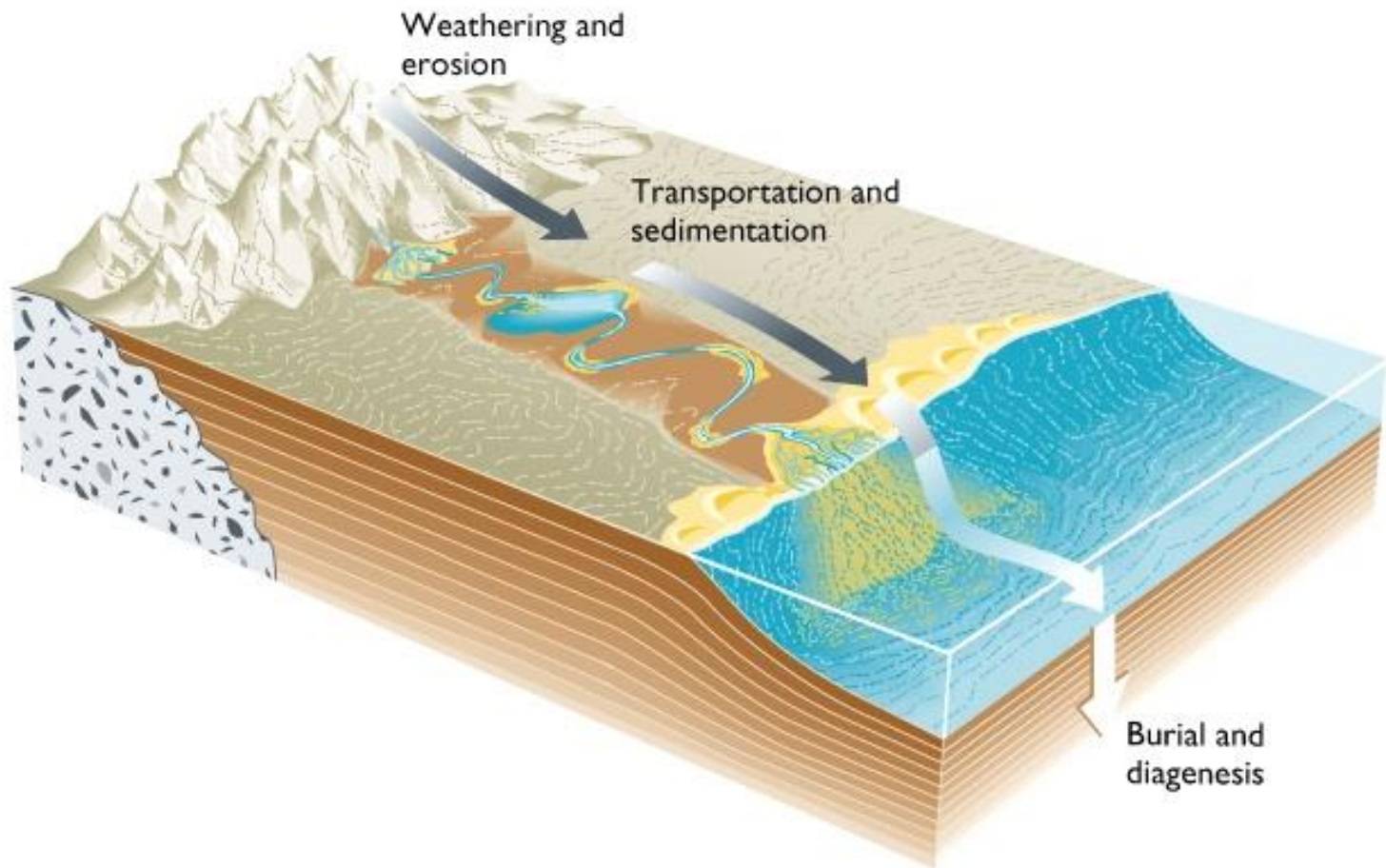


3 – GMPF - Geoarcheologia degli ambienti alluvionali

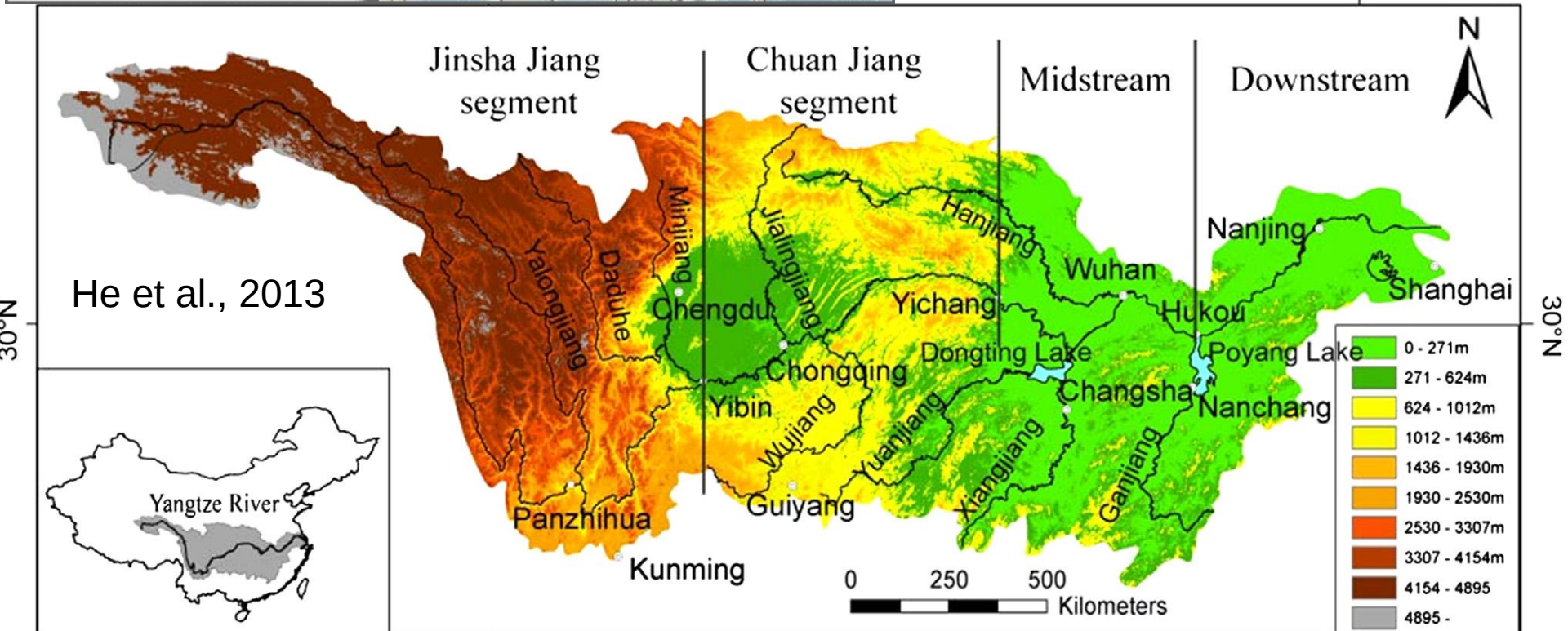
Stefano Lugli

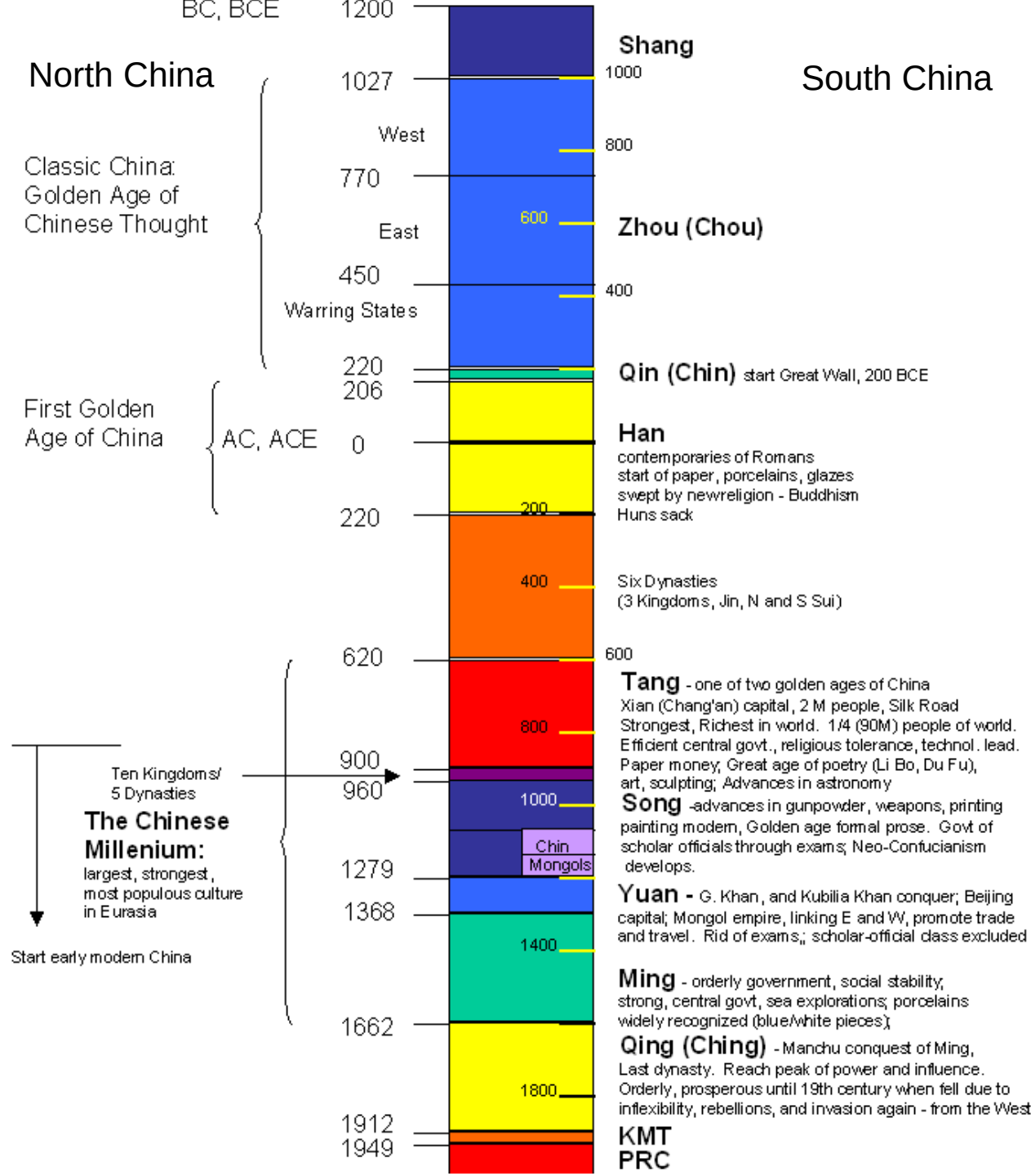




Yangtze (Fiume Azzurro)
6300 km

120°E

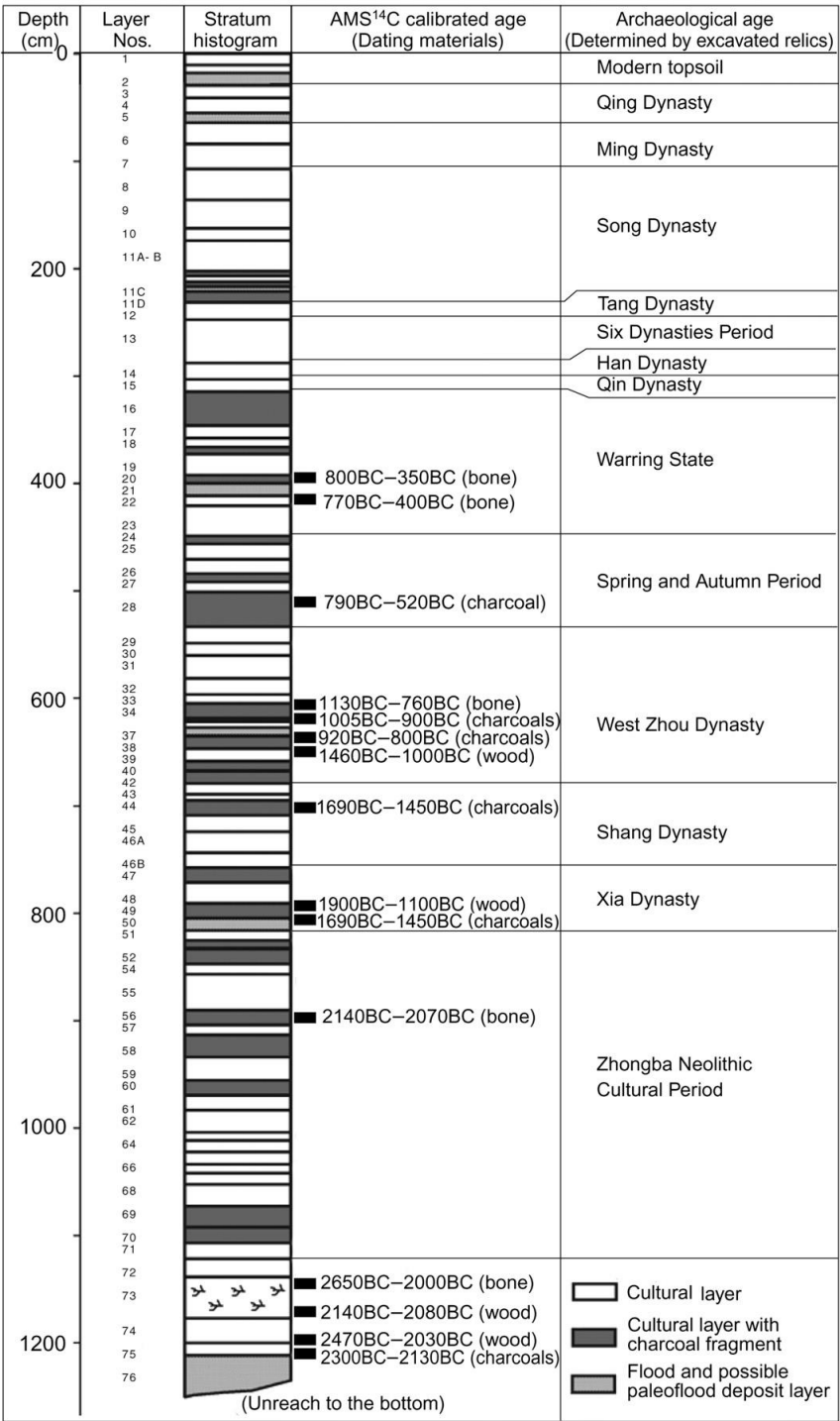




China
Sichuan

Sanxingdui culture (ca. 1900 - 1150 BC)

six areas encircled with walls. Within two burial pits, large amount of elephant tusks, delicate and complex bronze vessel, mask and statues, and crafted jades were found. Evidence shows that the artifacts had been deliberately burnt and broken before being buried in the pits. After the Sanxingdui city was declined or been abandoned, another similar city arose near Chengdu which left its cultural remains in the Jinsha site, dated between the later Shang and early Zhou



Sanxingdui culture (ca. 1900 - 1150 BC)



Jinsha
(later Shang and early Zhou)



Elephant tusks
Wild board tusks
Jade ware
Bronze artifacts

文物保护工作进行中

Jinsha
(later Shang and early Zhou)



Jinsha (later Shang and early Zhou)



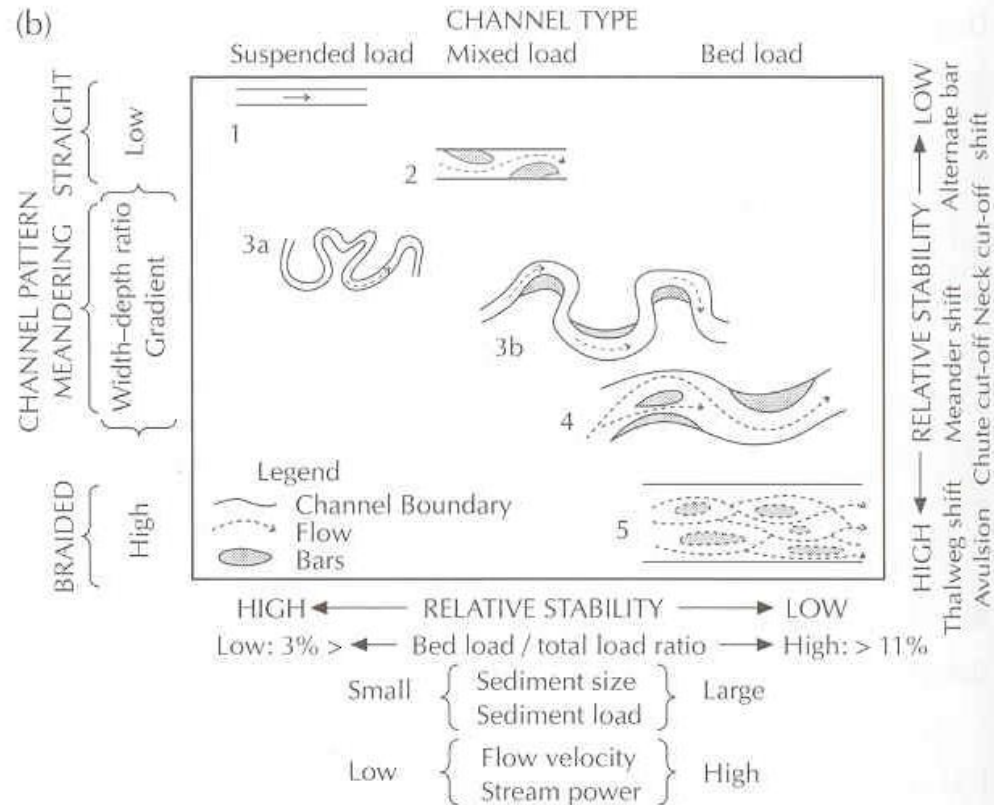
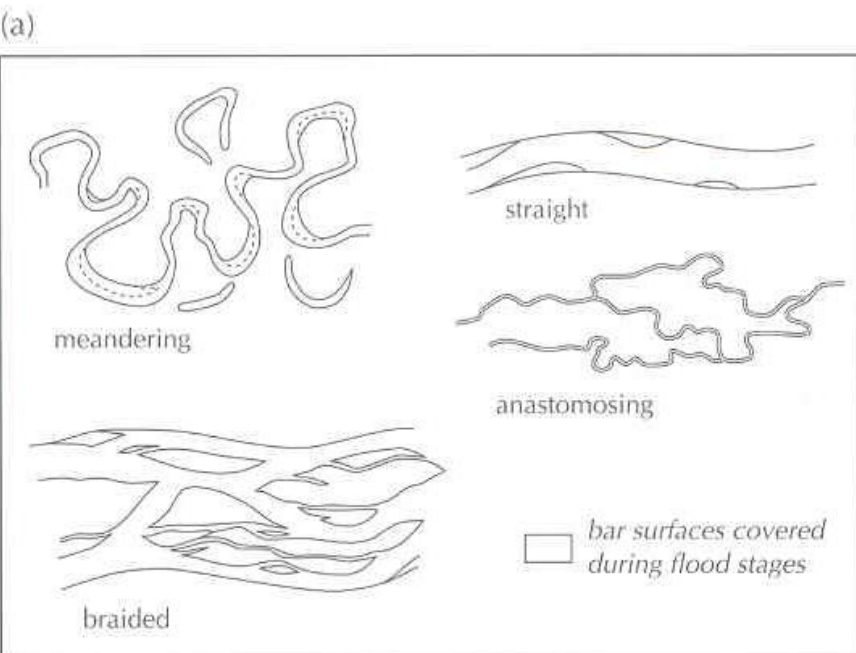
Jinsha (later Shang and early Zhou)

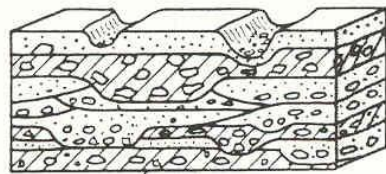




Jinsha
(later Shang and early
Zhou)

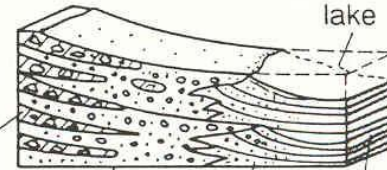
Classificazione canali





ALLUVIAL FAN SYSTEM

longitudinal section

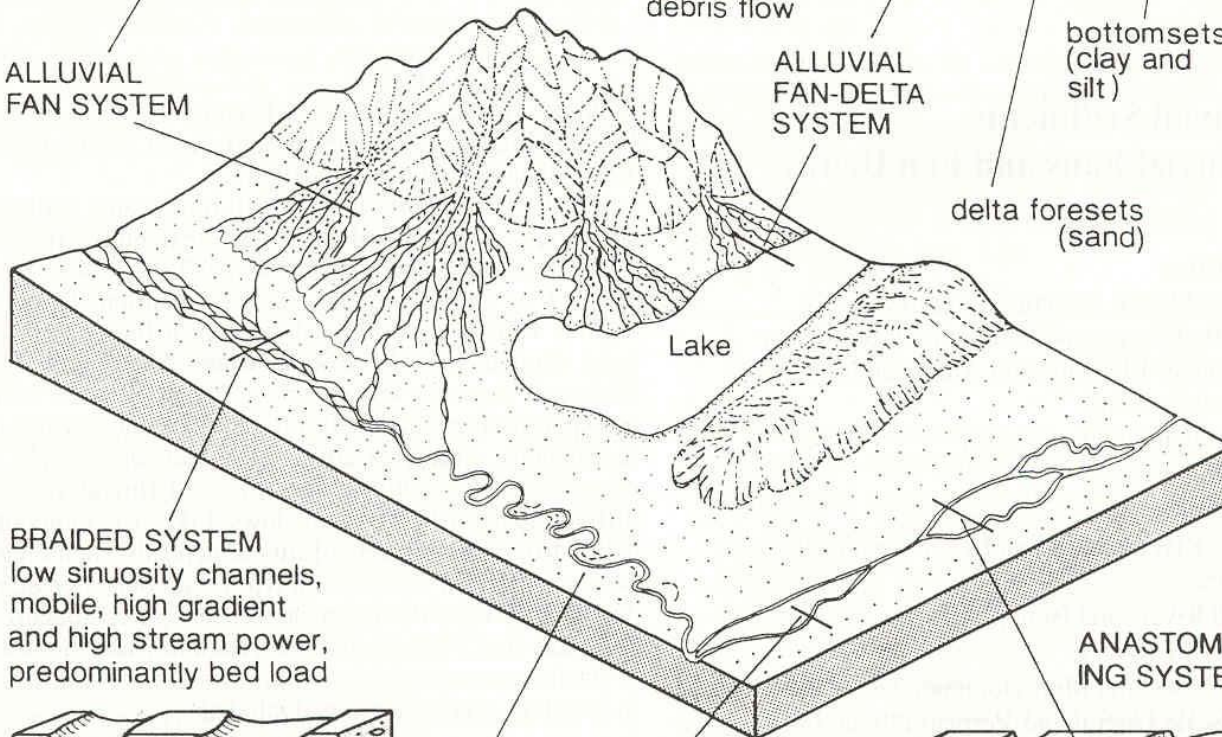


debris flow

ALLUVIAL FAN-DELTA SYSTEM

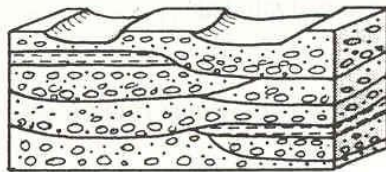
bottomsets (clay and silt)

delta foresets (sand)



BRAIDED SYSTEM
low sinuosity channels,
mobile, high gradient
and high stream power,
predominantly bed load

ANASTOMOS-
ING SYSTEM



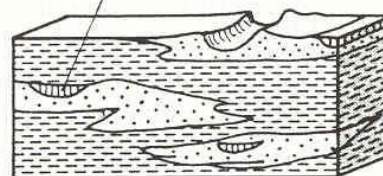
MUD-DOMINATED
LOW GRADIENT
SYSTEM
($\pm$ anastomosing)



channels partly straight,
partly sinuous, but
rather stable

MEANDERING SYSTEM
low gradient, low stream
power, mainly suspended
and mixed load (ratio
bed load/susp. load < 3)

OXBOW LAKE SEDIMENT



SAND

MUD



Alluvial fans



Conoidi alluvionali (fig. 13)

Si sviluppano allo sbocco dei fiumi in pianura; comprendono una porzione apicale, una intermedia ed una basale.

Morfologia: canale principale incassato (apicale) da cui si diramano canali instabili verso la zona di raccordo con il livello di base (piana alluvionale o lacustre).

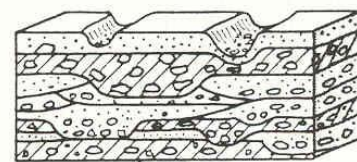
Processi: correnti torrentizie intermittenti, flussi concentrati ricchi di materiale grossolano, colate di fango e detriti (*debris flows*).

Corpo sedimentario: in pianta si sviluppa una forma a ventaglio, corrispondente ad un tronco di cono con sezione trasversale a forma di lente. Limiti inferiori erosionali, con passaggio netto a depositi alluvionali o lacustri (delta-conoide).

