INSIGHT INTO THE ENVIRONMENT OF AN EARLY MODERN OXBOW LAKE (RHINELAND, GERMANY), USING A MULTI-PROXY APPROACH

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Introduction

In a multi-proxy approach sediment deposits of an oxbow lake, located in the Lower Inde Valley (Fig. 2), were analysed. The investigation area is situated in one of the most fertile landscapes in western Germany, in the vicinity of the cities of Aachen, Cologne and Jülich.
To generate better comprehensive and interdisciplinary understanding of historical land use of the Inde River in Early Modern Times, the archaeobotanical results (pollen and macro-remains) were weaved with heavy metal analyses, micromorphological investigations and written sources. The latter mention mining activities and help to link the results into the land use und mining history in the drainage area of the Inde River.

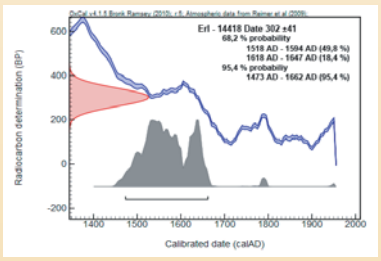


Fig. 1

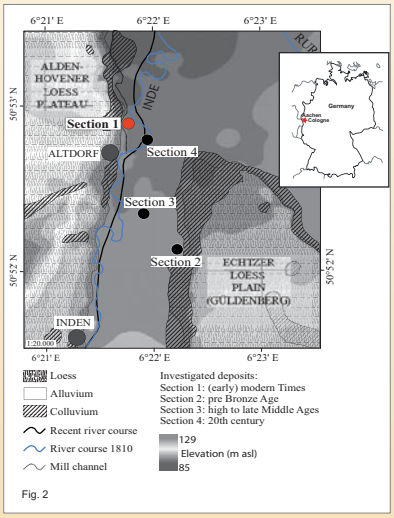


Fig. 2

Methods

Archaeobotanical Analysis
(palynology and macro remains; Kropp, Schamuhn and Zerl)

33 Samples have been prepared following Faegri & Iversen 1989. Pollen identification followed the acknowledged literature. The average pollen sum is around 500.
For analyzing the macro remains, 14 samples were sieved (at 2 mm, 1 mm and 0.25 mm) using 'semi-flotation'.

Micromorphological Investigations
(Röpke)
Two micromorphological samples have been taken from zone one and three. The samples were impregnated with resin and after desiccation, the polished blocks were sawn and prepared for thin sections. The thin sections were analysed under a petrographic microscope, applying plain polarized light and crossed polarized light. The description follows the terminology of Stoops 2003 and Bullock et al. 1985.

Heavy Metal Analysis
(Schmidt-Wygasch)
Heavy metal concentrations were measured *in situ* every five centimetres, using a portable X-Ray fluorescence spectrometer (FPXRF, Niton Xlt 700 series) (Fig 3). The device detects up to 22 chemical compounds.Measurement time was 90 s per sample. To point out man-made pollution, we studied selected heavy metals, there zinc concentrations as an example.

