Dimensions and Architecture of Submarine 'Lobes' off East Corsica*

By
Mark E. Deptuck[1], David J.W. Piper[2], Bruno Savoye[3], and Anne Gervais[4]

Search and Discovery Article #50124 (2008)
Posted September 30, 2008

*Adapted from oral presentation at AAPG Annual Convention, San Antonio, TX, April 20-23, 2008

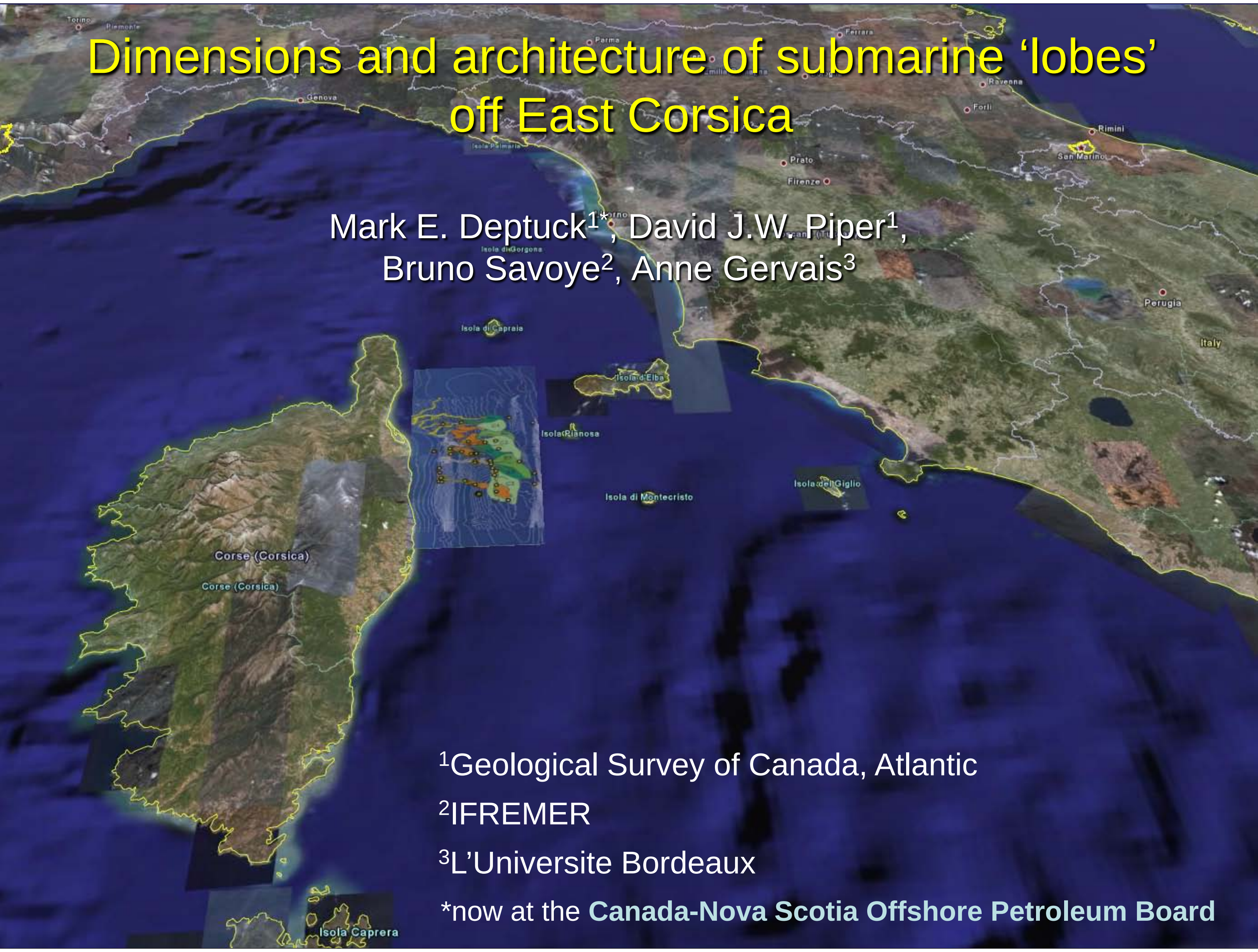
[1]Canada-Nova Scotia Offshore Petroleum Board, Halifax, NS, Canada. (mdeptuck@cnsopb.ns.ca)
[2]Geological Survey of Canada Atlantic, Dartmouth, NS, Canada.
[3]Ifremer, Plouzané, France.
[4]DGO, Bordeaux 1 University, Bordeaux, France.

Abstract

Sandy lobes on submarine fans are sensitive recorders of the types of sediment gravity flows supplied to a basin and are economically important as hydrocarbon reservoirs. Off East Corsica, a wide range of lobe bodies were mapped and measured using a tightly spaced grid of ultra-high resolution boomer profiles. Repeated crossings of lobe bodies were used to measure spatial changes in thickness, width, cross-sectional area, and stratigraphic architecture. Most lobes increase abruptly down-slope to a peak thickness of 8 to 42 m, beyond which they typically show a more gradual decrease in thickness, thinning below seismic resolution or passing into drape on the basin plain. Lobe areas range from 3 to 70 km^2 and total lengths from 2 to 14 km, with the locus of maximum sediment accumulation from 3 to 28 km from the shelf-break. Lobes vary from small, simple single-storey bodies to large complex multi-storey bodies. What accounts for this range in lobe location, dimensions, and complexity? Flume tank experiments and numerical models show that variations in flow properties (e.g., volume, duration, grain size, sediment concentration, and velocity) influence the length, width, thickness, and composition of lobe-building beds. Knowledge of sea level position, triggering mechanisms for flows, and sediment source character may help constrain flow properties. The final architecture of lobes constructed by multiple flows, however, also reflects several other interrelated factors including: a) the number/frequency of flows, and their variation through time, b) gradient change and seafloor morphology, c) lobe lifespan prior to avulsion or abandonment, and d) feeder channel geometry and stability. This presentation explores the factors important in controlling lobe location, dimensions and architecture, and the challenges in determining which factors are most important.

Dimensions and architecture of submarine 'lobes' off East Corsica

Mark E. Deptuck[1*], David J.W. Piper[1],
Bruno Savoye[2], Anne Gervais[3]

