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TWO MAIN LATE PLEISTOCENE – HOLOCENE EVENTS IN THE BLACK SEA

The refined seismic stratigraphic model of the structure and formation of the Upper Pleistocene-Holocene section of the Black Sea is offered for discussion. There are two major events that are ubiquitously recorded in the section: a large-scale regressive-transgressive cycle of Post-Karangatian-Neoeuxinian age and a regressive- transgressive cycle at the Pleistocene-Holocene boundary.

At this stage, we would like to offer for discussion a refined model [13] of the structure and formation of the Upper Pleistocene-Holocene section, which is based on large volume of seismic profiling data in various part of the Black Sea. Until a comprehensive drilling program exists along a wide range of depths, seismic profiles are the only materials that allow us to link the existing near-surface sampling and geo-acoustic investigations, deeper seismic exploration studies, and a limited number of drilling in shallow-water regions. Obviously, a seismic stratigraphic model (fig. 1) can have only an approximate character; however, taking into account the constant spatial-geometric basis of such a model, the primary boundaries and their relationships would not change even when future drilling uncovers different lithological and chronological data.

Based on all available data, there are two major events that are ubiquitously recorded in the Upper Pleistocene-Holocene section in various settings, including coastal depressions (straits, bights, limans, incised river valleys) – shelf – alluvial fan – abyssal plain. These events include a large-scale regressive-transgressive cycle of Post-Karangatian-Neoeuxinian age and a regressive-transgressive cycle at the Pleistocene-Holocene boundary. The facts about them are well known as is their global character.

Following is a general evolutionary scheme (fig. 2) for the Black Sea basin during this period (the causes and water balance of regressive-transgressive phases and the special role of Bosporus are not considered in detail because they are the subject of a separate discussion).

The sea level during Post-Karangatian regression was always placed at –(80-90) m by the majority of investigators [22, 23 among others]. Subsequent data on the relict coastal forms of this age found at the edge of the shelf [7, 12 and others] resulted in placing the sea-level position much deeper (maximum: – 155 m). However, it is important to recognize that such a wide range of the discovered coastal landforms correlates with the variable depth of the shelf break itself: from –80 m to –(150-170) m (and even to –200 m). This is mainly the result of expression of multi-directional neotectonic processes and especially

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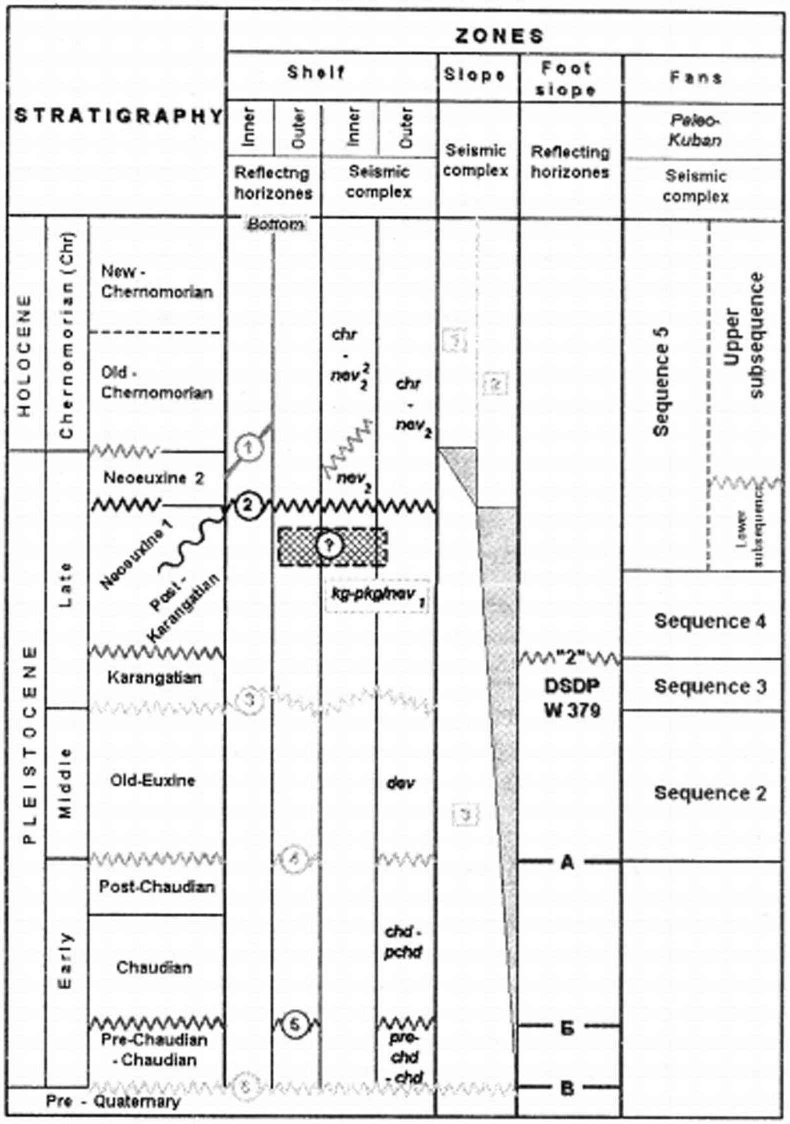
Fig. 1. **Correlation Seismic Stratigrafic Model**



