Fieldwork observations from the 'Rinnen' quarry near Consthum (19-23 September 2022)

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1. Introduction

Early august 2022, palaeontologists from the national natural history museum of Luxembourg found an almost complete Eurypterid, identified as belonging to the species *Adelophthalmus sievertsi* (Poschmann, 2006). This near-complete arthropod was found within the 'Rinnen' quarry near Consthum (N 49° 58' 3774", E 6° 2' 8122" Parc Hosingen, Clervaux canton, Luxembourg). This large quarry is actively exploited by the 'Rinnen' company, extracting shales and sandstones, serving as granulates and cut stones for building and construction purposes (cobblestones). After the spectacular find of the previously mentioned Eurypterid, the Luxemburg museum of national natural history received the authorisation to access the quarry for one week and search the surrounding strata for additional fossil remains. From 19th till 23rd September 2022, Eight volunteers and scientific collaborators from Luxemburg, Germany and Belgium, led by the curator of the paleontological department of the museum (dr. Ben Thuy), searched through the surrounding layers, for additional eurypterid remains. The most spectacular findings of that week were placoderm bones, some unidentified eurypterid fragments, a few arthropod ichnotraces such as *Cruziana* isp. and *Diplichnites* isp. and several species of vascular plants and their fertile parts.

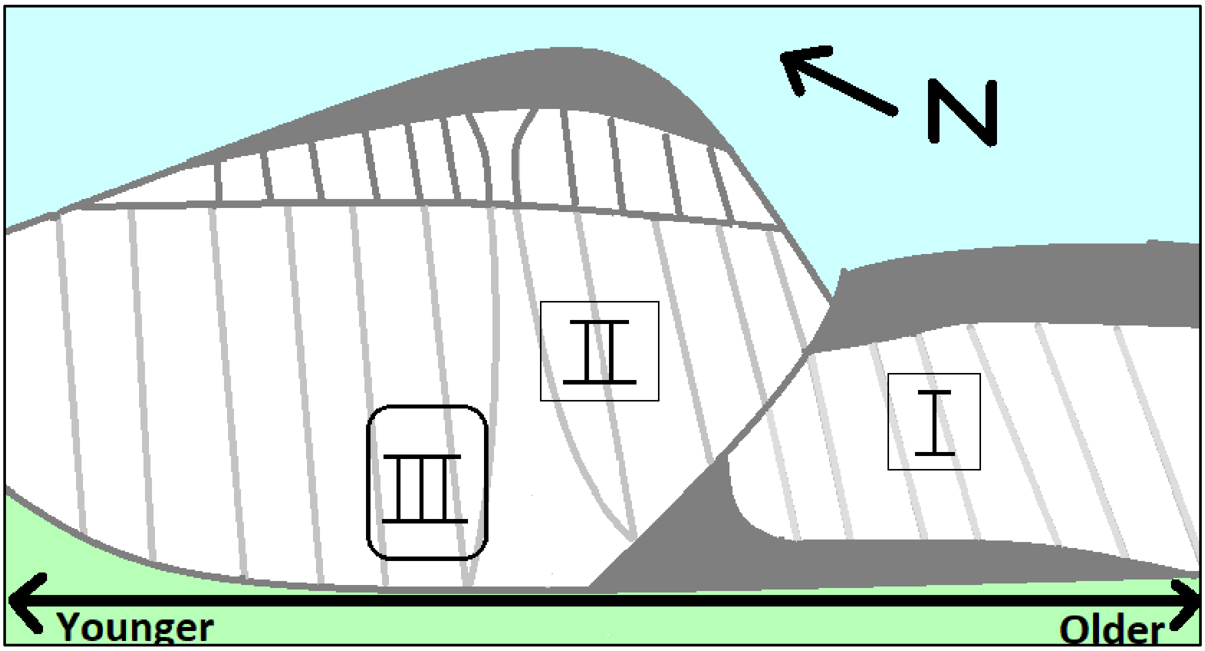


Fig. 1A (p.1): Overview of the situation in the 'Rinnen' quarry on 19th sept 2022. The picture shows NE section of the quarry near the main entrance and exit road. Fig 1B (p.2): Diagram, contextualising the three parts of the section (in roman numerals)that were sampled and documented in this paper. Part III comprises the area of strata 29,30 and 31 (cf. Lithostrat log p. 9), who were documented by Marcus Poschman and excavated extensively during fieldwork.

