

Bacias de Antepaís

- Contexto tectônico
- Mecanismos de subsidência
- Estrutura
- Evolução
- Estilos de preenchimento
- Exemplos e geologia do petróleo

Antepaís- área estável, adjacente a um cinturão orogênico, em direção à qual ocorre transporte tectônico por cavalgamentos e dobras assimétricas. Geralmente é uma parte da crosta continental, na borda de um cráton ou plataforma.

Contexto tectônico – Bacias de antepaís ocorrem em áreas adjacentes a zonas de espessamento crustal, principalmente por flexura causada pela sobrecarga de grandes cavalgamentos.

- **Bacias de retroarco de antepaís (*retroarc foreland basins*)**

- **Bacias colisionais de antepaís (*collisional foreland basins*)**
 - Bacias periféricas de antepaís (*peripheral foreland basins*)

 - Bacias colisionais de retroarco (*collisional retroarc basins*)

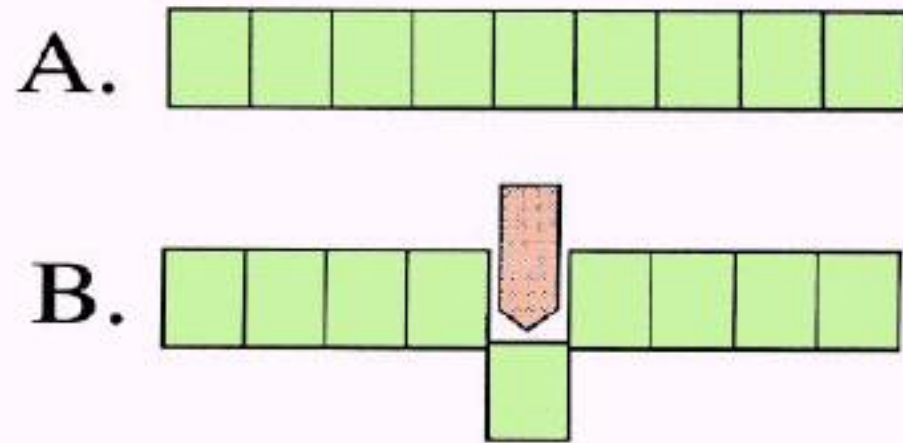
Uma sobrecarga (e.g. cavalgamento, edifício vulcânico) também causará compensação isostática.

Se a litosfera fosse formada por blocos separados com movimento vertical independente, essa compensação não causaria subsidência, pois não haveria abatimento da superfície.

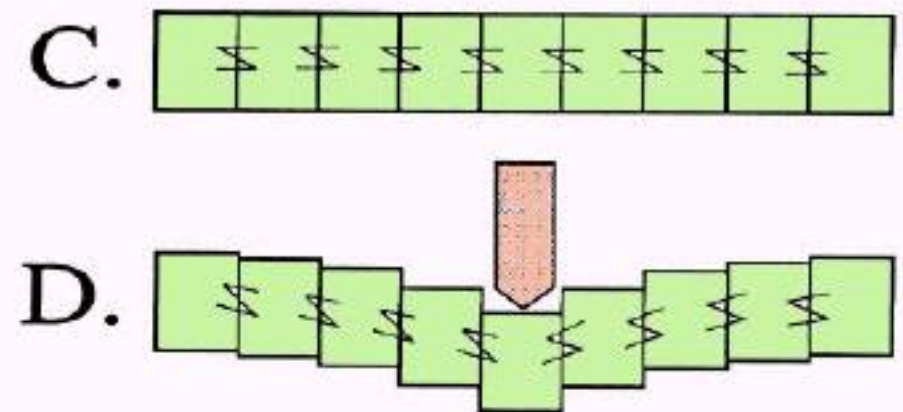
Na realidade a crosta tem uma rigidez que implica em abatimento por flexura de áreas adjacentes à sobrecarga.

Esse abatimento é denominado **subsidência flexural**.

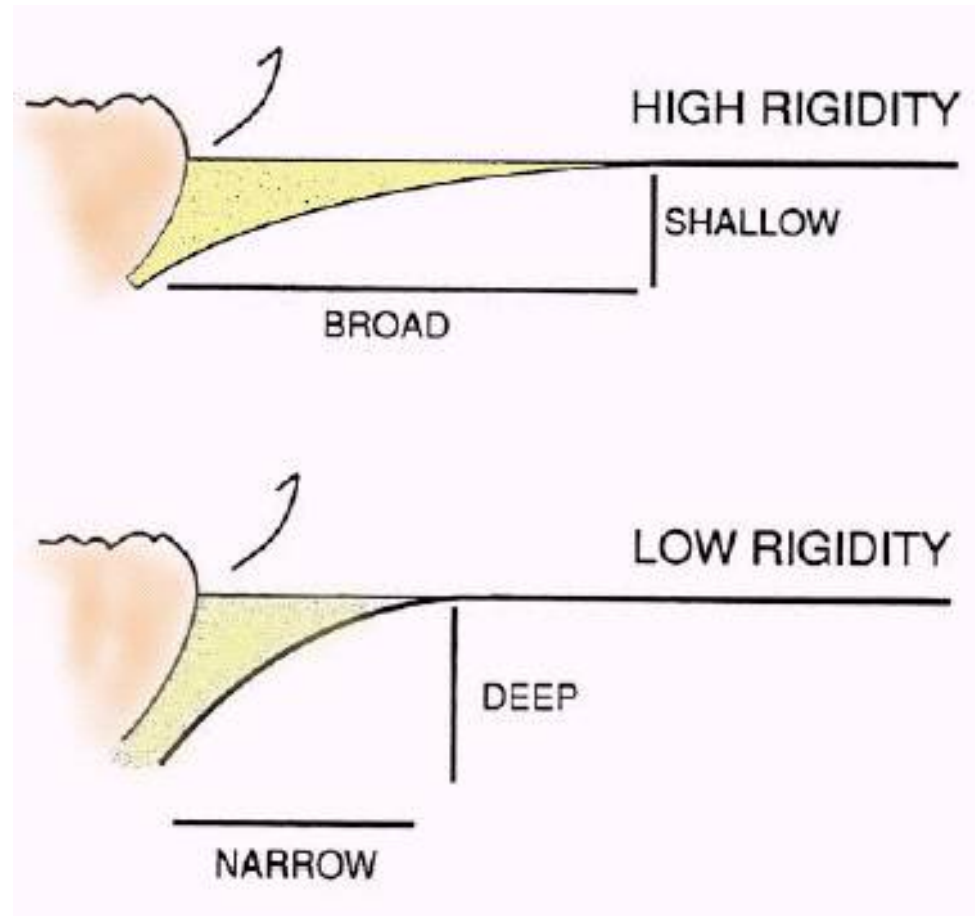
LOCAL ISOSTASY

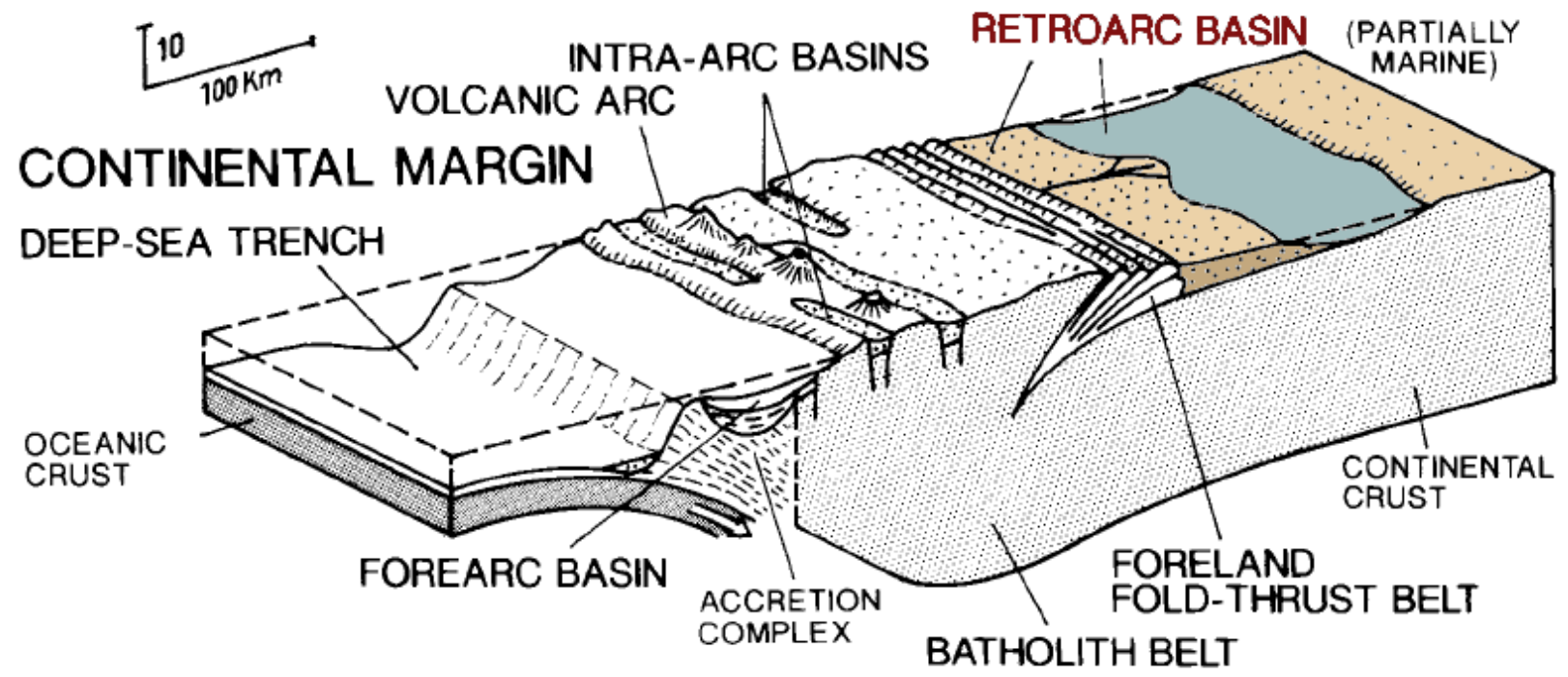
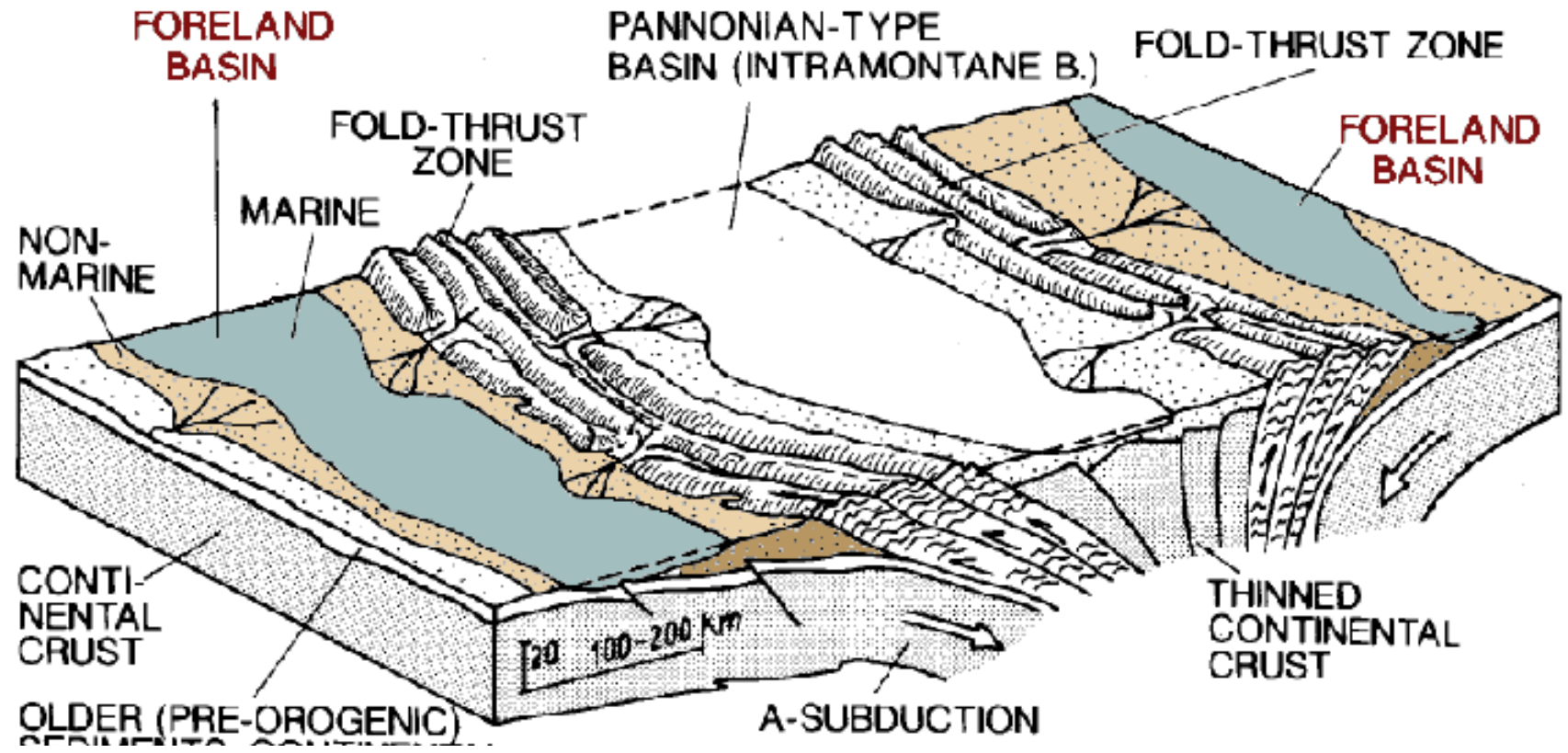


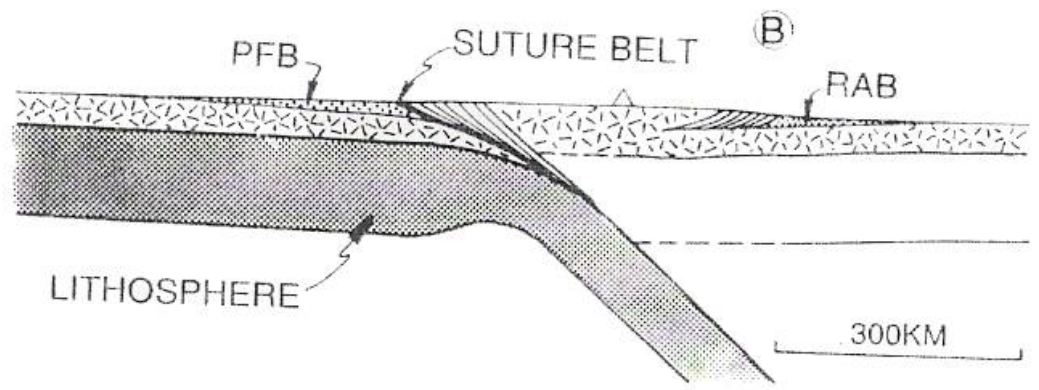
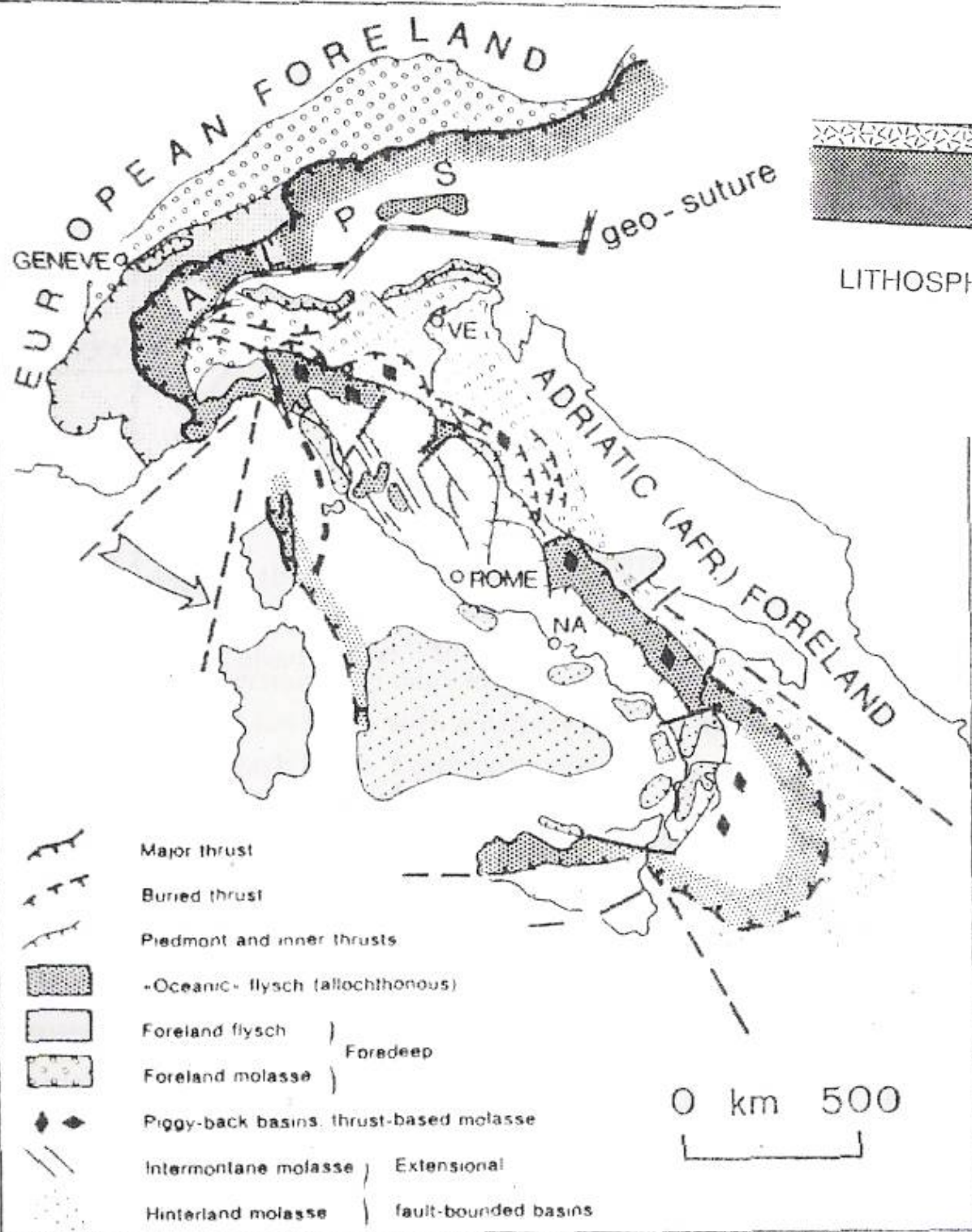
FLEXURE (REGIONAL ISOSTASY)



A distância a partir da área de sobrecarga afetada pela subsidência e a profundidade dessa subsidência dependem da rigidez flexural da crosta.







Desenho de ambiente geográfico

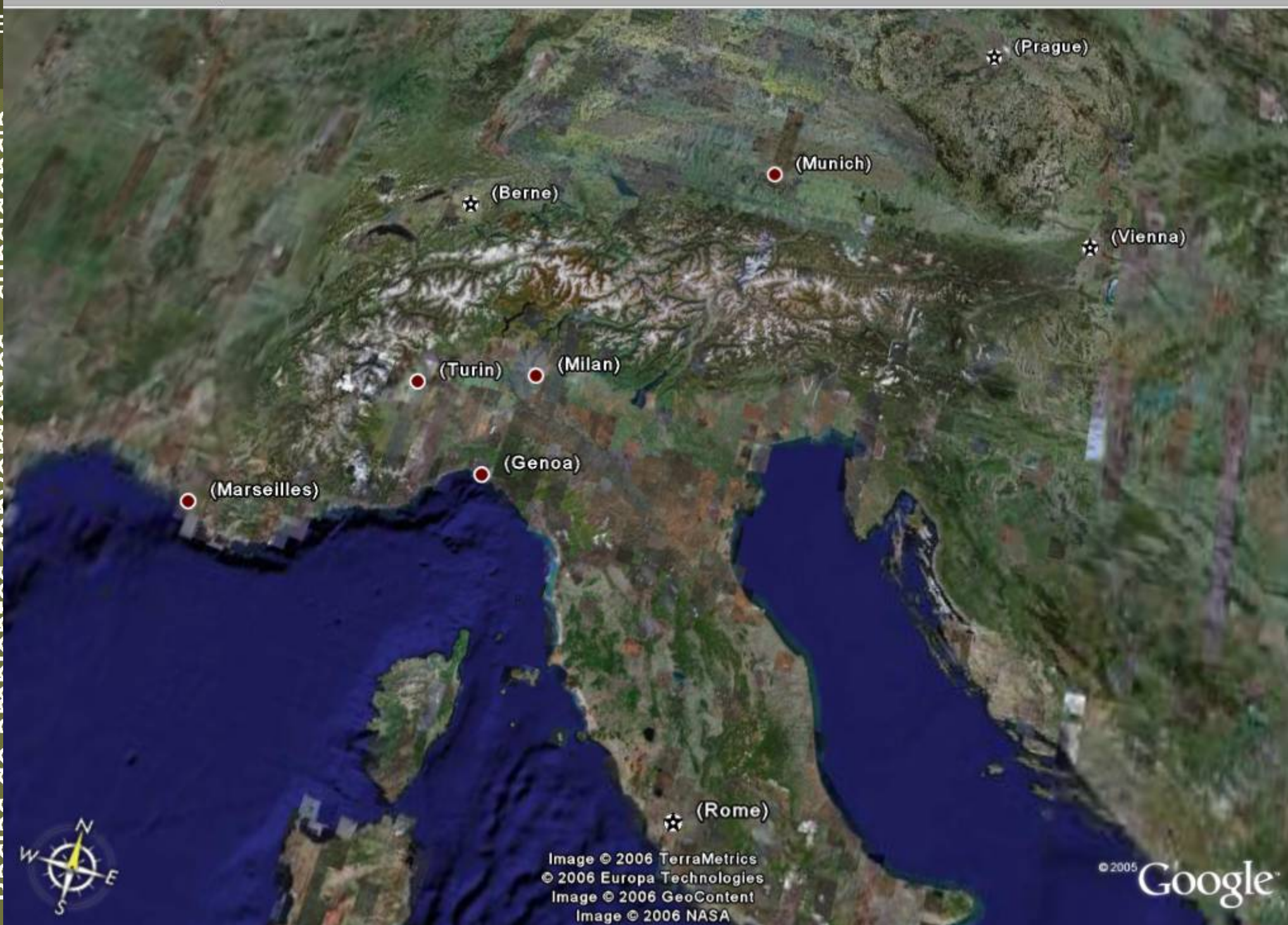


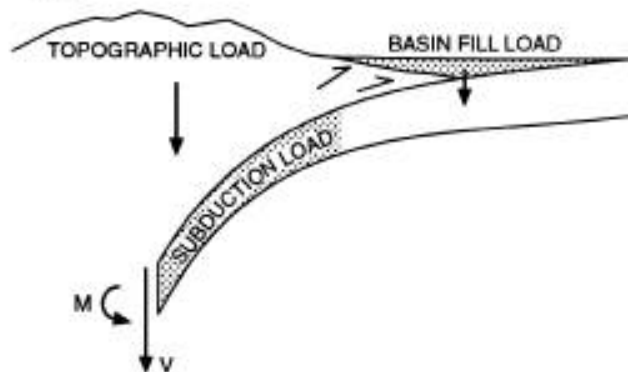
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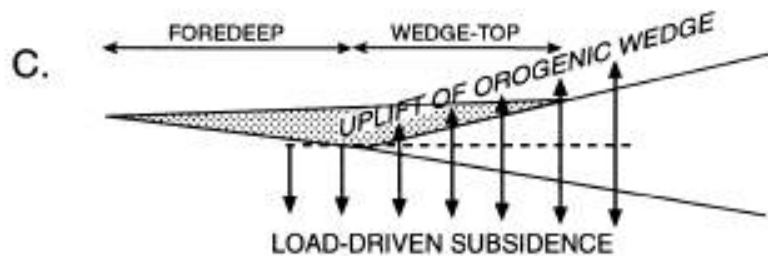
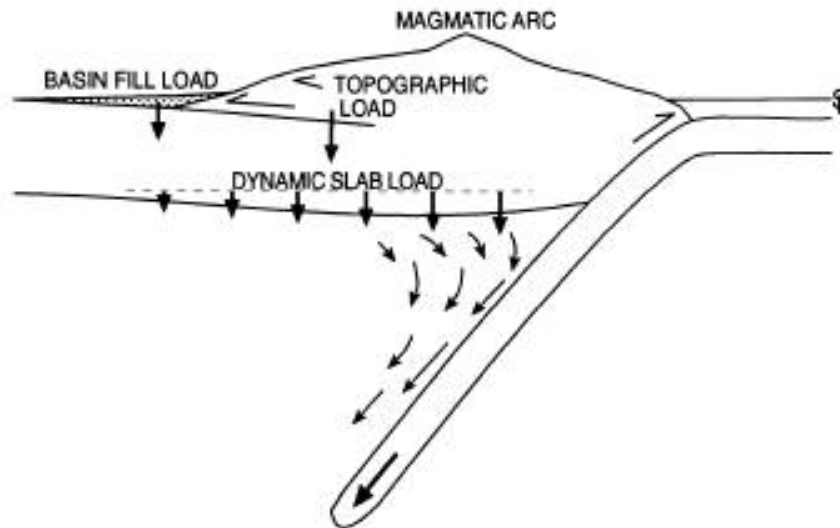
Mecanismos de subsidência:

- Flexura adjacente a alto topográfico (sobrecarga do orógeno)
- Sobrecarga do sedimento
- Efeitos da subducção tipo A
- Efeitos da topografia dinâmica (em retroarco)

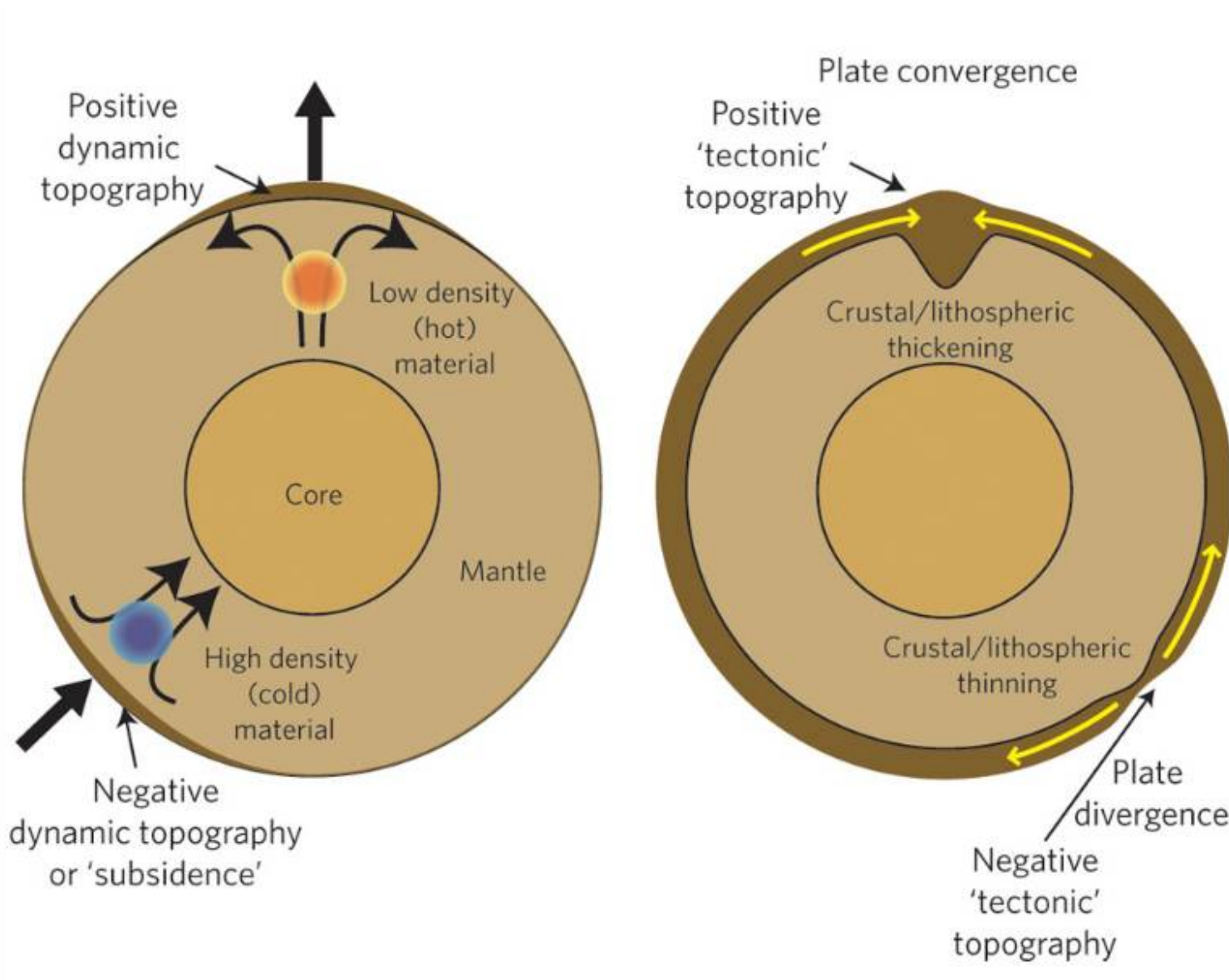
A. PERIPHERAL SETTINGS



B. RETROARC SETTINGS



Efeitos da dinâmica mantélica (topografia dinâmica)



Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

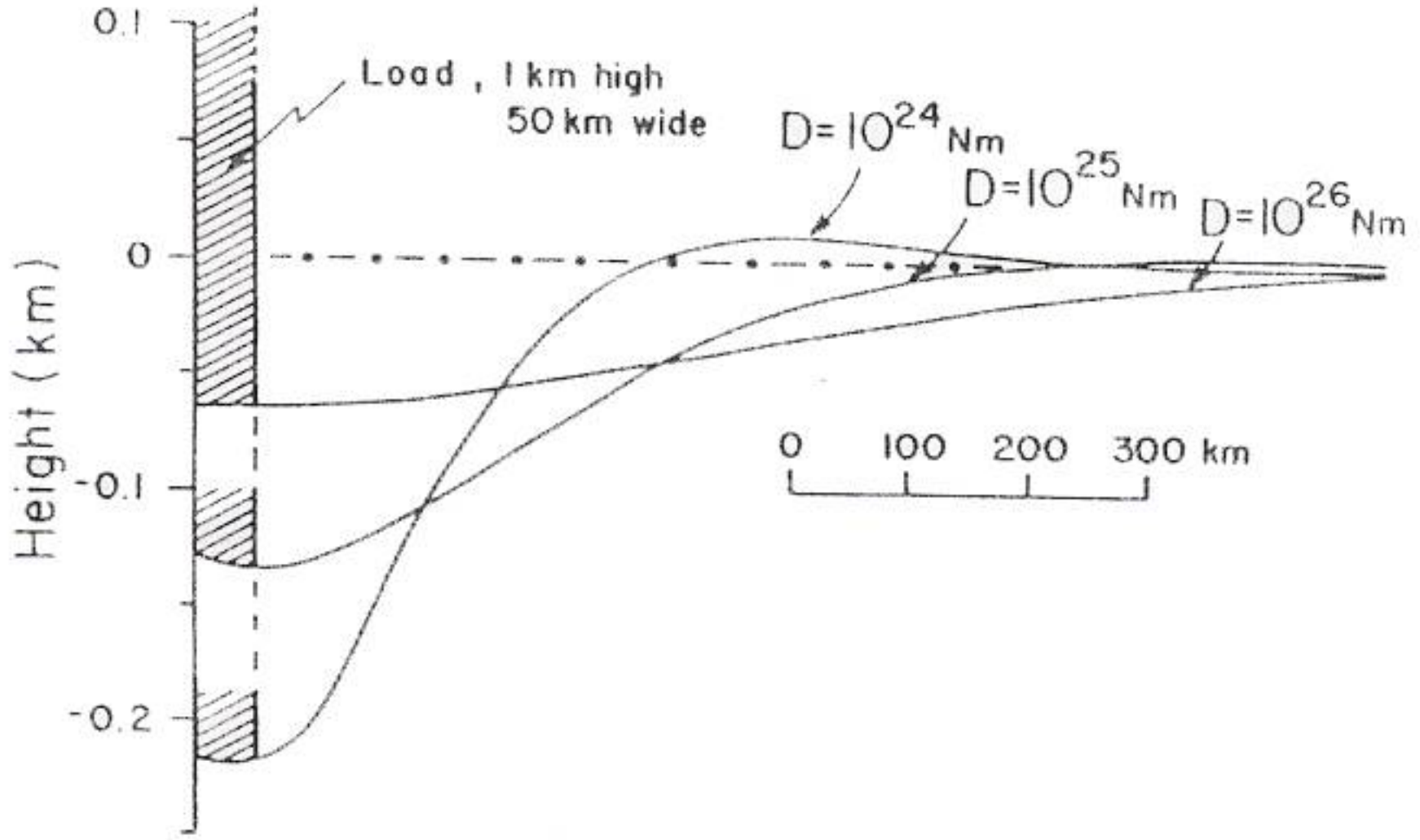


Table 4.1 Equivalent elastic thickness (T_e) compiled by Watts (2001) for the continental lithosphere at sites of foreland basins. Particular foreland basins may appear more than once if estimates have been made by different authors. Sources given in Watts (2001, Table 6.2, pp.251–3).

