Unconformities, Bauxites, and Tectonics

The case of the Transdanubian Range (Hungary)

Andrea Mindszenty & The Hungarian REEBAUX-Team

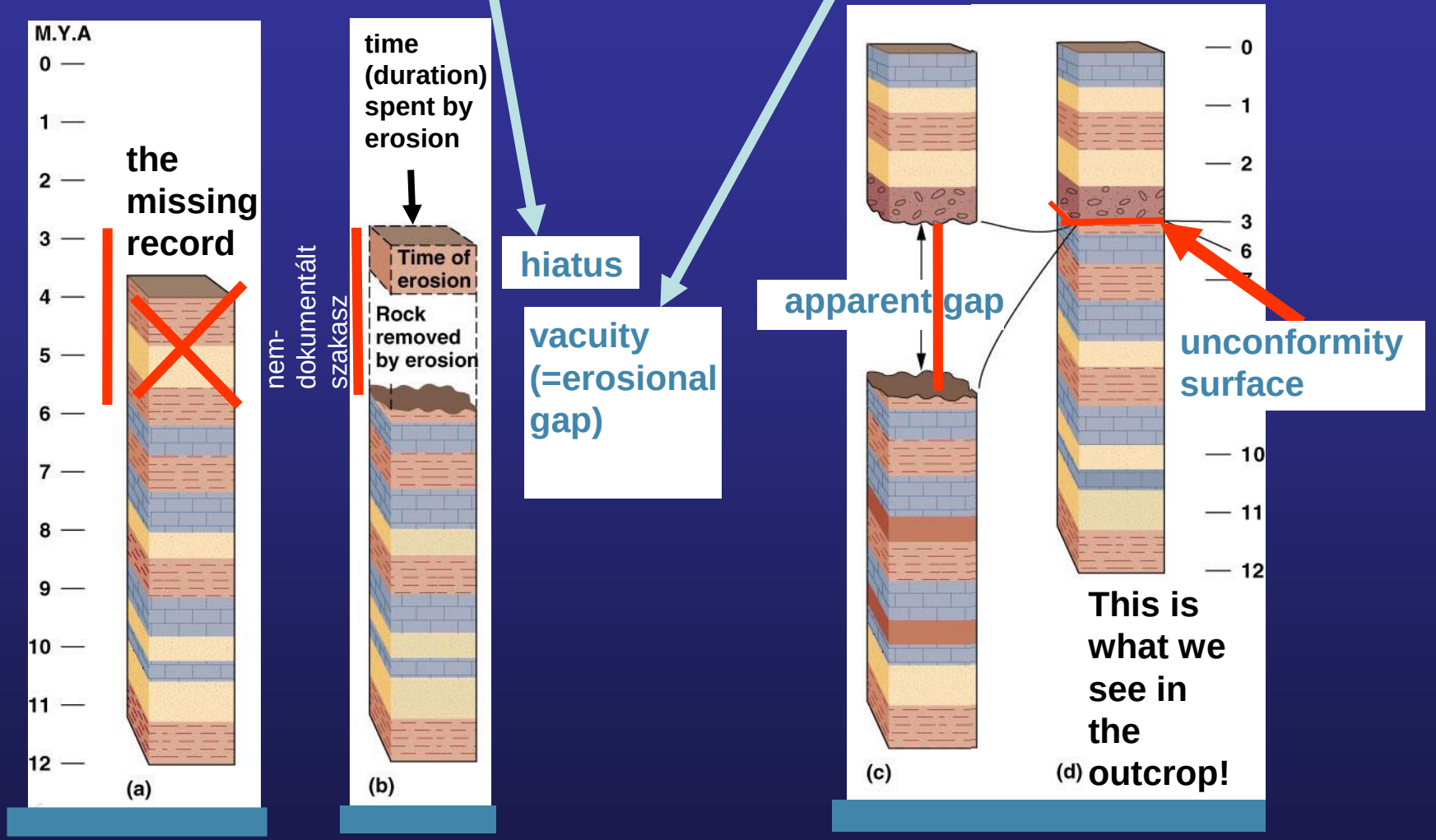
Unconformity

= a surface of interruption in the stratigraphic record, representing an episode of non-deposition and/or erosion

(Geologically significant time-interval not documented by sediments)

Hiatus = the duration of non-deposition/erosion (removal of part of the sedimentary record); this is the true **GAP**)

Vacuity = time represented by sediments eroded during the hiatus



Hiatus + Vacuity = „Lacuna” (apparent stratigraphic gap)

„vacuity” (Sloss 1949)

Lacuna > Hiatus

According to their **duration** , unconformities were recently grouped by MIALL into four broad classes

1) Major (long lasting) regional gaps (10^6 – 10^7 yr)
2) Moderate gaps (10^4 – 10^5 yr)
3) Brief hiatuses (10^0 – 10^3 yr)
4) Minor (ephemeral) gaps (10^{-6} -10^{-1} yr)

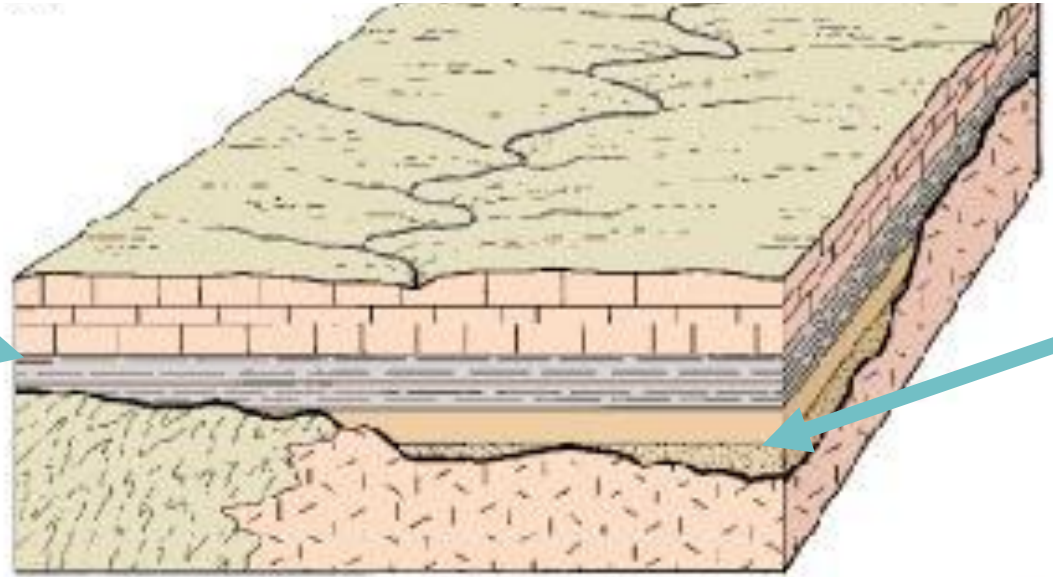
(Miall 2010, 2013, 2014, 2016)

Within each **major** gap there may be hidden stories of several shorter or longer gaps, as well!

To establish **the exact age and duration of gaps** is a very **difficult** if not impossible task! What is more: unconformity surfaces are often **diachronous** because of the topography formed during the hiatus

Diachronism of the deposition of coverbeds over an erosional topography

younger



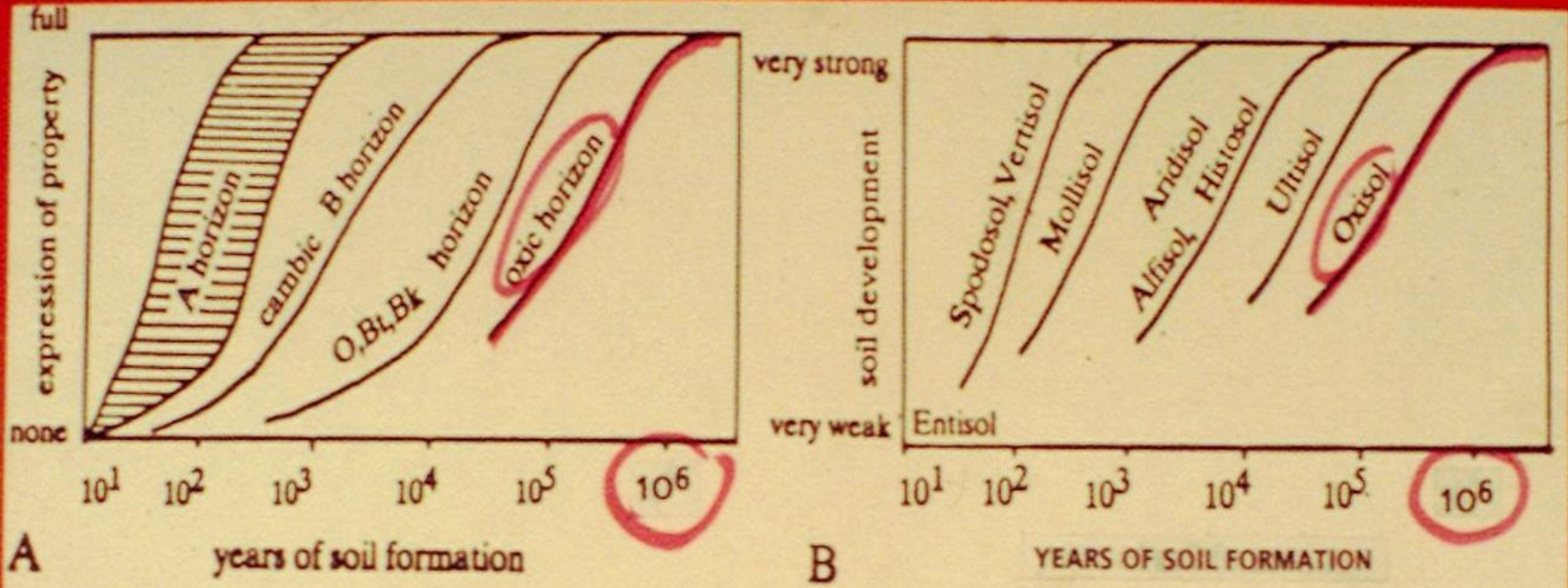
older

Deposition begins in topographic „lows”

When unconformities are marked by BAUXITES, they may help us to understand what exactly has happened during the gap….

They may provide information about climate, landform-formation and many other things!

DURATION of EXPOSURE necessary for BAUXITE-FORMATION
(the Soil-Science Analogue)
Bauxites (=oxisols) are products of long-lasting tropical weathering



Schematic representation of the times needed to attain at various properties of soils (A) and orders of soils recognized by the Soil Conservation Service of the US Department of Agriculture (B); modified from Birkeland 1984.

(after RETALLACK 1990)

Bauxites of the Karstic Association

= Karst Bauxites

(related to major subaerial unconformities)

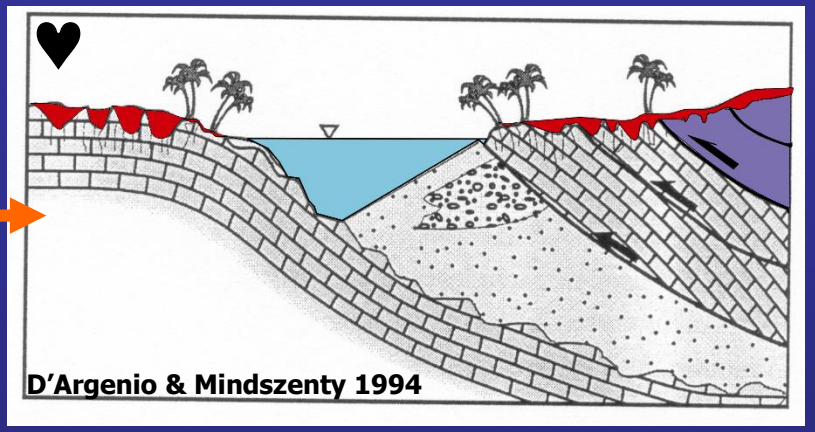
signs of

long-lasting subaerial exposure + hot humid climate

Long lasting exposure in carbonate depositional environments needs tectonics!!!

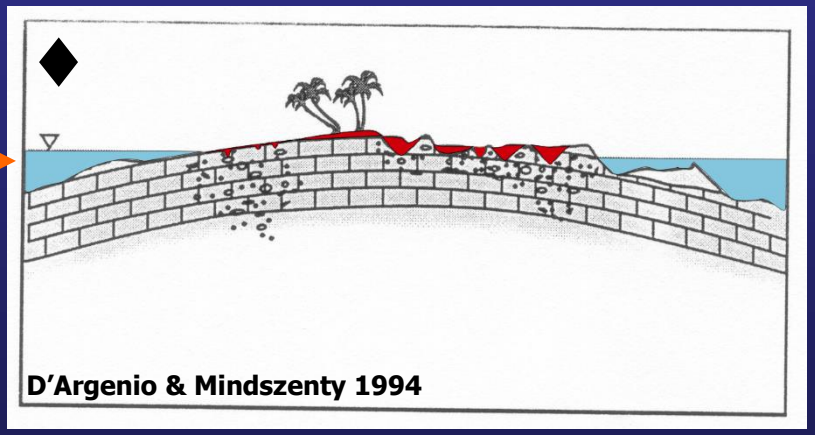
Tectonics/geodynamics potentiallly generating bauxitiferous unconformities in carbonate depositional environments

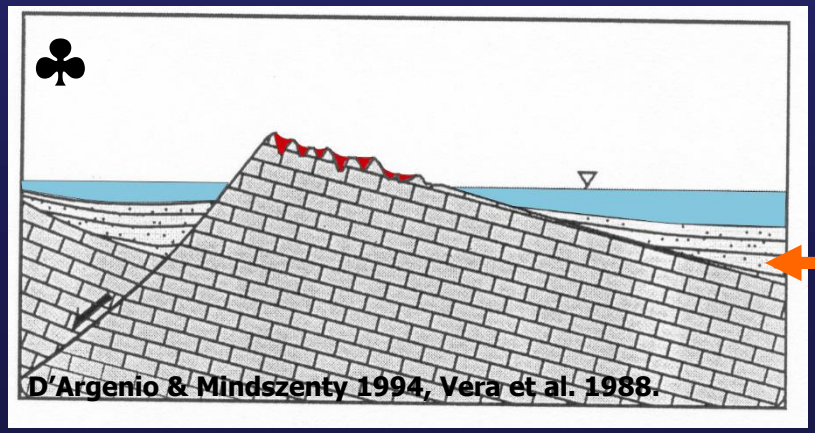
„Collision" zones ♥
(flexural deformation, thrusting)



P R E S E R V A T I O N !!!

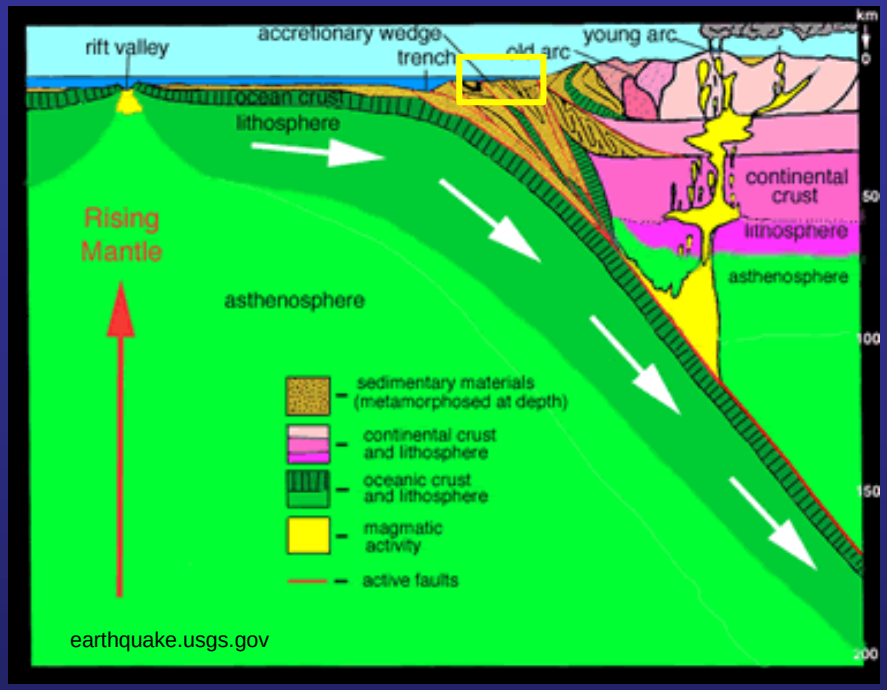
„Passive" plate-interiors ♦
(intra-plate deformation)

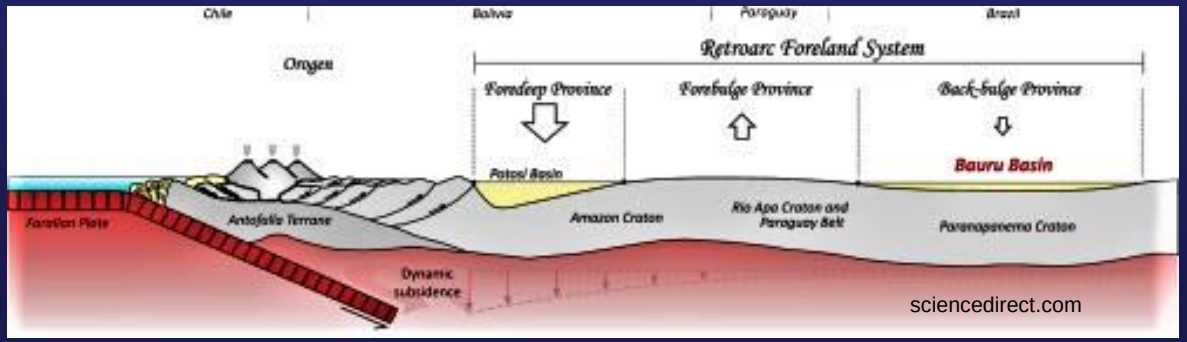




Rifting, strike-slips, transtensional deformation) („block-rotation") ♣

The „big” framework





Geological controls of primary REE-enrichment (Goodenough et al. 2016) fit into the „big"framework

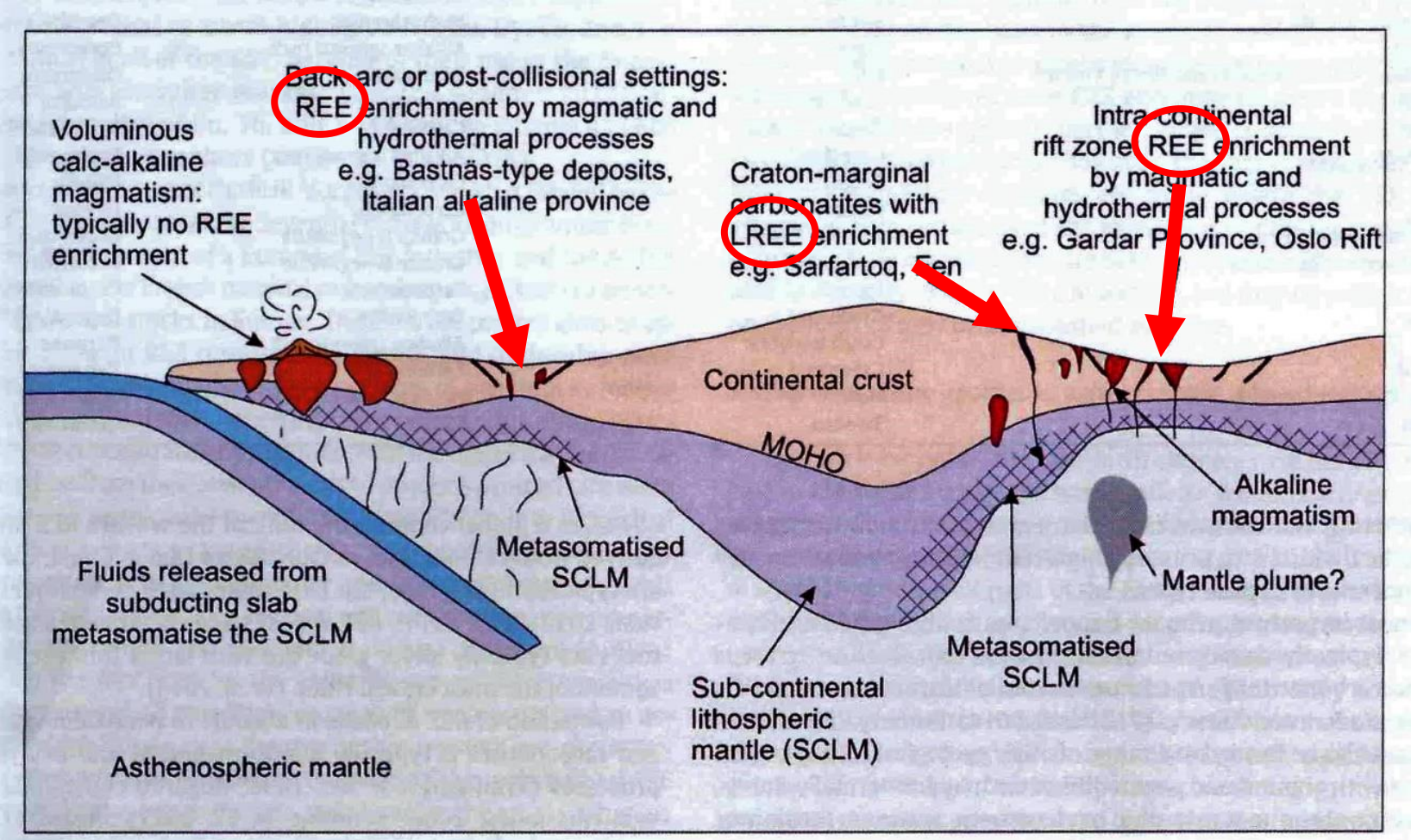
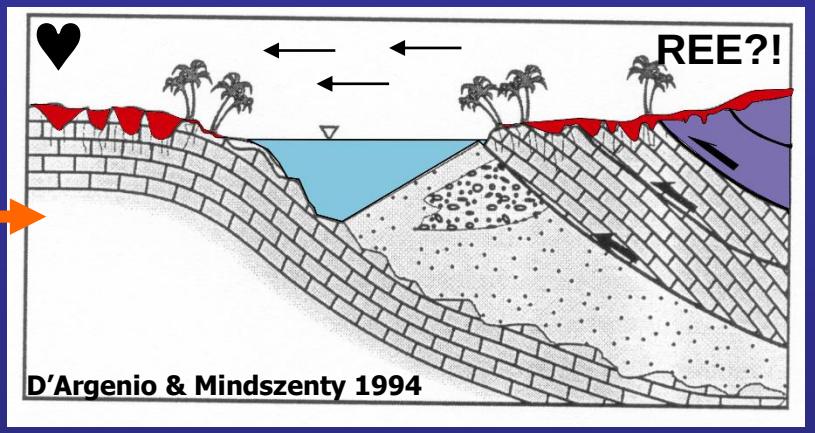


Fig. 1. Schematic diagram to illustrate the main environments of formation of alkaline igneous rocks and carbonatites, major hosts of many REE deposits.

