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ABOUT THE FLUCTUATIONS OF THE BLACK SEA BASIN AFTER THE LAST GLACIAL MAXIMUM AND EARLY HOLOCENE

The aim of this paper is to determine the causality between the cycles of Solar Luminosity on the one hand, and the palaeoclimatic data for the Black Sea region and the fluctuations of the Black Sea Basin on the other hand. The established cycles of Solar Luminosity can explain the short-periodicity fluctuation of the Black Sea level. It is considered, that the regression of the Black Sea Basin to the depth of −90...−100 m below the contemporary sea level during the Early Holocene is not abrupt event.

Introduction. The fluctuations of the Black Sea Basin depend on the eustatic global sea level variations and the climate dynamics. This article aims to determine the causality between the cycles of Solar Luminosity on the one hand, and the palaeoclimatic data for the Black sea region and the Black sea Basin fluctuations on other hand.

The solar insolation proxy record in a speleothem from Duhlata Cave, Bulgaria is measured by Stoykova [16]. The latest results suggest that the solar insolation, which results from Solar Luminosity self variations, can produce climatic variations with intensity comparable to that of the orbital variations [17].

It is ascertained that for the Black Sea region there is a cycle recurrence in the change of the climate after the Last Glacial Maximum until present [14]. Most likely the understanding of the processes governing a formation of palaeoclimatic records for the mentioned period can give the established cycles of Solar Luminosity with the different duration. Furthermore, in [13] the variations of the solar insolation in the past climatic conditions, caused by variations of orbital parameters and Solar Luminosity self variations were distinct.

Materials and Methods. In this paper the luminescent solar insolation proxy record obtained from Duhlata Cave, Bulgaria speleothem is used. The orbital variations are extracted from this record by a band-pass Tukey filter. The same speleothem was dated by TIMS U/Th dates from [16]. The methods of spore-pollen, dinoflagellate cysts and moluscan fauna analysis from different authors were employed to reconstruct the climatic changes in continental and marine environment. The climatic archives of the Black sea region, which are dated in conventional ^{14}C years were converted to calendar years using the calibration curve of [18], in order to correlate them with cycles of the Solar Luminosity, which are dated in U/Th years. The special features of the palaeoclimatic archive, namely “reservoir correction” and “detrital carbon input” for TOC and TCC [10] are also taken into account.

Results and Discussion. The variations of the total amount of solar radiation at the Earth's surface (insolation) produce global changes in the climate as it was established by [12]. Traditionally, it is considered that all such variations of the insolation are due to the orbital variations. This presumption is not precise because insolation depends also on:

- variations of the solar insolation due to the Solar Luminosity variations;
- variations of the atmosphere transparency;

According to different authors the theoretical curves of orbital variations of insolation explain only a half of the real variations due to some incorrect assumptions made by Milankovitch in his theory. For quantitative correlation, it is thus necessary to use experimentally determined records of solar insolation.

There are various paleoclimatic archives, such as:

- ice cores;
- deep-sea sediment cores;
- continental records,

Speleothems are continental records and they are secondary cave formations (stalagmites, stalactites, etc.). They are interesting because:

- they are the best samples for preparation of high-resolution paleoclimatic records;
- they may grow continuously for hundreds of thousands of years, preserving in their layers records of changes in different environmental parameters;
- they can be dated by TIMS U/Th dates in calendar years, thus they don't need to be calibrated.

Speleothem luminescence is still the only proxy producing such records for long spans of time. Stoykova et al. [17] used such records to study real variations of past insolation. They ascertained that both Solar Luminosity and orbital variations cause variations of solar insolation, which affect the climate by the same mechanism.

The transition of the Black Sea system from a freshwater lake to a marine environment is one of the most debatable scientific Late Quaternary environmental event (fig.1).

During the LGM – Vurm III the Black Sea was a gigantic freshwater lake, which were not connected to the Marmara Sea. During that period the Black Sea level fluctuations were not synchronous with the global sea level fluctuations. On the contrary the global curve of the sea level changes in the last 20 000 cal.yrs was synchronous with the Mediterranean water level [4]. During the same period the surface level of the Black Sea Lake was approximately –90...–100 m [3]. The palaeo-shores of the Marmara Sea were reaching up to –100 m below the contemporary sea level [3, 9], while those of the Aegean Sea up to –115...–120 m [2] (fig. 2A). For the period of maximum low eustatic global sea level (18 000–15 000 cal.yrs BP) it can be concluded that there were three entirely separated basins each with its own water-mass configuration.

