

Sedimentary development of a continuous Middle Givetian to Lower Carboniferous section from the fore-reef fringe of the Brilon reef-complex (Rheinisches Schiefergebirge, Germany)

Pas, D.¹ Da Silva, A.C.¹ Cornet, P.¹ Pierre Bultynck² Königshof, P³ Boulvain, F.¹

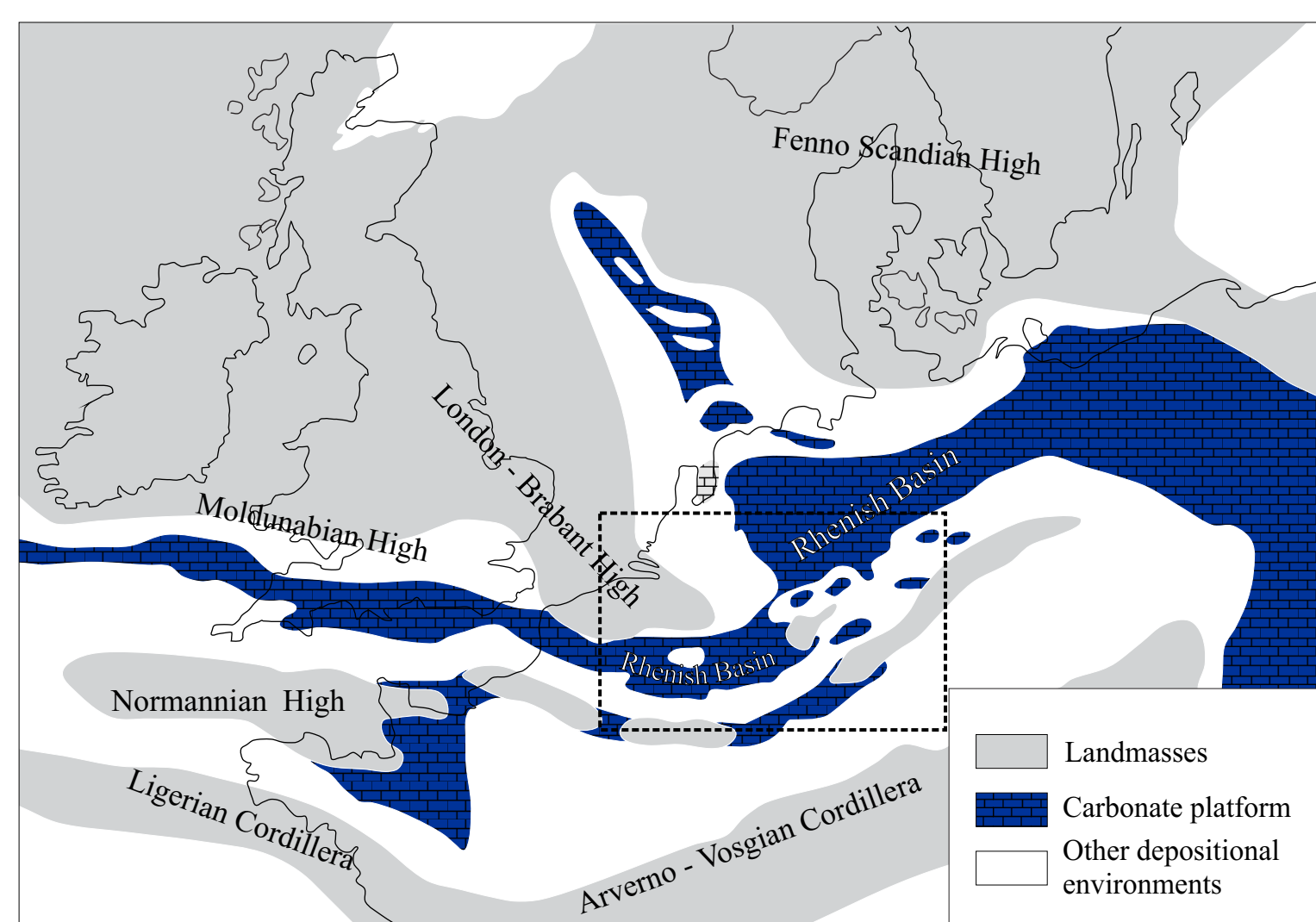
¹Sedimentary Petrology, B20, Université of Liège (ULg), Sart-Tilman B-4000 Liège, Belgium

²Department of Paleontology, Royal Belgian Institute of Natural Sciences, rue Vautier 29, BE-1000 Brussels, Belgium

