Дискусия

Comment on “Holocene sedimentation in the southwestern Black Sea: Interplay between riverine supply, coastal eddies of the Rim Current, surface and internal waves, and saline underflow through the Strait of Bosphorus” by O. Ankindinova, A. E. Aksu, R. N. Hiscott [Marine Geology, 420 (2020) 106092]

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Коментар на „Холоценска седиментация в югозападното Черноморие: Взаимодействие между речното снабдяване, крайбрежните вихри на контурното течение, повърхностните и вътрешните вълни и соления вток през Босфорския проток“ от О. Анкиндинова, А. Е. Аксу, Р. Н. Хискот [Marine Geology, 420 (2020) 106092]

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Резюме. Ankindinova et al. (2020) описват серия от хидроложки събития, довели до утаяване и стратиграфски промени при постепенното потъване на черноморския шелф по време на Холоцена. Ключов аспект на изследването е опитът да се осигури надеждна стратиграфска основа за доказване на трансгресия в басейна през холоценския интервал. Заклученията от този подход обаче противоречат на стратиграфските правила: преотлагане и значителен хиатус в трансгресивна фаза, промяна на дълбочина на местоположение на седиментна ядка (M05-03P) – принцип на суперпозицията; обединяване на трансгресивни и регресивни отложения в обща стратиграфска единица (противоречи на секвентната стратиграфия). По тази причина стабилността на заключението на Ankindinova et al. (2020) за изцяло трансгресивното холоценско развитие на Черно море е съмнително. Освен това изследването се базира на тълкуването, че покачването на отношението $^{87}\text{Sr}/^{86}\text{Sr}$ е зависимо единствено от приток на океанска вода, което за затворени и полузатворени басейни не винаги е правилно.

Ключови думи: Черно море, водно ниво, секвентна стратиграфия, Плейстоцен–Холоцен.

Abstract. Ankindinova et al. (2020) describe a series of hydrological events that have led to sedimentation and stratigraphic variations in the gradual sinking of the Black Sea shelf during the Holocene. A key aspect of the study is the attempt to provide a reliable stratigraphic basis for proving of a transgression in the basin throughout the Holocene. However, the conclusions of this approach run counter to the stratigraphic rules: redeposition and significant hiatus in the transgressive phase change of depth of sediment core location (M05-03P) – principle of superposition; merging of transgressive and regressive deposits into a common stratigraphic unit (contradicts the sequential stratigraphy). For this reason, the stability of the conclusion of Ankindinova et al. (2020) for the totally transgressive Holocene development of the Black Sea is doubtful. In addition, the study is based on the interpretation that the increase in the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio is solely dependent on ocean water inflow, which is not always correct for enclosed and semi-enclosed basins.

Keywords: Black Sea, water level, sequence stratigraphy, Pleistocene–Holocene.

Introduction

Ankindinova et al. (2020) favored the Black Sea level curve they derived for the end of the Pleistocene and Holocene. But they do not take into account that the ^{14}C dates they use confirm the evolution of the

Black Sea over the period in question, according to Genov (2016, 2018). They represent a significant number of calibrations of the conventional ^{14}C dating in calendar years (Williams et al., 2018; Ankindinova et al., 2019, 2020). These calibrations depend mainly on the correct determination of the reservoir

age offset for the basin at each time interval of its development. For the Black Sea, the impact of the reservoir effect is still uncertain and controversial (Kwiecien et al., 2008; Soulet et al., 2011; Yanchilina et al., 2017; Williams et al., 2018). However, the calibrations presented by the authors provide a satisfactory opportunity to compare their curve and the curve of the Black Sea level according to Genov (2016, 2018) because the last one is with ^{14}C years only. The stratigraphic interpretations of the mentioned Black Sea level curves using dating are a key point of comparison. Through them, it is possible to estimate the reliability of each curve.

