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Valentina Yanko
Odessa National University

Yücel Yilmaz
Istanbul Technical University

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# Controversy over the great flood hypotheses in the Black Sea in light of geological, paleontological, and archaeological evidence

Valentina Yanko-Hombach[a,*], Allan S. Gilbert[b], Pavel Dolukhanov[c]

[a]Avalon Institute of Applied Science, Charleswood Technology Centre, 3227 Roblin Blvd, Winnipeg, MB, Canada R3R 0C2
[b]Fordham University, Bronx, NY 10458, USA
[c]School of Historical Studies, University of Newcastle upon Tyne, NE1 7RU, UK

## Abstract

Legends describing a Great Flood are found in the narratives of several world religions, and the biblical account of Noah's Flood is the surviving heir to several versions of the ancient Mesopotamian Flood Myth. Recently, the story of the biblical deluge was connected to the Black Sea, together with the suggestion that the story's pre-Mesopotamian origins might be found in the Pontic basin [Ryan, W.B.F., Pitman, III, W.C., 1998. Noah's Flood: The New Scientific Discoveries About the Event That Changed History. Simon and Schuster, New York]. Based on the significance of this flood epic in the Judeo-Christian tradition, popular interest surged following publication of the idea.

Currently, two Great Flood scenarios have been proposed for the Black Sea: (1) an Early Holocene event caused by catastrophic Mediterranean inflow at 7.2 ky BP (initial hypothesis of [Ryan et al., 1997. An abrupt drowning of the Black Sea shelf. Marine Geology 138, 119–126]) or 8.4 ky BP (modified hypothesis of [Ryan et al., 2003. Catastrophic flooding of the Black Sea. Annual Review of Earth and Planetary Science 31, 525–554.); and (2) a Late Pleistocene event brought on by Caspian influx between 16 and 13 ky BP [Chepalyga, A.L., 2003. Late glacial Great Flood in the Black Sea and Caspian Sea. GSA Annual Meeting and Exposition, 2–5 November 2003, Seattle, USA, p. 460]. Both hypotheses claim that the massive inundations of the Black Sea basin and ensuing large-scale environmental changes had a profound impact on prehistoric human societies of the surrounding areas, and both propose that the event formed the basis for the biblical Great Flood legend.

This paper attempts to determine whether the preponderance of existing evidence sustains support for these Great Floods in the evolution of the Black Sea. Based upon established geological and paleontological data, it finds that the Late Pleistocene inundation was intense and substantial whereas the Early Holocene sea-level rise was not. Between 16 and 13 ky BP, the Late Neoeuxinian lake (the Late Pleistocene water body in the Pontic basin pre-dating the Black Sea) increased rapidly from ∼−14 to −50 m (below the present level of the Black Sea), then rose gradually to ∼−20 m by about 11 ky BP. At 11–10 ky BP (the Younger Dryas), it dropped to ∼−50 m. When the Black Sea re-connected with the Sea of Marmara at about 9.5 ky BP, inflowing Mediterranean water increased the Black Sea level very gradually up to ∼−20 m, and in so doing, it raised the salinity of the basin and brought in the first wave of Mediterranean immigrants. These data indicate no major drawdown of the Black Sea after the Younger Dryas, and they do not provide evidence for any catastrophic flooding of the Black Sea in the Early Holocene.

In addition, available archaeological and paleoenvironmental evidence from the Pontic region reveal no recognizable changes in population dynamics between 14 and 6 ky BP that could be linked to an inundation of large magnitude [Dolukhanov, P., Shilik, K., 2006. Environment, sea-level changes, and human migrations in the northern Pontic area during late Pleistocene and Holocene times. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, Dordrecht, pp. 297–318; Stanko, V.N., 2006. Fluctuations in the level of the Black Sea and Mesolithic settlement of the northern Pontic area. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, Dordrecht, pp. 371–385]. More specifically, Mesolithic and early Neolithic archaeological data in southeastern Europe and Ukraine give no indications of shifts in human subsistence or other behavior at the time of the proposed catastrophic flood in the Early Holocene [Anthony, D., 2006. Pontic-Caspian Mesolithic and Early Neolithic societies at the time of the Black Sea Flood: A small audience and small effects. In: Yanko-Hombach, V.,

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*Corresponding author. Tel.: +1 204 4894569; fax: +1 204 4895782.
*E-mail address:* valyan@avalon-institute.org (V. Yanko-Hombach).

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Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, Dordrecht, pp. 345–370; Dergachev and Dolukhanov, 2006. The Neolithization of the North Pontic area and the Balkans in the context of the Black Sea Floods. In: Yanko-Hombach, V., Gilbert, A.S., Panin, N., Dolukhanov, P.M. (Eds.), The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement. Springer, Dordrecht, pp. 489–514].

## 1. Introduction

Several of the world's religions describe a legendary Great Flood in their historical literature. The story of Noah's Flood, an important element in the Judeo-Christian tradition, is the surviving heir to several versions of the ancient Mesopotamian Flood Myth. This biblical narrative has recently been connected to the Black Sea with the suggestion that its pre-Mesopotamian origins might be found in the Pontic basin (Ryan and Pitman, 1998).

Two Great Flood scenarios have recently been proposed for the Black Sea. The earlier flood was suggested by A.L. Chepalyga (also spelled Tchepaliga), who dates it to the Late Pleistocene (Chepalyga, 2003, 2006). The later one has been promoted by W.B.F. Ryan and W.C. Pitman (Ryan et al., 1997), who place the event within the Early Holocene. Both the Late Pleistocene and Early Holocene flood scenarios claim that a massive inundation of the Pontic basin had a profound impact on the culture of prehistoric humans, forcing large-scale migration out of the affected area and creating a basis for the biblical Great Flood legend.

The *Late Pleistocene Great Flood* scenario assigns the source of flooding in the Pontic basin to the Khvalynian transgression of the Caspian Sea (16–13 ky BP) [all BP dates in the paper are $^{14}$C uncorrected], which created a spillway (Figs. 1 and 2) via the Manych Depression, the Don River, the Sea of Azov, and the Kerch Strait (Chepalyga, 2003, 2006). As a result, water level in the brackish Neoeuxinian lake (the Late Pleistocene water body in the Pontic basin pre-dating the Black Sea) rose from ~−100 to −20 m (below the present level of the Black Sea) by about 11 ky BP without incurring significant change in salinity. This relatively new hypothesis has not yet been discussed internationally, but its initial publication is stimulating new research in the Manych-Azov-Kerch region.

The *Early Holocene Flood* scenario initially argued that, between 14.7 and 10 ky BP, the Pontic basin contained a freshwater Neoeuxinian lake, the surface of which had been drawn down to −140 m (Ryan et al., 1997). At 7.2 ky BP, saline Mediterranean water from the rising post-glacial world ocean broke through a barrier within the narrow Bosphorus channel and abruptly filled the Pontic basin, submerging more than 100,000 km$^2$ of previously exposed shelf. According to the hypothesis, coastal farms were flooded, and early Neolithic foragers and farmers were forced to evacuate, moving into the interior of Europe and carrying with them agriculture as well as the memory of the deluge, which became the historical basis for the biblical story of Noah's Flood (Ryan and Pitman, 1998).

This hypothesis triggered tremendous fascination among the public, the scientific community, and the media—e.g., BBC (1996); New Scientist (Mestel, 1997; Hecht, 2003); Scientific American (Morrison and Morrison, 1999); Der Spiegel (2000); National Geographic (Ballard, 2001); GSA Today (Aksu et al., 2002a); and Frankfurter Allgemeine Zeitung (2003)—and Black Sea studies experienced a surge in interest. The wave of popular sentiment toward such a sensational idea led to media coverage that, on occasion, pandered to peoples' curiosity about the historical veracity of the Bible (Jablonka, 2002). Among scientists, however, some (e.g., Ballard et al., 2000; Algan et al., 2002; Algan, 2003; Haarmann, 2004; Lericolais et al., 2004) discovered evidence that appeared to support the hypothesis, but many others rejected the claim of an Early Holocene flood in light of their own contradictory findings (e.g., Görür et al., 2001; Aksu et al., 2002a, b; Yanko-Hombach et al., 2002, 2004; Yanko-Hombach, 2003). Archaeologists generally reacted with dismay to the oversimplified and uncritical assumptions of agricultural dispersal and Indo-European language spread that the hypothesis proffered in the absence of strong archaeological evidence (e.g., Rose, 1999).

In response to criticism, and based on their own data re-evaluation, the authors of the Early Holocene Flood hypothesis pushed the date of their inundation back 1200 years to 8.4 ky BP (Ryan et al., 2003). Instead of one lowstand and one flooding event as was originally proposed, the authors suggested two lowstands (−120 m at 13.4–11 ky BP, and −95 m at 10–8.4 ky BP) and two flooding events (sea-level rise from −120 to −30 m at 11.0–10.0 ky BP, and another from −95 to −30 m at 8.4 ky BP). The second flooding event at 8.4 ky BP was the one popularized as having been a catastrophe of biblical proportions.

The importance of the Pontic region in current environmental research is reflected in the 2005–2009 UNESCO and IUGS funding received by the IGCP 521 project, the main goal of which is to study the "Black Sea–Mediterranean Corridor during the last 30 ky with respect to sea-level change and human adaptation" (www.avalon-institute.org/IGCP). Testing the flood hypotheses is among the main tasks of the project.

Preparation of the IGCP project was preceded by a series of international conferences devoted largely to the late Quaternary history of the Black Sea-Mediterranean Corridor, especially as it relates to climate change, coast-

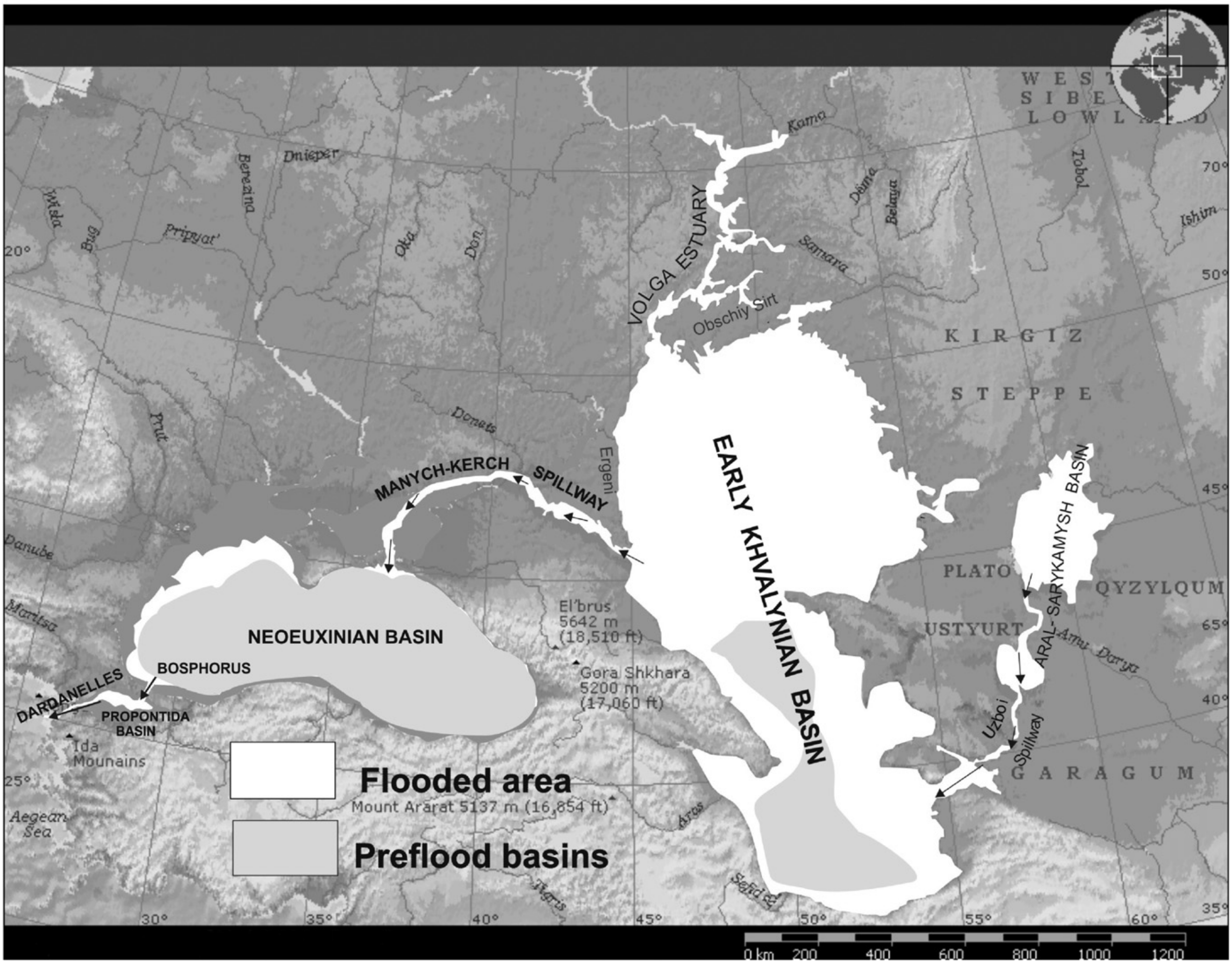

Fig. 1. Ponto-Caspian Great Flood basins (after Chepalyga, 2006).

