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The First Dated Eemian Lacustrine Deposit in Romania

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A complex interglacial sequence of lacustrine sediments has been found near the village of Turbuta in NW Romania. Mollusc, plant macrofossil, and pollen analyses reflect climatic and environmental changes around the last interglacial climatic optimum. U-Th TIMS dating of snails strongly indicates an Eemian age of the organic sediments.

Key Words: **last interglacial; pollen, mollusc; U-Th TIMS dating; ICP-MS; Turbuta, Romania.**

INTRODUCTION

Well-dated continental climate records of the last interglacial period from midlatitude European regions are scarce. Situated well beyond the limits of the Scandinavian ice sheet, Romania may have been an important refuge for the temperate flora and fauna that had spread out over Europe since the penultimate glaciation, and the knowledge of its Eemian flora and fauna is therefore important for understanding the present biogeography of Europe. Although intensive work has been carried out in Romania during the last 50 years on various fields of Quaternary geology (pollen, mammals and micromammals, plant macrofossils), the Pleistocene geochronology of Romania has not yet been established due to the lack of radiometric dates. The only radiometric ages available for the last interglacial period in NW Romania are derived from U-Th dating of speleothems (Onac and Lauritzen, 1996; Lauritzen and Onac, 1999; Tamas *et al.*, 2000).

Here we report the first results of an ongoing multiproxy study of lacustrine deposits consisting of clays, clay gyttja (sediment with 6%–30% organic detritus), gyttja[1] (>30% organic detritus) and sandy drift gyttja from Mare Valley at Turbuta, NW Romania.

SITE DESCRIPTION AND GEOLOGICAL SETTING

The interglacial site under investigation is located on the Valea Mare gully just north of the village of Turbuta (Salaj county, Transylvania; Fig. 1a). The site, identified in the early 1970s during geological mapping of the region, is located in an area of late Middle and Late Pleistocene terraces of the River Somes, at an elevation of ca. 275 m (Diaconeasa *et al.*, 1976).

The interglacial deposit at Turbuta consists of an almost 3-m-thick profile of blue-gray, black, or brown lacustrine clays, light

[1] A brown to black, organic-rich sediment.

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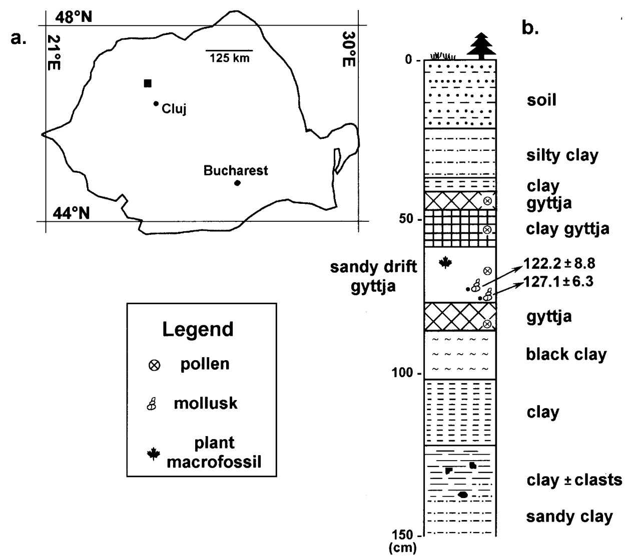

FIG. 1. (a) Map of the investigated area; (b) lithological sequence and the location of samples.

brown clayey gyttja, gyttja, and dark brown to blackish sandy drift gyttja. The investigated part of the profile (the uppermost 150 cm) starts with a 10-cm-thick sandy clay underlain by a blue-gray plastic clay layer, which contains medium-sized angular pebbles and fine sand (Fig. 1b). This sediment indicates a short distance to the source, transport by fairly strong currents, as well as deposition of suspended matter. Between 120 and 85 cm the facies is dominated by clayey deposits which darken upwards.