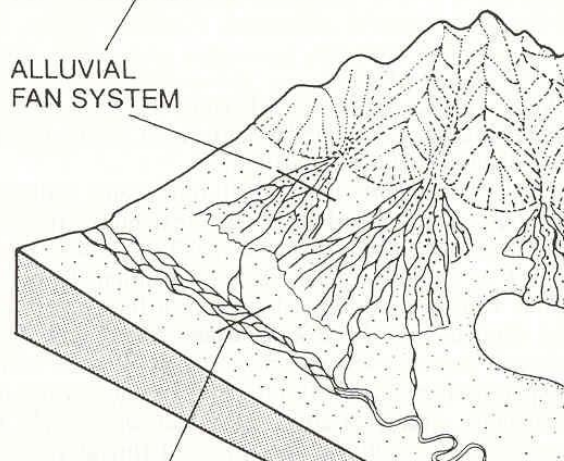
Organizzazione interna: insieme di corpi allungati a stratificazione spessa e mal definita. Non si sviluppano sequenze positive o negative.

Associazioni di facies: ghiaie disorganizzate, molto mal selezionate, raramente con gradazione inversa e ricche di blocchi e massi, alternate a depositi ghiaiosi fango-sostenuti nella regione apicale. Sequenze di argine dei canali costituite da ghiaie e argille ciottolose. Ghiaie a stratificazione massiva e sabbie a stratificazione incrociata tabulare e concava nella regione basale. Assenza di fossili.

Paleocorrenti: radiali, uni- o bimodali.



ALLUVIAL
FAN SYSTEM



Braided streams



b. *Piane alluvionali a canali intrecciati* (fig. 15)

Sono caratterizzate dallo sviluppo di canali a media o alta sinuosità. Si differenziano dalle piane a canali anastomosati per la frequente tracimazione di sedimenti fini ed il conseguente sviluppo di ampie piane di inondazione sabbioso-fangose; forme relativamente stabili nel tempo.

Morfologia: reticolo di canali sinuosi o rettilinei tra loro intersecati e connessi, relativamente stretti e profondi, con argini e piane di inondazione fittamente vegetate.

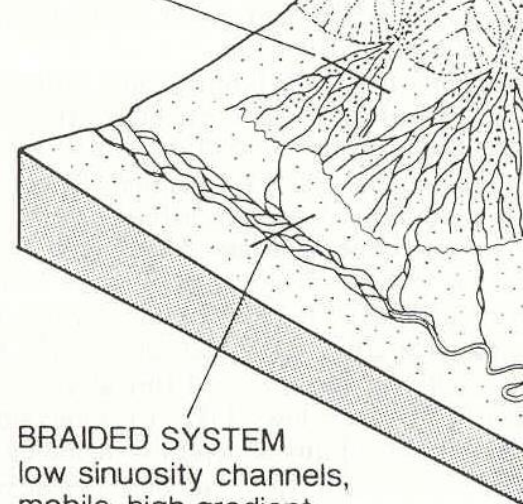
Processi: trazione di sabbie al fondo, decantazione di sedimenti fini in specchi d'acqua effimeri.

Corpo sedimentario: nastri sabbiosi di sedimenti limo-argillosi e sabbie fini.

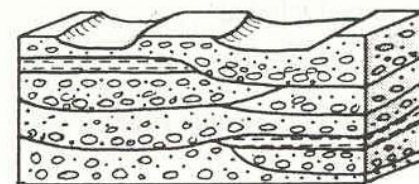
Organizzazione interna: lenti sabbiose piano-concave, interdigitate e ritagliate entro sedimenti fini.

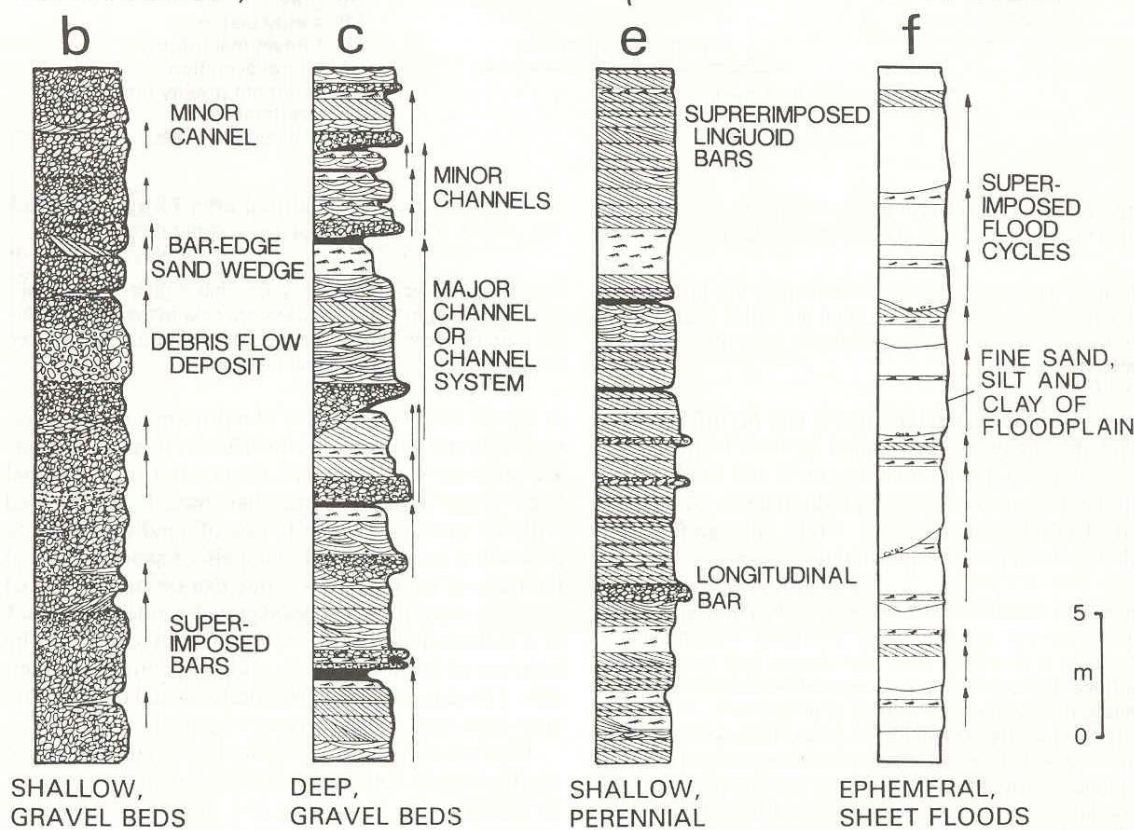
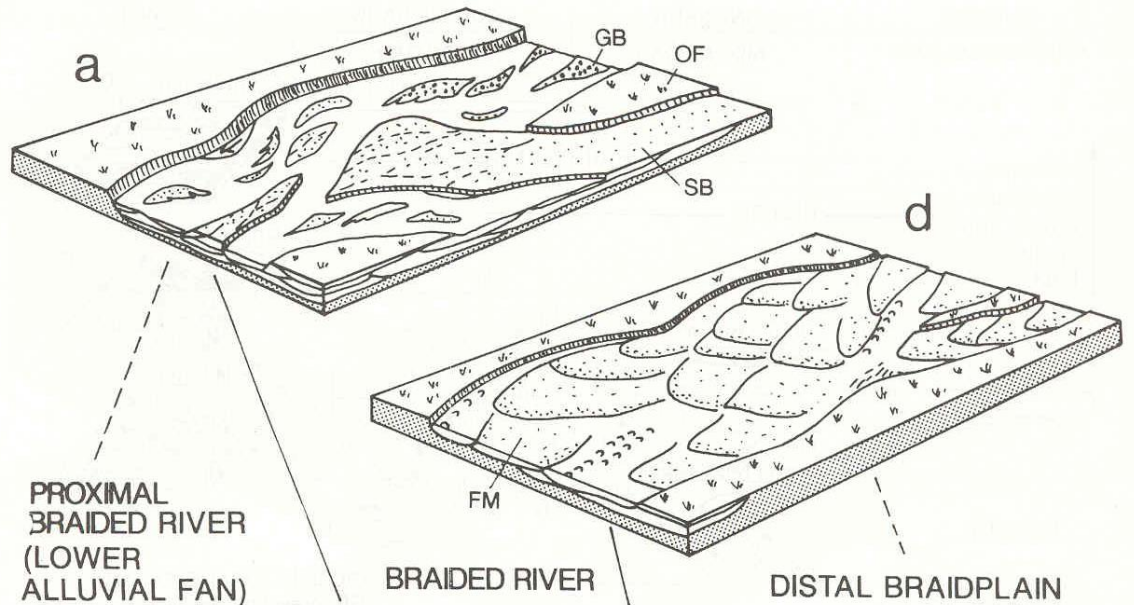
Associazione di facies: sabbie e ghiaie massive o stratificate nei canali. Stratificazioni incrociate concave. Limi e argille nelle sequenze di argine. Sabbie fini, limo e argille con livelli a ligniti e/o carboni nelle piane di intercanale fangose. Bioturbazione frequente. Rari fossili continentali.

Paleocorrenti: uni- o bimodali, dispersione entro i 60° .

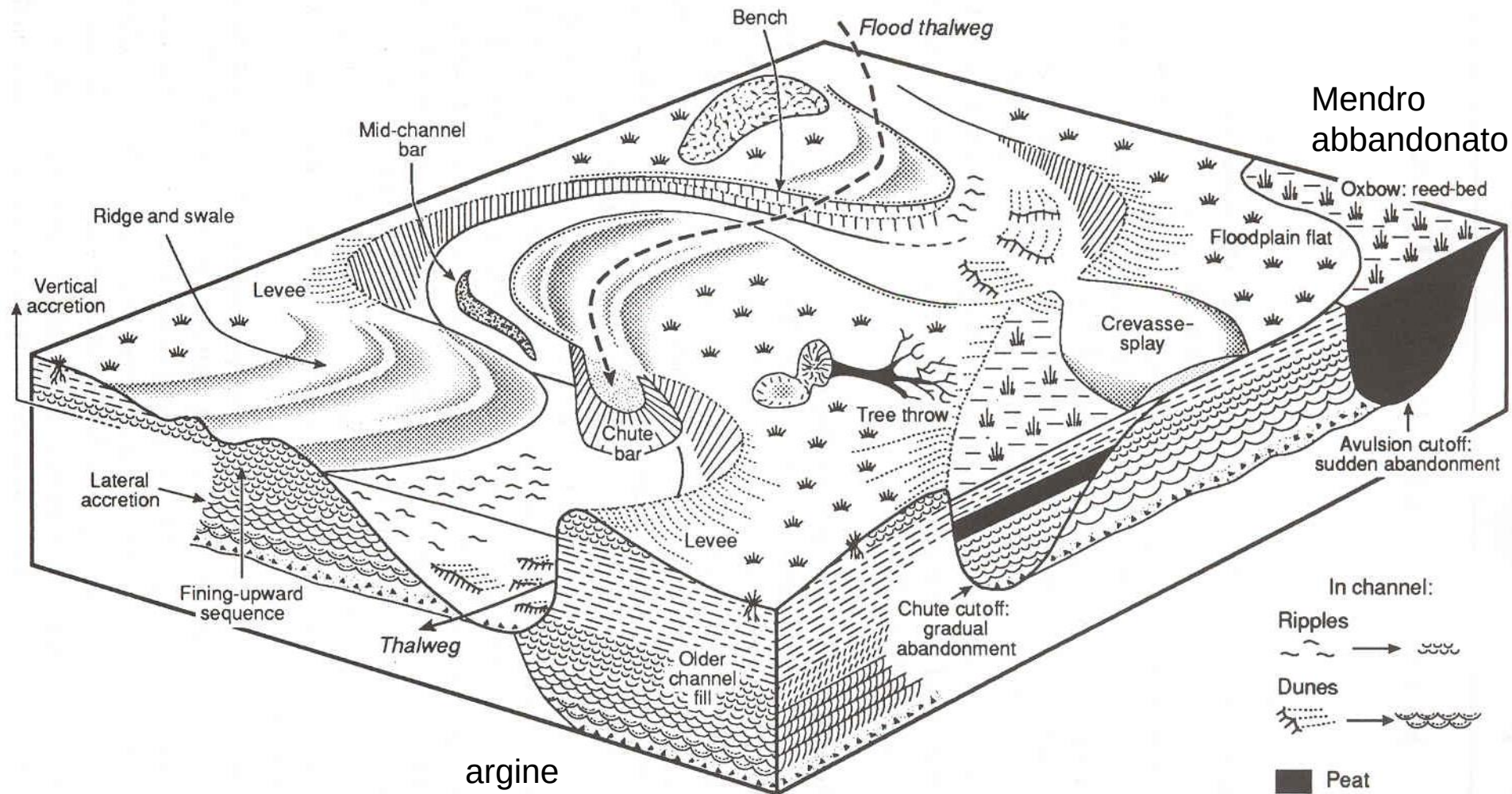


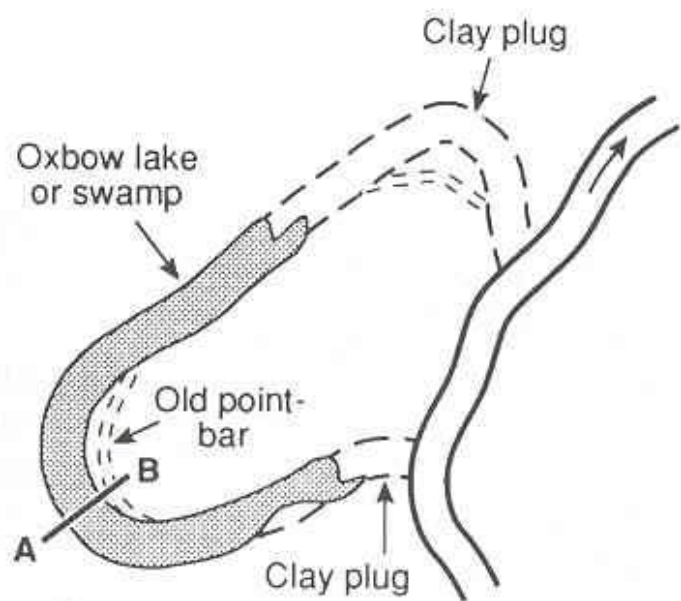
BRAIDED SYSTEM
low sinuosity channels,
mobile, high gradient
and high stream power,
predominantly bed load



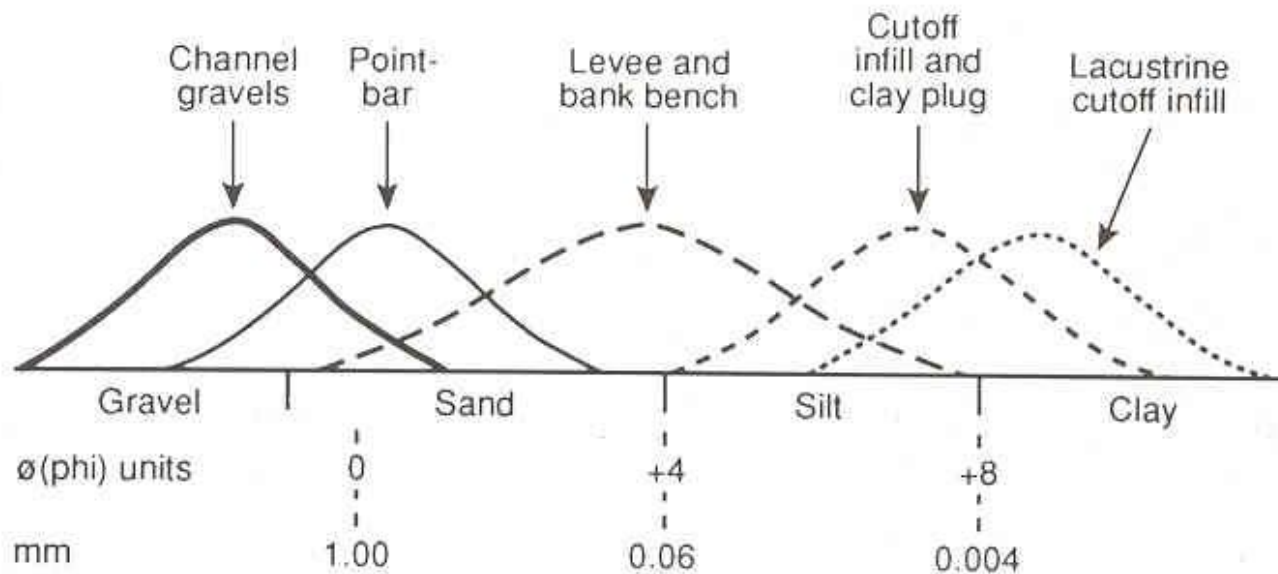
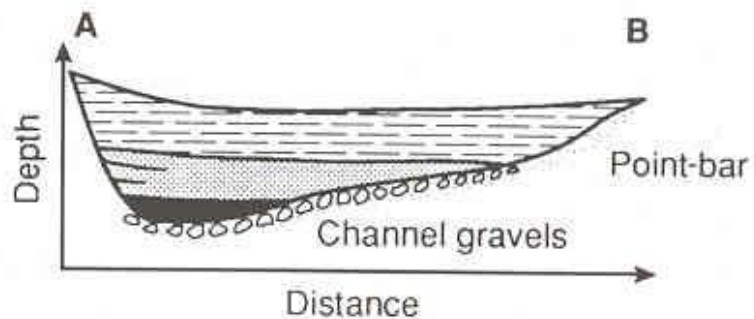


Forme

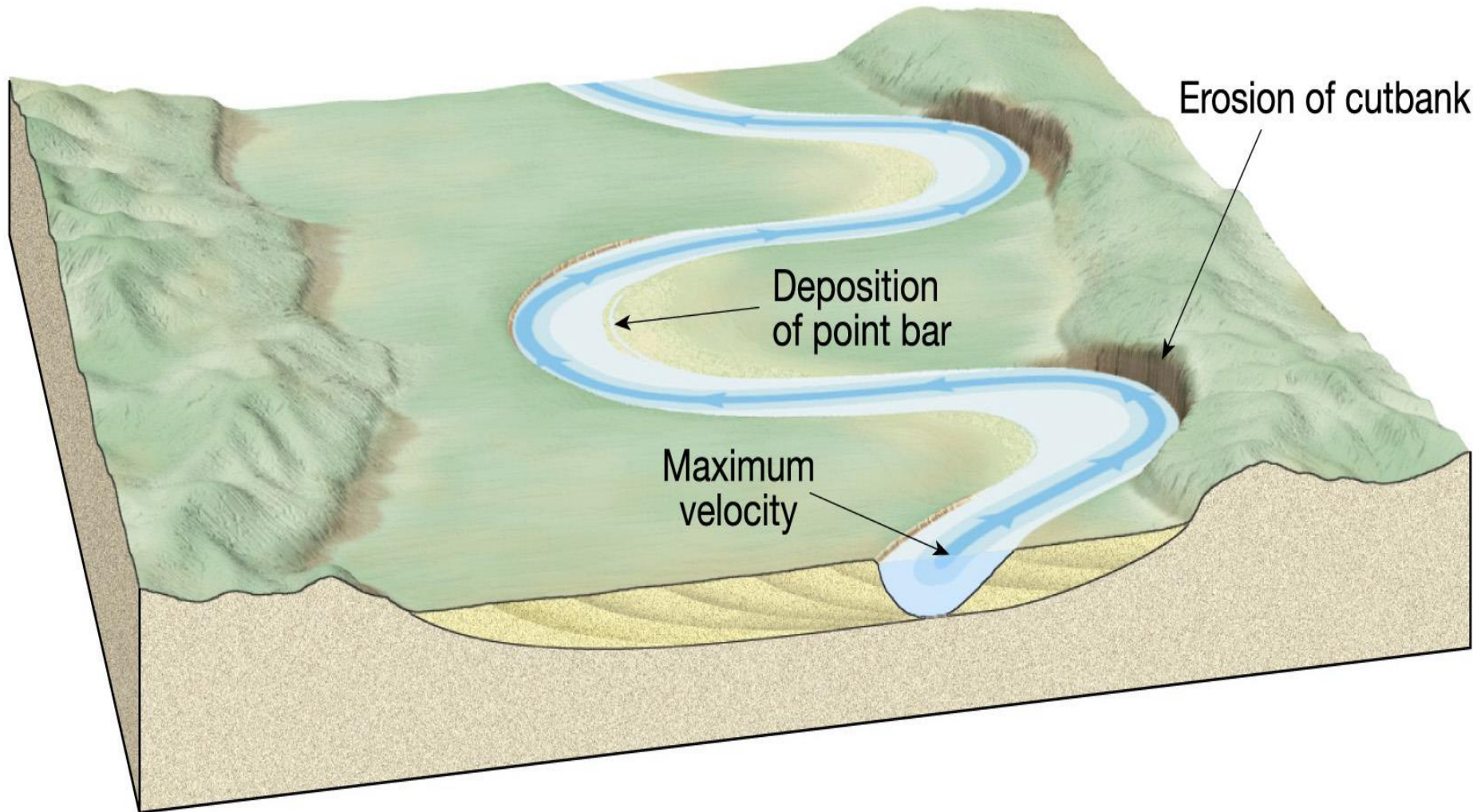


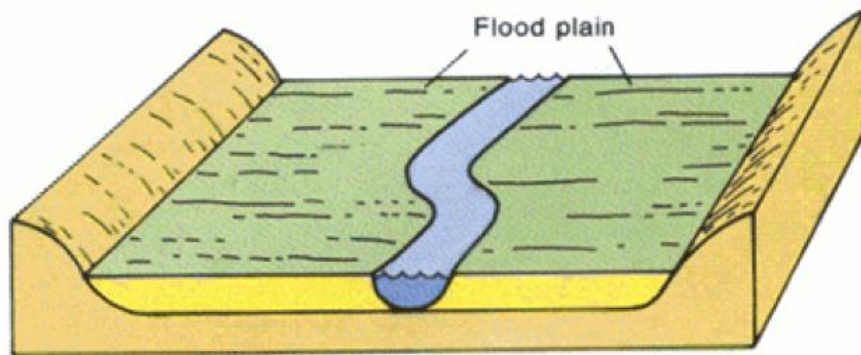


-  Silt/clay infill
-  Sandy/silt inwashes
-  Peat or silty peat infill
-  Lacustrine clay

