Land plants and terrestrial environmental changes during the onset of the end-Triassic event

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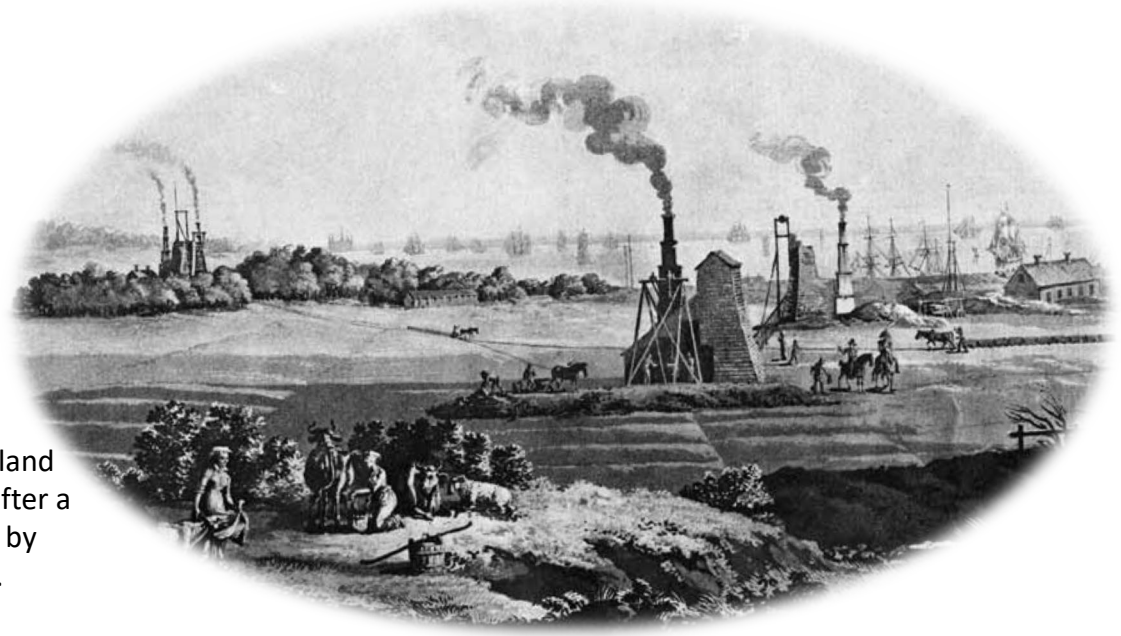
Triassic-Jurassic coal and clay were mined for centuries in Scania, southernmost Sweden



M.R. Heland (1805) after a drawing by Billqvist.

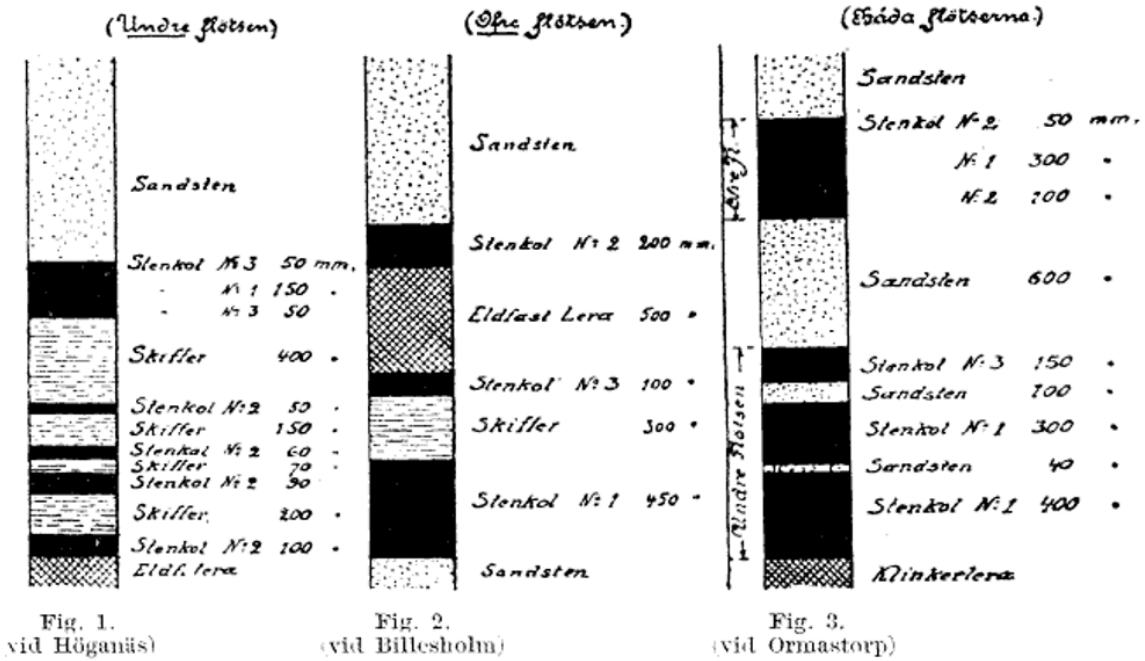


Fig. 1. vid Höganäs) Fig. 2. (vid Billesholm) Fig. 3. (vid Ormastorp)

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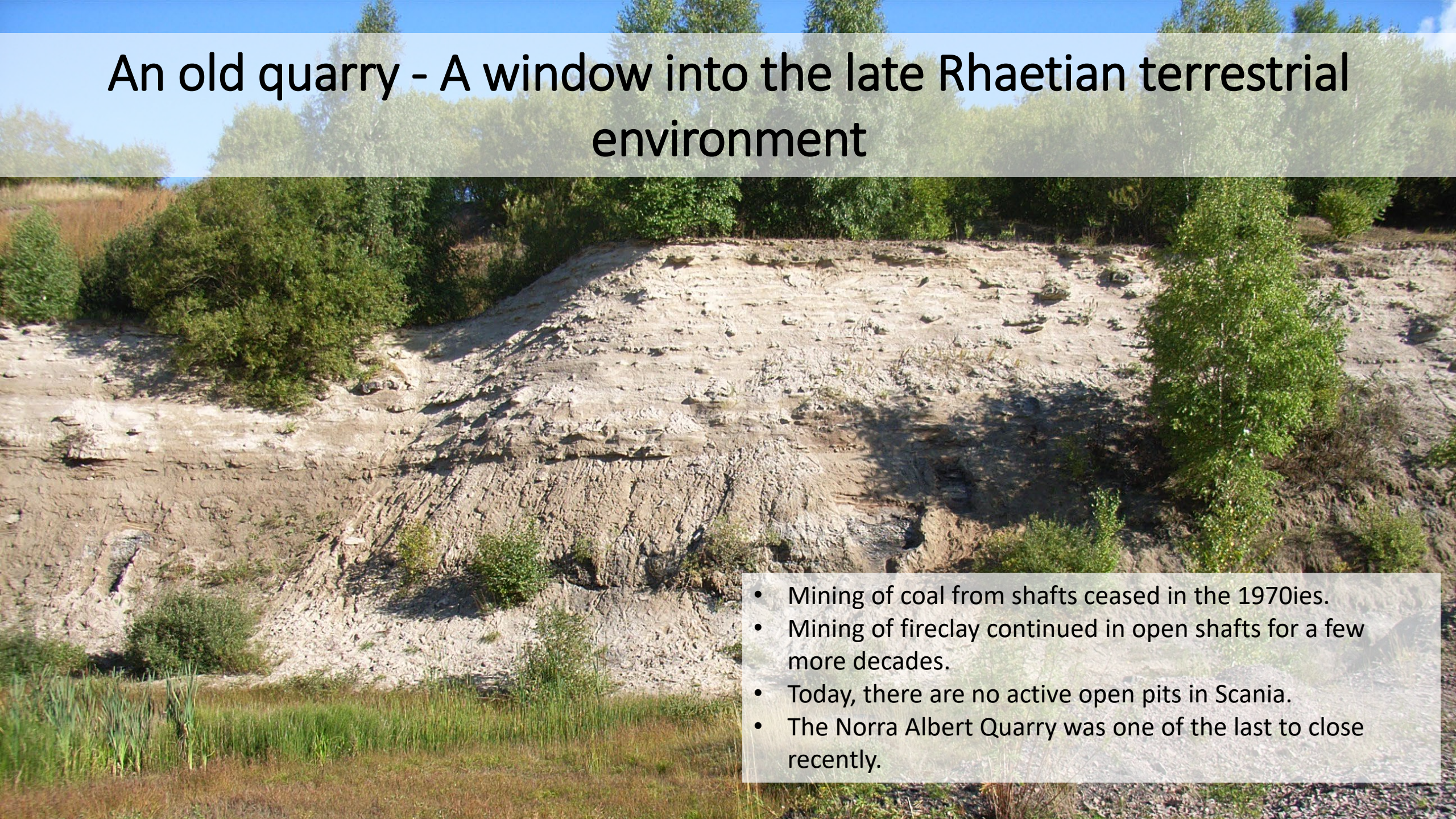
- Early mining activity stripped the landscape of trees.
- Mining in shafts often took place under difficult conditions.
- The mining led to extensive geological investigations (e.g. Troedsson 1951).
- Open pits have been important excursion and fieldwork localities for generations of geologists. But not any more…

