Zootaxa 5739 (1): 075–082
https://www.mapress.com/zt/

Article

ISSN 1175-5326 (print edition)
ZOOTAXA
ISSN 1175-5334 (online edition)

https://doi.org/10.11646/zootaxa.5739.1.12
http://zoobank.org/urn:lsid:zoobank.org:pub:1B6108CD-1561-4B67-82D1-C619DEFA4B4A

The first occurrence of water boatmen family Micronectidae (Nepomorpha: Corixoidea) in Eocene Baltic amber

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Abstract

The fossil record of true aquatic bugs (Heteroptera: Nepomorpha) in amber outcrops is scarce, hampering our knowledge of their diversification. Recently, numerous discoveries have been made in mid-Cretaceous Kachin amber, whereas there is only one taxon described in Cenozoic ambers (Popov & Heiss, 2014), despite the abundance of such specimens in lacustrine deposits. We report the first reliable fossil occurrence of Micronectidae, which is tentatively attributed to the extant genus *Micronecta*. The taxonomic affinities of the fossil are discussed, as well as the scarcity of Nepomorpha in Cenozoic amber deposits.

Key words: Baltic amber, Hemiptera, Micronectidae, *Micronecta*, preservation

Introduction

Our knowledge of the fossil record of insect lineages is biased by the different Konservat-Lagerstätten (Labandeira & Sepkoski, 1993), especially with the numerous amber deposits since the early Cretaceous (Maksoud *et al*., 2017). Amber fossils in particular, strongly lead our current interpretations of the palaeoentomofaunas. Studies on insect fossils in amber are predominant in the literature, as the specimens embedded inside fossil resins display morphological features that are often poorly preserved in compressions (Labandeira, 2014). However, the amber deposits are not evenly scattered in time and space (Schachat & Labandeira, 2021) and the amber assemblages are not accurate records of the past biodiversity of the corresponding ecosystems since taphonomy and ecological behaviours shaped the arthropod communities preserved in amber (Solórzano Kraemer *et al.,* 2018). Insects living far from the source of resin production are less likely to be encountered in amber. It is the case for aquatic insects, and especially for the Nepomorpha. This bug clade has one of the most ancient and abundant fossil records among the Heteroptera (Grimaldi & Engel, 2005). The Nepomorpha or true aquatic bugs are recorded from the early Triassic (Shcherbakov, 2010; Criscione & Grimaldi, 2017; Criscione-Vastano & Grimaldi, 2025) and are quite abundant in Mesozoic and Cenozoic lacustrine deposits (Sinitshenkova, 2003). Interestingly, the Nepomorpha are quite infrequent in amber, with Corixoidea, Ochteridae, and Gelastocoridae representatives described in mid-Cretaceous Kachin amber, and an Ochteridae in Miocene Dominican amber (Popov & Heiss, 2014; Poinar & Brown, 2016; Zhang *et al*., 2022; Xian *et al*., 2025). The two last families are probably the least dependent on aquatic environments. In the well-studied Eocene Baltic amber, despite 25% of bioinclusions accounting for aquatic insects (Wichard *et al*., 2009), this proportion largely reflects taxa with aquatic immature stages but winged, dispersing adults; in contrast, no formally

Accepted by C.-Y. Cai: 29 Dec. 2025; published: 31 Dec. 2025

described nepomorphan taxa are known. Bachofen-Echt (1949) figured three nymphs of Corixoidea and Wichard & Weitschat (1996: pl. 6) figured a nymph of Corixoidea, but no other occurrences of true aquatic water bugs in Cenozoic ambers have been formally reported.

Herein, we provide the first description of a Nepomorpha in Eocene Baltic amber. This fossil is the first reliable fossil representative of Micronectidae. It is assigned to the extant genus *Micronecta*. We discuss the fossil record of Nepomorpha through time and their scarcity in amber deposits.

Material and methods

Fossil imaging

Photographs were taken using Keyence VHX-6000 digital microscope. All images were optimized and organized into plates using Pixelmator Pro v.3.6.11 Archipelago software.

CT-scan reconstruction

X-ray tomographic acquisition of the specimen was performed at Université of Poitiers (Institut de Chimie des Milieux et Matériaux de Poitiers - IC2MP) on an EasyTom XL Duo device (RX-Solutions, France) equipped with a Hamamatsu L10711 nanofocus X-ray source (LaB6 cathode) and a Varian PaxScan 2520DX flat-panel detector (pixel size: 127 µm). The acquisition was conducted using a tube voltage of 70 kV and a target current of 99 µA. A total of 4320 projections were recorded over 3 turns (1440 projections per turn). The geometric configuration utilized a source-to-object distance (SOD) of 5.23 mm and a source-to-detector distance (SDD) of 442.63 mm, resulting in an isotropic voxel size of 1.50 µm.

