Global and Planetary Change 66 (2009) 65–75

Contents lists available at ScienceDirect

Global and Planetary Change

journal homepage: www.elsevier.com/locate/gloplacha

High frequency sea level fluctuations recorded in the Black Sea since the LGM

G. Lericolais [a,*], C. Bulois [a,b], H. Gillet [a,c], F. Guichard [d]

[a] IFREMER, Centre de BREST, BP 70, F29200 Plouzané cedex, France
[b] UCD School of Geological Sciences, University College Dublin, Belfield, Dublin 4, Ireland
[c] UMR 5805 - EPOC, Université Bordeaux 1, Avenue des Facultés, F33405 Talence, France
[d] LSCE, CNRS-CEA, Avenue de la Terrasse, BP 1, 91198- Gif-sur-Yvette cedex, France

ARTICLE INFO

Article history:
Received 5 July 2007
Accepted 14 March 2008
Available online 30 November 2008

Keywords:
sea level changes
rapid transgression
forced regression
enclosed basin
Black Sea

ABSTRACT

This paper presents a 3D geometric interpretation of very high resolution seismic Chirp profiles acquired on the Romanian shelf during ASSEMBLAGE European Project. The results provide a solid record of the Black Sea Last Glacial Maximum (LGM) water level fluctuations. This pseudo-3D seismic interpretation shows that the Black Sea lacustrine shelf deposits form a significant basinward-prograding wedge system. On top of these prograding sequences is a set of sand dunes that delineates a wave cut-terrace like feature around the isobath −100 m. Landward of this dune field are small depressions containing barkhan-like bodies. The upper part of the last prograding sequence is incised by anastomosed channels which end in the Danube (Viteaz) canyon which are also built on the lacustrine prograding wedge. Ten stratigraphic units were distinguished and correlated with analyses of cores retrieved from this area. The results demonstrate that the first eight sequences represent lacustrine prograding wedges, the ninth sequence is the dune system itself and the tenth is a marine mud drape which covers the entire continental shelf. The lacustrine prograding wedges represent a lowstand deposit characterised by forced regression-like reflectors mapped from the pseudo-3D seismic data. Their hinge point corresponds to the wave erosion surface mapped around −100 m isobath on the multibeam mosaic. Dated cores give age control on this lowstand period, which lasted from 11 to 8.5 kyr ^{14}C BP as implied by: (1) the continuously dry climatic conditions in the region inferred by high percentages of herbs and steppe elements determined from ASSEMBLAGE cores and, (2) the formation of dunes between 10 and 8.5 kyr ^{14}C BP on the desiccated north-western Black Sea shelf at −100 m and (3) all of these covered by a marine mud drape confirming that the dune system is no longer active. The buried, anastomosed fluvial channels that suddenly disappear below 90 m depth, and a unique wave-cut terrace between 95 and 100 mbsl on the outer shelf are also consistent with a major lowstand base-level at around −100 m water depth. Preservation of sand dunes and the occurrence of small, buried incised valleys mark a rapid transgression within less than a century during which ravinement processes related to the water level rise had no time to significantly erode the seafloor.

1. Introduction

As part of its evolution, the Paratethys basin went through a small, semi-isolated basin phase at the end of the Oligocene. The link between resulting marginal basins and the ocean was episodically restricted or even severed in response to sea level changes. The Black Sea is a present-day example of such a marginal basin where the connection changes dramatically with sea level (Ross et al., 1970; Ross, 1971; Ross and Degens, 1974; Ross, 1978; Ryan et al., 1997; Ryan et al., 2003). The Black Sea is at present the world's largest anoxic basin, making it an important modern analogue for past anoxic conditions, while during the last glacial period, it was a low salinity oxygenated lake, isolated from the Mediterranean (Deuser, 1972; Deuser, 1974; Wall and Dale, 1974; Lericolais et al., 2006). The location of this inland sea, between Europe and Asia, makes its water level dependent on Eurasian climatic fluctuations. As the Black Sea has experienced a limnic situation, the deposited lake sediments are valuable archives for the study of past climate changes. During glacial periods, the ice cap prevented major rivers flowing north as they do today. Then, these rivers were diverted to the south in the direction of the Black Sea and Caspian Sea receiving basins and consequently have increased the size of these Drainage Basins (Arkhipov et al., 1995). Isolation of the Black Sea from the Global Ocean led to the establishment of unique conditions specific to the Black Sea, and avoiding the hysteresis effect which corresponds to the latent period needed by the Global Ocean to respond to the consequences of ice melting. During these isolation phases, the Black Sea was more sensitive to climate changes than the Caspian Sea is today. Some authors interpret the Caspian Sea fluctuations as opposed to those of the Global Ocean to have been caused the possible connection between the Black Sea and the Caspian Sea through the Manych Strait (Chepalyga, 1984; Arkhipov et al.,

* Corresponding author.
E-mail address: Gilles.Lericolais@ifremer.fr (G. Lericolais).