An organic-rich unit occurs between 85 and 44 cm. It appears as a sandwich of light and dark-brown gyttja and clay gyttja that encloses a ∼20-cm-thick layer of compact sandy drift gyttja. This unit is rich in mollusk shells in its lower part, making up ca. 5% of the total sediment, and in plant macrofossils in the upper part. The amount of mineral matter decreases from 50% to 30% in the upper part. The lithology suggests a shallow water environment, possibly culminating as a swamp. All samples presented in this study were collected from this unit (Fig. 1b). The upper part of the profile (44 cm) consists of clay, silty clay, and soil.

The entire Quaternary sequence lies on top of Upper Eocene (Lutetian-Priabonian) deposits represented by marls, clays, and sandstones (Meszaros and Moisescu, 1991). Clichici *et al.* (1976) suggested that the Quaternary lake developed after a sudden landslide that involved downslope movement of the thick sandstone layer along the lubricated bedding plane at the sandstone-clay interface. This process resulted in the formation of a raised threshold across the stream pathway, acting as a natural dam behind which the lake formed. The flat lake paleosurface is an obvious geomorphological feature across the landscape in the investigated area.

METHODS

The preparation of the four pollen samples (ca. 2 cm^3) followed standard methods (Moore *et al.*, 1991). Microscope slides were prepared from the residue and analyzed for pollen (at least 250–300 grains in each subsample). Pollen counts were made at 400× magnification. Pollen keys and illustrations in Moore *et al.* (1991) and Reille (1992) were used for pollen identification. Pollen nomenclature largely follows Moore *et al.* (1991).

The sandy drift gyttja and clayey gyttja samples were disintegrated with water and washed through a sieve with a 250-μm mesh. Both plant macrofossils and snails were picked out under a binocular microscope.

Two U-Th TIMS dates were performed using two instruments, the Finnigan MAT262 (Laboratoire des Sciences et de L'Environment, Gif sur Yvette, France) and VG Sector 54-30 (Danish Center for Isotope Geology, Copenhagen, Denmark). The standards used for calibration were (HU-1) and NBS 960 (U 112A), respectively. The chemical procedure was essentially the same as that described by Lally (1992). Both U-Th measurements were carried out on *Gyraulus albus* snail shells extracted from the lower part of the sandy drift gyttja. Prior to the radiometric dating, shells of this snail species were x-rayed and found to be composed of aragonite.

Samples of sandy drift gyttja and mollusks (same genus as the dated sample) were analyzed by means of inductively coupled plasma-mass spectrometry (ICP-MS) in order to determine their uranium content with high precision. The ICP-MS measurements were made on VG Elemental Plasma Quad II at Department of Earth Sciences, University of Bristol, UK.

RESULTS AND DISCUSSION

The pollen data are presented in a percentage diagram with all terrestrial pollen types included in the calculation sum (Fig. 2). In general, the pollen data show a transition from a forest type dominated by *Quercus* and *Ulmus* (and some *Pinus*, *Tilia*, and *Fraxinus*) to a type dominated by *Corylus*, *Ulmus*, *Tilia*, and *Quercus*. The herb pollen sum is comparatively high in all samples. However, the main contributors are wetland taxa, such as Apiaceae and *Typha angustifolia*-type, which most likely originate from the local vegetation around the lake. In the bottom sample, *Artemisia* is of a higher value, indicating slightly more open vegetation.