An old quarry - A window into the late Rhaetian terrestrial environment

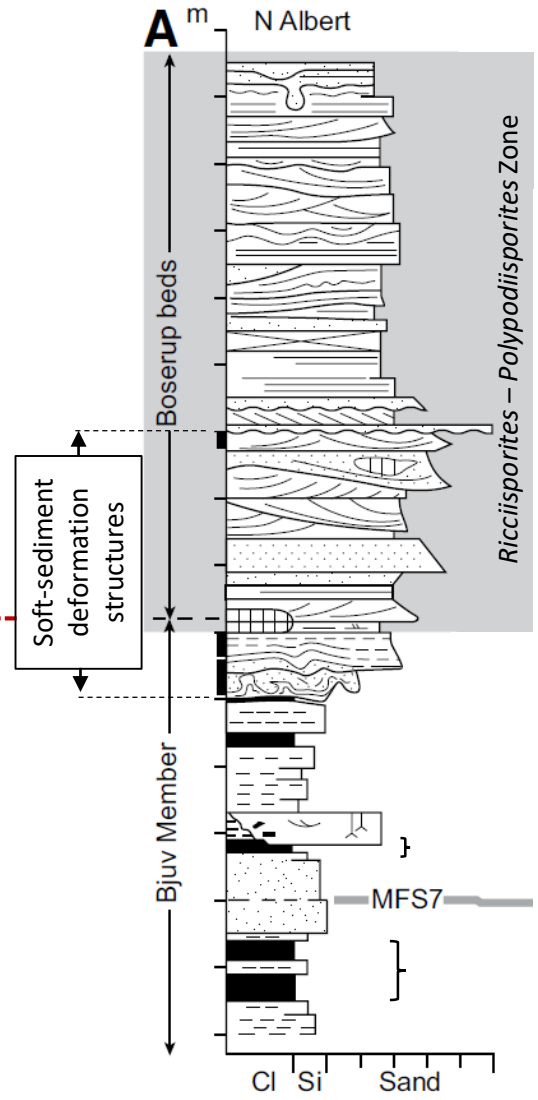


- Mining of coal from shafts ceased in the 1970ies.
- Mining of fireclay continued in open shafts for a few more decades.
- Today, there are no active open pits in Scania.
- The Norra Albert Quarry was one of the last to close recently.

The exposed mid- to late Rhaetian succession

Boserup Beds, Helsingborg Member

Bjuv Member



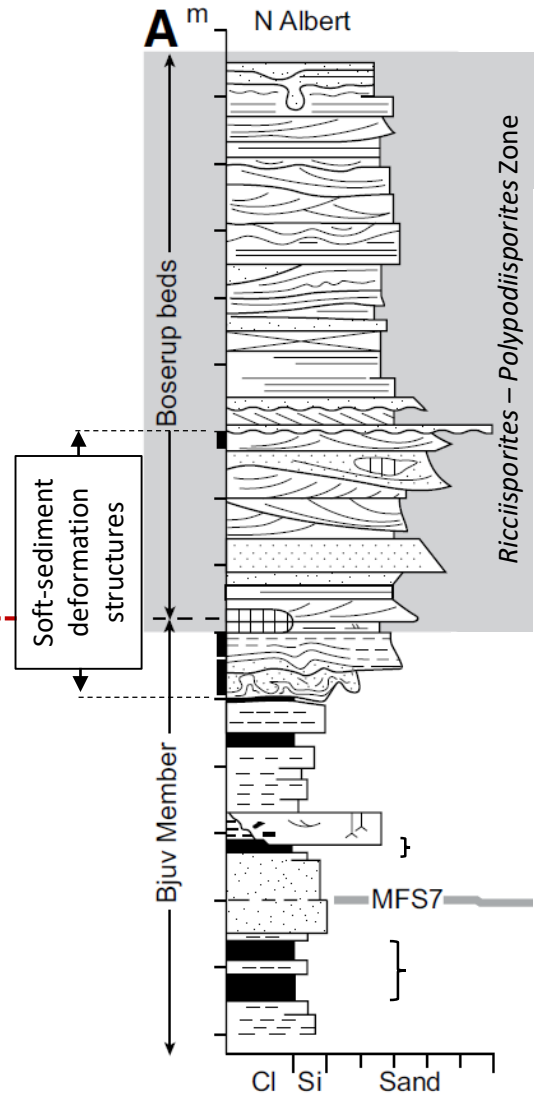
Lindström et al. (2015)

Bjuv Member: mid/late-Rhaetian coal mires

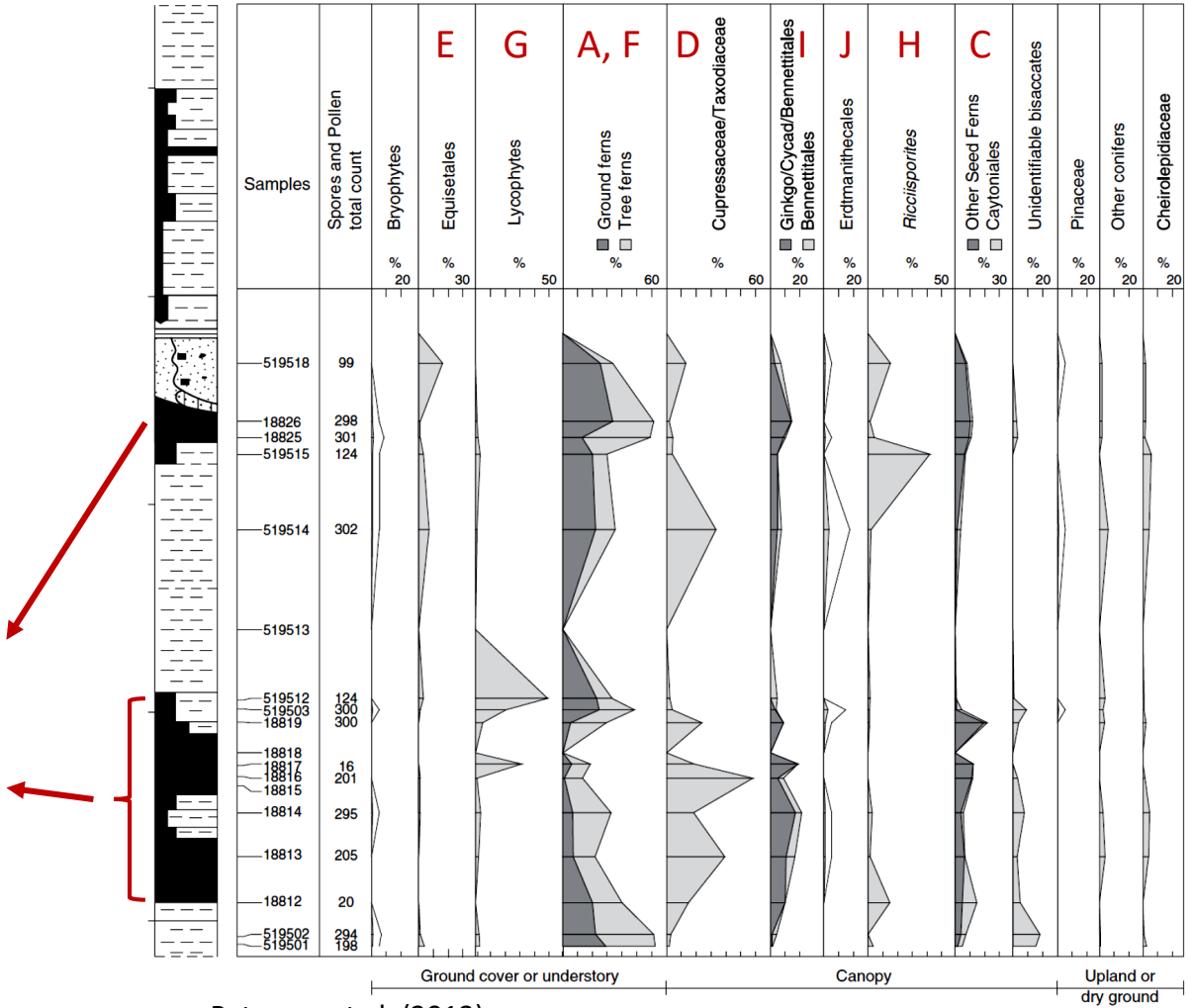
- Coal seams B and A can be traced over NW Scania
- The mires were deposited during the late Rhaetian transgression (MFS7 of Nielsen 2003)
- Mires dominated by Cupressaceae, tree ferns, ground ferns, ginkgo/Bennettitales and Caytoniales

