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THE ROLE OF NEO-TECTONICS IN THE VARIATION OF THE RELATIVE MEAN SEA LEVEL THROUGHOUT THE LAST 6000 YEARS ON THE TAMAN PENINSULA (BLACK SEA, AZOV SEA, RUSSIA)

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Abstract. Sediments, carbon-datings on seashells, allow us to reconstruct the evolution of the average sea level for some 6000 years on the Taman Peninsula. The current sea level, regionally, appears to be the highest level ever reached on the peninsula. It seems that for the Anapa area and Tchouchtchka Spit area it is possible to propose a sea level curve characterised by a slow, continuous rising during the past 6000 years. On the Taman Peninsula itself, the sedimentary record of this slow ascent has been distorted by a heavy tectonic subsidence. We have identified this neo-tectonic subsidence effect on at least two areas on the peninsula. The south of the peninsula, Burgaz Spit and Vityazevos Lagoon, is the most affected area. The Taman Gulf is an intermediate area. The tectonic subsidence is particularly noticeable from 1500 to 500 BC, which we believe to have been misinterpreted until now, and to be at the origin of the notion of "Phanagorian Regression".

Key words: sea level, geo-archaeology, neo-tectonics, Holocene, Black Sea, Russia.

INTRODUCTION

According to the results of studies over the last thirty years, it seems that the Holocene transgression in the Black Sea, which starts later than the global ocean evolution around 7500 BP (Ryan, Pitman, 1998), was characterised by a succession of rapid sea level fluctuations (Pirazzoli, 1991; Ismailov *et al*., 1989). Those fluctuations (Fig. 1) have been related mostly to climatic changes during the Holocene and the possible distortion due to the neo-tectonic factor has been neglected. The new data we obtained on the Taman Peninsula (Fig. 2) confirm the importance of the neo-tectonic effect.

The results presented here have been obtained within the frame of the Franco/Russian archaeological survey of the Taman Peninsula, directed by Christel Müller and Youri Gorlov. This survey is the result of a partnership between the Russian Academy of Sciences, the French School of Archaeology in Athens, the "Black Sea" GDR and the French Ministry of Foreign Affairs. The first objective of our palaeogeographical study was to prove that the extremity of the Taman Peninsula was composed of one main island and four islets during the time of Grecian colonisation in the 6th century BC (Fouache *et al*., 2000a). With the deposit of its alluvium, its successive changes of course and the progradation of its delta, the Kuban River is at the origin of the attachment of the islands to dry land. But this attachment came late, during the Late Antiquity or the Early Middle Ages. Greek colonisation founded settlements such as Hermonassa, Phanagoria, Kepoi and Patrasys, to name but the most important ones, and these cities were still in activity until the 4th century AD and the war against the Scythians. Our reconstruction confirms the models proposed by Nevesky (1958) (Fig. 3). One question remains in this reconstruction: what about the extension of beach-barriers and spits all along this period? We decided to carry out a core programme on different beaches of the peninsula to identify palaeobeaches facies and to obtain radiocarbon datings. Our objective was also to obtain sea level curves with these data.

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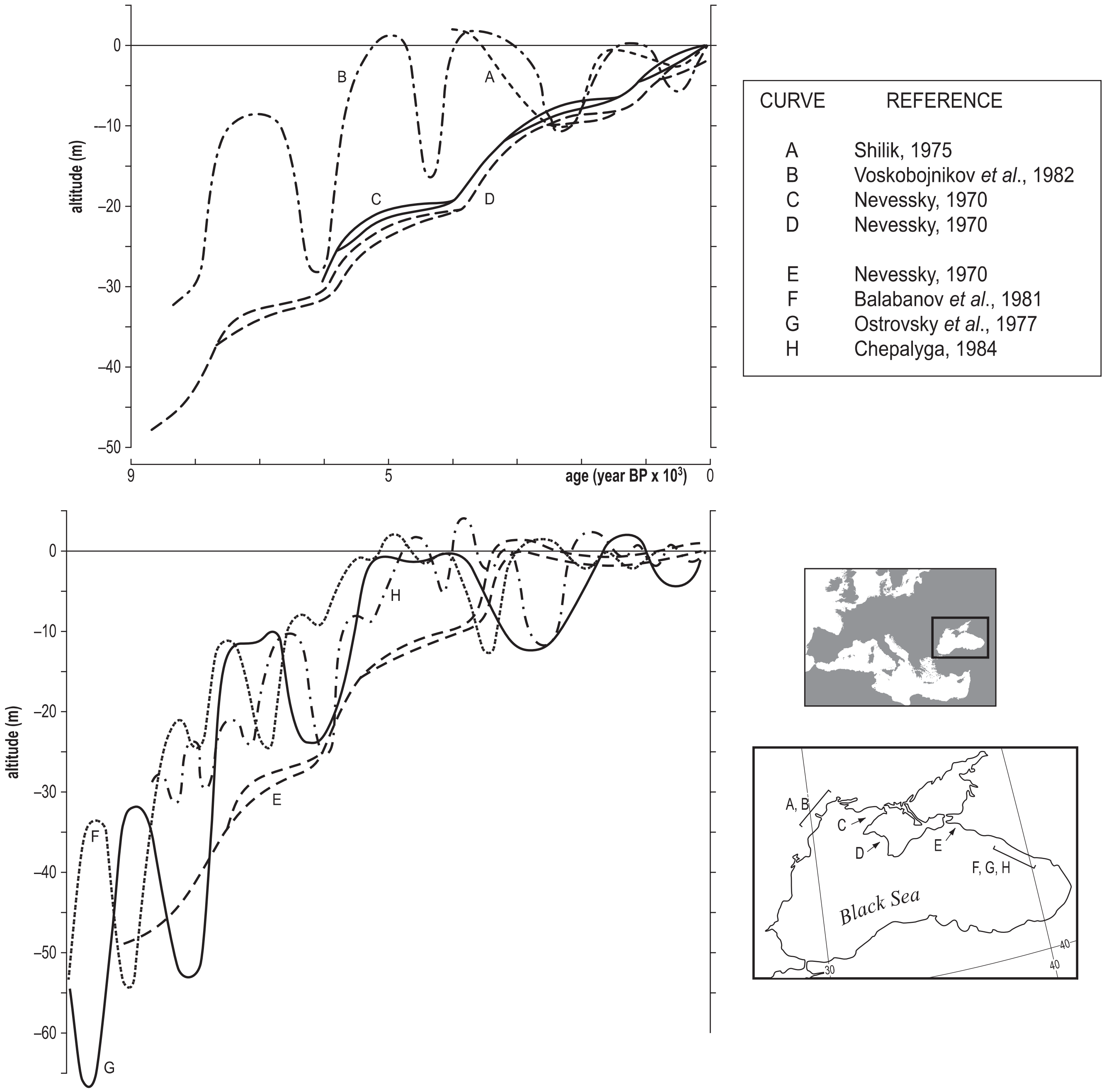


