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SHORT COMMUNICATION

NPP-ID: Non-Pollen Palynomorph Image Database as a research and educational platform

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Abstract

Non-pollen palynomorphs (NPPs) form a large group of biological objects found in palynological slides besides pollen grains. This includes various remains of algae and fungi, shells, resting stages and eggs of invertebrates, among others. Publications of NPP-types started in the 1970s with studies of BvG and colleagues, and large numbers of new types continue to be published every year. For an overview of this diverse world of "extra fossils", we created the Non-Pollen Palynomorph Image Database (NPP-ID) to gather NPP knowledge, structured by acronyms and known taxonomy to assist identification and palaeoecological interpretation (https://nonpollenpalynomorphs.tsu.ru/). An integral part is a database of illustrations, descriptions and ecological background of NPPs. While numerical data are routinely stored in open access repositories, the NPP-ID enables the definitions, identification and interpretation of the NPP taxa to be shared. The NPP-ID operates as an open research project aiming to provide open access to descriptions and illustrations of NPPs. However, due to publication rights, access to some original images is restricted and registration by users is required. We encourage palynologists to contribute to the further growth of the database by uploading their own microphotographs or drawings under an open access license. Contributors will be acknowledged by co-authorship in publications on updates of the NPP-ID.

Keywords Palynology · Fungal remains · Algal remains · Unknown palynomorphs · Identification tool

Motivation

Non-pollen palynomorphs (NPPs) form a large group of microscopic remains found in palynological slides besides pollen. Such microfossils have received attention since the very beginning of palynology (Rudolph 1917; Hesmer 1929; Frey 1960, 1964). A systematic approach to the documentation and taxonomic identification of such objects in Quaternary palynology was started in the 1970s by the work of the fourth author and his colleagues of the Hugo de Vries-Laboratory at the University of Amsterdam (e.g. van Geel 1972, 1978; Pals et al. 1980; van Geel et al. 1981, 1983a, 1983b, 1989, 2006; Bakker and van Smeerdijk 1982; van der Wiel 1982; Kuhry 1985, 1997). During routine pollen counting, they documented all unknown microfossils under a type number (Type 1, Type 2, Type 3 etc., later known as HdV-1, HdV-2 etc.). Morphological descriptions were provided with microphotographs and known assignment to extant taxa, in combination with discussions on their stratigraphic position and ecological indicator values. The identification was carried out with help of biological literature and consulting specialists in mycology, phycology, zoology and plant anatomy. The known ecological requirements of every identified taxon allow NPPs to be an additional proxy for reconstructing past environments. Even some taxonomically not yet identified types work well as palaeoecological indicators using empirical knowledge.

The usefulness of NPPs is demonstrated by a great variety of new insights into the past (Marret et al. in press). One

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of the most frequently used NPP-groups are the spores of coprophilous fungi, which offer a unique proxy of grazing activities or mammal diet (e.g. Gill et al. 2009; van Geel et al. 2011b; Basumatary and McDonald 2017; van Asperen et al. 2021). Algal palynomorphs, zoological microfossils, and many fungal spores provide information on former local processes like natural and human-induced fire, hydrological conditions and erosion processes (Kuhry 1997; van Geel and Aptroot 2006; Montoya et al. 2010; van Geel et al. 2011a; Kołaczek et al. 2013; Schlütz and Shumilovskikh 2013; Shumilovskikh et al. 2015a, b, 2017, 2021; McCarthy et al. 2021; Mudie et al. 2021). In geoarchaeology, NPPs contribute to a more holistic view of the past (Brinkkemper and van Haaster 2012; Revelles et al. 2016; Shumilovskikh and van Geel 2020; Shumilovskikh and Schlütz 2021).

The systematic approach of NPP documentation led to a strong development in the field of palaeoecology over the last 50 years. Based on a review of classical NPP literature published between 1972 and 2011, Miola (2012) provided a list of recorded Quaternary NPPs and proposed a uniform acronym system. Meanwhile, more than 1,600 classified NPP-types exist, making it difficult to maintain an overview. Morphological identification of NPP-types is based mainly on published images. Due to journal publication rights, some restriction in the use and re-publishing of original images exists. Difficulties in access to literature and images can easily lead to incorrect identifications and may result in questionable palaeoecological interpretations.