Stratigraphic issue

Ankindinova et al. (2020) defined the erosion surface (α) on the basis of seismic records and sediment cores from the SW part of the Black Sea, as the last transgressive ravinement for the basin under consideration. They also assumed that prior to the last transgression, there were at least two regressions and one transgression, the sediments of which the authors combined into a single seismic subunit (allunit) 1a. According to the modern sequence stratigraphy (Embry, 2009; Catuneanu et al., 2009, 2011; Catuneanu, 2017, 2020) this should be more than a sequence, but such a seismostratigraphic unit is not defined, because basic stratigraphic principles for tracing transgressions and regressions in individual sequences are ignored. This is a clarification that should reflect on the general stratigraphic scheme shown in the article. But Ankindinova et al. (2020) did not adhere to the recommendations of the modern sequence stratigraphy, i.e. search and recognition of genetic units (T, transgressive, FR, forced regressive, HNR, highstand normal regressive, LNR, lowstand normal regressive) and sequence stratigraphic surfaces (SU, subaerial unconformity, CC, correlative conformity, BSFR, basal surface of forced regression, RSME, regressive surface of marine erosion, MRS, maximum regressive surface, MFS, maximum flooding surface, TRS, transgressive ravinement surface) on the seismic records (Embry, 2009; Catuneanu et al., 2009, 2011; Catuneanu, 2017, 2020). This leads to confusing conclusions in the stratigraphic interpretations such as the illogical assignment of shells aged 10 600 calendar years (core M05-03P) to the subunit 1a (Ankindinova et al., 2020 – Figs 13, 14). It is inconsistency with the Black sea level curve shown in Figure 19 (Ankindinova et al., 2020).

In order to prove the type of surface α , a real cross-section must be constructed through boreholes that have reached this surface. This cross-section would be informative if it covers boreholes located

in the shallowest and deepest parts of the study area with the maximum possible distance from the impact of the saltwater flow from the Bosphorus. Because the location of the surface α under borehole M05-50 was determined by seismic recording, the cross-section shown in Figure 1 is the most suitable for this purpose. This cross-section also intersects the seismic record A (Ankindinova et al., 2020), which has been taken into account. This record was adjusted according to the seabed by bathymetric map (Fig. 2) (Ankindinova et al., 2020 – Fig. 3). Placing some of the data, shown in the article in question (Ankindinova et al., 2020 – Fig. 19, Tables 1–3), on the cross-section proves that the surface α is impossible to be transgressive ravinement, because fossils, dated to an older age, are found higher than fossils at a younger age, that is, there is redeposition. Redeposition is also found over the surface α in the sedimentary cores shown in the next chapter (Table 1). Details regarding the interpretation of the surfaces α , $\alpha 0$, $\alpha 1$ and $\alpha 2$ are also shown in the next chapter.

The authors try to prove Holocene transgression using hydrological processes to explain unconformities that pass into conformities. In this way, they seek to solve the problem of radiocarbon dating of samples in sediment cores from the study area showing redeposition and hiatus. But the significant hiatus from 12 500 to about 3700 calendar years with few exceptions during transgression (Ankindinova et al., 2020 – Figs 18, 19), showing that there is an almost complete absence of Lower Holocene and most of the Middle Holocene is difficult to be explained for reasons that they highlight.

Stratigraphic interpretations

Ankindinova et al. (2020) used short, high-resolution seismic sections that do not intersect a significant portion of the shelf and continental slope in the study area. This leads to a vague general idea of the geological setting. But adhering to the rules of sequence stratigraphy, stratigraphic interpretations of radiocarbon-bound dates by Williams et al. (2018), Ankindinova et al. (2020), the records might appear as those shown in Figures 2–5 (Table 1). They confirm the curve of the sea level according to Genov (2016, 2018), i.e. $\alpha 0$ and α represent erosion surfaces of two regressions in two successive sequences. It should be noted that LNR-1 is not detected between FR-1 and T-1 units in the youngest sequence, with MFS being considered as the sequential limit. This is the reason for claiming that the flooding of the Black Sea lake with saltwaters through the Bosphorus was rapid. Another significant point is that the last regression for the Black Sea (FR-1) was relatively short but deep due to the arid climate (Genov,

Fig. 1. Section crossing core sites M05-03P, M05-22P, M11-30P and M05-50P
TRS, transgressive ravinement surface (shoreline ravinement)

Фиг. 1. Разрез през местоположенията на седиментни ядки M05-03P, M05-22P, M11-30P и M05-50P
TRS – трансгресивна ерозионна повърхност (ерозия на бреговата линия)