REE's are enriched in the SCLM and may occur in alkáli carbonatites in igneous and hydrothermal formations of intracontinental rift settings and (supposedly) also in obducted ophiolites

Tectonics/geodynamics potentiallly generating bauxitiferous unconformities in carbonate depositional environments

„Collision" zones ♥
(flexural deformation, thrusting)



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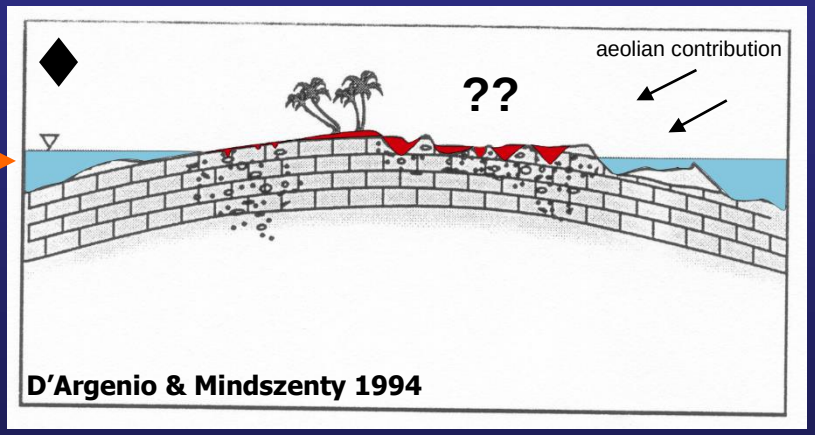
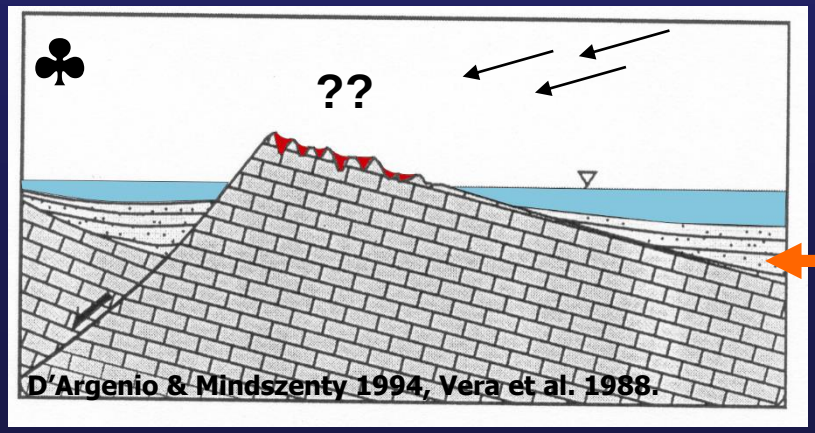
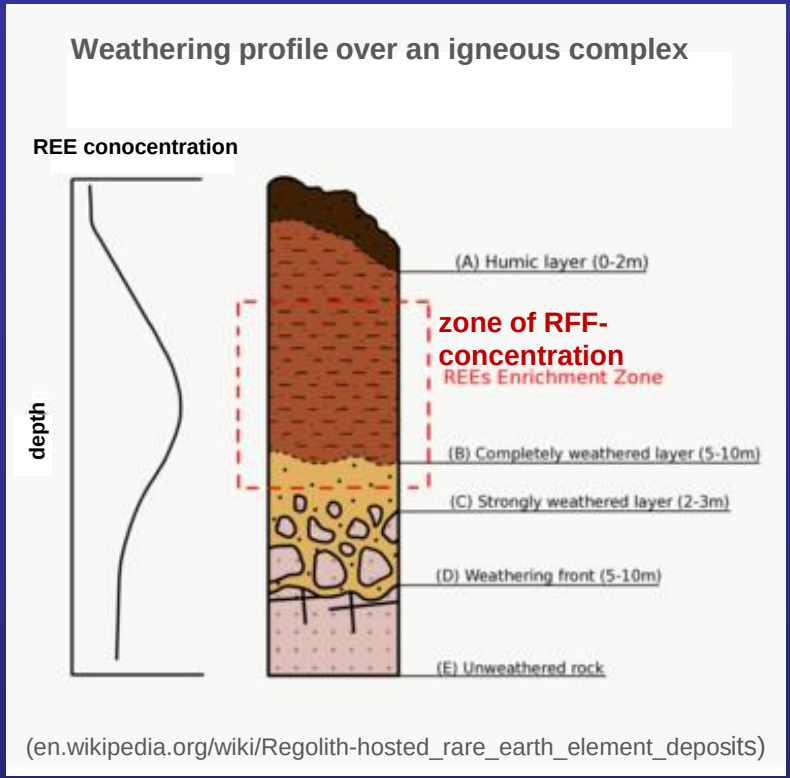
(intra-plate deformation)





Rifting, strike-slips, transtensional deformation) („block-rotation") ♣

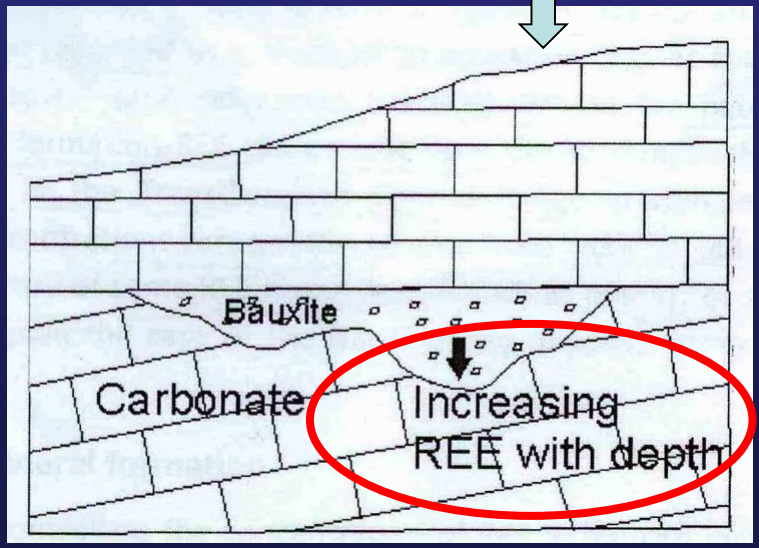
Secondary enrichment of REE's (related to surface alteration of igenous or metamorphic rocks)



Trnaslocation of REE's in a Karst bvauxite

(REE-enrichment at the bauxite/bedrock contact)

In the course of chemical wethering and pedogenesis REE's are mobilized and become fractionated/eniched according to the pH and Eh conditions of the weathering environment **(tropical weathering!)**



(Bárdossy 1982)

Bányászati technológia!!! (recens vs fosszilis)

The story behind a long-lasting subaerial exposure

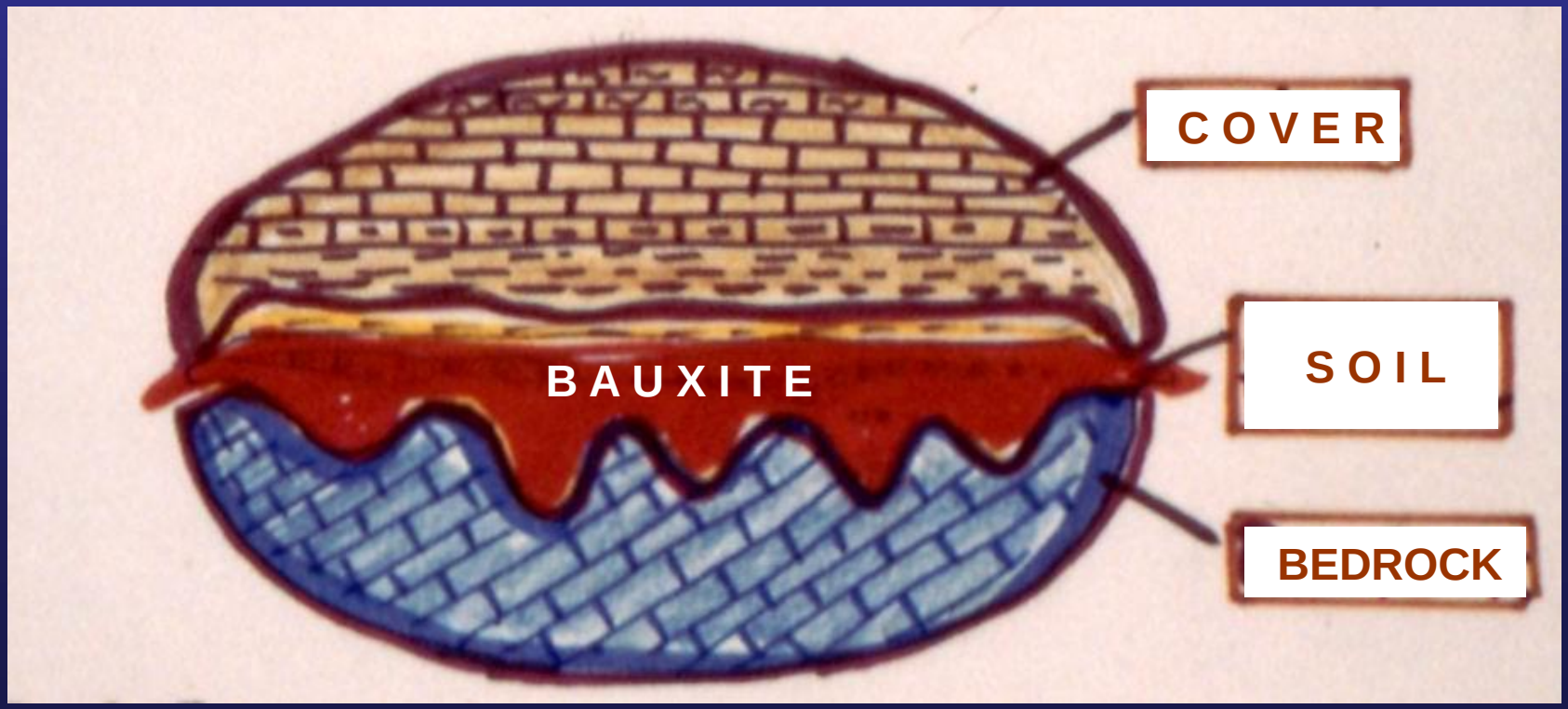
What happened

...before..

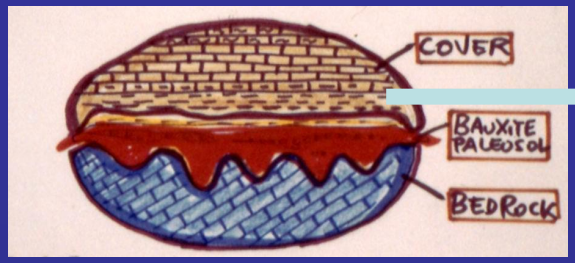
...during..

...after..

...the exposure

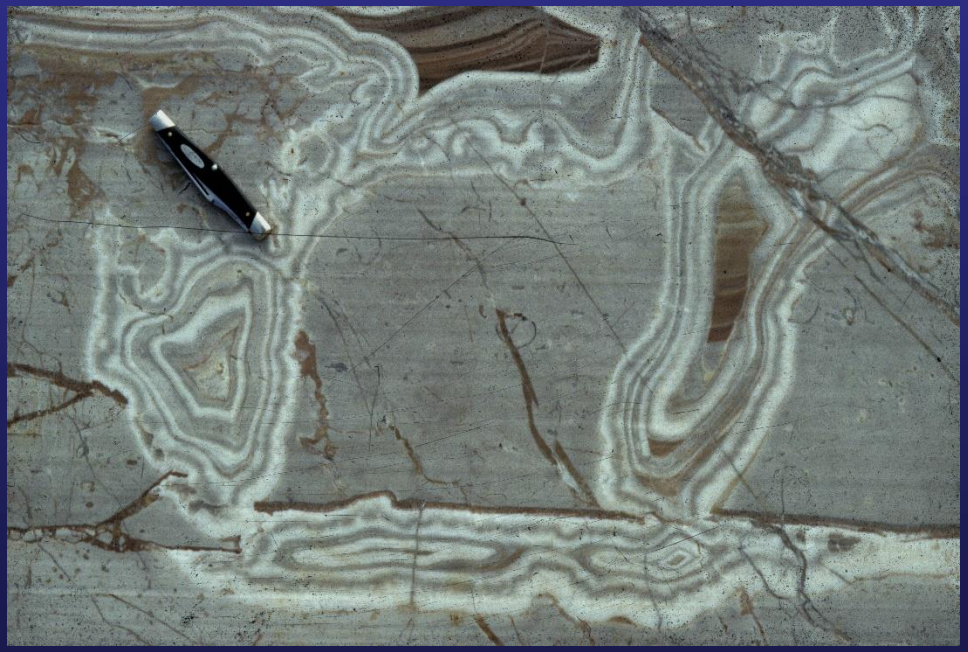


BAUXITE = Palaeoenvironmental signal for the EXPOSURE PHASE



BEFORE...

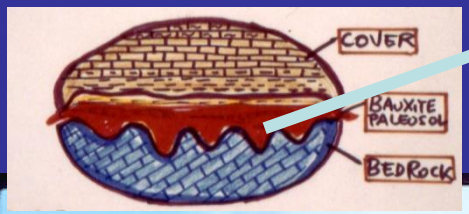
AFTER...



Cover:

The style of submergence

Bedrock: The story of the uplift/karstification



Bauxite: The significance of micro-extraclasts (<0,X%) (0,06-0,2 mm Ø)

Information regarding exposed rocks in the wider surroundings

Transdanubian Range: denudation history of the surrounding non-carbonate terrains

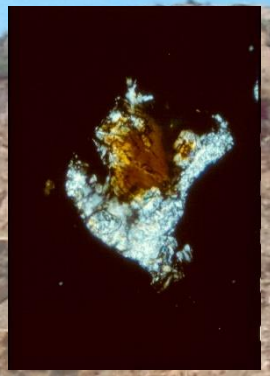
DURING...

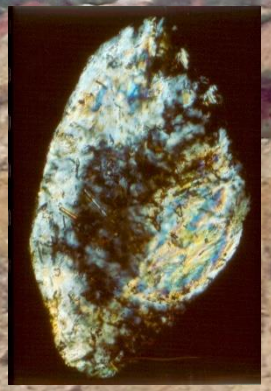
Albian

titanite

alk.amphibole

Santonian





calc-alkaline igneous, anchimetamorphic

Paleogene

rock-fragments with kyanite, sillimanite

Staurolite, zircon, ilmenite, volcanic rock fragments

The Karst Relief (hydrology!)

morphofacies + lithofacies-I.

Position as related to **groundwater table** reflected by **mineralogy** (Fe-minerals) and **geochemistry** (COLOUR!!!) of bauxite

HIGH-LEVEL KARST	SLOPING TERRAIN	LOW-LEVEL KARST
(par)autochthony	parallochthony	allochthony
in situ processes predominant	transitional	resedimentation

karsztvízszint watertable

red matrix

pale-yellow to grey matrix

topographic high: unsaturated (vadose) **oxidizing environment**

topographic low: saturated (phreatic to semiphreatic) **reducing environment**

High-level Karst:

deep-sinkhole-filling deposits,

Fe3+ minerals

predominant

(deep red color)

Low-level Karst:

layer-like deposits filling

uvalas-, poljes

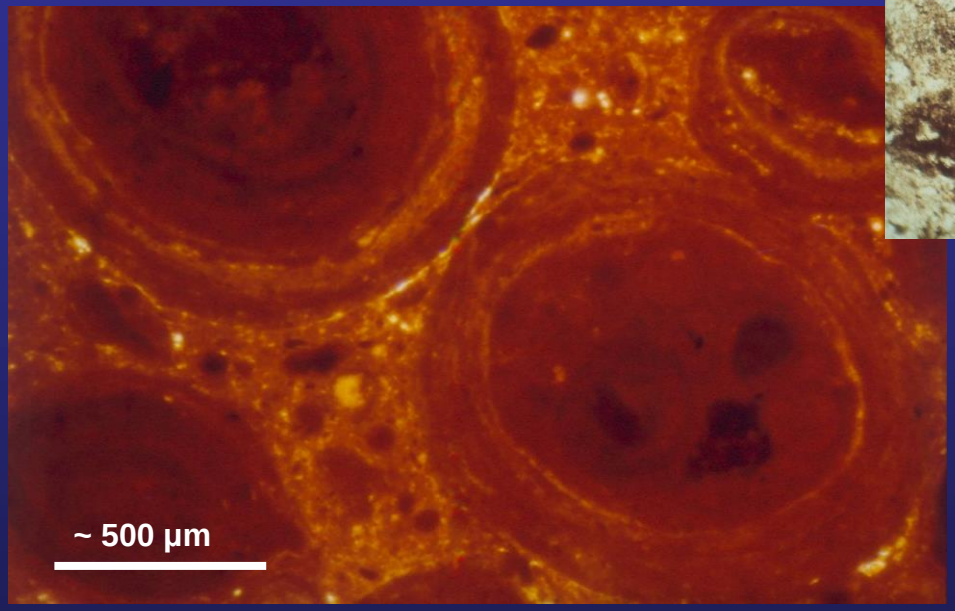
Fe3+ minerals

subordinated,

(pale, yellow, pink or grey color)

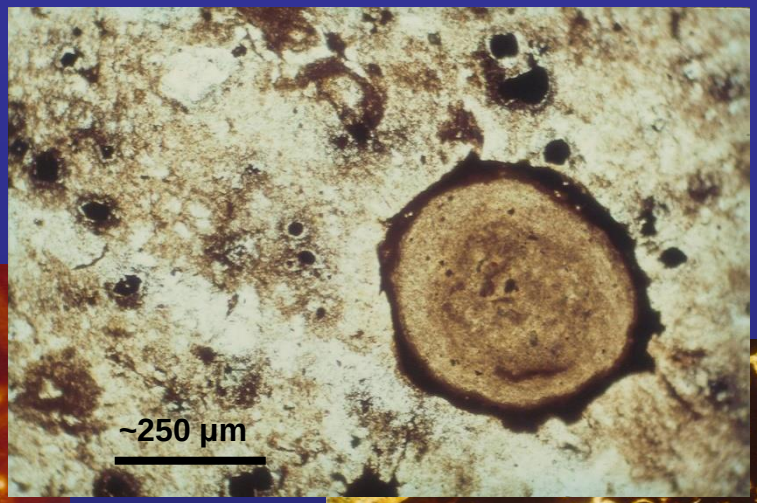
Both morpho- and lithofacies are controlled by the topographic position as related to base-level of erosion (=karst watertable)

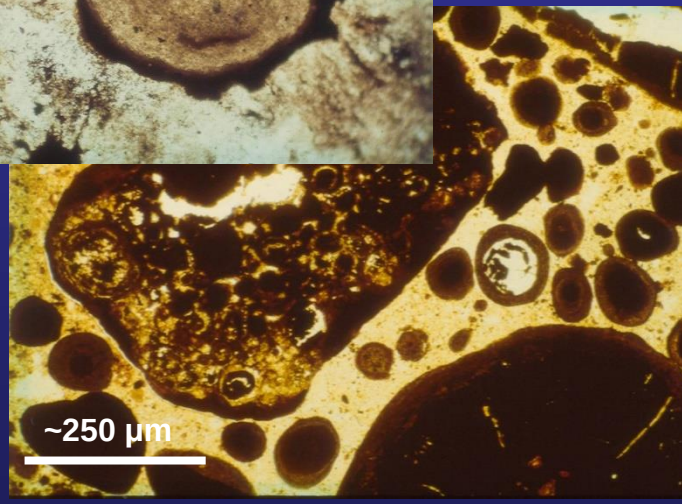
High-level Karst



in-situ oolithic textures,
predominant autochthony,
gibbsite (boehmite) haematite

Low-level Karst





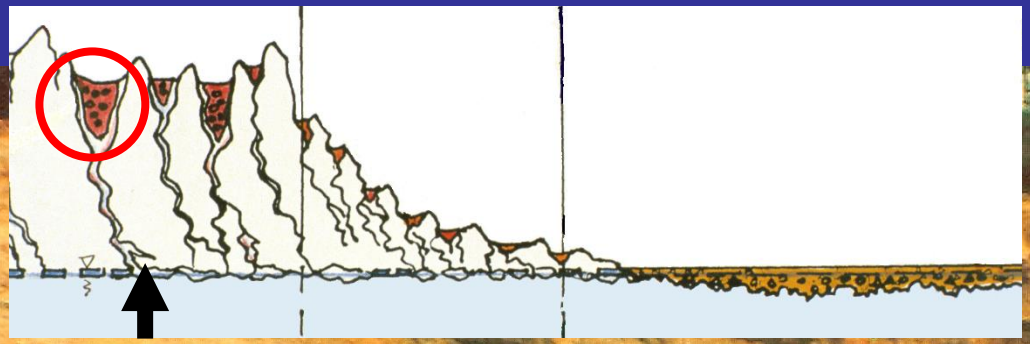
Clastic textures/structures,
Predominant allochthony,
boehmite (diaspore), goethite,
siderite,
chamosite, (pyrite)

RELIEF =

TECTONICS + EROSION +/- SEDIMENTATION

RECONSTRUCTION OF PALEORELIEF →

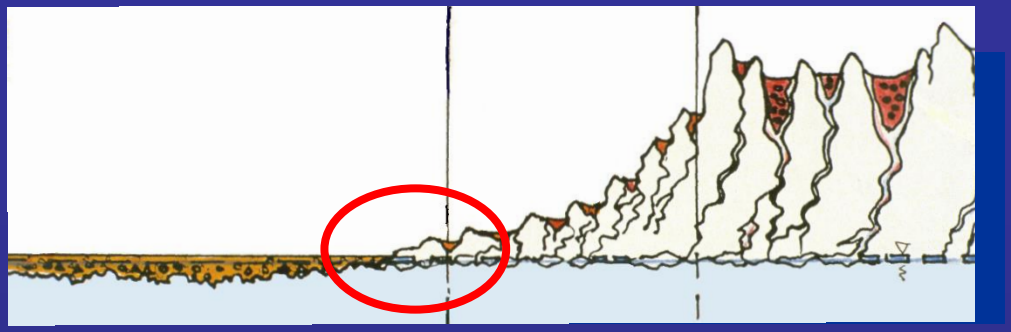
TECTONIC INFORMATION????



