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Holocene marine transgression in the Black Sea: New evidence from the northwestern Black Sea shelf

Valentina Yanko-Hombach[a,b,c,*], Petra J. Mudie[d], Sergey Kadurin[a,b], Evgeny Larchenkov[a,b,1]

[a] Department of Physical and Marine Geology, Odessa I.I. Mechnikov National University, 2 Shampansky Per., Odessa 65052, Ukraine
[b] Interdisciplinary Scientific Centre of Geoarchaeology, Marine and Environmental Geology, Odessa I.I. Mechnikov National University, 2 Dvoryanskaya Str., Odessa 65082, Ukraine
[c] Avalon Institute of Applied Science, 976 Elgin Ave., Winnipeg, MB R3E 1B4, Canada
[d] Department of Earth Sciences, Memorial University of Newfoundland, St Johns, NL A1B 3X5, Canada

A R T I C L E I N F O

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A B S T R A C T

For two decades, the timing and rate of Holocene marine transgression and the level of the Black Sea prior to the transgression has been the focus of many geological, palaeoecological and archaeological studies. The potential importance of confirming or rejecting the catastrophic flood hypothesis by refining the chronology of the marine transgression and determining the water level of the early Holocene Black Sea (Neoeuxinian) lake is the aim of many ongoing Black Sea palaeoecological studies.

In this report we review previous studies and present new data on the early Holocene marine transgression obtained from multidisciplinary studies of several cores from different parts of the Black Sea. Core 342 from the edge of the Dniester paleovalley on NW shelf is particularly important because it provides wood and leaf material from several peat and muddy peat beds, each up to ~10 cm thick, interlayered in a coastal succession with mud, clay, and shell coquina. AMS ages for wood fragments and sedge leaves in the peat layers provide critical new data for calibrating and "re-tuning" of previously published shell and bulk detrital peat ages.

Our multi-disciplinary study of geological material recovered from different shelf areas of the Black Sea refines the chronology of the marine transgression and clarifies conflicting interpretations of the water level and salinity of the Neoeuxinian lake prior to the initial Mediterranean inflow (IMI) and transgression of Mediterranean water in the Holocene, We find that: (1) The level of the Late Neoeuxinian lake prior to the early Holocene Mediterranean transgression stood around −40 m bsl but not −100 m or more as suggested by advocates of catastrophic/rapid/prominent flooding of the Black Sea by Mediterranean water. (2) At all times, the Neoeuxinian lake was brackish with salinity not less that 7 psu. (3) By 8.9 ka BP, the Black Sea shelf was already submerged by the Mediterranean transgression. An increase in salinity took place over 3600 years, with rate of the marine water incursion being estimated in the order of 0.05 cm–1.7 cm a^{-1}. (4) The combined data set of sedimentological characteristics and microfossil data establish that the Holocene marine transgression was of a gradual, progressive nature in the early Holocene.

1. Introduction

For two decades, the timing and rate of Holocene marine transgression and the level of the Black Sea prior this transgression has been the focus of many geological, palaeoecological and archaeological studies (Yanko, 1990; Yanko-Hombach, 2007; Nicholas et al., 2011; Yanko-Hombach et al., 2011a, 2011b). The idea of a catastrophic marine flood that broke open a sediment dam in the Bosphorus Strait, filling a freshwater Black Sea lake with about 30 m of Mediterranean sea water in a few years and driving away early Neolithic farmers (Ryan, 2007, was related to the legend of Noah's Flood despite lack of any direct geological (Görür et al., 2001; Hiscott et al., 2007), palynological (Mudie et al., 2002, 2004; Marret et al., 2009), paleontological (Yanko-Hombach,

* Corresponding author. Odessa I.I. Mechnikov National University, Palaeontological Museum, 2 Dvorianskaia Str., 65082 Odessa, Ukraine.
E-mail addresses: valyan@avalon-institute.org, valyan@onu.edu.ua (V. Yanko-Hombach).
[1] Recently deceased.