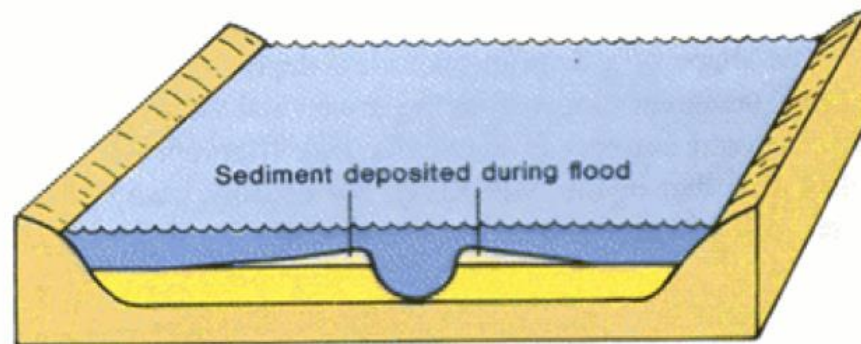


Erosion and deposition along a meandering stream

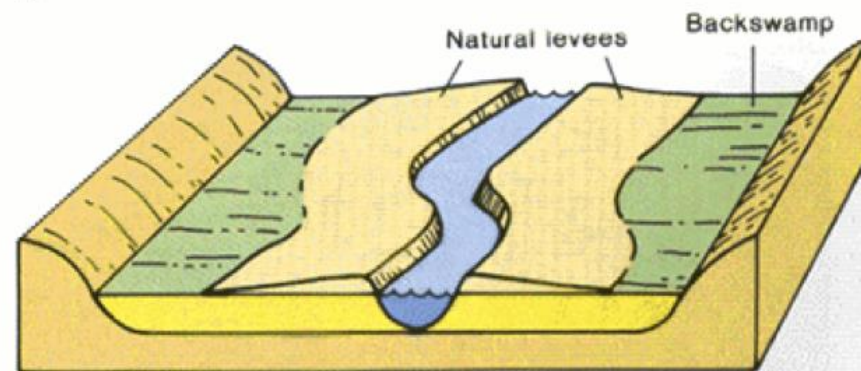




A



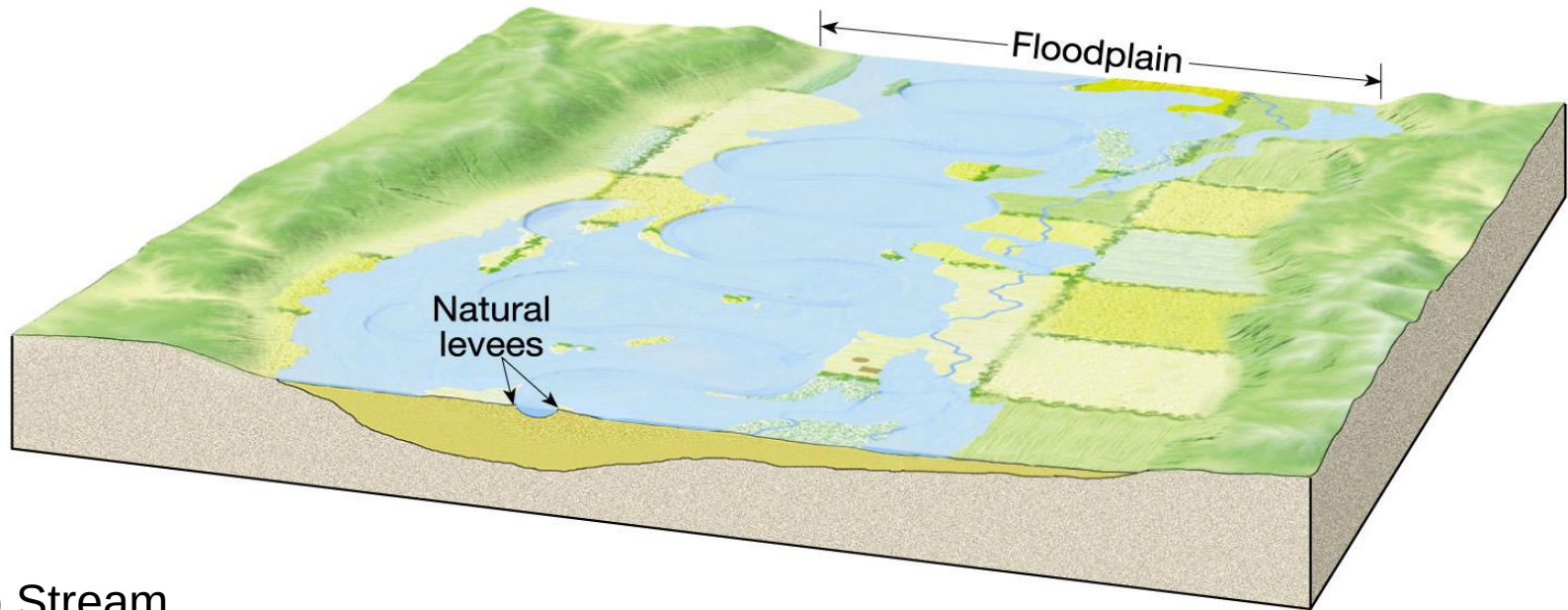
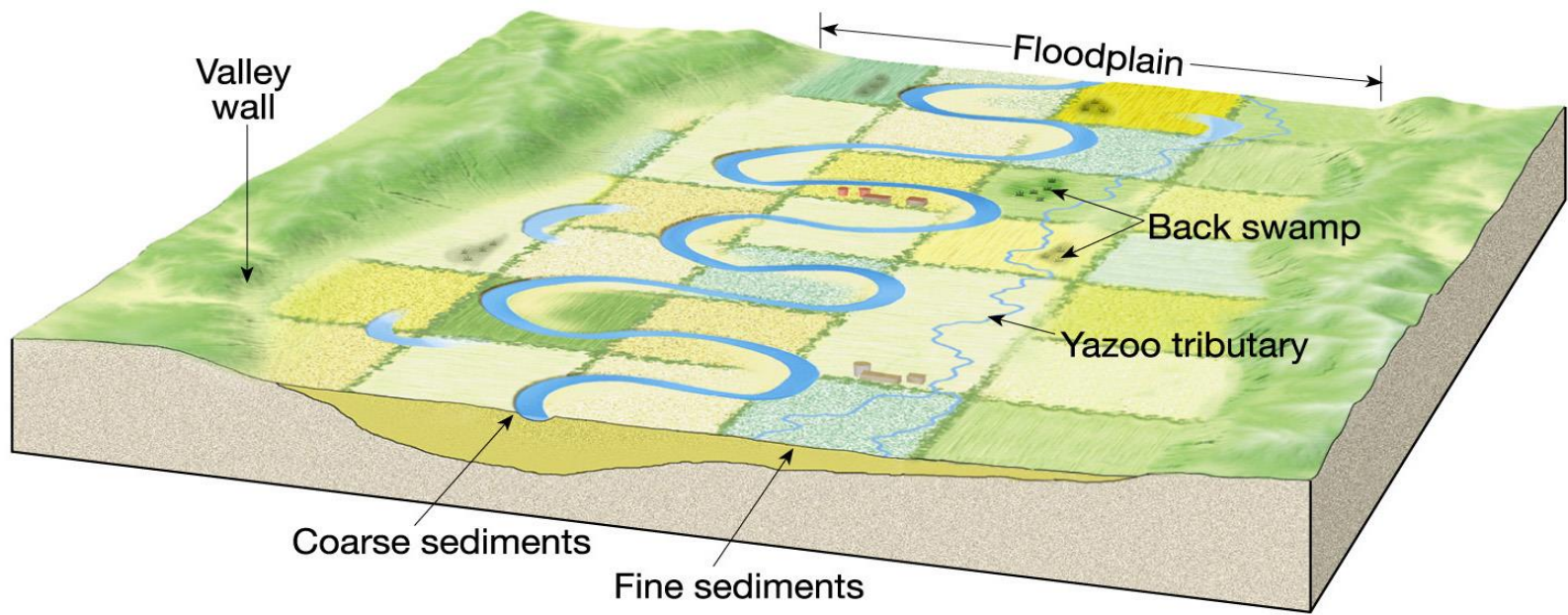
B



C

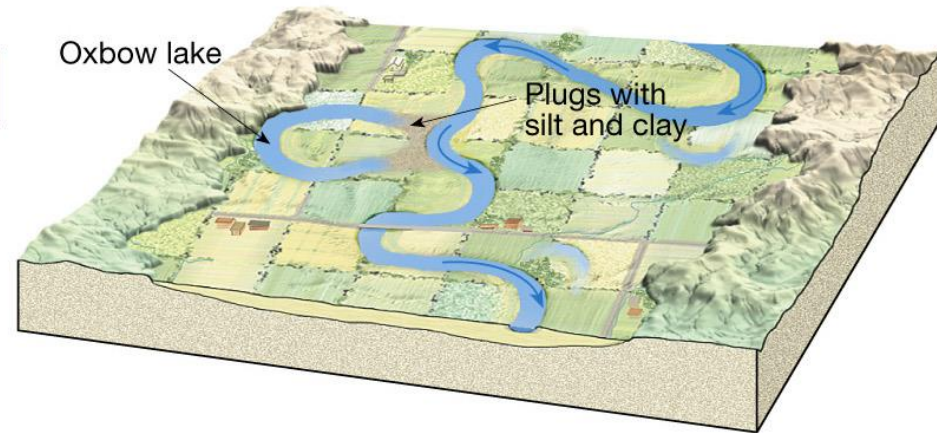
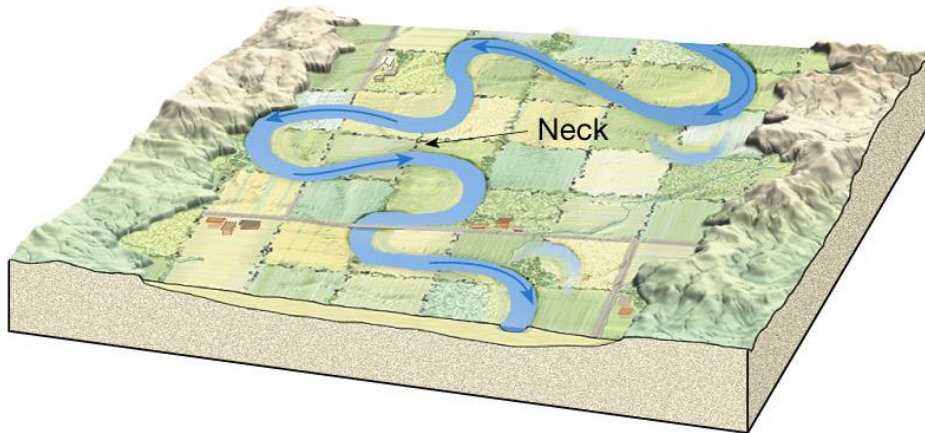
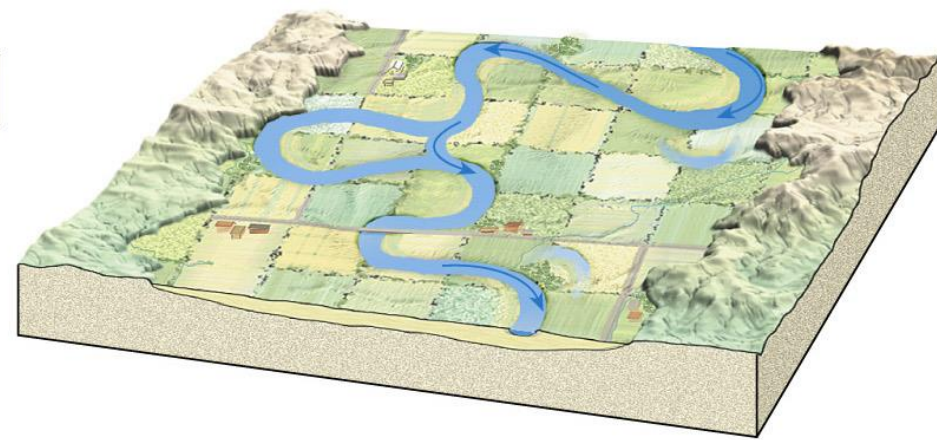
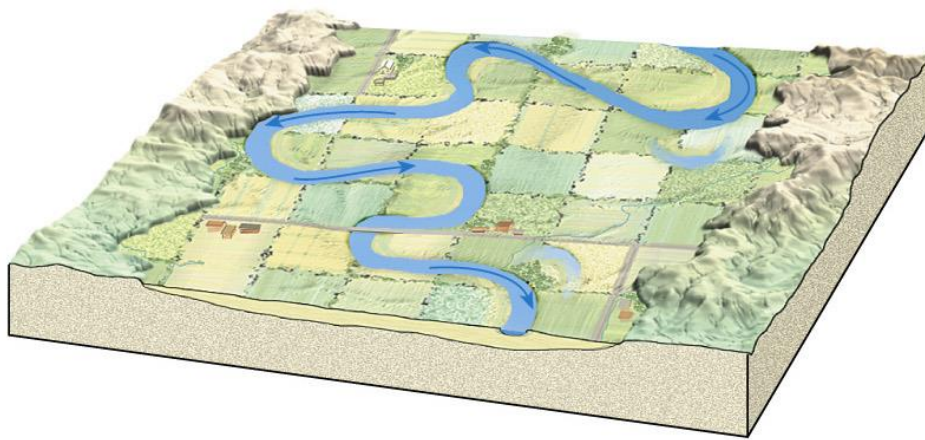
Figure 10.36

Natural levee deposition during a flood. Levees are thickest and coarsest next to the river channel and build up from many floods, not just one. (Relief of levees is exaggerated.) (A) Normal flow. (B) Flood. (C) After flood.



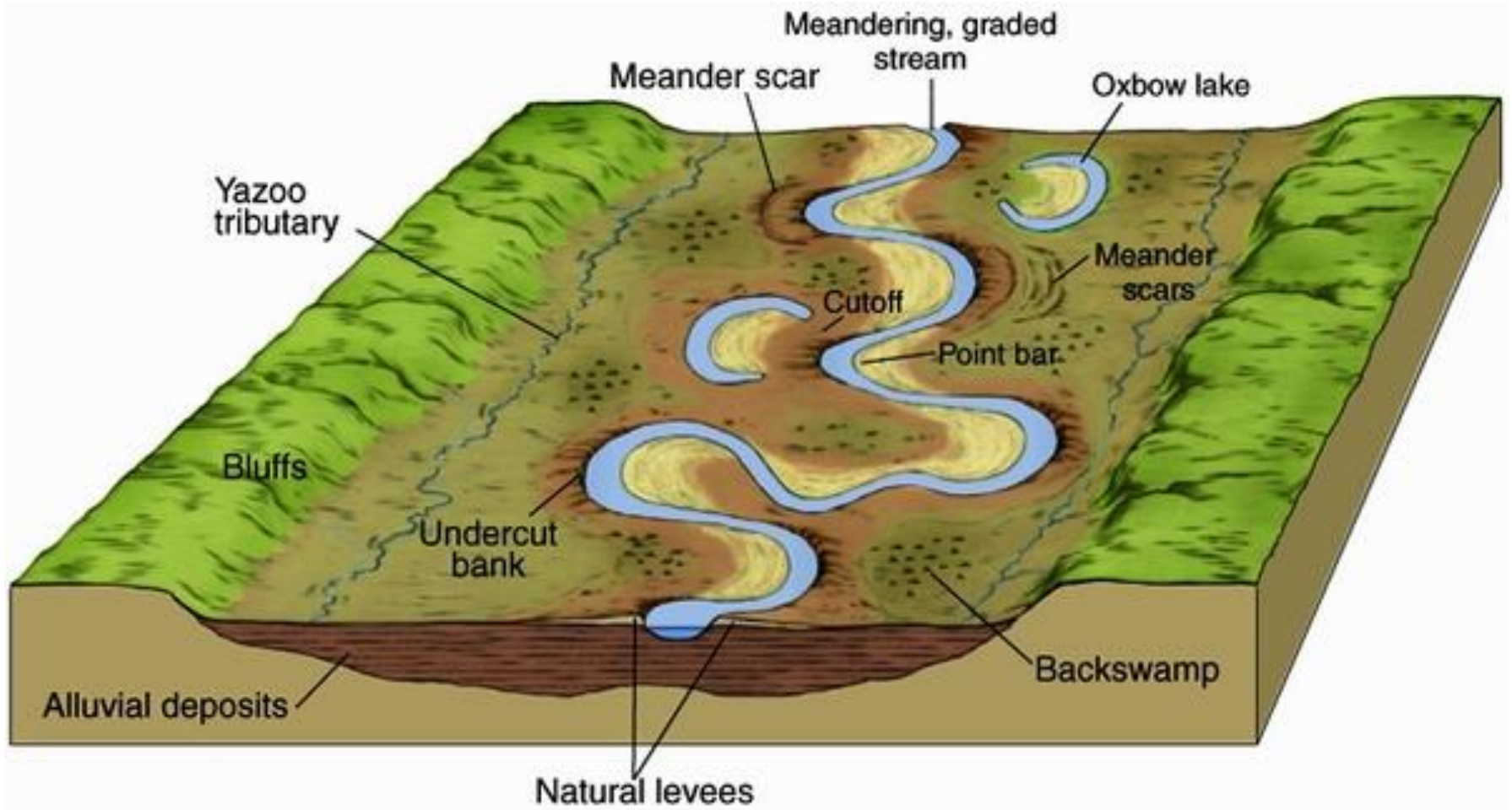
Yazoo Stream

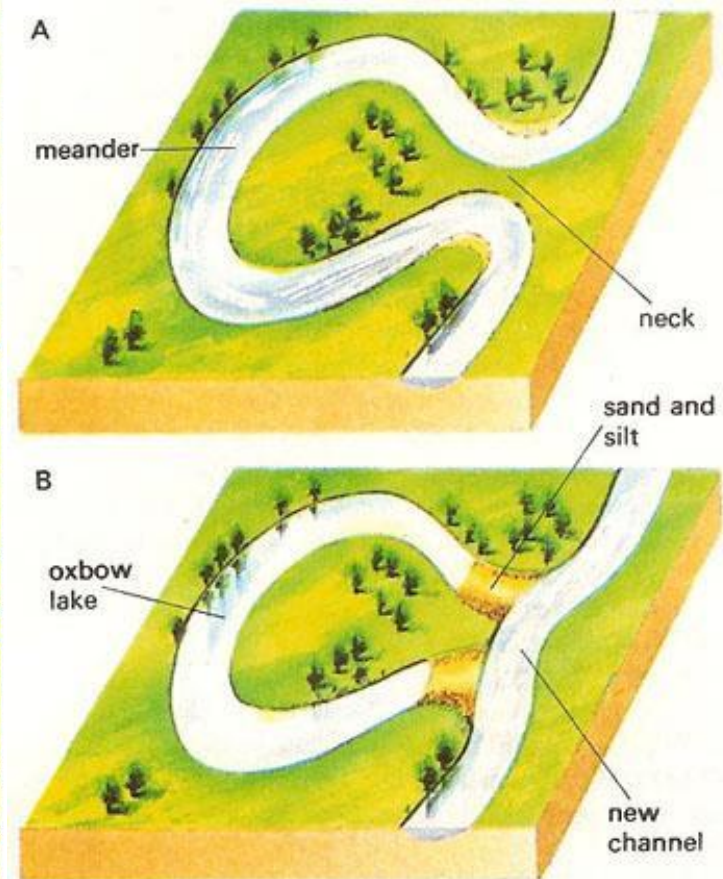
A tributary that parallels the main channel of a stream for a considerable distance. Joining of these streams is normally blocked by a natural levee along the larger stream.

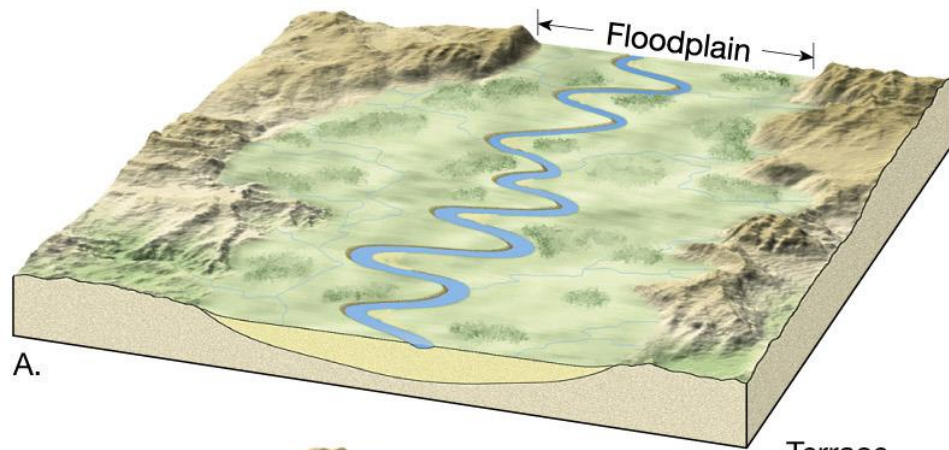


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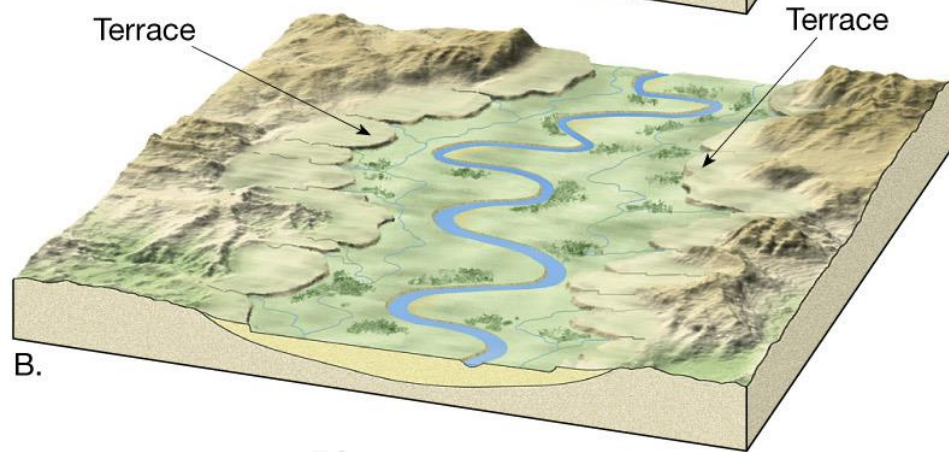
meandering stream



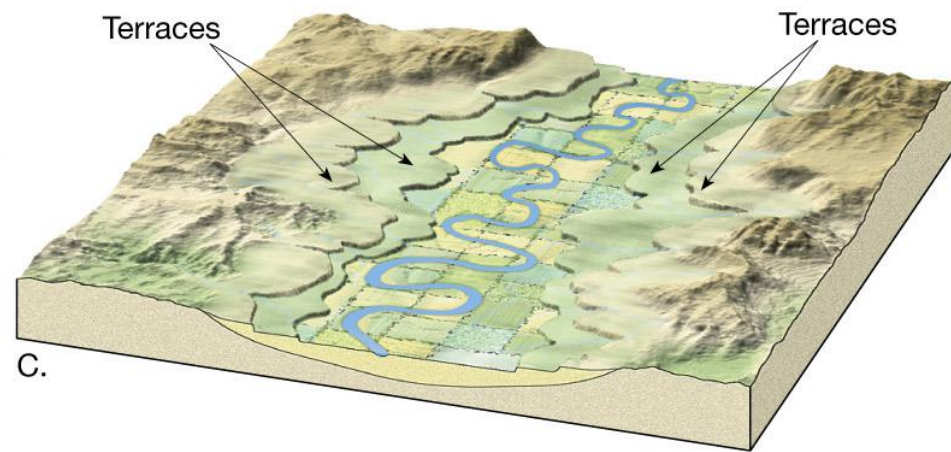




A.



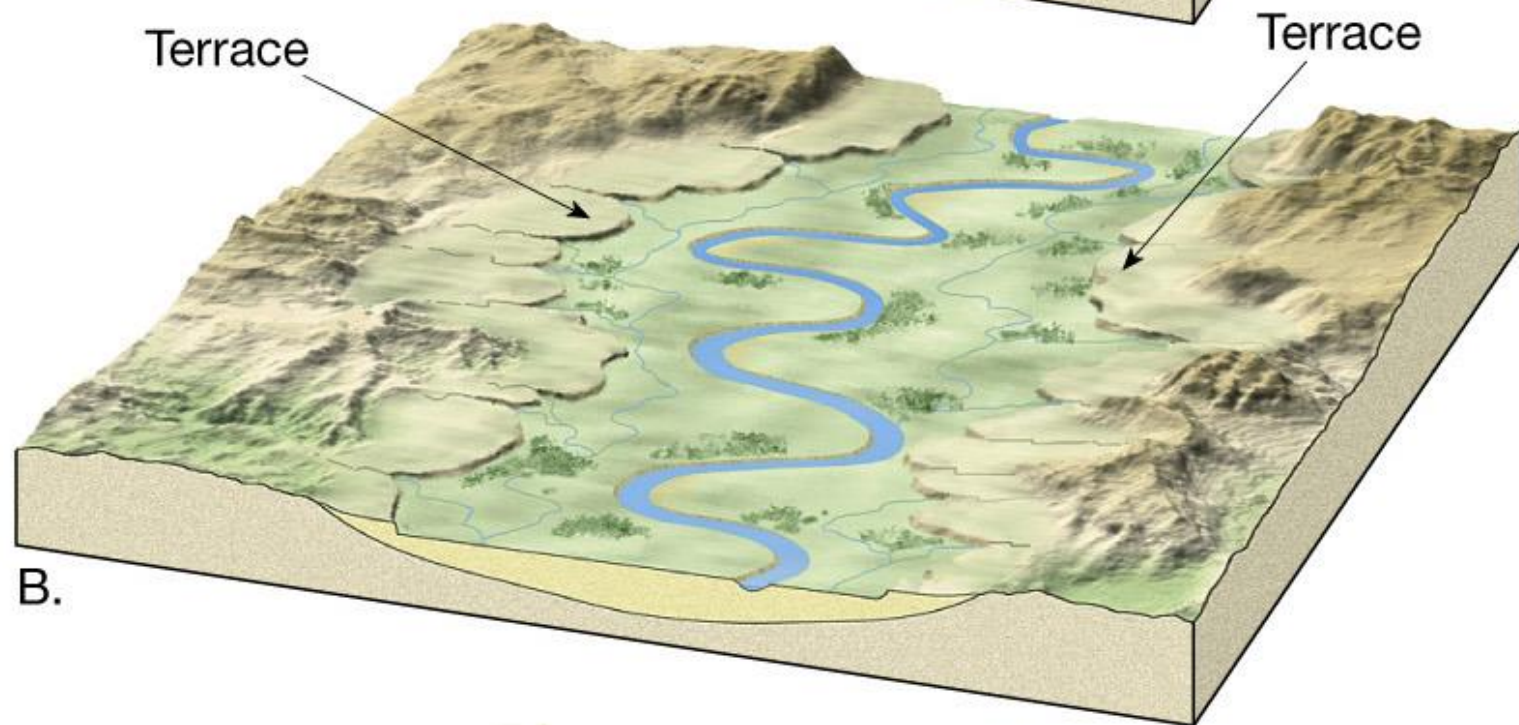
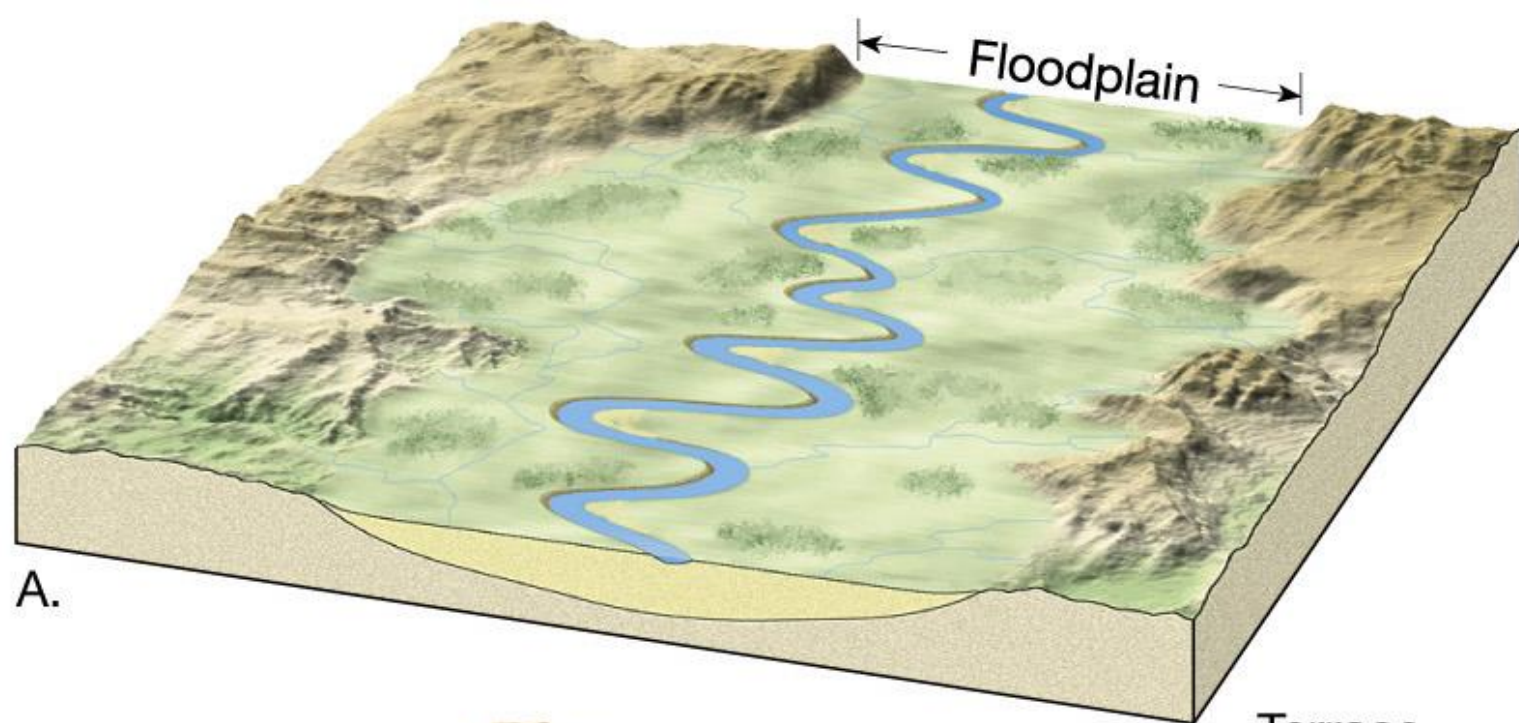
B.