In order to gather and sort the available information on NPPs spread over numerous publications and to assist correct identification, we created the on-line resource Non-Pollen Palynomorphs Image Database (NPP-ID) in 2016.

Non-Pollen Palynomorph Image Database

The NPP-ID is a platform for sharing information on NPPs for research and education. The platform functions as a research project with the goal of enabling free data sharing and open access to information on NPP-types. While numerical data can be stored in open access repositories like PANGAEA or *Neotoma*, the NPP-ID provides a means of sharing the definition of the underlying NPP taxa in a similarly standardised way. Due to restrictions caused by publication rights, sharing of some published images is possible only within a defined group of researchers. The NPP-ID research group is organized for this purpose, and registration is needed for full access.

Research group

The NPP-ID is operating as an open research project. All members may use the NPP-ID content for scientific and educational purposes. The current goals of the NPP research group are: (1) storage of NPP images from the community for open access; (2) structuring of information on NPPs; and (3) revision of and assistance with NPP identifications.

Experienced palynologists are invited to contribute by submitting their own original microphotographs or drawings and background information of newly published or already established NPPs. All rights to the submitted images remain with the submitter. After a short evaluation, images are added to the NPP-ID under the Creative Commons license CC BY-NC-ND (http://creativecommons.org/licenses/by-nc-nd/4.0/). The contributors are credited in the image captions unless they explicitly choose not to be.

Webpage

The NPP-ID webpage (https://nonpollenpalynomorphs.tsu.ru/) also provides information on current publications and upcoming events related to NPP research (Fig. 1). It offers definitions and descriptions of major NPP-groups. Users can easily find the acronym table and access the database in form of an NPP image gallery or an NPP list. A growing list of NPP publications, and links to related databases facilitate further studies. Images can be contributed to the NPP-ID through the homepage.

Organisation of the database

The NPP-ID platform shares all kinds of practical information on published NPPs. It is designed for research and educational purposes within the scientific and education communities. The following information is provided for the individual types: acronym and number (e.g. HdV-14); latest known or supposed affiliation to an extant genus or species (e.g. *Meliola ellisii*); higher related taxonomic grouping; morphological description; palaeoecological context of findings; original taxonomical affiliations in chronological order; ecological information on affiliated taxa; map of NPP records; first publication; reference list of cited materials. Acronyms correspond to the NPP list started by Miola (2012) and extended by later publications. For NPPs published without a type number, an artificial acronym NN (no number) is created. A search function with filters based on simple morphological characteristics (Coles 1990) is available to navigate the database.

Technical information

The website https://nonpollenpalynomorphs.tsu.ru/ is hosted by the Tomsk State University and works on a PHP server and the database is set up in MySQL™. Webpages are written with help of HTML, CSS, JS, jQuery and Bootstrap, and planned to be refactored with React.js to provide a more

