20

Was the Black Sea Catastrophically Flooded during the Holocene? – geological evidence and archaeological impacts

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Two hypothetical flood scenarios have been proposed for the Black Sea, describing events that may have profoundly affected prehistoric settlement in Eastern Europe and adjacent parts of Asia. The first, a Late Pleistocene 'Great Flood' (Chepalyga 2003, 2007), suggests that the brackish Neoeuxinian Lake in the Black Sea basin was rapidly inundated by Caspian Sea overflow via the Manych Spillway shortly after the Late Glacial Maximum (LGM), c. *17–14 ka BP. The second, an Early Holocene 'Noah's Flood', proposes catastrophic inflow of Mediterranean seawater to a Black Sea freshwater lake at either 7.2 ka BP (Ryan* et al. *1997) or at 8.4 ka BP (Ryan* et al. *2003) when an abrupt sea-level jump accompanied the Laurentide Ice Sheet collapse (Turney and Brown 2007). These hypotheses claim that massive inundations of the Black Sea basin, and ensuing large-scale environmental changes, drastically impacted early societies in coastal areas, forming the basis for Great Flood legends and other folklore, and accelerating the spread of agriculture into Europe. We summarize the geological, palaeontological, palynological, and archaeological evidence for prehistoric lake conditions, vegetation, climate, water salinity, and sea-level change, as well as submerged prehistoric settlements, agricultural development, coastline migration, and hydrological regimes. Comprehensive analysis shows that the Late Glacial inundation in the Black Sea basin was more prolonged and intense than the Holocene one, but there is no underwater archaeological evidence to support any catastrophic submergence of prehistoric Black Sea settlements during the Late Pleistocene or Early Holocene intervals.*

Keywords: archaeological oceanography, megaflood, Neolithic catastrophe, palynology, foraminifera

Introduction

The Black Sea is the world's largest anoxic (oxygen-free) marine basin. Its strongly stratified water column possesses (1) a thin, well-oxygenated surface layer (20–30 m) with low salinity and warm temperatures, (2) a low-oxygen (suboxic) transition layer (30–150 m), and (3) a thick bottom layer of colder, denser, and more saline water lacking oxygen but high in sulphides. Few organisms feed on organic material in its oxygen-starved depths; thus the uniquely favourable underwater environment preserves archaeological material, like shipwrecks, creating the world's largest underwater museum (Ballard *et al.* 2008).

Over geologically recent time, the Black Sea has been intermittently linked to the global ocean through narrow, shallow straits at each end of the Marmara Sea (Fig. 20.1). Its surface area has waxed and waned greatly with climate

Figure 20.1: Map of the Caspian–Black Sea–Mediterranean Corridor showing the topography and major rivers. Dotted yellow lines show the study area of IGCP 521-INQUA 0510 projects. Names of important archaeological sites mentioned in the text are given along with locations of cores 721 and MAR02-45

and sea-level changes. During glacial times of low global sea level, the Black and Marmara seas were isolated from the Mediterranean, becoming inland lakes comparable to the present Caspian Sea (Fig. 20.1). The history of isolation and marine reconnection of the Black Sea, and its impact on regional human occupation and development have been the concern of projects IGCP 521 and INQUA 501 (Yanko-Hombach and Smyntyna 2009). Both projects focus on climate, sea-level change, and coastline migration in the Caspian–Black Sea–Mediterranean corridors during the past 30,000 years, testing hypotheses about catastrophic flooding in the Black Sea. Did abrupt sea-level and salinity changes disperse early cultures, or did gradual and oscillating changes permit people to adapt? Did climate and sea-level dynamics affect the activity of late Palaeolithic hunter-gatherers as well as the later mercantile ventures that moved raw materials and luxury goods between the Mediterranean and hinterlands of Europe and Asia? Catastrophic is defined here as 'very rapid (annual–decadal scale), irreversibly destructive events; any large and disastrous event of great significance; a disaster beyond expectations' (Grishin 2001: 895).

Two abrupt flood scenarios have been proposed for the Black Sea. The first, or Late Pleistocene 'Great Flood' of Chepalyga (2003, 2007) – the CH hypothesis – states that the brackish Neoeuxinian Lake in the Black Sea basin filled rapidly with Caspian Sea brackish overflow via the Manych Spillway shortly after the Late Glacial Maximum, 17–14 ka BP. The second, or Early Holocene 'Noah's Flood' of Ryan *et al.* (1997) and Ryan and Pitman (1998) describes a catastrophic inundation of the Neoeuxinian Lake by inflow of Mediterranean salt water at either 7.2 ka BP (RP1 hypothesis) or 8.4 ka BP (RP2 hypothesis: Ryan *et al.* 2003; Ryan 2007). Turney and Brown (2007) suggest that a jump in sea level was triggered by the Laurentide Ice Sheet collapse (TB hypothesis). These hypotheses propose that the massive inundations of the Black Sea basin and ensuing environmental changes profoundly impacted prehistoric humans in surrounding areas and formed the basis for Great Flood legends. In this chapter, we review the geological, palaeontological, palynological, and archaeological evidence to determine whether it supports an abrupt Holocene flood scenario, or a gradual, fluctuating Holocene sea-level rise (Hiscott *et al.* 2007a, 2007b; Yanko-Hombach 2007a, 2007b) following the megafloods of the Late Pleistocene deglaciation (Chepalyga 2003, 2007).

Previous underwater archaeological studies

Blavatsky (1972) provided the first English language review of underwater archaeological studies in the Black Sea, describing submerged

Graeco-Roman ruins at water depths of 4–8 m near the Azov Sea entrance and in Taman Bay, near Phanagoria (Fig. 20.1). Similar submerged historical archaeological sites were found in the Bug River estuary, Olbia Pontica (Kryzhitskiy *et al.* 1999) in the Dniester estuary, ancient Tyras (Samoilova 1988), and off the southeastern Crimean Peninsula (Bolikhovskaya *et al.* 2004). None of these studies reported any submerged prehistoric settlements.

Dimitrov and Dimitrov (2004: 45–52) reviewed underwater archaeological studies related to a 'Varna Culture' that appeared near the present-day coast of Bulgaria around 5000 BC (assumed to be 'cal BC' but not identified as such in the publication). Drowned settlements in Lakes Durankulak and Varna were dated to 5270 BC (Dimitrov and Dimitrov 2004: 49) by correlation with dated settlements on their shores. They claimed that, 'Before the Flood [about 7600 years ago], Neolithic people inhabited not only today's coast but also that part of the bottom (called the shelf) which was land' (Dimitrov and Dimitrov 2004: 51). So far, however, drowned prehistoric archaeological sites have only been found close to the present Black Sea shore of Cape Shabla north of Varna and in Lake Varna, in water less than 10 m deep (Peev 2009). The Shabla site was indirectly dated to the Eneolithic by correlation with the sea-level curve of Peychev and Peev (2006), and submerged settlements in the coastal Varna–Beloslav Lake were indirectly dated to the Late Eneolithic and Early Bronze Age (Peev 2009: 91).

Coleman and Ballard (2007: 677) reviewed evidence for submerged palaeoshorelines in the southern and western Black Sea and their implications for prehistoric inundation. Despite clusters of Neolithic to Bronze Age sites near the present coastline, evidence of prehistoric occupation at water depths greater than 10 m is restricted to one ceramic plate of debatable Neolithic age from a depth of 90 m off Varna, and photographs of boulders at 90 m depth off Sinop (Fig. 20.1) possibly related to human habitations along a shoreline inundated during the Neolithic, over 8000 years ago (Ballard *et al.* 2001). In fact, underwater artefacts and shipwrecks recovered to date from this region are of historical age (Ward and Ballard 2004; Ward and Horlings 2008). However, Algan *et al.* (2009) found archaeological remnants of a Neolithic culture in Istanbul dating between 8.4 and 7.3 ka BP, indicating shoreline occupation when sea level was 6 m lower than today. These Archaic Fikirtepe pottery sherds are immediately overlain by Early Iron Age artefacts, associated with mollusc shells that were ^{14}C dated to *c.* 3.3 ka BP.