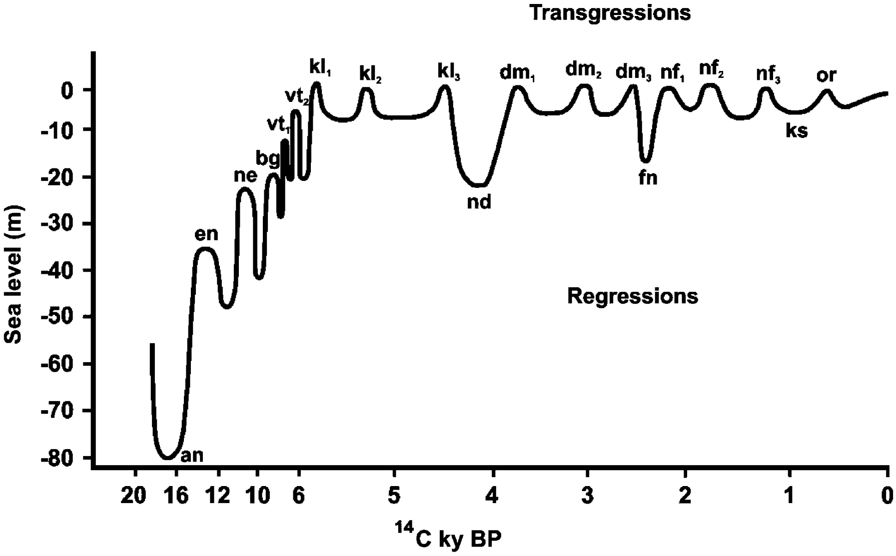

Fig. 2. Sea-level changes over the last 20 ky (after Chepalyga, 2002). Abbreviations for regressions and transgressions: an = Ant; en = Enikalean; ne = Neoeuxinian; bg = Bugazian; vt = Vityazevian; kl = Kalamitian; nd = Kundukian; dm = Dzhemetinian; fn = Phanagorian; nf = Nymphaean; ks = Korsunian; or = Orda.

line migration, and human adaptation. Among these conferences were

1. the NATO Advanced Research Workshop "Climate Change and Coastline Migration" (1–5 October 2003, Bucharest, Romania; http://www.avalon-institute.org/NATO_ARW.html);
2. the International Conference "The Black Sea Flood: Archaeological and Geological Evidence" (Columbia University Seminar on the Ancient Near East, 18–20 October 2003, New York, USA; http://www.columbia.edu/cu/seminars/special-event/black-sea-conference); and
3. the GSA Topical Session "'Noah's Flood' and the Late Quaternary Geological and Archaeological History of the Black Sea and Adjacent Basins," (Geological Society of America Annual Meeting, 4 November 2003, Seattle, USA; http://gsa.confex.com/gsa/2003AM/finalprogram/session_9644.htm).

These three conferences brought together geologists, climatologists, and archaeologists for presentations and discussions, and 35 of the resulting papers were edited as a collective monograph entitled *The Black Sea Flood Question: Changes in Coastline, Climate, and Human Settlement* (Yanko-Hombach et al., 2006). Much of the discussion contained within the volume concerns the two Great Flood scenarios in the Black Sea.

The present review focuses on the late Quaternary (30 ky BP to the present) of the Pontic basin in an attempt to determine whether existing geological, paleontological, and archaeological evidence provides any support for the proposed Great Flood scenarios in the geological evolution of the Black Sea. It finds that the Late Pleistocene inundation brought substantial sea-level increases to the Pontic basin between 16 and 13 ky BP, but that reliable geological and paleontological data, judiciously interpreted, do not demonstrate any Early Holocene drawdown of the Black Sea and therefore provide no evidence for catastrophic flooding in the interval between 8.4 and 7.2 ky BP. In addition, available archaeological and paleoenvironmental evidence reveals no significant changes in population dynamics between 14 and 6 ky BP that could be linked to a catastrophic flood (Dolukhanov and Shilik, 2006; Stanko, 2006), and thus, archaeological documentation provides no support for the sudden culture changes that would follow in the wake of a major environmental disaster.

## 2. Oceanographic settings

The Black Sea is one of the world's largest marginal seas, possessing a maximum water depth of 2250 m. It is a paleoenvironmental amplifier and a sensitive recorder of climatic events, which are especially pronounced due to its semi-isolation from the global ocean (Degens and Ross, 1974; Yanko-Hombach, 2006). Located between the Paleozoic Russian Platform and the folded Alpine Belts of Crimea, Caucasus, and the Pontic Mountains, the Black Sea is underlain by oceanic crust formed in a back-arc tectonic setting (e.g., Zonenshain and Le Pichon, 1986), and it exhibits the standard oceanic provinces of continental shelf, slope, and abyssal plain. The continental shelf is widest in the northwest between the Danube Delta and Crimea, and it is narrowest in the south along the Turkish and Caucasian coasts. The shelf supports marine life, but the rest of the Black Sea bottom is anoxic and lifeless (Yanko, 1990a). The salinity of the Black Sea (average 18‰) is almost half that of the Mediterranean Sea due to strong river discharge and restricted connection with the ocean.

On the west, the Black Sea is connected to the Sea of Marmara through the relatively shallow Bosphorus Strait (average water depth 35.8 m). On the east, it lies adjacent to the Caspian Sea. Today, the Black Sea is isolated from the Caspian Sea, but geological and paleontological traces of periodic connections between the basins, most likely via the Manych-Azov-Kerch spillway (Fig. 1), have been clearly documented (Fedorov, 1978, 1982; Popov, 1983; Yanko, 1990a; Chepalyga, 2003, 2006). These periodic re-connections were produced largely by climate change and sea level fluctuations, leading to drastic modifications in basin morphology, salinity, biota, sedimentary and geochemical systems, as well as human settlement.

## 3. The Late Pleistocene flood scenario: geology, paleontology, stratigraphy

Prior to 28 ky BP, Marine Isotope Stage (MIS) 3 incorporated the prolonged 'Middle-Valdaian Megainterstadial', during which several episodes of generally mild and unstable climate (Hengelo, Arcy-Denekamp, and Bryansk) fostered the spread of predominantly pine and birch forests along the valleys of the East European Plain (Velichko, 2002). At the time, the Mediterranean transgression locally known as the Tarkhankutian (Nevesskaya and Nevessky, 1961) and dated to 31,330 ± 719 ky BP according to Chepalyga (2002) brought salt water and marine organisms into the Pontic basin, increasing its salinity to 8–11‰ (Nevesskaya 1965; Yanko 1989, 1990a). Submerged accumulative coastal bars of synchronous age at water depths of −22 to −30 m on the northwestern and Romanian shelf show that the level of the Tarkhankutian basin reached −30 m (Caraivan et al., 1986; Chepalyga et al., 1989; Chepalyga, 2002). Some authors (e.g., Popov, 1983) refer to this transgressional basin as the Surozhian. Other researchers (e.g., Svitoch et al., 1998) consider the Tarkankutian and Surozhian basins to be coeval. Whichever name is used, scientists understand that the post-Karangatian transgressional basin of 40–25 ky BP was inhabited by euryhaline Mediterranean biota (Svitoch et al., 1998).

Temporally, Tarkhankutian sediments correspond to Unit 3 (Çağatay, 2003) in the Sea of Marmara, which contains marine mollusks and benthic foraminifera indicative of a weak Mediterranean marine incursion during the early part of MIS-3. The Middle Weichselian (Tarkhankutian) basin was connected with the Sea of Marmara via a south-flowing river or strait (Aksu et al., 2002a, b), which apparently also had a northward flow as indicated by the presence of Mediterranean species in the Tarkhankutian beds. The location of this connection is not known with certainty, and it is instructive to note that sediments similar to those of the Tarkhankutian beds have been recovered in Izmit Bay in borehole S5 (Fig. 11), but none have yet been found within the Bosphorus Strait (Meriç et al., 1995; Yanko-Hombach et al., 2004).

At the Last Glacial Maximum (LGM), the connection between the Pontic basin and the Sea of Marmara was disrupted, and from 28 to 18 ky BP, water level in the Tarkhankutian Sea dropped to ~−100 m below present. The sea was transformed into a brackish Early Neoeuxinian lake. Water level then rose again to ~−20 m between 17 and 11 ky BP without significant change in salinity. What was the main reason for this dramatic sea level rise?

One classical theory (e.g., Fedorov, 1978) explains the rise of the Neoeuxinian lake level as the result of Scandinavian ice sheet decay and meltwater discharge via tributary rivers. According to Chepalyga (2003, 2006) and Mamedov (1997), water also overflowed from the Khvalynian basin (Caspian Sea at 17–9 ky BP) into the Neoeuxinian lake. Popov (1983) offered a two-part subdivision of the Khvalynian sediments (Fig. 3):

(1) marine Lower Khvalynian ($mQ_3hv_1$), and
(2) lagoon-alluvial Upper Khvalynian ($lalQ_3hv_2$) beds.

Chepalyga (2003, 2006) has divided the Khvalynian sediments into three stages:

(1) Early Khvalynian (17–14 ky BP),
(2) Middle Khvalynian (13–11 ky BP), and
(3) Late Khvalynian (11–9 ky BP).

According to Chepalyga, the Late Pleistocene Great Flood occurred during the Early Khvalynian stage, when water level in the Caspian basin rose 180–190 m (Maev, 1994), and a great Cascade of Eurasian Basins (the Vorukashah Sea) extended from the Aral Sea in the east to the Aegean Sea in the west, connected via the former spillways of the Uzboy and Manych-Azov-Kerch as well as the current Bosphorus and Dardanelles Straits (Fig. 1). The Cascade encompassed about 1.5 million km$^2$, contained about 700,000 km$^3$ of semi-fresh to brackish water (salinity varying between 1‰ and 12‰) (Fig. 4), and it left traces on coastal plains (marine transgressions as in Fig. 3), in river valleys (megafloods), on watersheds (thermokarst lakes), and on slopes.