Deep sinkhole filling = high karst

(tectonically controlled relief)

Iharkút (Transdanubian Range, Hungary



on the regional scale-I

Cretaceous paleorelief in the S-Central Apennines

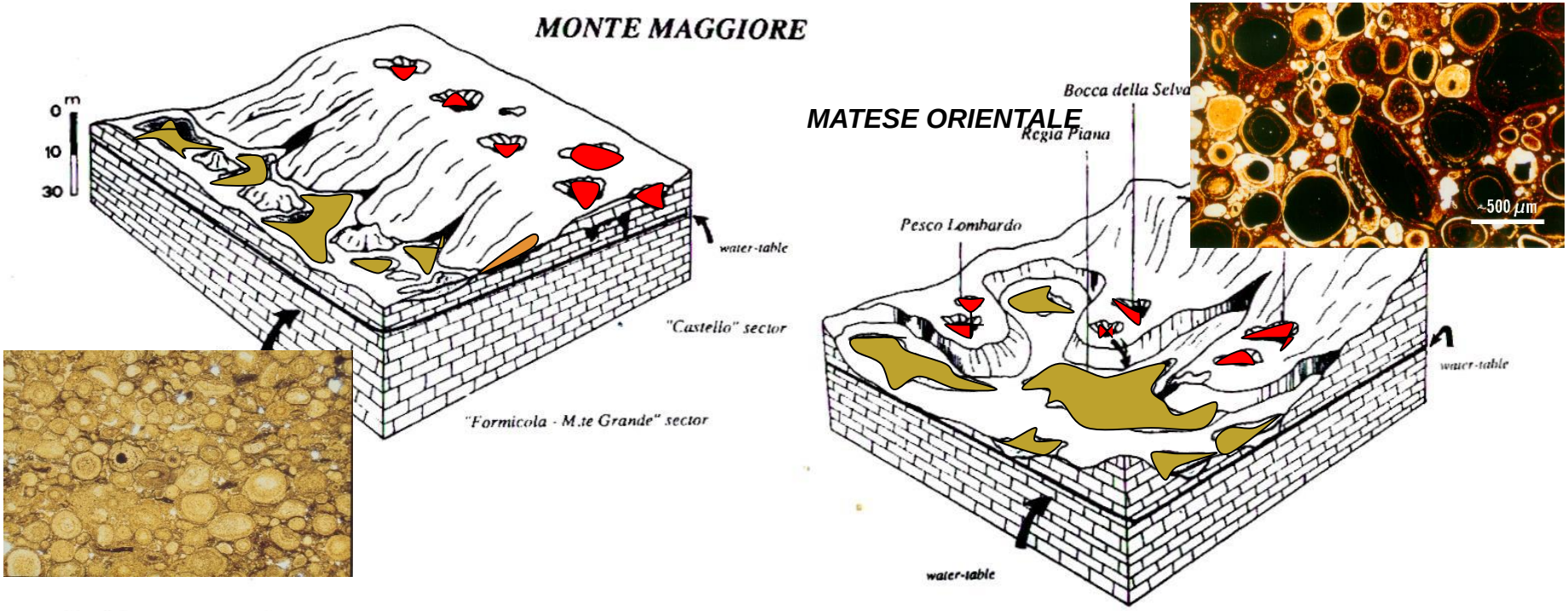
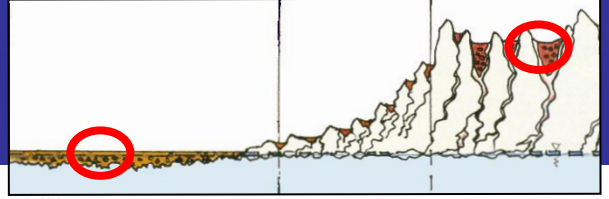


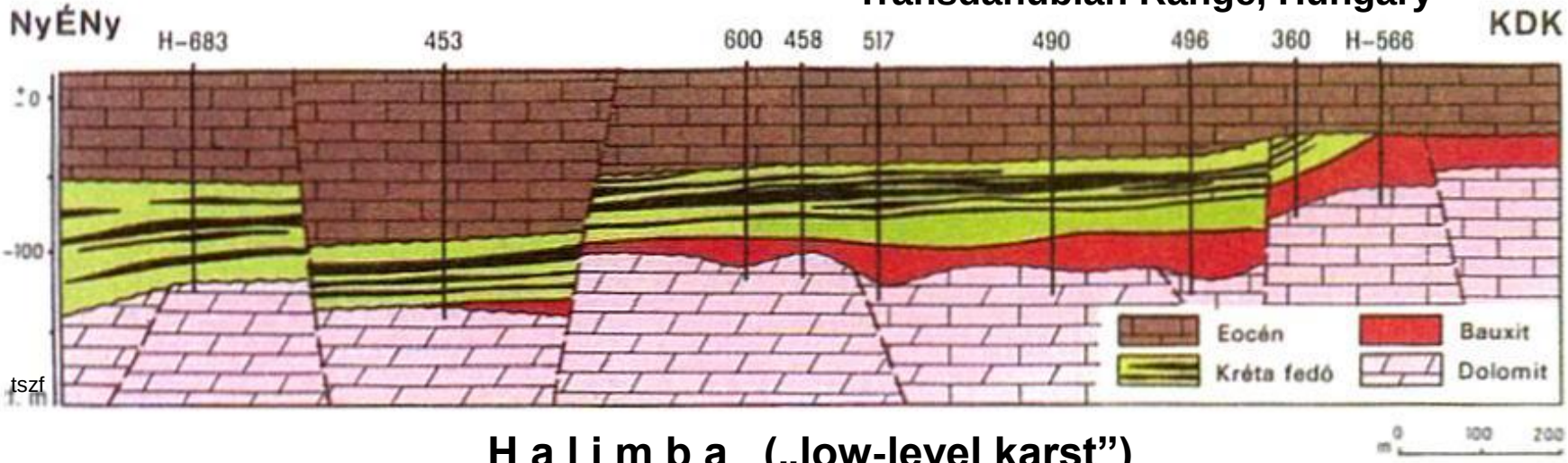
Fig. 3 - Lithofacies analysis of calcareous bedrock and the overlying bauxites allows small scale paleomorphologic restoration of emergent carbonate-platform-interior terrain (Middle Cretaceous of the Campania Apennines: M. Maggiore and Matese).

Carannante et al 1994

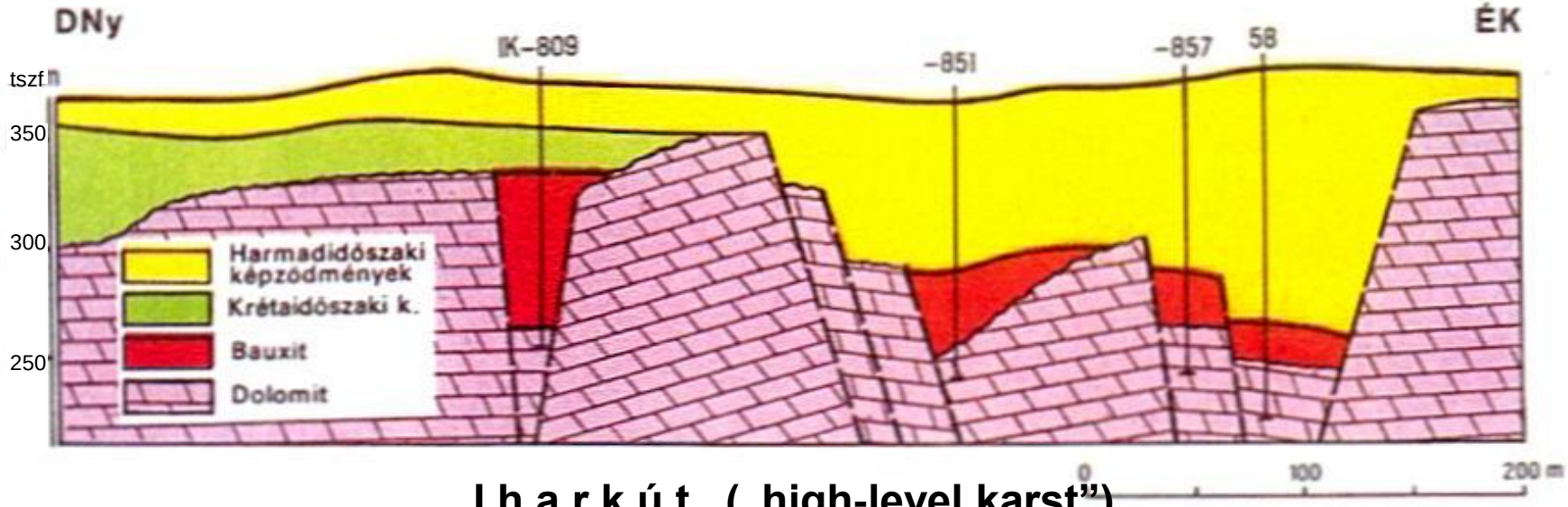
on the regional scale -II

Paleo-karst-morphology of Cretaceous bauxites in the Transdanubian Range, Hungary



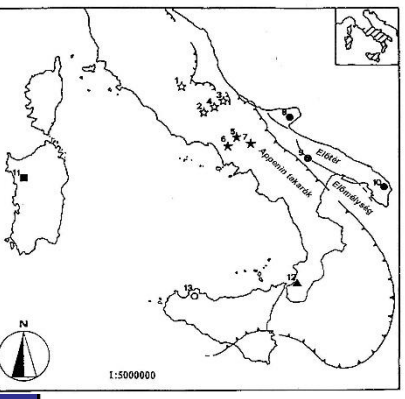


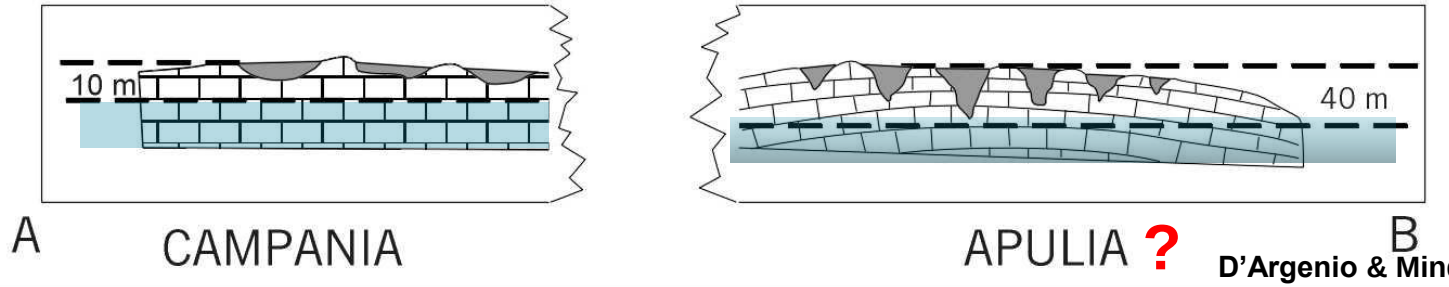
H a l i m b a („low-level karst”)



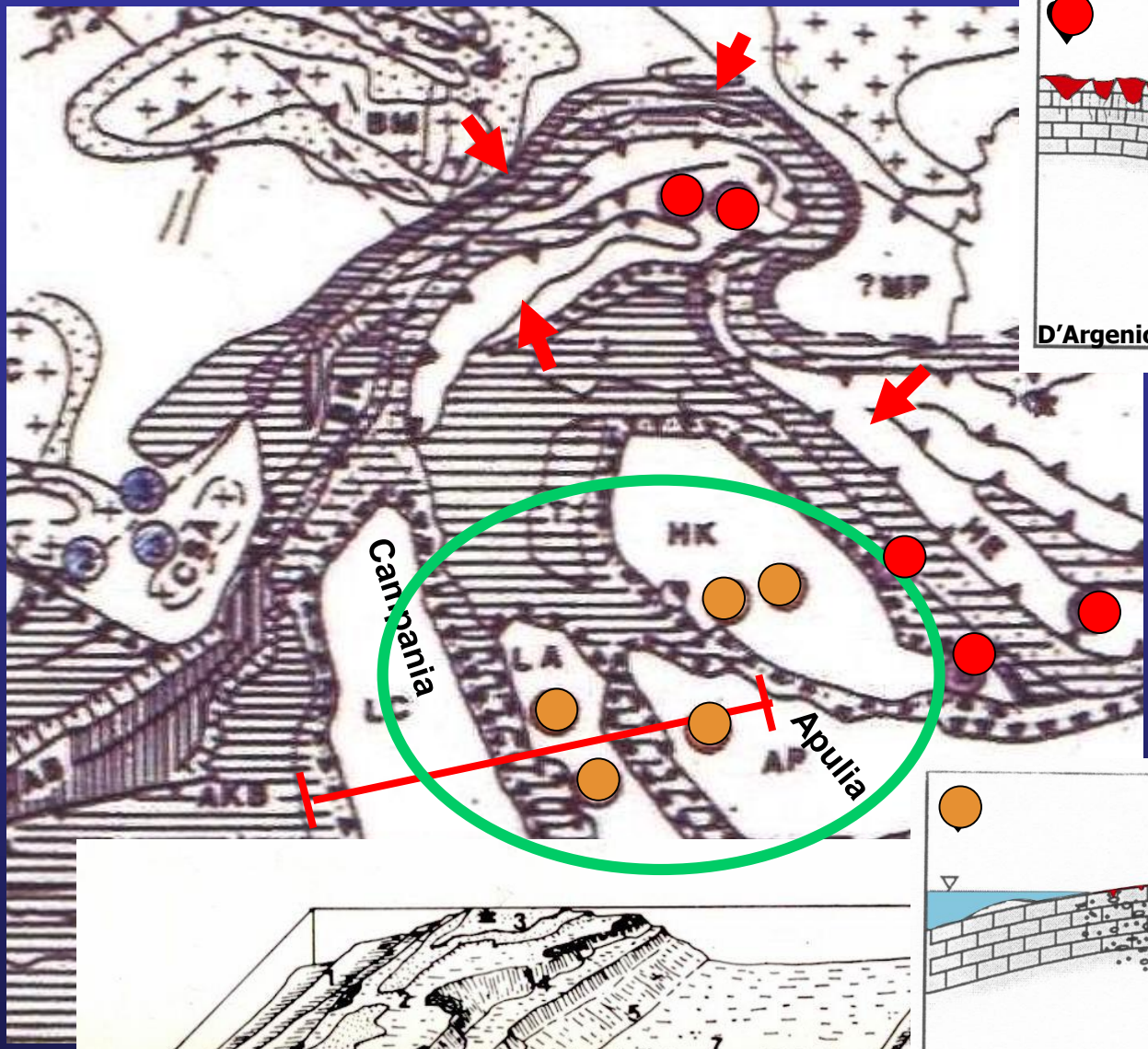
I h a r k ú t („high-level karst”)

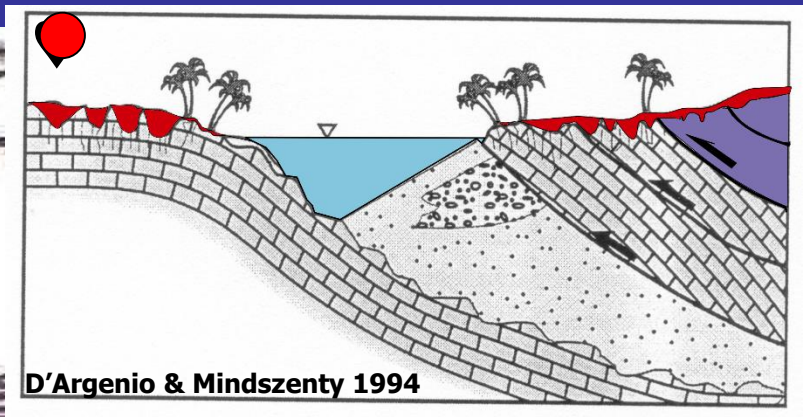
on the interregional scale... (across peninsular Italy)



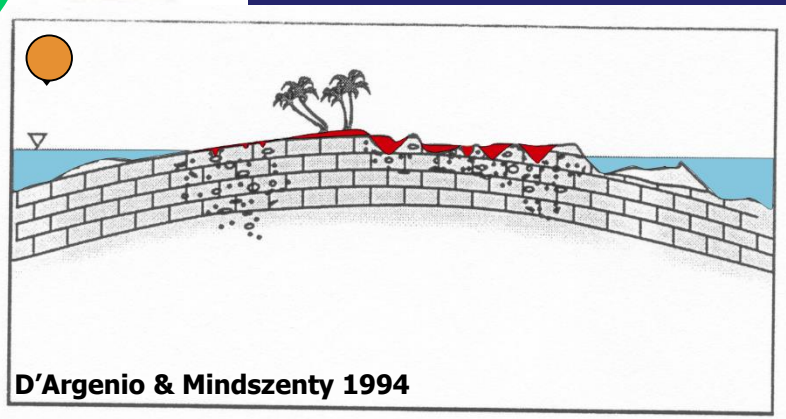


D'Argenio & Mindszenty 1994



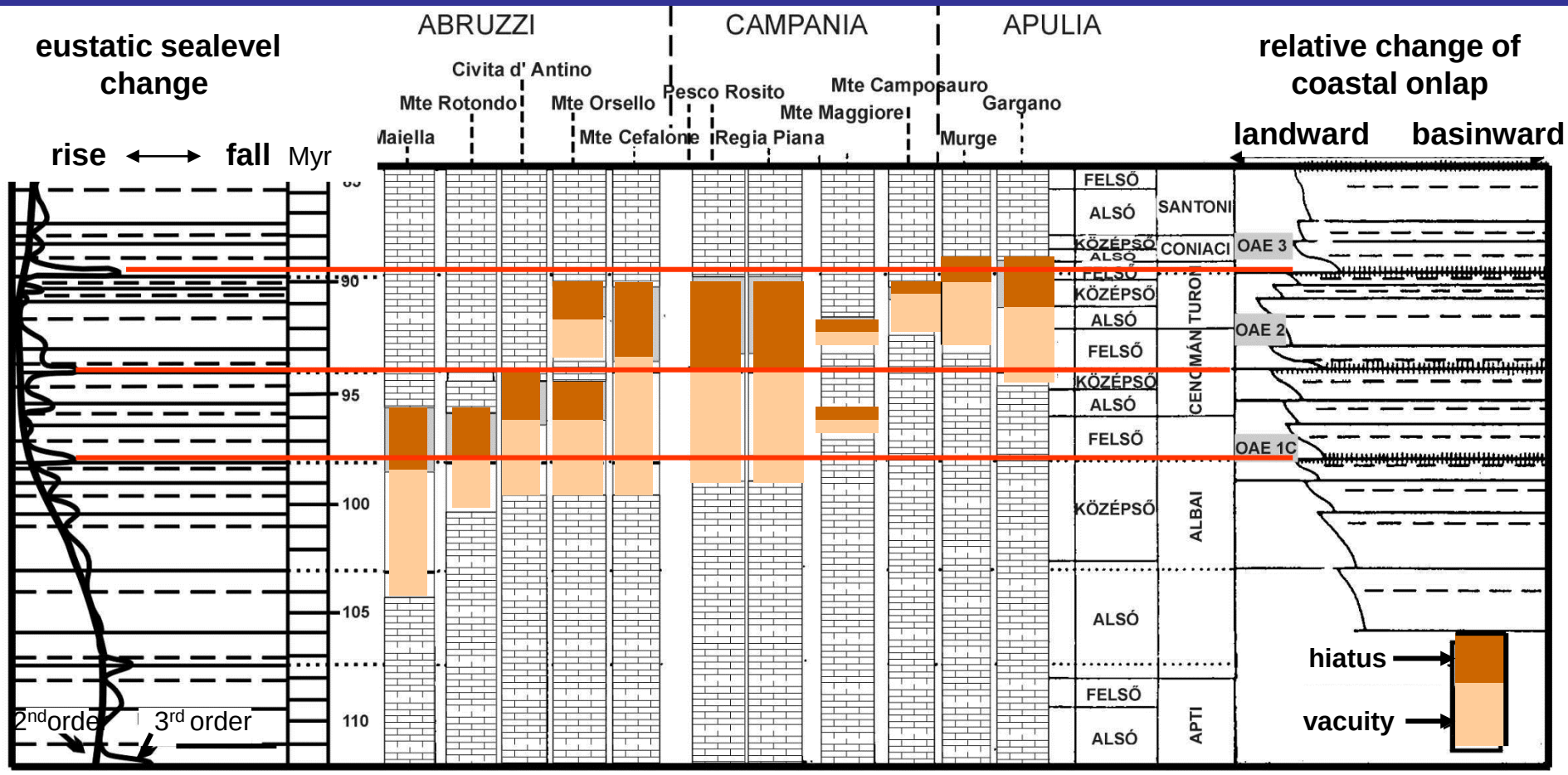


CARBONATE PLATFORMS
IN TECTONICALLY „QUIET"
PLATE-INTERIOR POSITION



Catalano & D'Argenio 1982

Bauxitic stratigraphic gaps in the Cretaceous of the Appennines



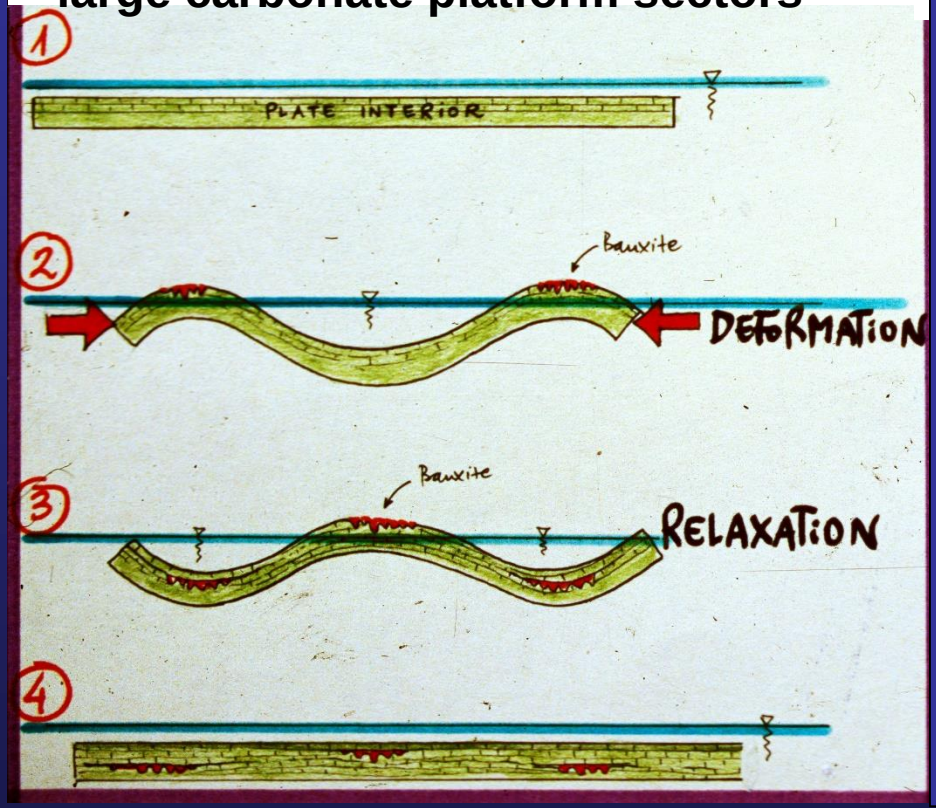
Hardenbol et al. 1998

D'Argenio & Mindszenty 1995

Considerable diachronism → tectonic control

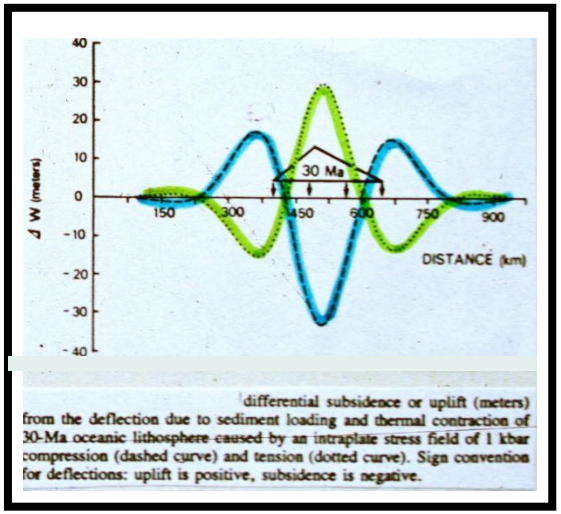
Deformation of passive plate-interior areas (due to changing intraplate stress field)

Deflection of the lithosphere as suggested by CLOETINGH, possibly resulting in subaerial exposure of large carbonate platform sectors



D'Argenio & Mindszenty 1994

Effect of changing stress-field in the plate-interior resulted by compression (blue line) and tension (green line)

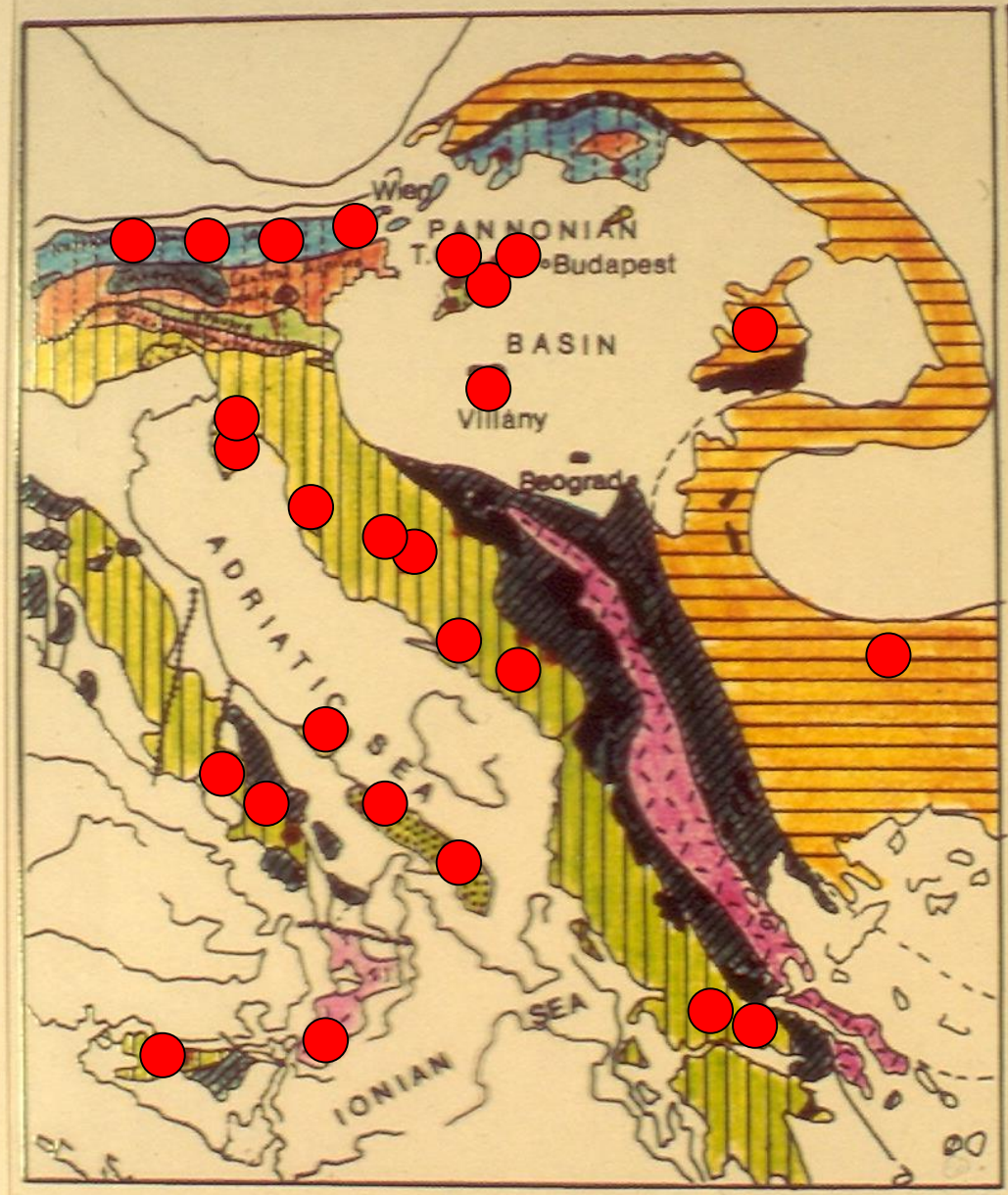


differential subsidence or uplift (meters) from the deflection due to sediment loading and thermal contraction of 30-Ma oceanic lithosphere caused by an intraplate stress field of 1 kbar compression (dashed curve) and tension (dotted curve). Sign convention for deflections: uplift is positive, subsidence is negative.