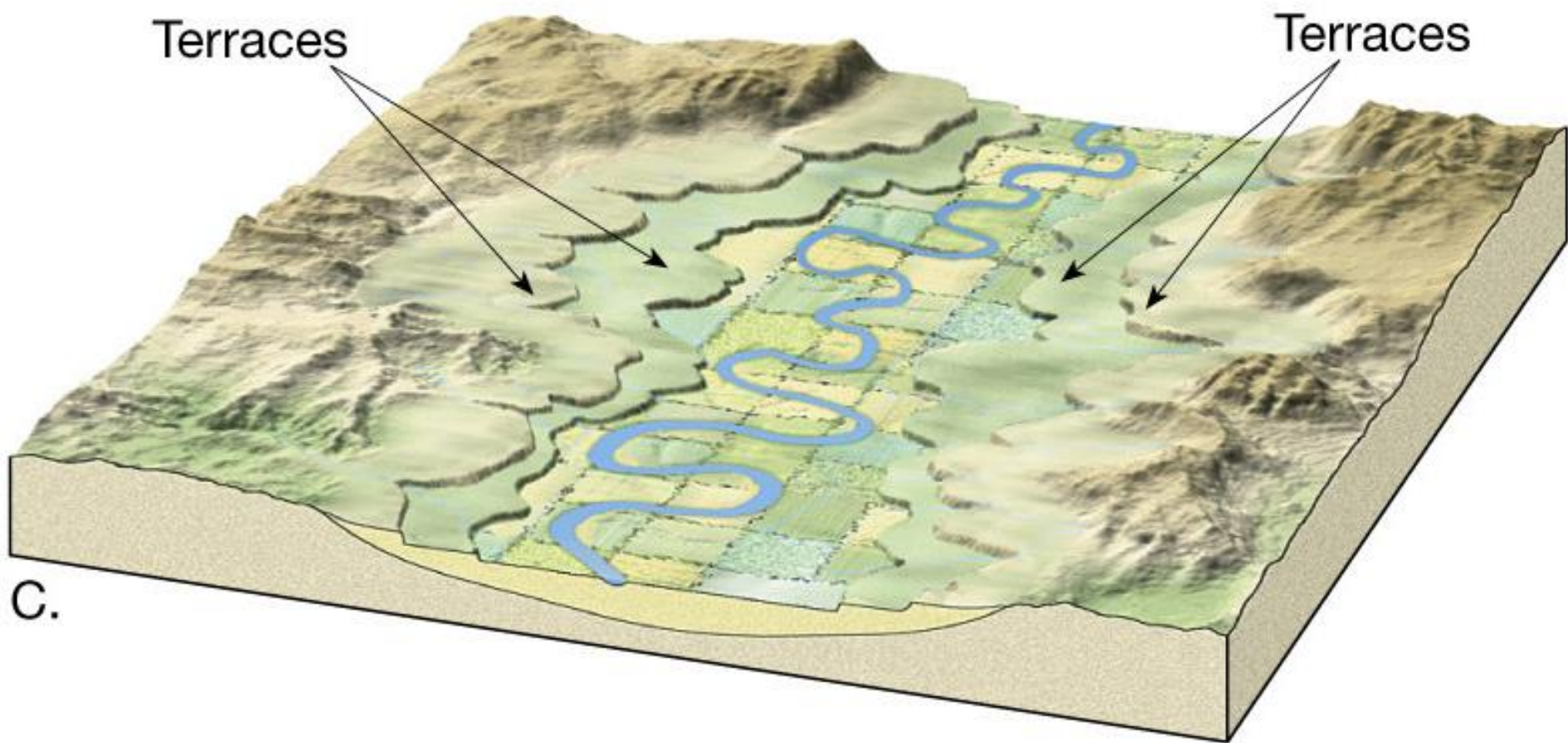


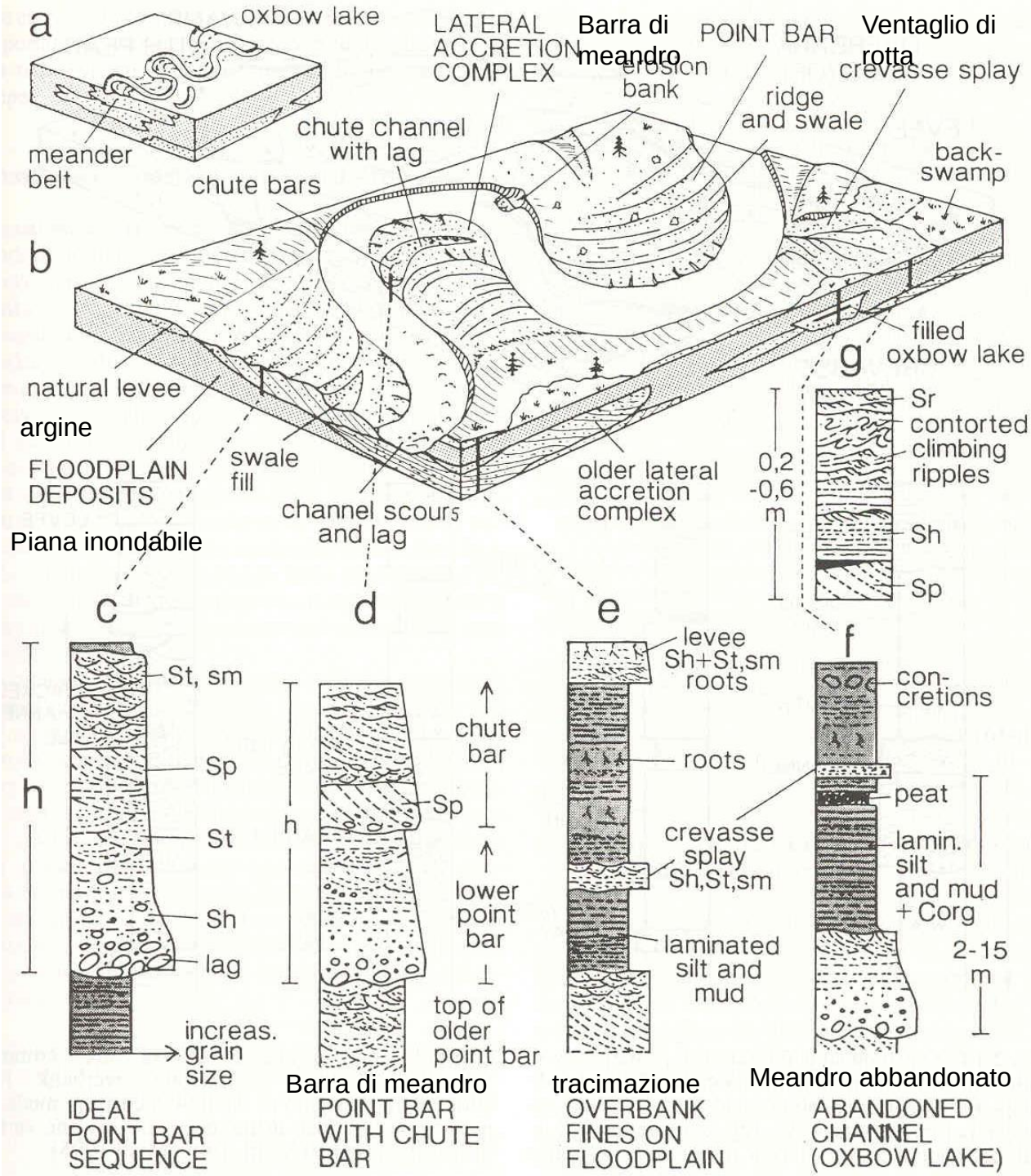
C.

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Terraces







c. *Piane alluvionali a canali meandriformi* (fig. 16)

Sono caratterizzate dallo sviluppo di canali altamente sinuosi.

Morfologia: canale meandriforme, profondo ed asimmetrico, migrante in una fascia lievemente rilevata e separata con argini dalle piane inondabili. Elementi fondamentali: canale attivo, canali abbandonati e laghi, argini e ventagli di rotta d'argine (*crevasse*), barre di meandro e piane inondabili.

Processi: correnti trattive incanalate, trasporto al fondo e in sospensione, correnti libere per rotte di argine e tracimazione, decantazione nei canali abbandonati nei laghi e nelle piane d'inondazione. Accrezione laterale della barra di meandro (riva convessa del canale attivo); erosione della sponda concava e accrezione verticale degli argini per tracimazione. Chiusura con peliti dei canali abbandonati (tappo di argilla).

Corpo sedimentario: l'intera piana costruisce un corpo tabulare al cui interno la fascia di meandro costituisce prismi nastriformi sabbiosi, a sezione lenticolare, singoli o dendriformi, inquadrati da peliti di piana inondabile.

Organizzazione interna: lenti e nastri sabbioso-ghiaiosi interdigitati con siltiti e peliti.

Associazione di facies: sequenze di canale, caratterizzate da gradazione da ghiaia ad argille, pavimento di ciottoli su superficie erosionale, sabbie a stratificazione incrociata a grande scala passanti verticalmente a sabbie fini a laminazione obliqua a scala media e piccola, peliti a tetto; sequenza di barra: accrezione laterale a base ghiaiosa, gradante a sabbie a stratificazione incrociata concava a scala decrescente verso l'alto; sequenze di argine: sabbie fini e peliti alternate con intercalati livelli ciottolosi o a clasti d'argilla; sequenze di tracimazione e di rotta: sequenze positive di sabbie a stratificazione incrociata a piccola scala e sabbie a laminazione parallela passanti ad argille, sabbie fini a stratificazione sottile e lenticolare; sequenze di piana: alternanze di argille e limi, frequentemente interrotte da livelli di tracimazione e di rotta, sabbiosi ed associati a livelli a ligniti o carboni. Rari fossili continentali. Frequenti bioturbazioni.

Paleocorrenti: unimodali con dispersione molto ampia (fino a 270°).

a. *Piane alluvionali a canali anastomosati* (fig. 14)

Morfologia: reticolo di canali intrecciati scarsamente sinuosi, a fondo piatto e poco profondo, separati da barre longitudinali che passano sottocorrente a barre trasversali.

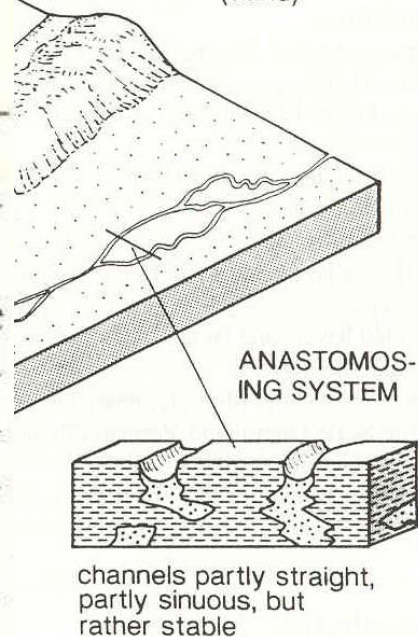
Processi: correnti trattive incanalate, intermittenti, con prevalente trasporto di fondo. Migrazione di forme al fondo a scale diverse; frequente avulsione (abbandono e migrazione laterale dei canali), decantazione di sedimenti fini nelle limitate piane di inondazione, frequente asportazione erosionale di sedimento.

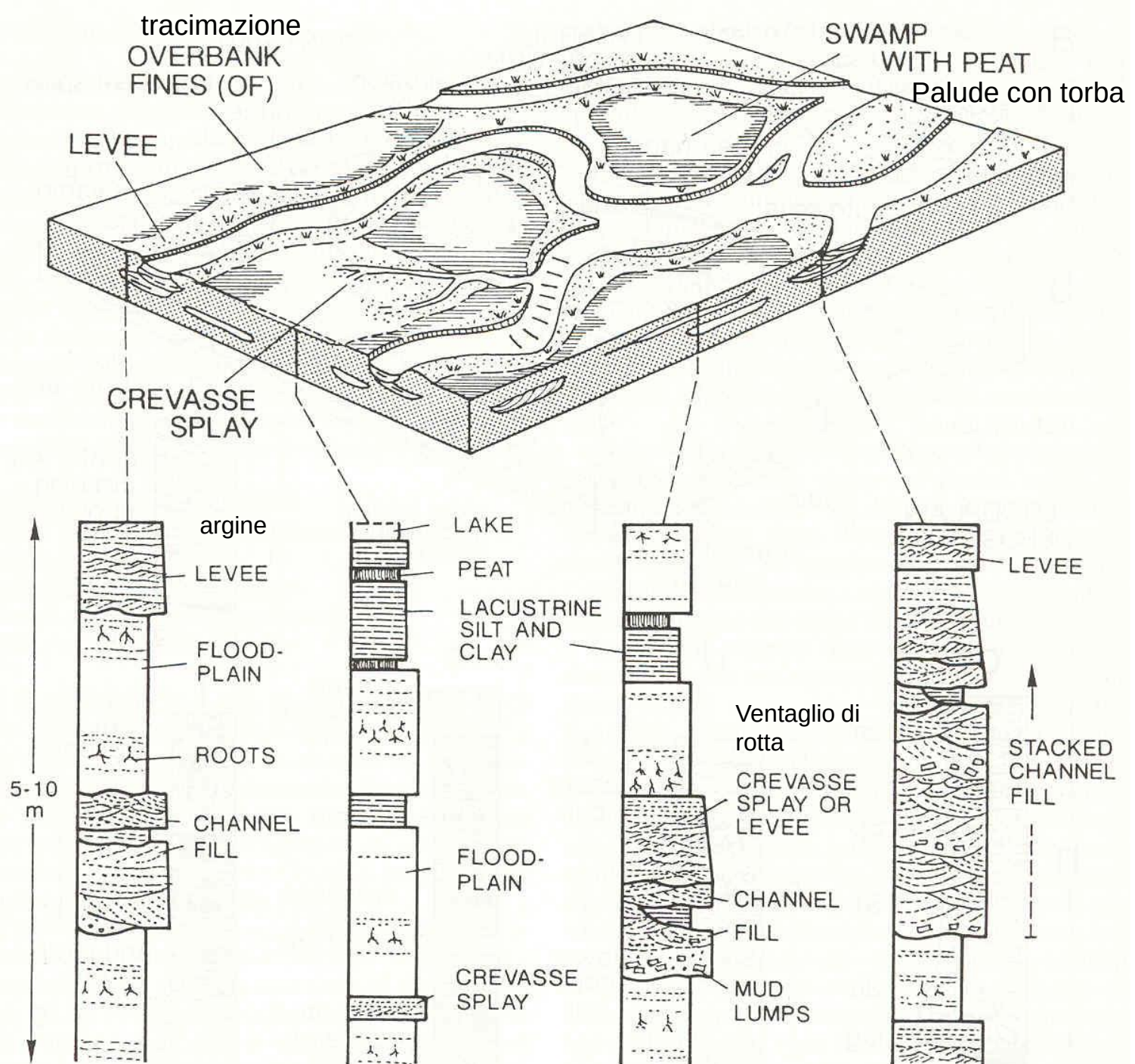
Corpo sedimentario: corpo prismatico o tabulare delimitato da superfici di erosione.

Organizzazione interna: lenti a base concava erosionale, interdigitate, solitamente prive di sequenze o con sequenze positive appena accennate.

Associazione di facies: ghiaie e sabbie grossolane passanti a sabbie più fini e rare argille e limi. Sequenze di abbandono di canale: ghiaie disorganizzate su superficie erosionale tappezzata da pavimento di ciottoli con inclusi argillosi, passanti a sabbie a laminazione obliqua concava o massive e peliti. Sequenze di barra longitudinale: ghiaie a stratificazione massiccia e sabbie a stratificazione piana orizzontale o incrociata, tabulare, a grande scala. Sequenze di barra trasversale: sabbie a stratificazione incrociata concava, passanti a sabbie fini a laminazione obliqua concava (*ripple marks*). Assenza di fossili.

Paleocorrenti: unimodali, dispersione entro 60° circa.







River

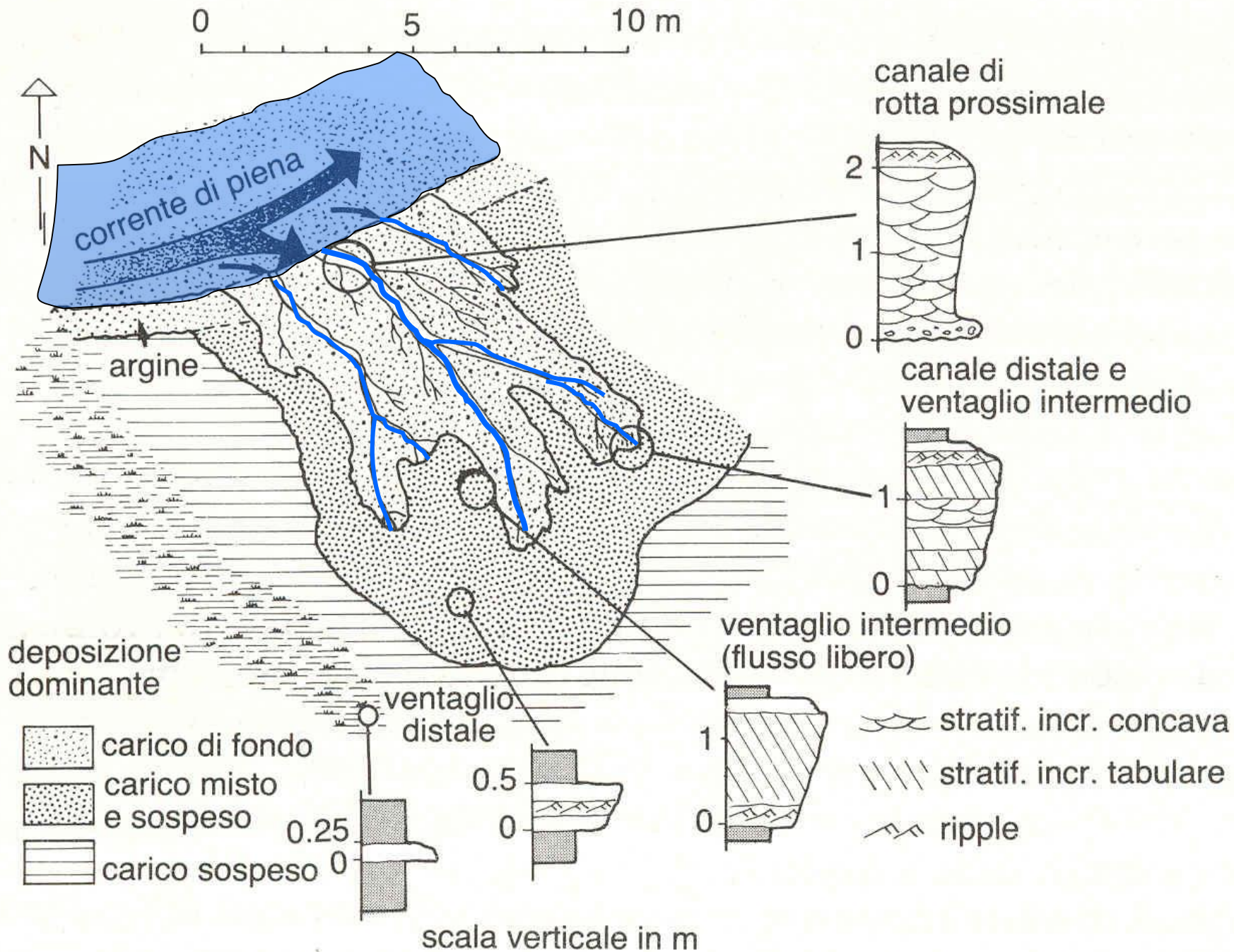
Break in Levee

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**Levee failure
Monroe county Illinois, 1993**



Rhine-Meuse delta: crevasse splay

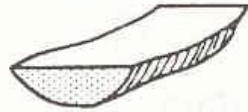


FLUVIAL CHANNELS

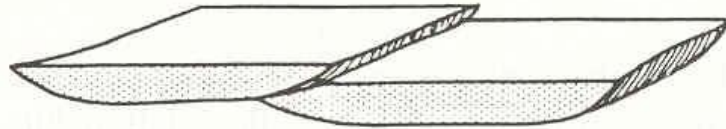
NARROW
ISOLATED

a

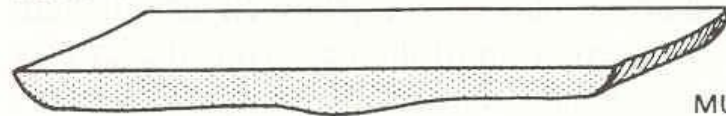
BROAD ISOLATED
RIBBON



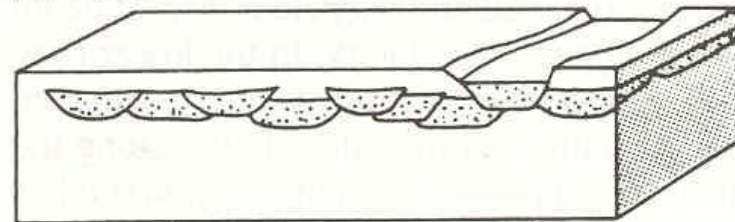
OVERLAPPING RIBBONS



SAND SHEET

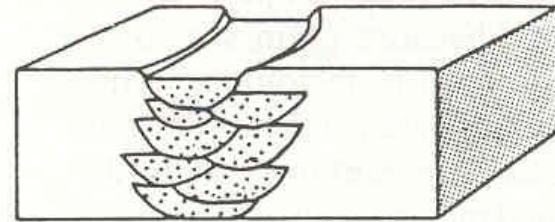


LATERAL CHANNEL MIGRATION
(LITTLE CONTEMPORANEOUS SUBSIDENCE)

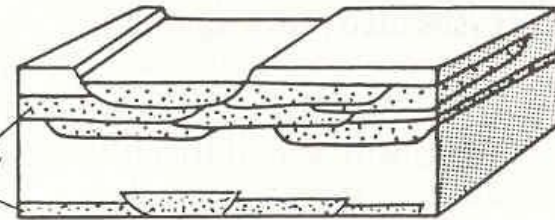


b

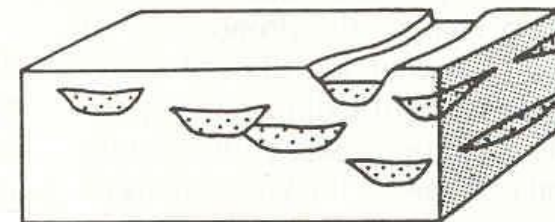
VERTICAL STACKING
(RAPID SUBSIDENCE)



LATERAL STACKING
(SLOW SUBSIDENCE)