Fig. 1. Reconstruction of Holocene sea level fluctuations in Black Sea (adapted after Pirazzoli, 1991)

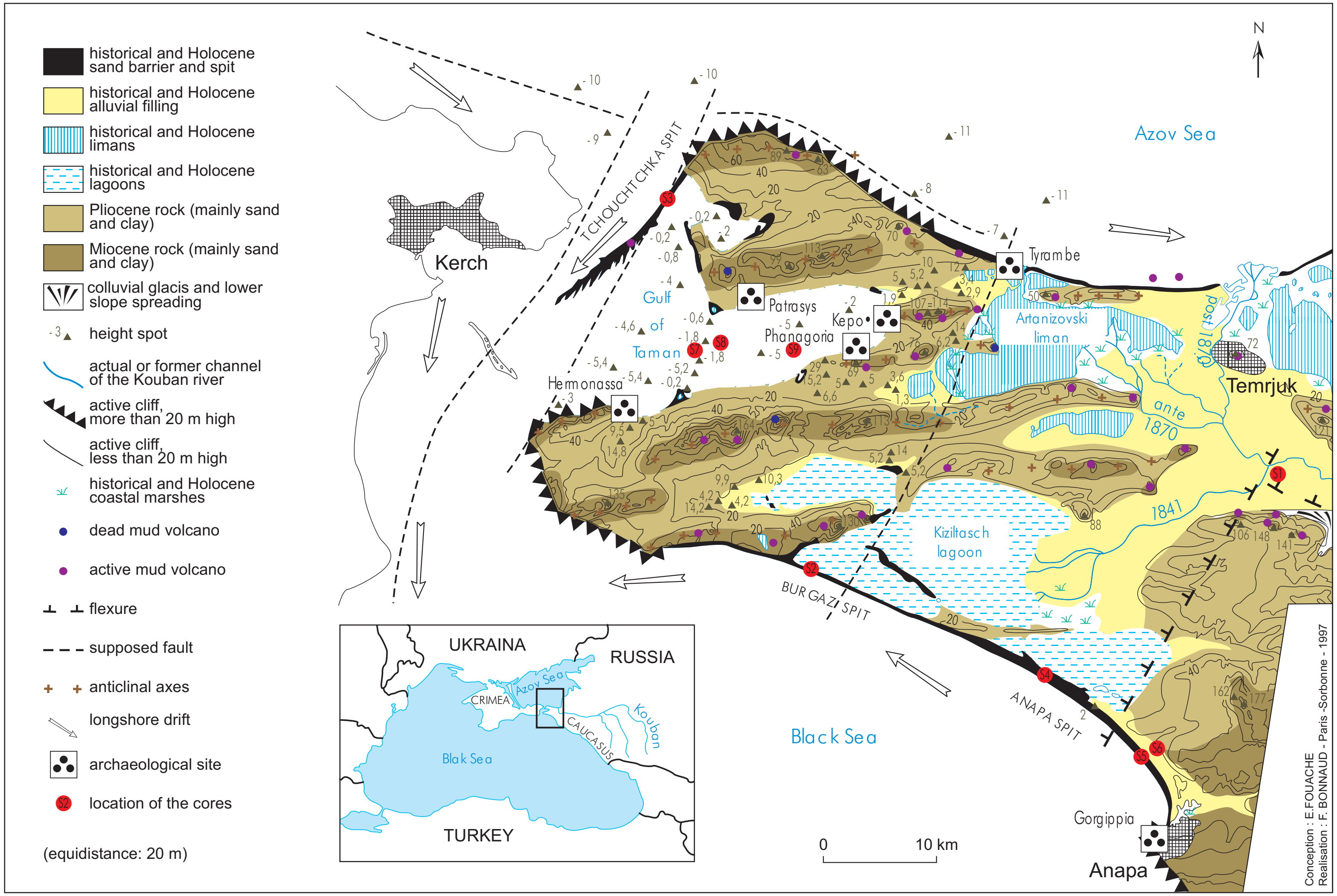


Fig. 2. Geomorphological map of the Taman Peninsula

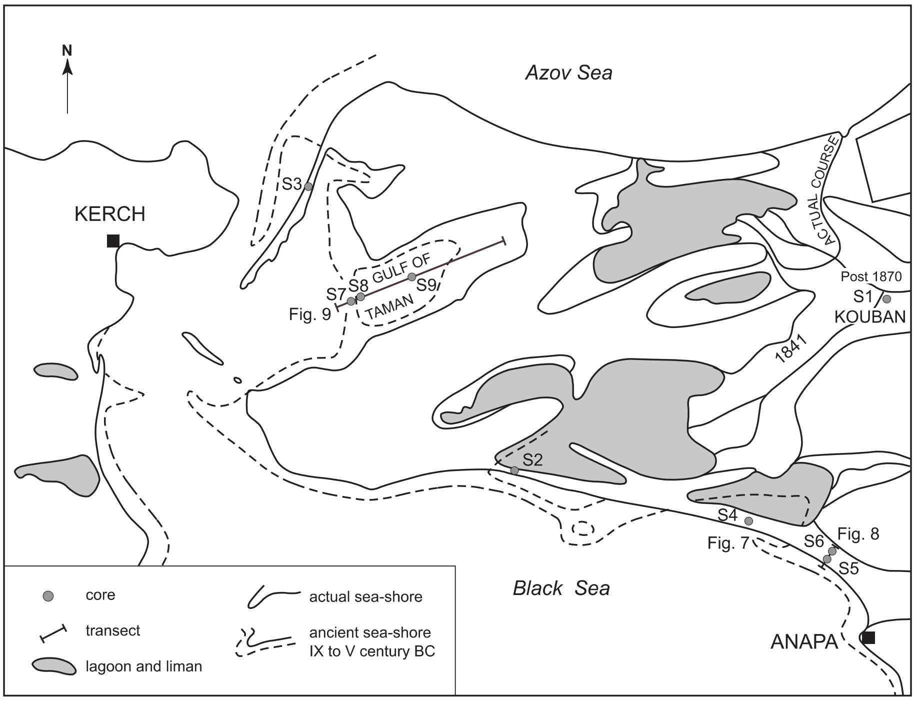


Fig. 3. Possible reconstruction of sea-shore IX to V century BC (adapted from Nevesky, 1958)

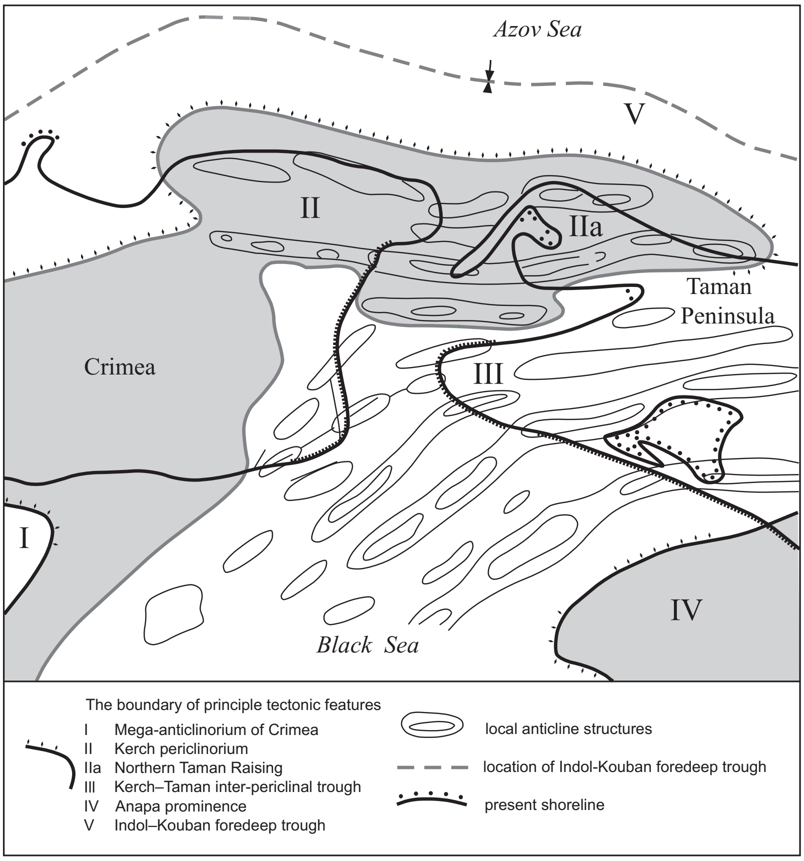
GEOLOGICAL SETTING

The Taman Peninsula (Fig. 2), situated to the south of Russia, is located at the end of the Western part of Caucasus. The formations of which it is made are to be found on the other side of the Kerch Strait in the Crimea. These formations are made up of Miocene and Pliocene rocks, essentially clay, sands and very occasionally chalk (Touzla Cape or Achileion Cape). These rocks were deposited on the bottom of a sea, in the position of a retro-arc basin which stretched from the north of the Viennese Carpathians to the present Black Sea. The Alpine orogenesis, through its compressive tectonics originated the emergence of these rocks, of their folding along the anticlinal and synclinal WSW/ENE axes and the group of NNE/SSW faults (Chnioukov *et al.*, 1981). The current relief of the Taman Peninsula is the result of the evolution in the open air of folded ridges since the end of Pliocene. The folded ridges have been levelled (Blagovolin, 1962; Blagovolin, Pobedonostsev, 1973), which explains the extension of plateaux eroded into cliffs. Along the anticlinal axes diapirism has caused, since as early as the end of the Pliocene, alignments of mud volcanoes (Chnioukov *et al.*, 1981), giving birth to eruptive cones, the largest of which are over 100 m high and occupy the highest point of the topography.

The general features of the geological structure of the Taman Peninsula are defined by its disposition in the area of contact between the folded structure of the Caucasus and mountainous Crimea. According to the recent geological data (Chniukov *et al.*, 1981; Andreev *et al.*, 1981; Peklo *et al.*, 1974; Naumenko, 1977), this area includes several tectonic zones (Fig. 4). The northern Taman zone (IIa, Fig. 4) is linked with the uplifting movement of Crimea's mega-anticlinorium. The Anapa prominence (III, Fig. 4) is in the same type of uplifting context due to the proximity of the Caucasus. Between these two areas, the Kerch–Taman inter-periclinal trough is located (II, Fig. 4).