Boserup Beds, Helsingborg Member

Bjuv Member

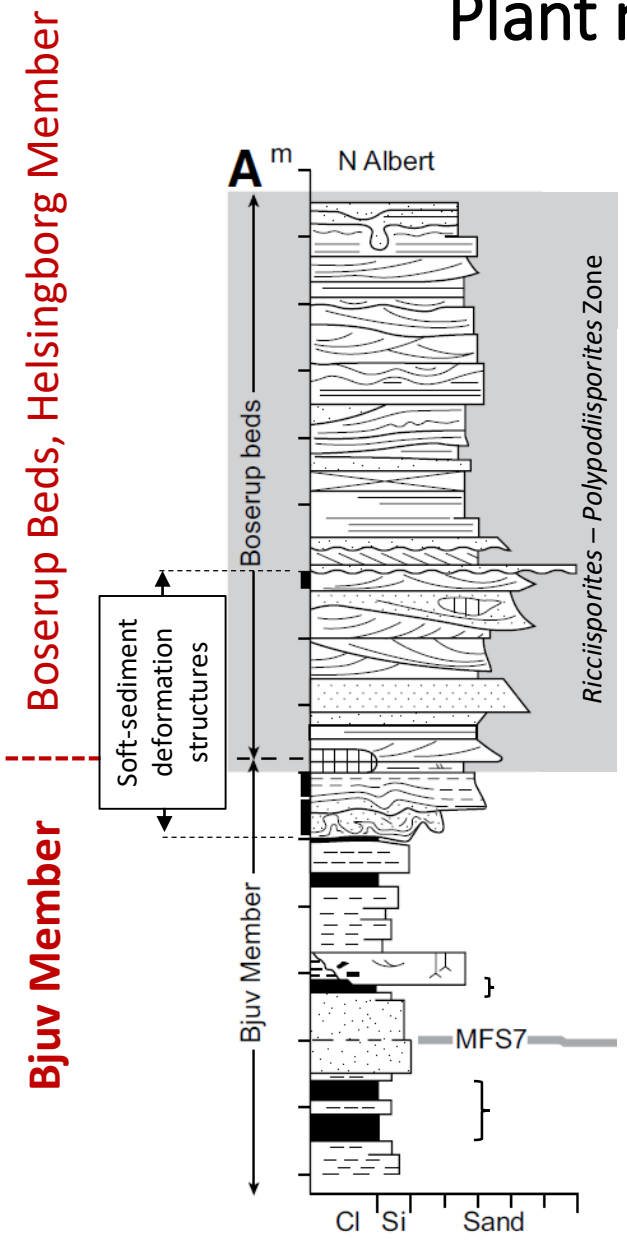


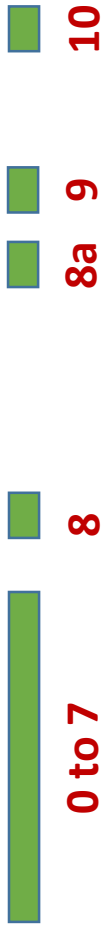
Lindström et al. (2015)



Petersen et al. (2013)

Plant macrofossil assemblages: mid/late-Rhaetian record

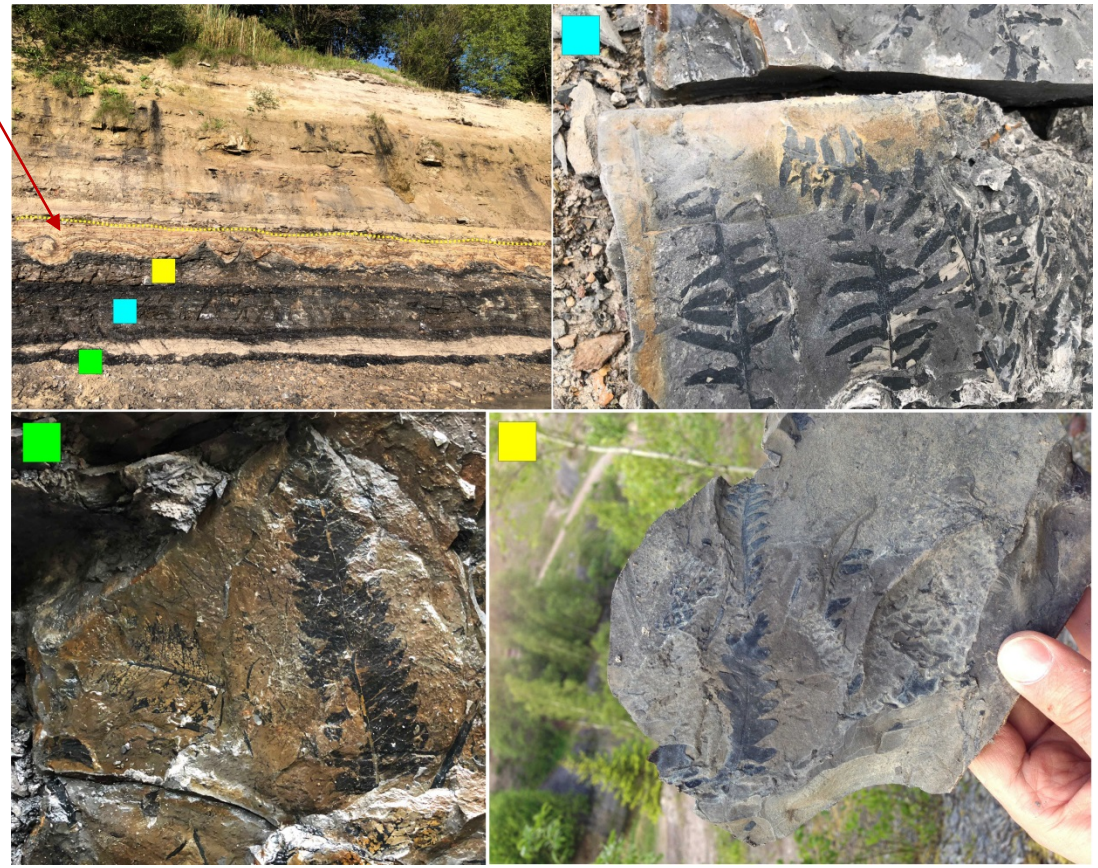




Beds with plant macrofossil assemblages

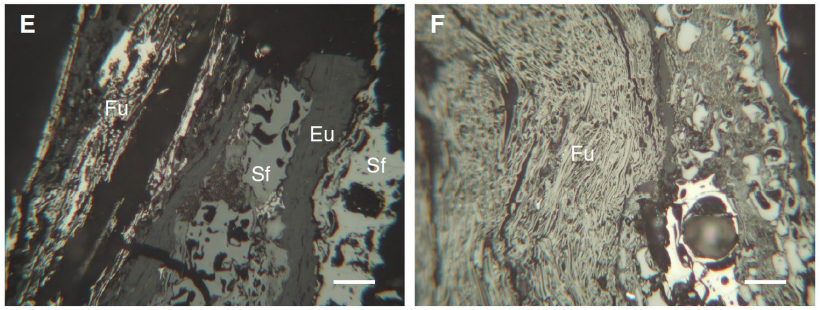
- More than 3000 specimens of plant macrofossils were collected from the Norra Albert section
- Material comes from 12 successive beds (0-7 beds: Bjuv Mb.; 8, 8a-10 beds: Boserup Beds)
- Bjuv Mb claystones/siltstones has yielded about 2500 foliar compressions and impressions, this material is under preliminary taxonomic study
- Boserup Beds has yielded numerous beds with carbon-rich organic debris (charcoal, lignified wood debris) and rare plant macroremains preserved as sideritized, lignified or silicified wood fragments and rare foliar compressions or impressions

