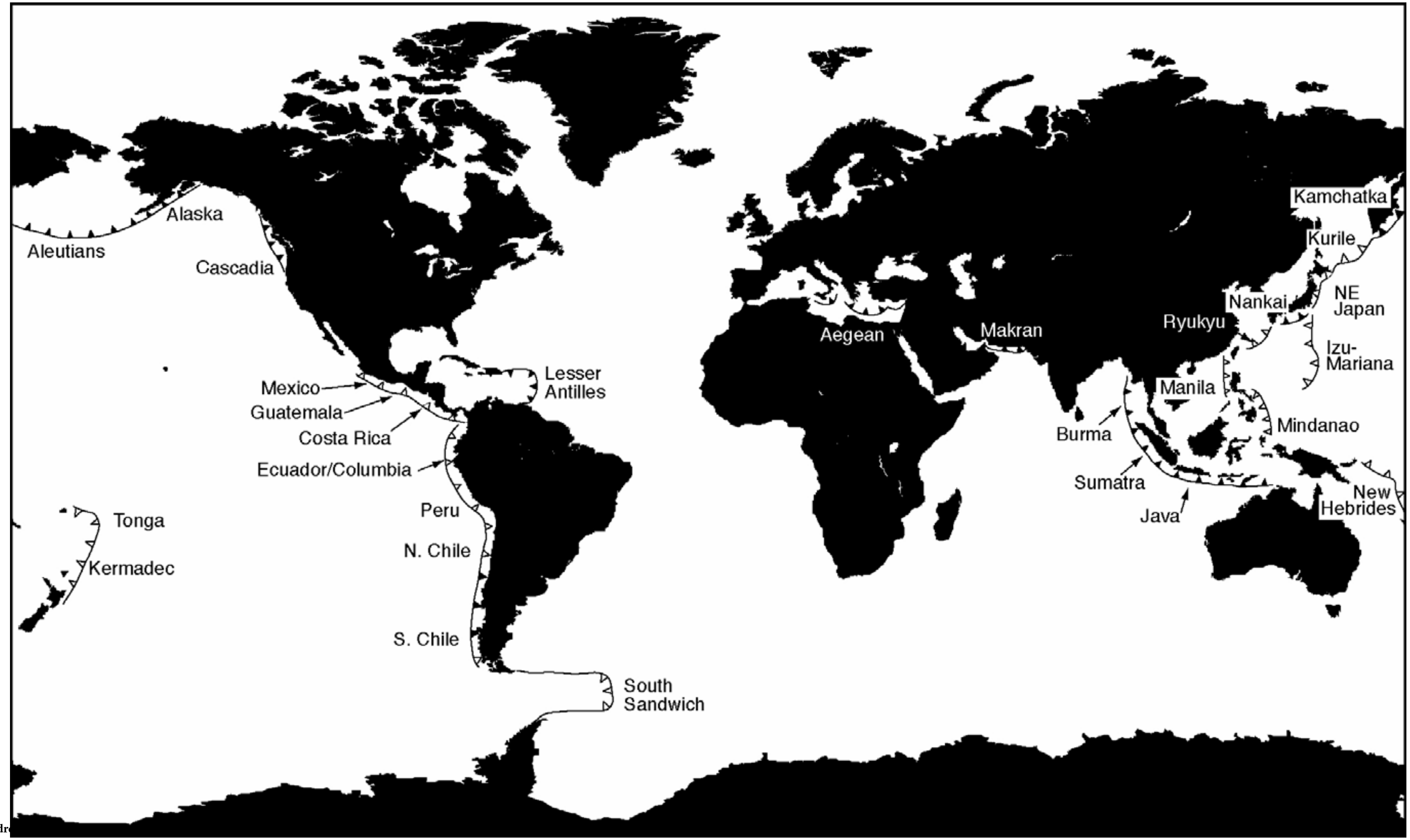
5. Basins associated with subduction processes

The global subduction system



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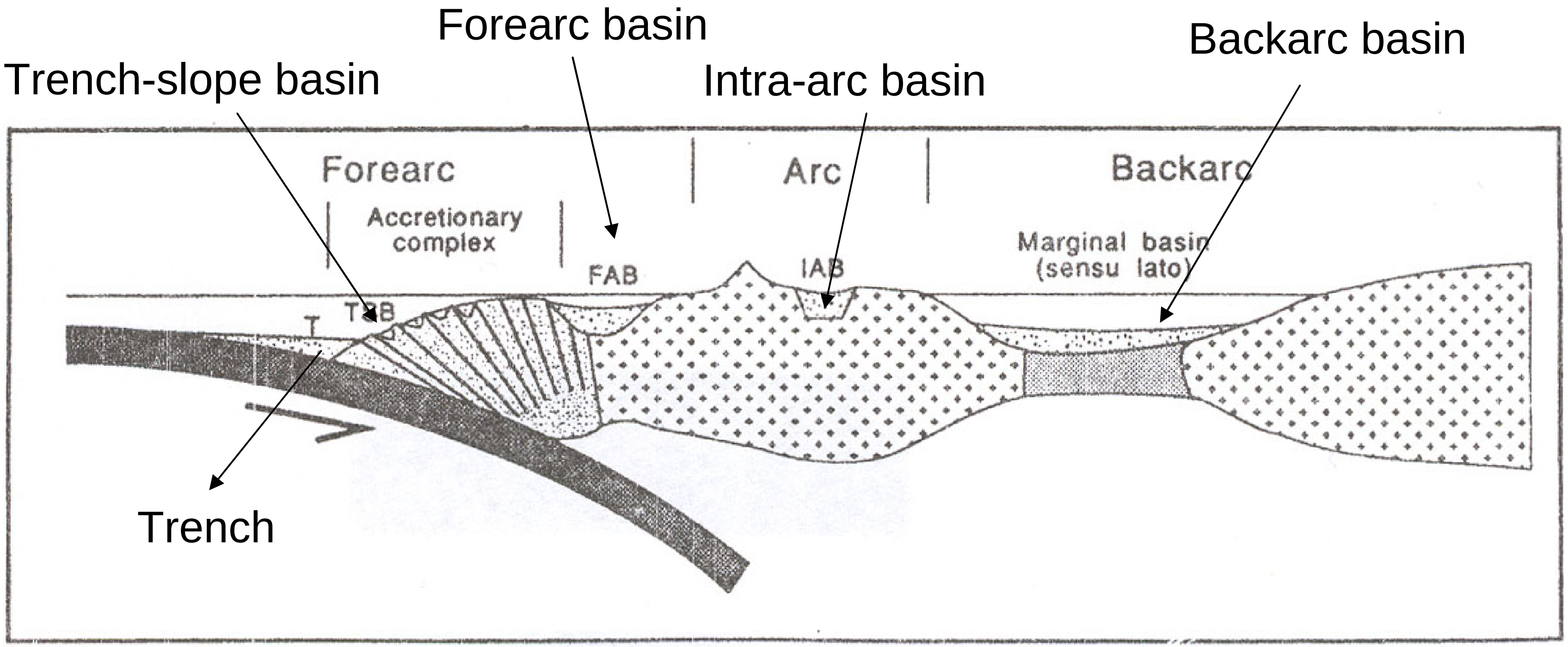
Convergent setting – arc-trench system



the major sites of sediment accumulation at convergent margins discussed in this paper. T, trench; TSB, trench slope basin; FAB, fore-arc basin; IAB, intra-arc basin; note that an ensialic setting is shown here, but the terminology applies equally to intra-oceanic convergent margins.

Trenches: situated on the downbent oceanic lithosphere
Slope basins: perched on the accretionary subduction complex
Forearc basins: located between the arc and the subduction complex
Backarc basins: found on the landward side of the arc.

Prepared by Dr. Andrew T. Lin
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Three families of arc-systems (Dewey, 1980)

1. **Extensional arcs**: velocity of roll-back (a) > oceanward velocity of the overriding plate (b). Producing backarc extensional basins
   e.g., Mariana and Tonga arcs, eastern Indonesia.

2. **Neutral arcs**: (a) $\approx$ (b)
   Producing well-developed subduction complexes, but no backarc extension.
   e.g., Alaska-Aleutian and Sumatran arcs.

3. **Compressional arcs**: (a) < (b)
   Causing thrusting in both overriden oceanic and overriding continental crust.
   e.g., Canadian – western USA Cordillera, Peruvian Andes.

