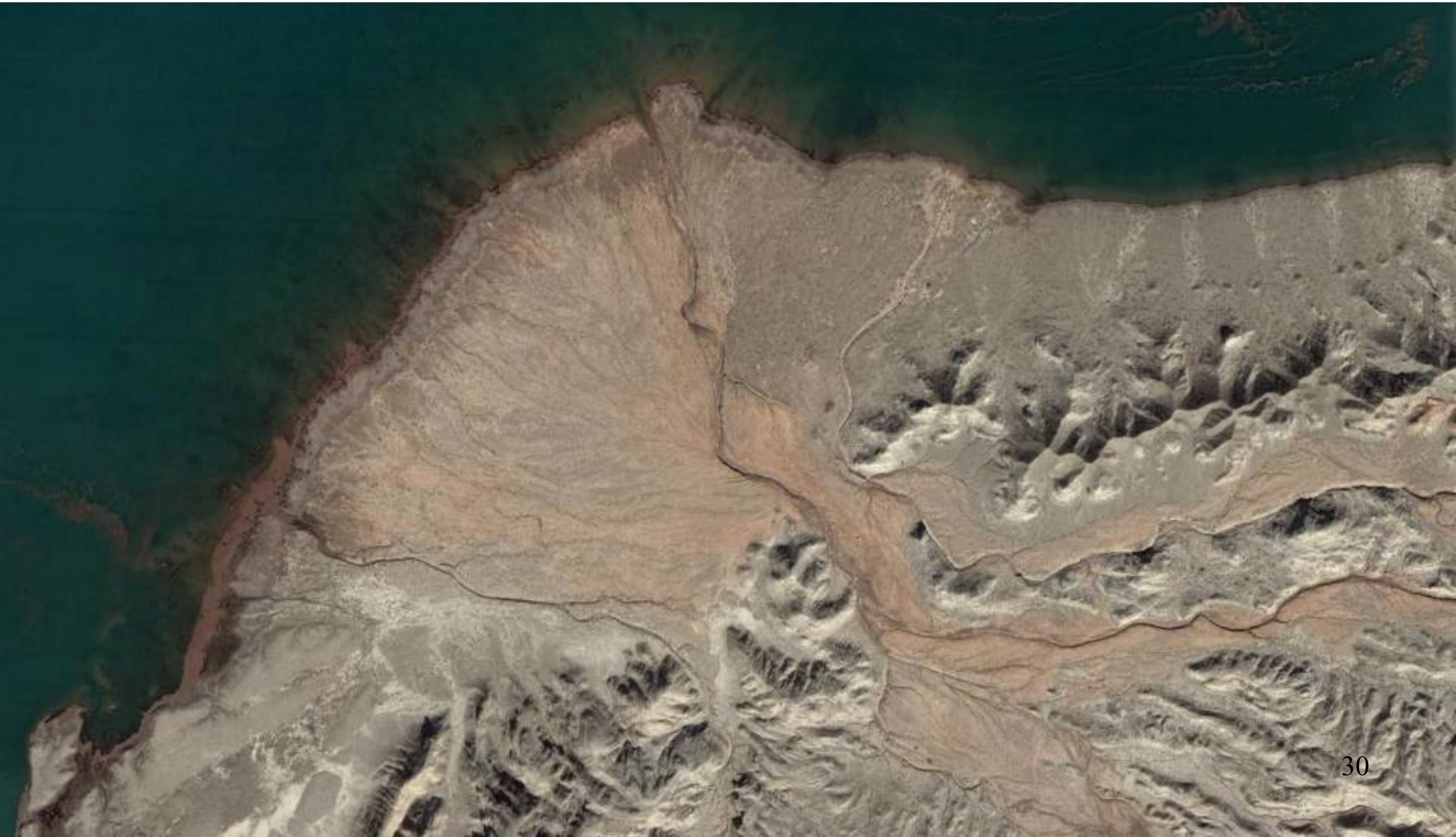
in this case alluvial fans flank deserts (Sinkiang, China).



Interaction with fluvial deposits (so called axial drainage) is quite common and frequently produces the whole reworking of alluvial fan deposits. The transitional area between an alluvial fan and a fluvial system is rarely preserved in the stratigraphic record (see next slide).