Soft-sediment deformation (see slide 10)

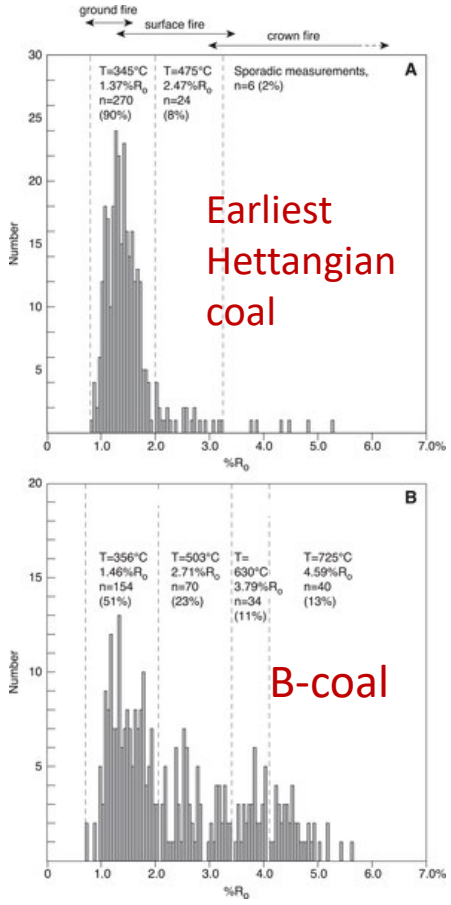


Some examples of plant fossils from upper part of Bjuv Mb (Photo: G. Niedzwiedzki)

Bjuv Member: intense wildfires and deforestation of mires



Fu=fusinite, Sf=semifusinite and Eu=ulmenite in samples from the B-coal (Petersen et al. 2013)



Earliest Hettangian coal

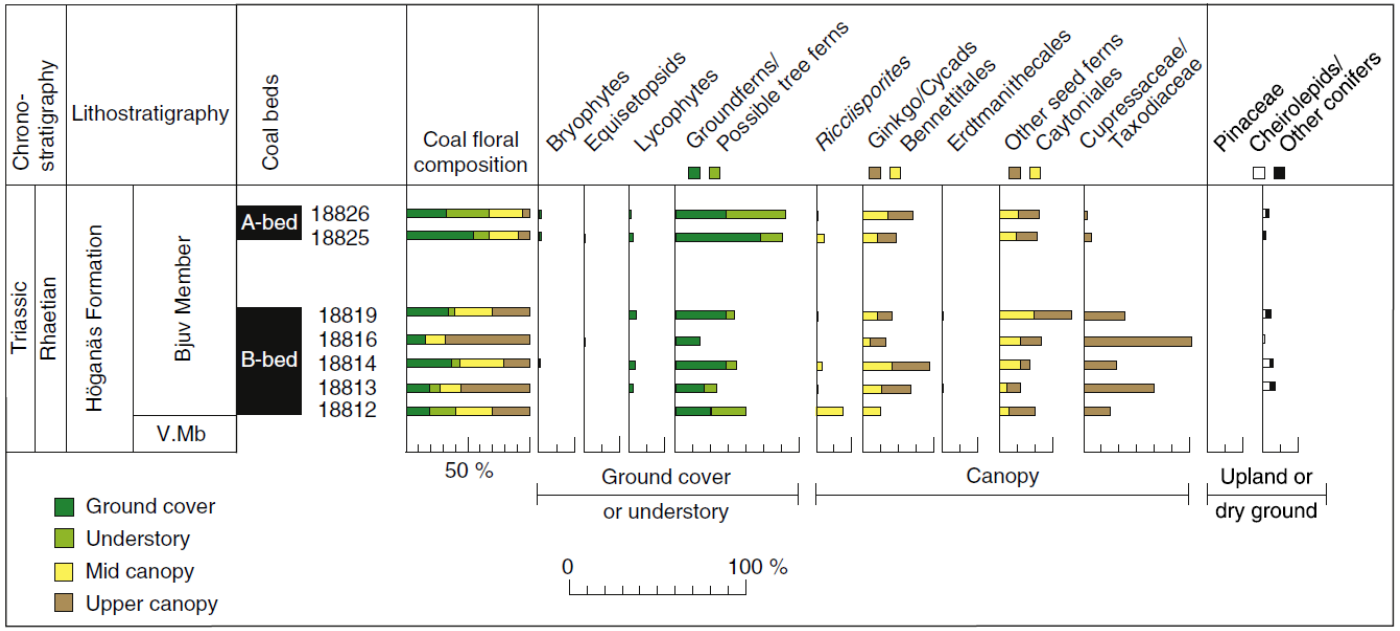
B-coal

Palynology and wildfire burning temperatures calculated from inertinite reflectance in the coals show the same trend:

Deforestation of mires across the Triassic-Jurassic boundary

Petersen & Lindström (2012)

Petersen et al. (2013)



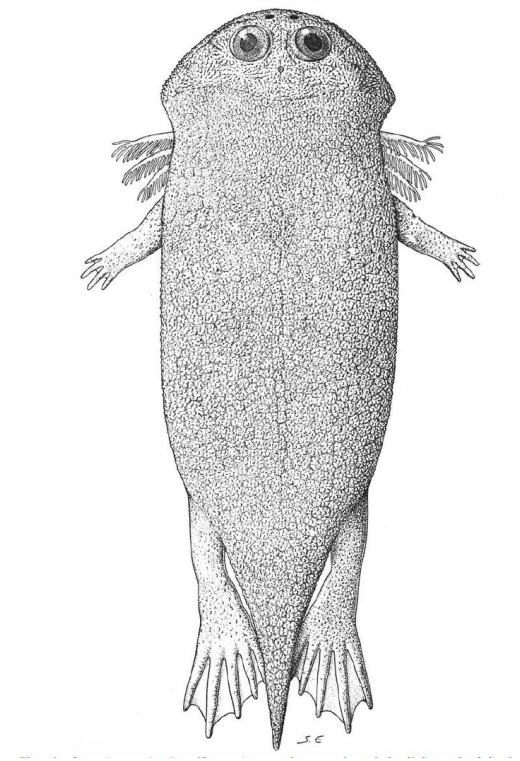
Petersen et al. (2013)

Bjuv Member: dinosaurs tracks and temnospondyl bones

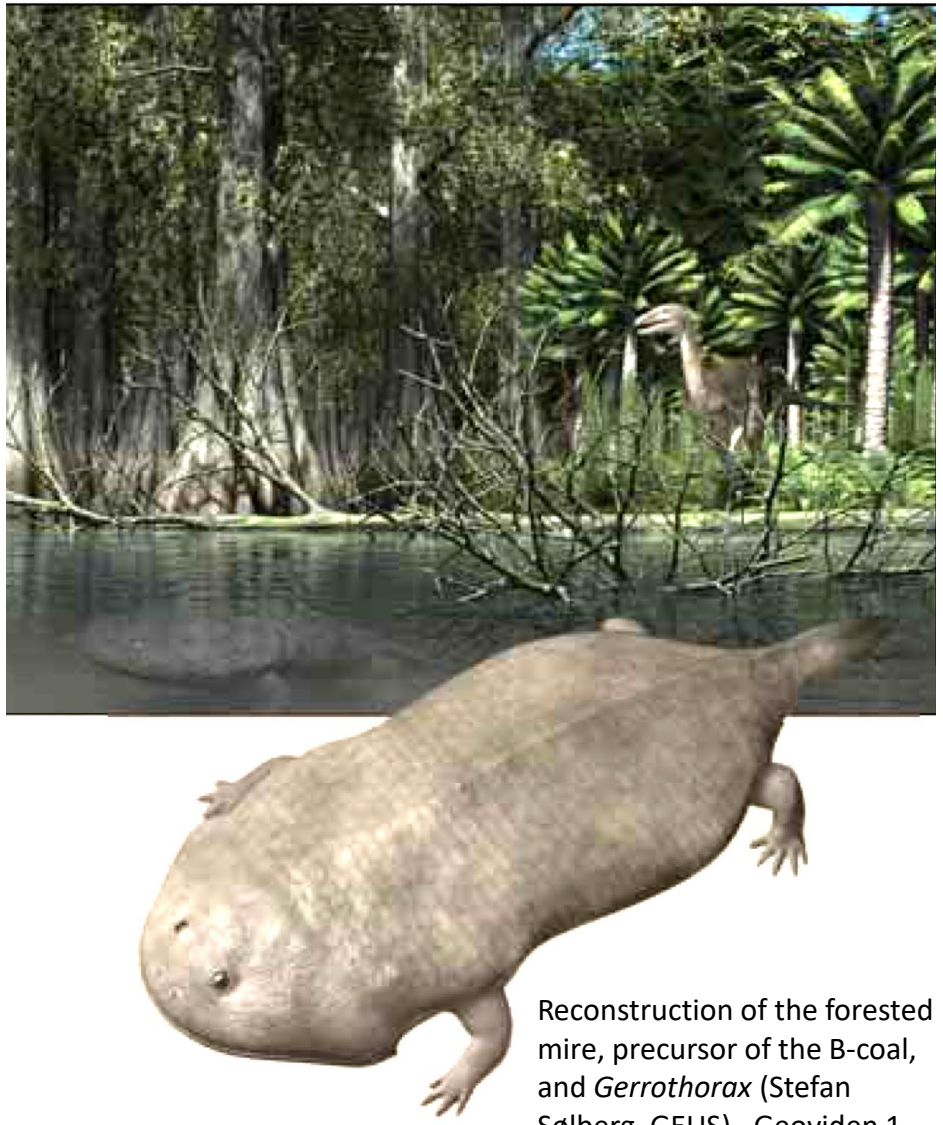
Dinosaur footprint from Södra Vallåkra (Photo: M. Erlström). Geoviden 1 (2016)

