RUSSIAN JOURNAL OF EARTH SCIENCES
vol. 17, 5, 2017, doi: 10.2205/2017ES000613

New evidence of the age of the Black Sea Pontian substage

Alena I. Rybkina[1] *and Yuliana V. Rostovtseva*[2]

[1]Geophysical Center of the Russian Academy of Sciences, Moscow, Russia

[2]Geological Faculty, Lomonosov Moscow State University, Moscow, Russia

Abstract. For the five years a set of various data was obtained from the relatively deep-water Upper Miocene sediments exposed in the Zheleznyi Rog section (Taman Peninsula, Russia). The data includes measurements of magnetic susceptibility (MS) and its further time-series analysis. The aim of these studies is to recognize the astronomic cycles correspond to the obliquity and precession variations. The results of this study reflect the strong correlations to the Messinian Salinity Crisis (MSC) of the Mediterranean. The study was supported by the RFBR 17-05-01085 A.

This is the e-book version of the article, published in Russian Journal of Earth Sciences (doi:10.2205/2017ES000613). It is generated from the original source file using LaTeX's **ebook.cls** class.

Introduction

The object of our study is Pontian deposits of the Black Sea coast in the area of the Zheleznyi Rog Cape in the Taman Region (Figure 1). A detailed description of the Zheleznyi Rog section, which comprises the Pontian, Maeotian, and Upper Sarmatian sediments, has been given in numerous works [*Andrusov*, 1917; *Pevzner et al.*, 2003; *Popov and Zastrozhnov*, 1998; *Rostovtseva*, 2009b]. The successions is mainly represented by clays that allows implementation of the methods of astronomical cyclicity identification based on the measurements of the magnetic susceptibility. We can identify the Lower Pontian (Novorossian according to Eastern Paratethys stratigraphy) as well as the Upper Pontian including the Portaferian and Bosphorian beds [*Andrusov*, 1917]. Based on the data from complex stratigraphic studies, the age of the base of the Pontian can be $\sim 6.1 - 6.04$ Ma [*Krijgsman et al.*, 2010; *Radionova et al.*, 2012]. The age of the top of the Pontian is estimated in different ways. Most scientists believe that transition of the Pontian Kimmerian happened at 5.3–5.2 or 4.7 Ma [*Krijgsman et al.*, 2010; *Radionova et al.*, 2012; *Trubikhin*, 1989]. According to their ideas, the Pontian Regional Stage

Figure 1. Zheleznyi Rog section (Taman Peninsula).

is correlated with the upper part of the Messinian and probably corresponds to the Lower Pliocene. In this case, the maximum Messinian Salinity Crisis, which resulted in the formation of the Messinian erosional surface (MES) in the Mediterranean in the period of 5.6–5.5 Ma, occurred within the Euxinic and Caspian basins in the Pontian. According to some researchers, the Messinian erosional surface (MES) in the Mediterranean is isochronous to the erosional boundary surface between the Lower and Upper Pontian, which has been identified both in Central and Eastern Paratethys [*Gillet et al.*, 2007; *Rostovtseva*, 2009a; *Rostovtseva and Kosorukov*, 2012] (Figure 2).

Materials and Methods

A detailed description of the Zheleznyi Rog section, which comprises the Pontian, Maeotian, and Upper Sarmatian sediments, has been given in numerous works [*Andrusov*, 1917; *Pevzner et al.*, 2003; *Popov and Zastrozhnov*, 1998; *Rostovtseva*, 2009b]. In order to obtain the cyclostratigraphic data, the magnetic susceptibility (K) of rocks in the studied intervals of the section was measured. Measurements were made every $20 \pm (1-2)$ cm across the strike of the layers using a

