Preserving the Nieuwdonk collection, a hidden Pleistocene mammal assemblage from the Flemish Valley (Berlare - Belgium)

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In the midst of the coronavirus pandemic, the municipality of Berlare (East Flanders, Belgium) acquired an important collection of Late-Pleistocene remains from the former Nieuwdonk quarry (near Uitbergen and Overmere, province of East Flanders). This previously private collection comprises a diverse assemblage of Pleistocene mammals from the Flemish valley and covers an important part of Belgium's Quaternary fossil record, offering a window into the regional biodiversity of the last Ice Age and Interglacials (ca. 10 Ka - 126 Ka). Within the collection, various remains (318 specimens) of roughly 20 different taxa are represented, as well as reworked Tertiary ichnofossils and Stone Age artefacts, including a bone tool. Although sampling bias occurred during collecting in the 1970s, it still counts as one of the most complete Pleistocene collections from this classic location within the Scheldt basin and Unesco Global Geopark (Schelde Delta). As a result of years of poor storage conditions, almost all of the specimens suffered from desiccation and pyrite decay. A restoration project was set up during the coronavirus pandemic with restrictions imposed by the Belgian government on daily activities. In this article, we focus on the lessons we learned from both the restoration and inventorisation project during the pandemic, as well as the challenges faced in transitioning a former private collection into a public one.

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The Nieuwdonk collection was gathered between 1973 and 1978 by private collector Benedikt Timmerman. During his years as a biology student at Ghent University, he collected hundreds of Pleistocene mammal fragments from the Nieuwdonk quarry (Timmerman 1982). This former quarry, located between the municipalities of Uitbergen and Overmere (since 1977 part of Berlare), was owned by the DDS (Dender, Durme, Schelde) intermunicipal company since 1972. Preliminary investigations conducted by the Belgian Geological Survey (Paepe 1971), the Smet-Dessel n.v. company (1971) and geologist Gustaaf Lambrechts from the 'Rijksinstituut voor grondmechanica' (1972) were carried out to determine the industrial quality of the sediments. The Quaternary sands proved to be ideal as a primary product for the construction of the nearby E17 highway connecting Antwerp and Ghent, as well as local building projects (Stevens 2015). Under the supervision of DDS, the quarry was exploited by the "André Maes" Company from Lichtervelde (province of West Flanders) who was in charge of all excavation activities between 1972 and 1979 (Stevens 2014). During these years, three distinct bonebeds in the lowermost part of the quarry yielded important remains of fossil fauna and flora from the late glacial and interglacial periods. The collection gathered by Benedikt Timmerman was only one of many private collections amassed in this particular period of time. Although sampling bias occurred, the Timmerman collection was partially studied for the first time by Dr Anton Ervynck in 1985-1986 who, at the time, worked for Prof Dr Achilles Gauthier and his team at the paleontology lab (Geological Institute) of Ghent University (unpublished letter between Timmerman and Ervynck Archive of the historical association of Overmere). A short note was published later in the Dutch journal 'Cranium', based upon the study of this collection (Germonpré and Ervynck 1988). The studied specimens were also included in an osteometric study (Germonpré 1993a) but the collection as a whole remained private property. Around 1999, Timmerman sold his collection to Herman Rupus, the director of DDS-VERKO intermunicipal company. A large proportion of the specimens were exhibited in four display cabinets in one of the corridors of the DDS-VERKO headquarters in Dendermonde. The other specimens were stored in the archives of the same building and remained unseen for nearly 20 years. As a result of internal changes, the board of the DDS-VERKO intermunicipal company decided to donate the entire collection to the municipality of Berlare in November 2020. The collection was re-housed at the cultural center of Berlare as decided by the alderman council. The council requested an inventorisation and after a first visit by Palaeontologica Belgica to the collection on 17th February

2021, they agreed to include a thorough restoration as a result of pyrite decay and related damage due to previous storage conditions. Within this project the entire collection was documented, labeled, identified, registered and opened up for research and the general public in the spring of 2021.

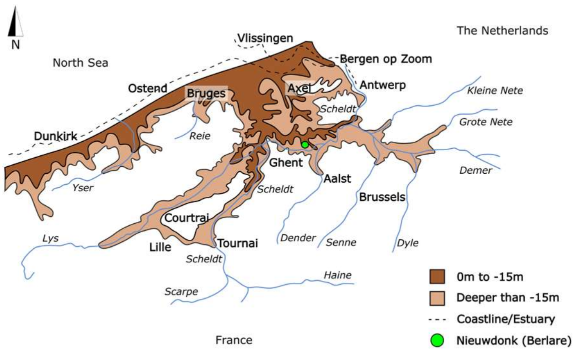

Figure 1. Morphological map of the Flemish Valley (after: Gullentops and Wouters 1996). The location of the Nieuwdonk quarry is highlighted in green.

Geology and stratigraphical context

The former (now flooded and inaccessible) Nieuwdonk quarry (N 51° 02' 04.9", E 3° 58' 28.3") held fossil-bearing strata from the Weichsel and Eemian stages of the Late Pleistocene (De Moor and Heyse 1976) and is located in the Flemish valley (Figure 1). The Flemish valley is an old basin eroded into its Tertiary (Eocene) substrate and filled up with fluviatile and aeolian sediments during the (Late) Pleistocene. It covers a large part of Flanders and has been shaped by the course of several braided proto-rivers. The meandering remnants of these once highly dynamic rivers are known today as the Scheldt, Leie, Dender, Zenne, Rupel, Dijle and Demer (Borremans 2015). The temporary exploitation of the Nieuwdonk quarry allowed for a detailed lithostratigraphic profile of the strata, which serves as a useful tool to reconstruct the sedimentological history and different paleoenvironments to some extent. The first lithostratigraphic profile was documented by Prof Dr Guy De Moor and Prof Dr Irénée Heyse (Ghent University) in 1976 (Figure 2). It clearly shows the complex nature of the sandy and clayey deposits ranging approximately 15-18 m under ground level. When we take a look at the fossils within the different formations, we notice a varied mix of reworked Eocene (but also Oligocene, Miocene and Pliocene) shark teeth, ichnofossils, late Pleistocene vegetation, bivalves, stone artefacts and vertebrate material from both glacial (Weichselian) and interglacial (Eemian and Holocene) periods. The fact that reworked materials are represented within the whole quarry is a clear sign that erosional effects (mainly resulting from fluviatile activity) generated an important impact onto the paleoenvironment. This reworked material however makes it difficult to attribute an absolute dating to some of the specimens in certain strata, especially the interglacial fossils which could either belong to the late Eemian period or early Holocene epoch. The taphonomy might provide some answers in this perspective, but not entirely. Often a lighter colour might suggest subfossil or recent preservation, but as peat formed during the Holocene (Stockmans 1946), we can find subfossil remains with a darker patina, falsely suggesting a much older age. Although we have no exact documentation on the provenance of each specimen, some samples documented by Dr Mietje Germonpré in the late 1980's are attributed to three distinct bonebeds. These bonebeds were defined as: Overmere 1 (OV I), Overmere 2 (OV II) and Overmere 3 (OV III). Based on the documented fauna, OV I (belonging to the Oostwinkel Formation) was attributed a (Late) Eemian age (Germonpré 1993b). The OV II and OV III bonebeds and their characteristic mammoth fauna suggest an Early-Weichselian age (Formation of Eeklo - Dendermonde Member) ranging between 73,000 – 113,000 years (Stuart 1991). However, until this day, no absolute radiometric dating was carried out on the studied samples. As an alternative, a relative dating based on faunal occurrences and taphonomy was proposed to distinguish the three bonebeds (Germonpré 1993a). OV I primarily holds heavily fossilised mammal remains represented by an interglacial fauna. OV II on the other hand is represented by a glacial fauna with a few representatives of a warmer (forest-like) fauna (e.g. deer, beaver, wild boar). The OV II bonebed is therefore considered as a transitional fauna between the OV I interglacial fauna and the OV III pleniglacial fauna comprising the typical mammoth steppe fauna. A fourth faunal group was briefly reported in younger deposits without naming any specific lithostratigraphic unit (Germonpré and Ervynck 1988). A Holocene (or even Medieval) age was suggested based on the light discoloration and remains of domesticated animals. Since no-one had the opportunity to collect and document any samples in-situ, it is advised not to draw any extensive conclusions merely based on paleoecological observations built on the collection itself.