2. Geological context

2.1 Stratigraphy

Dejonghe (2020) described the Rinnen quarry as being Emsian in age, belonging to the Our Formation and more particulary being part of the 'Schuttbourg' 'SCO' member (Eb1) (cf. Fig. 4). The our Formation is divided into two members by Lucius (1950) but in the field, the distinction between them is rather difficult to define. Both members consist of alternating strata of shales and sandstone, originating from the detrital (siliciclastic) sediments transported from either, the Londen-Brabant platform, the Stavelot massif or the Rheno-hercynian platform. Dejonghe mentions a reddish (*Lie de vin*) colour on some of the sandstones, which we observed as well. Quartz veins is also very common within this formation, corresponding to the intense tectonic activity the strata were exposed to. A good biological marker to make the distinction between both members of the Our formation has yet to be proposed and tested.

2.2 Tectonics

The strata in the entire section have a dip ranging between 70 and 90° SSW as a result of Variscan orogeny. Associated with this tectonic activity, we observe folds and fault zones, similar to the ones we find throughout the whole of the Ardennes, Oesling–Eifel region. Boudinage compression however, was not observed. The Rinnen quarry is located between the 'Le Dickt' fault in the SE, the Hosingen and Wahlhausen fault in the NNE and the 'Fridbësch' and the Schüttbuergermillen faults in the S(S)W (cf. Fig 3). A lot of the strata containing <50% shales were often difficult to measure due to schistosity. The tectonic activity was also visible in many slickenside deposits and a multitude of small to medium faults, joints and cracks. These spaces in-between strata are predominantly filled up with Silicium-rich ground water, which leads to the formation of milky quartz veins (for small cracks and faults) and pockets with well-developed centimetre-large transparent quartz crystals (fig. 2).

Fig. 2: picture of a milky quartz pocket wih well-developed crystals in the centre. Found ex situ in the 'Rinnen' quarry

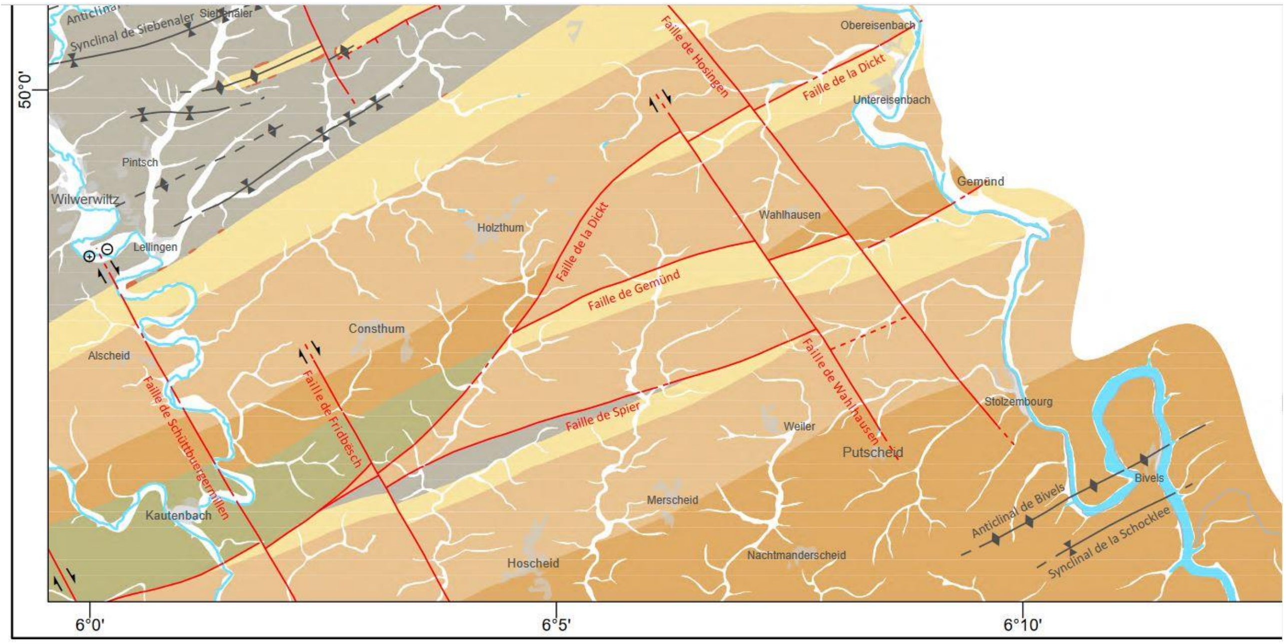


Fig. 3: Detail of the geological map of the greater Consthum area (Dejonghe 2020)

2.3 Lithology

The lithostratigraphic profile (p.7-11) does not comprise the whole quarry, but was divided over two sections in the outcropping NNE area of the fieldwork location. Like previously mentioned, the quarry consists of many different lithologies; primarily ranging between shales and sandstones. These alternations between both lithologies is indicative of a highly dynamic environment. Sandstone originates from sand deposits (grain sizes ranging between 0.0625 to 2 mm), whilst shales are derived from clayey deposits (with grain sizes > 0.002 mm). Both sediments were deposited in an aquatic environment, but clay particles are only deposited in environments with low kinetic energy. A strong current would not allow for the clay to settle, but rather keep it in motion and transport it. Sandy sediment are much heavier and requires in much more kinetic energy before being lifted and transported , so a stronger current is required.