2009, 2016, 2018; Koleva-Rekalova et al., 2018) and therefore often formed an embankment (levee) or embankments. Perennial dry climates are characterized by a low terrigenous supply to the marine realm, where the carbonate sedimentation may be well developed (Zecchin, 2007). Consequently, due to the rapid fall of the base level and the absence of LNR-1 because of the sudden occurrence of the last transgression (T-1), part of the non-marine sediments are formed during the Holocene regression (FR-1). They consist mainly of slowly downstream transported sediments of residual water bodies on and near land during the fall of the lake level under conditions of arid climate. If the regression (FR-1) was not interrupted abruptly, then there would be an LNR-1 tract that would contain much of these non-marine sediments (excluding the non-marine sediments in the transgressive tract above). An older sequence has also been identified, but due to the short seismic records, only part of the seismic units within it (FR-2, LNR-2, T-2) are recognized. SU ($\alpha 0$) for this sequence represents the erosion cut of regression corresponding to the last glacial maximum (Genov, 2016, 2018). Therefore, the strati-

graphic interpretation of the cross-section shown in Figure 1 should look as shown in Figure 6. This means that distinct portions of the sediments in the M02-45P and M05-03P cores are redeposited and consequently the age model (Ankindinova et al., 2019) is partially correct. But if assuming that this model is approximately true overall because of the difficult transportation of non-marine sediments to the basin under dry climatic conditions and consider that the benthic organisms reflect the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the sediment substrate and the water in which they live (as an additional feature for correlation), the seismostratigraphic units according to Genov (2016, 2018) are applied as shown in Figure 7. The ^{87}Sr enrichment in the Black Sea (lake) during the Holocene regression (FR-1) is explainable because the basin was encompassed with old continental rocks under the influence of erosion and weathering. A part of the material as result of these processes (weathering, erosion, downward discharge) has been entering the sedimentary substrate in which the benthic organisms have been living and $^{87}\text{Sr}/^{86}\text{Sr}$ ratio of the substrate has been increasing. This explains why the euryhaline mol-

Table 1

Radiocarbon ages for cores M02-45T, M02-45P, M05-03P, M05-50P, M05-51G, M11-23P, M11-08T, M05-19G, M05-19P, M11-09T and M11-22P (after Ankindinova et al., 2020 with modifications and additions)

Таблица 1

Радиовъглеродни възрасти за седиментни ядки M02-45T, M02-45P, M05-03P, M05-50P, M05-51G, M11-23P, M11-08T, M05-19G, M05-19P, M11-09T and M11-22P (по Ankindinova et al., 2020; с изменения и допълнения)

