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Palaeoecological significance of the spores of the liverwort *Riella* (Riellaceae) in a late Pleistocene long pollen record from the hypersaline Lake Urmia, NW Iran

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ABSTRACT

Spores of the liverwort *Riella* are documented in a long late-Pleistocene to early Holocene pollen record from the hypersaline Lake Urmia in NW Iran. The pollen record indicates that *Riella* aff. *cossoniana* Trab. has played an important role in the aquatic vegetation in the plains around Lake Urmia, particularly in the late Pleistocene. The concentration of *Riella* spores was greater during the high lake stands corresponding to the middle part of the last glaciations (MIS 3) and the upper part of the penultimate glaciations (MIS 6). The presence of *Riella* suggests that during these periods numerous brackish ponds and marshes developed on the present salt flats around the lake, creating suitable habitat for colonization. The spores of *Riella* can therefore be used as a palaeoecological indicator of lake level changes in saline lake environments situated in semi-arid regions.

1. Introduction

Liverworts appeared on the Earth in the late Middle Devonian (VanAller Hernick et al., 2007) and perhaps as early as the Ordovician (Wellman et al., 2003), becoming one of the first spore-producing terrestrial plants. Vegetative parts of liverworts, like many other bryophytes, are soft and rarely found in the fossil record. However, their spores, which are more robust, can be preserved in the sedimentary record. Liverwort spores have very characteristic features and can be identified with certainty to the lowest taxonomic levels (Boros et al., 1993). However, their palaeoenvironmental significance, especially in Quaternary palynological studies, has rarely been investigated. This is partly due to the rarity of their occurrences and partly due to their unfamiliar morphology to many palynologists. Spores of some liverworts can give information on the history of human activities, such as the Cereal farming (Koelbloed and Kroeze, 1965). This is because the modification of landscapes by ditch digging or the formation of stubbed and fallow lands can favour some liverworts like *Anthoceros punctatus* and *A. laevis* (Koelbloed and Kroeze, 1965; Boros et al., 1993).

This study presents a long late Pleistocene record of the liverwort *Riella* aff. *cossoniana* from Lake Urmia, NW Iran. The palaeoecological significance of this record is discussed with reference to pollen percentages of other aquatic and land plants (Djamali et al., 2008) and with knowledge of the ecology of modern stands of *Riella*.

2. Study area

2.1. Physiography and hydrology

The study site, Lake Urmia, is a very large (4610–5700 km^2), shallow (8–12 m), hypersaline lake (surface water salinities more than 200 g/l) situated in a tectonic depression in northwestern Iran (Kelts and Shahrabi, 1986; Sharifi, 2002; Alipour, 2006). Lake level is maintained by direct precipitation and inflow from thirteen major rivers (Fig. 1).

Two vast salt plains border the eastern and southern shores of the lake (Fig. 1). In the East, the topographic gradient of the Talkherud River plain is very low (3/5000), and the plain is covered by saline mud flats. The Talkherud River, which flows from Tabriz, partly evaporates and partly infiltrates towards the lake and forms an inaccessible large water-logged area covered by reddish mud flats overlying a 40–80 cm thick organic rich clay. In the South, a complex ecosystem has developed over the gently-sloping Zarrinerud River plain, which includes a mixture of fresh and saline marshes and ponds (Kelts and Shahrabi, 1986). Due to this gentle slope, even a slight rise in lake level causes the inundation of large areas of marginal lake environments and the displacement of the lake shorelines over several kilometres.

