Geological Evidence for Fluid Overpressure in Mature Source Rocks within Foreland Basins of the Americas*

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Abstract

In the Americas, many foreland basins have produced oil or gas from conventional reservoirs. However, new techniques of hydraulic fracturing are facilitating production from unconventional reservoirs, especially in source rock. As well data accumulate, they are showing that overpressure is common within mature source rock. Here I will consider independent geological evidence for such overpressure, either at regional scale or at sample scale. Outcropping source rock is especially common at the edges of foreland basins, because of out-of-sequence thrusting and exhumation.

At regional scale, evidence for overpressure within source rock comes from thin-skinned flat-lying detachments, which have formed during thrusting. In many developing foreland basins, the deformation front coincides with the maturity front (entry into the oil window or gas window), at a depth of a few km. This suggests that overpressure develops as the source rock reaches maturity. In the past, many researchers have attributed such overpressure to mechanical compaction. Indeed, the volume increase, from kerogen to oil, is probably too small to cause overpressure by itself. On the other hand, according to recent physical modeling, chemical compaction and loss of strength of a solid framework cause the weight of overburden to transfer to pore fluids. Here I will review evidence for coincidence of the maturation front and the deformation front in the Magellan Basin (southern Patagonia), the Neuquén Basin (Argentina) the Chaco Basin (Bolivia and NW Argentina), various foreland basins in the U.S. and western Canada, and the North Slope (Alaska).

At sample scale, direct evidence for overpressure comes from bedding-parallel veins. By analogy with physical models, original hydraulic fractures have dilated vertically, against the force of gravity, because of overpressure gradients (seepage forces). The fractures progressively filled with material, becoming solid veins. The most typical infilling material is fibrous calcite (beef) or gypsum. Calcite beef is especially common in source rock of the Neuquén Basin (Argentina). A less common infilling material is asphaltite, which has solidified from oil by loss of volatile constituents. I will make the case for such asphaltite being the product of an abnormally high thermal gradient, due to magmatic intrusion, hydrothermalism, or a shallow Moho.

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Geological Evidence for Fluid Overpressure in Mature Source Rocks within Foreland Basins of the Americas

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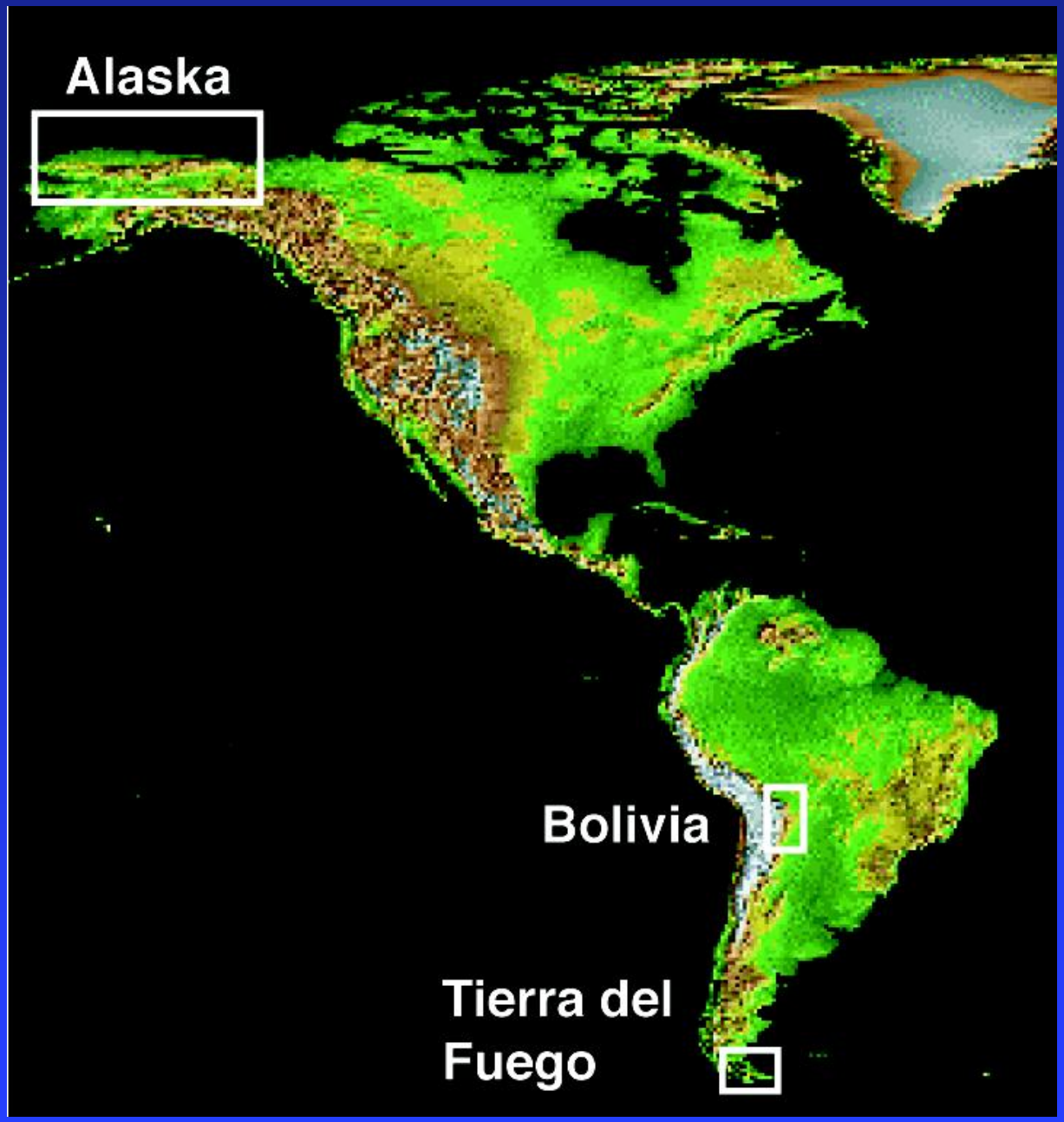
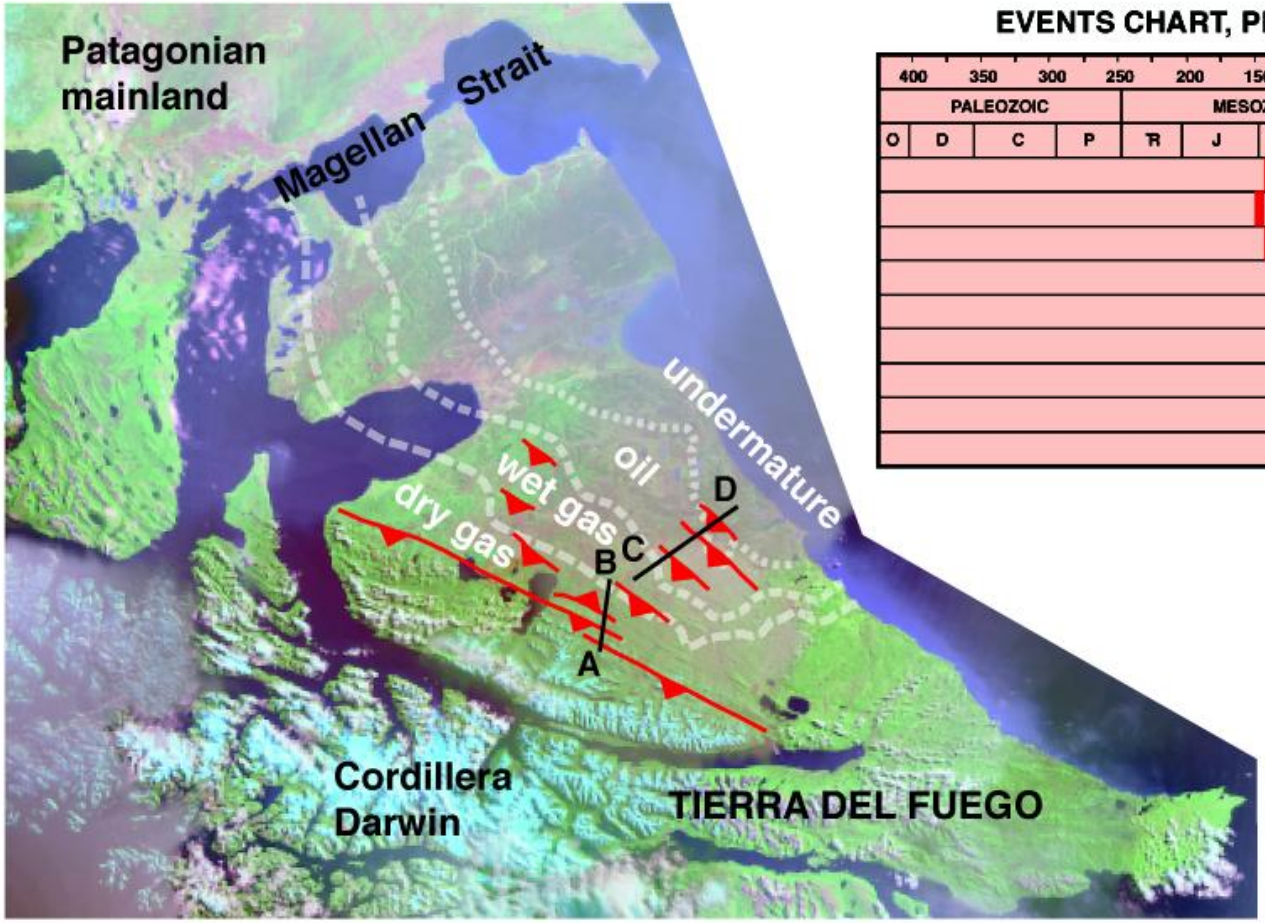
AAPG ICE, Cartagena

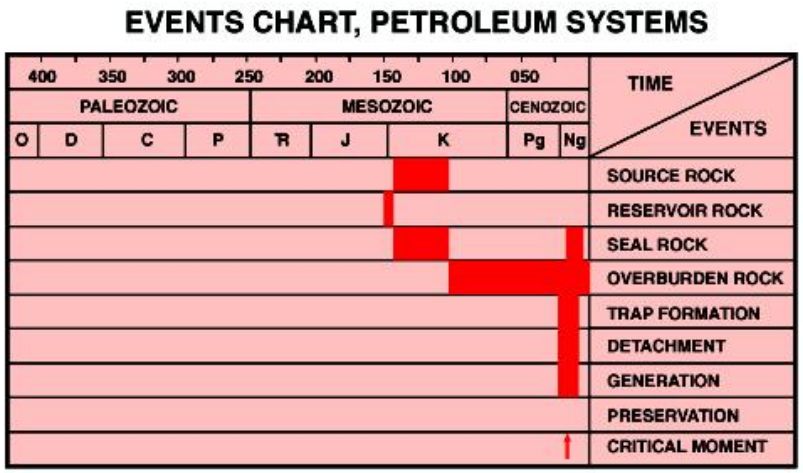
8-11 September 2013

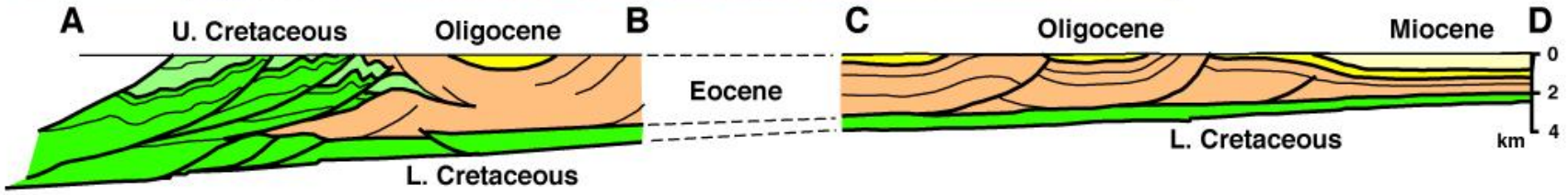


Foreland basins of the Americas

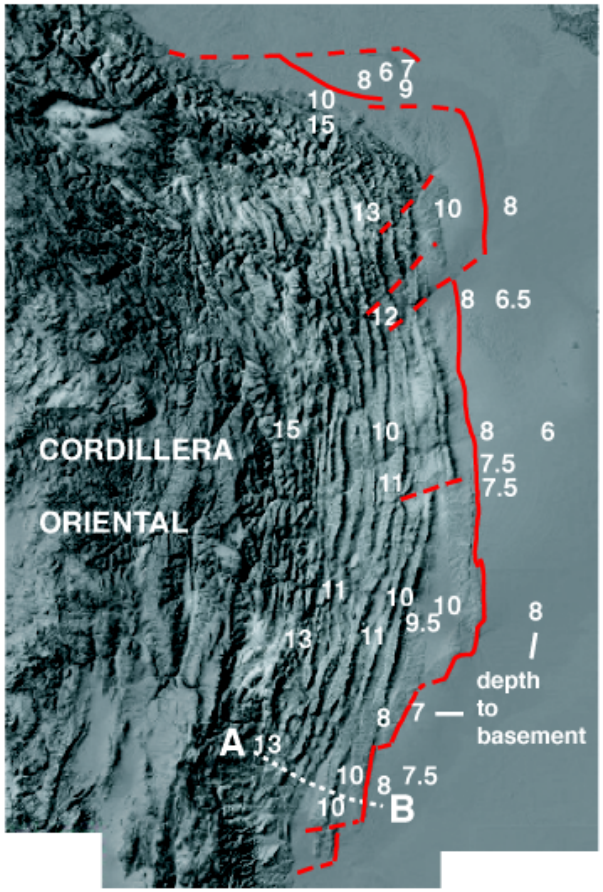
Tierra del Fuego
(Cobbold, 2005)

