Recent advances in the applications of organic petrology to archaeology

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INTRODUCTION

From the beginning of the sixties, Marlies Teichmüller began to use organic petrology to solve archaeological tasks (Rochna et al. 1961) with the purpose of characterizing the organic-rich sediments which were used in Europe, principally during the Iron Age, to produce dark or black colored ornaments, especially armlets, and to determine their nature and their geographical provenance in order to reconstruct the Celtic trade connections.

Her article on this topic, published in 1992 and entitled "Organic petrology in the service of archaeology" demonstrates the extent of her work in this field of research. Also, the article reveals the potential of organic petrology in connection to the study of these kinds of archaeological objects.

By chance, in 1991, archaeologists from the State Office for Monument Conservation in Baden-Württemberg, having knowledge of Teichmüller´s works, asked us to analyze several Celtic armlets that were preliminary labeled "lignite" because of their dark brown color. For us, this was a great opportunity to continue developing the application of organic petrology to the study of the dark archaeological objects initiated by Marlies Teichmüller.

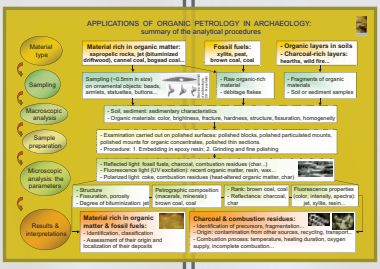
The first part of our poster presents some aspects of our works done in this field of application during the last twenty-five years in Germany, Switzerland and France (Ligouis 2000, 2006, 2010, 2012, 2013; Vogler 2014). We focus principally on the methodology used for the identification of the sources of the raw materials (oil shales, liptinite-rich sapropelites, liptobioliths, jets) of these archaeological objects.

The second part of the poster is dedicated to a very promising field of application of organic petrology in archaeology, namely the petrographic analysis of the organic matter in combustion features, as well as in anthropogenic deposits of prehistoric (Goldberg et al. 2009; Stahlschmidt et al. in press) and historic sites (Villagran et al. 2013). Our first studies in this field of research, dating back to the 2000s, were devoted to the petrographic characterization of the microscopic combustion residues (low reflecting- and high reflecting fusinite, fat-derived char, bone char) in Paleolithic burnt bone horizons from the Swabian Jura and in ashes from fire experiments using different kinds of fuels (various plant materials; mixture of plant materials and bones; bones) (Schiegl et al. 2005). A number of studies focused on the investigations of ashy hearth horizons of Middle Palaeolithic sites in Israel (Kebara, Hayonim; Schiegl et al. 2004) and of Middle Stone Age sites in South Africa (Clark and Ligouis 2010), for example the Sibudu Cave whose part of organic petrological results are presented here.

CELTIC BLACK OR DARK BROWN ARCHAEOLOGIC OBJECTS IN EUROPE

Materials and methods

Germany
1 Heuneburg (Sigmaringen): 2 armlet fragments (Early Iron Age)
France
2 Autun: 1 armlet fragment (Hallstatt C-D1)
3 Aix-en-Provence: 1 burnt armlet fragmet (Early Iron Age)
Switzerland
4 Vidy (Lausanne): 1 ring (Iron Age)
5 Onnens-Beau-Site, Le Motti: 1 armlet fragment (Final Bronze Age)
6 Chevenez: 1 armlet fragment (La Tene C)
7 Cornol, Mont Terri: 1 armlet fragment
8 Delemont-En La Pran:
- 2 armlet fragments (Early Iron Age)
- 1 armlet (Early Iron Age)
- 1 armlet fragment (Final Bronze Age)



The investigated archeological material - armlets, armlet fragments and 1 ring - was collected from 8 sites in Germany, France and Switzerland and are dated from Final Bronze to Final Iron Age (see map above). For the organic petrological investigation, polished sections - perpendicular to bedding - were microscopically analyzed, both under reflected light and with fluorescence mode. In order to respect the value of the archeological artefacts, only fragments in the range of a few mm^2 were sampled from the ornaments. For determining the source and provenance of the raw material, the organo-mineral microfacies of each artefact was described, with respect to their structure and composition. For determining the provenance of the raw material, reference material was collected in several oil shale basins of France, as well as at the Dorset coast of South England. The reference materials were collected regarding accessibility during the relevant archaeological times and the existence of signs of workshops and remains of armlet production.

Description and identification of the raw materials

Microfacies of armlets

Onnens

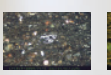
Microfacies of suggested reference material

B = Bituminite lense; M = mineral bituminous groundmass; BG = Bituminite groundmass

Kimmeridge Clay oil shale
Oil shales from the Kimmeridge Clay Formation are characterised by high contents of liptinite which mostly presents itself as bituminite. Especially rich in bituminite is the so-called Blackstone, which also has a bituminite groundmass - in contrast to "traditional" oil shales which have a mineral-based bituminous groundmass.