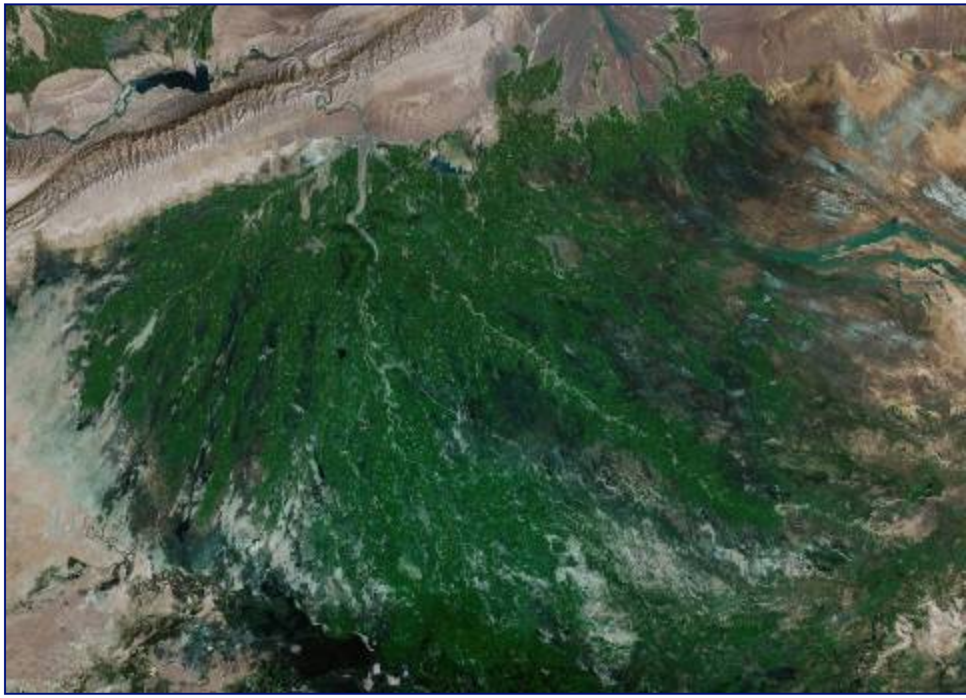

Alluvial fan
Alluvial plain

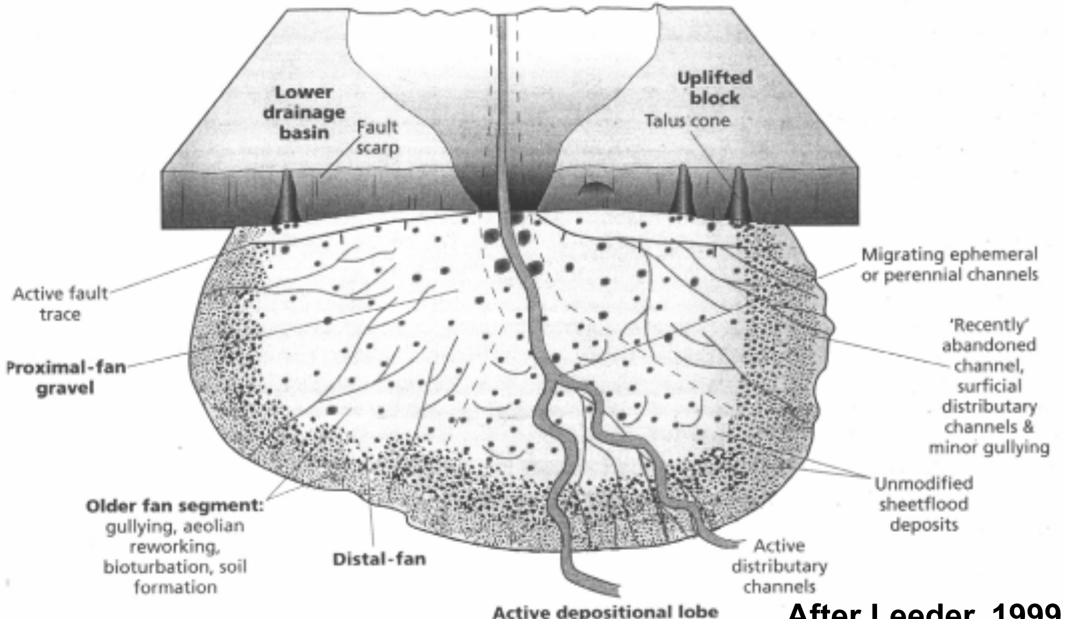
A classic example of interaction of an alluvial fan with a nearby system is represented by its progradation in a standing body of water, which originates a fan delta. The subaerial depositional processes of a fan delta pertain to an alluvial fan setting, whereas its subacqueous portion shows features proper to deltaic systems (see deltaic depositional environment).



Alluvial fan generally develop along morphological lineation, forming laterally associated complex alluvial fan systems. Interfan areas are occasionally characterized by small ponds with fines sedimentation. In the stratigraphic record, these deposits occur as fine-grained lens-shaped bodies within coarser deposits.

In the past decades, particular attention has been paid to the climatic control on the development of different types of alluvial fans. Given the same tectonic context and source area (in terms of lithology), it can be said that climate is a major factor controlling the development of alluvial fans and determining the nature of their sedimentary processes. Specifically, short-lived and rainshowers proper of alluvial fans of arid areas will promote mass transport processes, whereas selective processes will characterize perennial drainages of alluvial fans under humid climates.