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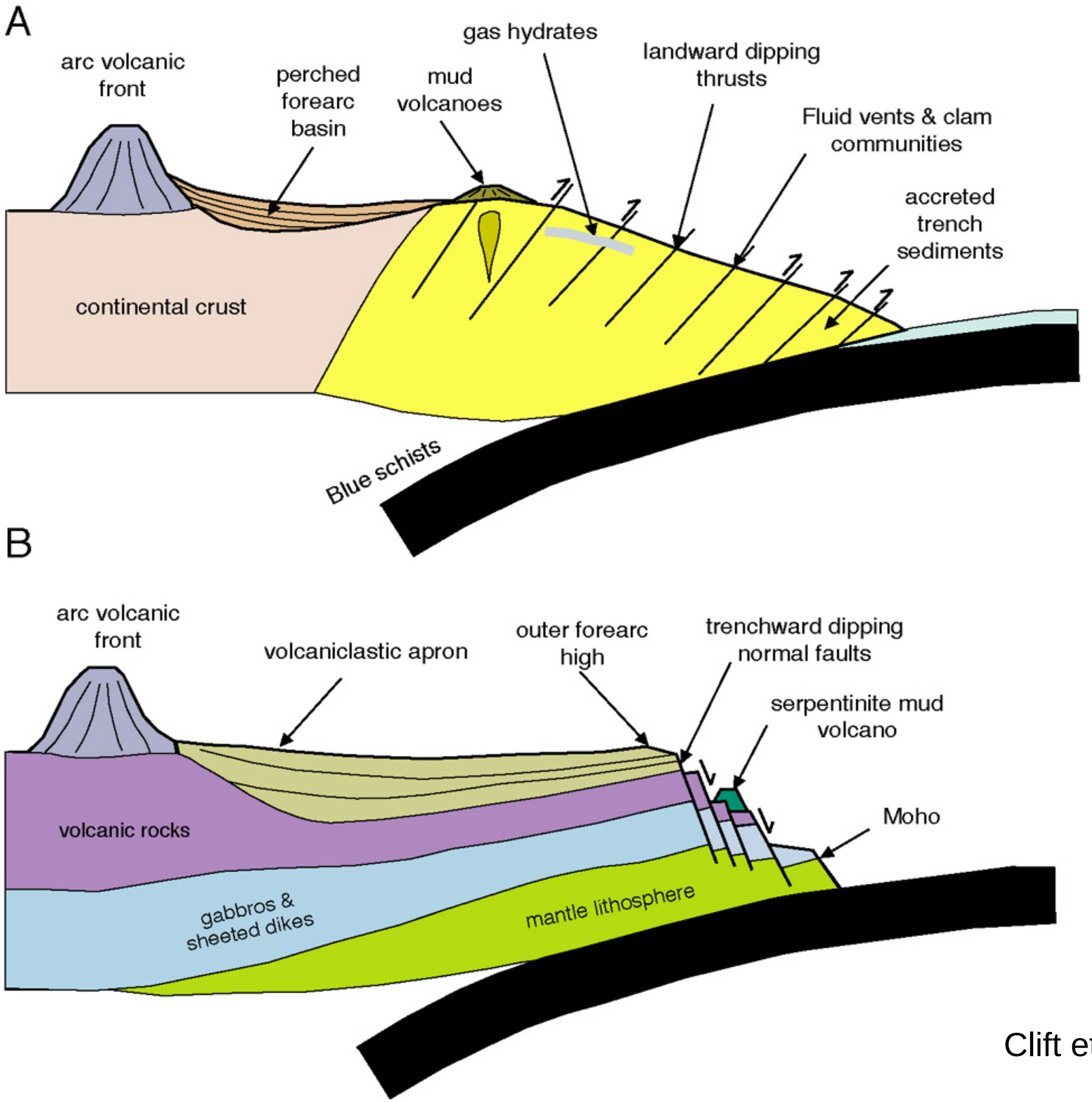
Erosive versus accretionary margins



Clift et al. (2003)

Prepared by Dr. Andrew T. Lin
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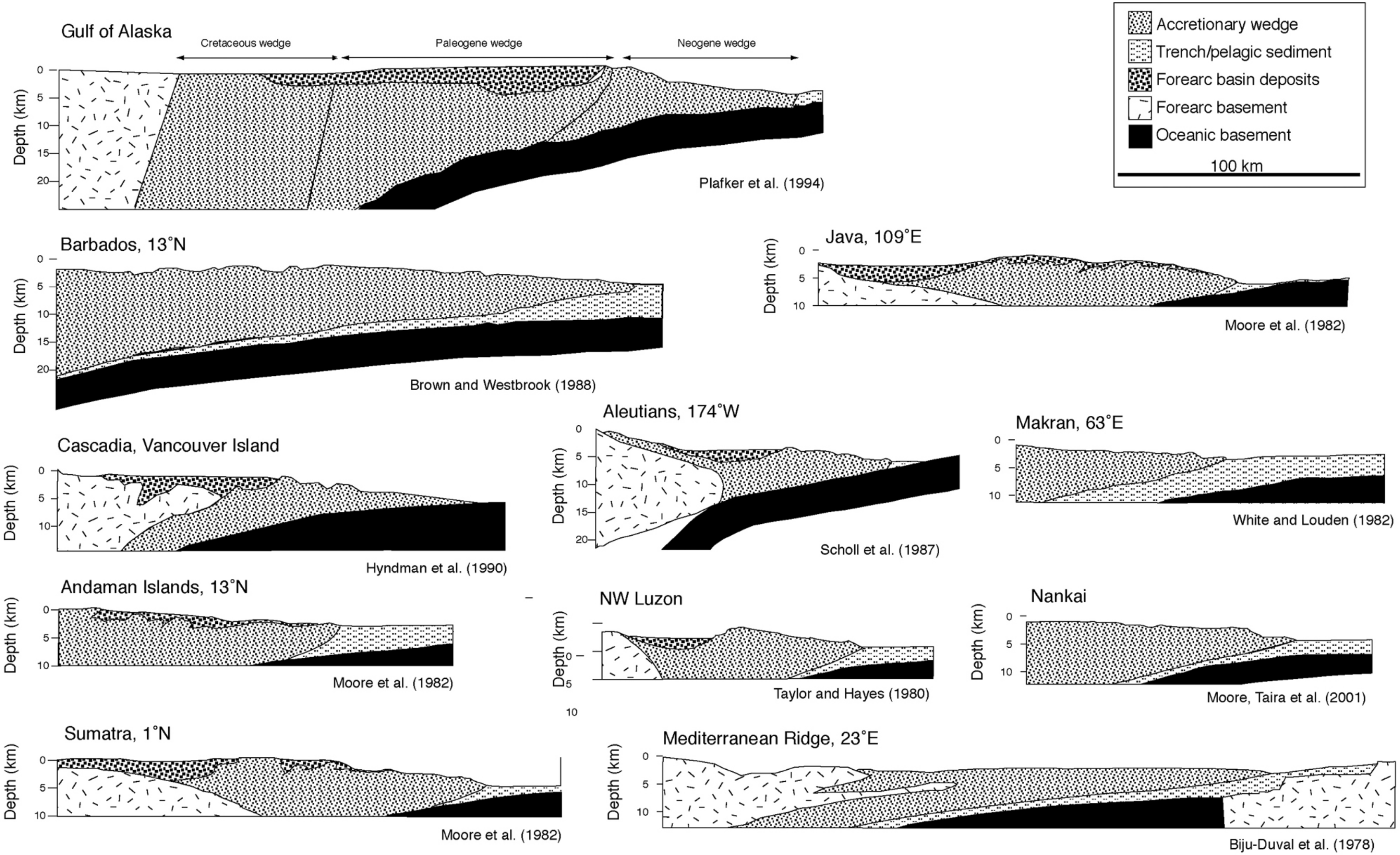
Global compilation of accretionary margins



Clift et al. (2003)

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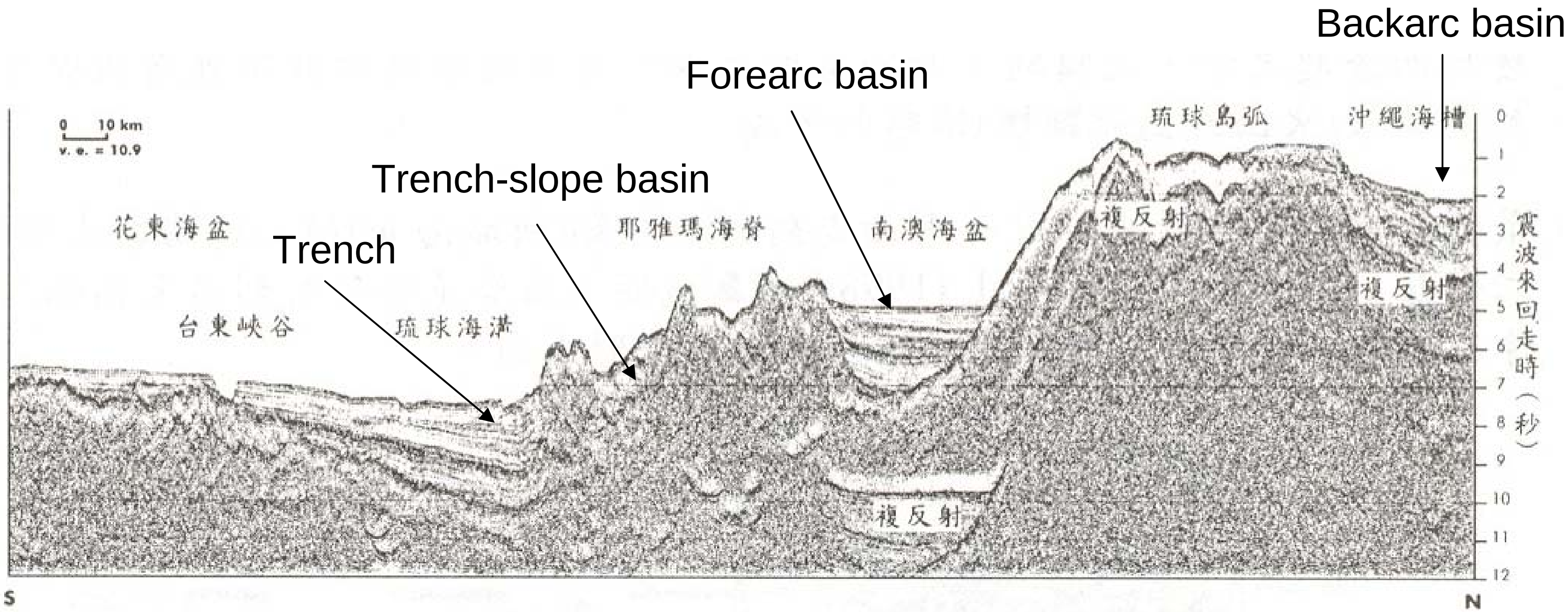
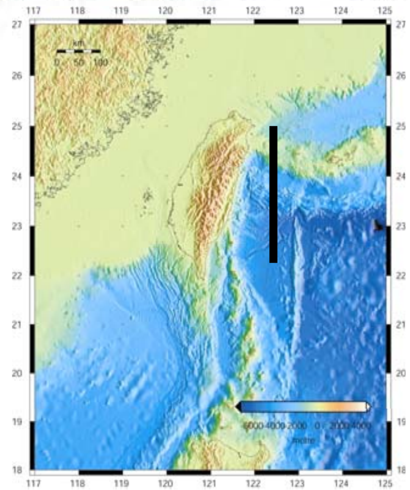
Example of an accretionary margin (Ryukyu arc-trench system)



圖二十七、南北走向從花東海盆經琉球海溝、耶雅瑪(八重山)海脊、南澳海盆到琉球島弧的多頻道反射震測剖面 EW9509-1（摘自 Liu et al., 1997b）。反射剖面清楚顯示地形與大地構造單元的密切對應關係，並顯示弧前盆地座落於琉球島弧基盤之上。剖面位置見圖二十五 AA'線。