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2007), and archaeological evidence (Jablonka, 2002; Yanko-Hombach, 2007, 2011a, 2011b; Dolukhanov et al., 2009). This catastrophic flood hypothesis was proposed in 1997, based on evidence from seven short (about 1.25 m) sediment cores and 350 km of seismic profiles collected on the northern shelf margin of the Black Sea (Fig. 2) at water depths of 49–140 m (Ryan et al., 1997), where a thin layer of sapropelic mud overlies a shelf-wide unconformity (Ryan, 2007).

The speed of this catastrophic marine flooding in a presumed "freshwater Neoeuxinian lake" was estimated by AMS (Accelerator Mass Spectrometry) radiocarbon dating of intact mollusk valves from the sapropel in five cores from water depths of 68–125 m bsl. The individual mollusk shell ages were not listed in the 1997 paper, but they were reported as having an average of 7150 $\pm$ 100 uncal. BP, with all being within error limits of ages for the sapropel-base in nine cores from depths of -200 to -2200 m bsl reported by Jones and Gagnon (1994). In Ryan and Pitman (1998), the calendar ages of these shells differed by up to 110 years but were called "statistically identical", and interpreted as marking an abrupt switch from oxygenated freshwater to euxinic marine conditions. Later, however, studies of oxygen, carbon and strontium isotopes in mollusk shells by Major et al. (2006) led to an earlier age assignment of 8400 $\pm$ 100 BP for the start of a rapid Black Sea Holocene transgression.

The potential importance of confirming or rejecting the catastrophic flood hypothesis by refining the chronology of the marine transgression (Soulet et al., 2011a,b) as well as by quantifying the palaeosalinity (Bahr et al., 2008; Soulet et al., 2010; Mertens et al., 2012) and the water level (Yanko-Hombach et al., 2011a, b) of early Black Sea (Neoeuxinian) lake before this transgression is the aim of many ongoing Black Sea palaeoecological studies.

To pinpoint the time of the marine transgression, Soulet et al. (2011a) recently recalibrated the shell ages using wood samples from Sakarya Delta, because land plant material does not require ^{14}C marine reservoir age corrections and can be free of lake hardwater errors (HWE). The new age assigned to the IMI by Soulet et al. (2011a) is 8390 $\pm$ 35 BP for Black Sea water above 400 m bsl. The IMI marks the start of the Mediterranean transgression when water of marine salinity began to flow into the Black Sea basin through Bosphorus Strait.

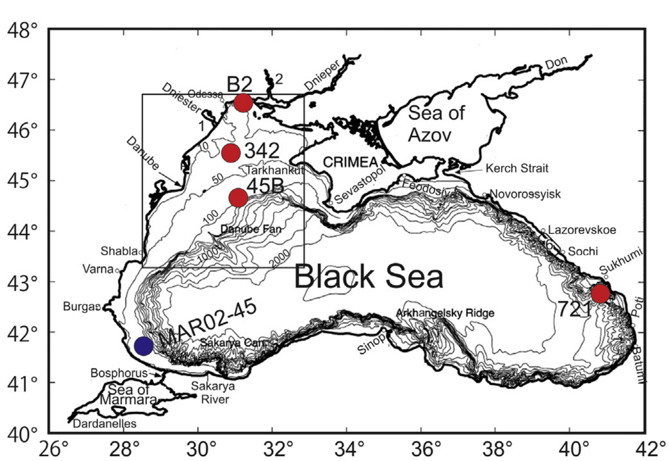

Fig. 1. Map of the Black Sea and adjacent regions, showing the extent of the shelf areas, the connection to Marmara and Aegean seas via Bosphorus and Dardanelles Straits, and locations of key reference cores with 14C ages. Circles mark location of cores described in this paper; dark circle is MAR02-45 core of Hiscott et al. (2007, 2010). 1-Dniestrovian liman, 2-Berezan liman.