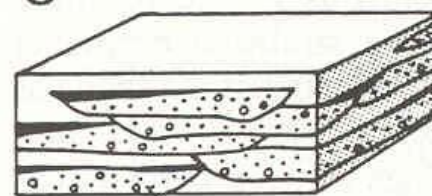


ISOLATED STACKING



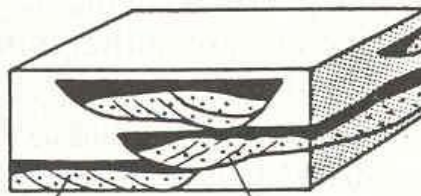
c

BEDLOAD CHANNELS



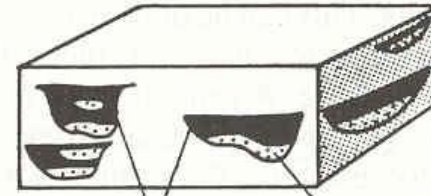
SAND AND GRAVEL

MIXED LOAD CHANNELS

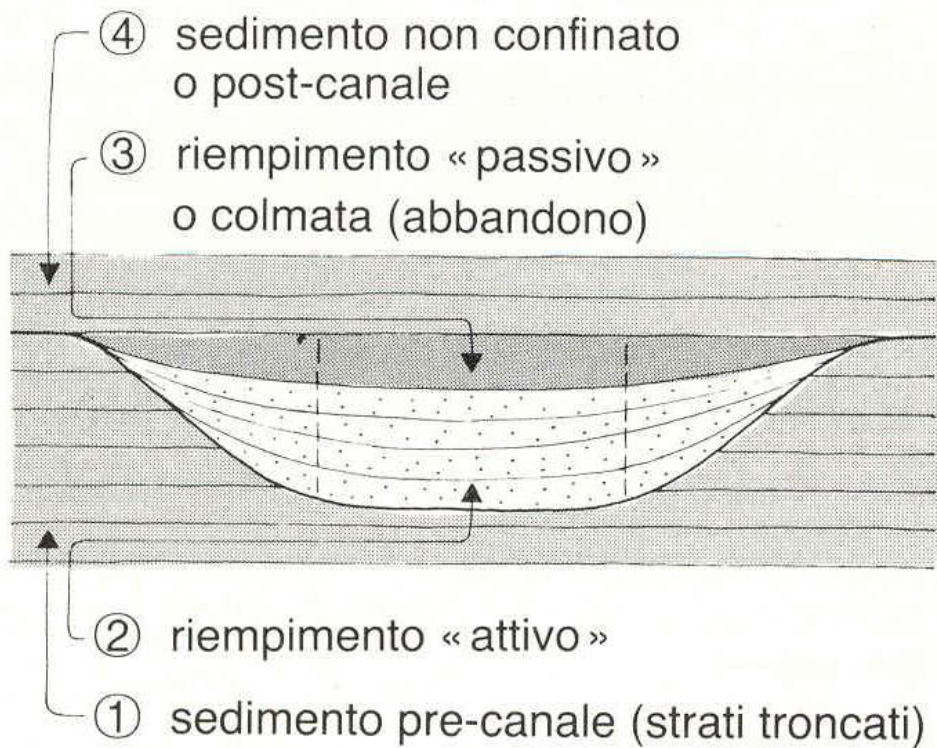


SAND LATERAL ACCRETION

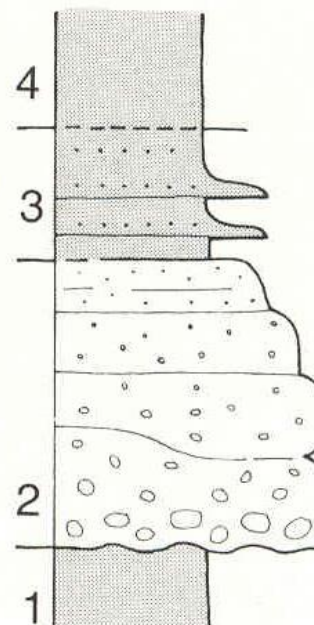
SUPENDED-LOAD CHANNELS

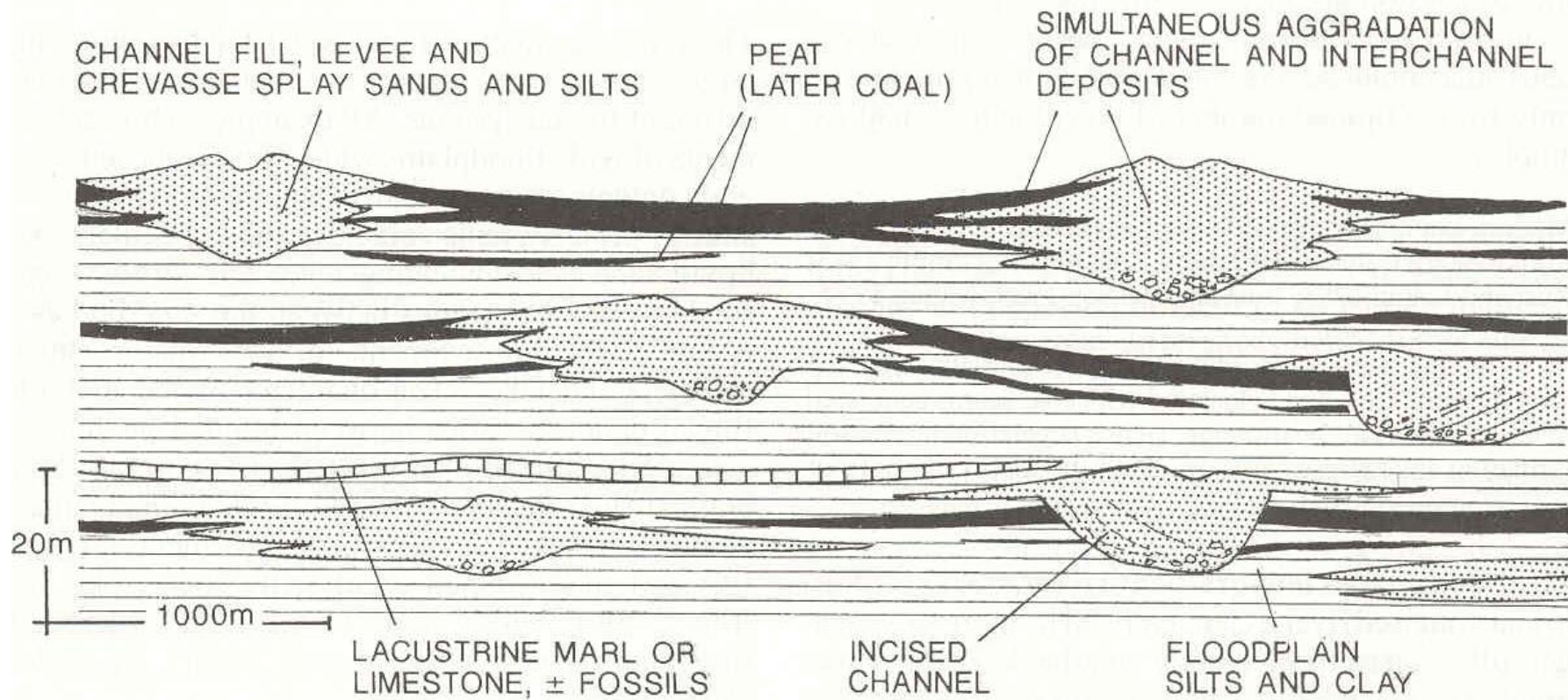


MUD SAND

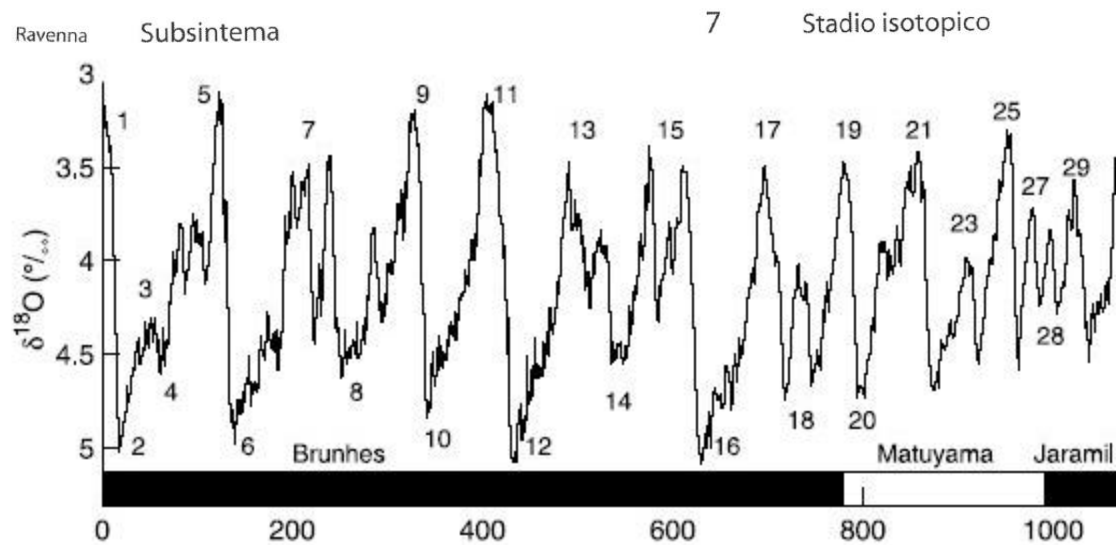
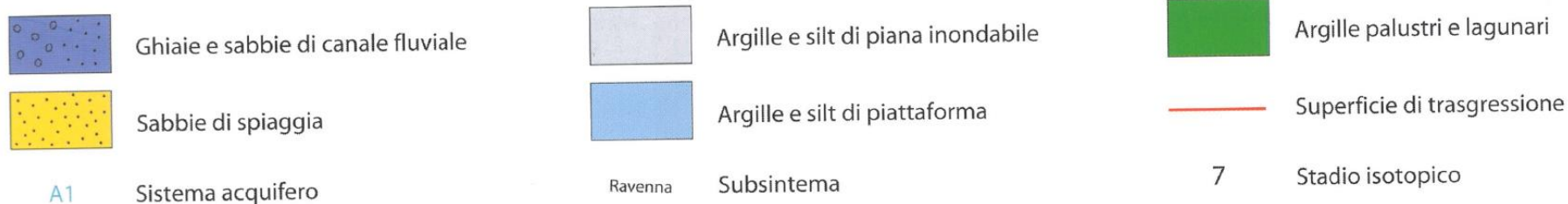
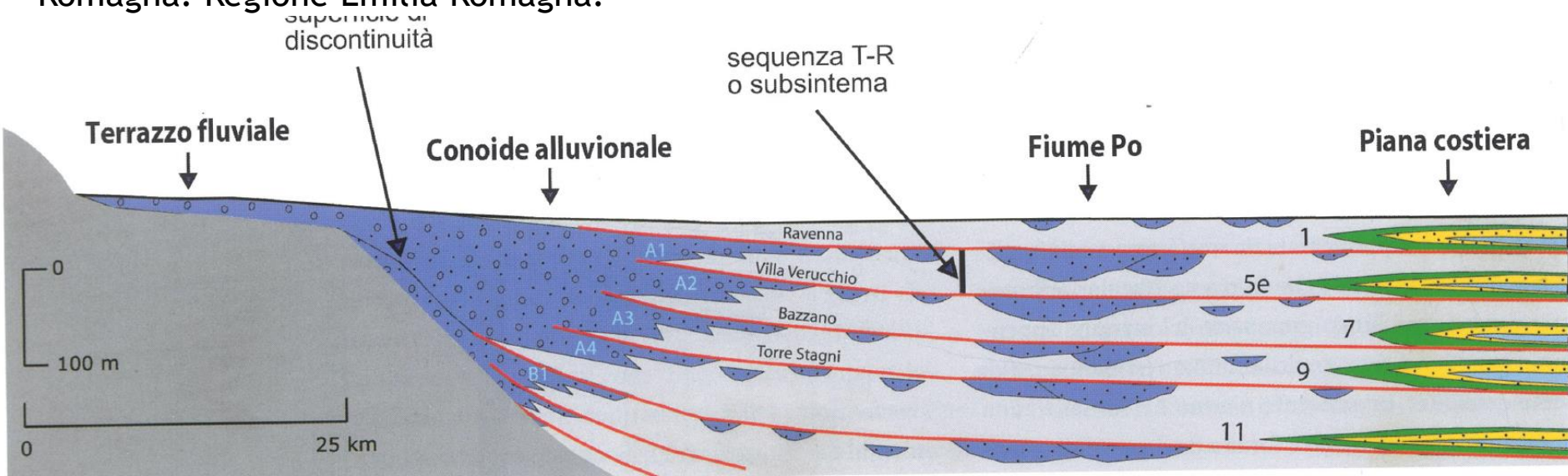


sequenza complessiva (FU o positiva)





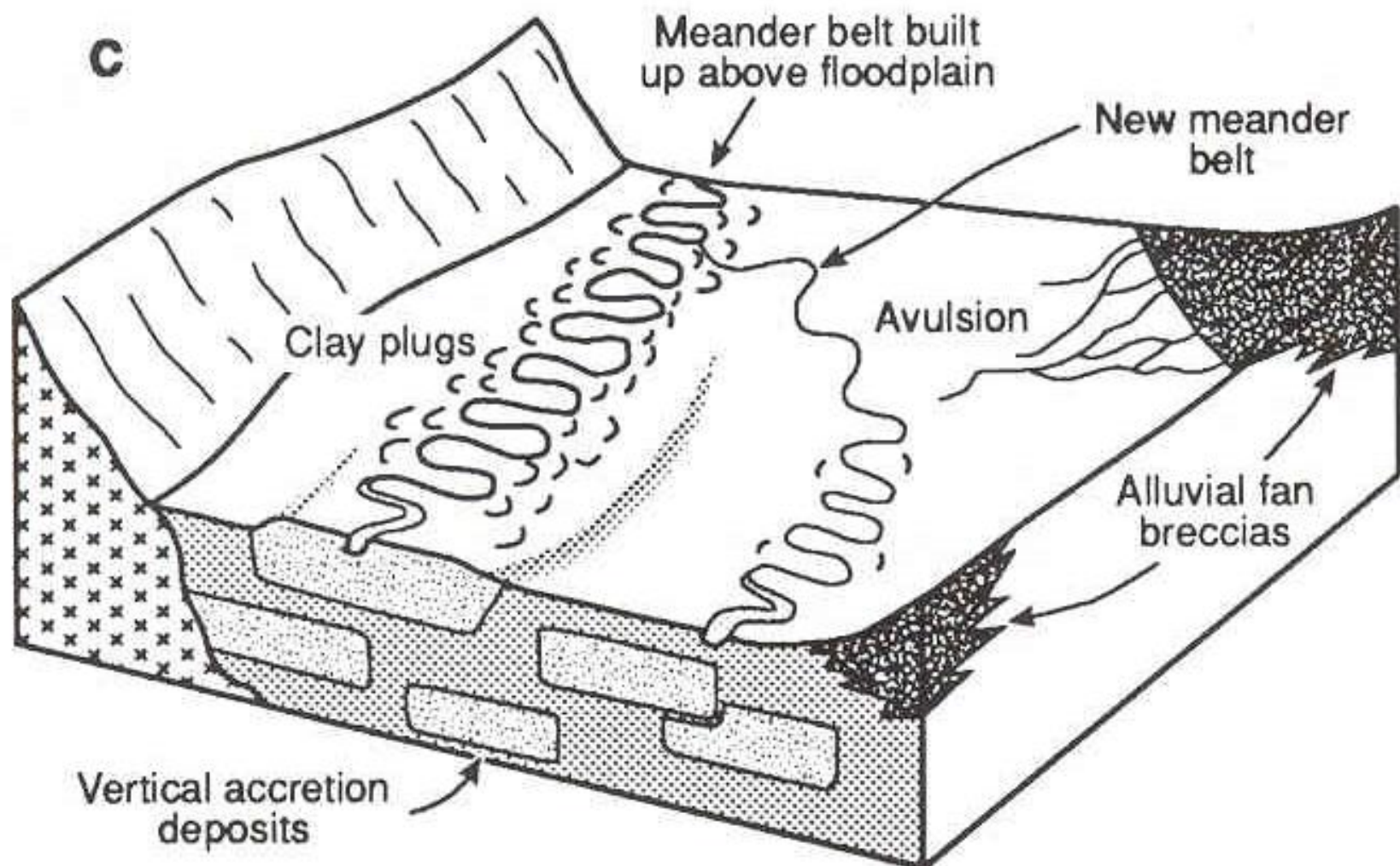
Amorosi e Pignone (a cura di), 2009, La pianura - geologia, suoli e ambienti in Emilia-Romagna. Regione Emilia Romagna.



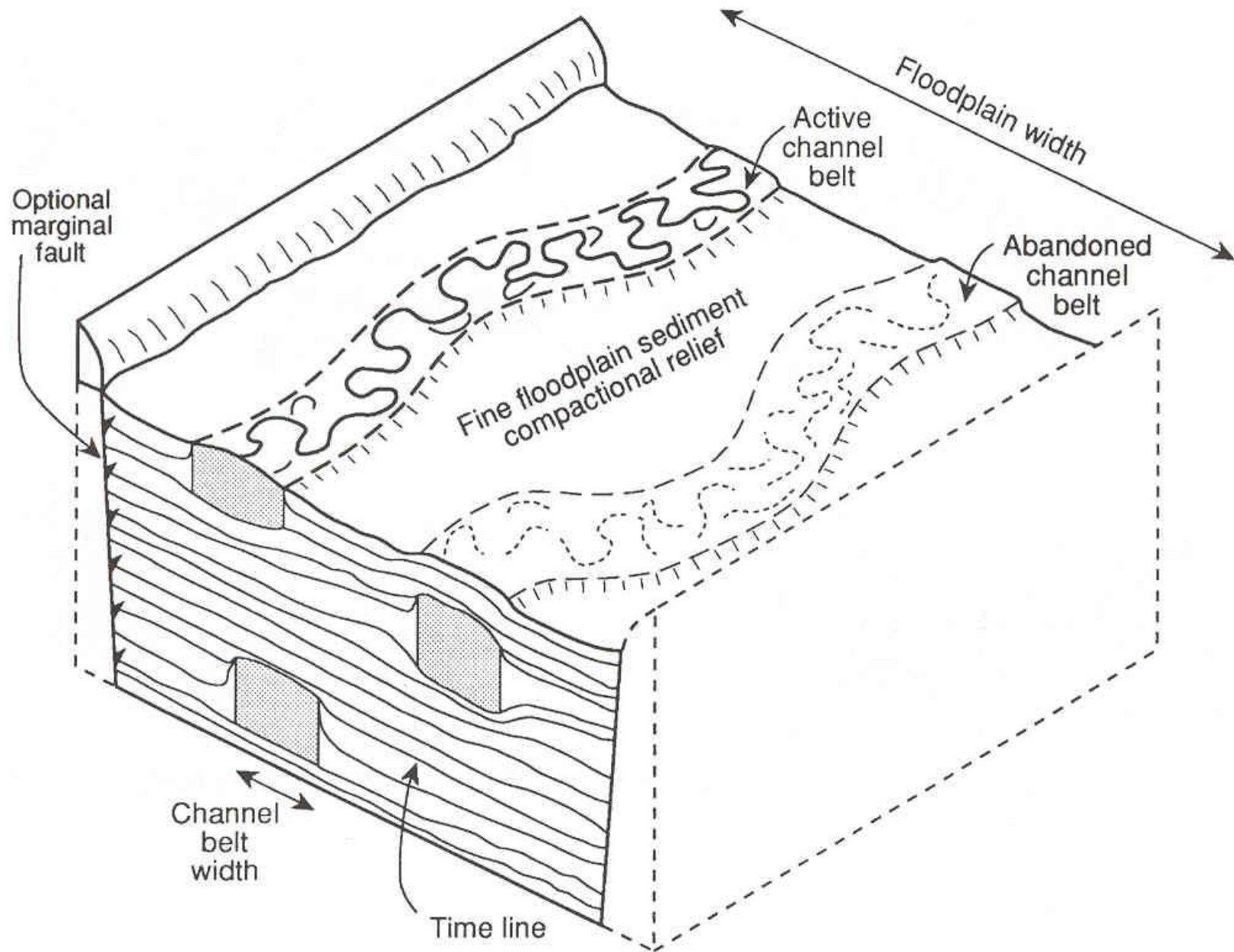




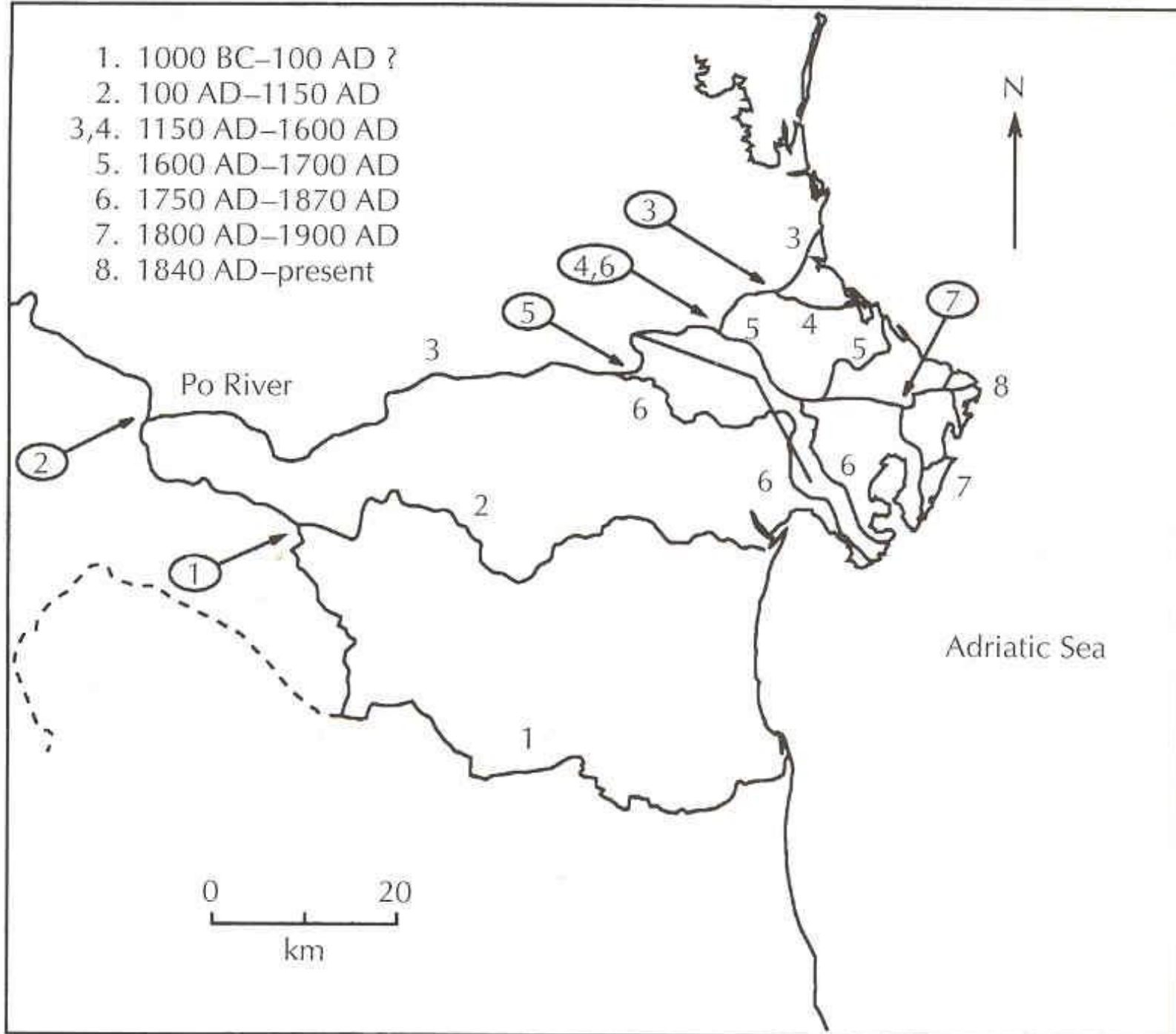


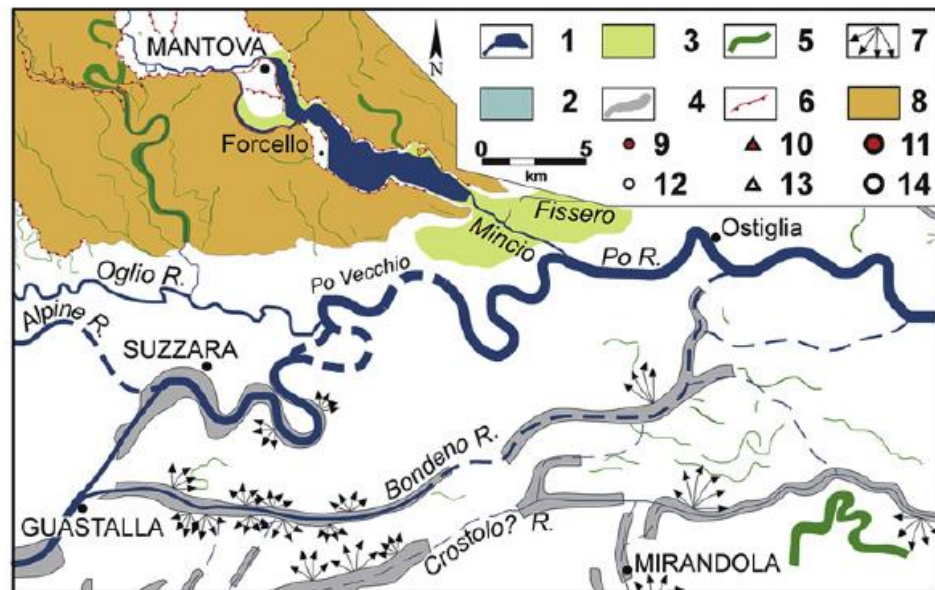


Avulsione



1. 1000 BC–100 AD ?
2. 100 AD–1150 AD
- 3,4. 1150 AD–1600 AD
5. 1600 AD–1700 AD
6. 1750 AD–1870 AD
7. 1800 AD–1900 AD
8. 1840 AD–present