The collection

The current Nieuwdonk collection is represented by a total of 318 specimens mainly collected by Benedikt Timmerman and extended with donations by Mr Georges Schneider-Huylebroeck, a private collector. The Pleistocene and Holocene remains represent the majority of all specimens (total of 296 items) whereas the ichnofossils (four specimens), the iron concretions (two items) and stone artefacts (15 items), embody the other part of the former Timmerman collection. The previously mentioned Elasmobranchii (ca. 800 specimens) were also sampled by B. Timmerman but not included into the Nieuwdonk collection, as they are part of the privatee lection of the 'historical association of Overmere'. Other finds from the original Timmerman collection, known

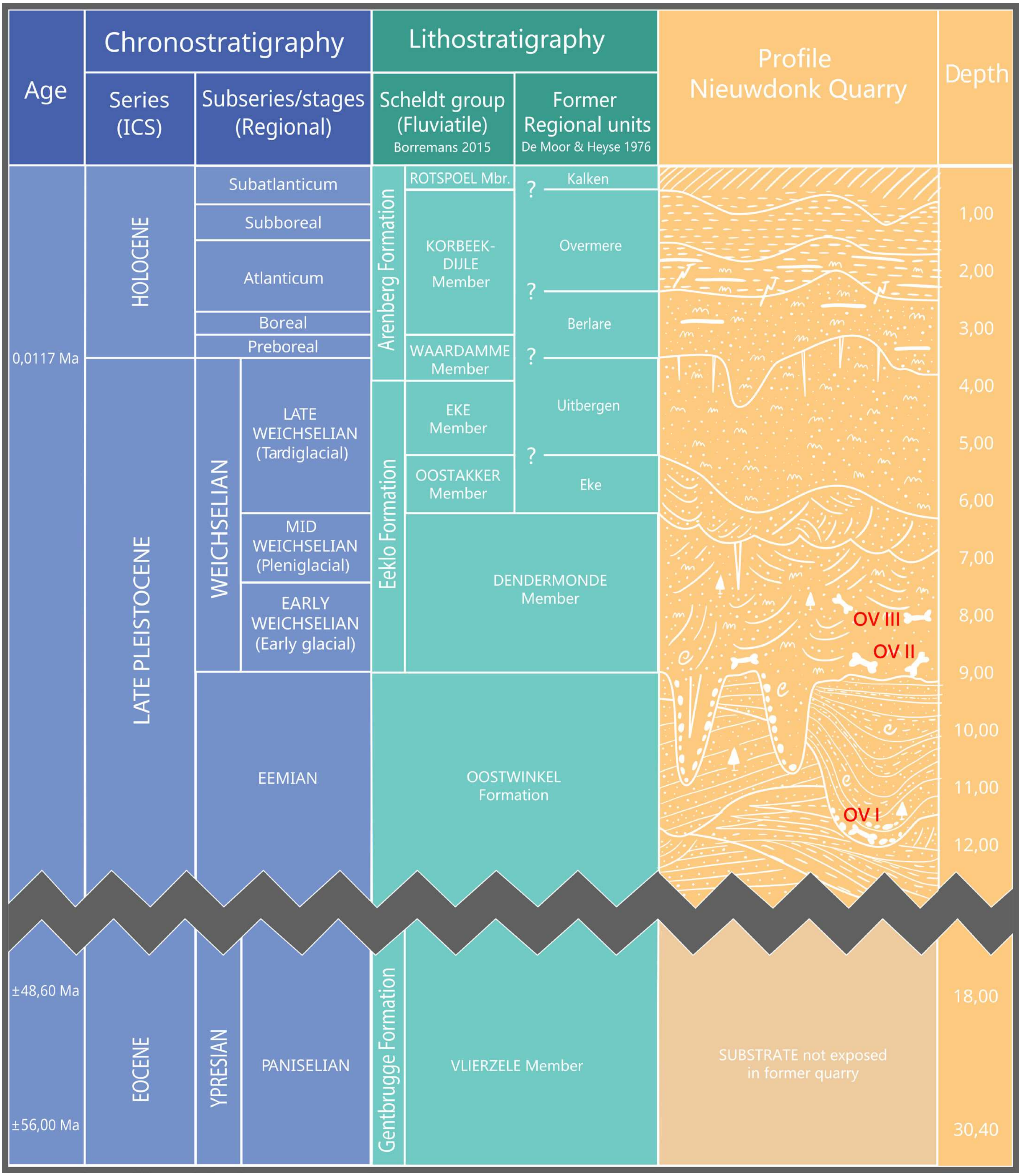

Figure 2. Chronostratigrapic and lithostratigraphical profile of the Nieuwdonk Quarry (updated after: Borremans 2015, De Moor and Heyse 1976, Paepe 1971, and updated with ICS, Blytt-Sernander system and Databank Ondergrond Vlaanderen (DOV) database). The hiatus between the Eocene substrate and the Late Pleistocene deposits indicates a disconformity and a related erosional period. The fact that no Oligocene, Miocene, Pliocene or Early Pleistocene deposits were documented, but fossil remnants of these periods are found within younger (Late Pleistocene) strata, is a clear indication of vast erosional (fluviatile) activity. OV I – OV III marks the position of three distinct bonebeds (cf. Fobe 1996; Gullentops and Wouters 1996; Storme 2020).