Site	Age of plate (Ma)	Plate age error (Myr)	Age of load (ka)	Load age error (kyr)	T_e (km)	T_e error (km)
Idaho–Wyoming	2650	50	125	25	22.0	0.0
Alps East	350	50	110	0	50.0	10.0
Alps West	275	25	110	0	25.0	10.0
Appalachians	1050	50	375	75	105.0	25.0
Himalaya East	1200	500	52	2	90.0	10.0
Ganges	1500	500	52	2	86.5	25.0
Kunlun–Tarim	800	200	52	2	40.0	5.0
Apennines	300	50	5	0	11.5	6.5
Carpathians Southeast	1600	200	110	0	30.0	10.0
Bolivian Andes	950	350	60	0	45.0	20.0
Transverse Ranges S	100	0	50	0	10.0	10.0
Transverse Ranges N	100	0	50	0	50.0	0.0
Zagros	700	200	35	10	50.0	25.0
Ebro	275	25	40	5	18.6	6.9
Aquitaine	275	25	40	5	25.5	5.0
Colville	1900	100	140	20	65.0	5.0
Carpathians	1600	200	110	0	22.0	0.0
Calabria	300	50	2	2	18.7	4.7
Urals	1500	100	325	50	75.0	25.0
Apennines	300	50	5	0	20.0	5.0
Oman	700	200	85	10	13.0	3.0
Urals	1500	100	325	50	75.0	25.0
Verkhoyansk	1950	150	230	40	50.0	10.0
Pamir	300	100	52	2	15.0	5.0
Tien Shan Tarim	800	200	52	2	40.0	20.0
Sicily	275	25	25	0	6.0	4.0
Himalaya West	1200	500	52	2	34.0	6.0
Greater Caucasus	1600	200	100	0	45.0	5.0
Kilohigok	2575	75	1965	45	12.0	4.0
Thelon front	2575	75	2000	0	58.0	0.0
Grenville front	2700	100	1050	50	126.0	0.0
Labrador Trough	2575	75	1585	50	120.0	0.0
Cape Smith	2575	75	1800	50	74.0	0.0
New Guinea East	700	100	25	0	10.0	0.0
New Guinea West	700	100	25	0	75.0	25.0
Tarim	1800	50	900	50	55.0	5.0
Ebro	275	25	40	0	20.0	0.0
Dzhungarian	1800	50	900	50	12.5	12.5
Alps West	275	25	17	0	10.0	5.0
Po Basin	275	25	30	0	5.0	0.0
Apennines	300	50	5	0	6.3	2.2
Guadalquivir Betics	275	25	25	0	10.0	5.0
Apennines	300	50	5	0	20.0	0.0
Carpathians	1600	200	110	0	40.0	0.0
Hellenides	300	50	2	2	70.0	0.0
Himalayas	1200	500	52	2	80.0	0.0
East Alps	350	50	110	0	40.0	0.0
South Alps	300	50	110	0	20.0	0.0

Estratigrafia
GSA0307

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

Table 4.1 *Continued*

Site	Age of plate (Ma)	Plate age error (Myr)	Age of load (ka)	Load age error (kyr)	<i>T_e</i> (km)	<i>T_e</i> error (km)
West Alps	275	25	110	0	50.0	0.0
South Alps	300	50	110	0	15.0	0.0
Apennines	300	50	5	0	15.0	0.0
Oman	700	200	85	10	35.0	13.0
Apennines–Dinarides Plio–Quaternary	300	50	2	2	12.5	2.5
Apennines–Dinarides Eocene–Oligocene	300	50	40	5	7.5	2.5
Kopet Dag	1600	200	52	2	25.0	5.0
Karakorum India	1200	500	52	2	90.0	10.0
Karakorum Asia	1200	500	52	2	110.0	10.0
Andes Peru	950	350	60	0	39.0	16.0
Himalaya East	1200	500	52	2	90.0	0.0
Tarim	1800	50	900	50	40.0	0.0
Atlas East	300	50	25	0	20.0	1.0
Atlas West	300	50	25	0	9.0	1.0
Appalachians	1050	50	375	75	70.0	20.0
Alps East	350	50	110	0	25.0	10.0
Alps West	275	25	110	0	10.0	5.0
Carpathians Southeast	1600	200	110	0	12.0	8.0
Andes Colombia	950	350	80	0	45.0	40.0
Andes Ecuador	950	350	80	0	25.0	20.0
Andes North Peru	950	350	60	0	35.0	35.0
Andes Peru	950	350	60	0	25.0	20.0
Andes Peru–N. Chile	950	350	60	0	45.0	40.0
Andes Argentina	950	350	60	0	30.0	20.0
Ouachita	1050	50	375	75	50.0	10.0
E. Papua New Guinea	97	32	30	5	20.0	10.0
W. Papua New Guinea	387	132	30	5	75.0	5.0

A rigidez flexural (ou espessura elástica equivalente) varia com a temperatura:

Te coincide com isoterma de 450° ou varia de 900 a 300?

Aumento da temperatura reduz muito Te.

Descolamento da crosta em relação ao manto é outro processo possível de redução de Te:

Para grandes curvaturas de inflexão, o esforço pode superar o envelope de deformação, causando descolamento e flexura independente das porções rúpteis de crosta e manto.

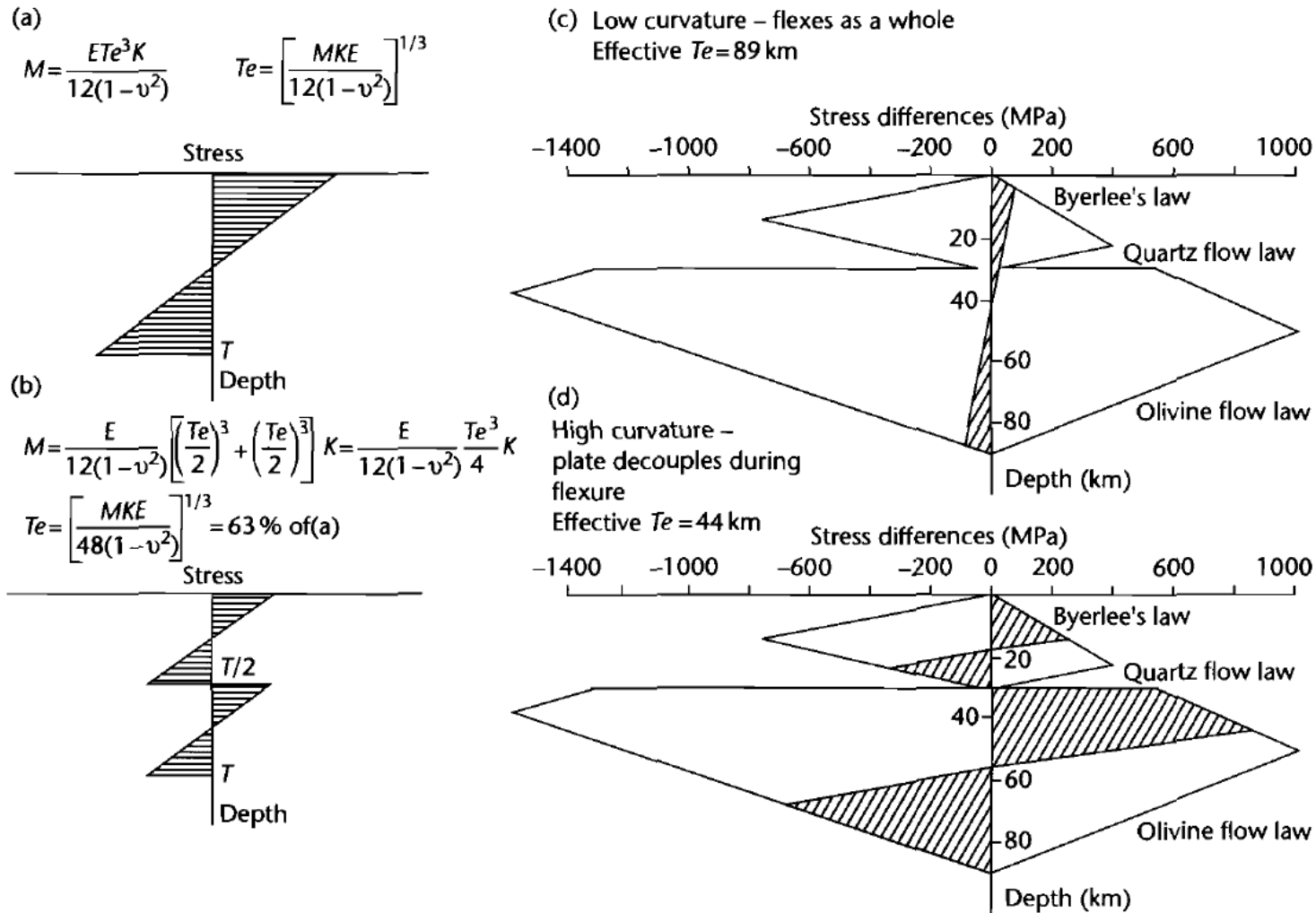


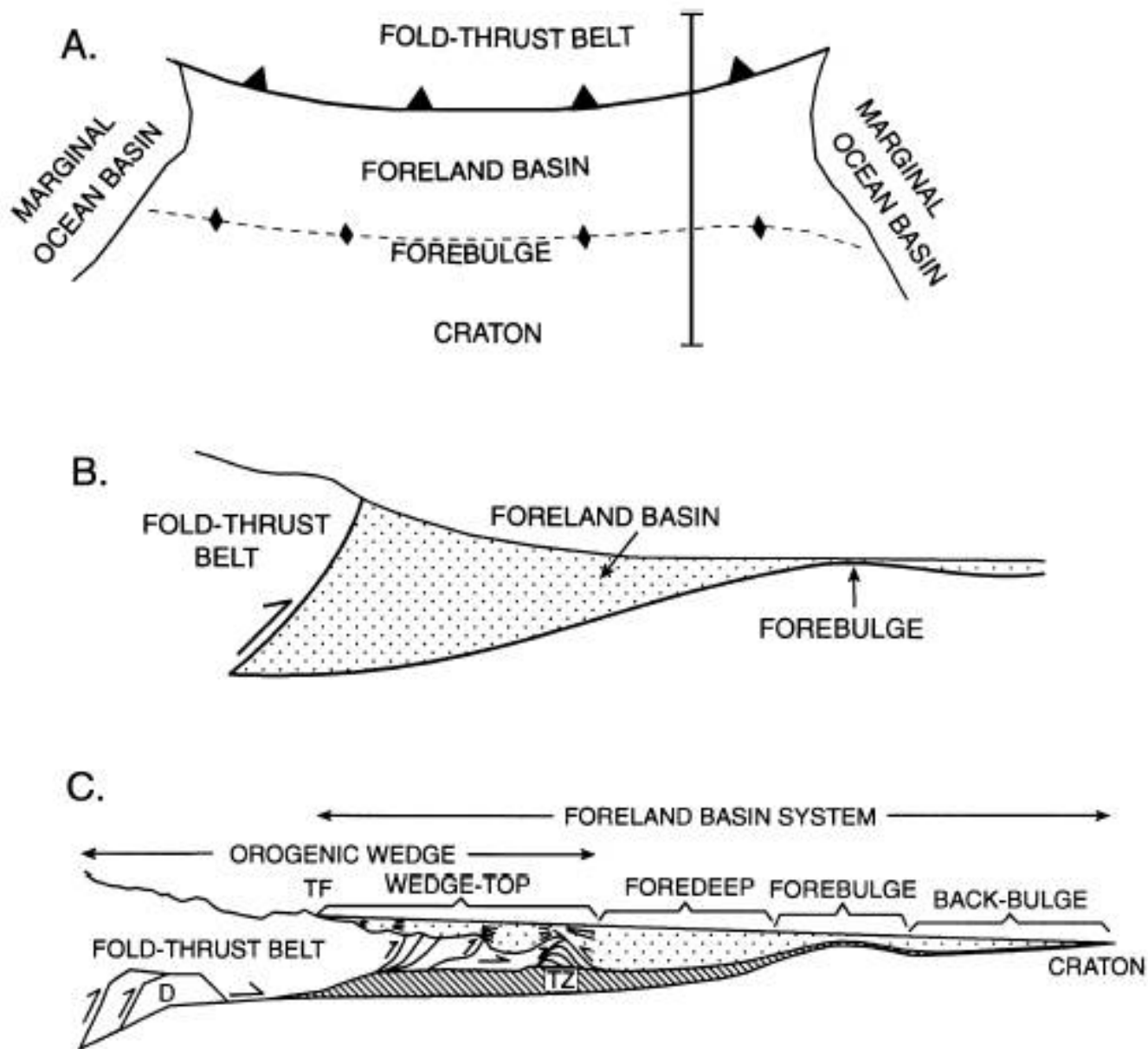
Fig. 4.15 The effects of decoupling at high curvatures illustrated by cross-sections of stress in the flexed lithosphere (after McNutt et al. 1988). (a) Distribution of fiber stresses in an elastic plate of thickness T showing extension in the upper half of the plate and compression in the lower half; (b) A purely elastic plate that is decoupled at $T/2$ so that the upper and lower portions flex independently with the same radius of curvature as in (a). The equivalent elastic thickness is 63% of that in (a). M is the bending moment, K the radius of curvature, E Young's modulus, ν Poisson's ratio; (c) and (d) Rheologically layered continental lithosphere showing the failure envelope under extension (positive stress) and compression (negative stress). The strength is limited by frictional sliding (Byerlee's law) in the upper crust and uppermost mantle and by ductile flow in the lower crust and lower lithosphere. The hatched areas represent the stress resulting from flexure superimposed on the failure envelope. In (c) the plate is flexed at a very low curvature. The fiber stresses rarely exceed the failure criterion of the plate (there is a small amount of yielding at the top and bottom) and the equivalent elastic thickness (89km) is almost exactly the same as the thickness of the elastic plate. In (d) the plate is flexed to a high curvature. This leads to the failure criterion being exceeded and a decoupling zone forms in the lower crust. The equivalent elastic thickness calculated for the total bending moment sustained in both the crust and the mantle is just 44km. Decoupling therefore has strong potential mechanical implications for flexure.

Estrutura geral - o sistema de bacias de antepaís

Bacias de antepaís são fortemente assimétricas, com fundo inclinado em direção ao orógeno e subsidência diferencial (em gangorra), com as maiores taxas nas proximidades da sobrecarga.

A subsidência e deposição não ocorrem apenas na depressão periférica (antefossa – *foredeep*), mas também:

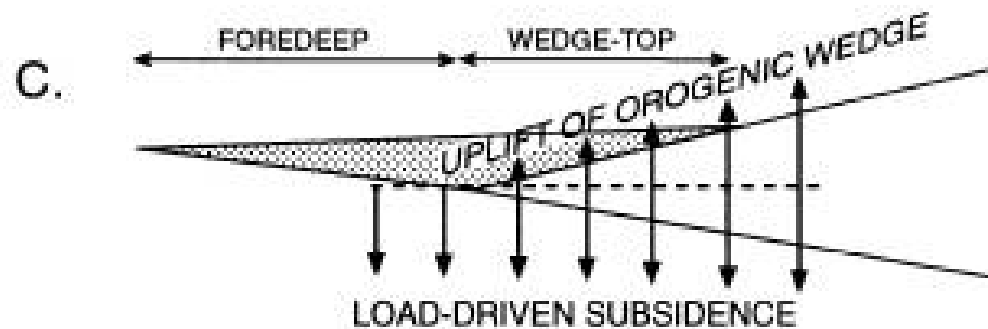
- Sobre a cunha orogênica cavalgante (*wedge-top*)
- Sobre a área soerguida da porção distal da bacia (*forebulge*)
- Atrás do *forebulge* (*back-bulge*)



Principais características de cada zona

Wedge-top: Em muitas zonas de colisão a elevação topográfica não coincide com a falha frontal de cavalgamento, havendo deposição significativa sobre a frente da cunha cavalgante.

Essa zona deposicional é uma área proximal, com granulação mais grossa, deformação progressiva, abundantes discordâncias e preservação como bacias isoladas sobre blocos cavalgantes (bacias tipo *piggy-back* ou *thrust-top*)



Antefossa (*foredeep*): Área principal de subsidência, com maior potencial de preservação.

O aporte sedimentar principal vem do orógeno, formando cunhas clásticas com grande espessamento em direção à borda ativa e rápida diminuição da granulação para a porção distal.

A deformação compressiva sin-sedimentar também diminui para a porção distal, com cavalgamento do orógeno na borda, importante deformação por falhas inversas e dobras assimétricas na porção proximal e dobramentos progressivamente mais suaves na porção distal.

Sucessivos eventos de reativação podem causar discordâncias angulares na bacia.

Forebulge: Normalmente, a subsidência flexural adjacente ao orógeno tem como consequência a elevação de uma área na outra borda da bacia (*forebulge*).

Essa área pode ter apenas subsidência diminuída, com menores taxas de geração de espaço de acomodação e maior recorrência de discordâncias por tectonismo ou queda eustática, ou pode ser área de soerguimento, com erosão de depósitos anteriores e potencial como área-fonte.

No caso de soerguimento, pode ocorrer distensão decorrente do arqueamento, com potencial para desenvolvimento de pequenas bacias distensionais de subsidência mecânica.

Back-bulge: A área além do *forebulge* pode estar sujeita a uma subsidência flexural secundária, com a formação de bacias rasas sobre a área cratônica.

Evolução

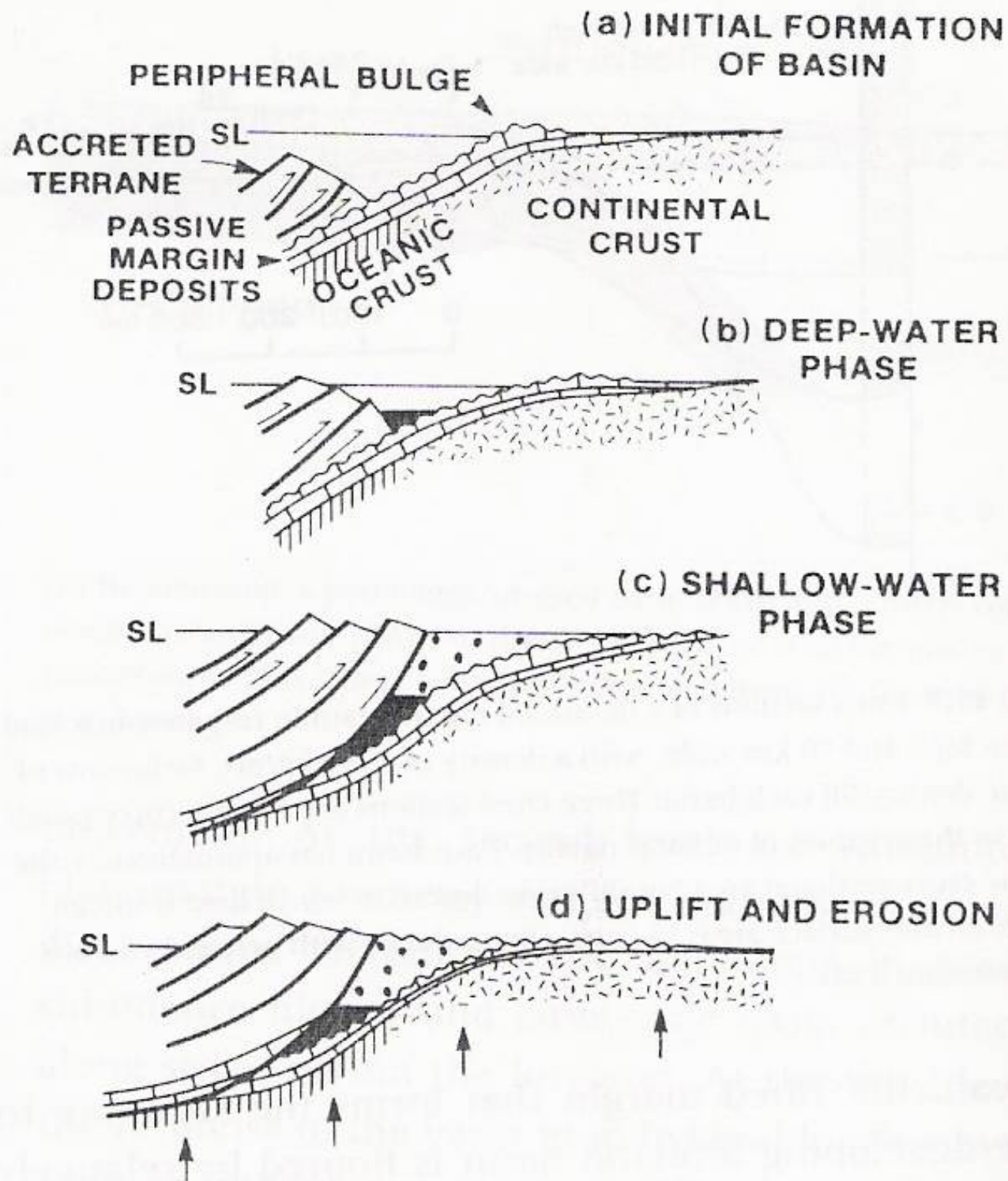
O momento anterior:

- Bacias colisionais de retroarco – ocorrem sobre a área de retroarco, onde haviam bacias vulcano-sedimentares distensionais ou bacias de retroarco compressivo (*retroarc foreland basins*).
- Bacias periféricas de antepaís – ocorrem sobre margens continentais passivas da placa que sofre subducção (a placa cavalgada).

Evolução

Etapas:

- 1- Fechamento de oceano – bacia oceânica remanescente – importante sedimentação de água profunda – "*flysch*".
- 2- Início do cavalgamento – aumento da declividade do talude – turbiditos e olistrólitos – reativação das falhas normais pré-existentes – "*flysch*".
- 3- Fase de águas profundas – reversão das estruturas herdadas (falhas lítricas normais passam a cavalgamentos) – subsidência flexural acentuada – muita geração de espaço e pouco aporte – sedimentação de águas profundas com fonte no orógeno – "*flysch*" sin-orogênico.
- 4- Fase continental e de águas rasas – grande elevação da área-fonte – grande aporte sedimentar – colmatação da bacia – *molassa* orogênica.
- 5- Inversão da bacia – deformação, erosão de sedimentos previamente depositados – formação de discordâncias.



Evolução

A cada evento de reativação repetem-se as fases 3 a 5, com deformação das unidades anteriores, formação de discordância e avanço do depocentro em direção ao cráton.

As discordâncias são mais marcantes no *forebulge*, que também migra em direção ao cráton em eventos sucessivos.

A preservação de bacias de antepaís no registro geológico antigo depende da evolução geológica posterior. O potencial de preservação é pequeno, pois quando a área soerguida é erodida, a sobrecarga deixa de existir e a bacia soergue.

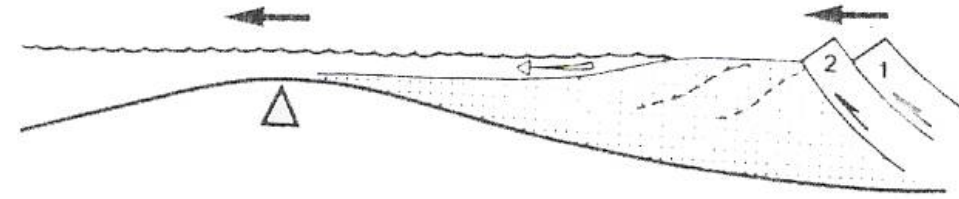
A parte preservada é aquela mantida pela deformação visco-elástica da litosfera (parte da deformação é permanente), e pela carga do sedimento da bacia.

O aquecimento da litosfera pelo espessamento crustal pode causar um relaxamento térmico, resultando em deformação viscoelástica após a deformação elástica inicial.

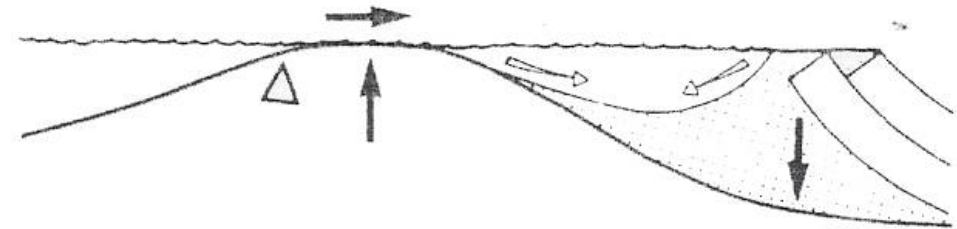
A diminuição da rigidez flexural causa aumento da taxa de subsidência, diminuição da área e aproximação do *forebulge*.

Sucessivas reativações podem causar repetição do processo.

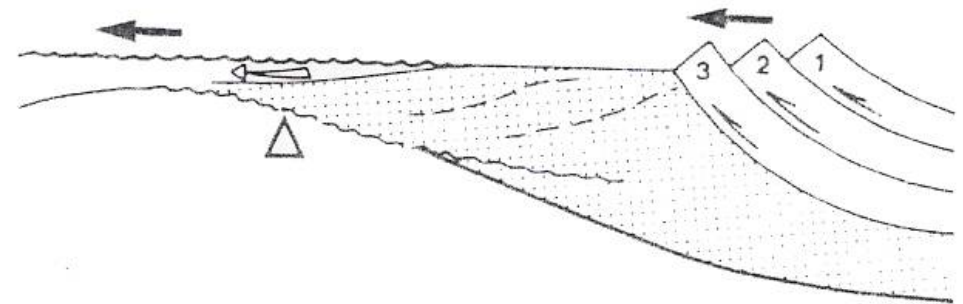
1. OVERTHRUST LOADING - Flexural deformation



2. RELAXATION PHASE - Viscoelastic response



3. RENEWED OVERTHRUST LOADING - Flexural deformation



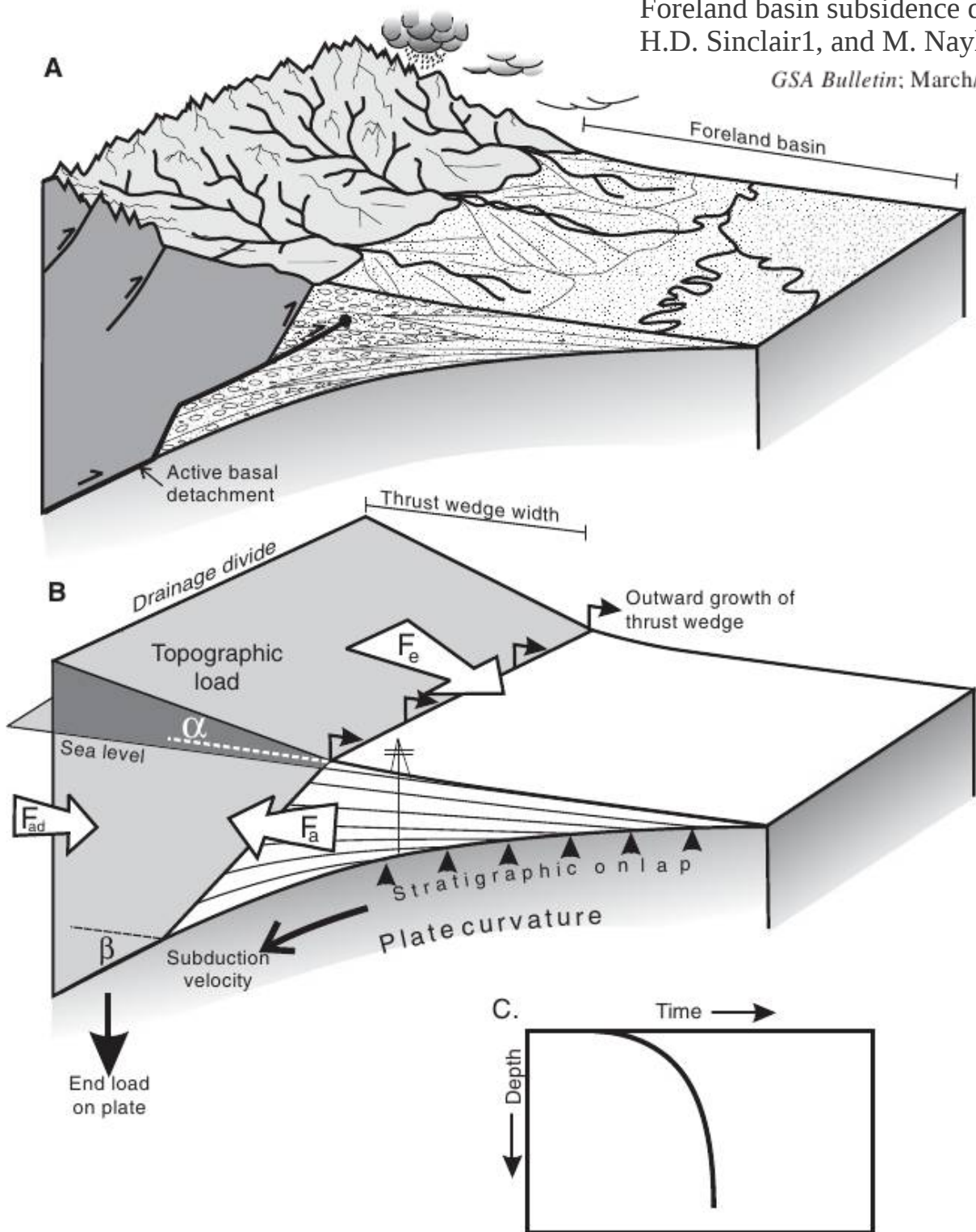
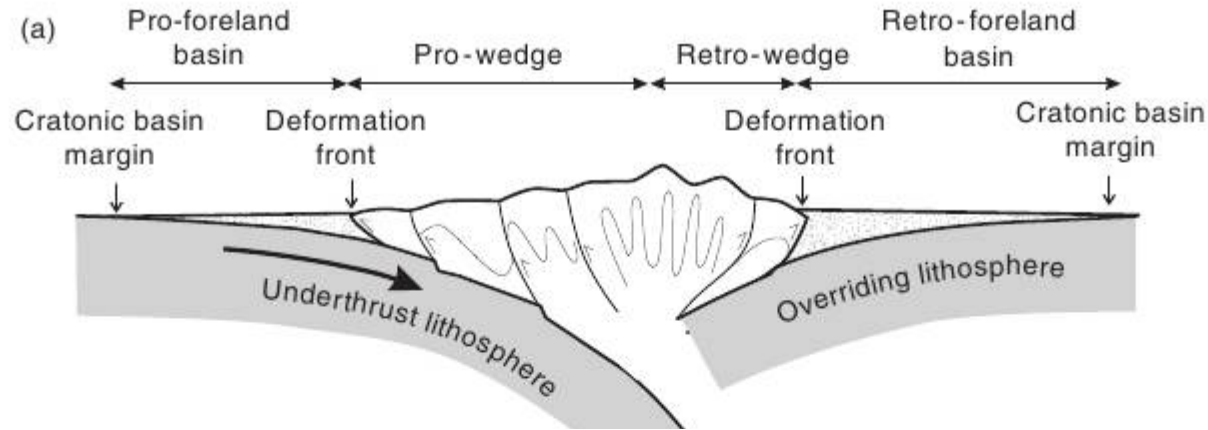


Figure 1. Thrust wedge–foreland basin systems showing the primary controls on basin subsidence. (A) The geological processes involved in the growth of mountain topography and the subsidence and infilling of foreland basins. (B) Primary quantifiable components of thrust wedge–foreland basins systems. Three primary fluxes determine the development of the foreland basin (F_e —erosional flux) and the thrust wedge (F_a —frontal accretion, F_{ad} —advection into rear of thrust wedge). The topographic load can be approximated by a thrust wedge (Davis et al., 1983), and it grows by the outward propagation of the deformation front, which is continually countered by the process of internal shortening. (C) The present paradigm for the signal of accelerating subsidence of foreland basins (Allen and Allen, 2005; Angevine et al., 1990; DeCelles and Giles, 1996; Miall, 1995; Xiangyang and Heller, 2009).

Pro- vs. retro-foreland basins

M. Naylor and H. D. Sinclair



Basin Research (2008) doi: 10.1111/j.1365-2117.2008.00366.x

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Pro- vs. retro-foreland basins

M. Naylor and H. D. Sinclair

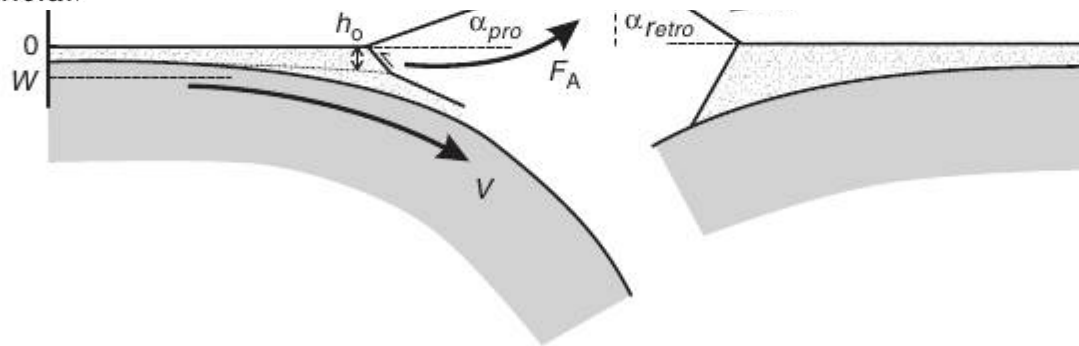


Fig. 1. Cartoon of a steady-state doubly vergent orogen. (a) The pro-foreland basin lies in the flexural depression over the subducting slab which advances towards the orogen at the regional convergence rate, v . The retro-foreland basin lies in the flexural depression above the over-riding slab which is predominantly stationary with respect to the orogen. (b) The mass budget of the wedge system is controlled by the relative rate of the accretionary and erosive fluxes (F_A and F_E , respectively). The rate of accretion of new material from the downgoing plate is a function of the convergence rate and the thickness of material that is accreted from that plate, h_0 . The cross-sectional area of the mountain's topography is described by two triangles of height H and surface taper angles α_{pro} and α_{retro} that abut at the load divider.