Fig. 3

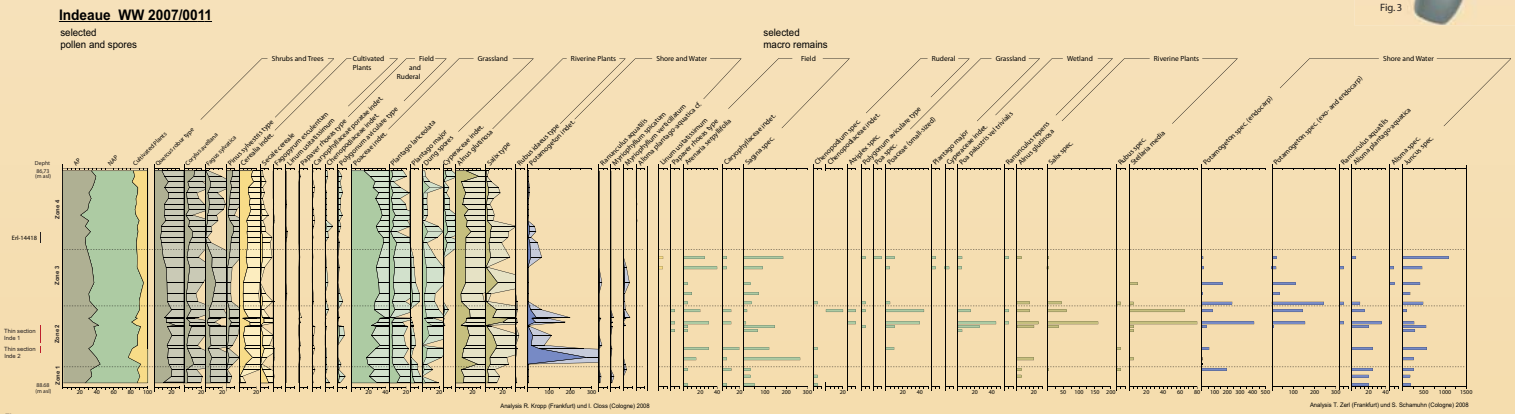


Fig. 4

Archaeobotanical Analysis

Pollen of trees and shrubs, grassland, shore and water plants as well as field and dung spores were present in all samples. NAP dominated the spectrum. That signifies a stable vegetation pattern around the lake.
Besides this continuity the samples could be distinguished in four zones:
Zone 1: A high amount of grassland taxa, especially Poaceae, were present and the grassland dominated extensively. Significant is the high amount of *Plantago lanceolata* which indicates meadows.
Secale cereale was found up to 9 %. *Fagopyrum esculentum* was present in the bottom-sample. Buckwheat was found in the Rhineland not before the 14th century. So the presence of *Fagopyrum* biostratigraphically dated the sample in the 14th century or later on.
Zone 2: In this zone a higher variety of species and a distinctly higher pollen concentration occur. Remarkable is the very high amount of *Potamogeton* spec. The shore plant, which is barely present in Zone 1, indicates temporarily desiccation of the oxbow lake.
Zone 3: This zone returns to a calm curve progression, a lower variety of species and a lower pollen concentration. The growing amount of *Fagus sylvatica* (11.9 %) indicates a temporary slide increase of the woodland. The continuing low number of pollen of *Pinus sylvestris* dates the samples before the afforestation of the 19th century.
Zone 4: This zone is characterized through an obvious decline of *Fagus sylvatica* up to 1 %. The grassland changes from pasture land to hay meadow [decrease of *Plantago major* and increase of sedges (Cyperaceae)].

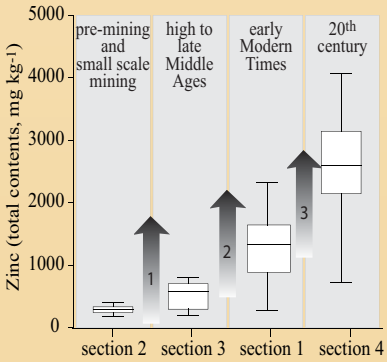


Fig. 7

Heavy Metal Analysis

The comparison of the heavy metal contents in the overbank deposits of varying ages, gave an estimation of the contamination degree during the individual mining phases in this region. Three main phases of zinc mining can be distinguished. In Fig. 7 the zinc concentrations in four sections, representing different sedimentation phases, are shown. Since the High and Late Middle Ages (section 3 dated by artefacts), there was a profound increase in contamination of fluvial sediments with zinc; sections 2 presents the local background without anthropogenic pollution. The arrow 1 marks the first mining phase.
Due to the relatively high concentrations of zinc in section 1 is over twice as the medieval deposits. The higher pollution resulted from enlarged mining activities, started at the end of the 16th century. At this time, brass makers moved from Aachen to Stolberg (second phase, marked by arrow 2); caused by religious and economic reasons. The third mining phase (arrow 3) portrays the industrialization, resulted in quite elevated zinc pollution. Section 4 presents these contaminated sediments of the 20th century.