In summary, in spite of decades of searching for submerged prehistoric habitations on the previously subaerially exposed shelves of the Black Sea, there have been no definite finds below a water depth of 10 m, and all reports of Neolithic settlements are based on debatable Early Holocene sea-level estimates.

In this chapter, we outline the geological, palaeontological, and palynological methods used to study Late Glacial to Holocene sea-level and climate changes in the Black Sea. We also summarize the scientific evidence for catastrophic inundation scenarios, the counter-evidence for gradual and oscillating sea-level rise during Late Mesolithic and Neolithic times, and the archaeological impacts implied by the different hypotheses.

Methods

Fieldwork

Geological data presented here were obtained during large-scale surveys of the Black Sea after 1973, using standard modern survey and sampling methods. The surveys accumulated vast databases of stratigraphic, sedimentological, geochemical, and palaeontological information on Pleistocene–Holocene deposits, supported by correlation of bottom sediments with key marine stratotypes (Yanko 1990a) and onshore alluvial and loess sections. Surveying was performed from ships using seismic profiling and seafloor sampling from which hundreds of boreholes, piston, and gravity cores were collected and studied (e.g. Balabanov *et al.* 1981; Shnyukov 1984; Yanko 1990a; Aksu *et al.* 2002a; Hiscott *et al.* 2002; Balabanov 2007, 2009; Ryan 2007). Ultra high-resolution seismic surveys (e.g. Hiscott *et al.* 2007b: 21) also mapped the seafloor (to 50–100 m depth) and sediment cover on a centimetre scale to locate core sites with thick sediment sequences (Fig. 20.2) using a Huntec deep tow system (DTS) boomer profiler. The survey lines were spaced 2–4 km apart, and DTS profiles have a depth resolution of 15–30 cm. During the surveys, seabed surface samples were taken by grab samplers, together with measurements of seawater temperature and salinity to link modern faunas and floras with concurrent oceanographic

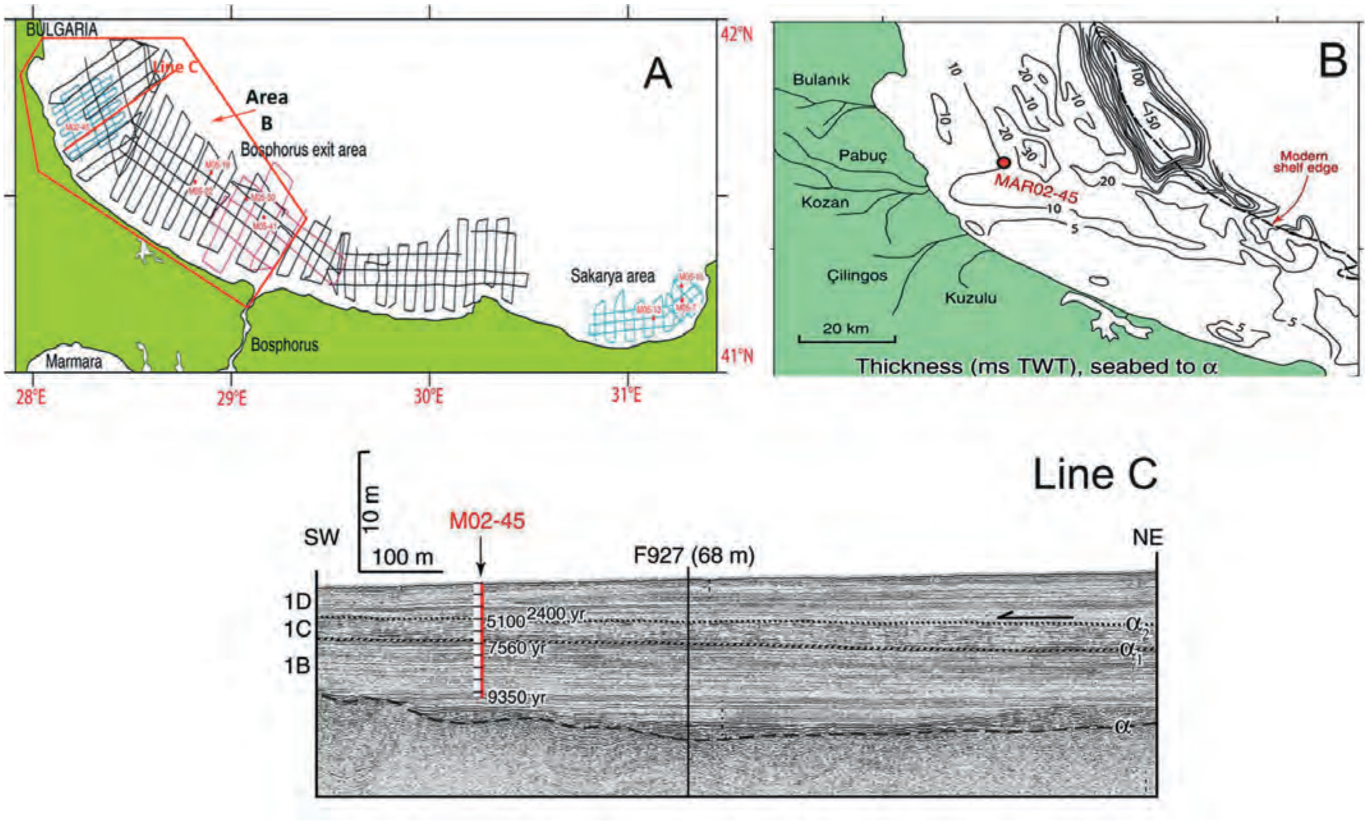

Figure 20.2: Ultra high-resolution seismostratigraphic survey data from the southwestern Black Sea shelf, showing A) line coverage on the southwestern Black Sea Shelf; B) reconstructed sediment thicknesses for the shelf within Area B; and C) a representative profile of sediments along Line C above the a and a-1 unconformities (from Hiscott et al. *2007b); ms TWT = milliseconds of two-way travel time*

conditions. Sediment cores were routinely logged for colour, texture, and structure, presence of shell, wood, and peat. Subsamples were taken for studies of molluscs, foraminifera, coccoliths, ostracods and (rarely) diatoms, and also for palynological studies, including pollen, fern and moss spores, algal spores, fungal remains, and charcoal analysis. Subsamples were also taken for geochemical analysis of oxygen isotope ($\delta^{18}O/^{16}O$) and stable carbon isotope ($\delta^{13}C/^{12}C$) ratios, total carbon, sulphur, and sometimes trace elements, e.g. iron, manganese, magnesium, barium, titanium, and strontium.

Foraminifera

Foraminifera inhabit all marine environments. Planktonic foraminifera live in near-surface water (*c.* 30–100 m depth), and benthic foraminifera live in and just above seabed sediments. Planktonic foraminifera occur in the Aegean and Marmara seas but not in the Black Sea; they are described by Aksu *et al.* (1995a, 2002b) and used to estimate past surface temperature and salinity from oxygen isotopic data. Benthic foraminifera in the Marmara Sea were described by Alavi (1988) and Kaminski *et al.* (2002). Their oxygen and carbon stable isotopes were used (Yanko *et al.* 1999; Aksu *et al.* 2002b) to reconstruct the palaeoceanography of this gateway, including two-way water mass exchange between the Black and Mediterranean seas.

Benthic foraminifera in the Black Sea have been described and supplemented with ecological data (Yanko and Troitskaya 1987; Yanko 1990a, 1990b). In the Black Sea, 101 recent foraminifera species live on the shelf only, with a few living down to 220 m; 86% have a Mediterranean genesis. In the Caspian Sea, 26 mostly endemic species live down to 70 m. The ecostratigraphic alternation in foraminiferal assemblages (Fig. 20.3) mainly reflects responses to isolation and reconnection to the Marmara and Caspian seas as related to sea-level and salinity oscillations (Yanko-Hombach 2007a). The classification of Tchepalyga [Chepalyga] (1984) delineates five palaeobasin salinity categories: fresh <0.5‰, semi-fresh 0.5–5‰, brackish 5–12‰, semi-marine 12–30‰, and marine 30–40‰.