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

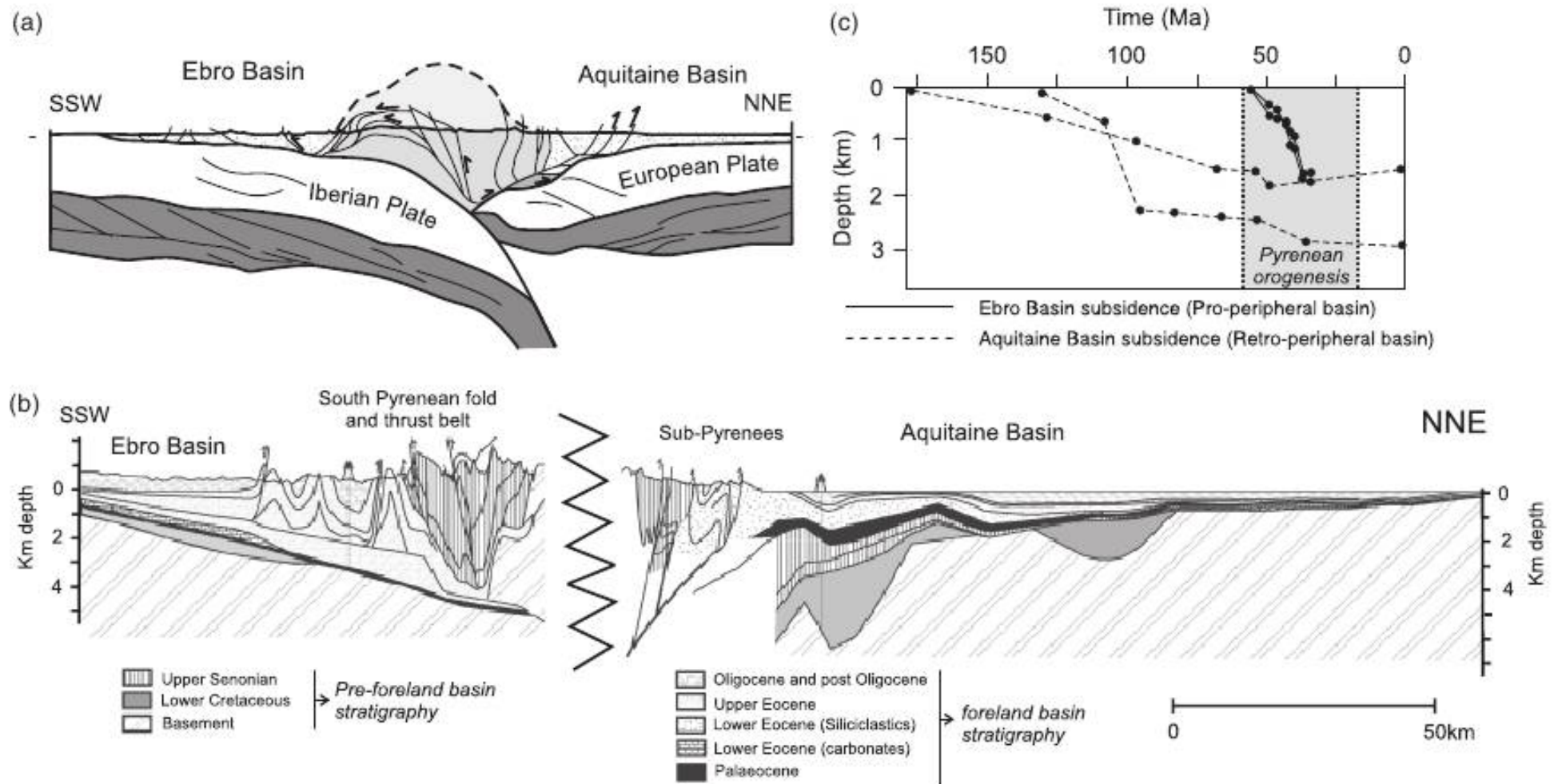
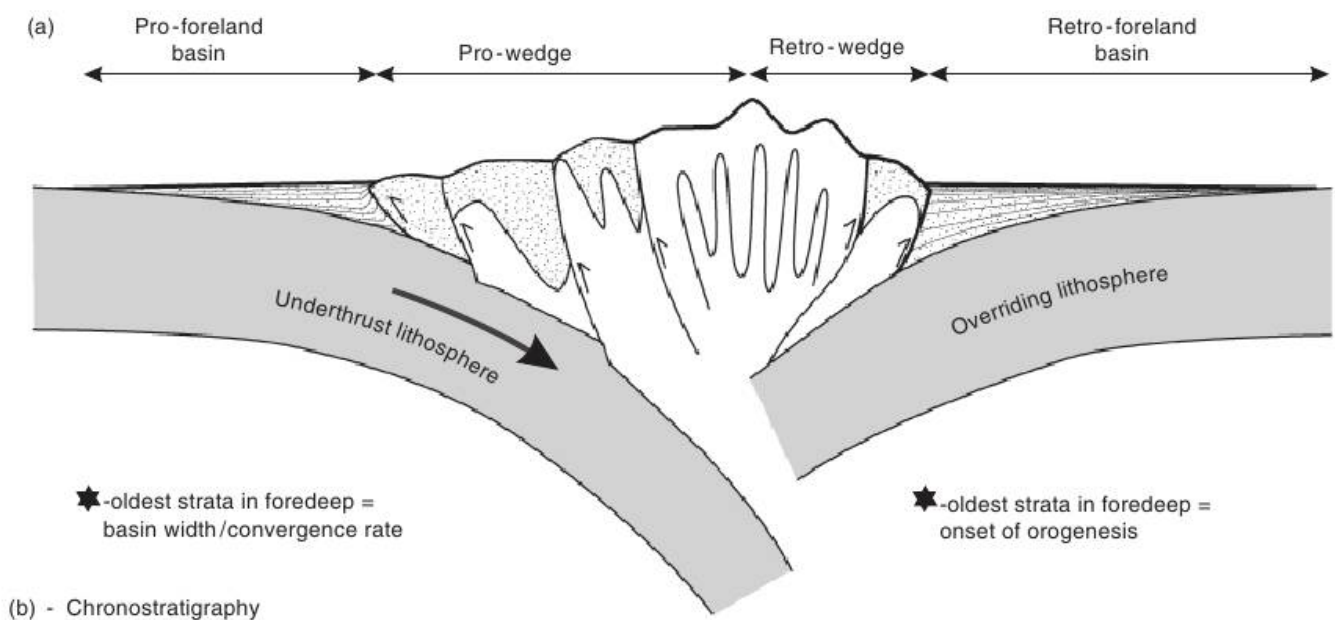
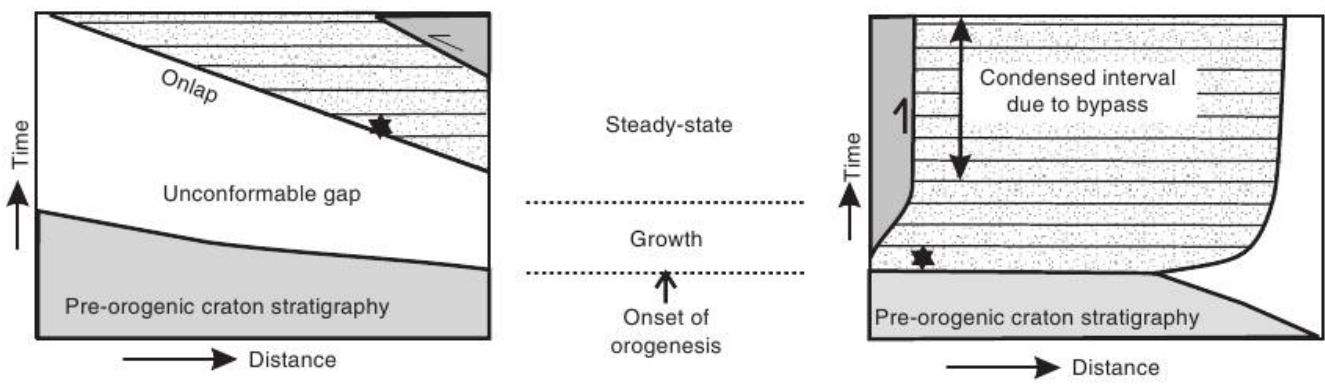


Fig. 8. The Pyrenees mountain belt as a type example of a system with a pro-foreland (Ebro Basin) and retro-foreland (Aquitaine Basin) foreland basin that can be compared in terms of their stratigraphic infill and tectonic subsidence histories. (a) Summary cross-section of the Pyrenean mountain belt formed by the Iberian plate of Spain subducting beneath the European Plate of south-western France. This section is constrained by the ECORS deep seismic section (Choukroune, 1989), other geophysical measurements (Pous *et al.*, 1995) and surface geology (Muñoz, 1992). (b) Close-up of the stratigraphy of the Ebro (Vergés, 1999) and Aquitaine Basins (Desegaulx *et al.*, 1991). (c) Subsidence plots from two wells located near to the deformation front in the Aquitaine Basin (Desegaulx & Brunet, 1990) and from structurally restored stratigraphic profiles from the central South Pyrenean fold and thrust belt (Vergés, 1999). Note that the Ebro Basin contains a limited section of stratigraphy dominated by Upper Eocene strata; the subsidence plots through this record a rapid phase of accelerating subsidence at this time. In contrast, the Aquitaine Basin contains a much broader chronostratigraphic range, and shows only minor tectonic subsidence during the early stages of orogenesis, but this decreases to zero. These contrasts match predictions made for pro-foreland vs. retro-foreland foreland basin development, respectively.



(b) - Chronostratigraphy



(c) - Tectonic subsidence



Fig. 9. Summary figure contrasting the basin characteristics of Pro-foreland (left-hand side) and Retro-foreland (right-hand side) foreland basins. (a) The Pro-foreland foreland basin exhibits dramatic basin onlap of the cratonic margin, at a rate greater or equal to the plate convergence rate dependent upon whether the thrust wedge is in a growth or steady-state phase, respectively; in contrast the Retro-foreland basin records little onlap except in the early stage of growth. This contrasting onlap pattern is clearly seen in the chronostratigraphic equivalent, (b) which also illustrates the relatively limited chronostratigraphic interval preserved in the pro-foreland basin relative to the retro-foreland basin. Note that the reference frame for both chronostratigraphic figures are their respective cratonic plates (cf. Appendix B and Fig. 10), and not an absolute frame. The degree to which foreland basin deposits are accreted and preserved in the thrust wedges also contrasts markedly due to the ongoing advection of the pro-foreland basin's succession into the pro-wedge, in contrast to the retro-foreland basin succession which will only be accreted during growth of the mountain belt. Hence, the oldest deposits preserved in the foredeep of the pro-foreland basin equal the width of the basin divided by the convergence rate. In contrast, the oldest strata preserved in the foredeep of the retro-foreland basin record the initiation of orogenesis. The tectonically driven subsidence of the two basins also contrasts, (c) The pro-foreland basin records accelerated subsidence over a relatively short interval of orogenesis. In contrast, the retro-foreland basin records the full history of the basin with initial uniform subsidence during growth of the mountain belt, and hence of the retro-thrust wedge, followed by zero subsidence during steady-state when the retro-wedge no longer accretes new material. During this latter stage, the retro-foreland basin record a condensed stratigraphic succession which is likely to be dominated by bypass of the sediment generated in the mountain belt and exported farther afield.

Preenchimento

Bacias de antepaís têm proveniência do alto soerguido (orógeno colisional), com abundantes litoclastos metamórficos e assembléias de pesados ricas em minerais metamórficos.

Outros fatores, como o clima e o padrão de drenagens podem influenciar muito o tipo de preenchimento – grande diferença entre os depósitos das bacias Alpinas, Himalaianas e do Golfo Pérsico.

A proveniência metamórfica não é exclusiva de bacias de antepaís. A idade do metamorfismo tem que ser próxima da idade da bacia.

Exemplos de diagramas discriminantes de proveniência

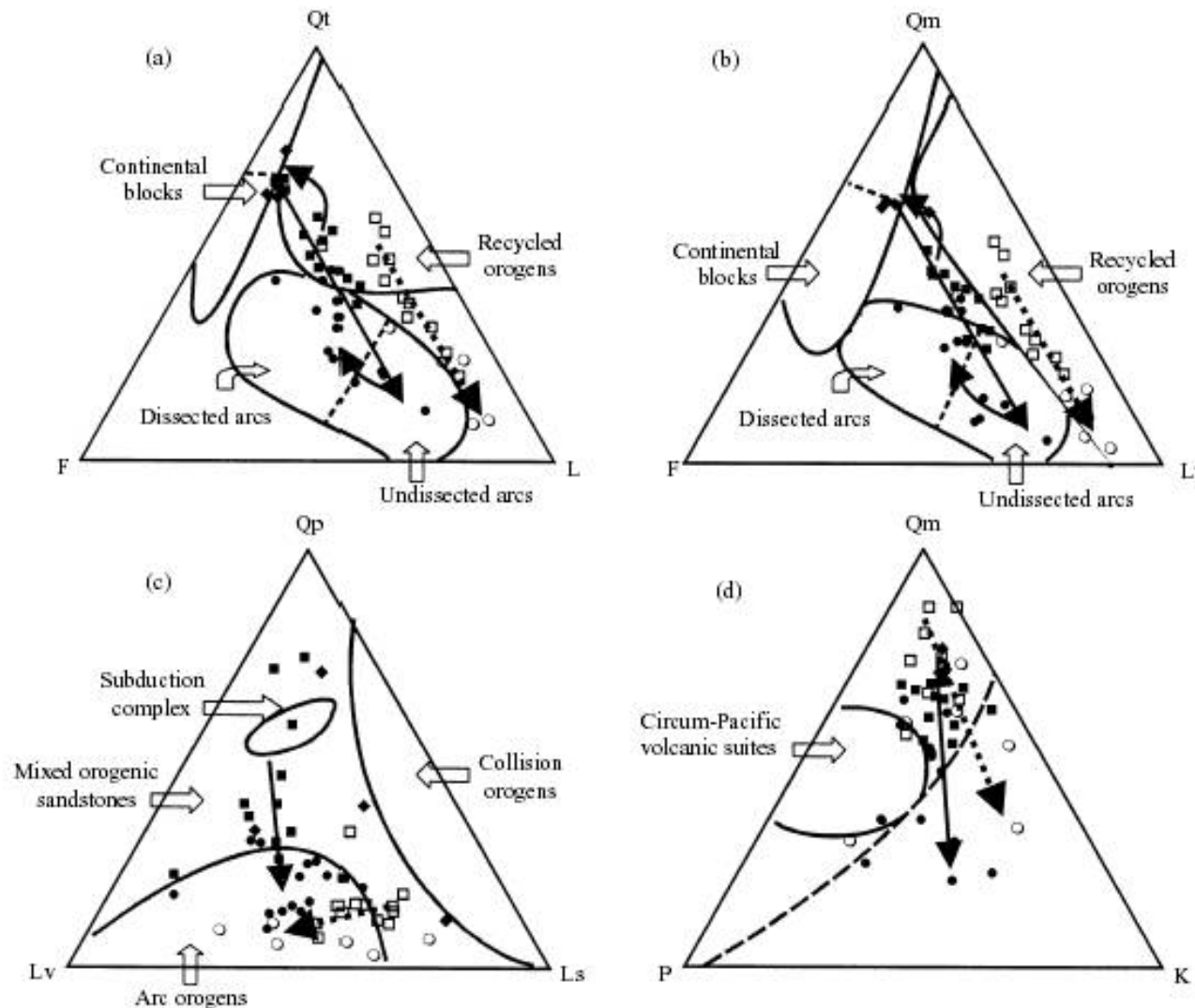


Fig. 3 Sandstone framework detrital compositions and their provenance types. Framework mode diagrams according to Dickinson and Suczek (1979), and data from Table 1. (a) Qt-F-L; (b) Qm-F-Lt; (c) Qp-Lv-Ls; and (d) Qm-P-K. Jurassic provenance evolution of the Feixi and the Huoshan sections are indicated by solid arrows and dotted arrows, respectively. The component codes of the triangular plots are the same as those in Table 1. ○, Fenghuangtai Formation; □, Sanjianpu Formation; ●, Zhougengshan Formation; ◆, Yuanlongshan Formation; ■, Fanghushan Formation.

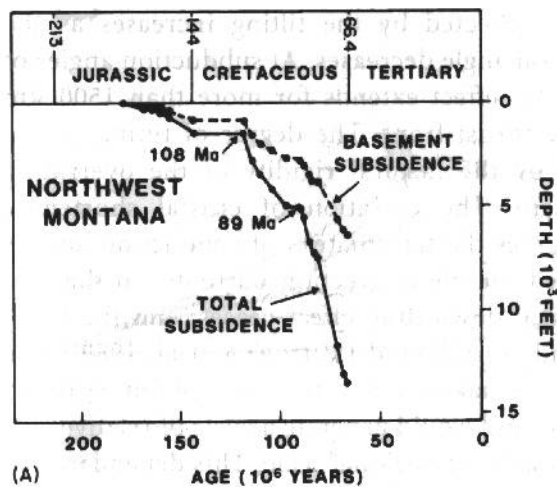
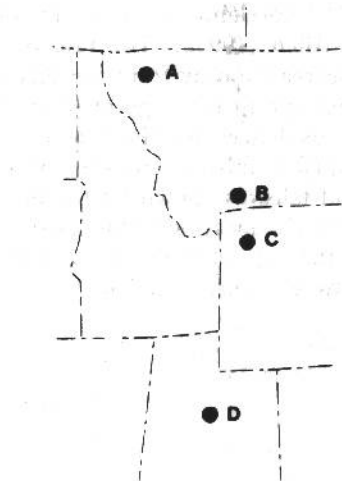
Preenchimento

Bacias de antepaís são assimétricas, com maior subsidência próximo à sobrecarga.

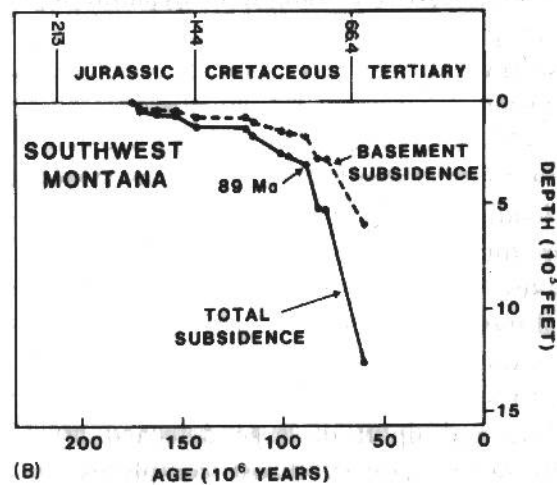
A assimetria é contrária àquela de bacias de margem passiva, pois o aporte sedimentar principal vem diretamente para a área de maior subsidência.

A ciclicidade é controlada principalmente pela variação das taxas de subsidência e de aporte sedimentar, que obedecem a ciclos de reativação tectônica. A eustasia é mascarada pelas altas taxas de subsidência durante os cavalgamentos e por eventos de soerguimento que simulam queda eustática.

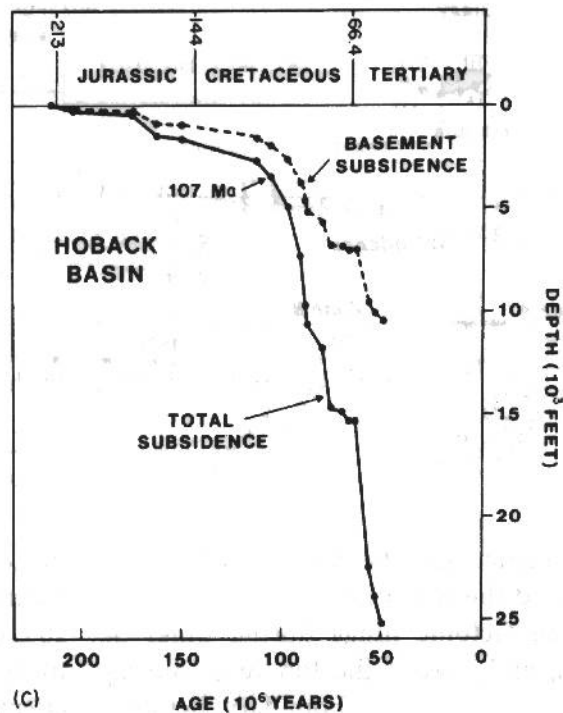
Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



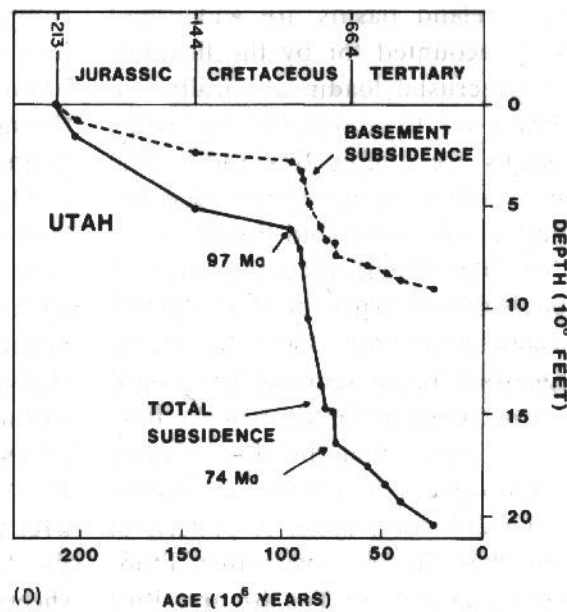
(A)



(B)



(C)



(D)

Exemplos

- Himalaia
- Bacias Alpinas
- Golfo Pérsico

O sistema de bacias dos Orógenos da Eurásia.



Image © 2006 TerraMetrics

Image © 2006 NASA

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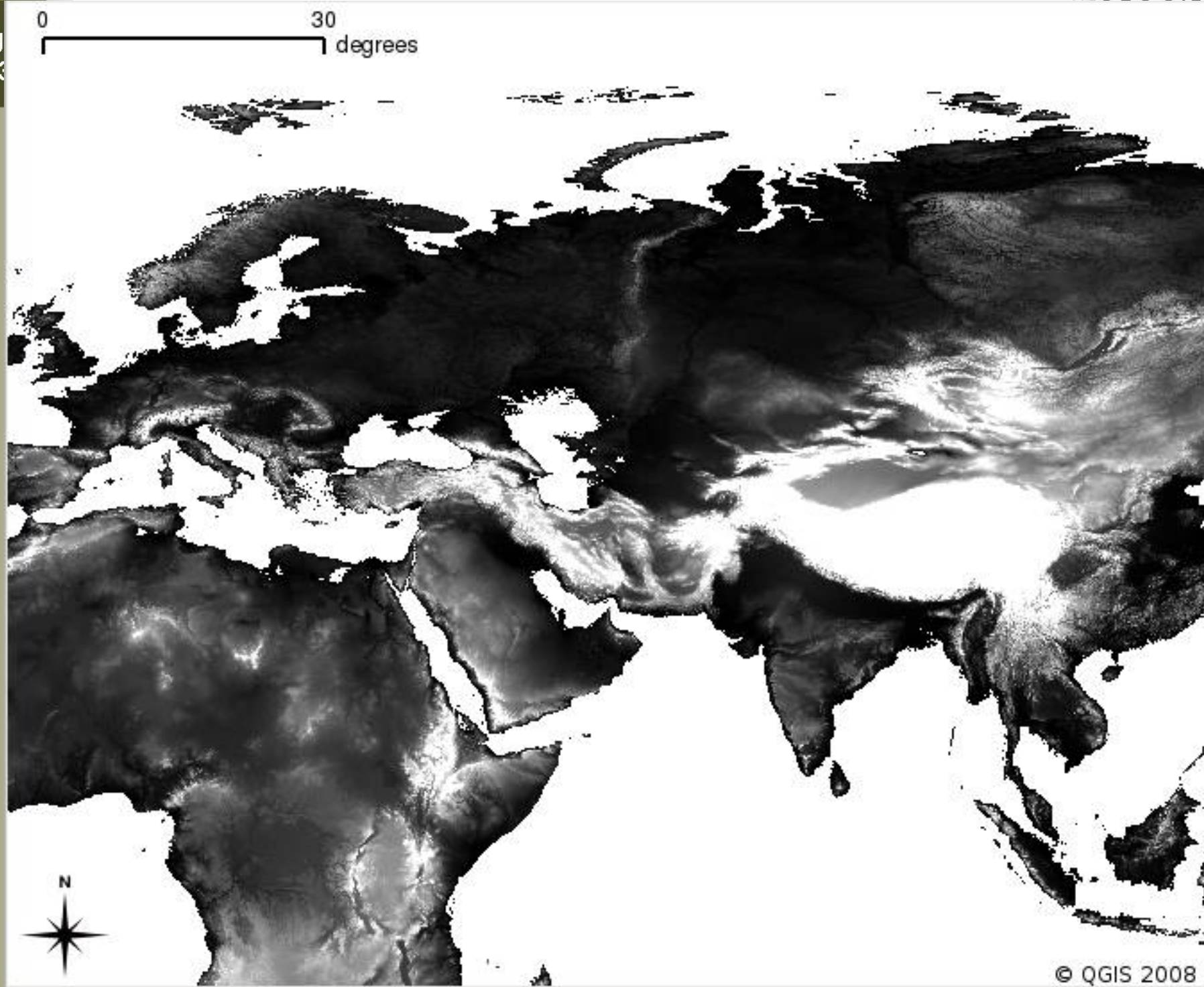
Pointer 42°25'38.72" N 49°27'15.99" E

Streaming ||||| 100%

Eye alt 8002.45 km

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GSA03

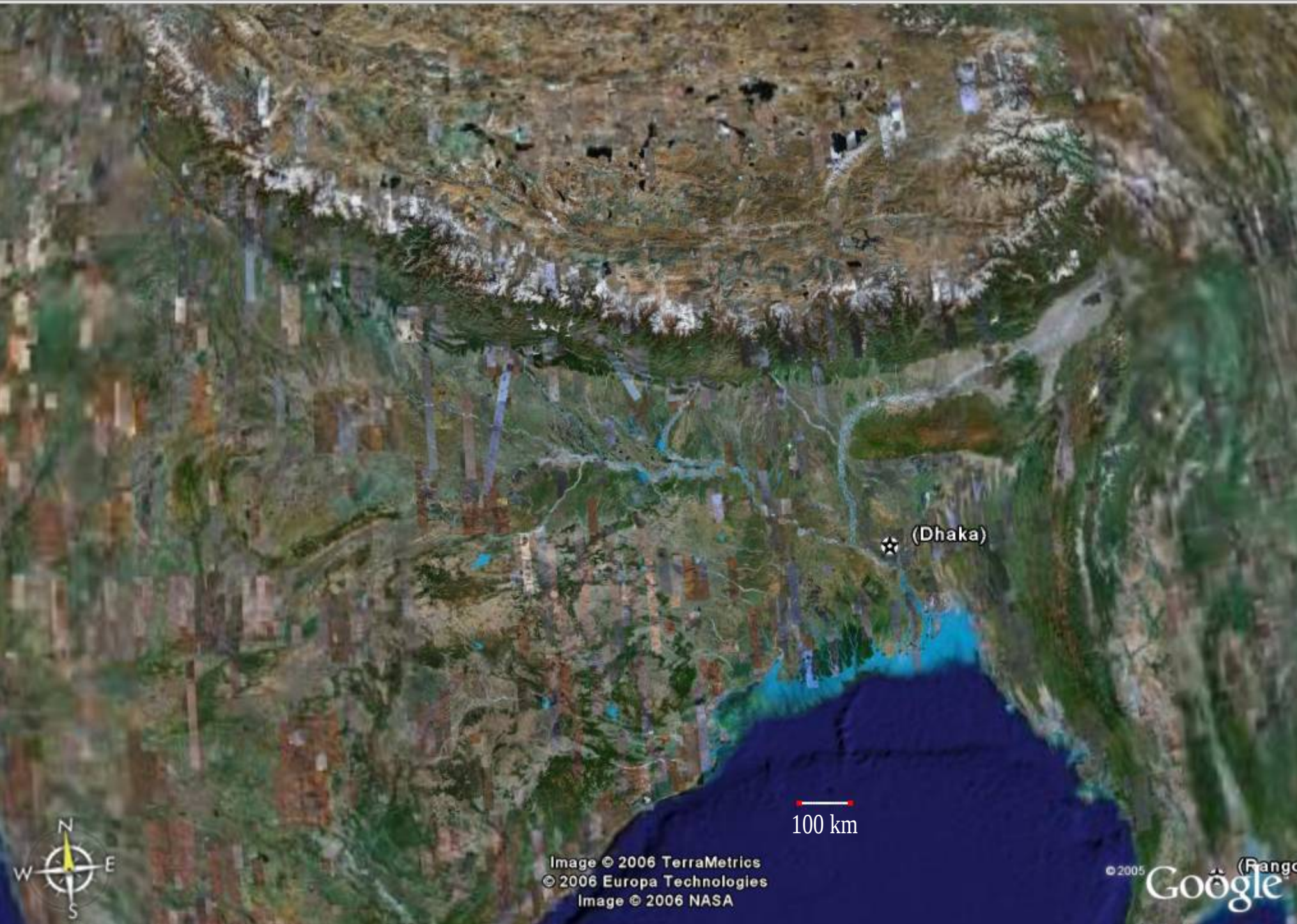
Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



A Bacia do Ganges

- Resposta a cavalgamento da Ásia sobre a Índia
- Grande T_e (~90 km)
- Flexura menor que a prevista pelo modelo (força contrária à flexura?)
- Preenchimento aluvial tropical

Desenho de ambientes construídos e paisagens



(Dhaka)



100 km

Image © 2006 TerraMetrics
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 Image © 2006 NASA

© 2005 Google (Rangoon)

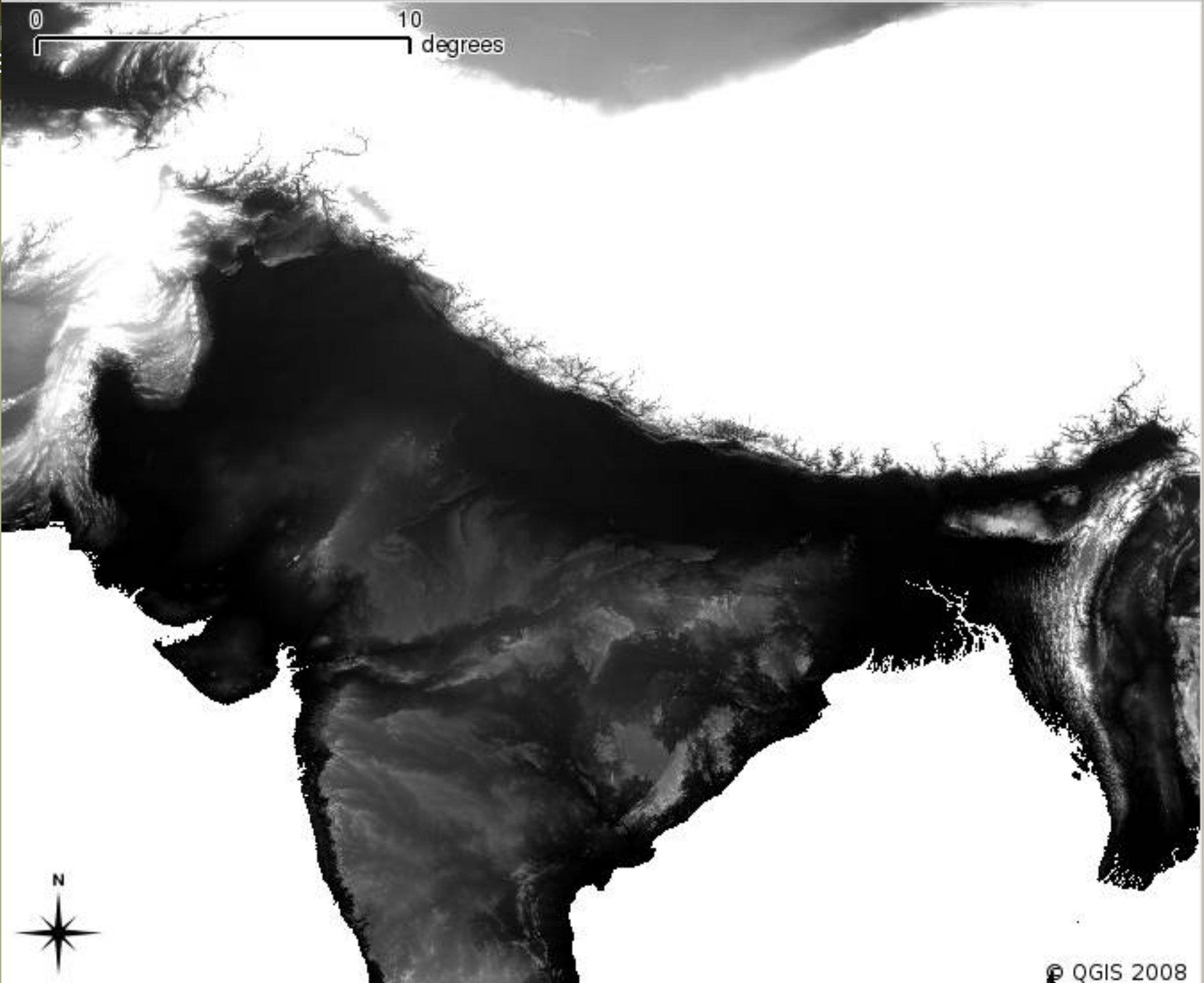
Pointer 25°15'46.14" N 86°09'19.80" E

Streaming ||||| 100%

Eye alt 2139.34 km

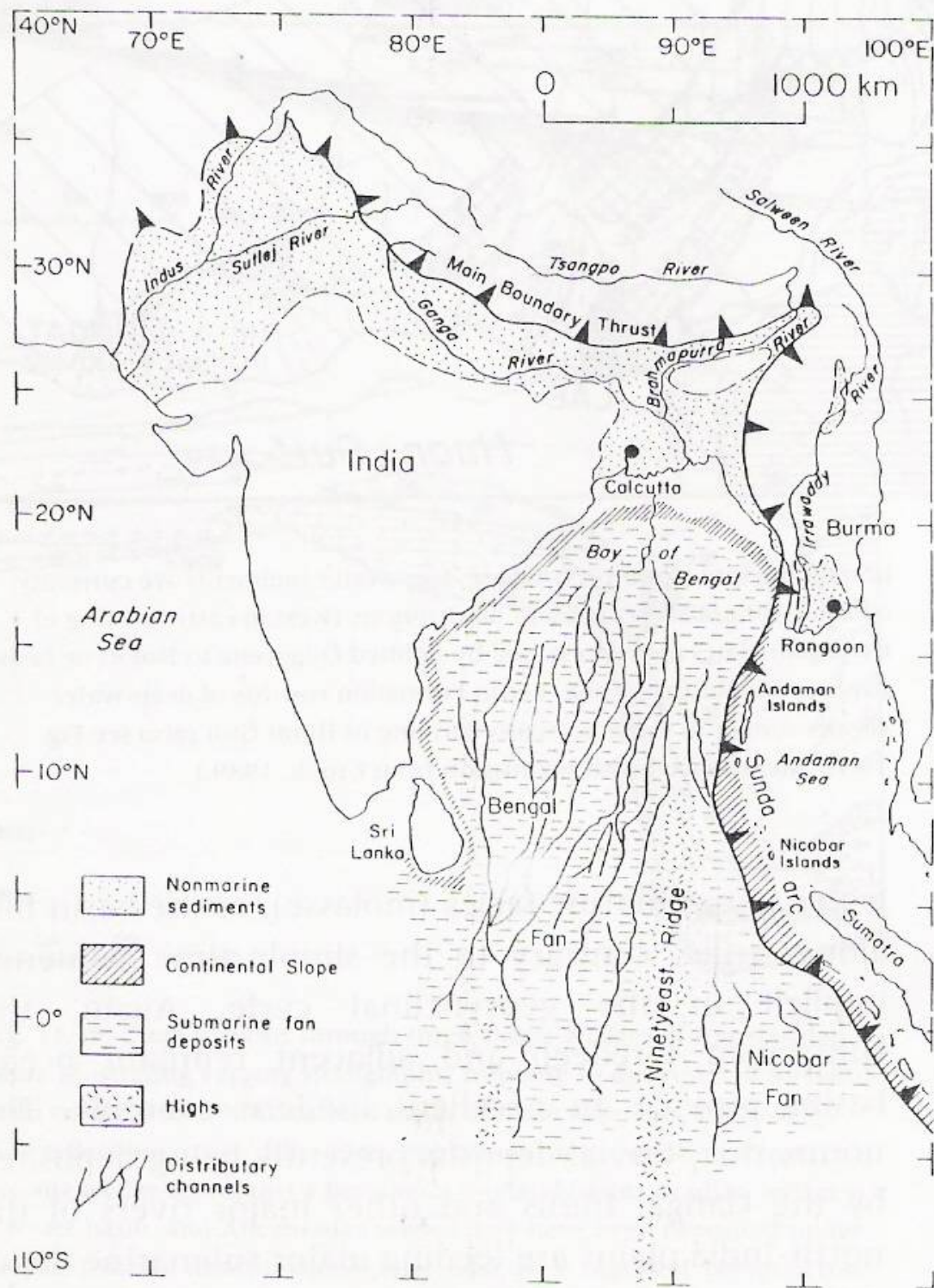
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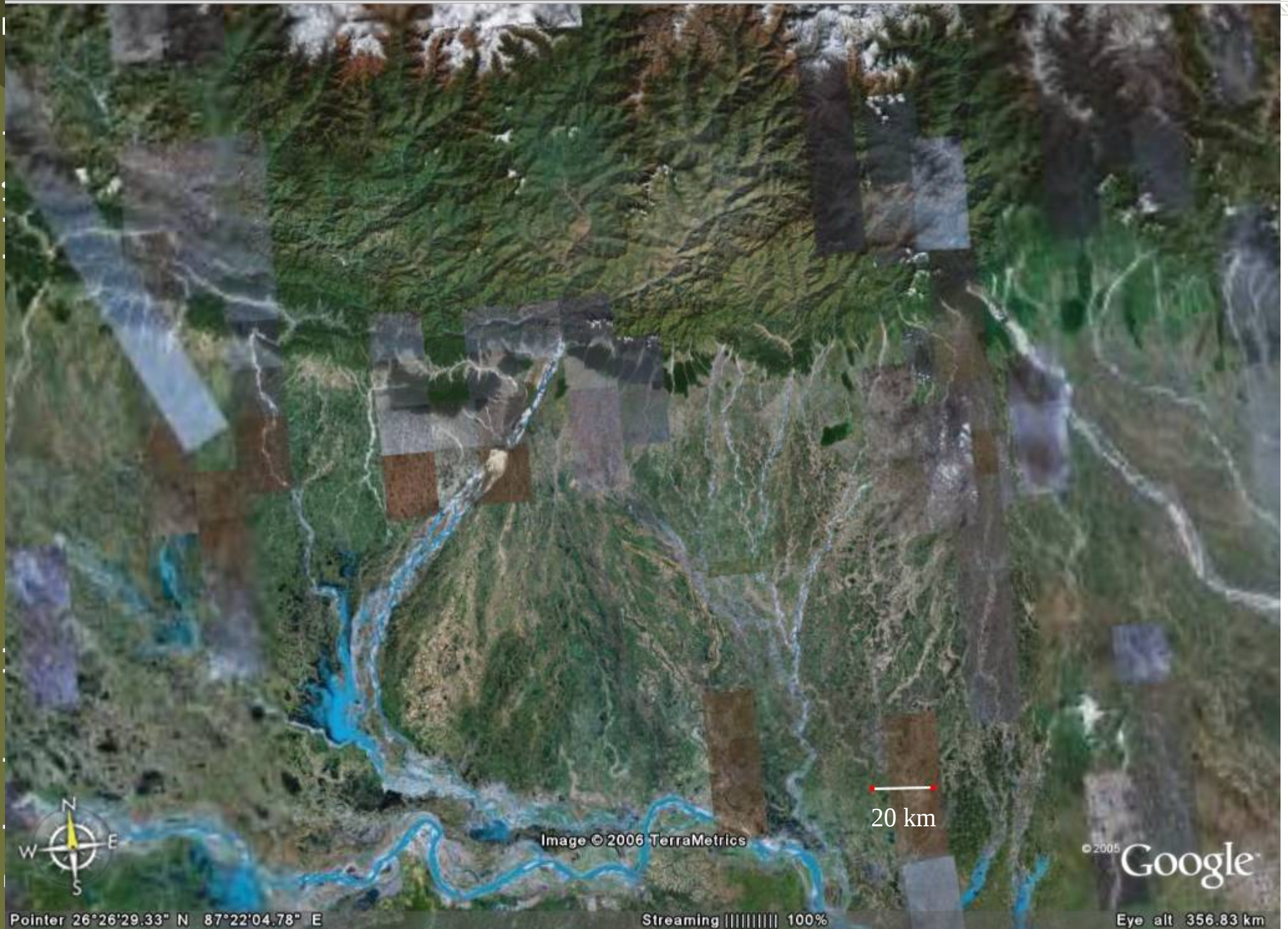
Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