Core	Depth (cm)	Composite depth (cm)	Material dated	Raw date (¹⁴ C yr BP)	Calendar age (cal yr BP)	Seismo-stratigraphic unit according to this study
M02-45T	92	92	<i>Spisula subtruncata</i>	730±50	365±50	deposits of water currents (T-1)
M02-45P	33	143	<i>Spisula subtruncata</i>	730±40	365±45	
M02-45T	145	145	<i>Spisula subtruncata</i>	770±50	395±55	
M02-45P	158	268	<i>M. galloprovincialis</i>	2400±60	2025±80	
M02-45P	174	284	<i>M. galloprovincialis</i>	5115±20	5480±40	T-1
M02-45P	220	330	<i>M. galloprovincialis</i>	5190±50	5535±55	
M02-45P	302	412	<i>M. galloprovincialis</i>	5900±60	6310±65	
M05-03P	183	485	<i>Cardium edule</i>	6810±25	7330±35	
M02-45P	406	516	<i>Monodacna pontica</i>	7560±60	8030±70	nonmarine
M05-03P	226	528	<i>Adacna? Laeviuscula</i>	7785±25	8305±45	
M02-45P	495	605	<i>Truncatella subcylindrica</i>	8380±70*	9150±100*	
M05-03P	342	644	<i>Monodacna caspia</i>	8340±25*	9070±55*	
M02-45P	569	679	<i>Didacna? Praetrigonides</i>	8570±70	9380±80	
M02-45P	639	749	<i>Didacna spp</i>	8620±70	9440±70	
M02-45P	700	810	sediment (carbonate)	13 570±35**	16 335±90**	FR-1
M02-45P	754	864	<i>Dreissena rostriformis</i>	8840±70	9700±120	
M02-45P	810	920	<i>Dreissena rostriformis</i>	9370±70*	10 480±100*	
M02-45P	822	932	<i>Dreissena polymorpha</i>	9340±70*	10 450±100*	
M02-45P	835	945	<i>Theodoxus spp.</i>	9070±70*	10 010±115*	
M05-03P	678	980	<i>Dreissena spp.</i>	9510±25	10 600±45	
M05-03P	712	1014	<i>Dreissena spp.</i>	10,475±30	12,240±120	T-2
M05-50P	44	94	<i>M. galloprovincialis</i>	2590±90	2255±120	deposits of bottom currents (T-1)
M05-51G	145	145	<i>M. galloprovincialis</i>	3280±60	3095±95	
M05-50P	180	230	<i>M. galloprovincialis</i>	3240±50	3045±75	
M05-50P	200	250	<i>M. galloprovincialis</i>	3590±15	3470±35	
M05-50P	279	329	<i>M. galloprovincialis</i>	3250±70	3055±105	
M05-50P	310	360	<i>M. galloprovincialis</i>	4130±20	4175±45	
M05-50P	340	390	<i>M. galloprovincialis</i>	4320±60	4435±90	
M05-50P	435	485	<i>M. galloprovincialis</i>	5330±70	5695±80	
M05-50P	550	600	foraminifera/ostracod	7710±40*	8235±55*	FR-1
M05-50P	620	670	foraminifera/ostracod	8540±50*	9320±70*	
M05-50P	625	675	foraminifera/ostracod	7570±40*	8040±60*	
M05-50P	670	720	<i>Dreissena polymorpha</i>	9880±110	11 095±135	
M05-50P	737	787	<i>Dreissena spp.</i>	10 270±90	12 010±205	
M11-23P	45	170	<i>Cyclope spp</i>	990±25	570±30	T-1
M11-08T	178	178	<i>Abra alba</i>	1130±20	670±20	
M11-08T	227	227	<i>Cyclope donovania</i>	1445±20	970±35	
M11-08T	253	253	<i>Nuculana commutata</i>	3910±15	3870±35	
M11-08T	264	264	<i>Monodacna pontica</i>	7870±20	8390±25	buried surf zone (T-1)
M11-23P	270	395	<i>Cyclope spp.</i>	9190±25*	10,190±25*	T-1 redeposition
M11-23P	366	491	<i>Dreissena polymorpha</i>	9105±25*	10,090±60*	
M11-23P	464	589	<i>Dreissena polymorpha</i>	10 555±25*	12 320±105*	
M11-22P	51	91	<i>Spisula subtruncata</i>	3990±20	3980±50	T-1
M11-09T	117	117	<i>Cyclope spp</i>	6470±20	6950±40	
M11-22P	239	279	<i>Dreissena rostriformis</i>	10 670±25*	12 530±45*	
M05-19G	31	31	<i>Cerastoderma lamarcki</i>	2230±60	1820±75	T-1
M05-19P	36	36	<i>Cerastoderma lamarcki</i>	2880±50	2620±75	
M05-19G	132	132	<i>Macra corallina</i>	4390±50	4535±80	
M05-19P	149	149	<i>Macra corallina</i>	4960±60	5285±95	
M05-19P	211	211	white mussels	8070±60*	8605±90*	non-marine
M05-19P	318	318	<i>Dreissena r. distincta</i>	32 360±290*	36 245±330*	non-lacustrine
M05-19P	445	445	<i>Dreissena r. distincta</i>	36 590±440*	41 210±425*	non-lacustrine (FR-2)
M05-19P	556	556	bivalve fragments	32 040±280*	35 940±295*	
M05-19P	685	685	<i>Dreissena r. distincta</i>	37 260±430*	41 745±325*	

*re-deposition

преотлагане

**it is a dating of probably near shore carbonate formed which might be re-deposited
датиране на вероятно формиран близо до брега карбонат, вероятно преотложен

Genetic units of the younger sequence: T-1 (transgressive-1), FR-1 (forced regressive-1), FR-2 (lowstand normal regressive-2), T-2, FR-2 (only its erosion surface SU exists in this figure); α (*dashed red line*), SU of FR-1 unit; $a0$ (*green line*), SU of FR-2 unit; $a1$ (*pink line*), RSME of FR-1 unit; $a2$ (*grey line*), coincide with erosion surface of the bottom currents; *MRS* (maximum regressive surface), yellow line; *MFS* (maximum flooding surface; sequence boundary), dashed blue line; *TRS* (transgressive ravinement surface), dashed green line; X – a mistake of the interpretation of Ankindinova et al., 2020 and according to this study these surfaces should be removed; a circle with a cross *inside*, water stream