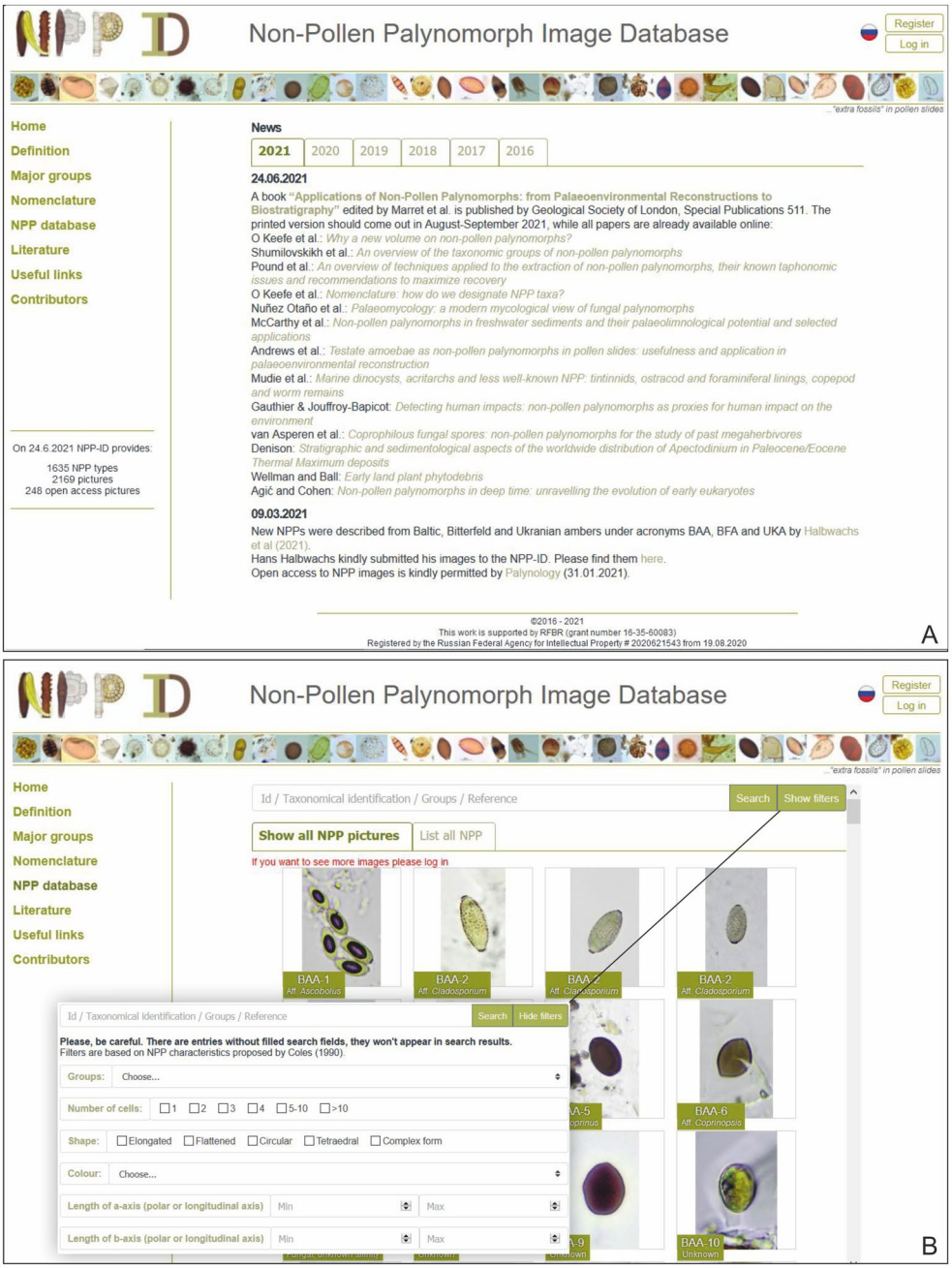

Fig. 1 Screenshots of the Non-Pollen Palynomorph Image Database (NPP-ID; https://nonpollenpalynomorphs.tsu.ru/): **A** homepage; **B** search function in the database with filters

modern user experience. The information on NPPs is organized in several related tables (Fig. 2).

Access to the database

The access to NPP-ID is open to every user of the internet. Due to journal licence politics, access to some original pictures and information requires registration with the NPP-ID research project.

(1) Open access to the NPP-ID provides original descriptions of the NPPs, open access microphotographs/drawings, a map showing the geographical position of related records and all references. The available data of the NPP-ID are free to use for non-commercial purposes under the Creative Commons license CC BY-NC-ND (http://creativecommons.org/licenses/by-nc-nd/4.0/).