Several dinosaur footprints have been recovered during mining operations, and tunnel constructions in NW Scania (Gierlinski and Ahlberg 1994).

Eubrontes isp. theropod dinosaur footprint from Gustaf Adolf Mine, Höganäs, specimen described by Gierlinski and Ahlberg 1994



Remains of the plagiosaurid *Gerrothorax pulcherrimum* found in the Bjuv coalmine, were described by Nilsson (1946)



Reconstruction of the forested mire, precursor of the B-coal, and *Gerrothorax* (Stefan Sølberg, GEUS). Geoviden 1 (2016)

Bjuv Member: new finds of dinosaurs tracks!
Boserup Beds: first finds of dinosaurs bones!

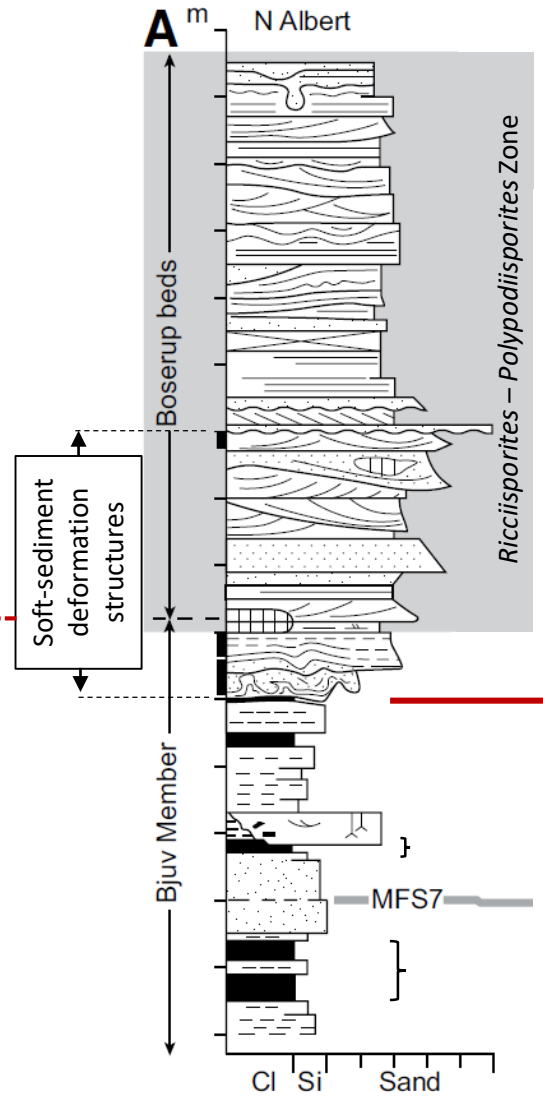
Grallator isp., isolated footprint of small theropod dinosaur found in the Norra Albert Quarry

Fieldwork campaign in the Norra Albert Quarry, June 2019

A change in flora, fluvial style and onset of seismic activity

Boserup Beds, Helsingborg Member

Bjuv Member



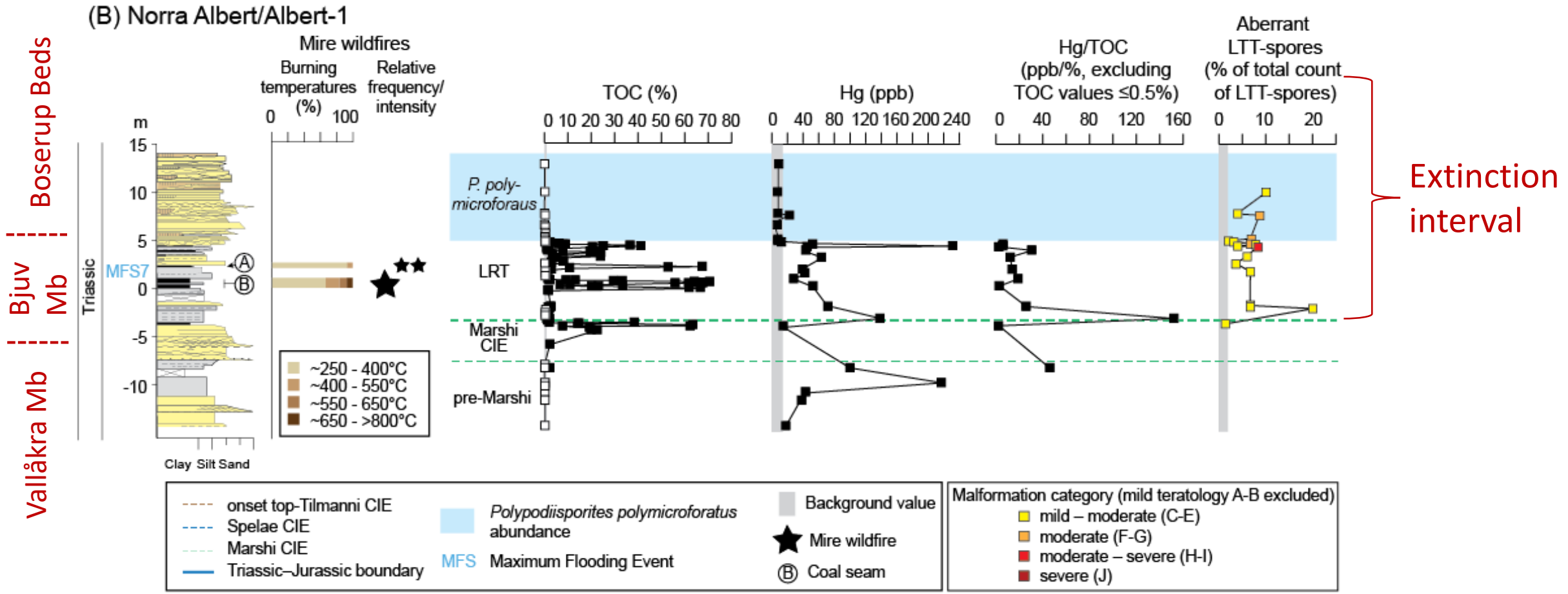
Lindström et al. (2015)

- A change from sluggish mire environment with confined channels to unconfined, braided river-type deposits. Linked to change in palynoflora - deforestation.
- Boserup Beds: *Ricciisporites-Polypodiisporites* Palynofloral Zone.
- Seismites recognized all over NW Europe; tectonic activity linked to the Central Atlantic Magmatic Province - CAMP (Lindström et al. 2015)

Volcanic mercury and mutated fern spores

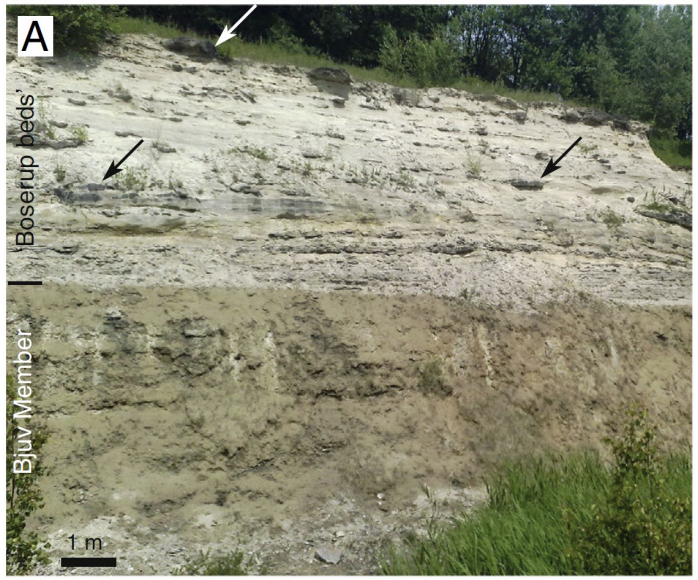
Normal spore Mutated spore

- The Albert-1 core, drilled in 2010 provide data on the Norian-mid-Rhaetian succession.
- Mercury (Hg) analysis reveal several Hg-anomalies, and an increase in mutated fern spores.
- Mercury most likely derived from CAMP (Lindström et al. 2019).