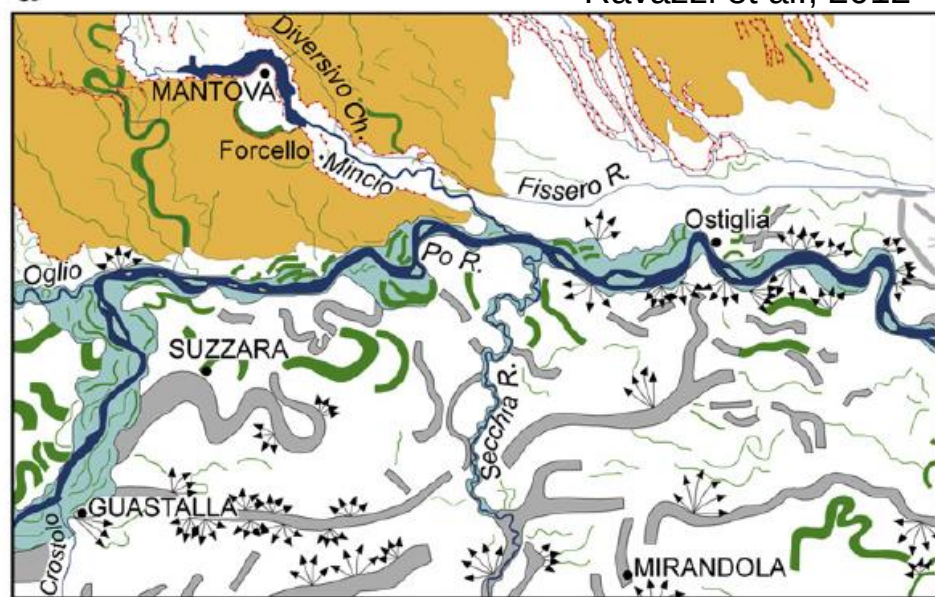




c

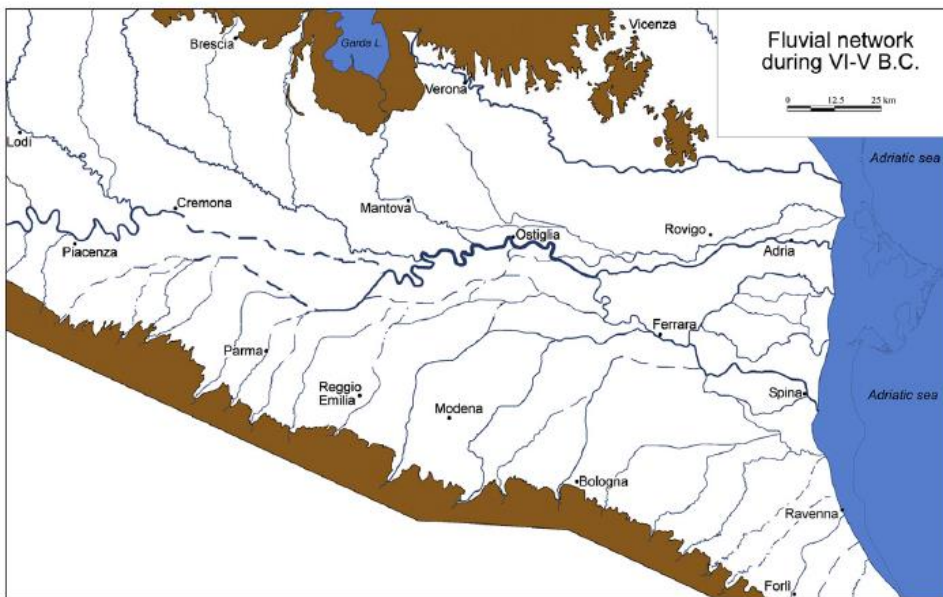
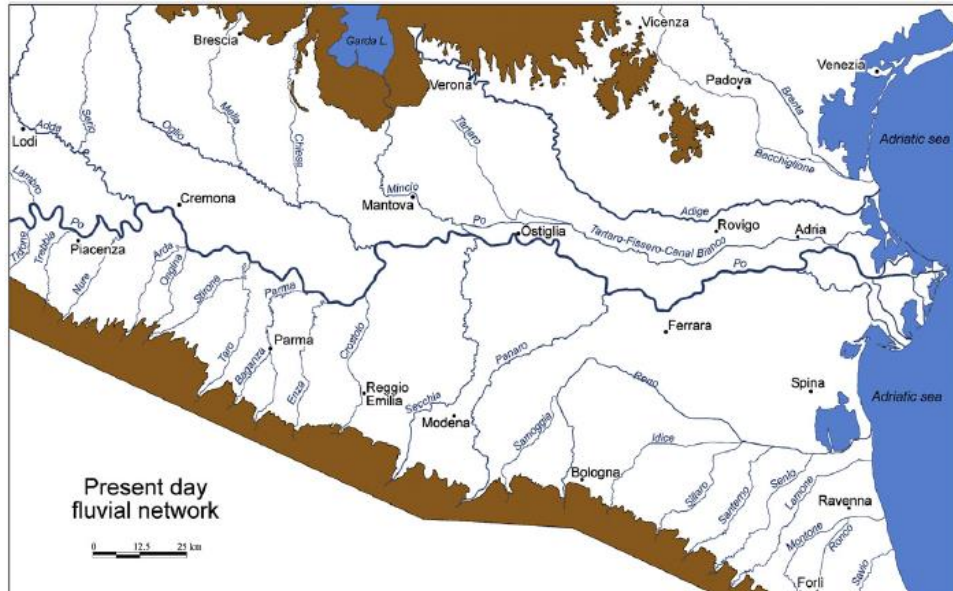
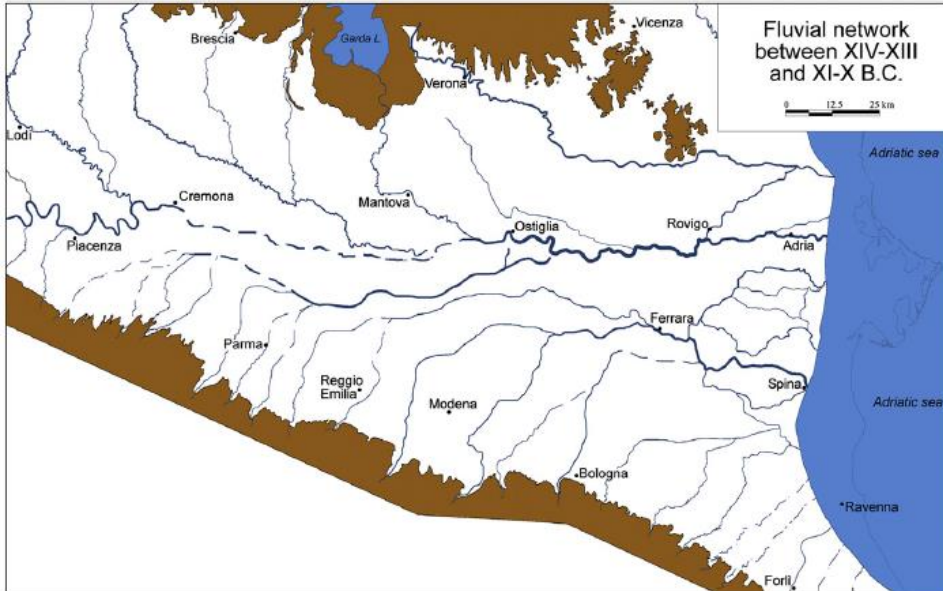


d



Ravazzi et al., 2012

Fig. 6. Geomorphological maps of the lower Mantova plain (central Po Plain). a. Late Bronze Age hydrography and location of Bronze Age settlements; b. 5th century BC hydrography; c. 3rd century AD hydrography; d. Present day hydrography. Legend: 1) Rivers and lakes (dashed lines depict presumed fluvial tracks), 2) High water fluvial bed, mostly between main levees, 3) Poorly drained lowland, 4) Alluvial ridge, 5) Abandoned fluvial course, 6) Main fluvial scarp, 7) Crevasse splay area, 8) Main Plain Level (surface marking the last aggradation phases, before the beginning of deglaciation). 9–12) Location of Middle to Late Bronze Age archaeological settlements. 9) Sites smaller than 1 ha, not buried; 10) From 1 to 4 ha, not buried; 11) Over 4 ha, not buried; 12) Smaller than 1 ha, buried; 13) From 1 to 4 ha, buried; 14) Over 4 ha, buried.



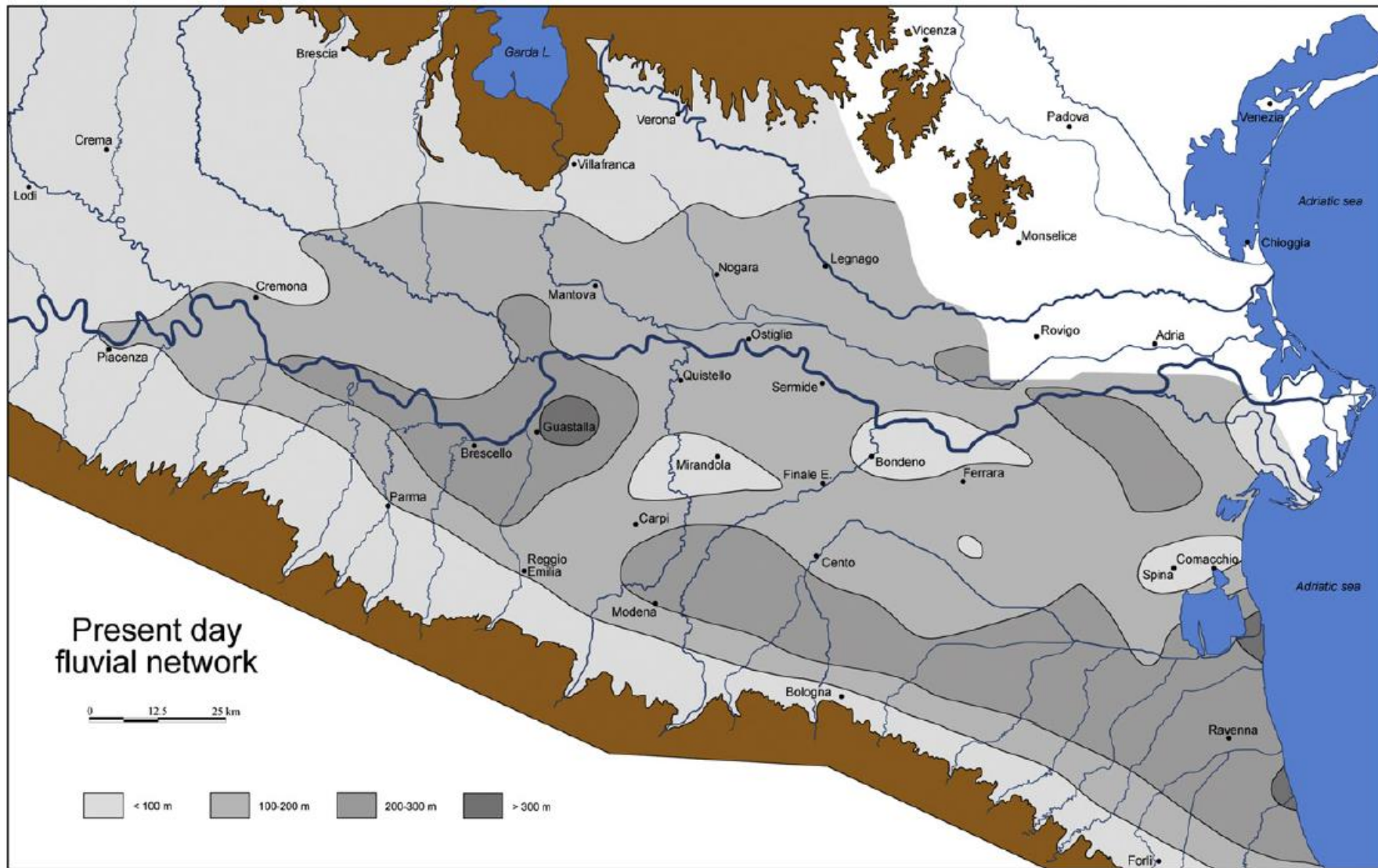
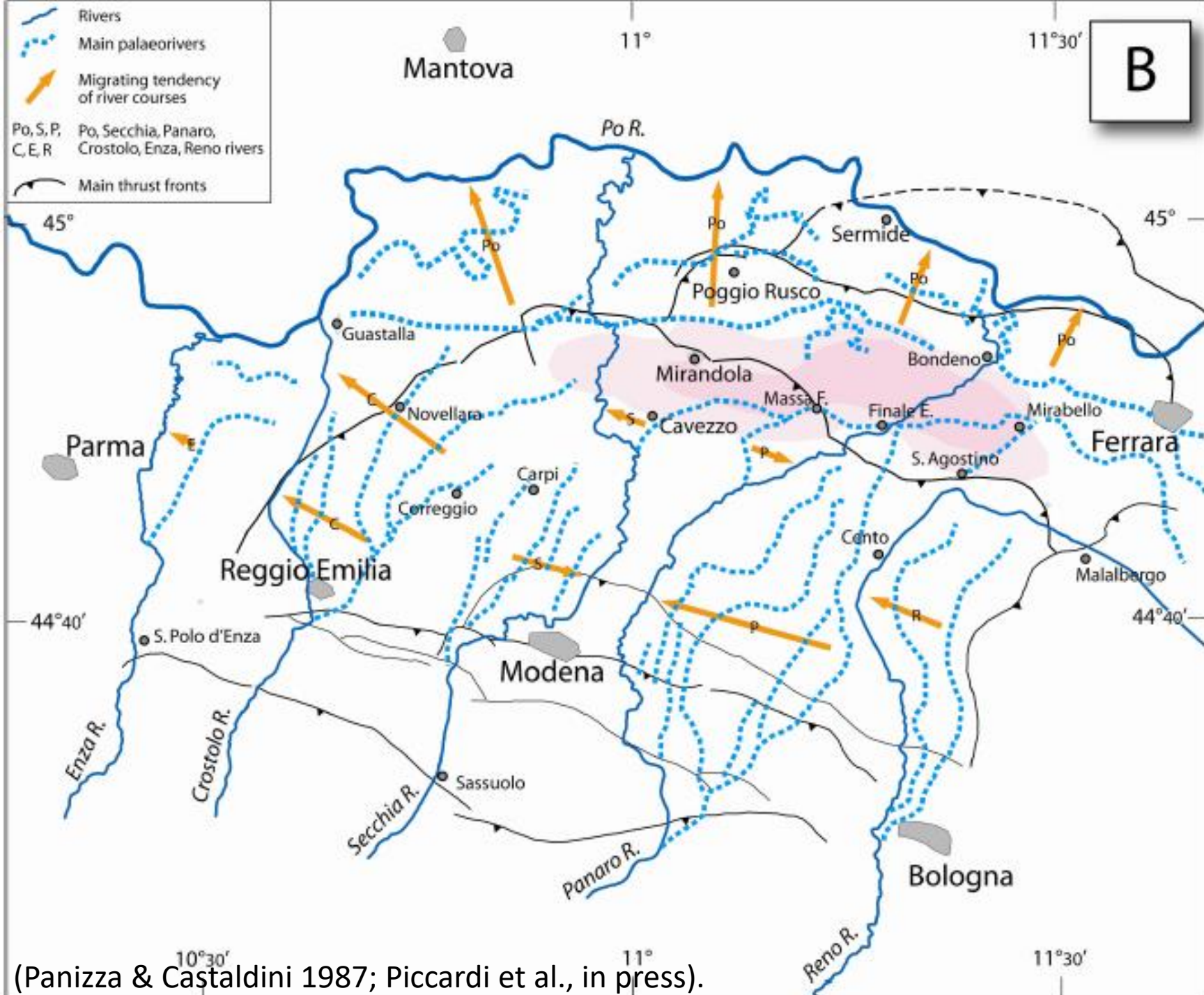


Fig. 9. Subsidence and accumulation rates along the central and eastern Po plain during the last 0.45 ma. The modern fluvial pattern is associated with four classes representing the isopachs of the 0.45 Ma stratigraphic surface (data from Carcano and Piccin, 2002).



(Panizza & Castaldini 1987; Piccardi et al., in press).



Eastern levee

Repairing the levee



Eastern levee





Bomporto



Flooded area

Levee collapse area

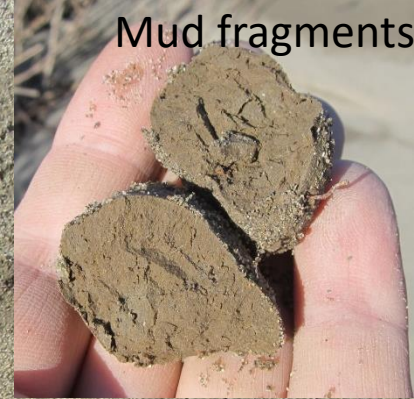


Sand with
ripple marks

S. Matteo, 26/1/2014

Laminated sand

Mud fragments









flooded area with mud settling
to the bottom

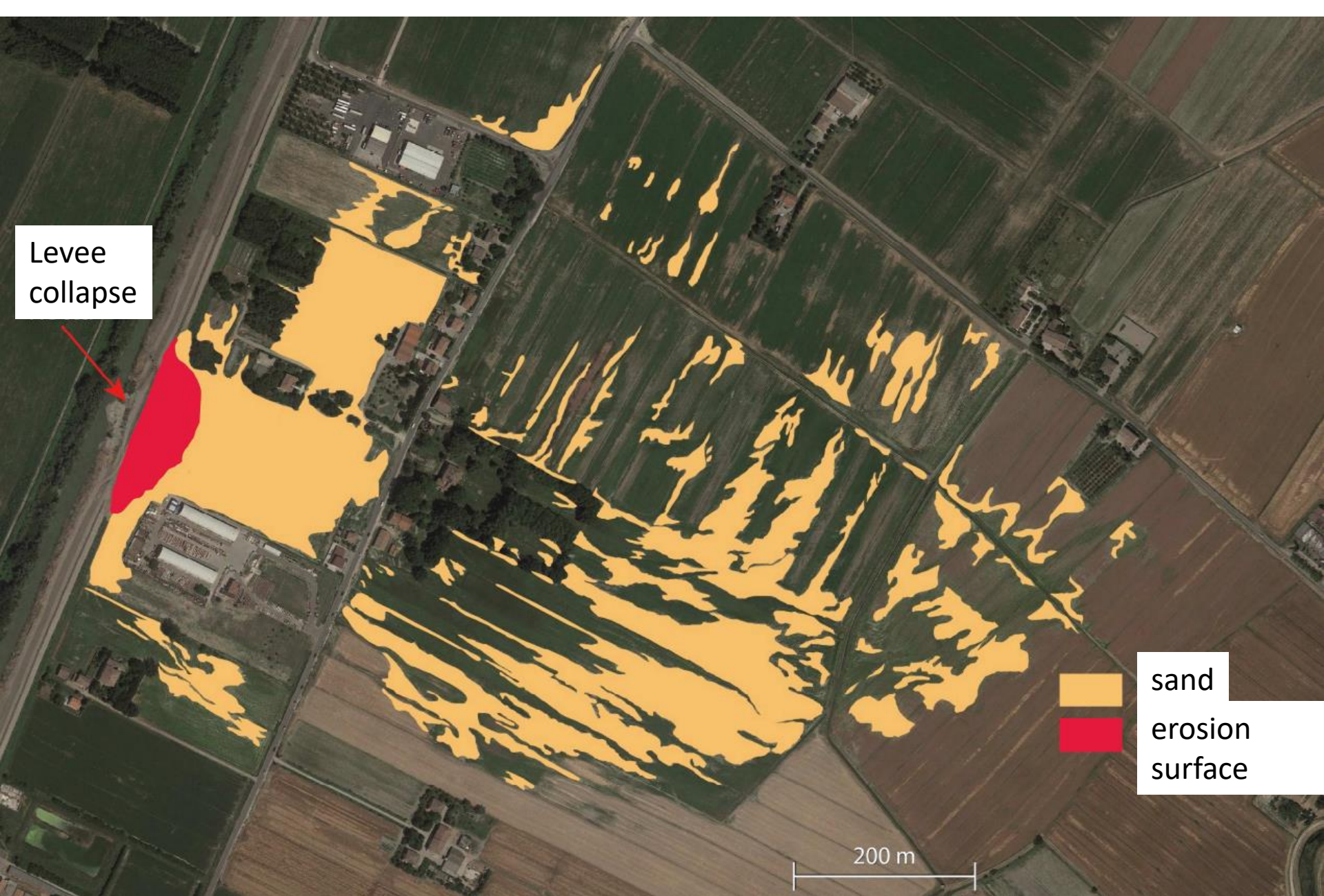
Mud carried in suspension
by turbulent water



Mud and worms

About 8 km away from the
break in the levee

Bastiglia, via Chiaviche, 26/1/2014



Bigi D., Lugli S., Fontana D., 2015, Caratteristiche sedimentologiche dei depositi di ventaglio di rotta prodotti dal Fiume Secchia durante l'alluvione del 19 gennaio 2014. Atti della Società dei Naturalisti e Matematici di Modena, 146, 63-69.