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GSA0307

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação





20 km

Image © 2006 TerraMetrics

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Pointer 26°26'29.33" N 87°22'04.78" E

Streaming ||||| 100%

Eye alt 356.83 km



20 km

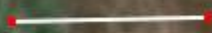


Image © 2006 TerraMetrics

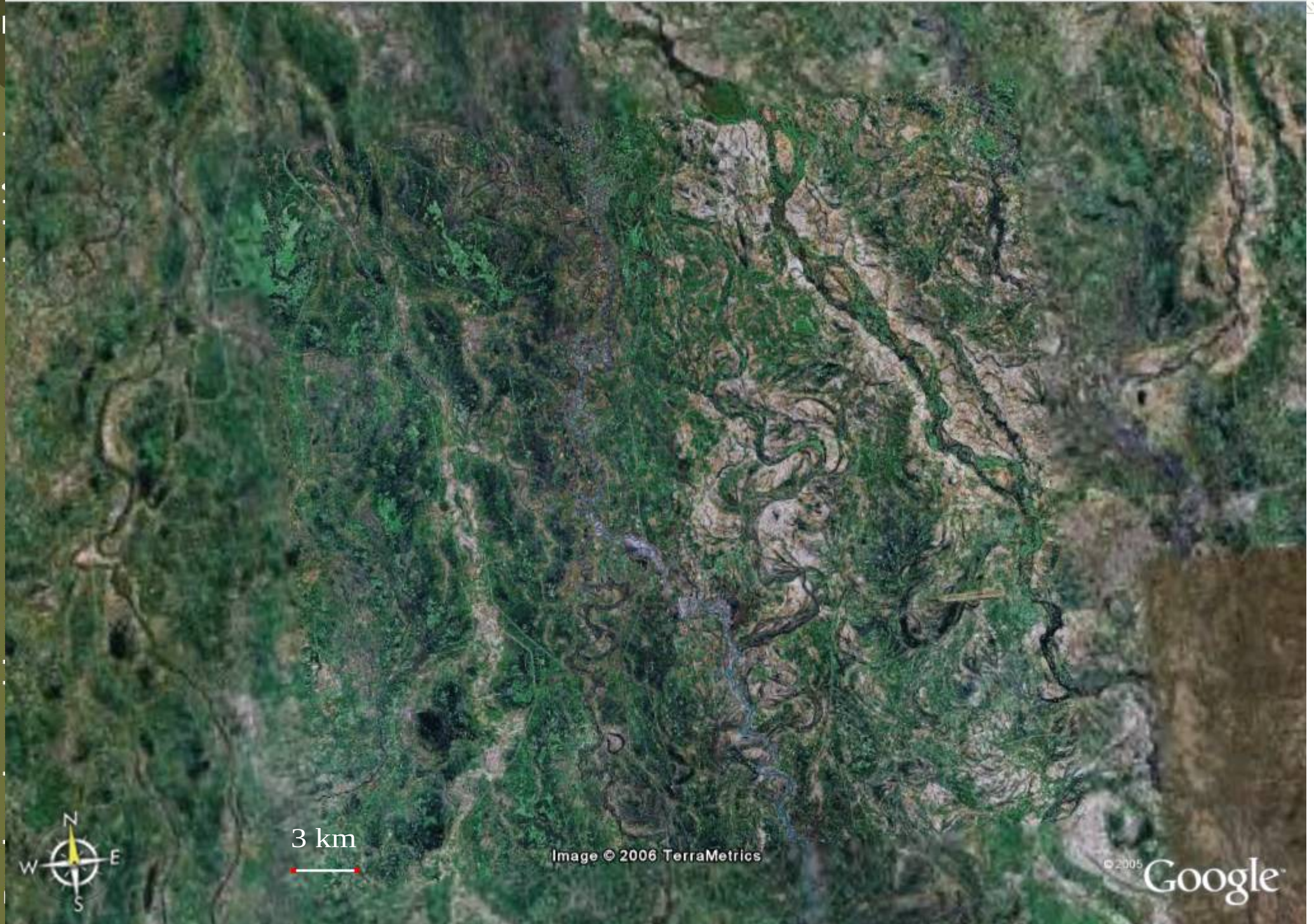
© 2005 Google



Pointer 25°59'37.24" N 87°16'54.80" E

Streaming ||||| 100%

Eye alt 177.57 km



3 km



Image © 2006 TerraMetrics

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Pointer 25°49'23.36" N 87°16'10.23" E

Streaming ||||| 100%

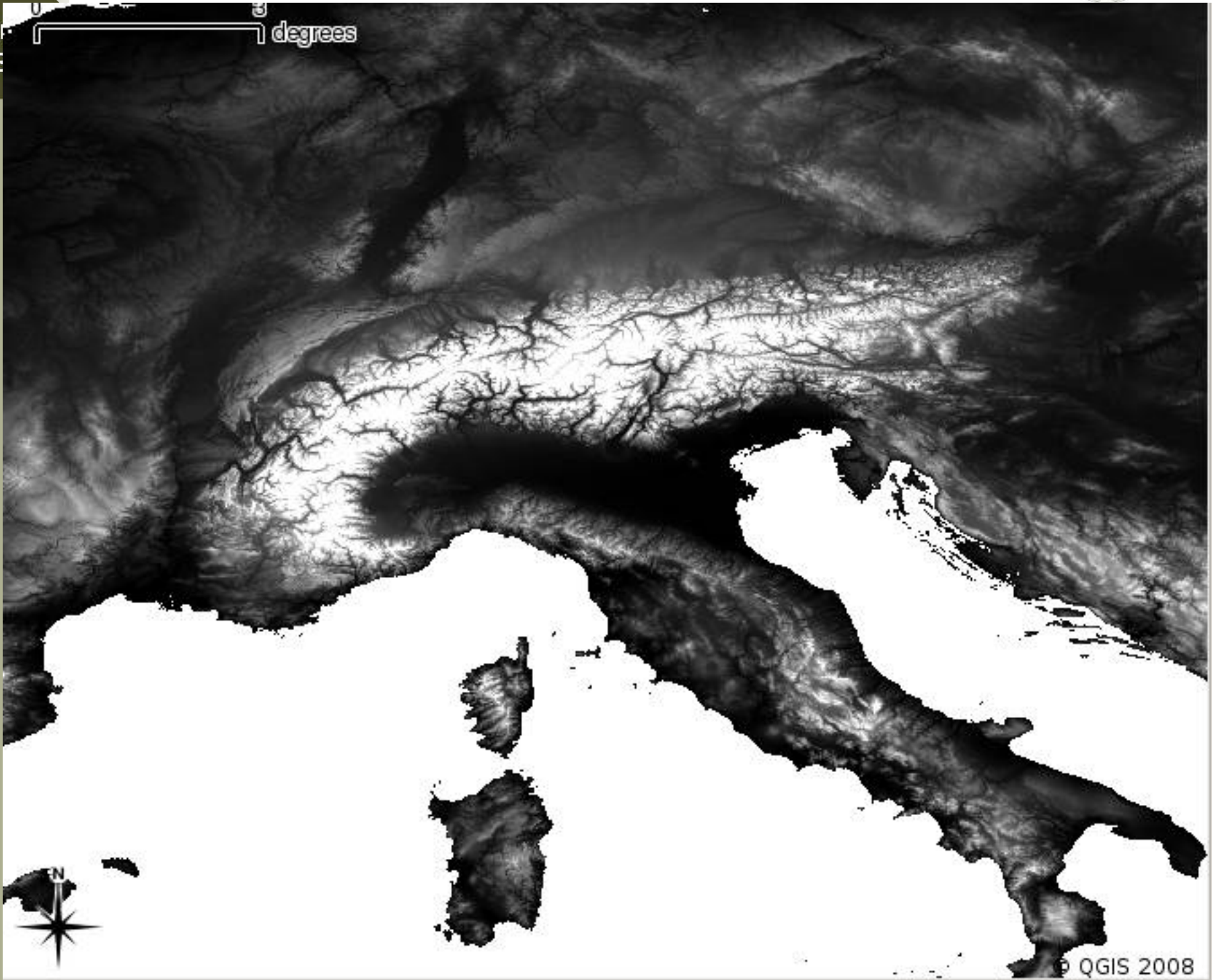
Eye alt 51.87 km

A Bacia do Pó

- Resposta a cavalgamento dos Alpes e interação com subducção do Mediterrâneo.
- Te muito pequeno (<10 ou ~5 km!)
- Preenchimento aluvial e marinho.

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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



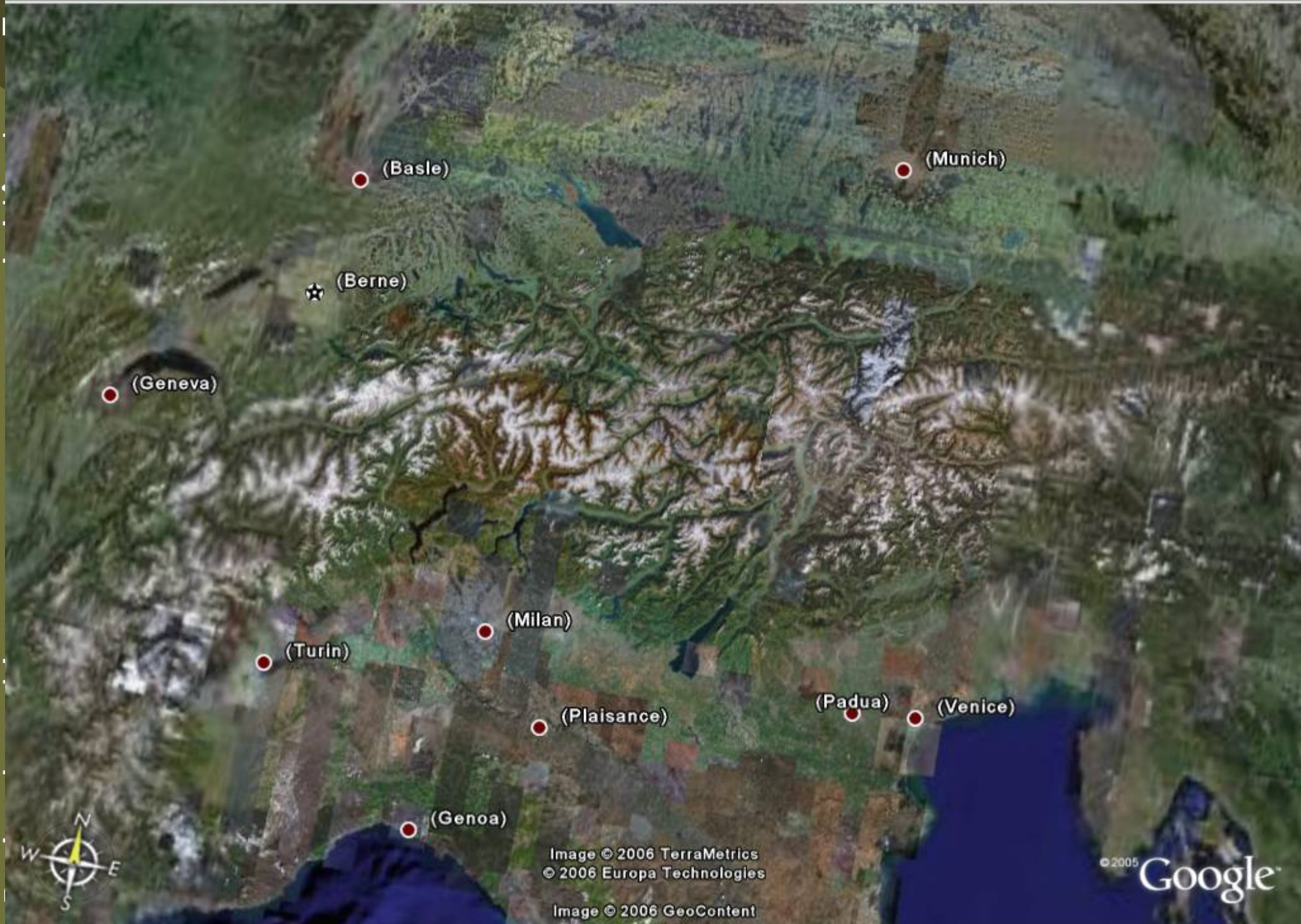


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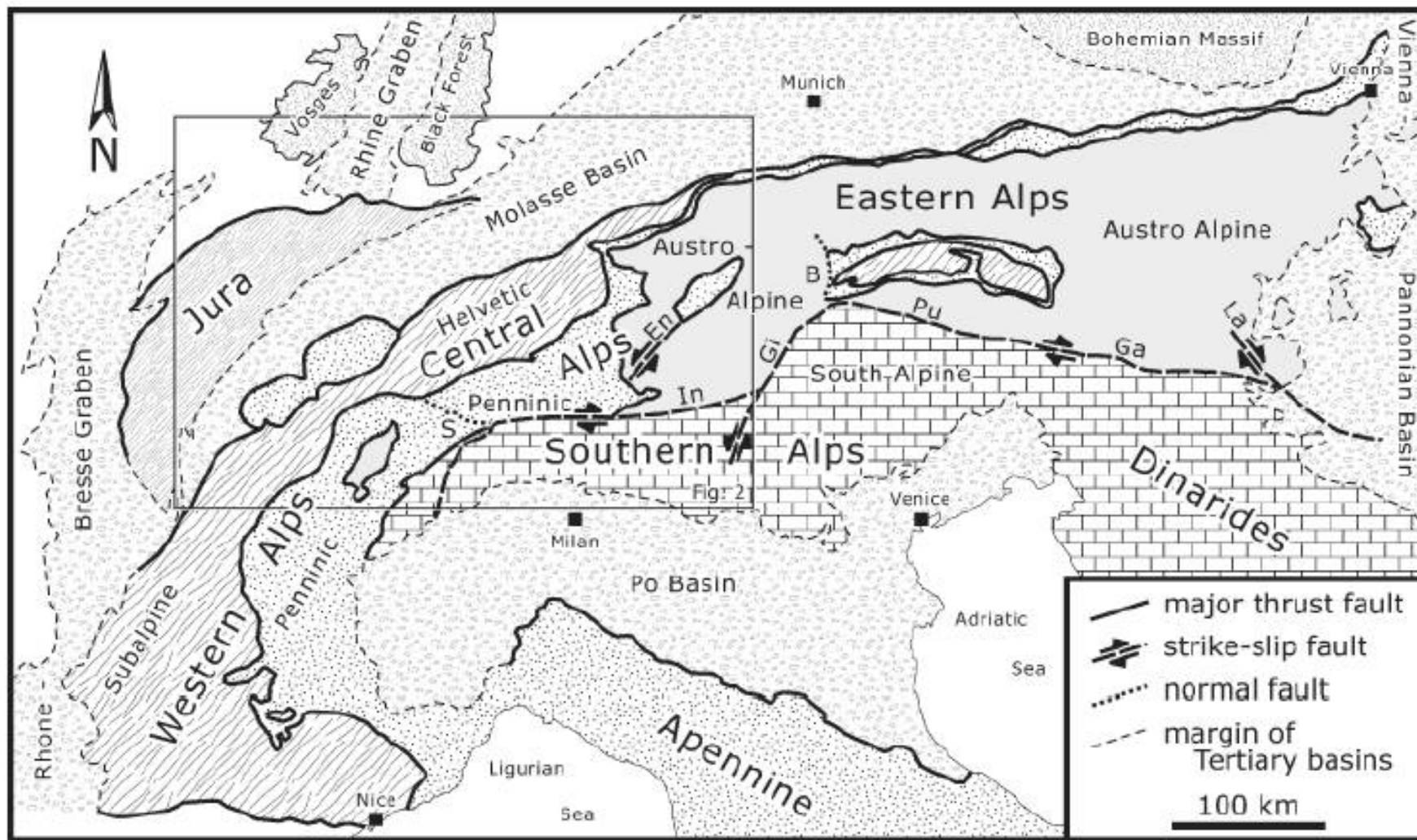
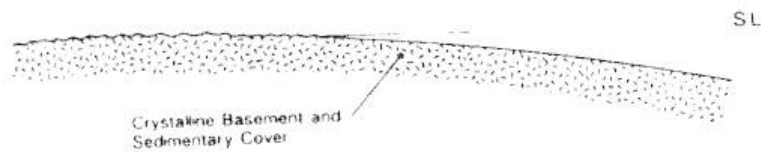


Fig. 1. Structural map of the Alps showing major tectonic units and fault systems, as well as the associated foreland basins. The study area (Fig. 2) is outlined.

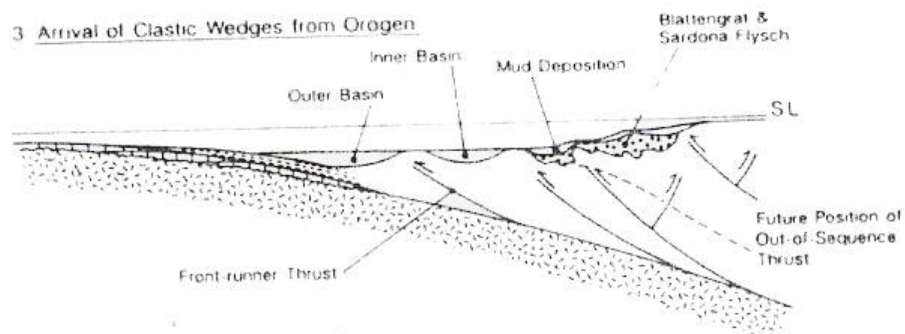
1 Pre-Luteitan



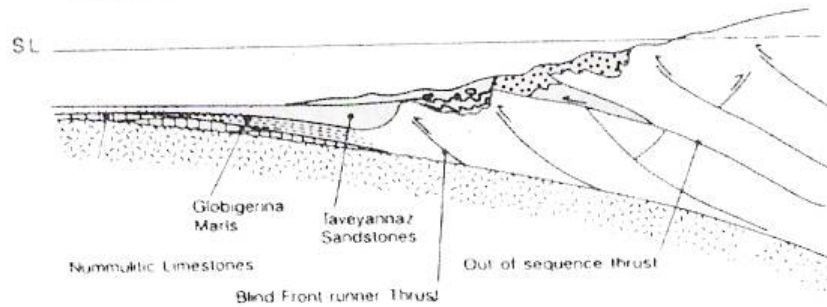
2 Carbonate Ramp Development



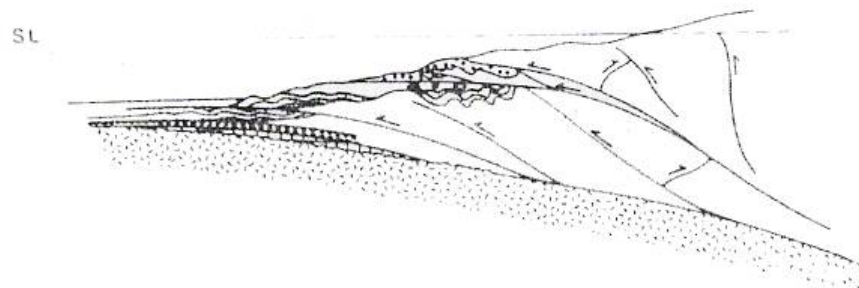
3 Arrival of Clastic Wedges from Orogen



4 Emplacement of Surface Mud Sheets



5 South Helvetic/North Penninic Sheets Thrust over Basin-Fill



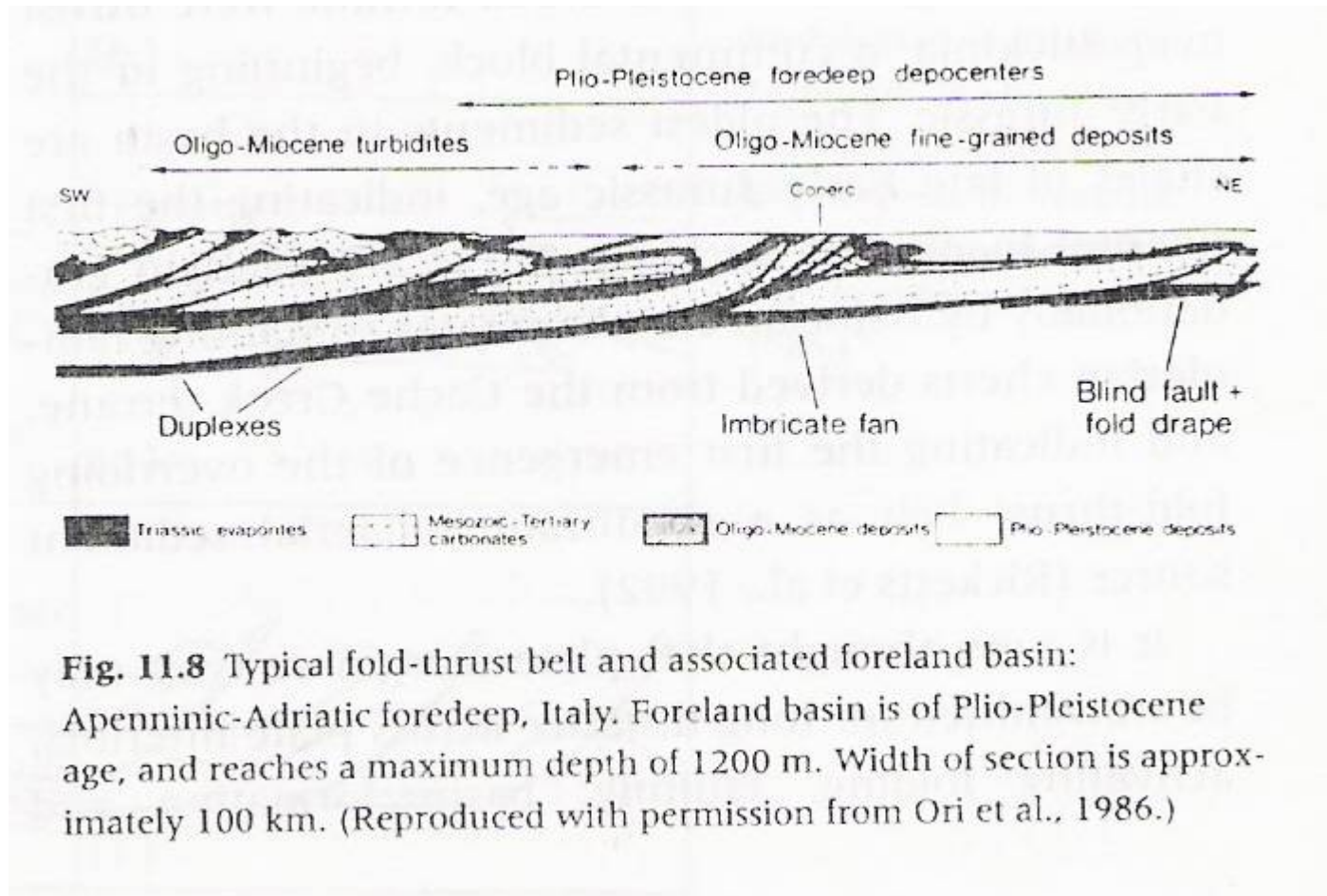
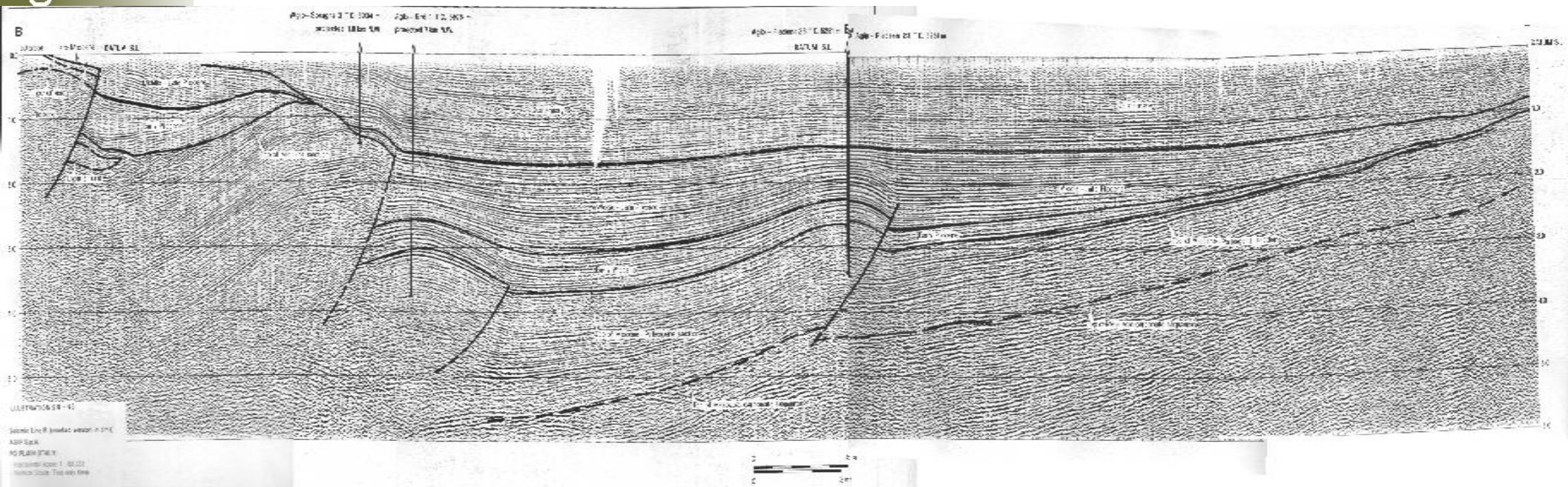
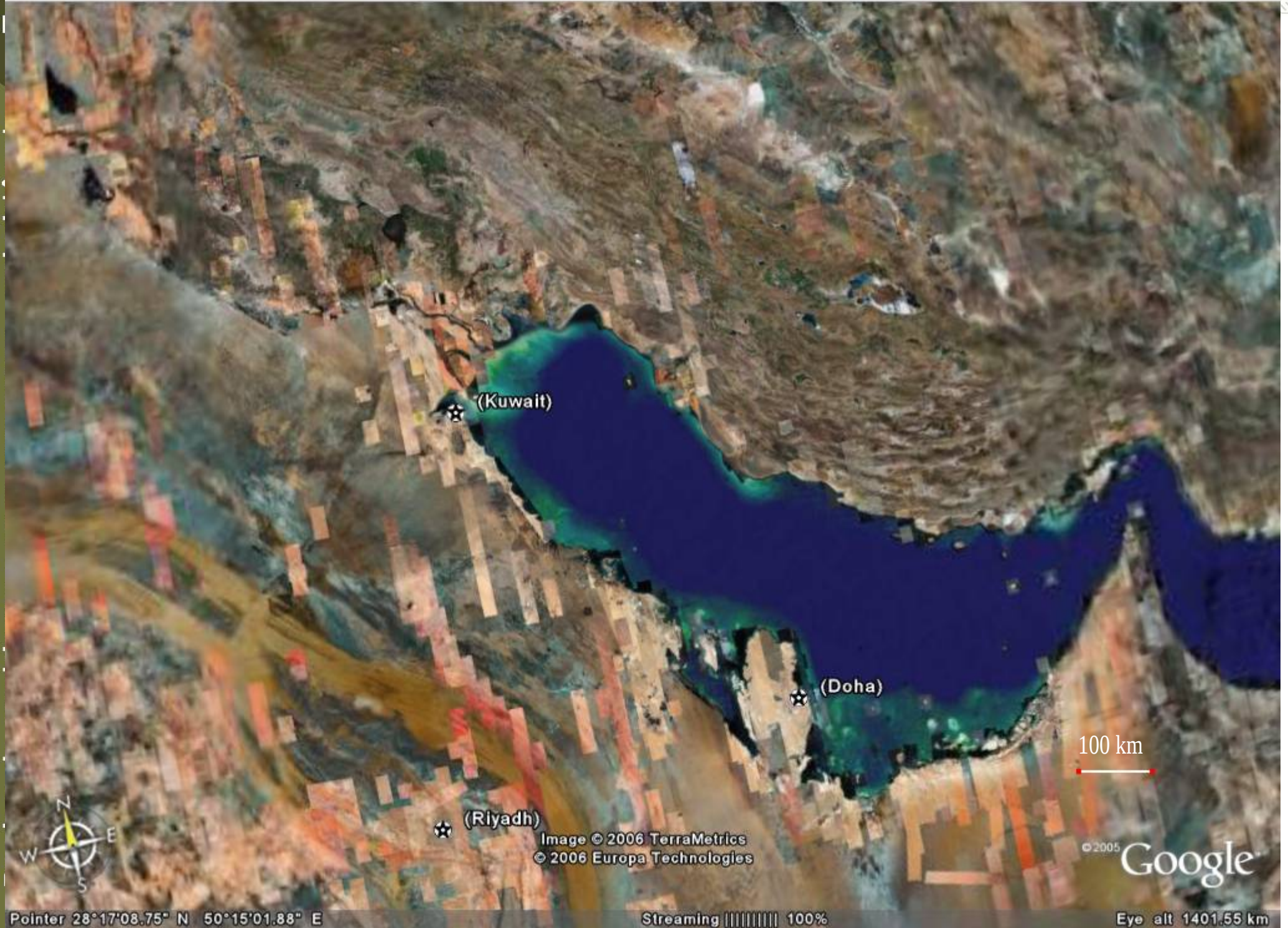


Fig. 11.8 Typical fold-thrust belt and associated foreland basin: Apenninic-Adriatic foredeep, Italy. Foreland basin is of Plio-Pleistocene age, and reaches a maximum depth of 1200 m. Width of section is approximately 100 km. (Reproduced with permission from Ori et al., 1986.)



A Bacia do Golfo Pérsico

- Resposta a cavalgamento dos Zagros sobre a Placa da Arábia
- Te 50 km
- Preenchimento marinho, costeiro e aluvial árido
- Flexura maior que a esperada (força adicional de subsidência?)