The pollen data seem to correlate well to an early, possibly warm phase of the Eemian. The general vegetational development for the Eemian in northwestern and northeastern Europe is uniform (Zagwijn, 1996) and can be described as a transition from an initial dominance of herbs and *Betula* pollen, followed by a short *Pinus* phase, then by a *Quercus* and *Corylus-Alnus* phase, and finally by a dominance of *Carpinus-Picea* pollen assemblages (Nilsson, 1983). This development may have characterized the Eemian in central and southeastern Europe, although *Tilia* and *Ulmus* were probably more abundant in this region. If this assumption is correct, the transition from a dominance of *Quercus* pollen to a dominance of *Corylus* in the diagram from Turbuta (Fig. 2), which is a typical Eemian feature in large parts

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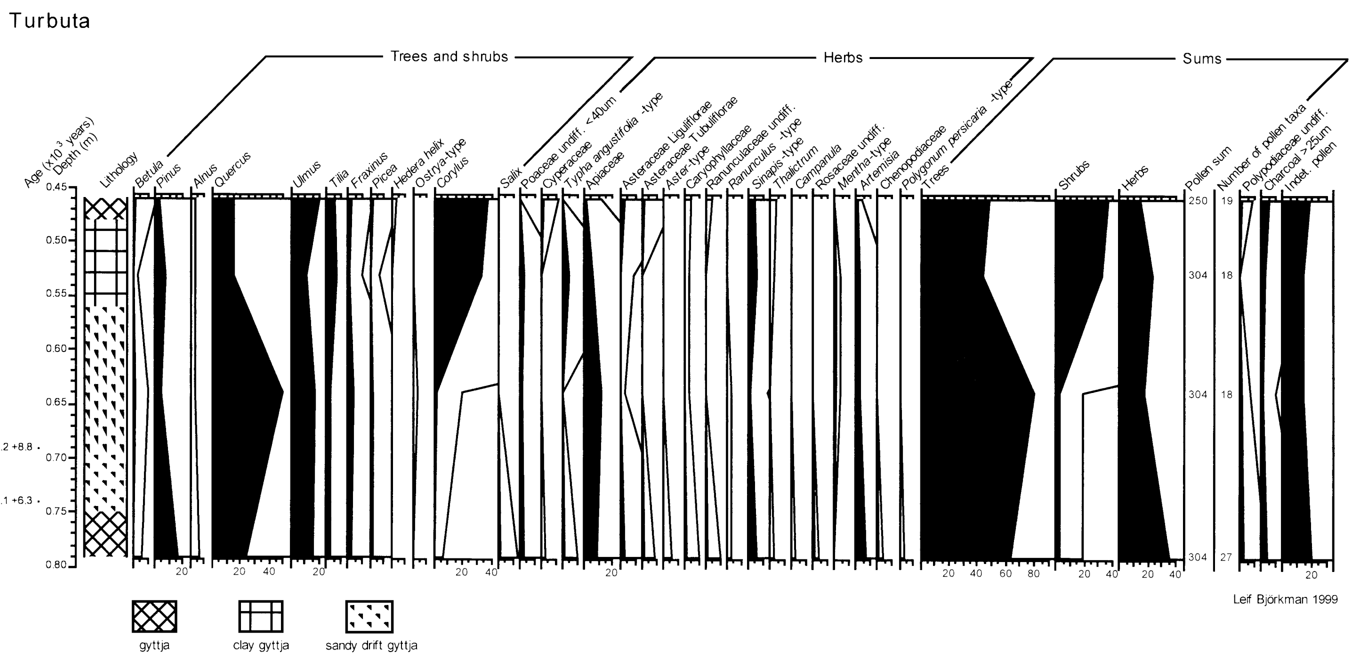

FIG. 2. Percentage pollen diagram from the Turbuta site with all identified pollen and spore taxa presented on a depth scale (covering the profile between ∼45 and ∼80 cm, cf. Fig. 1b). The finer lines are a 10× exaggeration of the pollen percentages.

of Europe (Zagwijn, 1996), strongly suggests that our pollen diagram represents an early phase of the Eemian. The complete lack of *Carpinus* and relatively low values of *Picea* pollen also indicate that the analyzed layers were deposited before the expansion of *Carpinus* and *Picea*, which is a characteristic signature of the middle part of the Eemian.