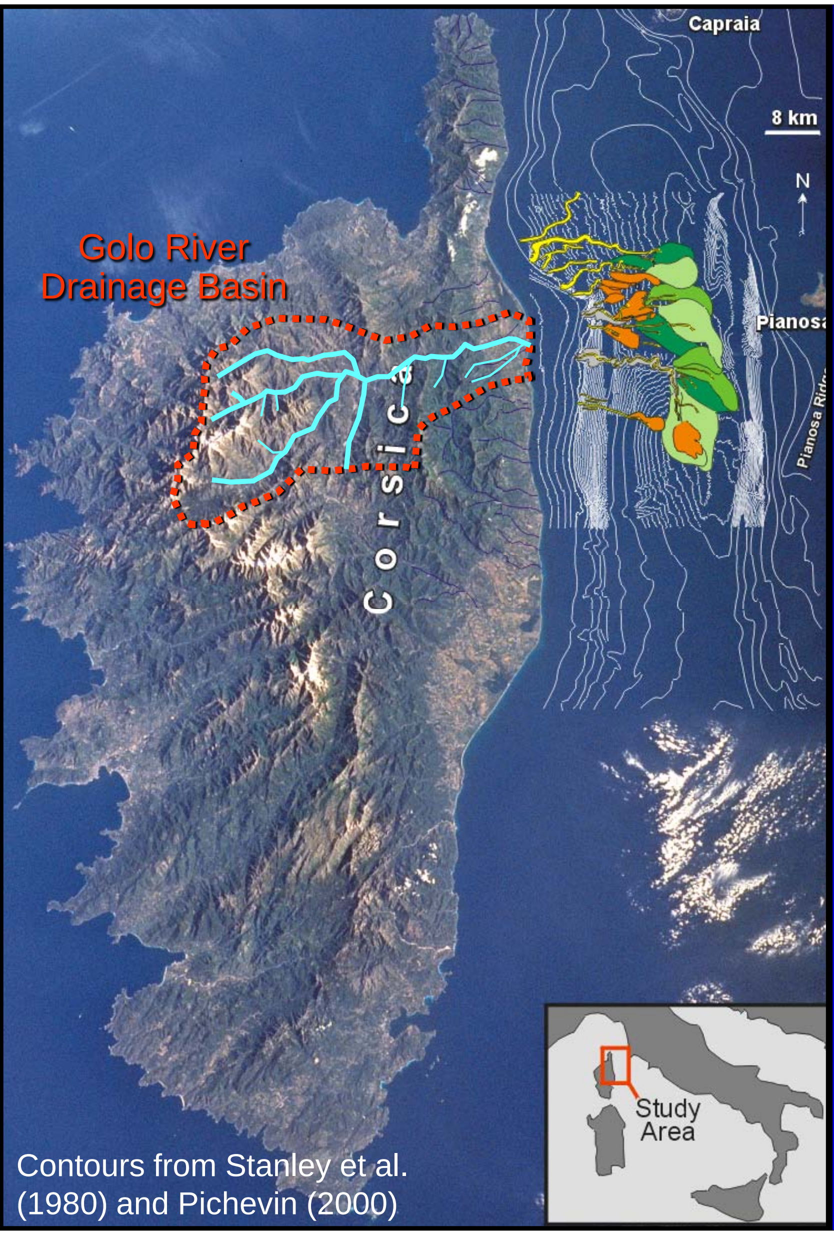


[1]Geological Survey of Canada, Atlantic

[2]IFREMER

[3]L'Universite Bordeaux

*now at the **Canada-Nova Scotia Offshore Petroleum Board**



Study Area

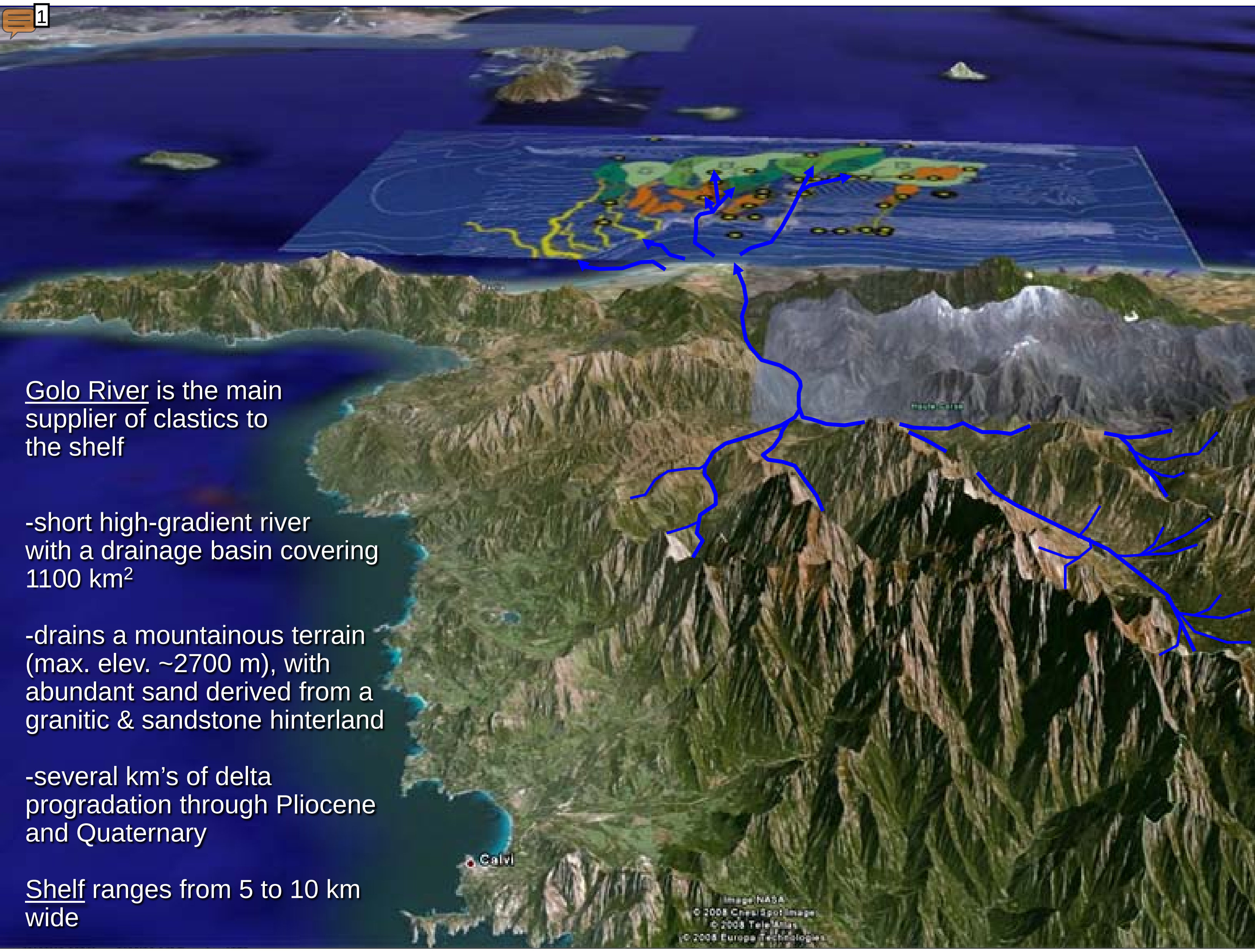
- Corsican Trough - a confined depression flanking the eastern margin of Corsica with a maximum water depth of 900 m

- underlying structure is a large extensional graben initiated in the late Miocene (after a period of mountain building)

Joint investigation by the Geological Survey of Canada (Atlantic) and IFREMER

- 1300 line km of tightly spaced profiles covering the outer shelf to the basin floor were collected

- Huntec DTS profiles were used to map a series of inter-fingering submarine fans of various sizes in the upper 100 m of section
  => the 'Golo fan system'


Golo River is the main supplier of clastics to the shelf
-short high-gradient river with a drainage basin covering 1100 km²
-drains a mountainous terrain (max. elev. ~2700 m), with abundant sand derived from a granitic & sandstone hinterland
-several km's of delta progradation through Pliocene and Quaternary
Shelf ranges from 5 to 10 km wide
Calvi
Image NASA
© 2008 Cnes/Spot Image
© 2008 Tele Atlas
© 2008 Europa Technologies

Notes by presenter

The Golo River winds its way through the mountainous terrain until it reaches the coastal plain where it discharges a mixture of sand and mud on a relatively narrow shelf.

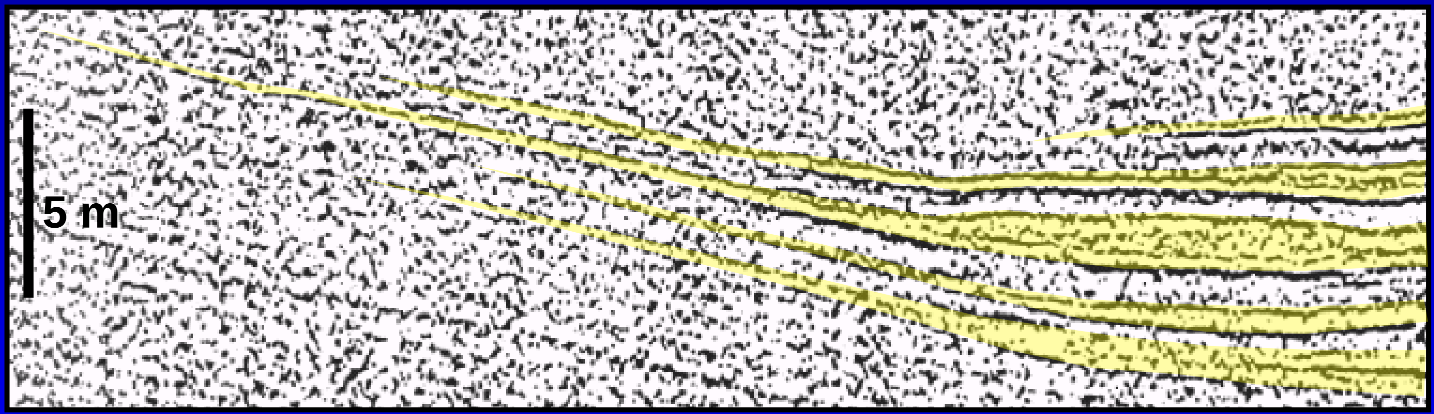
Outline

1. Huntec deep-tow seismic system
2. Why is understanding lobe dimensions and architecture important?
3. Regional profiles across the margin
   => from <u>shelf break</u> to <u>distal basin floor</u>
4. Observations - variations in lobe measurements off East Corsica
5. Potential controls of lobe dimensions

Huntec deep-tow seismic (DTS) system

- Huntec ‘fish’ towed at depths ranging from 40 to 400 m below the sea surface
- Frequency range from 900 to 7000 Hz
- Vertical resolution about 0.5 m!
- Penetration up to 100 m in muddy sections, to as little as 10 m in coarse sand or gravelly sections

The Huntec™ deep-tow system has helped bridge the "resolution gap" between outcrop and traditional fan studies, and is particularly useful when combined with lower resolution tools (e.g. 2-3 m resolution sparker profiles – Gervais et al.) and piston cores.



Upper Eocene Annot Sandstone, SE France (photo by Ru Smith)

So why do we care about lobe <u>dimensions</u> and <u>architecture</u>?