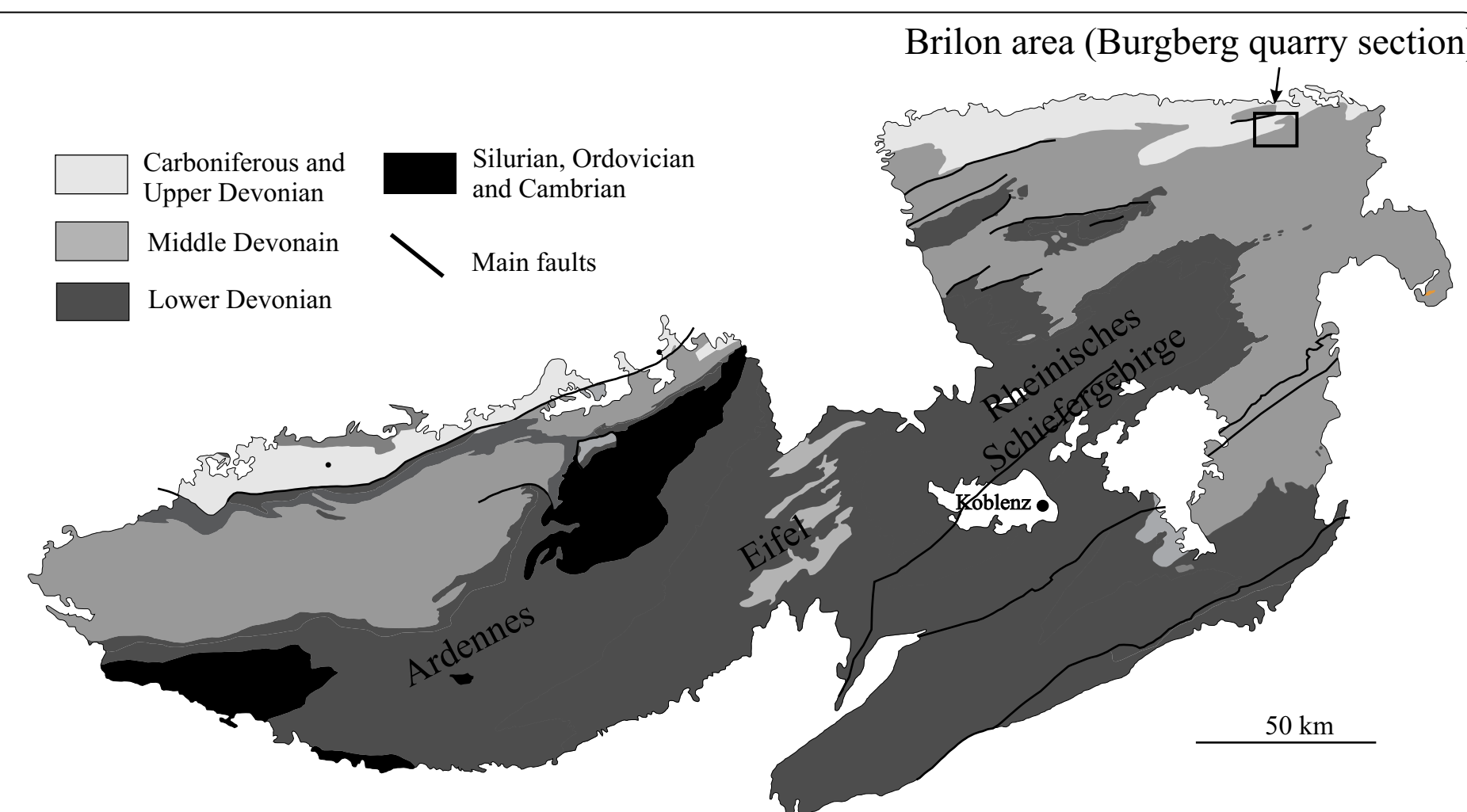
³Senckenberg, Forschungsinstitut und Naturmuseum Frankfurt, Senckenberganlage 25, 60325 Frankfurt, Germany

Summary

The Brilon-reef complex is one of the biggest Devonian carbonate buildups (~80 km²) of the Rheinisches Schiefergebirge. The Burgberg section is located in the south-eastern fore-reef area of the Brilon reef-complex and exposes a succession of strata (17 m thick) which extend from the Middle Givetian (middle varcus conodont zone) to the Lower Carboniferous. This outstanding outcrop offers the opportunity to investigate the main phases of development, demise and drowning of the Brilon reef-complex from a fore-reef setting. Field and microfacies observations led to the definition of five lithological units (1-5) and nine microfacies which are integrated into a sedimentary model divided into off-reef, intermediate fore-reef and proximal fore-reef sedimentary domains (SD). SD1 is the most distal setting observed and is characterized by fine-grained sediment, dominated by pelagic biota and the local occurrence of gravity flow deposit. SD2 is characterized by a mixture of biota and sediments coming from both deeper-water and shallow-water sources and is influenced by storm and gravity flow currents. In this domain Renalcis mound-like structures could develop locally. Finally, SD3 corresponds to the most proximal setting which is strongly influenced by gravity flow currents derived from the reef and the back reef of the Brilon reef-complex, bringing significant proportion of reef-builder remains. The microfacies stacking pattern through the Middle Givetian to Carboniferous of the Burgberg section indicates five main paleoenvironmental trends corresponding to the lithological units (U1-5). From the base to the top of the section, these units are: (U1) - initial development of reef building upon submarine volcanoclastic deposits during the Middle Givetian (middle varcus zone); (U2) - the significant seaward growth of the reef from the Middle Givetian to the Early Frasnian, marked by the high increase of reef-derived material to the fore-reef area; the maximum development of the Brilon reef-complex to the south extending from the dispiralis to the falsivialis conodont biozones; (U3) - the stepwise withdrawal of the reef influence from the Middle to the Late Frasnian (garniaae conodont biozone) characterized by a progressive decrease in shallow-water derived materials and increase in fine-grained sediments and deep-water biota; (U4) - demise and drowning of the Brilon reef-complex as a result of the Late Frasnian Kellwasser events (upper rhenana and triangularis conodont biozones) and development of a submarine rise characterized by nodular and cephalopod limestone deposits extending from the Late Frasnian to the Late Famennian; (U5) - significant deepening of the Burgberg area starting in the Late Famennian, marked by pelagic shales overlying the nodular limestone deposits.