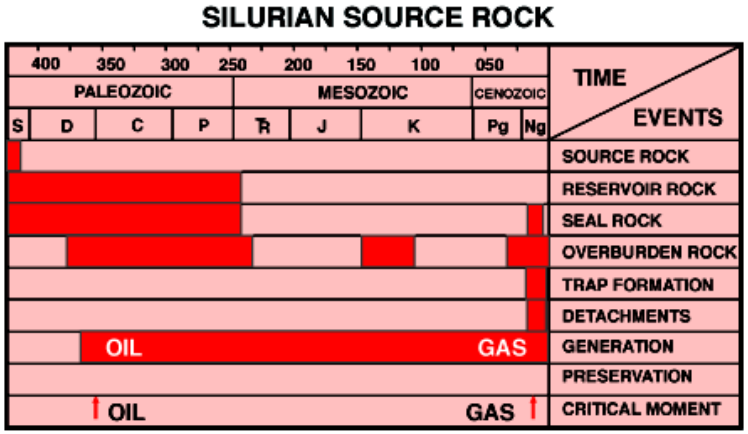


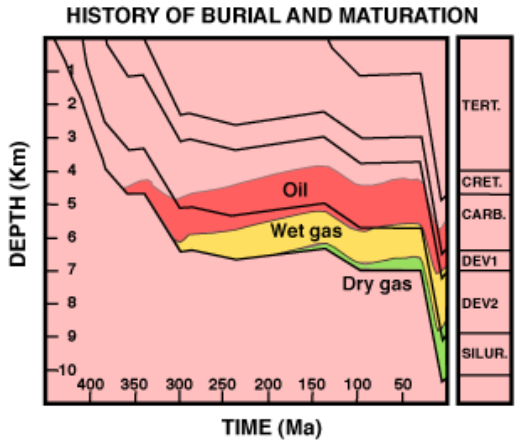


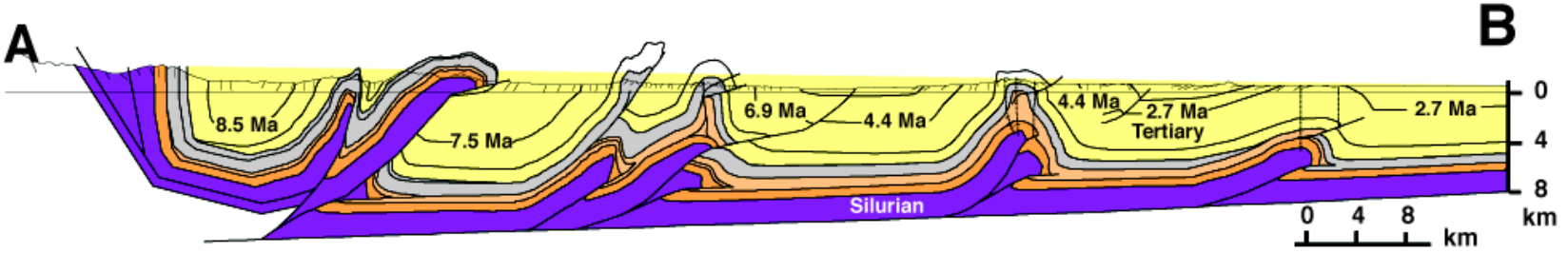


Sub-Andes, NW Argentina
(Cobbold, 2005)

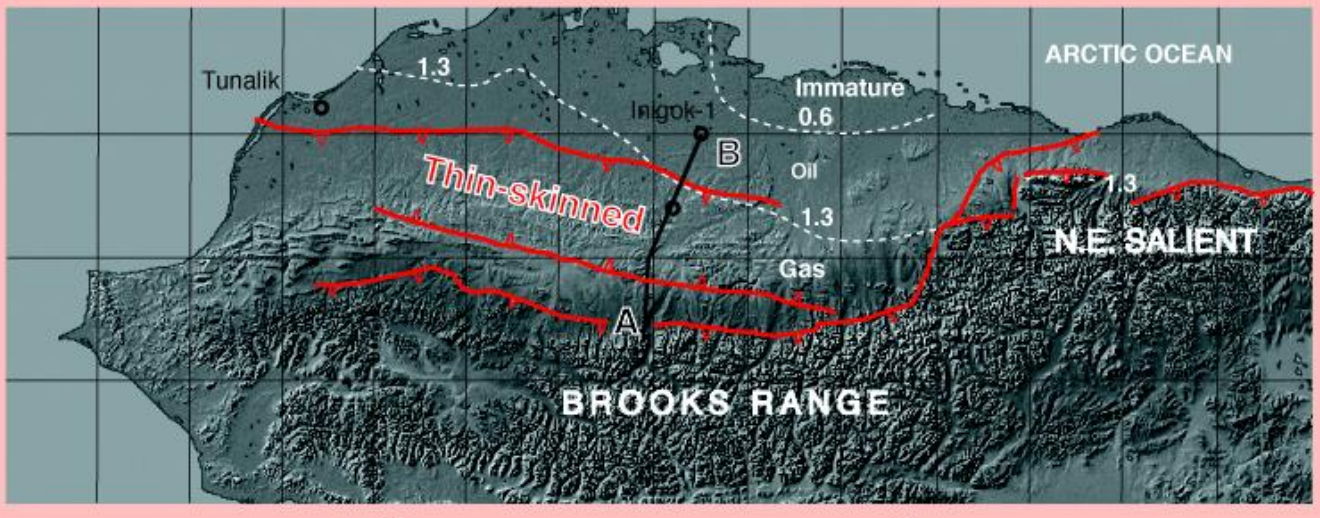


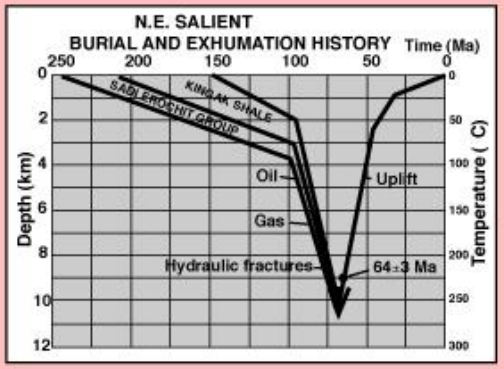


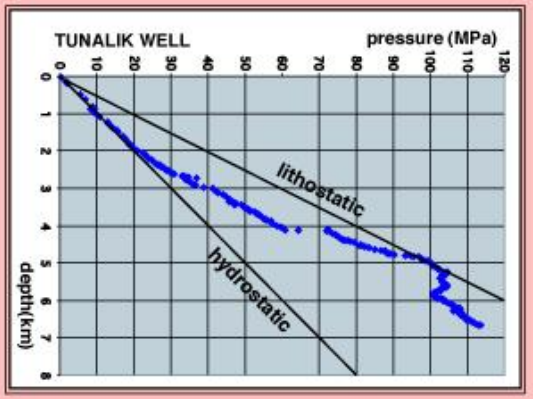


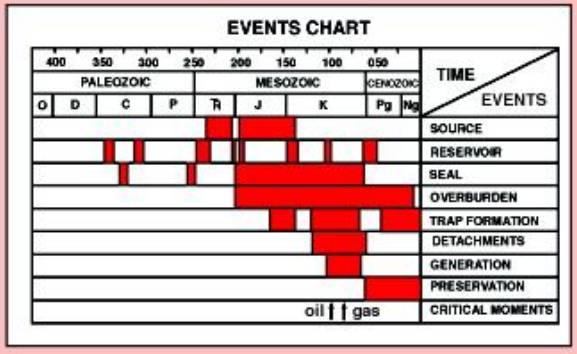


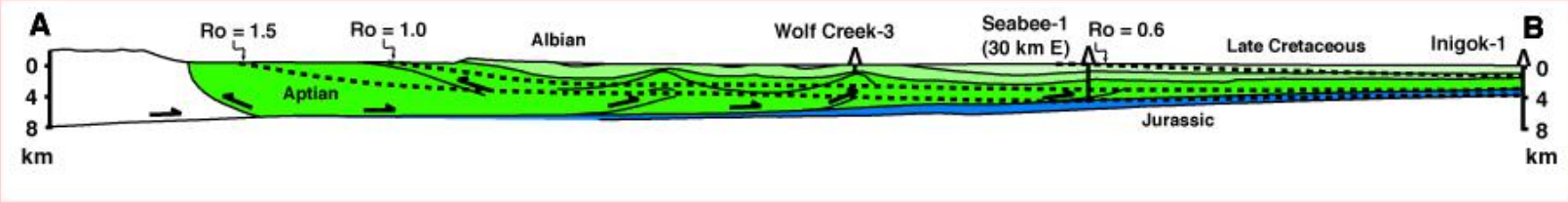
Alaska
(Cobbold, 2005)