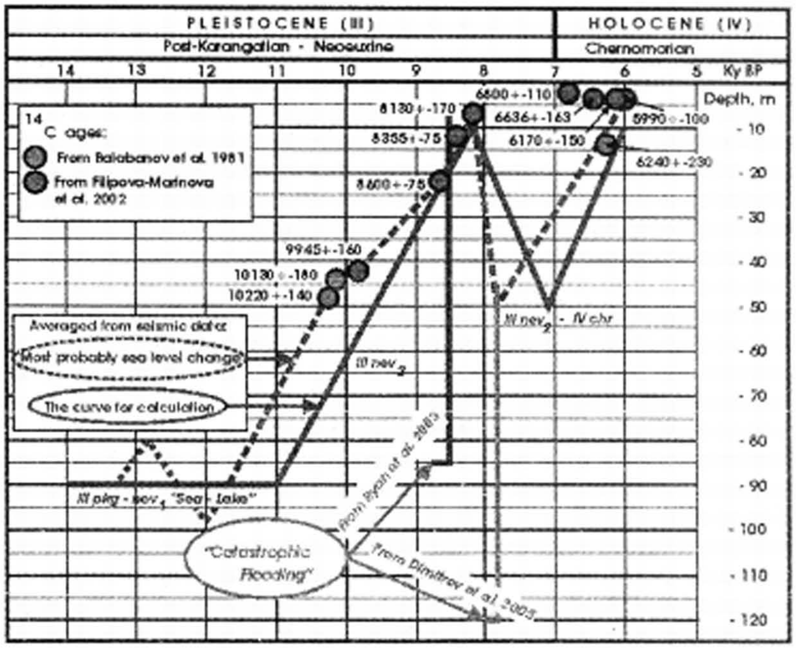


Fig. 2. **Sea Level Changing**

their overprinting by the general process of steady downwarping of the Black Sea depression during Cenozoic and until present along with its expansion [27, 12, 14, 15]. This process is expressed in the subsequent flexure of the continental slope and lowering of the outer shelf up to the formation of the final stage of slump terraces along its edge. Based on this evidence, the model uses an average depth of regression as – 90 m.

During this deep regression, an alluvial fan of the paleo-Kuban River was formed along the NE slope of the Black Sea depression [3]. Its Post-Karangatian development reliably correlates along seismic boundaries from well 379 (DSDP, Leg 42). The calculations of the time and volume of accumulation of the fan and its separate phases lead to the beginning of the last clearly defined sea-level lowstand ca. 14 ky BP. This age brings together the terms "Post-Karangat" and "Neoeuxinian" and correspond to "Neoeuxinian I" proposed by Fedorov [10]. The duration of this last phase of Neoeuxinian "sea-lake" is estimated to be 3-4 ky [22], which corresponds to eustatic sea-level data (the level of the World Ocean before the transgression was 90-95 m lower than present during 11-12 ky BP [9, 5]); it also corresponds to the conclusion about the initiation of the subsequent transgression ca. 11 ky BP, which was proposed on the basis of highly detailed investigation near the Bosporus region of the Black Sea [1]. The 11 ky BP age is sufficiently well known for its geochronological significance in a number of aspects and is even accepted as the Pleistocene-Holocene boundary [24].

