Review of Palaeobotany and Palynology 255 (2018) 43–56

Contents lists available at ScienceDirect

Review of Palaeobotany and Palynology

journal homepage: www.elsevier.com/locate/revpalbo

Phytolith characteristics and preservation in trees from coniferous and broad-leaved mixed forest in an eastern mountainous area of Northeast China

Guizai Gao, Dongmei Jie *, Lidan Liu, Hongyan Liu, Zhuo Gao, Dehui Li, Nannan Li

School of Geographical Science, Northeast Normal University, Changchun 130024, China
State Environmental Protection Key Laboratory of Wetland Ecology and Vegetation Restoration, Changchun 130024, China
Institute of Grassland Science, Northeast Normal University, Key Laboratory for Vegetation Ecology, Ministry of Education, Changchun 130024, China

ARTICLE INFO

Article history:
Received 13 March 2016
Received in revised form 12 August 2016
Accepted 8 May 2018
Available online 11 May 2018

Keywords:
Phytolith
Broad-leaved tree
Coniferous tree
Morphology
Preservation

ABSTRACT

Research on phytolith morphology and the preservation of phytoliths in soils provides the theoretical basis for reconstructing shifts in forest–grassland ecotones and the evolution of plant communities. Based initially on anatomical origin, then shape and finally texture, phytoliths in broad-leaved trees were divided into six major types, 10 types and 33 sub-types, respectively; and correspondingly phytoliths in coniferous trees were divided into seven major types, 9 types and 20 sub-types. Results of detrended correspondence analysis showed that broad-leaved trees were characterized by epidermal phytoliths, hair, hair base, sclereid, elongate attenuate, stomate and tracheids; while the main coniferous phytoliths were elongate, tabular, blocky and margin-cuneiform. In Pinaceae, *Larix* closely corresponded to elongate and margin-cuneiform; *Picea* and *Abies* to blocky scrobiculate, stomate and tracheids; while *Pinus* corresponded well with epidermal, blocky and tabular. Only five kinds of broad-leaved phytoliths and seven kinds of coniferous phytoliths appeared in soils. The preservation degree of different phytolith types was determined by comparing the contents of the same phytoliths in plants and soils. Evidence showed that coniferous phytoliths were better preserved than broad-leaved ones. Among coniferous phytoliths, the cubic, tabular echinate and elongate cavate phytoliths were better preserved than other types. Among broad-leaved phytoliths, sclereid and blocky facetate showed the best preservation. Overall, this research will support the more accurate use of tree phytoliths in interpreting paleo-environments and paleo-vegetation.

1. Introduction

Phytolith analysis is an increasingly useful tool for revealing historic vegetation patterns and human activities in the fields of paleo-ecology, paleo-climatology and archeology (Blinnikov, 2005; Piperno, 2006). Considering that phytoliths can be used to classify plants and are preserved well in soil, scholars have conducted studies on the evolution of forest–grassland ecotones and timberlines using phytoliths in tropical areas. As the paleo-ethnobotanical interpretation of phytoliths relies on the comparison of soil phytoliths with morphotypes extracted from living vegetation, so the exploration of phytolith morphology in living vegetation and the preservation of phytolith in soil are important.

The grass phytoliths, especially in Poaceae, have been systematically described and classified. Morphological parameters were measured to describe typical phytoliths, such as bilobate and bulliform, and can be used to classify Poaceae to the levels of families, genera and even species (Wallis, 2003; Lu and Liu, 2003; Li et al., 2005; Mercader et al., 2010; Liu et al., 2016). However, compared with grass phytoliths, reports describing and classifying phytoliths in trees ("woody phytolith" for short) are rare. The few reports describing and naming woody phytolith types, have resulted in seven kinds of coniferous phytoliths and eight kinds of broad-leaved phytoliths (Rovner, 1971; Wilding and Drees, 1971; Geis, 1973; Klein and Geis, 1978; Kondo and Sumda, 1978). In recent years, the study of woody phytoliths in tropical and subtropical regions has increased gradually and described in more detail the characteristics of shape and texture. Therefore, the classifications of woody phytoliths in tropical and subtropical regions are relatively systematic (Wallis, 2003; Xu et al., 2005; Mercader et al., 2009). Additionally, globular granulates, the distinctive type of woody phytoliths in tropical and subtropical areas, have been found widely in soils, thus providing forest and grass phytolith indexes in soil that have been used to interpret forest–grassland ecotones in this area (Bremond et al., 2005; Barboni et al., 2007; Coe et al., 2013). In contrast, in temperate zones, few studies have focused on woody phytolith morphology and classification. On the one hand, the understanding of woody phytoliths is not comprehensive and systematic, merely relying on the descriptions of a small