The sandstone occurs in centimetre to several-decimetres thick beds, ranging from massif to finely laminated strata. These layers are often interbedded with layers of shales and or shaly nodules or vice-versa. Load casts (a form of pseudonodules) are also present in multiple strata, and occur as a result of the difference in density between heavier sandstones being deposited on softer and ductile shale (clayey) deposits.

In layer 23 several symmetrical ripple marks were found, symmetrical ripple marks indicate wave ripples. These wave ripples are indicative of a tidally influenced water body or aquatic environment. The ripples form as a result of a continuous kinetic force, rocking the sediment back and forth and resulting in the formation of symmetrical ripples. These ripple marks can be found on shorelines, riversides of even lakeshores. Several wave ripples with an identical orientation were superimposed, which indicates that, over time, the orientation of the tides stayed in approximately the same place over many sedimentary deposit cycles.

A number of lenses were also observed within the section. Lenses are often the result of erosion which allows for the deposit of a different kind of sediment in a delineated area (discontinued or laterally restricted). These lenses or depressions can occur in aquatic environments, as a result of a strong current, eroding the original bedding. After a normalisation of the current to its former equilibrium, the depression will gradually start to fill up (resulting in a fining upwards sequence). Another possible explanation for the occurrence of the observed lenses, are ‘ephemeral ponds or a tidal pool in a terrestrial environment which fills up. Several lenses were observed in layer 13, 15 and 21, and might be the result of depressions within a terrestrial (continental) environment.

All of the sedimentological observations point towards a highly dynamic system with fast rates of sediment transportation.

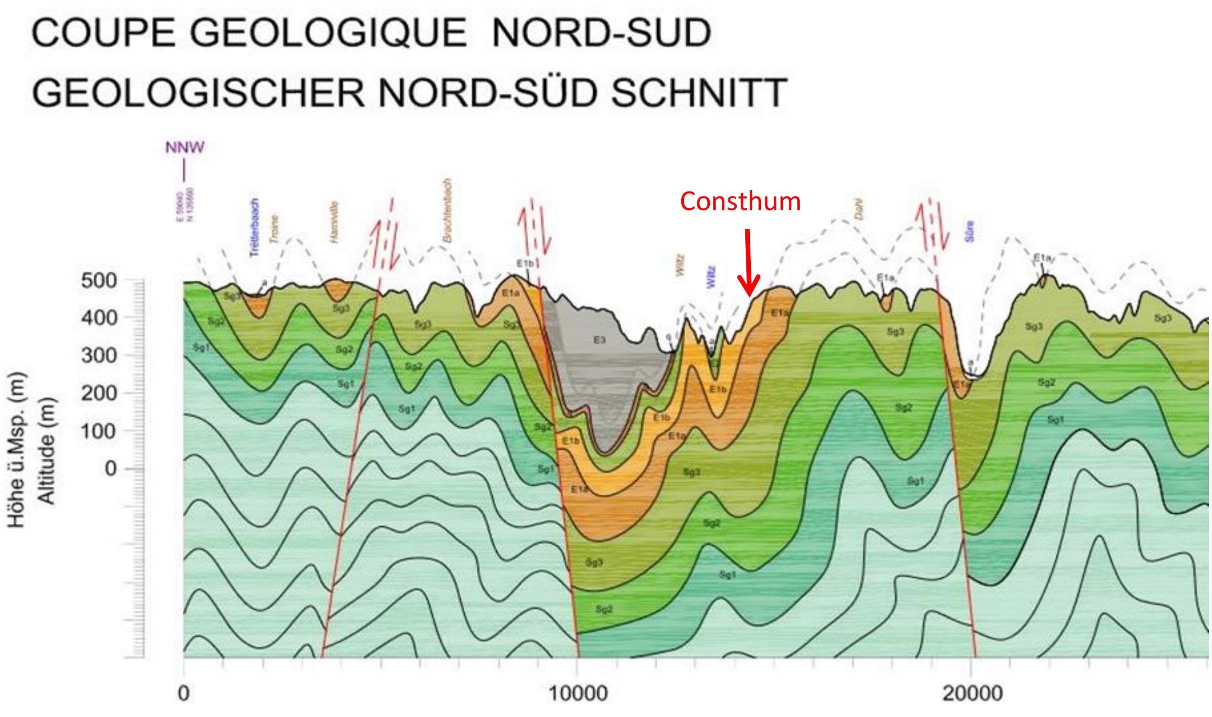


Fig. 4. Geological profile of the Oesling region with an indication of the Consthum outcrop (Colbach 2007)