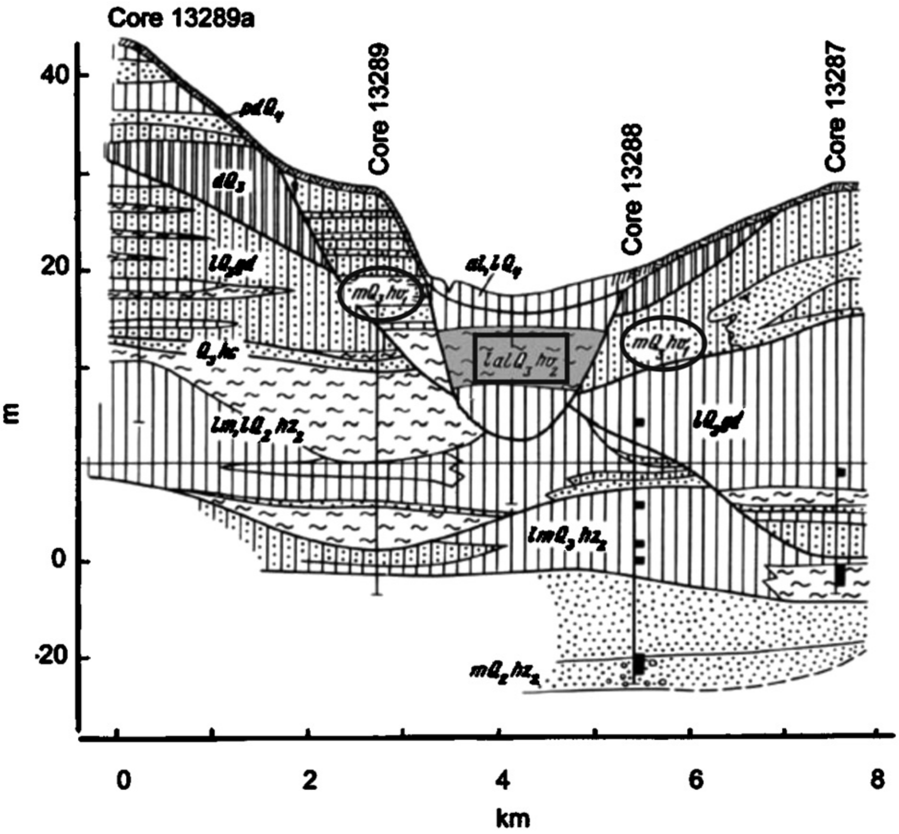

Fig. 3. Geological section across the Manych Spillway: $mQ_3hv_1$ (within circles) = marine Early Khvalynian beds; $lalQ_3hv_2$ (within rectangle) = lagoon-alluvial Upper Khvalynian beds (from Popov, 1983).

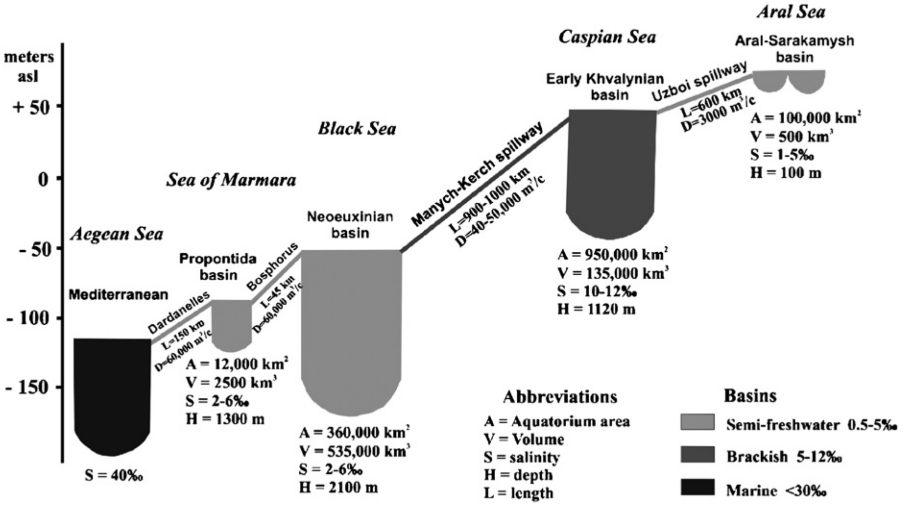

Fig. 4. Cascade of Eurasian Basins at 16–13 ky BP (after Chepalyga, 2002, 2006).

The vast amount of water could have been supplied from (1) the melting of the Scandinavian ice sheet, (2) river megafloods, (3) permafrost melting, (4) a higher runoff coefficient under conditions of permafrost, (5) an increased catchment area (including Central Asia, which is an interior-draining, endoreic basin today), and (6) a lower rate of surface evaporation due to winter ice cover. Chepalyga views 'river megafloods' as the main causal mechanism, and this superflood phenomenon was first inferred from studies of macromeanders in river valleys (Sidorchuk et al., 2003).

A different scenario, suggested decades ago by several Russian scientists (Kvasov, 1979; Grosswald, 1980), proposes that ice sheets blocked the north-flowing rivers, forming huge ice-dammed lakes during the LGM. These rivers were consequently diverted to the south, becoming 'chains of lakes', which Kvasov assumed to have been the main causal mechanism behind the Khvalynian transgression. This hypothesis has recently been revisited by Mangerud et al. (2004), who suggest that, during the LGM, ice-dammed lakes were dispersed across Russia's entire northeast as well as the West Siberian Plain. This basin then spilled into the Aral Sea via the Turgay Pass, after which water reached the Caspian Sea through the Uzboy Channel, thereby triggering the Khvalynian transgression.

The Early Khvalynian basin could not retain the huge volume of inflowing water, and so the excess was discharged through the Manych-Azov-Kerch Spillway into the Late Neoeuxinian lake with an estimated speed of about 50,000 $m^3 s^{-1}$ (or 1000 $km^3 year^{-1}$), and from thence across the Bosphorus Strait into the Sea of Marmara (Mamedov, 1997; Chepalyga, 2003, 2006). This flow pattern can be traced by following the wide distribution of 'chocolate clays,' loams, and sands of 20–30 m thickness that contain endemic Caspian mollusks (*Didacna*, *Monodacna*, *Adacna*, and *Hypanis*), and foraminifera (*Mayerella brotzkajae*) (Fig. 5). Such sediments can be found within all the intervening basins and linking waterways from the Caspian Sea to the Dardanelles Strait.

The Manych-Azov-Kerch spillway route comprises a large depressional trough, deeply eroded into solid rock, which connects the Caspian and Black Seas (Fig. 1). It was inherited from an older strait between the two seas that existed (with interruptions) since the Late Pliocene Akchagylian basin (Popov, 1983; Chepalyga, 2006). It follows a tectonic fault-line depression that skirts the southern periphery of the Karpinsky Swell (an elevated Mesozoic structure forming the southern margin of the East European platform and confined between the Donbass and Mangyshlak). The full length of the spillway amounted to 950–1000 km (depending on the location of sea level), with maximum and minimum widths of 50–55 and 10 km, respectively, and depths of 30–50 m (Chepalyga, 2003). The spillway bed is covered by silts and clays, 5–10 m thick.

When the Khvalynian transgression reached its maximum (50 m above sea level), the spillway depth attained 30 m (its average depth was 20–25 m). Flow velocity has been estimated at approximately 0.2 m $sec^{-1}$ and maximum discharge at 40,000–50,000 $m^3 s^{-1}$. Total runoff would have exceeded 1000 $km^3 year^{-1}$, an output six times greater than that of the Volga River and three times that of the Mississippi River (Chepalyga, 2006).

Water influx from the Early Khvalynian basin raised the Late Neoeuxinian lake level by 60–70 m (Fig. 2) and then spilled into the Sea of Marmara, forming the second midshelf delta (Δ2) described by Hiscott et al. (2006) as expanding southward at the southern exit of the Bosphorus Strait between 16 and 14.7 ky BP.

## 4. The Late Pleistocene flood scenario: archaeology

Chepalyga (2002) argues that Paleolithic sites predating the Late Pleistocene Great Flood—such as the site of Avdeevo on the Seym River—are located at lower

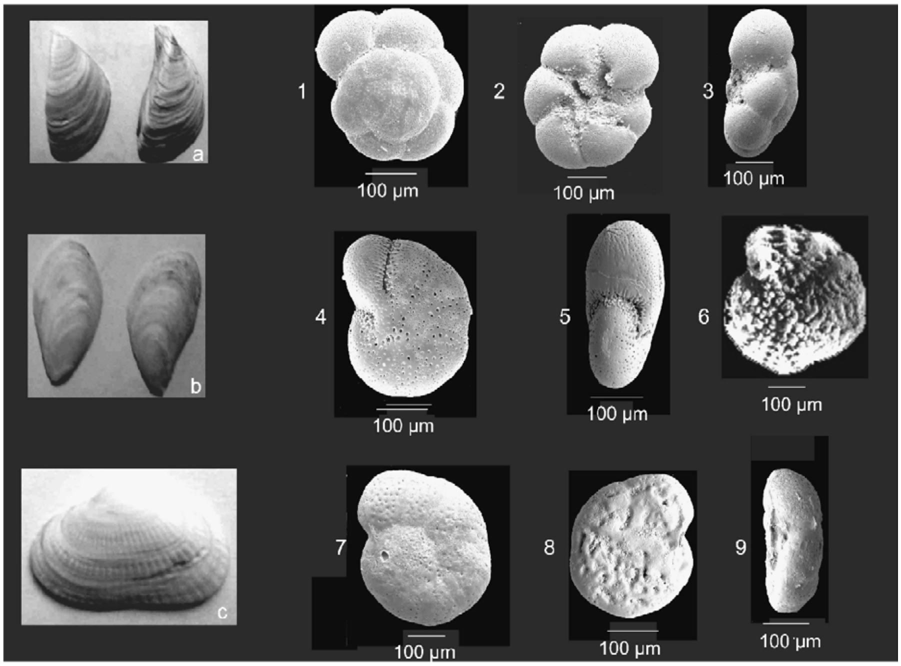

Fig. 5. Caspian mollusks (a)–(c) and foraminifera (1–9) in the Lower Khvalynian sediments: (a) *Dreissena polymorpha* (Pallas), (b) *Dreissena rostriformis* (Desh.), (c) *Didacna protracta* (Eichwald); 1–3 *Ammonia caspica* Shchedrina, 4,5 *Mayerella brotzkajae* Yanko, 6 *Elphidium caspicum* Mayer, 7–9 *Trichochyalus aguajoi* (Bermudez).

elevations within the valley, while younger sites are situated much higher on the slopes, possibly because of superfloods engulfing the valley bottoms. This statement is incorrect, as nearly *all* Upper Paleolithic sites inhabited during the various stages of the last glaciation on the East European Plain are found on elevated river terraces. This was apparently due to the fact that these rivers were major channels for meltwater discharge to the south; they were in essence 'chains of lakes'. The site of Avdeevo is a notable exception. Its lower position within the valley may be attributed to seasonal fluctuation in water level.

Quoting Leonova's (1998) data on the presence/absence of specific microlithic tools in the inventory of the Kamennaya Balka site, Chepalyga suggests (Chepalyga, 2002, 2006) that the Great Flood must have disrupted contacts with the south. As shown by the frequencies of radiocarbon-dated sites (Dolukhanov, 2001), the density of Upper Paleolithic sites markedly increased in the periglacial zone of the East European Plain between 24 and 20 ky BP, a time when the brackish Early Neoeuxinian lake had dropped to the level of ~−100 m. During the the Neoeuxinian transgression (18–14 ky BP), and during an environment of gradually rising temperature and humidity, groups of Paleolithic foragers moved into the Pontic Lowland from the north and settled within the valleys of small rivers. At 18 ky BP, specialized bison hunters occupied the large site of Anetovka 2, which combined the functions of tool-making workshop, butchering site, and cult center (Stanko et al., 1989). Another site of approximately similar age, Amvrosievka, was a short-lived bison hunters' kill-site (Krotova, 1999). Similar settlements were very likely established on the exposed Pontic shelf, which is submerged today. During the Late Glacial period (14–10 ky BP), the local industries became enriched with microlithic elements, and this apparently developed locally without any major influx from outside (Sapozhnikov, 2005). Hence, the development of the microlithic technique was a common phenomenon for the entire Pontic steppe and was in no way related to the occurrence of Chepalyga's Great Flood.