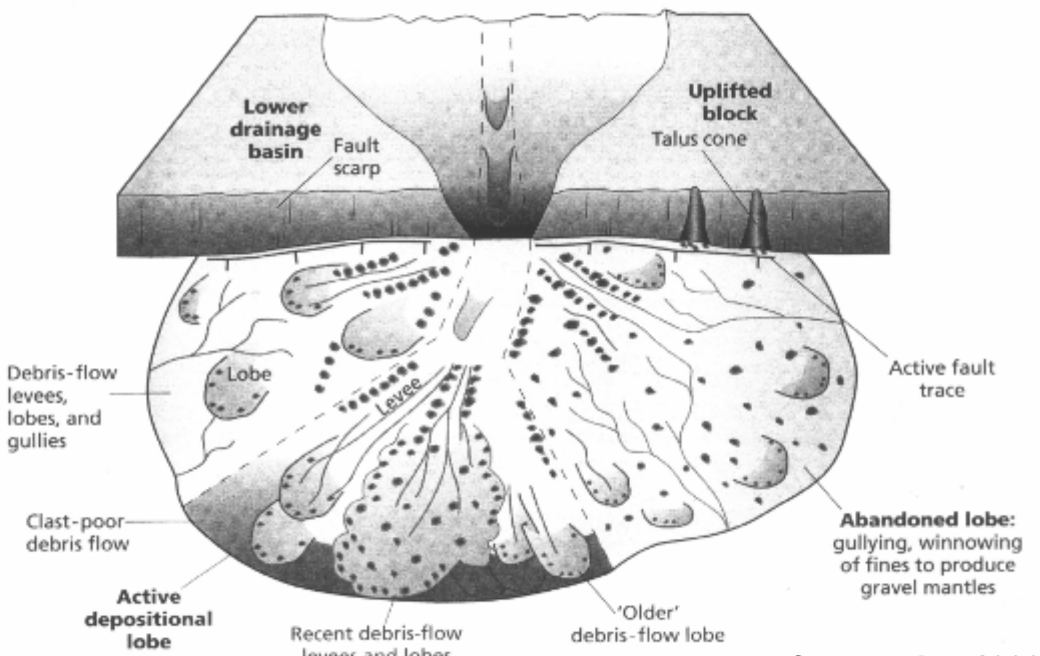




After Leeder, 1999

In **arid settings**, alluvial fans are dominated by debris flows and hyperconcentrated flows, since short-lived and intense rainfall will promote the transport of high volumes sediment due to the absence of soil.

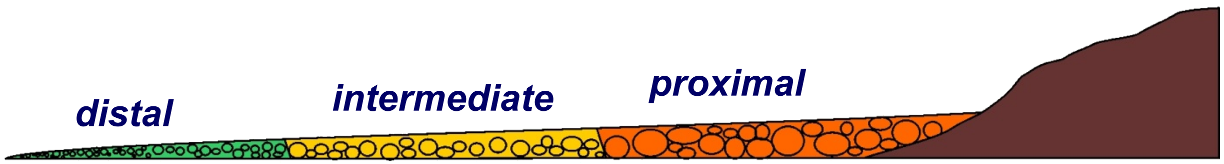
Sediment bodies are rarely channellized and characterized by tabular geometries.

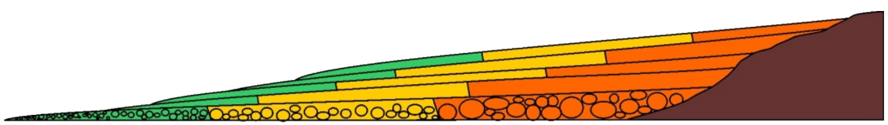


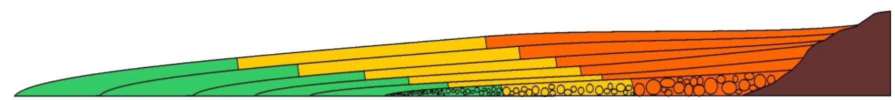
after Leeder, 1999

In **humid settings** alluvial fans are dominated by tractional processes, although debris flow processes and hyperconcentrated flows can be relatively common especially in the apical area. Sedimentary bodies are typically channellized and comprises bars, occasionally showing lateral accretion processes.

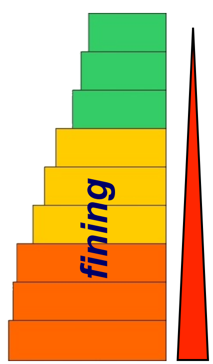
Of major importance in the study of alluvial fan successions is to determine its progradational or retrogradational character, i.e. the tendency of more proximal facies to rest onto more distal ones, and vice versa.