3. Paleontological observations

3.1 Materials & Methods

While documenting the lithostratigraphic profile, most layers were only superficially examined, which resulted in a less accurate idea of their contents. However, a few layers in the log (layers 29-31), (documented by Marcus Poschmann), received far greater attention due to occurrence of well-preserved fossil remains. This resulted in a sampling bias for the documented section where not every layer received an equal amount of attention. In the section of paleontological interest (Strata 29-31), large boulders were extracted in-situ, after which they were systematically broken down using hand tools or small battery operated hand tools. Even within this section a certain degree of sampling bias occurred since there was mainly focussed on lenses containing only the best preserved fossils.

In some layers the severe weathering of the stones made it nearly impossible to examine them on their paleontological or sedimentological contents. Especially certain strata with high chlorite content (shales), were often so brittle and fragile that they fell apart upon touching. Other layers posed more of an challenge to break or tilt them out of their bedding plane. Some sandy-shaley layers were equally challenging to crack open, since they only cleaved in small shell-shaped chips. A few almost did not split at all, whichs resulted in a small amount of planes where the accumulation of fossils might be visible, but could not be freed entirely with hand tools on the field. Some of the shales did possess their typical slatey cleavage making the search for fossils easier on them.

3.2 Vascular plants

Many fragments of early vascular land plants were observed, their occurrence in both shales and sandstones indicate that they were deposited in an aquatic environment. Although they seemed to be more commonly found and better preserved in shales. They were generally preserved as flattened reddish (Fe-enriched) imprints sometimes even possessing a thin coalified film in between the two imprints. This ‘coal’ film was sometimes slightly curved, hinting towards the once round stem and being indicative of a fair amount of organic material being converted into coal. These imprints were not detailed enough to observe any stomata but in some fertile parts they were easily recognisable. Often the plants had accumulated in a lenses, often manifesting themselves with quite a high density. Many of them were fragmented into pieces of approximately 10 cm, with a few exceptions, both these observations make it likely that they had been blown or washed away during storms, accumulated and fossilied in pools and ponds. We found three different groups of plants, the most common was the *Psilophyton* sp. Dawson,1859, which often had beautifully preserved dichotomous branching (Fig. 5B). The two other groups were less common, they were only observed in layer 29 to 31, but they stuck out because of their enigmatic morphology and anatomical structure; *Drepanophycus* sp. Göppert, 1852 was recognised by the microphylls of a few mm placed all over the stem and *Sawdonia* sp. (Hueber, 1971) was distinguished by the spines visible on the stem (fig.5A). Those were only seen in layers. Maybe some other zosterophylls were also collected, but further research has yet to confirm this. Layers 29 to 31 were also sampled for palynological research at the Lille university. Hopefully this will yield additional data to the previous analysis performed by the P. Steemans from ULg paleobotany dept. in 2003 (Delsate *et al*., 2003).

