

Basin Scale Typing of Deepwater Sediments*

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Abstract

General deep-water depositional models are fundamental to understand the evolution of a gravity flow and the global distribution of the depositional elements between slope and basin floor. Practical experience suggests however that it is not a good practice to export the architecture of a deep water system across different geological settings. The massive increase in the last 20 years of the deep water E&P activity and the consequent spread of outcrop studies in various settings provide some foundation to attempt at least an empirical generalisation. After a first review, the number of key deepwater setting types appears quite small, and it could be limited to 3: Passive margins, Confined troughs and Intracratonic basins. Although very different between them, so much that they are barely comparable, the same system type in various part of the world tends to show a good set of similar features. The key building elements of a deep water system, like canyons, channel-levee systems or basin floor fan appear to be present in all settings. However, relative proportions, distribution and sizes vary enormously. For example, the Passive margins systems are essentially made of channel-levee elements, but these elements may have a very limited expression in confined foredeep basins. Basin floor elements of Intracratonic basins could be at a walking distance from their feeding deltas, while it may take several hours for a vessel in the Gulf of Mexico to cover the distance. Examples throughout the world will be presented to illustrate the main distinctive features. In Passive margins, large channel - levees elements dominate the panorama down and far in to the abyssal plain and contain highly complex channel-fill bodies. Sheet systems are occasionally developed; they do not appear to be cyclical and are possibly correlated with major tectonic events. Confined systems, like foredeeps, are characterised by relatively minor canyon and channel-levee development, widespread unconfined lobes, and ubiquitous chaotic sediments. Most of the channel-fill elements are smaller and less complex than in the large passive margins. Dominant sandy facies in confined basins are represented by even, parallel beds with “Bouma sequences”. Intracratonic basins are essentially lacking of significant preserved channel-fill features and they lay very close to their feeding deltas. They are essentially made up of unconfined lobe systems at the toe-set of prograding clinoforms. They may display evidences of flood sedimentation and local hint of wave reworking because of their shallow depth of sedimentation.

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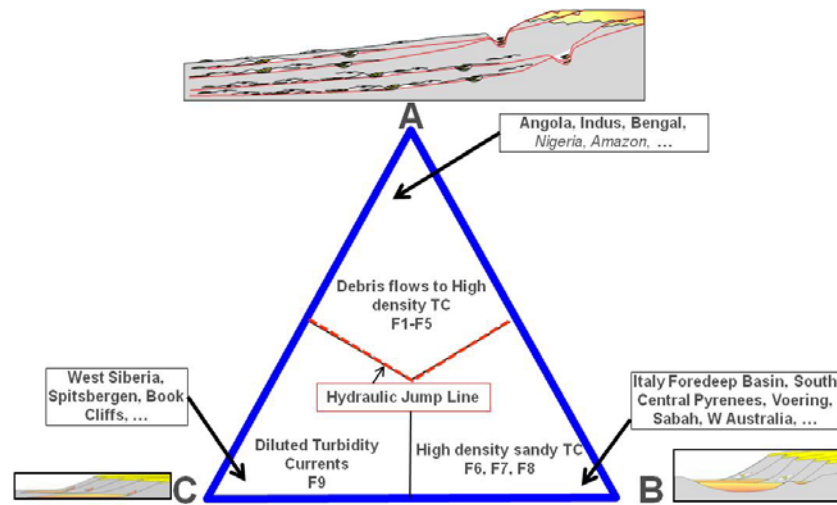
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Basin Scale Typing of Deepwater Sediments

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- ▶ Errors are accidental and they are the responsibility of the author.
- ▶ This is a geological presentation and is not comprehensive. It should not be used as the basis for any investment or financial decision.



Deepwater Systems At the Basin Scale

- ▶ This presentation illustrates a general review, at the systems scale, of the nature of the dominating deep water sediments in the main structural settings.
- ▶ The objective is to highlight the common ground between similar basin types in terms of :
 - the dominating transport mechanisms
 - the dominating sedimentation processes.
- ▶ The scope is to provide a typing of the deep water systems based upon the dominating turbidite processes to facilitate the predictivity of the distribution of the turbidite elements.



Plan Of the Presentation

- ▶ The key parameters controlling the deep water sedimentation.
- ▶ The main types of deep water basins and systems.
- ▶ A review of selected case histories
- ▶ Discriminating elements
- ▶ Conclusions



Key controlling parameters of deepwater sedimentation

- ▶ **External factors** * : linked to the basin structural setting and sea level changes. They include:
 - Nature of the available sediment
 - Slope Profile
 - Shape of the Receiving Basin
 - Relative sea-level changes

- ▶ **Internal factors** : linked to the dominant size of the gravity flows and their variability in a given basin.
 - Nature of the dominant flows: Volume, shape, relative amount of shales vs sands and conglomerate in the flow, ... Continuous small volumes flows like long lasting floods in an tropical delta may be expected to generate generate different sediment accumulations than episodic large volumes flows like the collapses that fed the 1929 Grand Banks turbidite event (Piper and Aksu, 1987).

*cfr Martinsen, 2010



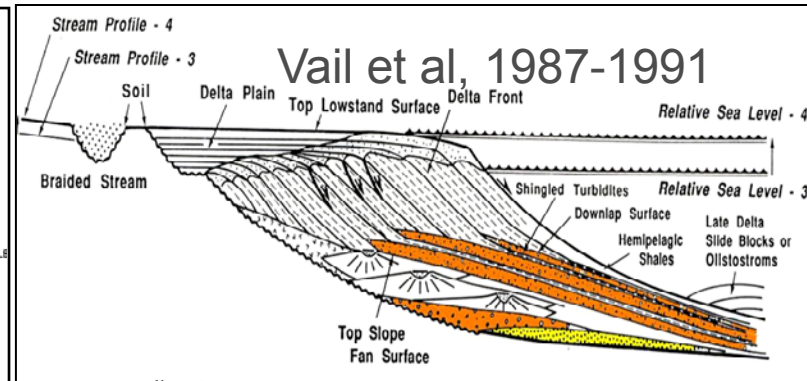
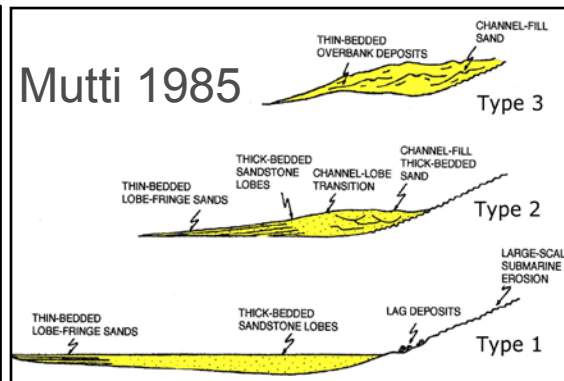
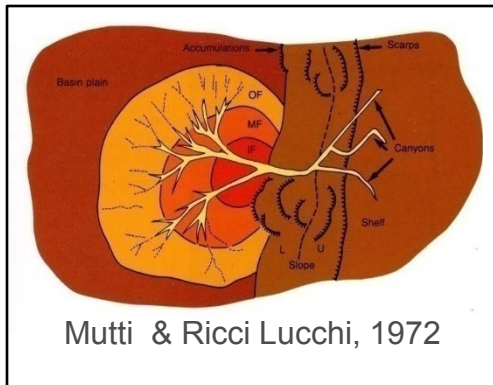
Existing Models & Approaches I

- ▶ The early models of the 70's were focused at generalising the studied case histories, and heavily relied to the present day analogues (Normark 1970, Mutti & Ricci Lucchi 1972) available at the time.
- ▶ The fundamental sequence stratigraphy based models of the 80's defined the key relationships between turbidite systems and sea level changes (Mutti, 1985, Vail et al., 1987-91). In the late '90s and 2000's important reviews focused on slope profile nature and evolution to characterise the infill of the deep basins (Steffens et al. 2003, Prather 2003, Somme et al, 2009) . Although clearly a fundamental parameter, one of the issues with the slope profile, an « external » parameter, is to reconstruct the depositional profile geometry for a given interval of the geological record. For a better understanding of the depositional dynamics of a deep margin it helps to compare also the « internal parameters », like turbidite flow size variability within a specific basin, as inferred by outcrop and subsurface data.
- ▶ The presented model is heavily inspired by the seminal Mutti's 1985 model relevant to active margin systems, for which it remains the key reference (type B systems described below, with Types I, II, and III: further details in Mutti, 1985). The contribution of this presentation is to include types and examples beyond the active margin systems and to integrate the main gravity flow reservoir-generating processes in order to fine tune and broaden its applicability.



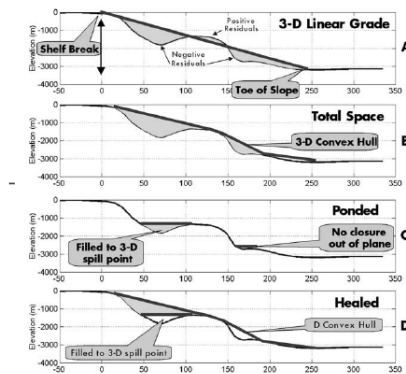
Existing Models & Approaches II

The Origins: Basin Scale Models

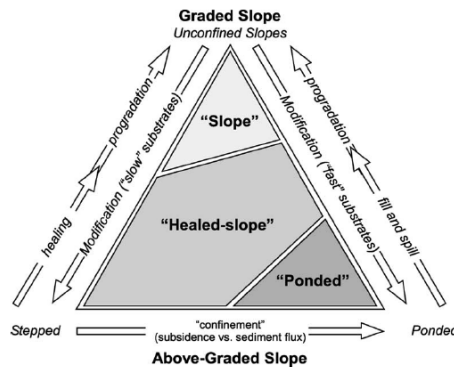


Current Trends : The analysis of the Slope profile

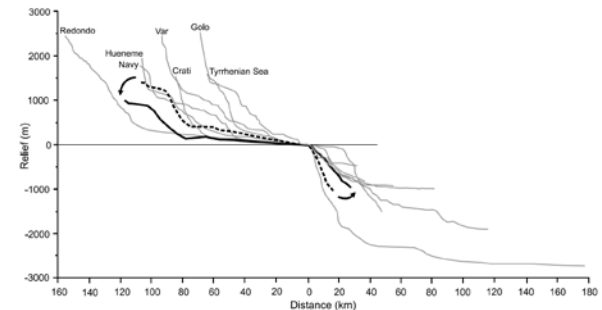
Steffens et al. 2003



Prather 2003



Somme et al. 2009

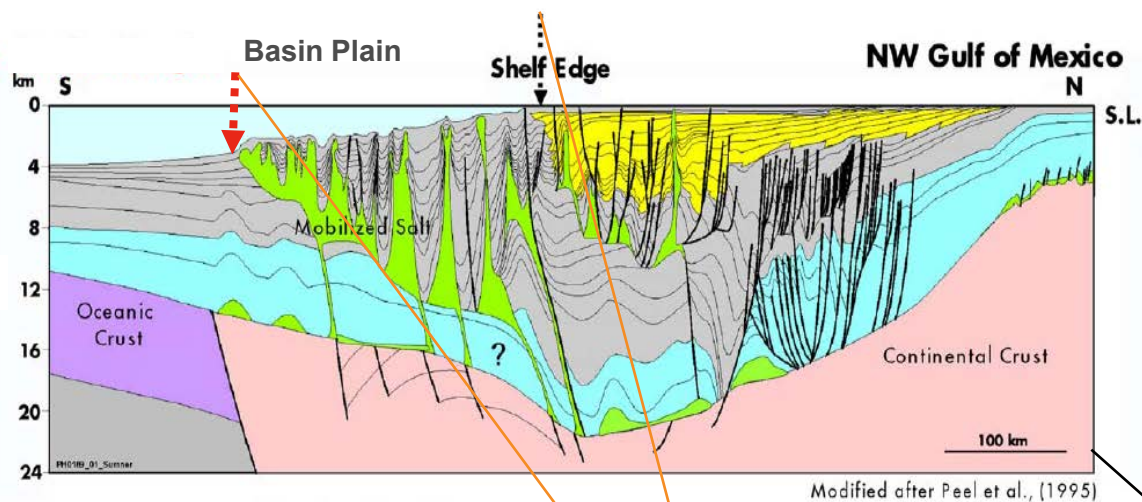


...And mud vs sand rich systems of Reading and Richards, 1994, mostly based on lithological criteria for discriminating the various deep water systems.



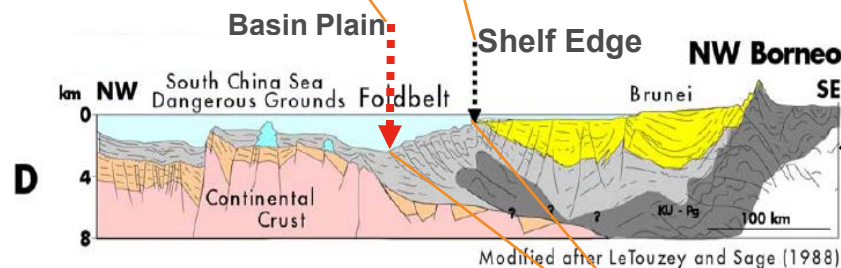
Scale Variability of Deep Water Systems

Passive Margin Basin

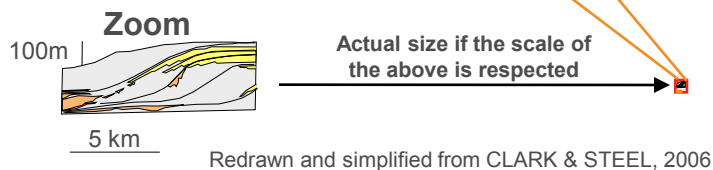


From Steffens et al., 2003

Active Margin/ Confined Basin



Cratonic Basin



The deep water basin margins show a wide range of size: A passive margin's slope is several times wider than an active margin's, on which much steeper slopes are observed. The cratonic basins may show slopes two or three order of magnitudes shorter than passive margins.