Volume reconstruction was executed via XAct software (RX-Solutions) using a filtered back projection algorithm with a Tukey filter. The process incorporated corrections for X-ray spot drift, ring artefacts (kernel size 13), and phase retrieval (manual mode, parameter 0.315). The final reconstructed volume consisted of 1651 × 2964 × 1672 voxels, with grayscale values normalized within a range of -0.04 to 0.80.

Volumetric data rendering and segmentation were conducted using Dragonfly 3D World (provided by Comet Technologies Canada Inc., Montreal, Canada) and Drishti (version 3.2; Limaye, 2012).

Morphological and systematic frameworks

Morphological terminology mainly follows Hebsgaard *et al*. (2004) and taxonomic attribution relies on the systematic framework supported by the phylogenetic analyses of Hebsgaard *et al*. (2004), Ye *et al*. (2023), and Xian *et al*. (2025).

Systematic palaeontology

Order Hemiptera Linnaeus, 1758
Suborder Heteroptera Latreille, 1810
Infraorder Nepomorpha Popov, 1971
Superfamily Corixoidea Leach, 1815
Family Micronectidae Jaczewski, 1924
Subfamily Micronectinae Jaczewski, 1924
Genus *Micronecta* Kirkaldy, 1897

Type species. *Micronecta minutissima* (Linnaeus, 1758)

***Micronecta* sp. sensu lato**
(Figs 1, 2)

Material. The specimen is currently housed in the private collection of Christel and Hans Werner Hoffeins (Hamburg, Germany) (CCHH) under the number CCHH 1751-1 and will be deposited at Senckenberg Deutsches Entomologisches Institut (SDEI) in Müncheberg, Germany.