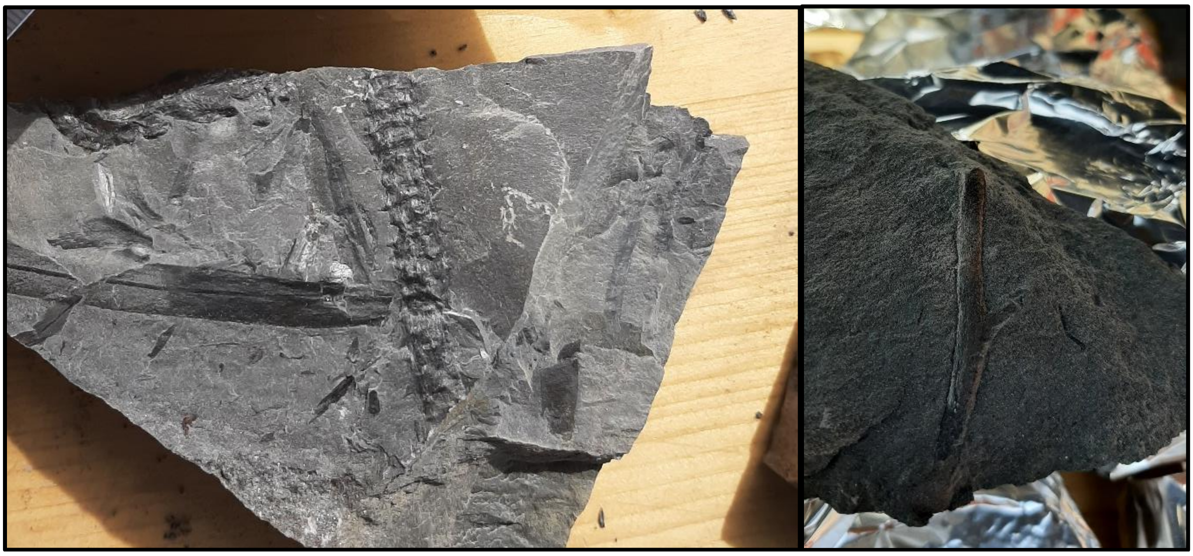


Fig. 5A (left): picture of Sawdonia sp. fossil and undefined plant material. Fig. 5B (right): picture of a Psilophyton sp. fossil with dichotomous branching and a thin coal(ified) layer.

3.3 Vertebrates

Another spectacular find in layer 31 was a fossilized fragment of an armoured plate of a placoderm. This osteoderm measured roughly 20 to 30 centimetres, had no tubercles and was still largely embedded in its matrix, it was unclear to which anatomical part of the animal it once belonged.

Based on the size, this species lived in deeper waters where it had an abundance of prey and space to hunt, yet surprisingly this remain was found in layer 31 alongside the previously mentions eurypterid remains and accumulated plants debris and bivalves. This probably indicates that this animal was transported post mortem into shallow waters with high tide of springtide. In layer 31 several placoderm scales were also found. Around 2001-2002 fish scales plates belonging to the *Coelacanth*-like genus: *Porolepis* sp.Woodward, 1891 were also found within the quarry (Delsate et al., 2003)

3.4 Invertebrates

Many bivalves were observed in different layers , a large portion of them were still in living position with both valves still attached to each other or even closed. This means that they were buried in their habitat and that there had been minimal changes in their position after they died. The bivalves were approximately 1,5-2,5 cm wide, and belong to three distinct genera being: *Pterinea* sp. Goldfuss, 1832, *Goniophora* sp. Philips, 1848 and *Modiomorpha* sp. Whitfield, 1869. In the same layers some Ostracoda were found as well, these belong most likely to the Leperditicopids (communicated by M. Poschmann) (Fig. 6). These animals lived in environments that were subjected to environmental stress, like salinity and temperature fluctuations often this means they are found in tidal flats, estuaries, and/or lagoons (Vannier *et al*., 2001).

Fig. 6: picture of a fossilized Ostracod of approximately 6 mm in its shaley matrix.

3.5 Ichnofossils

Quite a bit of smooth ichnofossils of annelids were found in several beds. These traces are nearly impossible to connect to a certain species or even higher taxa. Apart from the traces of annelids other ichnofossils were also found, *Cruziana* isp. and *Diplichnites* isp., both are evidence of the locomotion of arthropods. Usually they are associated with the locomotion and burrowing of trilobites, but since no trilobites were found during fieldwork, it makes one wonder if these traces are generated by trilobites. Even better evidence are the complete eurypterid remains found around 10th august 2022. During the fieldwork, additional remains and fragments of Eurypterids were uncovered, who all belong to the species *Adelophthalmus sievertsi*, as well as a juvenile Pterygotid. These animals lived in both marine and continental environments, and has been recorded to live in a variety of different habitats, the species are therefore considerd to be euryptopic, this is an adaption to the changing selection pressures (Poschmann 2006). All Eurypterid remains were found within layer 31, while one *Cruziana* isp. was found in layer 42. Even though there were no means to determine whether these traces belong to a eurypterid or another arthropod it is clear that arthropods lived in that area over a long period of time while trilobite remains are not yet recorded from these strata.