(Kuwait)

(Doha)

(Riyadh)

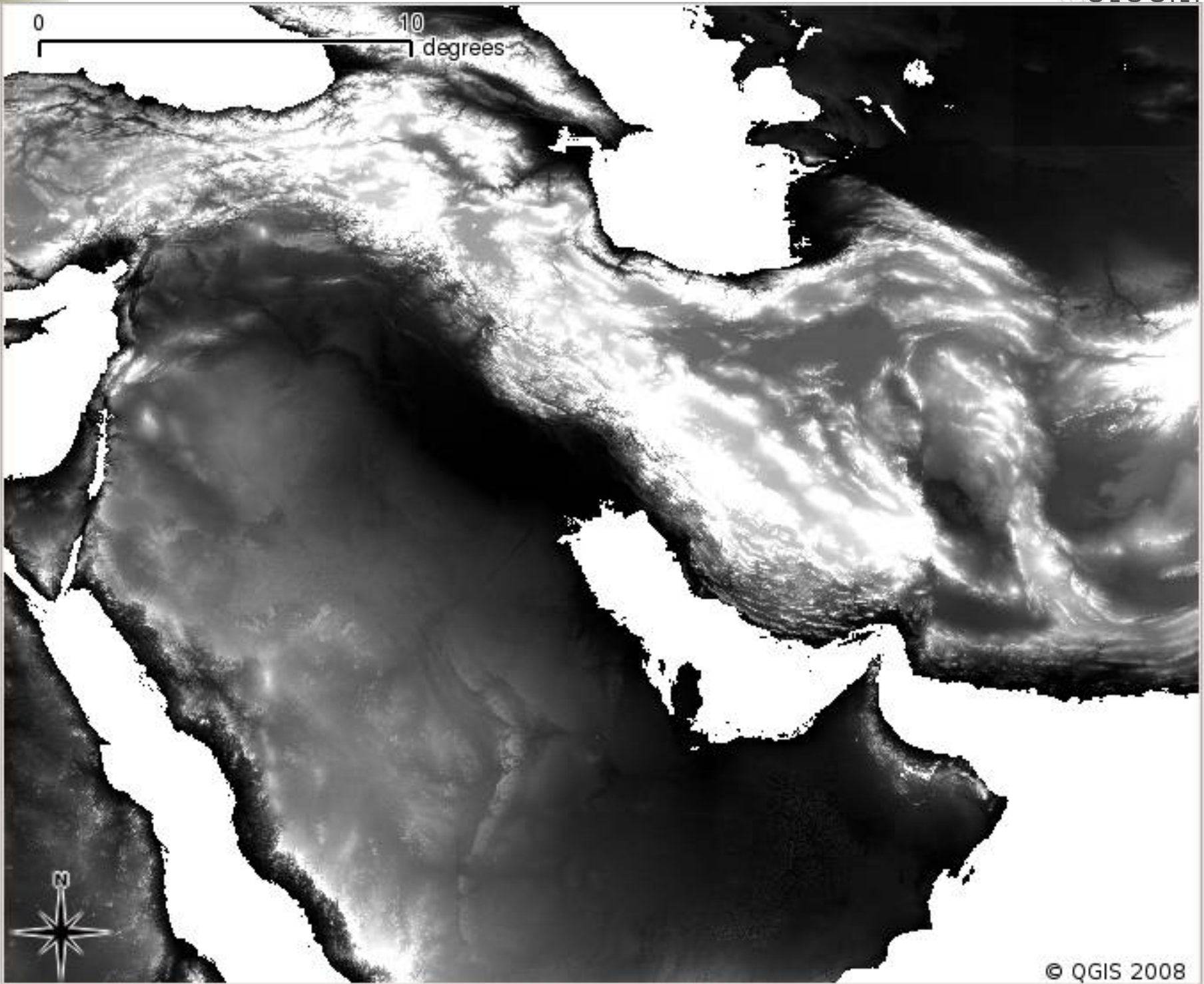
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100 km

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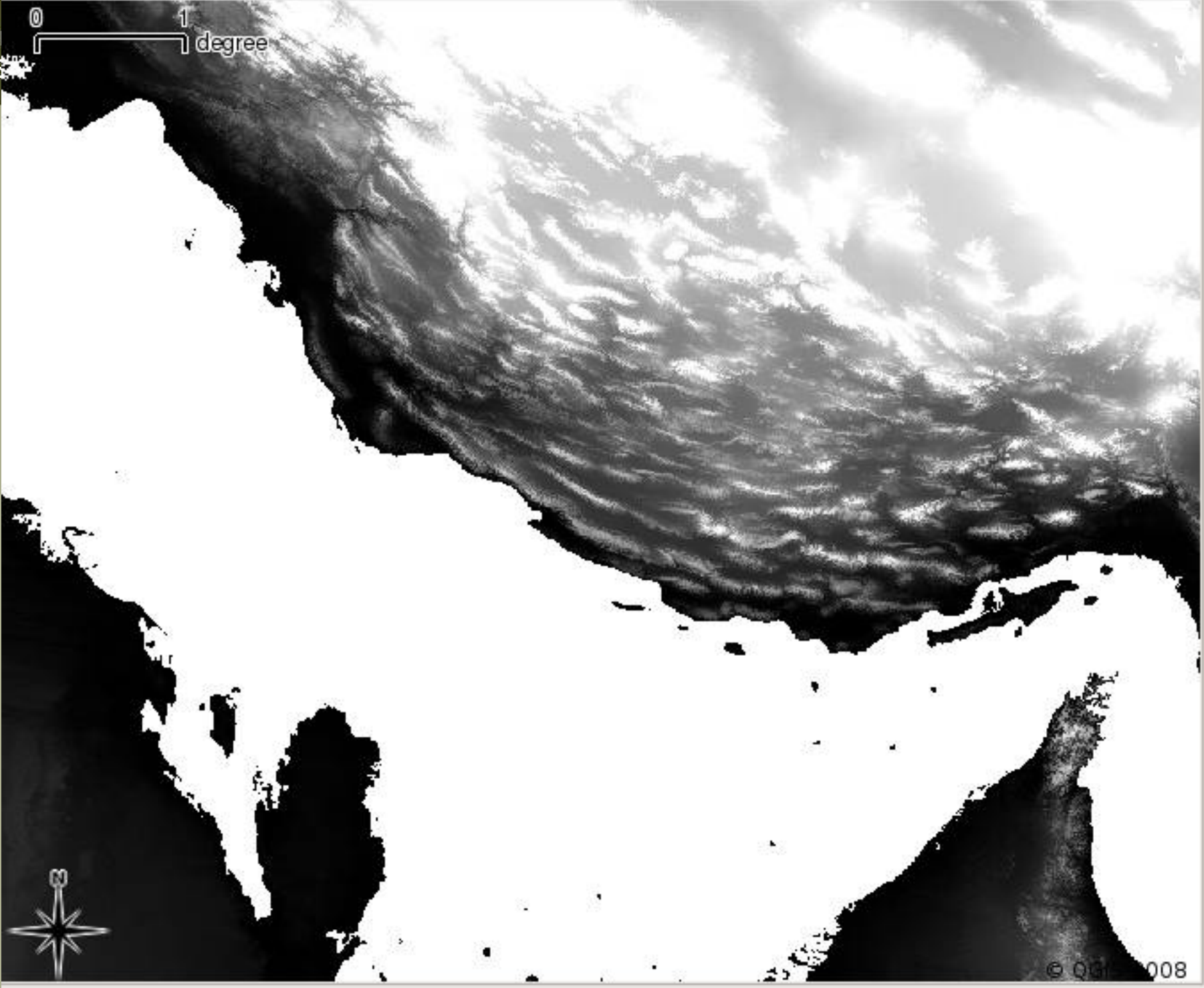
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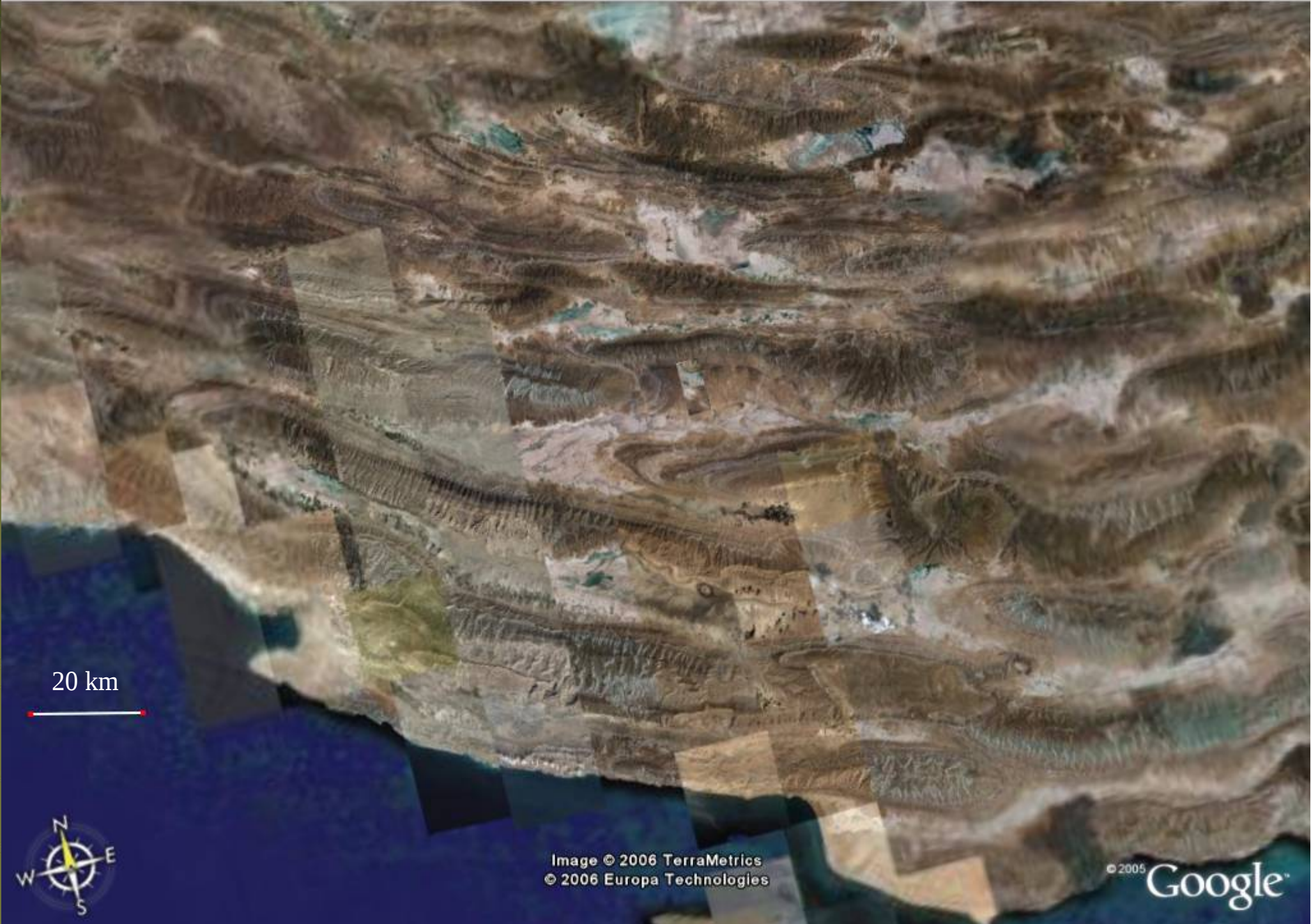
Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação





20 km



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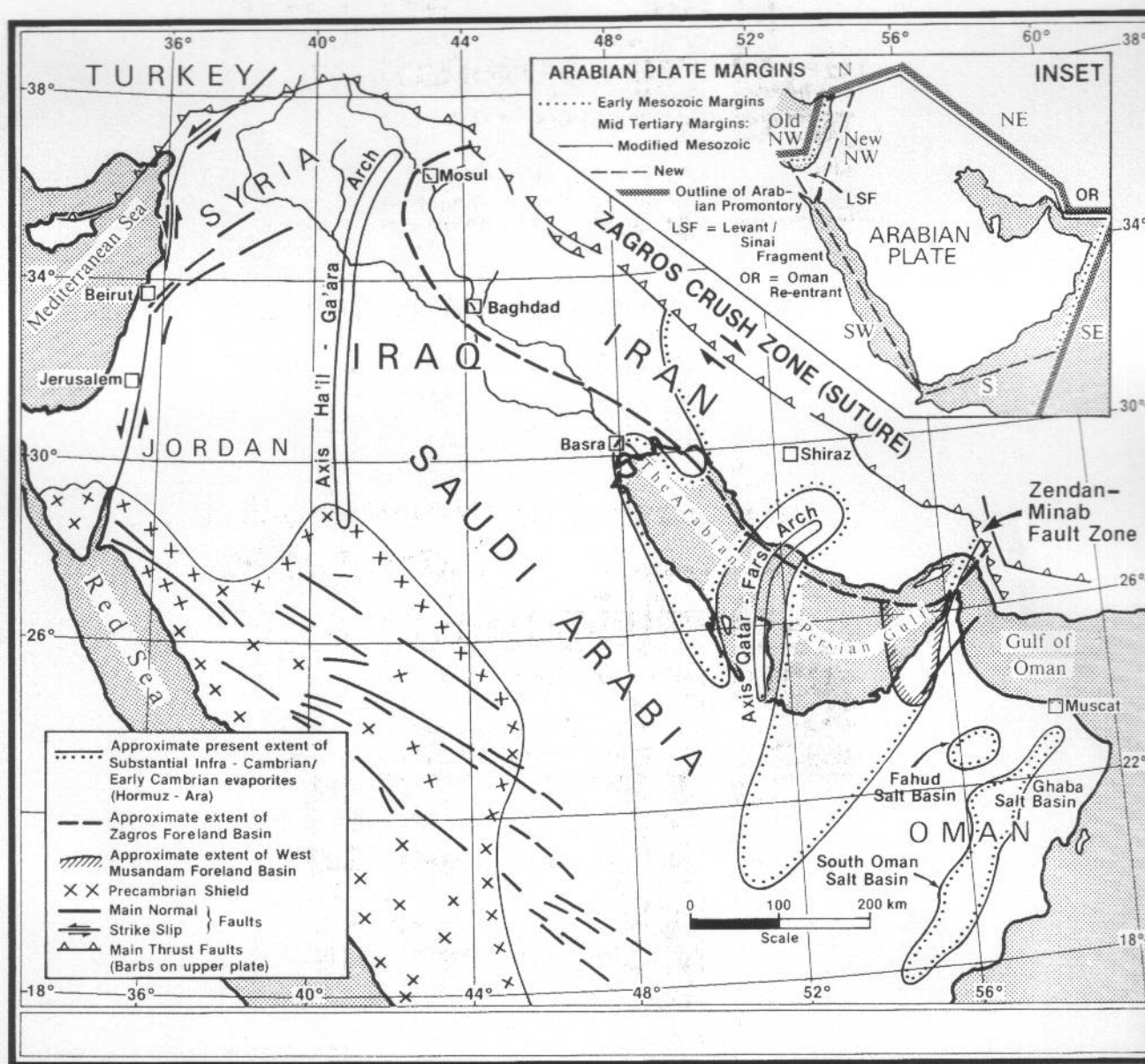


FIGURE 1. Orogenic setting of the Zagros foreland basin.

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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

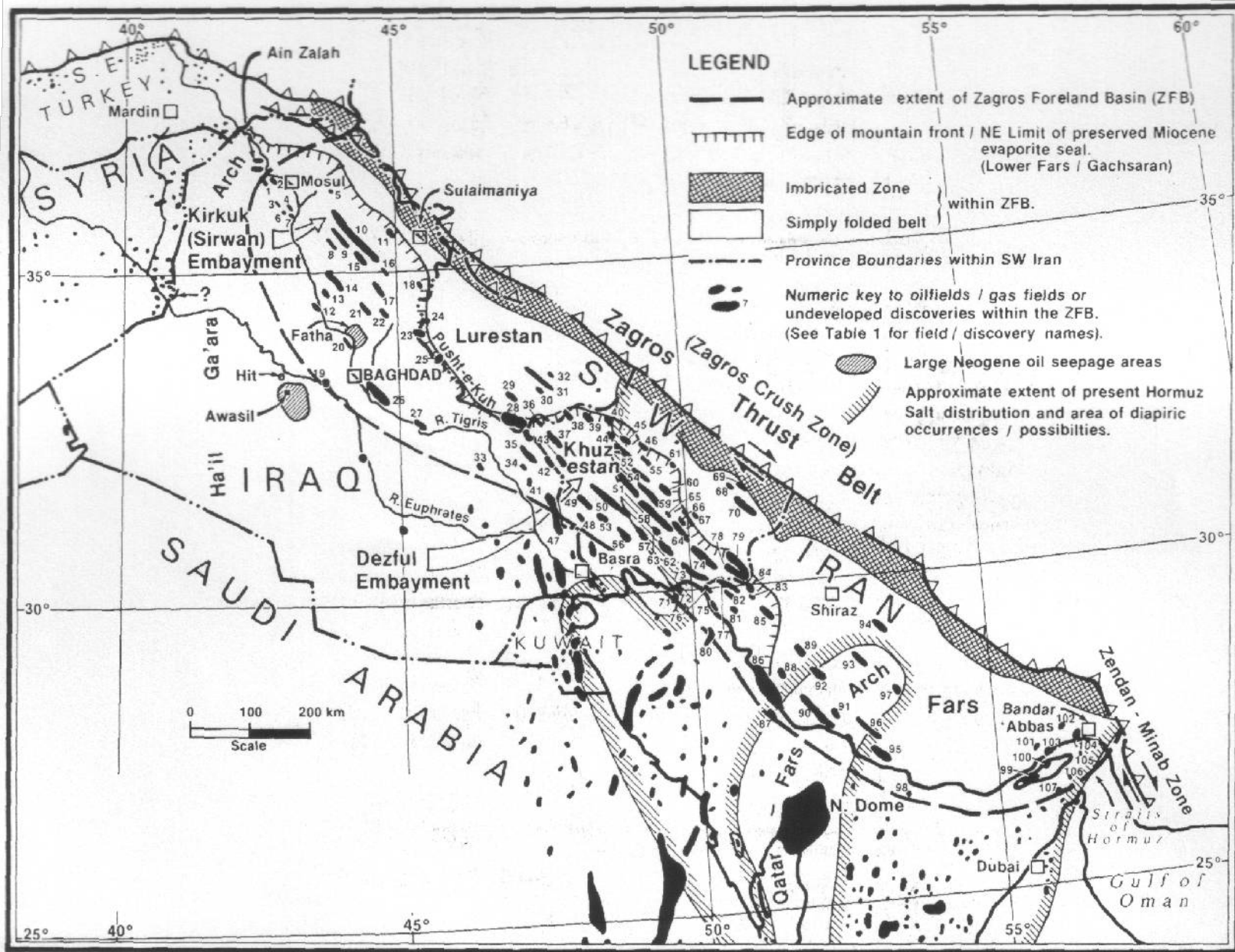


FIGURE 2. Regional oil and gas map showing locations, provinces, and key structural elements in the Zagros foreland basin.

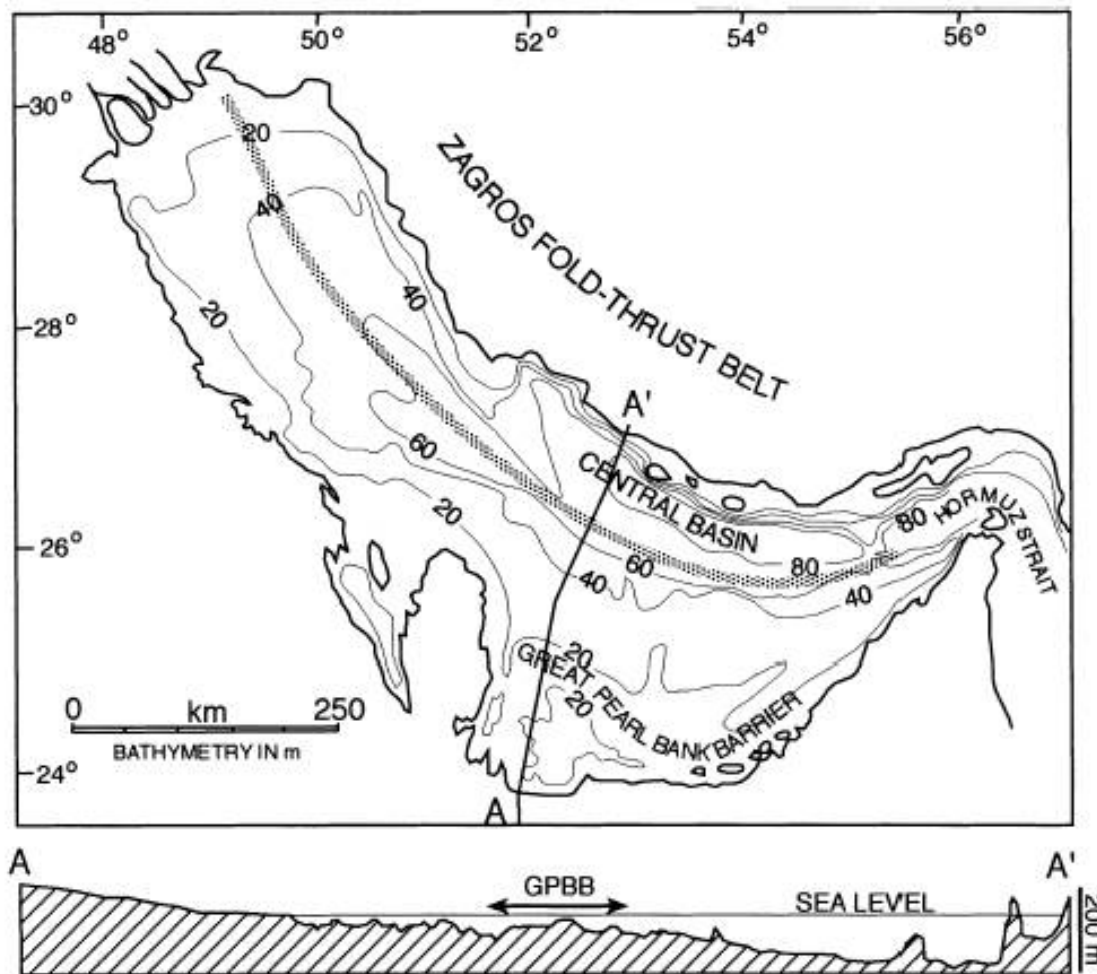


Fig. 6. Bathymetric map and cross-section of the Persian Gulf, which is the shallow-marine part of the peripheral foreland basin system along the south-west side of the Zagros collisional orogenic belt. The shaded line on the map shows the approximate front of the Zagros fold-thrust belt and the modern wedge-top depozone. The Great Pearl Bank Barrier (GPBB in cross-section) is a broad carbonate shoal that may be related to forebulge uplift. After Kassler (1973).

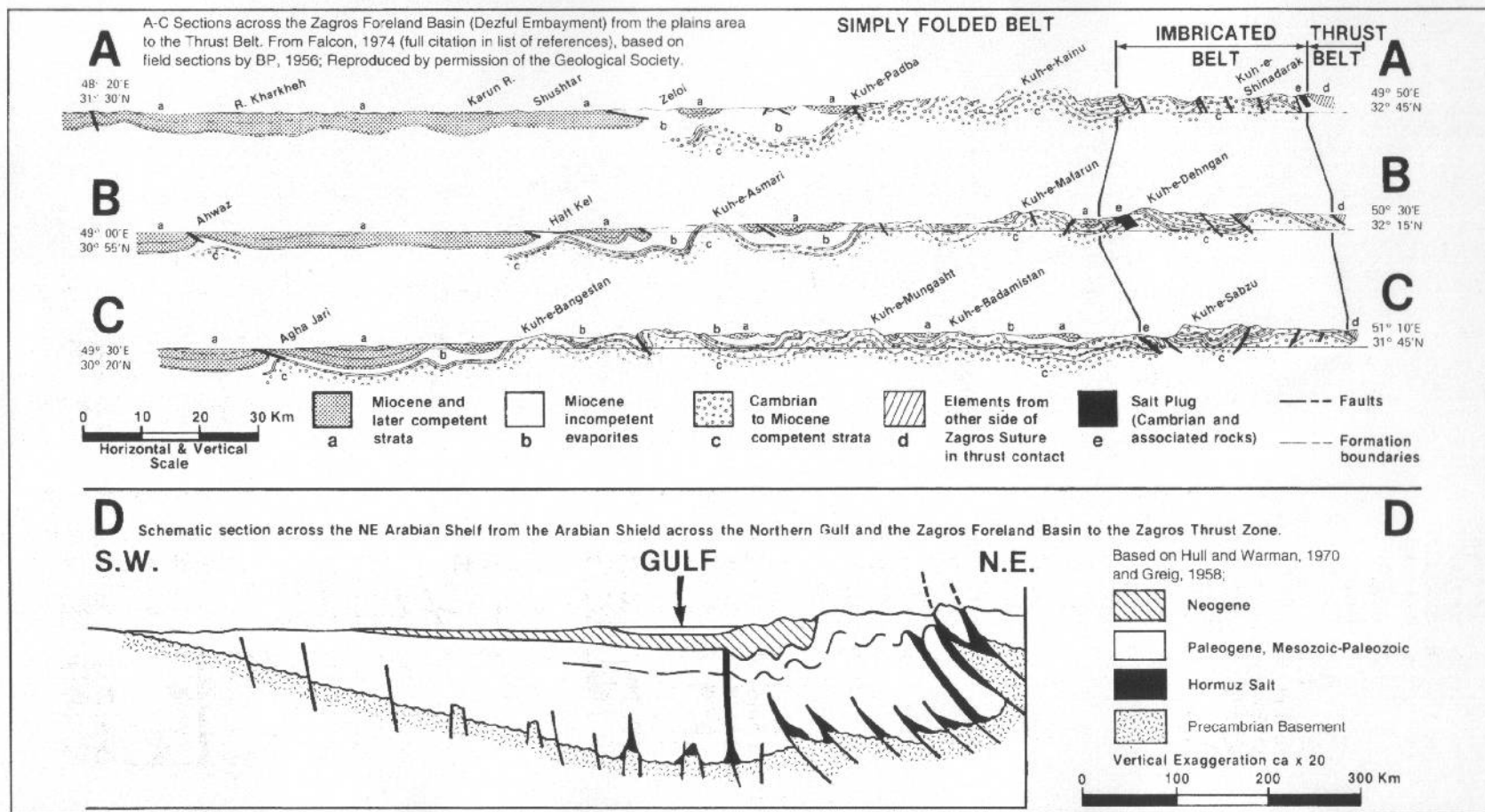


FIGURE 8. Zagros structural cross sections. Sections A to C are sections across the Zagros foreland basin (Dezful embayment) from the plains area to the thrust belt. Section D is a schematic section across the northeastern Arabian shelf from the Arabian shield across the northern Gulf and the Zagros foreland basin to the Zagros thrust zone. Sections A to C from Falcon (1974), based on field sections by BP (1956). Reproduced by permission of The Geological Society (London). Section D is based on Hull and Warman (1970) and Greig (1958).

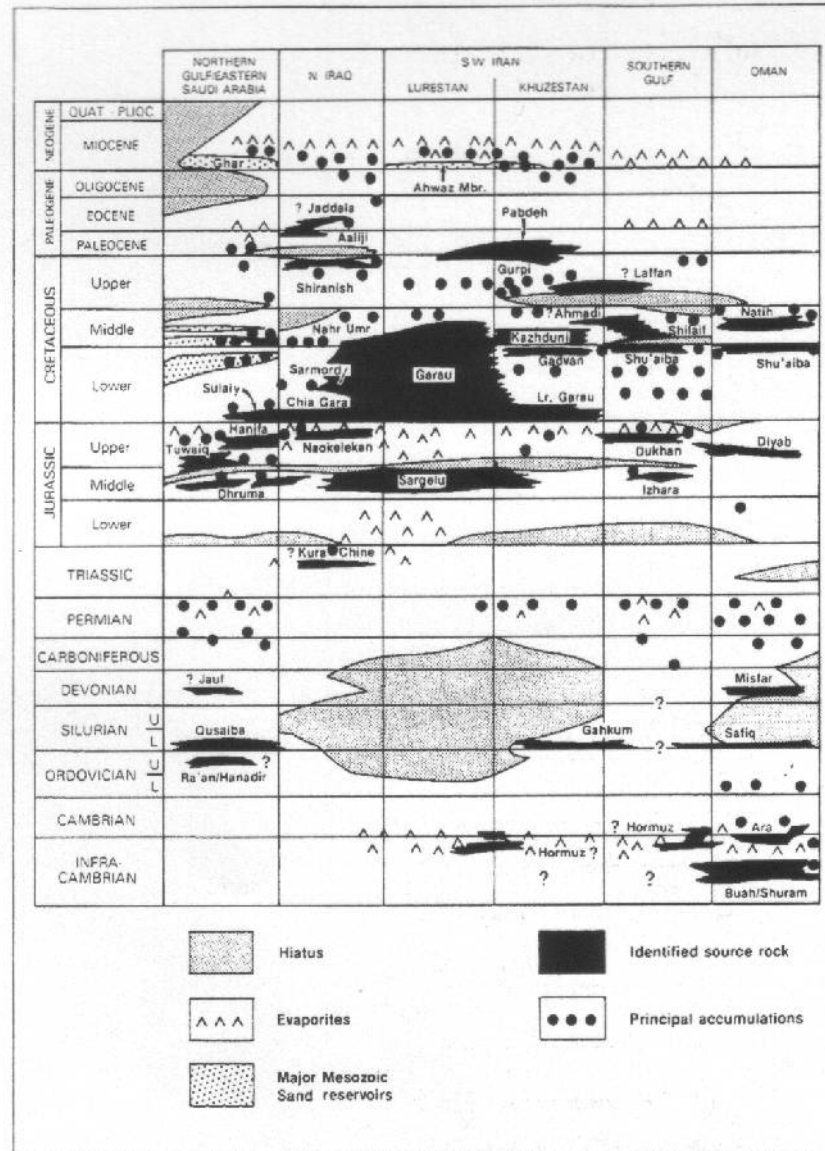


FIGURE 10. Stratigraphic position of the identified source rocks in the northeastern Arabian shelf region and Oman. Expanded and modified from Stoneley (1990). Reproduced by permission of The Geological Society (London).

Questões:

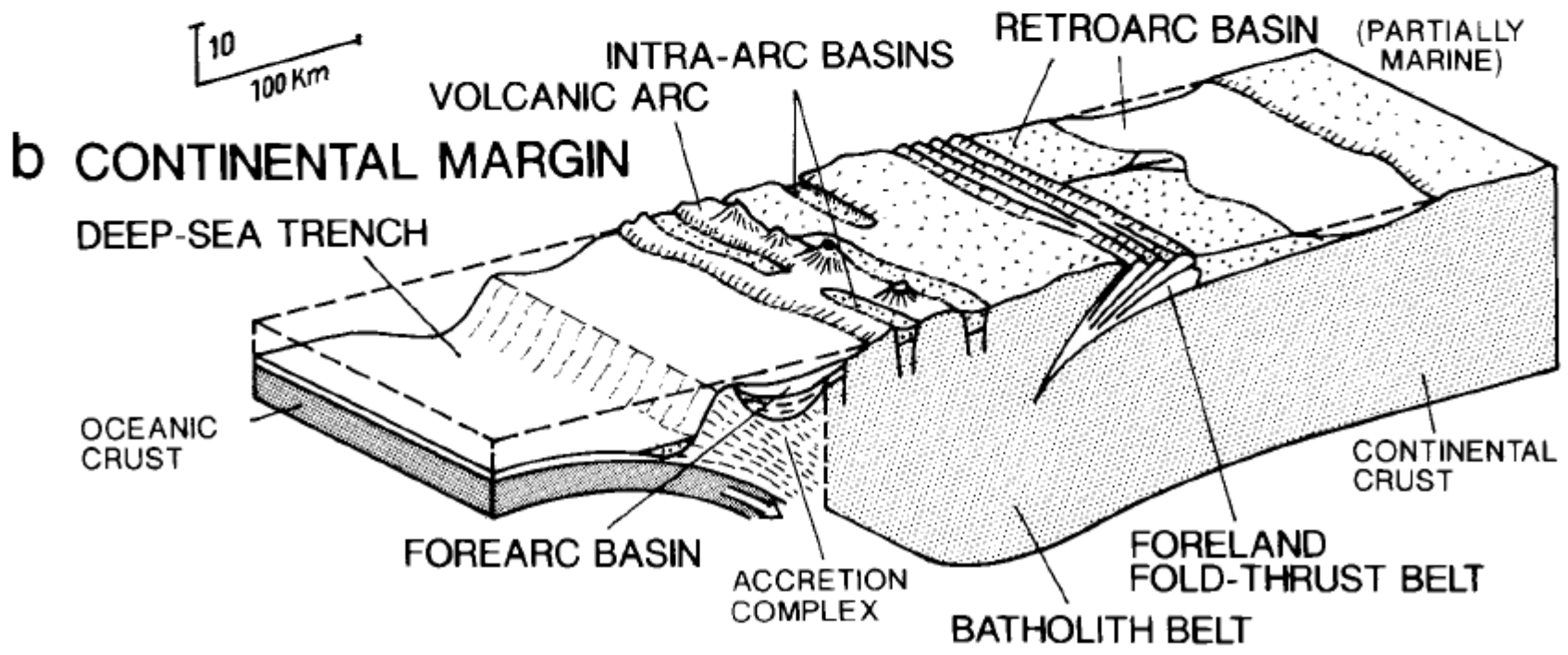
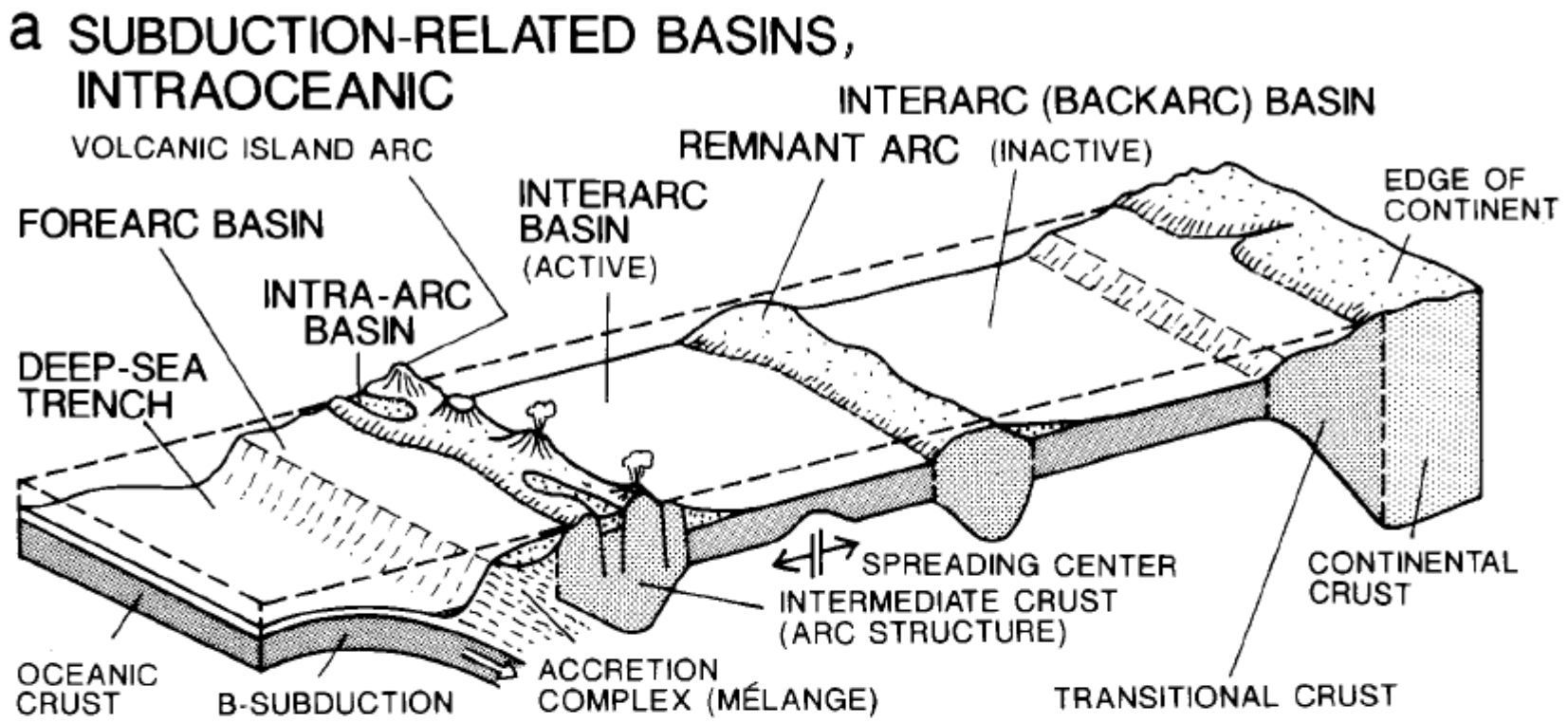
- Qual o potencial de preservação de bacias de antepaís no registro geológico antigo, considerando-se seus mecanismos de subsidência?
- Como a evolução da litosfera e da astenosfera desde o Arqueano pode ter influenciado a formação de bacias de antepaís nos diferentes éons?
- Como reconhecer uma bacia de antepaís fóssil?

Bacias de Margens convergentes 2: Orógenos de Subducção

- Bacias de Ante-arco
- Bacias de Backarc

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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



Bacias de Ante-Arco

- Posicionadas entre o arco e a trincheira de subducção
- Sedimentação simultânea ao vulcanismo e plutonismo do arco
- Também simultânea à deformação e metamorfismo do complexo de subducção

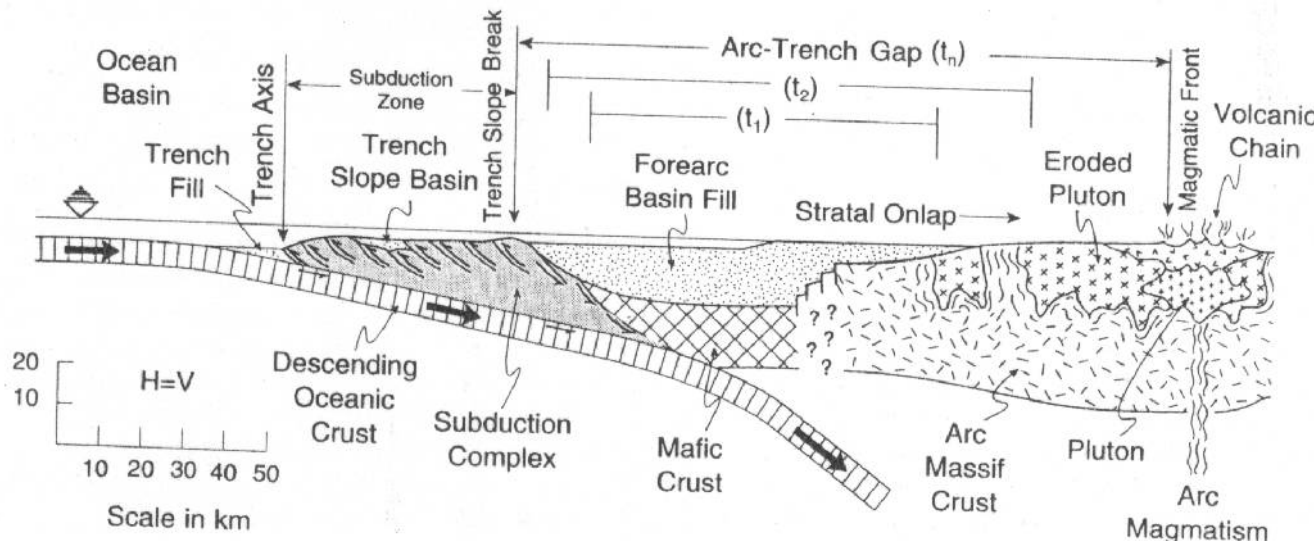


Fig. 6.1 Geotectonic features of forearc basins in transverse profile. See Fig. 6.5 for internal structures of subduction complex and Fig. 6.6 for origins of forearc ophiolites (mafic crustal substratum). Stipples indicate undeformed sediment accumulations. Diagram shows ideal case for which sedimentary infilling of forearc basin keeps pace with accretionary growth of subduction complex, and omits potential faults (thrust, normal, strike-slip) that may cut forearc sediment prism. Cases lacking subduction complex not depicted (see-text for discussion).

Relação com o complexo de subducção:

- Pode ser embasamento de parte da bacia (a parte principal fica sobre fundo oceânico)
- É caracterizado por uma *mélange*, presença de lascas ofiolíticas e xistos azuis.

Pela relação com o complexo de subducção, as bacias de ante-arco têm baixo gradiente térmico, diferindo das bacias de *backarc*.

Em situações em que todo sedimento da trincheira é subductado, não ocorre desenvolvimento de complexos de subducção, e a bacia de ante-arco é apenas um prisma curto.