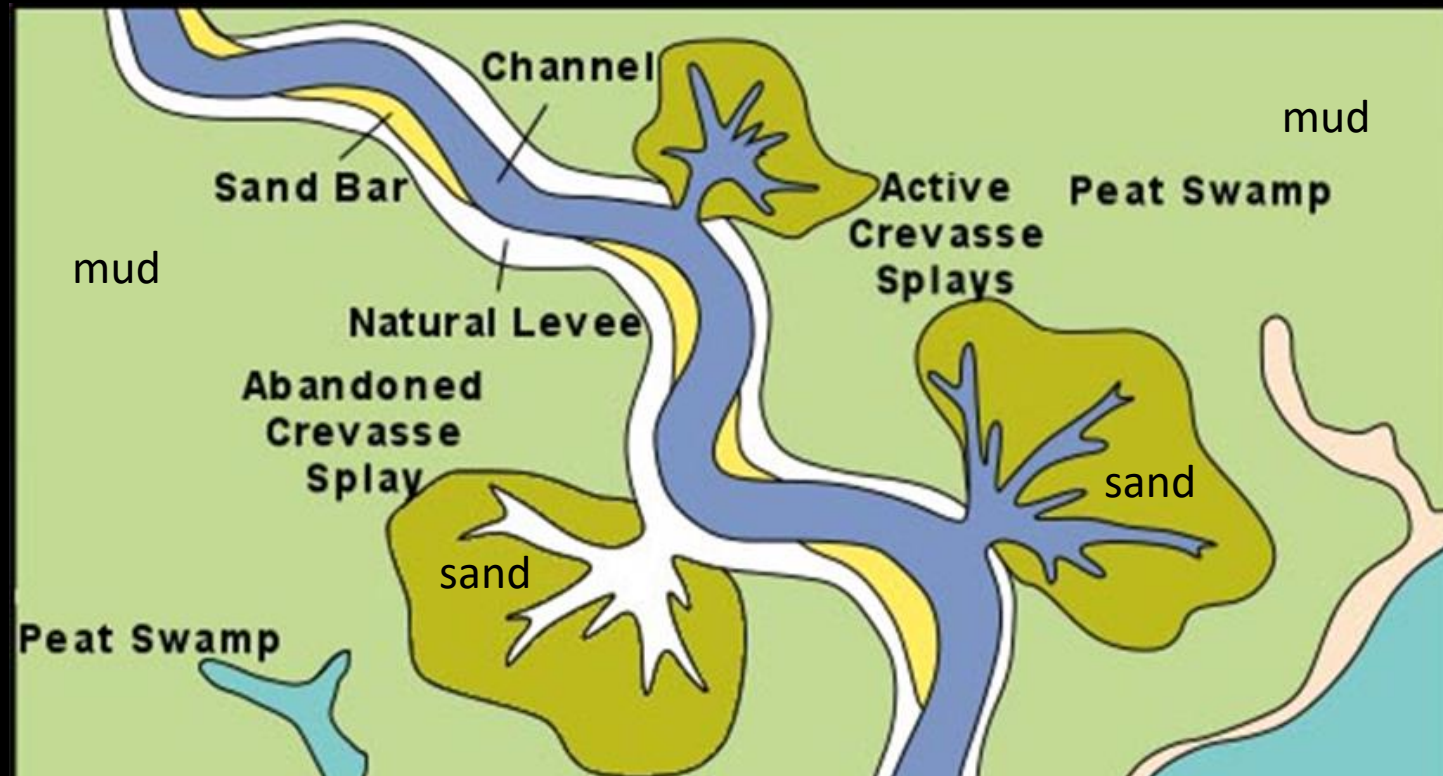


Rhine-Meuse delta: crevasse splay

Crevasse splay

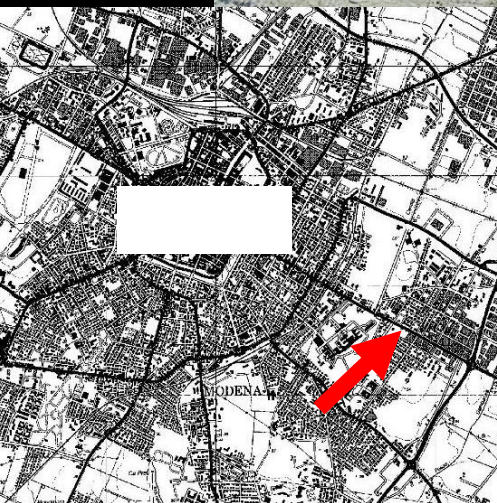
fan-shaped
prism of
sediment

left by a flood
after a break
in the levee



sand close to the river
mud far from the river

La necropoli di Via Emilia Est (Modena)

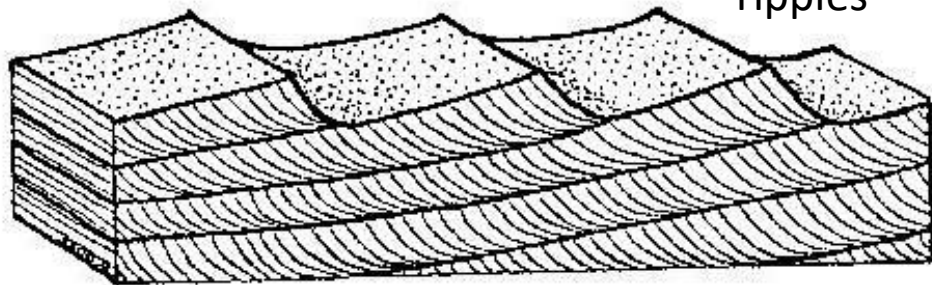




flow



ripples



Present-day ground level

stone

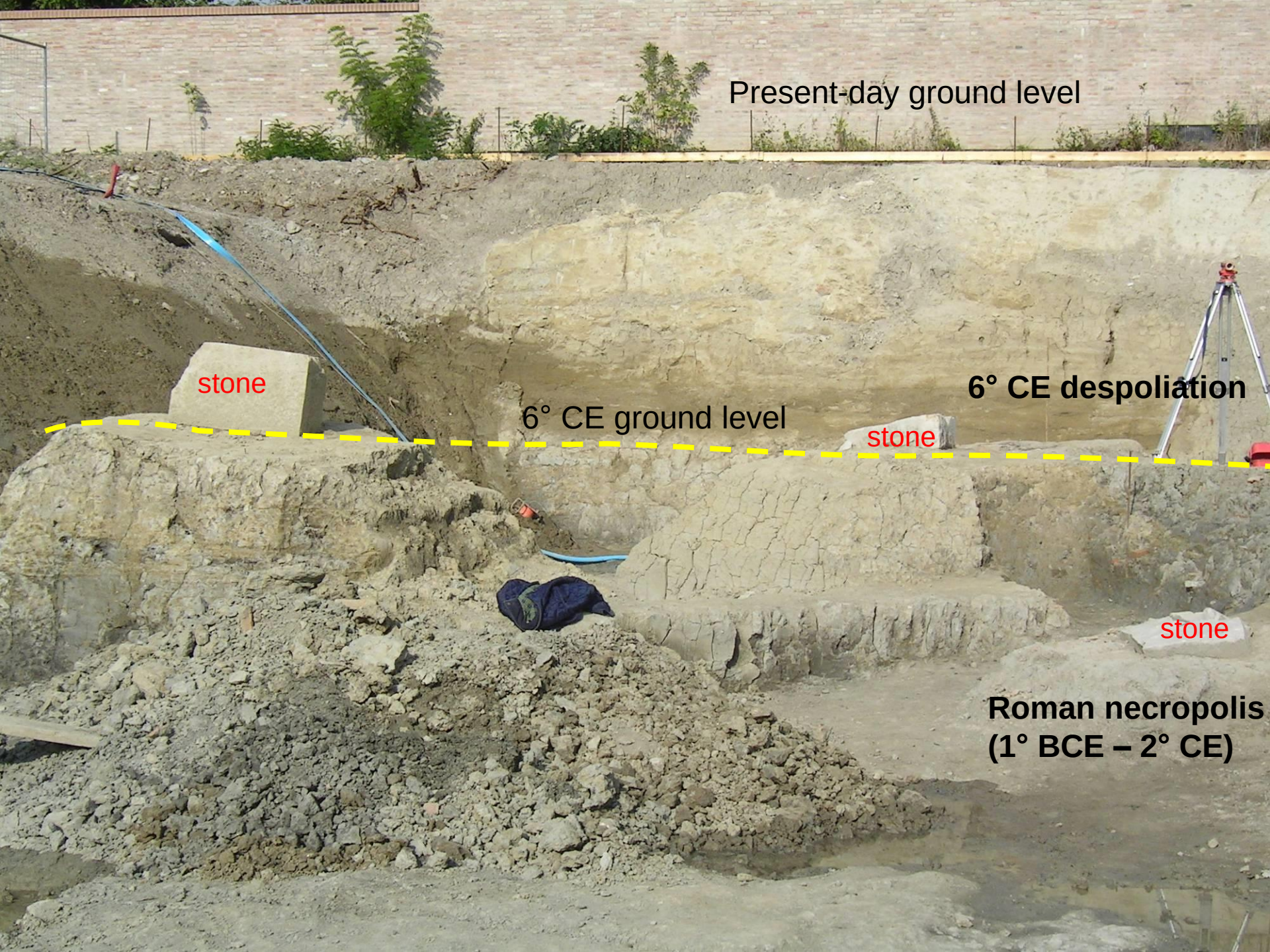
6° CE ground level

6° CE despoliation

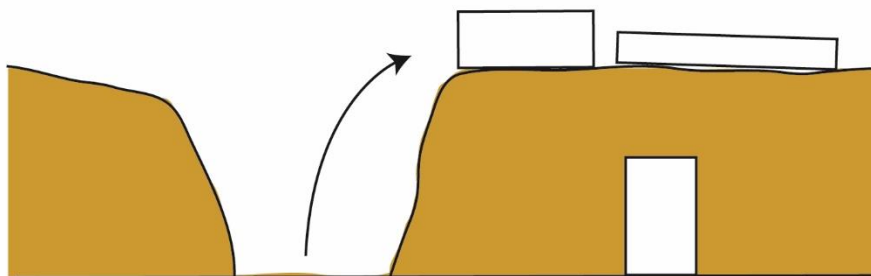
stone

stone

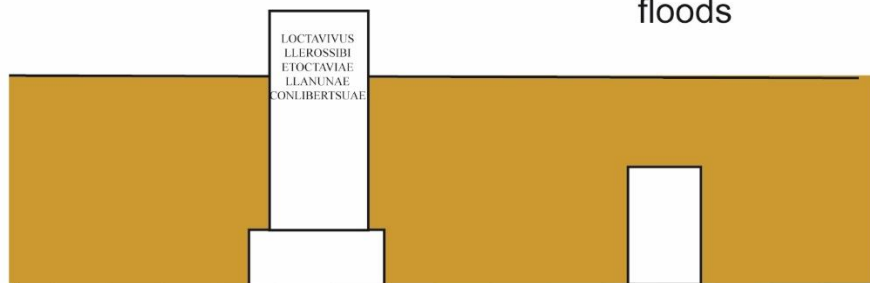
Roman necropolis
(1° BCE – 2° CE)



despoliation



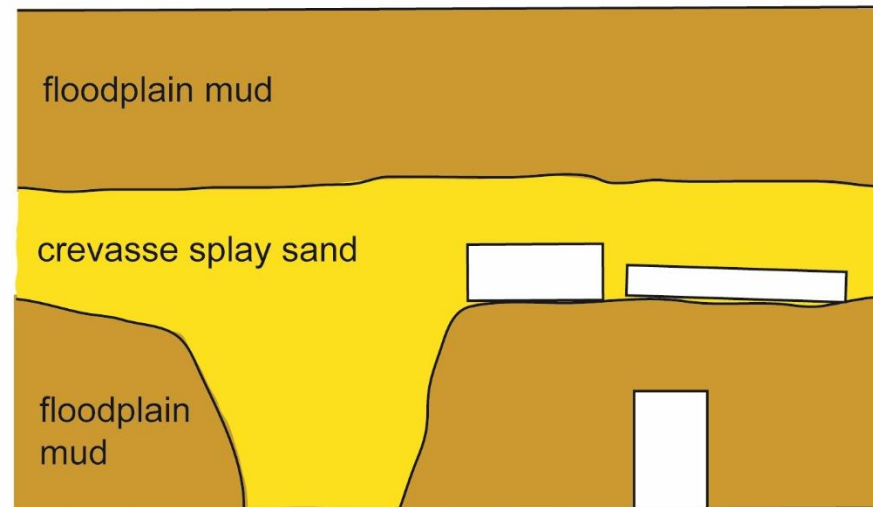
floods



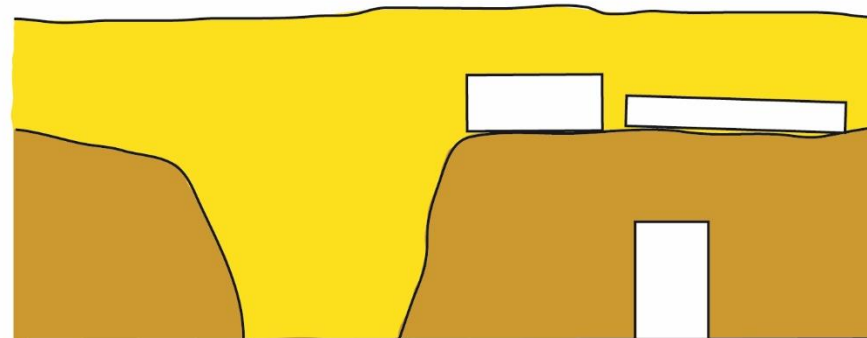
Roman necropolis



today



flood





sand with ripples



Mud with convoluted laminae

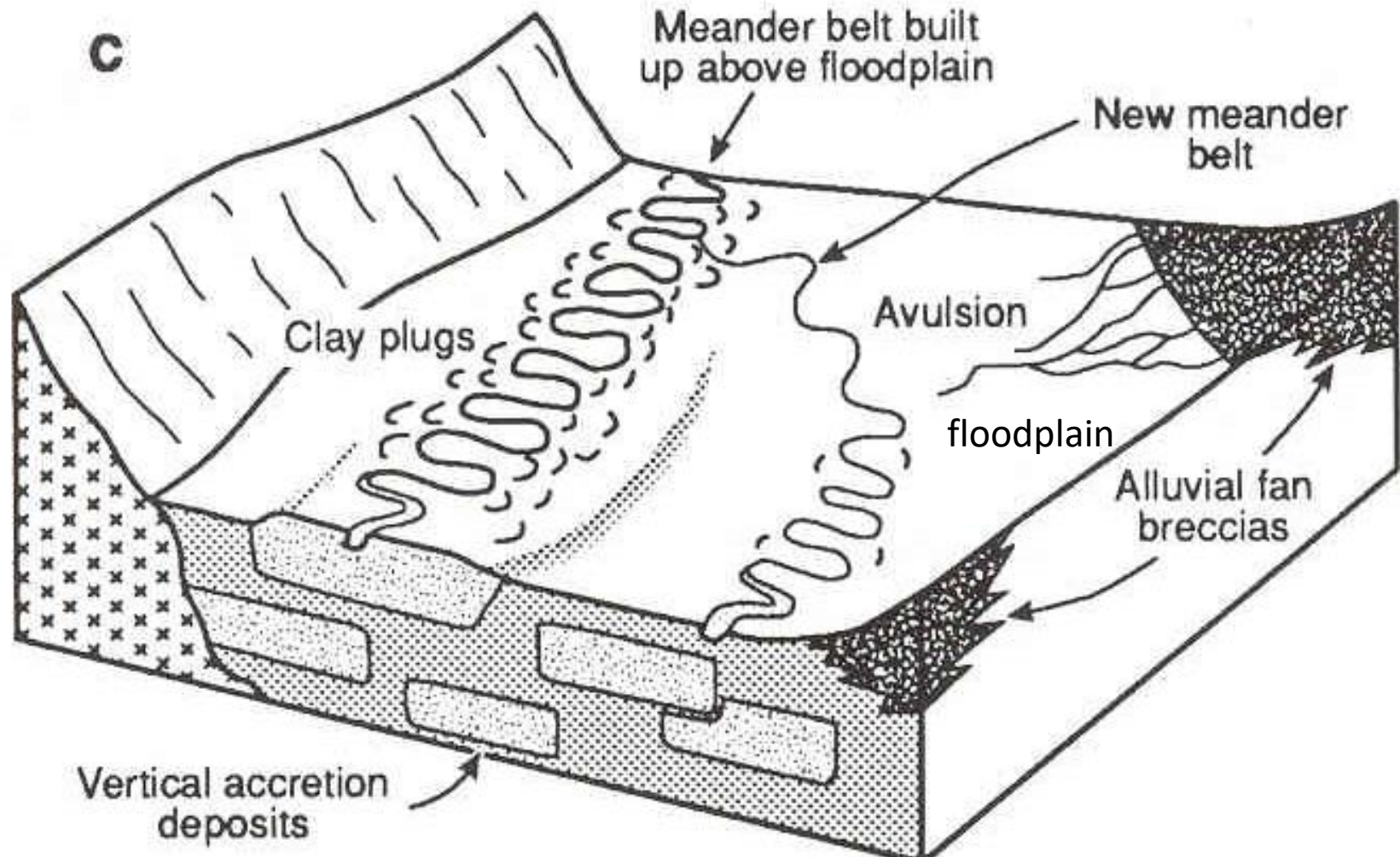


Crevasse splay: close to the river



Floodplain deposits: far away from the river

Avulsion: natural abandonment of a river channel with the formation of a new river channel



Novi Sad
Novi Ark



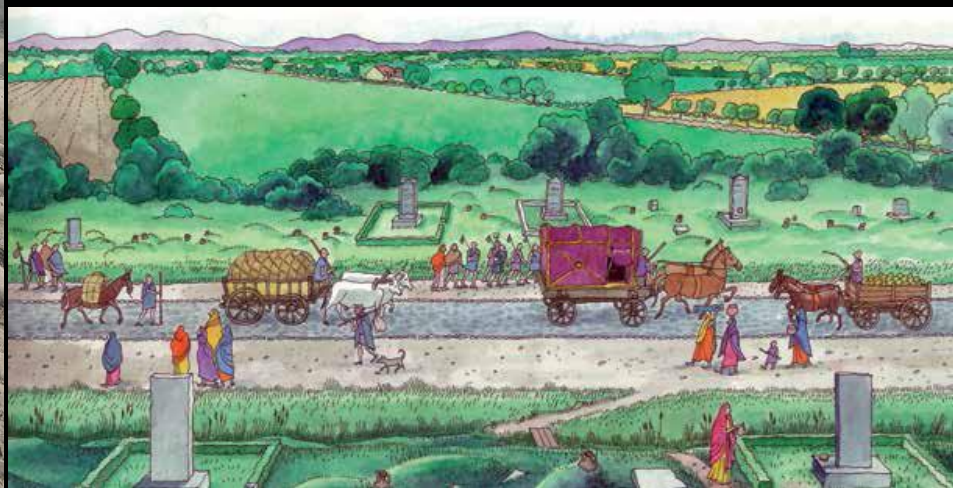
Novi Sad
Novi Ark



Roman amphora

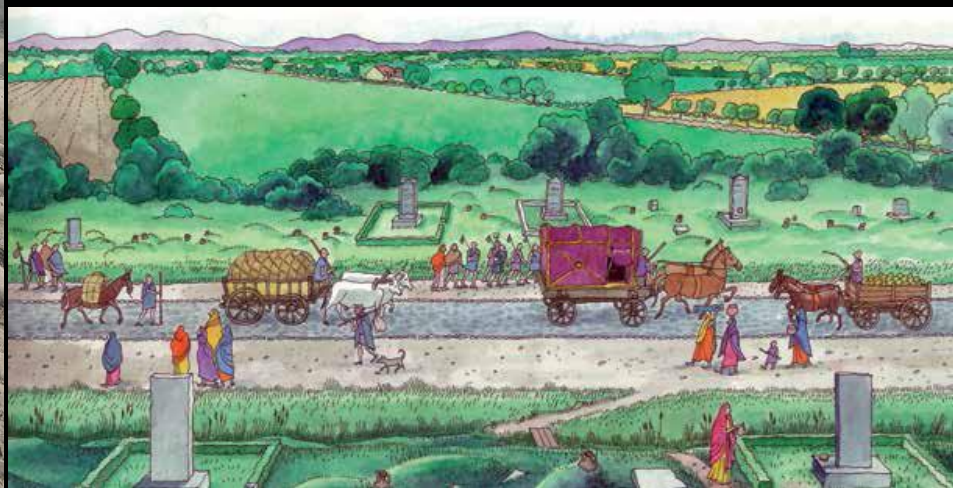


Novi Sad
Novi Ark





Novi Sad
Novi Ark



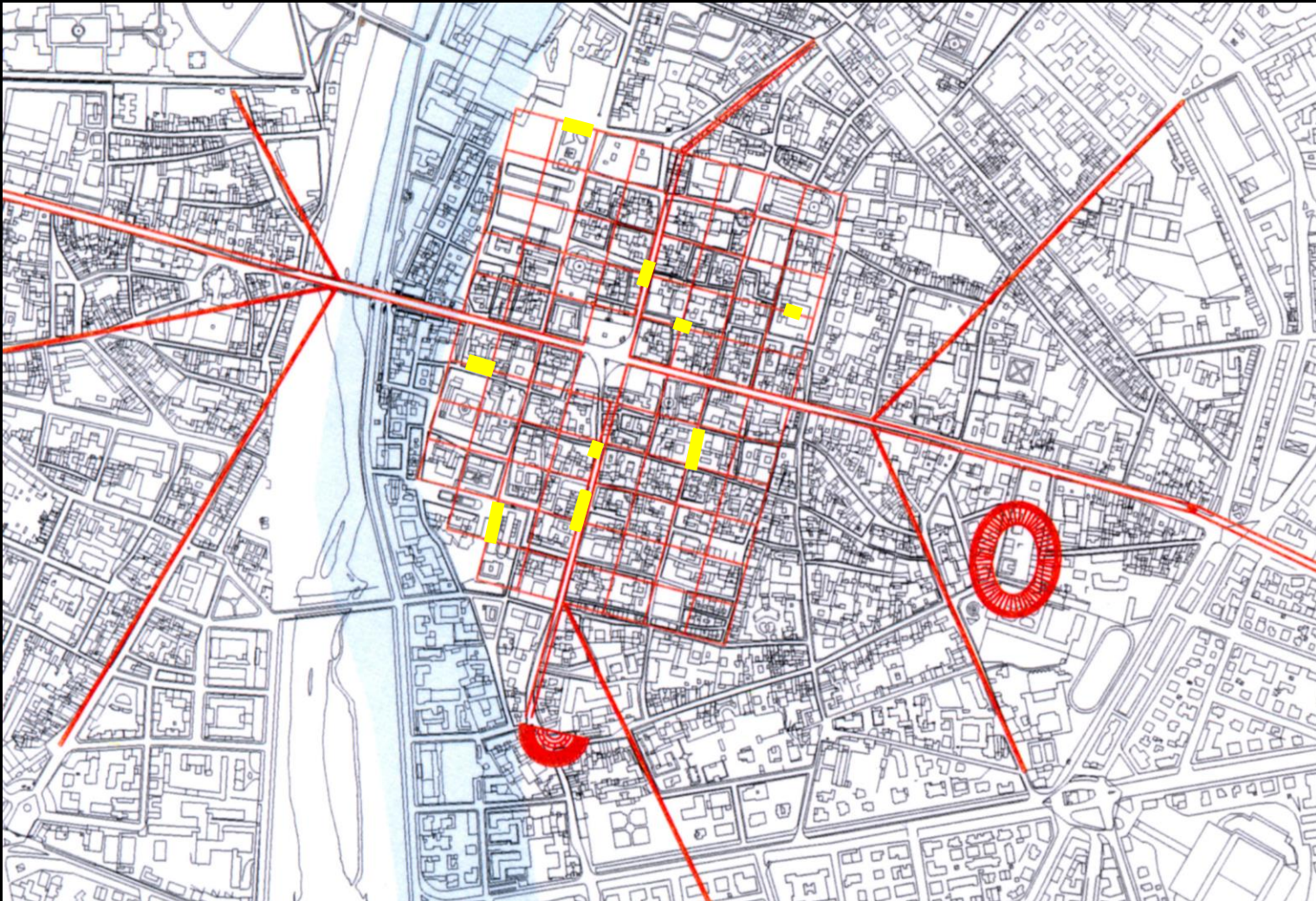


Ara di Vetilia Egloge

Piazza Ghiaia (PR)