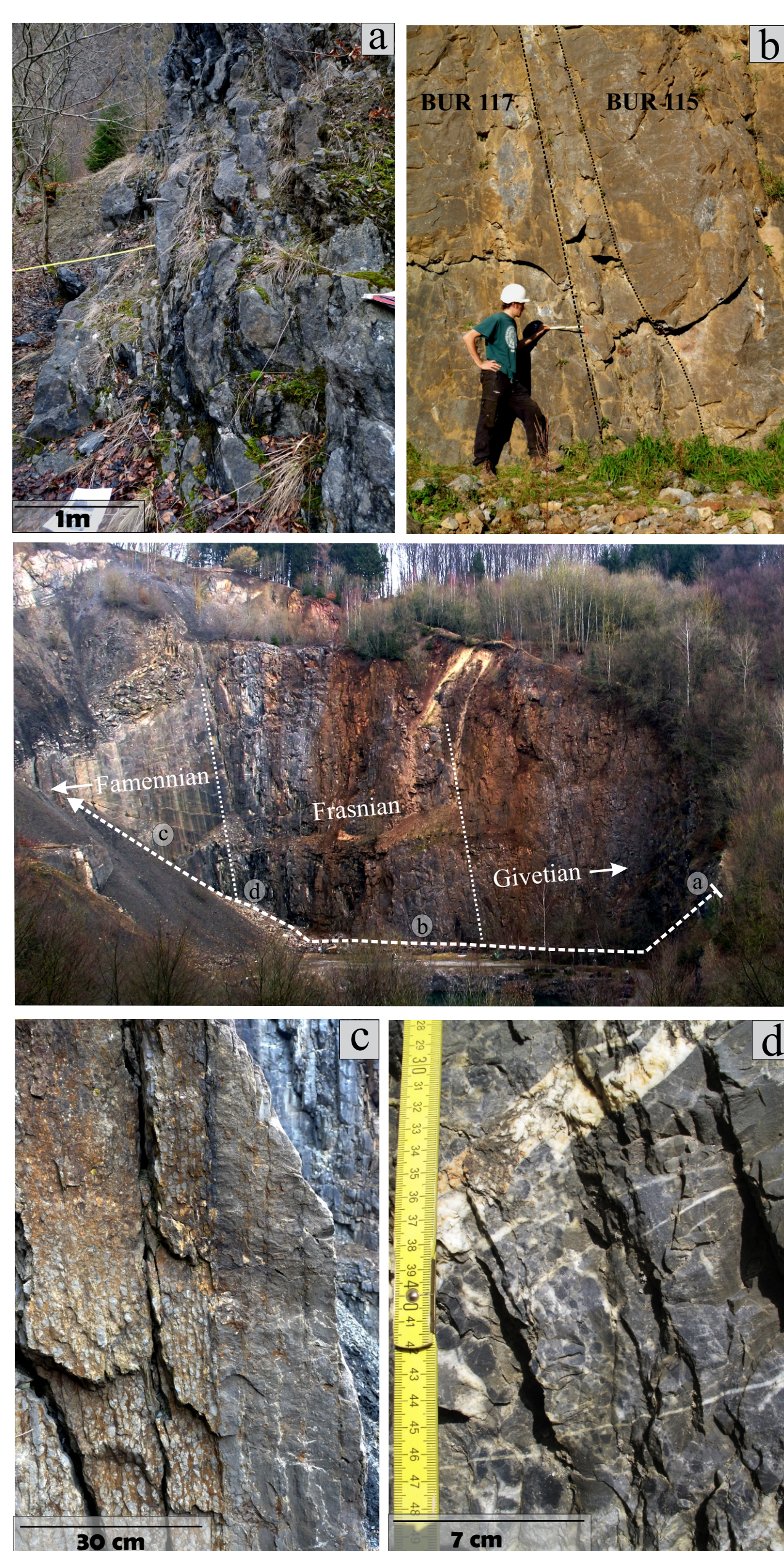


Palaeogeographical setting showing the large carbonate platform developed in northern Europe during the Middle Devonian, modified after Ziegler (1982) and McKerrow and Scotese (1990)