劉家瑄(2002)



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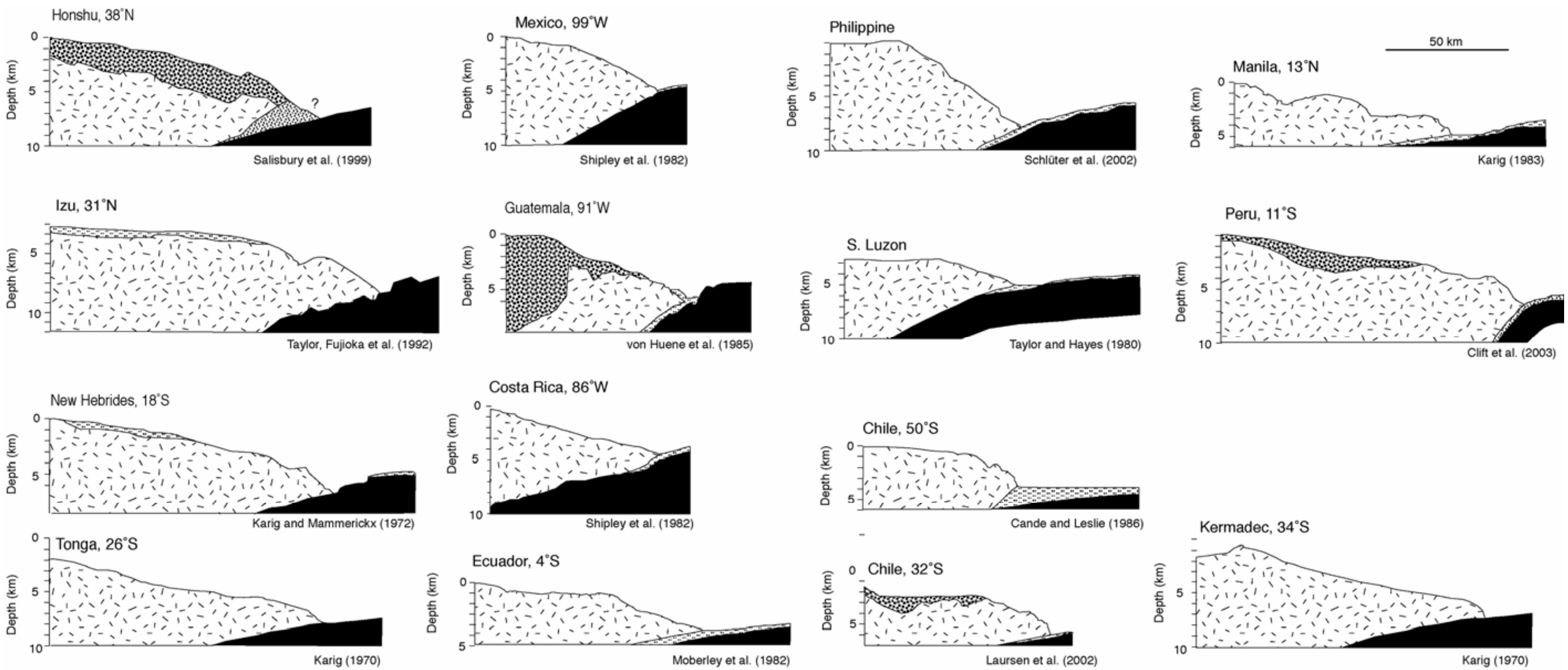
Global compilation of erosive margins



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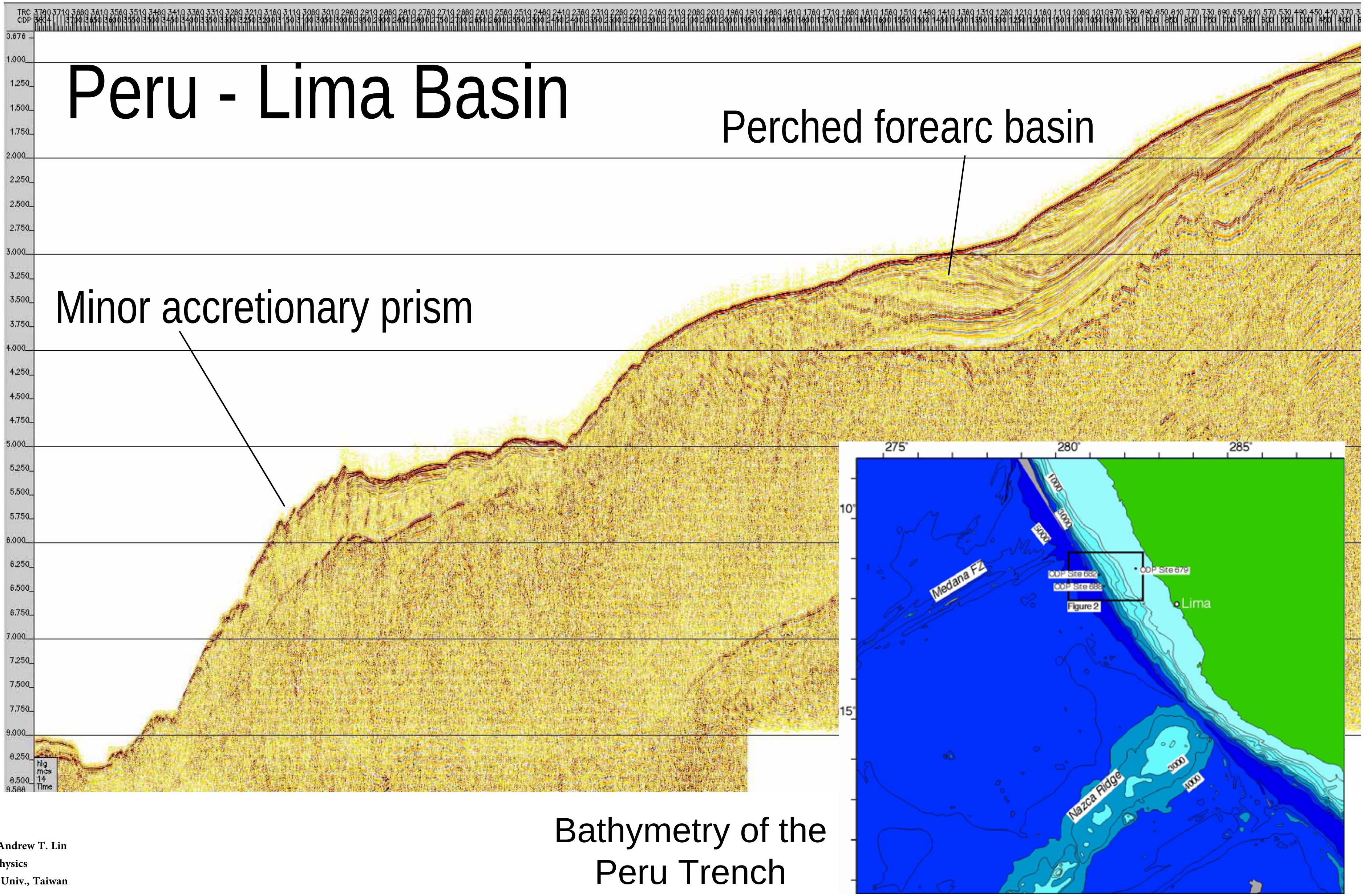
Classic example of the erosive margin



Bathymetry of the Peru Trench

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What are characteristics of erosive plate margins?

- Landward retreat of volcanic arc
- Subsidence of forearc basin
- Arc igneous rocks exposed in inner trench slope
- Normal faulting/extension in forearc
- Trenchward tilting of forearc

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Dynamics of accretionary/orogenic wedges

Accretionary wedges attain dynamic balance between:
(1) the gravitational forces arising from the slope of the wedge;
(2) The horizontal "push" from the rear;
(3) The basal shear force or "traction".

A **critical taper** (Davies et al., 1983) is the shape for which the wedge is on the verge of failure under horizontal compression everywhere.

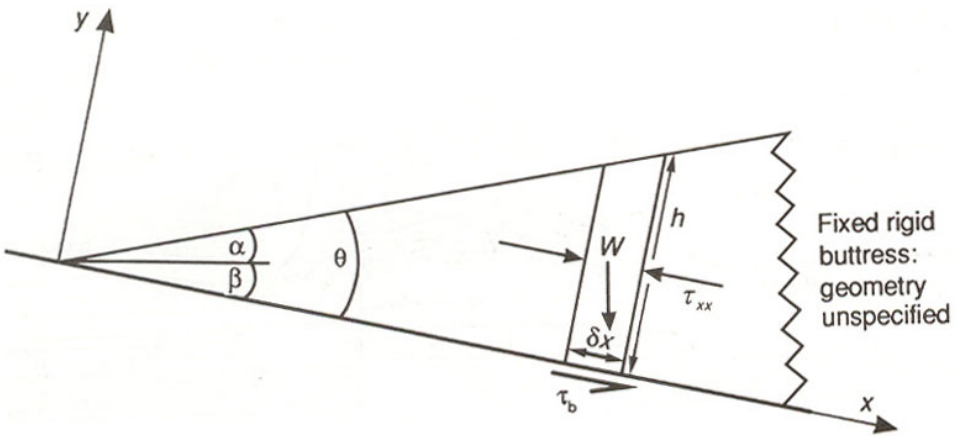
$$\tau_b = \boxed{\rho g h \alpha} + (1-\lambda)K\rho g h\theta$$

Basal shear gravity horizontal push

Western central Taiwan (Davies et al., 1983):
The regional surface slope of α = 2.9°; β =6°
is well explained by the critical taper theory.