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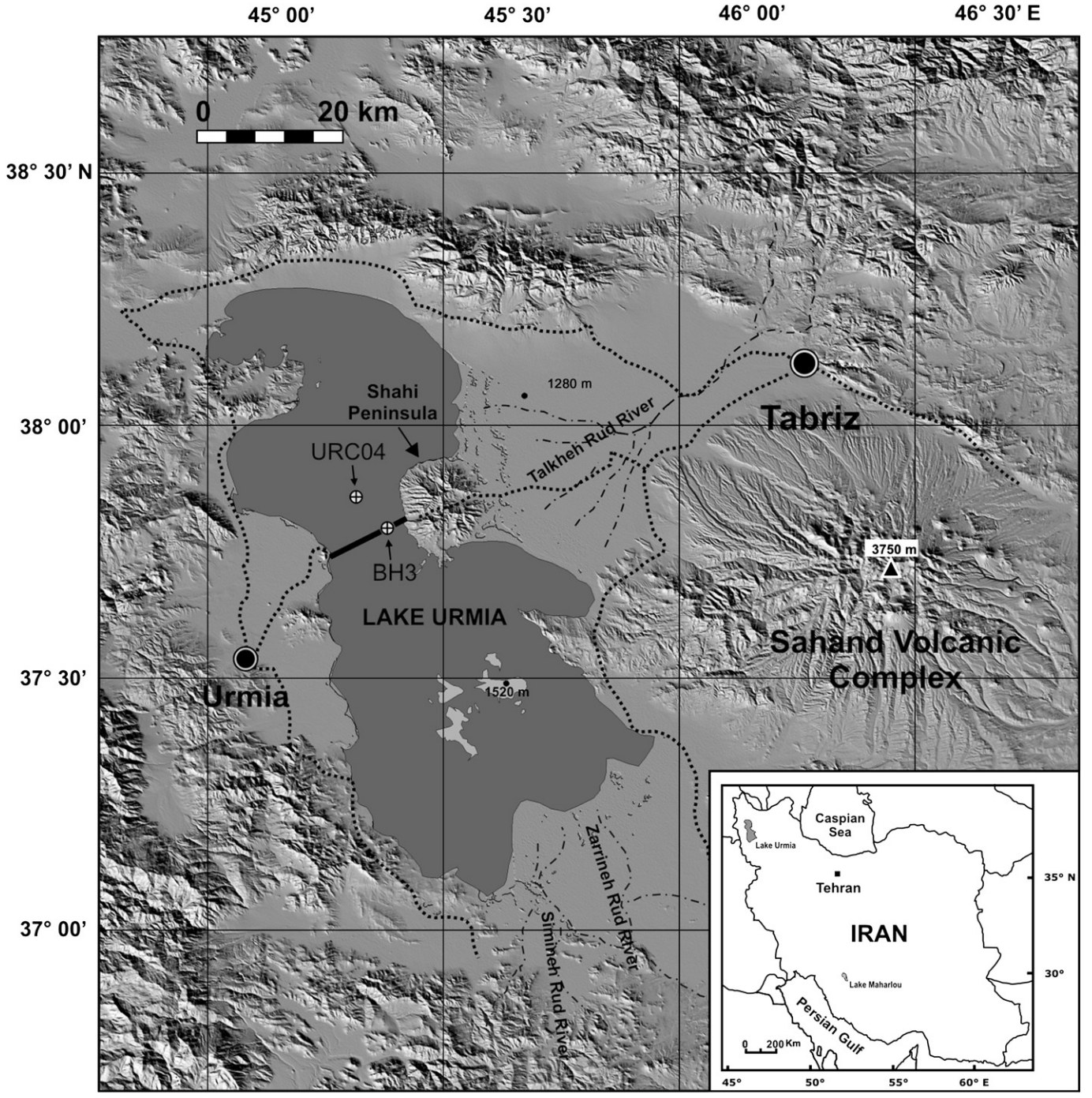

Fig. 1. Shaded relief map of northwestern Iran illustrating the main geomorphological features and the geographical position of Lake Urmia in the Near East (inset) and the location of the studied cores (BH3 and URC04) and some other sites mentioned in the text.

Large water-level fluctuations on the order of several meters are not unusual for Lake Urmia (Kelts and Shahrabi, 1986). Observations from topographic maps, aerial photographs and satellite images document seasonal variations in surface area that range from 5400 to 6000 km^2. Mean annual surface area can vary from 5310 to 5827 km^2 over a dozen years (1972–1984) (Sharifi, 2002). The most recent high stand occurred in 1969 (1284 m), during which the Shahi Peninsula (Fig. 1) became an isolated island for several years (Kelts and Shahrabi, 1986; Sharifi, 2002). According to some historical documents, lake level fell considerably during the Little Ice Age (ca. AD 1500–1850), permitting access to the islands by walking (Kelts and Shahrabi, 1986). Elevated palaeolacustrine terraces indicate dramatic fluctuations during the Pleistocene, one of which occurred in the penultimate glacial period (Kelts and Shahrabi, 1986; Djamali et al., 2008). In recent years, intensive damming on the rivers flowing to the lake and over-exploitation of ground water around the lake have drastically reduced the surface area and water depth of the lake, causing an increase in salinity and the aerial exposure of large salt flats.

2.2. Climate

Climate of the Lake Urmia region is semi-arid, pluviseasonal-continental Irano-Turanian steppe climate with mean annual precipitation of 341 mm and mean annual temperature of 11.2 °C. The wet season lasts for 7 months with two pronounced peaks in precipitation