from documents (Timmerman 1982) and personal communication by Mr Timmermann have been lost or missing from the DDS-VERKO archive and have not been retraced at this point. Focusing on the Pleistocene and Holocene vertebrates, the collection is represented by the following species: woolly mammoth, *Mammuthus primigenius* (Blumenbach 1799), 89 specimens; straight-tusked elephant, *Palaeoloxodon antiquus* (Falconer and Cautley 1847), five specimens; woolly rhinoceros, *Coelodonta antiquitatis* (Blumenbach 1799), 39 specimens; Merck's rhinoceros, *Stephanorhinus kirchbergensis* (Jäger 1839), six specimens; horse, *Equus ferus* (Boddaert 1785), 36 specimens; steppe bison, *Bison priscus* (Bojanus 1825), 33 specimens; aurochs, *Bos primigenius* (Bojanus 1825), 19 specimens; musk ox, *Ovibos moschatus* (Zimmermann 1880), one specimen; sheep, *Ovis aries* (Linnaeus 1758), two specimens; European cattle, *Bos taurus* (Linnaeus 1758), one specimen; Irish elk, *Megaloceros giganteus* (Blumenbach 1799), nine specimens; red deer, *Cervus elaphus* (Linnaeus 1758), 16 specimens; roe deer, *Capreolus capreolus* (Linnaeus 1758), two specimens; reindeer, *Rangifer tarandus* (Linnaeus 1758), two specimens; Eurasian or European beaver, *Castor fiber* (Linnaeus 1758), six specimens; grey wolf, *Canis lupus* (Linnaeus 1758), one specimen; domestic dog, *Canis familiaris* (Linnaeus 1758), three specimens; red fox, *Vulpes vulpes* (Linnaeus 1758), two specimens; brown bear, *Ursus arctos* (Linnaeus 1758), one specimen; European wildcat, *Felis silvestris* (Schreber 1777), four specimens; Eurasian cave lion, *Panthera leo spelaea?* (Goldfuss 1810), maybe one specimen; and several fragments of Anseriformes (Ducks, Geese and Swans) and Galliformes (Ground feeding birds), red junglefowl, *Gallus gallus* (Linnaeus 1758), and pheasant, *Phasianus sp.* (Linnaeus 1758). A rare find is the presence of an *Ovibos moschatus* (Musk ox) vertebra (ND0242), which is not very common in the Flemish Valley aside from an isolated cranial fragment in Dendermonde (Germonpré 1993a). Another remarkable occurence are some (pre)-molar and postcranial remains of *Stephanorhinus kirchbergensis* (Merck's rhinoceros) whose first occurrence in the Belgian Quaternary fauna was recognised during the restoration project and confirmed by Dick Mol, Bjorn De Wilde and Albert Hoekman (pers. comm. 2021). These specimens are what makes this collection important from a scientific point of view (Nolis et al. 2021). In addition to this scientific value, we also observed predation, gnawing and scratch marks. A fairly obvious mark can be found on the condylar process of specimen ND0231 (right maxilla of *Coelodonta antiquitatis*). Judging by the morphology of the shattered bone this would have been the result of behavioral actions related to the spotted hyena, *Crocuta crocuta* (Erxleben 1777), or its subspecies the cave hyena, *Crocuta crocuta spelaea* (Goldfuss, 1823). This indirect proof of scavengers is an important argument to confirm the occurrence of carnivores in the assemblage, whose quantitative occurrence in a fauna is often inferior to that of herbivores in open or fluviatile sites. It is therefore exceptional to possess a left mandible of wolf (Canis lupus) within the collection (ND0269). The only omnivore represented within the collection is defined by the radius or radial bone (ND0100) of a brown bear (Ursus arctos) or cave lion (Panthera spelaea) which needs further research. A final important specimen consists of a bone tool (probably used as a hammer) carved out of a Cervus elaphus antler (ND0234). A complete overview of the collection and additional specimens in private collections is described by Nolis et al. (2021). A team of experts used comparative datasets to identify all the specimens.

During interviews with Benedikt Timmerman, it became clear that vegetation (wood, cones, leaves, peat), sediments, (reworked) bivalves or small fragments of bone were not collected. During fieldwork, Mr Timmerman exclusively focused on sampling vertebrate material. Although the collection as a whole comprises a valuable variety of vertebrate taxa, this sampling bias is unfavorable to recreate a more or less complete ecological reconstruction or draw any conclusions on the approximate number of animal occurences in the region or dominance of certain taxa. The thorough cleaning of sediment inside the cranial and postcranial cavities (e.g. medullary or sinus cavities) and the fixation of loose sediment inside the osseous chambers, did not allow us to find any puparia of subarctic blowflies, Protoformia terranova (Robineau-Desvoidy 1830), who are often reported from Pleistocene remains in the Flemish Valley (Gauthier and Schumann 1973; Gautier 1974, 1995; Germonpré and Leclerq 1994; Hellemond 2018; Vervoenen 1991). A preliminary inventorisation of the vertebrate specimens was attempted by Mr Timmerman, but unfortunately any documentation regarding the exact code system has not yet re-surfaced. However, we noticed that specimens with the prefix 'A' concerned molars, whilst specimens with the letter 'C' often represent antlers or cranial remains. Other letters (K, O, SA, SG, SI, SJ, K, T) have no obvious reference to a collector or anatomical (skeletal) part. Unfortunately, Mr. Timmerman did not remember upon what basis he founded this inventorisation system (pers. comm. May 2021).

The initial numbers had been applied to the specimens with India (Chinese) ink and withstood ethanol and acetone treatments during restoration. Some of these former specimens were used for osteometric analysis (Germonpré 1993a) and all of the former numbers were included into a new custom-made digital database in Microsoft Access. A new number was attributed to each specimen starting with the suffix 'ND' (referring to Nieuwdonk), followed by a four digit code. The numbers were added with a fine 'Uni Super Ink' permanent marker (pigment oil-based ink, reversible in ethyl alcohol). This particular ink can withstand UV light, acetone, bleach and similar organic solvents. A small hand-written ID card was also physically attached to each specimen containing a short description of the anatomical part, the osteological features, the presumed age or bonebed, the dimensions, the photo reference in the database, the performed restorations (past and recent) and the identification of the animal it belonged to. The combination of a reference in permanent ink on the specimen, combined with an ID card, easily refers to the printed and open online database of the collection, where all additional information can be found. This inventorisation will facilitate future research and was necessary to transfer this former private collection to a public one (Figure 3).

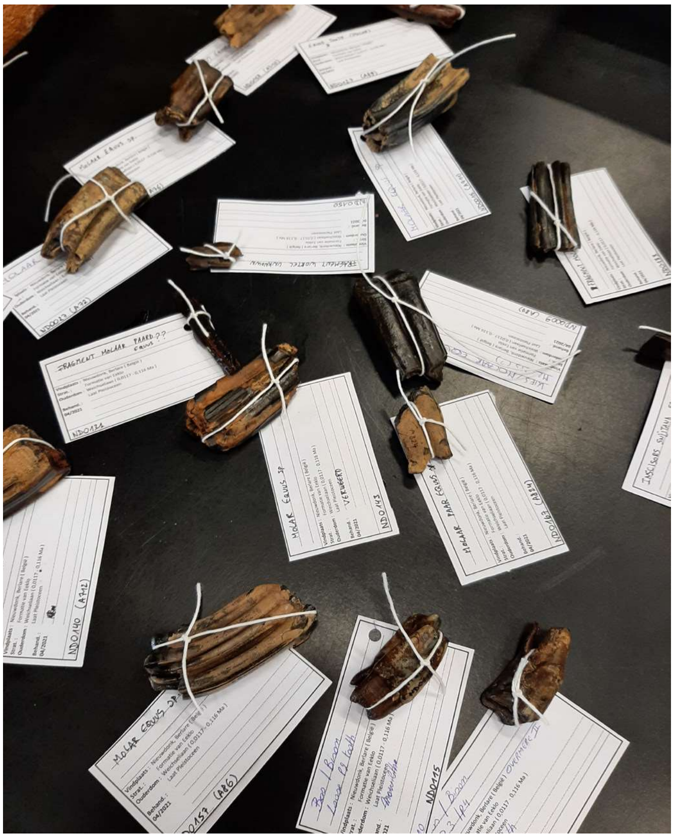

Figure 3. Examples of the temporary ID cards accompanying each specimen during the project.

Restoration and inventorisation project

The restoration and inventorisation of the Nieuwdonk collection proved itself to be quite a large undertaking. After being kept in poor storage conditions for more than two decades, almost all specimens showed signs of pyrite decay and desiccation. During their stay at the facilities of DDS-VERKO, the often disarticulated specimens were exposed to direct sunlight in glass display cabinets and/or underwent severe fluctuations in temperature and associated relative humidity in the DDS-VERKO archives. For 20 years these fluctuations impacted the specimens whilst being wrapped in old newspapers, creating a mildly acid environment. All of these factors contributed to the deterioration of a large part of the collection. Pyrite decay was visible on most specimens, with one fossil being reduced to nothing more than dust (Figure 4). Other effects included desiccation, efflorescence of salt crystals, tears and cracks on the surface and disintegration of the interior cancellous (spongy) bone matrix (Figure 5).