Main Types of Deep Water Systems & Turbidite Processes

- ▶ As highlighted by Mutti, 1992, the hydraulic jump zone location is thought to have a critical impact on the nature of the genetic facies tract for a turbidite flow with given properties.
- ▶ Facies analysis represent a practical tool to identify the dominant hydraulic jump location with respect to the dominant sediment type, dominant flow properties, and provide indications of paleoslope of the systems.
- ▶ The characterisation of the dominating facies types will therefore provide useful indications about the key “physiological characters” of a deep water basin. It was used in this presentation to help discriminate the main types of deep water systems.

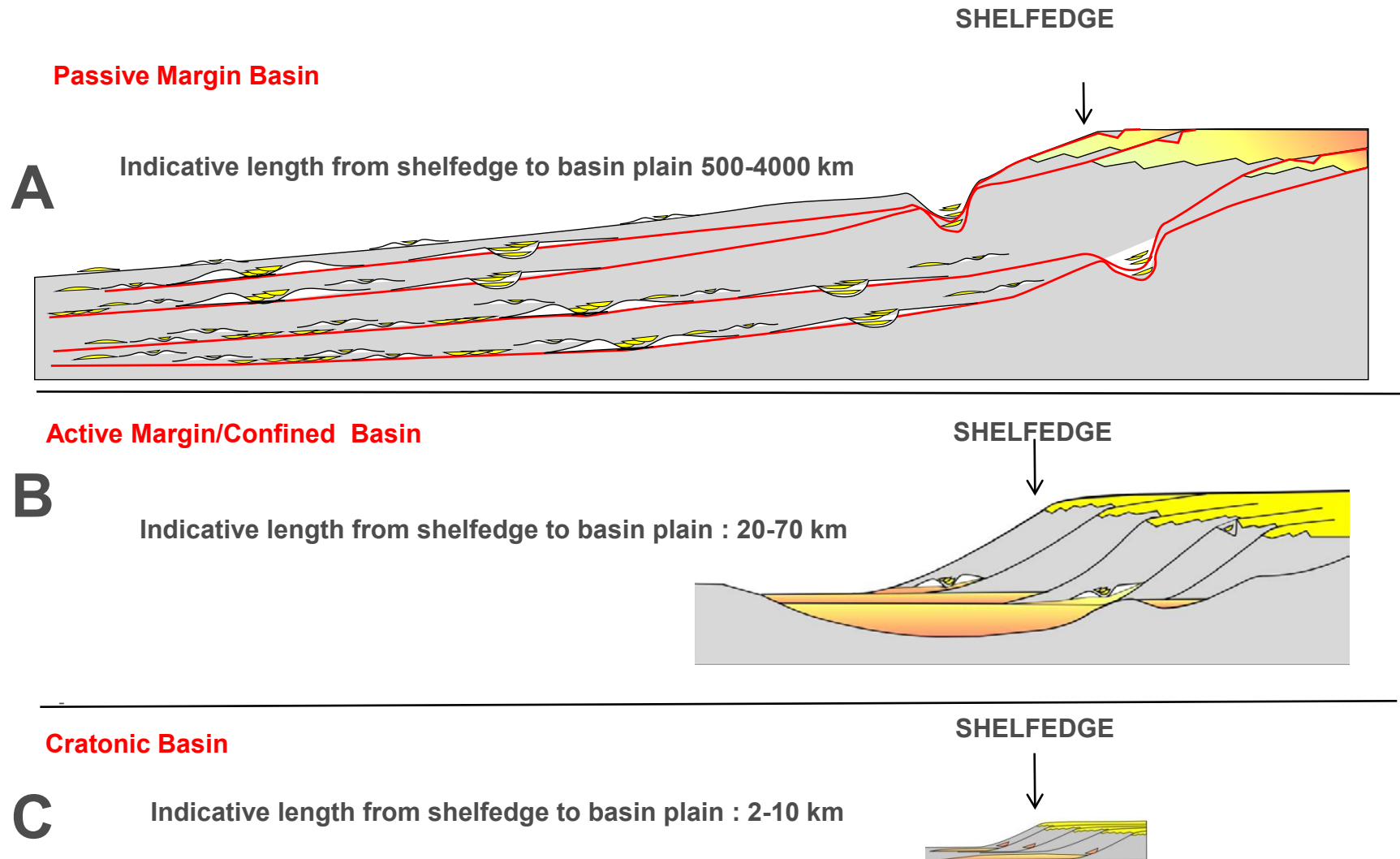


Main Types of Deep Water Systems

- ▶ Based on dominant facies types, 3 general types of systems may be recognized.
 - The **Type A**, is characterised by a smooth slope profile. The dominating sedimentation process is suggested to be represented by long lasting flows (weeks or months?) depositing their coarser grained material along wide segments of the slope. Along a smooth profile, small topographic variation may slow down the current, causing partial fall-out of the denser part of the turbidity flow, containing the coarser available material. The dominating sand bodies have essentially a “**lag**” **character** as they represent the amalgamation of multiple events (hundreds or thousands) depositing a **limited part** of their sediment load. The dominant reservoir type deposits left behind are therefore developed updip of the hydraulic jump.
 - The **Type B** is mostly developed at the toe of a relatively steep slope. The density flows bypass most of the slopes and expands and collapses at the slope-break at the toe of slope, with some of the diluted tail continuing their path in the basin plain because of their momentum. The dominating sedimentation of sand is expected to occur near and beyond the toe of the slope. The sands accumulations are anticipated to contain both part of the denser component of the turbidity flow and part of the low density “diluted” component. One of the peculiar characters of these systems is that the main sand bodies shale out up-dip and may form pinch-out hydrocarbon traps. Most of the sand is interpreted to have bypassed the slope and sedimented near or after the hydraulic jump.
 - In the **Type C**, mostly developed at the toe of a prodelta of a slowly subsiding cratonic basins. They have similar overall geometry than type B, but instead of filling a through, they prograde together with the deltaic system. The sandy sediments are anticipated to contain mostly the diluted component of the turbidity flow. This is possibly because of the general lack of coarse grained material in the feeding deltaic system, which had to cross very wide low relief delta-plains. The dominating sedimentation of sand is anticipated to occur, as in type B, at and down dip of the hydraulic jump zone.



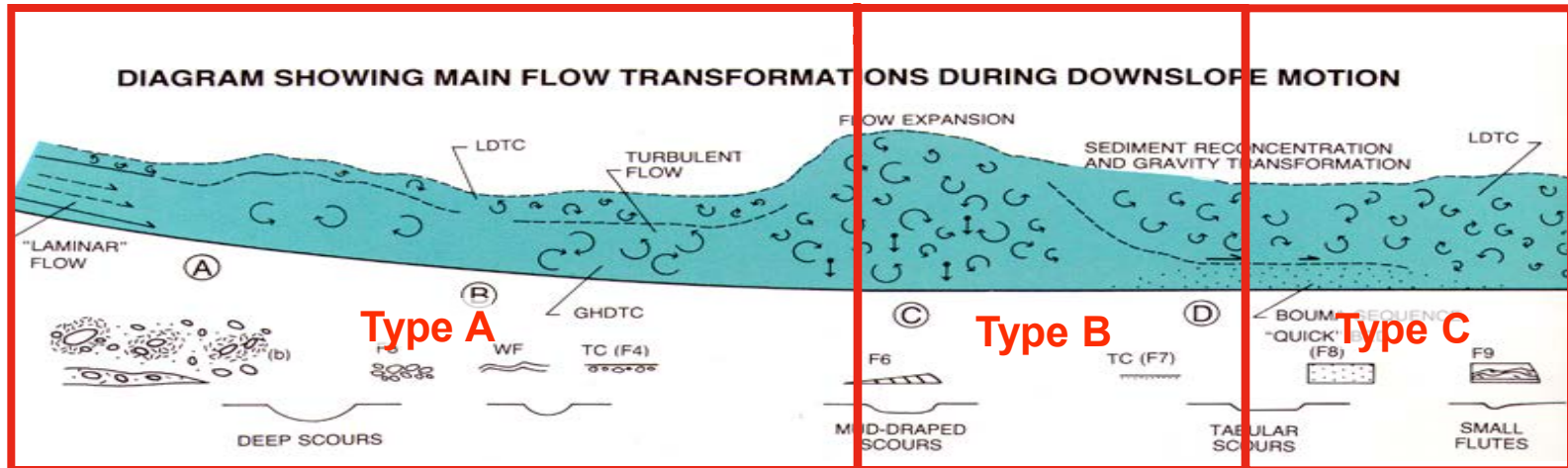
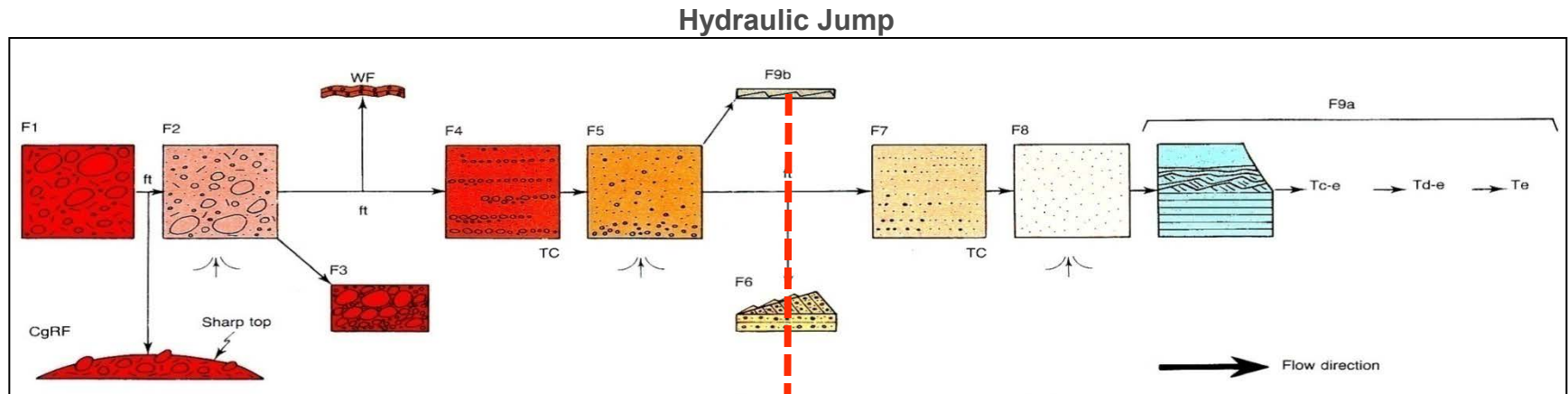
Main Types of Deep Water Systems, at 3rd to 4th order cycle scale



The Three end members of deep water margins proposed in this presentation are schematically illustrated by the sketches above. **Type A** in passive margins, typically in front of major deltaic systems along passive margins, **Type B** along the steep slopes along confined basins in both active and early (young) passive margins, **Type C**, mostly in shallow epicratonic basins.



Main Types of Deep Water Systems & Mutti's'92 Facies Model



The three types of systems described in the previous section are characterised by different dominating depositional elements, made of sediment bodies resulting from different dominating depositional processes along the slope and the basin.

In this image, on the downslope evolution of the processes of a gravity flow (Mutti, 1992) are overlapped the Types A, B and C of deep water systems to illustrate the dominating reservoir generating processes anticipated in each type.

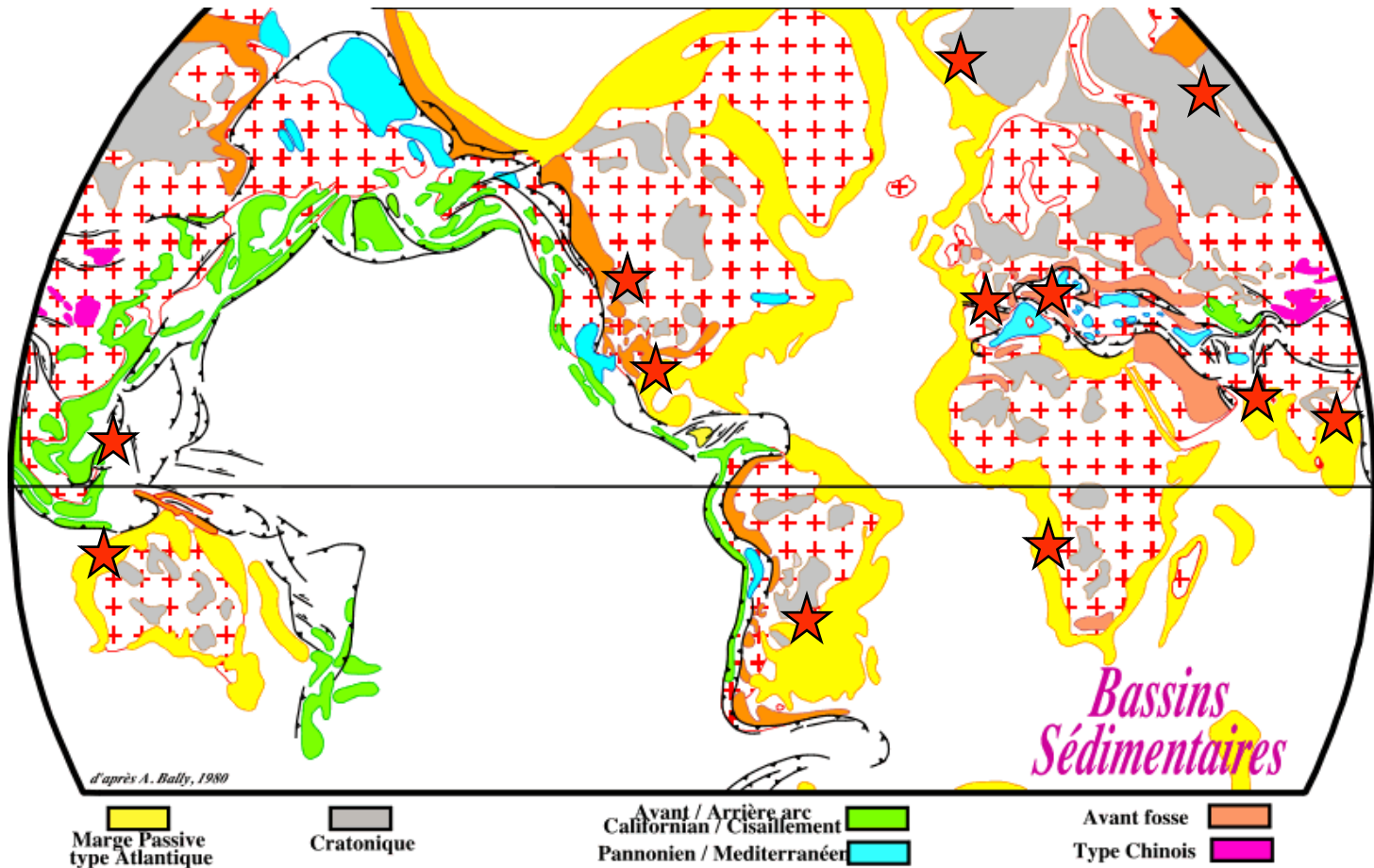


ILLUSTRATION OF MAIN DEEP WATER SYSTEMS TYPES THROUGH SELECTED EXAMPLES

Selected examples to illustrate the various Types of deep water margins are derived from published documentation