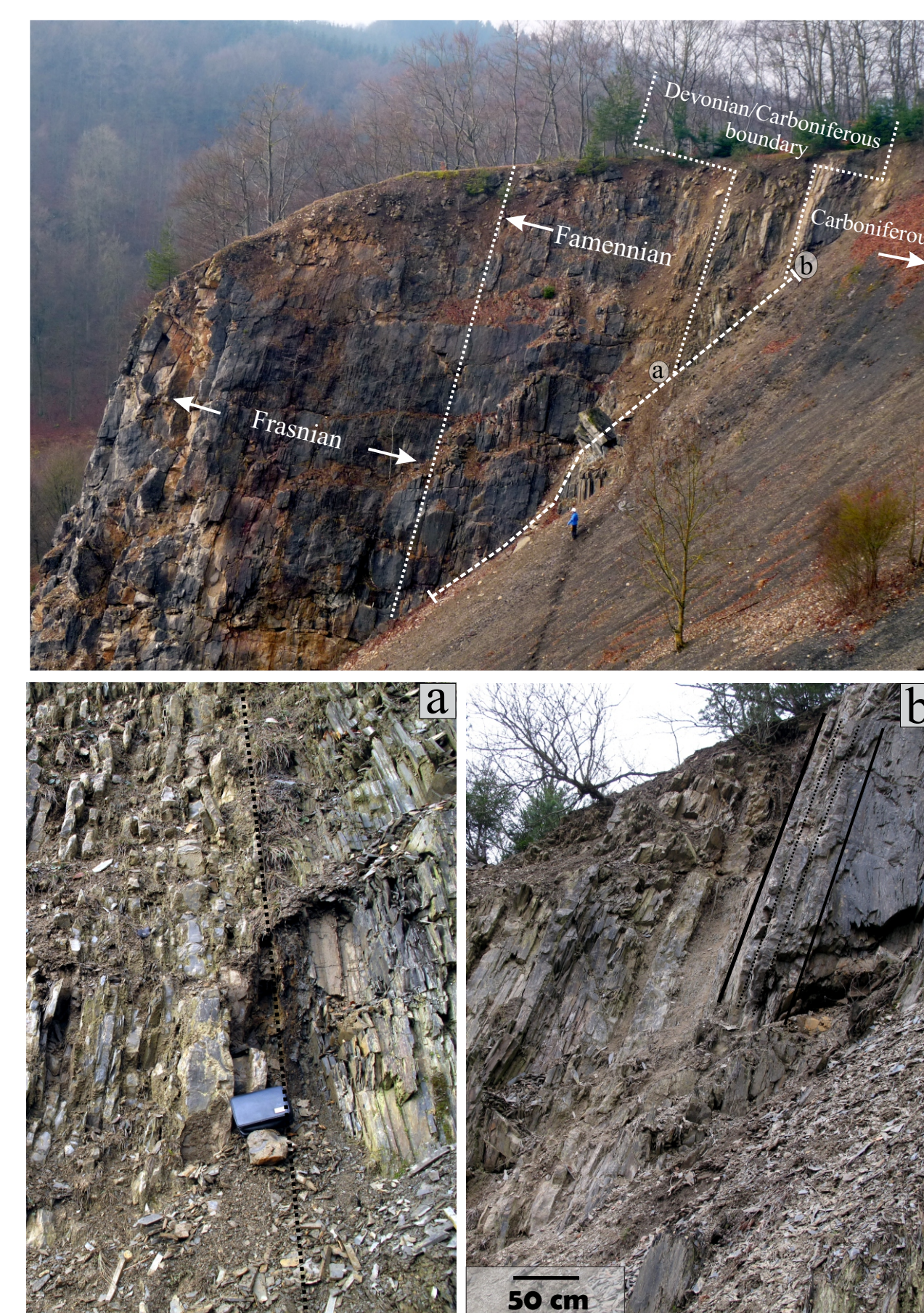


Simplified geological map of the Rheno-hercynian massif, modified from Ribbert and al. 2006.

The Burgberg section

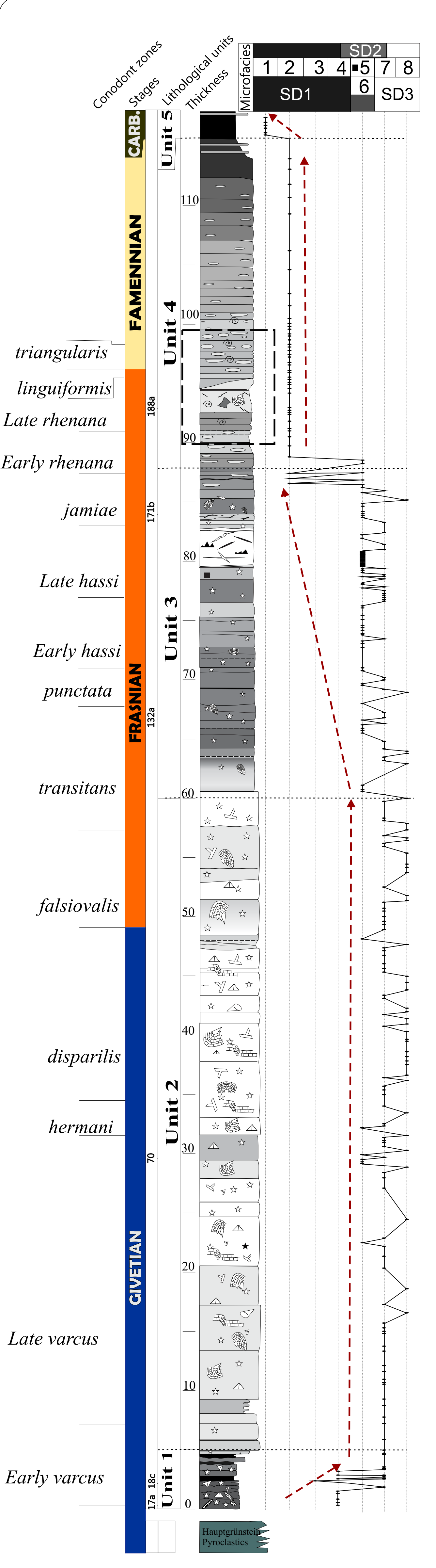


In the centre of the figure: Section 1 of the Burgberg quarry (view from the south) with location of the pictures a-d. alternation of thick lenticular-shaped coarse-grained limestone with thin carbonaceous black shale characterizing the base of the section. b channel-like structure within bed number 117, c thin-bedded limestone passing upward to nodular limestone. d zoom on the breccia texture characterizing the micritic breccia (MFB).



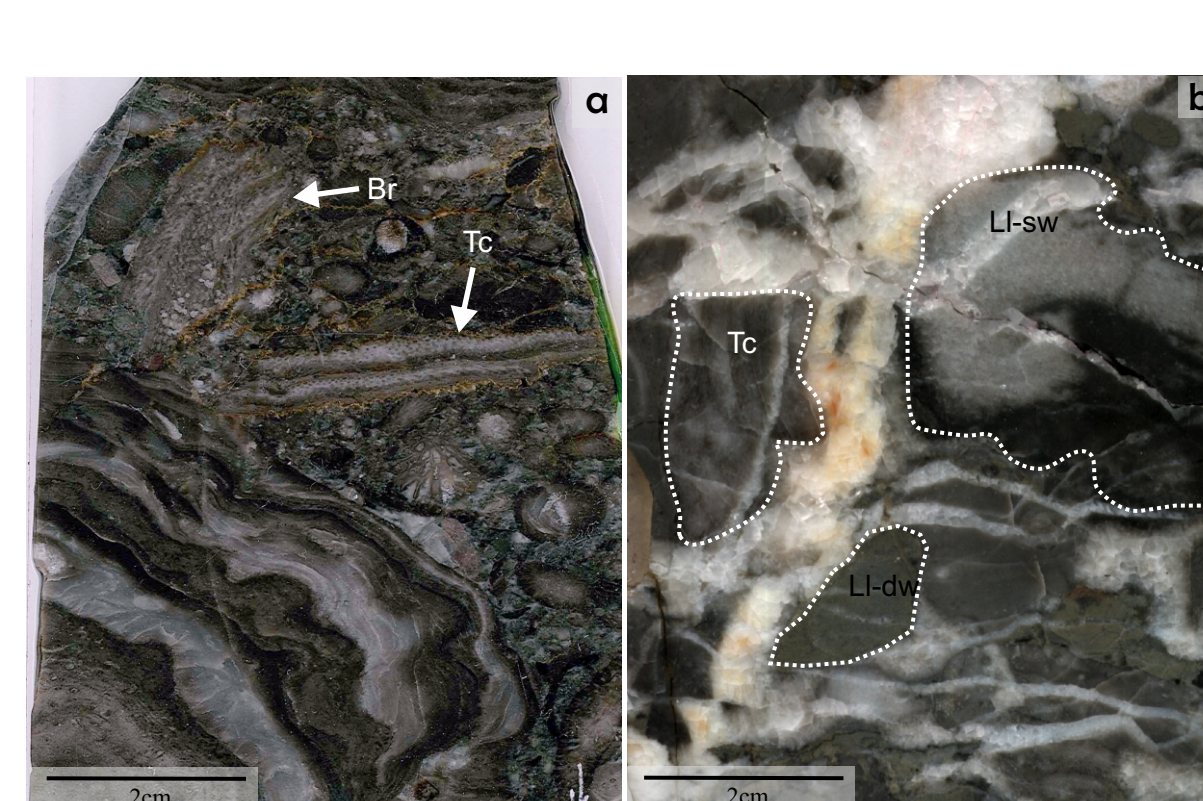
In the top of the figure: Section 2 of the Burgberg quarry (view from the north) showing the location of the Devonian-Carboniferous boundary and location of pictures A and B. a transition from thin-bedded limestone with very thin shaly interbeds to the "Lower Alaua Shale." This transition corresponds to the petrographic Devonian-Carboniferous boundary. b. Interbedding of three limestone beds called the "Crenistria beds" (Rudiger Stritzke, personal communication). These beds contain crenistria goniatites typical of the Lower Carboniferous.