Генетични единици на по-младата секвенция: T-1 (транскриптивна-1), FR-1 (интензивна регресивна-1), FR-2 (нисходяща нормална регресивна-2), T-2, FR-2 (само нейната ерозивна повърхност на тази фигура); α (*прекъсната червена линия*) – SU на единица FR-2; $\alpha 1$ (*розова линия*) – регресивна повърхност на морска ерозия (RSME) на единица FR-1; $\alpha 2$ (*сива линия*) – съвпада с ерозивната повърхност на дънните течения; *MRS* (максимална регресивна повърхност) – жълта линия; *MFS* (максимална повърхност; граница между секвенциите) – прекъсната синя линия; *TRS* (транскриптивна ерозивна повърхност) – прекъсната зелена линия; *X* – грешка на интерпретацията на Ankindipova et al., 2020 и според това изследване тези *г* и трябва да отпадат; *кръг c*

вътрешен кръст — воден поток

Fig. 4. Sequence stratigraphic interpretation of the seismic section, close to core site M05-19P (after Ankindinova et al., 2020)

Genetic units of the younger sequence: T-1 (transgressive-1), FR-1 (forced regressive-1); genetic units of the older sequence: LNR-2 (lowstand normal regressive-2), T-2, FR-2; α (dashed red line), SU of FR-1 unit; $\alpha 0$ (dashed red line), SU of FR-2 unit; pink line, RSME of FR-1 unit; $\alpha 2$ (dashed green line), TRS of T-1 unit; MRS, yellow line; X, a mistake of the interpretation of Ankindinova et al., 2020 and according to this study these surfaces should be removed

Фиг. 4. Секвентно-стратиграфска интерпретация на сеизмичен разрез до местоположението на седиментна ядка M05-19P (по Ankindinova et al., 2020)

Генетични единици на по-младата секвенция: T-1 (трансгресивна-1), FR-1 (интензивна регресивна-1); генетични единици на по-старата секвенция: LNR-2 (нискостояща нормална регресивна-2), T-2, FR-2; α (прекъсната червена линия) – SU на единица FR-1; $\alpha 0$ (прекъсната червена линия) – SU на единица FR-2; розова линия – регресивна повърхност на морска ерозия (RSME) на единица FR-1; $\alpha 2$ (прекъсната зелена линия) – TRS (трансгресивна ерозионна повърхност) на единица T-1; MRS (максимална регресивна повърхност) – жълта линия; X – грешка на интерпретацията на Ankindinova et al. (2020) и според това изследване тези линии трябва да отпаднат

lucks appeared with delay in the Black Sea – lake during the increasing of the $^{87}\text{Sr}/^{86}\text{Sr}$ ratio, i.e. their appearance was impossible despite $^{87}\text{Sr}/^{86}\text{Sr}$ ratio increase when the basin was isolated (FR-1) and was possible only when the tributary of Mediterranean (Marmara) waters existed (T-1). According to Genov (2009) the $^{87}\text{Sr}/^{86}\text{Sr}$ -ratio as a marker for a flow of marine waters into the Black Sea is uncertain because high values of this ratio were measured for interval 17 000–15 000 calendar years (Major et al., 2006), i.e. when influx of marine waters to the regarded basin didn't exist. Actually

the $^{87}\text{Sr}/^{86}\text{Sr}$ values for the interval 20 000–15 000 calendar years (Major et al., 2006) are related with LNR-2 unit when the base level has been below or around the shelf edge (Genov, 2016), and the $^{87}\text{Sr}/^{86}\text{Sr}$ values for the interval 15 000–9650 calendar years (Major et al., 2006) are related with T-2 unit (Genov, 2016).