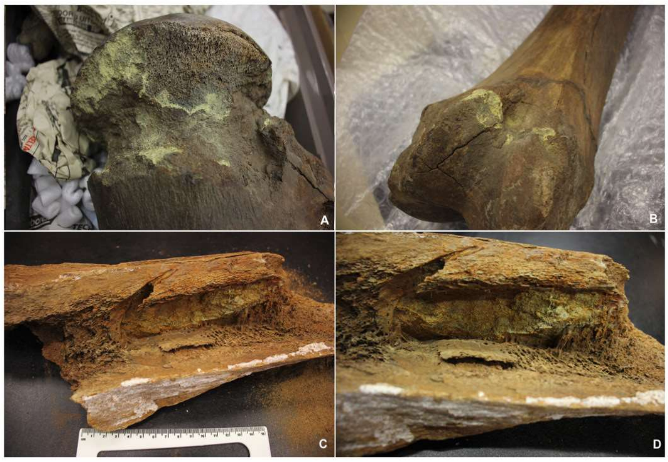

Figure 4. Composite picture of multiple specimens displaying pyrite decay as a result of pyrite bloom. Photos taken before the restoration project. A) Detail of specimen ND0193 where pyrite decay is visible on the femoral head (caput femur) of a woolly mammoth, Mammuthus primigenius (Blumenbach 1799). This specimen also shows predation marks from hyenas. B) Left femur of a male Mammuthus primigenius (Blumenbach 1799). Several spots of pyrite bloom out of the medial (epi)condyle of the bone. C) Distal portion of a right femur of an adult woolly mammoth, Mammuthus primigenius (Blumenbach 1799). This specimen was beyond any possible restoration or repairs and therefore not included in the collection; because it created a potential hazard for other specimens, the box of crumbled fragments was disposed of. D) Detailed view of the same specimen. Clearly visible are the thick compacta and materia compacta with the adjacent materia spongiosa which is almost completely decayed by dehydration. Brown-grey to greenish pyrite blooms out of the materia spongiosa.

In addition to the insufficient storage conditions, previous treatments and attempts at restoring certain specimens resulted in further deterioration, caused by the structural and chemical decay of different types of formerly applied adhesives, paints and waxes. As a result of taphonomy, pyrite had already formed within the bones before excavation. The aim of this restoration project is to prevent further pyrite decay. To remedy the effects of pyrite deterioration and desiccation, a reversal of the initial restorations was in order. In the past, broken fragments were bonded by a solution of animal glue and glycol or Araldite^{TM} (an Epoxy Bi-component adhesive). Other specimens were wrapped in gypsum (plaster) or had it internally inserted to prevent collapsing. During the restoration process, we applied CARBOWAX^{TM} Polyethylene glycol 400 to dissolve the formerly used adhesives. CARBOWAX^{TM} is a non-volatile liquid that is soluble in water and has low toxicity, making it a practical choice for this particular project.

As the restoration process took place amidst the COVID-19 pandemic (April 12th – August 28th, 2021), there were various other practical matters to take into account when organising a suitable lab set-up and assembling a team of five to eight people in order to comply with restrictions put into place by Belgian Federal Governmental decree. Even though regulations were eased during the course of the project, precautions such as wearing a face mask, keeping a minimum distance of one and a half meters and applying basic hygiene were still mandatory. The financial support for this entire project was funded by the municipality of Berlare.

Figure 5. Composite picture of specimens displaying desiccation, efflorescence of salt crystals, tears and cracks on the surface and disintegration of the interior cancellous (spongy) bone matrix. Photos taken at the beginning of the restoration project. A) Severely weathered and dessicated pelvic fragment (acetabulum) (ND0184) of a woolly mammoth, Mammuthus primigenius (Blumenbach 1799). B) Dehydrated bone fragments of the woolly mammoth, Mammuthus primigenius (Blumenbach 1799). Pyrite from within the spongy tissue, the materia spongiosa, has reduced the osteological structures to powder. C) Severely dessiciated left femur (ND0229) of a woolly mammoth, Mammuthus primigenius (Blumenbach 1799), held together with brown tape from previous restorations. Note how the tape has left behind stains on the specimen. D) Upper part (head) of the same left femur (caput femoris) of an adult woolly mammoth, Mammuthus primigenius (Blumenbach 1799) displaying the efflorescence of pyrite and salt crystals. The caput femoris is not completely fused with the diaphysis.

Firstly, an assessment of the collection needed to be done with the purpose of determining which specimens could fall within the scope of future palaeontological studies (such as dating of the fauna, paleoecology and morphometrics). At the same time, we included an overview of the number of specimens in need of a thorough pyrite and/or desiccation treatment. This was done during a first examination of the collection on February 17th, and reported to the alderman council of Berlare the following day. The following list of criteria were used to determine the state of the collection:

- Number of specimens affected by pyrite decay;
- Number of specimens affected by desiccation;
- Number of specimens belonging to carnivores;
- Number of specimens belonging to rare or unknown animals;
- Number of specimens with future scientific interest;
- Number of specimens containing bite, gnawing or scratch marks;
- Number of specimens previously treated with irreversible products;
- Number of specimens containing an ID number;
- Number of specimens with original sediment attached to them;

Based on the assessments, the scientific potential of the collection as a whole, became clear. A plan was made to set up a temporary lab, in accordance with the restrictions on daily activities imposed by the Belgian government.

Methods and materials

With the prohibition of cultural activities due to the pandemic, a temporary lab was constructed within the large auditorium of the cultural center of Berlare. The hall itself was large enough to ensure enough distance between the tables (minimum 1.5 meters) as imposed by the Belgian government. A flexible team consisting of five to eight volunteers were gathered, most of them with previous experience in the treatment of Pleistocene remains such as the restoration of the Dendermonde Mammoth (Hellemond 2019). To safeguard the necessary (social) distance between all team members, each conservator could work on two tables opposite each other. One side of the hall was dedicated to the treatment of pyrite, whilst the opposite side was used to treat desiccation, apply or remove adhesives and administer pigmentation. To assure enough air flow, all available emergency exits were opened during the day. All team members wore lab coats, face masks, gloves and safety goggles. Work surfaces were disinfected with Umonium 38 Master, an antiviral and antibacterial disinfectant. Prior to the setup, risk assessments were carried out for different aspects of the project, including: safety, work methods and waste disposal. The restoration team was chosen by the Palaeontologica Belgica executive board and consisted of a variety of professional preparators and citizen scientists with different skill sets.

Because different types of treatments were to take place in the auditorium, different areas were set up to prevent possible mixing of materials. Since there was no option to install laminar flows (LAF) or fume hoods, special attention was given to prevent the spreading of aerosols or pyrite dust between treated and untreated specimens. In total, the lab consisted of a dozen tables, where each area included a cluster of tables where different treatments and actions could be performed: pyrite treatment, wet treatment(s), dry treatment(s), numbering, photographing, database and storage (Figure 6).