Sedimentary log

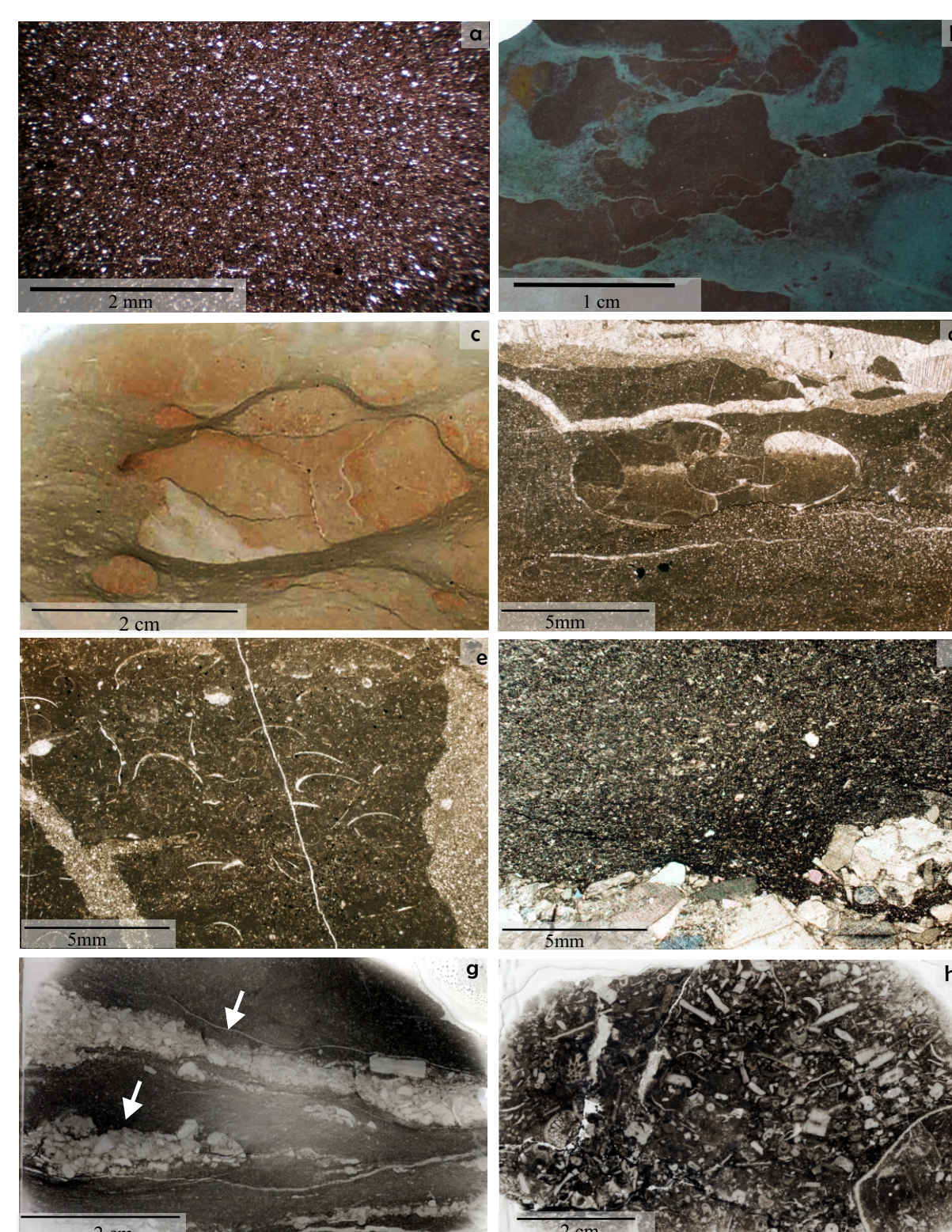


Schematic sedimentological log showing lithological units (U1-5) and microfacies curves. Arrows represent trends in MF curves. The enlargement of the dotted line area corresponds to the Kellwasser events