About 15 000 cal.yrs BP the 1st meltwater pulse (IA) along the Barbados coral reef is dated. The melting led to a rise of the Word Ocean level. The Word Ocean level was approximately –95 m in 14 500 cal.yrs BP [4]. For the period

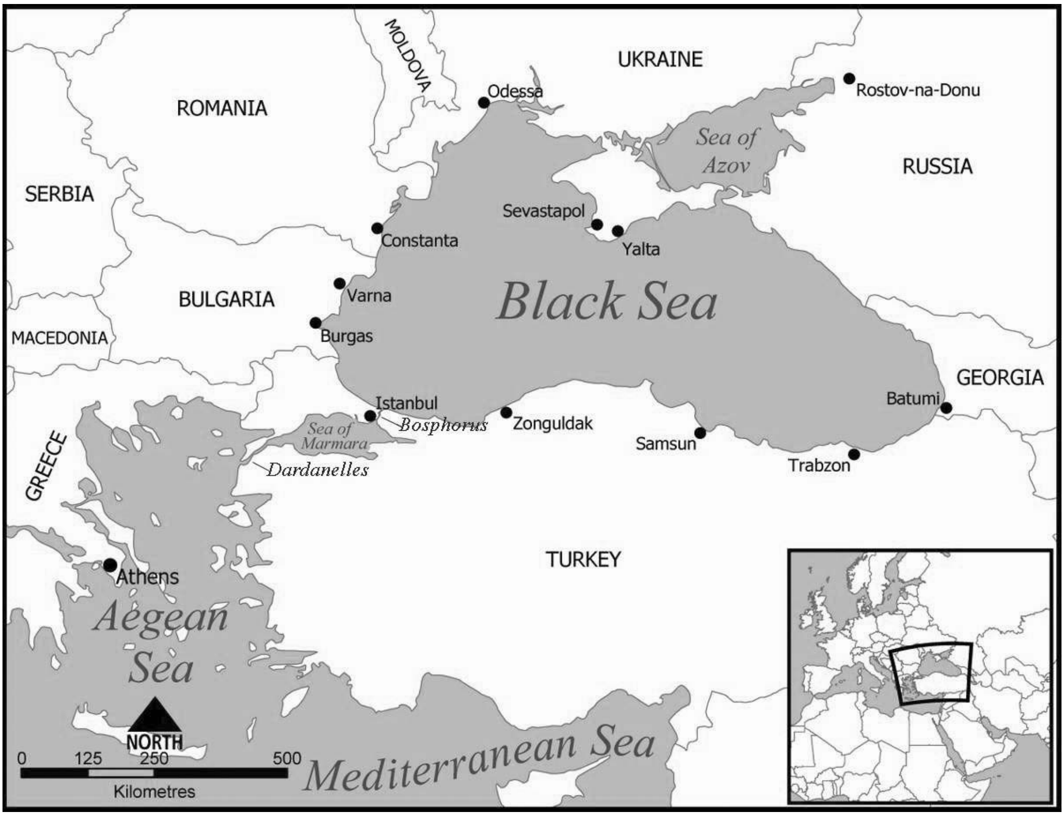

Fig.1. Location of the Black Sea, the Marmara Gateway (the Bosphorus Strait, the Sea of Marmara, and the Dardanelles), the Aegean Sea, the Eastern Mediterranean

15 000–14 500 cal.yrs BP the climate warming was expressed in quick melting of large glacial covers in North Europe and the Alps. It also helped for the sudden inflow of melted water carried by the Danube River, the Dnepr River, the Dnester River, the South Bug and the river Don into the Black Sea. The Caspian Sea also reacted to the process of glacial melting, raising its level up to the overspill point in the Black Sea through the Manichkata Valley [11].

In 14 500 cal.yrs BP (~12 500 ^{14}C yrs BP), the Black Sea was still in freshwater stage with rapid rise of its level [15]. As a result large volumes of water flowed out from the Black Sea into Marmara Sea through the Bosphorus and later – through the Dardanelles into the Aegean sea (fig.2B). For the same period there was a freshwater sedimentation in the Bosphorus strait, and its southern sill (bar) was formed initially by means of the interaction between the back current and the Black Sea inflowing current [7].