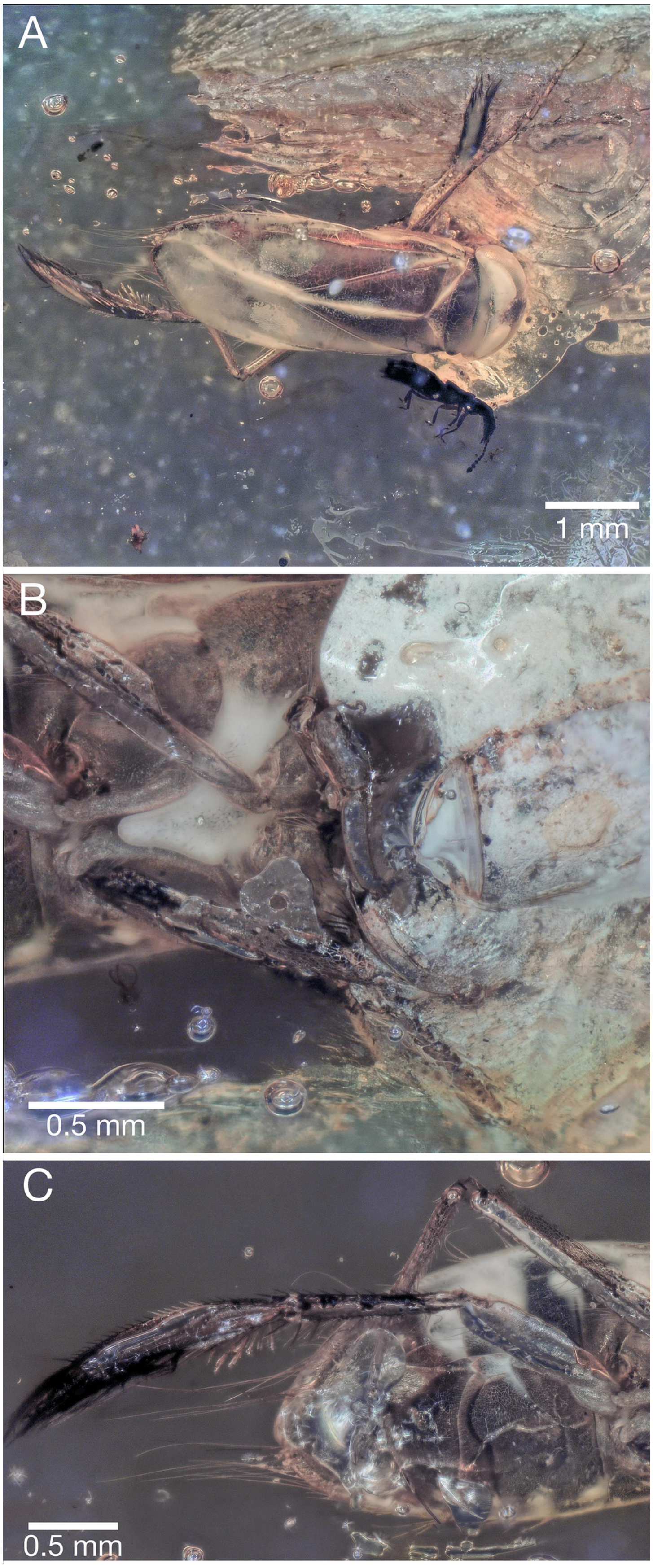

FIGURE 1. *Micronecta* sp. specimen CCHH 1751-1 (Nepomorpha: Micronectidae) photographs. **A**, Dorsal habitus. **B**, Ventral view of thorax. **C**, Ventral view of abdomen, meso- and metathoracic legs.