Tectonic faults are superimposed on this general feature (Plachotny *et al.*, 1989). On the base of geophysical, geological and geomorphological data, the Taman area comprises several blocks limited by a number of local and regional faults (Fig. 5) of sublatitudinal and submeridional directions. Three principal blocks are observed from west to east: the Kertch/Gdanovsky, the Vishestebleevsky and the Djiginsky areas.

Fig. 4. General features of geological structure of Kerch–Taman region



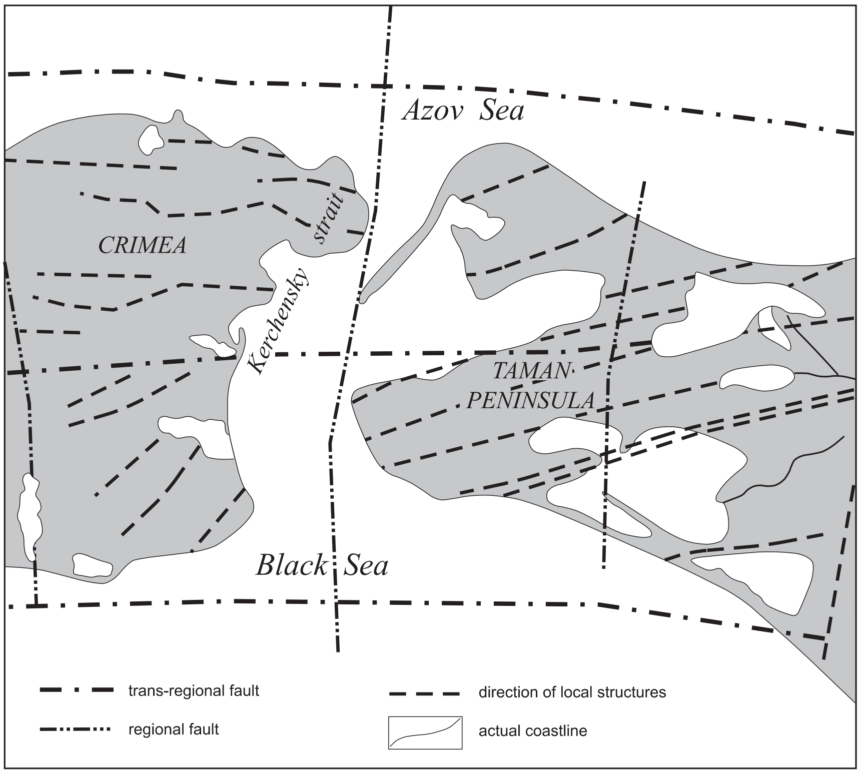


Fig. 5. Regional pattern of tectonic structure Kerch–Taman region

METHOD

For this study we have drilled six boreholes (Fig. 2) on the peninsula down to 12 metres deep: one in the Kouban delta (S1), one on the Burgaz Spit (S2), one on the Tchouchtchka Spit (S3) and three on the Anapa Spit (S4, S5 and S6). We have also used the archival material collected in the end of the 1960s by E.N. Nevesky (1967) for the Russian Shirshof Institute of Oceanology. This material was kindly given to us by Professor L.A. Nevesky and concerns the Gulf of Taman (S7, S8 and S9). Due to practical reasons, we were obliged to collect samples on the field and to determine the stratigraphy and lithology on the spot.

To reconstruct the relative sea level fluctuations, it was not possible to use archaeological indicators except for determination of a global submersion since Late Antiquity (Abramov, 1999; Nikonov, 1994; Blavatsky, 1985). We have been unable to find precise archaeological indicators,