Western Caucasus was another area where Upper Paleolithic occupations are acknowledged beginning about 32 ky BP. They consisted predominantly of cave sites restricted to the western mountain ranges facing the Black Sea coast (Imeretian Culture) and the northern slopes of the Greater Caucasus. During the final stages of the last glaciation, these Paleolithic settlements disappeared, and much smaller sites emerged in the southern part of the Pontic Lowland (such as Bol'shaya Akkarzha, near Odessa).

All Paleolithic sites occupied during Neoeuxinian time belonged to groups of foragers specialized in hunting big game. Similarities in lifestyle and lithic tools suggest that human groups circulated freely along coastal areas, including the now submerged shelf floor (Fig. 6). No major changes in settlement or subsistence that could be related to a major ecological catastrophe are recognizable; the only exception is the disappearance of bison in Late Glacial sites, but this was apparently the result of overkill. Contacts between human groups seem not to have been severed by any calamitous events, so contrary to Chepalyga's views, population movements were not likely blocked or disrupted by a major Manych-Azov-Kerch spillway.

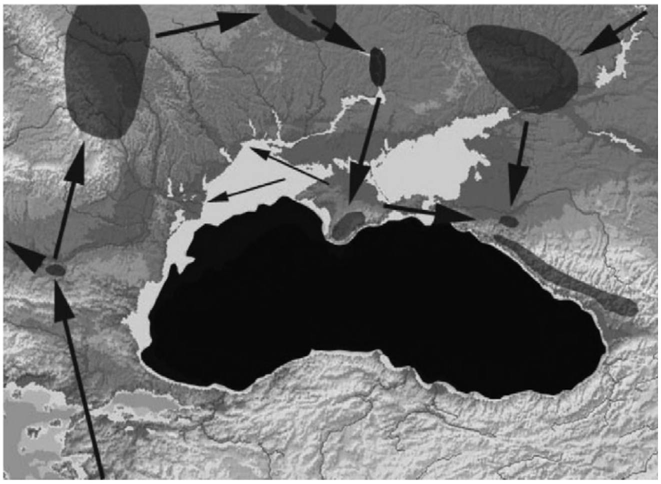

Fig. 6. Population concentrations (gray areas) and migrations (arrows) in the Black Sea area during the last glaciation (from Dolukhanov and Shilik, 2006).

## 5. Early Holocene flood scenario: geology, paleontology, stratigraphy

Ryan et al. (1997) proposed in their initial flood scenario that, between 14.7 and 10.0 ky BP, the Black Sea was a giant freshwater lake (the Late Neoeuxinian lake) with its surface and coastlines at −140 m. A rapid transgression in the world ocean subsequently brought the level of the Mediterranean and Marmara Seas up to the Bosphorus sill, where it eventually broke through a barrier blocking the channel at about 7.2 ky BP, rapidly filling the Neoeuxinian lake. According to the hypothesis, saltwater funneled through the narrow Bosphorus Strait at a speed of 50 mph and poured into the Black Sea with 200 times the force of Niagara Falls, thereby sharply increasing salinity and rapidly raising the lake level (Ryan and Pitman, 1998). At the proposed rate of 15 cm day$^{-1}$, sea level would have risen 100 m over the course of 2 years, inexorably submerging more than 100,000 km$^2$ of exposed shelf and flooding any coastal farms or settlements that might have existed within the impact zone. This catastrophe forced early Neolithic foragers and farmers, as well as speakers of the ancestral Proto-Indo-European language to retreat into the interior of Europe, and according to the authors, the event formed the historical basis for the biblical story of Noah's Flood. The flood then initiated deposition of a single structureless and uniform layer of jelly-like sapropel, which currently drapes all of the undulations of the unconformity formed during the previous regressional stage at ca. 10.1–9.8 ky BP (Yanko-Hombach, 2006).

This flood scenario was recently modified after a re-evaluation of collected data (Ryan et al., 2003). The timing of the flood was moved back to 8.4 ky BP, and instead of a single inundation, two lowstands (−120 m at 13.4–11 ky BP; and −95 m at 10–8.4 ky BP) and two catastrophic floods (sea-level rise from −120 to −30 m at 11.0–10.0 ky BP; and from −95 to −30 m at 8.4 ky BP) were proposed. The second of these two major transgressions was labeled the Great Flood.

The initial Early Holocene Flood scenario of Ryan et al. (1997) was based on limited geological data that included 350 km of high-resolution seismic profiles and a few short sediment cores (maximum length 150 cm) obtained on the northwestern shelf and south of the Kerch Strait at water depths of −49 to −140 m (Fig. 7).

The modification of the Early Holocene Flood scenario was based on a study (Major et al., 2002, their Fig. 1) of two sediment cores recovered at water depths of −240 (length 840 cm) and −378 m (length 759 cm), respectively. High Sr isotope values in the core sediments indicated that the re-connection of the Black and Marmara Seas might have been over a millennium earlier than previously estimated.

In contrast to the evidentiary foundations underlying the Early Holocene Flood hypothesis, no support for an abrupt marine inundation of the Black Sea emerges from analyses of substantial scientific data obtained by eastern researchers over many decades in the course of a large-scale geological survey of the Black Sea shelf and continental slope (e.g., Andrusov, 1918; Arkhangel'sky and Strakhov, 1938; Nevessky, 1961; Nevesskaya, 1963, 1965; Il'ina, 1966; Semenenko and Kovalyukh, 1973; Tsereteli, 1975; Shilik, 1977; Fedorov, 1978; Shcherbakov et al., 1978; Komarov et al., 1979; Malovitsky et al., 1979; Kuprin et al., 1980; Balabanov et al., 1981; Popov, 1983; Shcherbakov, 1983; Gozhik, 1984a–d; Molodykh et al., 1984; Kuprin et al., 1985; Shnyukov et al., 1985; Gozhik et al., 1987; Yanko and Troitskaya, 1987; Balabanov and Izmailov, 1988; Panin, 1989; Yanko, 1990a; Yanko and Gramova, 1990; Khrischev and Georgiev, 1991; Gorshkov et al., 1993; Glebov et al., 1996; Mel'nik, 1997; Shilik, 1997; Stanko, 1997; Kuprin, 2002).

According to the eastern scientific evidence, the overlapping of Upper Neoeuxinian sediments by peats and/or coarse sediments in coastal areas demonstrates that the level of the Late Neoeuxinian lake rose to −20 m at about 11 ky BP, then dropped to −50 m (Fig. 2; Balabanov, 2006). Radiometric age ranges for the peats at −50 m cluster around 10–11 ky BP: 10,600–9900 BP (Inozemtsev et al., 1984); 10,550 BP (Kind, 1976); 10,130 BP (Balabanov et al., 1981); and 9580 BP (Yanko and Troitskaya, 1987), all falling within the interval of the Younger Dryas. By 9.8 ky BP, a warmer climate led to a water-level increase within the basin from −50 to −30 m (Balabanov, 2006, Fig. 3), which allowed an initial influx of Mediterranean water and organisms into the Black Sea.

The eastern data also show that, after about 9.8 ky BP, water level in the Pontic basin never again dropped below the −40 m isobath, nor did it exhibit a maximum amplitude of fluctuation greater than 10–15 m (Fig. 2; Balabanov, 2006, Fig. 3). Evidence collected during decades of geological survey work has clearly demonstrated that the Neoeuxinian lake experienced a regressional (lowstand) stage followed by a transgressional (highstand) stage

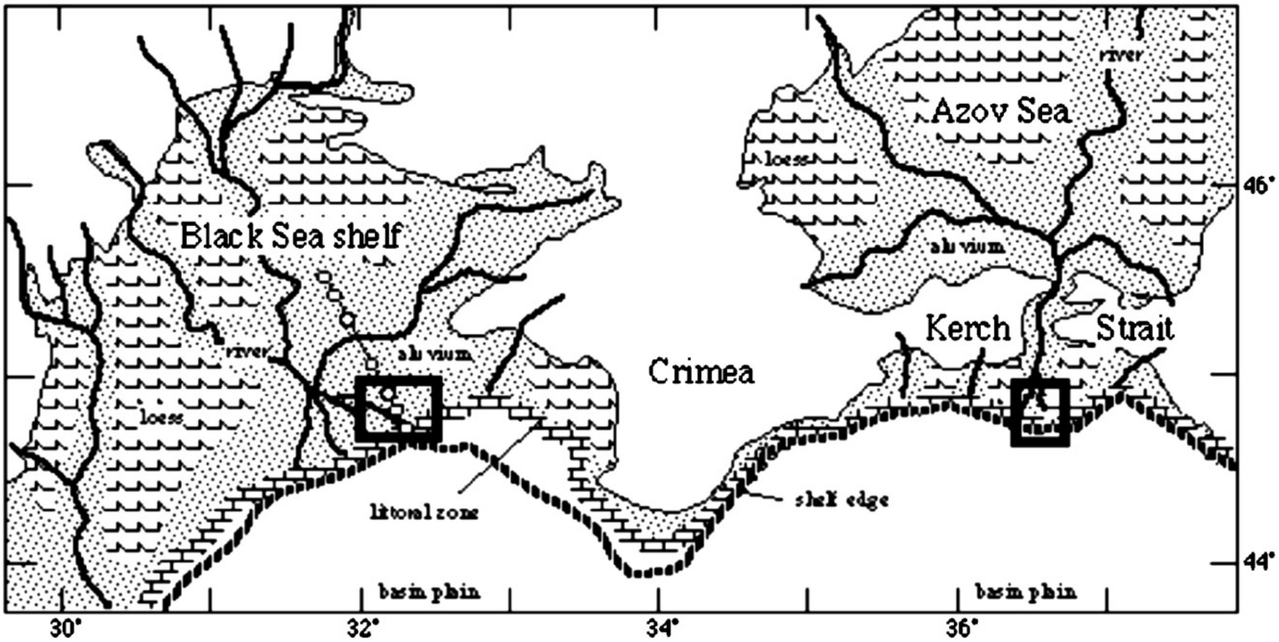

Fig. 7. The arid landscape of the northern coastal area of the Black Sea at 14–10 ky BP; modified by Ryan et al. (1997) after Shcherbakov et al. (1978). The soils of the exposed shelf were dominated by wind-blown loess (wavy pattern) and alluvial deposits (stippled pattern) from meandering rivers that flowed hundreds of km beyond their present mouths to shelf-edge deltas. The line with small circles west of Crimea indicates a transect line of cores; black squares indicate the areas of geophysical survey conducted during the joint Russia-US expedition in 1993 (Ryan et al., 1997).

(Fig. 8), and that it was never fresh but always a brackish water body (Nevesskaya, 1963, 1965).

Assessing the validity of the Early Holocene Flood hypothesis depends upon an accurate understanding of three crucial factors: (1) the level and salinity of the Neoeuxinian lake prior to the Mediterranean transgression, (2) the Mediterranean transgression and migration of organisms, and (3) the route of the Mediterranean transgression.