We are quickly discovering that many 'lobes' are <u>NOT</u> simply sheets of sand. Their architecture is <u>complex</u> with many potential <u>baffles</u> and <u>barriers</u> to fluid flow. Studying **lobe architecture** in modern systems helps us understand…

-how to correlate sand bodies from well to well
-hierarchy of potential baffles/barriers to fluid flow
-level of architectural complexity needed to build reservoir models

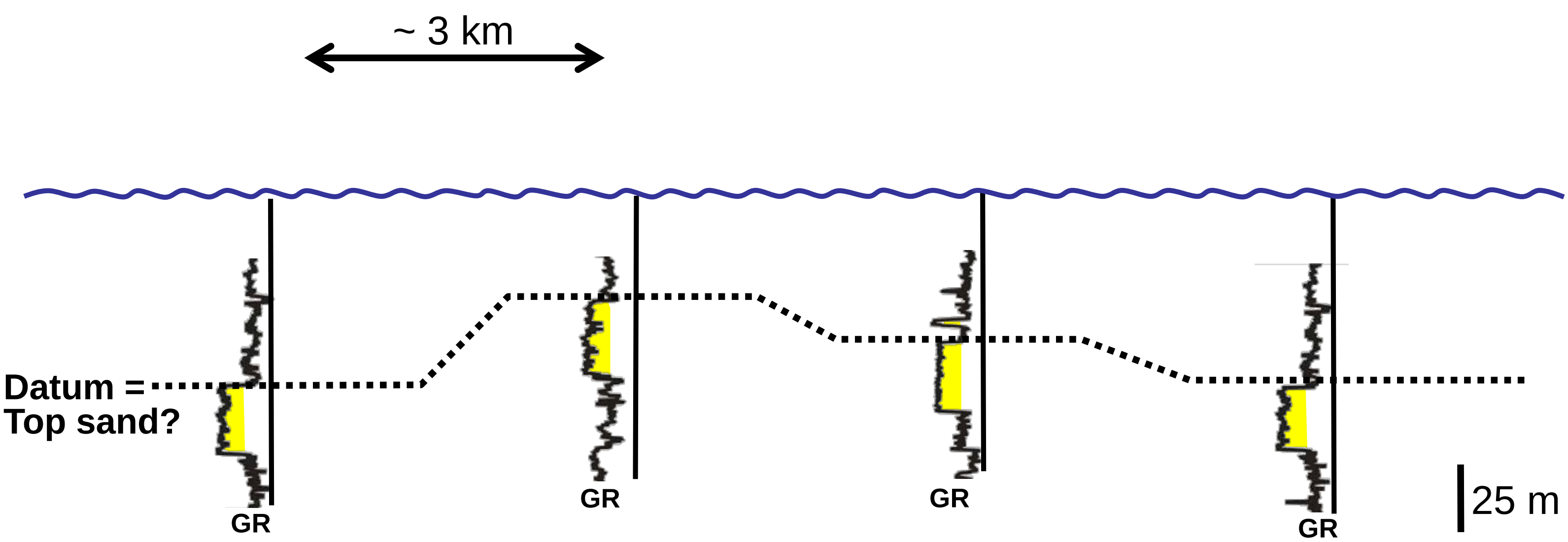
Compared to channel dimensions, knowledge of <u>**'lobe' dimensions**</u> is poor. Dimensional data for lobes provide…

-<u>quantitative</u> information that helps predict the areal extent and thickness of reservoir/aquifer away from the borehole
-quantitative justification for reservoir models
-knowledge that helps constrain/guide correlations from one well to another

Consider the following example….

1

How would you correlate these GR logs?



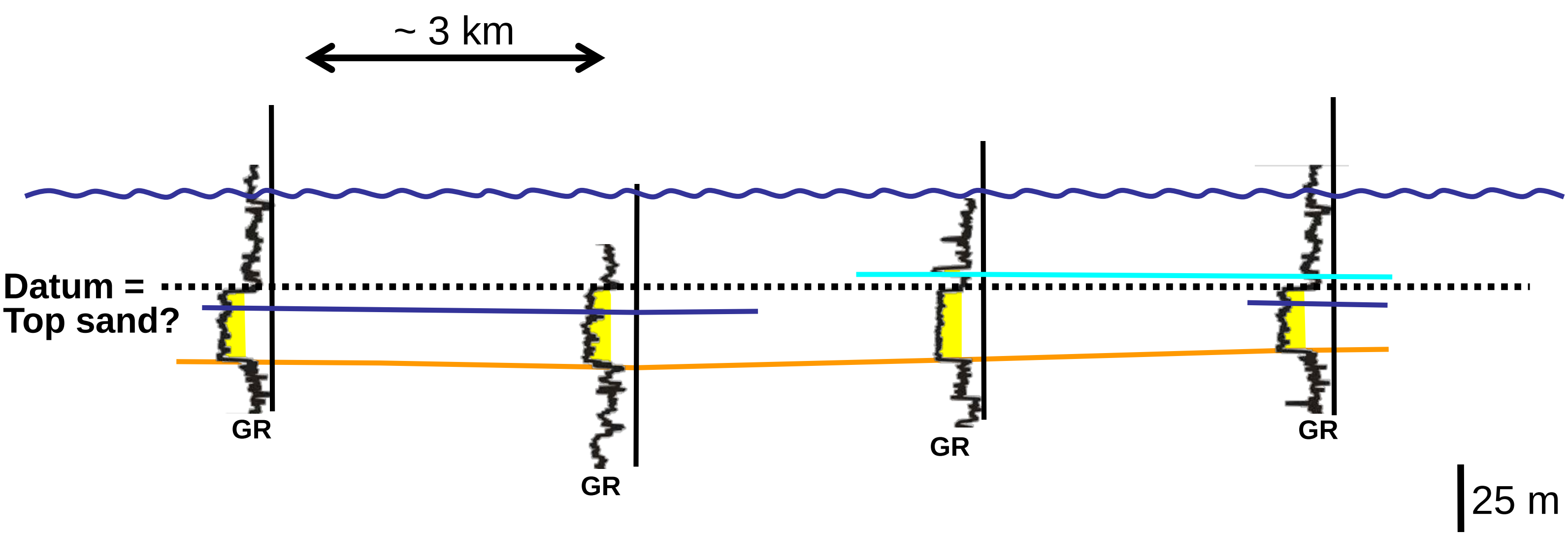
Four wells, each penetrates a 25-30 m thick 'blocky' sand
Distance between wells = ~ 3 km

These logs are from small, sandy Paleocene 'basin-floor fans' in the Jeanne d'Arc Basin, offshore Eastern Canada

Notes by presenter

Here we have the GR logs from 4 deepwater wells – each penetrates a 25-30 m "blocky" sand and are separated by 3 km. So the question is, how would you correlate these wells?

How would you correlate these GR logs?

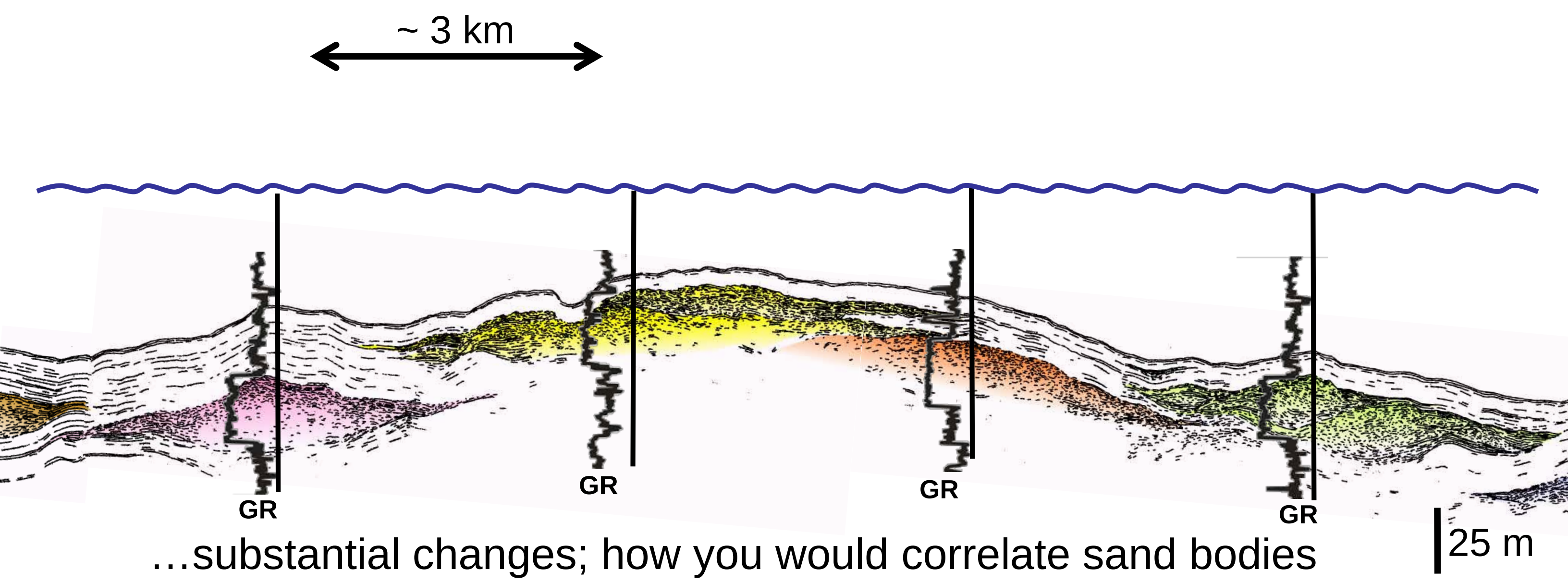


Four wells, each penetrates a 25-30 m thick 'blocky' sand
Distance between wells = ~ 3 km