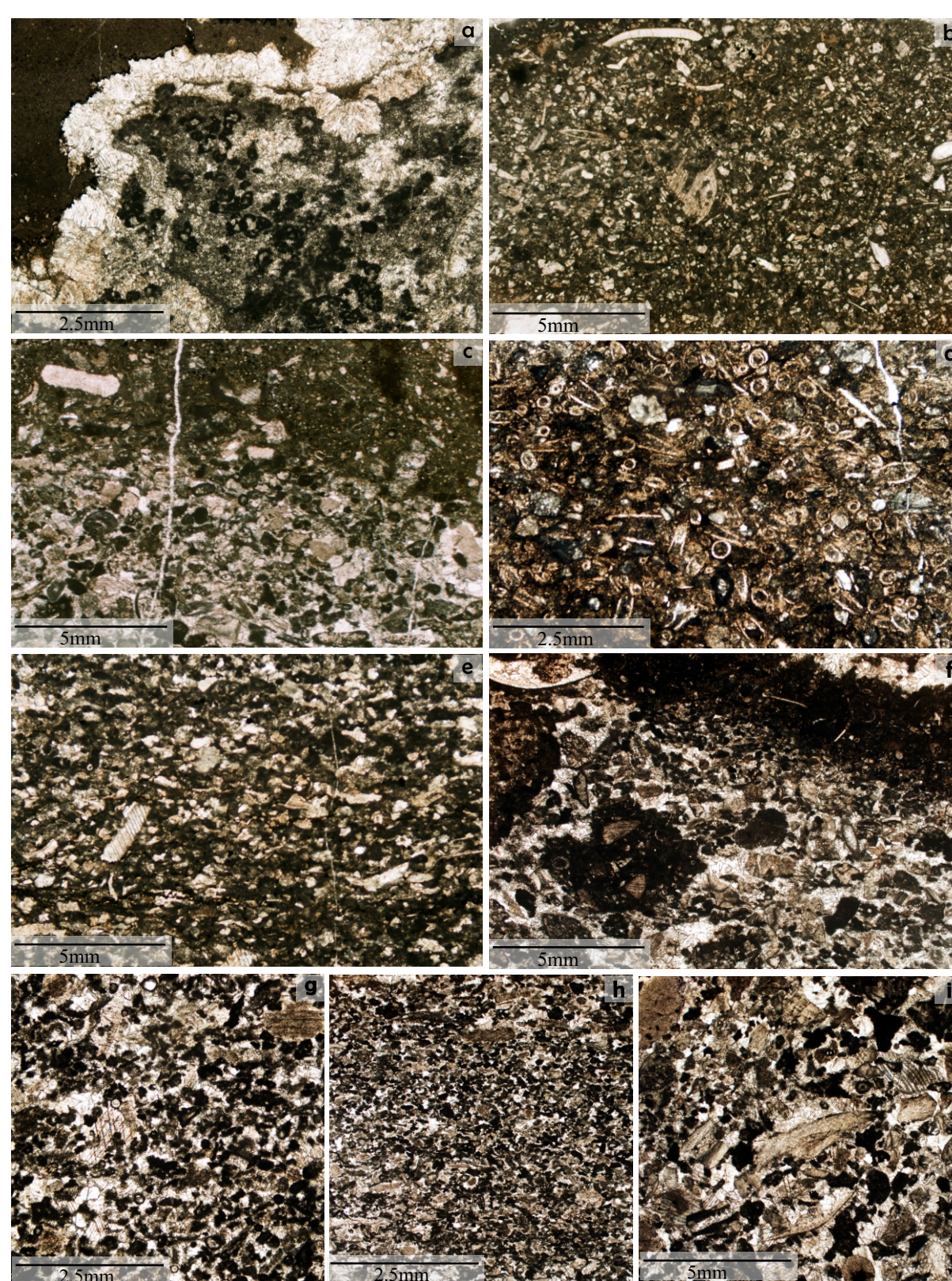
Microfacies



Microfacies of the Burgberg section (ctd.). Numbers in brackets correspond to bed numbers. a MF8 (proximal reef-slope facies): reef-builder rudstone with bryozoan (Br), tabulate coral (Tc), and in the lower-left part multiple encrustations of stromatoporoids and bryozoans, scanned thin-section (BUR 112a), normal light. b MF1 (distal reef-slope setting): breccia with tabulate coral and lithodasts of shallow-water (Li-sw) and deeper water (Li-dw) origin. Numerous calcite-filled veins cross the breccia texture, scanned polished slab (BUR 189b).