The plant macrofossil assemblage extracted from the sandy drift gyttja layer comprises more than 26 genera. The most common ones are *Lemna giba, Nymphaea alba, N. candida, Atriplex patulata, Carex elongata, C. cf. pseudocyperus, Viburnium opulus*, and *Potamogeton crispus*. A large part (40%) of the seeds found is specific to plants growing in stagnant or slow-running waters. All indicate a warm, humid, continental climate (Clichici *et al.*, 1976).

The molluscan fauna is very rich and differentiated both in the lower sandy drift gyttja and below it (within the gyttja and the upper part of the clay layers). It contains 28 taxa and more than 200 specimens throughout the collected samples. Most of the specimens found are stagnant water snails (*Planorbis planorbis, P. carinatus*, *Lymnaea palustris, Gyraulus albus, G. laevis*), while land snails are less frequent (Clichici *et al.*, 1979). The authors found a rich population of *Gyraulus laevis* (a species with wide climatic tolerance), as well as other cold-tolerant mollusks (*Succinea elegans, Anisus vortex, Armiger crista*), in the lower part of the black plastic clay layer, indicating boreal forests. In contrast, the middle and upper part of this layer and also the gyttja and the sandy drift gyttja layers are rich in mollusks that require warmer climates, such as *Gyraulus albus, Lymnaea stagnalis*, and *Valvata cristata*.

The mollusk assemblage documented from Turbuta has many similarities to that described by Alexandrowicz (1997) from the Eemian interglacial site of Kochanow (Poland). The hypothesis that the Turbuta section represents at least part of the last interglacial age is supported by the two U and Th isotopic measurements on snails. The ages of 112,200 yr and 127,100 yr B.P. (Table 1) certainly imply an Eemian age, but unfortunately the scatter between them does not allow a more precise age determination. In light of the pollen data, the lower dating of 127,000 yr B.P. seems reasonable, whereas the younger age is at least 10,000 yr too young to be of early Eemian age. However, the dating error is also larger for the latter measurement.

Mollusk shells are generally considered unreliable materials for U-Th dating, as they do not always behave as closed systems with respect to these elements (Kaufman *et al.*, 1971). However, recent studies on U-Th dating of fossil land snails indicate that this method can be reliable under some circumstances (Causse

TABLE 1
Summary of the U/Th Measurements (Reported Errors are 2 Standard Deviations)

Sample	Depth (cm)	U (ppm)	$^{234}U/^{238}U$	$^{230}Th/^{232}Th$	$^{230}Th/^{234}U$	Age (10^3 yr)
Turbuta 1	69	0.41	1.309 ± 0.0073	22.2 ± 0.2	0.665 ± 0.034	112.2 ± 8.8
Turbuta 2	74	0.47	1.308 ± 0.006	26.7 ± 0.1	0.778 ± 0.003	127.1 ± 6.3

et al., 1989; Goodfriend, 1992). One of the most frequently accepted criteria for no significant loss or gain of either uranium or thorium (closed system model) is the preservation of original aragonitic shells (Schwarcz and Blackwell, 1992). As previously mentioned, the X-ray diffraction of our dated shells revealed then to be of aragonitic composition. Therefore the main prerequisites for reliable ages are fulfilled.

In addition, the ICP-MS measurements showed the sandy drift gyttja to have sixfold-higher uranium content (3.01 ppm) than the mollusk shell (0.493 ppm) collected from within this organic-rich unit. This value is identical to those obtained by TIMS on our dated samples (see Table 1). The U-content discrepancy between the sediment and the shells further supports the existence of a closed system.

Part of the difference between the two dates arose from their position within the sandy drift gyttja (see Fig. 1b), but most of the discrepancy could be related to the permeability of various parts of the sediment. It has been found that algal-rich sediments or even peat can be impermeable enough to prevent postdepositional movement of uranium (Israelson *et al.*, 1997; Lowe and Walker, 1997). The too-young age for the upper dating could imply higher permeability for that part of the drift gyttja. However, both dates clearly suggest that the Turbuta sediments are of Eemian age and are thus the first dated Romanian lacustrine deposits from the last interglacial age.

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