Notes by presenter

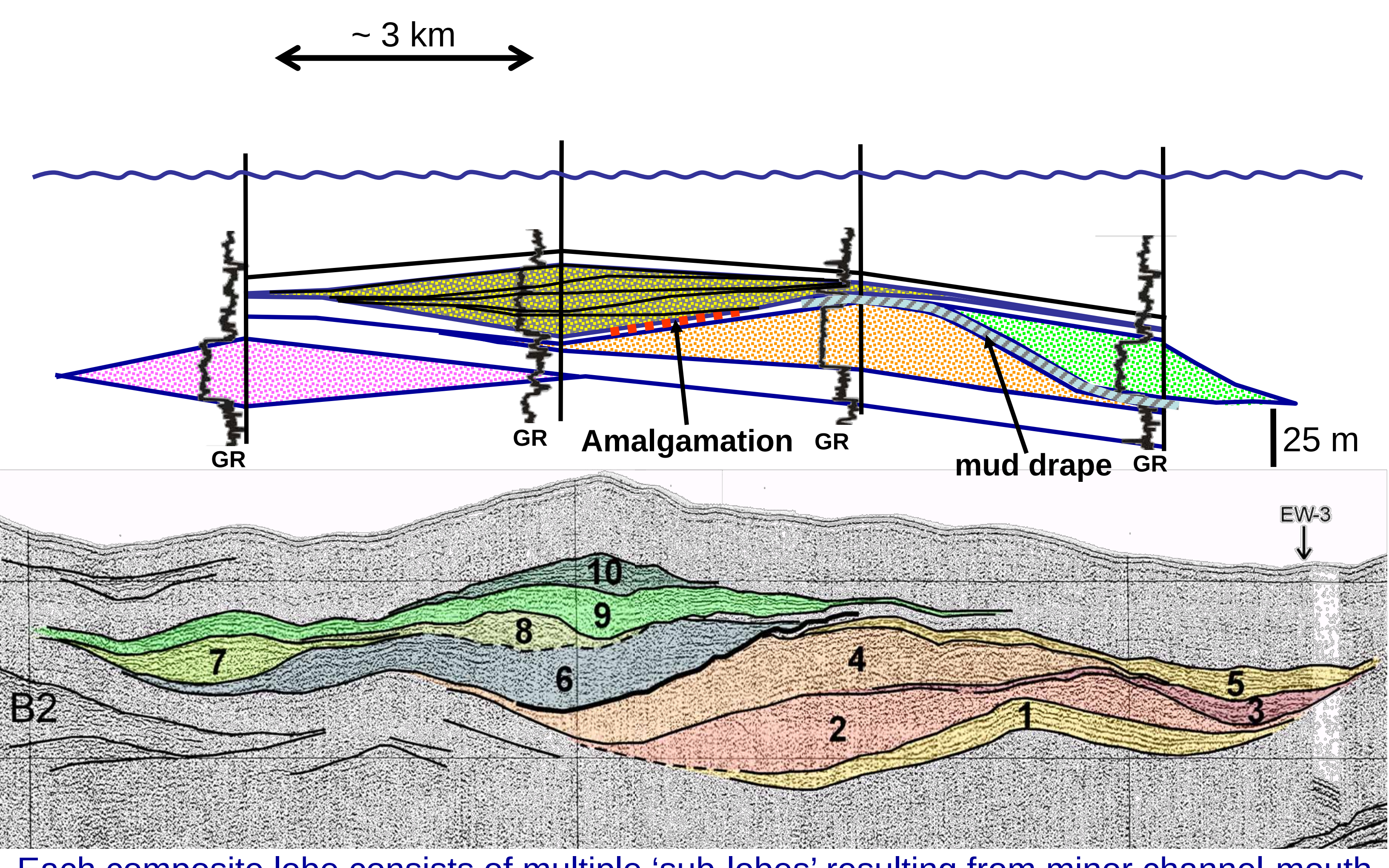
A few years ago, before I started studying lobes in high res data, I would have had no problem with a correlation like this!

Correlation of 4 wells with the same spacing off East Corsica…



…substantial changes; how you would correlate sand bodies

Using East Corsica lobes as a template….

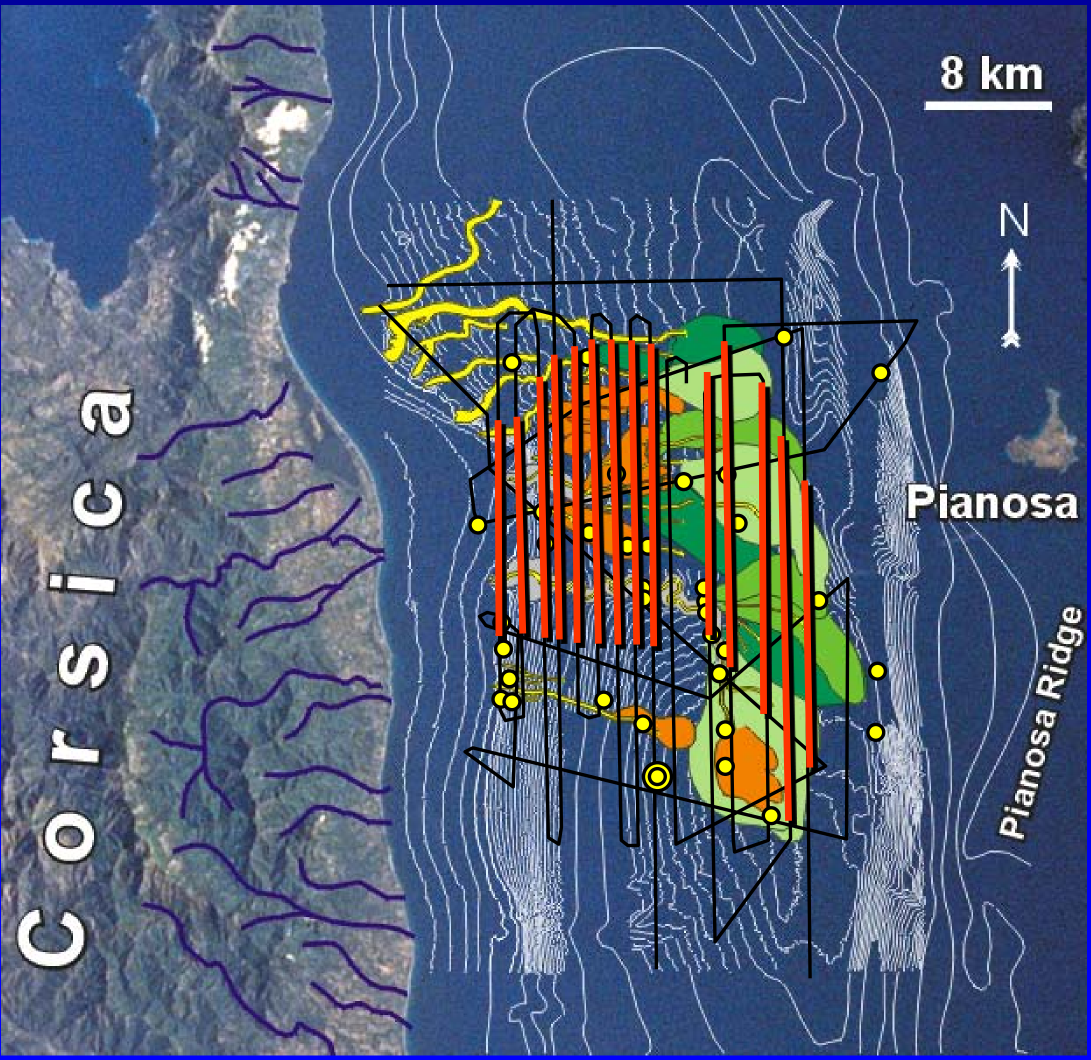


Each composite lobe consists of multiple 'sub-lobes' resulting from minor channel-mouth avulsions or changes in the types of sediment gravity flows