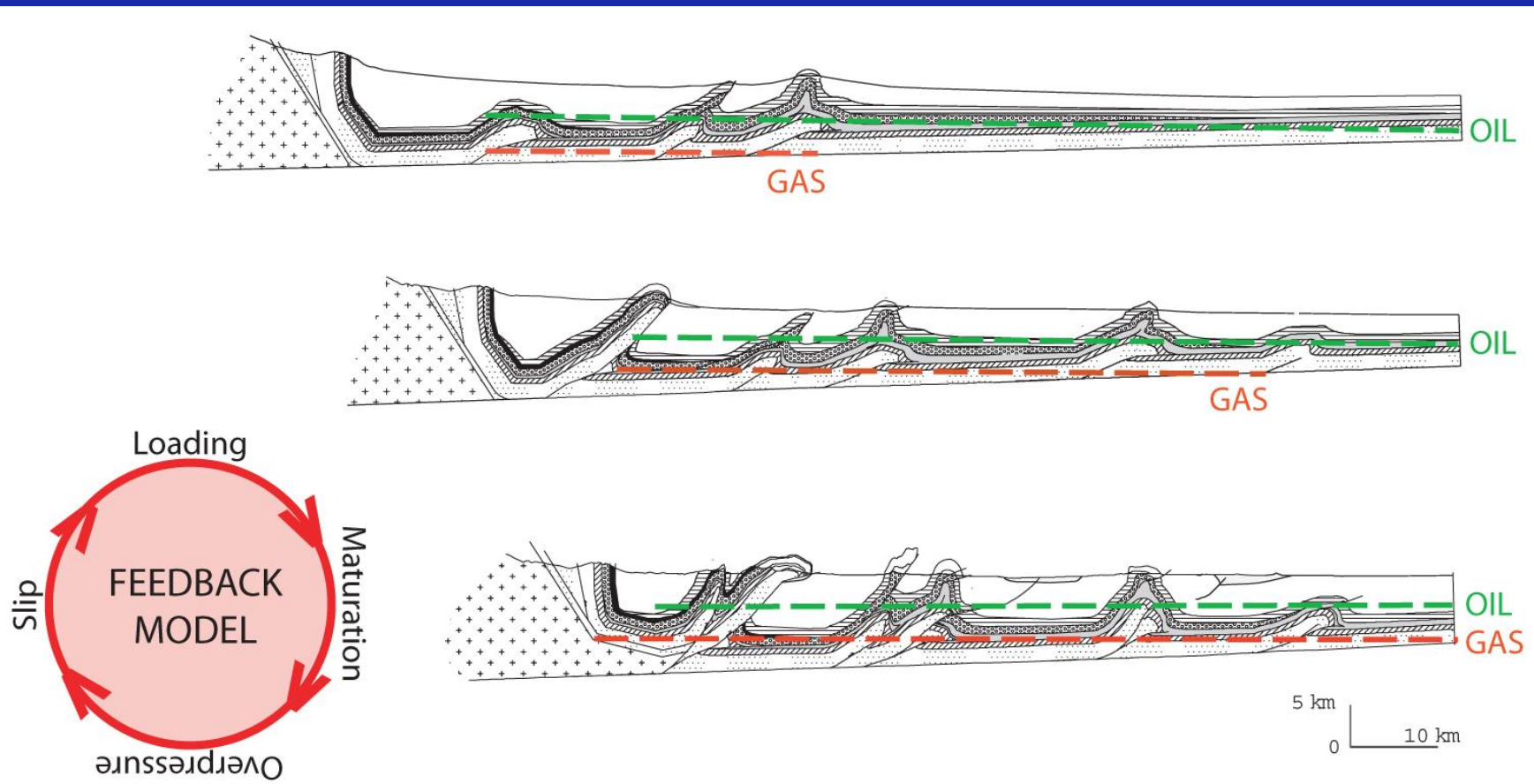




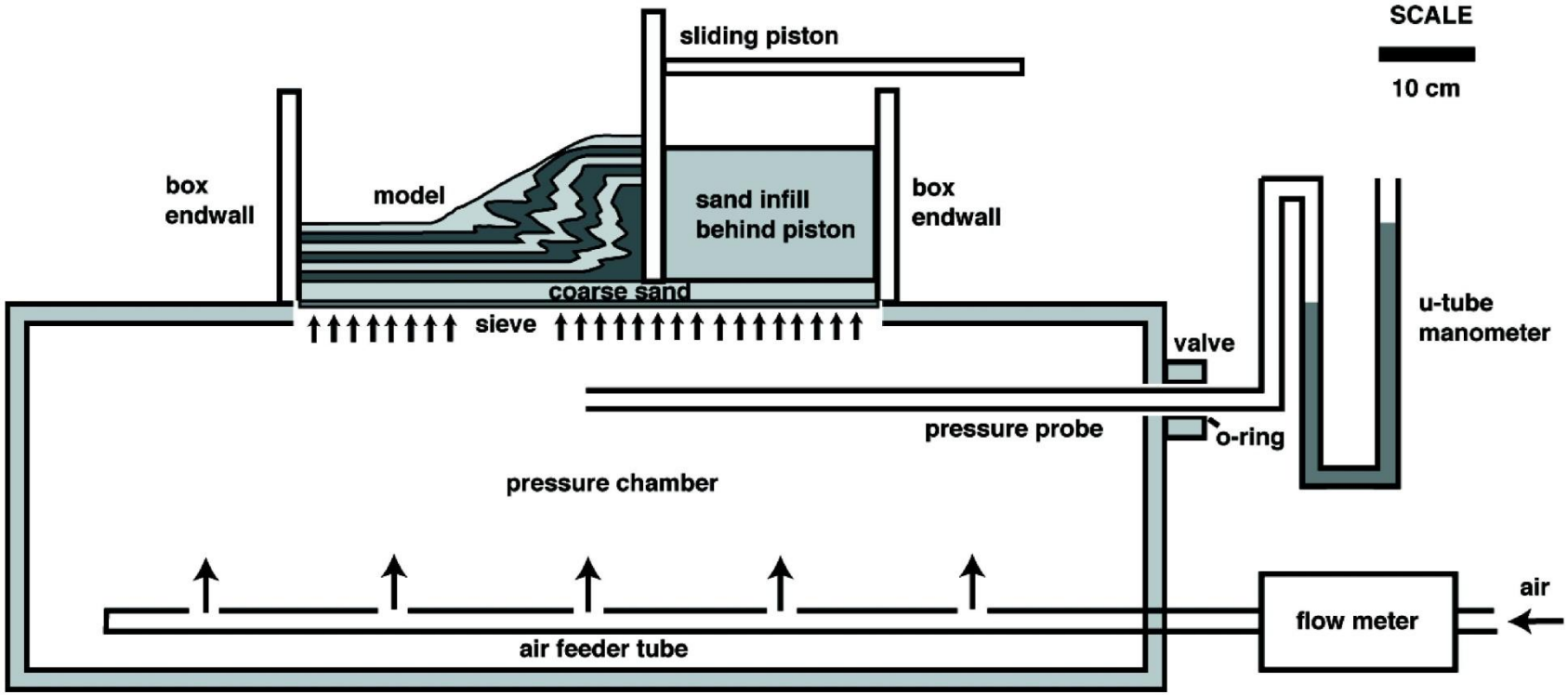




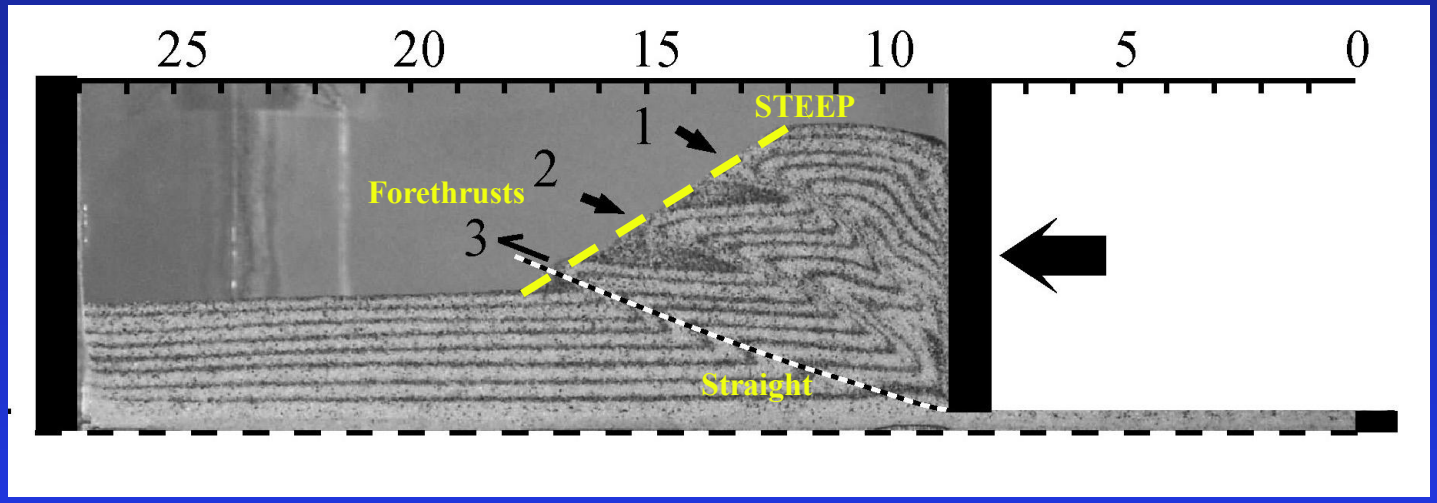
Feedback model of thrust propagation



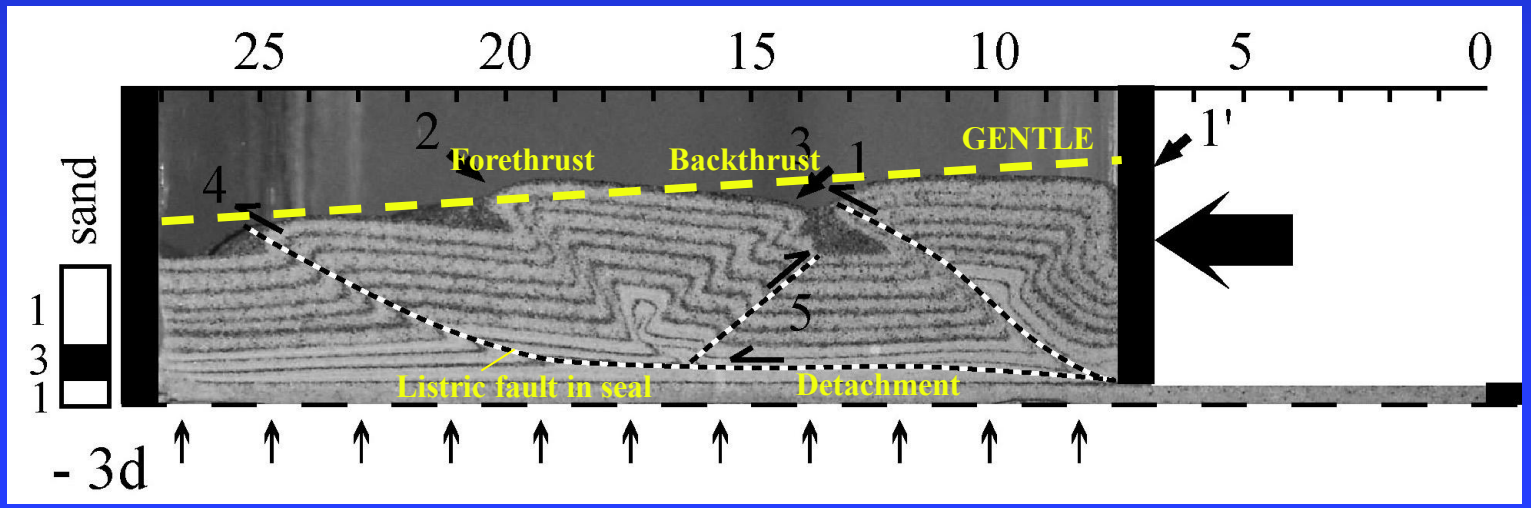
Experiments on thrust wedges
(Cobbold, Durand & Mourgues, 2001)



Models with or without overpressure
(Mourgues & Cobbold, 2006)

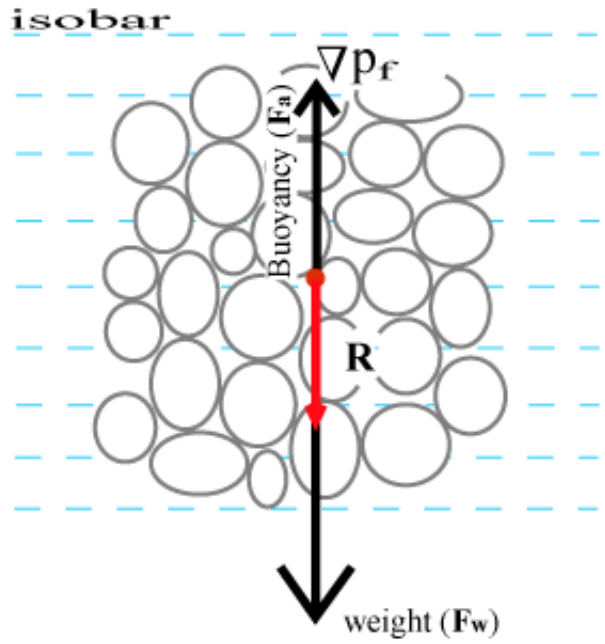


1.Normal pressure.
2. Uniform model.

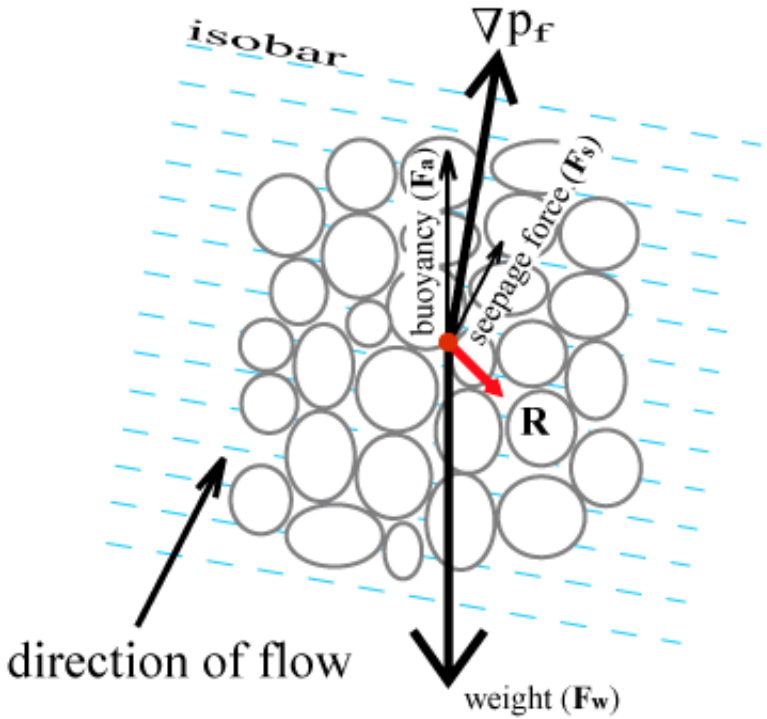


1. Over-pressure.
2. Basal seal.

Forces acting on a porous medium
(Mourgues & Cobbold, 2003)