Cloetingh 1988

SEPM Spec.Publ.42, 19-29

„Austro-Hungarian", Dinaric and Appenninic bauxites



Base map: Channel-D'Argenio-Horváth 1979.

AFRICAN ARABIAN FORELAND

SOUTHERN TETHYAN CONT. MARGIN COMPLEX

AUSTROALPINE DOMAIN

OCEANIC REMNANTS INCLUDING CONT. ELEMENT

PIENINY KLIPPEN BELT

"MEDIAN MASSIFS" Metamorposed pre-Alpine and Alpine complexes

NORTHERN TETHYAN CONTINENTAL MARGIN COMPLEX

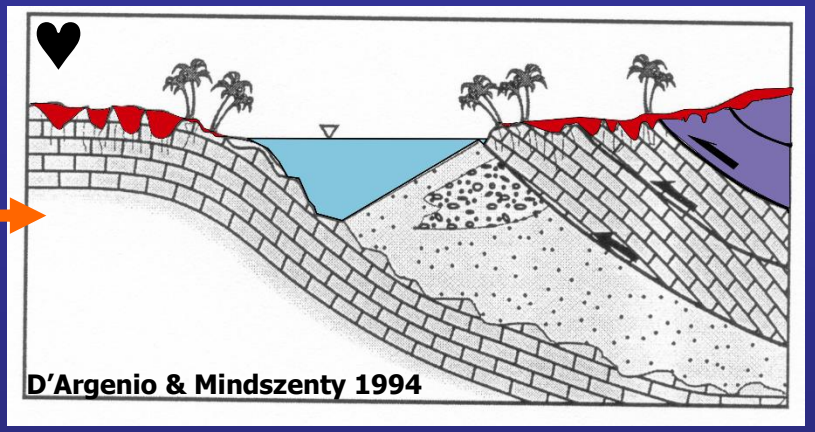
MAJOR TECTONIC LINES in Periadriatic area

BAUXITE DEPOSITS

LOCATION OF BAUXITE DEPOSITS AND THEIR RELATIONSHIP TO THE TECTONIC UNITS OF THE PERIADRIATIC AREA

Tectonics/geodynamics potentiallly generating bauxitiferous unconformities in carbonate depositional environments

„Collision" zones ♥
(flexural deformation, thrusting)



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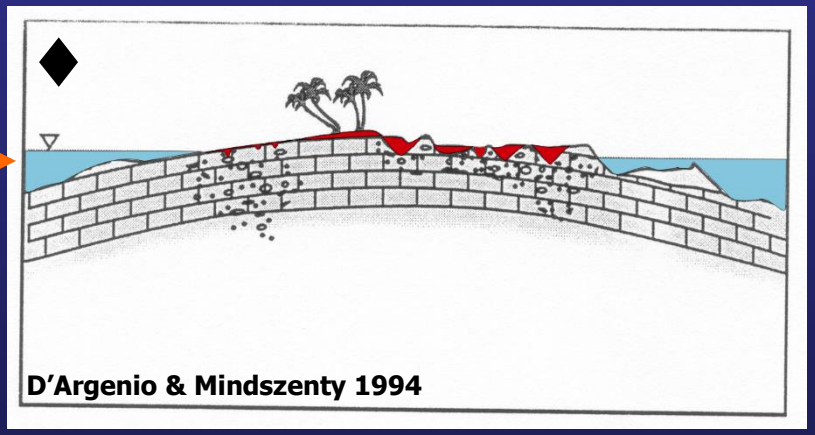
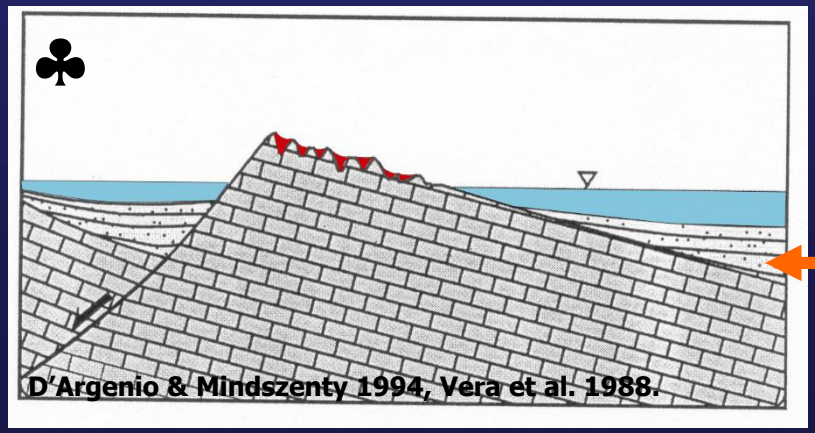
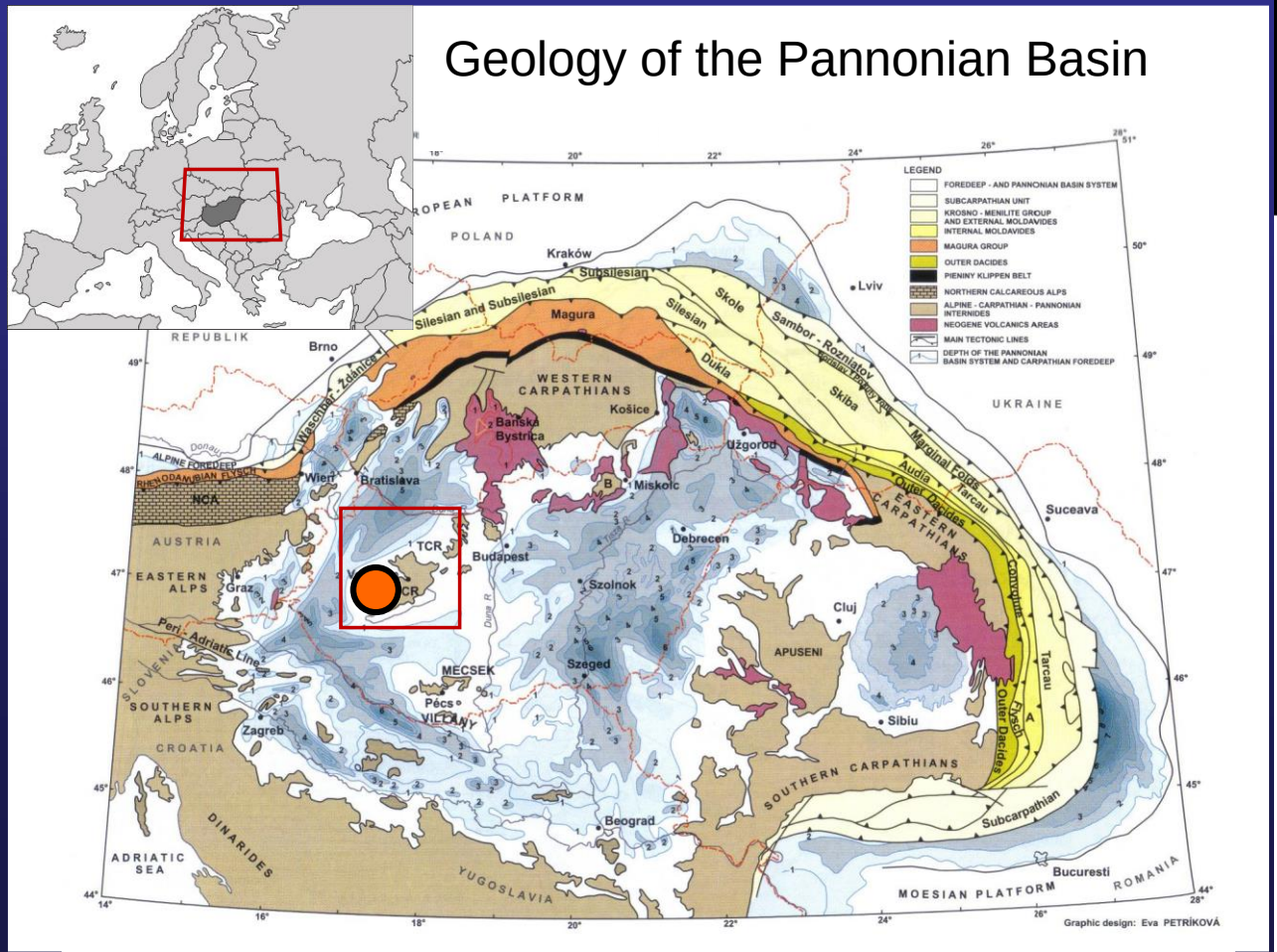


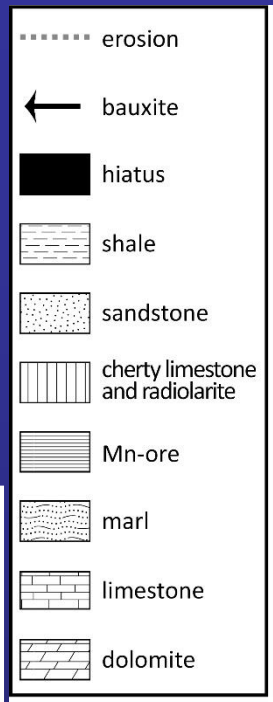


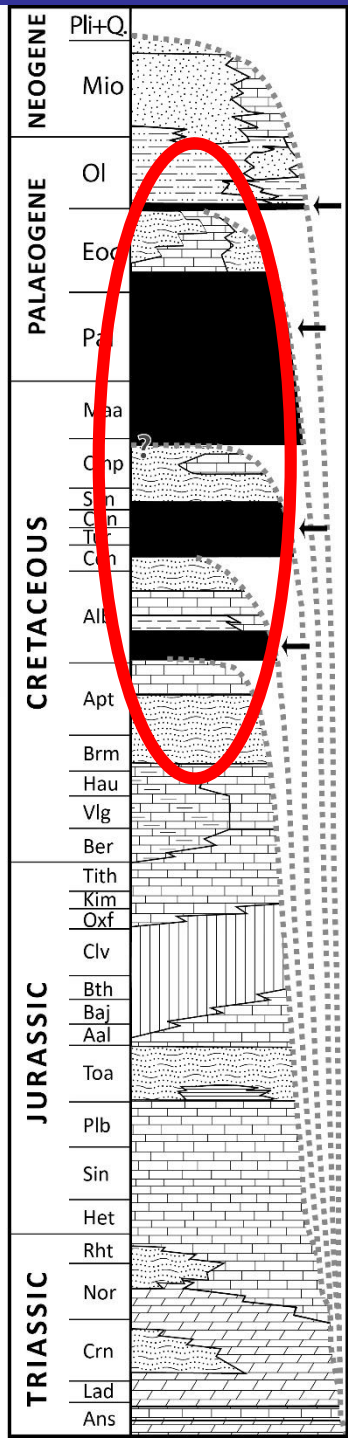
Rifting, strike-slips, transtensional deformation) („block-rotation") ♣

Contribution of a bauxitic unconformity to the reconstruction of a tectonic story

A regional-scale example from the Transdanubian Range, Hungary







The Early Cretaceous (intra-Berriasian) bauxite of the Villány Hills)

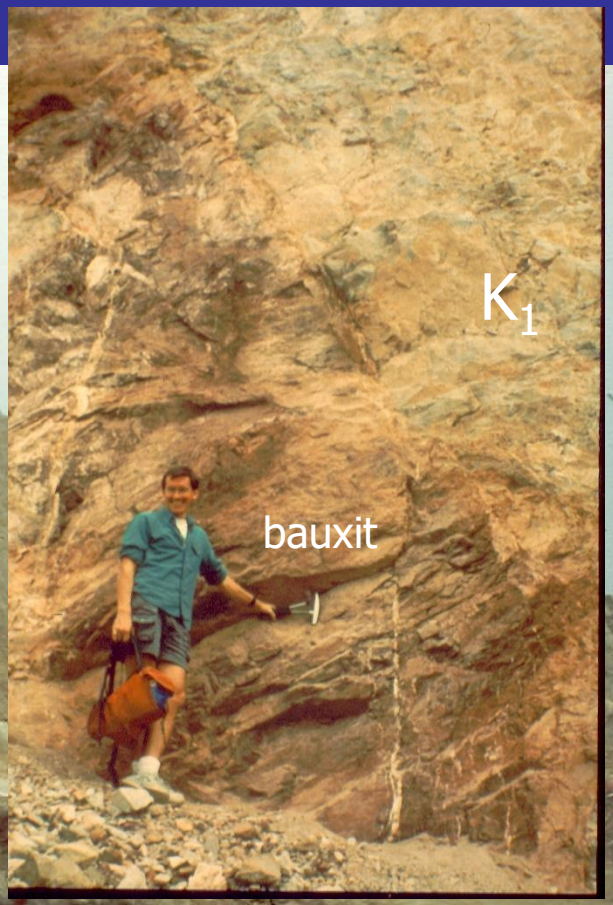
In a relatively small stratigraphic gap

fekű

J_3-K_1

fedő

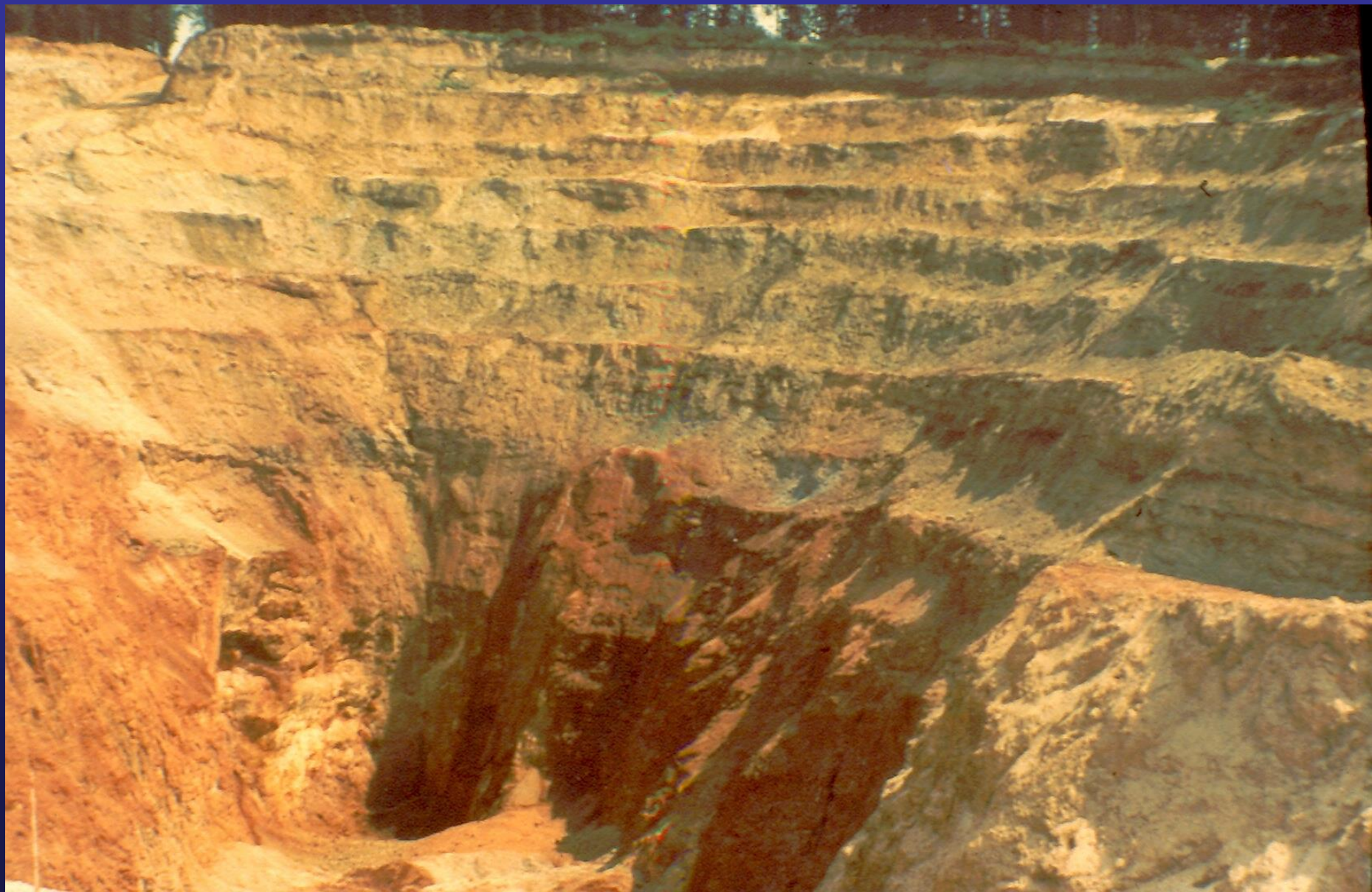
K_1



Early-Mid Cretaceous Bauxite (Alsópere, Transdanubian Range)

Deep sinkhole, filled by Late Cretaceous bauxite at Iharkút

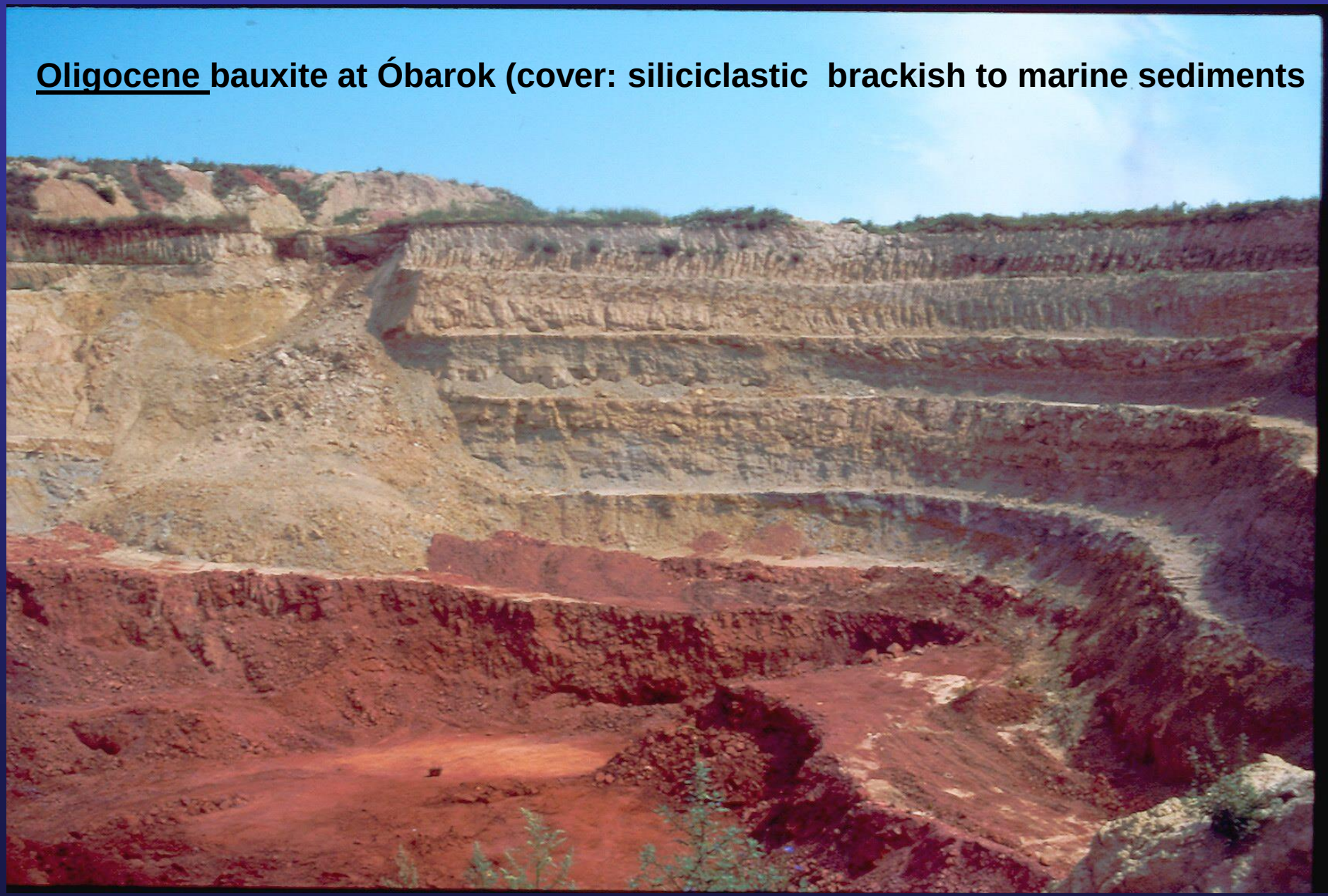
(Cover sequence: alluvial sediments)