1. *The level and salinity of the Neoeuxinian lake prior to the Mediterranean transgression*

   The $\sim -100$ m lowstand of the brackish (salinity about 5‰) Neoeuxinian lake occurred during the Würm-Valdai glaciation and the LGM, when climate in the Pontic area was dry and cold (Pop, 1957; Komarov et al., 1979; Nikhonov and Pakhomov, 1993), and river discharge was low (Kvasov, 1975; Skiba et al., 1975; Fedorov, 1978; Shcherbakov et al., 1978; Abashin et al., 1982; Shcherbakov, 1983; Shnyukov et al., 1985; Fedorov, 1988; Svitoch et al., 1998). Much of the shelf was exposed, eroded, its basement downcut to $\sim -40$ m by the Pre-Danube, Pre-Dnieper, and Pre-Dniester Rivers, and its surface overlapped by subaerial loams (e.g., Shcherbakov et al., 1978; Shcherbakov, 1983; Inozemtsev et al., 1984; Fedorov, 1988). The ancient river mouths were located 80–100 km seaward compared to their present locations (Gozhik, 1984b; Shnyukov et al., 1985; Konikov, 2006), and, lacking proper deltas, they opened directly into their respective canyons on the continental slope (Fig. 8). The river valleys and canyons were filled with thick (22–40 m) alluvial sediments (Kuprin and Sorokin, 2006) of Ant age, 22,800–16,900 BP (Gozhik, 1984b, c).

   The arid landscape illustrated by Ryan et al. (1997) in their Fig. 1 (our Fig. 7) was identified by them as a relic of the Neoeuxinian lowstand (14–10 ky BP) based upon radiocarbon dating. This landscape was, in fact, attributed by Shcherbakov et al. (1978) to the LGM (20–18 ky BP) based on the fact that the lithology of more than 250 sediment cores contained only shallow water brackish (not freshwater!) foraminifera, ostracoda, and mollusks of Caspian affinity (Govberg et al., 1979; Yanko, 1990a; Yanko and Gramova, 1990; Yanko-Hombach, 2003, 2004, 2006).

   In some cores taken below the $\sim -100$ m isobath, the submerged sediments indicative of an arid landscape are covered by a single uniform layer of dark, jelly-like sapropel, as was accurately documented by Ryan et al. (1997, 2003). In most cores recovered above the $-100$ m isobath, however, the drowned arid landscape is overlapped unconformably by brackish Upper Neoeuxinian sediments (Yanko-Hombach, 2006, Figs. 4, 8(a), 9(a)). One would conclude from these facts that Upper Neoeuxinian sediments were washed out below the -100 m isobath. Khrischev and Georgiev described this phenomenon (Khrischev and Georgiev, 1991, Fig. 2) and showed that a regional washout is not limited to the isochronal surface and therefore is not the product of a single event, even a disastrous one. Instead, it may relate to seismic processes or slumping on the shelf edge and continental slope, although the possibility of

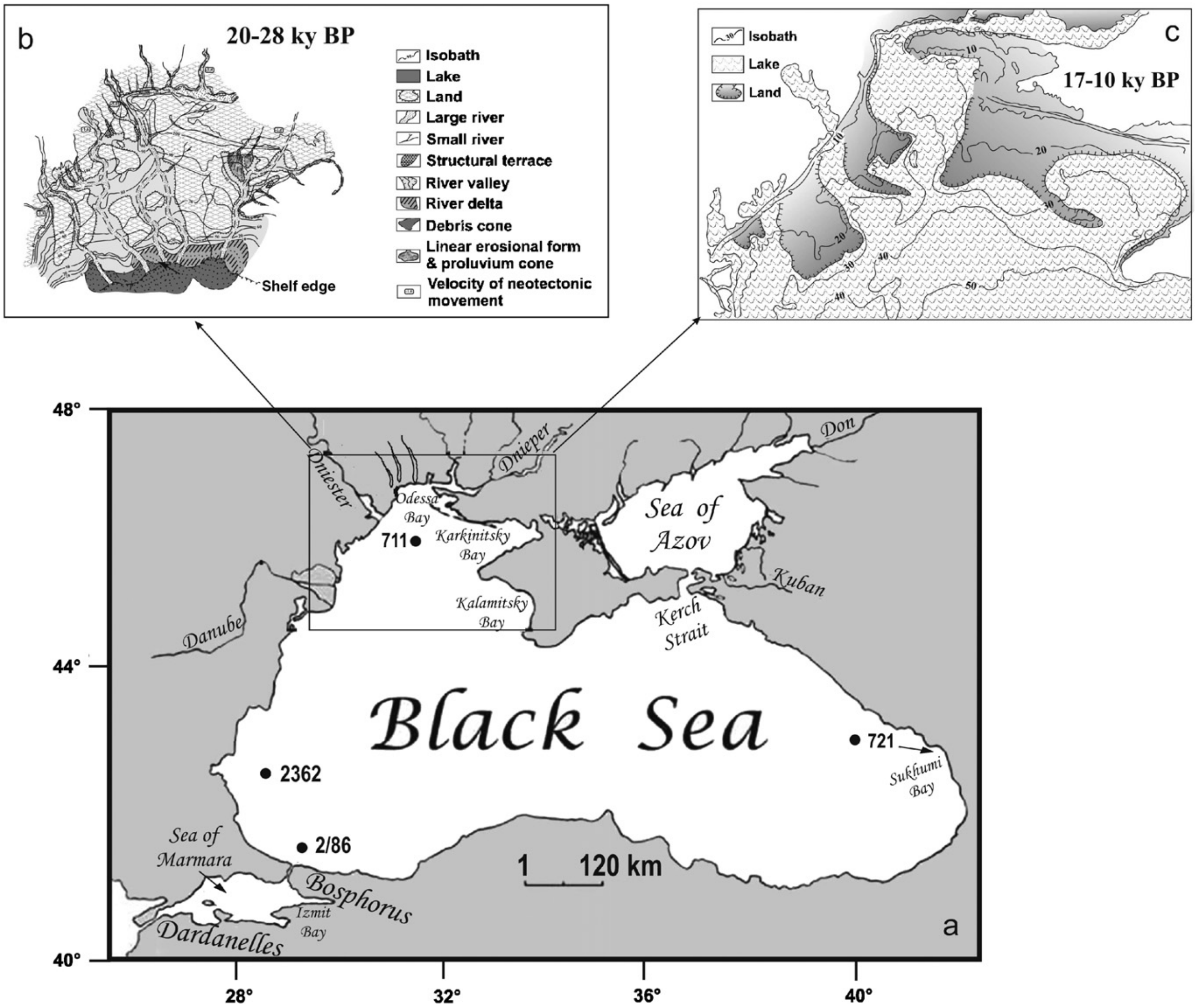

Fig. 8. Northwestern shelf of the Black Sea during regressional (b) and transgressional (c) stages; modified after Konikov (2006); (a) shows location of the studied area.

reorganization of the hydrological regime in the basin should not be excluded.

Above the shelf edge, there is no washout, and Lower Neoeuxinian beds are overlapped by Upper Neoeuxinian sediments deposited during post-LGM time (17–11 ky BP). Climate became warmer and moister than that of the Early Neoeuxinian as indicated by the replacement of pine by broad-leaved forests recognizable in pollen records (Komarov et al., 1979; Kvavdze and Dzeiranshyili, 1989). Upper Neoeuxinian sediments reach approximately the −20 m isobath across the shelf: −20 m in the northwest (e.g., Gozhik et al., 1987; Konikov, 2006), −18 m on the southern shelf of Turkey (Görür et al., 2001), −30 m on the Bulgarian shelf (Filipova-Marinova, 2006), −30 m on the Crimean (Shnyukov et al., 1985) and Caucasian (Balabanov et al., 1981; Yanko and Gramova, 1990) shelves, and −11 m in the Kerch Strait (Put', 1981). The thickness of the Upper Neoeuxinian sediments varies from 0 to 25 m (Put', 1981), and in some places (e.g., the western part of the Golitsin Uplift at the mouth of Karkinitsky Bay; see Fig. 1 for location), they are even exposed on the sea floor (Ishchenko, 1974; Tkachenko, 1974; Yanko, 1974, 1975, 1989). Lithologically, the Upper Neoeuxinian beds on the shelf are monotonous accumulations of light gray, sandy coquina and/or bluish-gray, stiff clays that fill pre-Neoeuxinian depressions and paleo-river valleys (e.g., Arkhangel'sky and Strakhov, 1938; Nevesskaya, 1965; Semenenko and Kovalyukh, 1973; Ostrovsky et al., 1977; Malovitsky et al., 1979; Balabanov et al., 1981; Skryabina, 1981; Yanko, 1982; Gozhik 1984a–d; Shnyukov et al., 1985; Voskoboinikov et al., 1985; Gozhik et al., 1987; Fedorov, 1988; Yanko, 1990a; Yanko and Gramova 1990; Glebov et al., 1996). Molluscan, foraminiferal, and ostracod assemblages are strongly reminiscent of (but not identical to) Lower Neoeuxinian assemblages, indicating a paleosalinity of approximately 5–7‰ (Yanko-Hombach, 2006) and even

11‰ (Nevesskaya, 1965), which is in good agreement with the salinity of interstitial water (Manheim and Chan, 1974; Konikov, 2006). Despite a relatively high salinity in the Late Neoeuxinian basin, no Mediterranean species are present. Instead, Caspian immigrants are abundant.

The authors and supporters of the catastrophic Early Holocene flood hypothesis cite the depth of the submerged Neoeuxinian coastline as supportive of its dating, however, the position of this coastline does not adequately reflect the true level of the Neoeuxinian lake. Reports of its depth and age vary from −155 m at 7.5–6.8 ky BP on the Turkish shelf off Sinop according to Ballard et al. (2000), −90 m at 11.8 ky BP beyond the Sakarya Valley according to Algan et al. (2006), −95 m at 10.2–8.6 ky BP on the Romanian shelf according to Lericolais et al. (2006), −100 m at the LGM MIS-2 on the Romanian shelf according to Winguth et al. (2000), −140 m at 14.7–10.0 ky BP on the northwestern shelf according to Ryan et al. (1997), −120 m at 13.4–11 ky BP on the northwestern shelf according to Ryan (2003), −100 m at 20–18 ky BP on the Crimean shelf according to Shcherbakov et al. (1978), −100 m during the Chaudinian (780 ky BP) on the Bulgarian shelf according to Krystev et al. (1990), and depths ranging from −147 to −70 m on the Caucasian, Bulgarian, and Kerchenian shelves according to Skiba et al. (1975), Esin et al. (1980), Goncharov and Evsyukov (1985), Glebov (1987), Glebov et al. (1996), and Glebov and Shel'ting (2006). Abashin et al. (1982) document the presence of shallow lacustrine facies and coastal bars covering the Early Neoeuxinian terrace that vary from −110 m in the vicinity of the Kerch Strait to −90 m in the central part of the southern Crimean shelf, and even −160 to −200 m in its western part. Such variations in elevation and age of submerged coastlines might have arisen from several factors:

(1) The impact of neotectonics (Tkachenko et al., 1970; Tkachenko, 1974; Abashin et al., 1982; Tkachenko, pers. commun., 5 January 2005) comparable in magnitude to recent events of the coastal zone in other basins, such as Izmit Bay (Sea of Marmara), where a 1999 earthquake produced local subsidence and uplift of different blocks (Öztürk et al., 2000).