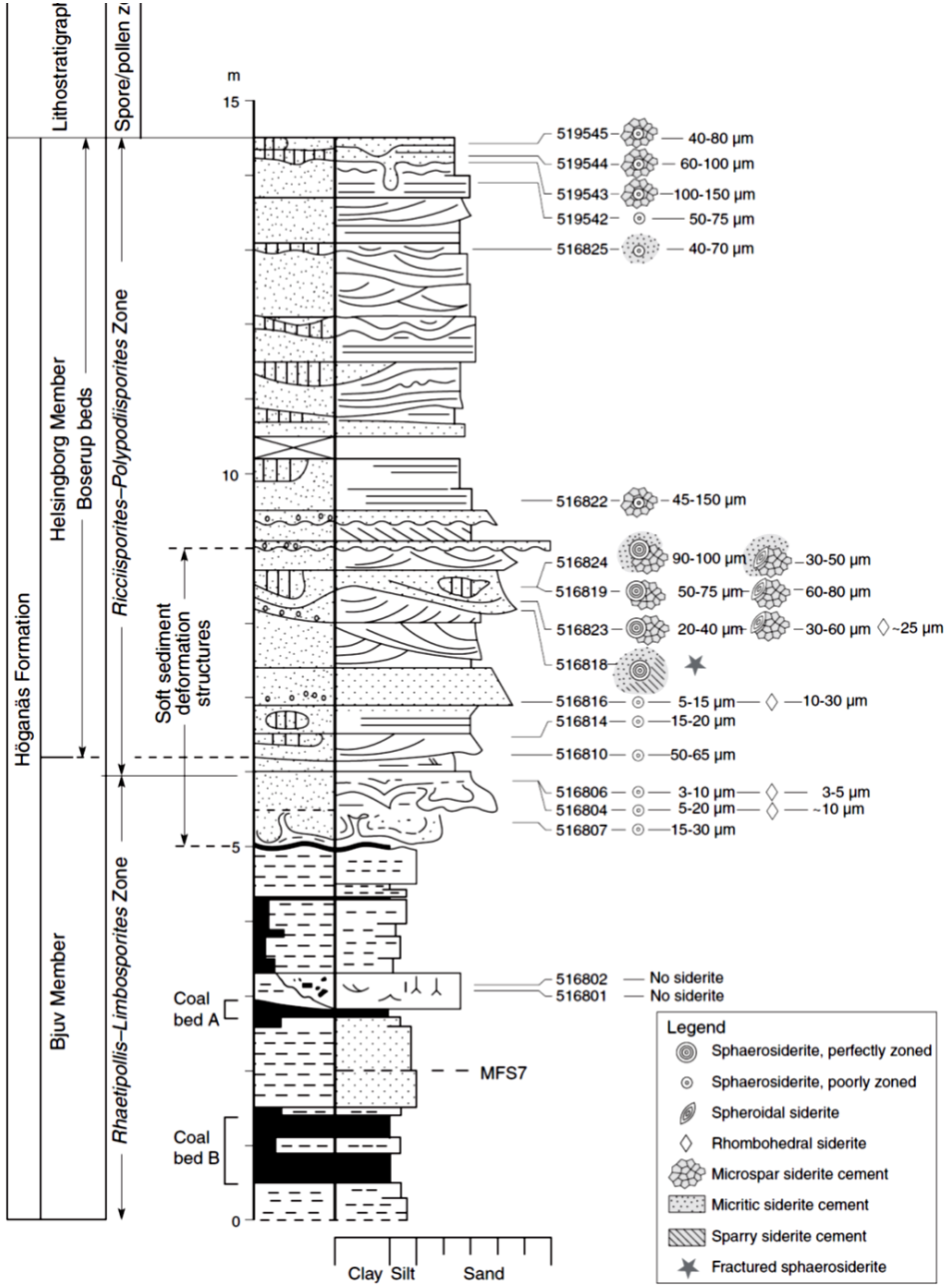
Lindström et al. 2019, Sci Adv

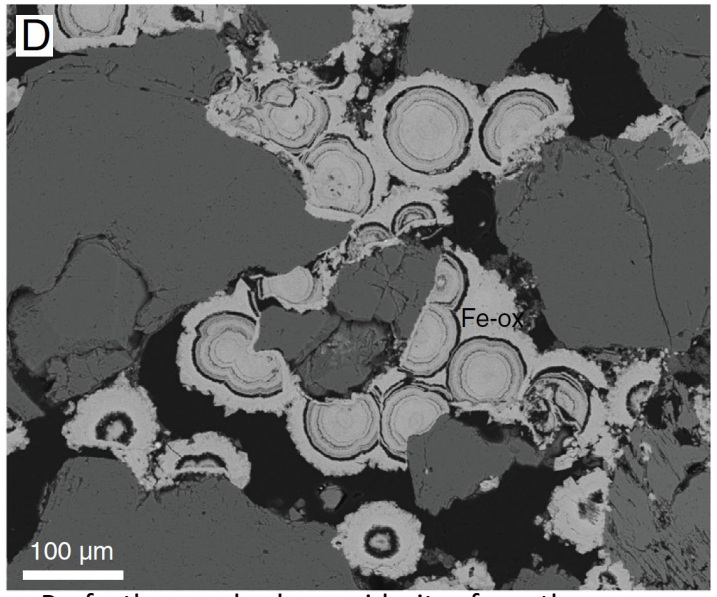
Siderite and groundwater levels



Arrows point to siderite concretions (Weibel et al. 2016).

Siderite concretion formed around a tree trunk (Weibel et al. 2016).