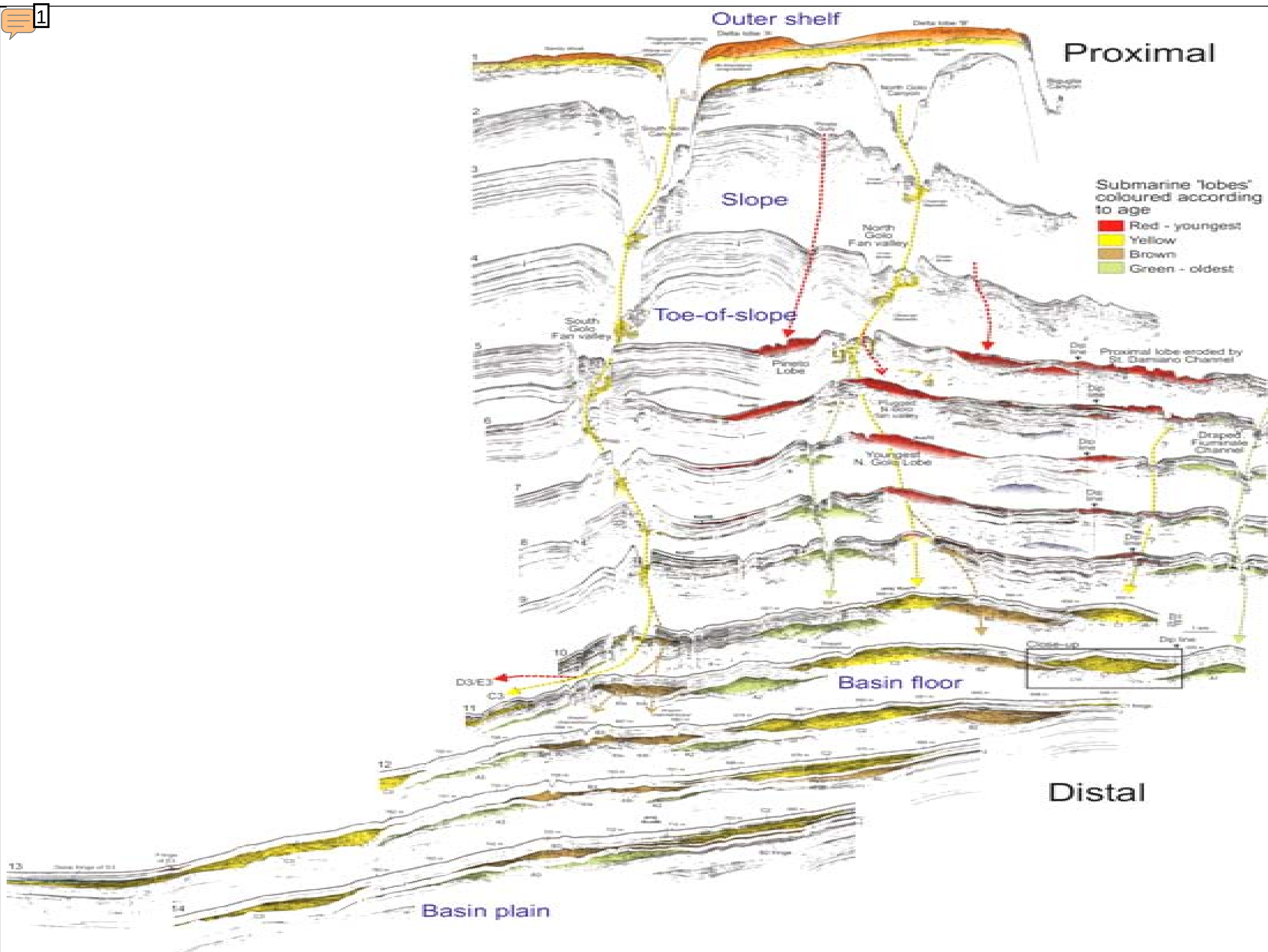
Notes by presenter

Some aspects may improve connectivity between 'lobe' bodies (e.g., erosion), while other aspects may hinder fluid flow, for example if bodies are separated by shale drapes during periods of abandonment or when active deposition is focused elsewhere. May have multiple hierarchial scales of drape, as seen here. Is it reasonable to correlate a single sand body more than 3 km? More dimensional information from a wide range of fan systems will help answer this question…
...but for East Corsica the answer is no (at least not without a substantial change in thickness). For other fan systems, that question is still up in the air.

Proximal to distal strike lines



Cores from **Anne Gervais** Ph.D. dissertation

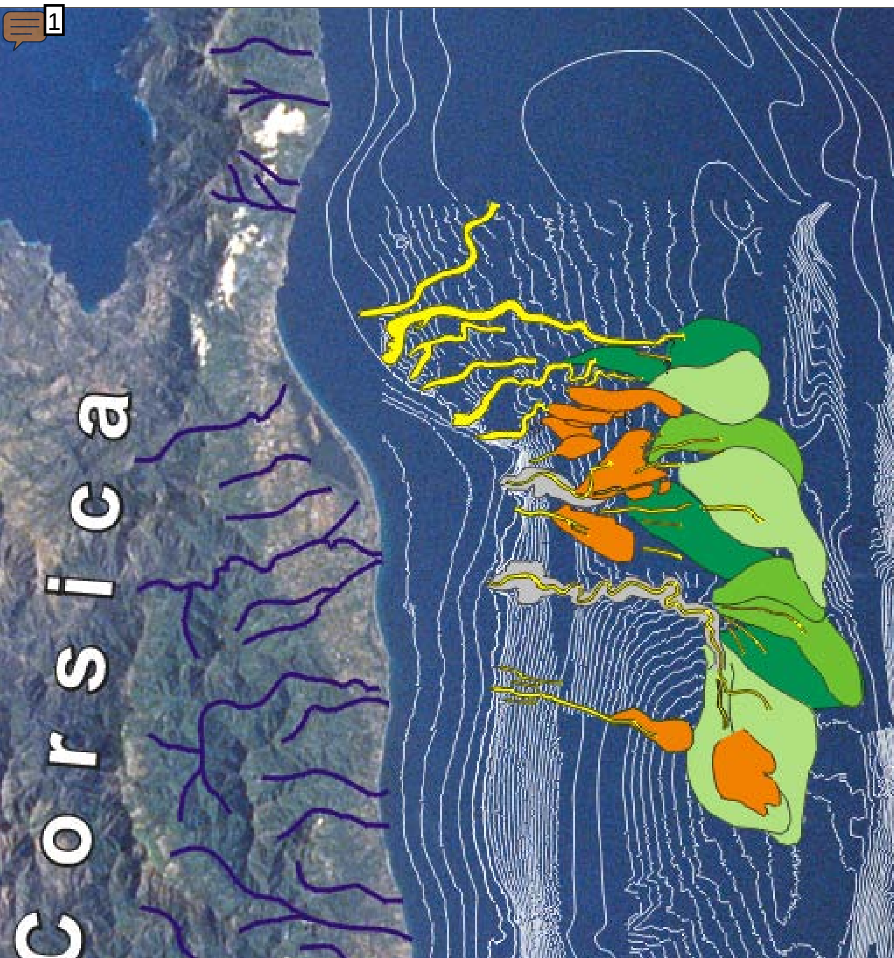


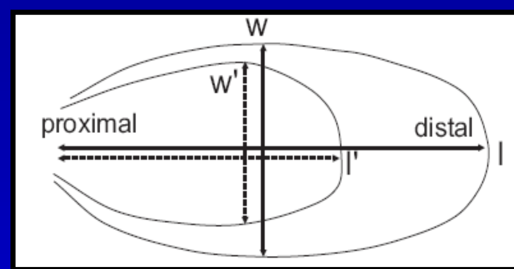
Outer shelf
Proximal
Slope
Submarine "lobes" coloured according to age
Red - youngest
Yellow
Brown
Green - oldest
North Golo Fan valley
Toe-of-slope
South Golo Fan valley
Pineto Lobe
Proximal lobe eroded by St. Damiano Channel
Youngest N. Golo Lobe
Close-up
D3/E3
C3
Basin floor
Distal
Basin plain

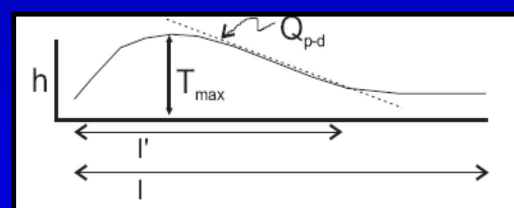
Notes by presenter

This kind of data allows us to study lobe distribution through time and space, provides us with detailed insight into lobe architecture, and measurements provide us with quantitative information about lobe dimensions We also know precisely where we are in the fan system, what the gradients are and the regional geography; so this kind of outcrop scale data has some advantages over surface exposures of lobes.