Therefore, approximately 11 ky BP (and possibly earlier, but not prior to 14 ky BP), the eustatic sea-level rise has begun. It left a sufficiently clear footprint in the shelf section as a reflection horizon "2". Subaerial paleorelief forms and seismic facies are found below this boundary. Above the boundary, the base of the overlying sequence contains nearshore accumulation forms and shallow-water seismic facies of the fluctuating-advancing transgressive sea. Higher in the section, they are replaced by parallel-bedded transgressive seismic facies. The thickness of this entire transgressive seismic-stratigraphic complex of Neoeuxinian deposits on the pre-Caucasus shelf is more than 14 m. During the same time, a layered sequence was formed within the Kuban alluvial fan. According to drilling data on the NW shelf, in the limans of the northern Black Sea plain, in Novorossiysk and Gelendzhik bights the maximum of Neoeuxinian transgression of this cycle reached (10-8) m [29, 19, 16, 12]. The absolute age of ingressive Neoeuxinian deposits in the limans is 8.2 ka [29].

The suggested model accepts as the averaged quantitative evaluation, the period of transgression as from 11 ky BP to 8.2 ky BP, and its amplitude as from – 90 m to – 10 m below the present level. Based on that assessment, an average speed of sea level rise is estimated as about 29 mm per year. Taking into account the minimal decline of the sea bed (0.3° observable on the north-western part of the Black Sea only) the flooded coastal area could reach 63 m per year. This evaluation does not take into account sea level oscillations detectable in the geological sequences.

Before the Neoeuxinian age came to a close, a regression occurred that was evidently linked with Pereslav cooling (western Europe analog "Piottino

Stage"). The layers of this interval – between Younger Dryas and Boreal – "Super-YD horizon", or "second half of Pre-Boreal" [6]. Although much less substantial than the preceding glaciation, this anomalous event with its cold and dry conditions occurred at 8.2 ky BP. From [18, p. 23]: "The Younger Dryas is followed by a brief return to warm, moister conditions (early Holocene), then cooler, drier conditions again (the so-called 8200 yr BP event (Alley et al., 1993; von Grafenstein et al., 1999)".

Traces of reworking between Neoeuxinian (Pleistocene) and Chernomorian (Holocene) deposits in the nearshore regions have been documented virtually everywhere. In seismic profiles, reflection horizon "1" corresponds to this cycle and is traced to a maximum of – 47 m. It is highlighted by the buried fluvial paleo-channels with depths of incision at – (50-52) m, which were revealed during the latest investigations along the pre-Caucasus shelf. This level corresponds to a previously suggested regression to a depth of – 55 m ("Kolkhida regression" [26, 30]). It is this level (approx.– 50 m) which is often accepted as a pause/deceleration in the Neoeuxinian transgressive phase of the aforementioned earlier cycle. It is interesting to note that in its time and amplitude (–50 m) this regression correlates with Mangyshlak regression in the Caspian Sea.

Below – 50 m on the shelf (it is this region that was studied by the proponents of the "Flood" theory), there are no observed traces of the interruption within the Pleistocene-Holocene section [22], i.e., marine conditions persisted there. However, this region had shallow-water conditions during the maximum regression. It resulted in the formation of a sharply expressed boundary between Neoeuxinian and Drevnechernomorian [Old Chernomorian] strata [22], appearance of signs of reworking along this boundary within the upper portions of older subaqueous sandbars [8], and extensive input of terrestrial relics into this area noticed by the authors of the "Flood" hypothesis [20, 21]. The maximum water depth along the shelf edge at this time perhaps did not exceed – 30 to – 35 m, i.e., the modern depth of wave reworking in the Black Sea (if we consider signs of reworking of the outer ridges on the Bulgarian shelf, mentioned by Dimitrov et al. [8]). The occurrence of all these shallow features at the present depths of about – 100 m is defined by the arithmetics of modern bathymetry (35 m + 50 m = 85 m) with the addition of the aforementioned neotectonic subsidence of the outer shelf. Therefore, the – 100 m depth can hardly be considered the "initial mark" of the subsequent "Flood". The transgression had occurred, but the infilling of the Black Sea began from the level of approximately – 50 m.