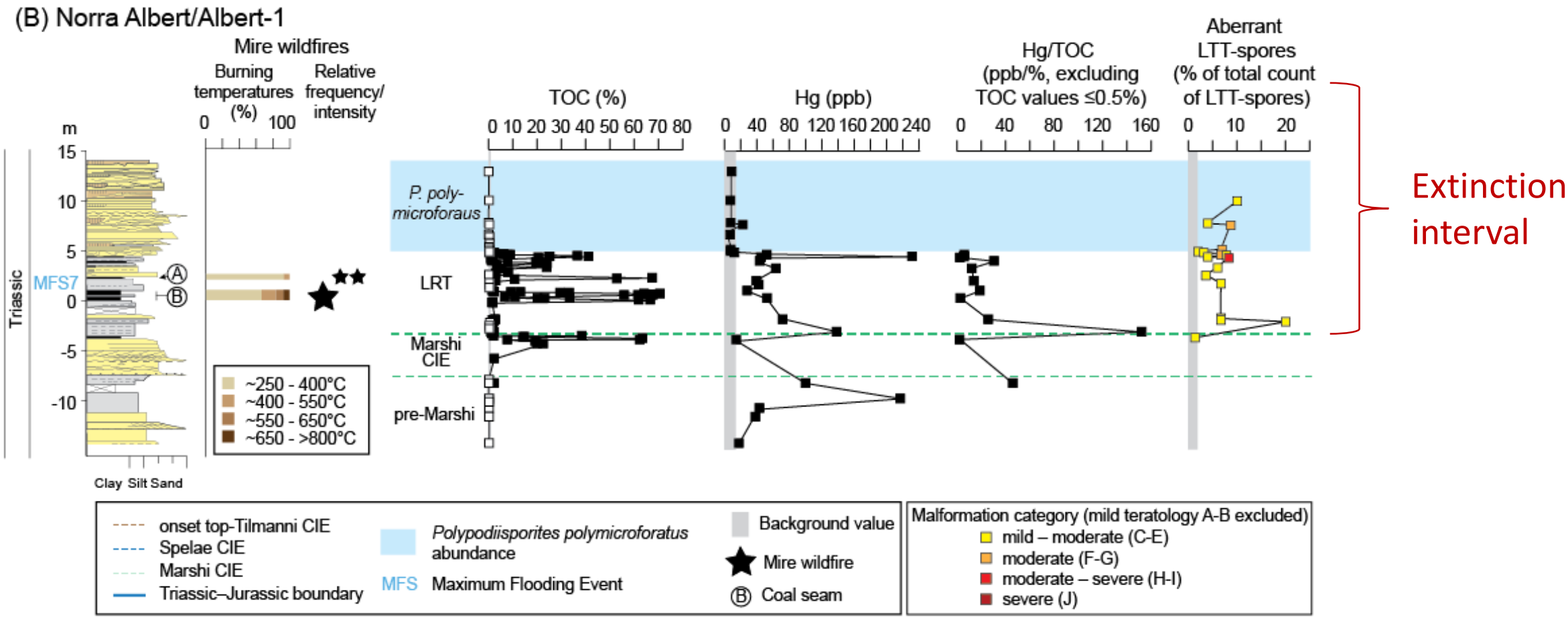




Perfectly zoned sphaerosiderites from the Boserup Beds (Weibel et al. 2016).

- Siderite formation varies through the section.
- Perfectly zoned sphaerosiderites are confined to the Boserup Beds.
- Sphaerosiderite-zonation alternating between Fe- and Mn-dominating suggest strongly fluctuating groundwater levels (Weibel et al. 2016).

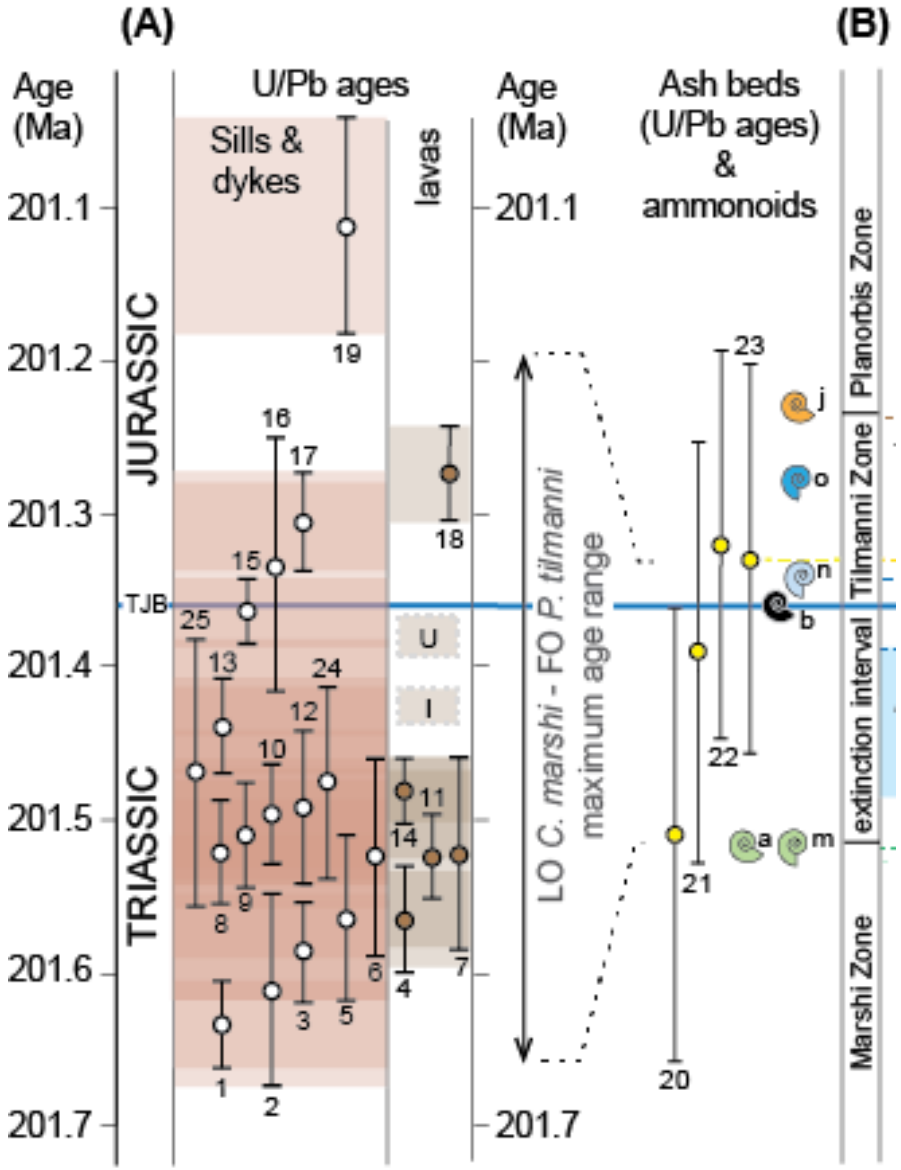
Late Rhaetian succession at Norra Albert Quarry



Extinction interval

Lindström et al. 2019, Sci Adv

Why is Norra Albert important? - The CAMP volcanism and ETE

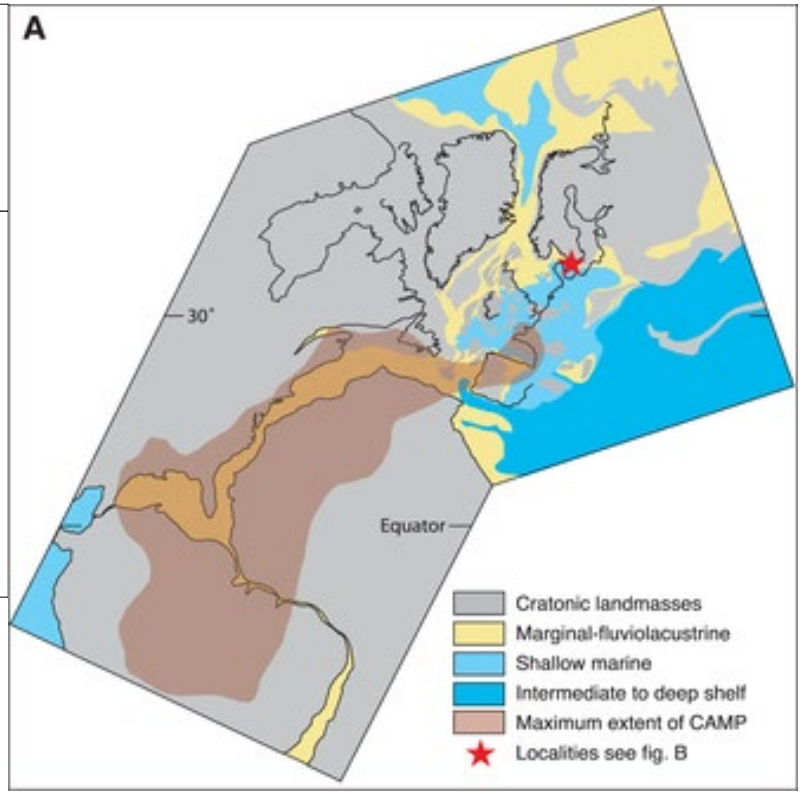


End-Triassic mass extinction (ETE)

•Age ~ 201.564 Ma (Blackburn et al. 2013)

Central Atlantic Magmatic Province (CAMP)

- Volume: 2.3 x 10^6 km^3
- Duration maximum ~700.000 years
- Individual lava flows <0.5 kyrs (Marzoli et al. 2019)