It should be noted that the *UNESCO Practical Salinity Scale* of 1978 (PSS78) is now always used in preference to parts per thousand (‰). The PSS defines salinity in terms of a conductivity ratio, and so is dimensionless. On the PSS open ocean salinity is generally in the range 30–40,

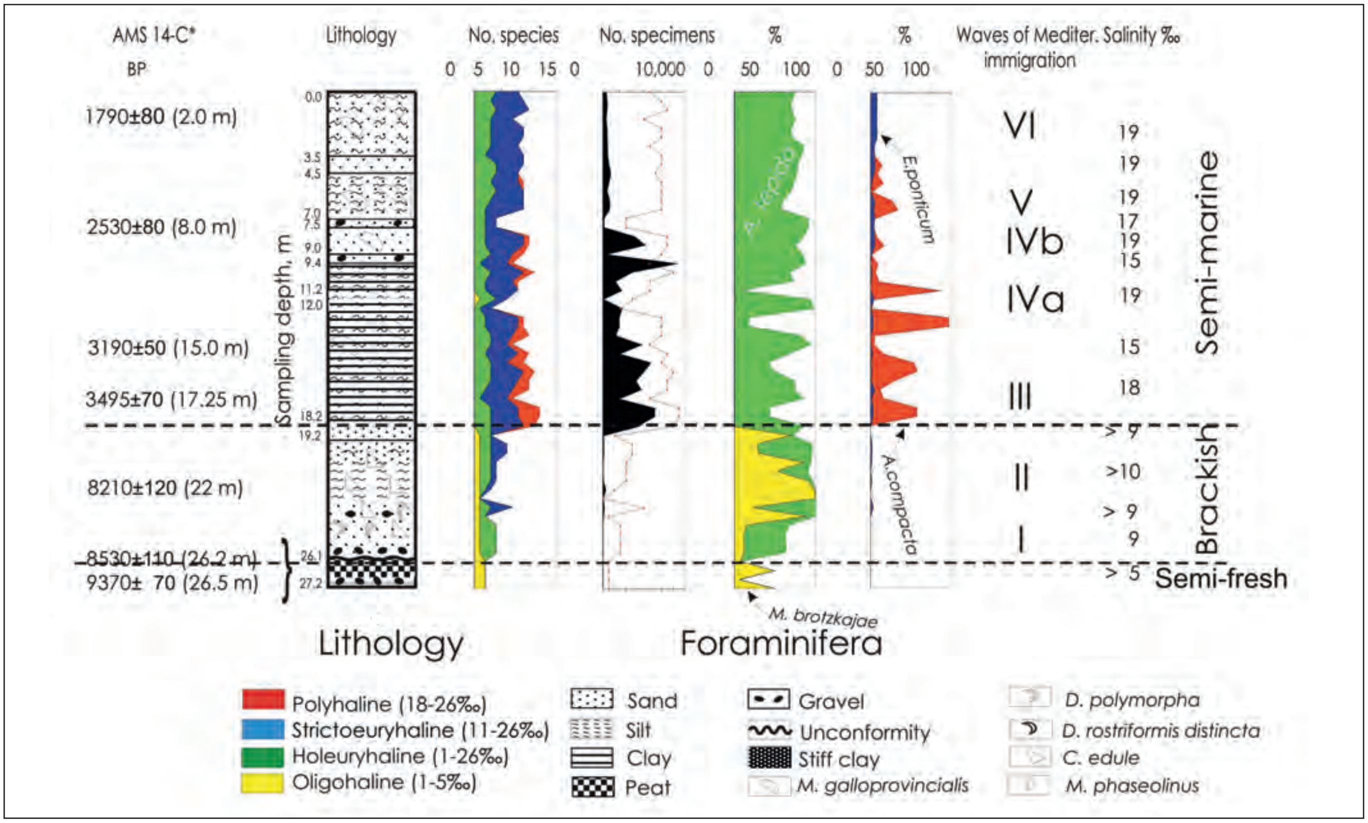

Figure 20.3: Diagrams showing changes in Core 721 recovered at 14.9 m below MSL in Sukhumi Bay (see Fig. 1 for location): (a) lithology, (b) number of species, (c) number of specimens, (e) percentage of dominant foraminiferal species; I–VI waves of Mediterranean immigration (Modified after Yanko-Hombach 2007a; AMS ^{14}C data from Nicholas et al. *2009)*

while brackish seas/waters have salinity in the range 0.5–12. Approximately equivalent values expressed in ppt are 30–50‰ (open sea) and 0.5–30‰ (brackish sea). In this chapter, when salinity is reported without ‰, it refers to the PSS (Mudie *et al.* 2011).

Coccoliths and ostracods

Black Sea shelf sediments younger than *c.* 3.4 ka BP contain low diversity coccolith assemblages (mostly *Emiliania huxleyi*), which live in the surface water (0–20 m) and are used to determine temperature and salinity from their alkenones and DNA. The pre-2.72 ka BP coccolith record is sparse (Jones and Gagnon 1994); consequently, coccoliths cannot be used to reconstruct palaeoceanographic conditions during the Neolithic. Benthic ostracods are relatively abundant back to about 8.5 ka BP on the southwestern Black Sea shelf (Hiscott *et al.* 2007a), and Caspian marker species have been used to fix shelf water salinity at 5 during the Early Holocene (Hiscott *et al.* 2007b).

Palynology

Direct evidence for Neolithic agriculture on formerly subaerially exposed shelves of the Black Sea can come only from palynological studies of cores taken from submarine sediments. Details of such Black Sea cores were described by Mudie *et al.* (2002a, 2002b, 2004, 2007), Atanassova (2005), Filipova-Marinova (2007) and Marret *et al.* (2009), who have established a succession of pollen zones for the Late Pleistocene–Holocene. Some marine pollen zones have been cross-correlated with the pollen zones of surrounding upland areas to reconstruct circum-basin temperature and precipitation conditions during the past 20 ka (Cordova *et al.* 2009). However, correct chemical extraction methods in marine palynology are essential because use of the standard acetolysis method greatly biases dinocyst assemblage composition. Here, we use only reliable data from dinocyst studies that employed the cold HCl and HF extraction method (Mudie *et al.* 2007). We also use dinocysts to estimate sea-surface salinity based on the correlation between percentages of *Spiniferites cruciformis* and salinity estimates using oxygen isotope data from planktonic foraminifera (Mudie *et al.* 2001). Recently, variations in spine length of the dinocyst *Lingulodinium machaerophorum* have been correlated with salinity and temperature at 30 m water depth (Mertens *et al.* 2009) and used to calculate salinity when temperature is known. *L. machaerophorum* is present throughout most of the Black Sea Holocene sediment section (Marret *et al.* 2009; Verleye *et al.* 2009).

Radiocarbon dating

All radiocarbon dates in this chapter are in uncalibrated years BP unless indicated otherwise as 'cal BP'. Calibrated ages use the IntCal04 (Reimer *et al.* 2004) and Marine04 curves of Hughen *et al.* (2004). We prefer conventional ^{14}C ages because (1) uncertainty surrounds the marine reservoir correction required for Black and Caspian seawater, where living molluscs are much older or younger than the global ocean average of +410 years used for the calibration curves, and (2) controversy and compounding of error are introduced when the early Black Sea lake is classified as 'freshwater' requiring no marine reservoir correction. Abundant data indicate that this lake was brackish with salinity of 5–12 (Nevesskaya 1965; Chepalyga 2002a, 2002b, 2007; Hiscott *et al.* 2007b; Yanko-Hombach 2007a, 2007b).