Sedimentary basins of the World & their structural type: ★ = case histories in this presentation



Modified after Bally, 1980, From C. Cramez, 1997-1998



Reviewed Examples are located in various basins around the globe



TOTAL

Type A Systems - Passive Margins

Passive Margin Basin

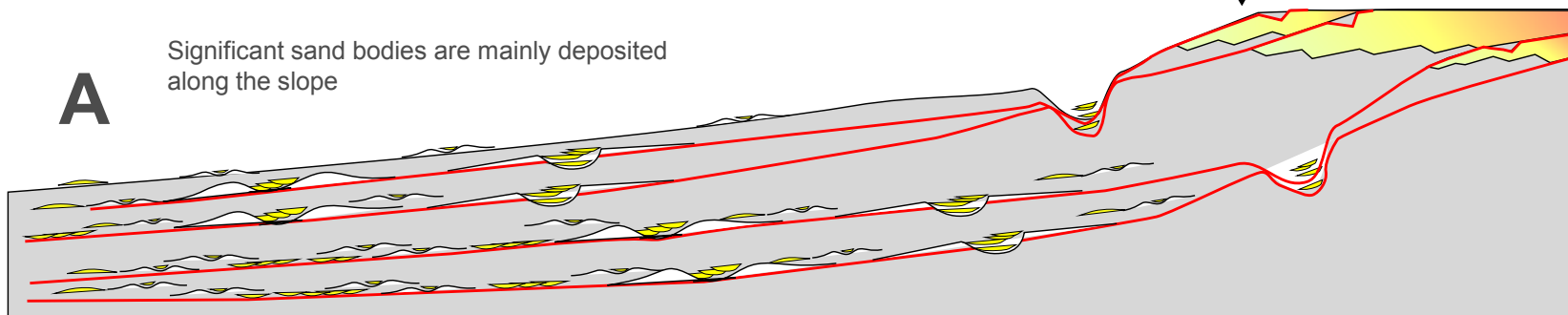
Indicative length 500-4000 km

SHELFEDGE



Significant sand bodies are mainly deposited along the slope

A



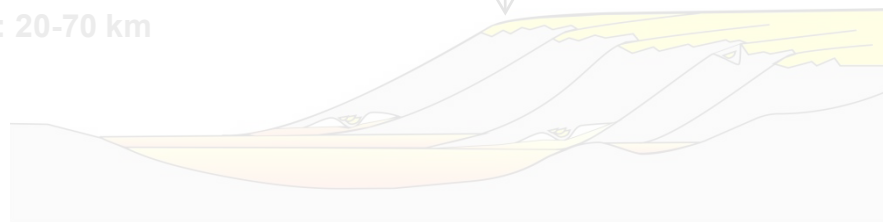
Confined Basin

Indicative length: 20-70 km

SHELFEDGE



B



Cratonic Basin

Indicative length: 2-10 km

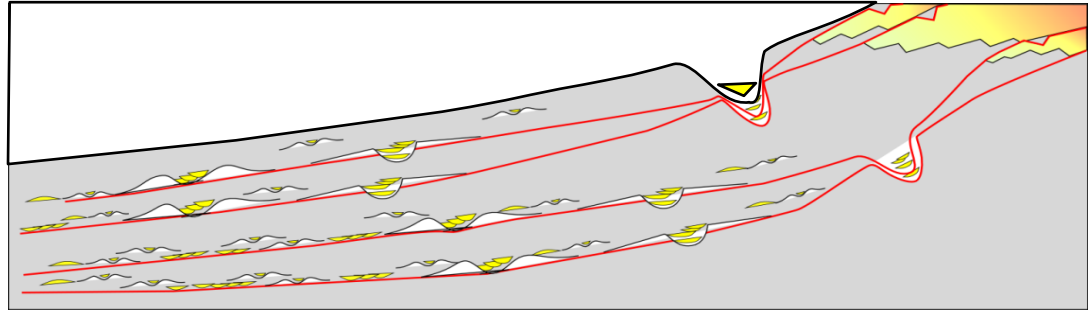
SHELFEDGE



C



Type A Systems - Main Characters



- ▶ **Dominating Lithology:** Shale makes up most of the volume of the system.
- ▶ **Size:** Length range, from shelfedge to basin plain, between 500 to 4000 km (*Curray et al., 2003*)
- ▶ **Duration / life span:** several tens of million years. Long lived canyon-channel systems attached to long lived river systems.
- ▶ **Remarks :**
 - ▶ **A significant part of the turbidite flows may have lost most of their sediment load before reaching the channel mouth (Cfr. Mutti, 1985):** The slope is possibly sufficiently smooth and irregular to allow sediments to “freeze” along the fairways or to be left behind in sort of lag deposits before the end of the system. Sands are confined in channel fills & pathways; F1 to F5 (Mutti, 1992) facies dominates the coarse grained deposits.
 - ▶ **Relatively small scale lobes (avulsion and terminal) occur along the slope, genetically related to channels.**
 - ▶ The basin floor fan as per Vail (1987) sequence stratigraphic model is not common in this setting. This is probably because no clear slope break at the junction with the basin plain area is present. The profile is smoothed out by continuous flows, lasting days of weeks, mostly fed by river floods.
 - ▶ Lowstands are recorded by rejuvenation of same channel complex system, or by lateral shift of the active sediment path after cutting of a new complex.



Type A Systems - Passive Margins : Deepwater Angola I

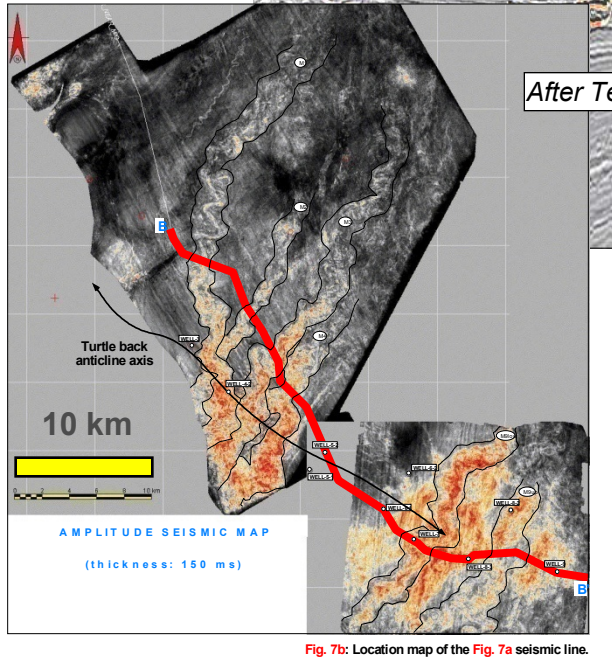
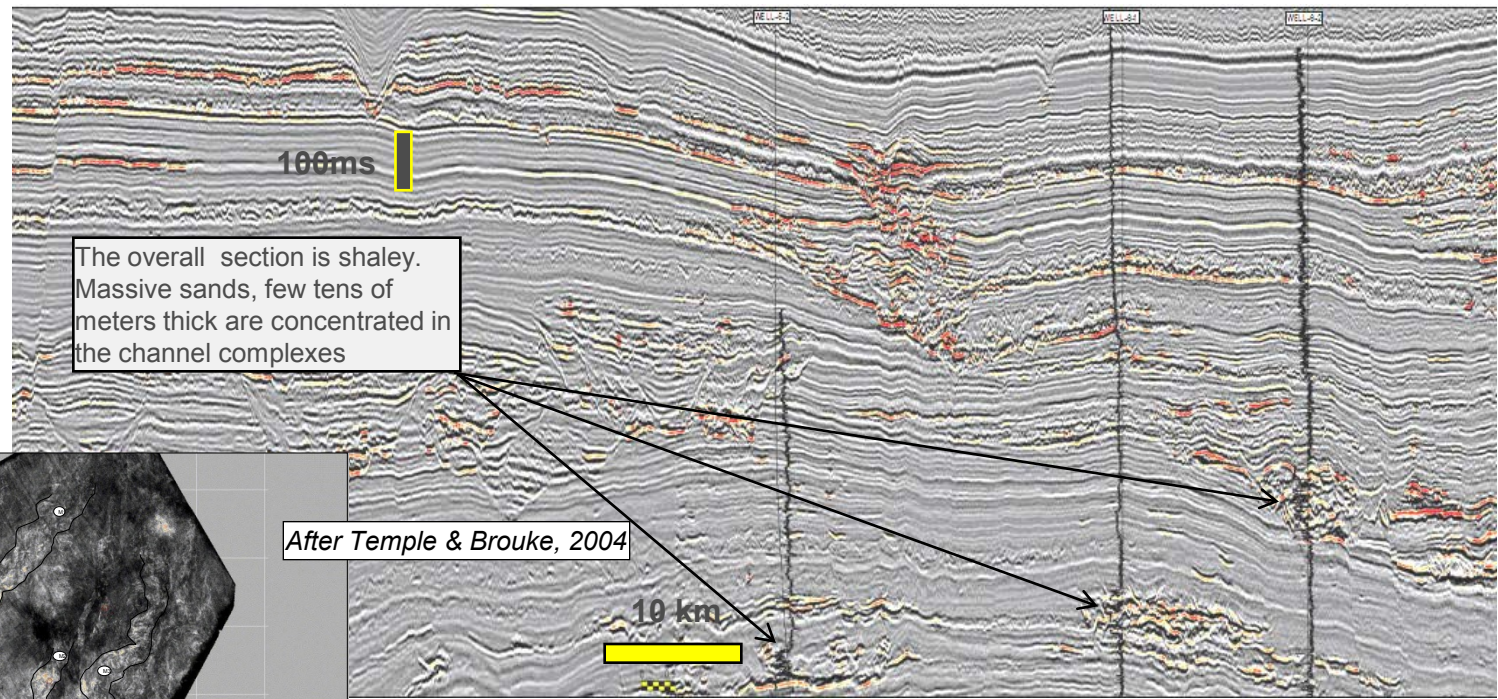
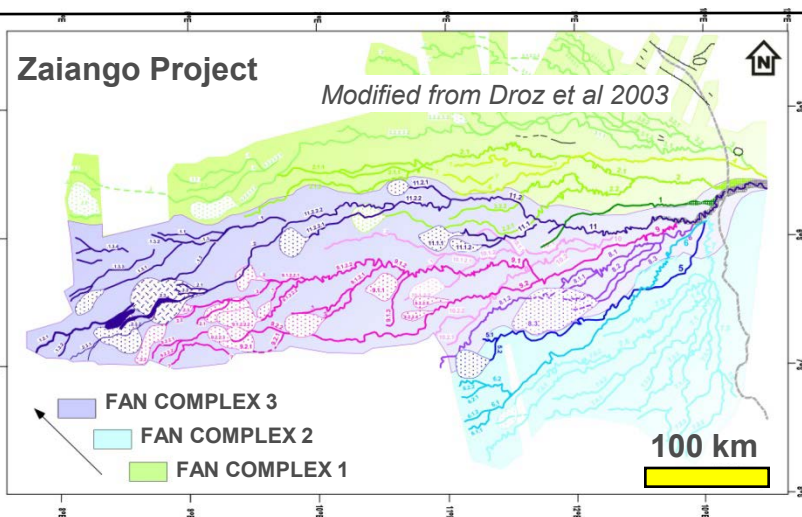


Fig. 7b: Location map of the Fig. 7a seismic line.