Parameters

τ_b = basal shear stress
ρ = density
g = gravitational acceleration
h = depth below surface
α = surface slope of wedge
λ = ratio of pore-fluid to lithostatic pressure
K = yield strength of the wedge
θ = angle at the front of the wedge = $\alpha + \beta$
β = basal slope



Davis, Suppe and Dahlen (1983) & Platt (1986)

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Young

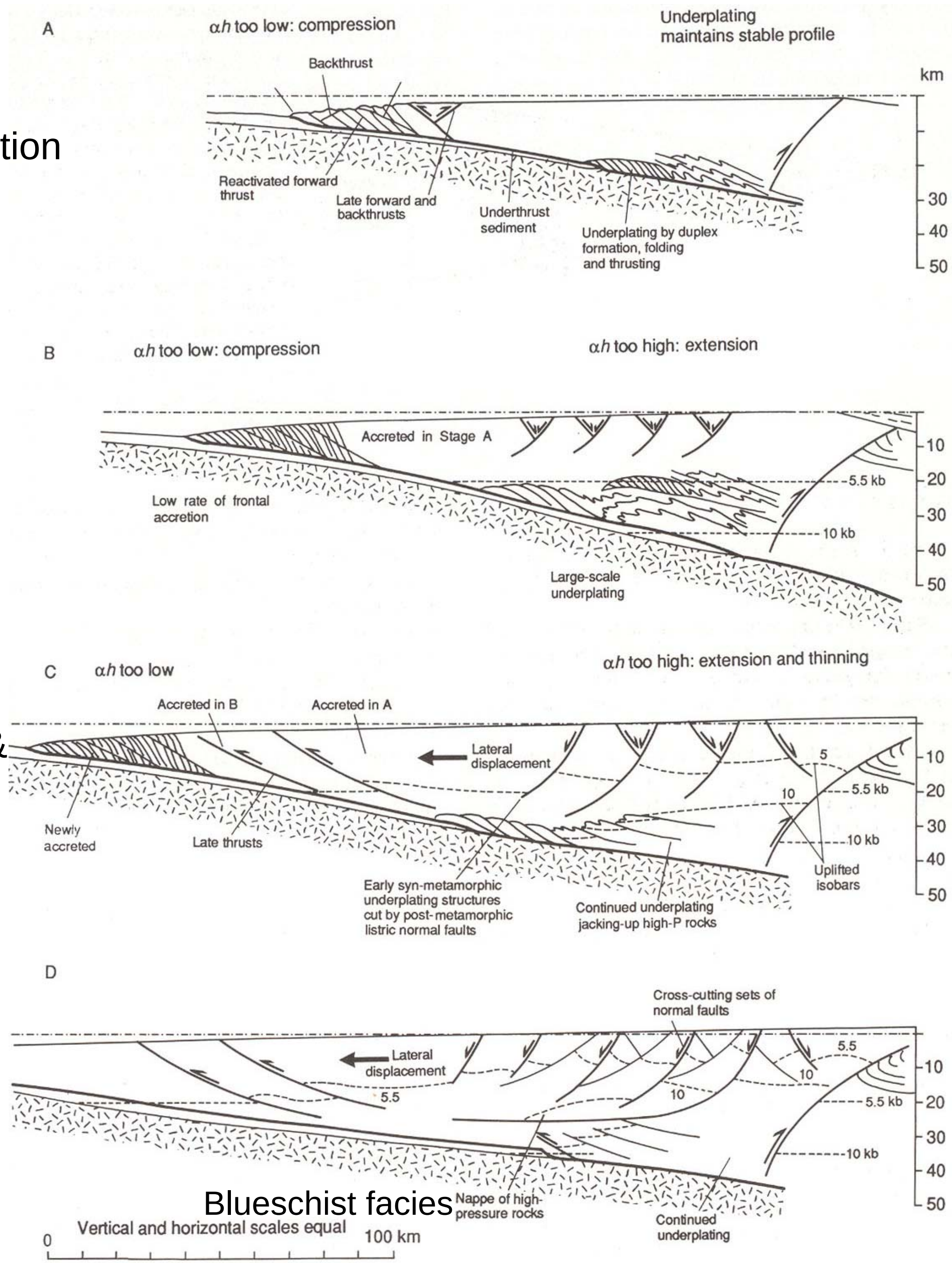
Frontal accretion dominant

Underplating dominant

Underplating & extension dominant

Underplating, Extension & erosion dominant

Old

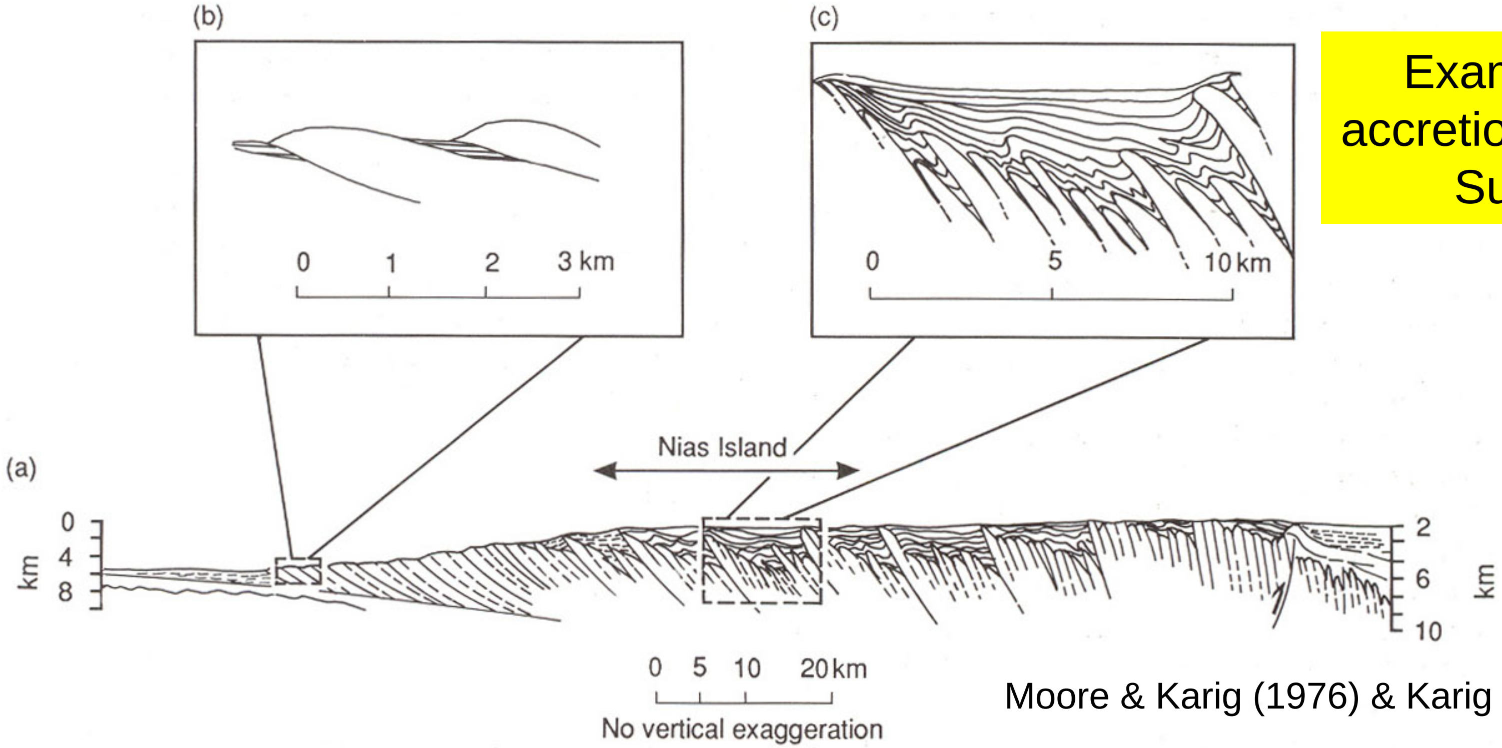


Platt (1986)

Evolution of an accretionary prism from youth to maturity (A to D)

Patterns of deformation:

- Frontal accretion
- Underplating
- Erosion
- Changes in basal shear stress



Example of an accretionary prism – Sunda arc

Moore & Karig (1976) & Karig et al. (1978)

Structural geometry based on seismic profiles across the subduction complex of the Sunda arc. The subduction complex is made of a series of imbricate thrust sheets composed of a melange of sheared sedimentary rock debris.

On the Nias island the "debris" comprises the following:

- basalt, rare peridotite, dunite, serpentinite derived from the oceanic crust.
- chert, red shale and pelagic limestone derived from the sedimentary cover of the oceanic crust.
- turbiditic conglomerates, sandstones, and mudstones derived from the adjacent arc and especially the Bengal Fan through longitudinal sediment supply.

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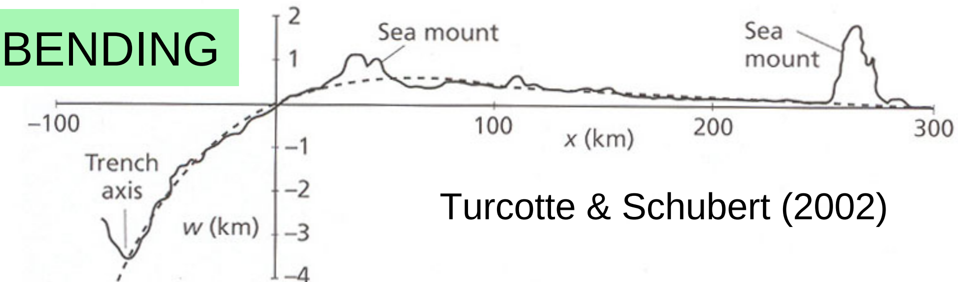
Bending, sedimentation and accretion near trenches

The bending of the Pacific plate (solid line) as it enters into the Mariana Trench. Pecked line shows profile according to flexural theory.