Table 1

Radiocarbon datings from the Taman Peninsula

N°/Depth (m)	Index		^{14}C Age (years BP)	Calibrated age (yrs cal.)
S1 (11–11.5)	GIN-9942	Peat	5949 ±80	4884 BC
S2 (3.2–3.5)	GIN-9934	*Ostrea edulis*, *Cerastoderma glaucum*, *Chlamys glabra*	1330 ±100	1310 AD
S2 (3.6–3.8)	GIN-9935	*Ostrea edulis*, *Chione gallina*, *Cerastoderma glaucum*	1380 ±90	1287 AD
S2 (7.8–8.0)	GIN-9939	*Cerastoderma glaucum*	2080 ±100	605 AD
S2 (8.1–8.2)	GIN-9938	*Cerastoderma glaucum*	2820 ±110	317 BC
S2 (10–10.3)	GIN-9937	*Cerastoderma glaucum*	3180 ±100	767 BC
S3 (2.8–3.0)	MGU 1504	*Cerastoderma glaucum*, *Chione gallina*, *Solen vagina*	1260 ±60	1380 AD
S3 (4.2–4.5)	MGU 1520	*Cerastoderma glaucum*, *Cardium exiguum*, *Chione gallina*, *Loripes lacteus*, *Divaricella divaricata*, *Mysella bidentata*, *Paphia discrepans*, *Gastrana fragilis*, *Abra alba*, *Ostrea edulis*, *Mytilus galloprovincialis*	3390 ±150	945 BC
S3 (7.7–8.0)	MGU 1502	*Cerastoderma glaucum*, *Mytilus galloprovincialis*, *Chione gallina*, *Sollen vagina*, *Paphia discrepans*, *Cardium exiguum*, *Ostrea edulis*, *Gastrana fragilis*, *Abra ovata*, *Loripes lacteus*	4700 ±150	2633 BC
S3 (9.0–9.3)	MGU 1501	*Cerastoderma glaucum*, *Chione gallina*, *Ostrea edulis*, *Paphia discrepans*	5430 ±120	3611 BC
S4 (6.7–7.0)	MGU 1575	*Cerastoderma glaucum*, *Loripes lacteus*, *Ostrea edulis*, *Chione gallina*, *Donax* sp.	1930 ±60	711 AD
S4 (7.8–8.1)	MGU 1565	*Cerastoderma glaucum*, *Ostrea edulis*, *Chione gallina*, *Donax* sp.	2660 ±60	69 BC
S4 (10–10.3)	MGU 1574	Cerastoderma glaucum, Abra ovata	3370 ±45	918 BC
S5 (2.5–3.0)	MGU 1517	*Cerastoderma glaucum*	1595 ±50	1051 AD
S5 (3.0–3.5)	MGU 1529	*Cerastoderma glaucum*	3390 ±140	945 BC
S5 (5.5–6.0)	MGU 1516	*Cerastoderma glaucum*	3730 ±70	1399 BC
S5 (6.5–7.0)	MGU 1515	*Cerastoderma glaucum*	4220 ±100	1989 BC
S6	?	?	1570 ±100	?
S6	?	?	3340 ±80	?
S7 (1.2–1.5)	MGU 1549	*Chione gallina*, *Loripes lacteus*, *Mytillus galloprovincialis*, *Ostrea edulis*, *Cardium exigum*, *Paphia discrepans*, *Irus irus*, *Tellina fabula*, *Gastrana fragilis*, *Abra ovata*	1250 ±50	1392 AD
S7 (1.8–2.0)	MGU 1553	?	2450 ±70	160 AD
S8 (0.8–1.05)	MGU 1564	*Cerastoderma glaucum*, *Abra ovata*, *Mytilaster lineatus*, *Loripes lacteus*, *Gastrana fragilis*	1160 ±50	1141 AD
S8 (1.9–2.4)	MGU 1548	*Abra ovata*, *Loripes lacteus*, *Cardium exiguum*	2130 ±70	551 AD
S9 (1.0–1.15)	MGU 1545	*Cerastoderma glaucum*, *Mytilaster lineatus*, *Chione gallina*, *Loripes lacteus*, *Abra ovata*, *Chlamys glabra*, *Gastrana fragilis*, *Nassa reticulata*, *Retusa trunculata*, *Gifrobia ventrosa*, *Rissoa* sp., *Bittium reticulatum*	1240 ±50	1398 AD
S9 (2.0–2.35)	MGU 1546	*Cerastoderma glaucum*, *Chione gallina*, *Gastran fragilis*, *Ostrea edulis*, *Cardium exiguum*, *Abra ovata*, *Nassa reticulata*, *Terusa trunculata*, *Gidrobia ventrosa*, *Rissoa* sp., *Bittlium reticulatum*	2060 ±70	624 AD

Index: MSU — Geographical Faculty of Moscow State University, GIN — Geological Institute RAN such as jetties and fish ponds on the peninsula, and the method proposed by Flemming (1969, 1979) or Pirazzoli (1979), used by us in Turkey (Fouache *et al*., 1999) and Croatia (Fouache *et al*., 2000b), was impossible to enforce here. So we concentrated on identification of shell assemblages, characteristic of thanatocenose fauna accumulated at a medium sea level, that reflect an average position of sea level with an error margin of ±1 m.

Extracted shell material has been determined and palaeoenvironmentally interpreted (Kaplin *et al*., 2001) by T. Yanina at the Geographical Faculty of Moscow State University (Tab. 1). Classical radiocarbon dating on these shells was performed at the Geological Institute of the Russian Academy of Sciences and at the Geographical Faculty of Moscow State University. A calibration was carried out, following Stuiver and Braziunas (1993), taking into account the sea water reservoir effect.

RESULTS

From the bottom to its upper part, the S1 core (Fig. 6), located in the Kouban Delta, contains peat, marine semi-closed bay sediments and then deltaic sediments. Palynological analysis confirms that there was a marine environment during the Greek colonisation (Bolihovskaya *et al*., in press). The radiocarbon dating obtained on the peat (5940 ±50 BP) shows that the maximum penetration of the sea occurred at that time.

The other cores show an alternation between sandy biodetritic sediment characteristic of beaches and mainly clayey sediments rich in shells (S2 and S3 Fig. 6, S4 Fig. 7, S5 and S6 Fig. 8, S7, S8 and S9 Fig. 9). The biggest palaeographical change since Antiquity occurs in the Gulf of Taman, where most of the city of Phanagoria is now under water (Fig. 3). Was this post-antic submersion homogenous all over the peninsula?