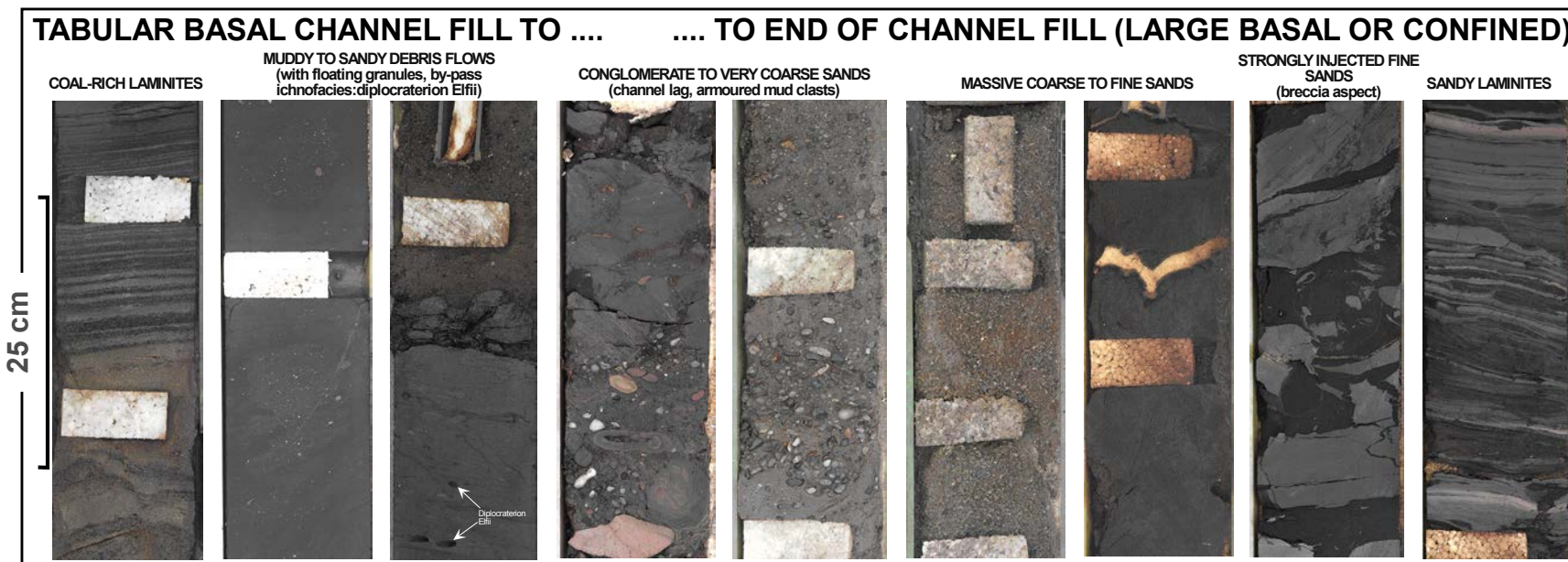


Type A Systems- Passive Margins : Deepwater Angola II

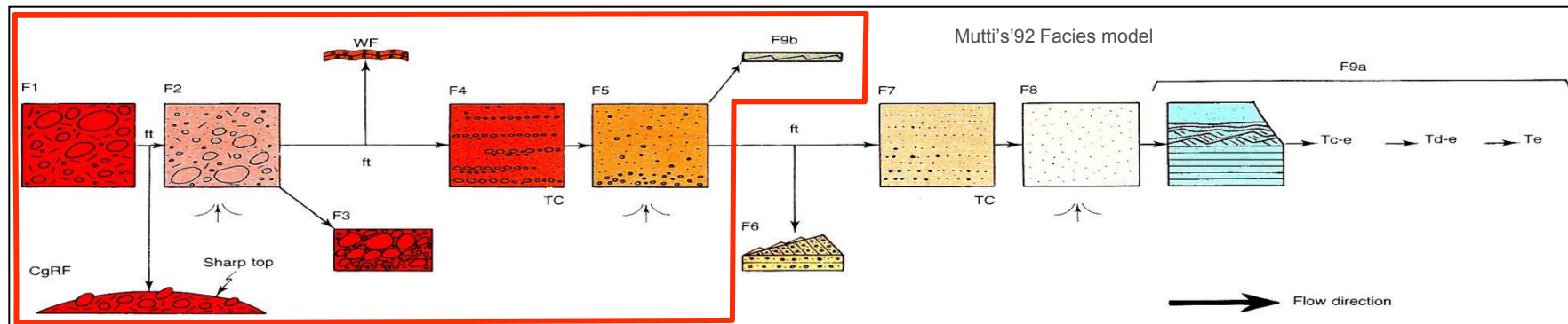
- The deep water system is made of a wide network of migrating channels and associated sediments. Each individual sand body results from a complex assemblage of the remains of a large number of individual events.
- The overall sand/shale ratio is typically less than 10-15% of the gross drilled section
- Very large systems; their size is comparable or in excess of their drainage basin.
- the canyons and the various orders of channels appear to cover a much larger surface than the associated lobe(s), which appear relatively accessory



Type A Systems - Facies variability in a channel fill, Angola



After Temple & Brouke, 2004

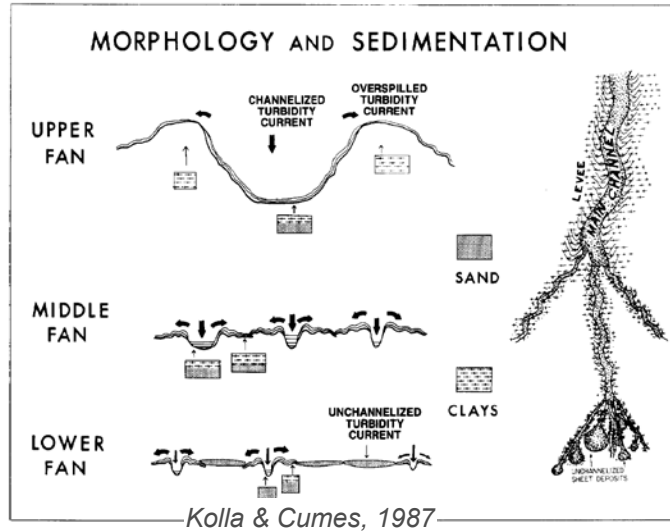


Various "*Pre hydraulic jump*" facies dominate the sandstone sediments in channel infill. The background fine-grained sedimentation records the fall-out from diluted sediment clouds or the diluted tail/edges of a nearby flow. These fine grained deposits make up overbank and interchannel systems.

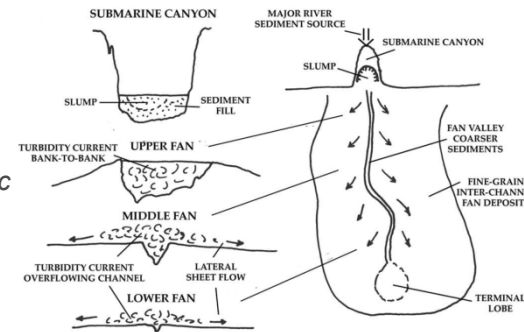
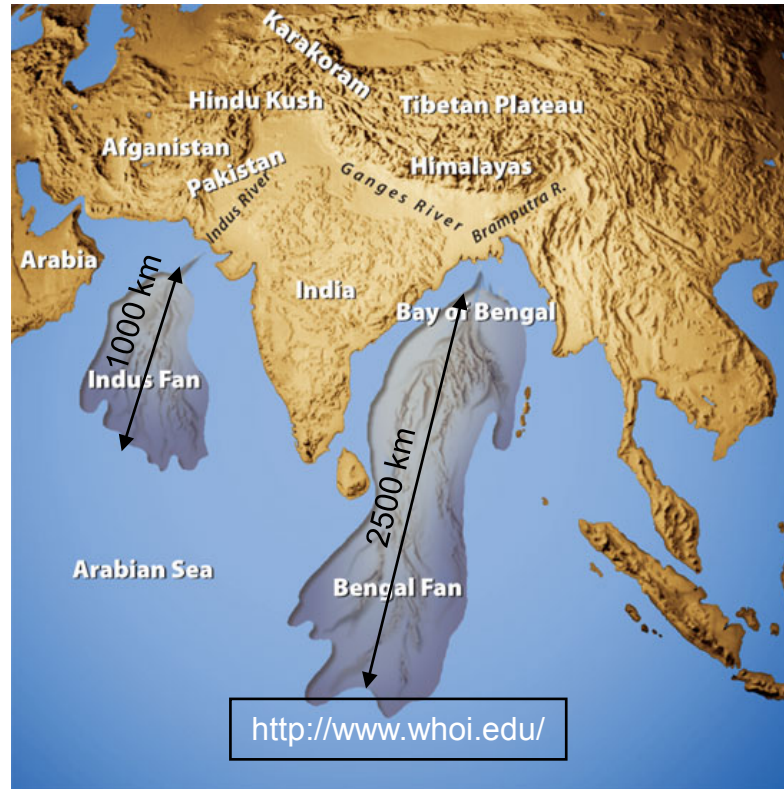


Type A Systems - Other examples of Passive Margins : Indus and Bengal fans

- More Examples:
 - Niger Delta
 - Amazon



Both examples show similar general patterns than the Zaire example illustrated before. A wide and deep canyon updip, branches out in progressively smaller and shallower channels/channels complexes. The occurrence of lobes is largely subordinated to the various canyon/channel distributary systems and complexes.



Curry et al., 2003c

Type B Systems - Confined Basins

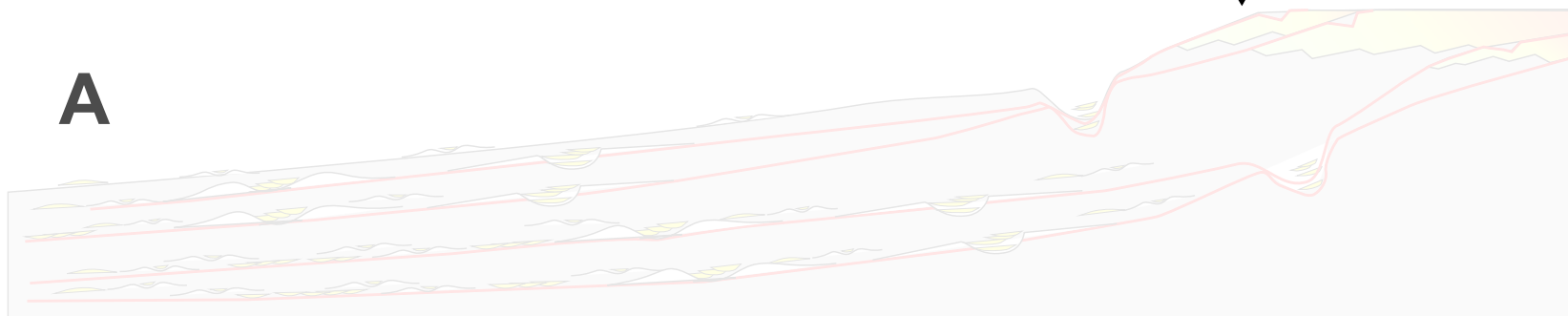
Passive Margin Basin

Indicative length 500-4000 km

SHELFEDGE



A



Confined Basin

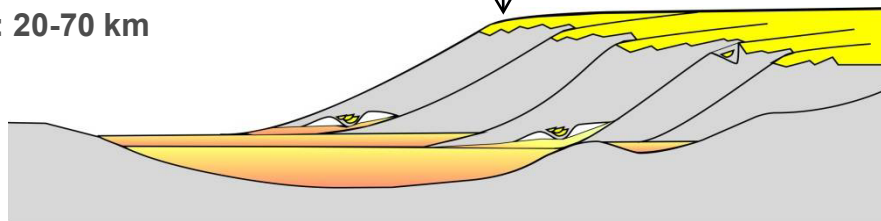
Indicative length: 20-70 km

SHELFEDGE



B

Significant sand bodies occur mainly in the basin plain



Cratonic Basin

Indicative length: 2-10 km

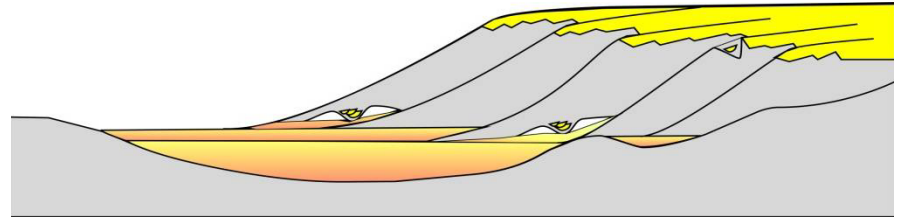
SHELFEDGE



C



Type B Systems - Main Characters

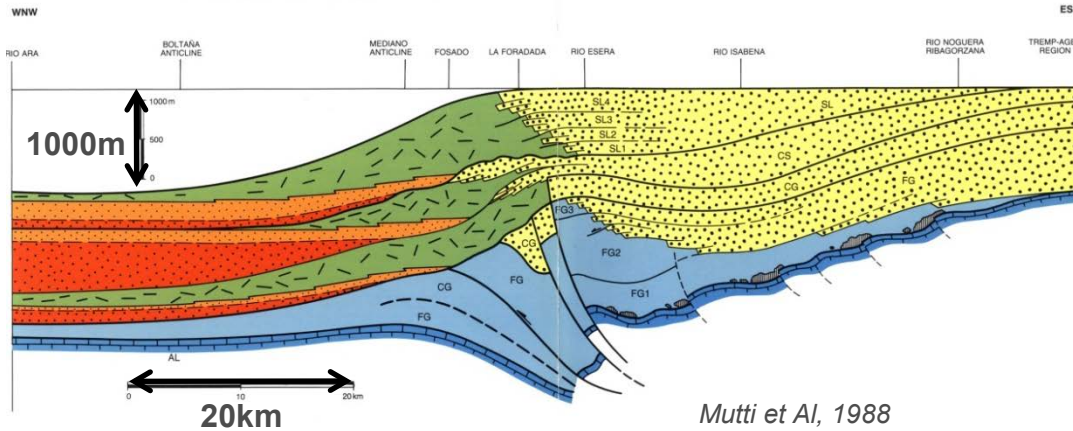


- ▶ **Dominating Lithology:** Sand dominates in the basin plain. Variations are observed along strike depending on paleotopography.
- ▶ **Size:** Few to several tens of kilometers from shelfedge to abyssal plain. Narrow, relatively steep slope, on which no significant sand sedimentation occurs during peak deep water system activity.
- ▶ **Duration / life span:** Relatively short lived (few million years): the time to fill the through generated by a major structural event (emergence of a thrust belt, the onset of a rifting phase).
- ▶ Strong, continuous link to tectonic events, seismicity, river floods; shelf collapses represent a significant sedimentation processes.
- ▶ Massive ponded sands in the depth of the trough. F7-F8 facies, F9 (Mutti, 1992) at the edges of the basin.
- ▶ Occurrence of large events blanketing wide surfaces of the basin floor (ex: Elmore et Al, 1979, Ricci Lucchi & Valmori, 1980).
- ▶ Re-orientation of the flows along the axis of the through.
- ▶ Small, isolated channel systems, laterally compensating in the updip part of the system.