4. Conclusions

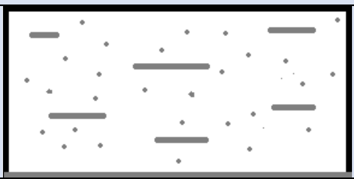
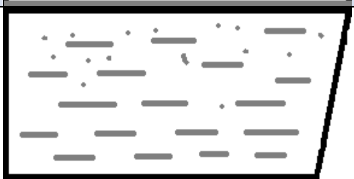
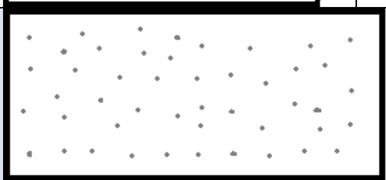
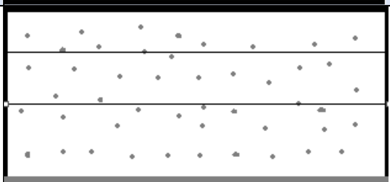
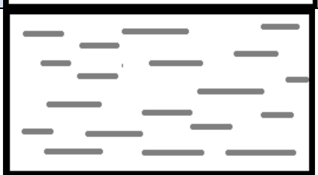
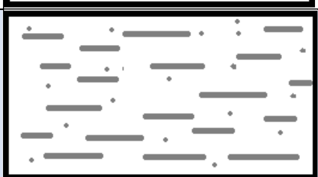
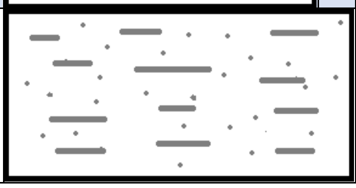
The environment in which the strata of the Rinnen quarry in Consthum formed, probably consisted of shallow water (shoal deposits) varying between calm, slow streaming, turbulent an fast flowing water. This environment was alternated by periods of draughts with desiccation and dry land in which small (or large) ephemeral ponds could have emerged. Some of these water bodies would have dried out eventually, and in some cases this would even result in the formation salt and anhydrite deposits. These environments could all have existed within a deltaic region formed by the channels of many streams. In between these streams the land could have been filled with small and large ponds, tidal ponds or even lagoons and sabkha's. There was no clear evidence suggesting salt, fresh or brackish water, so no particular environment can as such be proven factually. The paleontological observations, mainly consisting of worm burrows as ichnofossils , bivalves in life position and Ostracoda indicate a shallow water habitat while the plants indicate the presence of land nearby. The placoderm remains indicate deep marine waters, but they could be drifted or washed inland from a marine setting to more shallow waters in a backshore setting.

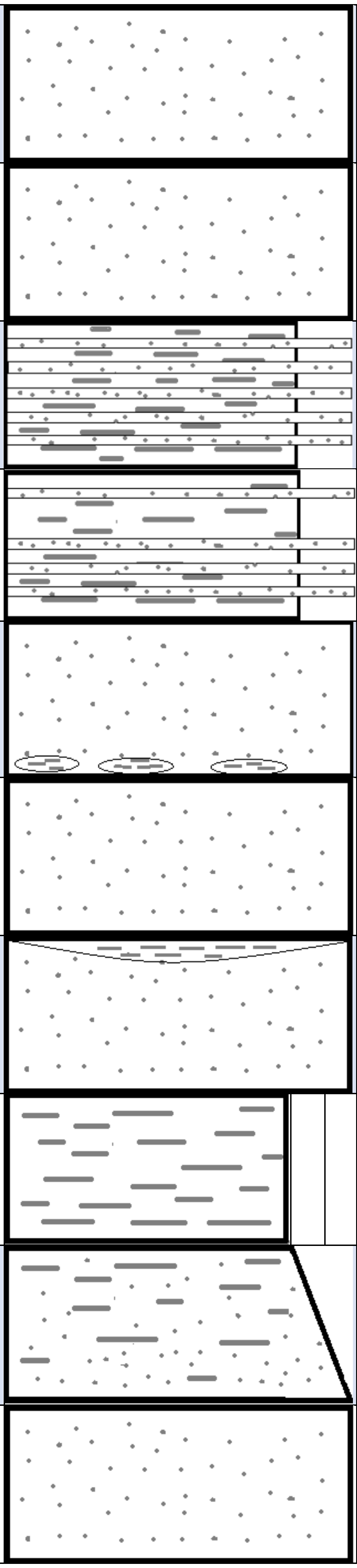
The layers who received most of our attention were layers 29 till 31. Layer 29 is a thin layer of shale that splits open fairly easily. This layer held a lot of well-preserved fossils, especially bivalves, vascular plant material and ostracods. The layer had a wavy contact with the top layer. Layer 30 was a fine layer of sandstone, with three interbedded layers of shale, this layer also contained a lot of fossils from the same group as the previous layer. Layer 31 was a broader layer than the previous two, consisting of shales and rich in fossils contents. The most common fossils in this layer include: bivalves, vascular plant remains plant and Ostracoda, similar to the previous two strata. These fossils all imply an environment of shallow water with land close by. However in the last layer we found two other groups as well, the first were eurypterid fossils (a juvenile Pterygotid comm. M. Poschmann) which also suggest a shallow water environment, but we also found some fossilized placoderm bones of a substantial size (20-30cm). A predator of this size would normally not be found so deep inland or in such shallow waters, resulting in limited movements and a restricted area to hunt for prey. This could indicate a species that was able to sustain itself despite his size in a large and deeper pond or channel. Hypothetically it is also possible that the placoderm carcass had drifted to shallow water and maybe even ended up in a tidal pond at high or springtide. The accumulations of plant debris can be attributed to storm event and washing the plant debris together in pools.