(2) Use of samples (e.g., mollusk shells) from redeposited sediments for radiocarbon dating. It is well known that the distribution of fossil *Dreissena* in the Black Sea is much wider than that of living specimens. The difference between the two increases with distance from the shore, reaching its maximum on the continental slope due to reworking processes (Arkhangel'sky and Strakhov, 1938). Such processes are intensified by alternating transgressive and regressive phases and lead to the reworking of organic-rich deposits of various ages and depositional environments (Shnyukov et al., 1985; Yanko and Gramova, 1990). For example, the gravel-pebble beach sediments described by Ballard et al. (2000) as relics of the Neoeuxinian paleoshoreline at a water depth of −155 m contain a mixture of Caspian (*Dreissena, Turricaspia*) and Mediterranean (e.g., *Modiolus phaseolinus*) mollusks (see their Table 1). Yet *M. phaseolinus* immigrated into Black Sea at about 3 ky BP. Presently, it occurs at a water depth of 40–120 m under salinities ⩽18‰ (Nevesskaya, 1965). Consequently, these mollusks are ecologically incompatible and cannot occupy the same environment. Either those of Caspian or Mediterranean affinity (or both of them) must be redeposited and, presumably, transported to the bottom together with coarse material by underwater currents (Kuprin and Sorokin, 2006). A similar phenomenon was also observed on the Crimean (Arkhangel'sky and Strakhov, 1938) and Caucasian continental slope (Kuprin et al., 1985; Solov'eva and Sorokin, 1993).

In addition, species of *Dreissena*, e.g., *D. polymorpha*, *D. rostriformis*, do not indicate a Neoeuxinian sediment age, as was wrongly suggested by Ryan et al. (1997, 2003), Ballard et al. (2000), Major (2002), Algan et al. (2002), and Lericolais et al. (2004). The stratigraphic distribution of *Dreissena* is much wider, as they are found in all semi-fresh/brackish facies of the Pontic basin since the Miocene (e.g., Meotis, *D. polymorpha*) and Pliocene (e.g., Apsheron, *D. rostriformis distincta*) (Nevesskaya, 1965; Il'ina et al., 1976) to about 7 ky BP. AMS dates conducted on *Dreissena* shells and cited by the authors of the Early Holocene Flood hypothesis also show a wide age range, from 24.2 to7.9 ky BP (Major, 2002), as well as their co-occurrence with Mediterranean forms.

2. *Mediterranean transgression and migration of organisms*

Judging from core evidence (Figs. 9 and 10), the first Mediterranean immigrants appeared in Holocene sediments of the Black Sea at about 9.8–9.5 ky BP (Yanko and Troitskaya, 1987).

This date is much earlier than that suggested by both the proponents (e.g., Ryan et al., 1997) and opponents (e.g., Aksu et al., 2002a, b) of the Early Holocene Flood hypothesis. Had re-colonization of the Neoeuxinian Lake by Mediterranean organisms been rapid, a dramatic increase in Mediterranean species and specimens in the Early Holocene beds (Bugazian strata, according to Balabanov's terminology) would have been observed. Their diversity and abundance is low at the start, however, and their frequency varies upcore, almost completely disappearing in the Kolkhidian regression beds (Kh-R in Fig. 9). Such a finding contradicts any proposed scenario suggesting progressive re-colonization (e.g., Kaminski et al., 2002).

According to reliable evidence, re-colonization of the Black Sea followed a fluctuating pattern, and immigration of Mediterranean species occurred in six major waves over the course of an oscillating Holocene transgression (Balabanov et al., 1981; Yanko, 1990a; Yanko-Hombach, 2003, 2004, 2006). The strong shift in the Sr isotope signature toward marine values at

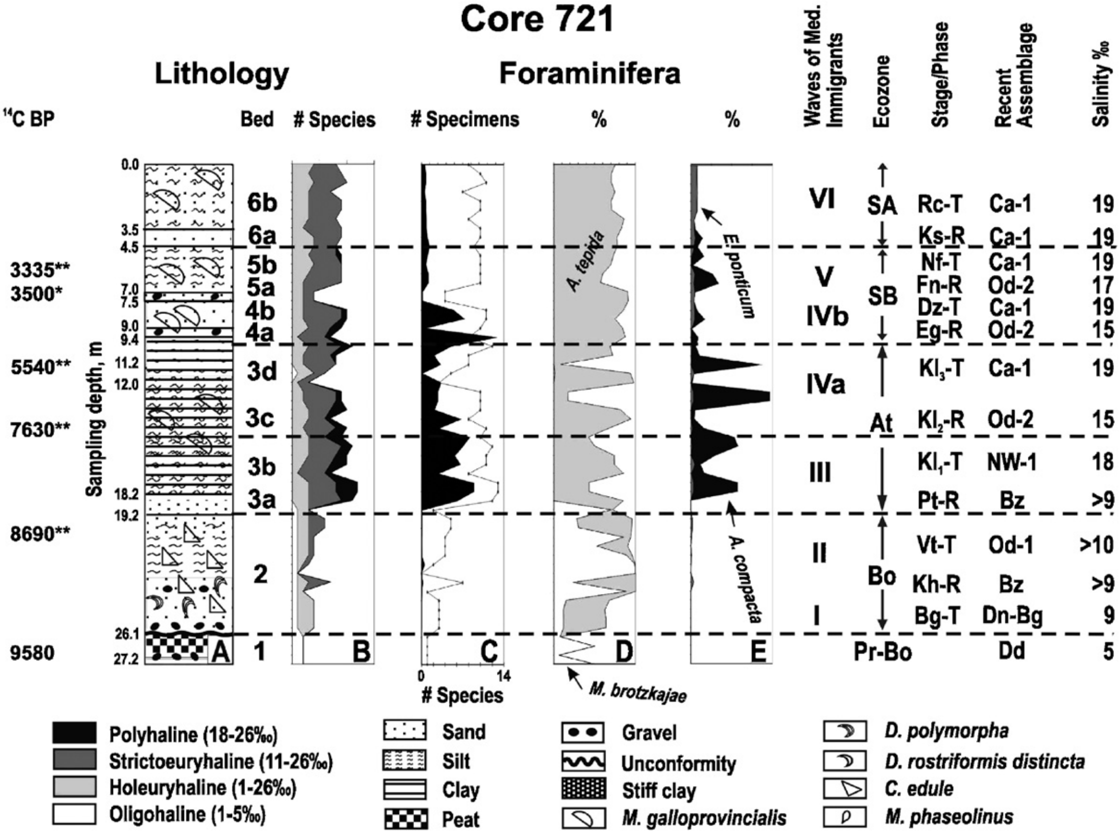

Fig. 9. Variation in the frequency of benthic foraminiferal species in Core 721 (see Fig. 8(a) for locations). I–VI = waves of Mediterranean immigration.

8.4 ky BP that Major (2002) views as signaling the beginning of re-colonization and re-connection of the Black Sea and Sea of Marmara indicates, in fact, a progressive salination of the Black Sea caused by increasing Mediterranean inflow during the second (Vityazevian) Holocene transgression. By 7.2 ky BP (the time of the alleged catastrophic flood according to the initial scenario), the Black Sea was already fully re-colonized by Mediterranean organisms. Thus, Mediterranean immigration was neither rapid nor catastrophic. The fluctuating character of the Holocene transgression is detectable only above the −50 m isobath due to the low amplitude of the regression phases. These fluctuations are distinguishable only through a high-precision and high-resolution micropaleontological analysis of sediments using a 2 cm sample interval. The analysis also requires a precise knowledge of the ecological preferences of each identified species (Yanko and Troitskaya, 1987; Yanko-Hombach, 2006). For example, it is methodologically incorrect to use *Ammonia* as an indicator of shallow and low salinity paleoenvironments as was done by Kaminski et al. (2002). At least 10 species of *Ammonia* have lived in the Black Sea, each of which has its own ecological preferences varying from oligohaline (1–5‰) to polyhaline (18–26‰) (Yanko, 1990b).

3. *Route of the Mediterranean transgression*
Today, the Bosphorus Strait is the only passage for exchange of water and organisms between the Black Sea and Sea of Marmara. This zigzagging strait is about 35 km in length, 0.7–3.5 km in width, and 35.8 m deep on average, with a few elongate potholes (about 110 m in depth each) on the bottom. It possesses two sills, one in the north at a water depth of −59 m and one in the south at a water depth of −34 m, each located about 3 km from the corresponding entrance to the strait (Fig. 11(a)–(d)). The two directions of water flow within the strait overlap each other: the northward underflow (inflow) from the Sea of Marmara has an average salinity of 38‰ and a velocity of 5–15 cm $s^{-1}$, and the southward overflow (outflow) from the Black Sea has an average salinity of 18‰ and a velocity of 10–30 cm $s^{-1}$. Due to the sills, the interface between the two flow directions rises from −50 m at the northern end to −20 m at the southern end (Fig. 11(c); Filippov, 1968). The underflow is initiated by the difference in water density between the Black Sea and the Sea of Marmara; the pressure gradient pushes against the Black Sea and acts to power the underflow (Filippov, 1968). The outflow is initiated by two main factors: (1) the 30 cm elevation of the Black Sea surface above that of the Sea of Marmara, which, in turn, is 5–27 cm above the level of the northern Aegean Sea (Polat and Tuğrul, 1996), and (2) the positive balance of the Black Sea, where precipitation (575 $km^3$ $year^{-1}$) exceeds evaporation (350 $km^3$ $year^{-1}$), producing a discharge of about 600 $km^3$ of brackish water annually (Latif et al., 1990; Özsoy et al., 1995).

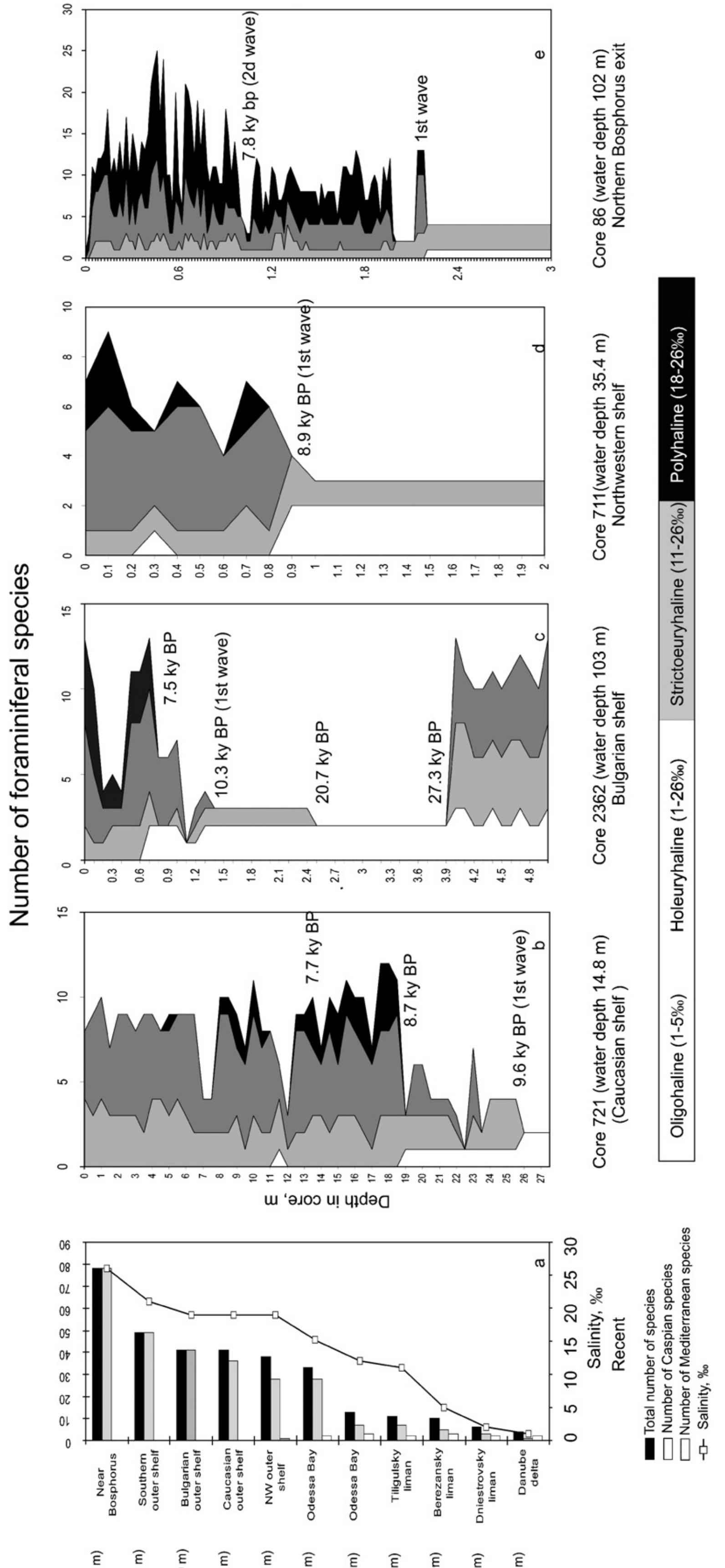

Fig. 10. Variation in the frequency of benthic foraminiferal species (and their salinity preferences): (a) = modern distribution; (b)–(e) = four cores compared (see Fig. 8(a) for locations). Note that the number of Mediterranean strictoeuryhaline and polyhaline species sharply increases with rising salinity.