The time of the initiation of this transgression, according to averaged estimates of the absolute age of Neoeuxinian and Drevenechernomorian deposits, can be placed convincingly around 7 ky BP [22]. In this regard, the youngest Neoeuxinian marine facies were deposited transgressively over the surface of reworking (reflection horizon "1"). They reached the – 20 m mark, which is often accepted as a maximum level of the Neoeuxinian transgression, combining two cycles (starting at 14-11 ky BP). Changes in sedimentation regime during the transgression (wave reworking of loosely consolidated sediments along geologically "recently" exposed shelf; developing changes of the balance toward Mediterranean waters) resulted in accumulation of a 2-m-thick "drape" [20] or "Unit 1D" [1]. It began forming from the edge of the shelf of a shallow pre-Holocene sea and caused "excellent preservation" [7] of nearshore features. These forms, when viewed in detail, are more ancient and correspond to the beginning of the Neoeuxinian transgression of the first cycle. Their expression in the modern relief, as well as in the upper parts of the section, is the result of sediment draping processes.

The transgression reached the point of maximum distribution of Neoeuxinian deposits of the preceding cycle – (10 – 8 m) at the end of Drevnechernomorian (Bugazian-Vityazevian) age according to drilling data, i.e., to ca. 6 ky BP. Therefore, the averaged interval of this regressive-transgressive cycle at the Upper Pleistocene-Holocene boundary, which can be used to calculate the rate of sea-level rise, is from 8.2 to 6.0 ky BP. From the standpoint of the "Flood" theory, it is not clear how a regressive-transgressive cycle with a 100m amplitude would fit into such a short time interval, as well as how to explain the cause and mechanism of not only the transgression but, in this case, also a "catastrophic" regression. It is important to note that neither such substantial amplitudes have been observed in sea-level changes of the World Ocean. In order to calculate the rate of transgression, its beginning is taken as the middle of the above interval, i.e., 7.1 ky BP, although it should be noted that in the Black Sea the regressive phases are shorter than transgressive [25]. The depth interval used for estimating the transgression rate is taken to be – 50 to – 10 m. This allows us to estimate an average rate of sea-level rise on the order of 36 mm/year. For minimal bottom gradients of 0.3є, which exist only on the NW shelf, the rate of land submergence may have reached 78 m/year.

Despite the fact that our model only estimates the order of transgression rate, it is possible to discuss whether the annual flooding of 80 m along a more populated NW part of the Black Sea can be considered a "Catastrophic Flood". Here it is also important to take into account a possibility of seasonal catastrophes linked to wind-driven surges, which can be significant in the shallowest areas. However, it is more likely that with refinement of the timing of transgressive phases in the model they will become longer, thereby decreasing the calculated rates of sea-level rise and consequently the area of submergence.

In conclusion, it is worth mentioning that there exists a colossal amount of factual materials, however there is no "key" database, i.e., a strategic drilling in already noted vital regions, which would put to rest the diversity of theoretical propositions.

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Предлагается к обсуждению уточненная сейсмостратиграфическая модель строения и формирования верхнеплейстоцен-голоценовой части разреза Черного моря. Выделяются два крупнейших события, повсеместно запечатленных в разрезе: значительный по масштабу регрессивно-трансгрессивный цикл посткарангат-новоэвксинского времени и регрессивно-трансгрессивный цикл на рубеже плейстоцена-голоцена.

Пропонується до обговорення уточнену сейсмостратиграфічну модель будови і формування верхньоплейстоцен-голоценової частини розрізу Чорного моря. Виділено дві найкрупніші події, повсюдно віддзеркалені у розрізі: значний за масштабом регресивно-трансгресивний цикл післякарангат-новоевксинського часу та регресивно-трансгресивний цикл на рубежі плестоцену-голоцену.