Mecanismos de subsidência:

É controverso, os principais mecanismos propostos são:

- Flexura pela infra-carga da placa subductada.
- Flexura pela sobrecarga do complexo de subducção
- Flexura pela sobrecarga sedimentar.
- Subsidência termal da lateral do maciço do arco.

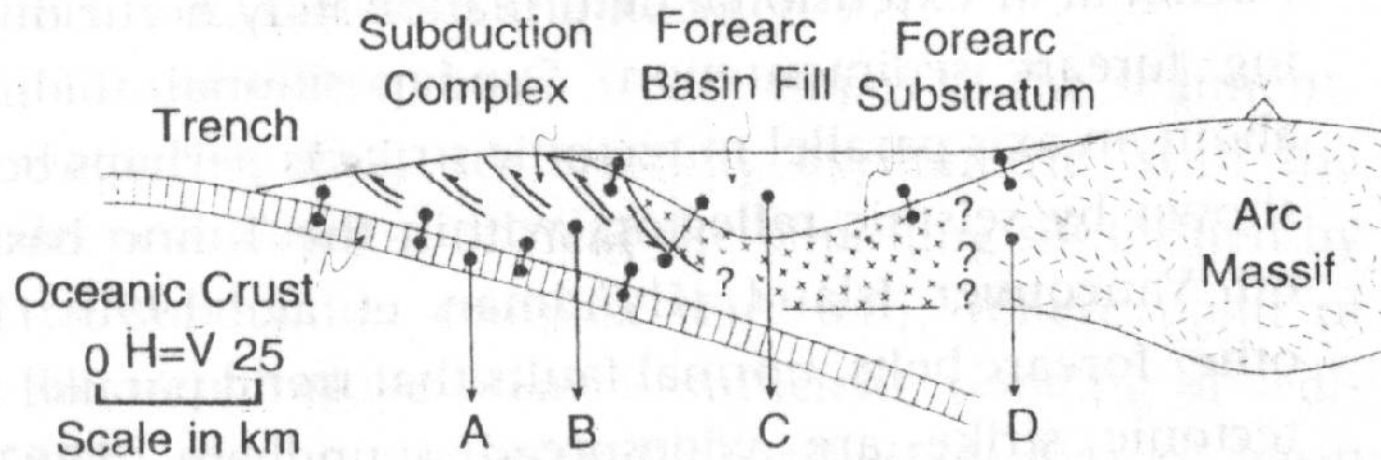


Fig. 6.7 Key factors (diagrammatic) at crustal levels influencing subsidence of forearc basins (arrows): A, negative buoyancy of slab of descending oceanic lithosphere (only capping oceanic crust shown); B, isostatic tectonic load of subduction complex; C, isostatic sedimentary load of forearc-basin fill; D, thermotectonic subsidence of flank of magmatic arc massif (arrows A,B,D potentially reversible to induce uplift of basin flanks and rebound of basin floor). Barbells denote flexural couplings of oceanic lithosphere and subduction complex, subduction complex and forearc-basin fill, and forearc-basin fill and arc massif.

Tectônica sin-deposicional

Pode ser:

- Compressiva, com cavalgamentos e dobras,
- Distensiva, com formação de hemigrabens
- Dominada por transcorrências.

Preenchimento

- O padrão típico é um megaciclo progradacional, causado pela diminuição progressiva da subsidência. Turbiditos passando a fácies de plataforma e subaéreas.

- A proveniência é dominada por fontes do arco magmático (ou de ilhas), com alguns casos especiais de rios que cortam o arco permitindo fontes do interior do continente. Geralmente evolui de vulcânica para plutônica com a exumação do arco.

No caso de complexos de subducção soerguidos, também a associação mélangé-ofiolito pode servir de fonte.

A grande profundidade dessas bacias (mais de 10 km) e a composição instável (vulcânica) dos sedimentos geralmente resulta em importante metamorfismo de soterramento.

A grande e rápida perda de porosidade resulta em maus prospectos para petróleo.

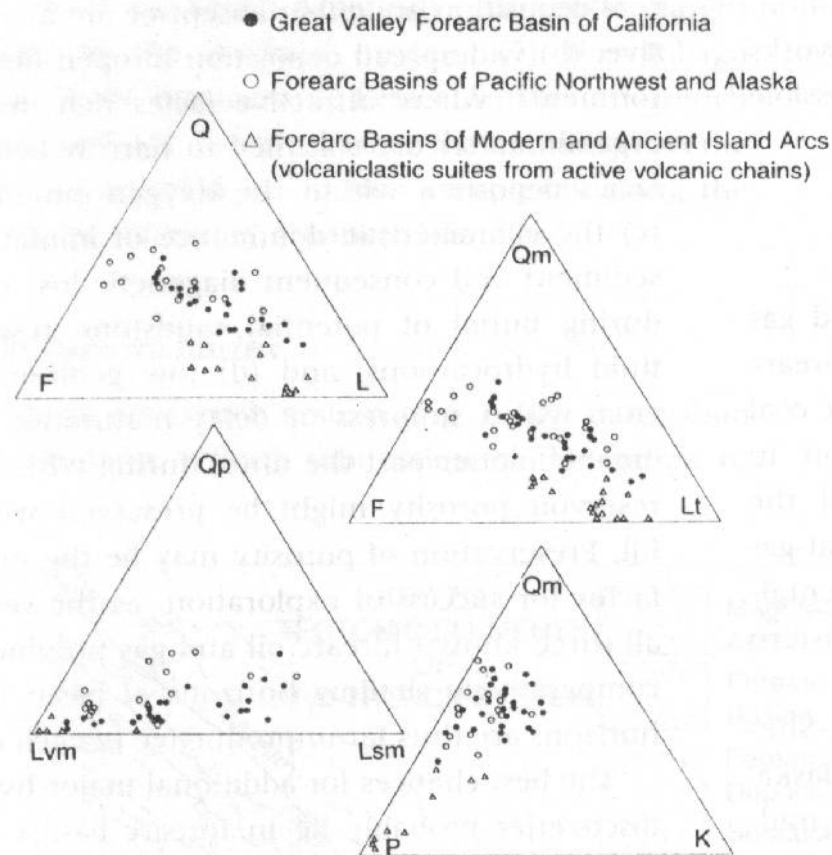
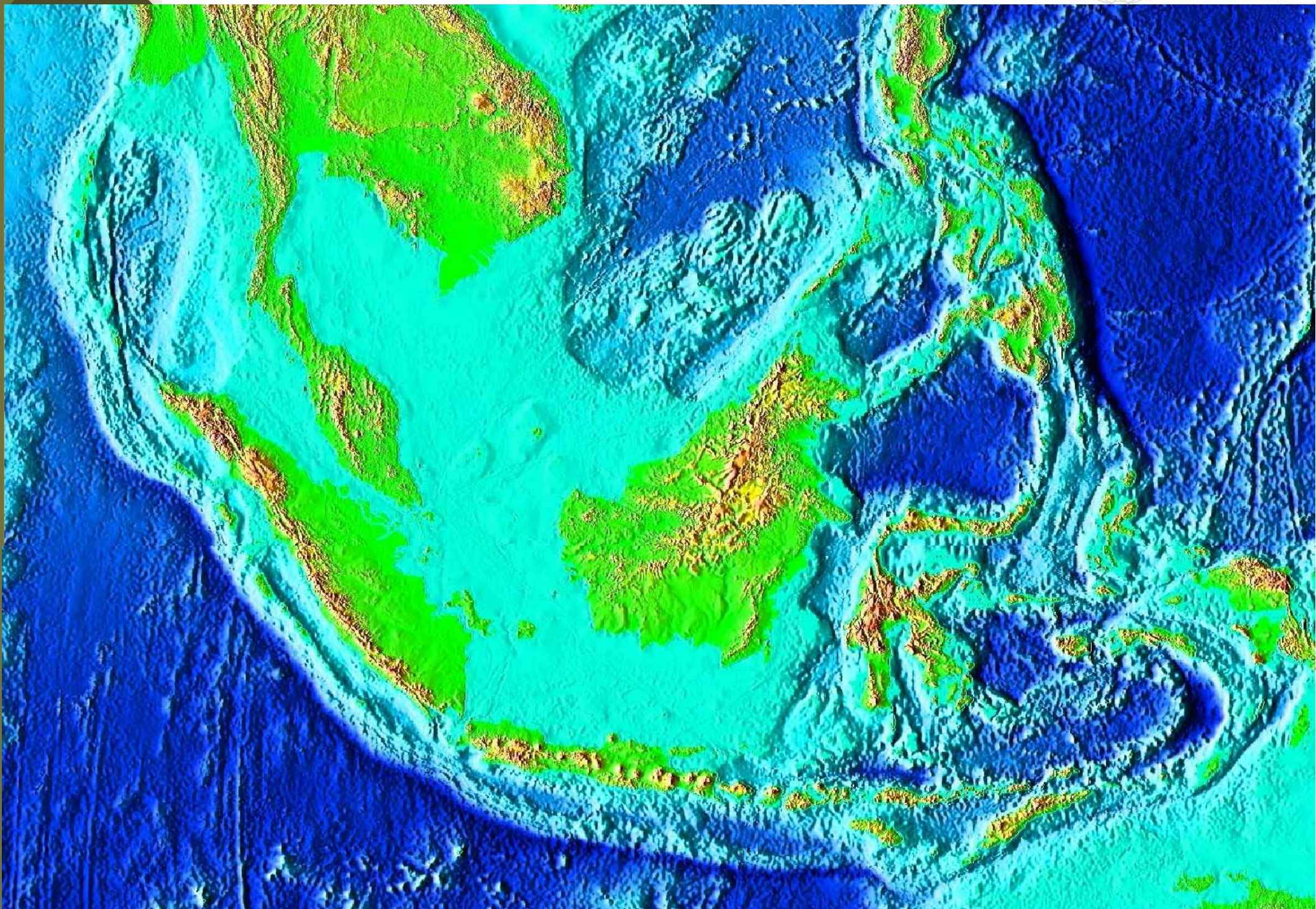


Fig. 6.9 Modal compositions of volcanoplutonic sandstone suites from forearc basins, where Q (total quartzose grains) = Qm (monocrystalline quartz grains) + Qp (polycrystalline quartzose lithic fragments), L (total unstable lithic fragments) = Lvm (volcanic and metavolcanic lithic fragments) + Lsm (sedimentary and metasedimentary lithic fragments), and F (total feldspar grains) = P (plagioclase grains) + K (K-feldspar grains). Points plotted are reported or calculated means for selected forearc sandstone suites from Dickinson (1982), Dickinson et al. (1982), Ward and Stanley (1982), Cawood (1983), Heller and Ryberg (1983), Ingersoll (1983), Johnson (1984), Korsch (1984), Short and Ingersoll (1990), and Lundberg (1991).

Exemplos

- Bacias atuais:
 - Arco de Sunda
 - Bacias do Orógeno Andino
 - Antilhas
 - Alaska-Aleutas
- Bacias antigas:
 - Great Valley california
 - Hokonui – Nova Zelândia



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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

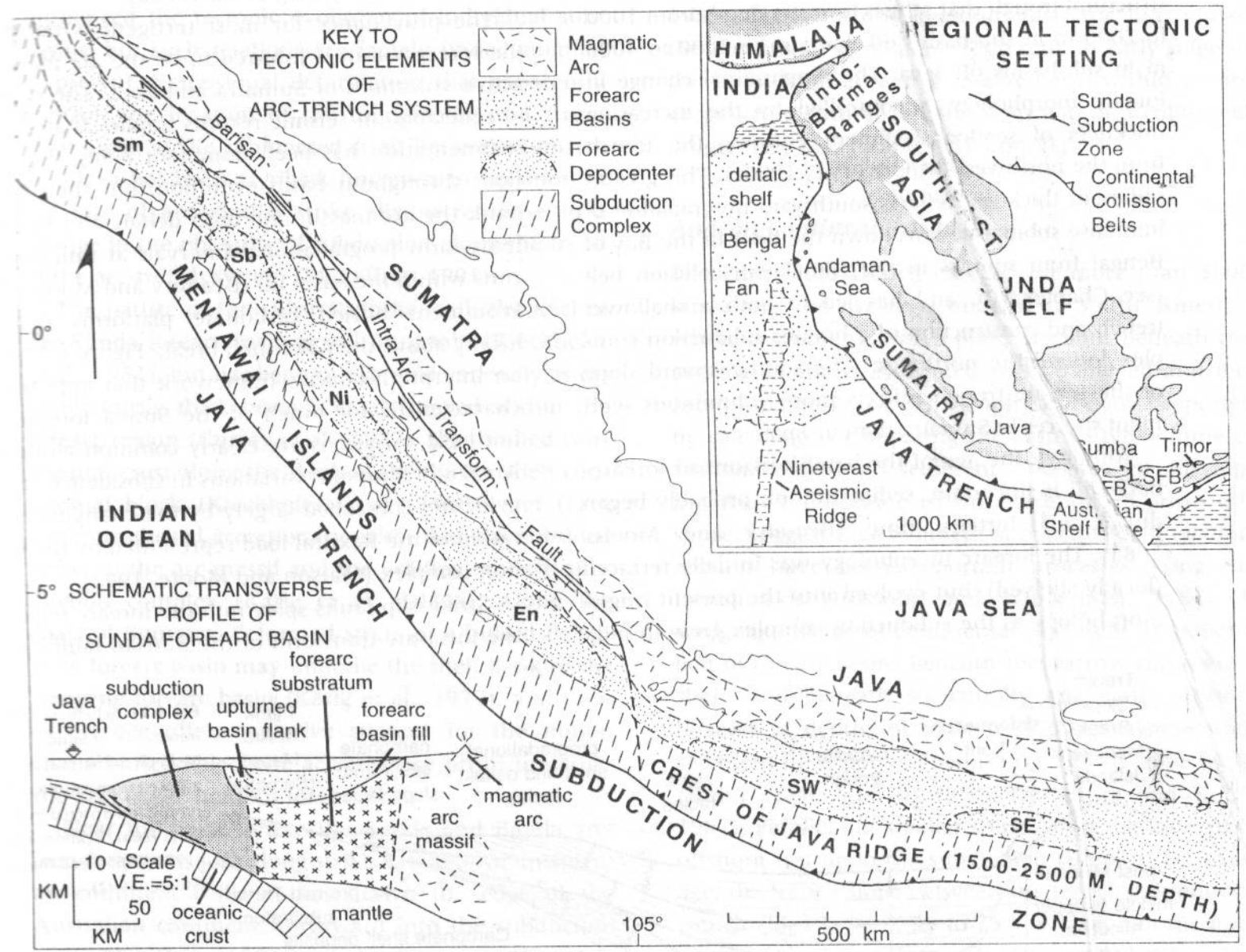


Fig. 6.10 Configuration of elongate forearc basin, with multiple depocenters, in Sunda arc-trench system of Sumatra and Java (Hamilton, 1979; Karig et al., 1979, 1980a; Kieckhefer et al., 1981). Inset shows relation of Sunda subduction zone (note position of Sumatra and Java)

to Himalayan suture belt and incipient arc-continent collision at Timor (LFB, Lombok forearc basin; SFB, Savu forearc basin). Forearc depocenters off Sumatra-Java (Table 6.1, III): Sm, Simeulue; Ni, Nias; Sb, Siberut; En, Enggano; SW, southwest Java; SE, southeast Java.

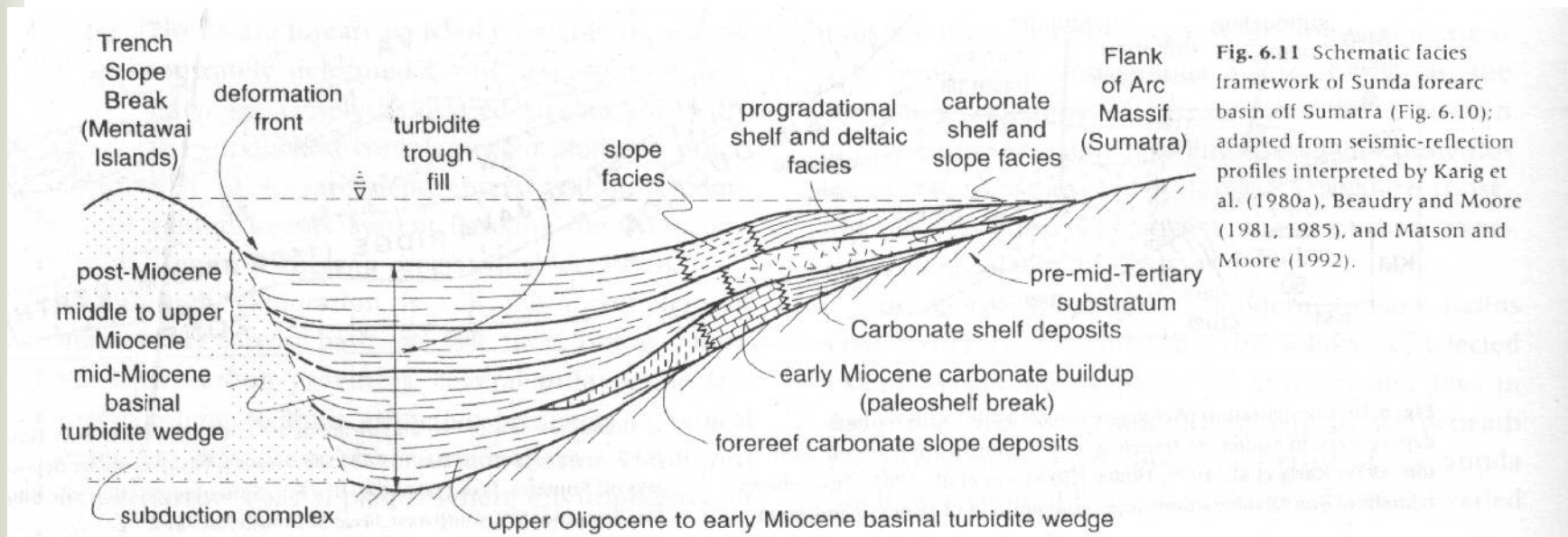
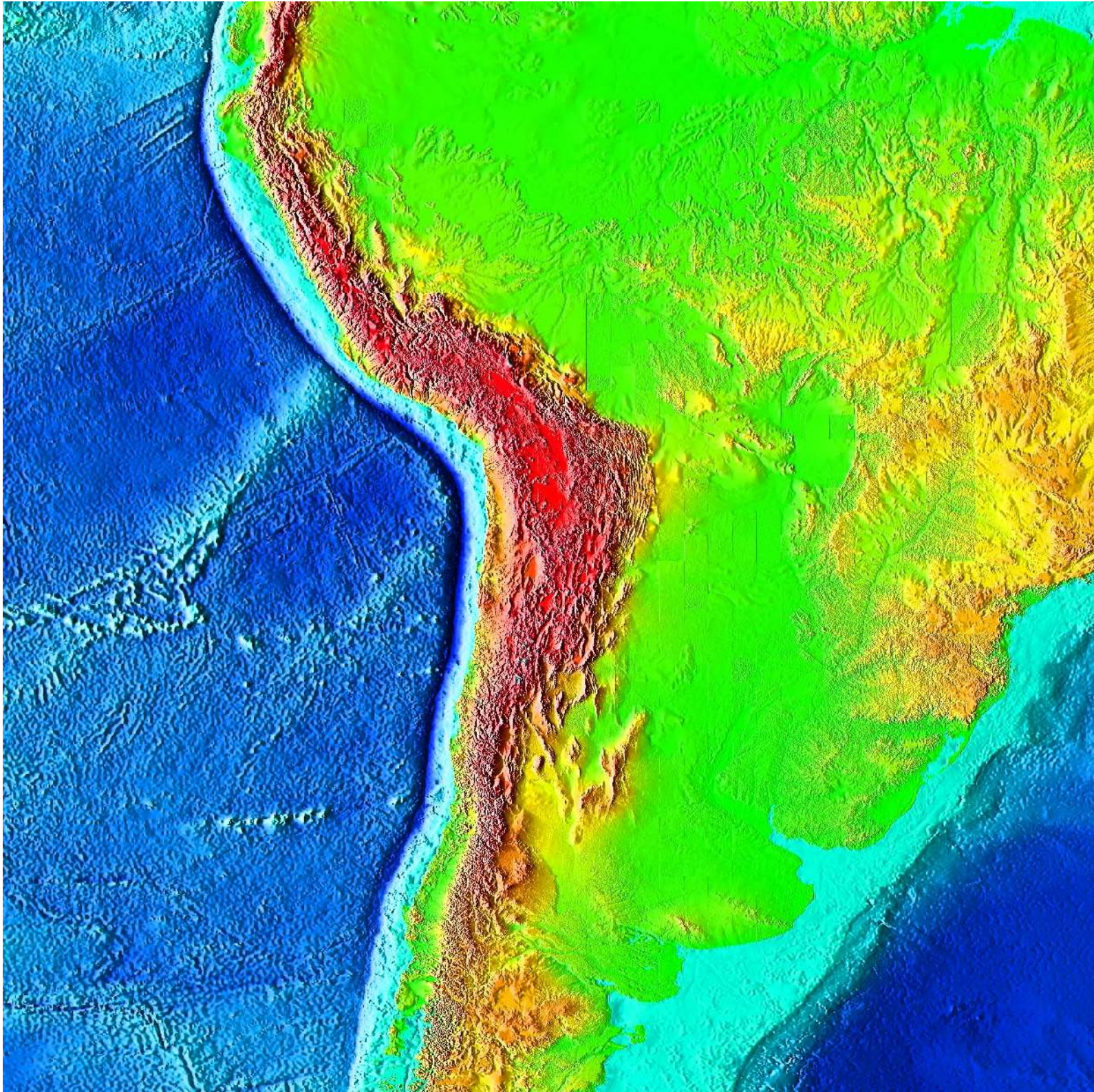


Fig. 6.11 Schematic facies framework of Sunda forearc basin off Sumatra (Fig. 6.10); adapted from seismic-reflection profiles interpreted by Karig et al. (1980a), Beaudry and Moore (1981, 1985), and Matson and Moore (1992).

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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

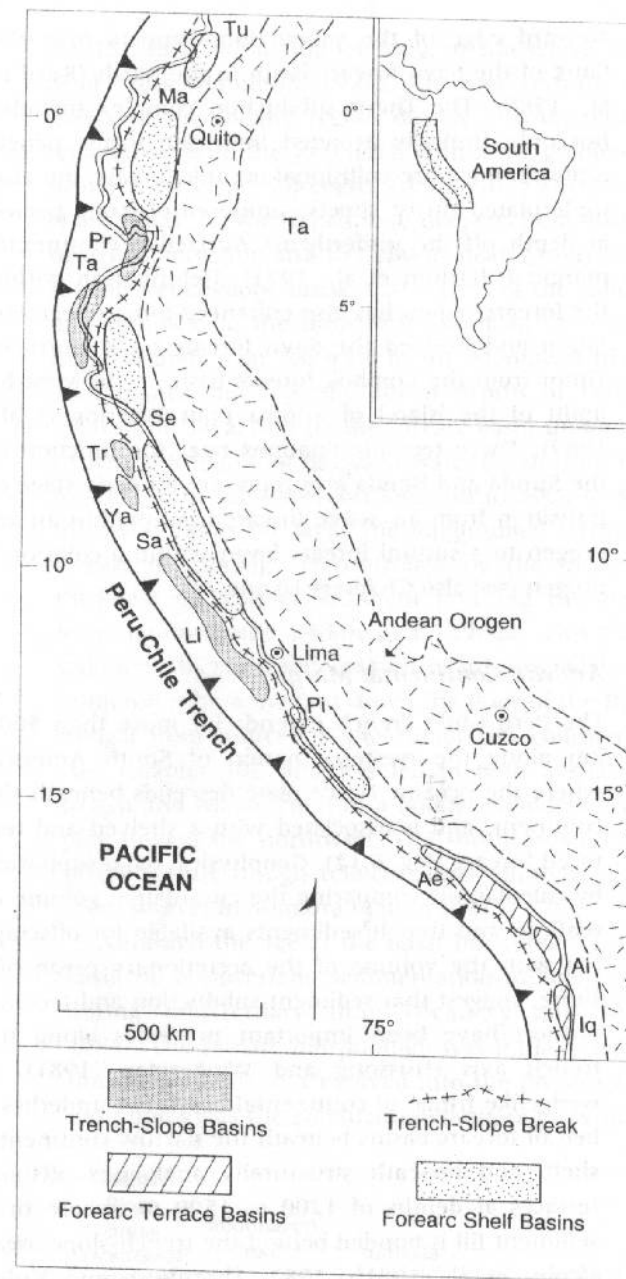
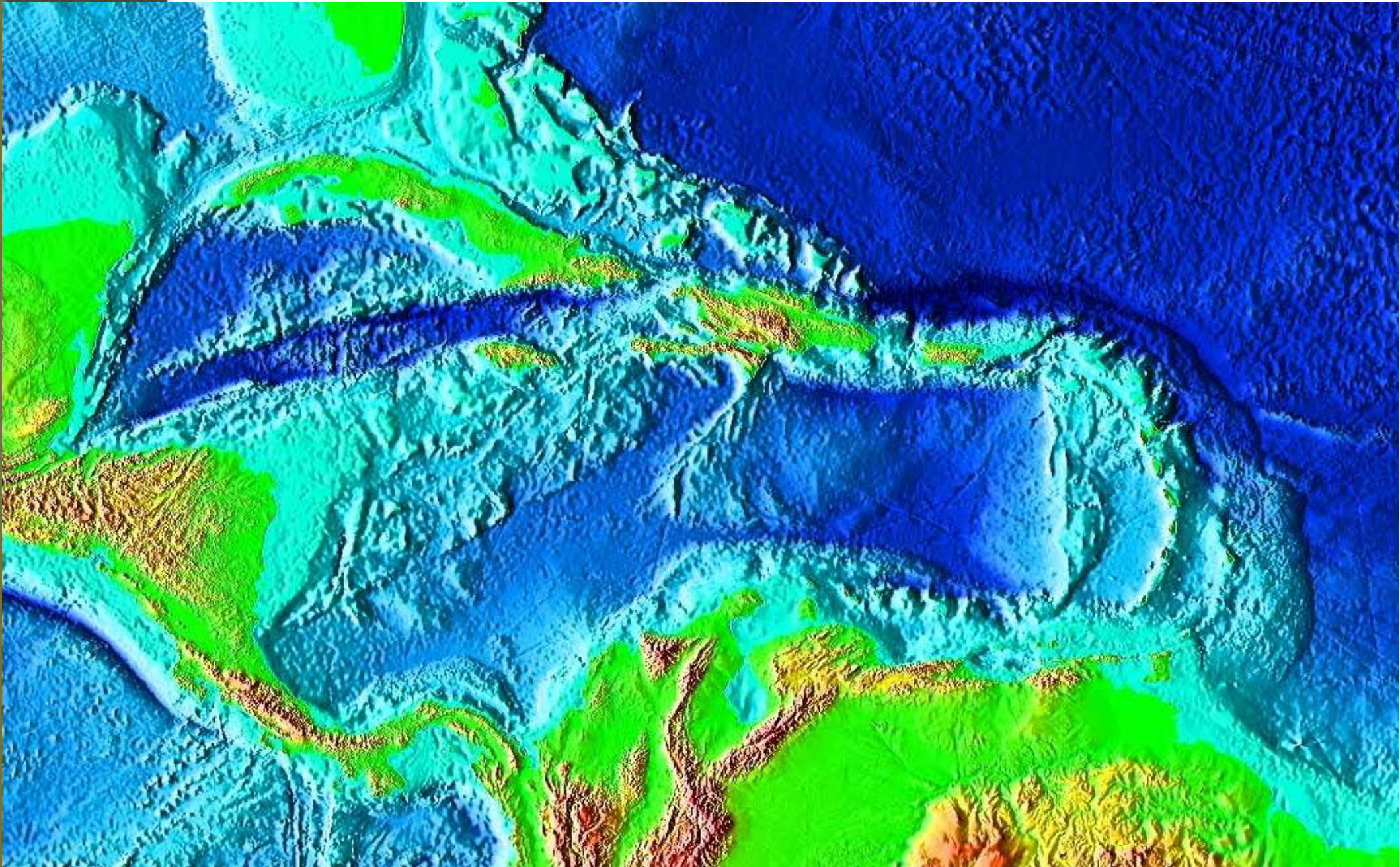
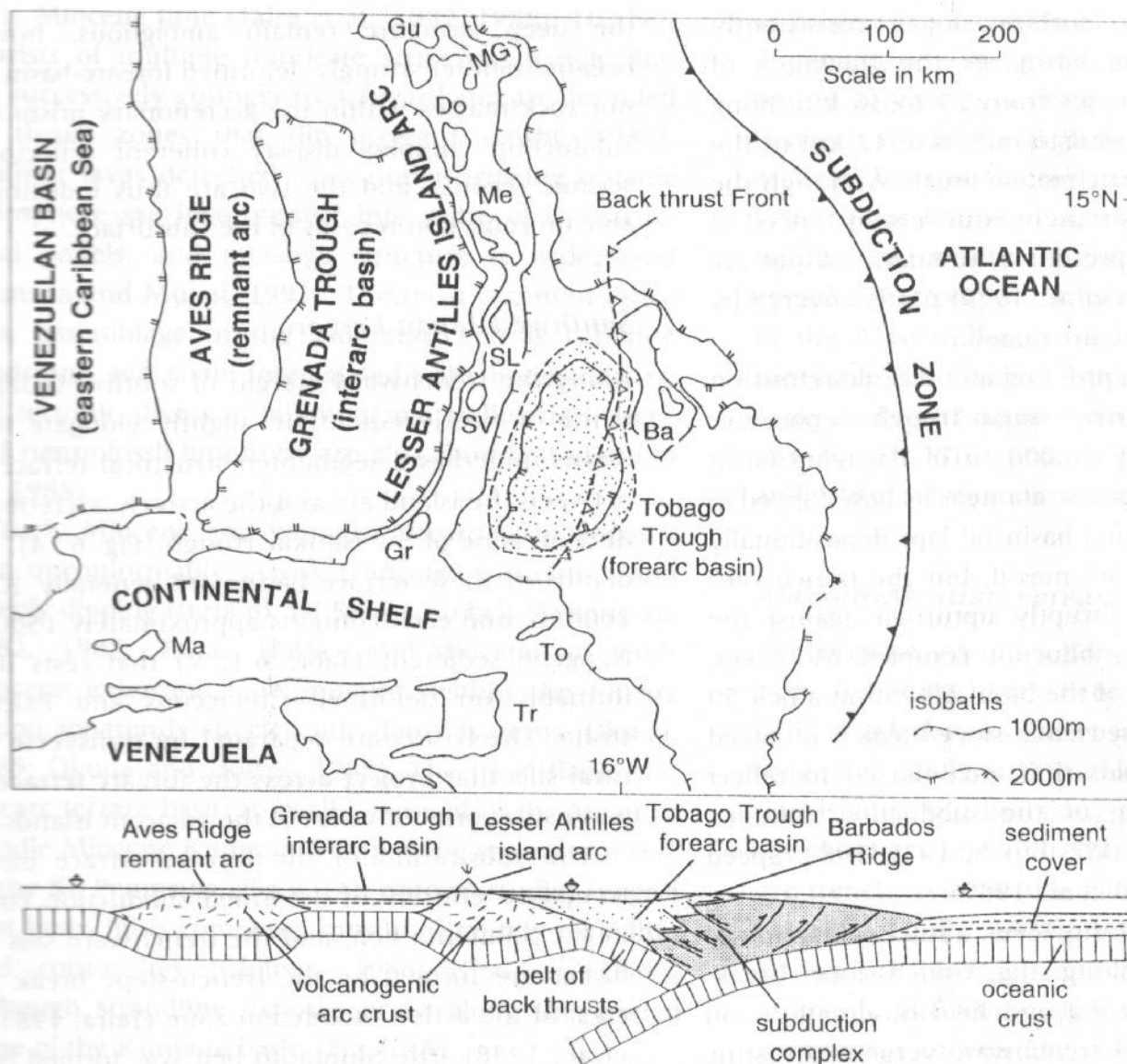


Fig. 6.12 Distribution of forearc basins of central Andean continental margin (Lonsdale, 1978; Coulbourn, 1981; Thornburg and Kulm, 1981). Double line indicates coastline. Inset shows location off South America. Basin names (Table 6.1, I): Ae, Arequipa; Ai, Arica; Iq, Iquique; Li, Lima; Ma, Manabi; Pi, Pisco; Pr, Progresso; Sa, Salaverry; Se, Sechura; Ta, Talara; Tr, Trujillo; Tu, Tumaco; Ya, Yaquina (onshore shelf basins include terrestrial deposystems). See Figure 6.4 for comparative morphology of shelf and terrace basins.