Previous efforts to quantify the palaeosalinity of the Neoeuxinan lake prior to the Mediterranean transgression used non-quantitative methods based on ecological affinities of bivalves (Nevesskaya, 1963, 1965) and gastropod mollusks (Il'ina, 1966), ostracods (Yanko and Gramova, 1990; Stoica and Floroiu, 2008; Ivanova et al., 2012), benthic foraminifera (Yanko, 1990; Yanko-Hombach, 2007) and dinoflagellate cysts (dinocysts) (Mudie et al., 2001, 2004; Marret et al., 2009). These non-quantitative data all indicated that Neoeuxinian lake was brackish, with a salinity range between 7 and 12 psu. Paleontological results are in good agreement with pore water salinities in bottom sediments of Neoeuxinian age measured by Manheim and Chan (1974). However, they contradict the data of Soulet et al. (2010) who used interstitial sediment water chlorinity and δ^{18}O values to determine that the Neoeuxinan lake was freshwater ($\sim$1 psu) until ca 9.0 cal ka BP at one site on the Ukrainian shelf margin. However, new quantitative estimates for the Turkish shelf near Bosphorus Strait (Mertens et al., 2012) firmly establish that the surface water salinity was between 8 and 15 psu from 9.3 to 8.6 ka BP.

Efforts to determine the elevation of the Neoeuxinian lake water level before the Holocene marine transgression include the work of Ryan (2007) who described dune fields on the Ukrainian Shelf between -65 and -80 m, and wave-truncated terraces with beach-like berms at -90 to -100 m. The dunes were interpreted as having formed during a post-Younger Dryas regression which reduced the lake surface below the level of the World Ocean. Lericolais et al. (2010) similarly reported seismostratigraphic evidence indicating that, "Following the Younger Dryas, 11,000–8500 ^{14}C BP, there occurred a new level lowering to the level of -100 m, identified by the forced regression deposits recorded on the Romanian shelf. This last [data source] and a belt of coastal dunes is also evidenced there by the prodelta at -100 m depth. All these coastal features as well as the incised anastomosed channel system remained preserved on the shelf resulting from a rapid ultimate transgression starting immediately after 8500 ^{14}C BP" (Lericolais et al., 2010:199). Nicholas et al. (2011) support this idea by writing, "The shelves were subaerially exposed from the LGM to the Younger Dryas (Nicholas et al., 2011:3787)". Thus, these authors concluded that immediately before the Holocene transgression, the Black Sea shelf was subaerially exposed to an isobathymetric depth of ~ -100 m and then the shelf was catastrophically (Ryan, 2007)/rapidly (Lericolais et al., 2007, 2010)/promptly (Nicholas et al., 2011) flooded by Mediterranean water at 8.4–8.6 ka ^{14}C BP. In contrast, the geological data from medium- to large-scale geological surveys of the NW shelf (Yanko-Hombach, 2007; Yanko-Hombach et al., 2010; Larchenkov and Kadurin, 2011) show that the level of brackish Late Neoeuxian lake was at $\sim$40 m bsl in the early Holocene, making catastrophic/rapid/prominent flooding of the Neoeuxinian lake by Mediterranean water in early Holocene impossible. High-resolution survey and core data of Hiscott et al. (2007) also indicate a water depth close to 40 m bsl by 8.6 ka BP (uncal).

The purpose of the present study is to refine the chronology of the marine transgression as well as the water level and salinity of the Neoeuxinian Lake prior to the IMI and Mediterranean transgression in the Holocene. Our primary data include sedimentary, micropaleontological (foraminifera and ostracoda), palynological and radiocarbon studies of selected samples from cores 342, B2 and 45B on the NW shelf of the Black Sea, in front of the Dniestrovian, Berezan limans and to the east of the Danube Delta mouth, respectively (Fig. 1; Table 1). The top section of 72.5 m-long Core 342 drillhole located in a water depth of 30.8 m bsl (Fig. 1; Table 1) at the edge of the Dniester paleovalley (Fig. 2) is extraordinarily valuable because it provides several peat and muddy peat beds, each up to $\sim$10 cm thick, inter-layered in a coastal succession with mud, clay, and shell coquina.