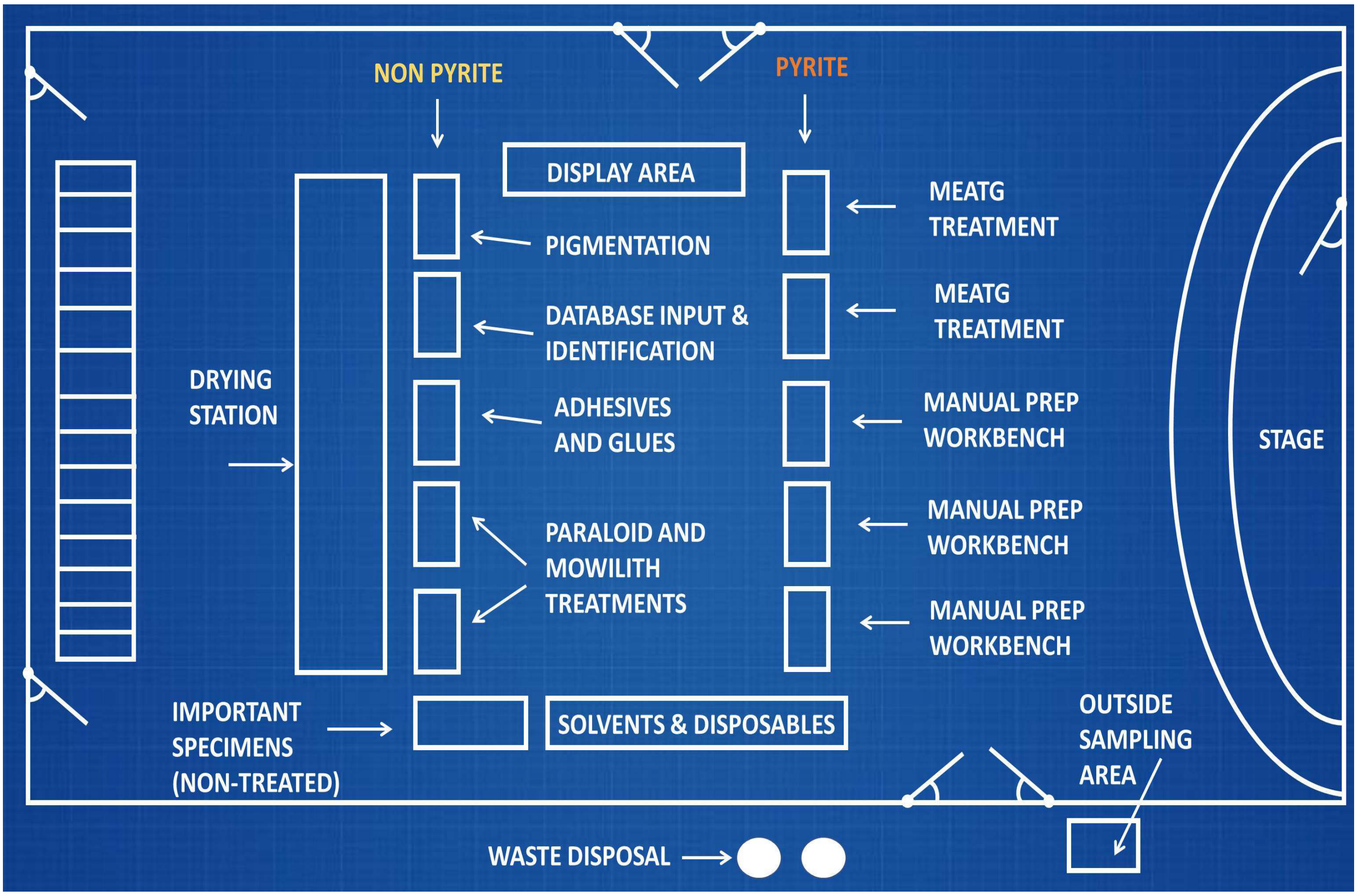

Figure 6. Diagram with a schematic representation of the lab. Although the setup changed slightly over the course of the restoration project, the fundamental setup remained true to the original plan with a pyrite and non-pyrite side. During visits, the area was sealed with barrier posts, ensuring social distancing between the preparators and visitors.

As the temporary lab space did not allow for an advanced exhaust system to be set up, the removal of the pyrite dust of the infected specimens happened outside, in open air. These pyrite-ridden specimens were also separated from the rest of the collection and placed on the tables facing the stage of the auditorium, until they were fully treated. Non-affected specimens were placed on tables facing the opposite side of the hall (Figure 7). Once assessed and physically separated, the treatment of the specimens started. Non-affected specimens were carefully cleaned with a variety of brushes and covered with either a polyvinyl acetate or an acrylic resin for the consolidation stage (Figure 8). During this restoration, both Paraloid B72 (in a 1:4 or 1:5 stock solution) and Mowilith 30 (in a 1:3 stock solution) were used to consolidate small fragments which were not included in the scope of future scientific research. These 'stock solutions' were diluted with acetone until their viscosity resembled a watery solution. Special care was taken to protect any former collection numbers or tags. The treatment was repeated two to three times until the specimens were saturated. After each application, the wet specimens were stored at the 'drying station', which was placed along the entrance of the auditorium, where a ventilator was placed to speed up the drying process. Specimens affected by pyrite oxidation were dusted off in open air and treated at separate tables.

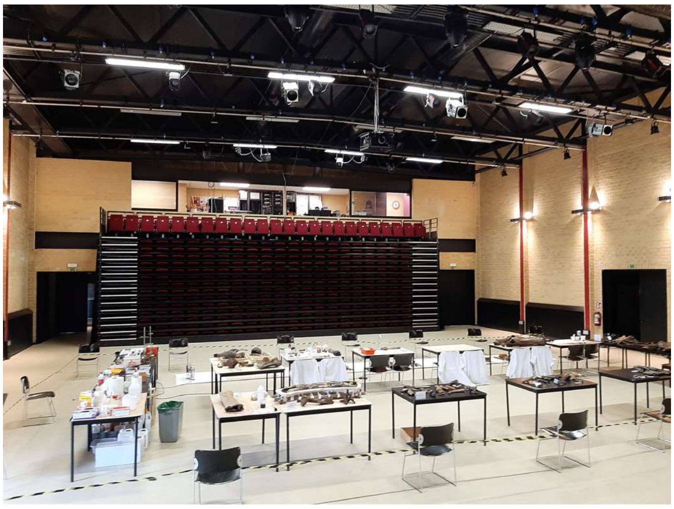

Figure 7. Photograph of the temporary lab set-up at the auditorium at the cultural centre 'De Stroming' in Berlare (BE).