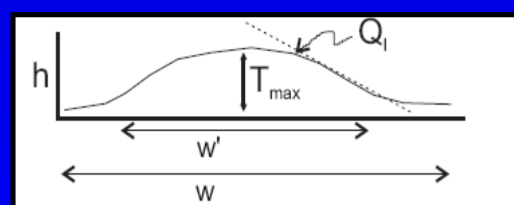
Multiple transects across each lobe allows for detailed measurements







Proximal to distal measurements



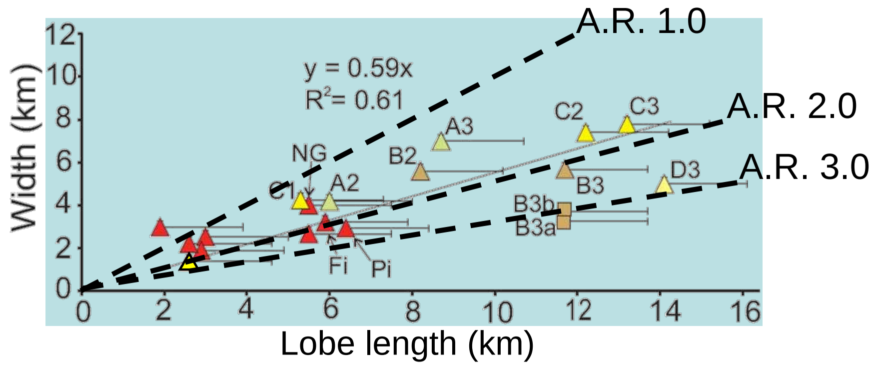
Cross-lobe measurements

<u>Lobe measurements</u>:
- length, width, thickness
- proximal to distal thinning rates
- lateral thinning rates
- ratio of different seismic facies

Notes by presenter

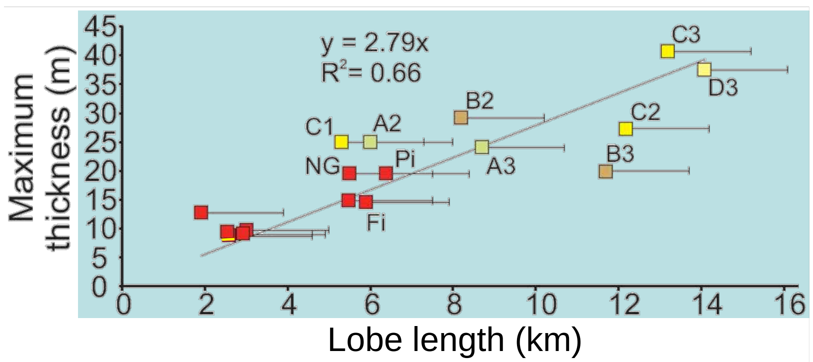
So we’ve used this data to measure the dimensions of lobes off East Corsica

Variations in lobe **dimensions**

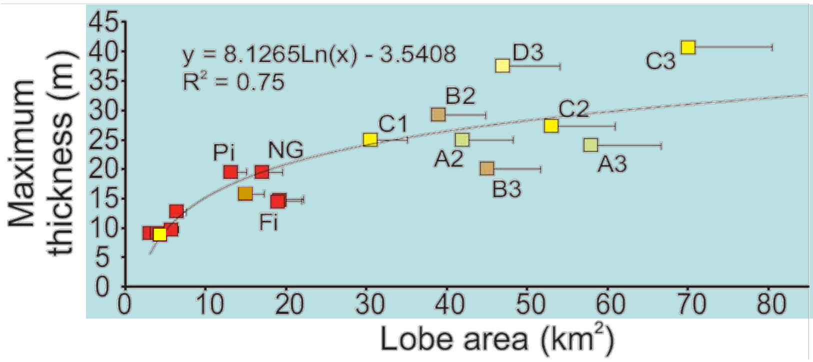


Cross-plots of various lobe measurements

- Aspect ratios vary from 1 to 3
- Longer lobes tend to be wider



- Longer lobes tend to be thicker



- Thicker lobes cover larger areas

Notes by presenter

As you can see from this chart, most lobes are elongated to various degrees. Lobe D3 is laterally confined – forcing it to be long and skinny! Note error bars – due to line spacing.

So what controls the dimensions of lobes off East Corsica?

Flume tank experiments and *numerical models* clearly indicate that variations in flow properties (e.g. volume, concentration, grain-size, velocity, duration, etc.) impact deposit **geometry** (e.g. shape, thickness, facies distribution) and **location** (proximal vs distal)

- **Grain-size** – coarser flows produce shorter/narrower deposits with more abrupt thinning rates; muddier flows cover wider areas, are longer, with more gradual thickness changes (Baas et al., 2004; Pratson et al., 2000; Al Ja'aidi et al., 2004)
- **Concentration** – hyperconcentrated flows have shorter run-out distances (Mulder & Alexander, 2001; Al Ja'aidi et al. 2004)
- **Duration** – sustained/longer duration flows produce longer/thicker deposits (streamwise elongated "central ridge-like lobes" (Alexander et al., 2007)
- **Volume** – larger volume flows cover wider areas (Pratson et al., 2000)

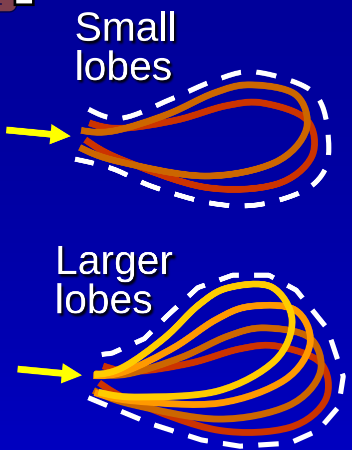
Flow properties are clearly important…

But…

…the lobes measured here (& the *reservoirs* they would form) are not deposits from single flows. Instead, they are multi-bed deposits, and hence other factors must also be important.

Notes by presenter

Variations in lobe location and dimensions can certainly be produced by varying the input parameters for flows. Many caveats attached to each of these…..we'll come back to this idea later. CARE MUST BE TAKEN NOT TO READ TOO MUCH INTO THE NUMBERS PRESENTED HERE -- BIG LOBES DON'T NECESSARILY MEAN BIG FLOWS.

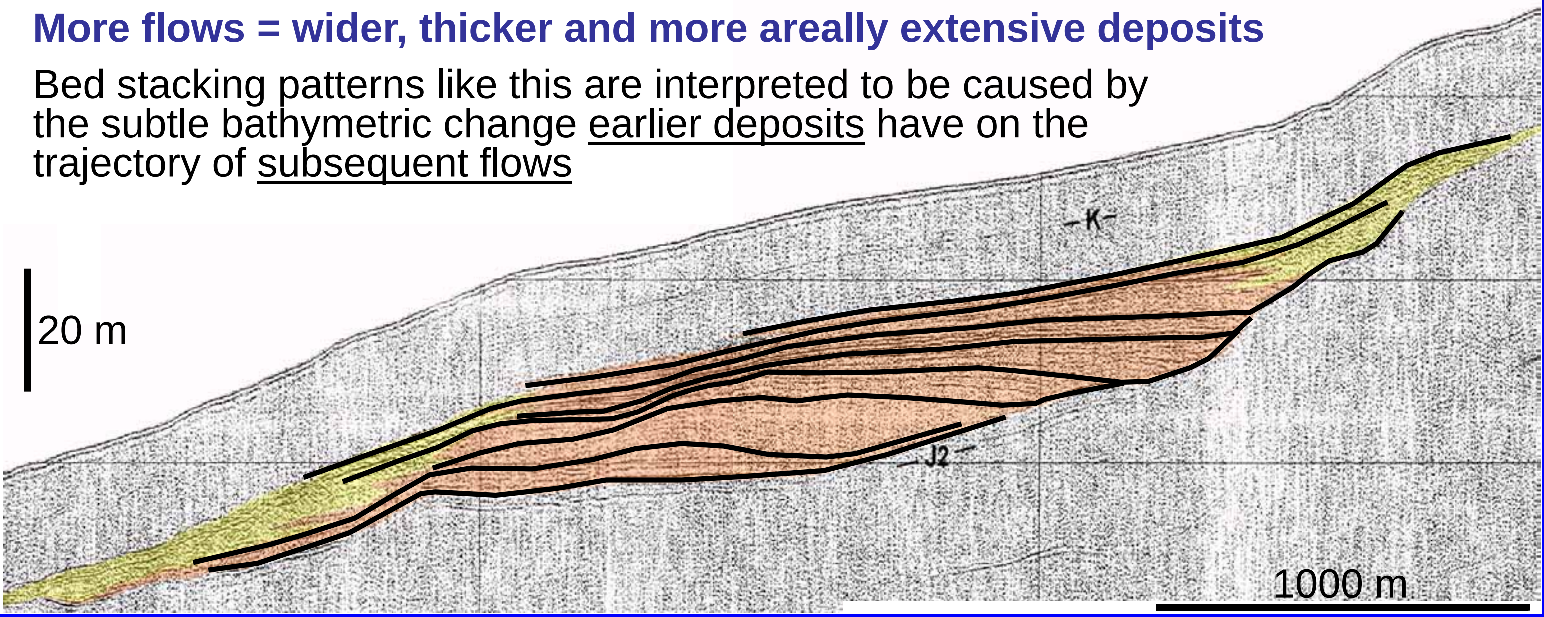


-number of flows (lobe life-span prior to avulsion or abandonment)