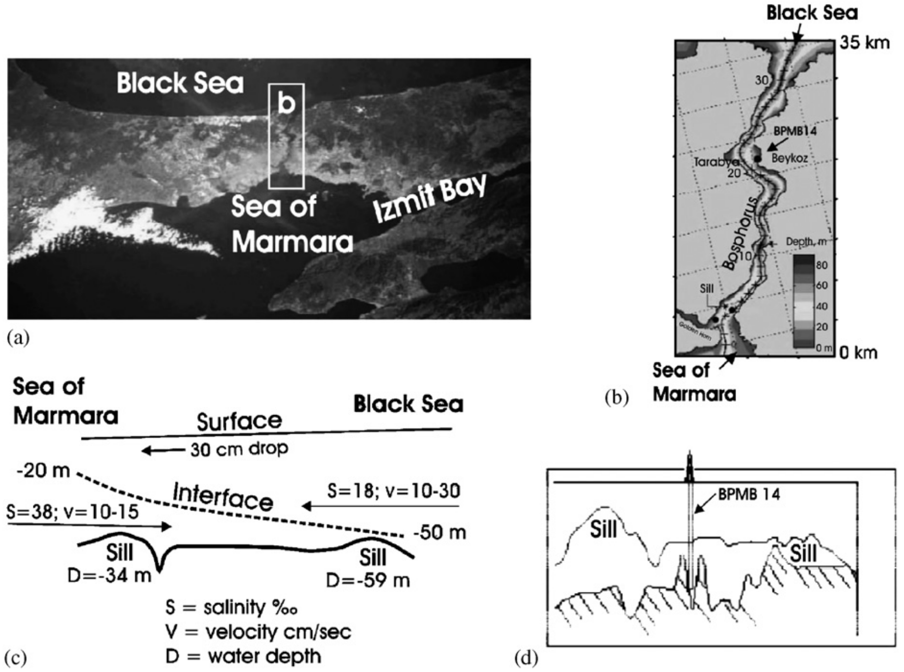

Fig. 11. Setting of the Bosphorus Strait: (a) satellite image, (b) length and water depth, (c) depth of the sills, salinity, velocity, and interface between the two directional flows, and (d) the bottom of the Bosphorus and location of borehole (BPMB) 14 (modified after Algan et al., 2001).

The underflow enters the Black Sea only if a strong wind from the south lowers the interface angle to such a degree that the north-bound water can be swept across the northern sill (Filippov, 1968; Scholten, 1974). If the Black Sea level were to drop lower than its present surface elevation, the overflow would be unable to pass through the Bosphorus because the southern sill would act as a valve or shunt system (Degens and Hecky, 1974). Thus, the two-flow regime in the Bosphorus is very sensitive to external factors.

Beneath the floor of the Bosphorus, Quaternary sediments have built up to a maximum thickness of more than 130 m in the southern part, but they exceed 100 m only within a few isolated, fault-controlled depocenters in the central part of the strait (Gökaşan et al., 1997). The faunal, sedimentological, and geophysical evidence indicates that Quaternary sediments deposited within the north-central part of the Bosphorus (Fig. 12) comprise two main units (A and B) that differ markedly in age, environmental characteristics, and provenance (Kerey et al., 2004).

In borehole BMPB 14, Unit A is represented by shelly sands and muds with Mediterranean mollusks. The radiometric age of the mollusks in the north-central part of the strait is 5300 BP, but older dates have been obtained toward the southern end of the Bosphorus, ranging from 6100 ± 1300–5100 ± 1200 BP in the Golden Horn (borehole A7) to 7400 ± 1300 BP in the southeast (borehole TB 116). Unit B is represented by a succession of lacustrine beach or coastal sands dating to 26 ± 16 ky BP, and it contains fresh to brackish water fauna of Caspian affinity (Algan et al., 2001) as well as possibly reworked Black Sea faunal elements of Middle Pleistocene age (Kerey et al., 2004). The delay between the first appearances of marine Mediterranean fauna in the north-central and southern parts of the Bosphorus is explained by Kerey et al. (2004) as the result of their separation by some sort of topographic barrier.

The Bosphorus plays a critical role in both the Early Holocene Flood and the opposing Outflow scenarios. The water depth of the northern sill is especially debated (e.g., Ryan et al., 2003). To satisfy the modified Early Holocene Flood hypothesis, it would have had to be shallow (less than 30 m deep) to decouple the second lowstand (−95 m at 10–8.4 ky BP) of the Neoeuxinian Lake from the rising world ocean. Prior to the Mediterranean transgression, however, the level of the Late Neoeuxinian Lake had already reached ∼−20 m, and the first Mediterranean immigrants appeared in the Black Sea far earlier (9.8–9.5 ky BP) than their first appearance in the central part of the Bosphorus (5.3 ky BP). Consequently, as Algan et al. (2001) have documented, any breaching of the northern Bosphorus by Mediterranean waters at 8.4 or 7.2 ky BP could not have been a first post-glacial reconnection of the two seas. The late date of immigrant mollusks in the Bosphorus contradicts the conclusions of Degens and Ross (1974) and Ryan et al. (1997), who suggest that the post-glacial Mediterranean and Black Seas were initially connected only between 9000 and 7000 years BP. Of course, it can be argued that the sediment record in the Bosphorus boreholes is incomplete and/or that the sediments in the strait were eroded during the regressions, which exposed the bottom of the strait. However, paleotopographic relief in the strait, at least below the mid-Holocene unconformity disclosed by geophysical profiles, contradicts this assumption (Kerey et al., 2004).

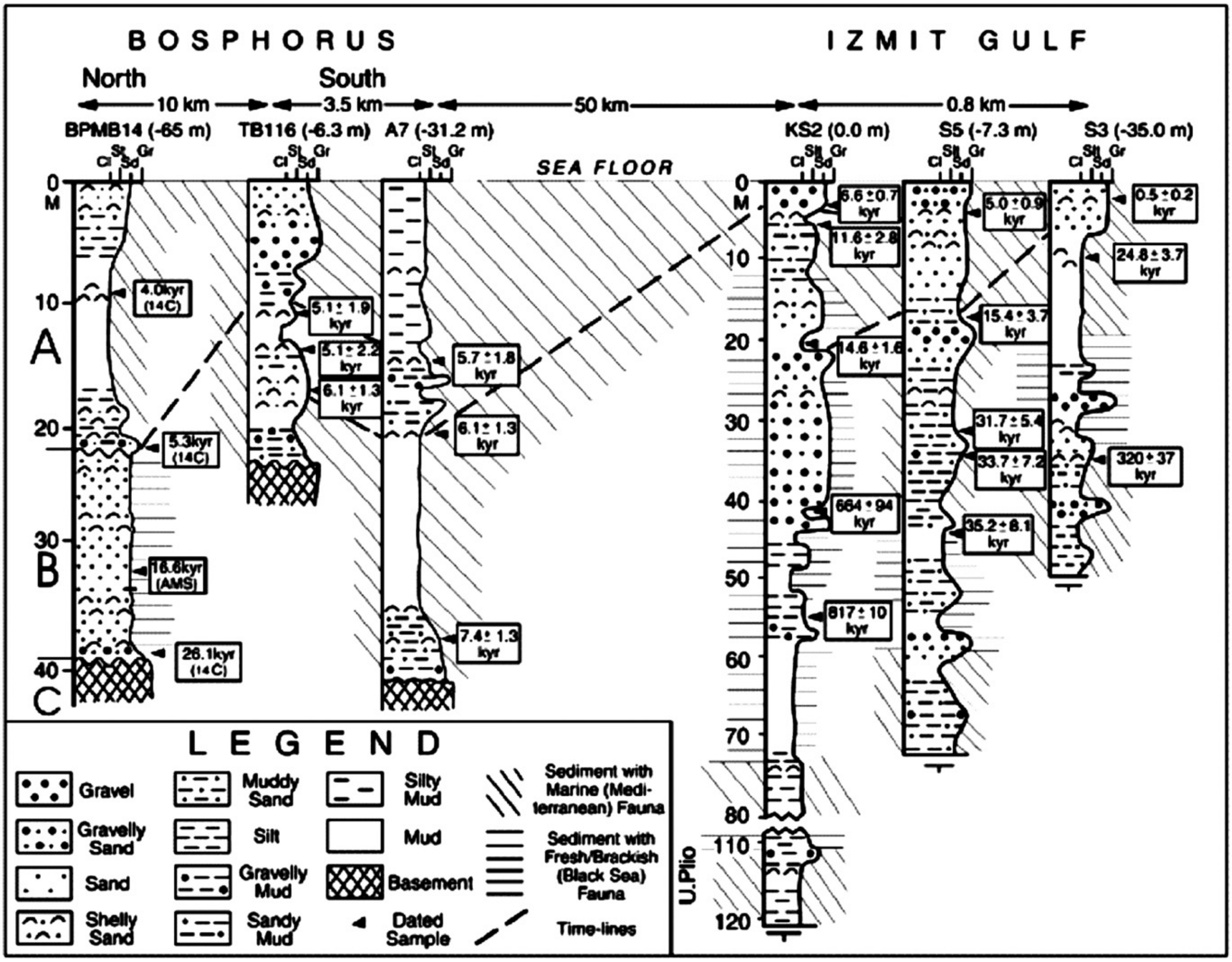

Fig. 12. Stratigraphic profiles from the Bosphorus Strait and Izmit Gulf modified after Kerey et al. (2004). (a) Mid- to Upper Holocene shelly sands and muds, 5340 + 125/−120 BP, with predominantly Mediterranean shallow fauna (Algan et al., 2001); (b) a succession of lacustrine beach or coastal sands, radiocarbon-dated to the Late Pleistocene, 26 ± 16 ky BP (Çağatay et al., 2000) but including Black Sea faunal elements of Middle Pleistocene age, which may be reworked; (c) basement. The sharp boundary between (a) and (b) represents a significant depositional hiatus and time gap. The surface separating these two major units is correlated with an unconformity recognized in geophysical profiles from the central and northern Bosphorus (Gökaşan et al., 1997).

The late appearance of Mediterranean species in the Bosphorus does not contradict the Outflow hypothesis of Aksu et al. (1999). The Black Sea had risen to a higher level than the Sea of Marmara by the end of the Pleistocene (e.g., Ostrovsky et al., 1977; Fedorov, 1978; Aksu et al., 1999), and the two pulses of outflow described by Ryan, Pitman, and co-workers coincide with the growth of two superimposed midshelf deltas, Δ2 (16–14.7 ky BP) and Δ1 (10.5–9 ky BP), documented by Hiscott et al. (2006) at the southern end of the Bosphorus Strait. Timewise, both deltas also coincide with a high Neoeuxinian lake level (∼−20 m below present), and continued brackish water outflow through the strait would have prevented the northward advection of Mediterranean water. This, in turn, could have obstructed the entry of open-marine species into the Black Sea until as late as 5.3 ky BP, the date of their earliest occurrence within the channel's bottom sediments. But by 5.3 ky BP, the Black Sea had already been successfully re-colonized by Mediterranean organisms (Yanko, 1990a; Yanko-Hombach, 2004, 2006).