Lithostratigraphic profile

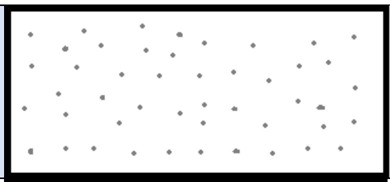
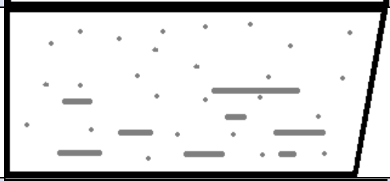
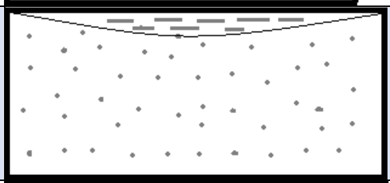
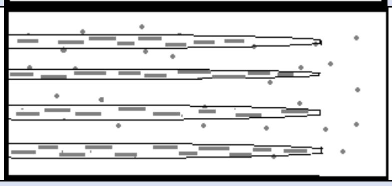
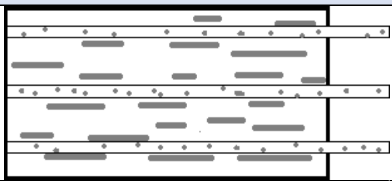
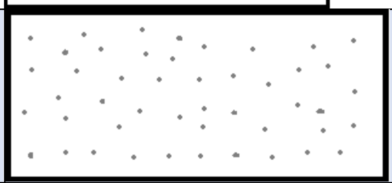
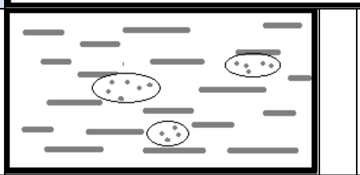
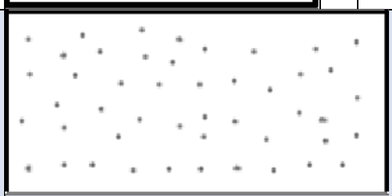
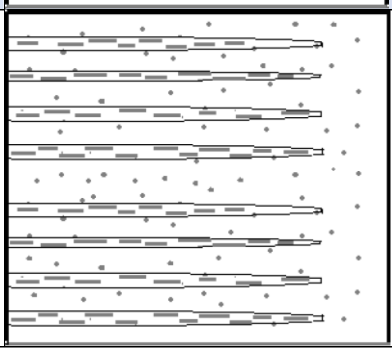
Granulation – Sediment fractions

C = Claystone
CS = Clay/Silt
S = Sand

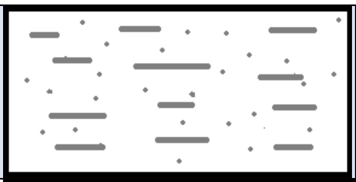
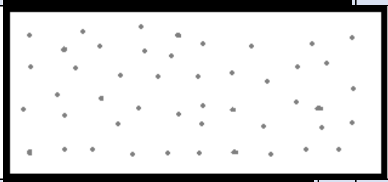
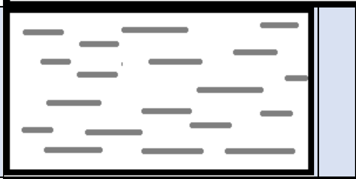
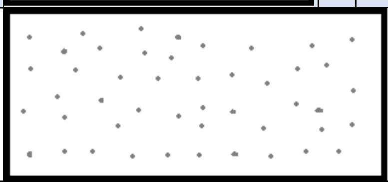
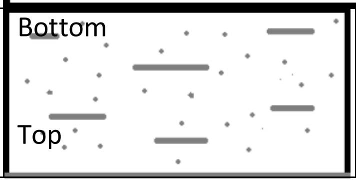
Nr	Depth (cm)	Lithology	C	CS	S	Color	Dip	Contact	Fossils and/or sedimentological features
	MEASURED SECTION I								
1	17					Grey/brown ochre oxidation	SSW 80°	Wavy	/
2	62					Grey	SSW 75°	Sharp	Finely laminated Coarsening upwards
3	24					Grey/ ochre oxidation	SSW 80°	Sharp	/
4	25					Grey/ ochre mottling oxidation	SSW 81°	Wavy/ unclear	Finely laminated (load casts)
5	50					Grey/ Bordeaux or Maroon oxidation	SSW 80°	Sharp	/
6	28					Grey/ Bordeaux oxidation ochre mottling	SSW 85°	Sharp	/
7	29					Grey/ Bordeaux-Maroon ochre oxidation	SSW 75°	Sharp	/
8	85					Grey/ Bordeaux-Maroon with ochre mottling	SSW 80°	Sharp	/