Microfacies of armlets

Autun



Vidy

Microfacies of suggested reference material

Permian oil shale, Buxières-les-Mines
Oil shales from Buxières-les-Mines have a mineral-based bituminous groundmass which is dolomitic and a bituminite groundmass. They are rich in macerals of the vitrinite group, pollen and spores. Typical of this oil shale is the occurence of migrabitumen (yellow-brown fluorescence). Faunal relics are numerous. There are filigree fusinite tissues that are compressed. Botryococcus algae are rare.

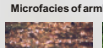
Microfacies of armlets

Heuneburg

Unknown material
This material represents a transition between a liptinite-rich sapropelite and a liptobiolith. Liptinite is the dominant maceral group consisting mainly of liptodetrinite and bituminite. The material shows a disturbed microstratification with microfolds, imbrications and microclasts of the same organic microfacies. The bituminite shows similarities to the one found in the Kimmeridge Clay oil shale.

Microfacies of armlets

Aix-en-Provence



Cornol

Microfacies of suggested reference material

Permian oil shale, Montcombroux-les-Mines
Oil shales from Montcombroux-les-Mines have a mineral-based bituminous groundmass which is mainly argillaceous. Botryococcus algae are numerous. Also, sporinite appears frequently. Typical for this oil shale are net-like bodies of lamalginite. The microphotographs above show a particularity. As the armlet is burnt, the fluorescence appears fade and the algae are not recognizable.

Microfacies of armlets

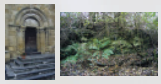
Chevenez

Microfacies of suggested reference material

Permian oil shale, Autun
Oil shales from Autun are rich in sporinite. Botryococcus algae and faunal relics appear locally accumulated. They have a mineral-based strongly bituminous groundmass. Macerals of the vitrinite group are rare and fusinite appears mainly as inertodetrinite. Discrete filaments of lamalginite can be found frequently.

Provenance of the raw materials

Landscape of the Dorset Coast where the exploitation of the oil shale for the fabrication of ornaments was strongly developped in the Iron Age (left image). The image in the centre shows the oil shales of the Kimmeridge formation and the Blackstone bed outcroping at low tide (October 2011). The right image has been taken in the Dorset County Museum in Dorchester (Dorset) . It shows "coal money" or shale waste left after the fabrication of armlets.



The use of oil shale for the fabrication of armlets in the Iron Age in the Buxières-Les-Mines Basin is well documented. Numerous "coal money" (shale waste) have been found in the fields and the excavations in the vincinity. However, armlets are rarely found. Thus, archaeologists think that the great majority was exported. The images show the entrance of the roman church with steps in oil shale (left) and a typical oil shale outcrop in the forest.

View of the Autun basin to the north (left image). At the horizon, the Morvan mountains and in the centre the two conical slag heaps of the previous oil shale mine. The second image shows a district close to the conical slag heaps where the upper oil shale formation crops out (Millery formation). Until today, the manufacture sites of the oil shale ornaments of the Iron Age in the Autun basin are unknown.

Landscape of the Montcombroux-Les-Mines basin to the north-west (left image). The oil shale is very close to the surface in the south border of the basin. Oil shale "coal money" is frequently found in the cultivated fields indicating that the armlets fabrication in the Iron Age occured there. Typical hillslope outcrop of oil shale (right image). The oil shales from this basin are generally dolomitic, rich in clay and fissile.

Suggested trade routes

Investigations of the archaeological ornaments and the relevant reference materials revealed that there are four known sources for raw materials, three of which are oil shales from the Permian basins in France, and one is a Jurassic marine oil shale, called Blackstone, from the Kimmeridge Clay Formation in Dorset, South England. Only the source for one raw material could not be determined, so far. For this reason, more field work and the sampling of reference material, is aspired. As can be seen in the map to the right, armlets made of Kimmeridge oil shale (Blackstone) were found in South Germany (Heuneburg) and Switzerland (Delemont-En La Pran and Onnens-Beau-Site, Le Motti). Permian oil shale from the Autun basin was only found as raw material for one armlet in north-west Switzerland (Chevenez), whereas oil shales from Buxières-les-Mines and Montcombroux-les-Mines were distributed in France as well as in Switzerland. It is striking that no armlets made of Permian oil shale from France is found in South Germany, so far. However, more ornaments have to be analyzed in order to complete the picture of trade routes.