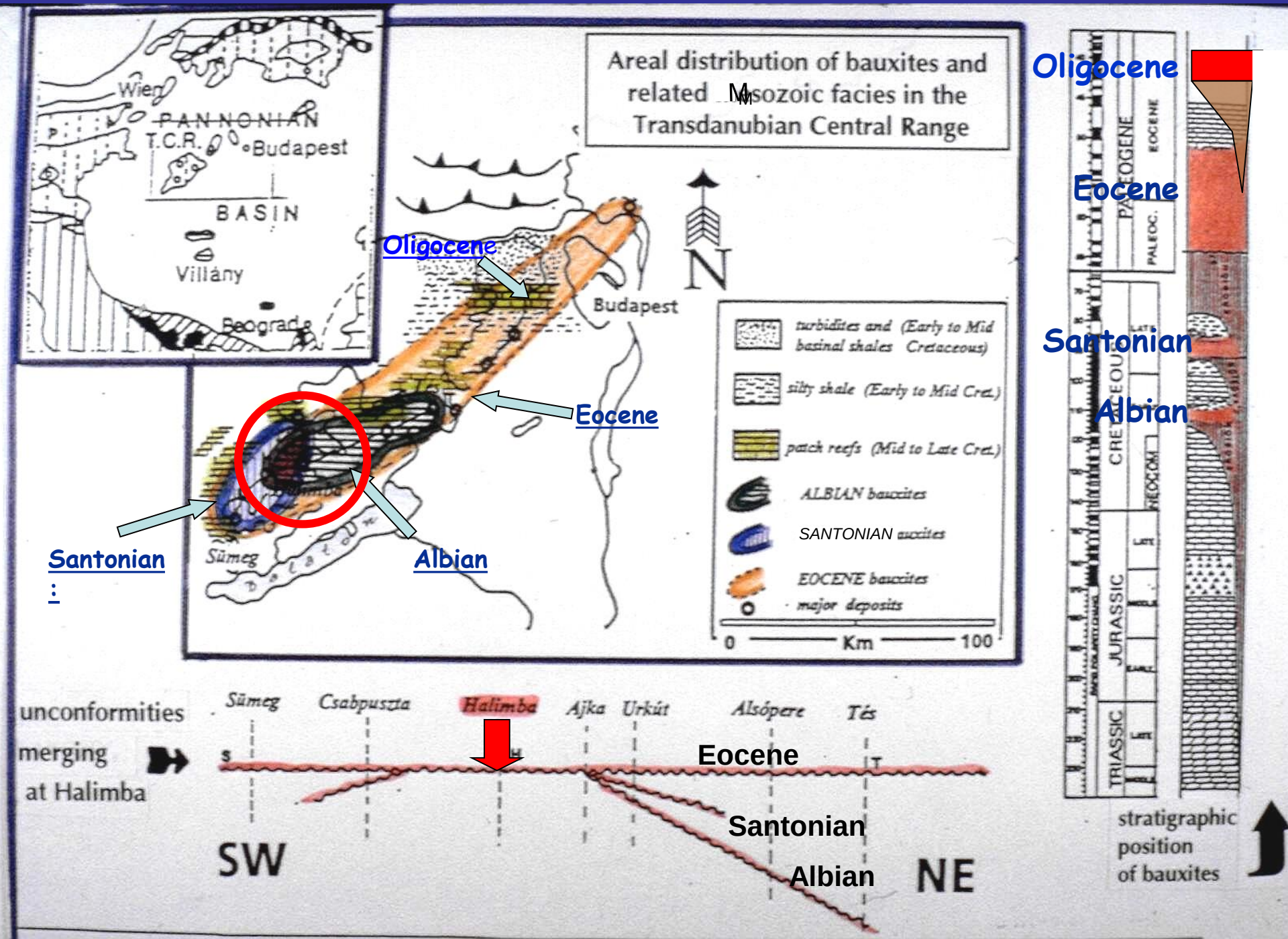


Historical outcrop of the Eocene bauxite at Gánt Bagolyhegy

Cover: lignitiferous Eocene transgression sequence

Oligocene bauxite at Óbarok (cover: siliciclastic brackish to marine sediments

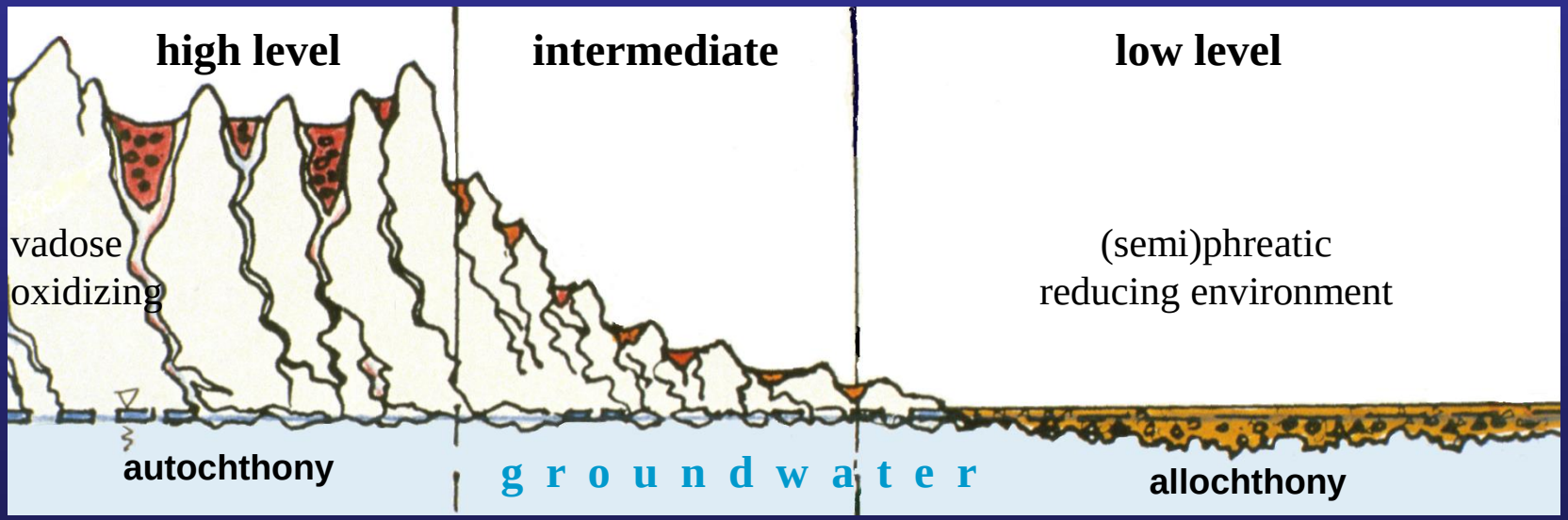



Areal distribution of bauxites and related Mesozoic facies in the Transdanubian Central Range
Wien
PANNONIAN
T.C.R.
Budapest
BASIN
Villány
Beograd
Oligocene
Eocene
Santonian
Albian
Budapest
Sümeg
N
turbidites and basinal shales (Early to Mid Cretaceous)
silty shale (Early to Mid Cret.)
patch reefs (Mid to Late Cret.)
ALBIAN bauxites
SANTONIAN bauxites
EOCENE bauxites
major deposits
0
Km
100
unconformities merging at Halimba
Sümeg
Csabpuszta
Halimba
Ajka
Urkút
Alsópere
Tés
Eocene
Santonian
Albian
SW
NE
Oligocene
Eocene
Santonian
Albian
PALEOGENE
EOCENE
PALEOC.
CRETACEOUS
JURASSIC
TRIASSIC
stratigraphic position of bauxites

Karst bauxites and the karst RELIEF

morphofacies + lithofacies-I.

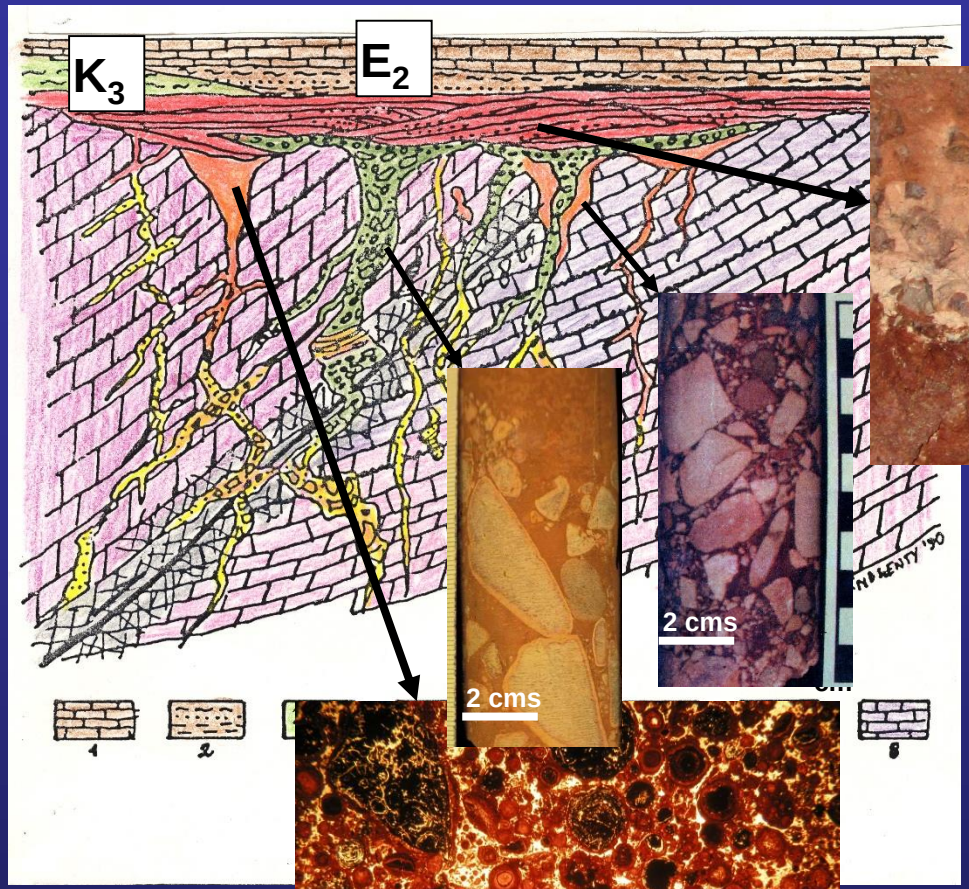
position as related to groundwater table reflected by mineralogy (Fe-minerals) and geochemistry (COLOR!!) of the bauxite



D'Argenio & Mindszenty 1995

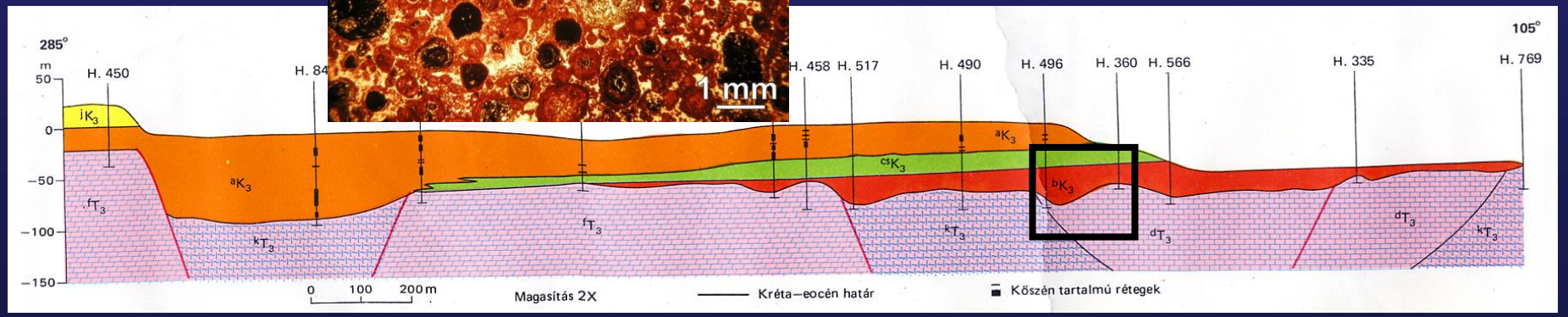
topographic high: unsaturated (vadose) oxidizing environment
topographic low: saturated (phreatic to semiphreatic) reducing environment

The Halimba Bauxite deposit

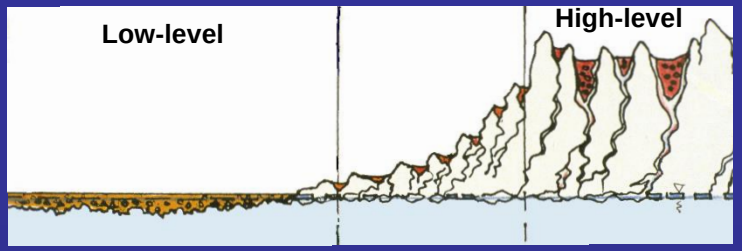


nty 1990

Bárdossy 2007



Haas J., Jocháné Edelényi E. 1978



Deep sinkhole filling bauxite

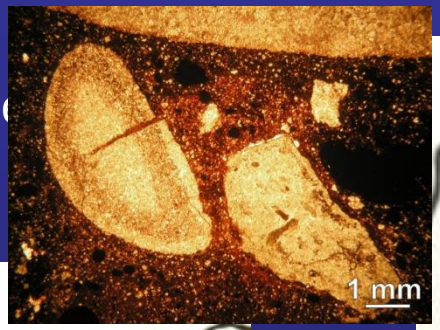
High-level karst

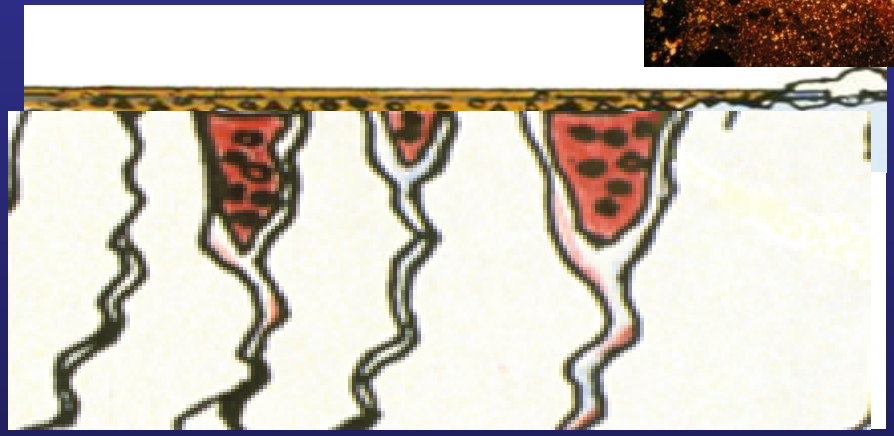
(uplifted terrain)

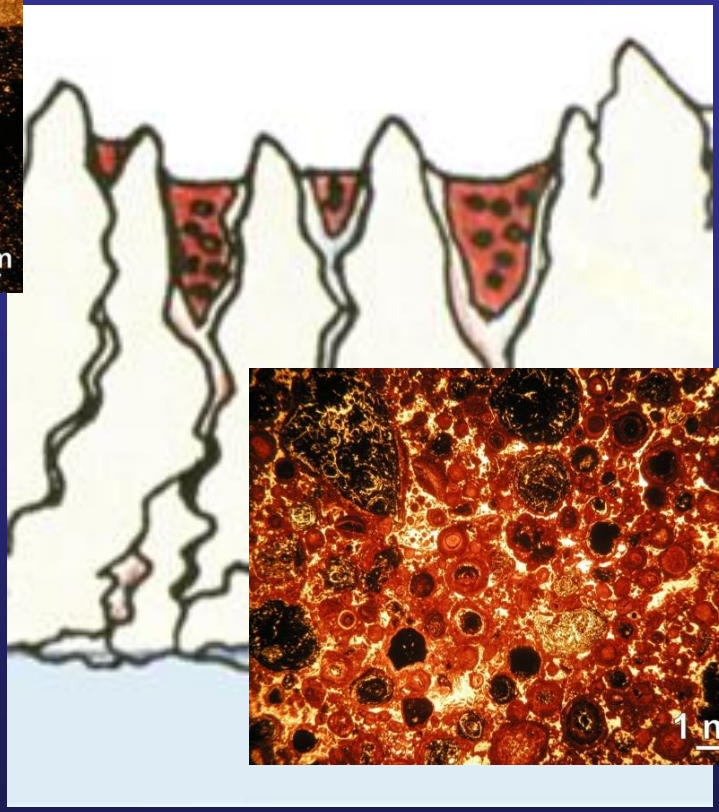
Shallow karst-fill

Low-l

topographic „low”







Superposition of the two

Uplift followed by subsidence and resedimentation

...A TECTONIC STORY BEHIND???