Using small scrapers and/or periodontal scalers, and needles, the team carefully removed all visible pyrite, whilst trying to preserve as much unaffected bone as possible. During these manipulations careful attention was given to disperse as little pyrite powder as possible. This process was repeated until all visible signs of pyrite decay were gone. After the manual removal, the neutralisation of residual byproducts was obtained by using Mono-Ethanolamine Thioglycollate (MEATG 2.5%). Although the use of MEATG has been criticised due to its toxicity (Tacker 2020), very few alternative treatments would have been a feasible option for this particular project. Modern alternative treatments such as thermal dehydration or ammonia gas treatments proved to be too costly and impossible to perform under the constraints of a temporary lab set-up and the lack of proper fume hoods. The rather large specimens measuring up to more than 1m would require large sealable glass or polyethylene containers. After careful consideration, the choice to use MEATG was made for this particular project based on costs, safety and user comfort. The specimens were placed on custom-made wire topped polypropylene (PP) containers and areas with visible pyrite bloom were injected with the MEATG 2.5% solution, using a syringe or beral pipette. Afterwards, the specimens were wrapped in aluminium foil, Parafilm® M and acid-free tape for two hours. Subsequently, the MEATG-soaked specimens were thoroughly rinsed with (Bio) Ethanol. The wire topped containers collected the waste liquid and were discarded after the restoration process in large waste solvent containers. This process was repeated until the discoloration of the MEATG stabilised. The neutralised pieces were dried and received a protective internal and external treatment (until they were saturated) with an (1:4 - 1:5) Acetone-Paraloid B72 solution or (1:3) Acetone-Mowilith 30 solution (cf. Hellemond 2019). Once dried, all specimens were heavier and shinier, and ready to be joined together with their respective counterparts. Large and heavy fragments were conjoined using an epoxy bi-component adhesive called 'AralditeTM AW 2017', only after careful consideration and discussion between the team members. AralditeTM AW 2017 is a non-reversible adhesive and used only in cases where reversible alternatives would fail to provide durable results. The choice for AralditeTM AW 2017 came for previous satisfactory applications on the Dendermonde Mammoth and the Bos van Aa collection (Hellemond and Spolspoel 2016). Other restorations were carried out using the reversible cyanoacrylates 'Starbond E150' (medium viscosity) and 'Starbond E02' (low viscosity), the latter being used to adhere suture lines of small fractures (<0.3cm). When rapid fixation was needed, a pipette containing a 'fixator' (a saturated solution of sodium carbonate (Na_2Co_3) and ethanol) was used to set the adhesive one drop at a time. Any white residue was immediately wiped away. For the specimens that will serve a museological purpose, all adhesive residue was coloured with natural pigments. When fractures and sutures were clearly visible on the surface of the newly restored specimens, they were filled with a reversible acrylic resin mixed with calcite paste by the name of 'Vallejo Plastic Putty 70.401'. This paste remains white after application and, depending on the specimen's future museal purpose, also requires colour-matching pigmentation (Figure 9). A full overview of all the conservation steps can be found in Plates I-II.

Figure 8. Composite photograph of treatments used during the restoration. A) Consolidation of the spongious bone by saturating the materia spongiosa of the bone with Paraloid B72 (using a small brush) on top of a small wire rack over a waste container. B) Example of a MEATG treatment to neutralise the byproducts of pyrite decay. C) Specimens placed on top of a wire rack at the drying station.

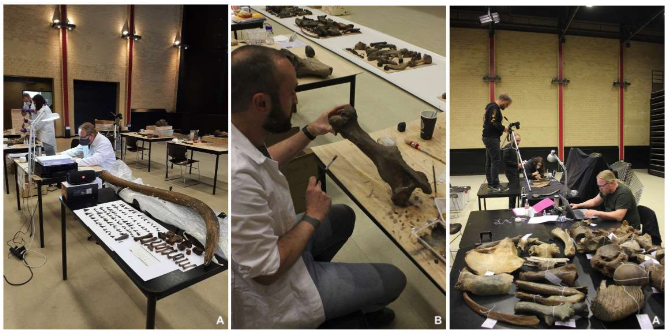

Figure 9. Composite photograph of the different, later stages of the restoration project. A) Left to right: assemblage and restoration of fragmented specimens; preliminary database set-up; drying station. B) A team member using different pigments to disguise previous or new treatments with adhesives. C) Inventarisation set-up of the treated specimens. Applying new collection numbers to the specimens, photographing, attaching a physical ID card and digitising the information in an online database.

Inventory and storage

After restoring and preserving the collection, new polypropylene storage containers were acquired and the next phase of the project could start. During this stage, all specimens were measured, numbered, photographed and inventorised into a digital database. A logical chain of action was set up over the different workstations. Firstly, specimens were inspected for former identification numbers, which were then linked to their new number (starting with 'ND' (Nieuwdonk) followed by a 4 digit code) and digitally registered. When applicable, new identification numbers were written next to, above or beneath the former numbers with an acetone resistant permanent marker (Uni-Ball Super Ink Marker). Specimens without any former identification, also received a new number which was written on a solid surface of the specimen, avoiding any fragile areas. Following numbering, specimens were measured and photographed from different angles on designated tables. Following this step, each specimen received a preliminary identification by the team experts, which was written on a tag card, together with the respective treatments each sample received. As a last step, all this information was registered into a custom made Microsoft Access database. To ensure that all this information is correct, a revision of the preliminary identification, and check up of the former and new treatments and identification numbers was held on August 28th, 2021. The database will be available online on the Palaeontologica Belgica website and printed versions accompanied by all published and consulted papers and articles will be open for consultation in Berlare and the historical association of Overmere. An open access approach to the collection is mandatory to facilitate future research and will be followed up by the municipality of Berlare.

After the Nieuwdonk collection was free of pyrite oxidation products, restored, inventoried and fully treated for future museological or research purposes, the specimens were encased in bubble wrap and placed in large plastic (PP) containers. These containers are a temporary storage measure, as the specimens will be stored in acid-free paper and boxes when kept in storage. The specimens will be on display in temperature-controlled cabinets when used in future exhibitions. Guidelines of storage were based upon standard lab conditions with relative humidity (RH) ranging between 30-55% and temperatures ranging between 20-25°C. These requirements have been communicated to the aldermans council of Berlare in a final report. Long term preservation will hopefully take place in a new building (visitor centre) near the former Nieuwdonk quarry which is currently being discussed by the council.

Cultural event

After the initial examination of the Nieuwdonk collection, it became clear that the collection held more than just scientific value. The impact of the resurfacing and realisation of the scale and importance of the collection set off a chain of events which would mark this collection as an exceptional part of the cultural heritage of the region. Regional and national press came to interview the team and report the history, size and prominence of the Nieuwdonk collection (Baten 2021; Piedfort 2021; PZC Editorial 2021; Radio 2 Oost Vlaanderen 2021; TV OOST 2021; Van de Velde and Verstichel 2021; Van Overstraeten 2021). The team further encouraged the general interest by accommodating extensive public outreach, including a social media and website blog with a day to day report on the progress of the project. All of this resulted in attracting other private collectors and receiving donations to accompany the Nieuwdonk specimens. A particularly successful initiative was the 'open lab visits', which were organised during two weekends at the end of April. During visiting hours, visitors could reserve time slots of fifteen minutes with their respective 'COVID-bubble' (all members of one household) and observe the team during the restoration. To comply with the restrictions in place, the visitors were held at a safe distance and could view the specimens from two meters away. In addition, a large screen was put up at the far end of the auditorium, displaying full body animal reconstructions. This way visitors could relate the visual image of the reconstructed animal to the fossils lying before them. Each visitor bubble received a guided tour of the laboratory with one of the members of the team. In retrospect, these visits were one of the most influential activities to valorise the collection as cultural heritage, as several politicians and many non-locals attended the 'open lab visits'. The downside of this initiative was that team members would have to halt their conservation practices and stop chemical treatments altogether during these weekends to give guided tours. This inevitably meant a delay in the restoration process and the assessed due date of the conservation project. A total number of 100 groups of visitors over 2 weekends attended the 'open lab' visits, with visitors from the region as well as beyond provincial borders. The groups were a diverse mix of all ages, including young families, young and old adults, elderly people, local politicians and people with a particular interest in paleontology. All of the visitors were keen to witness the conservation and even brought over self-found fossils for identification. We noticed that children and young adults in particular wanted to learn more about the restoration and came over to discuss their future ambition to study paleontology, geology or biology. Having underestimated the overwhelming response from the public, future outreach projects would benefit from two dedicated guides (volunteers) ensuring the progress of the conservation project.