0921-8181/$ – see front matter © 2008 Elsevier B.V. All rights reserved.
doi:10.1016/j.gloplacha.2008.03.010

1995). During the glacial periods, when the Black Sea was isolated, both the lack of saltwater input and the increase of fresh water run-off from the rivers, led to reduced salinity levels in the Black Sea. This process, linked to water level fluctuation, is measured in the fauna succession showing an abrupt change from salt-to fresh/brackish-water species. However, since 1997, a still unsolved controversy concerned the last re-connection of the Black Sea to the Marmara Sea. This question is still under debate, even though each opposing view is supported with data representing only a minute part of the Black Sea floor. Yet, not all of the 420 000 km^2 have been surveyed using modern scientific equipment and technology to precisely understand the water level fluctuation of the Black Sea in the Quaternary. Recently, an assessment of the North-western part of the Black Sea sedimentary systems from the continental shelf and slope down to the deep-sea zone, was provided by the ASSEMBLAGE European Project (EVK3-CT-2002-00090). Part of this project's deliverables consisted of applying sequence stratigraphic models to seismic data recorded on the north-western Black Sea shelf in order to correlate the sequences interpreted using seismic stratigraphy methods to sea-level fluctuations. In this paper, seismic sequences recognized on seismic profiles are interpreted in terms of systems tracts, by using the character of the erosional unconformity and of the strata truncated below it as well as the nature of the sediments above it.

To achieve these objectives, very high resolution seismic data were acquired during the BlaSON cruises (1998 and 2002) on board the research vessel "LE SUROÎT" and during the ASSEMBLAGE 2 (2004) cruise on board the research vessel "LE MARION DUFRESNE". During the early cruises paleo-shorelines and sand ridges were identified and a set of seismic data was acquired on these targets to support pseudo 3D analyses. Digital Terrain Models (DTM) were made to determine the paleo-bathymetry and to establish a sequence stratigraphy model to identify age and onset of observed paleo-shorelines and ridges. Digital Terrain Models also help to define the internal structure of these sand ridges and to decipher the nature and origin of paleo-valley fills. This coupled with a multiproxy approach emphasizes that the Black Sea water level is dependent on Eurasian climatic fluctuations. This sequence stratigraphy study is validated by dated samples obtained from long cores (up to 50 m long) providing a firm calibration of Black Sea water level fluctuation since the LGM. It especially shows that the Black Sea experienced a contemporary rise in water level with the melting of the Fennoscandian Ice sheet followed by a drop of the water level from the Younger Dryas to the PreBoreal. This recent lowstand is confirmed by the presence of the forced regression sequences, the wave cut terrace and the coastal dunes still preserved on the shelf, even after the Black Sea was rapidly invaded by Mediterranean/Marmara marine waters.