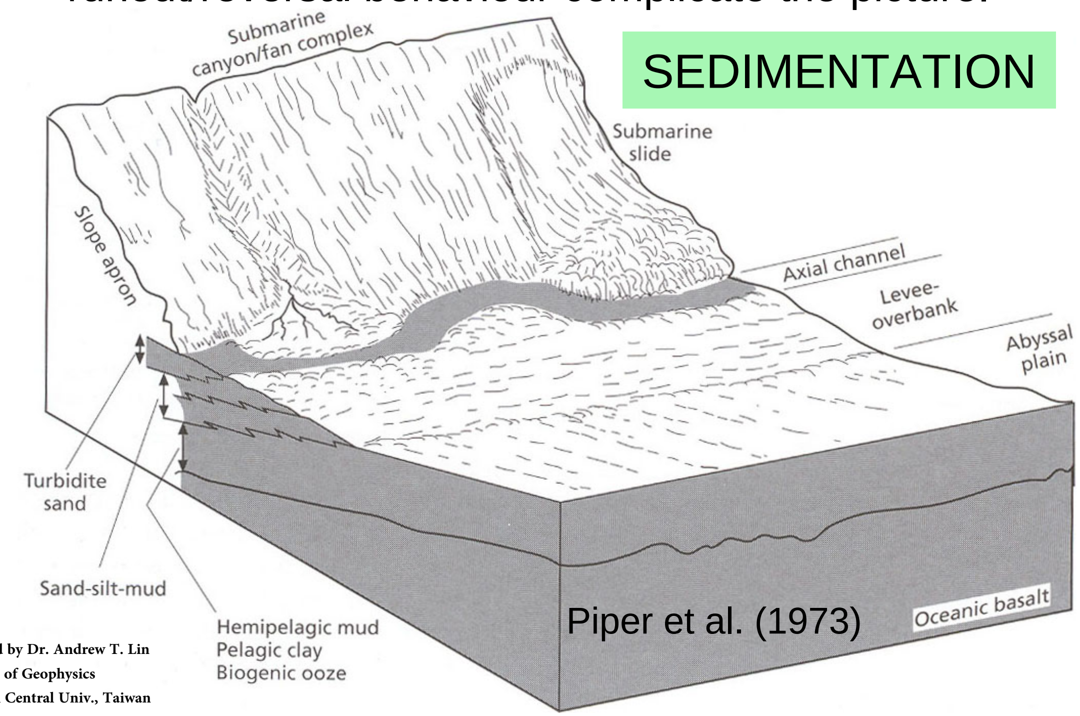
BENDING



Turcotte & Schubert (2002)

Simplest possible relationships for lateral submarine fan input to a subduction margin; a coarsening-upwards sequence is produced. In practice, inner slope basins, axial deflections and runout/reversal behaviour complicate the picture.

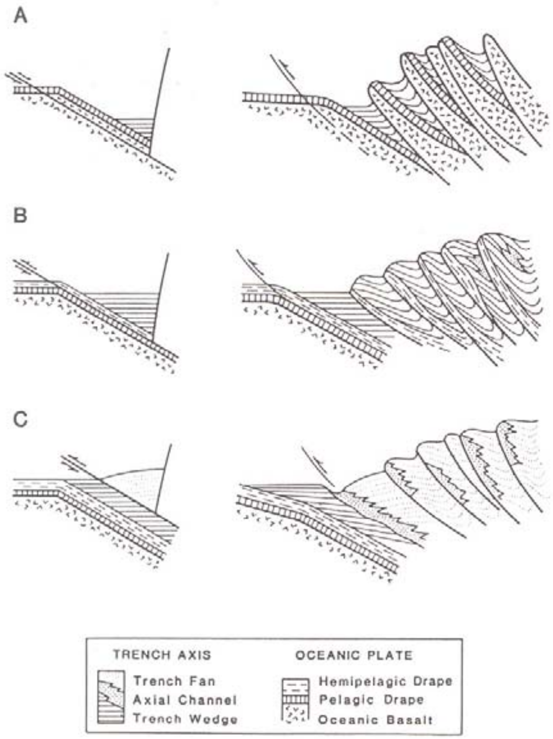
SEDIMENTATION



Piper et al. (1973)

ACCRETION

Accretion of trench-wedge and abyssal-plain deposits.



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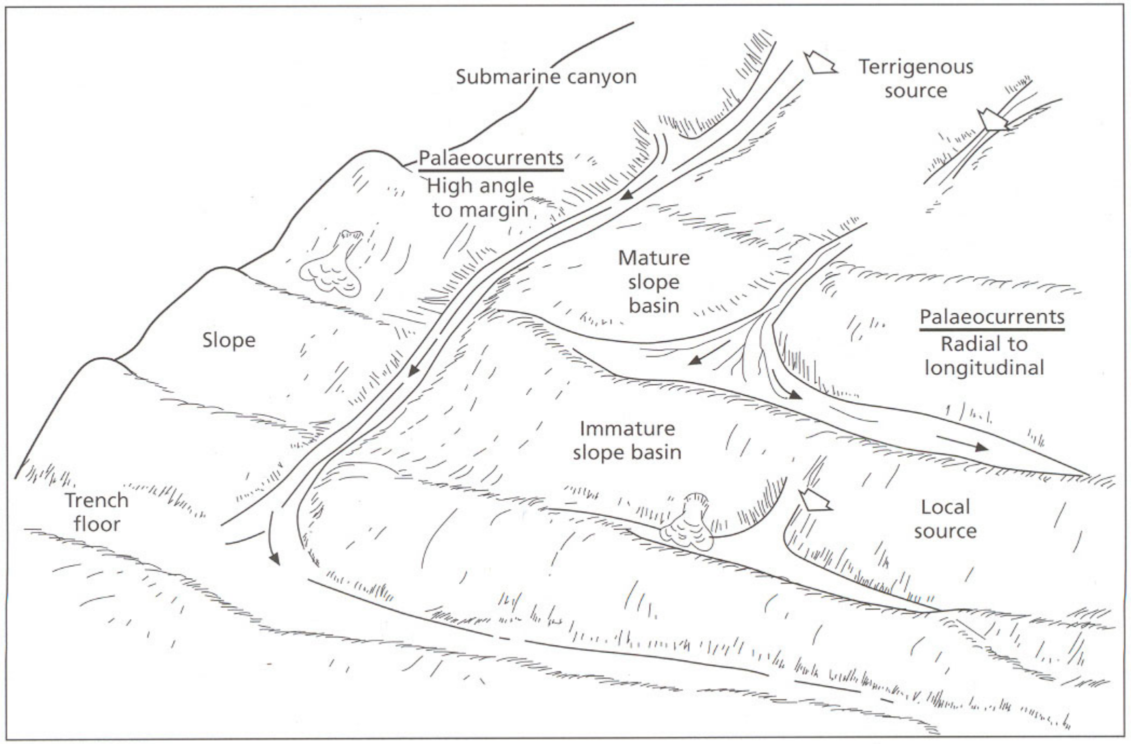
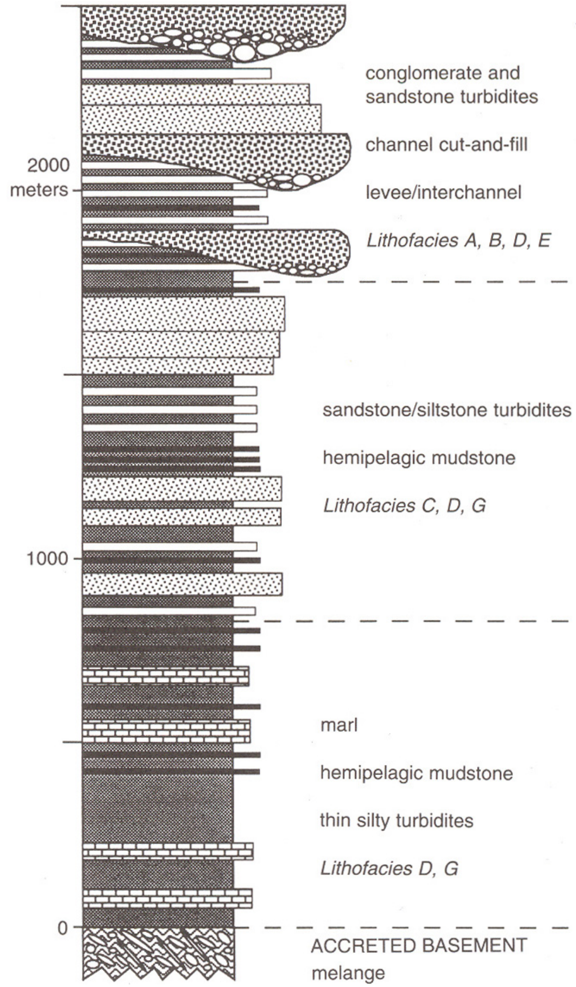
Trench-slope basins

Nature of an inner trench slope on an accretionary prism, with the many slope basins formed by the intersection of thrust faults with the prism surface.



Underwood & Bachman (1982)

An ideal sequence for trench-slope basins



Moore et al. (1980)