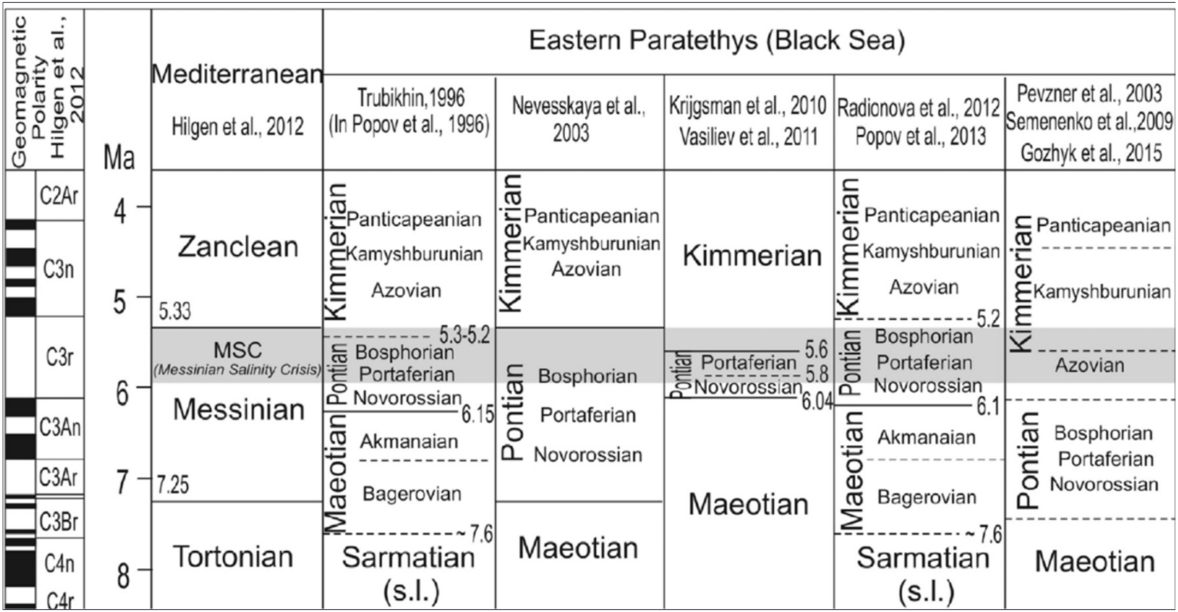

Figure 2. Time scales for the Mediterranean and Eastern Paratethys.

K 5 kappabridge (Geofyzika BRNO, Czech Republic). The data were then processed using statistical methods with the construction of Lomb-Scargle and REDFIT periodograms, as well as using AnalySeries program [*Paillard et al.*, 1996; *Schulz and Mudelsee*, 2002]. During the 2017 filed expedition the new data was obtained from the cross-sections of Zheleznyi Rog Cape. The variation of the signal characterizing the cyclicity of the same global geological process in between ~ 7 and ~ 8 m can be explained by variations in sedimentation rate, which increased in the Late Pontian. The sedimentation rate was $\sim$0.15–0.16 mm/year on average.

The magnetic susceptibility data was then analyzed using the AnalySeries program. It allows to use a Gaussian distribution and peaks from Lomb-Scargle periodograms. The periodicity of the cycles were used as a basis for Gaussian bandpass filter. Based on obtained Gaussian bandpass filter data it was established that transition beds between the Maeotian and Pontian are characterized by two extreme values of modulating curve. The modulating curve of Gaussian bandpass filter data for Upper Pontian deposits looks like two incomplete cycles, which are separated by two another cycles with less amplitude. Taking data on the age of the studied deposits into account, the obtained results are correlated with the Earth's eccentricity variation curve [*Laskar et al.*, 2004].

The thermomagnetic analysis of rock samples from the different parts of the section, which was carried out using the Multi-Function Kappabridge (ACICO, Czechoslovakia) in the laboratory of Dynamic Geology at Moscow State University established that the main minerals-carriers of magnetization in the studied deposits are iron sulfides (for example, pyrrhotite) [*Rostovtseva and Rybkina*, 2014].

Results

During the past studies and the new data obtained from the Taman peninsula a strong correlation of the Pontian deposits to the main steps of Messinian Salinity Crisis (MSC) of the Mediterranean was revealed. The results of the high-resolution cyclostratigraphic analysis of all the substages of the Pontian designated at the Zheleznyi Rog section (Taman Peninsula) were obtained [*Rostovtseva and Rybkina*, 2017]. It shows that astronomical tuning of the Maeotian/Pontian transition and the Pontian sedimentary record at the Zheleznyi Rog (Taman region, Black Sea Basin) confirms that the Pontian began at $\sim$ 6.1 Ma. The Maeotian/Pontianbeds were deposited from $\sim$ 6.3 to 6.1 Ma. The Novorossian sediments extending correspond to the first MCS step (5.97–5.6 Ma). The estimated ages of base and the top of Portaferian in the Zheleznyi Rog section are $\sim$ 5.65 Ma and $\sim$ 5.45 Ma, respectively. The Portaferian corresponds to the second MSC step, which is marked by development of the Messinian Erosional Surface (MES). The Novorossian/Portaferian boundary is marked by a hiatus of $\sim$150–160 kyr that agrees well with the presence of re-sedimented deposits and erosional boundaries in Portaferian sedimentary sequence and the concept of intra-Pontian unconformity [*Gillet et al.*, 2007; *Suc et al.*, 2015].