Hydrostatic state

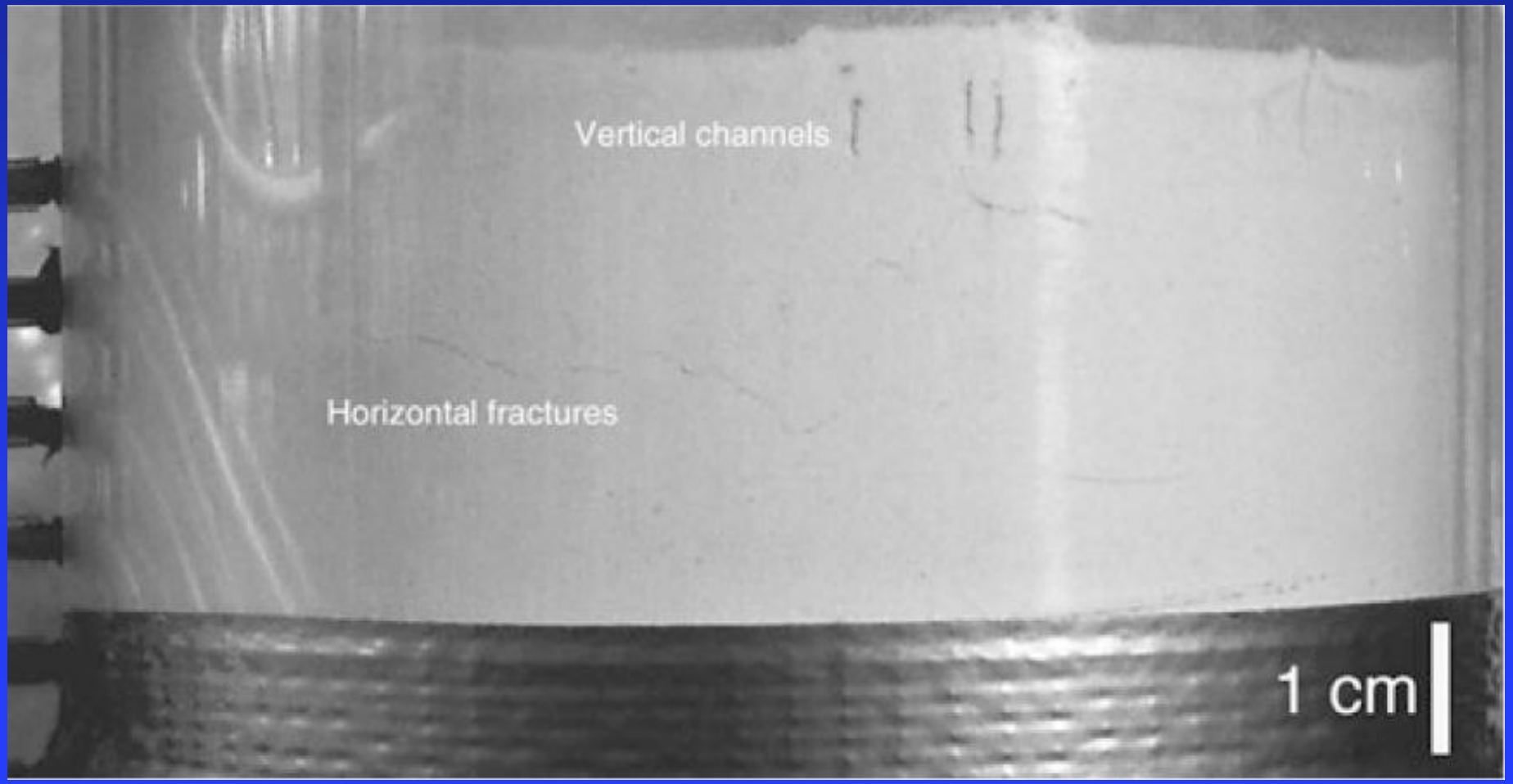


Fluid flow through porous medium

fig. 2

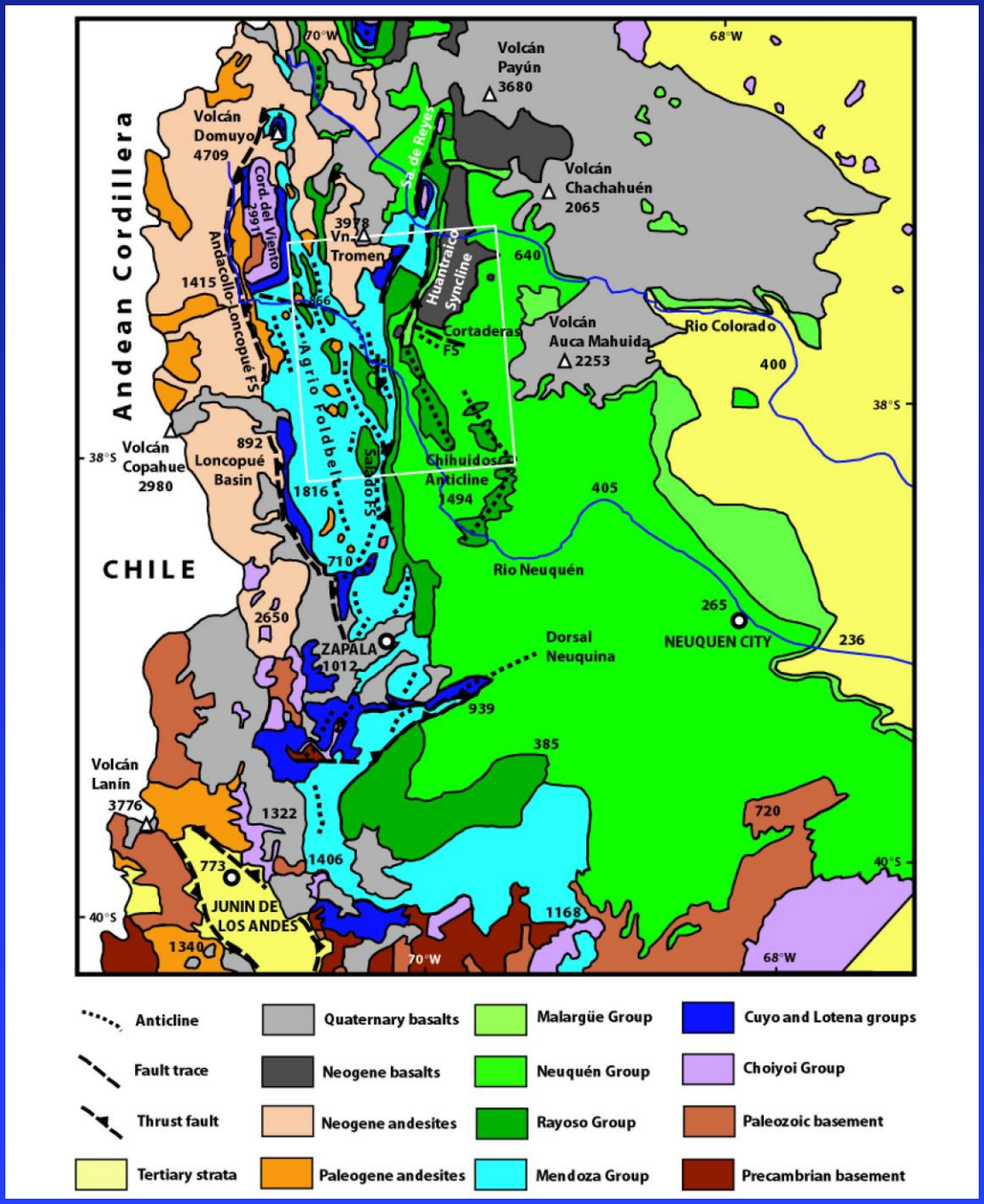
Fluid flow through cohesive powder

(Cobbold & Rodrigues, 2007)



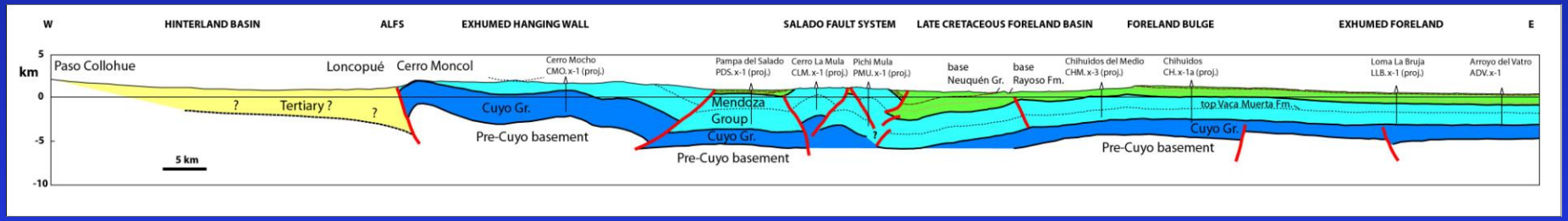
Neuquén Basin, geological map

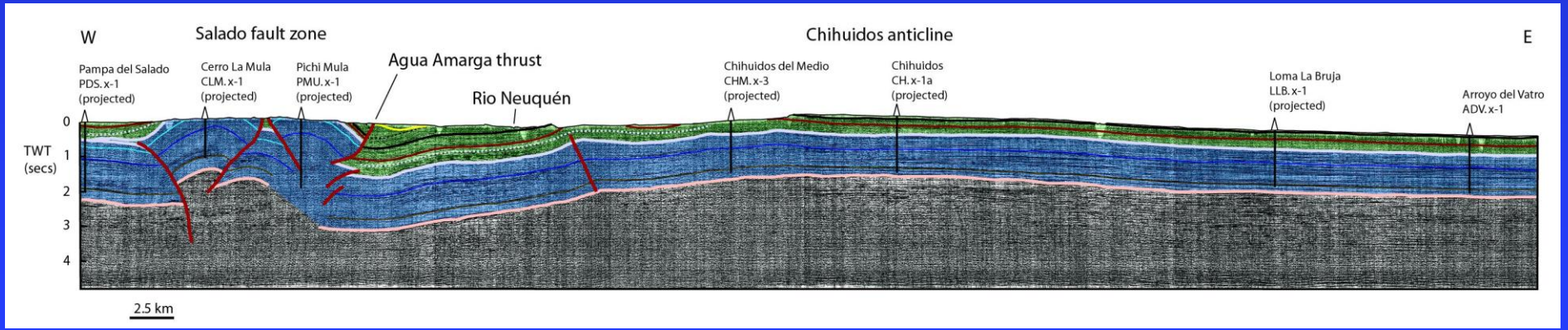
(Cobbold & Rossello, 2003)



Neuquén Basin, regional section

(Cobbold & Rossello, 2003)





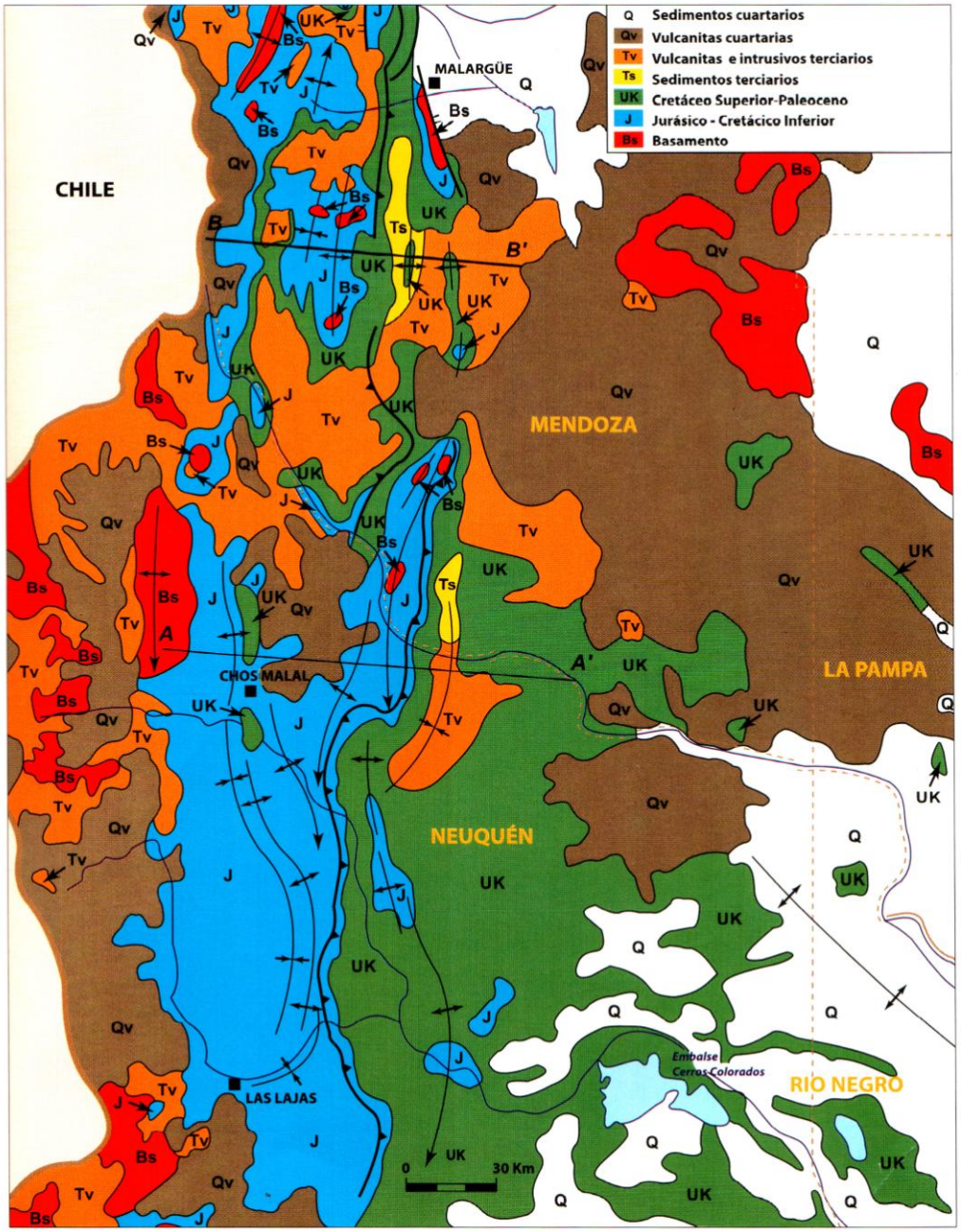
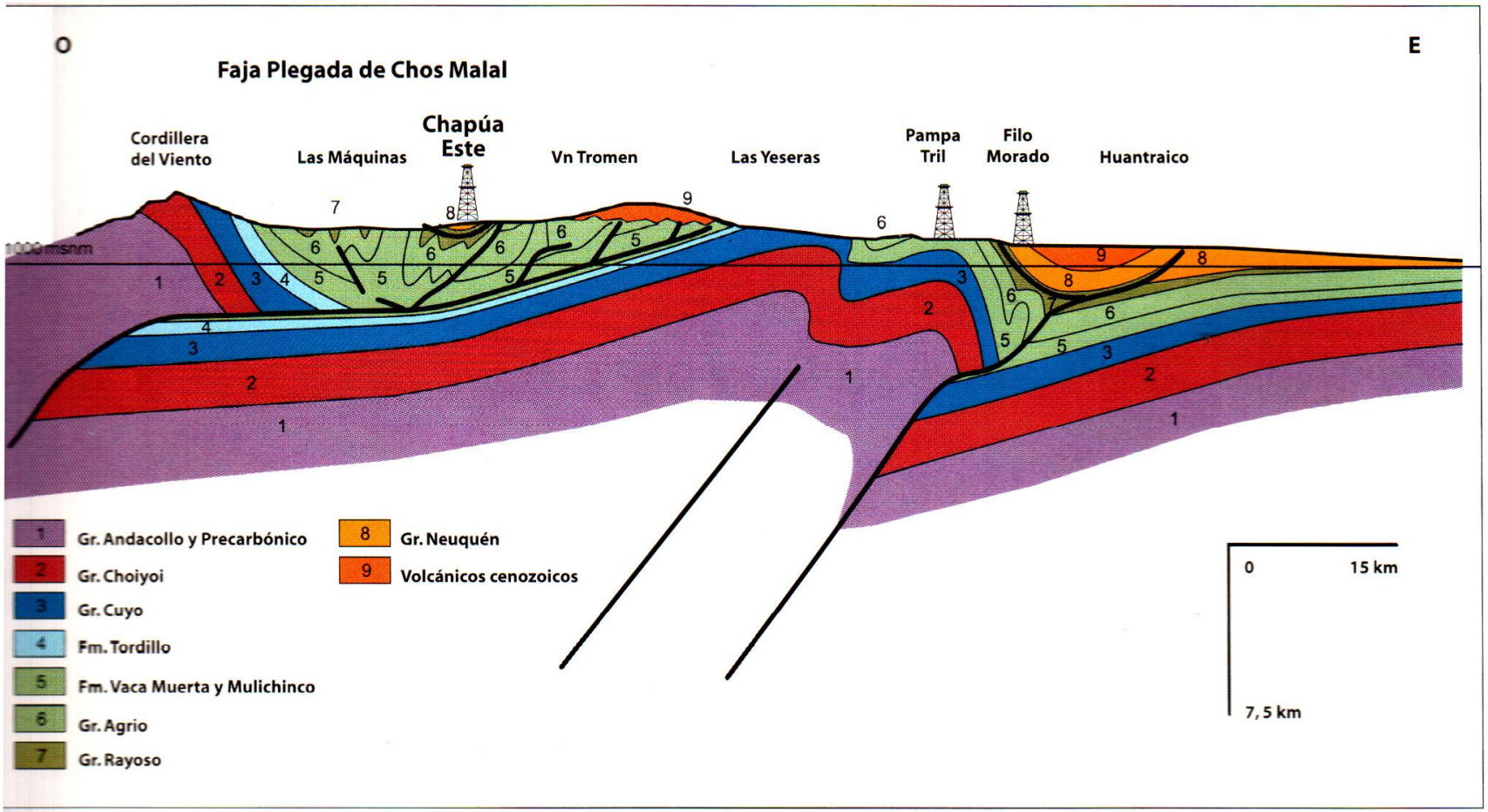