Protection and future research

Transitioning a former private collection into a public one requires a great deal of effort. In order to safeguard the Nieuwdonk collection for future generations, an official contract between the municipality of Berlare and the Royal Belgian Institute of Natural Sciences (RBINS) was created. In the case where the municipality of Berlare no longer wishes to house or display the collection, every documented specimen from the database should be transferred to the collections of the RBINS. This way, the risk of ending up in private hands or as commercial goods will be avoided. The Nieuwdonk collection is also the subject of an ongoing master thesis research at the Opole University (Poland), which is to be completed in 2022. This will include the history of the collection and restoration project, but also anatomical research on certain selected specimens. In addition, an article in 'Cranium' is currently in preparation (cf. Nolis et al. 2021), describing the fauna and historical framework. As mentioned before, dating the material will be a challenge, even if the Uranium-series (U-series) dating of the enam-

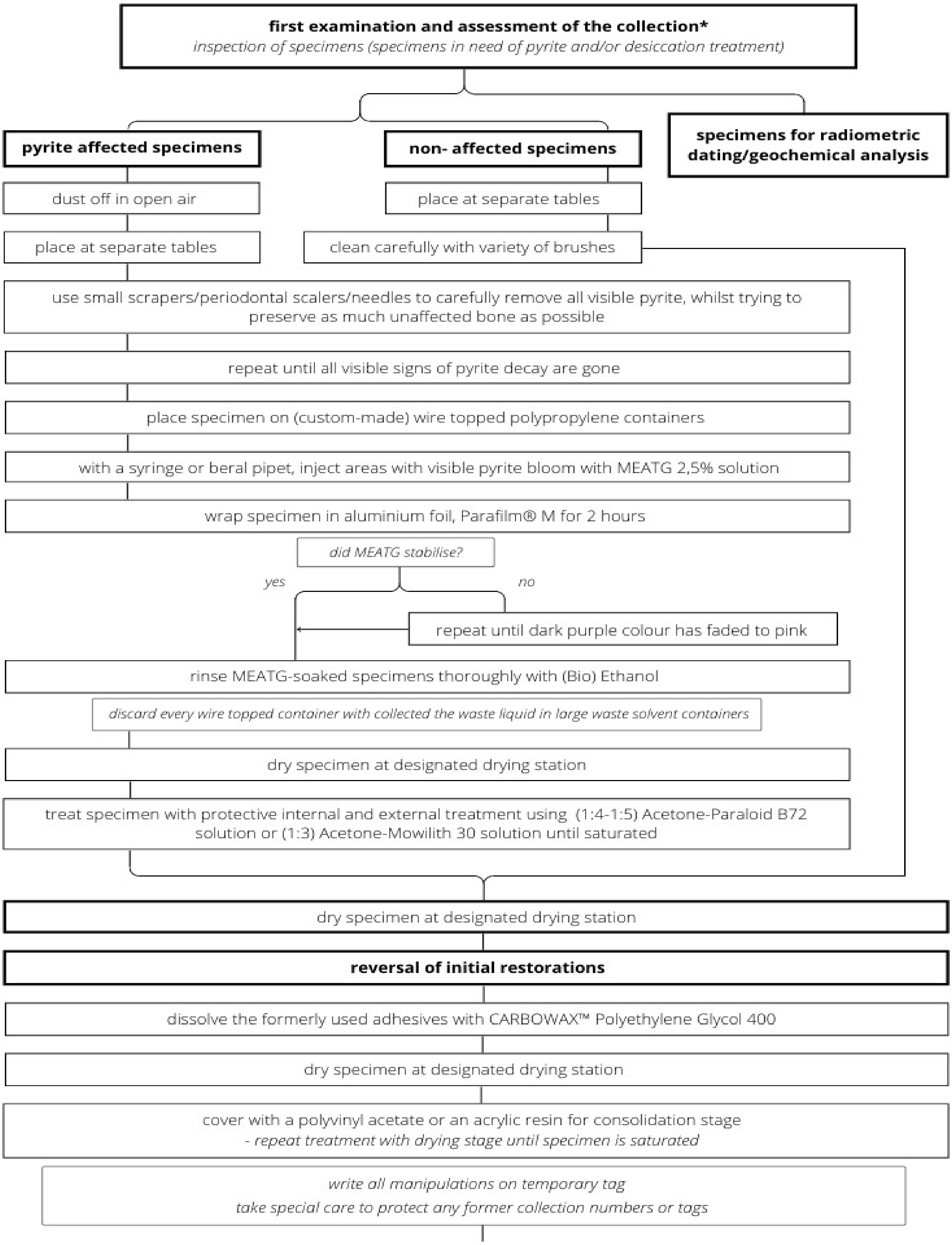

Plate I of II: Schematic overview of all the steps applied in the conservation and inventorisation of the Berlare collection.

Restoration/conjoining of fragments

large and heavy fragments: AralditeTM AW 2017 (epoxy bi-component adhesive – irreversible)
medium – small sized fragments: Starbond E150 (cyanoacrylate – medium viscosity – reversible) / Paraloid B72 (in a 1:4 or 1:5 stock solution) / Mowilith 30 (in a 1:3 stock solution)
small sized fragments/suture lines (<0.3 cm): Starbond E02 (cyanoacrylate – low viscosity – reversible)

when rapid fixation/setting of adhesive is required, use 'fixator' (= saturated solution of sodium carbonate ($Na_2 Co_3$) and ethanol)
wipe away white residue immediately

fill visible fractures and sutures on the surface of each specimen with Vallejo Plastic Putty 70.401 (reversible acrylic resin mixed with calcite paste – white colour)

will specimen serve as scientific study object?

yes → inventarisation

no → colour all glue residue on specimens with natural pigments → inventarisation

inventarisation

inspect specimen for former identification number(s) & link former number to new and register digitally

When applicable, write new identification numbers next to, above or beneath the former number(s) with acetone resistant permanent marker (ex. Uni-Ball Super Ink Marker)

write new number on specimen on a solid surface of the specimen, avoiding any fragile areas

measure and photograph specimen from different angles on designated station

each specimen can receive a (preliminary) identification by experts, which can be written on a tag card, along with measurements and photograph reference numbers

register all information in a database

As an additional step, the preliminary Identification can receive a revision and check up of the former and new treatments, and identification numbers

Storage

store in acid-free paper and boxes

specimens can be temporarily wrapped in bubble wrap and put in polypropylene storage containers

***Criteria used to determine state of collection:**
Number of specimens:
- affected by pyrite decay
- affected by desiccation
- belonging to carnivores
- belonging to rare or unknown animals
- with future scientific interest
- containing bite, gnawing or scratch marks
- previously treated with irreversible products
- containing a ID number;
- with original sediment attached to them

Guidelines of storage
(based on standard lab conditions)
- relative humidity (RH) ranging between 30-55%
- temperatures ranging between 20-25°C

Plate II of II: Schematic overview of all the steps applied in the conservation and inventorisation of the Berlare collection.

even if the Uranium-series (U-series) dating of the enamel or ESR (Electron Spin Resonance) dating techniques are applied. There is a lack of original sediment due to the inaccessibility (flooding) of the quarry and sampling bias. Any of the remaining sand attached to the original specimens is fixated with old adhesives within the bones themselves. To complicate matters even further, it is possible that the present sediments would not provide accurate dates, as the strata in which the specimens were found, consists of partially reworked sediments. 14C dating could prove to be a good alternative, as the collection carries certain molars which could be suitable for testing. When applying this method, it is necessary to account for the bias in the measurements caused by the bacterial activity of the decaying processes of the respective animals. A last objective for the future of this collection is the exhibition of some of the material. Permanent housing in the 'Nieuwdonk Museum' in Overmere would seem ideal but is still under review by the municipality. Meanwhile, there will be a temporary exhibition in the cultural center 'Stroming' (Berlare) in January 2022. To ensure the future of the collection, public outreach through popular scientific talks, such as an outdoor lecture in Overmere (Berlare) in the beginning of July 2021 and a talk at the cultural centre 'Stroming' on January 29th 2022, will keep the paleontological heritage of the Nieuwdonk collection alive.