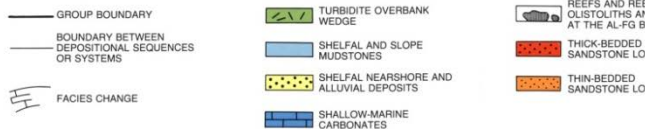


Type B Systems - Confined basins - Hecho Group Turbidites

SCHEMATIC CROSS SECTION OF THE EASTERN AND CENTRAL SECTORS OF THE EOCENE OF THE SOUTH-CENTRAL PYRENEES



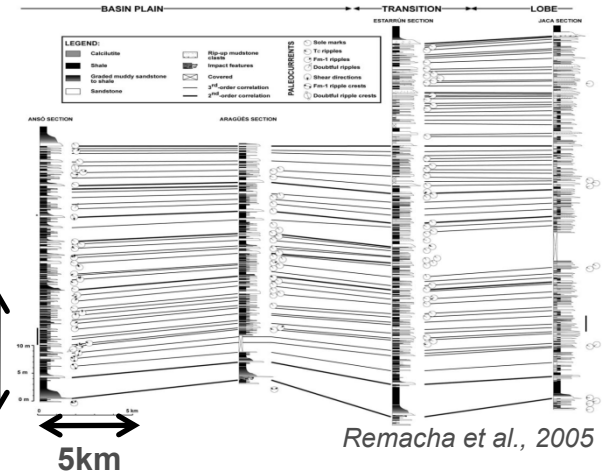
Mutti et Al, 1988



DATUM: SEALEVEL AT THE END OF SANTA LIESSTRA TIME.
FOR LOCATION SEE FIG. 59

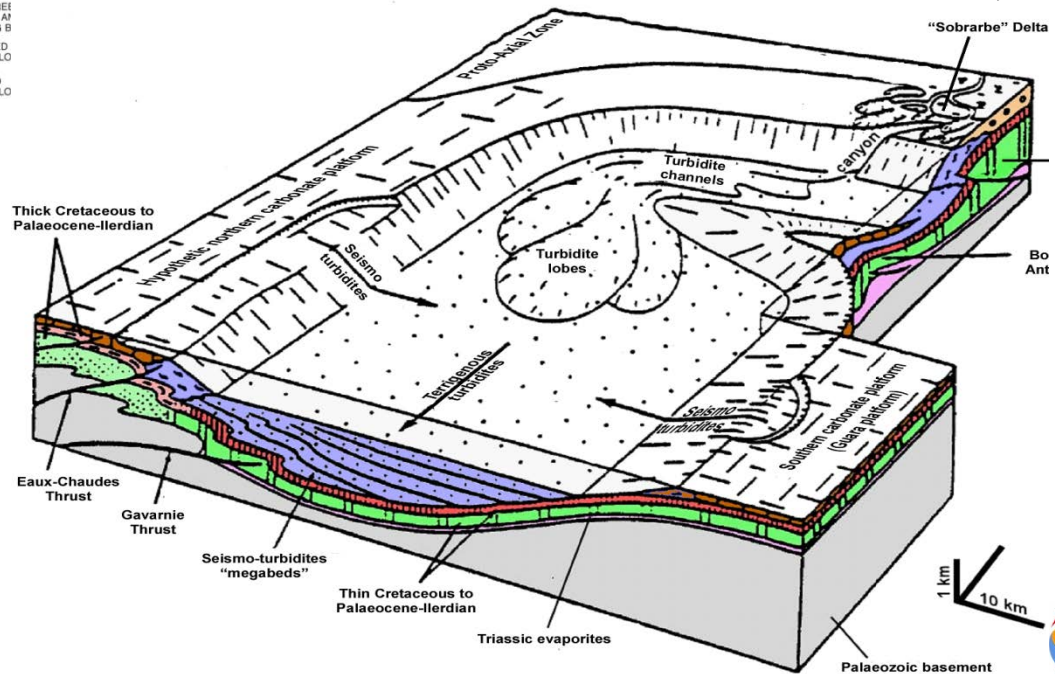
Fig. 60

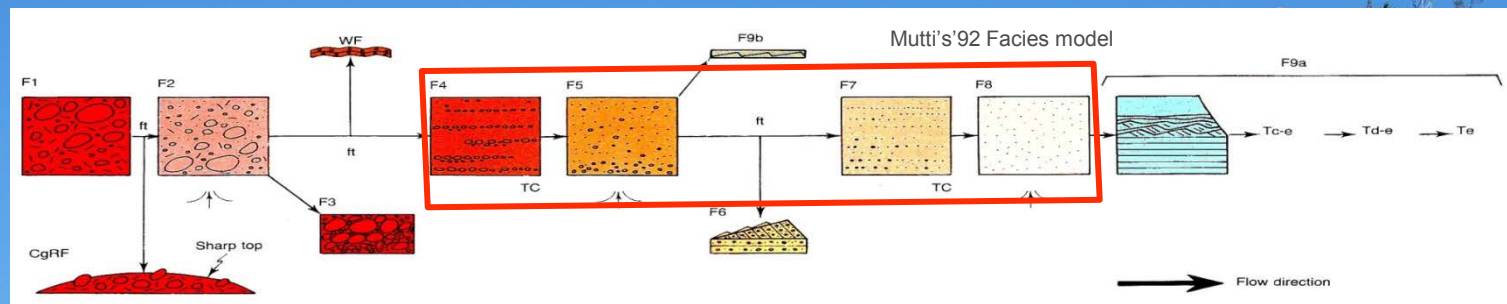
In the Southern Pyrenees, tectonics and river flood control of the Turbidite Fill (Mutti, 1988, Mutti & al.1999). Although individual sand bodies are not often easy to correlate, each system is several tens of km long and several hundreds m thick, made mostly of sheet-like elements. Note that the slope is only some 10-20 km long. A deep structural control impairs the progradation of the system during its peak activity. Turbidite flows follow the topographic controls and the final infill is parallel to the axis of the chain.



Remacha et al., 2005

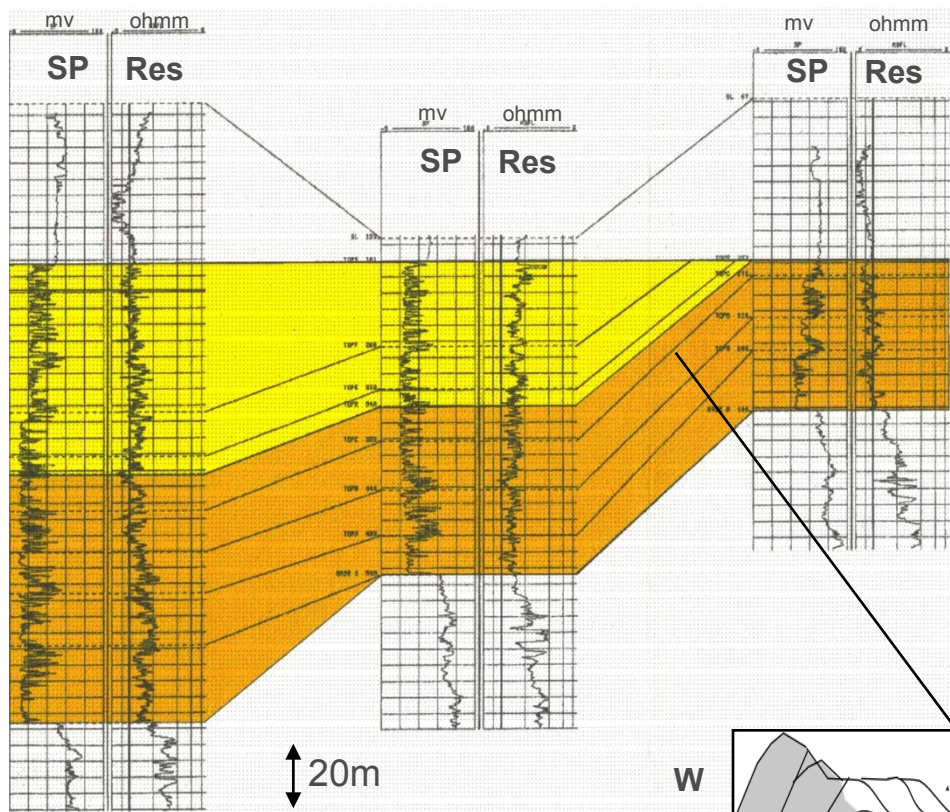
modified after Labaume et al., 1983



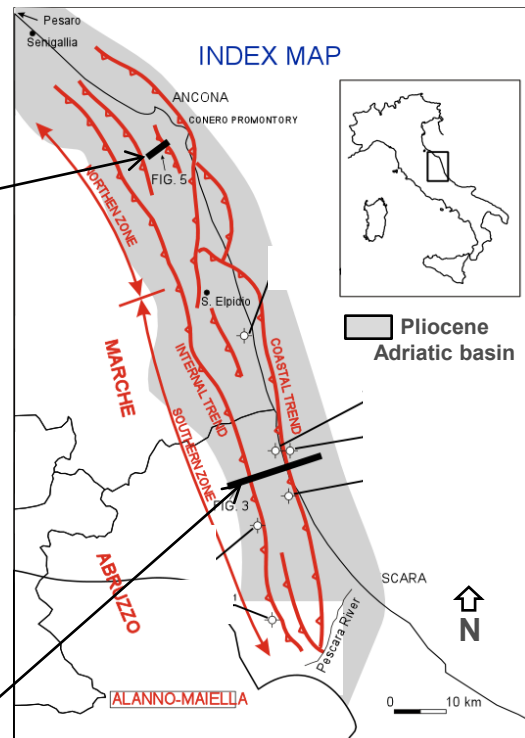


Example of lobes in the S.C. Pyrenees

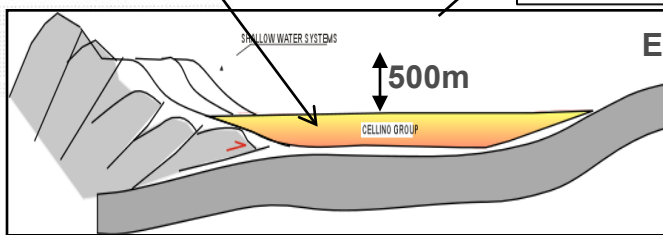
Type B Systems- Confined Basins – Compressional Tectonic Setting



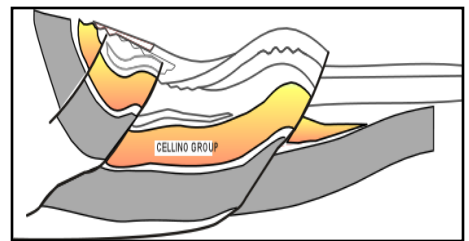
10 km



In the Adriatic basin, a foredeep facing a growing thrust belt, the dominating deposits are represented by massive sands in a confined, narrow trough. Deltaic and Slope sediments are not preserved because uplifted and re-sedimented ("cannibalised") in the deep basin. Continued compression causes the eastward shift of the foredeep). Illustrations modified from Dattilo, et al. 1999.



Pliocene basin geometry (before deformation affects the foredeep basin)

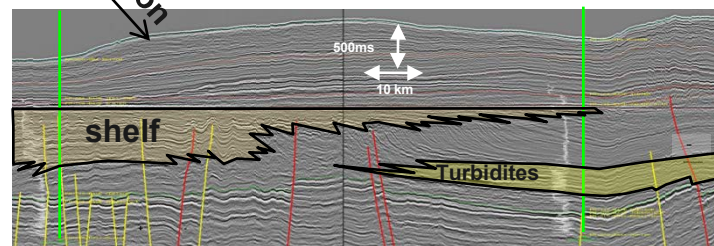
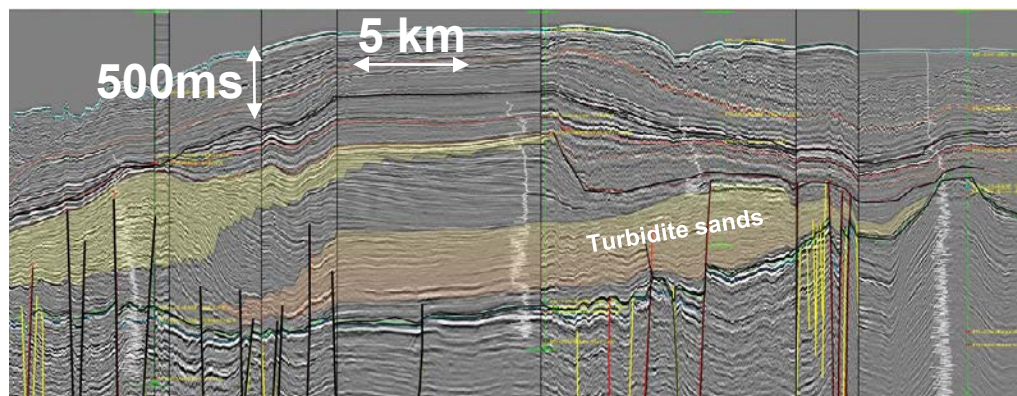
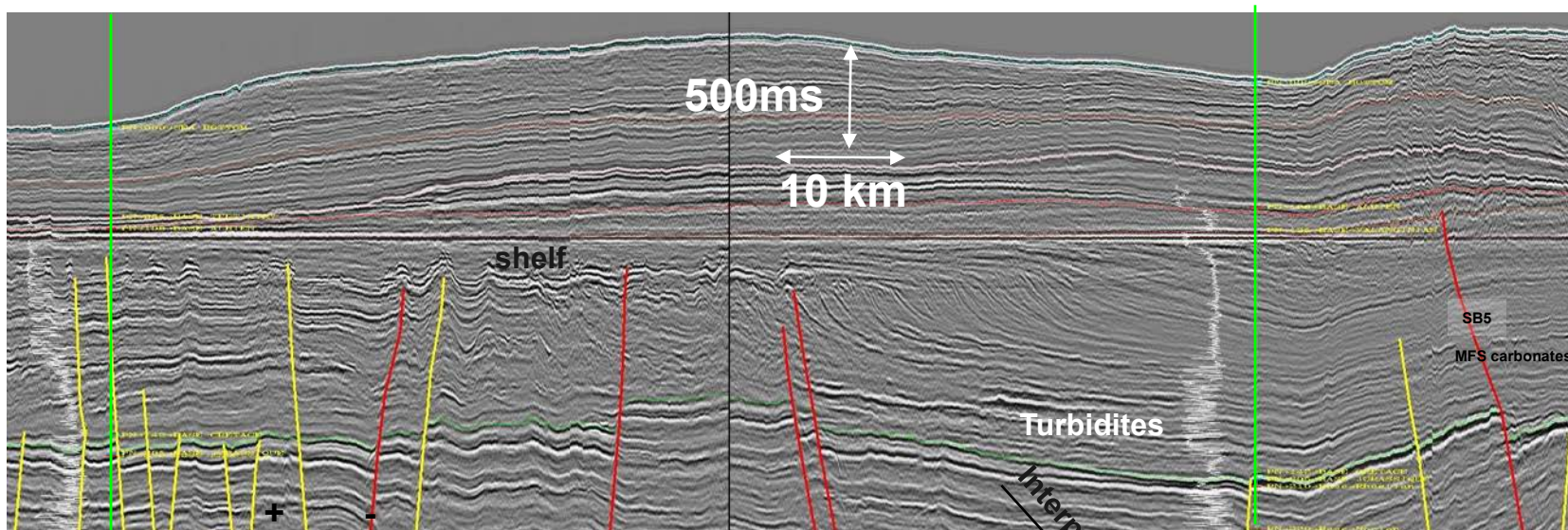