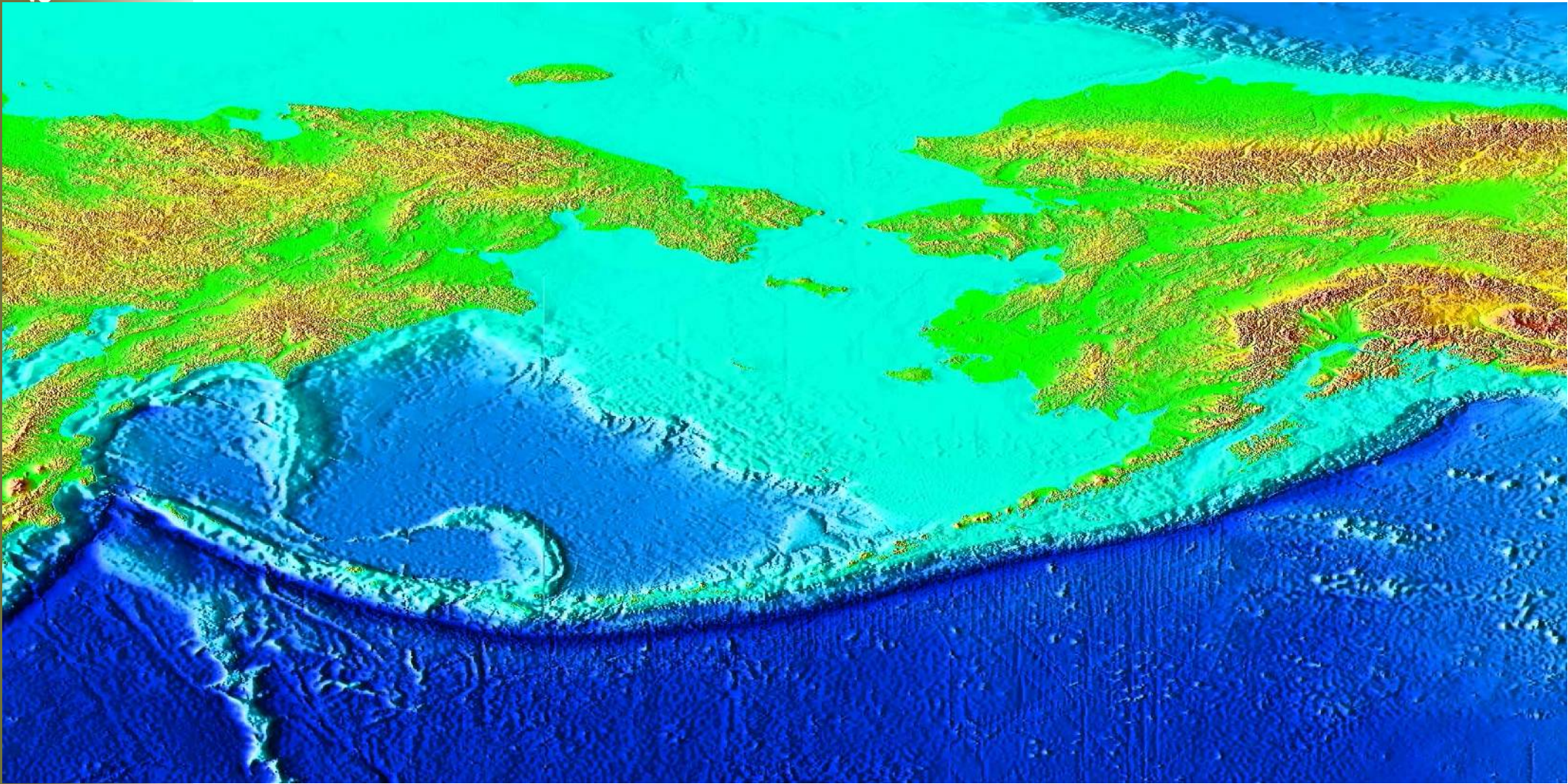




Schematic Crustal Profile Across Tobago Trough (V.E. = 2:1)

Fig. 6.13 Tectonic setting (map) and inferred structural relations (section) of Tobago Trough forearc basin (Table 6.1, VI) within Lesser Antilles arc-trench system (Westbrook, 1975, 1982; Speed et al., 1989; Torrini and Speed, 1989); arcward vergent folds deform forearc-basin fill at shallow levels above zone of backthrusting at depth. Islands shown: Ba, Barbados; Do, Dominica; Gr, Grenada; Gu, Guadeloupe; Ma, Margarita; Me, Martinique; MG, Marie Galante; SL, St. Lucia; SV, St. Vincent; To, Tobago; Tr, Trinidad.

a



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Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

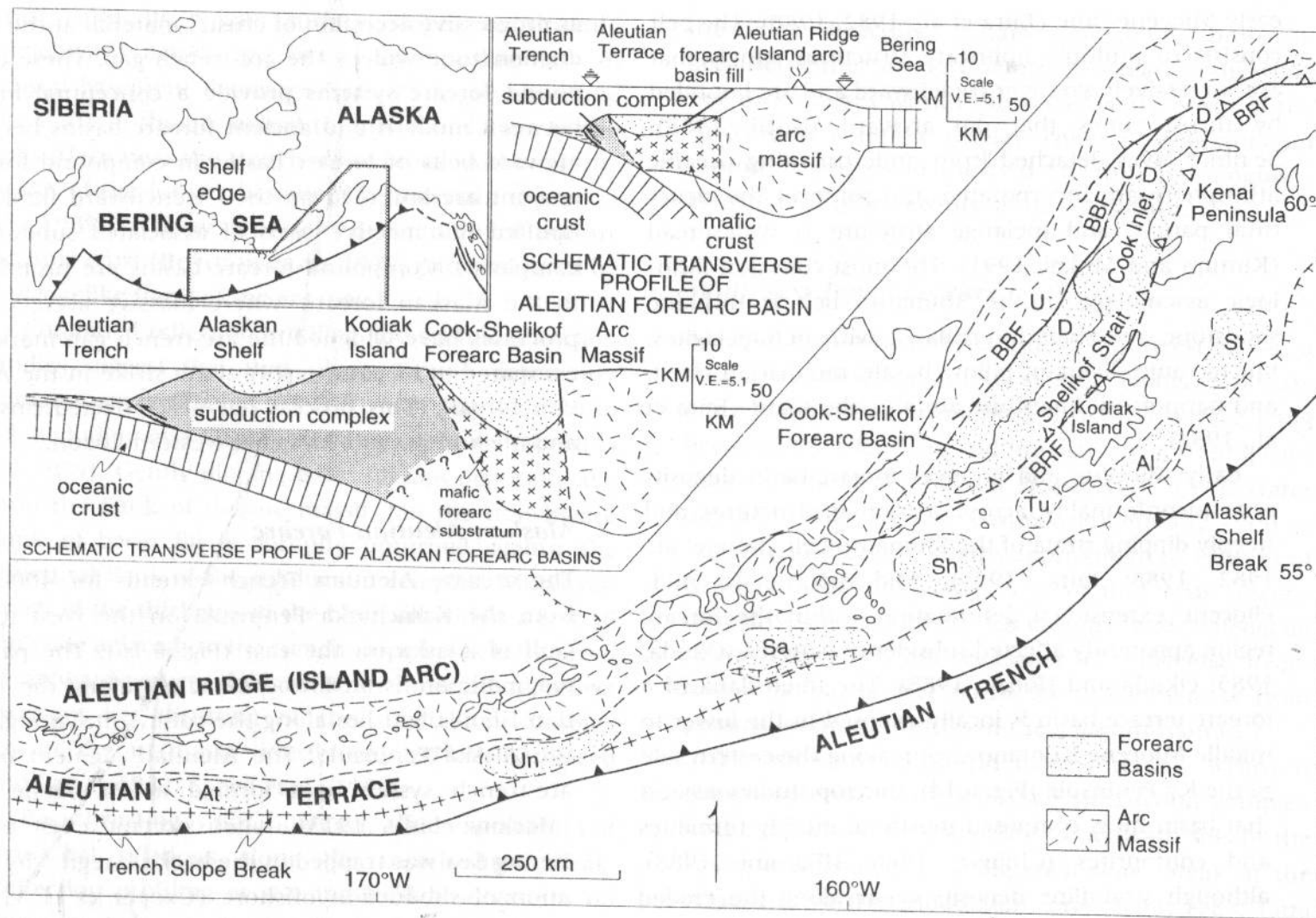


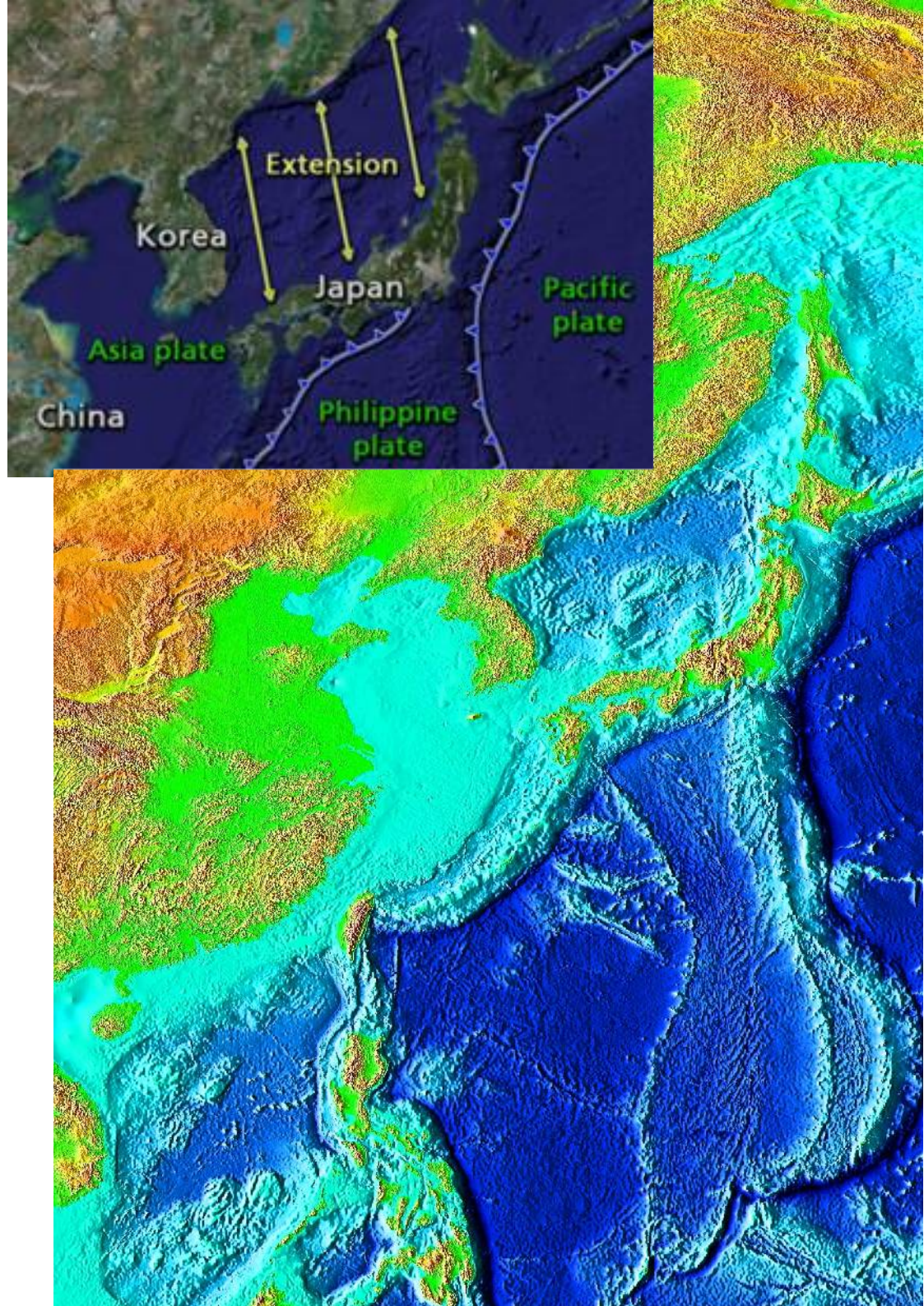
Fig. 6.16 Relations of multiple Alaskan and Aleutian forearc basins (Bruns et al., 1987; Fisher et al., 1987; Scholl et al., 1987b; von Huene et al., 1987): Aleutian terrace basins (At, Atka; Un, Unalaska), Alaskan shelf basins (Sa, Sanak; Sh, Shumagin; Tu, Tugidak; Al, Albatross; St, Stevenson), and Cook-Shelikof basin (Table 6.1, I, II, IV; Kanaga basin is

west of edge of map); inset map shows relations to continental blocks and linked transform system along continental margin. Mafic crust beneath Aleutian forearc basins can be regarded as buried flank of arc massif (Geist et al., 1988).

Ante arco composto por várias bacias devido à migração da trincheira.

Estratigrafia
GSA0307

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação



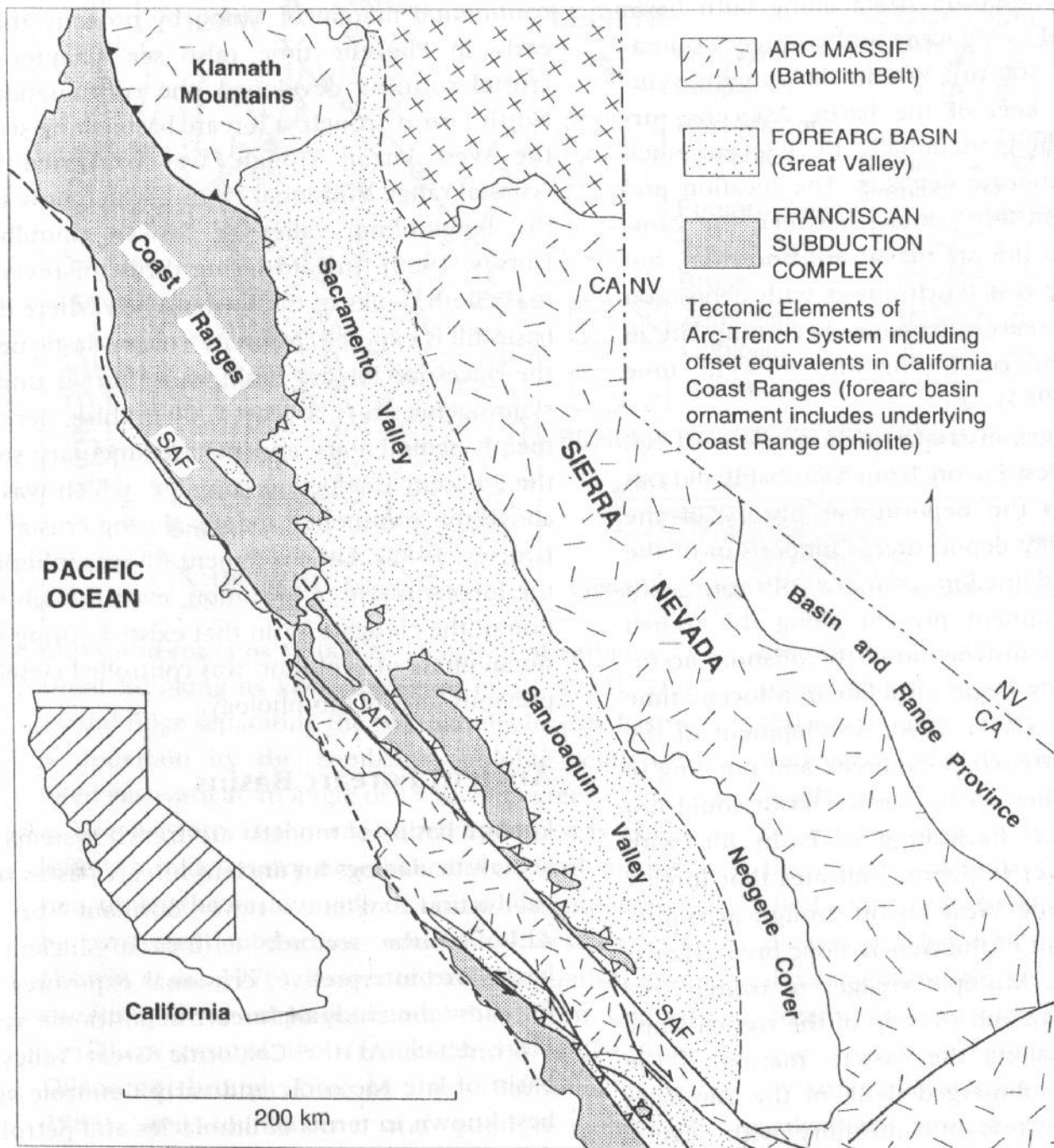


Fig. 6.18 Geologic setting of Late Jurassic to Paleogene Great Valley forearc basin (Table 6.2D) in California (Dickinson and Seely, 1979; Dickinson et al., 1979; Ingersoll, 1982b, 1988a). San Andreas (SAF), San Gregorio-Hosgri (SGF), and related Neogene strike-slip faults in California Coast Ranges obliquely disrupt older forearc trends. South Fork Mountain thrust between arc massif of Klamath Mountains and Franciscan subduction complex indicated by solid triangles, and Coast Range fault between Great Valley forearc-basin fill (including ophiolitic substratum) and Franciscan subduction complex indicated by open triangles.

Cretáceo a Terciário

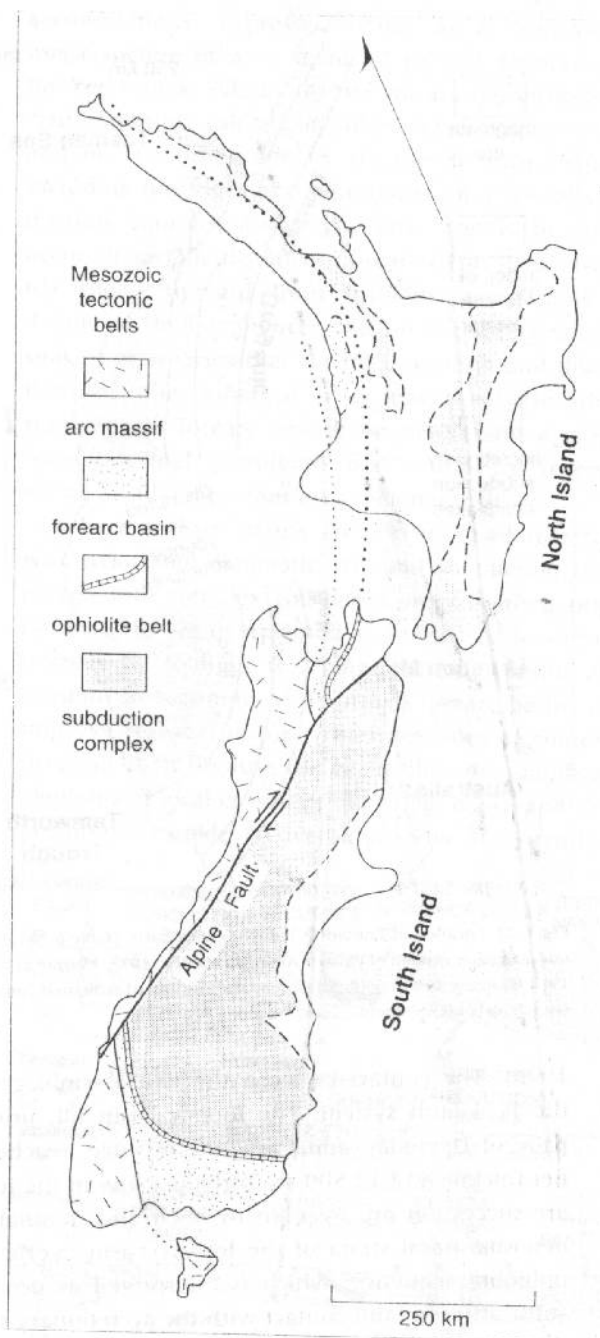


Fig. 6.21 Tectonic elements of Permian to Cretaceous arc-trench system, offset by Cenozoic Alpine fault, in New Zealand (Dickinson, 1971a,b; Landis and Bishop, 1972; Blake et al., 1974; Sporli, 1978): (a) flank of arc massif is western basement province, (b) forearc-basin belt (Table 6.2D) is Hokonui assemblage and other strata of Murihiku Supergroup, (c) ophiolitic assemblage is Dun Mountain ophiolite and associated strata, (d) subduction complex is Torlesse assemblage and related metamorphic rocks.

Sedimentação
Devoniana a
Carbonífera

Preservação de Bacias antigas de ante-arco

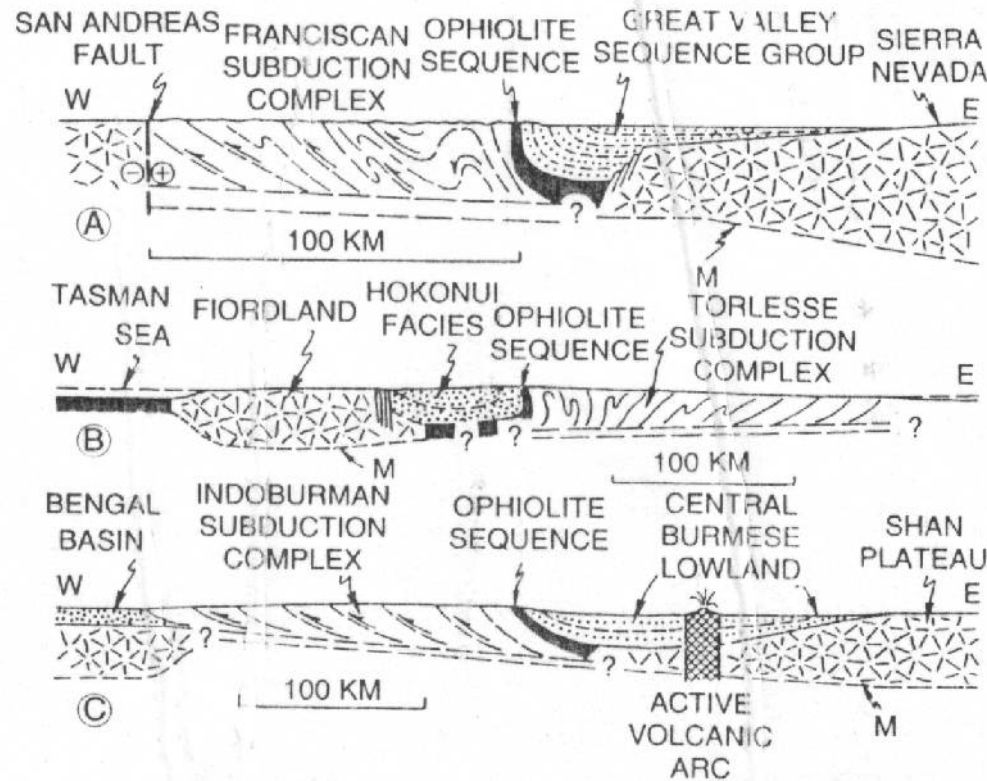


Fig. 6.24 Schematic crustal diagrams (M is base of crust) indicating scale of forearc basin fill (stippled with dashes to show bedding) in relation to arc massif (star-dash pattern) and subduction complexes (thrusts shown schematically): A, coastal California; B, New Zealand (South Island); C, Bangladesh and Burma (Bengal Basin is peripheral foreland basin formed by collision of arc-trench system with underthrust Indian subcontinent); no vertical exaggeration.

Evolução

Possibilidades de curto prazo:

- 1- Inversão durante colisão (destino final de todas as formas)
- 2 – Fim da subducção
- 3 – Migração da zona de subducção com expansão do complexo de subducção – soerguimento da bacia. Orógeno tipo turco.

Preservação: evidência de sutura

Sedimentação siluriana, devoniana e carbonífera (já durante a sutura).

Evidência de sutura dos Caledonides.

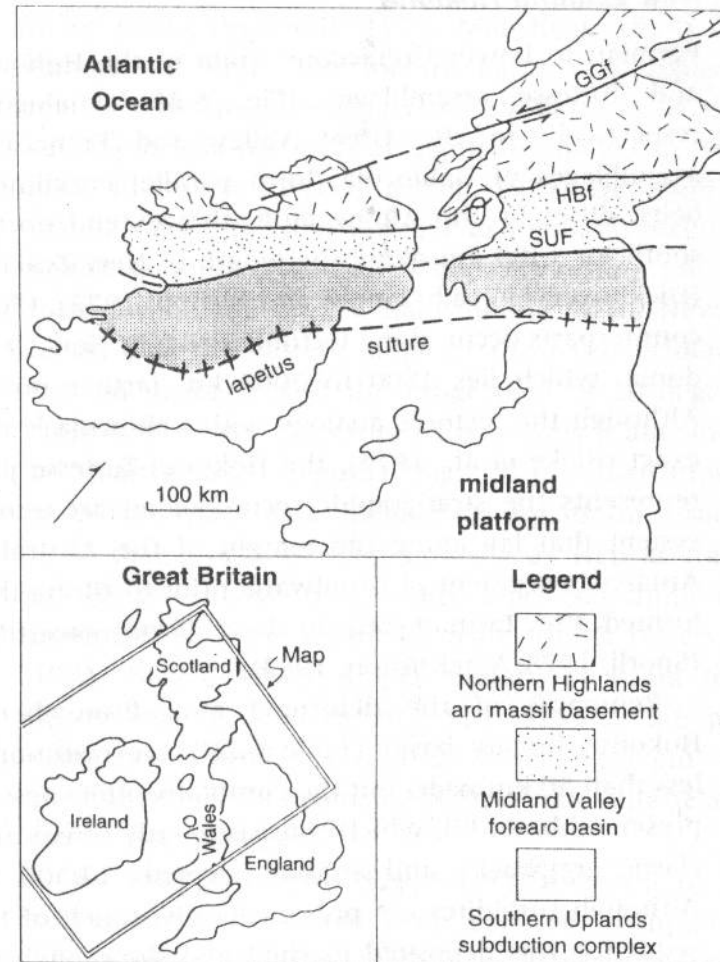


Fig. 6.23 Tectonic relations of remnant lower Paleozoic Midland Valley forearc basin (Table 6.2E) parallel to collisional suture marking closure of Iapetus Ocean within Caledonian orogen of British Isles (Dewey, 1971; Leggett et al., 1982; McKerrow and Soper, 1989); GGF, sinistral Great Glen fault; HBF, highland boundary fault; SUF, southern uplands fault zone.

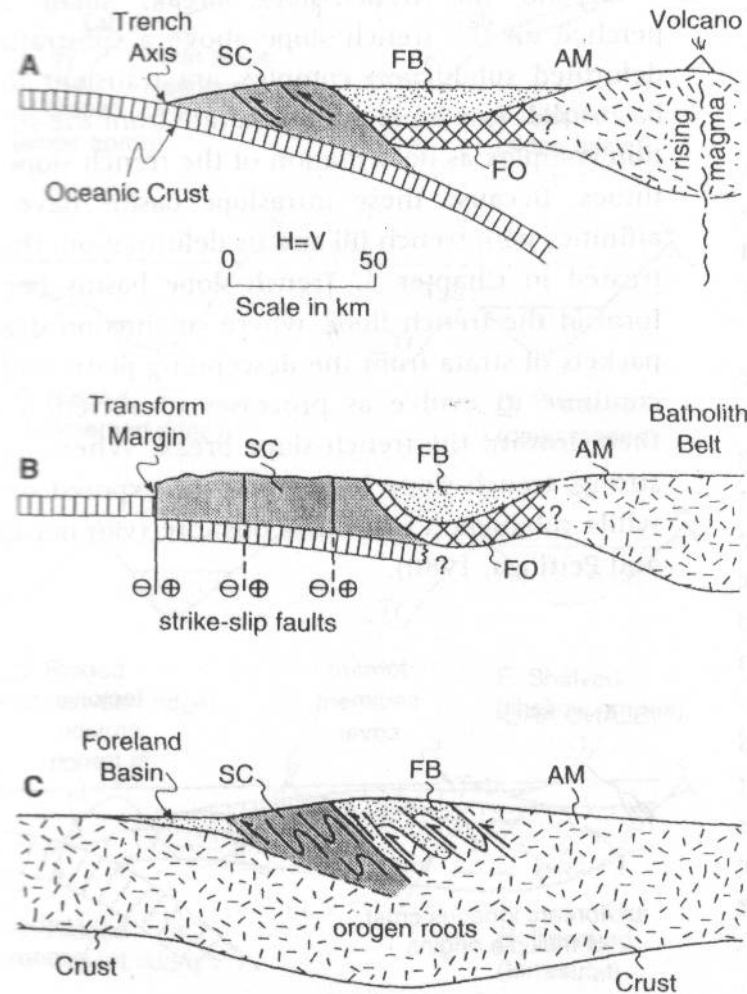


Fig. 6.2 Tectonic settings of forearc basins (schematic): A, origin within active arc-trench system (after Fig. 6.1); B, preservation of basin remnant after conversion of subduction to transform slip (e.g., Great Valley of California); C, deformation of basin fill by incorporation into suture belt of collisional orogenic system (e.g., Midland Valley of Scotland). Symbols: AM, arc massif; FB, forearc basin; FO, forearc ophiolite; SC, subduction complex (but forearc substratum not everywhere ophiolitic; see text for discussion).

Bacias de backarc

- Formadas por distensão atrás de um arco, geralmente de ilhas.
- Podem iniciar-se em crosta continental, mas a distensão continuada leva à formação de litosfera oceânica.

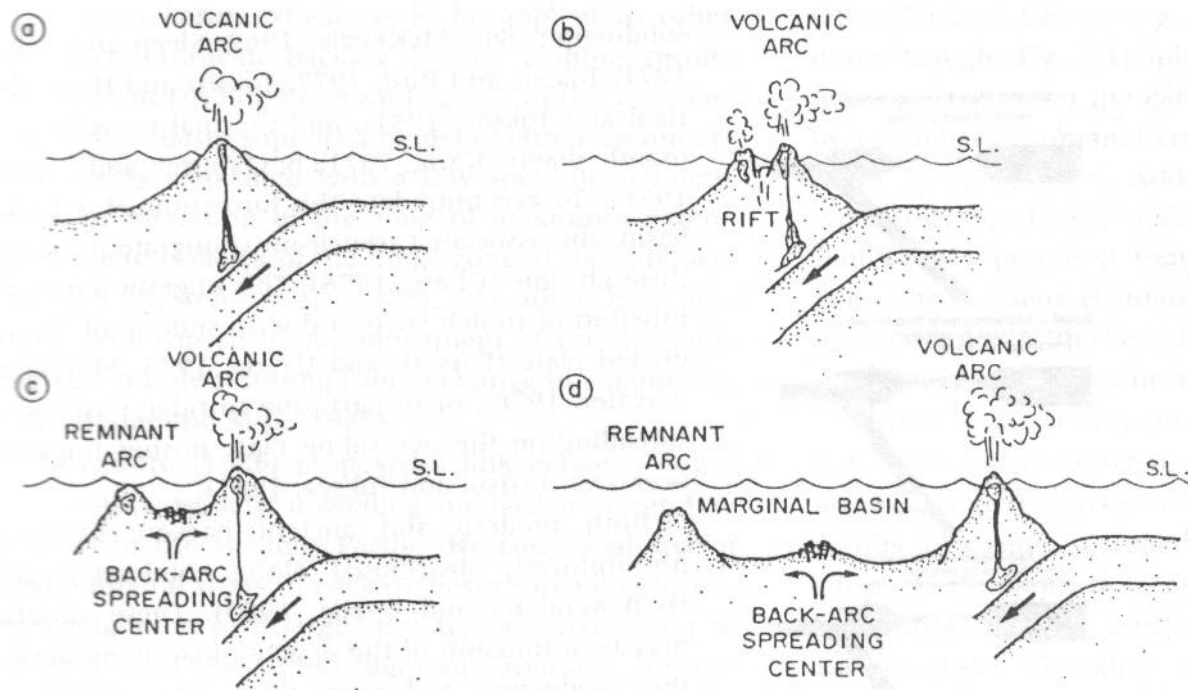
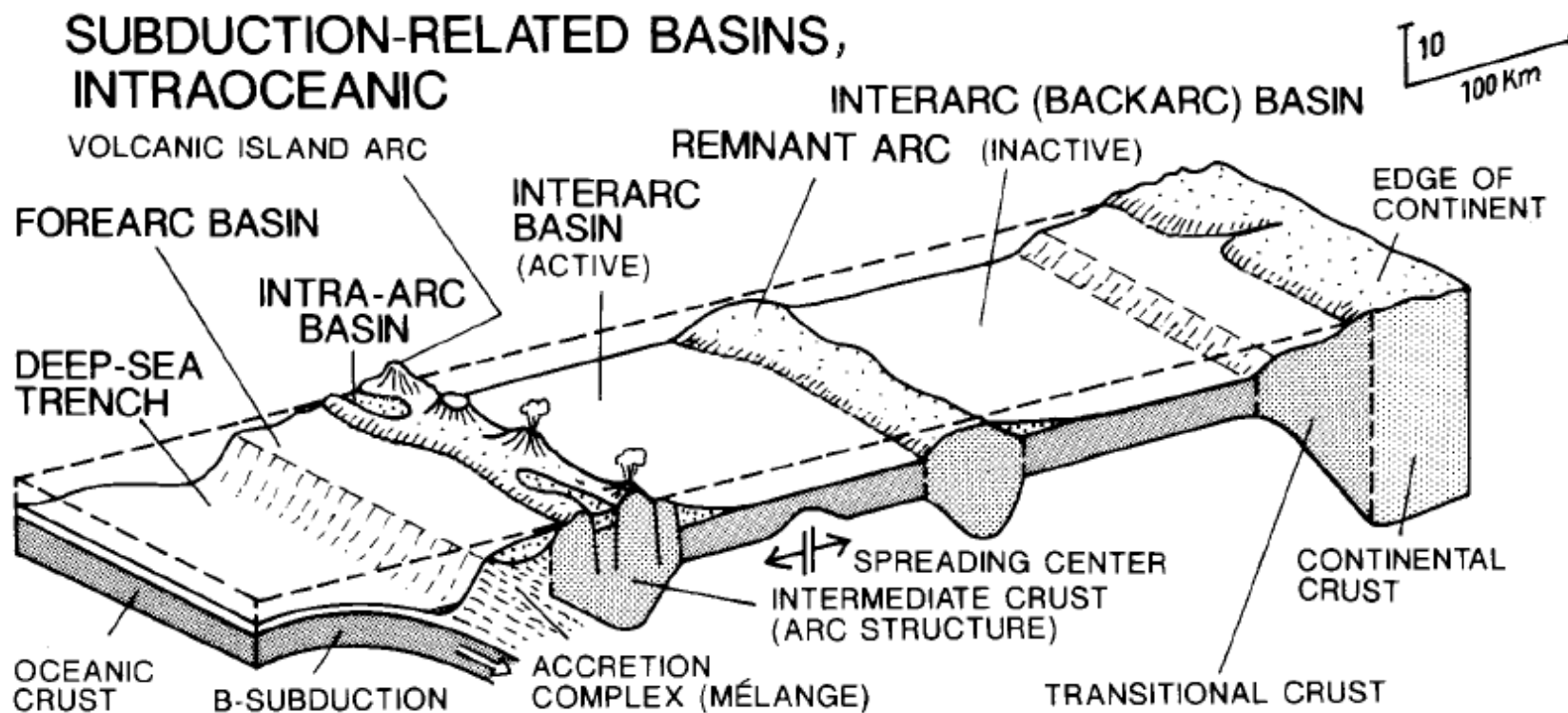


Fig. 8.2 Generalized tectonic evolution of an intraoceanic backarc basin. From Carey and Sigurdsson (1984). After Karig (1971a,b).



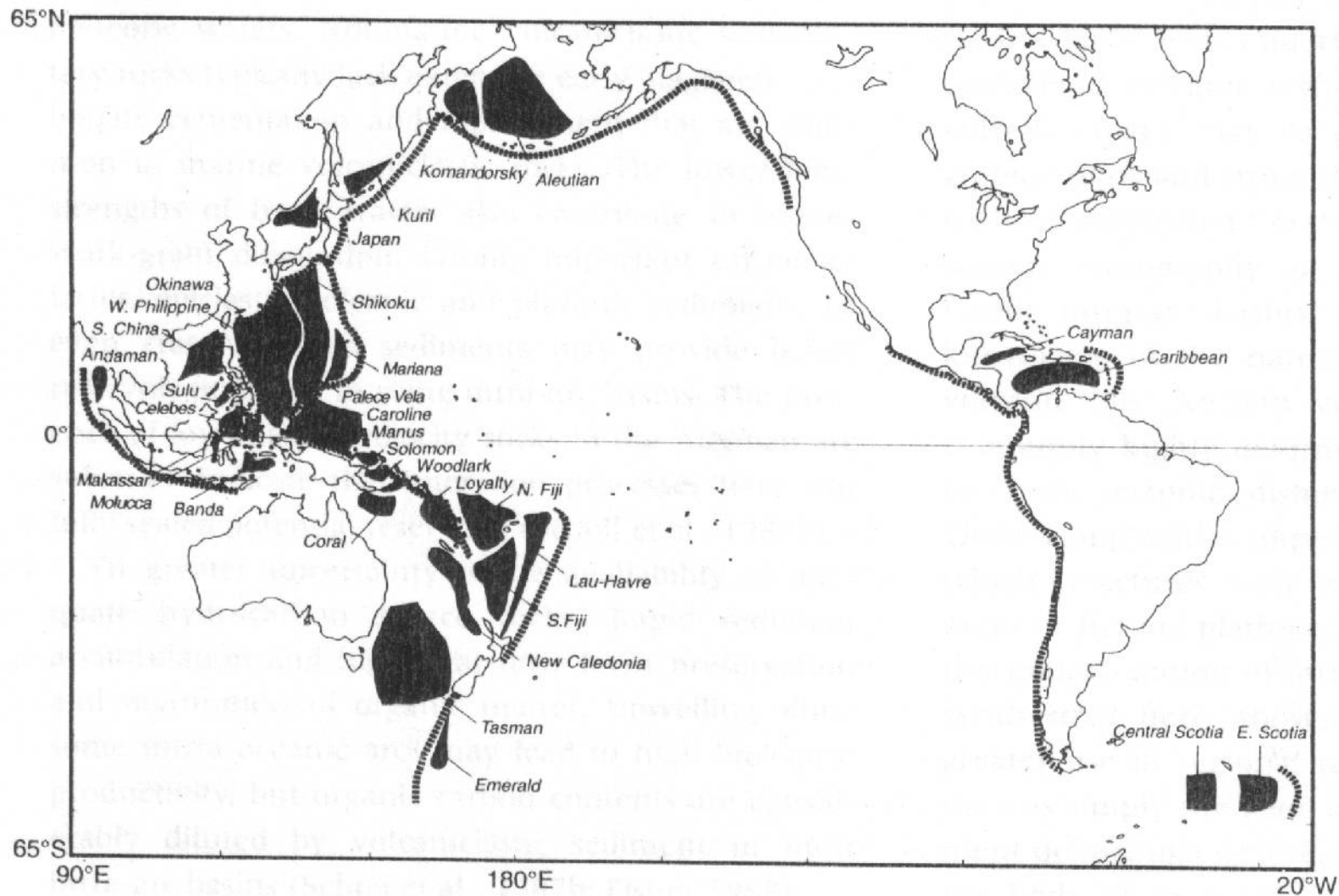


Fig. 8.1 Distribution of trenches (blocked lines) and backarc basins (solid areas) in the circum-Pacific region. After Tamaki and Honza (1991).