-interaction of flows with earlier deposits (bed compensation)

More flows = wider, thicker and more areally extensive deposits

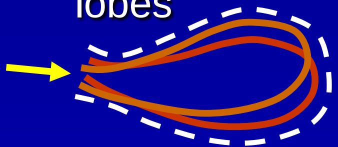
Bed stacking patterns like this are interpreted to be caused by the subtle bathymetric change earlier deposits have on the trajectory of subsequent flows



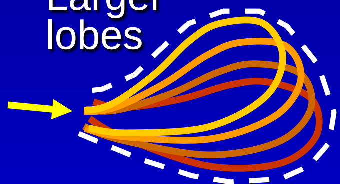
Notes by presenter

Some composite lobes are wider/longer because they are composed of several laterally offset lobe-elements More compensation stacking = Bigger = More complex architecture

Small lobes



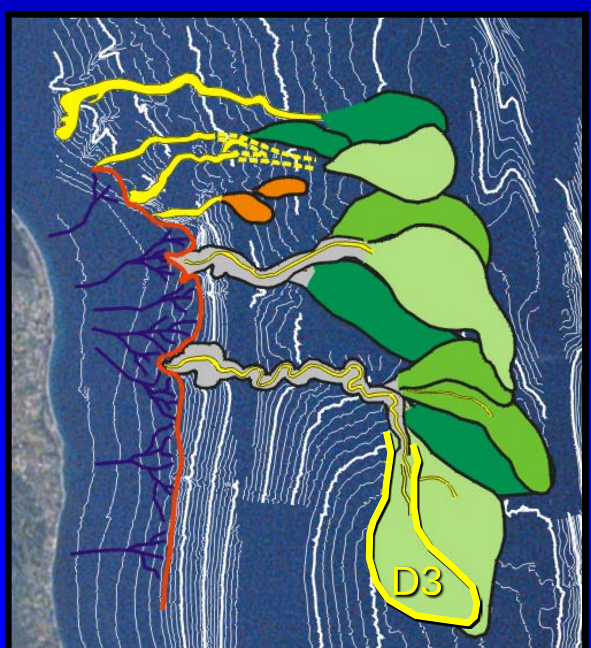
Larger lobes

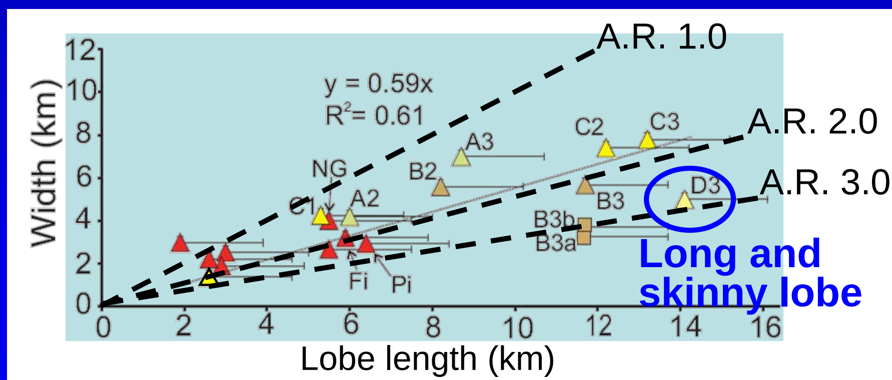


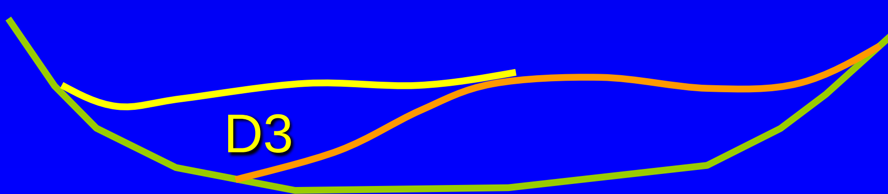
-number of flows (lobe life-span prior to avulsion or abandonment)

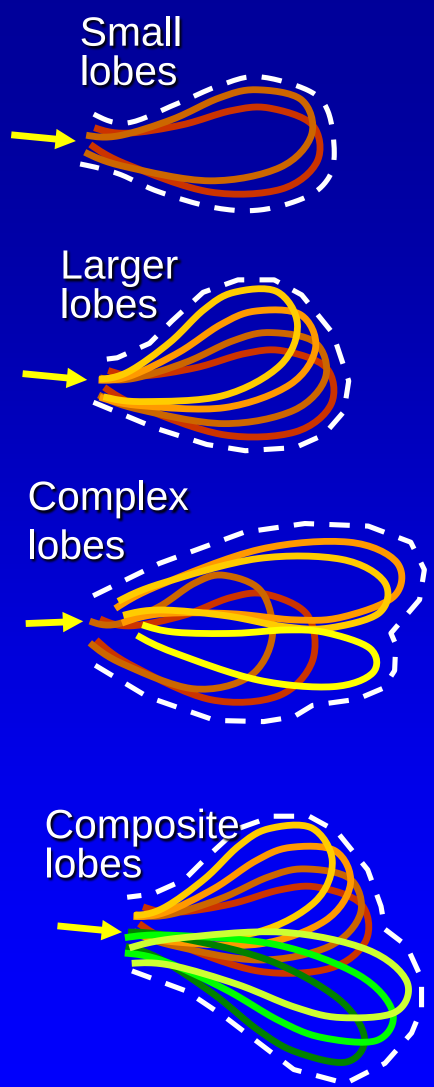
-interaction of flows with earlier deposits (bed compensation)

-seafloor morphology at channel mouth









-number of flows (lobe life-span prior to avulsion or abandonment)

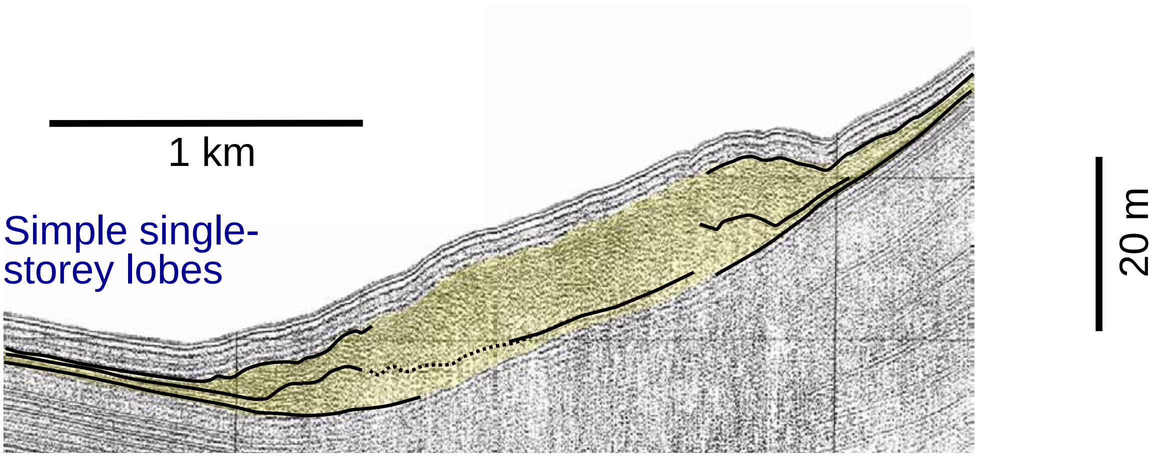
-interaction of flows with earlier deposits (bed compensation)