Results

Evidence for the CH hypothesis

Chepalyga (2003, 2007) first suggested the CH hypothesis and later provided detailed geological, geomorphological, sedimentological, and palaeontological evidence for flooding in the Ponto-Caspian Basin between 17 and 14 ka BP. Palaeoclimate was reconstructed from lake pollen records and oxygen isotopes from molluscs of the flooded Ponto-Caspian basin. The CH hypothesis describes a Late Pleistocene Great Flood during the Caspian Early Khvalynian stage, when water level in the basin rose 180–190 m, and a cascade of Eurasian Basins (the Vorukashah Sea) extended from the Aral to Aegean seas, connected via the former Uzboy and Manych–Azov–Kerch spillways as well as the current Bosporus and Dardanelles straits (Fig. 20.4).

The cascade inundated *c.* 1.5 million km^2 with a volume of *c.* 700,000 km^3 of semi-fresh to brackish water (about twice the present annual river inflow to the Black Sea), leaving traces on coastal plains, river valleys (megafloods), watersheds (thermokarst lakes), and slopes (solifluction) (Chepalyga 2007: 119). Yanko-Hombach *et al.* (2007) summarized evidence for the CH scenario and provided micropalaeontological data; Dolukhanov and Arslanov (2007) reviewed the archaeological and palaeoecological evidence, including pollen records from lakes north of the Black Sea. Vast amounts of meltwater originated from the Scandinavian ice sheet, river megafloods, and permafrost melting; lower evapotranspiration rates during the colder Late Glacial period were also postulated (Fig. 20.5). The Late Khvalynian water level rose by 50 m (Fig. 20.6), and outburst flooding from Altai Mountain ice-dammed lakes may also have contributed to early Holocene drainage into the Aral and Caspian seas (e.g. Reuther *et al.* 2006).

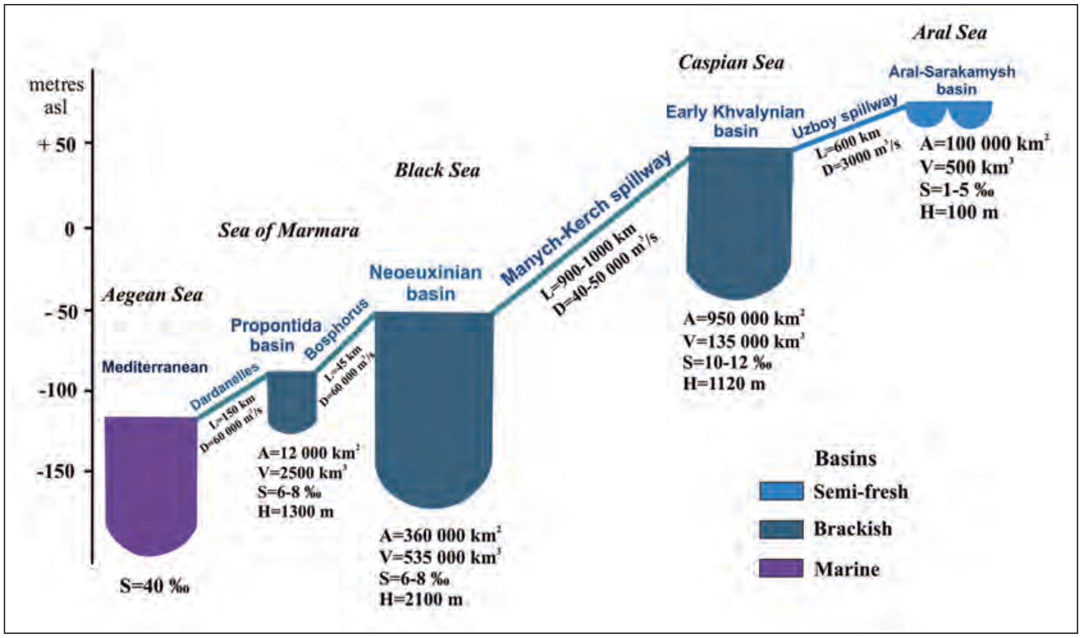

Figure 20.4: Cascade of Ponto-Caspian Great Flood basins (after Chepalyga 2002). A = basin surface area, V = volume, S = salinity, H = water depth, L = length of connected straits, D = speed of water current in the straits

The Early Khvalynian basin could not retain all the inflowing water, so excess was discharged through the Manych–Azov–Kerch Spillway into the Late Neoeuxinian Lake (Fig. 20.6) with an estimated speed of about 1000 km^3 per year – three times faster than the present river discharge. The water influx raised the Late Neoeuxinian Lake level 60–70 m, and then spilled into the Sea of Marmara. The drastic changes in sea level and coastal inundation (up to 10–20 km/year) submerged extensive floodplain areas, possibly forcing migrations of Palaeolithic people into 'safe areas' and stimulating cultural advances. This flow pattern was traced by following the distribution of 'chocolate clays' (cf. Ryan *et al.* 2003), loams and sands of 20–30 m thickness, containing endemic Caspian molluscs *Didacna, Monodacna, Adacna, Hypanis*, and foraminifera *Mayerella brotzkajae* and *Ammonia caspica* (Yanko-Hombach *et al.* 2007: fig. 5) across all the basins from the Caspian Sea to the Dardanelles Strait.

Evidence for the RP hypothesis

The RP flood hypothesis was introduced by Ryan *et al.* (1997) as an abrupt drowning of the Black Sea shelf; shortly thereafter, it appeared in a book (Ryan and Pitman 1998) that was heavily criticized by archaeologists for its speculations on 'sensational issues, such as Noah's Flood, the origin of the Sumerians, and the beginnings of agriculture and civilization' (Özdoğan 2007: 652).

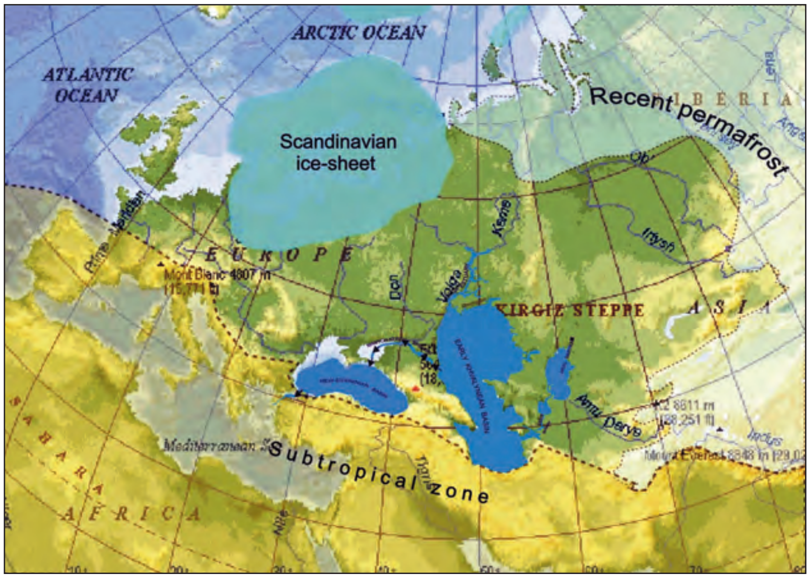

Figure 20.5: Area inundated by the Great Flood events (after Chepalyga 2007). Dotted line marks the northern boundary of the present subtropical climate zone

Figure 20.6: Map showing the sequence of Ponto-Caspian Great Flood basins (after Chepalyga 2007)

The general survey areas on the Black Sea's northern shelf were identified, but these seminal catastrophic flood publications gave no details on the methods used. The book mentioned a CHIRP (Concentrated High Intensity Radar Pulse) system that penetrated to a sub-bottom depth of 10 m. Later, Ryan *et al.* (2007: fig. 1) published high-resolution profiles of the outer shelf with a seismogram of a linear sandy ridge and riverbed fill at 65–70 m depth on the Danube shelf. Seven low-resolution cores about 1.25 m long formed the basis for the RP hypothesis. No details of the cores were given aside from the well-preserved euryhaline marine molluscs (*Cardium edule*, *Mytilaster lineatus*, *Mytilus galloprovincialis*, *Hydrobia ventrosa*, and *Abra ovata*) in soft sediment just above a stiff basal clay layer. AMS radiocarbon ages for the first three of the above molluscs yielded a conventional radiocarbon age of 7100±100 BP (OS-2323) for the shell layer in water depths of 49–123 m below MSL. Ryan *et al.* (1997: 122–3) extrapolated the age of the stiff clay from dredged shells of *Dreissena rostriformis* that they called freshwater 'Caspian' molluscs, although Nevesskaya (1965) indicated that the species tolerates salinities up to 12‰, as do co-existing molluscs (*Monodacna caspia*), ostracods (*Leptocythere bacuana*), and foraminifera (*Mayerella brotzkajae*) (Shornikov 1972; Yanko and Gramova 1990). These *D. rostriformis* shells came from shelf sediments below a gravel layer, and bleached fragments yielded ages from 14,700±65 (OS-2360) to 10,400±55 BP (OS-2358), though in other cores (Major *et al.* 2006) the ages were as young as 8250±35 BP (Major 2002). The stiff clay contained plant material, fluvial gastropods (*Viviparus viviparus*), desiccation cracks, and other features suggesting alluvial to coastal marsh environments.