According to this evidence, the Bosphorus could not have played a role in the initial water exchange or northward migration of Mediterranean organisms into the Pontic basin around 9.8 ky BP. An alternative connection between the Sea of Marmara and Black Sea should be considered, and one possible route is through Izmit Bay, Sapanca Lake, and the Sakarya Valley (Fig. 13; Brinkmann, 1976; Meriç, 1995; Kerey et al., 2004; Yanko-Hombach et al., 2004). A natural conduit following this course might have provided alternate access to the Black Sea for Marmara seawater that had been fully salinized and re-colonized by Mediterranean organisms by 12 ky BP (Hiscott et al., 2006).

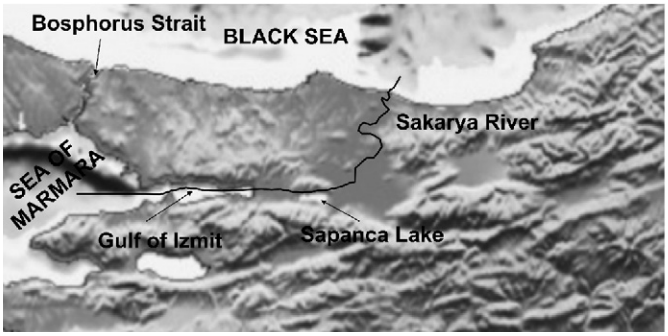

Fig. 13. The Sakarya Bosphorus: an alternative route between the Sea of Marmara and the Black Sea through Izmit Bay, Sapanca Lake, and the Sakarya Valley.

## 6. Early Holocene flood scenario: archaeology

Are there any significant cultural changes in the archaeological record of the Pontic-Caspian region during the 8.4–7.2 ky BP (7500–6000 calBC) interval that might be related to the proposed flood event?

This period corresponds to the emergence in both the North Pontic steppe and the Caucasian coastal area of Mesolithic forager groups who possessed neither domestic plants nor animals. Mesolithic food-getting strategies relied increasingly on the use of aquatic resources and harvesting of wild plant foods, and the lifestyle combined stability with seasonal transhumance. Sites cluster in landscapes with diverse and predictable wild resources, especially in marine estuaries, lakes, and river floodplains. Larger sites, some of which were base-camps inhabited on a year-round basis, were located on the marshy river bottomland of the limans, while smaller sites at higher elevations were occupied by groups budding off from the main centers during seasonal transhumance. Greater sedentism and increased territorial control are strongly indicated by the existence of communal cemeteries.

Existing evidence suggests that the principal Mesolithic cultural traditions (Kukrekian and Grebenikian) developed locally from the indigenous Paleolithic substratum. Stanko (1982) views the Central European affinities in the inventory of the Beloles'e site on the Sasyk Liman; yet, the radiocarbon age of this site (~8265 calBC) substantially predates the time of the proposed Black Sea inundation. There are no discernible signals in the archaeological record that could reflect a change in subsistence or population dynamics corresponding to the alleged time of the 'Flood', either 7400 or 6000 calBC (84.0 or 7.2 ky BP).

The earliest indications of agriculture, i.e., cultivation of cereals (barley and wheat), pulses (pea, chickpea, and lentils), and rearing of animals (goats, sheep, and later, cattle and pigs), come from the Zagros foothills in the Near East: 11,700–8400 BP (Bar-Yosef and Meadow, 1995), and correspond to the cool and dry Younger Dryas climatic period, including the subsequent rapid increase in rainfall at the beginning of the Holocene (by 10 ky BP).

During the early stages of agricultural development in the Levant, i.e., the 'Pre-Pottery Neolithic A and B', dated 10,000–8500 BP (9800–7500 calBC), a rapid increase in the number of sites is noticeable both in the foothills and adjacent plains, with the appearance of large settlements possessing complicated masonry structures (e.g., Jericho). Later, the core area of early agricultural settlements seems to shift northward to the eastern highlands and inner plateaus of Asia Minor. The most outstanding case of early agricultural development in this region is Çatal Hüyük, a Neolithic 'town' on the Konya Plain, dated about 7600–7000 BP (ca. 6500–5700 calBC) (Mellaart, 1967; Davison et al., 2006).

The earliest sites with developed agricultural economies in Europe date to 7500–7000 BP (6400–6000 calBC) and are found in the intermontane depressions of Greece (Thessaly, Boeotia, and the Peloponnese). Genetic features of the cultigens and a long list of similarities in the material culture leave no doubt about their Near Eastern origins (Perlès, 2001; Özdoğan, 2006).

Significantly, the early Neolithic sites in the Marmara basin (the 'Fiiktepe' culture) are of a somewhat later age, 7300–6700 BP (6100–5600 calBC), and are culturally distinct from the early Neolithic in Greece, which suggests (Cauwe et al., in press) that this area was settled by farming groups from the northern Balkans. The absence of early farming sites in the Marmara basin implies that the Neolithic communities penetrated the Balkan Peninsula from southern Anatolia by boat along the southern coast of Asia Minor, thus avoiding the straits.

The Neolithic spread farther afield, allegedly via the 'Strouma' axis in the northeast, and the 'Vardar-Morava' axis in the north. The ensuing development saw a rapid growth of Neolithic settlements in the lowlands of northern Thrace and the Lower and Middle Danube catchment—the 'Karanovo-Starčevo-Koros-Criş' [KSKC] cultural complex, 7100–6600 BP (5900/5800–5500 calBC).

The next stage in Neolithic development corresponds to the emergence of early Linienbandkeramik (LBK) sites on the Danube Plain at about 6800 BP (ca. 5700 calBC). At a later stage, LBK sites spread widely over the loess plains of Central Europe, mostly along the Danube, Rhine-Mainz, and Vistula axes. This spread occurred at a very rapid rate (averaging ca. 6 km per year) within the interval of 6700–5900 BP (5600–4800 calBC) (Dolukhanov et al., 2005). The spread of early agricultural communities farther east into the forest-steppe areas of the East European Plain was witnessed at the sites of Cucuteni-Tripolye, between 5600–5300 BP (4500–4300 calBC). All the above-mentioned groups demonstrate cultural affinities with the early agricultural communities of Western Asia, and thus they imply migrations or other cultural influences stemming from that area.

The above evidence demonstrates that neither the initial nor the modified dates of the alleged Early Holocene Flood correlate with any major shifts in culture or subsistence of prehistoric groups in Western Asia or Eastern Europe that might be linked to the spread of farming. The earlier date, 8.4 ky BP (7400 calBC) of Ryan et al. (2003), corresponds to a time when agriculture was restricted to the Levant and Zagros Mountain flanks, and all areas of the Black Sea region were occupied by Mesolithic hunter-gatherers, among whom no recognizable changes hint at an environmental catastrophe. The later date, 7.2 ky BP (6000 calBC) of Ryan et al. (1997), postdates the spread of farming communities in the greater Balkan Peninsula, and the expansion of farming groups in the northern Pontic area occurred at least 1500 years later. According to present evidence, Late Paleolithic and early Neolithic human populations apparently adapted successfully to all drastic changes in climate or coastline that might have occurred.

Significantly, periods witnessing major expansion of farming communities in the northwestern and northern Pontic area coincide with minor Black Sea transgressions (Anthony, 2006; Dergachev and Dolukhanov, 2006; Dolukhanov and Shilik, 2006). These sea-level rises did not exceed more than a few meters above present-day sea level and resulted in the inundation of only the lower stretches of rivers and the formation of estuaries (limans), so it is difficult to assign to them any critical or direct causal impact that could effect forced migration. Changes brought on by minor transgressions would probably have extended the feeding ground for Mesolithic hunter-gatherers, who were largely oriented toward marine resources. Furthermore, farming settlements were always located at higher elevations, which would not have been appreciably affected by minor coastline shifts. The expansion of agricultural areas was due more likely to general precipitation increases in the river catchment areas, and the consequent enhancement of their agro-climatic potential in the steppe and forest-steppe. Hence, no signs of sudden demographic movement, no shifts in material culture, subsistence economy, or settlement types, and no indications of new technologies emerging any time between 8.4 and 7.2 ky BP are observable that can be interpreted as indicating massive migrations outward from a flooded Black Sea basin (Anthony, 2006). Archaeological documentation does not support the Early Holocene Flood hypothesis in the Black Sea.

## 7. Conclusions

At the LGM, the Black Sea was a semi-fresh to brackish (but never freshwater) lake of Neoeuxinian age with a level ~100 m below present. At the time, it was isolated from both the Caspian Sea and the Sea of Marmara. In the warming climate of about 17 ky BP, multiple factors (e.g., massive water discharge from the melting of the Scandinavian ice sheet, river megafloods, and permafrost melting, probably from the Caspian Sea via the Manych Spillway) increased the level of the lake to ~−20 m. Excess semi-fresh water from the lake spilled into the Sea of Marmara, which conducted the discharge into the Mediterranean.

After about 9.8 ky BP, the level of the Black Sea never again dropped below the −50 m isobath, nor did it exhibit a maximum amplitude of fluctuation greater than about 20 m. The brackish lake was ultimately transformed into a semi-marine basin by a process that was neither rapid, nor gradual, nor catastrophic. Instead, it occurred in an oscillating manner, permitting periodic immigration of Mediterranean organisms into the Pontic basin. The first wave of immigration occurred at about 9.5 ky BP, a date much earlier than that proposed in the Early Holocene Flood scenario. The re-colonization was slow at the beginning and became more pronounced by 7.2 ky BP, finally reaching its climax between 6.0 and 2.8 ky BP. Most likely, the initial post-glacial connection between the Black Sea and Sea of Marmara was not through the Bosphorus Strait. An alternative route through Izmit Bay, Sapanca Lake, and the Sakarya River could have existed at the time.

During the last 10,000 years, water level in the Black Sea rose gradually, but in an oscillating manner, occasionally rising higher but eventually attaining its present situation. Its rate of increase averaged 3 cm 100 $\text{years}^{-1}$ but certainly not 15 cm $\text{day}^{-1}$ (almost 55 m $\text{year}^{-1}$) as was postulated by the Early Holocene Flood hypothesis. A sea-level increase of 3 cm 100 $\text{years}^{-1}$ would not have been noticed in the short term by people residing in coastal areas and would not have forced their dispersal into the interior of Europe. This evidence contradicts the suggestions of Ryan et al. (1997, 2003) and Ryan and Pitman (1998) that an intensive inland migration of cultural groups from the Pontic Lowland began sometime between 8.4 and 7.2 ky BP. On the contrary, there is indirect evidence that the beginning of the Holocene transgression coincided with human migration in the opposite direction, that is, from the Mediterranean area into the Pontic Lowland (Özdoğan, 1999).

Although the Late Pleistocene Flood scenario has a much stronger geological and paleontological basis in evidence, reliable archaeological indications do not yet demonstrate that such flooding had a major impact on human groups of the time. Barring new and more compelling data, one must conclude that the Early Holocene Black Sea "Flood" represents a contemporary legend. The intriguing geological and archaeological history of the Pontic region deserves more research and will eventually reward exploration with new discoveries, but media portrayals of a catastrophic turning point in human history on the scale of the biblical deluge have diverted serious attention away from its real geographical and cultural importance. The public perception that "Noah's Flood" happened there is not supported by any scientific evidence.

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