Stable improvement of the climate for the Black Sea coast after 15 000 cal.yrs BP is also proved by pollen analyses of the Black Sea sediments [11; 1; 6]. This regional improvement of the climate coincides with the established cycle of Solar Luminosity 15 100+/- 605 cal.yrs BP from the Duhlata Cave, Bulgaria proxy record [16; 13] – Table 1. Most likely this is the reason for this warm spell. Moreover, the latest results suggest that the solar insolation, which is results from Solar Luminosity self variations, can produce climatic variations with intensity comparable to that of the orbital variations [13].

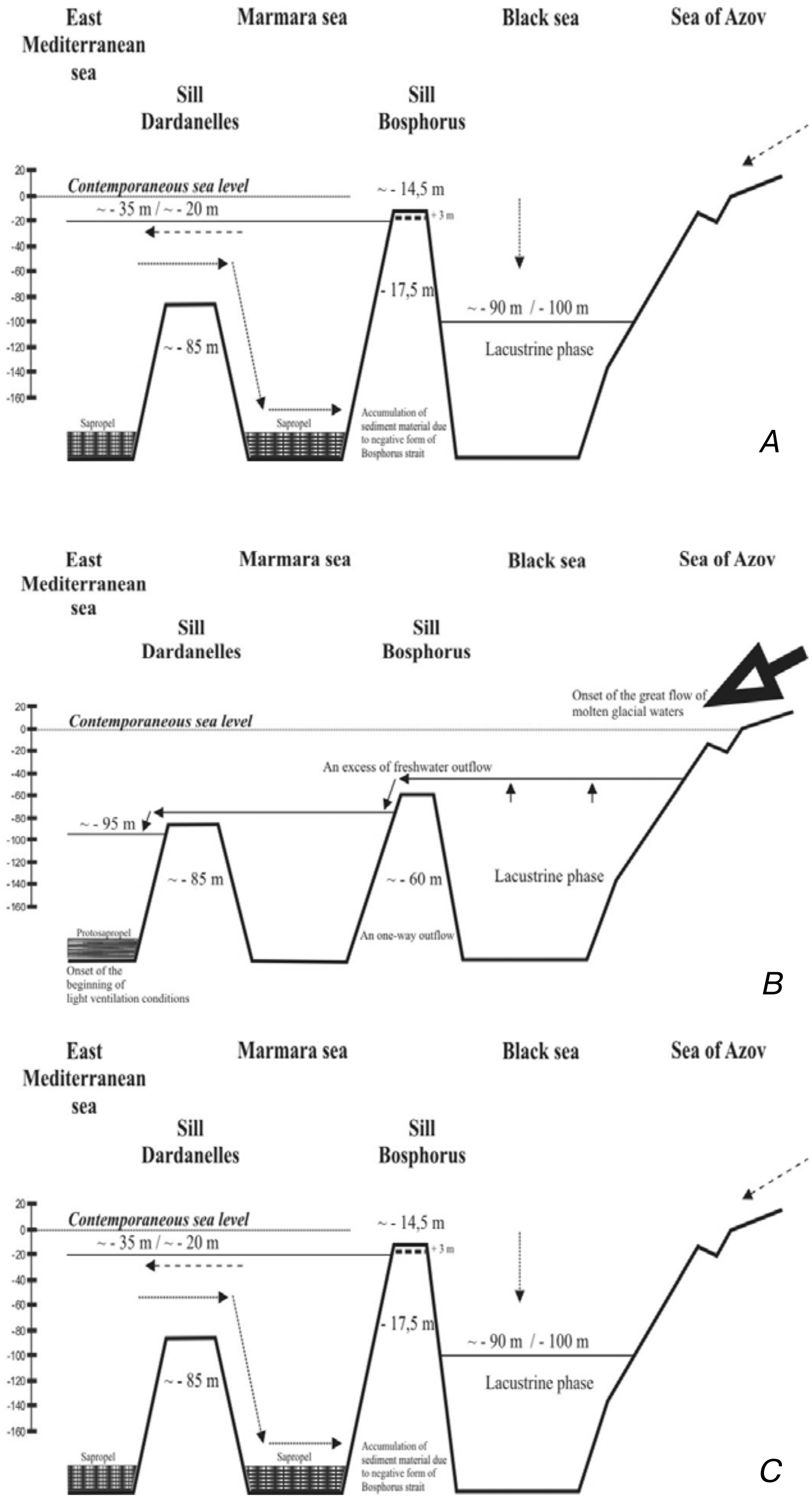

Fig. 2. A – Possible palaeo-exchange of water masses between the East Mediterranean Sea, Marmara Sea and Black Sea from 20 000 till 15 000 calendar years BP. B – Possible palaeo-exchange of water masses between the East Mediterranean Sea, Marmara Sea and Black Sea ~ 14 500 calendar years BP. C – Possible palaeo-exchange of water masses between the East Mediterranean Sea, Marmara Sea and Black Sea from 9 000 till 7 500 calendar years BP

Table 1

Cycles of the Solar Luminosity (in years) from the sample of Duhlata Cave, Bulgaria [16]

Cycle	Error	Intensity (%)
15100	+/- 605	99.8
10800	+/- 308	100
9400	+/- 236	53.1
8400	+/- 186	49.1
6900	+/- 125	70.5
5800	+/- 89	16.4
5500	+/- 80	23.4
5000	+/- 67	34.5
4700	+/- 57	24.1
4000	+/- 42	18.8
3600	+/- 33	8.7
3300	+/- 29	11.3
3100	+/- 26	8.3
3000	+/- 25	6.2

A mini glacial period “Younger Dryas” is dated to 12 500–11 800 cal.yrs BP in Europe. As a result of this event the water supply from glacial sheets melting in Europe to the Black Sea decreased.