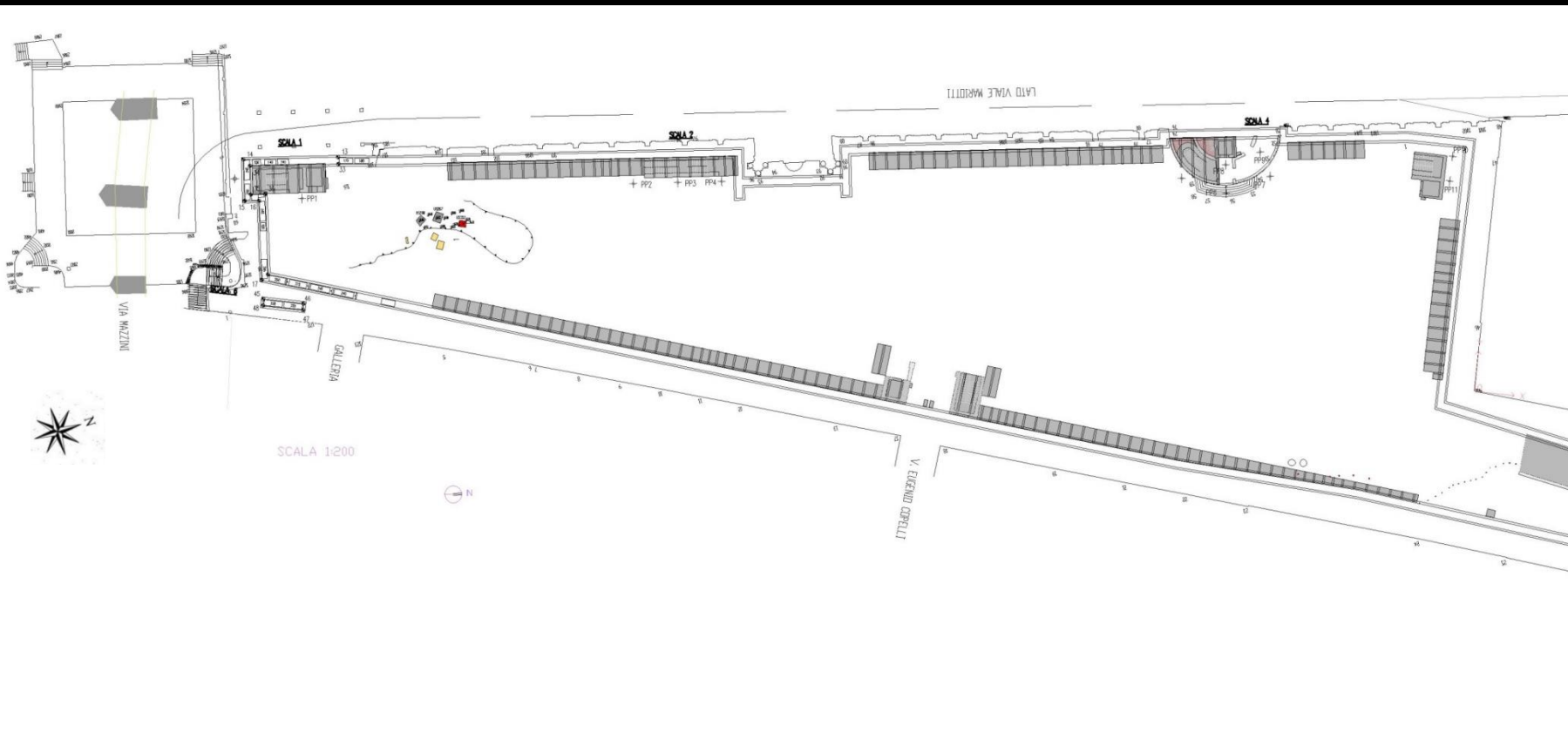


LA FORMA URBIS





Planimetria cantiere I fase



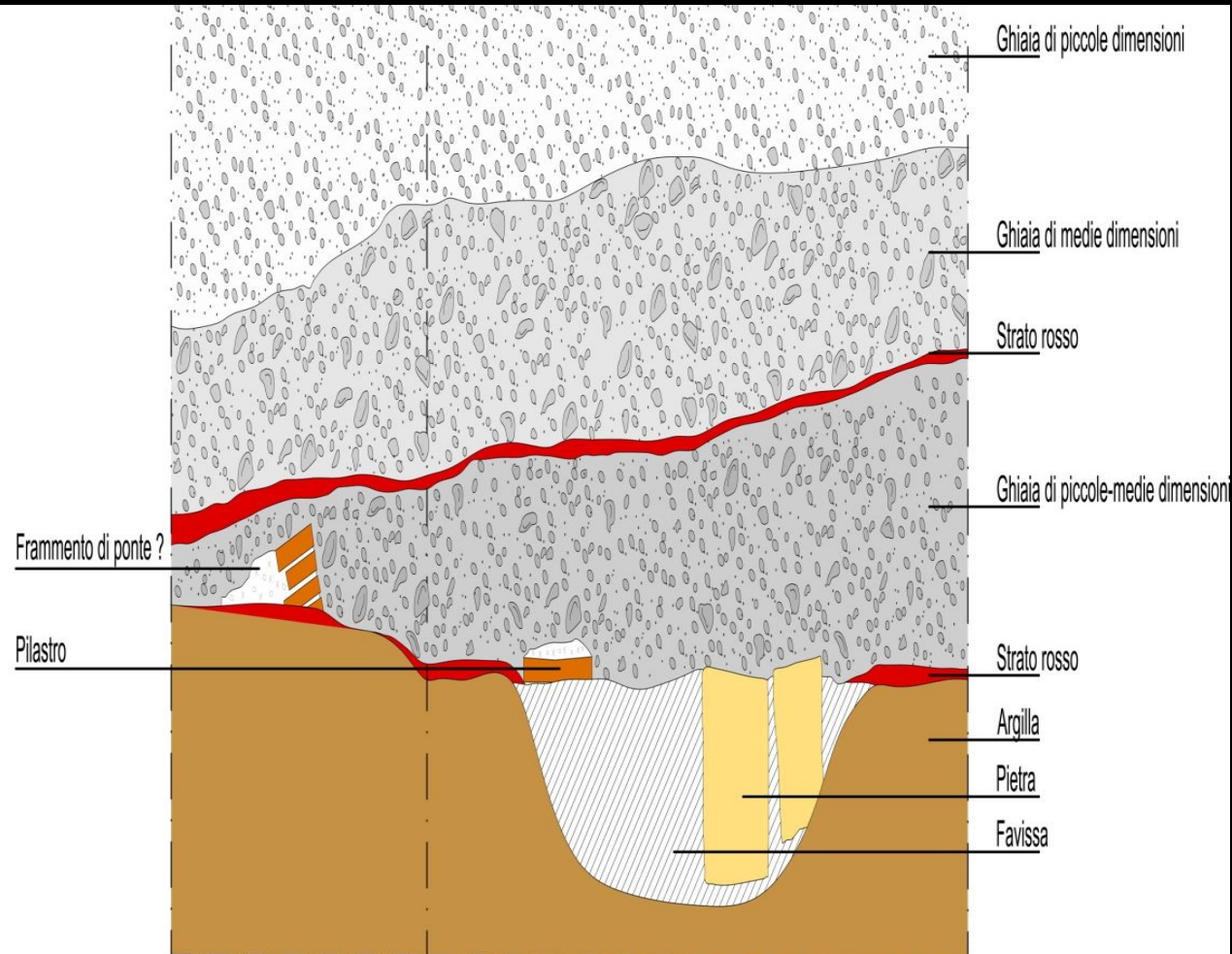
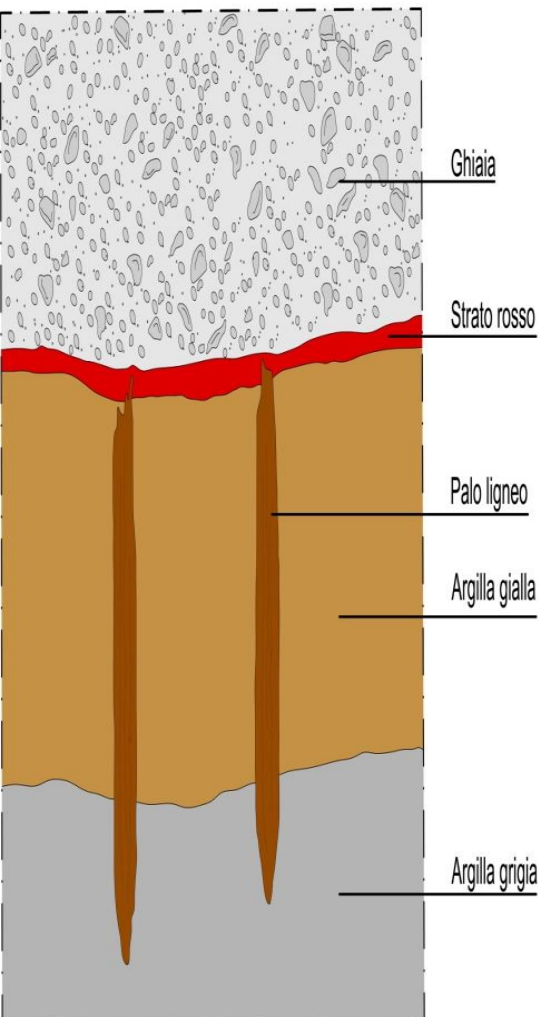
Pali lignei ad andamento NO-SE



Nella parte sud est del cantiere sono emersi una serie di pali lignei infissi in verticale nelle argille, ad andamento nord ovest-sud est.

Sezione stratigrafica

Lo strato rosso, rubefatto dalla presenza di ferro, copre chiaramente i pali.



La favissa

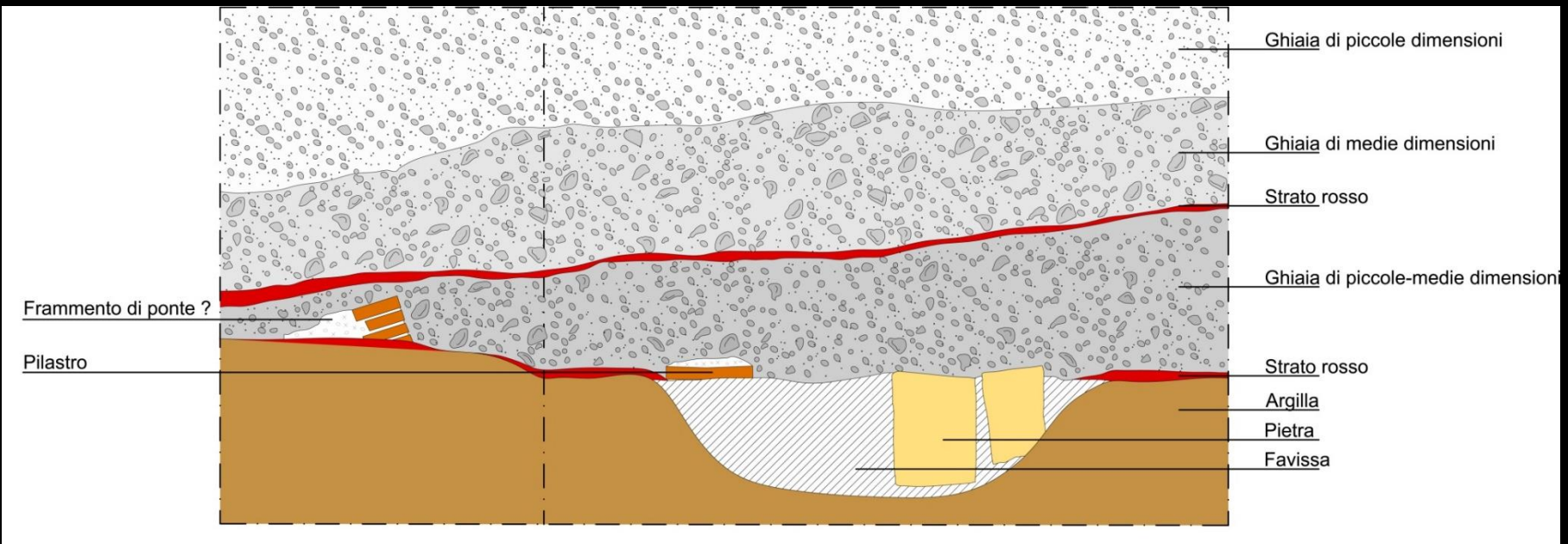


Alla stessa fase può riferirsi una grande buca colmata da numerosi oggetti metallici e monete. Tutti questi oggetti sembrerebbero essere legati ad offerte votive.





Sezione stratigrafica



La favissa appare sigillata da due grosse pietre quadrangolari legate probabilmente alla fase repubblicana e da un pilastro in muratura legato ad una fase successiva.

Gli elementi lapidei



Nei numerosi livelli di ghiaie si sono stati rinvenuti numerosi elementi architettonici e frammenti di statue.

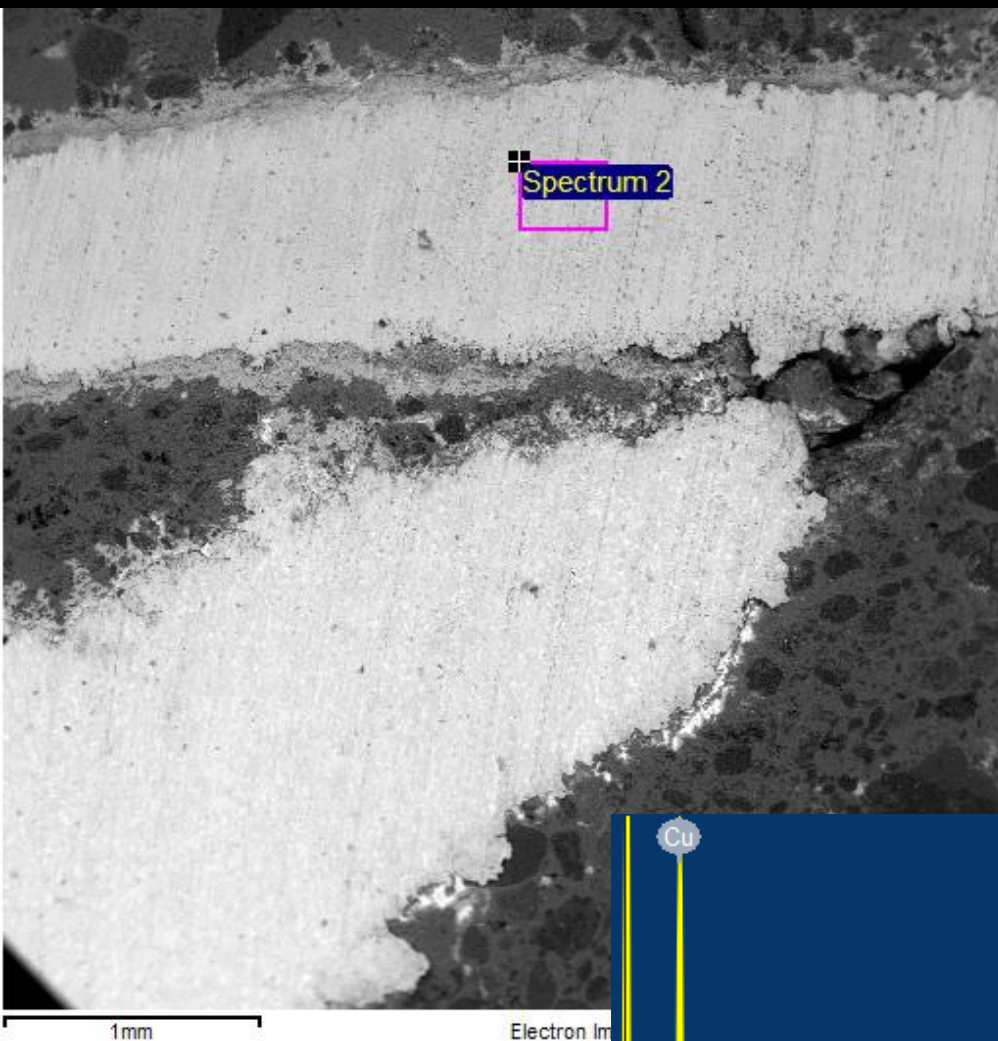




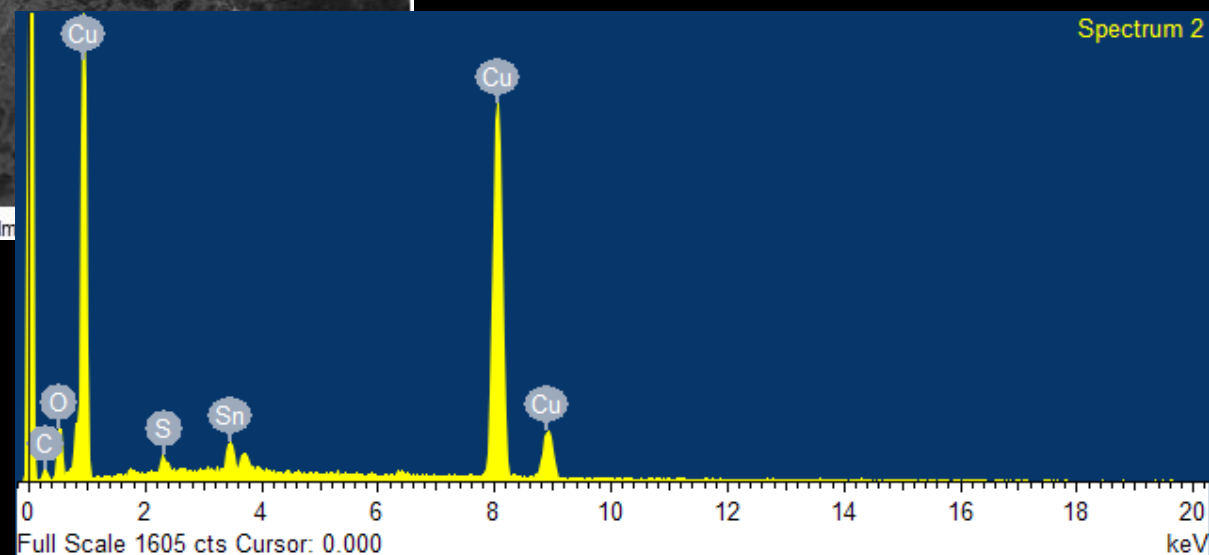


P Ghiaia A





Rame
Ferro
Piombo
Ottone
Bronzo



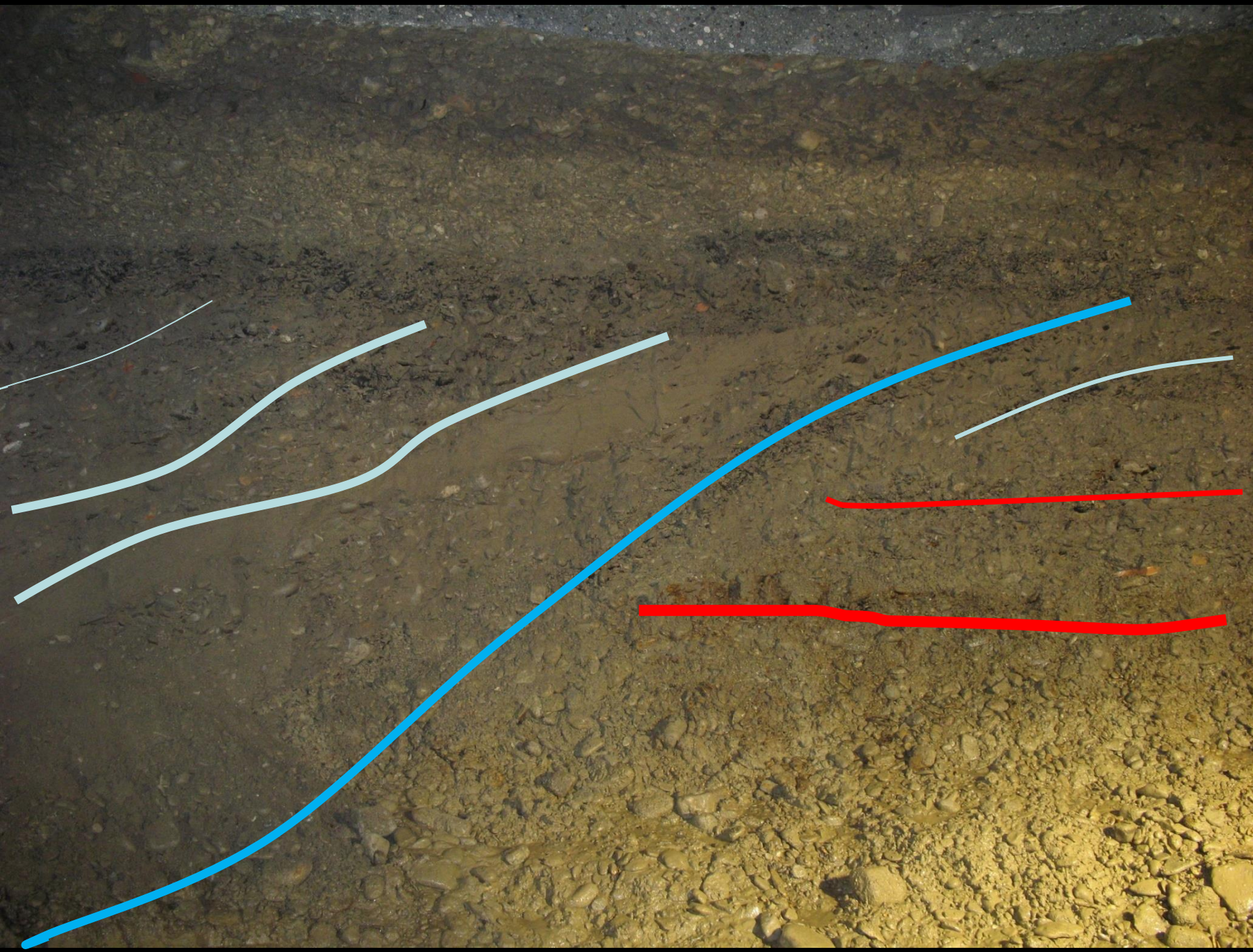
Microscopio
Elettronico
Ambientale
ESEM













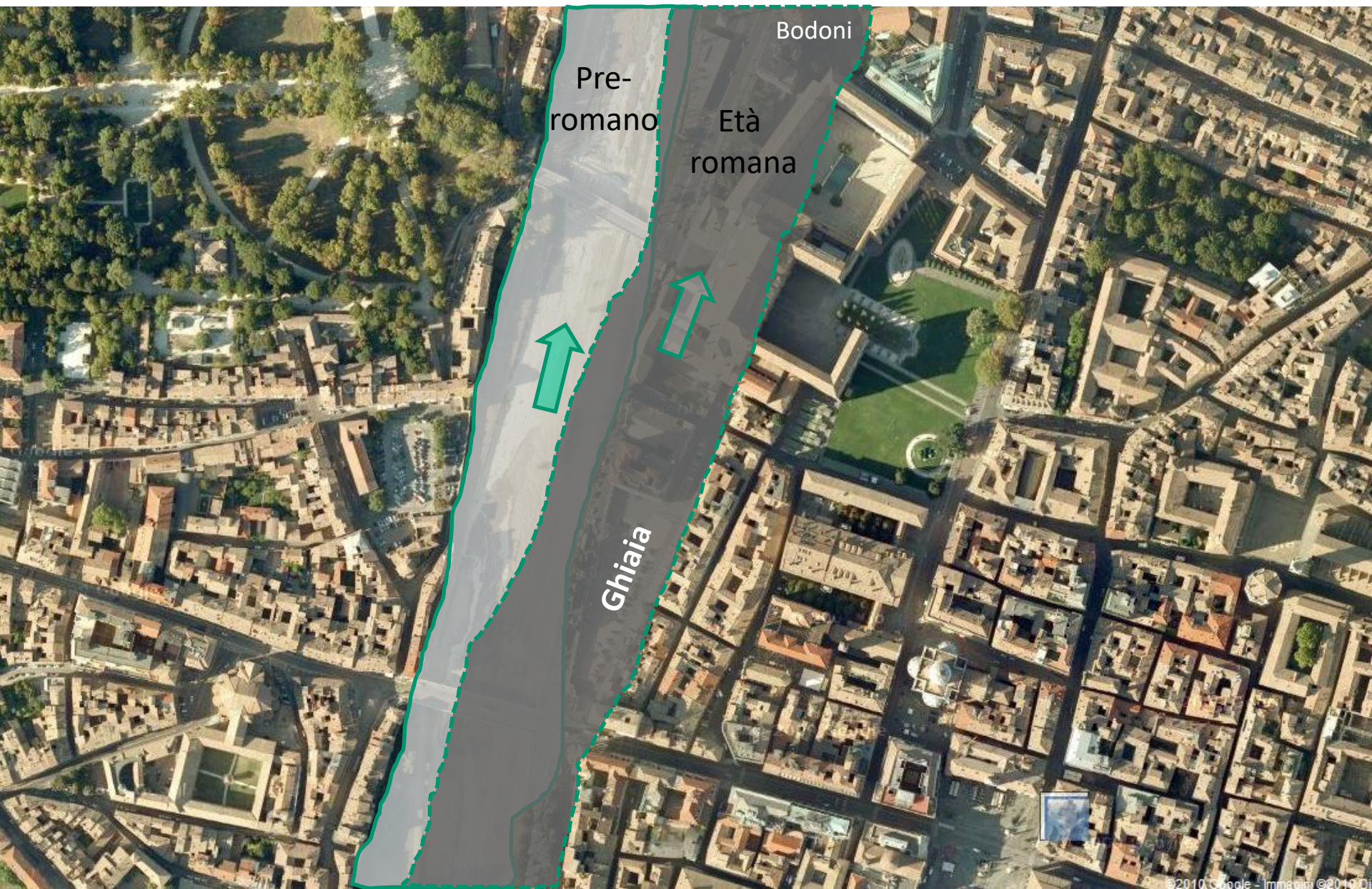


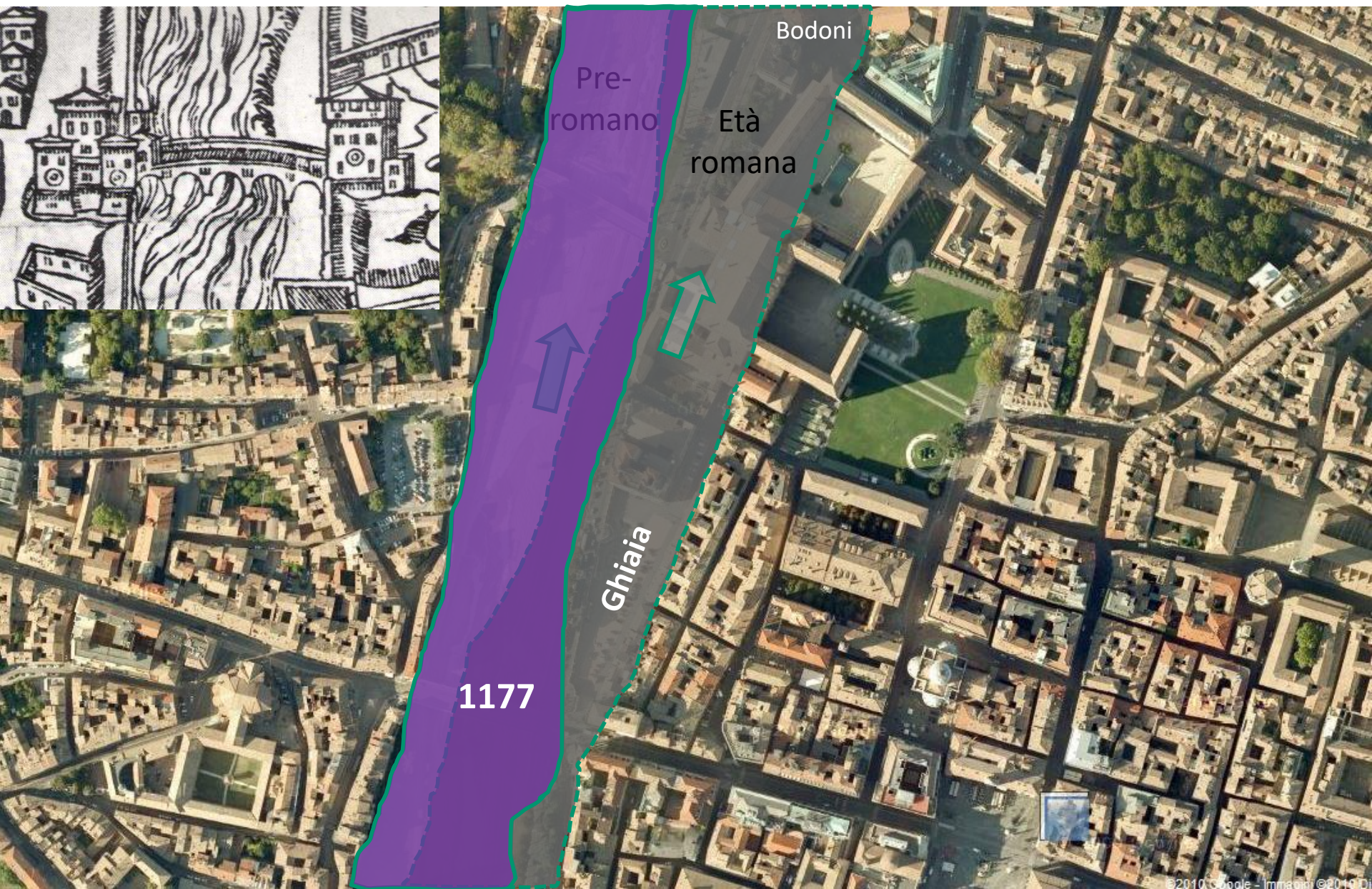


Bodoni

Ghiaia







Bodoni

Pre-romano

Età romana

Ghiaia

1177