* Corresponding author at: School of Geographical Sciences, Northeast Normal University, People Street Nanguan District, Changchun 130024, China.
E-mail address: jiedongmei@nenu.edu.cn (D. Jie).

https://doi.org/10.1016/j.revpalbo.2018.05.001
0034-6667/© 2018 Published by Elsevier B.V.

number of woody phytoliths; on the other hand, the nomenclature of some woody phytoliths is not in accordance with the International Code for Phytoliths Nomenclature (ICPN 1.0) (Carnelli et al., 2004; Morris et al., 2009; Ge et al., 2011). Furthermore, it is noteworthy that the plant physiognomy in tropical regions uses only globular granulates to represent all woody phytoliths, whereas plant physiognomy in temperate forest zones is constituted by coniferous and broad-leaved trees in different proportions. It is likely that coniferous and broad-leaved trees may be characterized by different phytolith morphology and assemblages, and so in temperate zones, the phytolith morphologies of coniferous and broad-leaved trees should be determined conclusively. In addition, it is considered that anatomical origin of phytoliths can fundamentally determine phytolith morphology. Summing up the above, compared with the research on phytoliths of herbaceous and woody plants in tropical areas, reports on woody phytoliths, especially in temperate areas, are relatively sparse and coarse. Additionally, compared with research on woody phytoliths in other regions, the morphological descriptions in Northeast China still followed the original system of Kondo (Wang and Lu, 1992). Therefore, the application of woody phytoliths in Northeast China was only confined to paleo-environmental reconstruction (Liu, 2010; Guo et al., 2012). The insufficient data concerning woody phytoliths have limited their further application, especially for reconstruction of timberline changes and forest–grassland ecotone shifts in temperate zones. Hence, clearly defining phytolith types and assemblages in woody plants and determining the representative woody phytoliths in temperate zones have become an important scientific issue in the field of phytoliths.

In this study, we selected plant samples, including 17 families and 57 species of broad-leaved trees and two families and 16 species of coniferous trees occurring in coniferous and broad-leaved mixed forest in Northeast China; as well as 10 typical soil samples. This research aimed to systematically classify the woody phytolith types, define the relationship between phytolith types and the plant of origin, and further identify the coniferous and broad-leaved phytoliths in the topsoil. We believe that research on woody phytoliths will provide a more accurate reference for the interpretation of paleo-vegetation, paleo-environment and forest–grassland ecotone shifts.

2. Materials and methods

The study region in Northeast China is located at 39°40′ N–53°30′ N, 115°05′ E–135°02′ E (Ma et al., 2007) (Fig. 1). The region can be divided into a cold temperate zone, a temperate zone, and a warm temperate zone from north to south, and a humid area, a semi-humid area, and a semi-arid area from east to west. Northeast China has four distinct seasons, with a long winter and a short summer. The annual average temperature ranges from −4 °C to 11 °C. The average annual precipitation, which is concentrated in the period from July to September, and, represents 70% of the yearly total, ranges from 1000 mm in the east to 350 mm in the west (Zhao et al., 2011). *Larix gmelinii* predominates in the cold temperate zone; needled and broad-leaved mixed forest covers the eastern part of the temperate zone; and *Pinus tabulaeformis* Carr. is found in the Liaoning Hills in the warm temperate zone. The influence of the monsoon is obvious at 115–135°E by the presence of needled and broad-leaved mixed forest, meadow steppe and steppe. The main soil types in Northeast China are brown coniferous forest soils in the cold temperate zone, dark brown forest soil in the temperate zone, and forest steppe chernozem and meadow steppe chernozem in the temperate zone (Sun et al., 2006).