Extinction interval

Norra Albert succession

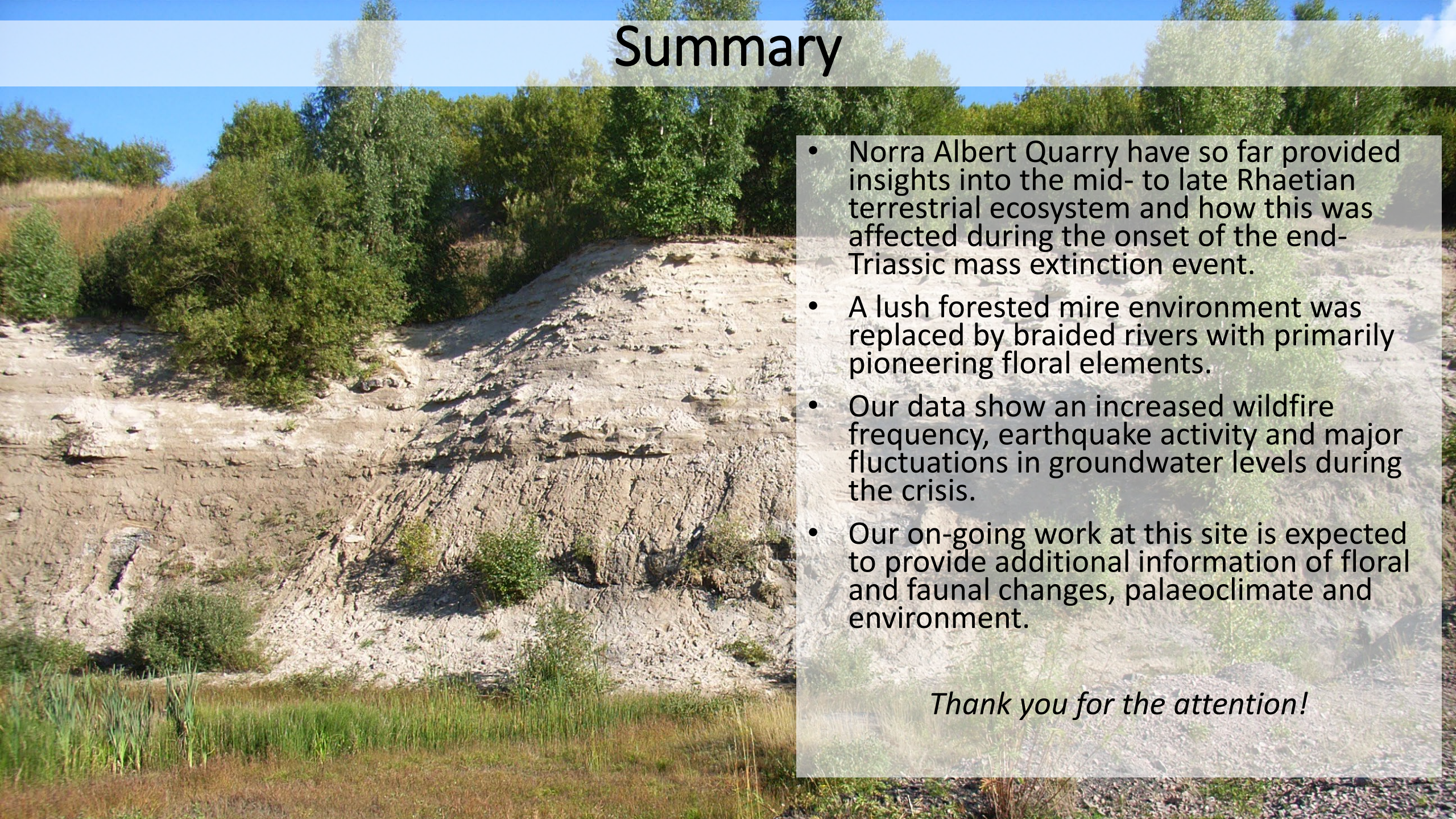
It is one of very few localities with a terrestrial succession of end-Triassic strata!

Blackburn et al. 2013; Davies et al. 2017; Heimdal et al. 2018; Lindström et al. 2017

On-going work

- Fieldwork Summer 2020, macropalaeontology (Niedzwiedzki).
- Biomarker analyses (Nytoft).
- Charcoal analysis (Petersen).
- Organic C-isotopes (Lindström).
- Sedimentology (Pedersen).
- Geochemistry (Pedersen, Weibel, Johansson, Tegner).
- Mercury and PGE (Tegner, Sanei, Lindström).
- High-resolution palynology (Lindström, Dybkjær).
- Aberrant spores (Lindström).

Summary



- Norra Albert Quarry have so far provided insights into the mid- to late Rhaetian terrestrial ecosystem and how this was affected during the onset of the end-Triassic mass extinction event.
- A lush forested mire environment was replaced by braided rivers with primarily pioneering floral elements.
- Our data show an increased wildfire frequency, earthquake activity and major fluctuations in groundwater levels during the crisis.
- Our on-going work at this site is expected to provide additional information of floral and faunal changes, palaeoclimate and environment.

Thank you for the attention!

References

Blackburn, T.J., Olsen, P.E., Bowring, S.A., MvLean, N.M., Kent, D.V., Puffer, J., McHone, G., Rasbury, E.T., Et-Touhami, M. 2013. Zircon U-Pb geochronology links the end-Triassic extinction with the Central Atlantic Magmatic Province. Science 340, 941-945.

Davies, J.H.F.L., Marzoli, A., Bertrand, H., Youbi, N., Ernesto, M., Schaltegger, U. 2017. End-Triassic mass extinction started by intrusive CAMP activity. Nature Communications 8,15596.

Gierlinski, G., Ahlberg, A. 1994. Late Triassic and Early Jurassic dinosaur footprints in the Höganäs Formation of southern Sweden. Ichnos 3, 99-105.

Heimdal, T.H., Svensen, H.H., Ramezani, J., Iyer, K., Pereira, E., Rodrigues, R., Jones, M.T., Callegaro, S. 2018. Large-scale sill emplacement in Brazil as a trigger for the end-Triassic crisis. Scientific reports 8, 141.

Lindström, S., Erlström, M. 2006. The Late Rhaetian transgression in southern Sweden: regional (and global) recognition and relation to the Triassic-Jurassic boundary. Palaeogeography, Palaeoclimatology, Palaeoecology 241, 339-372.

Lindström, S., Pedersen, G.K., van de Schootbrugge, B., Hansen, K.H., Kuhlmann, N., Thein, J., Johansson, L., Petersen, H.I., Alwmark, C., Dybkjær, K., Weibel, R., Erlström, M., Nielsen, L.H., Oschmann, W., Tegner, C. 2015. Intense and widespread seismicity during the end-Triassic mass extinction due to emplacement of a large igneous province. Geology 43, 387-390.

Lindström, S., van de Schootbrugge, B., Hansen, K.H., Pedersen, G.K., Alsen, P., Thibault, N., Dybkjær, K., Bjerrum, C.J., Nielsen, L.H. 2017. A new correlation of Triassic–Jurassic boundary successions in NW Europe, Nevada and Peru, and the Central Atlantic Magmatic province: A time-line for the end-Triassic mass extinction. Palaeogeography, Palaeoclimatology, Palaeoecology 478, 80–102.

Lindström, S., Sanei, H., van de Schootbrugge, B., Pedersen, G. K., Lesher, C.E., Tegner, C., Heunisch, C., Dybkjær, K., Outridge, P.M., 2019. Volcanic mercury and mutagenesis in land plants during the end-Triassic mass extinction. Science Advances 5, eaaw4018.

Nielsen, L.H. 2003. Late Triassic-Jurassic development of the Danish Basin and the Fennoscandian Border Zone, southern Scandinavia. Geological Survey of Denmark Bulletin 1, 459-526.

Nilsson, T. 1946. A new find of Gerrothorax rhaeticus Nilsson, a plagiosaurid from the Rhaetic of Scania". Lunds Universitets årsskrift. 42 (10).

Petersen, H.I., Lindström, S., 2012. Synchronous wildfire activity rise and mire deforestation at the Triassic – Jurassic boundary. PLoS ONE 7(10): e47236.

Petersen, H.I., Lindström, S., Therkelsen, J., Pedersen, G.K. 2013. Deposition, floral composition and sequence stratigraphy of uppermost Triassic (Rhaetian) coastal coals, southern Sweden. International Journal of Coal Geology 116-117, 117-134.

Troedsson, G. 1951. On the Höganäs Series of Sweden (Rhaeto-Lias). Lunds Universitets Årsskrift. N.F. 47, 269 pp.

Weibel, R., Lindström, S., Pedersen, G.K., Johansson, L., Dybkjær, K., Whitehouse, M., Boyce, A., Leng, M.J. 2016. Groundwater table fluctuations recorded in zonation of microbial siderites from end-Triassic strata. Sedimentary Geology 342, 47–65.

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