Origem da distensão

- Parece estar relacionada a altos ângulos de subducção.
- Vários modelos:
 - Recuo da trincheira
 - Movimento independente da placa que sofre subducção
 - Plumas

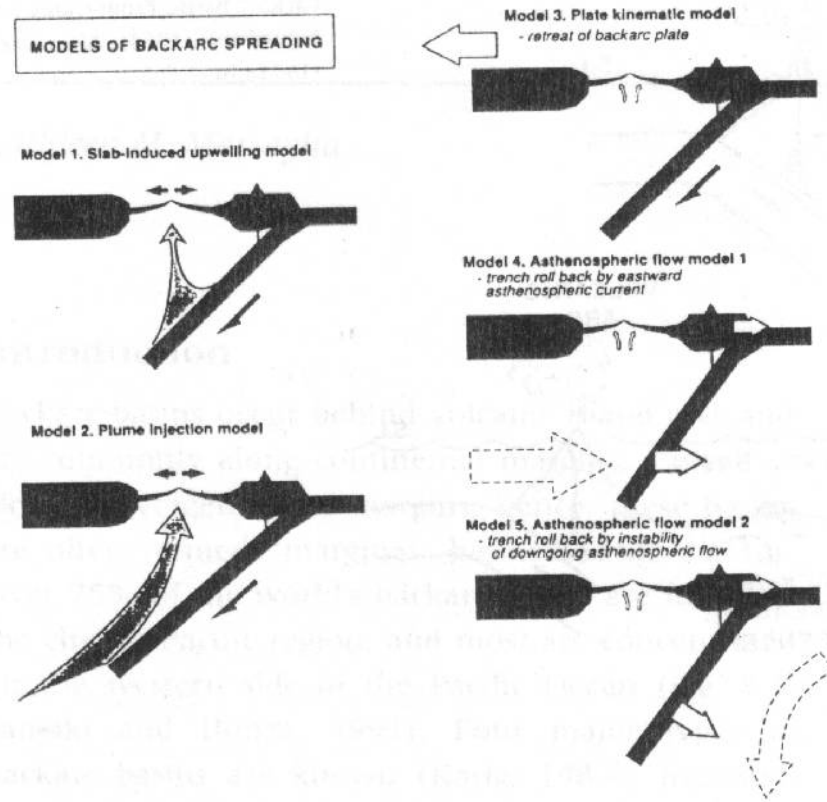
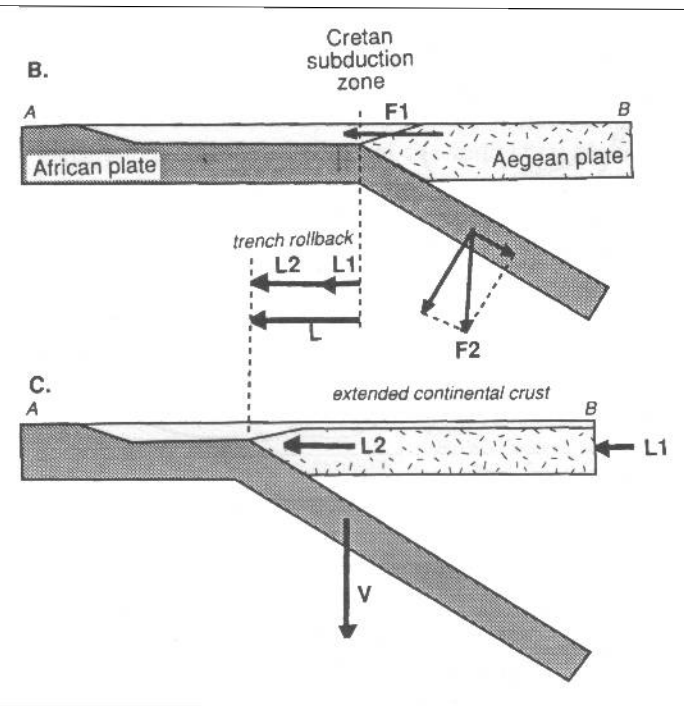
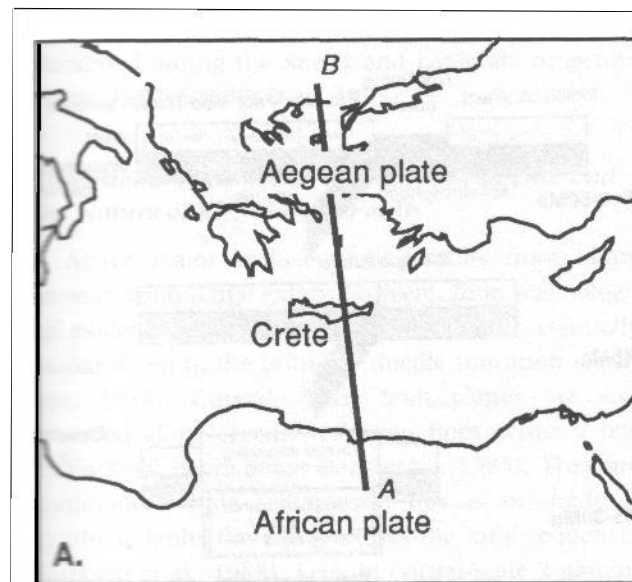
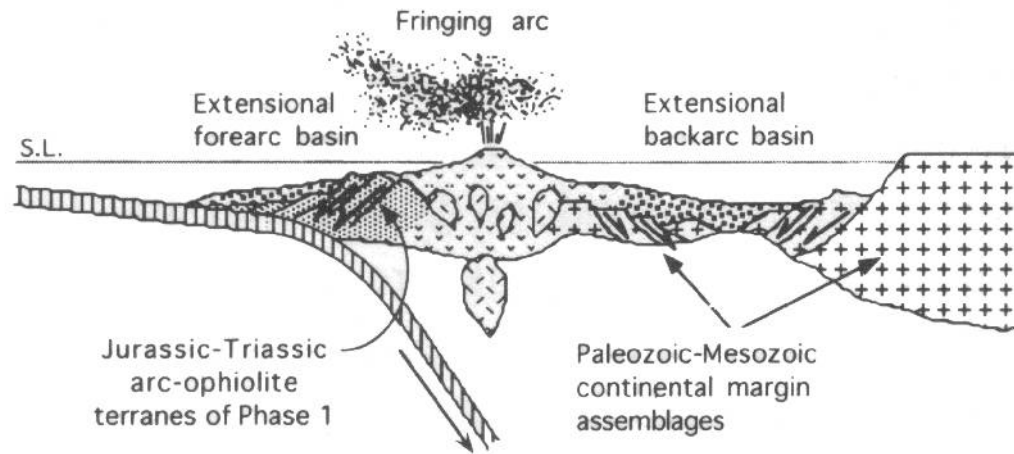
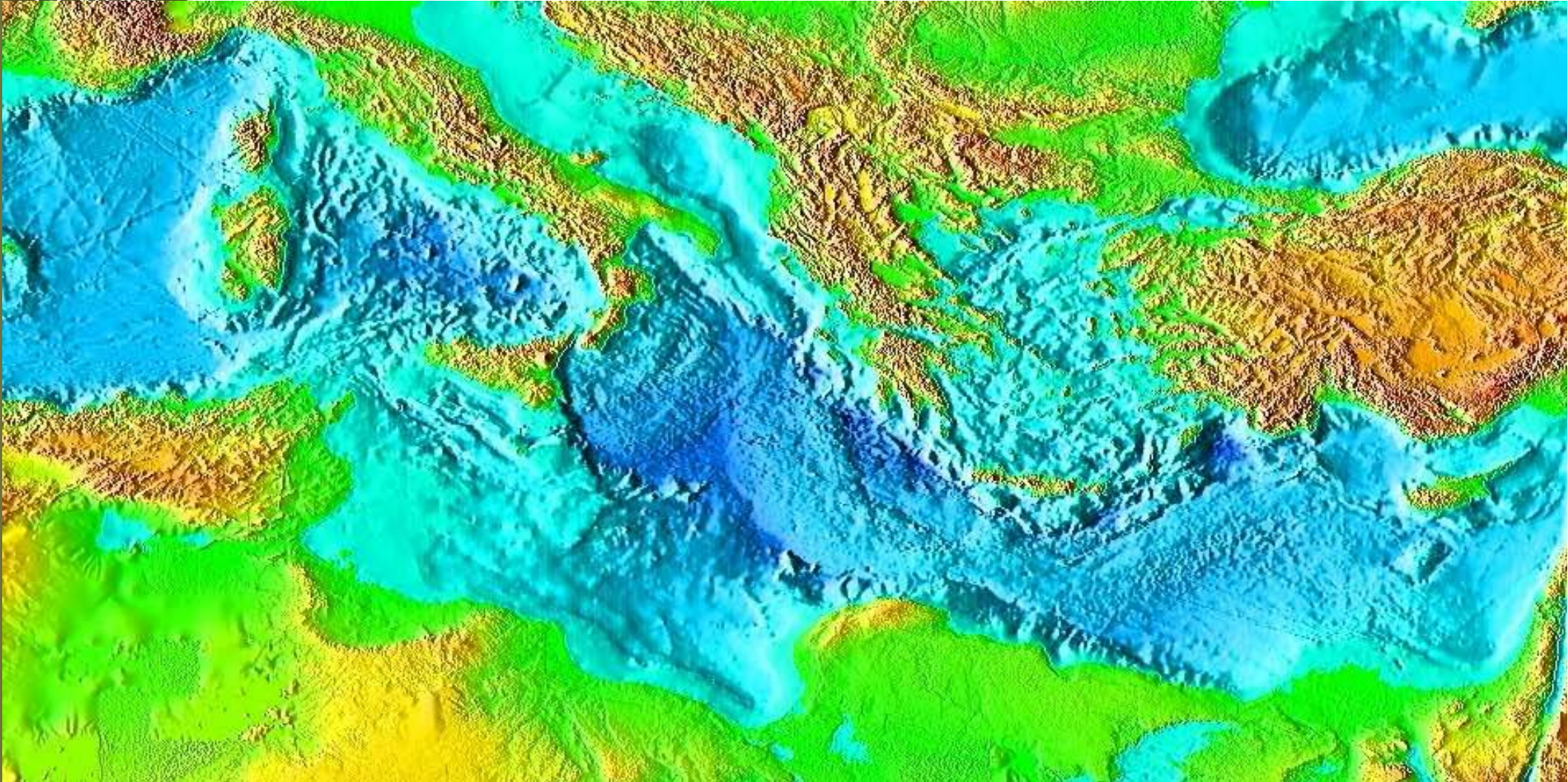


Fig. 8.3 Various models of backarc spreading. According to Tamaki and Honza (1991), Models 1 and 2 are active-opening models, Model 3 is a passive-opening model, and Models 4 and 5 may be classified as either passive, in terms of plate kinematics, or active, in that they depend on dynamic asthenospheric flow. Model 1 proposes mantle upwelling induced by slab subduction (Karig, 1971a; Sleep and Toksöz, 1971). In Model 2, backarc spreading is induced by injection of a mantle plume (Miyashiro, 1986). Model 3 is a kinematic model, where backarc spreading results from the retreat of the overriding plate from the subduction zone (Dewey, 1980). Backarc spreading in Model 4 is induced by eastward asthenospheric flow, possibly associated with the earth's rotation (Uyeda and Kanamori, 1979), and in Model 5, it is induced by global downward asthenospheric flow (slab pull)(Glatzmaier et al., 1990). From Tamaki and Honza (1991).

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação





Tectônica sin-deposicional

Distensão ativa na fase *rift*

Espalhamento de fundo oceânico na fase madura

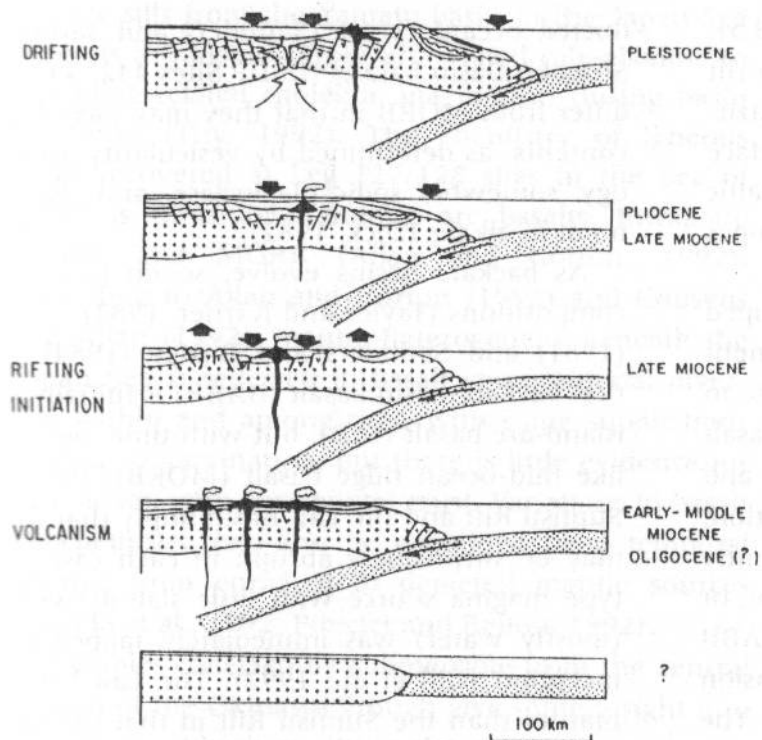


Fig. 8.11 Tectonic evolution of the Okinawa Trough. From Letouzey and Kimura (1985).

Preenchimento

- Turbiditos com proveniência do arco.
- Vulcanismo – evolução de composição de arco para de fundo oceânico
- Contribuição vulcanoclástica

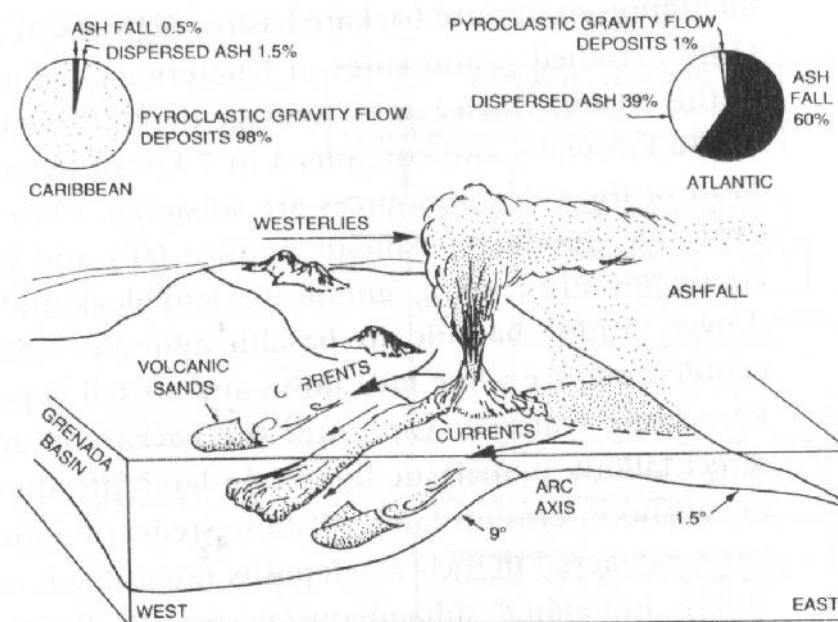


Fig. 8.13 Asymmetric distribution of volcanoclastic material across the Lesser Antilles arc, controlled by bathymetry and marine and atmospheric currents. Fine-grained ash is carried by the tropospheric westerlies to the east, whereas coarse-grained proximal sediments are preferentially distributed to the west. See text for discussion. From Sigurdsson et al. (1980).

Evolução

Evolução para oceano

Inversão em orógenos colisionais:

- Colisão do arco com o orógeno
- Fechamento do oceano

Tectônica e Sedimentação

Bacias de ambientes convergentes - subsidência flexural; Tectônica e Sedimentação

Transient sedimentological response to tectonic perturbation

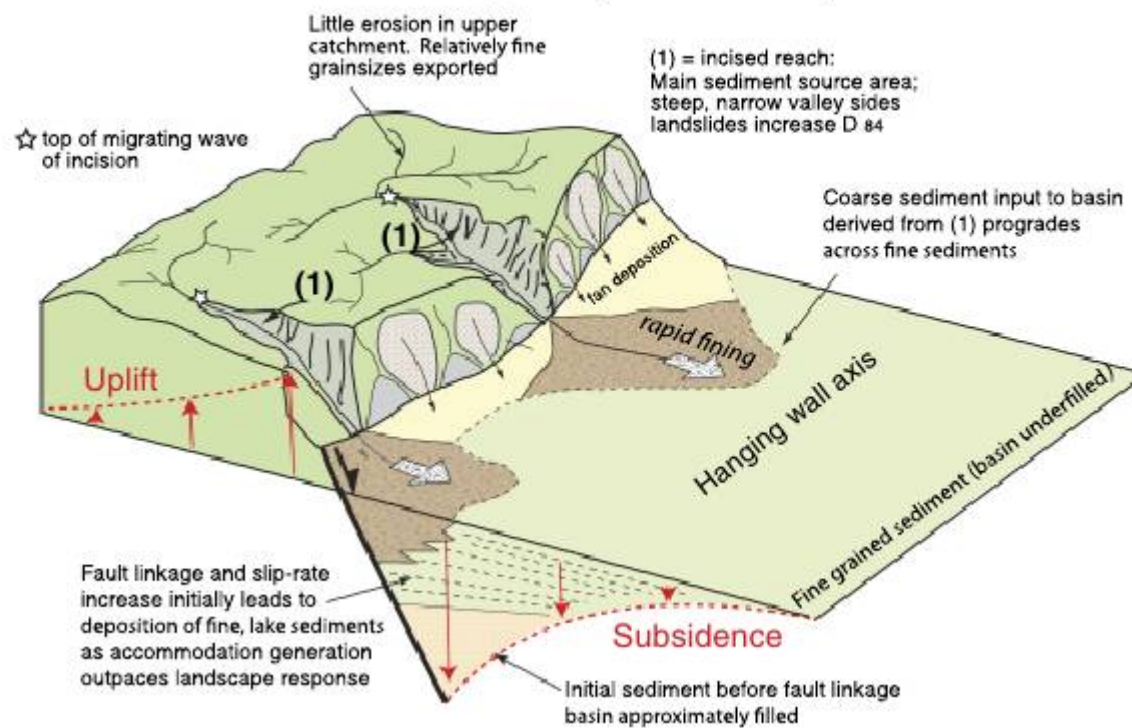
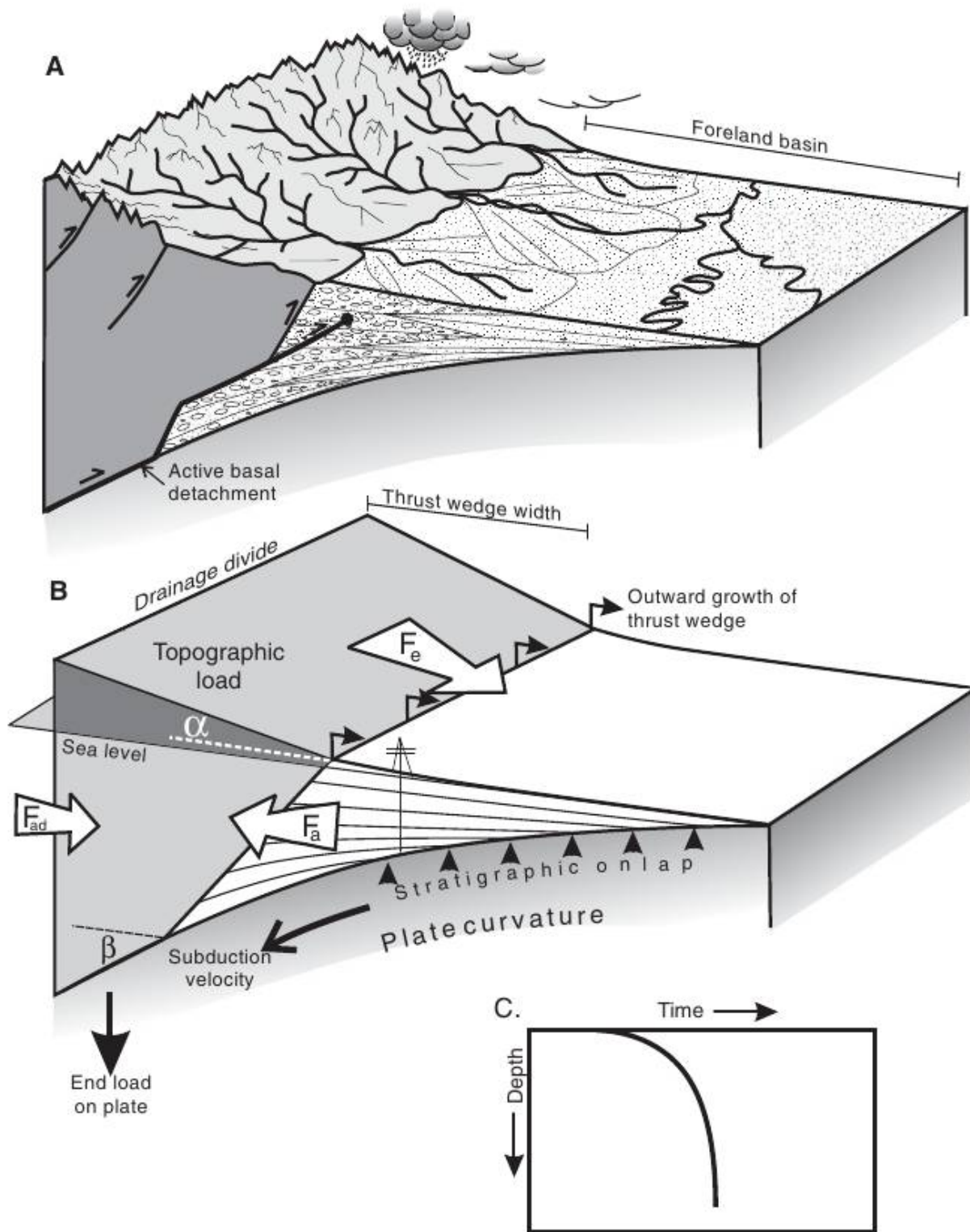


Fig. 11. Synthesis diagram showing the erosional and depositional patterns characterising the transient response of footwall catchments and hanging-wall basins to an increase in fault uplift rate as evidenced from the Central Apennines of Italy.



Whittaker et al.
Basin Research
(2010) 22, 809–
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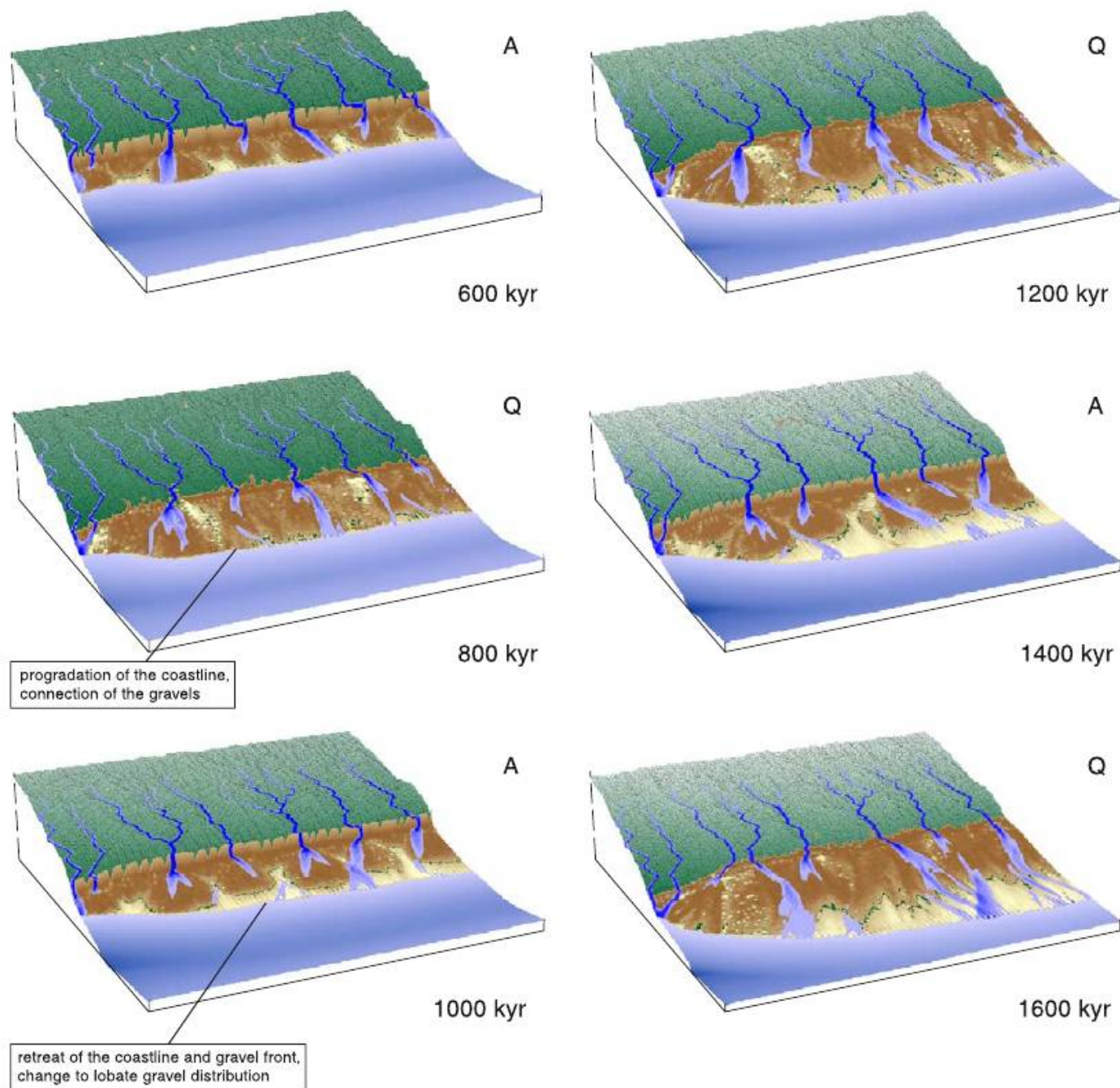
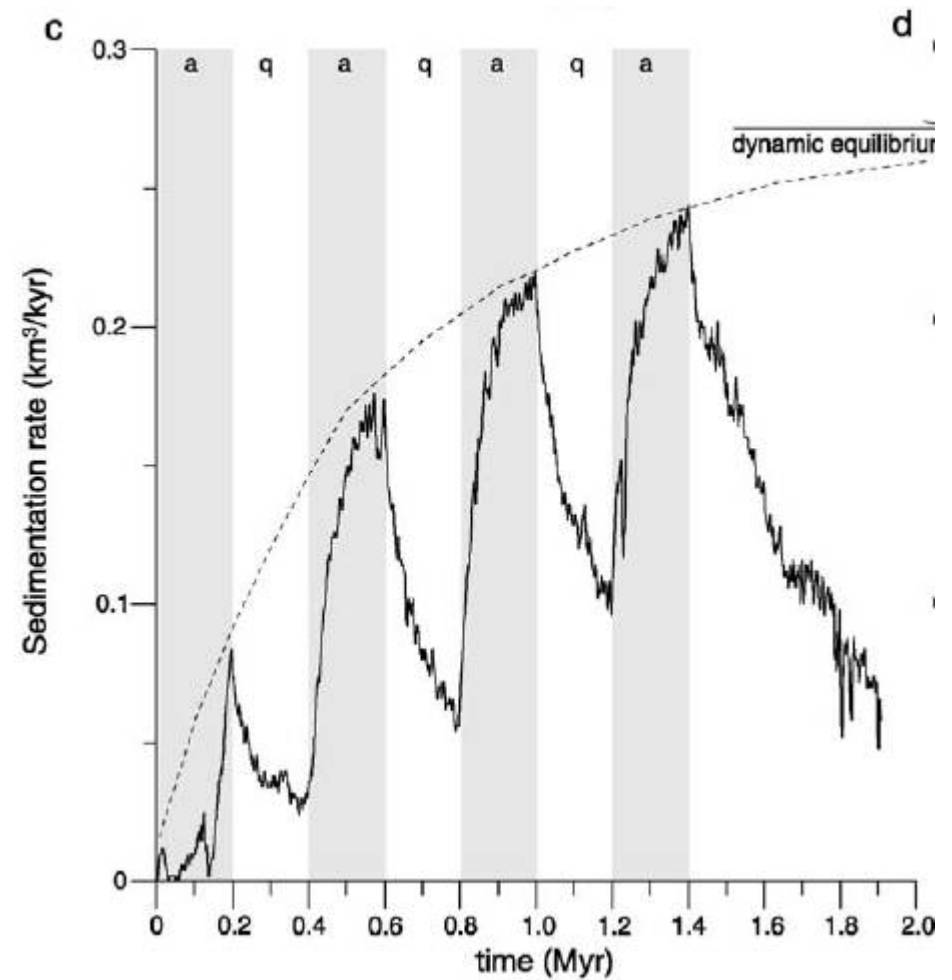
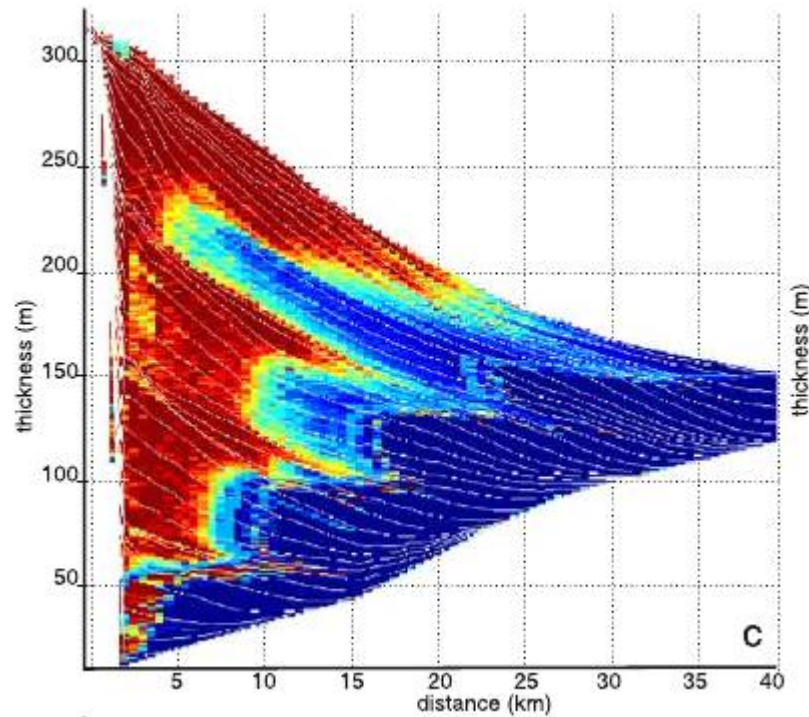
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GSA0307Bacias de ambientes convergentes - subsidência
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Fig. 10. Perspective views of successive stages of the landscape subjected to tectonic pulsations (experiment 8). Phases of tectonic activity (A) are reflected by faultward retreat of the coastline and the gravel front and by changes to lobate gravel patches. Quiescence (Q) is associated with their progradation and lateral connection of the gravels. See also animation 3.



Efeito estratigráfico de pulsos tectônicos em bacias flexurais (A – atividade de falhas, Q - quiescência)

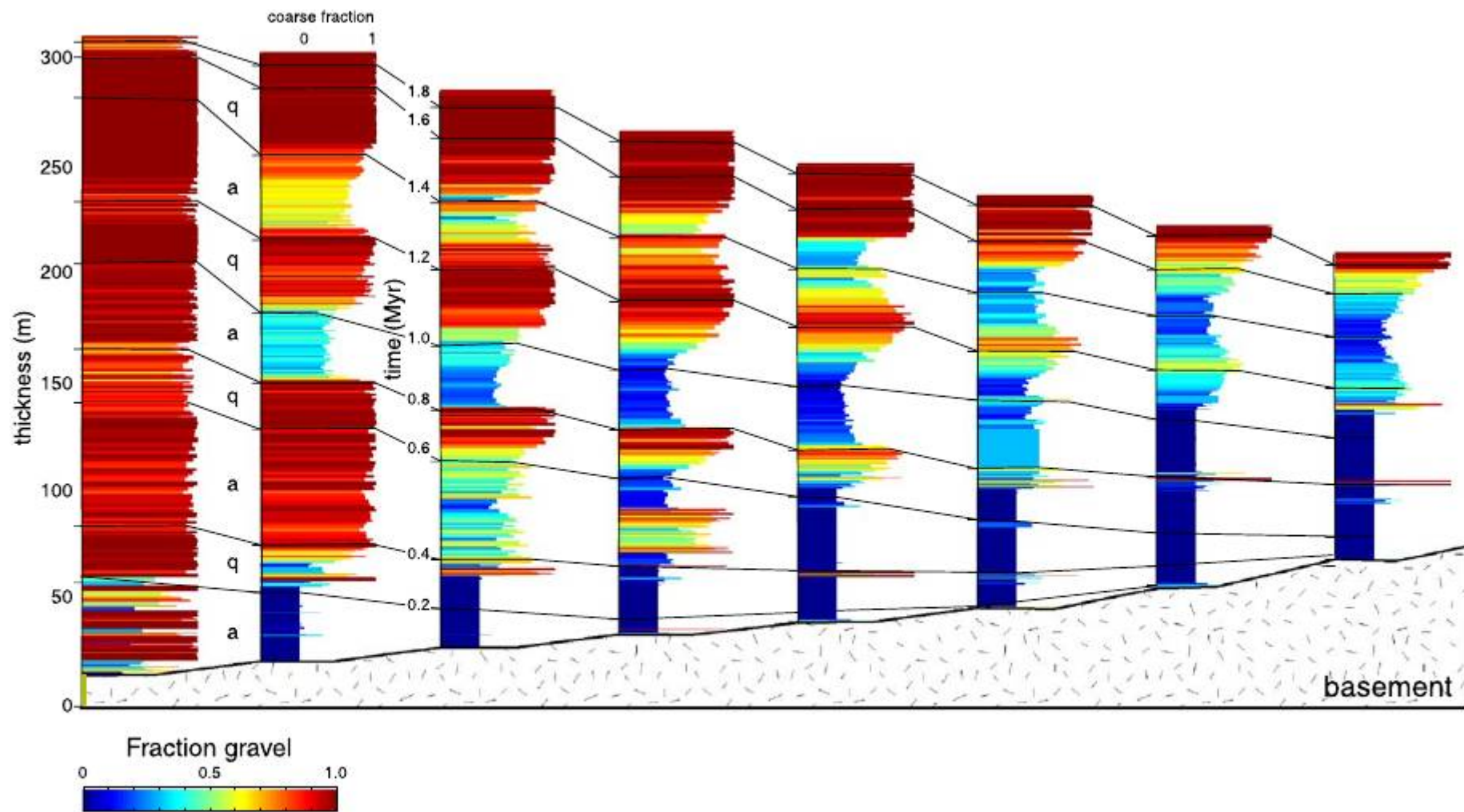


Fig. 13. Synthetic sedimentary logs sampled from the pulsating tectonic activity experiment in a section line perpendicular to the fault zone illustrating the vertical resolution of the subsurface dataset (< 1.0 m). Indicated are phases of activity (a) and quiescence (q) and correlative timelines (0.2-My time intervals). Locations of the logs are indicated in Fig. 11.

Padrões de empilhamento

Progradação – avanço dos sistemas deposicionais proximais (mais perto das fontes) sobre os distais.

Retrogradação – Recuo dos sistemas deposicionais proximais que são gradualmente recobertos pelos distais.

Controles – Espaço de acomodação e aporte sedimentar.

Quais os controles sobre o aporte e o espaço?