Ryan *et al.* (1997: 123) then correlated their low-resolution cores with short gravity cores from deeper-water areas studied by Jones and Gagnon (1994), and they extracted dinoflagellate, foraminiferal, and diatom data from studies of Wall and Dale (1974), Meriç and Sakınç (1990), and Shimkus *et al.* (1973) to compile a figure (Ryan *et al.* 1997: fig. 3) apparently showing an abrupt transition from 'freshwater' to euryhaline marine faunas and floras. Despite the low resolution of their geophysical surveys and palaeontological studies, and extrapolation of results from incomplete early work on dinoflagellate cysts (dinocysts), benthic foraminifera and diatoms, they considered that their findings complemented descriptions of emergent land surfaces with loess soils, littoral deposits, and beach terraces in shelf formations spanning 17.78–9.66 ka BP at depths of 93–122 m. Ryan *et al.* (1997: 119) outlined the first [RP1] catastrophic flood hypothesis (Fig. 20.7) as follows:

> 'During latest Quaternary glaciation, the Black Sea became a giant freshwater lake. The surface of this lake drew down to levels more than 100 m below its outlet. When the Mediterranean rose to the Bosporus sill at 7,150 yr BP, salt water poured through this spillway to refill the lake and submerge, catastrophically, more than 100,000 km^2 of exposed continental shelf. The permanent drowning of a vast terrestrial landscape may possibly have accelerated the

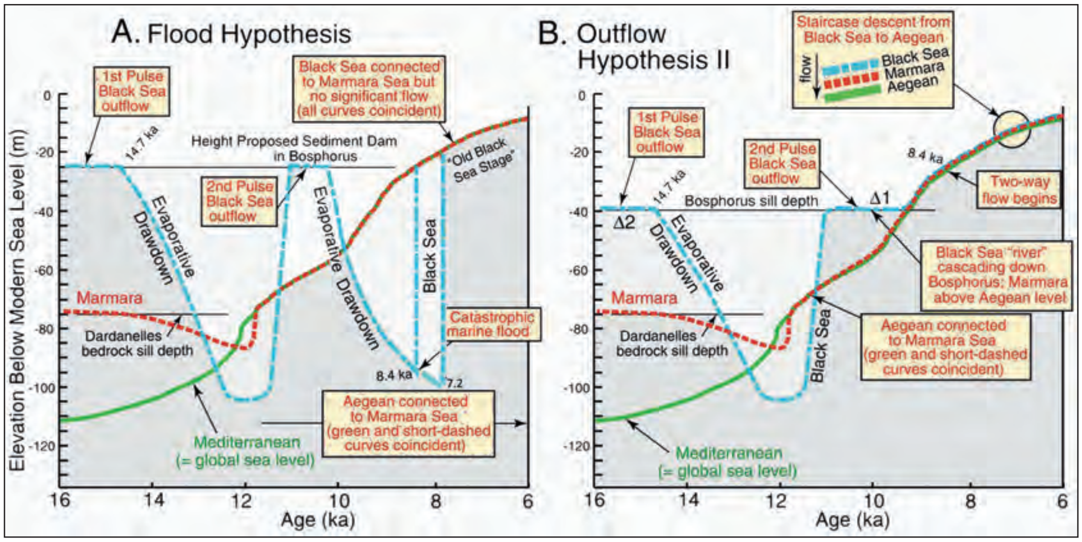

Figure 20.7: Left: RP catastrophic flood hypothesis, with two Holocene evaporative draw-downs of a freshwater Black Sea 'lake' terminated by a deluge of seawater at c. *7.2 ka BP (RP1) or 8.4 ka BP (RP2). Right: Hiscott* et al. *(2007a, 2007b) gradual flood hypothesis with strong but declining Black Sea outflow since* c. *11 ka BP, resulting in sapropel deposition in Marmara and Aegean seas and gradually increasing inflow of Mediterranean water over the southwestern Black Sea shelf after* c. *9.5 ka BP*

> dispersal of early neolithic foragers and farmers into the interior of Europe at that time.'

Subsequently, Major *et al.* (2002) examined longer (2–7 m) sediment cores from the upper Romanian continental slope that provided continuous 20,000-year, high-resolution records of sediments, clay mineralogy, carbonate, and stable isotope geochemistry of bulk carbonate (including reworked biogenic and detrital material). The RP1 hypothesis was then adjusted to include a possible gradual marine inundation like that recorded for the Marmara Sea (Çağatay *et al.* 2000; Aksu *et al.* 2002a) beginning *c.* 12.8 ka BP. Major *et al.* (2002: 32), explained the apparent delay in the introduction of marine fauna and flora into the Black Sea until 7.1 ka BP as the time required for gradual (not catastrophic) salinization of the water to a level suitable for these organisms.

Ryan *et al.* (2003: 549) then reviewed older low-resolution and younger higher resolution seismic data from 1997 and, using Major's geochemical data, determined that:

> 'Although the Black Sea witnessed at least eight marine flooding events in the past three million years, it is not possible from the available data to argue that these were catastrophic floods analogous to the Holocene event.'

They noted that sediments deposited between 8.4 and 7.1 ka BP showed a transition from brackish to marine water over about 1000 years (Ryan *et al.* 2003: 546). Although the term 'transition' was now used instead of 'abrupt', they still concluded that well-preserved dune features at water depths of 50–90 m were rapidly drowned between 8.5 and 8.4 ka BP, and cited other evidence for abrupt flooding such as absence of coastal onlap in the soft surface sediment unit. They also used onshore pollen studies from north of the Black Sea to infer that the climate was arid until after initial salinization (presumably 7.1 ka BP).

Major *et al.* (2006) and Ryan (2007) then focused on new geochemical data in the latest refinement, RP2, of the catastrophic flood hypothesis. Major *et al.* (2006) presented oxygen and strontium isotopic and strontium/calcium ratio measurements of mollusc and ostracod shells obtained from 27 cores in three areas of the northern shelf. They concluded that the Black Sea filled and flowed into the Marmara Sea twice between *c.* 15 and 13 ka BP, with a final shift to marine values in strontium and oxygen isotope ratios at 8.3 ka BP corresponding to connection with the global ocean earlier than previously suggested by appearance of euryhaline fauna and onset of sapropel formation in deep water. These abrupt (100–300 year) changes in strontium and oxygen isotope ratio were compatible with a Black Sea volume increase between an Early Neolithic lowstand at 80 m below present MSL and a Bosporus Strait spill-over depth of 35 m, but uncertainties in the dating, stratigraphy, and presence of older reworked material made it impossible to distinguish between a 'flood' and 'gradual inflow' scenario (Major *et al.* 2006: 2041). Nonetheless, Ryan (2007: 63) persisted with the view that rapid flooding best accounted for the evidence but accepted an earlier timing (8.4 ka BP) for the start of his Holocene flooding event, proposing that two lowstands (-120 m at 13.4–11 ka BP and -95 m at 10–8.4 ka BP) and two catastrophic transgressions (from -120 to -30 m at 11–10 ka BP; and from -95 to -30 m at 8.4 ka BP) occurred. The second transgression was called the Great Flood.