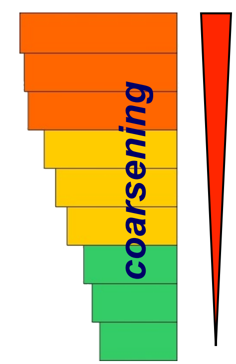


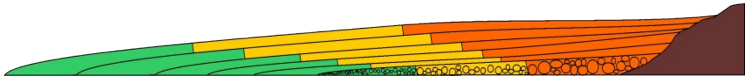


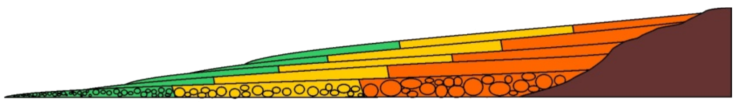
Retrograding alluvial fan: distal deposits rest onto the more proximal ones, originating fining-upward successions which are indicative of decreasing sediment supply.



Prograding alluvial fan: proximal deposits rest onto more distal ones originating coarsening upward successions, which are indicative of increasing sediment supply.



 A **progradational trend** implies the basinward shifting of proximal facies with their following superposition onto intermediate and distal facies. This process produces upward coarsening (increasing grain size) and thickening (increasing bed thickness) upward successions .

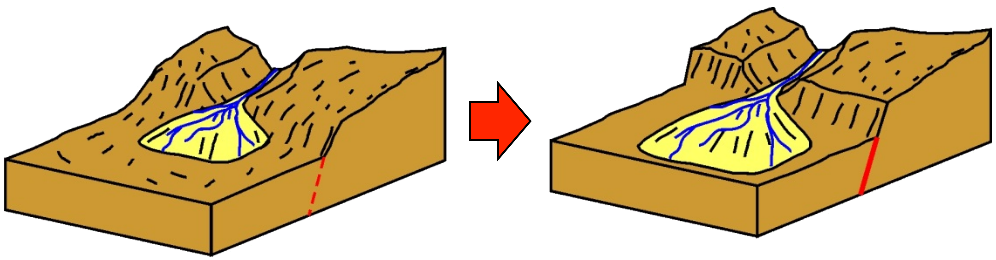
 A **retrogradational** trend implies the shifting toward the basin margin of the distal facies with their following superposition onto intermediate and proximal facies. This process produces upward fining (decreasing grain size) and thinning (decreasing bed thickness) upward successions.

The progradational or retrogradational trend of alluvial fan is primarily controlled by the amount of sediment supplied by its feeding drainage system.

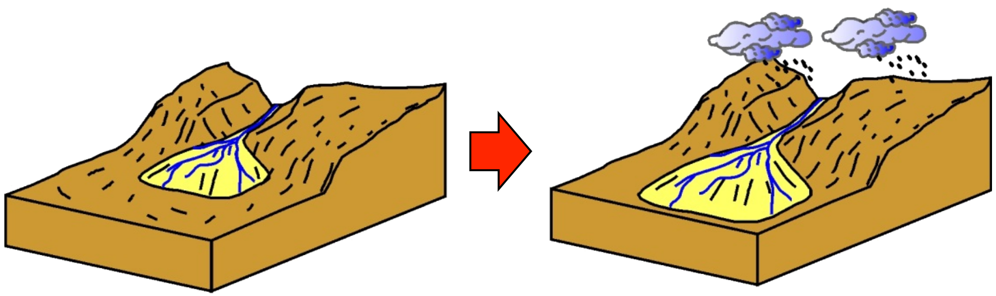
A coarsening and thickning upward succession manifests an increasing sediment supply.

A fining and thinning upward succession is indicative of a decreasing sediment supply.

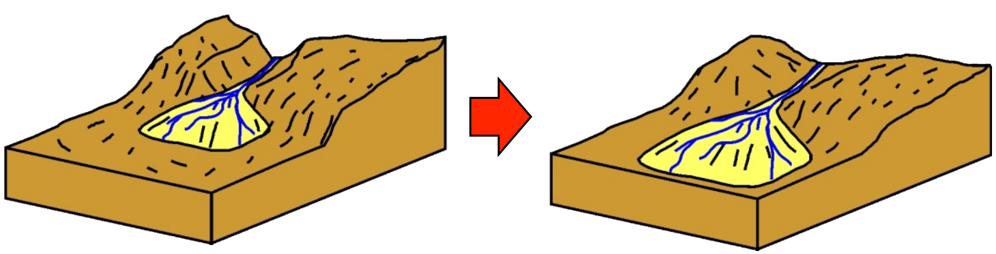
UPWARD COARSENING SUCCESSIONS
POSSIBLE CONTROLLING FACTORS:



Tectonic (source area uplift)