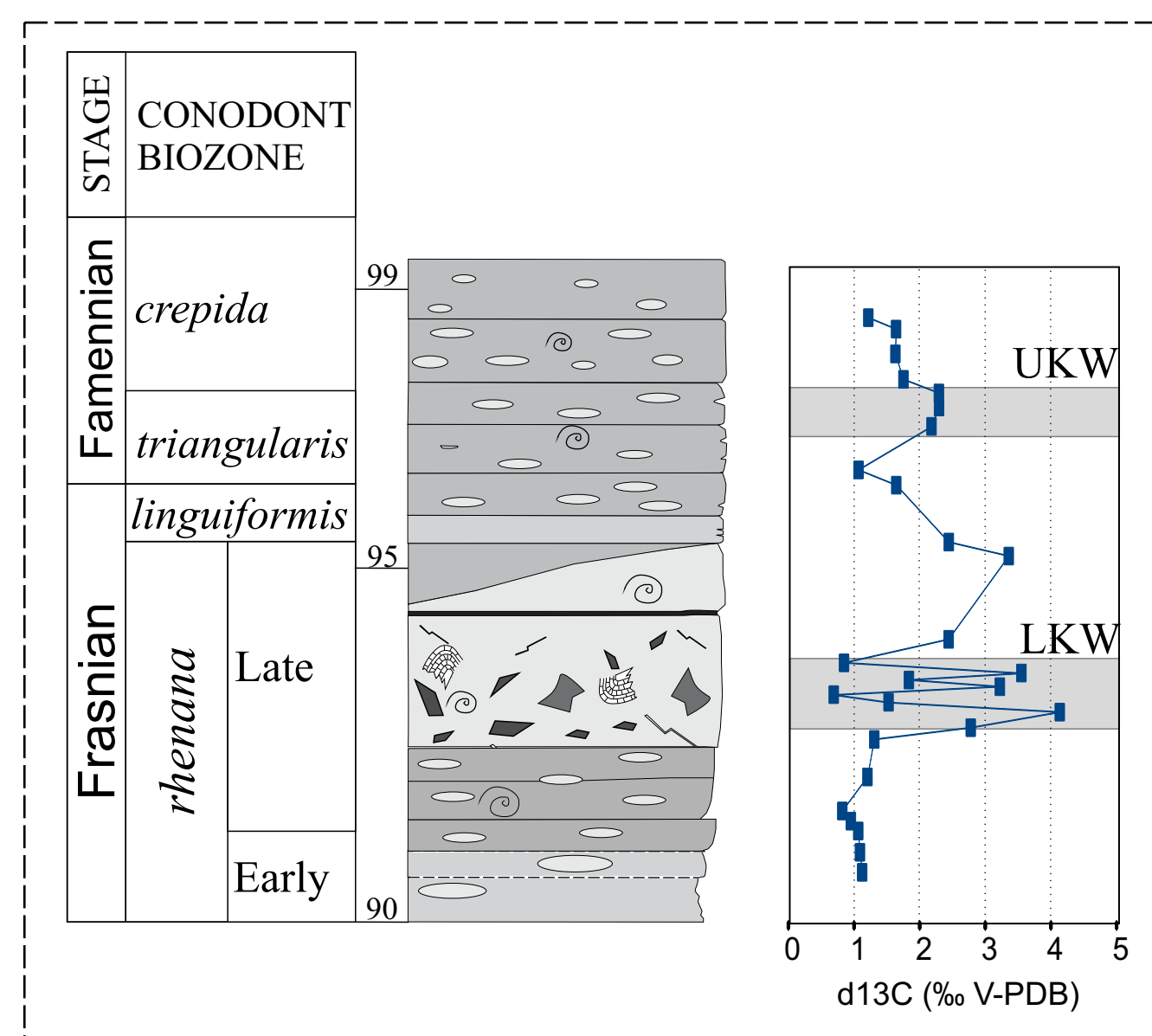


■ MF1 (off-reef deposit): silty shale, thin-section (BR712), normal light. ■ MF2 (distal reef slope to off-reef): microblastic mudstone-wackestone showing remarkable nodular/mottled fabric highlighted by the dark staining, coarse, thin-section (BR713), normal light. ■ MF3 (distal reef slope to off-reef deposit): Nodular, coarse, thin-section (BR738b). ■ MF4 (distal reef slope to off-reef deposit): fine-grained mudstone with a goniatite shell, thin-section (BR7192a). ■ MF5 (distal reef slope to off-reef deposit): microblastic mudstone with juvenile shells of pelagic bivalves, thin-section (BR1977a), normal light. ■ MF6 (distal reef slope to off-reef deposit): carbonaceous microblastic wackestone to packstone overlying coarse-grained crinoidal packstone. MF4, thin-section (BR718d), normal light. ■ MF7 (distal reef slope to off-reef deposit): microblastic wackestone to packstone, thin-section (BR718c), normal light. ■ MF8 (distal reef slope to off-reef deposit): coarse unsorted crinoidal packstone with brachiopod shells, thin-section (BR717d), normal light.



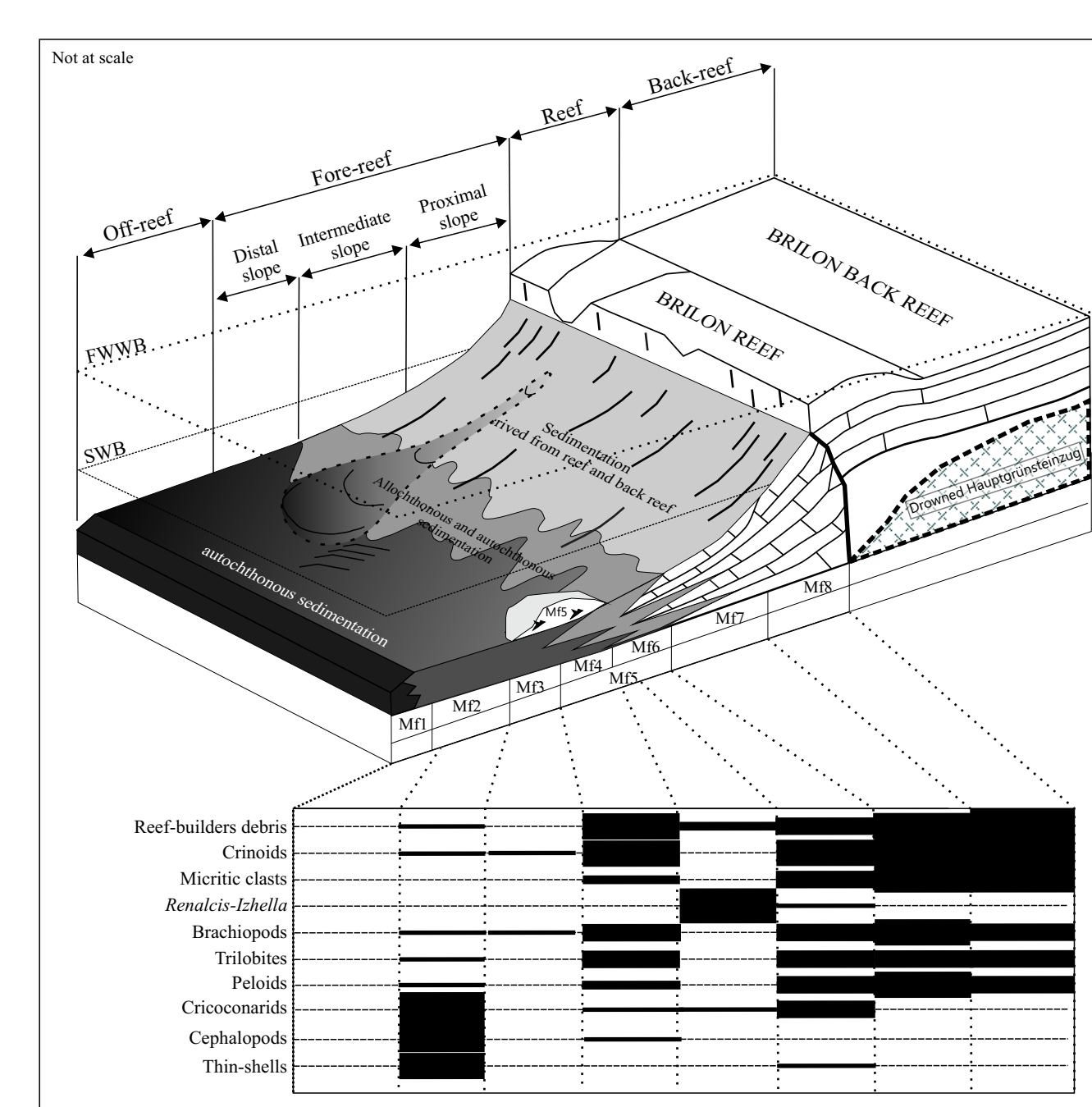
Microfacies of the Burgberg sections (std.) as MF6 (mound facies); renolitic/bella aggl. aggregate in a clotted structure with micritic matrix, thin-section (BUR 156B), normal light; MF5 (intermediate reef-slope); fine-grained crinoidal packstone with some crinocoralline shell, thin-section (BUR 146), normal light; MF4 (intermediate reef-slope); transition between MF5 (fine-grained crinoidal packstone) and MF7 (biostrophic grainstone), thin-section (BUR 122), normal light; MF3 (intermediate reef-slope); styllonidic packstone, thin-section (BUR 132A), normal light; a MF6 (intermediate reef-slope); crinoid debris within a micritic matrix, thin-section (BUR 57), normal-light; MF7 (proximal reef-slope) devoid; biostriate to lithostatic fine-grained packstone; lithobands of MF6 facies, thin-section (BUR 139), normal light; MF7 (proximal reef-slope); fine-grained peloidal grainstone, thin-section (BUR 36), normal light; h. MF7 (proximal reef-slope); fine-grained lithitic peloidal grainstone, thin-section (BUR 28), normal light; h. MF7 (proximal reef-slope); coarse-grained lithitic grainstone, thin-section (BUR 27), normal light.