Present day Deformed basin (foredeep deformed)

Compression →

Type B Systems - Confined Basins – Extensional Tectonic Setting

Flattened Seismic line – Australia NW shelf

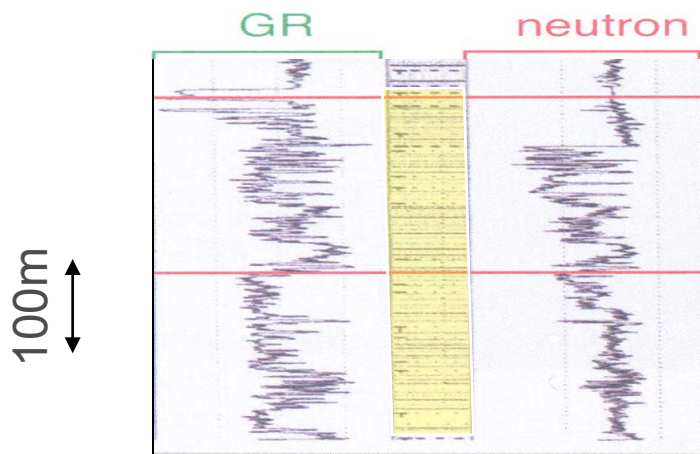


In the NW Australian extensional margin, the slope to basin relationship is preserved. Most of the sedimentation is represented by massive sand packages in the basin plain at the toe of the prograding units, within a confined basin. General blocky stacking pattern of the turbidite sands is similar to that in the previous active margin example.

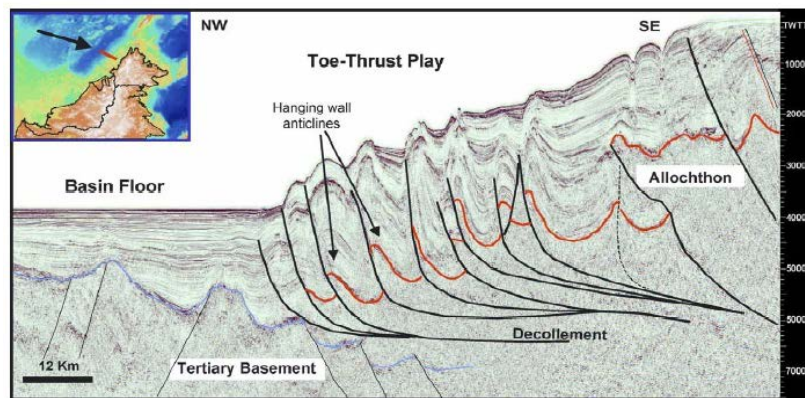


Confined Systems - Comparing deepwater sands stacking patterns in compressional and extensional domains

NW Borneo

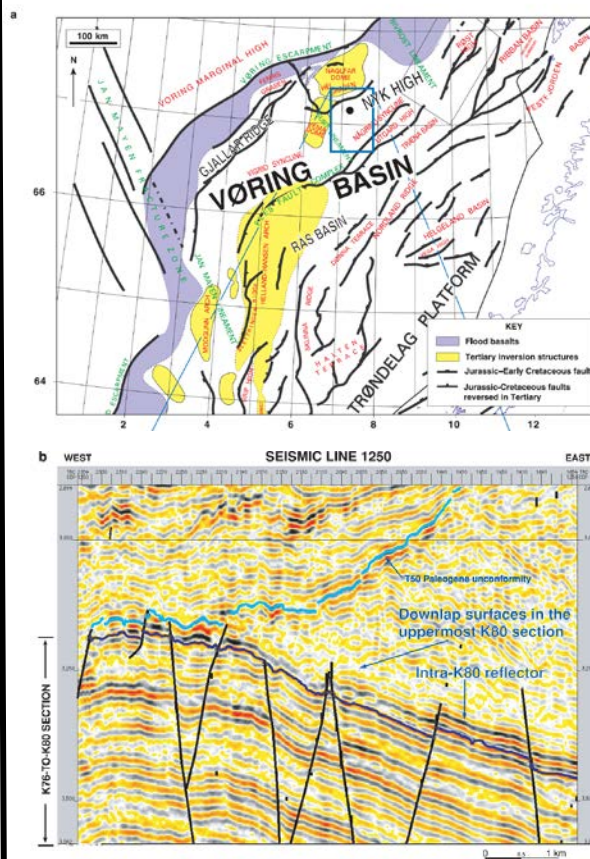


From Chronostratigraphic Chart of the Cenozoic and Mesozoic Basins of Malaysia, Petronas, 2007

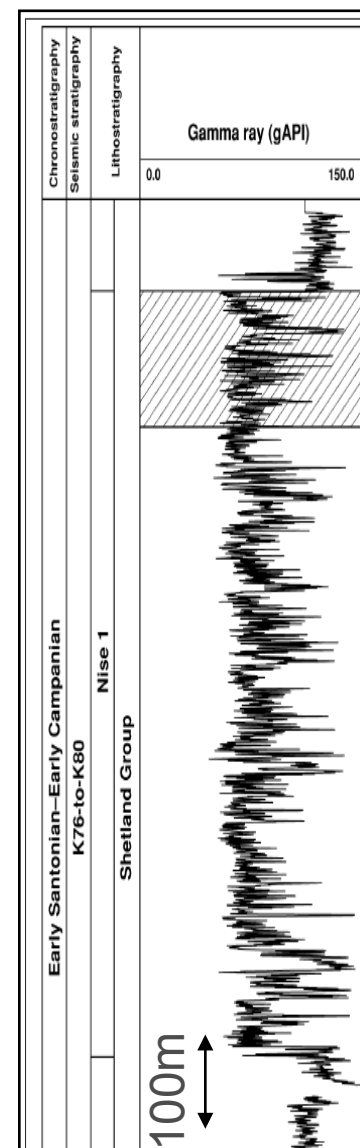


From Ingram, et al, 2004

North Sea's Voring Basin



From Goodall et al., 2003



In the NW Borneo example, to the left, several hundred meters of massive sands are observed within the « Toe Thrust » anticlines.

In the Norwegian North Sea example, to the right, a similar package is observed within a fault block in an extensional structural domain.

Both basin, although in very different settings, show overall very similar stacking patterns of monotonous packages of thick, massive turbidite sands.



Type C Systems – Cratonic Basins

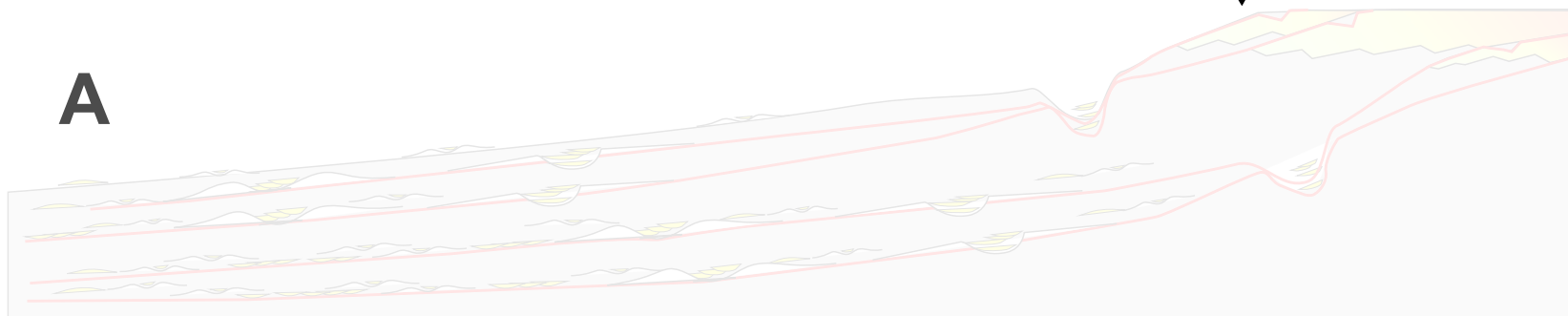
Passive Margin Basin

Indicative length 500-4000 km

SHELFEDGE



A



Confined Basin

Indicative length: 20-70 km

SHELFEDGE



B



Cratonic Basin

Indicative length: 2-10 km

SHELFEDGE



C



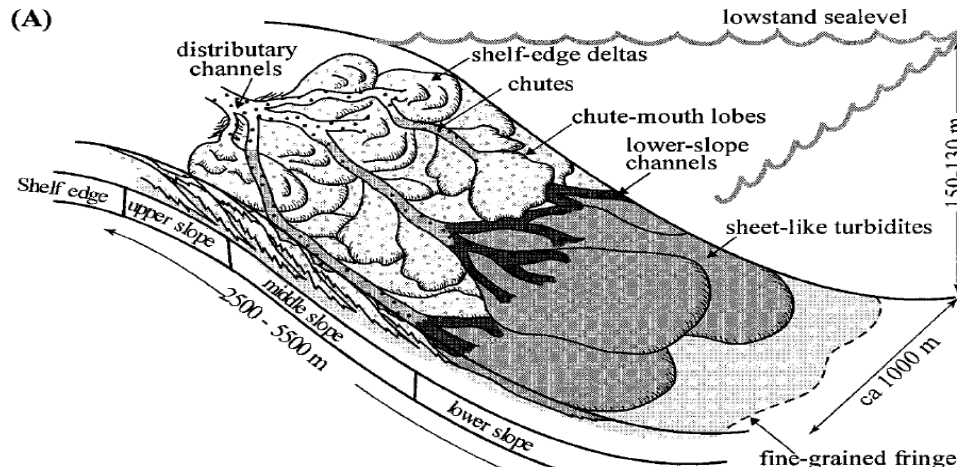
Type C Systems - Main Characters



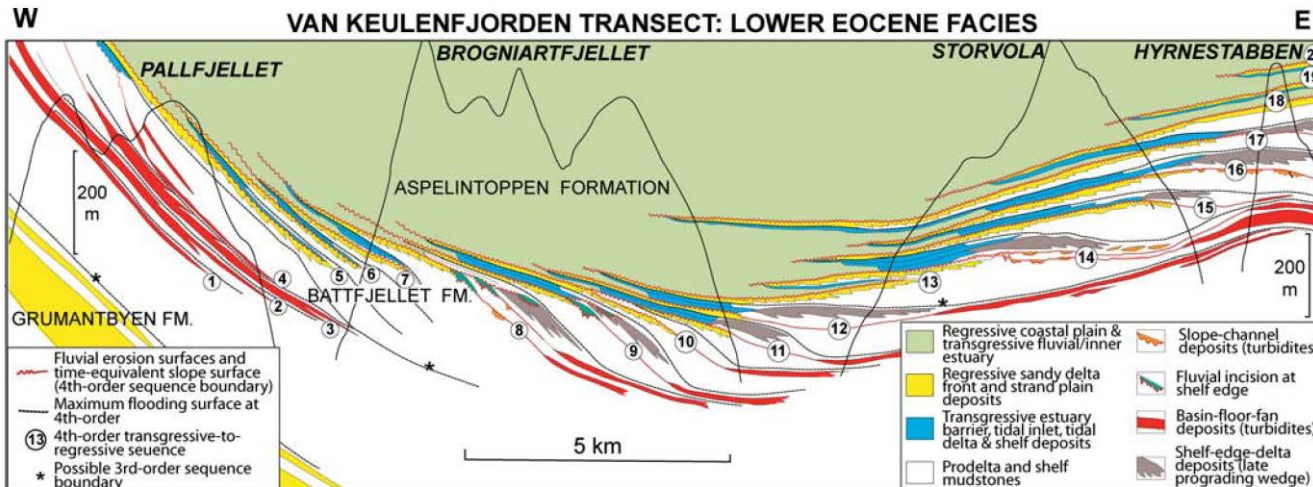
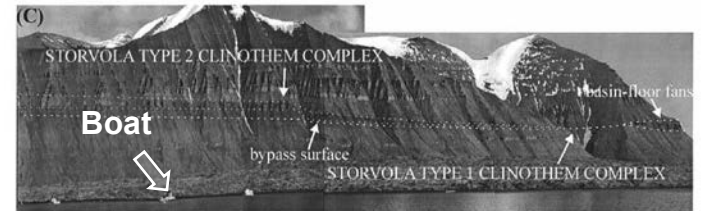
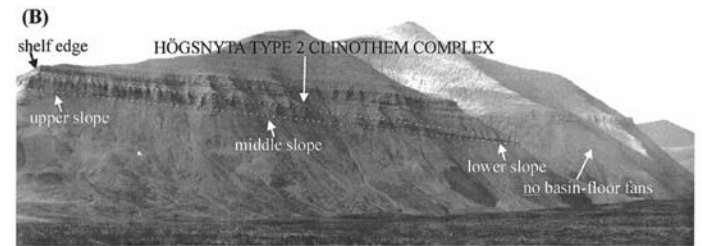
- ▶ **Lithology:** equivalent proportion of sand and shale. Moderately Sandy, F9 facies dominates. Insignificant channel development with respect to Lobe facies. Relatively small lobes (poor correlations) in the basin plain.
- ▶ **Size:** Few hundred meters or kilometers between shelfedge and basin plain (outer limits of basin floor fan). Very short distance between shelfedge and basin floor.
- ▶ **Duration/ life span:** each cycle is very short lived; individual units are in the range of 4th order cycles « basin floor fan ». The whole prograding system is active for few millions years, for example in response to a 2nd order sea level fall as the Valanginian of Siberia.
- ▶ **Fast progradation and forward shift of the turbidite systems due to the lack of subsidence. Relatively shallow water setting (few hundreds of m).**