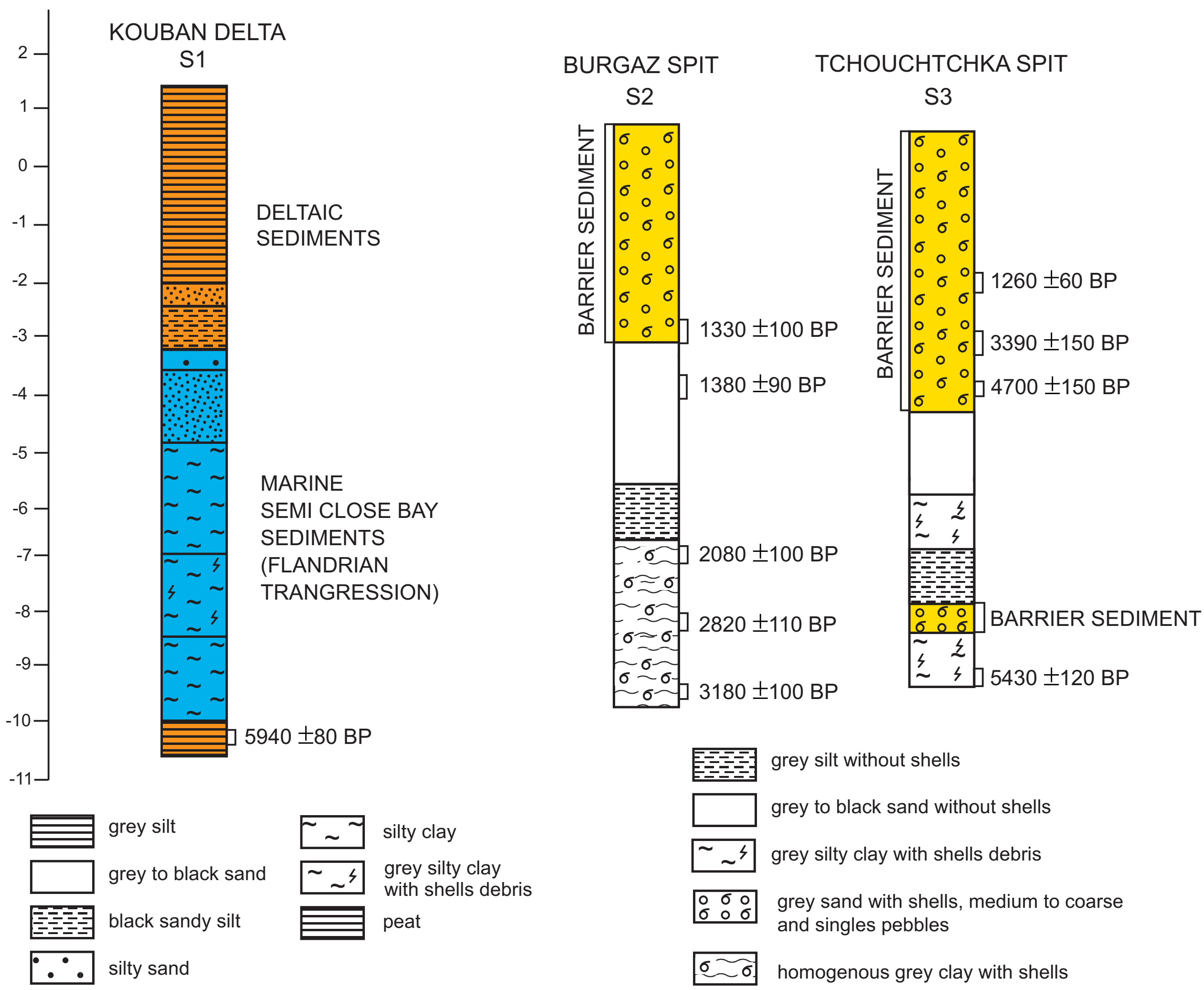


Fig. 6. Cores S1, S2, S3

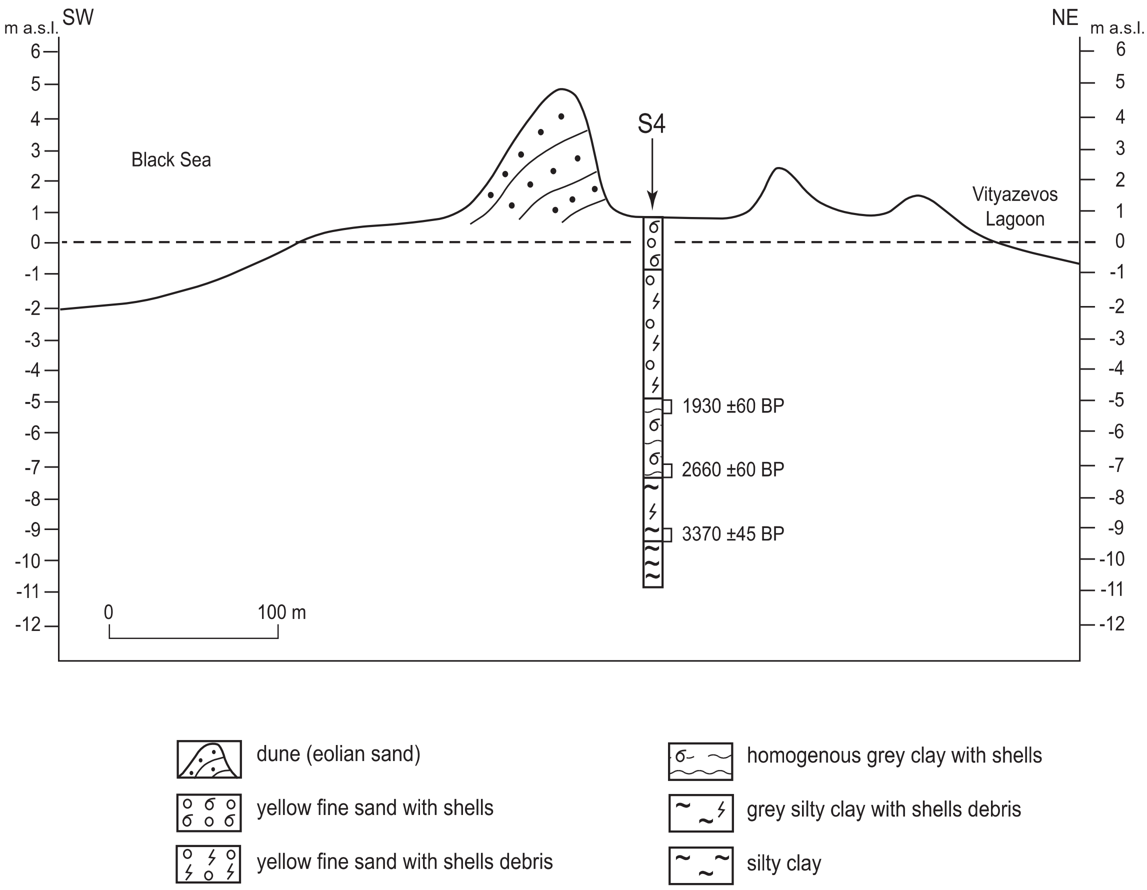


Fig. 7. Anapa Spit

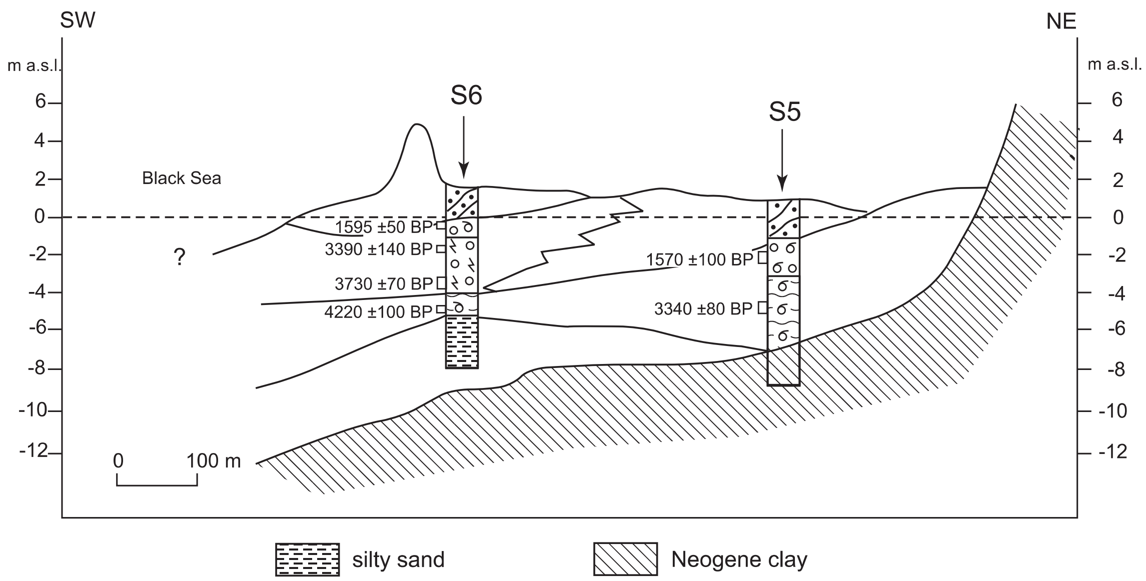


Fig. 8. Eastern part of Anapa Spit

For other explanations see Figure 7

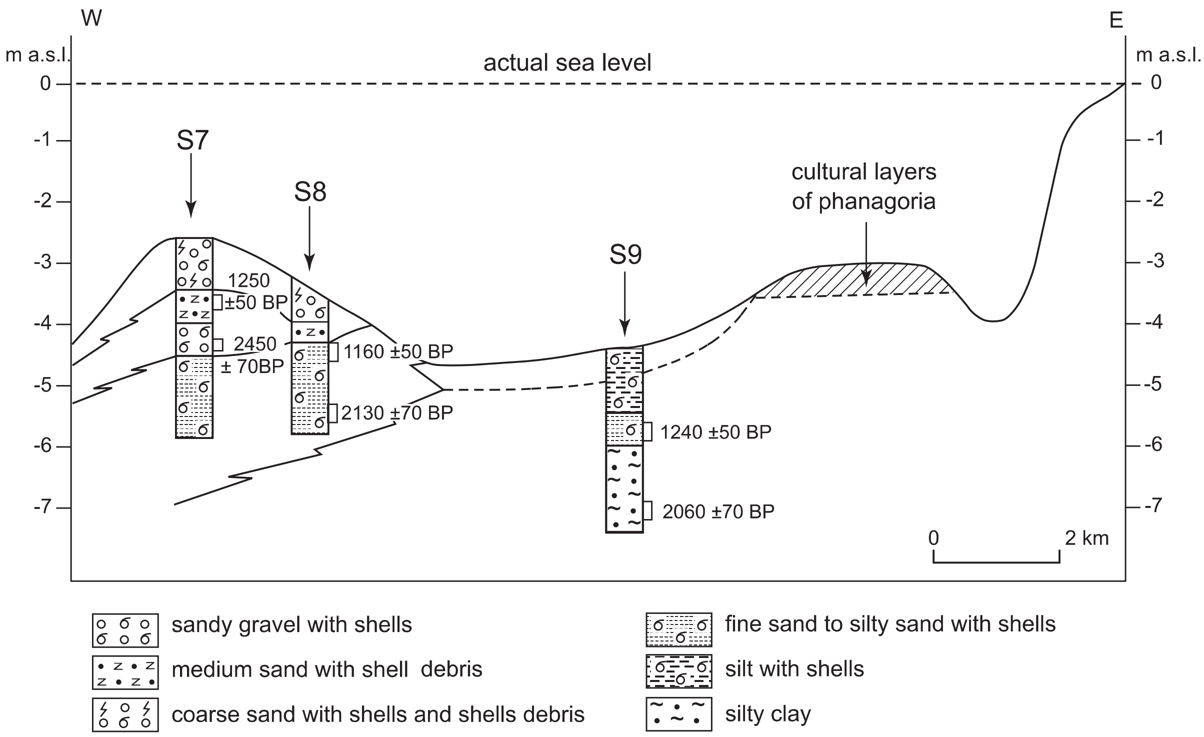


Fig. 9. Gulf of Taman

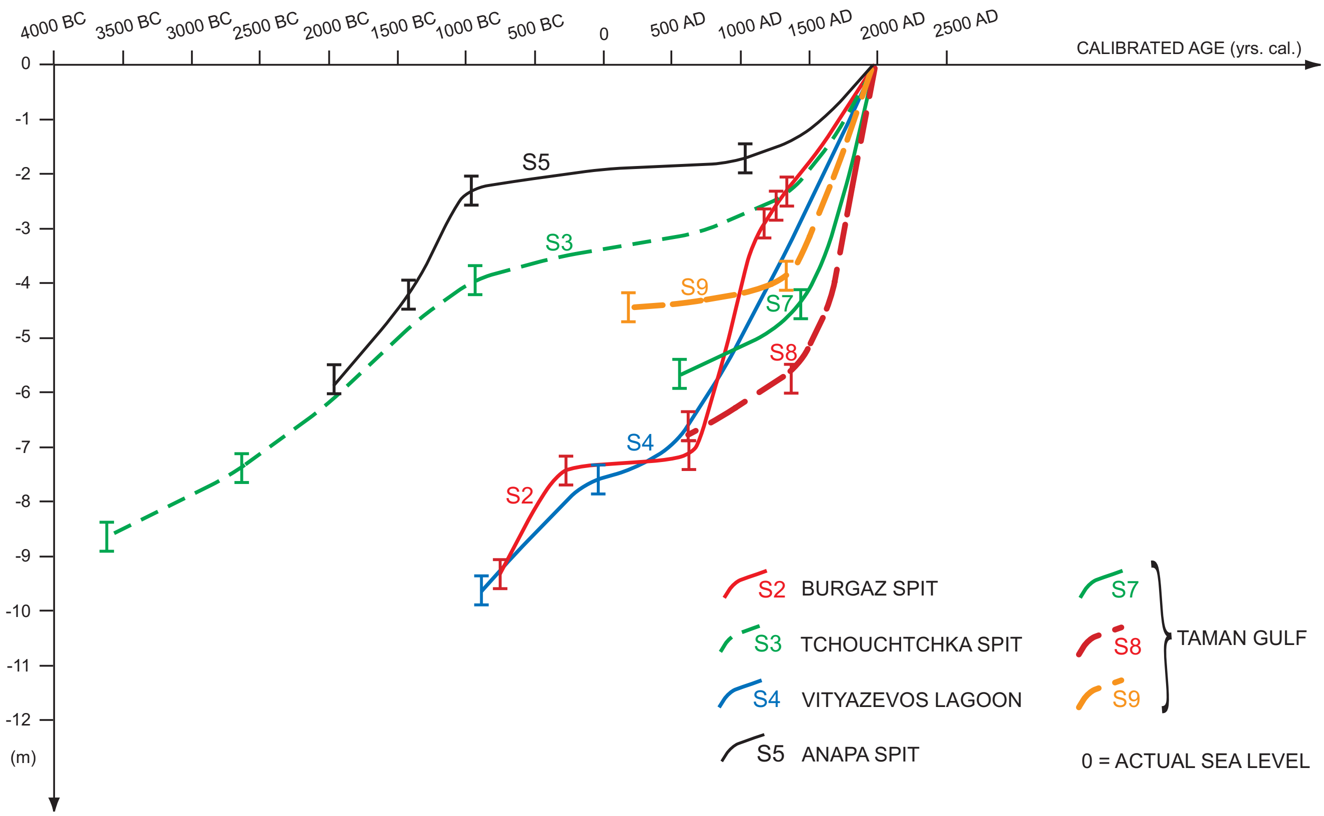


Fig. 10. Relative regional sea level fluctuations in Taman Peninsula

Following the coherence of our results, the deeper the shells, the older the radiocarbon dating, for each core we have reconstructed a local relative sea level curve (Fig. 10). Then, we could distinguish two zones with a rather similar curve: at Burgaz Spit and Western Anapa Spit (S3 and S5) on the one hand, at Tchouchtchka Spit and eastern part of Anapa Spit (S2 and S4) on the other hand. The Gulf of Taman is a transition zone between two other areas. We can also distinguish a global dissymmetry between contemporaneous sea levels. The greatest difference is observed for ancient sea levels. For example, in 1000 BC the sea level is located around –2 m below the present sea level in S5, around –4 m in S3 and around –9.5 m in S2 and S4. We observed for all the curves a relative sea level stabilisation between 500 BC and 500 AD.