Due to the reduction of the melted glacial water quantity, the intensity of the Black Sea outflow to the Marmara Sea also decreased. As a result, very intensive deposition of surplus sedimentary material and sill along the Bosphorus Strait should had begun [15]. There was still a freshwater sedimentation in the Bosphorus Strait.

On the Barbados coral reefs the Ist B melt water pulse of glacial waters is dated to 11 500 cal.yrs BP [5]. The boundary Pleistocene/Holocene for the Black Sea region is determined by pollen analysis as ~11 160 cal. yrs BP (10 035+/–65 ^{14}C yrs). On the other hand cycles of Solar Luminosity before 10 800+/–308 cal. yrs and 9 400+/–236 cal. yrs BP from the Duhlata Cave, Bulgaria proxy record are measured. A warm time interval for the Black Sea region, after the climatic warm maximum, results in increasing of the evaporation in the Black Sea region and the reduction of the Black Sea outflow and sediment accumulation in the Bosphorus Strait. But there are proofs of continuous freshwater outflow from the Black Sea Lake through the Bosphorus Strait to about 9 500 cal. yrs BP.

The chronostratigraphic scale for correlation between shelf sediments and the upper part of continental slope on the one hand, and sediments from more deepwater part on other hand in the Black Sea was created (Table 2). The general idea of the scale is to show that the boundary Neoeuxin/Lower Holocene is not possible to be fixed by a change of sedimentation conditions. The boundary Neoeuxin/Lower Holocene is a climatic boundary defined by pollen analyses.

The boundary Lower Holocene/Middle Holocene shows abrupt change of ecological setting of the basin, expressed in sharp change of sedimentation conditions [8]. The Black Sea Basin was again an isolated freshwater lake during

Table 2.

Chronostratigraphic scale of Neoeuxin/Holocene for the Black Sea [8]