Type C Systems - Cratonic Basins: Eocene Of Spitsbergen



← fold and thrust belt → eastern edge of the basin →



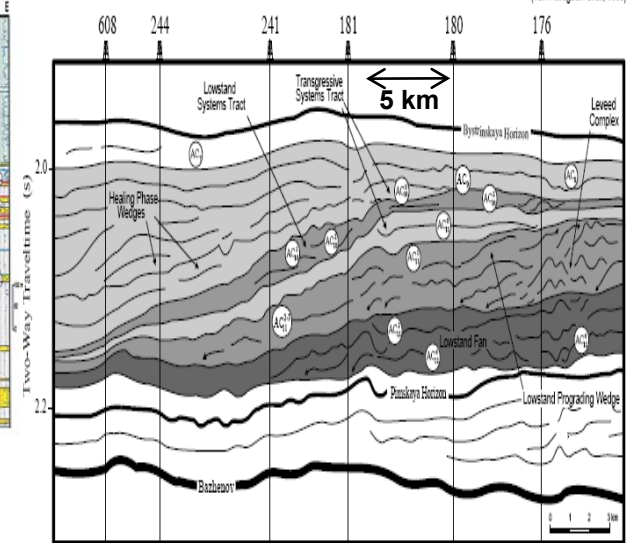
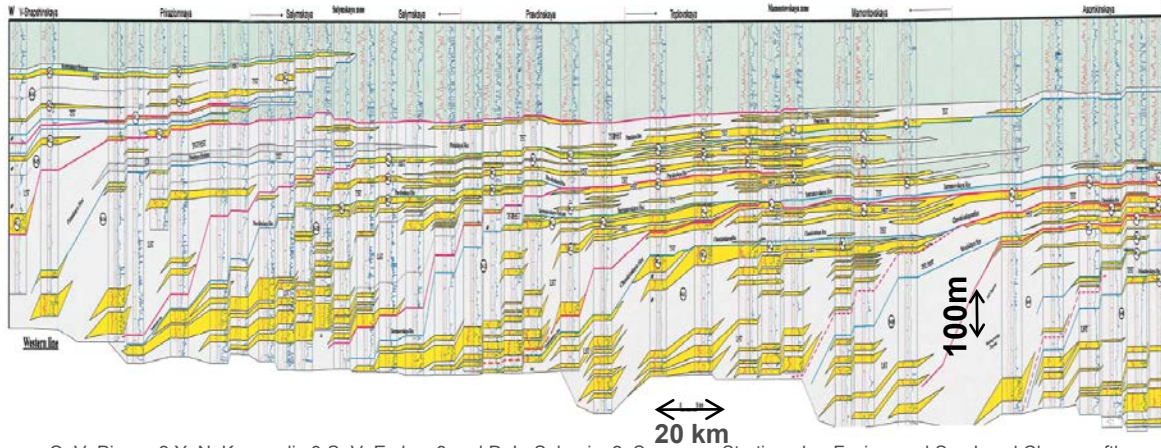
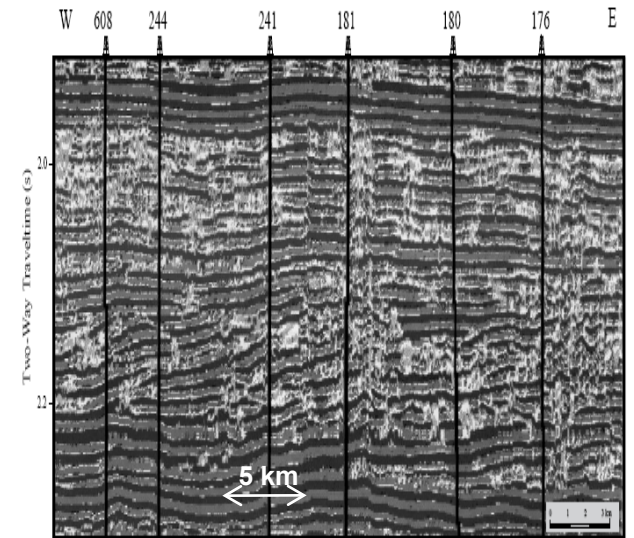
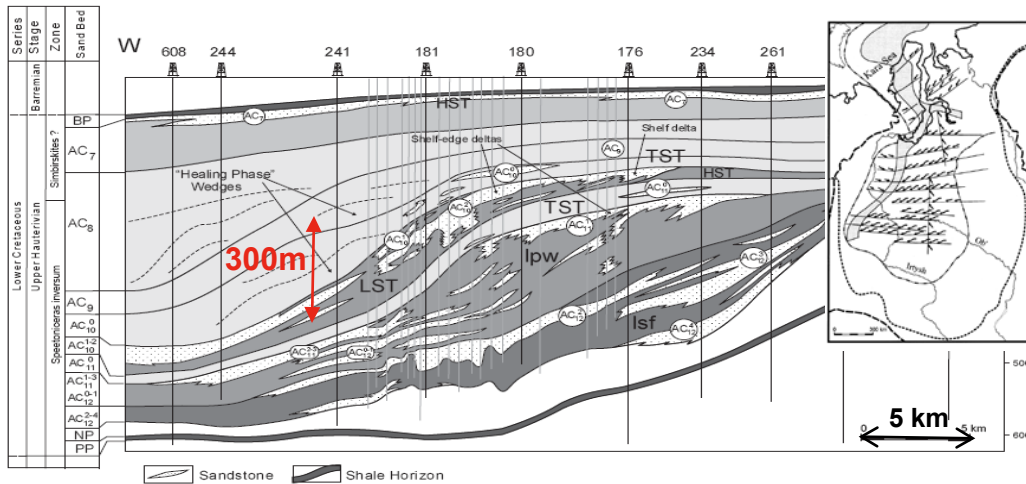
PIRET PLINK-BJORKLUND, DONATELLA MELLERE, AND RON J. STEEL: TURBIDITE VARIABILITY AND ARCHITECTURE OF SAND-PRONE, DEEP-WATER SLOPES: EOCENE CLINOFORMS IN THE CENTRAL BASIN, SPITSBERGEN

JOURNAL OF SEDIMENTARY RESEARCH, VOL. 71, NO. 6, NOVEMBER, 2001, P. 895-912

The distance between the basin floor turbidites and the correlative shelfedge is in the order of few hundred m. The inferred water depth (decompacted sediment thickness between turbidites and shelf) is typically 100-300m)



Type C Systems - Cratonic Basins: Achimov FM, West Siberia



O. V. Pinous,² Y. N. Karogodin,³ S. V. Ershov,³ and D. L. Sahagian², Sequence Stratigraphy, Facies, and Sea Level Change of the Hauterivian Productive Complex, Priobskoe Oil Field (West Siberia) AAPG Bulletin, V. 83, No. 6 (June 1999), P. 972–989.

O. V. Pinous, M. A. Levchuk, and D. L. Sahagian Regional synthesis of the productive Neocomian complex of West Siberia: Sequence stratigraphic framework. AAPG Bulletin, v. 85, no. 10 (October 2001), pp. 1713–1730

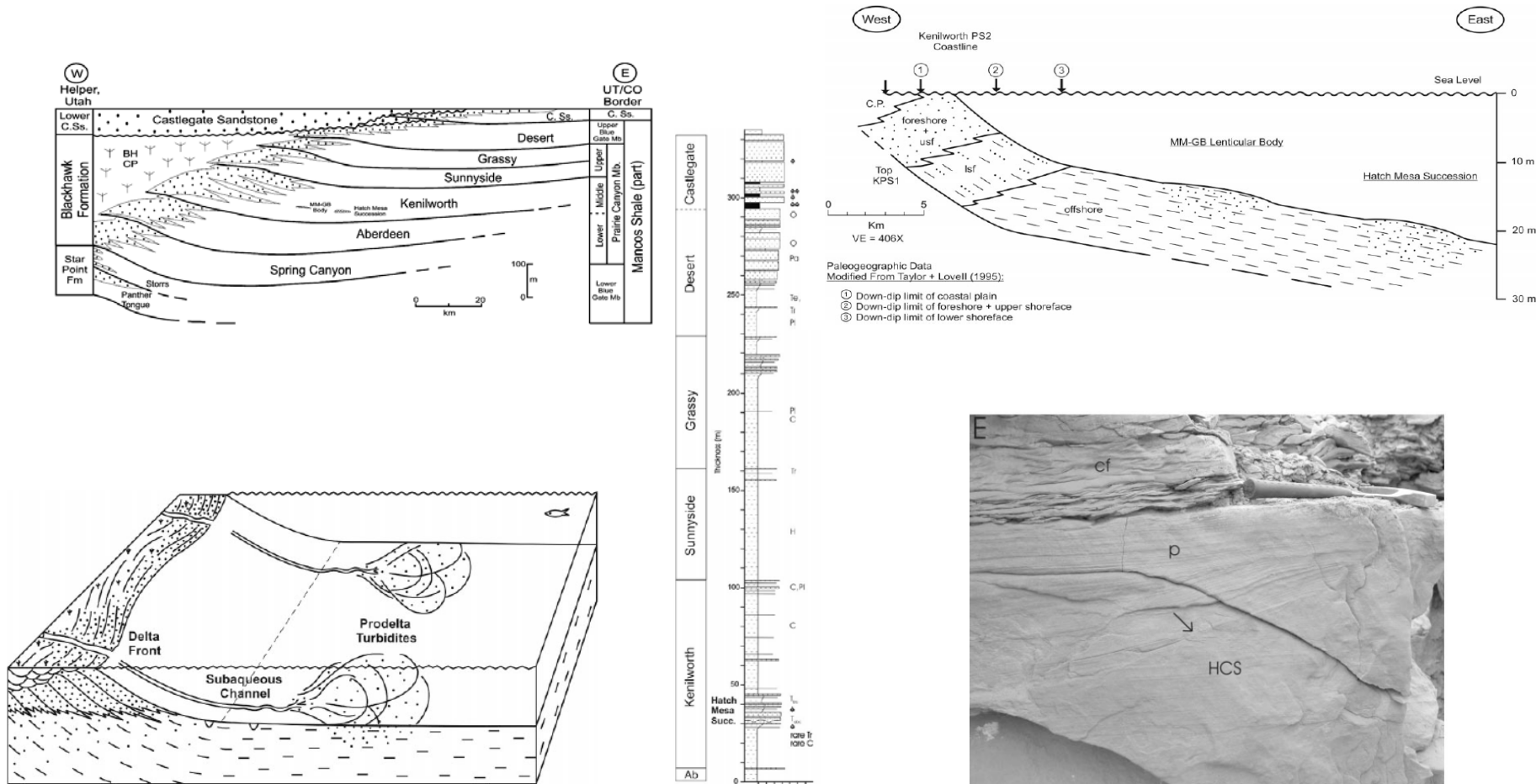
From Karogodin et al 1996 in Pinous et al. 2001

As shown in this example, each individual system appears to cover the time span of a 3rd to 5th order sequence. Sedimentation is clearly cyclical and possibly respond to high frequency sea level changes.



Type C Systems - Cratonic Basins:

Storm influenced turbidites of the Book Cliffs (From Pattison, 2005)



In this example, the relationship shelf-basin is preserved; The water depth at the basin floor may be so shallow that wave action may affect turbidite deposits.



CONCLUSIONS



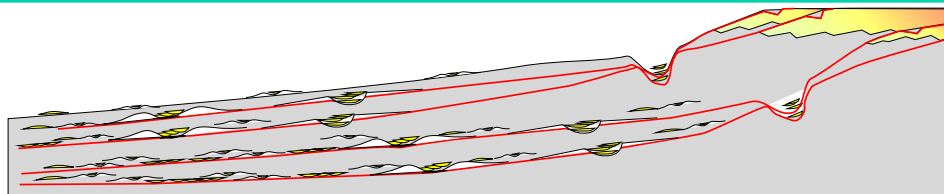
General Remarks

- ▶ The different type of system may be the result mainly of the interaction between the nature of the paleo-slope and the dominating size of the turbidity flows.
- ▶ The Type A, B and C may be represented as the end members of a classification which may permit to describe a deep water system depending on the dominating sand depositional process along a given slope type.
- ▶ A general relation between types of deep water systems and structural setting is observed, but it's more related to the structural margin “steepness” than to the tectonic regime: similar features are observed in active and extensional margins.
- ▶ Depending on the structural evolution, within a single basin one or more types may be superposed*.
 - In a passive margin for instance, Type B or C may develop during the earliest phases, when the basin margin are still steep and structurally controlled. If the basin margin stabilises, a smooth, “sediment controlled” slope may be built and a Type A may begin to form on top of a Type B.
- ▶ The “hydraulic jump line” in the triangular diagram of the following image below separates the systems in which the reservoir Facies are mainly deposited updip of the hydraulic jump to those where the dominant reservoir Facies are interpreted to have formed downip of the hydraulic jump.