Fig. 2. Mapa geológico sector Centro-Oeste Cuenca Neuquina. A-A'= sección Cordillera del Viento - Filo Morado. B-B'= sección Pehuenche - Cerrito Colorado. / *Central-western Neuquén Basin geologic map. A-A'= Cordillera del Viento - Filo Morado section. B-B'= Pehuenche-Cerrito Colorado section.*

Neuquén Basin, thrust belt

(Kozlowski et al., 1998)

Neuquén Basin, Chos Malal section
(Kozlowski et al., 1998)



g. 5. Corte estructural entre Cordillera del Viento y Huantraico. Ubicación: A-A' en Fig. 2. Detalle de Chapúa Este en Fig. 7. Detalle de Filo Morado en Fig. 8. Modificado Kozlowski et al. (1996). / *Structural cross section between Cordillera del Viento and Huantraico. Location: A-A' in Figure 2. Chapúa Este, detail in Figure 7. Filo Morado, detail in ure 8. Modified from Kozlowski et al. (1996).*

Neuquén Basin
(Kozlowski et al., 1998)

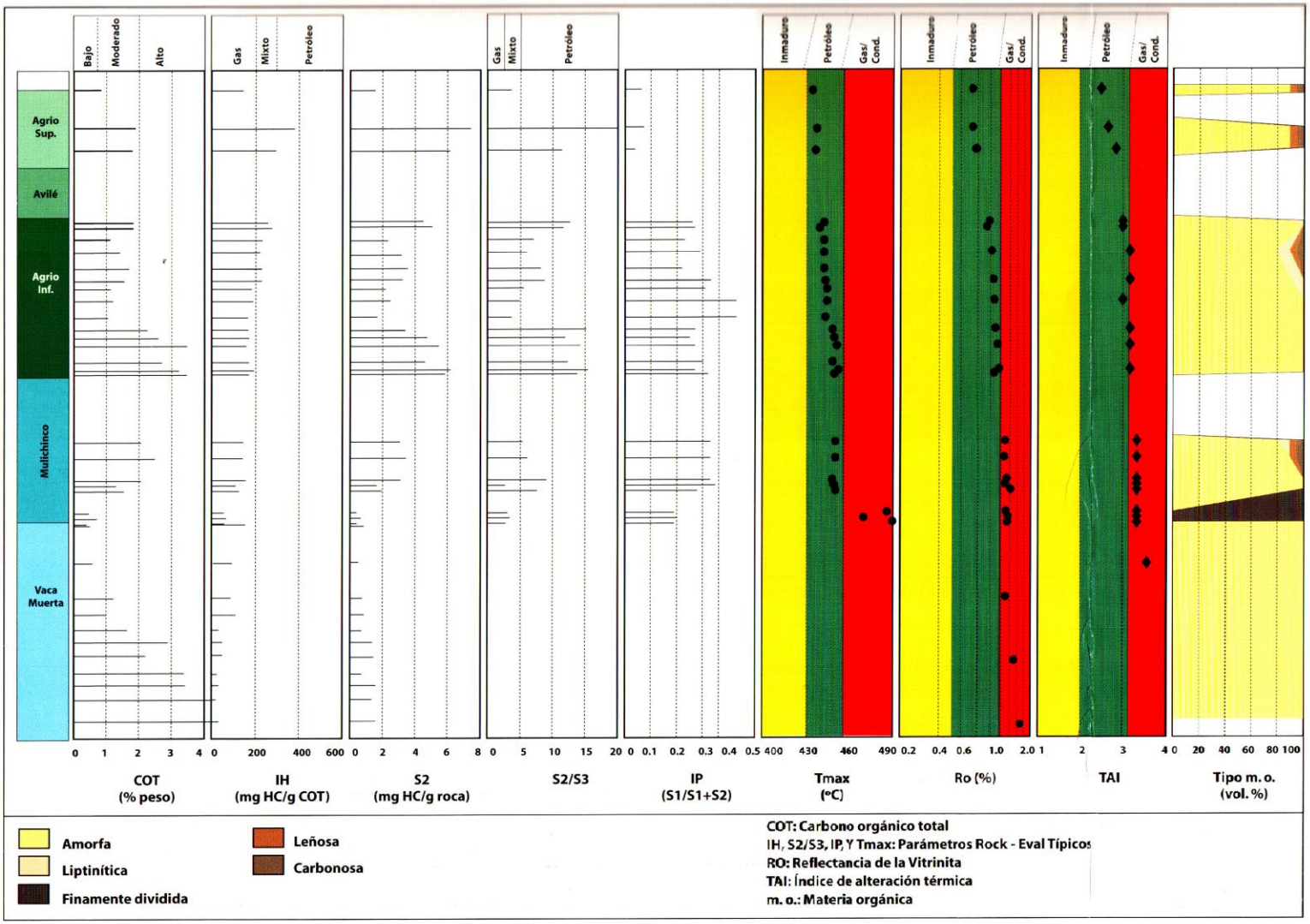
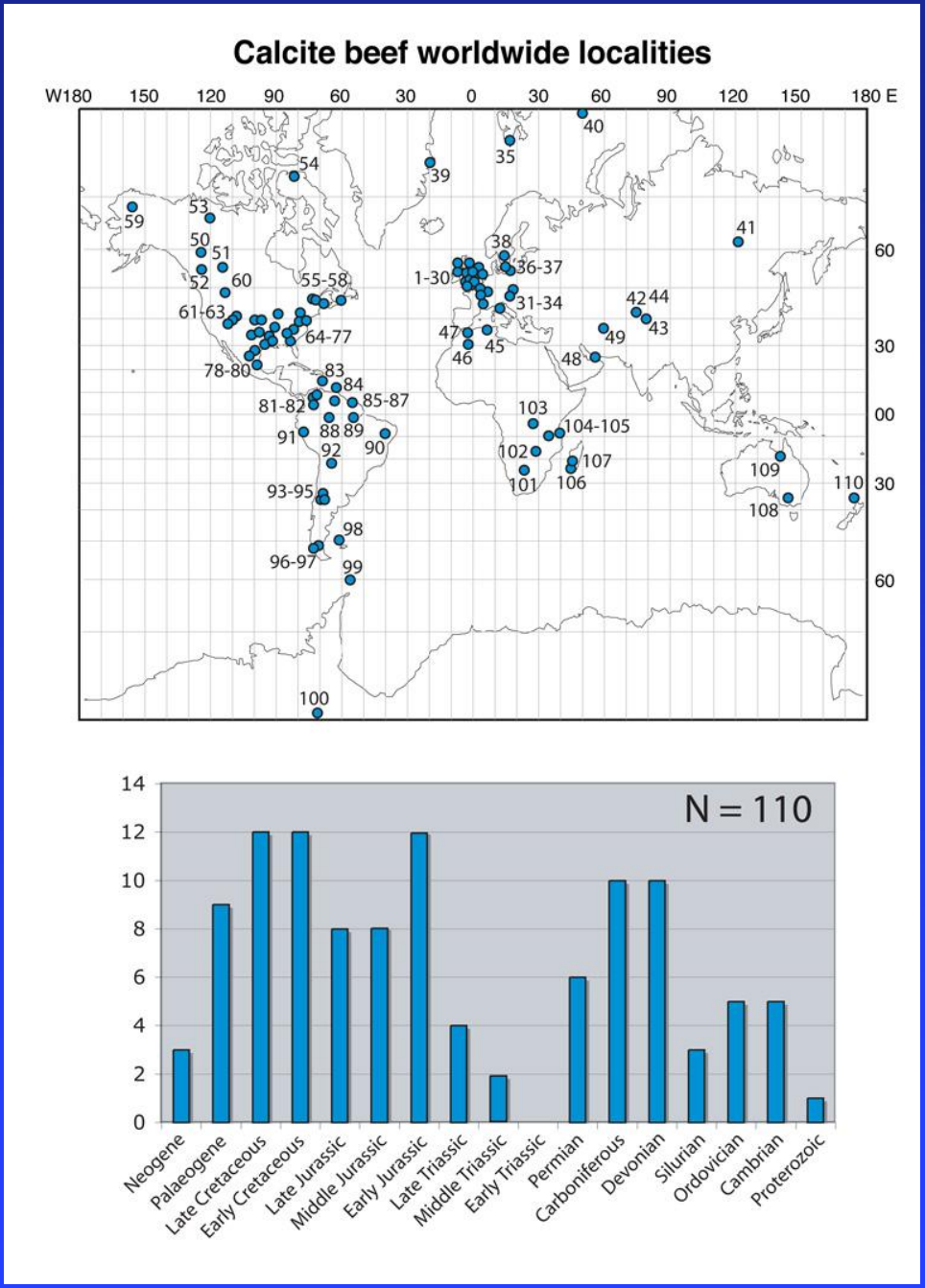


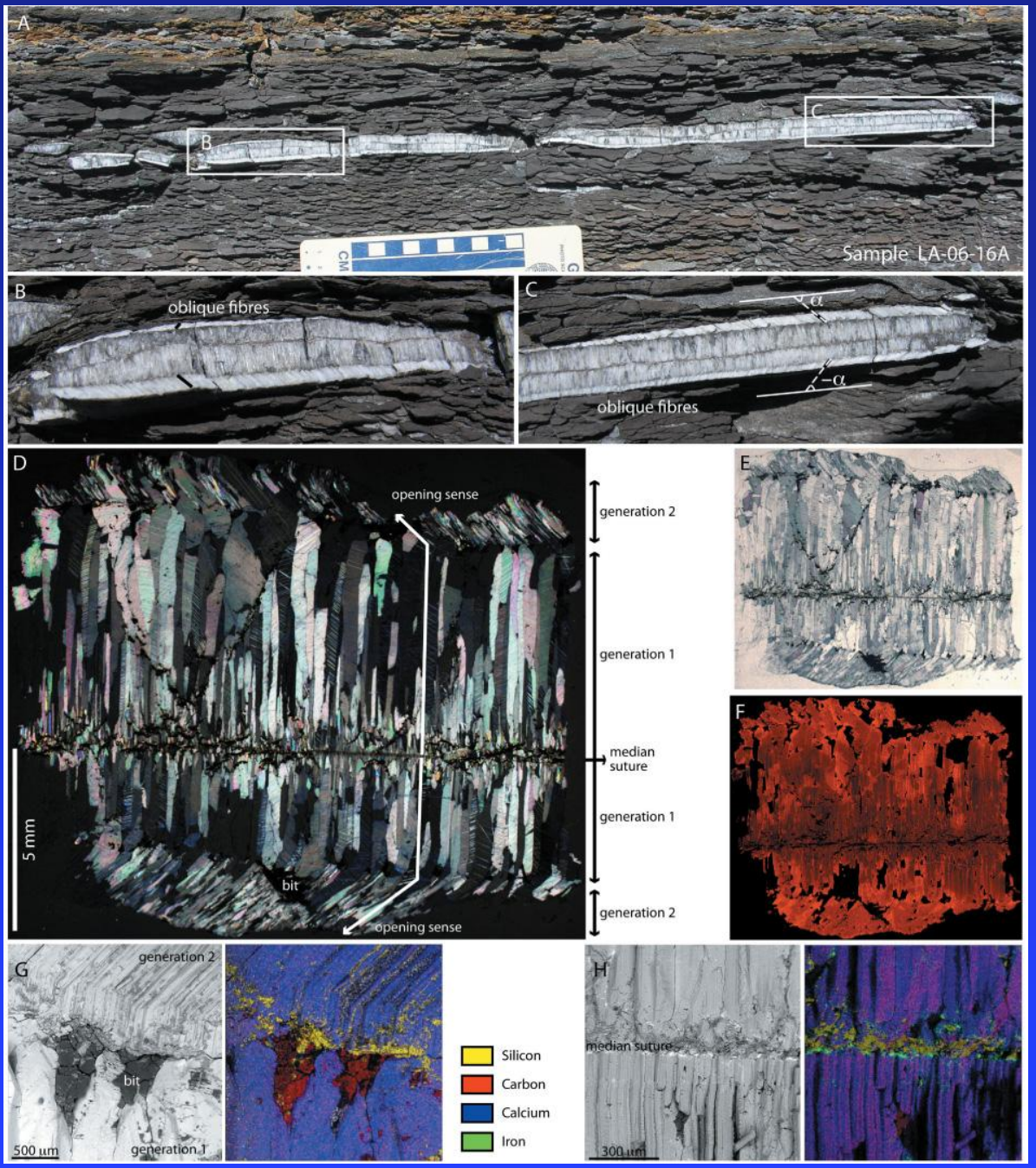
Fig. 11. Perfiles geoquímicos integrados de los pozos Chapúa Este x-1 y Tricao Malal x-1. Modificado de Cruz et al. (1996). / *Integrated Chapúa Este x-1 and Tricao Malal x-1 well logs. Modified from Cruz et al. (1996).*