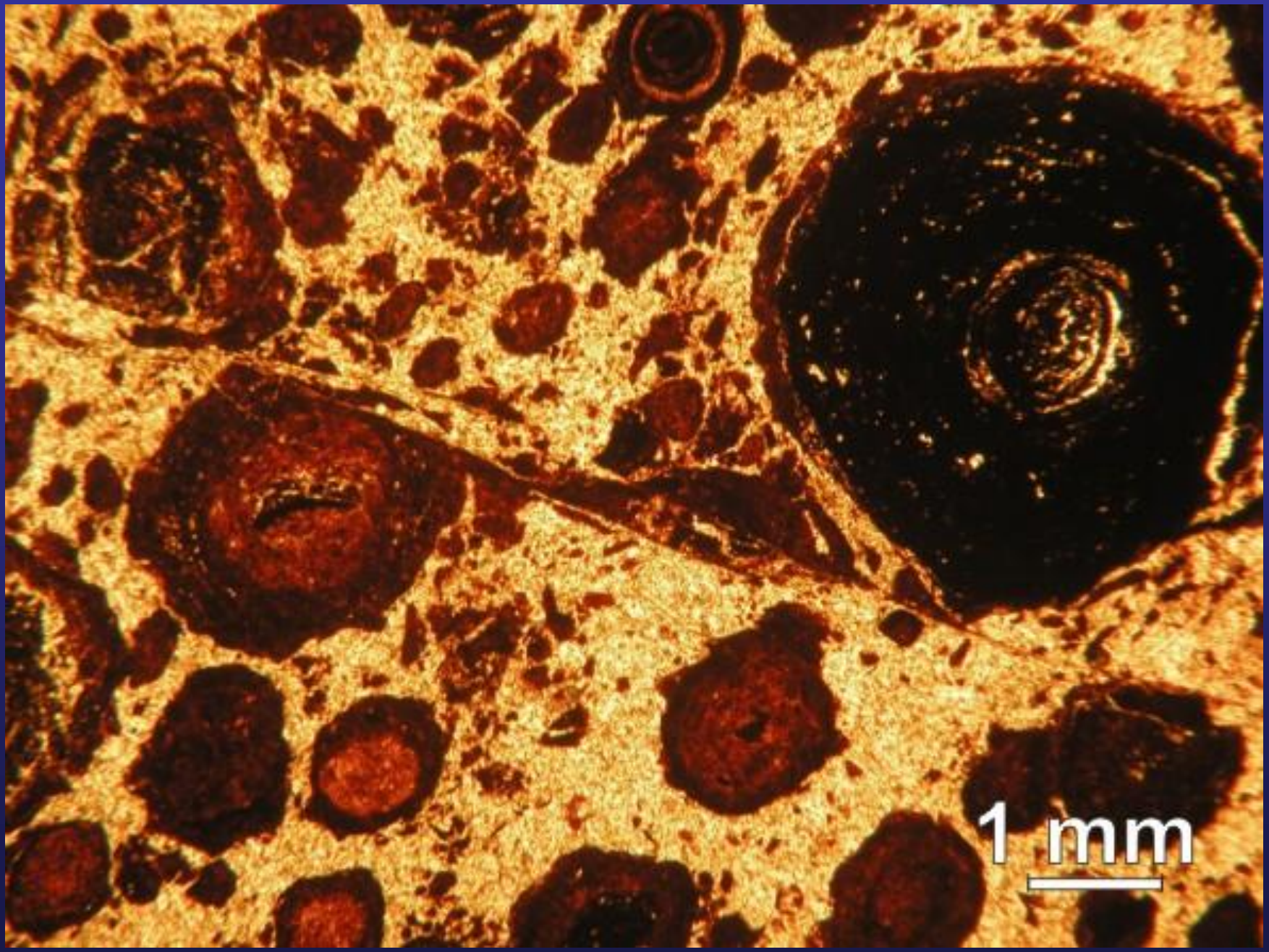


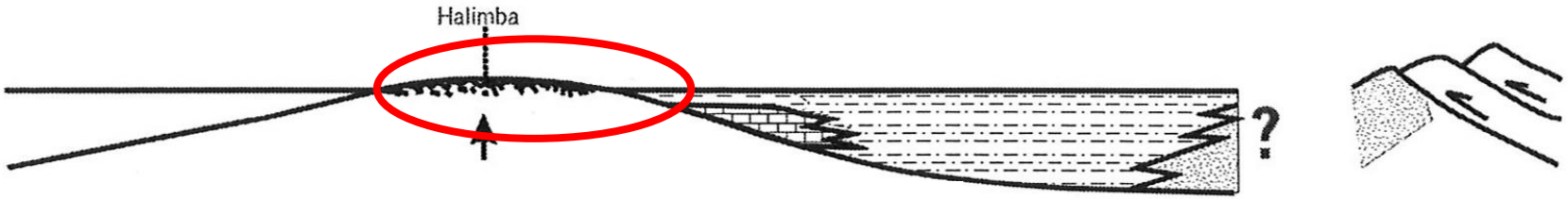
Photo: K.Pandur

DNY ÉK

1 KEZDETI ELŐTÉR-KIEMELKEDÉS

incipient bulge, low-level karst

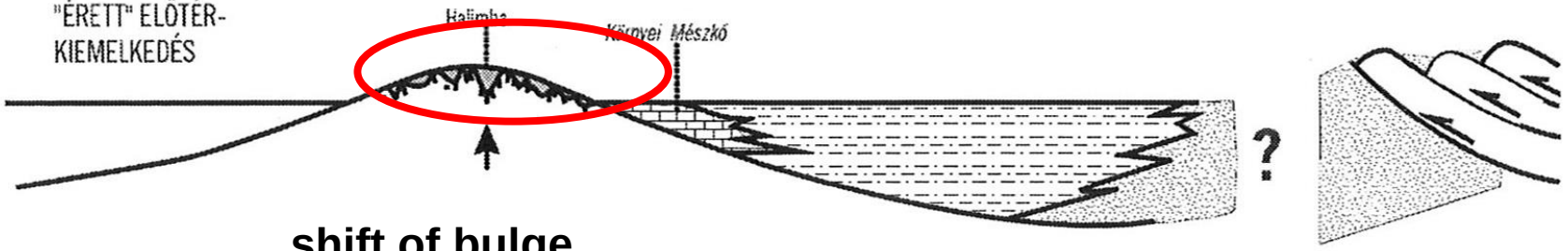
ALBAI



mature bulge, high-level karst

ALBAI

2 "ÉRETT" ELŐTÉR-KIEMELKEDÉS

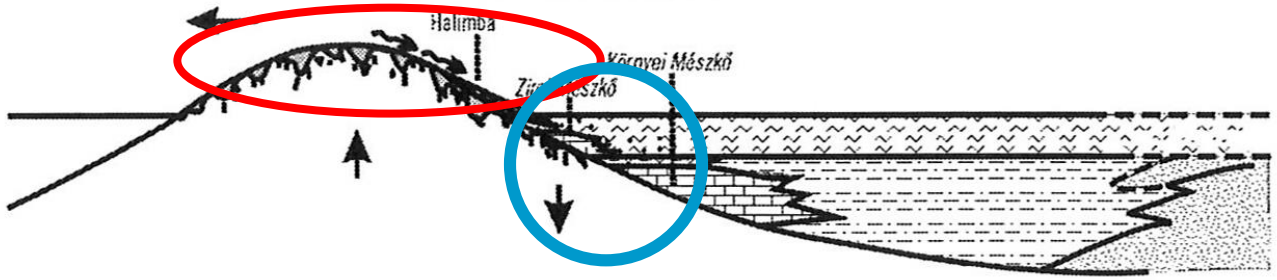


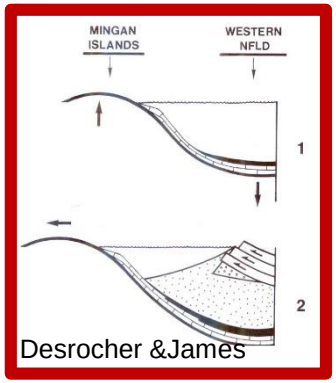
shift of bulge

resedimentation of bauxite

KORA SZENON

3 MIGRÁLÓ ELŐTÉR-KIEMELKEDÉS

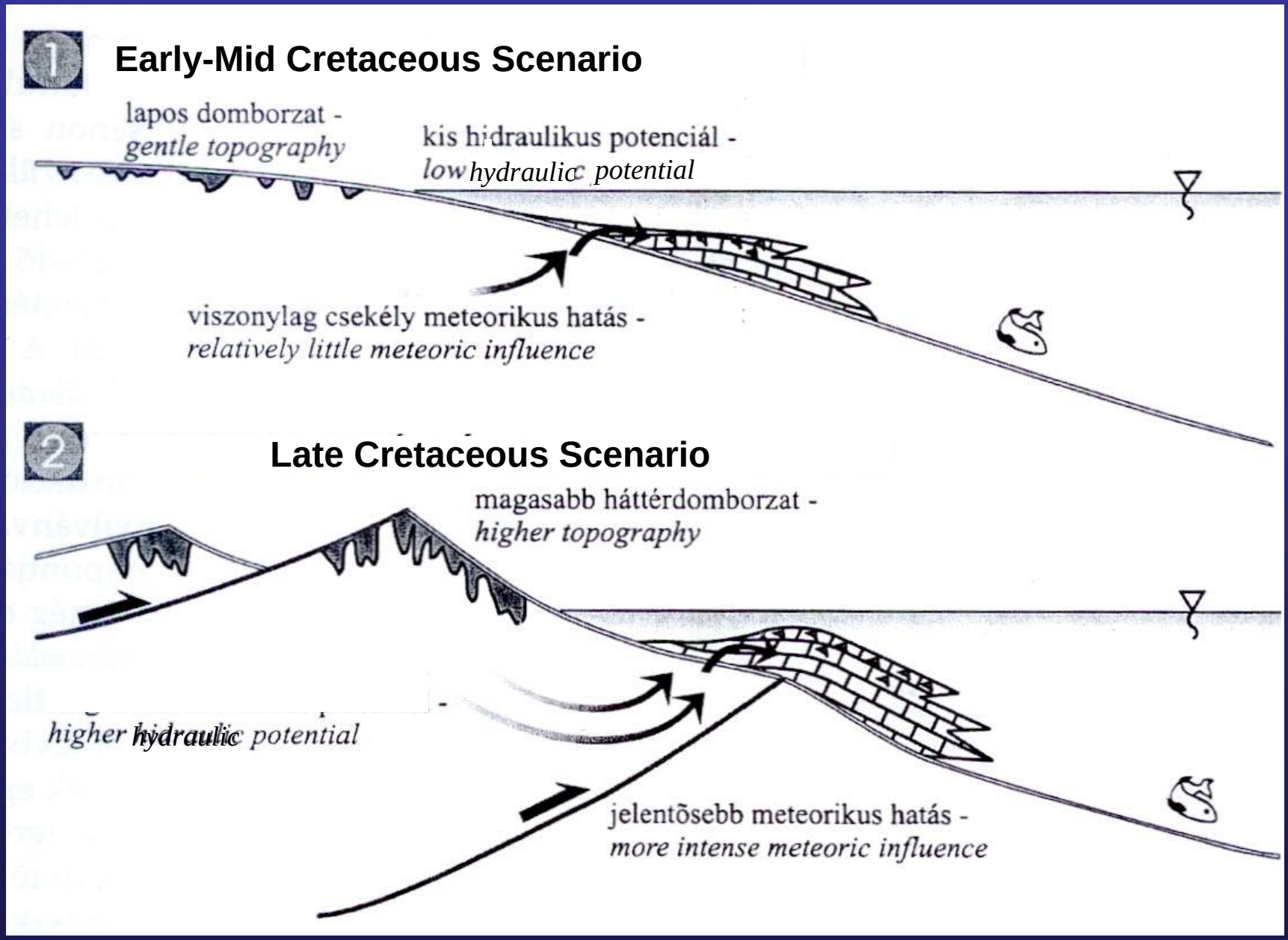




Desrocher &James

Based on Tankard (1986), Foreland Basins, Spec.Publ.,IAS, Mindszenty et al (2000) Földt.Közl.

POSSIBLE PALEOHYDROLOGICAL IMPLICATIONS



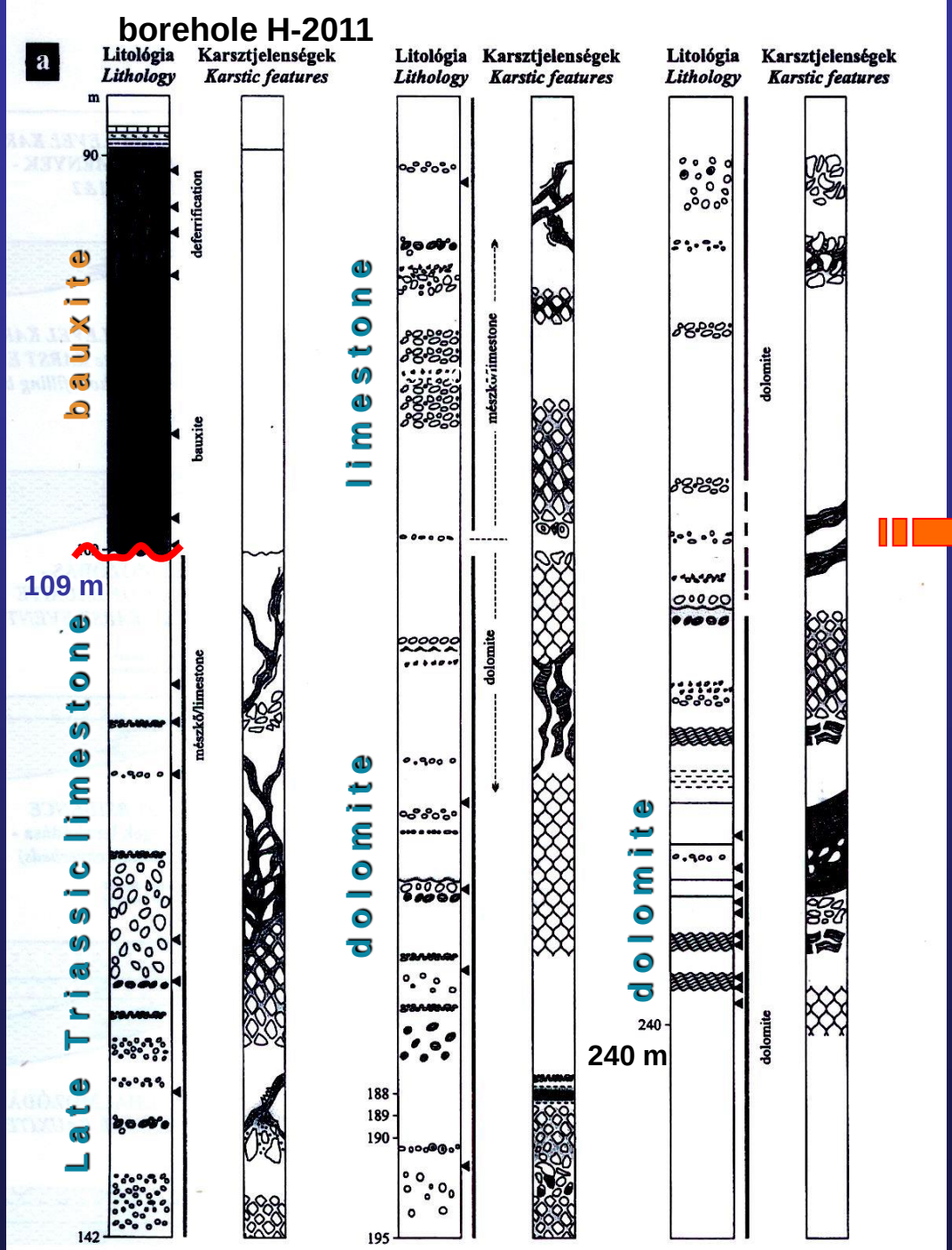
Possible BONUS: Paleohydrological information coded in the related paleokarst!!!

Let’s check the working hypothesis!

♥ Intense, deep, vadose karstification at the apex of the bulge (sign of meteoric recharge) ?

♥ fresh-water outflow at the discharge-end (e.g. early meteoric/mixing cements in reef-limestones) ?

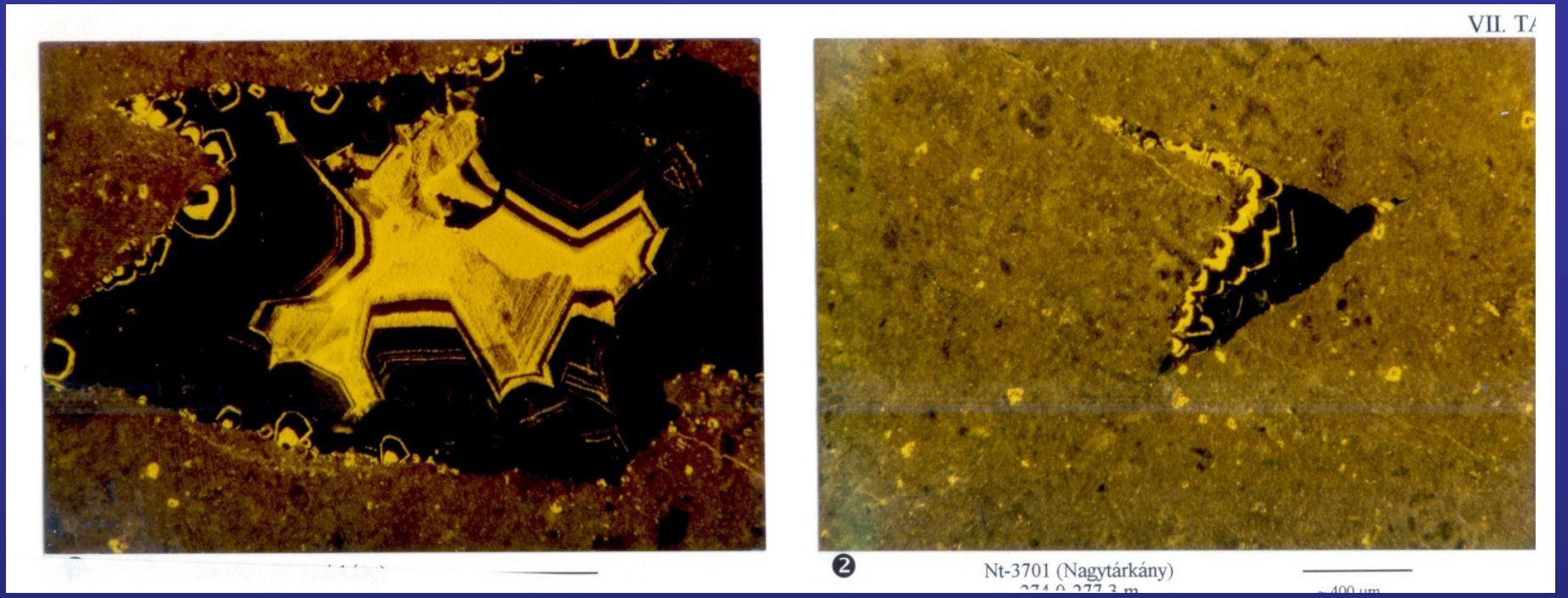
♥ phreatic-lens related underground karst-fills (speleothemes) both in recharge and discharge zones ?



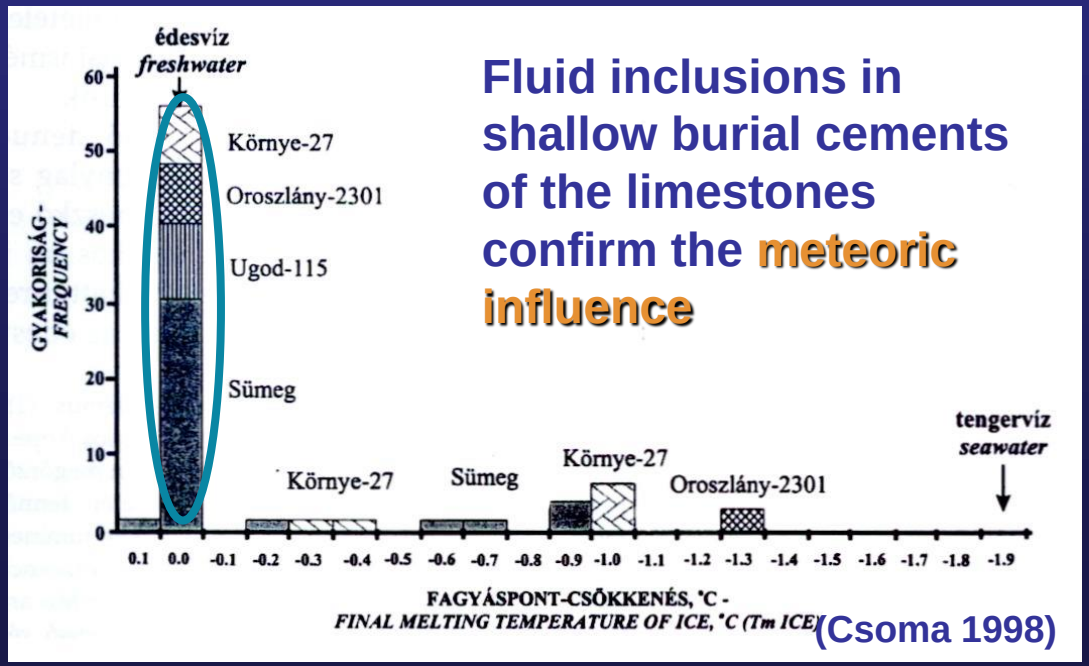
Karst features at the apex of the bulge

(Halimba)

> 100 m below the unconformity
vadose karst!!



CL-image of biomold-filling shallow-burial cements shows probable oxygenated **meteoric influx** during the early stages of diagenesis in limestones developed along the periphery of the bulge



Fluid inclusions in shallow burial cements of the limestones confirm the meteoric influence

(Csoma 1998)

There should be also infiltrated bauxites and

phreatic-lens related underground karst-fills (speleothems)

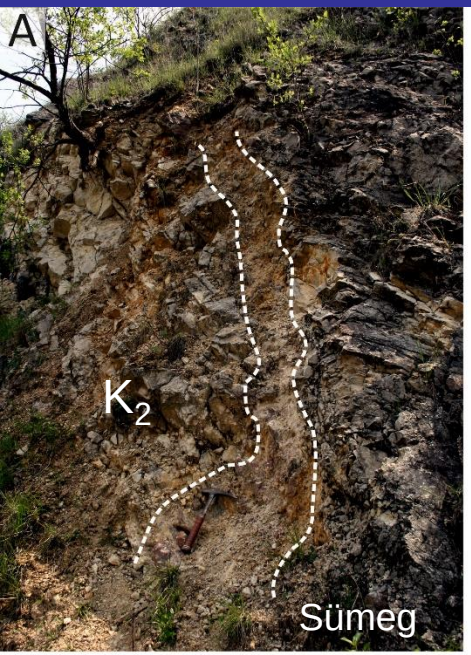
both in recharge and discharge zones

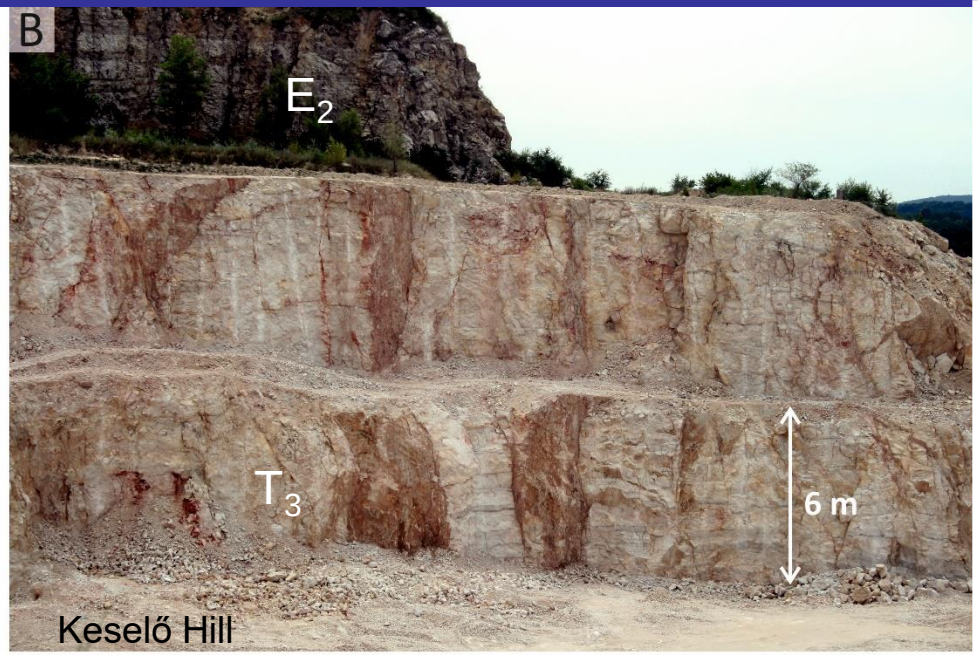
?

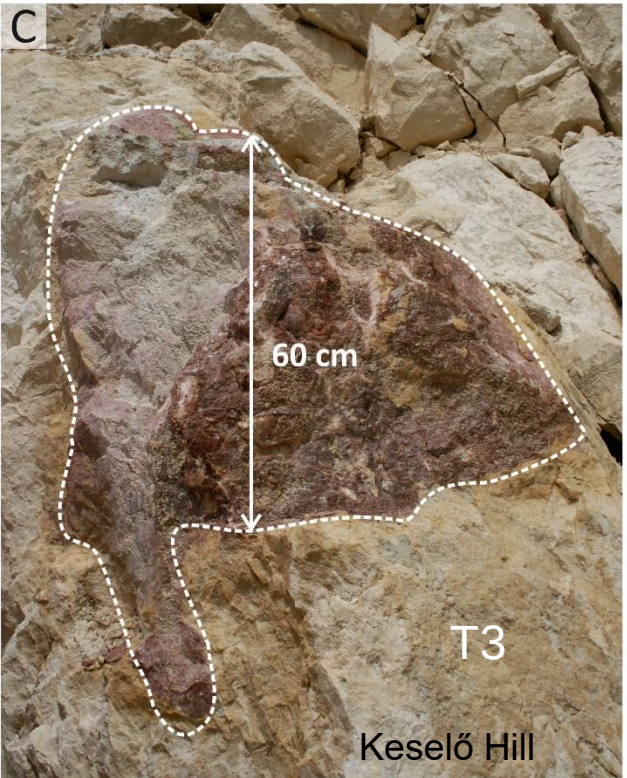
Vadose-zone paleocave-passage filled by infiltrated bauxite

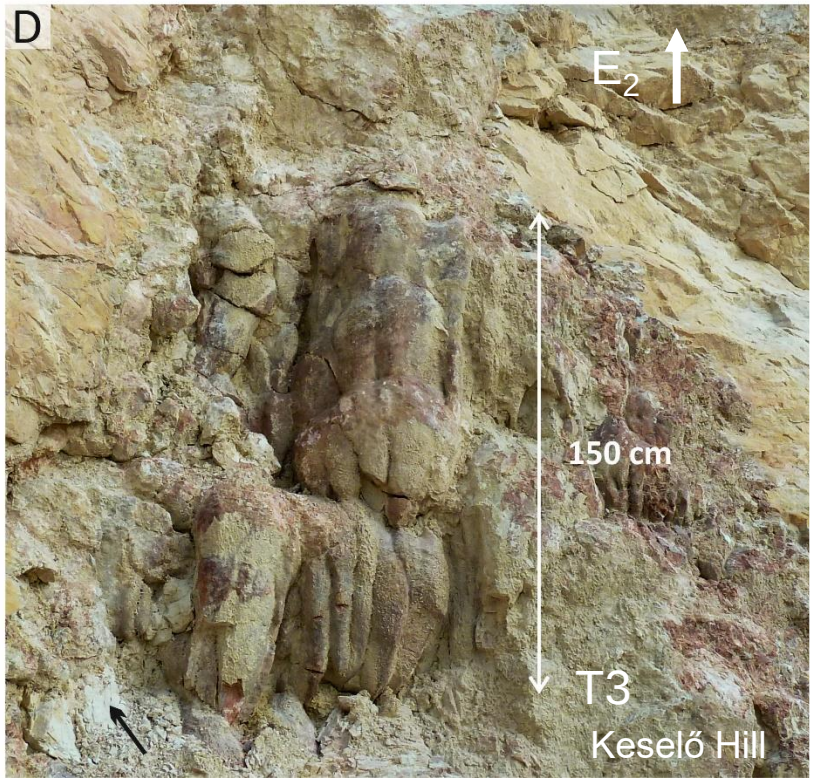
Budakeszi/Buda Hills (Hungary)

Kósa et al. 2003









Various cavity-fills and vadose speleothems

„Red calcites”