The magnetic susceptibility (MS) of the transition Maeotian/Pontian and Pontian rocks ranges widely with values from 0.016 to 0.937×10^{-3} SI units. The rocks at the Maeotian/Pontian transition exhibit MS values ranging from 0.04 to 0.16×10^{-3} SI units. Novorossian rocks exhibit MS values ranging from 0.016 to 0.937×10^{-3} SI units. Extraordinarily high values of MS (from 0.52 to 0.937×10^{-3} SI) occur in clays of the upper part of the Novorossian at the intervals 65.8–62.0 m and 59.2–51.6 m. Portaferian rocks exhibit MS values ranging from 0.03 to 0.19×10^{-3} SI units. The Bosphorian clays exhibit MS values from 0.05 to $0.32 \times$

10^{-3} SI units with higher values (up to 0.42×10^{-3} SI) at the top of these sediments. Spectral analysis of the MS-data of lower Pontian (Novorossian) sediments suggests strong periodicity. The Lomb-Scargle periodogram reveals only one significant signal with periodicity at 59.7 m. Significantly, the REDFIT periodogram with frequency values transformed into depth-domain also displays the signal at 6.1 m. This peak is supported by wavelet analysis that clearly illustrates the presence of a cycle between 5.6 and 7.4 m. It was suggested that the precession (signals at 3.1, 2.7 and 2.3 m), obliquity (signal at 6.1 m) and 400-kyr eccentricity (signal at 59.7 m) cycles are expressed in the MS-data of Novorossian sediments. Eccentricity, obliquity and precession cycles have been defined in the Miocene and Pliocene sedimentary record of the Mediterranean [*Gunderson et al.*, 2012; *Lirer et al.*, 2009] and of the Eastern Paratethys [*Popescu et al.*, 2006, 2010]. It is important to understand the changes in the environment during Pontian events. The beginning of Pontian could be identified as the transgression with low salinity less than 5–8% [*Popov et al.*, 2006]. Portaferian is the regressive event in Dacian Basin [*Krijgsman et al.*, 2010]. Bosphorian corresponds to transgressive event.

The interdisciplinary methods were applied to the investigated successions. It includes biostratigraphic, paleomagnetic and cyclostratigraphic approaches. It revealed that according to the calculaltions of the stratigraphic levels, the Portaferian layer in the investigated section is ∼5.45–5.65 Ma. Accordin to all data the hiatus appear between lower and Upper Pontian. It was identified based on lithological data and re-sedimented deposits. The durations of the hiatus could be considered as ∼150–160 ky. It is well correlated with the data of high-amplitude Mediterranean sea-level drop and the onset of the Messinian Erosional Surface (MES) in the Black Sea [*Krezsek et al.*, 2016; *Tari et al.*, 2015].

The calculations of the sedimentation rates also support the obtained results. the Maeotian/Pontian transition the sedimentation rate was estimated at 16.3 cm/kyr. For the Novorossian, the sedimentation rate was estimated at 13.5 cm/kyr, and for the Bosphorian it was estimated at 19.5 cm/kyr. These rates are consistent with the mean rate of deposition in the Black Sea [*Denisov*, 1998]. Thus during the Pontian, and at the end of the Maeotian, the average sedimentation rate varied from 13.5 to 19.5 cm/kyr.

Acknowledgments. Supported by the Russian Foundation for Basic Research (RFBR): grant. 17-05-01085 A.

References

Andrusov, N. (1917), Pontian stage, *Geology of Russia*, A. P. Karpinsky (Ed.) 4(2), p. 1–41, Petrograd, Russia. (In Russian)

Denisov, V. (1998), *Regularities of Formationsuspended Materialin the BlackSea,* Ph.D. thesis, p. 25, Rostov State University, Rostov-on-Don.

Gillet, H., G. Lericolais, J.-P. Rehault (2007), Messinian event in the Black Sea: evidence of a Messinian Erosional Surface, *Mar. Geol., 244*, 142–165, doi:10.1016/j.margeo.2007.06.004

Gunderson, K., K. Kodama, D. Anastasio, F. Pazzaglia (2012), Rock-magnetic Cyclostratigraphy for the Late Pliocene Early Pleistocene Stirone Section, Northern Apennine Mountain Front, Italy, *Special Publications 373*, Geological Society, London. doi:10.1144/SP373.8

Krijgsman, W., M. Stoica, I. Vasiliev, V. Popov (2010), Rise and fall of the Paratethys sea during the Messinian Salinity Crisis, *Earth Planet. Sci. Lett., 290*, 183–191, doi:10.1016/j.epsl.2009.12.020

Krezsek, C., Z. Schleder, Z. Bega, G. Ionescu, G. Tari (2016), The Messinian sea-level fall in the Western Black Sea: small or large? Insights from offshore Romania, *Pet. Geosci., 22*, No. 4, 392, doi:10.1144/petgeo2015-093

Laskar, J., P. Robutel, F. Joutel, M. Gastineau, A. C. Correia, B. Levrard (2004), A long term numerical solution for the insolation quantities of the earth, *Astron. Astrophys., 428*, 261–285, doi:10.1051/0004-6361:20041335

Lirer, F., M. Harzhauser, N. Pelosi, W. Piller, H. Schmid, M.