-seafloor morphology at channel mouth

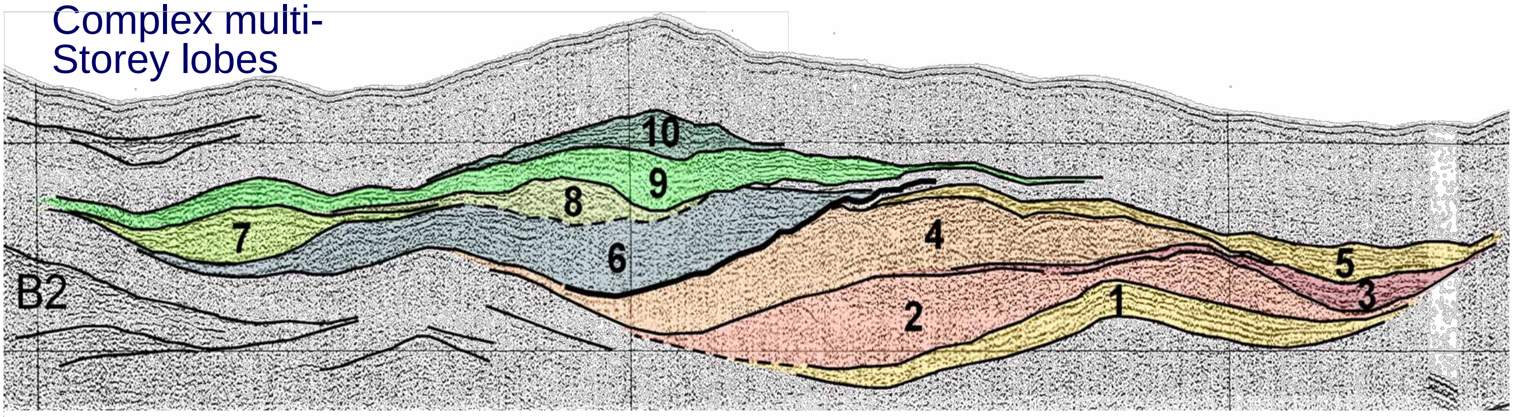
-degree of variation in properties from one flow to the next
(presumably a succession of relatively similar flows will have an increased tendency to ‘cluster’ as opposed to successive flows with widely varying properties)

-frequency of processes that trigger avulsions
(passage of particularly vigorous flow or autocyclic forcing of an avulsion once some threshold in bed stacking is achieved)

Composite lobes consist of multiple ‘sub-lobes’ that result from minor channel-mouth avulsions or changes in the types of sediment gravity flows



- Single storey lobes are narrower, thinner, shorter, and cover smaller areas, constructed of relatively few flows

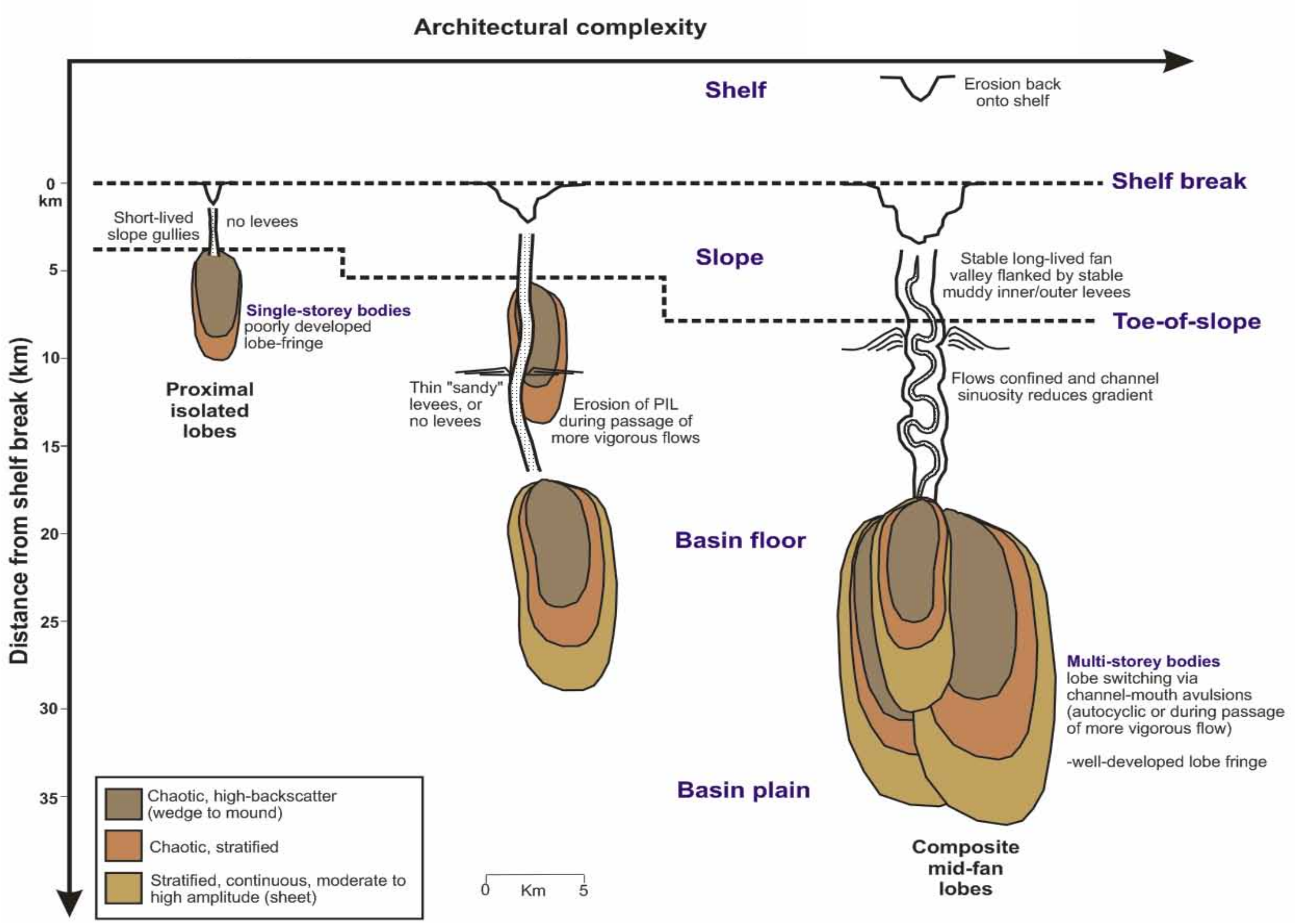


- Multi storey lobes are wider, thicker, longer, and cover larger areas, constructed of many flows

Notes by presenter

To go along with some of the wide variations in location and dimensions of lobes, they are also widely variable in terms of their architecture. Some lobes form simple, single storey deposits. Others form complex multistorey deposits. Some composite lobes are wider/longer because they are composed of several laterally offset lobe-elements. More compensation stacking = Bigger = More complex architecture

Is there evidence for general differences in flow properties between small proximal lobes and larger composite lobes?



Notes by presenter

Indeed, the difference in dimensions in lobes can be accounted for to some extent by the architectural complexity.
Increasing confinement – allows more flows to accumulate in composite lobes before a major avulsion or lobe abandonment;
increasing maturity of feeder channel; increasing number of flows; increasing variation in flow types; but are there differences in the average flow properties?

References

Al-Jaaidi, L.S., W.D. McCaffrey, and B.C. Kneller, 2004, Factors influencing the deposit geometry of experimental turbidity currents; implications for sand-body architecture in confined basins, *in* Confined turbidite systems: Geological Society (London) Special Publication 222, p. 45-58.

Alexander, J., S.J. McClelland, T.E. Gray, C.E. Vincent, M.R. Leeder, and S. Ellett, 2007, Laboratory sustained turbidity currents form elongate ridges at channel mouths: Sedimentology, v. 55/4, p. 845-868.

Baas, J.H., W. van Kesteren, and G. Postma, 2004, Deposits of depletive high-density turbidity currents; a flume analogue of bed geometry, structure and texture: Sedimentology, v. 51/5, p. 1053-1088.

Gervais, A., D.J.W. Piper, L. Pichevin, B. Savoye, M. Cremer, and T. Mulder, 2004, Present morphology and depositional architecture of a sandy confined submarine system; The Golo turbidite system (eastern margin of Corsica), *in* Confined turbidite systems: Geological Society (London) Special Publication 222, p. 59-89.

Gervais, A., 1975, Analyse multi-échelles de la morphologie, de la géométrie et de l'architecture d'un systéme turbiditique sableux profond (Système du Golo, Marge est-Corse, Mer Méditerranée); implications pour la reconnaissance des processus de transport et de dépéôt des sediments et pour la construction des lobes sableux en domaine profond: Thèse Doctorat, Sciences du vivant, Géosciences, Sciences de l'Environnement, Géologie marine, Université de Bordeaux 1, France, 285 p.

Mulder, T., and J. Alexander, 2001, The physical character of subaqueous density flows and their deposits: Sedimentology, v. 48/2, p. 269-299.

Pichevin, L., 2000, Etude sedimentaire et sismique d'uneventail turbiditiques sableux; le systéme recent du Golo (Marge Est-Corse): Université de Bordeaux I Memoir.

Pratson, L.E., J. Imran, G. Parker, J.P.M. Syvitski, and E. Hutton, 2000, Debris flows vs. turbidity currents; a modeling comparison of their dynamics and deposits, *in* Fine-grained turbidite systems: AAPG Memoir 72, p. 57-71.

Stanley, D.J., and P.H. Feldhausen, 1980, Hellenic trench sedimentation; an approach using terrigenous distributions: Marine Geology, v. 38, p. 21-30.


Thank you!