Conclusions and lessons learned

The Nieuwdonk collection provides us with a good insight into the mammal diversity of the Flemish valley during the last Ice Age and (Eemian-Holocene) interglacials. Although sampling bias resulted in the absence of associated (invertebrate) fauna, flora and sediments, the collection still counts as an important historical assemblage with scientific value. Along with collections of other classic Belgian Quaternary locations such as Hoboken, Lier, Hofstade, Zemst (Bos van Aa), Dendermonde, Oudenaarde, and dozens of temporary or isolated locations within the Flemish Valley (cf. Hellemond 2017), the Nieuwdonk collection helps us to broaden our view on Late-Pleistocene continental faunas of Belgium. Yet the occurrence of Eemian fuana is rather rare when we compare it to other classic locations. The Nieuwdonk quarry and fauna is therefore rather similar (quantitatively and qualitatively) to the Bos Van Aa quarry near Zemst in the province of Flemish Brabant (Bogemans 1983). The occurrence of Elasmobranchii and human artefacts from the same locations, are an added value from a paleontological point of view. However the collection is somewhat problematic from a scientific perspective. Lacking any precise documentation on the provenance of specimens to a specific bonebed makes it difficult to draw any palaeoecological conclusions. The absolute dating of Eemian material by ESR requires sediment which was largely removed or treated with undocumented chemical component(s) during previous conservation, rendering it improbable to obtain any accurate and trustworthy data from the specimens. The original sedimentological situation would have also made it problematic to date the Eemian specimens as a result of reworked sediments risking altering the measurements. However, other private collections (for example the Wim Plaetinck collection or Alexandre Verdonck collection) from the former Nieuwdonk quarry might yield sediment and dentine that could be used to conduct ESR dating in the future. Future research focused on determining the sedimentary context, the location in the stratigraphic sequence and the homogeneity of the sediments might make it possible to perform an ESR analysis after all. Ideally, sediment from drill core samples could be used to help with this undertaking.

The entire restoration and inventorisation process took place over the course of twelve days, during which different team members with different levels of expertise worked on restoring, researching and documenting the specimens. The team consisted of four people with professional expertise who could train and support four people with less or no expertise. Additional specialists were brought in to help identify different species and restore fragile specimens (Figure 10). One of the most challenging restorations was a highly fragmented male mammoth tusk, wrapped in gypsum from a previous restoration attempt. Specialist preparators Jef Segers and Marc Spolspoel from the Royal Belgian Institute of Natural Sciences (RBINS) accompanied our team to aid us with this task. Other guest team members include Dr Mietje Germonpré (RBINS), Frederick Mollen (Elasmobranch Research), Dick Mol (Natural History Museum at Rotterdam), Albert Hoekman (North Sea Fossils) and Dr Bjorn De Wilde. Dr Germonpré helped us identify the presence of a young female wolf in the collection, alongside some younger and domesticated northwestern European dog species, by measuring the different aspects and ratios of certain parts of the jaw (morphometrics) and comparing these measurements to other data within an international database of canidae. Mr Mollen spent a day at the lab to identify most of the associated shark teeth fauna found within the former Nieuwdonk quarry. Dick Mol and Dr Bjorn De Wilde helped with the identification and biostratigraphical dating of specimens during the entire process. At a later stage of the project, the bones will be measured and described as part of the thesis research at the Opole university (Poland) by the end of 2022.

At the start of the restoration process, the Nieuwdonk collection was in dire need of urgent care and attention. The urgency of treatment and the temporary lab set up resulted in some decisions being made out of necessity and practicality. Nevertheless, each treatment was carried out with the utmost care to safety regulations and only after being considered and discussed with the entire team and external experts. An example of such a decision is the use of AralditeTM on certain breaks and fractures in heavy bones. Although AralditeTM is a non-reversible adhesive, it was the most practical choice given the unique situation. Were the treatment carried out in a permanent lab facility, the team would have chosen a reversible alternative whilst being able to store the damaged specimens without fear of further deterioration. The impromptu lab set up, also meant that the team was forced to use products that were readily available and had a low toxicity. The usage of both Mowilith and Paraloid B72 as adhesives instead of working with one single product on all specimens is a case in point.

Figure 10. Photograph of weathered right tibia of a woolly mammoth, (Mammuthus primigenius), specimen ND0208.

To avoid the spreading of the pyrite and further cracking and breaking due to desiccation, the team was forced to treat all specimens at a rapid pace. As a consequence, the time available for the selection of certain specimens for further scientific research prior to treatment was limited. Another effect of the speed of treatment and the sheer size of the collection was that documentation of each treatment of each individual specimen was forced to be kept to a minimum.

The use of water-based solutions could have lowered the toxicity of the chemicals used on the specimens, but proved them to be insufficient to neutralise (framboidal) pyrite completely (Tacker 2020). The same study concludes that to effectively treat pyrite decay, a complete identification of every mineral present in each specimen is necessary. A permanent monitoring of the electrical conductivity as well as relative humidity (RH) and oxygen levels in a controlled environment would also prove to be useful to predict pyrite decay in time. Unfortunately for the Nieuwdonk collection, the imposed deadlines and limited budget did not allow for an extensive study or monitoring prior to the restoration.

Despite federal regulations and the limited resources on site, the team was successful in setting up and maintaining a safe work space, both for people and specimens. Work surfaces were organised in an orderly fashion with enough distance to ensure contamination was kept to the bare minimum and sufficient air flow was constant. The team used Umonium 38 Master as a disinfectant on every surface after each treatment and wore protective clothing and gear at all times. Dry removal of pyrite oxidation products was undertaken outside of the facility in the open air and the affected specimens were isolated indoors until further treatment. As a result of the alarming condition of the specimens, the small time frame in which the restoration could take place and limited availability of certain chemicals, the team used two different types of solvent: Paraloid B72 and Mowilith. Going forward, we will use only one type of resin during restorations to ensure a consistent use of products and reduce the risk of incorrect usage due to different ratios needed to apply the different products. Although temporary and basic, the lab set-up enabled the team to successfully treat and restore the specimens.

The restoration of the Nieuwdonk collection took place during the first Belgian lockdown (March 2020 - April 2020), as a result of the COVID-19 pandemic. The Belgian public was alerted to the rediscovery and restoration of this project through regional and national press, appearing in newspaper articles and news broadcasts. Encouraging public interest, the municipality of Berlare and the team of Palaeontologica Belgica organised 'open lab visits', during which locals and other visitors were allowed to take a look behind the scenes. Visits were scheduled on multiple weekends in 15-minute slots in which one family 'bubble' could enter the auditorium to receive a guided tour by one of the team members, at a safe distance. One side effect of the guided tours was that the initial schedule of the restoration was delayed as several team members had to halt their work to show the visitors around the lab. Although requiring some thought as to the safety of both the team and the visitors, these public events were a great success and helped the transition of the Nieuwdonk collection from a private collection to a public one.

The press coverage did not only generate great public interest, it also enabled other private collectors to come forward with their own collections and contact the team. With plans for a permanent exhibition, we hope this will encourage many other private collectors to come forward as well. During the next couple of months, further research will be performed on the Nieuwdonk assemblage to complete the identification of (most of) the bone (fragments) and to further analyse the regional biodiversity of the last Ice Age and interglacials.

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