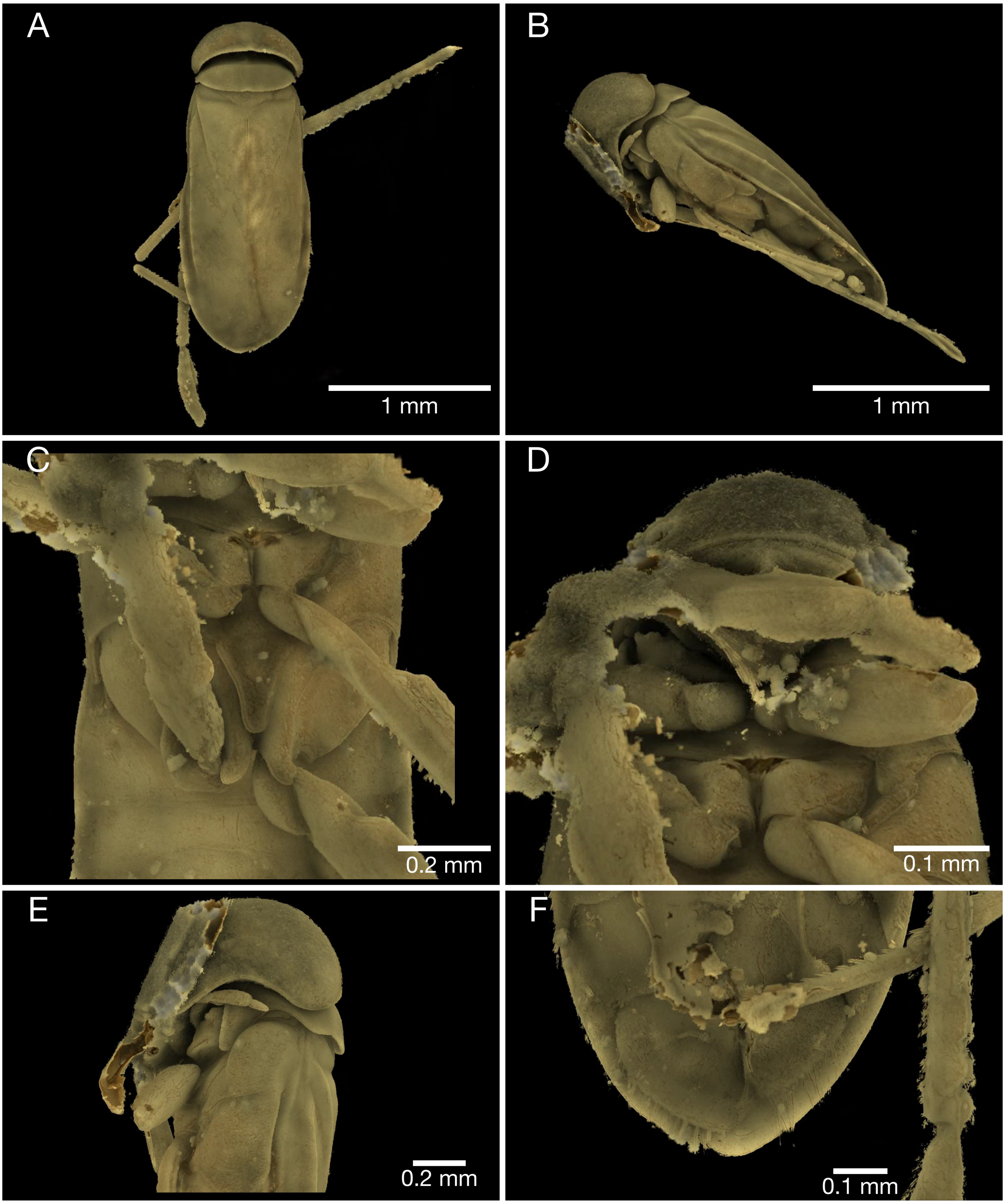

FIGURE 2. *Micronecta* sp. specimen CCHH 1751-1 (Nepomorpha: Micronectidae) CT-scan reconstructions. **A**, Dorsal habitus. **B**, Lateral side habitus. **C**, Thorax, ventral view. **D**, Head and thorax, ventral view. **E**. Head and thorax, lateral view. **F**, Abdomen, ventral view.

Locality and horizon. Eocene Baltic amber, exact country of origin unknown.

Description. Adult, male. Body elongated, parallel-sided, 2.0 mm long; greatest width 0.8 mm across abdomen; without apparent colour patterning. Mouthparts, forelegs, and genitalia obscured in ventral view. Head semicircular, three times wider than long, nearly as wide as pronotum; interocular distance shorter than eye width. Compound eyes large; ocelli absent. Antennae with three antennomeres; antennomere II longest and widest; antennomere III distinctly shorter. Rostrum poorly preserved. Pronotum narrow, three times wider than long, with posterior margin apparently convex, not covering scutellum, no prominent anterior pronotal carina; lateral margins slightly truncated. Scutellum short, triangular, 0.15 mm long. Metaxiphus short, tongue-shaped, 0.2 mm long. Tegmen 1.6 mm long, 0.3 mm wide, with nodal furrow diagonal and not reaching margin of tegmen. Meso- and metathoracic legs slender; mesothoracic legs distinctly longer than remaining legs. Prothoracic legs with tibia and tarsi unfused; foretibia subequal in length to spoon-shaped pala tarsi; arrangement of setae on forelegs indistinct. Mesofemur and mesotibia subequal in width; mesofemur longer than mesotibia; mesotarsi one-segmented and distinctly shorter. Metafemur distinctly broader than metatibia; both subequal in length; metatarsus subequal in length to metatibia and covered with long swimming setae.

Abdomen slightly asymmetrical, laterally bearing short setae and apically with long setae. Strigil not visible, the CT reconstruction reveals that there is no boundary identifiable between the wings and the body of the specimen.

Discussion

The new fossil fits in Nepomorpha based on the short, concealed antennae, visible only in ventral view, a unique synapomorphy of the Nepomorpha (Hebsgaard *et al*., 2004), the general habitus, and the presence of swimming hairs covering the metathoracic tarsi, which further supports this attribution (Schuh & Weirauch, 2020).

The general habitus of the specimen shows similarities with those of Corixoidea, including the antenna, shape of the head and pronotum in dorsal view, the hemelytra, the tarsal formula, the middle legs with two slender claws, oar-like swimming metathoracic legs. Additionally, the new fossil possesses features that are commonly found in Corixoidea and distinguishes it from other nepomorphan superfamilies such as head not firmly fused with the pronotum, scutellum concealed by the pronotum, and an elongated metathoracic episternum. Additionally, the new fossil presents synapomorphies of Corixoidea such as the unsegmented broadly triangular labium (poorly preserved) and the unsegmented fore tarsus, forming a spoon-shaped 'pala' (Hebsgaard *et al*., 2004; Ye *et al*., 2020; Ye *et al*., 2023).

Corixoidea are currently divided into three families: Corixidae, Diaprepocoridae, and Micronectidae. Initially, Micronectidae and Diaprepocoridae were considered as subfamilies of Corixidae but recent phylogenetic analyses justified elevations to family rank (Ye *et al*., 2023). Micronectidae appear to be paraphyletic in Ye *et al*. (2023) with the monophyly only supported by the small size of its representatives in Xian *et al*. (2025). Based on the identification key of Nepomorpha in Schuh & Weirauch (2020), the fossil falls into Micronectidae based on the scutellum broadly exposed; transverse pronotum and presence of three antennomeres. The exposed scutellum is rather a plesiomorphic feature in Corixoidea (Ye *et al.*, 2023).