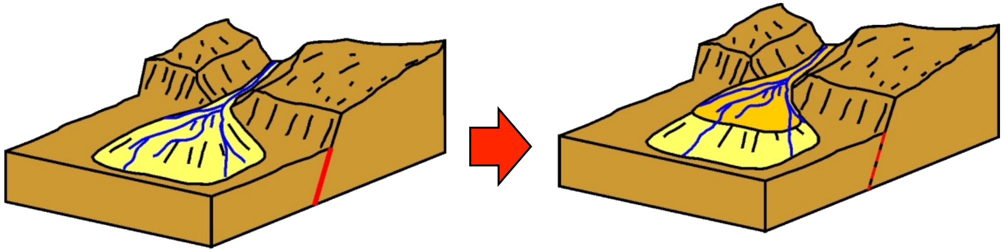


Climatic (increase in rainfall)

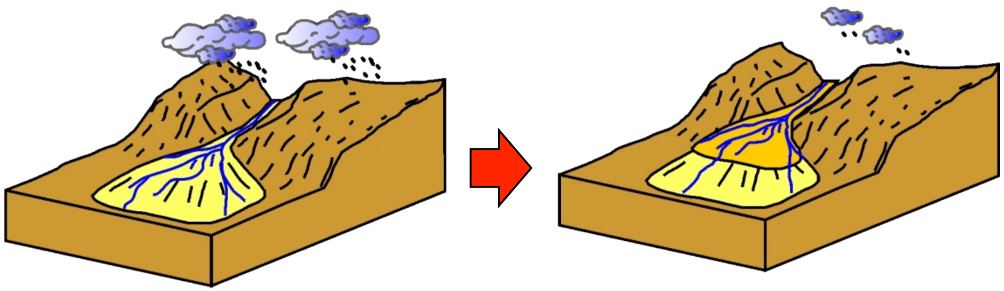


Re-equilibrium of the morphological profile (the uplift rate was too high to produce large amount of syn-tectonic sediment)

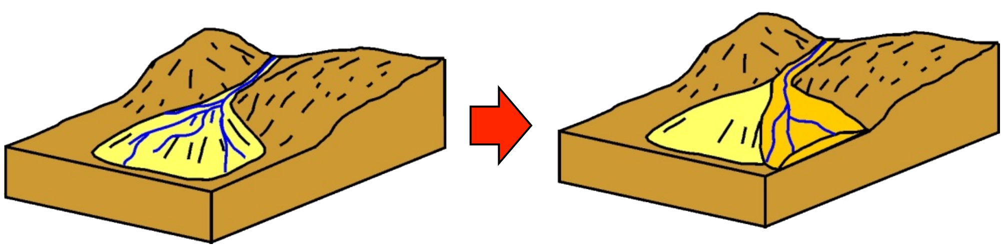
FINING UPWARD SUCCESSION
POSSIBLE CONTROLLING FACTORS:



Tectonic (deactivation of source area marginal faults)