The RP1 hypothesis received support from *The French Research Institute for Exploration of the Sea* (IFREMER) seismic surveys, which apparently indicated well-preserved drowned beaches, sand dunes, and soils (Lericolais *et al.* 2007a: 449), while Bahr *et al.* (2008) detected abrupt temperature and water chemistry changes in Black Sea ostracods over a 100-year interval during Early Neolithic time.

A refinement of the RP2 catastrophic flood hypothesis was introduced by Turney and Brown (2007), who recycled Major's published mollusc ^{14}C ages into a model based on 'high precision dating of the marine flooding of the freshwater Black Sea' (Turney and Brown 2007: 2040). The TB catastrophic flood model removed corrections for a hardwater or marine reservoir effect from the so-called 'freshwater' molluscs living in the Black Sea before 7940±75 BP, and assumed a mean ΔR of 50±63 years for the oldest Black Sea marine mollusc in order to narrow the age of the Early Holocene inundation. A Bayesian model was constructed for these age-adjusted data (Turney and Brown 2007: 2038) to show that the Mediterranean infilling of the Black Sea occurred between 8350 and 8230 cal BP. Turney and Brown connected this marine incursion with the *c.* 8.2 cal ka BP global cooling event associated with final collapse of the Laurentide Ice Sheet and outflow of floodwater from Lake Agassiz (Teller 2002; Clarke *et al.* 2004); they claimed this event was possibly accompanied by a 1.4 m sea-level rise.

Evidence for the gradual sea-level rise hypothesis

Ross and Degens (1974) first suggested a gradual reconnection and transition from isolated freshwater Black Sea lake to stagnant marine conditions, beginning *c.* 9 ka BP. Aksu *et al.* (1995b) also deduced a gradual sea-level rise and reconnection of the Black, Marmara, and Aegean seas from the occurrence of sapropel layers in Aegean Sea cores; sapropel formation requires sustained Black Sea outflow to stratify the ocean and increase terrigenous organic matter content. The start of this Black Sea outflow was dated to 9.6 ka BP, setting a minimum age for Holocene breaching of the Bosporus Strait at 40 m below MSL. More detailed work on the origin and timing of sapropel deposition in the Black, Marmara, and Aegean seas followed (Aksu *et al.* 2002a, 2002c). Thereafter, Hiscott *et al.* (2007a, 2007b) focused on the Late Pleistocene to Holocene history of the shelf north of the Bosporus Strait, where high-resolution seismostratigraphic surveys (Fig. 20.2) revealed a thick layer of soft sediment above the stiff clay and gravel – reflector α (= surface of seismic wave reflector) – that prohibited recovery of long cores on the northern shelf by Ryan *et al.* (1997, 2003) and on the southern shelf by Ballard *et al.* (2000, 2008). The study by Hiscott *et al.* (2007b) (Fig. 20.8) showed that, at a present water depth of 70 m on the southwestern shelf, 10 m of mud overlying the reflector α transgressive unconformity record an uninterrupted sequence of sedimentation during the Neolithic and Early Bronze Age from 9.3 to 4.5 ka BP. Fourteen AMS radiocarbon ages from molluscs in the reference core, MAR02-45, constrain the chronology of sedimentation and allow accurate calculation of rates of environmental change. Seven ages for in-place specimens of the 'semi-fresh' species *Dreissena polymorpha*, *D. rostriformis*, *Truncatella subcylindrica*, *Monodacna pontica, Didacna* spp., and *Theodoxus* spp. provided a very high-resolution record for the sediment unit C representing the palaeoenvironment from *c.* 9.3 to 7.6 ka BP, i.e. the time interval of the hypothetical RP and TB catastrophic sea-level transgression.

The sedimentology of Core MAR02-45 and neighbouring cores (Hiscott *et al.* 2007b: 25–7) shows that at 9.3 ka BP the central and outer shelf were not subaerially exposed but were already covered by semi-fresh water to a depth greater than 20 m. Filipova-Marinova (2007: 467) also reports that from *c.* 9.95 to 8.35 ka BP lagoon–estuarine sediments with *D. polymorpha* molluscs occurred in the Veleka River valley on the present Bulgarian coast, at depths of 25–40 m below MSL, showing that the entire western shelf was inundated by the start of the Neolithic. Ostracods from Core MAR02-45 indicate slightly brackish conditions: salinity of at least 5‰, and possibly as high as 7–13‰ (Marret *et al.* 2009).

About 4 m of these brackish-water, silty mud sediments in Core MAR02-45 were continuously deposited at an average rate of 36 cm/century from 9.3 to 7.56 ka BP. During this time, benthic foraminifera and dinocyst assemblages indicate a

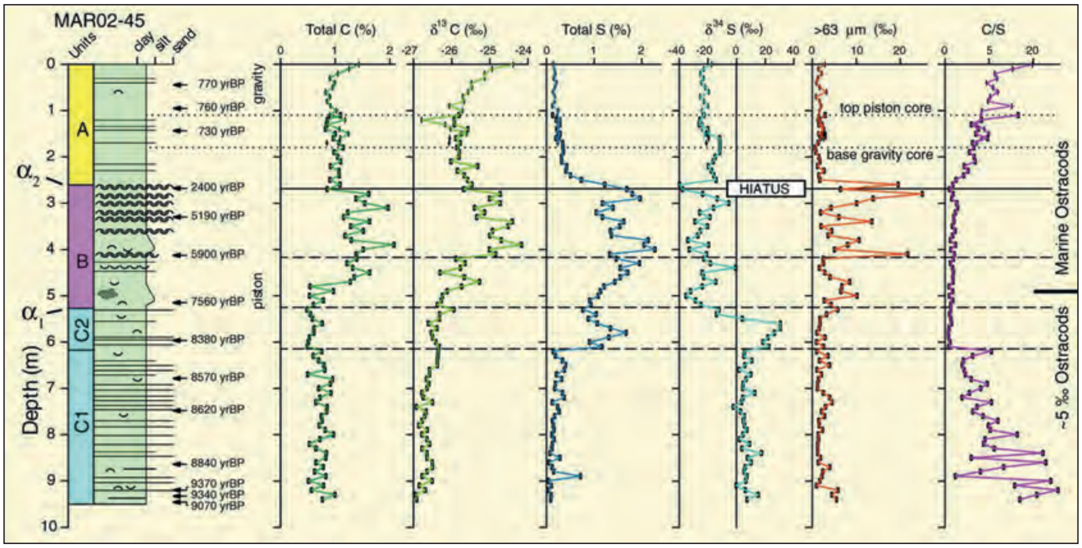

Figure 20.8: Core MAR02-45 sedimentology and geochemistry. A = colour-mottled/banded, burrowed mud with silt laminae and rare shells; B = alternating mud and shelly mud (mussels) with high sulphur and negative δ^{34}S; C = colour-banded mud with graded silt and very fine sand beds, and rapid changes in TS and δ^{34}S in the upper part (C2)

low but rising salinity and steady decrease in the carbon:sulphur ratio, as expected for inflow of seawater that has more sulphur than river water. From 8.4 to 7.6 ka BP (subunit C2, Fig. 20.8), a temporary increase in δ^{34}S (ratio of seawater sulphate to bacteria-reduced sulphides) marks the first sustained inflow of Mediterranean water from *c.* 8.3 to 7.9 ka BP. Subsequently, sulphur was precipitated, indicating establishment of the modern stratification with inflowing saline Aegean bottom seawater and outflowing low-salinity Black Sea surface water.