Results

The multi-proxy approach served to recognize the land use and consequences of the mining history in the Early Modern Times.
The evaluation of the pollen record as well as macro remains revealed that open landscape was predominant (30 % AP). On the upland loess sites agriculture was carried out, whereas the floodplain was used as grassland. A high amount of dung spores indicates animal husbandry.
The very high amount of *Potamogeton* spec. as well as results of the thin sections pointed out that the oxbow lake was characterized by slowly running water where suspension-settling sedimentation dominated.
Owing to the high concentrations of zinc in these deposits and the comparison with other sediments it can be assume, that the investigated samples reflects the heydays of the brass industry, beginning in the 16th century. The low AP supported this dating, reflecting the overexploitation of the woodlands to produce for the growing metal processing industry.
The Prussian afforestation with *Pinus sylvestris* is not visible within the pollen data. Moreover, an intense increase of the zinc concentrations was not discernible. This allows the conclusion that the main sedimentation on this part of the floodplain was stopped before the 19th century. This indirectaly defined time period has been confirmed by one radiocarbon date: 2σ (95,4 %) 1473–1662 AD (Fig. 1).

The intense land use in Early Modern Times is documented within the sediment deposits in various modalities. The archaeobotanical results in our study indicate that animal husbandry and farming were the most important historical anthropogenic activities in the Lower Inde Valley. Furthermore, the high concentrations of zinc and the intense deforestation were attributed to broad ore processing in the catchment area.
In conclusion, linking these interdisciplinary approaches is ideal for gaining insight into the historical anthropogenic impact on the environment.

Micromorphological Investigations

In order to describe the depositional processes of the oxbow lake micromorphological investigations were implemented:
-The bottom of Thin section Inde 1 consists of unlayered mud. In a matrix of fine sand and silt, charcoal and organic matter is embedded. No horizontal orientation is visible.
-Thin section Inde 2 (Tab. 1) was taken in the laminated sediments and can be distinguished into five units (A-E). They consist of clay, silt, fine sand, iron oxids and amorphous organic material, forming coarse to fine laminae (2 mm-10 µm) (Fig. 5). There is no evidence of erosional events, bioturbation or sedimentary structure produced by traction currents. Iron staining (Fig. 6) took place and formed bands up to 0.5 cm (E, D), maybe because of ferruginisation of amorphous organic matter. Additionally secondary iron hydroxids occur along former root channels which indicate changing groundwater table.
After a phase of mud-forming at the bottom, lacustrine processes have been dominated by suspension-settling sedimentation associated with periodic influx of layers including higher amounts of fine sand.

Fig. 5

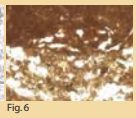
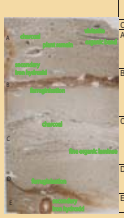


Fig. 6

Table 1 : Micromorphological description according Stoops et al (2003).

Sample	Micro-structure	c/f RDP	Coarse fraction	Micromass	Pedofeatures	Mineral/ organic/ anthropo-genic constituents	Comment
Oxbowlake Inde							
A	Massive, banded	close porphyric	silt size quartz	speckled/parallel striated b-fabric	Vivianit	charcoal, all kinds of organic mat. (roots etc.)	
B	massive banded	partly monic	iron oxid grains	undifferentiated b-fabric	iron oxid, banded, amorphous organic mat. (bottom)	few charcoal	band of iron oxid superimposed by vertical iron oxid
C	Massive, in the middle less compact, banded	close porphyric	silt size quartz	speckled/parallel striated b-fabric	few clay coatings	charcoal, all kinds of organic mat. (roots etc.)	
D	complex banded	partly monic	iron oxid grains	undifferentiated b-fabric	iron oxid nodules, clay crusts/micro-pans	few charcoal	band of iron oxid
E	Massive, banded	close porphyric	silt size quartz,	parallel striated b-fabric	iron oxid hypocoatings root	charcoal, all kinds of	



Literature:
Bullock et al. 1985: Bullock, P., Federoff, N., Jongerius, A., Stoops, G., Tursina, T., & Babel, U., Handbook for soil thinsection description (Wolverhampton1985).
Faegri & Iversen 1989: Faegri, K. & Iversen, J., Textbook of pollen analysis (Chichester 1989).
Stoops 2003: Stoops, G.: Guidelines for analysis and description of soil and regolith thin sections (Madison 2003).