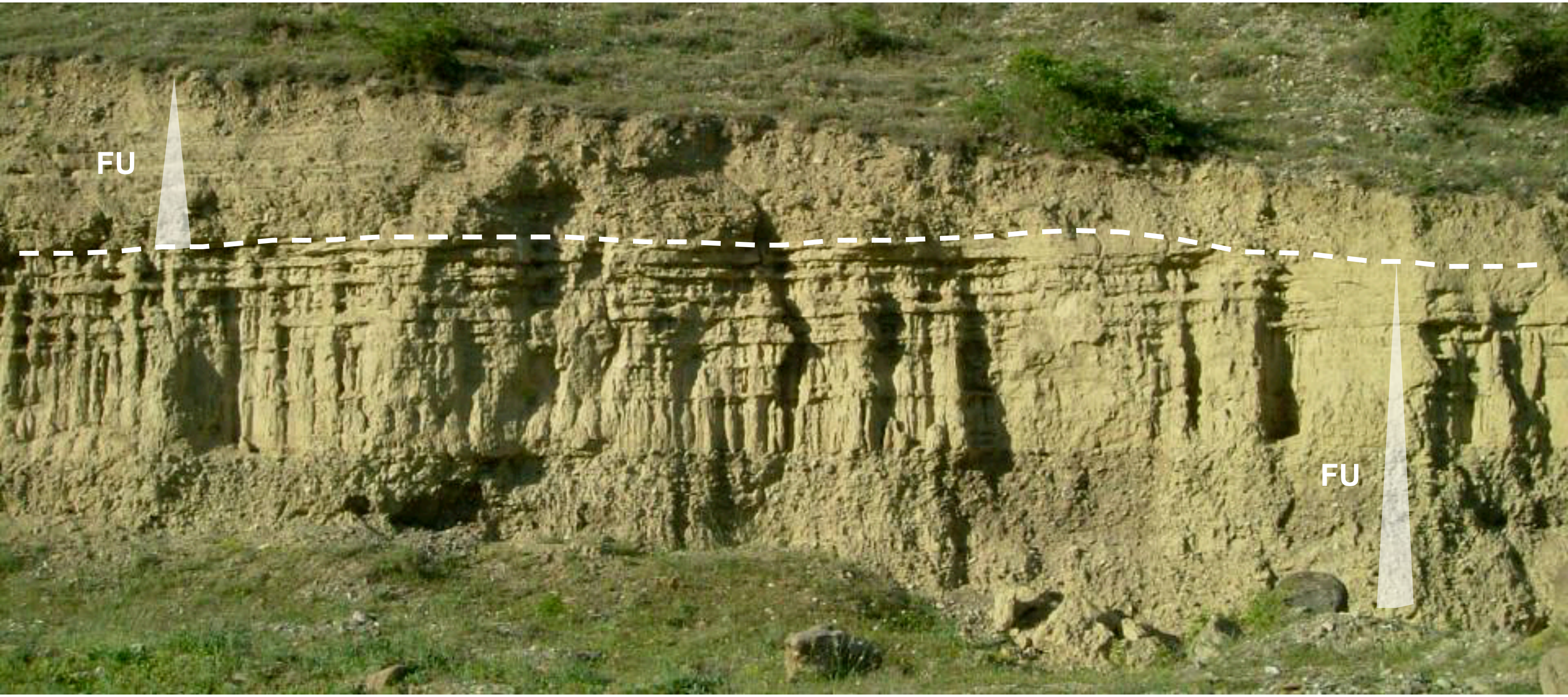


Climatic (decrease in rainfall)



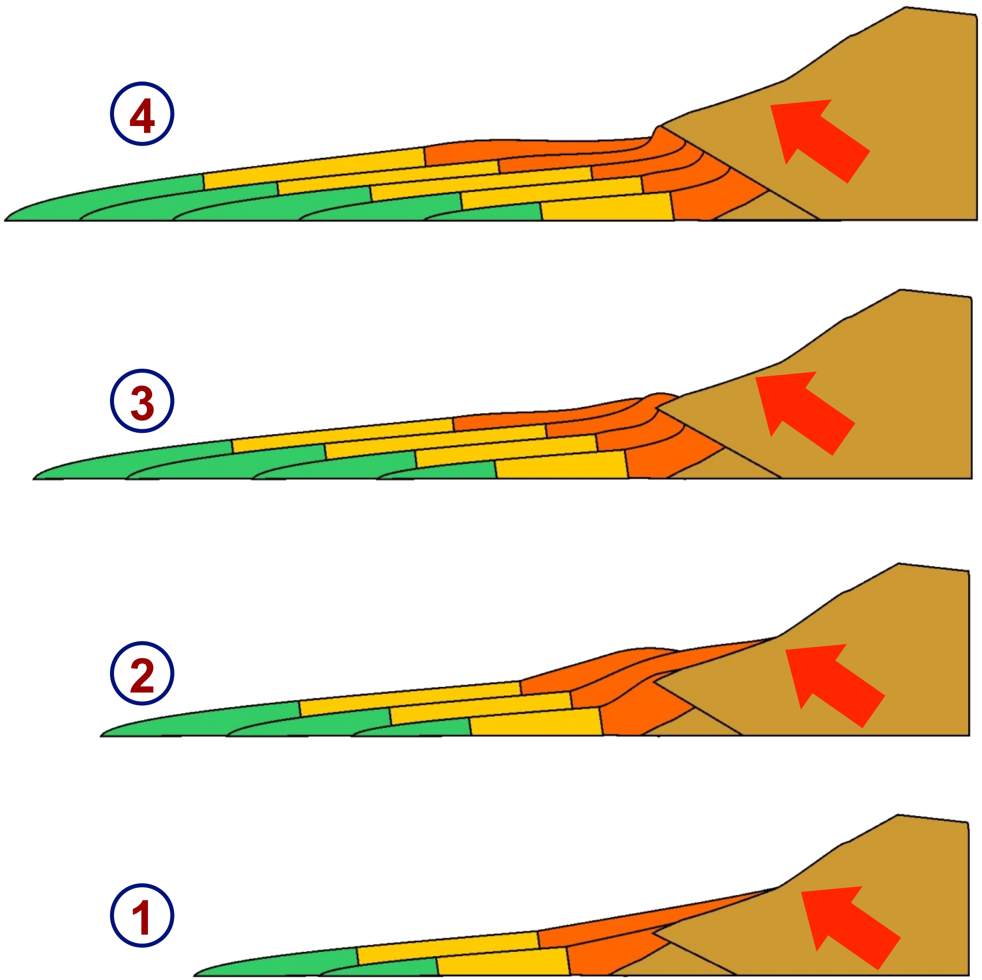
Lateral shifting of the main feeding area