The Kellwasser events



The Kalkaveren events have been recognized in the upper part of the Burgberg section beneath and within a brecciated level (see enlargement on the sedimentary log). The biotritrophic position of this breccia level in the late rhenaan conodont biozone as well as the major positive excursion in $\delta^{13}\text{C}$ corresponding to this level (amplitude of +4.1‰ and +3.5‰; Fig. 6b) correspond to the Lower Llanover Excursion (LLEW) displaying similar positive $\delta^{13}\text{C}$ excursions described in the Llanover section (see Fig. 6b). The LLEW is a well documented event in the Llanover section (Fig. 6b). The $\delta^{13}\text{C}$ excursions are usually associated with black shale levels and are interpreted to correspond to deepening events, although, our breccia level with high $\delta^{13}\text{C}$ values, is likely to be related to a shallowing event. This breccia level could thus correspond to the strong $\delta^{13}\text{C}$ excursion following the Llanover (Johnson et al., 1992; Borel and Bailey, 1994; Borel et al., 2002; Borel et al., 2004) occurring worldwide (Johnson et al., 1992; Borel and Bailey, 1994; Borel et al., 2002; Borel et al., 2004) and the Llanover section. The latter is generally accepted as a platform subsiding platform setting. The high values of $\delta^{13}\text{C}$ recorded in the breccia level suggest a reworking of the

Palaeoenvironmental model



Photographic analyses from the Burgers section led to the definition of 6 microfacies representing a fore- to reef-off profile along the environmental setting (Fig. 10). In this model, three sedimentary domains (SD) were defined. SD1 corresponds to the most distal setting observed and is characterized by off-reef to distal reef and reef-off to reef proximal facies. SD2 corresponds to the intermediate reef-off setting (SD2), sediments are composed of a mixture of deeper-water autochthonous and shallow-water allochthonous debris (MF6). In the most proximal mound-like structures could develop locally (MF5). In the upper reef-reef setting the most common facies association is observed (MF4 + SD3). These facies are strongly influenced by currents derived from the marginal reef edge of the Brilon reef complex containing a significant amount of reef-builder debris.

Acknowledgments

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References

- ✓ The Burgberg section provides an outstanding continuous succession of about 30Ma in a fore-reef facies setting. The stratigraphical framework of the entire section is well-documented by conodont biostratigraphy.
- ✓ The section ranges from the middle varcus conodont biozone to the Early Carboniferous and contains the global Kellwasser events as shown by biostratigraphical and carbon-isotope results.
- ✓ The main sedimentary processes playing a role in the Burgberg section are gravity flows (turbidite, debris and grain flows) and pelagic sedimentation (settling). Reworking by storms and bioturbation are locally important.
- ✓ Based on detailed microfacies studies the reef development of the Brilon reef can be reconstructed. The major evolutionary phases are (1) initial development of the Brilon reef which started within the middle varcus conodont biozone, (2) the establishment of the reef structure lasting from Middle Givetian to Early Frasnian with a culmination recorded from the disparilis to falsiovalis conodont biozones, (3) the stepwise withdrawal of the reef development from the Middle to the Late Frasnian, (4) the end of the reef development as a result of the global Kellwasser events, and finally (5) significant deepening of the Burgberg area starting at the Late Famennian, characterized by pelagic shale sedimentation overlying the nodular limestone deposits.
- ✓ The continuous sequence the Burgberg section represents an important contribution to Mid-Paleozoic reef deposits.

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