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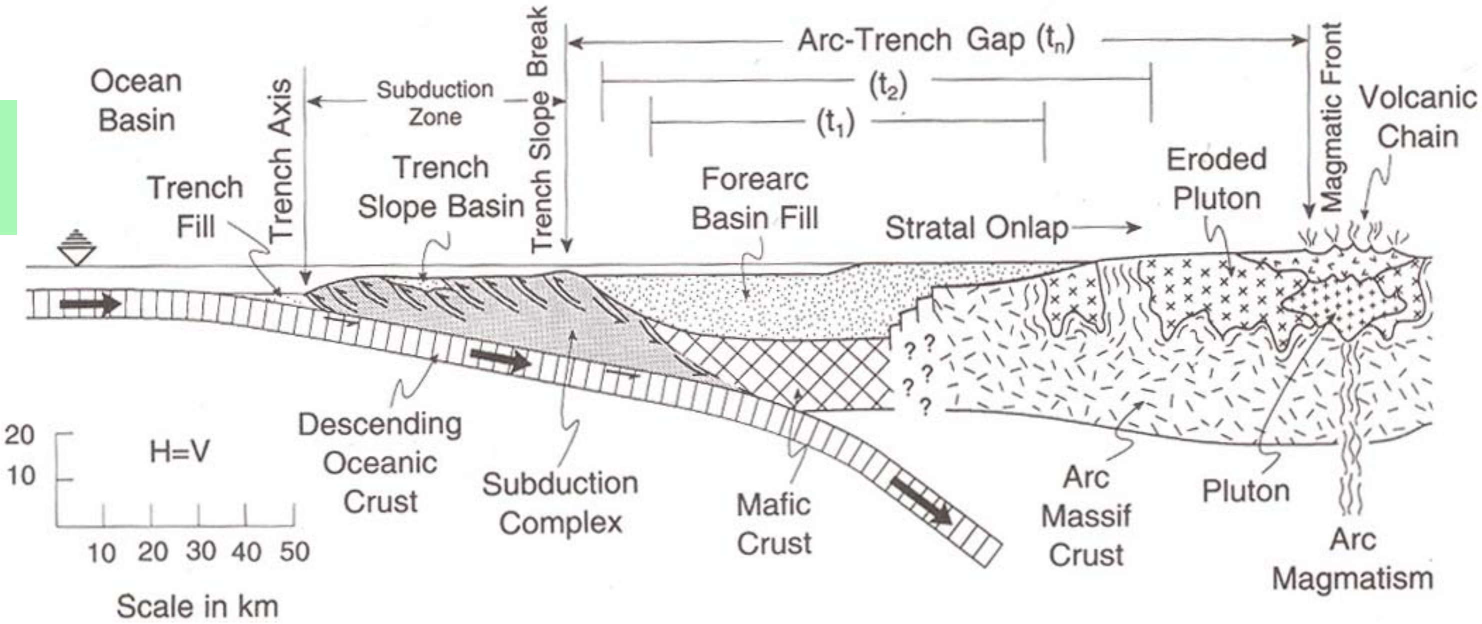
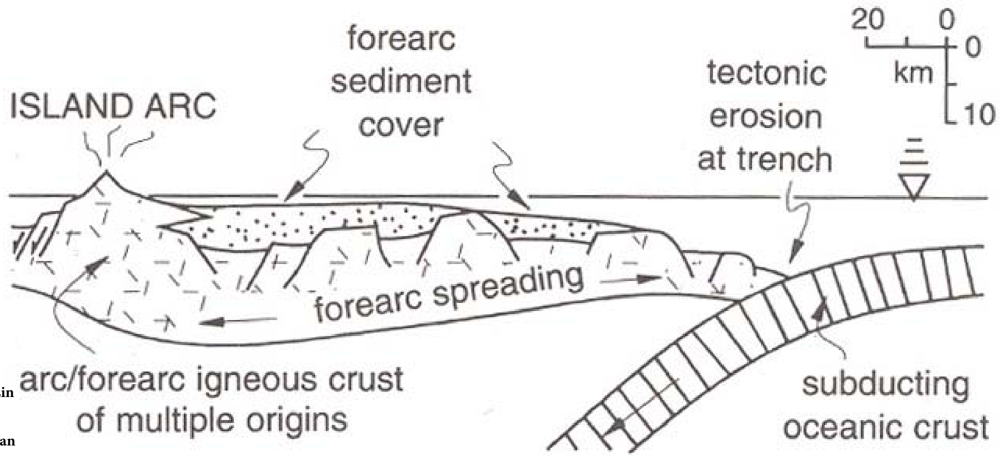
Forearc basins

Forearc basins lie between the axes of trench-slope breaks (or trenches) and the magmatic arcs.

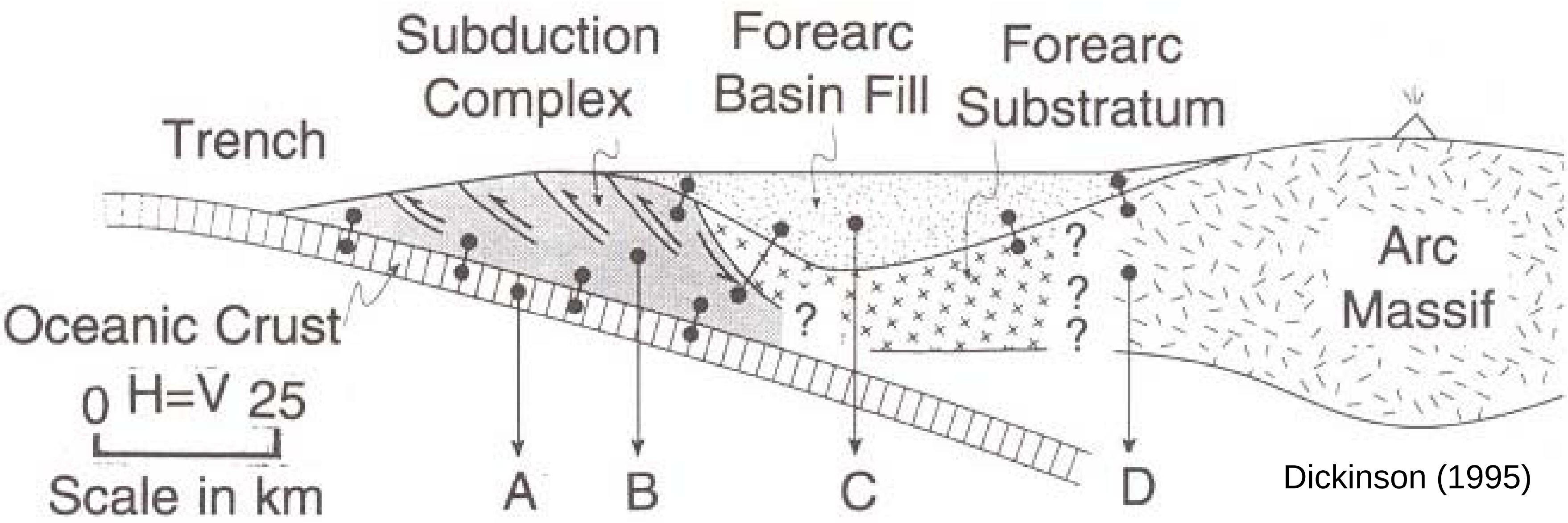
Accretionary margins





Erosive margins

Subsidence mechanisms



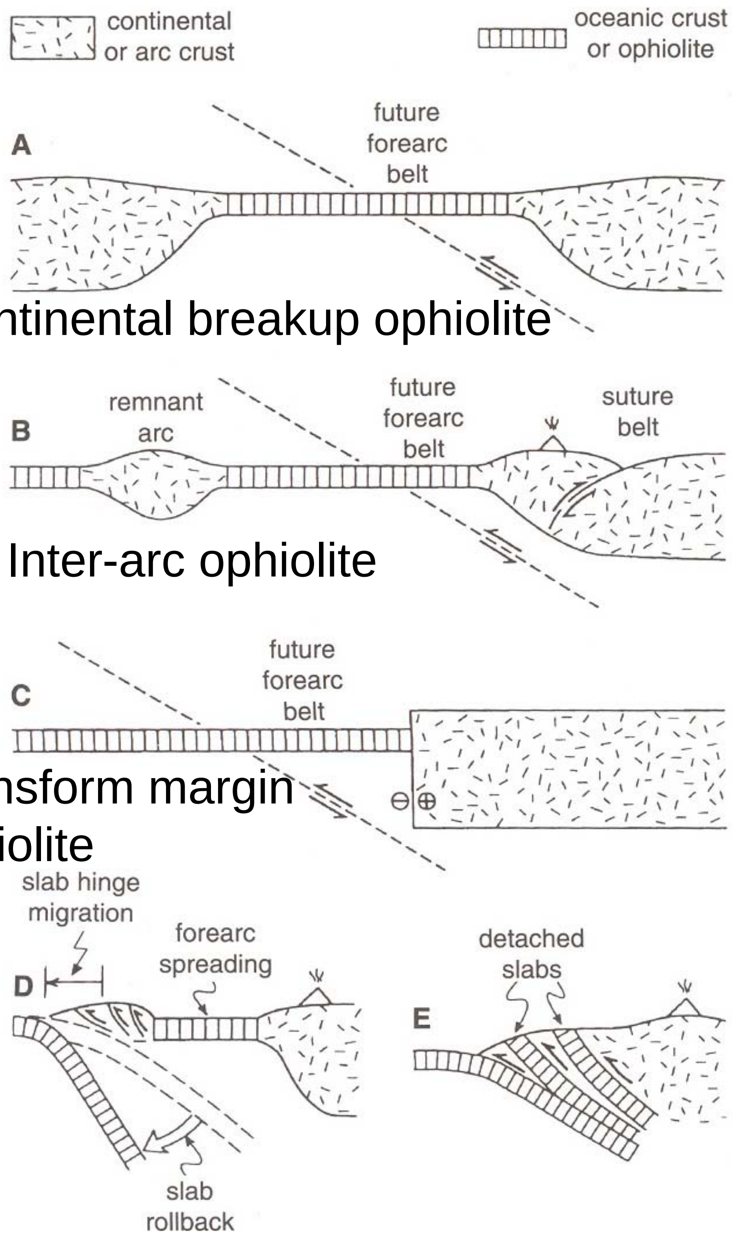
Dickinson (1995)

A. Negative buoyancy of slab of descending cold oceanic lithosphere
B. Loading by subduction complex
C. Loading by sediments
D. Thermal subsidence of arc massif.

Note: A,B,D are potentially reversible to induce uplift

Subsidence patterns for forearc basins are ambiguous as the large uncertainty in estimating the paleobathymetry of forearc sediments.

Basement of forearc basins



Continental breakup ophiolite

Inter-arc ophiolite

Transform margin ophiolite

Possible origins for ophiolitic basements in forearc basins

Dickinson (1995)

- Oceanic crust (or ophiolite)
- Thinned continental crust
- Subduction complex
- Extension of arc massif

Basements for many ancient forearc basins are commonly composed of ophiolite.

Ophiolite complex: Sequence of rock types, consisting of deep-sea sediments (e.g. red clay, chert, etc) lying above basaltic pillow lavas and dykes (dolerite or diabase), gabbro, and peridotite.