FU
CU

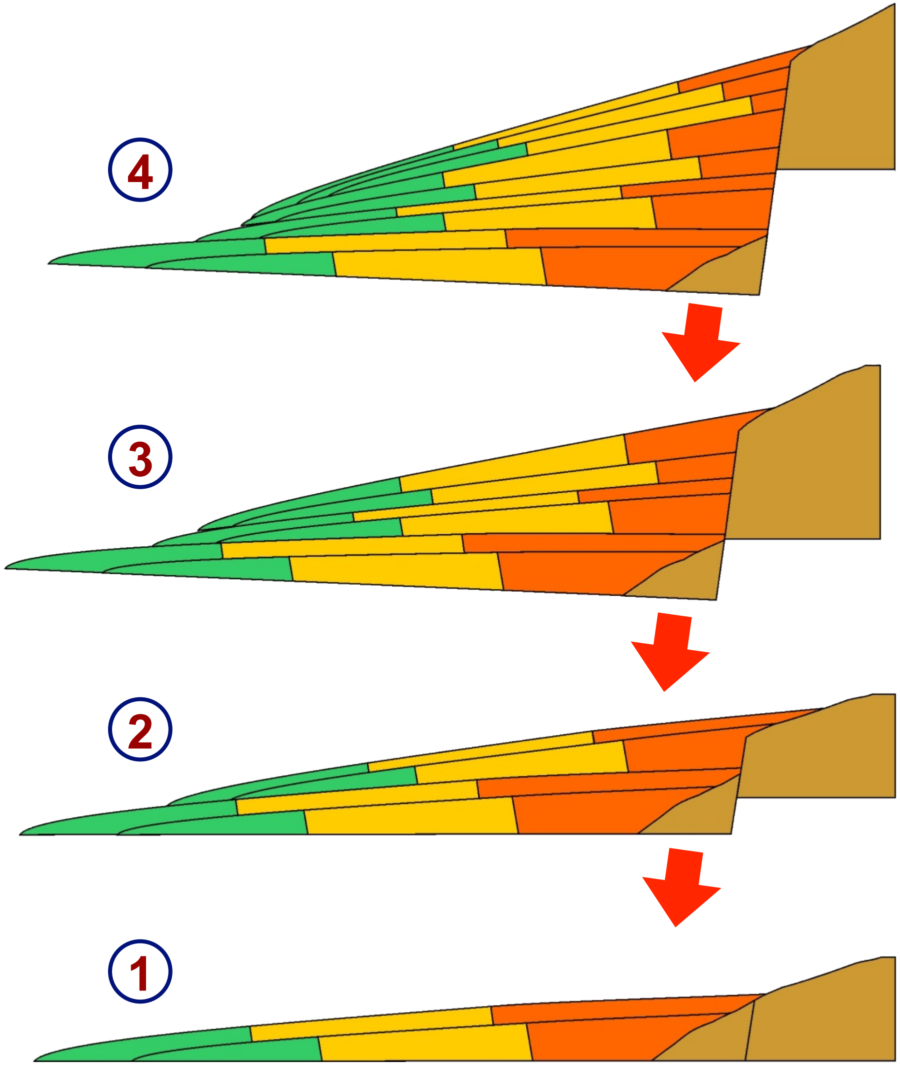

FU
FU

Alluvial fan systems are commonly found along sedimentary basin's margins. In the case of syn-depositional tectonic activity, the different geometries showed by alluvial fan deposits may constrain the associated tectonics.

Basin margins characterized by compressional tectonics are typically bounded by inverse faults, which promote their progressive uplift and the basinward pushing of the adjoining alluvial fan deposits. This implies a progressive deformation of the strata manifested by their over-inclination toward these faults.



Basin margins characterized by extensional tectonics are typically bounded by normal faults which produce a high marginal subsidence with related tilting of alluvial fan deposits towards the basin margins. This process leads to the accumulation of thick alluvial fan successions close to the faulted area.