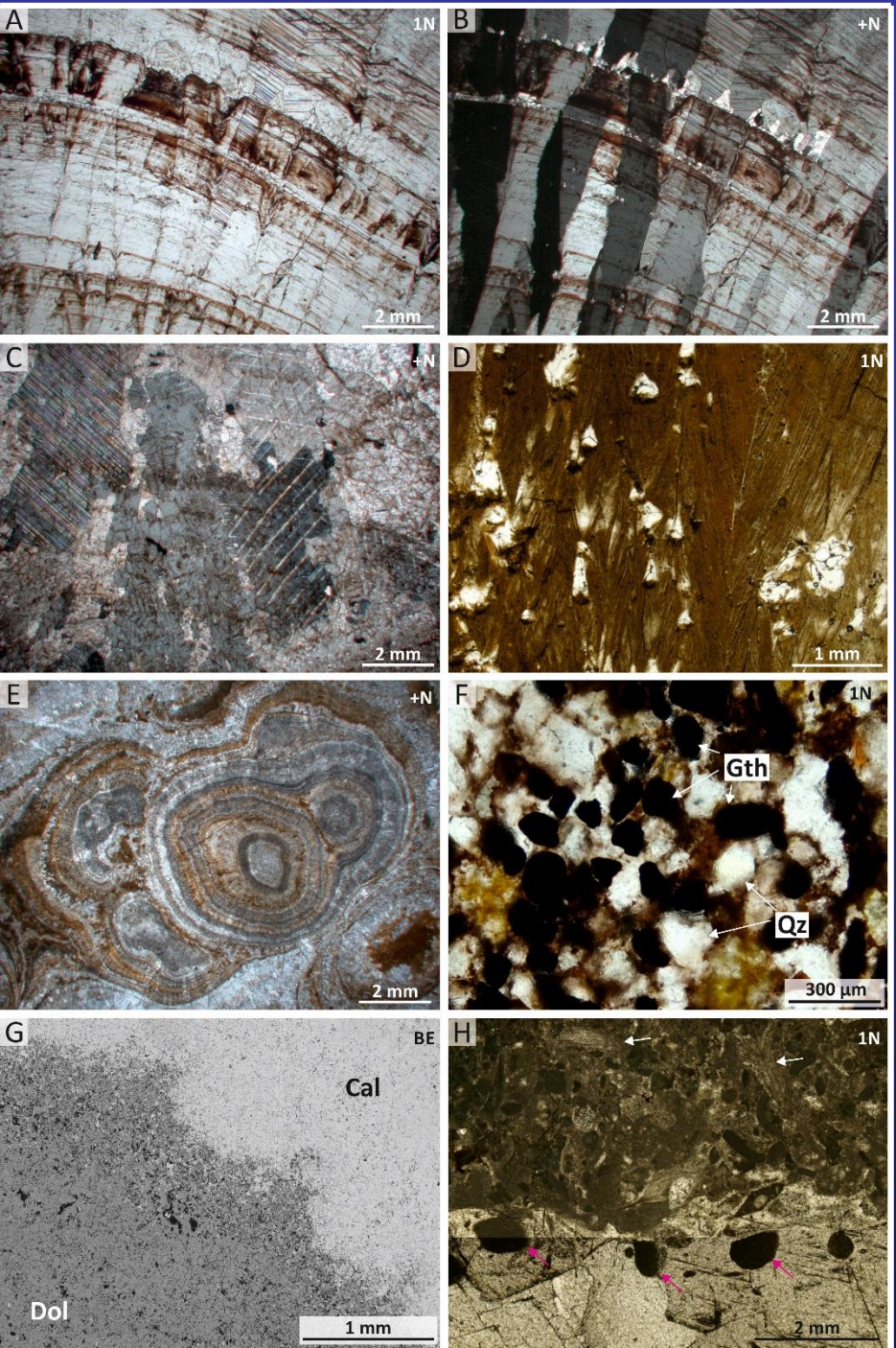
all over the Transdanubian Range related to Pre-Late Cretaceous and Pre-Eocene paleokarstic unconformities

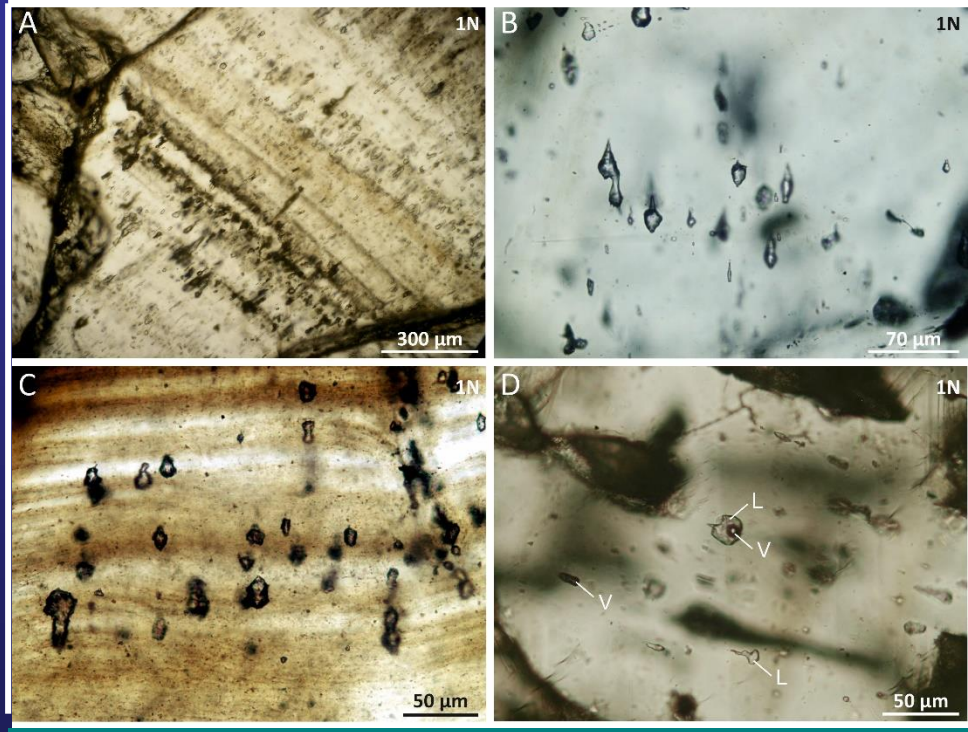
Győri et al 2013

Zoned, red calcite filling a dissolution cavity in Triassic dolomite

Győri O.,Orbán R.,Mindszenty A.,Fodor L., Erőss A., Benkó Zs.,Moonár F.(2014): Red calcites as indicators of paleokarst systems associated wiht bauxitic unconformities GEOFLUIDS 14 (4), 459-480

Thin-section photographs of „red calcite” samples

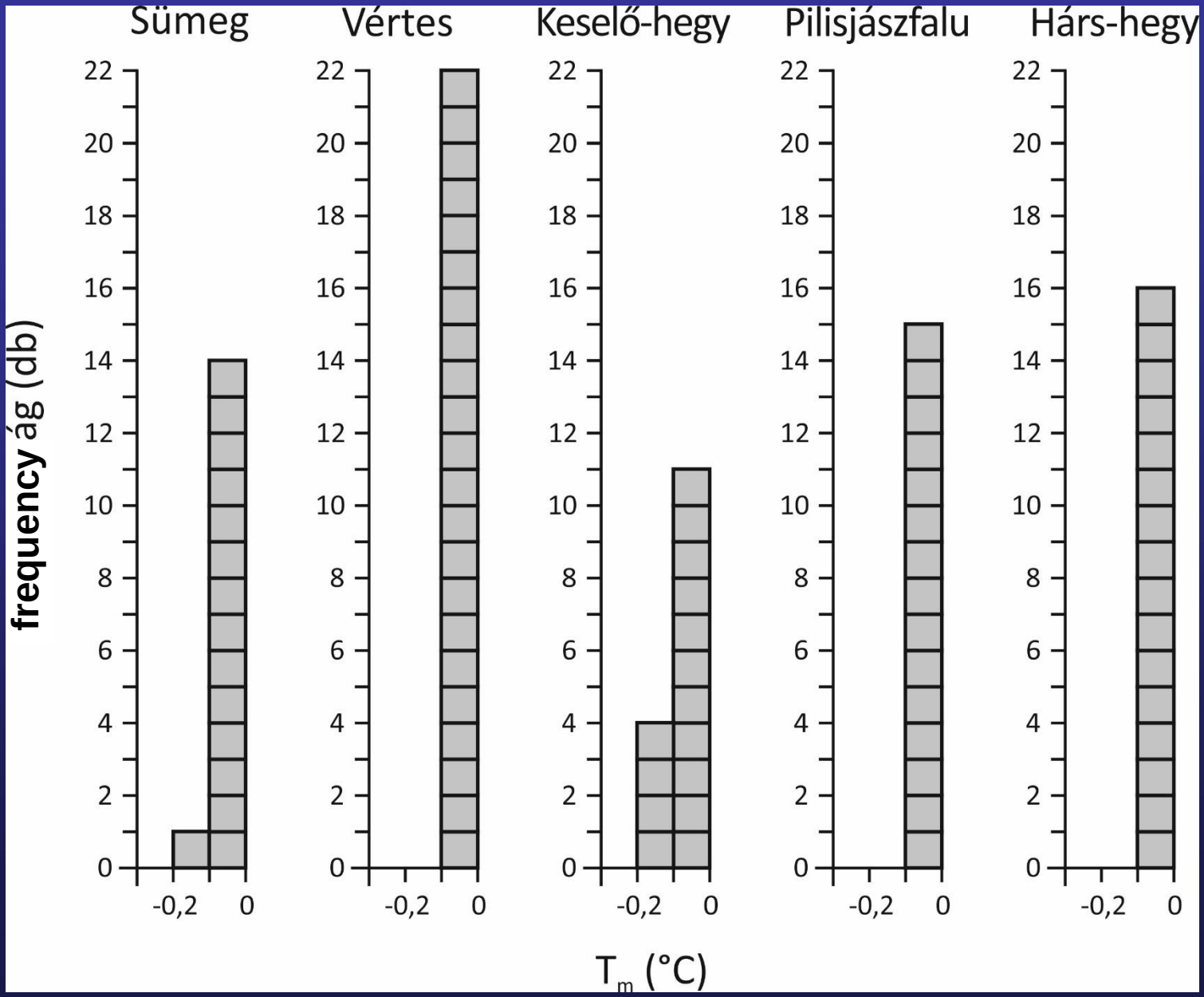




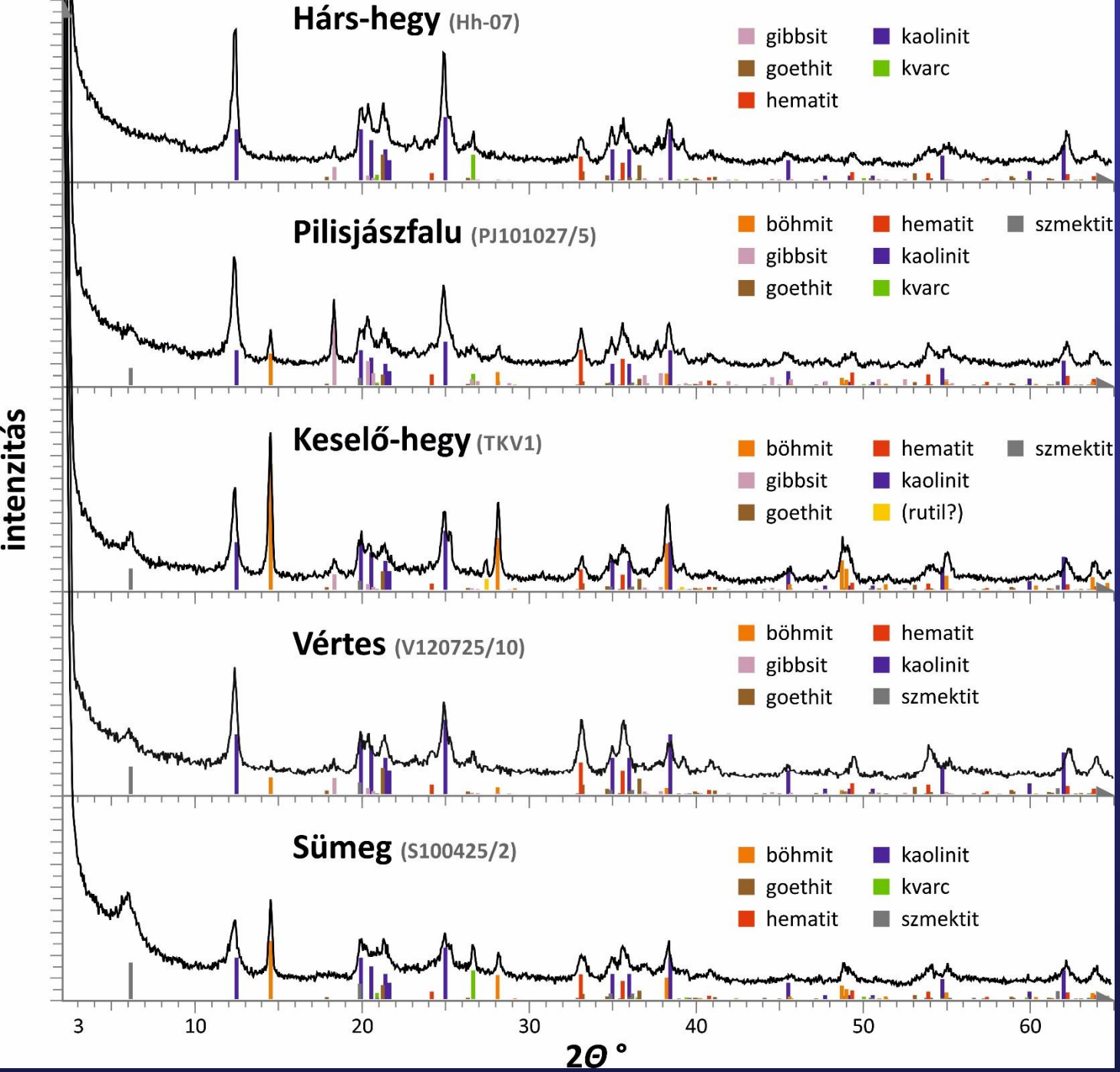
Fluid inclusions in „red calcites”

Győri et al. (2014), GEOFLUIDS 14 (4) 459-480

Melting temperatures measured on fluid inclusions from „red calcites” suggesting that the calcite precipitated from karst water



Győri et al. (2014), GEOFLUIDS 14 (4) 459-480



XRD pattern of solid inclusions separated from **red calcites** suggesting that fine bauxite-suspension was transported into the karst by infiltrating waters

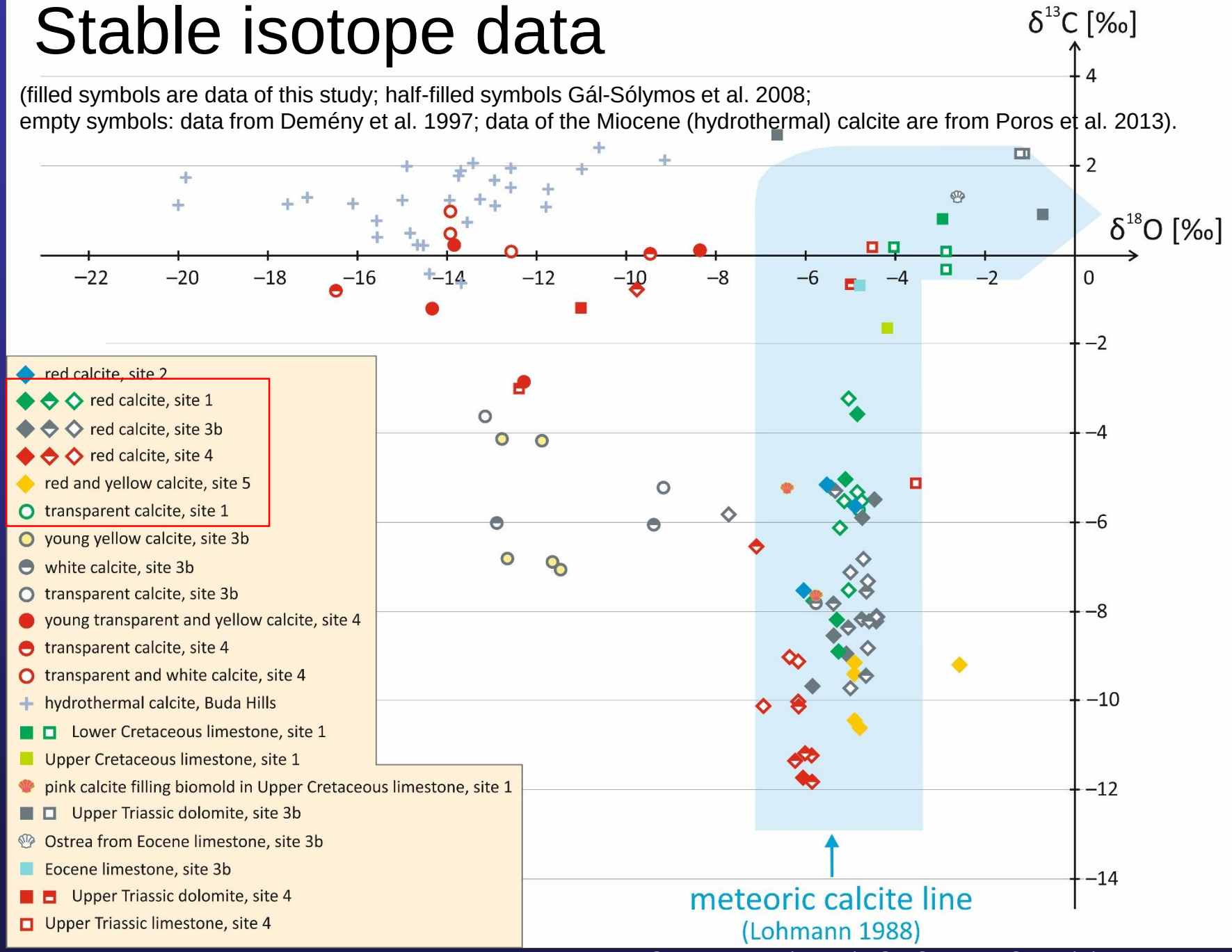
(Győri et al. (2014), GEOFLUIDS 14 (4) 459-480)

Thanks to B.D'Argenio, A.É.Csoma, Á.Török, K.Hips, Zs.Poros, O.Győri, L.Simone, G.Carannante, E.Hertelendi,
and (the late) Bakony Bauxite Mines, Hungary

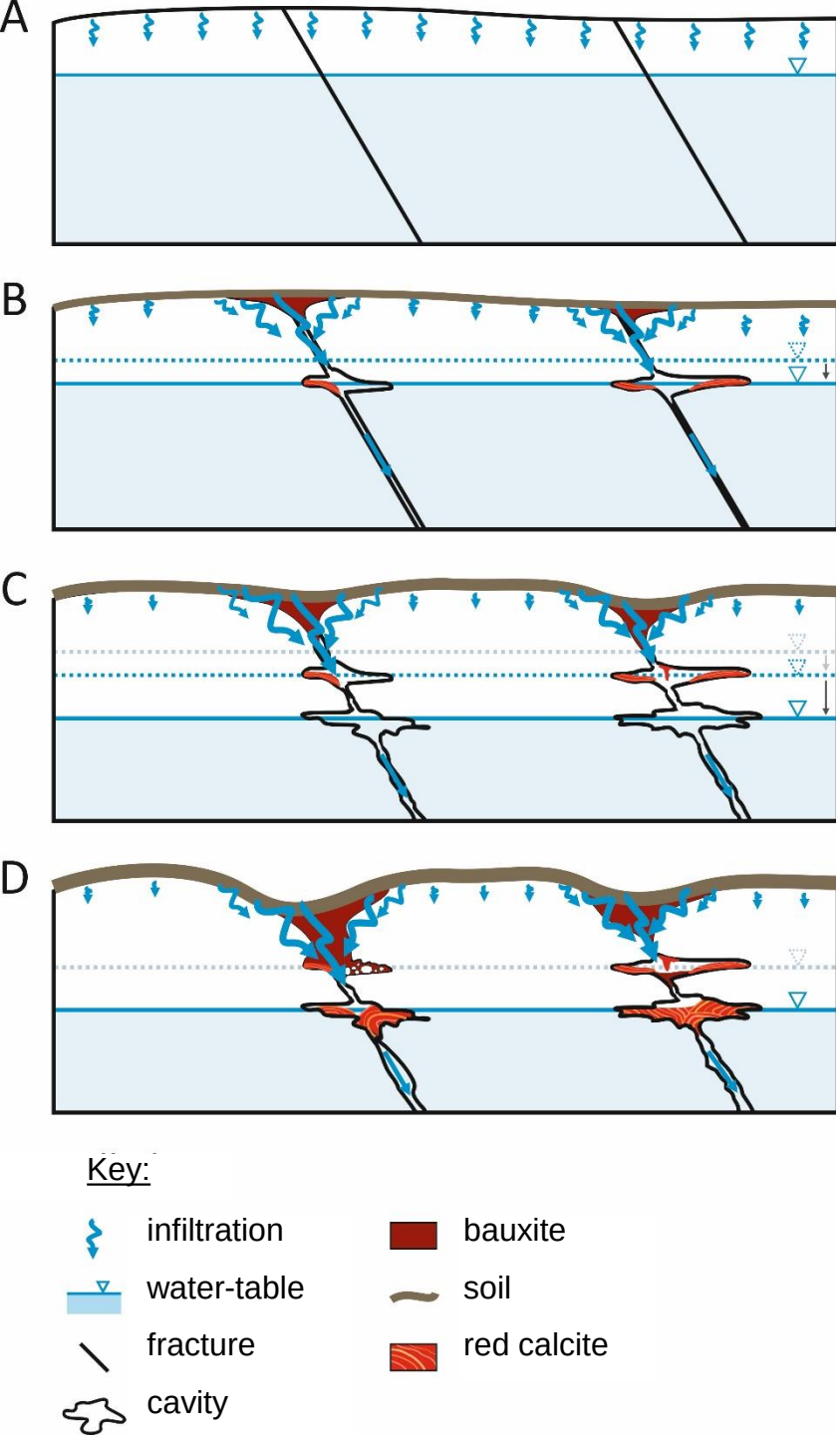
END

Stable isotope data

(filled symbols are data of this study; half-filled symbols Gál-Sólymos et al. 2008;
empty symbols: data from Demény et al. 1997; data of the Miocene (hydrothermal) calcite are from Poros et al. 2013).



Győri et al. (2014), GEOFLUIDS 14 (4) 459-480

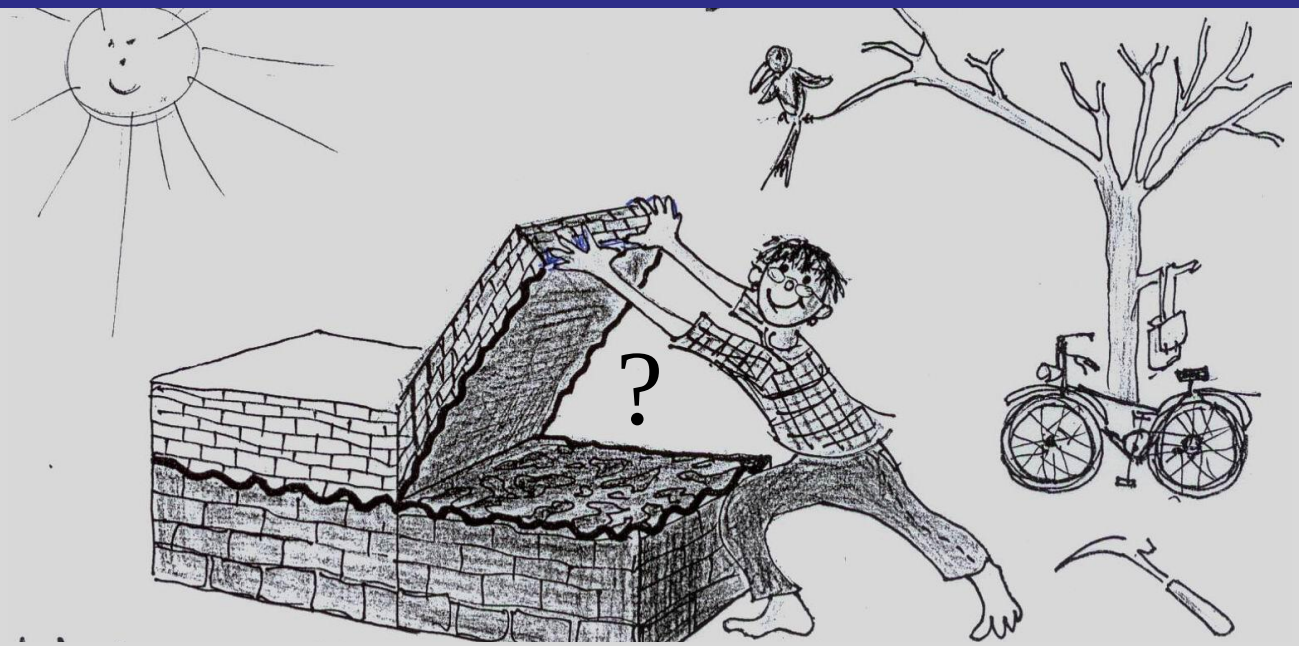


Conceptual model of fracture-controlled **karstification cum base-level lowering** in the TR suggested as the mechanism of development of surface karst and the underlying karstic cavities filled by infiltrated bauxite and the „red calcite" speleothems

Győri et al (2014) GEOFLUIDS 14 (4), 459-480

Though it is very difficult (but *not always impossible*) to find out **what exactly has happened when** - at the first sight - **nothing has happened**....