After this gradual establishment of the modern two-way circulation system through the Bosporus Strait over about 410 years, sedimentation slowed to 8.5 cm/century from 7.56–4 ka BP (Hiscott *et al.* 2007b: 28–9) commensurate with a gradual increase in surface-dwelling Mediterranean dinocysts, and slightly more rapid increases in bottom-dwelling Mediterranean ostracods and foraminifera that live today in salinities of 17–19‰ (Yanko 1990a; Yanko-Hombach 2007a). After 4 ka BP, the present-day low-salinity marine flora and fauna were established, with increases in sedimentation rate and terrigenous organic carbon influx marking landscape changes accompanying Bronze Age to Graeco-Roman farming and land clearance (Mudie *et al.* 2002a, 2007; Cordova *et al.* 2009). Overall, there was a gradual rise in water level over the shelf after the last evaporative drawdown of the Black Sea during the cold dry interval from about 13–11 ka BP and following the major outflow of water from *c.* 11–9.5 ka BP (Fig. 20.7).

The high-resolution chronology established for Core MAR02-45 (Mudie *et al.* 2007) provided the first decadal-scale resolution of vegetation records and allowed calculation of annual influx rates for pollen and spores on the Black Sea shelf (Fig. 20.9) in contrast to earlier studies (e.g. Mudie *et al.* 2002a; Atanassova 2005; Filipova-Marinova 2007) reporting relative abundances and concentrations. By 9.3 ka BP, pollen influxes from moisture-demanding forest trees like deciduous oak (*Quercus cerris*), lime (*Tilia*), beech (*Fagus*) and elm (*Ulmus*), together with shade ferns, aquatics, and swamp plants indicate year-round precipitation of >600–1000 mm, and warm winters are indicated by *Pistacia* (that requires winter temperatures of 5°C or more). These palynological data record conditions on the shelf and immediately adjoining coasts; they contradict the proposed early Holocene dry conditions essential to the RP and TB scenarios involving lake level drawdown to 110 m below present MSL. High-resolution shelf pollen data also provide direct archives of Neolithic and Eneolithic land

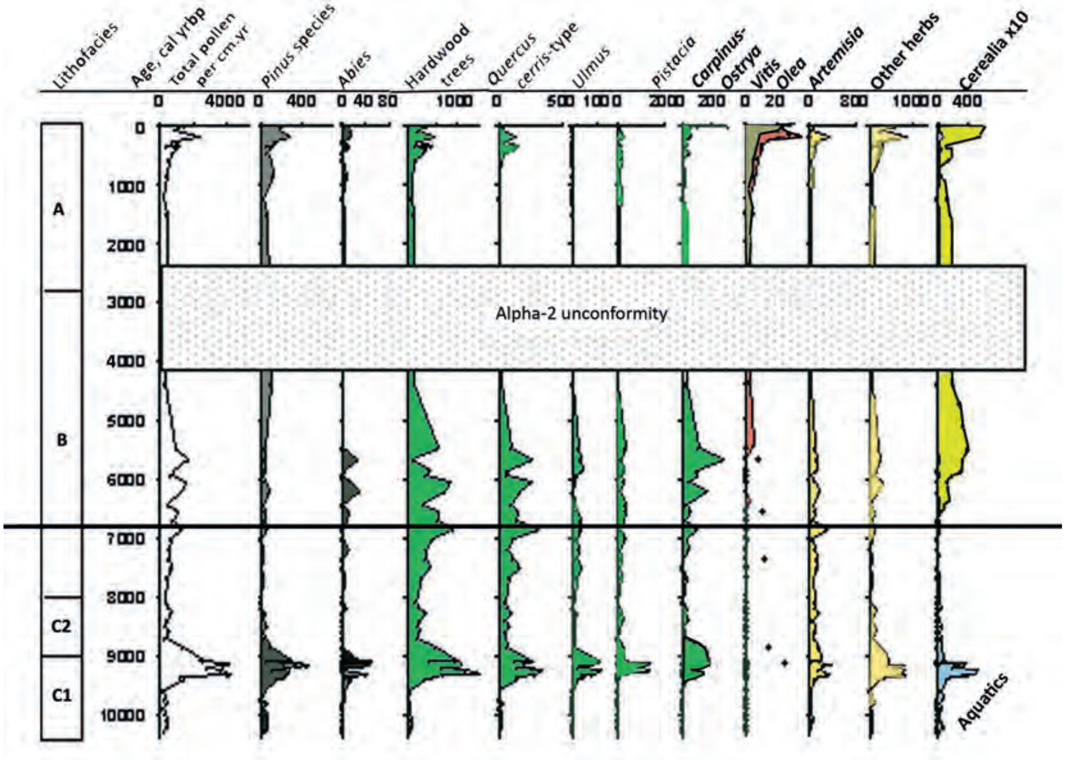

Figure 20.9: Pollen influx diagram for Core MAR02-45, showing selected tree pollen species that indicate temperature and moisture conditions, and markers of agricultural/horticultural activity: Cerealia, Vitis vinifera *(grapes) and* Olea *(olives). Influx scale is in grains per cm^2 yr^{-1}*

use and show no evidence of grain production (Cerealia pollen) before *c.* 6500 cal BP, when the first cereal pollen appears in the Bulgarian coastal lakes (Marinova and Atanassova 2006; Filipova-Marinova 2007; Filipova-Marinova and Angelova 2008). Sparseness of charcoal particles and fungal spores indicating animal herding further suggest neither Neolithic/Eneolithic grassland burning nor animal husbandry on the exposed Early Holocene shelf.

Evidence for oscillating sea levels

Evidence for oscillating sea levels during the gradual rise of Black Sea water is presented in many publications (Tchepalyga [Chepalyga] 1984; Voskoboynikov *et al.* 1985; Yanko 1990a, 1990b; Yanko and Gramova 1990; Shilik 1997; Chepalyga 2002a, 2002b; Balabanov 2007, 2009; and summarized in English by Yanko-Hombach 2007a, 2007b, and Yanko-Hombach *et al.* 2007). The oscillating scenarios state that Holocene water-level transformation was neither gradual nor catastrophic but fluctuated from a low point around -100 m from 27–18 ka BP to -20 m at *c.* 10 ka BP. Afterwards, sea level remained above -40 m and fluctuated within 20 m of present MSL. Holocene sea level showed an overall increase, in agreement with the 'gradual' hypothesis, but oscillating up to its present level. The re-colonization of the Black Sea by Mediterranean marine immigrants began *c.* 9 ka BP and became prominent at 7.2 ka BP. This re-colonization occurred over six oscillating transgression–regression stages (Fig. 20.3).

Discussion

Ryan's rebuttal of the gradual sea-level rise model

Despite substantial high-resolution data documenting the refilling and outflow of the Black Sea to the Aegean by *c.* 11 ka BP, and gradual but oscillating sea-level rise during the Early Holocene, Ryan (2007: 64–5) still rejected the evidence for a Black Sea surface rising with global sea level via an early connection through the Bosporus Strait or as outflow via Izmit Bay, Sapanca Lake, and Sakarya Valley (Brinkmann 1976; Kerey *et al.* 2004; Yanko-Hombach *et al.* 2004) at a lower sill depth of 85 m below MSL. Ryan (2007: 66–7, 72–3) pinned major importance on oxygen isotopic data that appeared to record low salinity in an isolated lake although the evidence was from mixed sediments containing reworked lithic carbon and shell fragments. Ryan (2007: 71–2) also emphasized earlier interpretations of freshwater dinocyst assemblages, apparently not recognizing the biasing impact of the oxidative acetolysis laboratory processing method (see Methods section, and Marret *et al.* 2009), and he contested the validity of the pre-2002 seismostratigraphic evidence for a gradual transgression of the southwestern Black Sea shelf, and post-flooding deposition of bedforms beneath inflowing Mediterranean waters (Ryan 2007: 78–9). It is now clear, however, that the southwestern shelf records continuous transgressive coastal onlap after 9.3 ka BP, and bedforms can change simply because of shifts in the rim currents scouring the outer shelves of the Black Sea (Hiscott *et al.* 2007b; Flood *et al.* 2009). Hence, the evidence supporting the gradual sea-level rise model remains intact and is further supported by new high-resolution studies of Giosan *et al.* (2009).