9	54	Grey/ ochre red oxidation	SSW 80°	Sharp	Ichnofossils (worms) *Skolithos*-like
10	51	Grey/ Bordeaux ochre oxidation	SSW 80°	sharp	Ichnofossils (worms) *Skolithos*-like
11	55	Grey/ Bordeaux ochre mottling	SSW 70°	Sharp	Load casts, Ichnofossils (worms) *Skolithos*-like
12	43	Grey/ Bordeaux ochre oxidation	SSW 79°	Unclear	Ichnofossils (worms) *Skolithos*-like
13	19	Grey/ Bordeaux oxidation	SSW 70°	Sharp	/
14	18,5	Grey/ ochre mottling	SSW 80°	Sharp	Various Ichnofossils indet.
15	52	Grey/ ochre mottling	SSW 80°	Sharp	Ichnofossils (worms) *Skolithos*-like
16	8,5	Grey	SSW 80°	Sharp	/
17	57	Grey/ Bordeaux oxidation ochre mottling	SSW 80°	Sharp	Various Ichnofossils indet. Fining upwards
18	63	Grey/ Bordeaux oxidation ochre mottling	SSW 79°	Sharp	Massif ->fine laminated (5-6cm) Ichnofossils (worms) *Skolithos*-like

19	20		Grey/ ochre oxidation	SSW 80°	Sharp	/
20	39		Grey/ bordeaux oxidation ochre mottling	SSW 70°	Sharp	Fine laminated Coarsening upwards
21	37		Grey/ bordeaux ochre mottling	SSW 80°	Sharp	Ichnofossils (worms) *Skolithos*-like
22	175		Grey/ bordeaux ochre oxidation	SSW 80°	Sharp	Ichnofossils (worms) *Skolithos*-like
?	MEASURED SECTION II					
23	155		Dark Grey/ bordeaux – Maroon Ochre oxidation	SSW 81°	Sharp	Symmetric ripplemarks, small bivalves, Ichnofossils
24	53		Dark Grey/ bordeaux – Maroon Ochre oxidation	SSW 80°	Sharp	/
25	188		Grey/ red oxidation	SSW 80°	Sharp	Intercalations of sandstone, folded
26	50?		Grey/red Ochre oxidation	SSW 70-80°	Wavy	Fine laminations
27	580		Grey/ red oxidation	SSW 90°	Wavy/ tectonic folding	Tectonic folding

28	226		Light grey/red Ochre oxidation	SSW 85°	Sharp	Milky quartz veins, channel cross bedding, various Ichnofossils (indet.)
		MEASURED SECTION III* completed with data from Marcus Poschman				
29	16		Grey/ red oxidation	SSW 90°	Wavy	Bivalves, plants, ostracoda
30	15		Grey/ yellow red oxidation	SSW 90°	Sharp	Bivalves, plants, ostracoda
31	116		Grey/ slighty bordeaux Ochre oxidation	SSW 90°	Unclear	Planar bedding, Eurypterid,bivalves, plants, Placoderms, Ostracods
	CONTINUATION OF MEASURED SECTION II					
32	460		Grey/ red Ochre oxidation	SSW ?	Unclear	Tectonic deformation, plants
33	14		Light grey/ Ochre oxidation	SSW ?	Unclear	/
34	380		Dark and light Grey/ red bordeaux ochre oxidation	SSW 80-90° ?	Wavy	Tectonic deformation, nodule forming, wavy beddings loadcasts, Ichnofossils (worms) *Skolithos*-like Coarsening upwards
35	20		Grey/ Ochre oxidation	SSW 90°	Sharp	/
36	94		Light grey/ slight ochre oxidation	SSW 83°	Sharp	Eroded
37	80		Dark grey/ red ochre oxidation	SSW 80°	Sharp	Quartz veins

38	50		Grey/ ochre oxidation	SSW 80°	Sharp	/
39	140		Dark and light Grey/ bordeaux Ochre oxidation	SSW 80°	Sharp	Quartz veins
40	160		Light grey/ bordeaux oxidation	SSW 80°	Sharp	/
41	13		Grey/ Ochre oxidation	SSW 85°	Sharp	/
42	40		Grey/ red bordeaux oxidation	SSW ?	Unclear	Tectonic deformation, nodule forming, pyriet, chaleopyriet, ichnofossils, (very scarce) plants, *diplinichtes* isp.

Bibliography

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Annex I - Pictures Fieldwork

Iron oxide precipitation around the fossil flora

Section II of the recorded profile a channel fill

Using electrical drilling tools to sample the section

Joints in the sandstone bedrock

Massive ex-situ sandstone with clasts (channel fill). Ex-situ

Outside of the recorded section: Interference ripples and symmetrical wave ripples (NNE section)