* In analogy to Deltaic systems, also classified in 3 end membes (Galloway 1975), tide, wave and fluvial, which vary within the same basin in function of the evolution of the controlling parameters.



Triangle



Dominating Processes and Reservoirs Facies in the three types of deepwater systems

Angola, Indus, Bengal, Nigeria, Amazon, ...

Debris flows to High density TC
F1-F5

Hydraulic Jump Line

Diluted Turbidity Currents
F9

High density sandy TC
F6, F7, F8

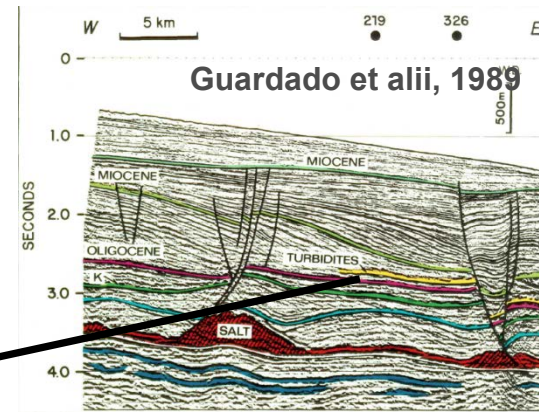
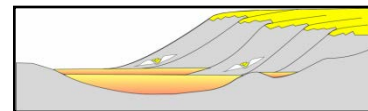
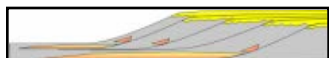


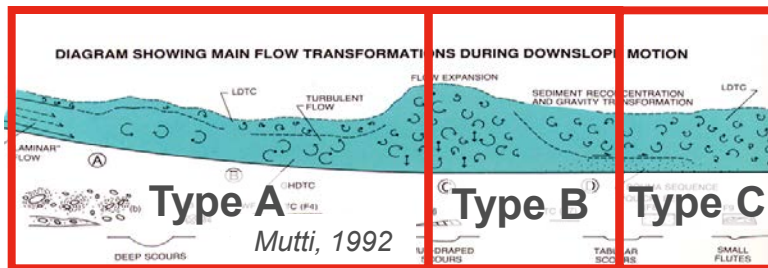
Figure 87—Seismic profile of Marlin field. Amplitude anomaly at underlying Oligocene turbidite. Location shown on Figure 85

Italy Foredeep Basin, South Central Pyrenees, Voering, Sabah, W Australia, ...

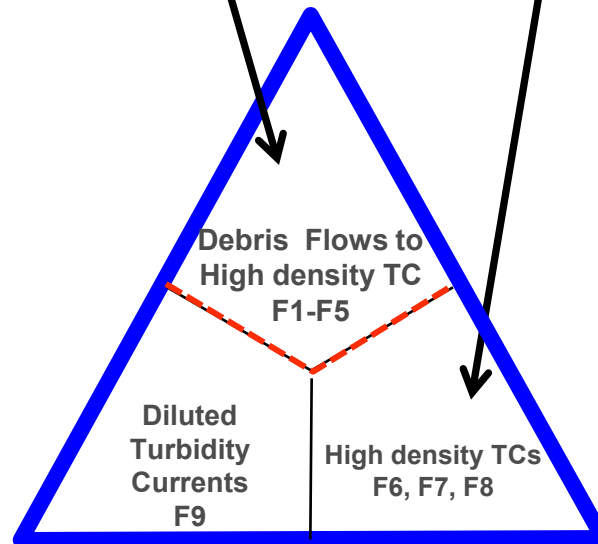
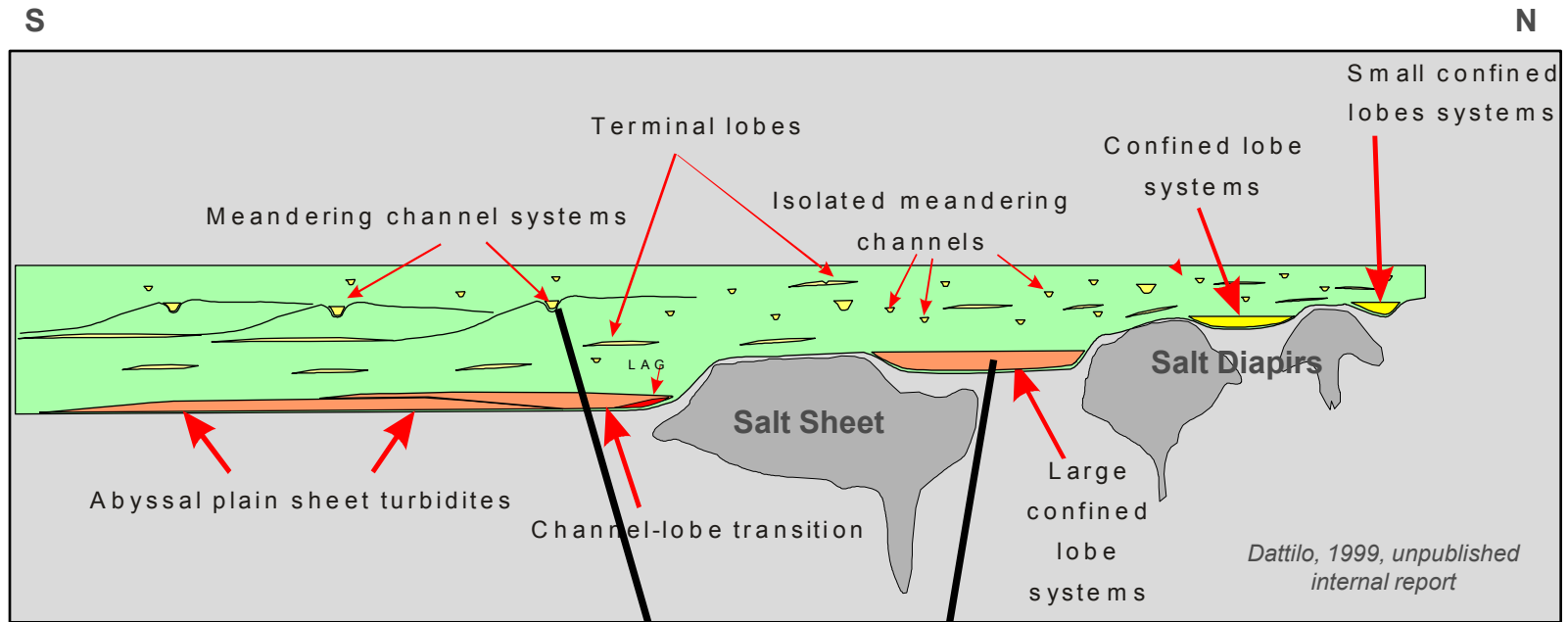


West Siberia, Spitsbergen, Book Cliffs, ...

Dominant processes and turbidite system type



In The Gulf Of Mexico: A double system - I



In The Gulf Of Mexico: A double system - II

■ In the gulf of Mexico, the Type A and B are alternating.

- Type A is clearly illustrated by the Plio- Pleistocene Mississippi Fan (Weimer, 1990);
- Type B is illustrated by sand laden minibasins (example: the Diana basin, Southern East Breaks – north Alaminos Canyon areas, Sullivan et alii, 2000).

■ The particularity of the GoM is that the passive margin is characterised by salt tectonics along the shelf affecting up to Plio-Pleistocene sediments (this control is virtually missing, for example, in the Neogene shelf sediments in Angola). Multiple sediment sources are therefore reactivated during lowstands. In the lowstand periods, the shelf salt diapirism (ex: Suter and Berryhill, 1985) causes accrued rejuvenation and instability of the shallow marine distributary systems. Slope failure could have occurred, locally permitting the development of Type B systems (Diana system, as an example).

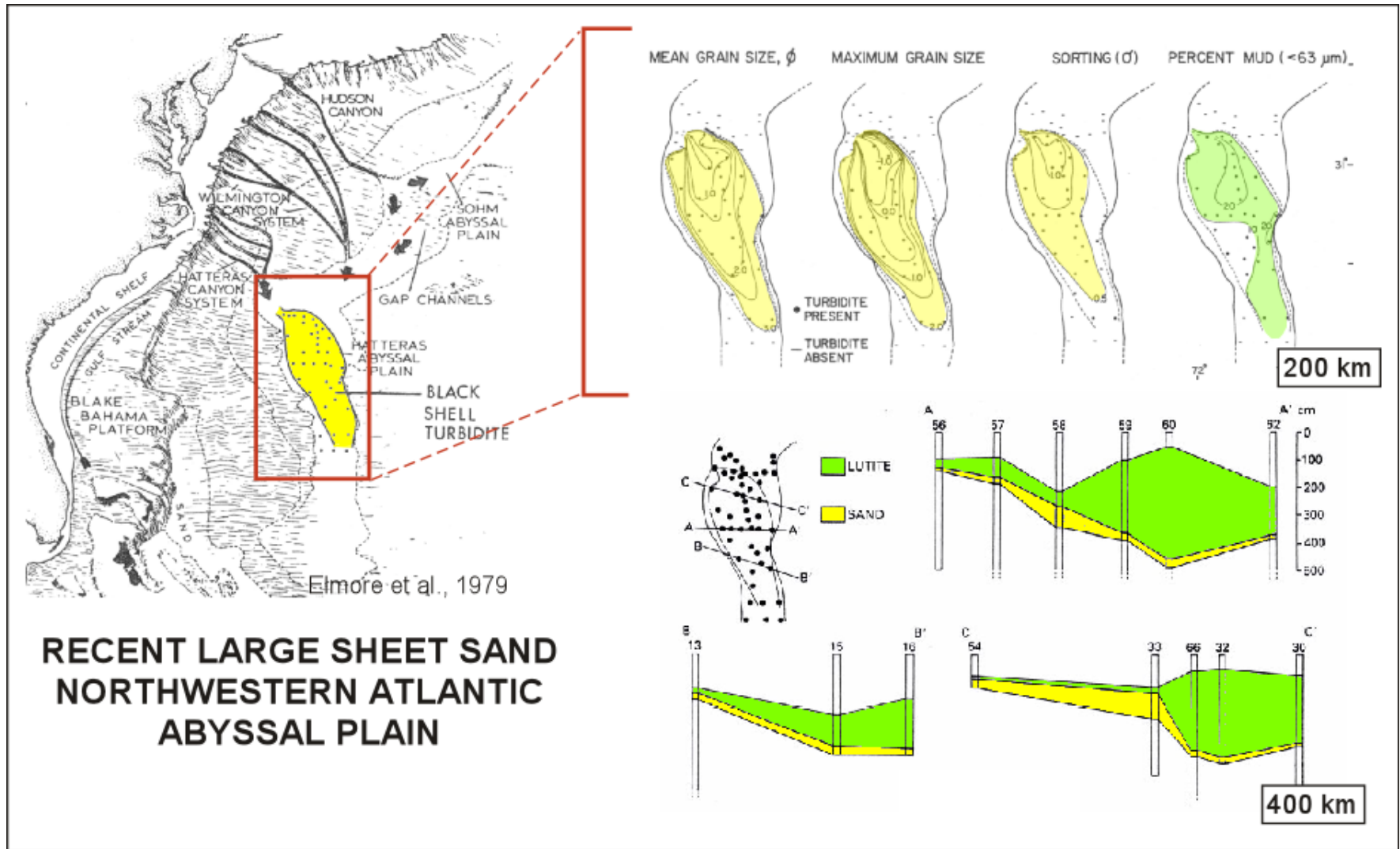
■ Another particularity of the GoM is represented by the Paleogene and Lower Miocene Abyssal Plain systems which may be assimilated to Type B as the largest volume of sand is in the basin plain. An example of Abyssal Plain turbidite is represented by the classical the Black shell turbidite of Elmore et alii 1979 –see following image- and Pilkey et alii, 1987). These deposits may be interpreted as seismoturbidites (Mutti & alii, 1984; Megaturbidites of Labaume et alii. 1987)

- The Paleogene and Lower Miocene Abyssal plain systems could be correlated to 2 major structural event in the drainage basin areas, which are respectively:
 - 1) the final stages of Laramide horogenesis,
 - 2) the eastward shift of tertiary depocenters and the onset of Mississippi river distributary system (Wenker, 1980)

These events may have been associated to an increased seismicity of the basin margins and of the sediment drainage areas.



Recent Abyssal plain turbidite (Elmore et Al., 1979)



Conclusions

- ▶ Three end members may help better describe the various deepwater settings.
- ▶ Deepwater margins show important variations but also striking similarities in different structural settings, like confined basins in compressional and extensional settings.
- ▶ Similarities and differences are probably related to the dominating processes and basin configuration, regardless of the nature of the basin shaping forces.
- ▶ Although analogies may exist between various turbidite systems, a case by case study is critical to approach each systems, as controlling parameters change through space and time.
- ▶ It is critical to try to integrate the analysis of sedimentary processes at the regional scale in order to build predictive scenarios.



Aknowledgments

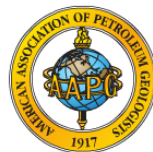
TOTAL



TOTAL

P. Imbert, for reviewing an early version of this presentation
M. Bez, F. Lafont, J.L. Rubino, P. Crumeyrolle, for continuous exchanges
F. Larrouquet, for encouraging to prepare this presentation
E. Mutti, for teaching to listen to the rocks

***PARA VOSSE,
NOSSA ENERGIA ESTA SEM LIMITES!
ATE LOGO!***



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