Evidence for drowned windblown dunes

The claim of Lericolais *et al.* (2007b: 177) that the Black Sea shoreline was at -100 m until about 8.5 ka BP is not based on direct dating of the dune-like features at that depth but comes from CHIRP sonar profile correlation with a shallower core site >100 m distant, where the Holocene section is only *c.* 0.7 m thick. CHIRP sonar profiles have an optimal vertical resolution of 10–15 cm; at best, this condensed core thickness means that the age of the dune top could be 9.5 ka or older. In contrast, the Holocene cores of Hiscott *et al.* (2007) and Giosan *et al.* (2009) are 10–45 m thick and have permitted direct dating of the first transgressive deposits, showing that the shoreline was above -40 m at 8.8 ka BP. These thicker deposits provide details of the reconnection process, including direct palynological proxy-data for local vegetation and a relatively warm, moist climate. In contrast, Lericolais *et al.* (2007a, 2007b, 2009) repeatedly claim evidence for a very dry Early Holocene climate based on pollen records from their shelf cores, but none of these have been published.

Was there really a catastrophic Black Sea flood that changed human prehistory?

General agreement now exists among researchers that megafloods occurred from 17–14 ka BP, inundating extensive areas of the Black Sea–Caspian region. Chepalyga (2007: 143) argues for a late Palaeolithic upland migration and a stimulus toward the development of water transport technology, as suggested by Mesolithic rock drawings in Gobustan of 9–8 ka BP (Dzhafarzade 1973). Stanko (2007: 377–82) recorded Mesolithic population increase in the lower Dniester valley from 14–12 ka BP, but no evidence of catastrophes for the time span of 14–6 ka BP. Dolukhanov *et al.* (2009: 4–5) describe coastal landscapes for the northern Black Sea and pollen data from Ukraine indicating likely effects on Palaeolithic groups due to the extermination of mammoth and woolly rhino by 18 ka BP and replacement by bison (Stanko 2007: 376). Not until *c.* 12 ka BP, however, is there evidence of a southward migration of people into the wetlands of the Danube, Dniester and Dnieper estuaries, where waterfowl hunting may have been important. Although it is reasonable to suggest that there may have been settlements on an emergent shelf (Dolukhanov *et al.* 2009: 4), no underwater sites or animal bones have yet been recovered, and the earliest evidence of regional farming dates to the Late Chernomorian stage (7–4 ka BP) for numerous sites in the upper Dniester basin and scattered sites near the Azov Sea (Dolukhanov *et al.* 2009). Özdoğan (1999) emphasized indirect evidence that the Holocene transgression coincided with human migration from the Mediterranean area into the Pontic Lowland, not the other way as flood avoidance would imply.

Whether or not a hypothetical Neolithic catastrophic inundation gave rise to the story of Noah's Flood, one can say only that, so far, no scientific data support a Holocene flood rate of 40 m per century – the best estimate of Ryan *et al.* (2003) for the drowning of sand dunes on the Danube shelf from -90 to -50 m between 8.5–8.4 ka BP. Turney and Brown's (2007) idea that an abrupt sea-level transgression at *c.* 8350–8230 cal BP was possibly associated with a 1.4 m sea-level rise during the final Laurentide Ice Sheet collapse is not supported by the model of Clarke *et al.* (2004: 404), who estimated a sea-level rise of 8–41 cm, and wrote:

> 'The effect on sea level cannot have been large. The maximum effect ... has a sea level equivalent of 0.41 m but for all reference models the released volume from above sea level was considerably less than the available volume, over a period of *c.* 100 years.'

A 40 m sea-level rise over 100 years would surely have discouraged settlement on the continental shelves, and there is still neither archaeological evidence for human habitation on the outer shelves nor marine palynological evidence of Neolithic land clearance or agriculture before the Eneolithic (Chalcolithic), *c.* 6 ka BP. Abundant geological survey evidence and sediment cores from the Turkish shelf north of the Bosporus (Hiscott *et al.* 2007a, 2007b, 2008) show the area was already flooded to -20 m by 9.3 ka BP, by which time the Danube shelf dunes in deeper water on the Romanian shelf would also have been submerged. Hence, the drowned dune data cannot be used as reliable evidence for catastrophic inundation of Neolithic occupation sites.

Advocates of the catastrophic flood hypothesis have also invoked an arid Early Holocene climate for the Black Sea but have failed to use pollen data from marine cores (Mudie *et al.* 2001, 2002a, 2007) that show the Early Holocene climate in the southern Black and eastern Marmara seas was warm, wet, and supporting mesic forest trees by 9.5 ka BP. Further, quantitative palynological data (Mudie *et al.* 2001; Marret *et al.* 2009; Verleye *et al.* 2009) establish that Wall and Dale's Early Holocene *Spiniferites cruciformi*s dinocyst flora indicates brackish conditions of 5–11, not the fresh water suggested in the earliest studies (Wall and Dale 1974).

Overall, there is a conspicuous lack of archaeological and archaeobotanical evidence to support the contention that Neolithic people occupied the shelves of the Black Sea much beyond the present shoreline. Anthony (2007: 345) concluded that even if the Black Sea rose catastrophically over the North Pontic plain from 7600–7300 cal BP, only an estimated 100–150 foraging bands of 50–75 people would have been impacted, and there is no certain evidence for a sudden change in human behaviour at this time. Likewise, Bailey (2007: 515) commented that '… proposed links between a dramatic rise in the Black Sea and spread of agriculture across Europe … are unhelpful', and recommended more refined documentation of Holocene changes in the Black Sea. Mesic Early Holocene conditions during cooler and wetter times than now must be incorporated into new palaeoenvironmental models involving human habitation of the Black Sea shelves. Direct evidence from high-resolution marine palynological cores (Mudie *et al.* 2002b, 2007) suggests a marshy and mosquito-infested region subject to periodic river flooding. This might provide good hunting and fishing but poor conditions for settled farming because of brackish water and soils prone to salinization and waterlogging; these problems still restrict coastal farming today.

To summarize, we cite two leading archaeologists to whose memory we dedicate this chapter: Pavel M. Dolukhanov (1937–2009) and Vladimir N. Stanko (1937–2008):

> 'Existing archaeological data strongly support a scenario of gradual environmental changes in the northern Pontic area during the Late Pleistocene and Holocene. Reliable evidence suggests that the changes in subsistence and cultural dynamics resulted from a combination of socio-economic and environmental factors, fluctuations in precipitation being the most important among the latter.' (Dolukhanov and Shilik 2007: 314)
>
> 'The emergence of farming was a gradual process deeply rooted in the local traditions, and in no way was it connected with a catastrophic flooding of the coastal area.' (Stanko 2007: 376).

Conclusions

Geological and palaeontological data records of Late Pleistocene inundations in the Black Sea–Caspian region indicate extensive megaflooding far greater in scale than the Holocene. Archaeological evidence for catastrophic impact on Palaeolithic foragers is controversial. As yet, no underwater Palaeolithic or Mesolithic settlements have been found.

The salinity of the Neoeuxinian Lake was brackish and non-potable, like that of the modern Caspian Sea, placing farming at risk of salinization. Temporary settlement on delta interfluves may have occurred, but the only evidence of early watercraft comes from rock art in the Caspian area.

When Late Pleistocene flooding ended at about 9.5 ka BP, water level was near the -40 m sill depth of the Bosporus Strait. Inflowing Mediterranean water raised the level gradually and in an oscillating manner up to about 20 m below present MSL by 7.56 ka BP, concomitantly raising salinity from brackish to semi-marine (16–22). Exposed shelf areas along the coastline would have been swampy and prone to salinization, not favourable for arboriculture, agriculture, or animal husbandry. No substantiated geological evidence for catastrophic Holocene flooding and no archaeological or palynological evidence for prehistoric occupation of the Black Sea shelves exists near the modern coastline in water depths greater than 10 m. The TB hypothesis of a catastrophic Black Sea flood overrunning shoreline Neolithic settlements at *c.* 8.4 ka BP is neither supported by calculations of global sea-level rise of 8–41 cm (less than a normal tsunami) nor by a Bayesian model for ^{14}C dating of molluscs from 8.4–8.2 ka BP due to unresolved questions about appropriate reservoir corrections for brackish water palaeoenvironments.

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