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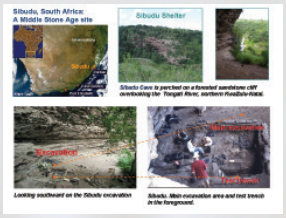
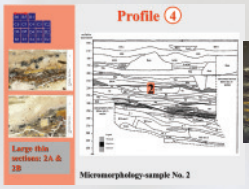
COMBUSTION FEATURES & ANTHROPOGENIC DEPOSITS OF PREHISTORIC & HISTORIC SITES

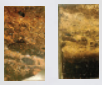
Materials and methods

In numerous Eastern Mediterranean Palaeolithic caves, as well as in South Africa Middle Stone Age (MSA) sites, ashy hearth remains make up a major portion of the sediments.

The ash-rich horizons represent a valuable record of the activities of prehistoric humans who lived at these sites.



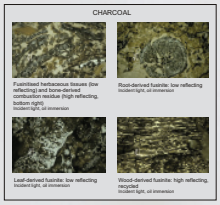




Polished blocks (60x30mm) for organic petrology investigations

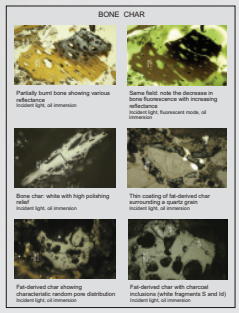
The profile 4 in Sibudu displays several cross sections of hearths which consist of alternating bright and dark bands composed of dominantly mineral matter in the bright zones and burnt organic substances in the dark layers. Investigation of ash-bearing sediments is generally carried out using FT-IR spectroscopy for the mineralogy, micromorphology for the fabric analysis and organic petrology to determine the fuel and the burning conditions. Micromorphology analysis is performed on large thin sections. Organic petrology is either carried out on fine polished thin sections or on polished blocks.

Organic constituents identified by organic petrology

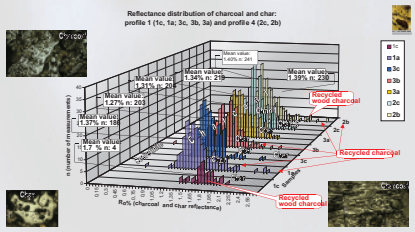


Organic petrography confirmed that a major organic constituent of the sediment at Sibudu is charcoal, both woody and herbaceous. Charcoal has been classified as fusinite and inertodetrinite. Most of the identifiable charred plant material was derived from herbaceous plants, with identifiable tissues from leaves, stems, roots and seeds (photomicrographs, left).

Two types of amorphous organic combustion remains were identified:
the first type resemble char with vesicles having often droplet-shaped occurence suggesting that these bodies were originally fluid and that they underwent a degassing process but have since hardened (photomicrographs, centre and bottom right);
the second type of amorphous bodies are similar to secretinite, although the origin of this material is not totally clear ("gel-derived char"). It is possibly a by-product of burning resin or gum, derived from trees or possibly from the burning of seeds (photomicrographs bottom left).



Characterization of the combustion residues: charcoal (fusinite) and char



Most charcoal particles have reflectance mean values in the range of 1.27%Ro to 1.40%Ro. Low reflecting charcoal particles ranging from 0.7%Ro to 0.90%Ro are frequent (left part of each histogram). The latter could have formed on the periphery of the hearth structure. High reflecting charcoal particles reaching up to 2.55%Ro are rare. Their higher reflectance could be due to repeated burning of charcoal formed in previous hearths (recycled charcoal).

Reflectivity measurements on the charcoal and the fat-derived char particles resulted in similar reflectance distributions within subsequent charcoal-rich sub-layers, indicating equivalent burning conditions.

Calculated temperatures of fusinite formation range from 268°C to 368°C. They are based on the formula established by Jones and Lim (2000) expressed as:

$T°C = 184 + 118 \times (\text{reflectance } R\%)$

Benefits of the use of organic petrology

Methods of organic petrology have proven useful in the identification of various burnt and unburnt organic substances (Ligouis 2006): unburnt and burnt plant tissues (wood tissues, herbaceous tissues, seed tissues, leaves) and humic gels (unburnt, oxidized or burnt).

In addition, organic petrology of hearth structures revealed the exitstence of fat-derived char particles which were ignored by micromorphologists until 2004 (Schiegl et al.,2004).

An inventory of the lateral and vertical variations in reflectance distributions of the numerous interfingering charcoal-rich layers can help to determine occupation surfaces and spatial organization.

In the absence in the hearth structures of large charcoal fragments, organic petrology allows the characterization of the microfragments of charcoal in order to determine the type of fuel and by the use of the reflectance measurement of fusinite to provide informations on the burning conditions.

Organic petrology has been also revealed useful in the identification of burnt bones by the identification of fat-derived char attached at the surface of the bone microfragments.

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