Forearc spreading (D)
Subduction accretion (E)

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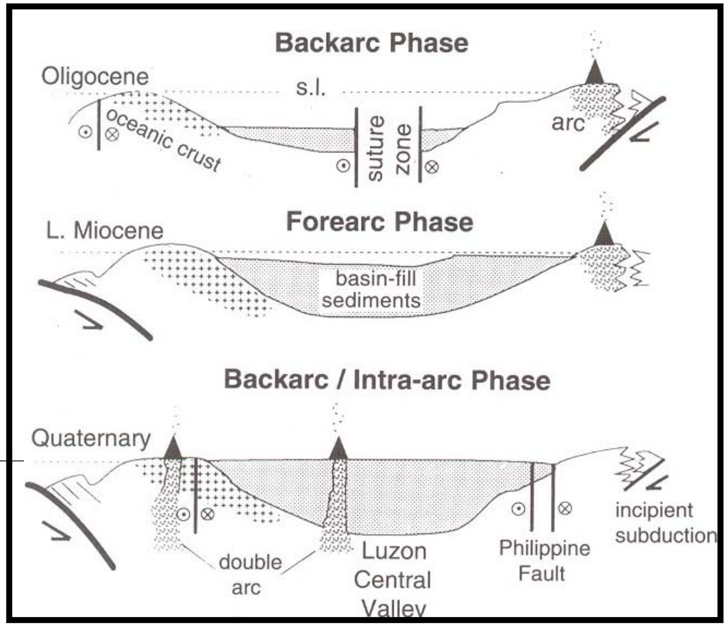
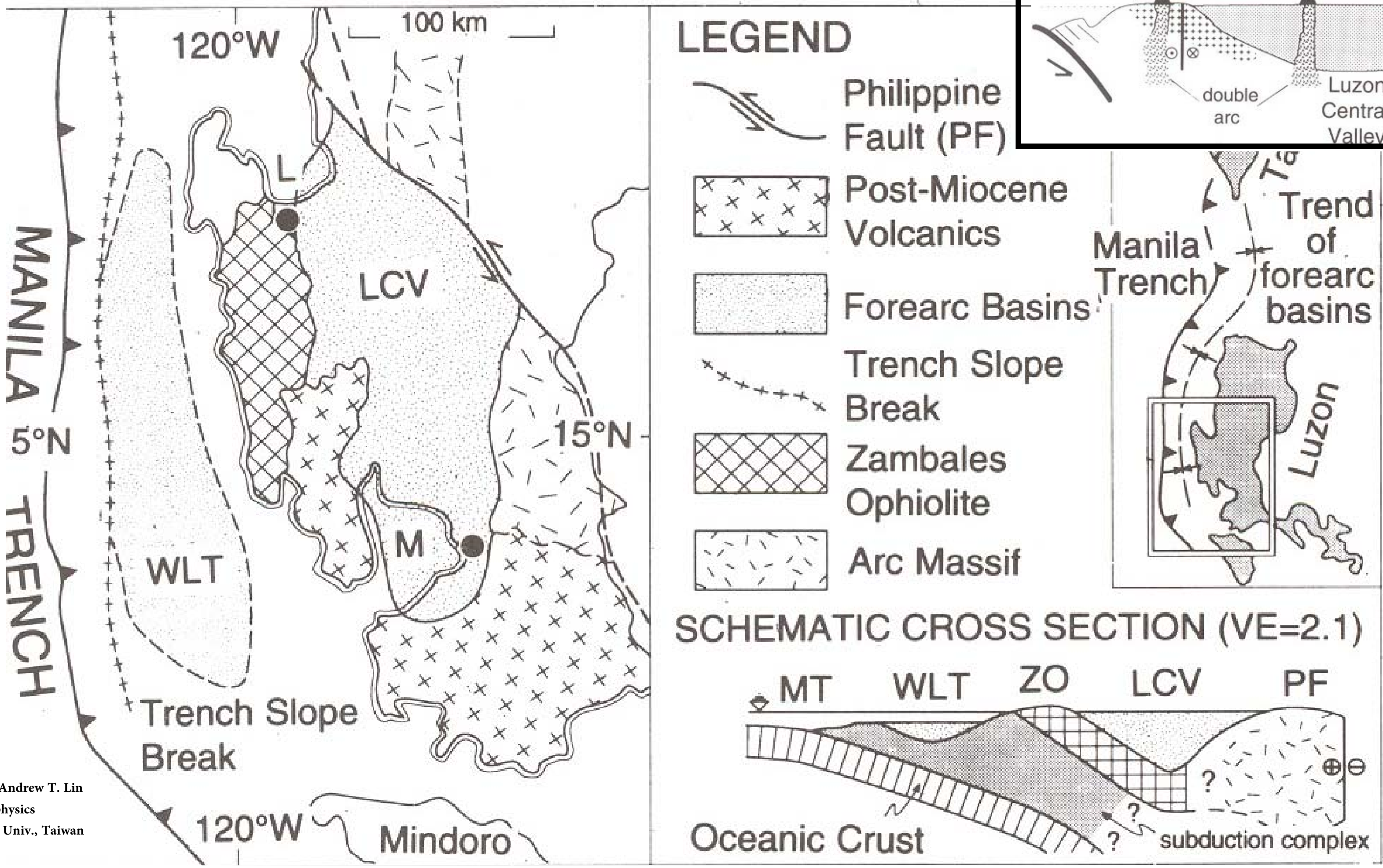
Forearc basins in the Luzon arc-trench system

Evolution of Luzon Central Valley





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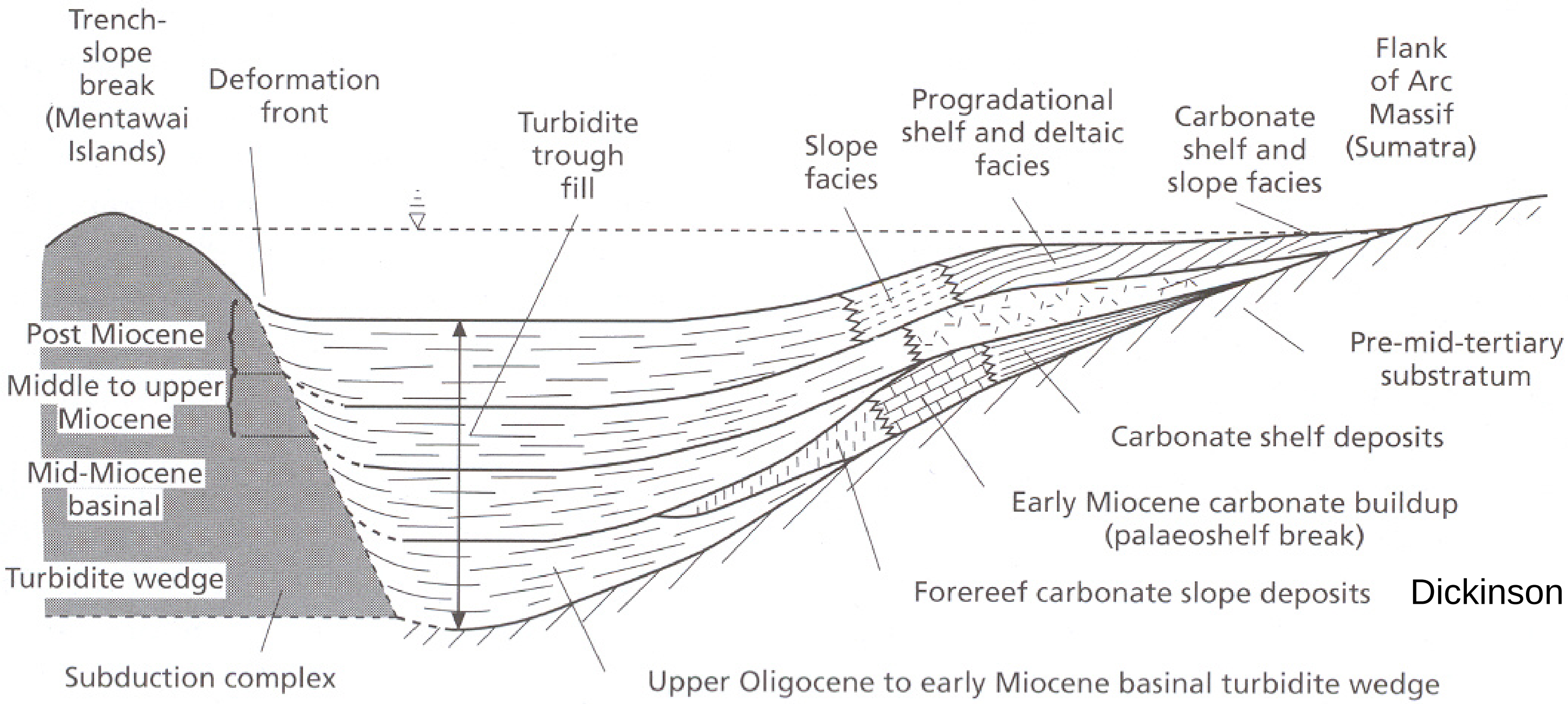
Facies framework of Sunda forearc basin off Sumatra



Dickinson (1995)

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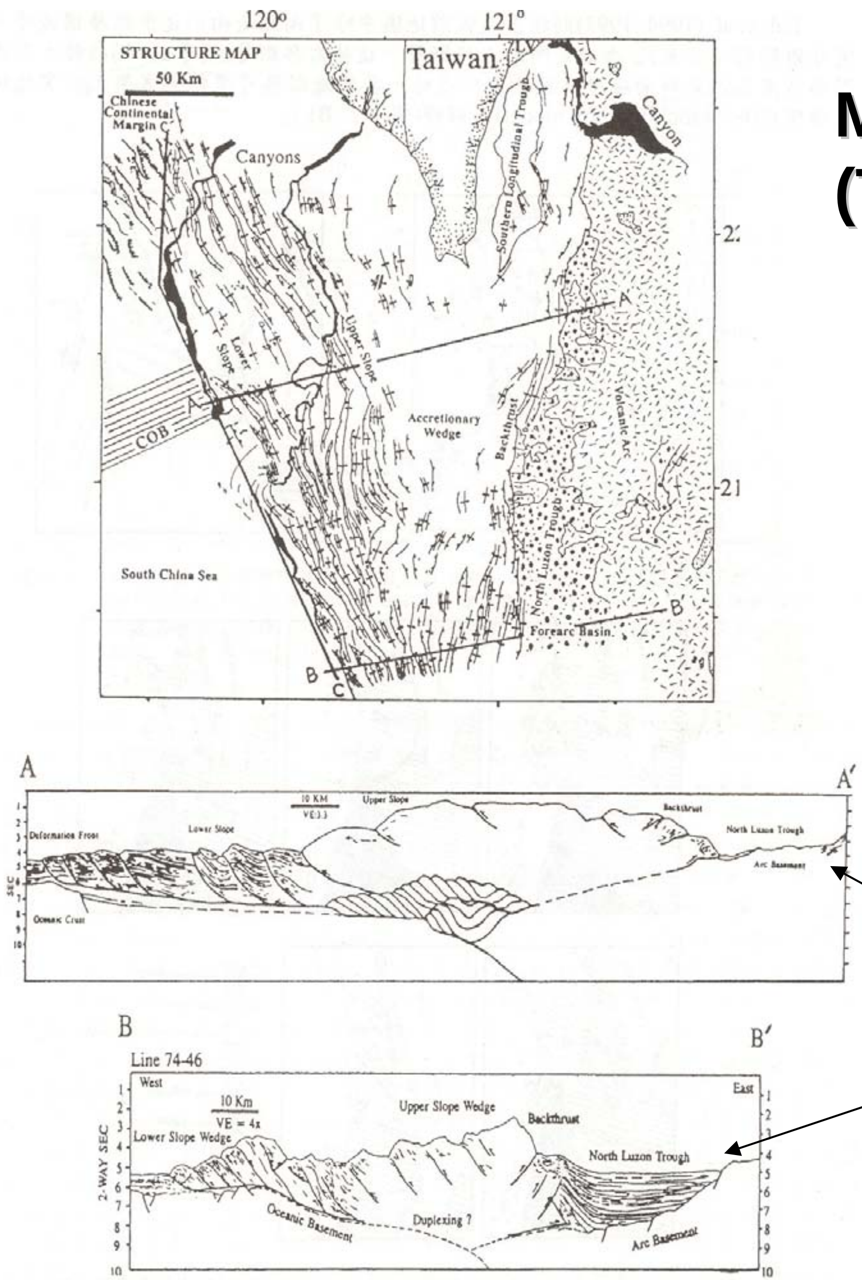
Modern forearc basin (Taiwan)