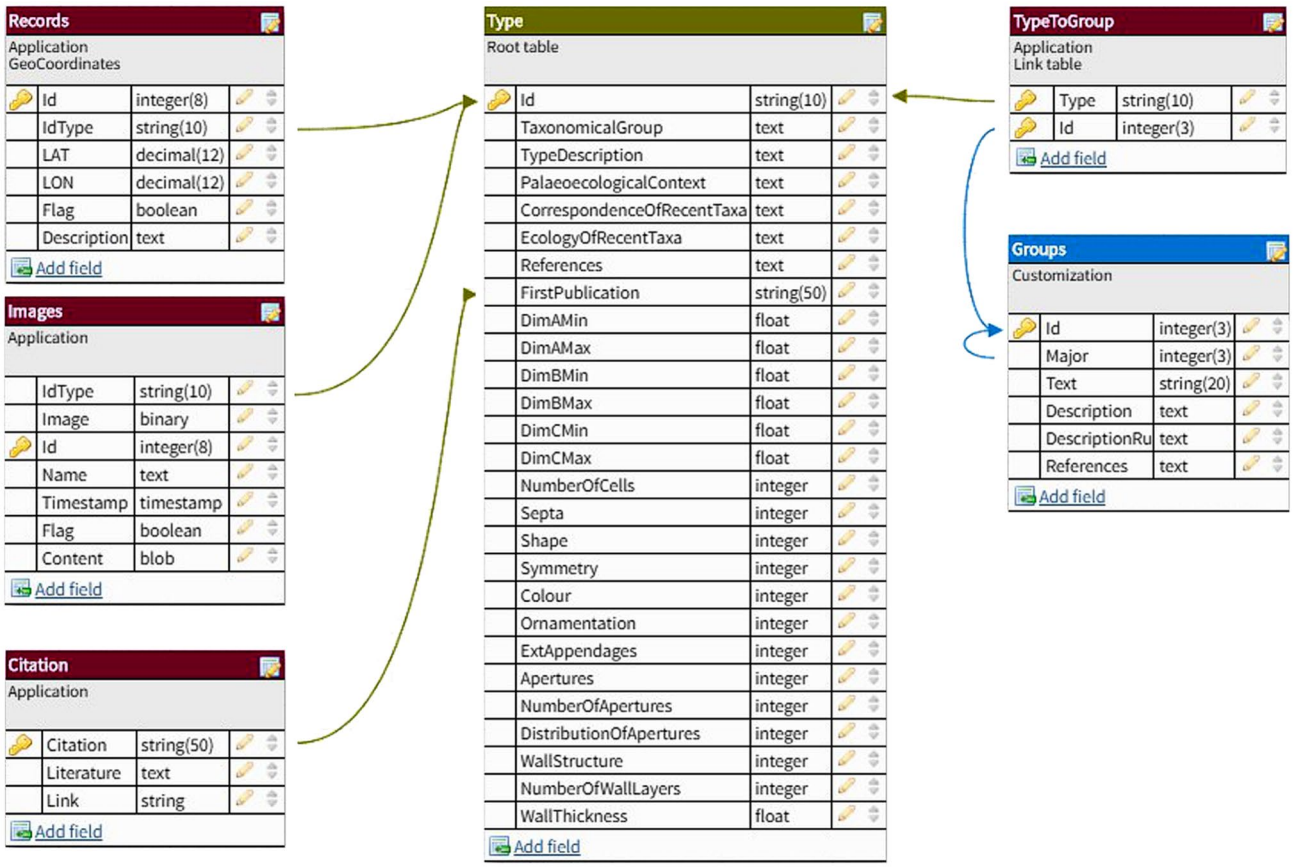

Fig. 2 Internal structure of the Non-Pollen Palynomorph Image Database

(2) Registration additionally offers the microphotographs from published literature and palaeoecological information provided therein, affiliation to taxonomical groups, and their ecology. Registered users can upload their microphotographs to the NPP-ID. Discussion on types and help in identification within the NPP research group can be addressed to all registered users.

For all users of (1) and (2) the common ethics regarding citing of scientific publications and co-authorship apply.

Perspectives of the NPP-ID

Up to now, the NPP-ID research group consists more than 200 registered scientists and the database offers information on 1,635 NPP-types including 2,169 images. About 10% of the images are open access. They have been submitted by research group members or were published in journals under Creative Commons licences.

Progress in the development of the NPP-ID is regularly presented at international meetings such as the VII and VIII Workshops on Non-Pollen Palynomorphs in 2017 in Liverpool (UK) and 2019 in Barcelona (Spain), the 10th European Palaeobotany & Palynology Conference in Dublin (Ireland) in 2018, and the XX INQUA Congress in Dublin (Ireland) in 2019.

We encourage palynologists to contribute to the further growth of the information stored in NPP-ID by uploading own data, such as microphotographs and descriptions. The best way to do it is to announce submissions of microphotographs to the NPP-ID during publication submission. For this, the authors should provide a statement in their manuscript: 'All photos have been uploaded to the Non-Pollen Palynomorphs Image Database (https://nonpollenpalynomorphs.tsu.ru/) and are free to use for non-commercial purposes under the CC BY-NC-ND licence'. The NPPs will appear online when the manuscript is accepted. Contributors will be acknowledged by co-authorship in publications on updates of the NPP-ID.

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Author contributions LS, ES, FS, BvG provide equal contribution for conceptualisation, LS made the first draft and visualisation, ES, FS, BvG provided review & editing.

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Availability of data and material Non-Pollen Palynomorphs Image Database (http://nonpollenpalynomorphs.tsu.ru/).

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