The geological setting near the Bosphorus differs from the examples discussed so far. Many of the negative forms formed during the Holocene regression (FR-1) and the subsequent transgression (T-1) are filled or buried with sediments. These sed-

Fig. 5. Sequence stratigraphic interpretation of the seismic section close to core sites M02-45P and M05-03P (after Williams et al., 2018; Ankindinova et al., 2020)

Genetic units of the younger sequence: T-1 (transgressive-1), FR-1 (forced regressive-1); genetic units of the older sequence: T-2, FR-2 (only its erosion surface SU exists on this figure); α (green line), RSME of FR-1 unit; dashed red line, SU of FR-1 unit; $\alpha 0$ (red line), SU of FR-2 unit; $\alpha 1$, TRS of T-1 unit; $\alpha 2$, coincide with erosion surface of the bottom currents

Фиг. 5. Секвентно-стратиграфска интерпретация на сеизмичен разрез до местоположенията на седиментни ядки M02-45P и M05-03P (по Williams et al., 2018; Ankindinova et al., 2020)

Генетични единици на по-младата секвенция: T-1 (трансгресивна-1), FR-1 (интензивна регресивна-1); генетични единици на по-старата секвенция: T-2, FR-2 (само нейната ерозионна повърхност SU съществува на тази фигура); α (зелена линия) – RSME на единица FR-1; прекъсната червена линия – SU на единица FR-1; $\alpha 0$ (червена линия) – SU на единица FR-2; $\alpha 1$ – TRS на единица T-1; $\alpha 2$ – съвпада с ерозионната повърхност на дънните течения

iments are eroded, carried and redeposited by the saltwater inflow into the Black Sea lake under the constantly rising water level of the basin. When the sea level has risen sufficiently, at the place where the saltwater inflow was not strong an accumulation occurred (Fig. 8). On this figure, the surfaces $\alpha 1$ and $\alpha 2$ probably reflect the origin and the end of the surf zone at the rapidly rising water level during the last Holocene transgression (T-1). Maybe in this case, α is more properly should be referred to as TRS of the T-1 unit.

Conclusion

The study of Ankindinova et al. (2020) does not provide indisputable evidence that during the Holocene there was only sea level rise. In addition, the megaunit 1a needs to be detailed according to the requirements of the modern sequence stratigraphy, so that there would be no doubt about the existence of regression during the interval 15 500–12 600 calendar years. From the shown stratigraphic interpretations, $\alpha 0$ and α are logically to be considered

Fig. 6. Sequence stratigraphic interpretation of the section crossing core sites M05-03P, M05-22P, M11-30P and M05-50P LGM, last glacial maximum; genetic units: T-1, FR-1, LNR-2, T-2

Фиг. 6. Секвентно-стратиграфска интерпретация на разрез, пресичащ местоположенията на седиментни ядки M05-03P, M05-22P, M11-30P и M05-50P

LGM – последен глациален максимум; генетични единици: T-1, FR-1, LNR-2, T-2

as SU of the regression that existed during the last glaciation on Earth and SU or RSME during the arid climate in the Black Sea region in the early Holocene, respectively.

Probably the way of proving Holocene transgression in the SW part of the Black Sea, through unconformities and hiatuses at great depth, is in principle incorrect. The neglect of Ankudinova et al. (2020) of a number of dates showing redeposition and not using the achievements of the modern sequence stratigraphy probably may have led to the wrong conclusions about the changes of the Black Sea level.

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Fig. 7. Interpretation of the $^{87}\text{Sr}/^{86}\text{Sr}$ record for the last 12 000 years (Ankindinova et al., 2019 with modifications and additions)
Genetic units: T-1, FR-1, HNR-1 (highstand normal regressive-1) and T-2 (Genov, 2016, 2018)

Фиг. 7. Интерпретация на $^{87}\text{Sr}/^{86}\text{Sr}$ запис за последните 12 000 години (Ankindinova et al., 2019, с изменения и допълнения)
Генетични единици: T-1, FR-1, HNR-1 (високостояща нормална регресивна-1) и T-2 (Genov, 2016, 2018)

Fig. 8. Sequence stratigraphic interpretation of the seismic section close to core sites M11-23P and M11-08T (after Ankindinova et al., 2020)

Genetic units: T-1, T-2; α (green line), TRS of T-1 unit; $\alpha 0$ (red line), SU of FR-2; $\alpha 1$ and $\alpha 2$, erosion surfaces

Фиг. 8. Секвентно-стратиграфска интерпретация на сейсмичен разрез до местоположенията на седиментни ядки M11-23P и M11-08T (по Ankindinova et al., 2020)

Генетични единици: T-1, T-2; α (зелена линия) – TRS на единица T-1; $\alpha 0$ (червена линия) – SU на единица FR-2; $\alpha 1$ и $\alpha 2$ – ерозийни повърхности

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