Stage	Shelf and upper most part of continental slope	Mollusc	Salinity, ‰	Age, cal.yrs	Deep see kettle
Holocene	Upper Holocene –Hl$_3$ (Djemetin)	*Modiolus phaseolinus* *Mytilus galloprovincialis* *Cardium edule* *Abra ovata* *Pitar rudis* *Corbula mediteranea* *Divaricela divaricata* *Rissoa parva* *Cerithidium pusillum* *Triphora perversa* и др.	18	0 3000	Upper Holocene–Hl$_3$ Cocculithic ooze *(continuous sedimentation)*
	Middle Holocene – Hl$_2$ (Kalamit - Vitiaz)	*Mytilus galloprovincialis* *Cardium edule* *Abra ovata* *Corbula mediteranea* *Rissoa parva* *Cerithidium pusillum* и др.	15	3000 7500	**Middle Holocene – Hl$_2$** Sapropel *(continuous sedimentation)*
	LITHOLOGICAL SHARP BOUNDARY (proving the change of ecological conditions in the Black sea basin)				
	Lower Holocene – Hl$_1$ (Bugaz) *(absence in vast shelf zones - regression)*	*Dreissena polymorpha* *Monodacna caspia* *Turricaspia lincta* *Clessiniola variabilis* *Abra ovata* *Cardium edule* и др.	11	7500 11000	**Lower Holocene – Hl$_1$** Freshwater or brakish sediments *(continuous sedimentation)*
CLIMATIC BOUNDARY (perceivable and fixed by pollen analyses)					
Pleistocene	**Neoeuxine – Ne**	*Dreissena polymorpha* *Monodacna caspia* *Dreissenarostriformis* *Theodoxus pallasi* *Turricaspia lincta* и др.	10 3-8	11000 30000	**Neoeuxine – Ne** Freshwater or brakish sediments *(continuous sedimentation)*

the period 9 500 – 7 500 cal.yrs BP without connection with the Mediterranean sea (Fig. 2C).

The period between 9 500–7 500 cal.yrs BP is discussible period in the Black Sea history. The proof for this regression is the dating of the old coastlines of the Western Black Sea (from –90 m to –100 m below the present sea level) as Lower Holocene. Moreover, it is established that regional erosion, which affects mainly the sediment layers deposited near the Pleistocene/Holocene boundary, corresponds to the drastic change in the hydrological regime. This hiatus shows that the shelf of terrestrial sediments was exposed and eroded at the time of low sea-level and that it was then flooded by sea waters at some time about 7 500 cal. rs BP.

The regression of the Black Sea Basin to the depth –90 m...–100m below the contemporary sea level during the Early Holocene is not accepted by many authors. They assert that only the established warm time interval on the climatic boundary Pleistocene/Holocene is not enough for such regression. Actually in this paper the author suggests that reasons for this regression are several successive events, namely:

- Younger Dryas mini glacial period is established about 12 500 cal. yrs BP in Europe and it led to decrease of melted glacier waters inflow into the Black Sea region.

- The climatic boundary Pleistocene/Holocene for the Black Sea region is fixed at ~11 160 cal.yrs BP and the cycles of Solar Luminosity at 10 800+/-308 cal. yrs BP and 9 400+/-236 cal. yrs BP according to the Duhlata Cave, Bulgaria proxy record are measured.

- In addition to arid climate and as a result of evaporation in the Black Sea region the connection between the Caspian Sea through the Manichka Valley with the Black Sea Lake was interrupted about 9 500 cal. yrs BP. The Black Sea Lake outflow into the Marmara Sea was stopped after 9 500 cal. yrs BP.

- The cycle of Solar Luminosity at 8 400+/-186 cal. yrs BP is sampled from the Duhlata Cave, Bulgaria.

- A second mini glacial period in Europe is established about 8 200–7 800 cal. yrs BP. It led to decrease of the melted Alpine glacial waters toward the Danube River and to the Black Sea basin, respectively and causes the deepening of the Black Sea regression.

Conclusion. The regression of the Black Sea Basin during the Early Holocene is not an abrupt event. This is a process, which had continued several thousands of years. The reasons for this are complex. Actually the Black Sea level fluctuations correspond to the climatic dynamics. The established cycles of Solar Luminosity are recorded in the changes of paleoecological settings in the Black Sea region and they can explain the fluctuations of the Black Sea level.

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Метою дослідження є встановлення причинно-наслідкового зв'язку сонячної світності з палеокліматичними даними та коливанням рівня Чорноморського басейну. Цикли сонячної активності пов'язані зі зміною палеокліматичної обстановки регіону та могли подіяти на дрібноперіодні варіації чорноморського рівня. Доведено, що регресія Чорноморського басейну до рівня −90...−100 м за раннього голоцену не є раптовою подією.

Цель настоящего исследования – установление причинно-следственной связи солнечной светимости с палеоклиматическими данными и колебаниями уровня Черноморского бассейна. Циклы солнечной активности связаны с изменением палеоклиматической обстановки региона и могли быть индикатором мелкопериодных вариаций черноморского уровня. Доказано, что регрессия Черноморского басейна до уровня −90... −100 м в раннем голоцене не является внезапным событием.