Micronectidae are currently divided into two subfamilies and eight genera, one of them is an extinct genus, *Acromocoris* Bode, 1953. However, the attribution of *Acromocoris* to the Micronectidae, as proposed by Popov (1992), is doubtful. The type specimen consists of a fragmented thorax and abdomen. Even if it has an exposed scutellum, this is not sufficient to confidently attribute the specimen to Micronectidae. The genus must be considered as a Nepomorpha *incertae sedis*, possibly a Corixoidea because of its small size.

Following Nieser & Chen (2006), the new fossil would fall into *Micronecta*, based on the following combination of characters: eyes gradually narrowed towards rostrum (ventral view); mesosternum without carina; metaxiphus short; three antennomeres; posterior margin of pronotum convex; hemelytra with nodal furrow; head without a dorsal impression on vertex; male prothoracic pala and tibia unfused. Also *Austronecta* Tinerella, 2013 is characterized by the acutely pointed triangular hind margin of head and a prominent anterior pronotal carina, which is not the case in the new fossil (Tinerella, 2013).

The new fossil shares with *Papuanecta* Tinerella, 2008 the small, 2.0 mm long body with parallel-sided, elongate body shape, and nodal furrow diagonal and not reaching margin of the wing vs more than 2.0 mm long, more ovoid-shaped body, and nodal furrow entire, marked by well-developed perpendicular suture, and reaching outer margin of wing in *Micronecta*, but the pronotum of the fossil is apparently convex along entire posterior margin vs with recessed short, squared area mediobasally in *Papuanecta* (Tinerella, 2008). But this last character is not obvious to observe. A more significant character to separate the fossil from *Papuanecta* would be the strigil small, indistinct with light microscopy in *Papuanecta* vs well developed and well visible with light microcopy in

Micronecta. *Papuanecta* is restricted to Papuasia and it would be rather surprising to find a representative of this genus in the Eocene baltic amber. But similar situations occurs for other insects from the Baltic amber (*e.g.*, the presence of the extant Australian termite family Mastotermitidae in this amber) (Engel *et al.*, 2007).

The systematics of *Micronecta* should be revised as preliminary mitogenomics analyses revealed paraphyly of the subgenus *Micronecta*, advocating for further revisions to provide clear diagnostic features (Xie *et al*., 2024). Our CT-scan reconstruction does not overcome the preservation issue of this specimen hampering clear observation of mouthparts, forelegs, and male genitalia. In addition to this constraint, the absence of a clear systematic framework prevents us from provide a clear assignation of the specimen to a subgenus rank or to clearly discriminate it from *Papuanecta*, the specimen is subsequently left unassigned in *Micronecta sensu lato*.

Conclusion

Nepomorpha represent the earliest lineage of true bugs to appear in the fossil record (Shcherbakov, 2010; Criscione & Grimaldi, 2017; Boderau *et al*., 2025a), they are very abundant in early Mesozoic lacustrine deposits (Popov & Wootton, 1977; Nel & Paicheler, 1992). From Mid- to Late Cretaceous, the fossil record of Nepomorpha is scarce with occurrences in mid-Cretaceous Kachin amber (Zhang *et al*., 2022; Xian *et al*., 2025) and a single Belostomatidae is reported from the late Cenomanian of Haqel (Boderau *et al*., 2025b). For the Cenozoic, numerous Nepomorpha are described (see in Nel & Paicheler, 1992) but only in lacustrine deposits. The rarity of Nepomorpha in amber deposits can be mostly linked to their aquatic lifestyle, reducing the likelihood of them being trapped in the resinous secretions of trees. Only small specimens are reported in Burmese amber (few millimetres long), facilitating the trapping and inclusion in the resin. Even if only few specimens are known in amber, the discoveries of Corixoidea in the 'mid'-Cretaceous Burmese amber (Xian *et al*., 2025), and here Micronectidae in the Eocene Baltic amber advocate for more intensive study of amber material to find new nepomorphan insects, that will help to fill gaps in their fossil record.

Acknowledgments

We thank the two anonymous reviewers for their comments and suggestions, which improved the manuscript. This work contributed to Mathieu Boderau's PhD thesis and was funded by Ludwig-Maximilian Universität and ISYEB. CT-scan acquisition was funded by ISYEB and computational resources were provided through equipment funded by the French National Research Agency under grant no. ANR-19-CE02-0023 (SocioGenomics project). The authors are grateful towards Dr. Arnaud Mazurier (UP) who performed the CT-scan acquisition.

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