Neuquén Basin, calcite beef

Calcite beef and cone-in-cone, worldwide

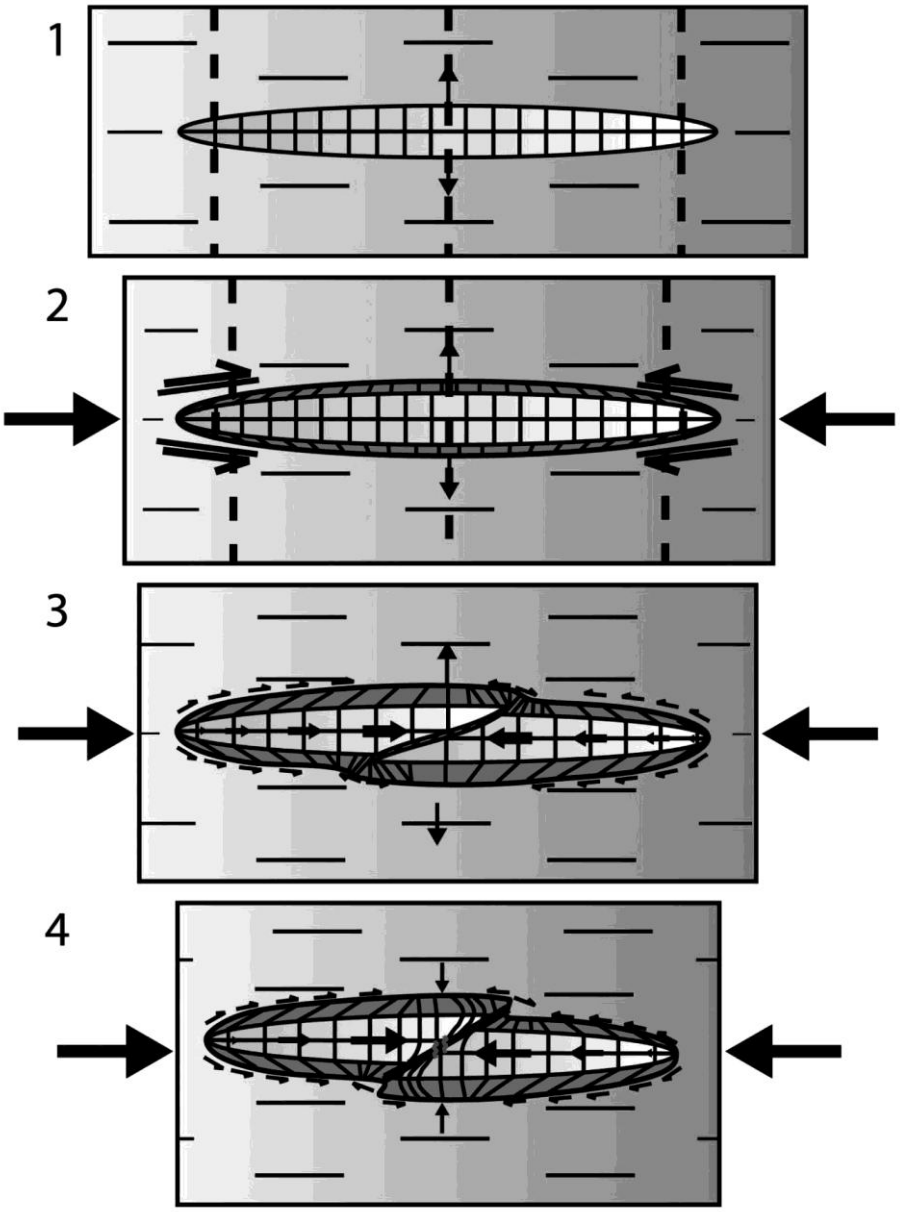
(Cobbold et al., 2013)





Neuquén beef

(Rodrigues, Cobbold Loseth & Ruffet, 2009)

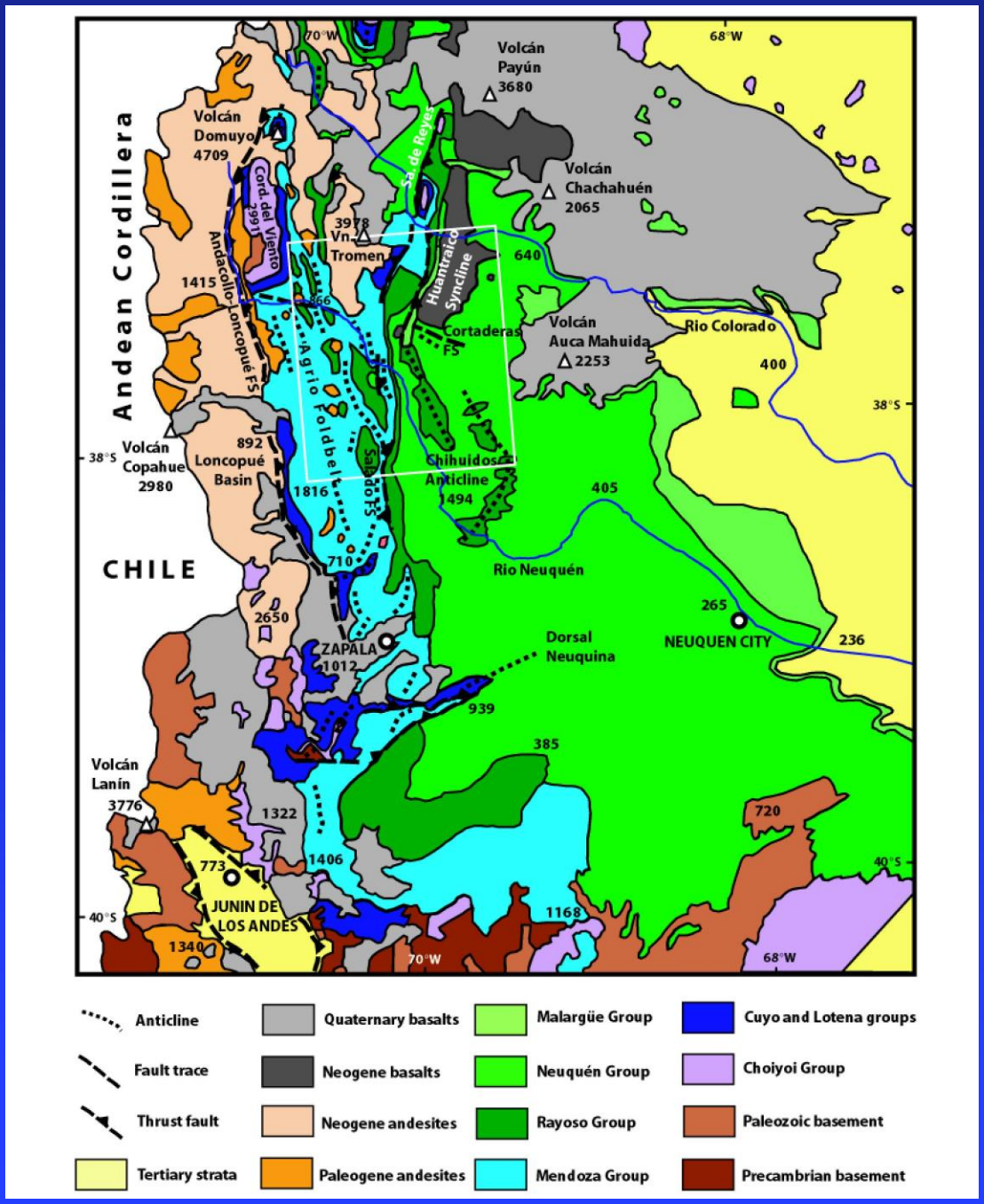


Development of beef, Neuquén Basin

(Rodrigues, Cobbold & Loseth, 2009)

Neuquén Basin, geological map

(Cobbold & Rossello, 2003)



Los Castaños bitumen mine, Mendoza
(Borrello, 1956)

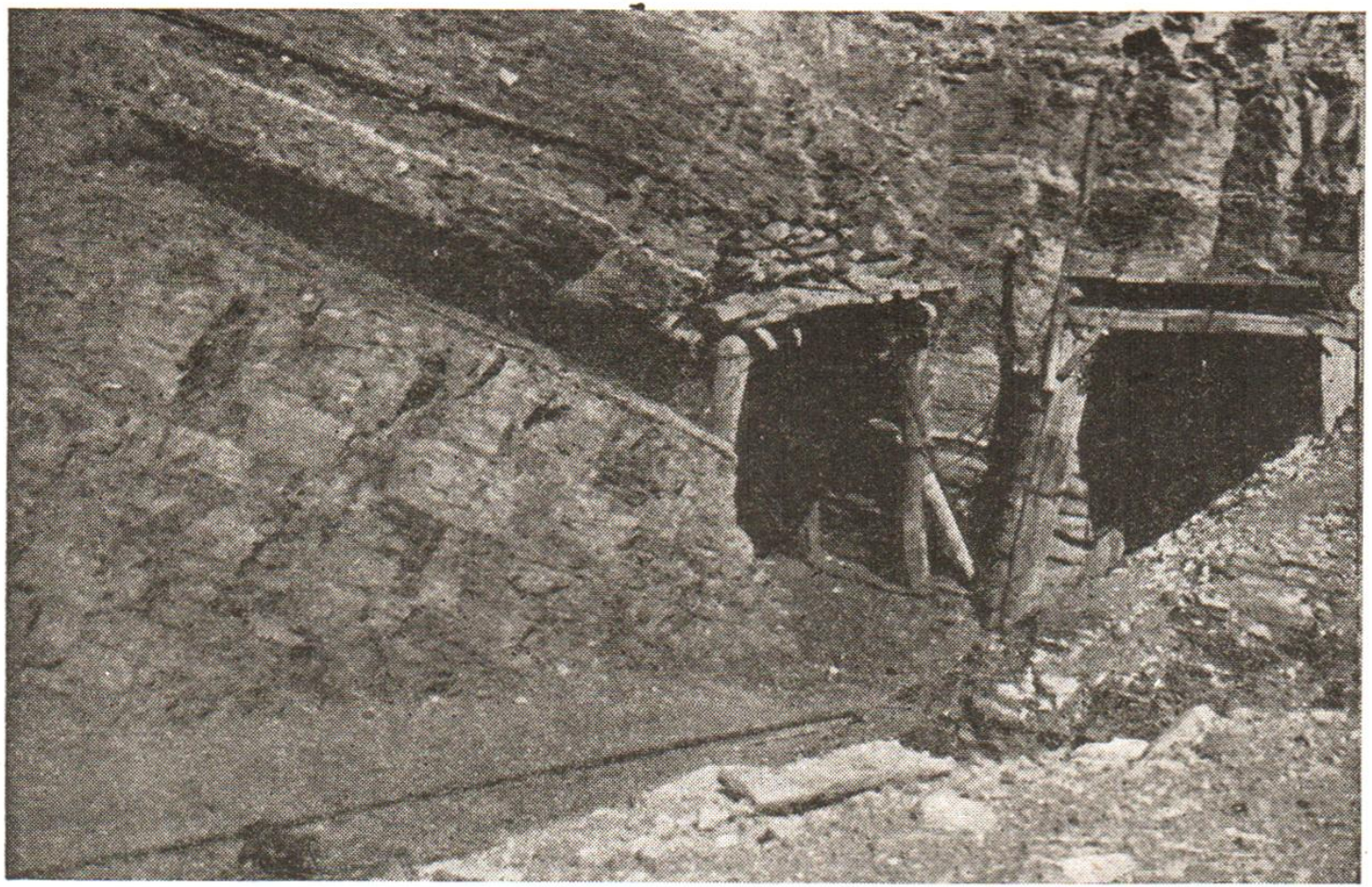
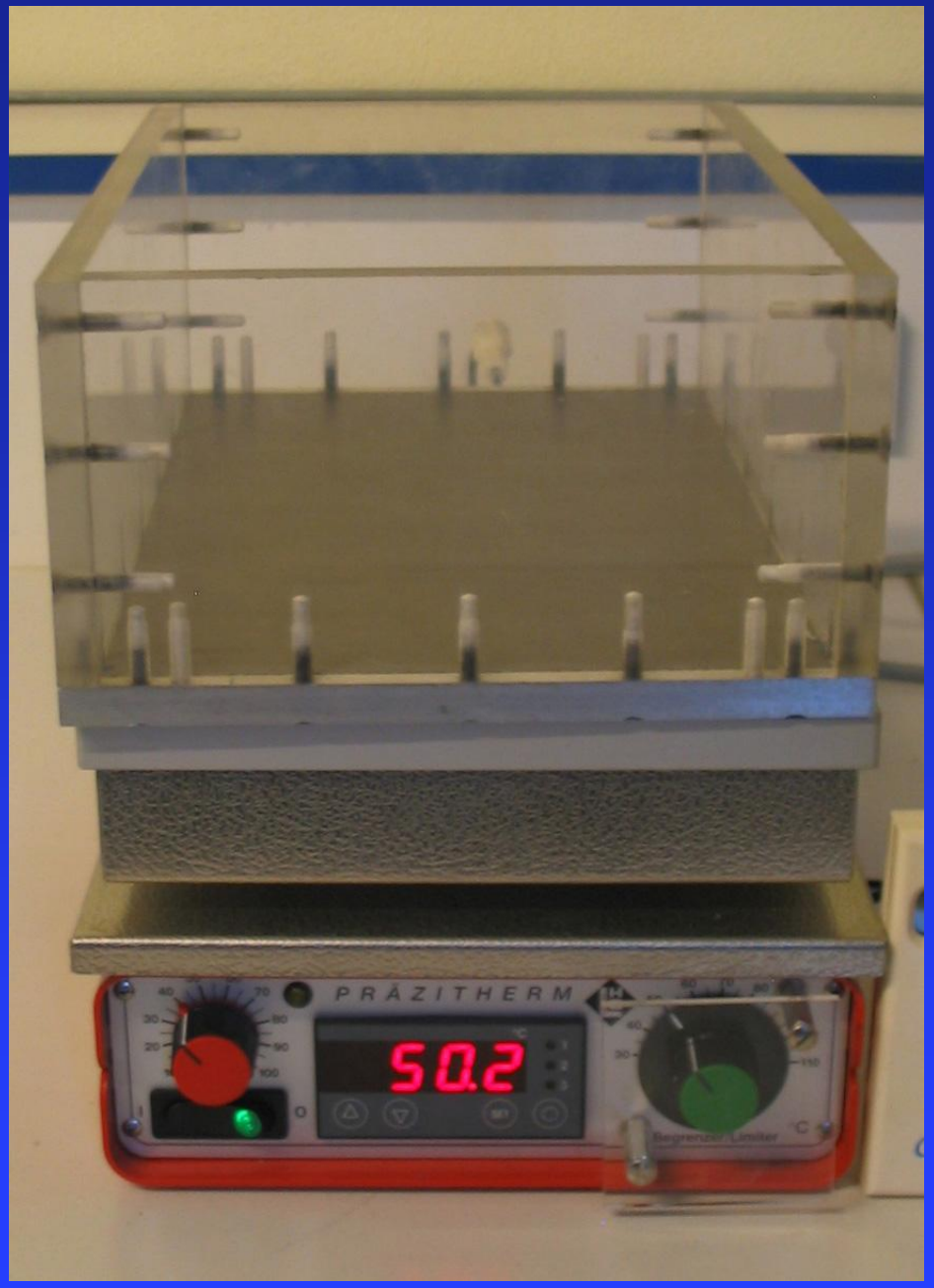