North Luzon Trough
(forearc basin)

圖十四、 台灣南部海域構造圖(上)及剖面 A-A' (中) 與 B-B' (下) 增積岩體的構造解釋（摘自 Reed et al., 1992）。增積岩體的西半部多為向東傾斜的逆衝斷層及褶皺，而其東緣則為向西傾斜的反向逆衝斷層（back thrust）。弧前盆地（North Luzon Trough）向北由隱沒(B-B' 剖面) 進入碰撞（A-A'剖面）而造成弧前盆地的閉合。增積岩體西半部之上部斜坡與下部斜坡不同地形與構造特徵在剖面中清楚顯示出來。

劉家瑄(2002)

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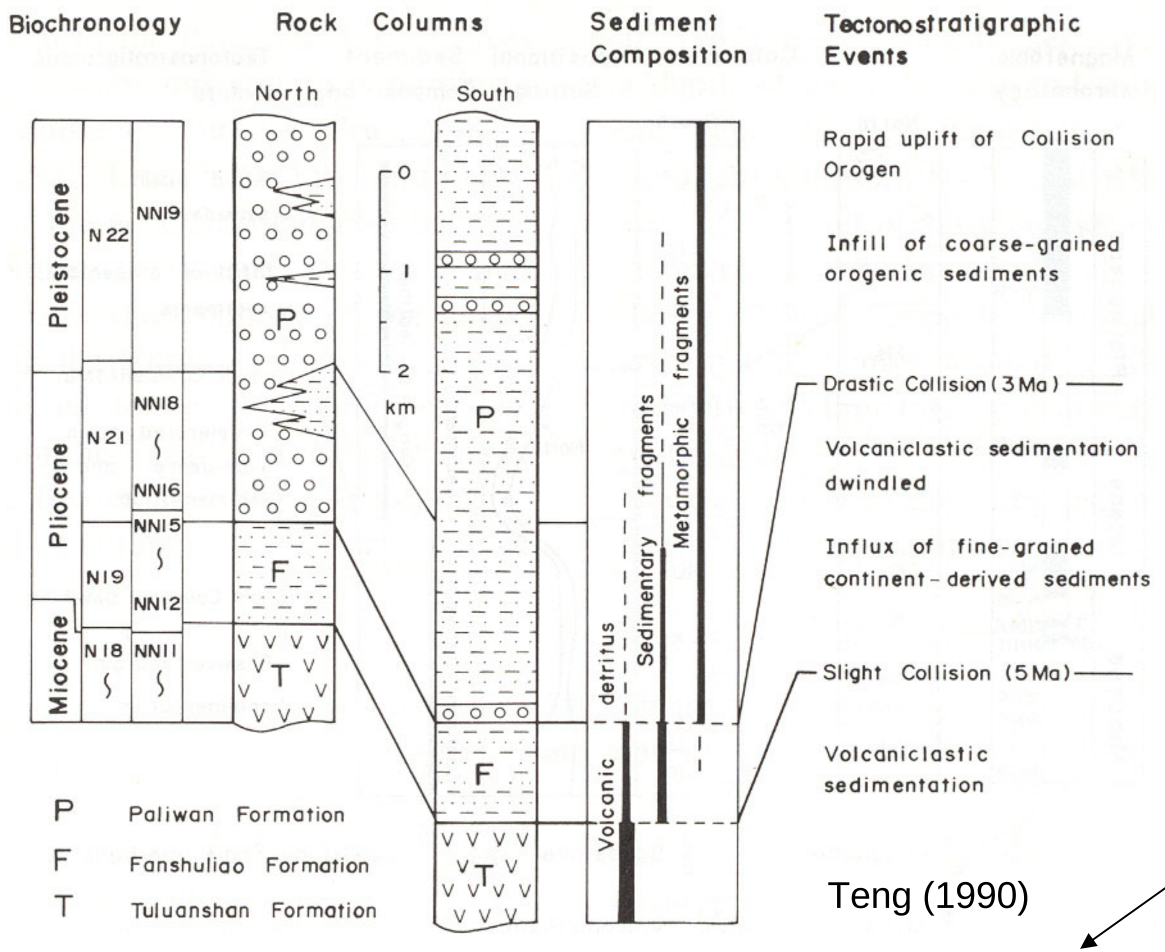
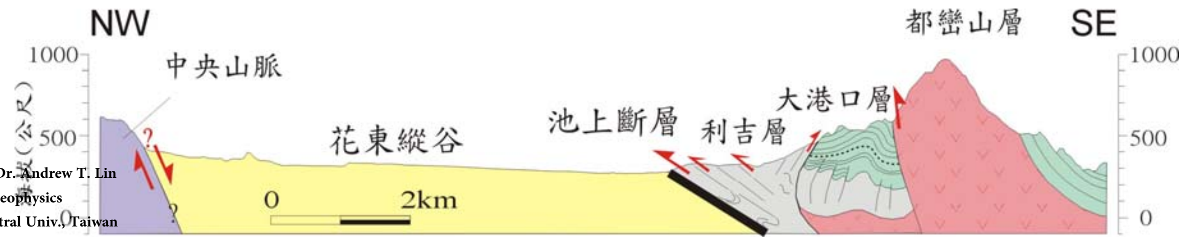
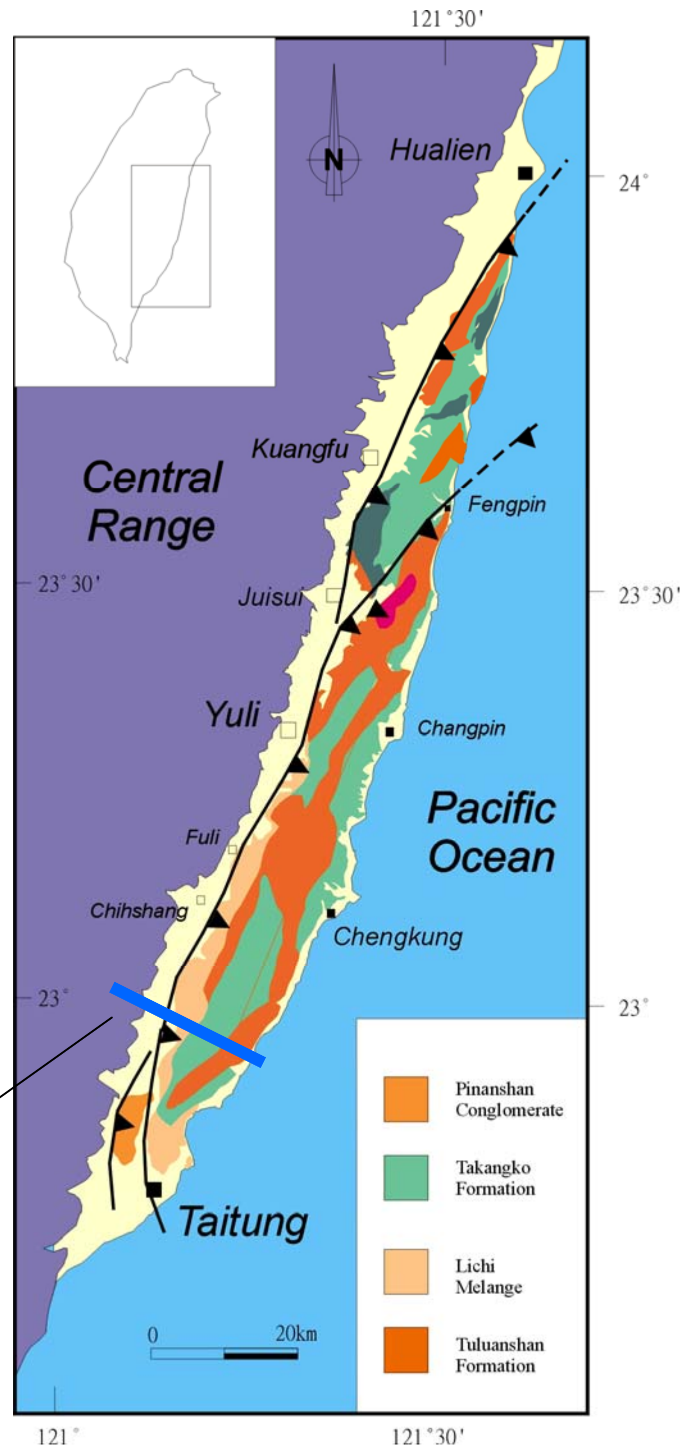
Forearc basin sequence (Taiwan)



Teng (1990)





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