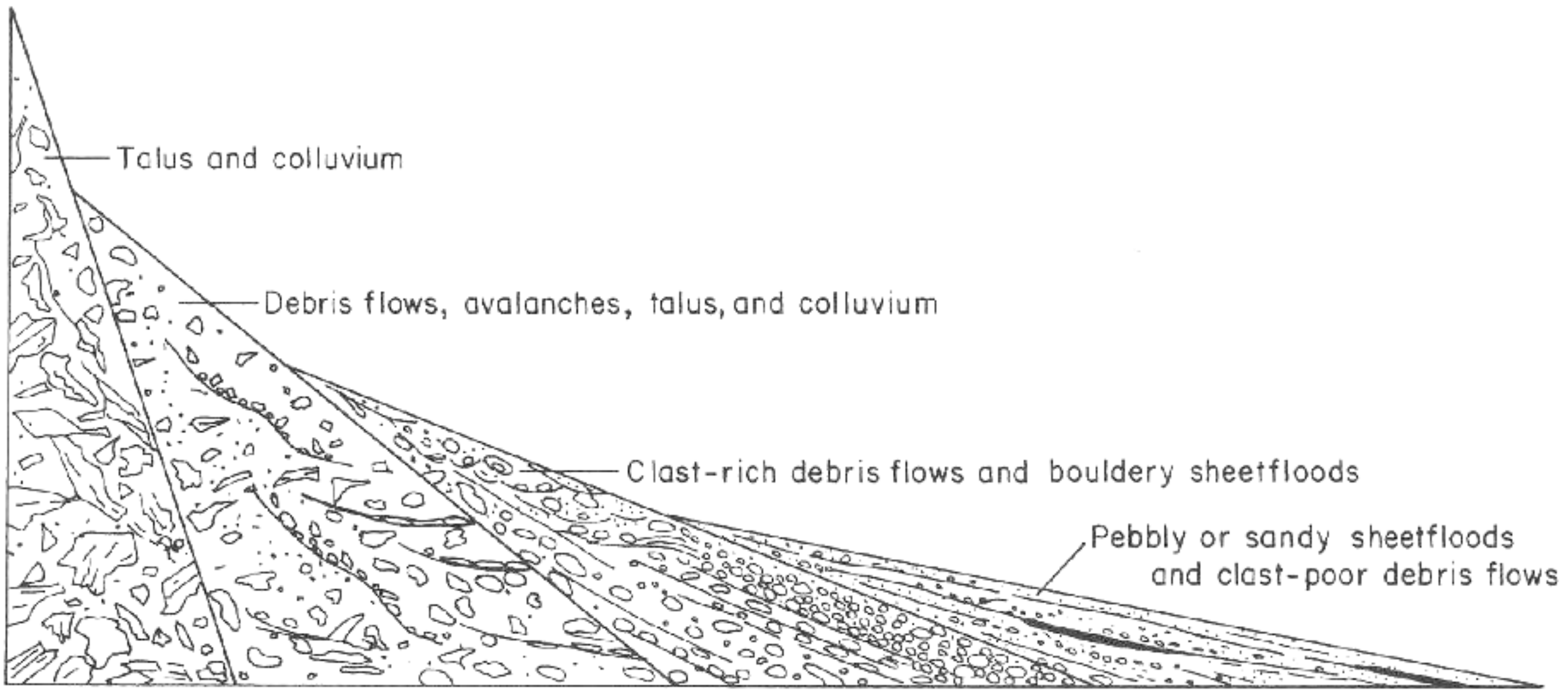
colluvial fans

If the drainage area feeding an alluvial fan is particularly small or even absent, sedimentary bodies similar to alluvial fans, named colluvial fans, may form. These peculiar depositional systems are dominated by gravity processes and are relatively common in present-day settings, although their potential preservation is low (and thus are poorly represented in the stratigraphic record). Such systems differ from the alluvial fans for many features (see next slide), among them the high gradient and the dominance of mass processes.

TYPICAL CHARACTERISTICS	colluvial fan	alluvial fan
Geomorphic setting:	mountain slope and its base (slope fan)	mountain footplain or broad valley floor (footplain fan)
Catchment:	mountain-slope ravine	intramontane valley or canyon
Apex location:	high on the mountain slope (at the base of ravine)	at the base of mountain slope (valley/canyon mouth)
Depositional slope:	35-45° near the apex, to 15-20° near the toe	seldom more than 10-15° near the apex, often less than 1-5° near the toe
Plan-view radius:	less than 0.5 km, rarely up to 1-1.5 km	commonly up to 10 km, occasionally more than 100 km
Sediment:	mainly gravel, typically very immature	gravel and/or sand, immature to mature
Grain-size trend:	coarsest debris in the lower/toe zone	coarsest debris in the upper/apical zone
Depositional processes:	avalanches, including rockfall, debrisflow and snowflow; minor waterflow, with streamflow chiefly in gullies	debrisflow and/or waterflow (braided streams)
EXAMPLES	 The Brotfonna colluvial fan, Trollvegen near Romsdal, Norway; one of the world's largest colluvial fans, with a height of 830 m and a plan-view radius of 1.5 km.	 The Badwater alluvial fan, eastern side of Death Valley, California; a modest fan, with a radius of *c.* 6 km.

After Blikra and Nemec, 1998

Colluvial fans often evolve into alluvial fans as a consequence of the expansion of the feeder drainage area. Accordingly, the core of an alluvial fan body may be represented by colluvial fan deposits.



After Galloway and Hobday, 1996