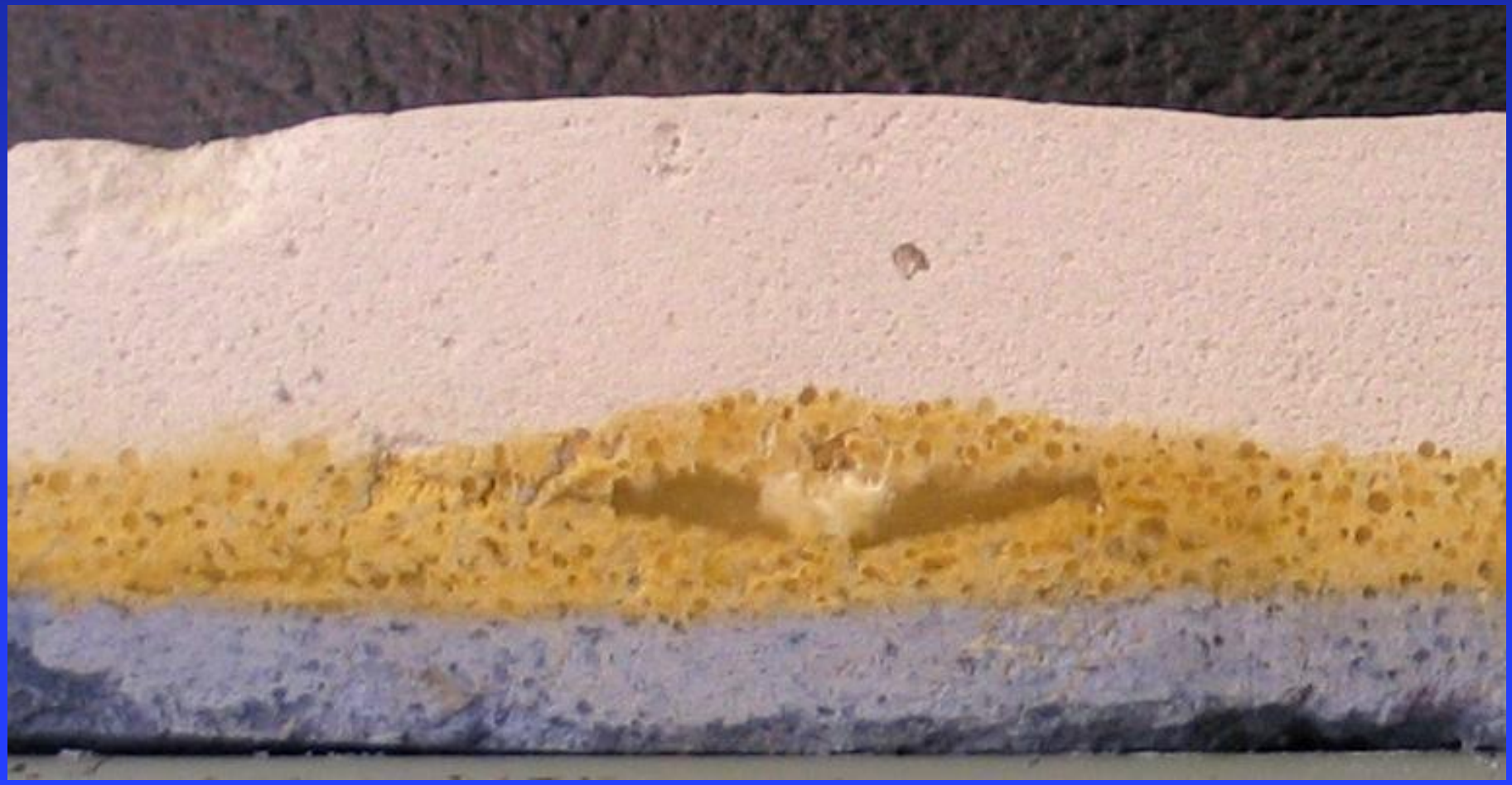
Fig. 96. — Mina « Los Castaños », río Salado, Mendoza. Afloramiento asfaltitífero abierto por una galería exploratoria en dirección. A la derecha, bocamina del chiflón N° 4. (Fotog. A. V. Borrello, 1951)

Experiments on load transfer

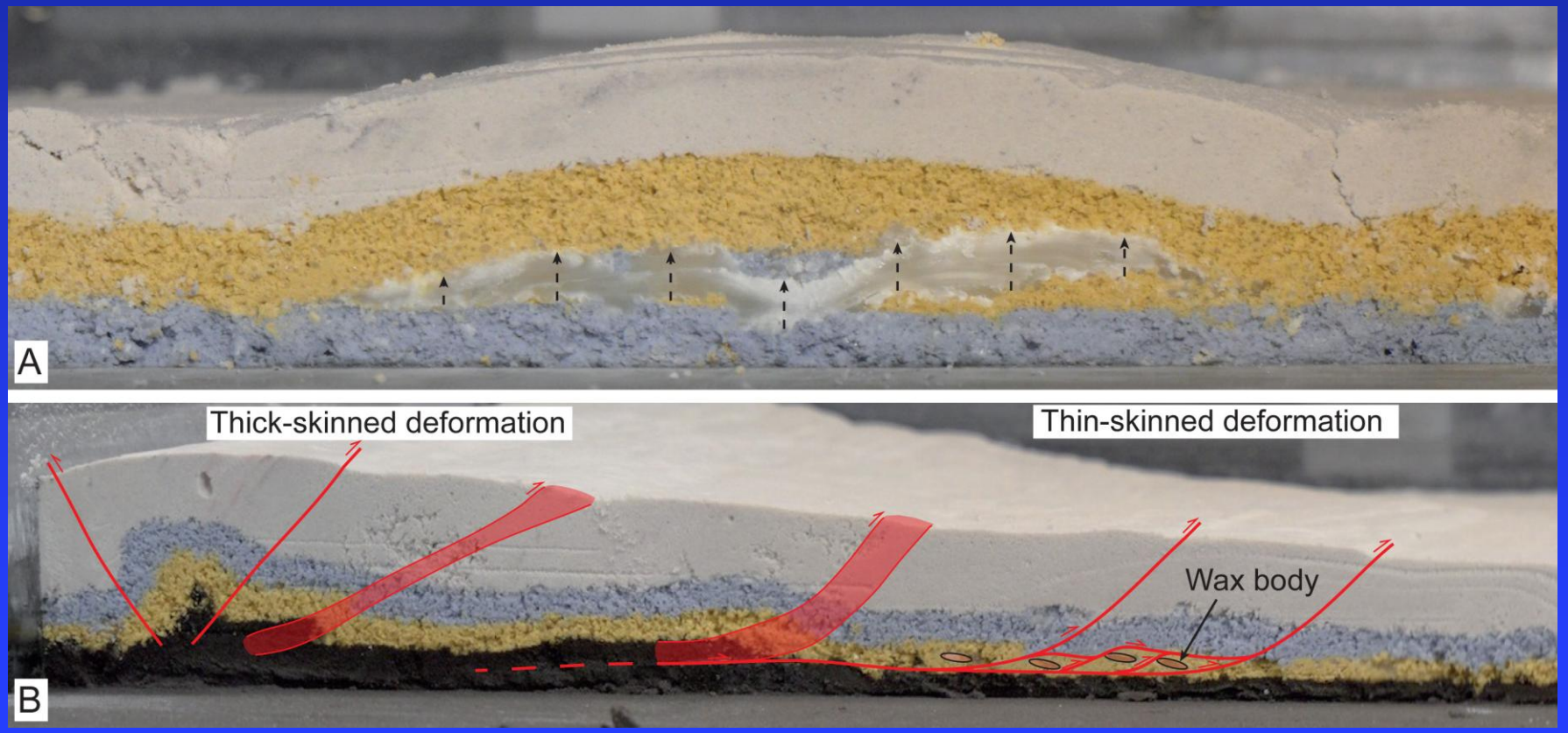
(Lemrabott & Cobbold, 2010)



Experiments on load transfer
(Lemrabott & Cobbold, 2010)

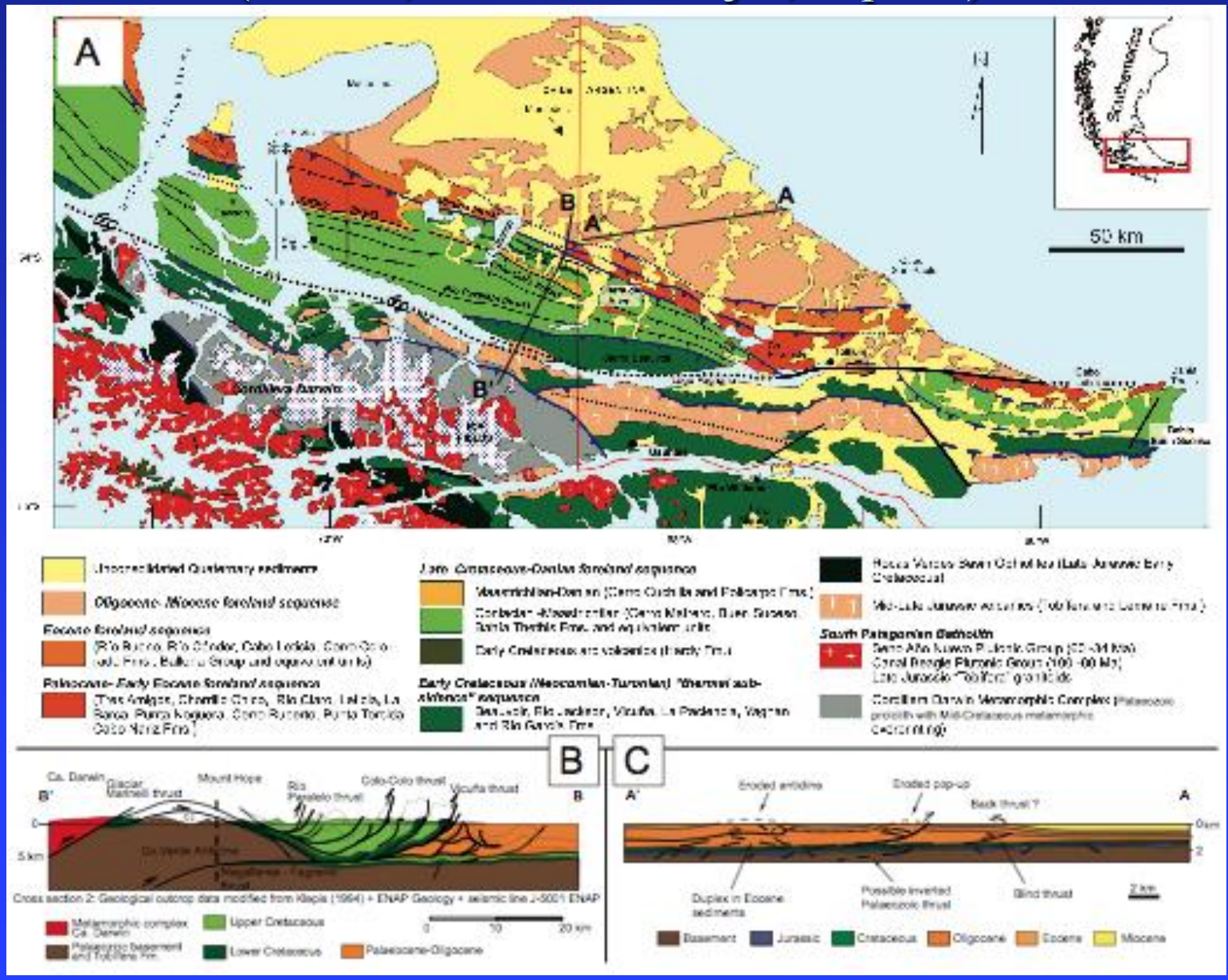


New experiments on load transfer
(Zanella & Cobbold, in review)