Sprovieri (2009), Astronomically forced teleconnection between Paratethyan and Mediterranean sediments during the middle and late Miocene, *Palaeogeogr. Palaeoclimatol. Palaeoecol., 275*, 13, doi:10.1016/j.palaeo.2009.01.006

Paillard, D., L. Labeyrie, P. Yiou (1996), Macintosh program performs timeseries analysis, *Trans Am. Geophys. Union, 77*, 379, doi:10.1029/96EO00259

Pevzner, M., V. Semenenko, E. Vangengeim (2003), Position the Pontian of the Eastern Paratethys in the magnetochronological scale, *Stratigr. Geol. Correl., 11*, 482–491.

Popescu, S.-M., J.-P. Suc, M.-F. Loutre (2006), Early Pliocene vegetation changes forced by eccentricity-precession. Example from Southwestern Romania, *Palaeogeogr. Palaeoclimatol. Palaeoecol., 238*, 340–348, doi:10.1016/j.palaeo.2006.03.032

Popescu, S.-M., et al. (2010), Pliocene and lower Pleistocene vegetation and climate changes at the European scale: long pollen records and climatostratigraphy, *Quat. Int., 219*, 152–167, doi:10.1016/j.quaint.2010.03.013

Popov, S., A. Zastrozhnov (1998), Neogene Key Sections of the Eastern Paratethys (Taman Peninsula), 20 pp., *Tour Guide*, Volgograd-Taman.

Popov, S., I. Shcherba, L. Ilyina, L. Nevesskaya, N. Paramonova, S. Khondkarian, I. Magyar (2006), Late Miocene to Pliocene palaeogeography of the Paratethys and its relation to the Mediterranean, *Palaeogeography Palaeoclimatology Palaeoecology, 238*8, 91–106, doi:10.1016/j.palaeo.2006.03.020

Radionova, E., et al. (2012), Middleeupper Miocene stratigraphy of the Taman Peninsula, Eastern Paratethys, *Cent. Eur. J.*

Geosci., 4, No. 1, 188–204, doi:10.2478/s13533-011-0065-8

Rostovtseva, Yu. (2009a), Lower Maeotian facies of the Taman trough, *Lithology and Mineral Resources, 44*, 451–464, doi:10.1134/S0024490209050046

Rostovtseva, Y. (2009b), The Layer by Layer Description of Upper Miocene Sediments of the Zheleznyi Rog Section. *Taman Peninsula (Eastern Paratethys)*, 109–114 pp., GEOS, Moscow.

Rostovtseva, Yu., V. Kosorukov (2012), Clay minerals in the middle-upper Miocene sediments of the Taman trough: composition and paleogeographic significance, *Lithology and Mineral Resources, 47*, 234–252, doi:10.1134/S002449021202006X

Rostovtseva, Yu., A. Rybkina (2014), Cyclostratigraphy of Pontian Deposits of the Eastern Paratethys (Zheleznyi Rog Section, Taman Region), *Mosc. Univ. Geol. Bull., 69*, No. 4, 236–241, doi:10.3103/S0145875214040103

Rostovtseva, Yu., A. Rybkina (2017), The Messinian event in the Paratethys: Astronomical tuning of the Black Sea Pontian, *Marine and Petroleum Geology, 80*, 321–332, doi:10.1016/j.marpetgeo.2016.12.005

Schulz, M., M. Mudelsee (2002), REDFIT: estimating rednoise spectra directly from unevenly spaced paleoclimatic time series, *Comput. Geosci., 28*, 421–426, doi:10.1016/S0098-3004(01)00044-9

Suc, J.-P., et al. (2015), The region of the Strandja Sill (North Turkey) and the Messinian events, *Mar. Pet. Geol., 66*, 149–164, doi:10.1016/j.marpetgeo.2015.01.013

Tari, G., M. Fallah, W. Kosi, J. Floodpage, J. Baur, Z. Bati, N. Sipahioglu (2015), Is the impact of the Messinian Salinity Crisis in the Black Sea comparable to that of the Mediterranean?, *Mar. Pet. Geol., 66*, 135–148, doi:10.1144/petgeo2016-003

Trubikhin, V. (1989), Paleomagnetic data for the Pontian, *Chronostratigraphie Neostratotypen, 7*, 76–79.