2. Geological setting

2.1. Black Sea Paleo-shorelines

Since the 1970's Russian scientists have documented Pleistocene lowstand shorelines on the north-western Black Sea shelf (Kuprin et al., 1974; Shcherbakov et al., 1978). Actually, many Soviet surveys were carried out in the Black Sea, and paleo-littoral zone near the shelf edge was identified and sampled from coring. Although these researchers had not published reflection profiles to document the exposed margin of the lake, their numerous piston and drill cores confirmed the ancient coast. Some of these cores provided evidence of an erosional surface already considered as a possible fluvial or aeolian surface (Shuisky, 1986). During this systematic exploration of the Black Sea shelf by Soviet and other eastern country researchers (Popp, 1969; Muratov et al., 1974; Shopov et al., 1986; Shimkus et al., 1987; Arkhipov et al., 1995; Evsylekov and Shimkus, 1995) paleo-incised valleys crossing the continental shelf were recognized. In the 1990's, the systematic survey of the Romanian shelf conducted by the GeoEcoMar Institute established the presence of ancient river valleys crossing the shelf and extensive down-cutting of the Danube (Viteaz) canyon (Popescu et al., 2004; Panin and Popescu, 2007; Lericolais et al., 2007a). This last observation leads us to propose the hypothesis of a major water-level drop of the Black Sea after the LGM and supports the interpretation made by Ostrovskiy et al. (1977b) and Shimkus et al. (1980) regarding the stratigraphy of Pleistocene marine terraces recognized on the shelf break off the Caucasus and Kerch–Taman region. These authors interpreted such terraces as evidence of a water level drop of about 110 m linked to an ice-age lowstand of the former Black Sea lake. In 1993, a new US–Russian–Turkish survey re-examined these lowstand shorelines and the river paleo-valleys of the Dniepr/Dniestr complex in more detail using very high resolution seismic reflection profiling methods and observed lowstand terraces (Ryan et al., 1997; Major et al., 2002a). Similar terraces have also been recognized on the Bulgarian shelf (Dimitrov, 1982; Genov, 2004) and on the northern Turkish shelf (Okyar et al., 1994; Demirbag et al., 1999; Ballard et al., 2000; Algan et al., 2002; Aksu et al., 2002b; Algan et al., 2007). Among these terraces, shells belonging to past coastal environments were dated between 19 to 9 kyr BP (Ostrovskiy et al., 1977a; Shcherbakov et al., 1978; Dimitrov, 1982; Lericolais et al., 2006). On the Romanian continental shelf, Popescu et al. (2004) noticed the absence of incised river channels below −90 m water depth where a wave-cut terrace-like morphology was mapped about 100 km from the Danube delta. These wave-cut terraces were interpreted to be erosional surfaces created by erosion from wave action indicating the position of the shoreline (Lericolais et al., 2007a,b). Since rivers do not always generate continuous incised valleys along the shelf (Wescott, 1993; Talling, 2000; Lericolais et al., 2001), their absence below isobath −90 m does not necessarily indicate the location of the paleo-coastline. A good indicator of the paleo-coastline is the wave-cut terrace around the head of the Danube (Viteaz) canyon and present between isobath −98 m and isobath −112 m (Popescu et al., 2004). North of the Danube (Viteaz) Canyon, the terrace deepens again to −97 m while the height increases to 10–15 m, and splits into two distinct steps. The last lowstand paleo-coastline should thus have been situated between this submerged terrace and the deepest buried fluvial channels (Lericolais et al., 2007a). All subsequent seismic reflection profiling acquired (e. g. BlaSON and ASSEMBLAGE surveys) show the same shelf-wide erosion surface (Gillet et al., 2003; Popescu et al., 2004; Lericolais et al., 2007a,b).

2.2. Black Sea water level fluctuations

Before today's controversy concerning the Black Sea water level fluctuation since the Last Glacial Maximum, the consensus was that the Black Sea lake's surface had risen in pace with global sea level, assuming that the connection between Mediterranean and Black Sea waters was already possible through an early existing Bosporus Strait. The increase in salinity in the Sea of Marmara is known to be at least 12 000 yr BP as determined from the mollusc assemblage and stable isotopes (Cagatay et al., 2000; Sperling et al., 2003) and could be even earlier (Popescu et al., 2003; Popescu, 2004). In 1997, based on results obtained from a joint Russian–American–Turkish expedition carried out in 1993, Ryan et al. (1997) provided evidence in support of a catastrophic flood of the Black Sea 7500 yr ago. Their interpretation was deduced from high-resolution seismic reflection profiles and carbon-14 Accelerator Mass Spectrometry (AMS) dating of fauna sampled from cores targeted on these profiles. In 2002, Aksu et al. (2002a) presented arguments for persistent Holocene outflow from the Black Sea to the eastern Mediterranean and for non-catastrophic variations in the Black Sea water level over the last 10 000 yr BP (Aksu et al., 2002b). Recently Yanko-Hombach et al. (2007b) published a book entitled "The Black Sea Flood Question; Changes in Coastline, Climate and Human Settlement" trying to address issues of geological evolution and human adaptation in the Circum-Pontic region during the Late Pleistocene and Holocene. Among the contributors of this book are many Eastern European scientists whose work has rarely