Plant samples represented 19 families and 73 species of woody plants commonly occurring in eastern mountain of Northeast China, including Fusong, Huadian, Chang bai and Changchun (Table 1). And matched with plant samples, 2–3 topsoil samples under the forest were collected respectively from the above sites (Table 2). For every topsoil sample, in the 10 m × 10 m quadrat, we collected the topsoil (0–5 cm under the surface) representing four corners and the center.

Phytoliths were extracted from leaves of woody plants which were cleaned in an ultrasonic shaking instrument, following oxidation of organic matter, using 65% HNO_3 heated to 90 °C until the reaction subsided. The acid was then washed, using distilled water three times.

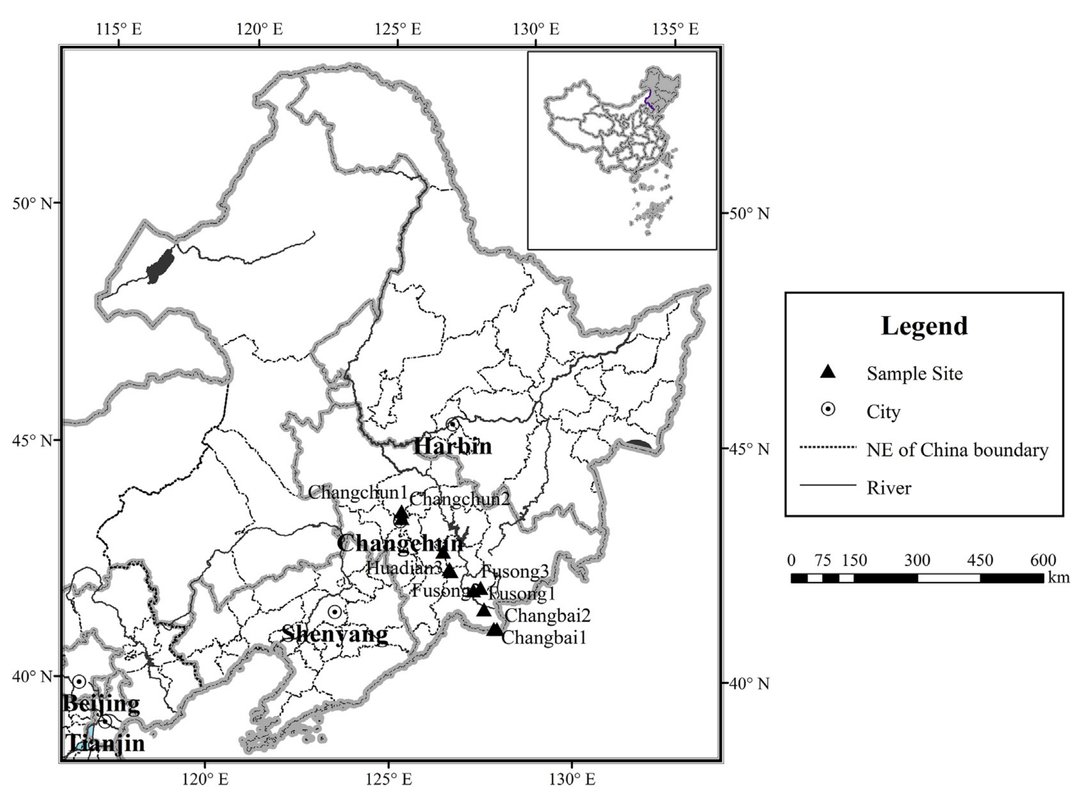

Fig. 1. Location of sampling sites.