



Contents lists available at ScienceDirect

## Review of Palaeobotany and Palynology

journal homepage: [www.elsevier.com/locate/revpalbo](http://www.elsevier.com/locate/revpalbo)

# Cryptospores from the Katian (Upper Ordovician) of the Tungus basin: The first evidence for early land plants from the Siberian paleocontinent

Elena Raevskaya<sup>a,\*</sup>, Andrey Dronov<sup>b,c</sup>, Thomas Servais<sup>d</sup>, Charles H. Wellman<sup>e</sup><sup>a</sup> FGUNPP "Geologorazvedka", Knipovich str., 11, block 2, Saint-Petersburg 191019, Russia<sup>b</sup> Institute of Geology, Russian Academy of Sciences, Pyzhevsky per. 7, Moscow 119017, Russia<sup>c</sup> Kazan (Volga Region) Federal University, Kremlevskaya ul., 18, 420008 Kazan, Russia<sup>d</sup> Evo-Eco-Paleo, UMR 8198 CNRS, Université des Sciences et Technologies de Lille, Sciences de la Terre, Lille, France<sup>e</sup> Department of Animal and Plant Sciences, University of Sheffield, Alfred Denny Building, Western Bank, Sheffield S10 2TN, UK

## ARTICLE INFO

## Article history:

Received 12 May 2015

Received in revised form 14 September 2015

Accepted 9 October 2015

Available online 31 October 2015

## Keywords:

Cryptospore

Upper Ordovician

Katian

Siberian Platform

## ABSTRACT

A diverse assemblage of cryptospores is reported for the first time from the Upper Ordovician of Siberia. It was discovered during a palynological study of a sedimentary succession of about 100 m, exposed along the Bolshaya Nirunda River, a right tributary of the Podkamennaya Tunguska River. The succession is located on the southern margin of the extensive epicontinental Tungus basin on the Siberian Platform between the Katanga and Yenisei land masses. The cryptospore assemblage was recovered from the siliciclastic-carbonate Dolbor Formation and scarcely from the overlying more carbonate Bur Formation. Both formations belong to the Katian Global Stage (Upper Ordovician). The cryptospores occur together with marine remnants (acritarchs, prasinophytes, chitinozoans, scolecodonts). It is similar to all known Upper Ordovician cryptospore assemblages in comprising naked and envelope-enclosed monads, dyads, tetrads and polyads. Although preservation is moderate to poor, the cryptospore taxa *Velatitetras laevigata*, *Tetraedraletes medinensis*, *Abditusdyadus laevigatus*, *Dyadospora murusdensa*, *Pseudodyadospora laevigata*, *Segestrespora laevigata* and *Sphaerasaccus glabellus* can be identified. This report represents the first record of spores of the earliest land plants from the paleocontinent Siberia and therefore extends the global paleogeographical coverage of Late Ordovician cryptospores.

© 2015 Elsevier B.V. All rights reserved.

## 1. Introduction

Cryptospores are considered to have been produced by the earliest terrestrial flora that probably consisted of bryophyte-like plants (Gray, 1985, 1991; Richardson, 1996; Strother et al., 1996; Wellman, 1996; Edwards et al., 1999; Steemans, 2000; Wellman et al., 2013). They are considered to represent the earliest evidence for continental vegetation and thus document a fundamental phase of land plant evolution (Gray et al., 1982; Wellman et al., 2003; Steemans et al., 2009; Spina, 2014).

The oldest cryptospores are known from the Middle Ordovician. More or less certain cryptospore taxa (i.e., '*Tetraedraletes cf. medinensis*') are recorded from the Dapingian of Argentina (Rubinstein et al., 2010). However, being represented by few specimens from one single sample this record still needs corroboration by further data before it can be unquestionably considered as the oldest evidence of cryptospores (Spina, 2014; Strother et al., 2015). Thus, for the present, generally accepted oldest cryptospores are from the Darriwilian of Saudi Arabia (Strother et al., 1996, 2015) since they are characterized by regular morphology and abundant population (Wellman et al., 2003; Spina, 2014). Numerous publications from many parts of the

world show the uniformity of cryptospore assemblages, in terms of their taxonomic composition and diversity, from the Middle Ordovician to the Early Silurian, leading to a concept of the existence of a conservative cosmopolitan bryophyte-like flora that remained almost unchanged for about 40 million years (Wellman, 1996; Steemans, 2000; Wellman and Gray, 2000; Rubinstein et al., 2010; Vecoli et al., 2011; Spina, 2014). However, the steady increase of new data from different paleocontinents is beginning to reveal a more complex pattern of cryptospore origination and spatial/temporal distribution (Wellman et al., 2013) that may possibly lead to a slight modification of existing ideas.

The reconstruction and interpretation of the early terrestrial vegetation mostly depend on the availability and adequacy of the fossil data (particularly of cryptospore records) that largely vary in both quantity and quality. While fairly representative data are now available from eastern North America (Laurentia), Western Europe (Laurentia, Avalonia, Baltica) and North Africa and Arabia (southern part of Gondwana), very little or nothing is known from other paleocontinents. As reviewed in Wellman et al. (2013) Ordovician (Dapingian–Hirnantian) cryptospore assemblages have been described from Gondwana (Libya, Saudi Arabia, South Africa, Australia, Argentina), Peri-Gondwana (the Czech Republic, southeastern Turkey), Avalonia (southern Britain, Belgium), Laurentia (USA and Canada), South China (Wang et al., 1997) and Tarim (Yin and He, 2000). The first records of Late Ordovician

\* Corresponding author.

E-mail address: [lena.raevskaya@mail.ru](mailto:lena.raevskaya@mail.ru) (E. Raevskaya).