....just as in the case of a major to moderate unconformity



Bauxites may teach us, how to do that!!!

THE EXPLANATION: FLEXURAL DEFORMATION (Tari 1994)

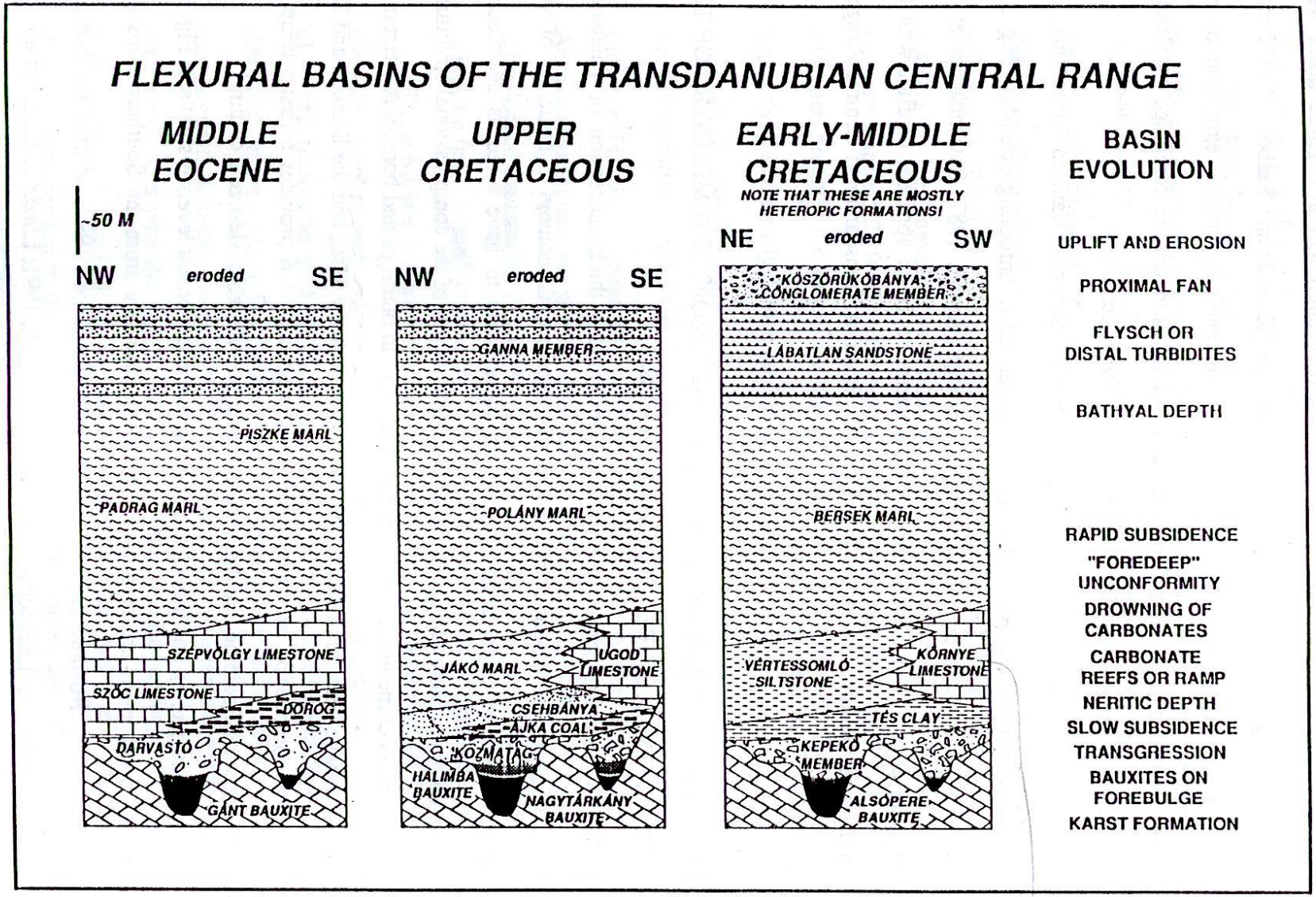
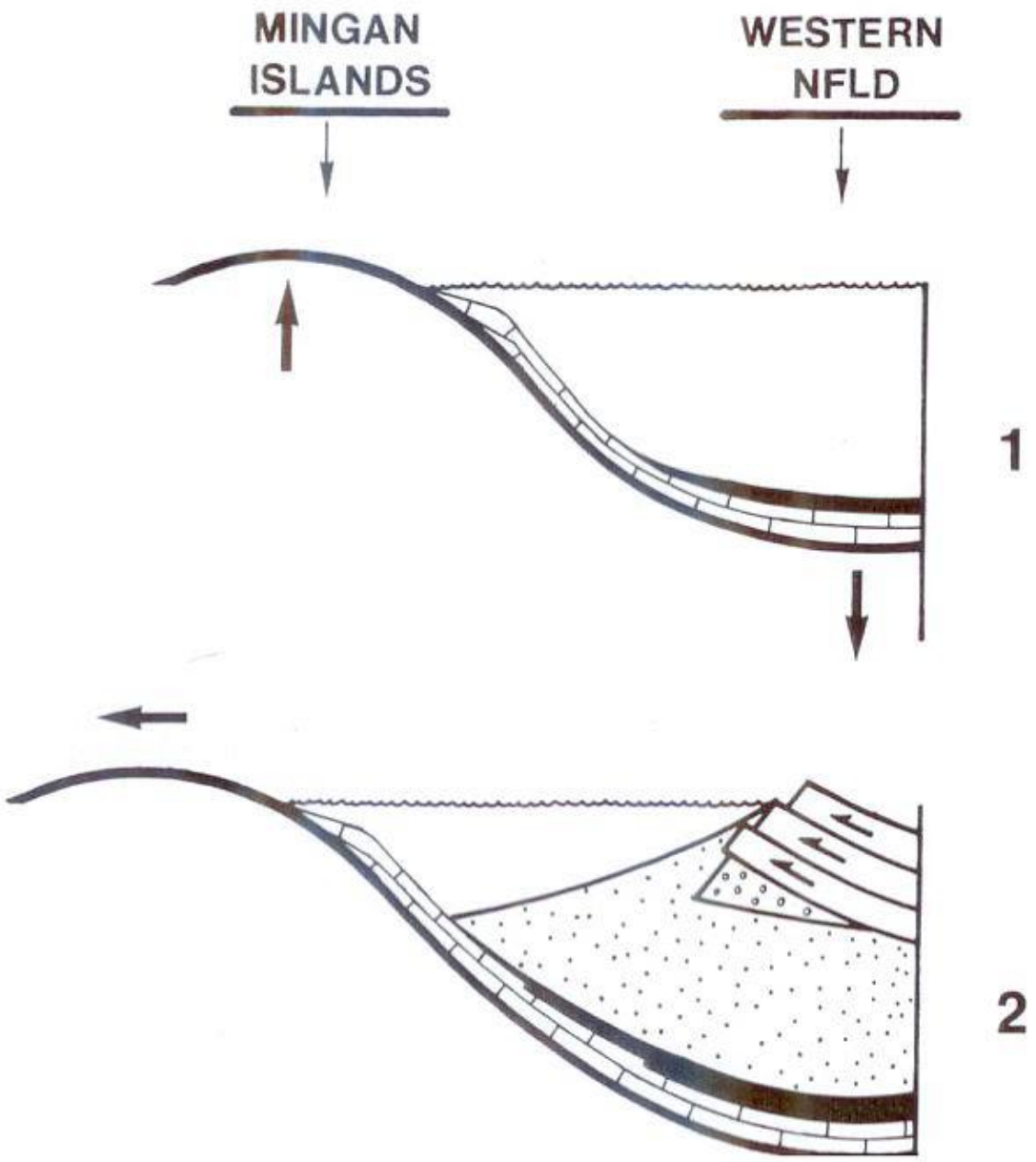


Fig. 5.27. Cretaceous-Eocene flexural basins of the study area.



Desrochers & James 1987

THE GEODYNAMIC MECHANISM BEHIND?

FLEXURAL FOREBULGE

A possible geodynamic mechanism for uplift in the Cretaceus of the Transdanubian Range (analogous to that of the Early Paleozoic Mingan Island paleokarst in Canada as suggested by Desrochers and James)

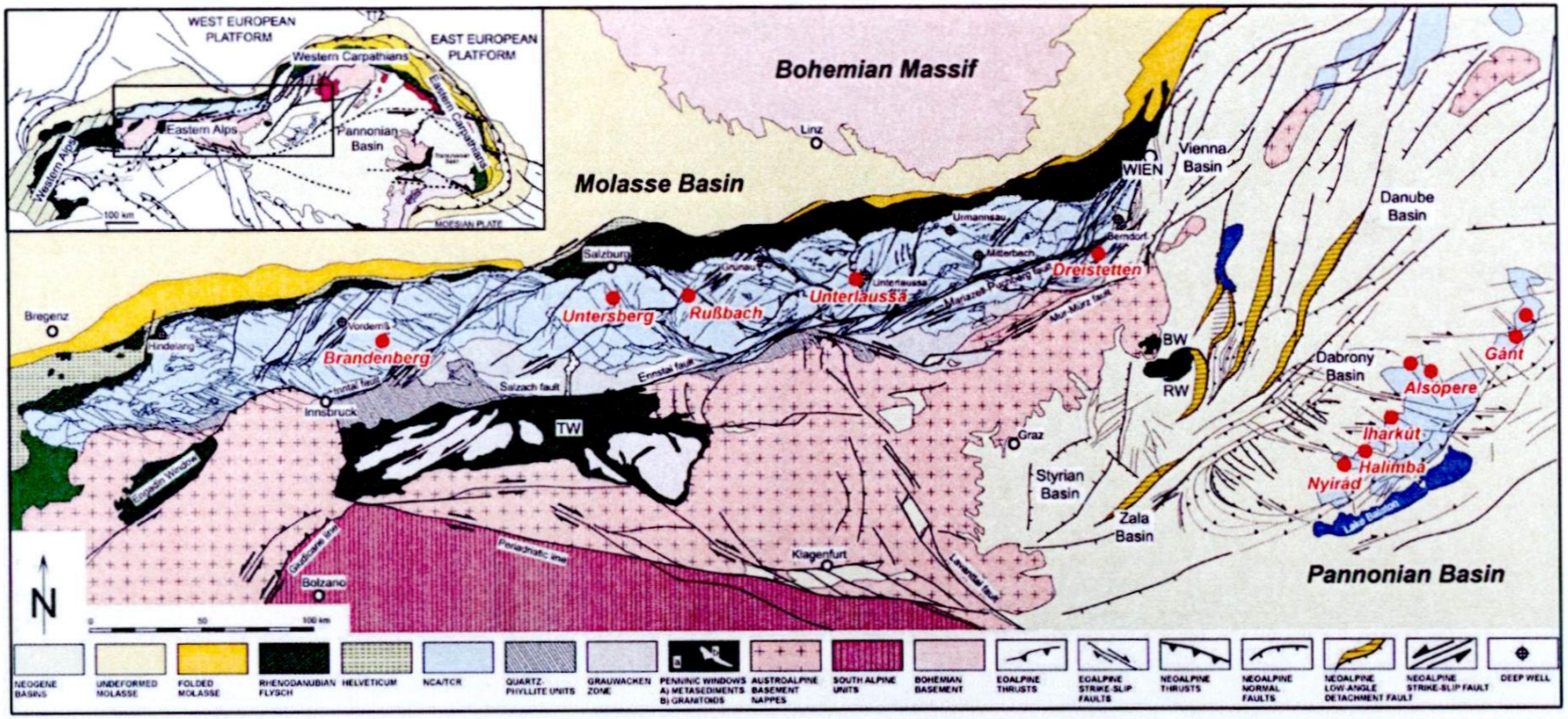
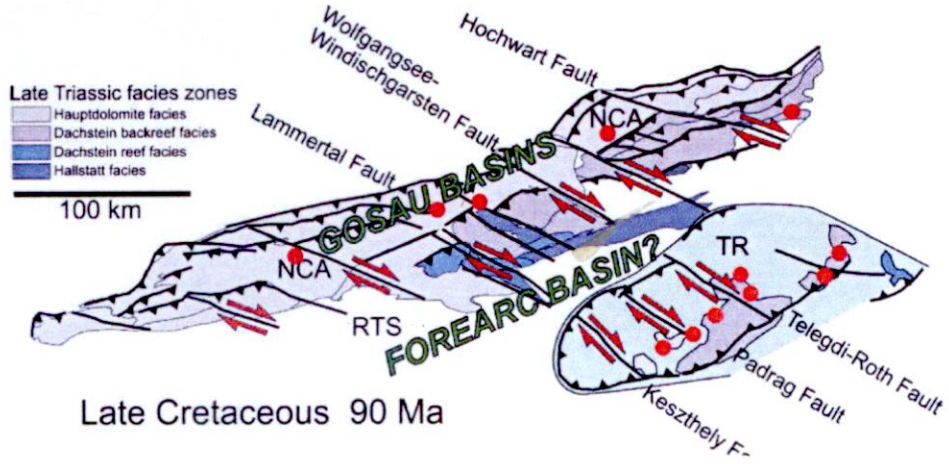


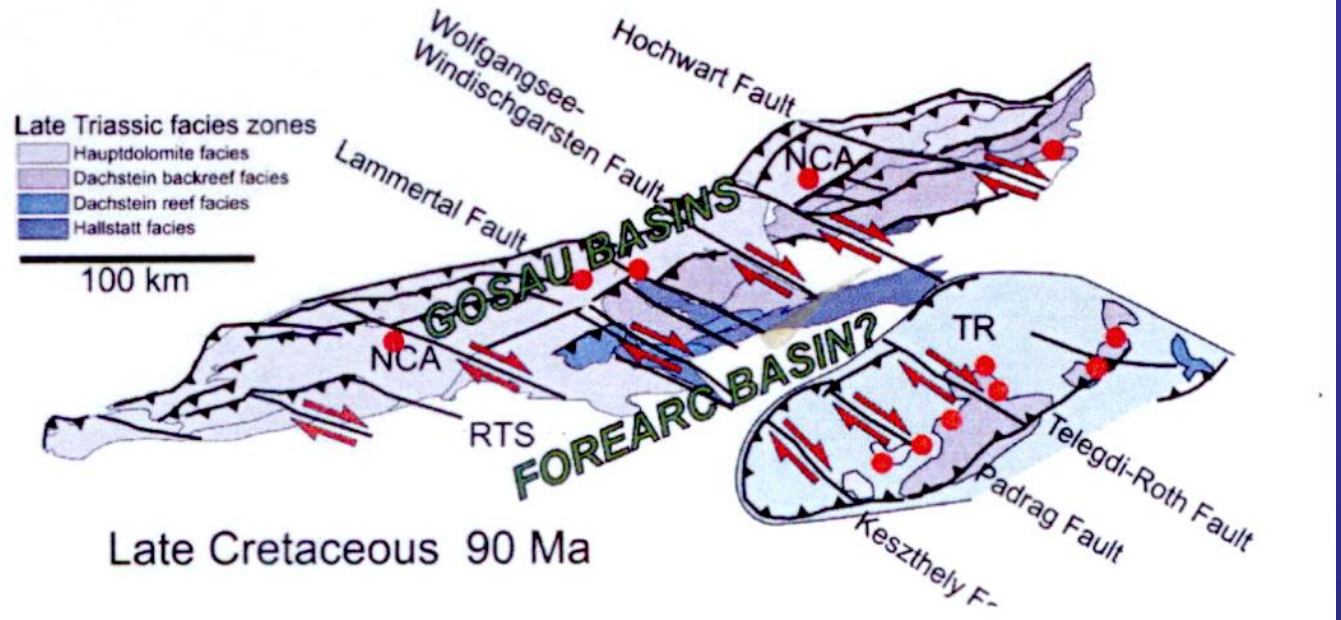
Figure 1. Alpine structural elements of the Eastern Alps and the western Pannonian Basin, modified from LINZER & TARI (2012). The locations of the Austrian and Hungarian bauxite occurrences mentioned in the text are highlighted by red dots. TW: Tauern Window; BW: Bernstein Window; RW: Rechnitz(Rohonc) Window

1. ábra. Alpi szerkezeti elemek a Keleti-Alpokban és a Pannon-medence nyugati részén, LINZER & TARI (2012) BW: Borostyánkői-ablak; RW: Rohonci-ablak



Present- and hypothetic Pre-Neogene position of the bauxite deposits of Austria and Hungary

(according to Linzer and Tari 2012)



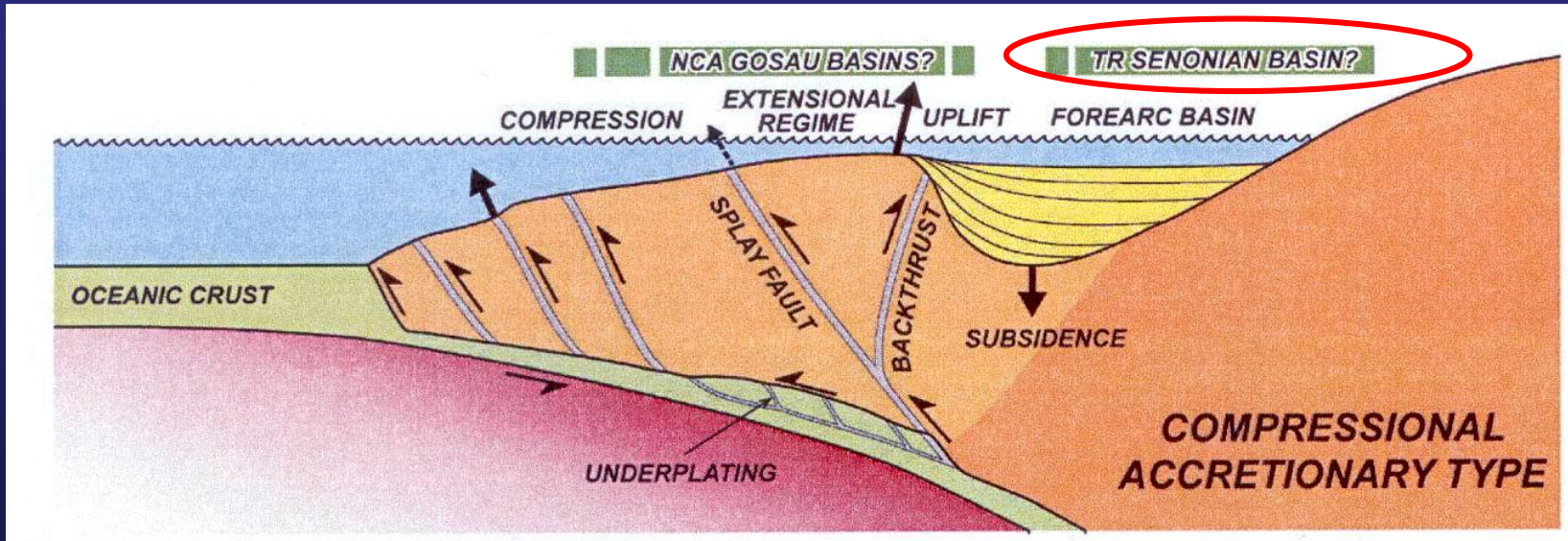


Figure 5. Summary of the main structural elements of a compressional accretionary arc (NODA 2016). The possible positions of the classic Gosau Basins of the NCA versus the Hungarian Senonian basin on the NW flank of the TR are tentatively shown. For a corresponding speculative map-view interpretation, see Figure 4.

„IMPERIAL" BAUXITES – STRATIGRAPHIC POSITION

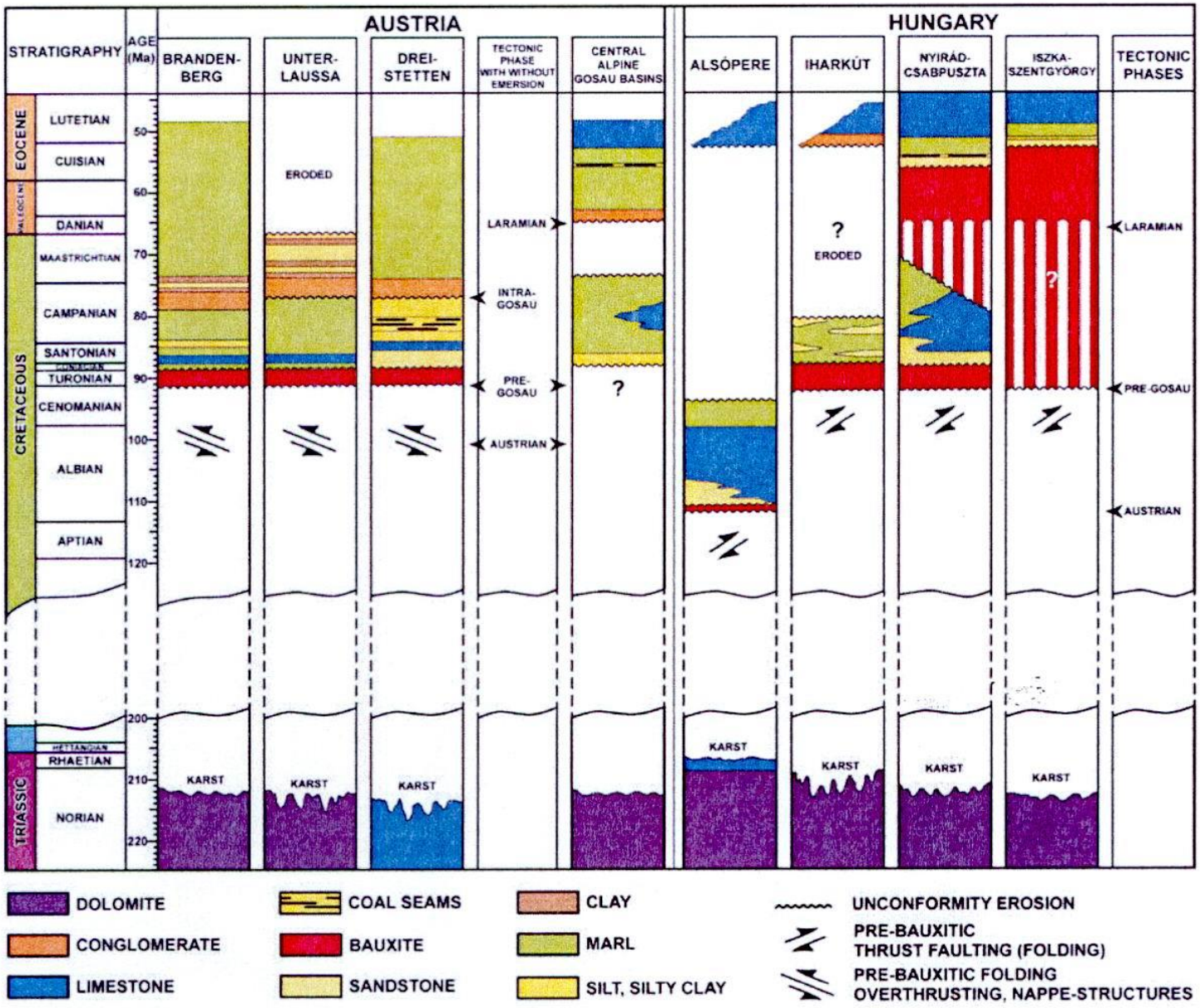


Figure 2. Stratigraphic position of the Austrian and Hungarian bauxites, reproduced from MINDSZENTY et al. (1987). For the locations of these occurrences see Figure 1.