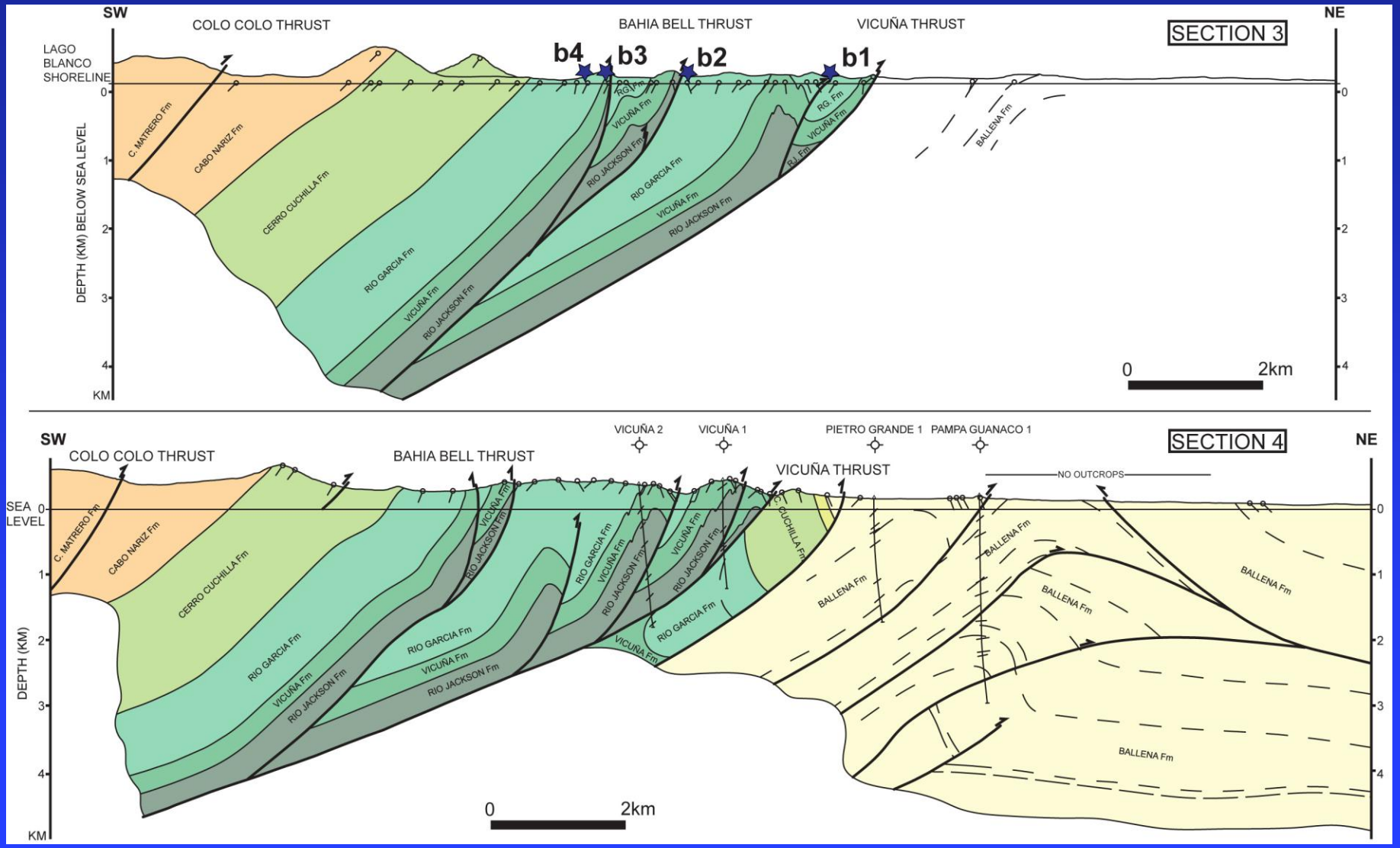
Tierra del Fuego

(Zanella, Cobbold & Rojas, in press)



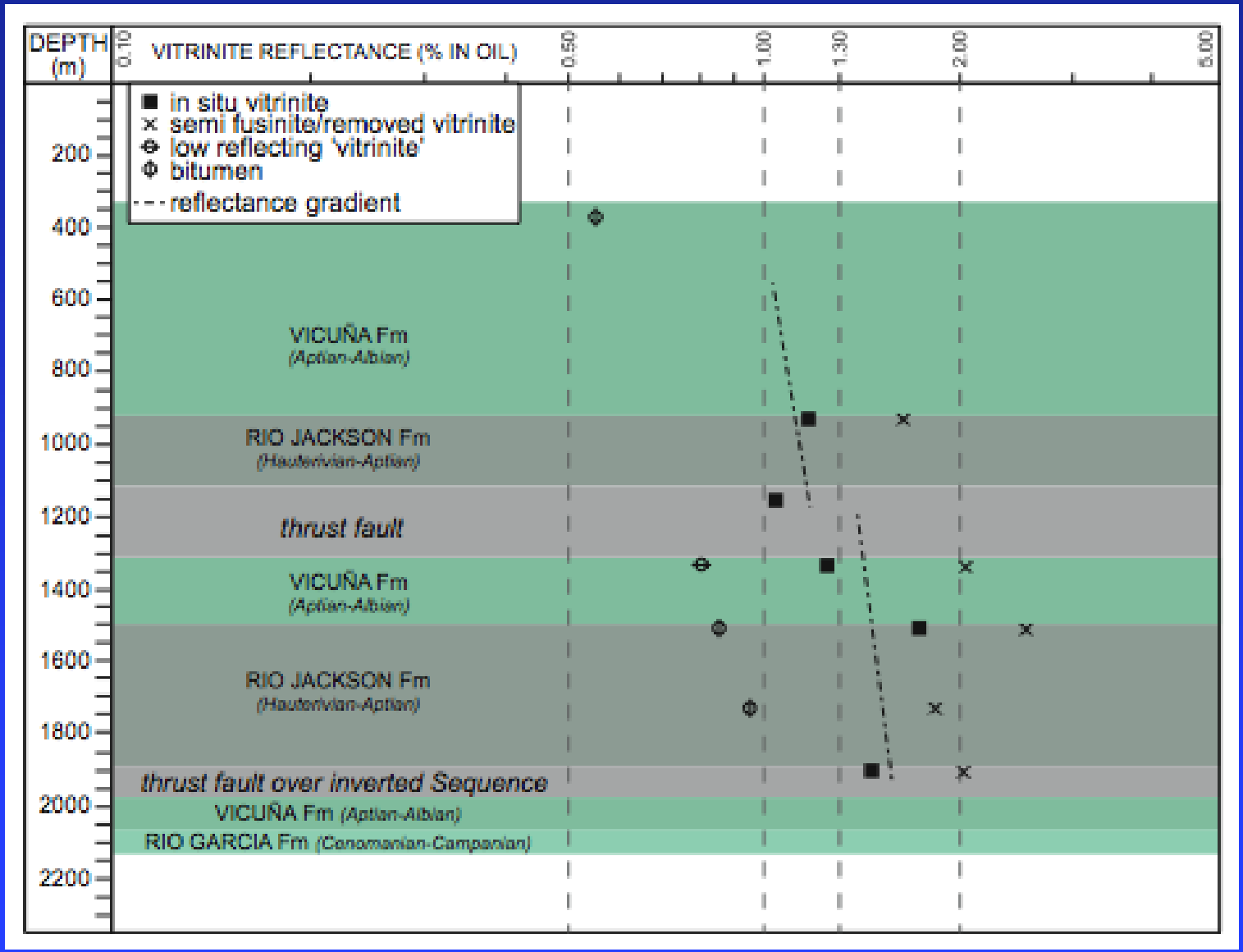
Tierra del Fuego - detachments in source rock!

(Zanella, Cobbold & Rojas, in press)



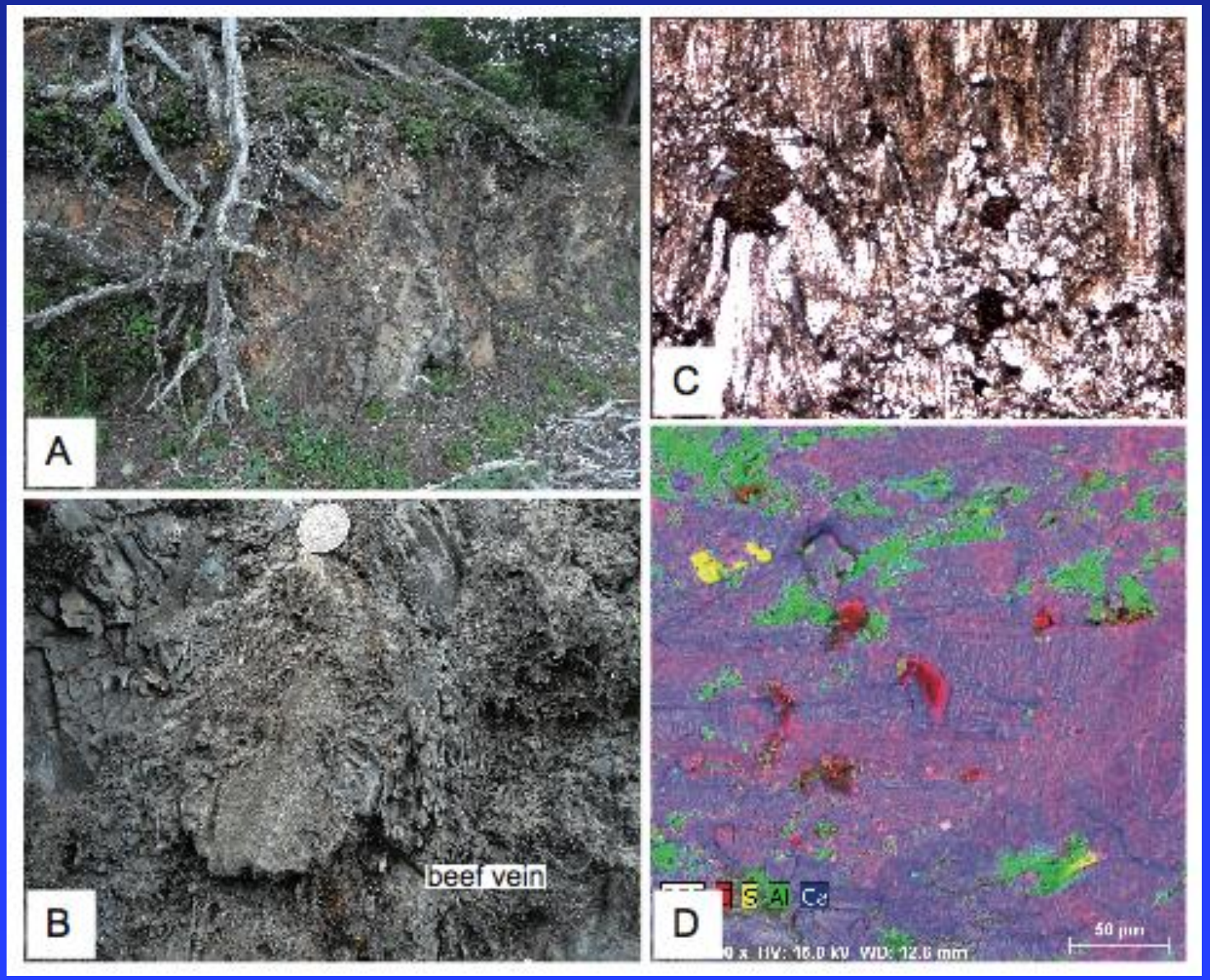
Tierra del Fuego - maturity of source rock

(Zanella, Cobbold & Rojas, in press)



Tierra del Fuego - beef in source rock!

(Zanella, Cobbold & Rojas, in press)



Colombia - detachment/beef in source rock!

(Villeta, Cordillera Oriental)

Conclusions

- In many source rocks, there is good subsurface evidence that maturation leads to overpressure.
- In foreland basins, overpressure leads to thin-skinned detachments.
- In marine-carbonate source rock, overpressure leads to beef, which may contain hydrocarbons.
- Scaled physical models, which allow for phase changes, result in supra-lithostatic overpressure, vertical tensile stress and horizontal hydraulic fractures.