Such differences for such a relatively small area at the scale of the Taman Peninsula are undoubtedly due to unequal subsidence, itself due to the neo-tectonic effect. How can this neo-tectonic effect be explained?

DISCUSSION

There is a perfect correlation between tectonic units and the three different groups we observe on relative sea level curves (Fig. 10). Burgaz Spit (S2) and Western Anapa Spit (S4) are located in two characteristic uplifting areas. The Gulf of Taman (S7, S8 and S9), Tchouchtchka Spit (S3) and the eastern part of Anapa Spit (S6 and S5) are located in a global subsiding zone. The Taman Gulf is a transition zone between two other areas. Tectonic measurements (Nikonov, 1994; Nikonov *et al*., 1997) confirm the neo-tectonic subsidence in the central zone of the Taman Peninsula. The actual subsidence at Temrjuk in the actual Kouban Delta is estimated between 3.5 and 4 mm/year, and the tectonic part is estimated between 2 and 3 mm/year. For the Black Sea side, south of the peninsula, the global subsidence rate, during the Upper Pleistocene, is estimated at 2.5 mm/year. These data confirm that the subsidence rate varies from one point to another in the peninsula.

We have not corrected our relative sea curves with these data to obtain real eustatic fluctuations. The principal reason is the fact that nothing allows us to consider that neo-tectonic subsidence was constant in its regional distribution.

There are two ways to understand the stabilization that we observe on all curves between 500 BC and 500 AD. It may be due to the fact that the subsidence is less important or to the fact that there is a sea level regression due to eustatism.

From a general point of view, our results confirm that the neo-tectonic effect explains rapid variations in relative sea level fluctuations on a regional scale. We may also wonder about all sea level curves which have been published on the Black Sea and on the real extent in the Black Sea of global regression as “Phanagorian regression” (Shilik, 1997).

CONCLUSION

The results of our analysis of regional sea level variations in different tectonic zones of the Taman peninsula, despite the limits of our methodology, confirm the differential tectonic movement during the historical times within an approximate rate of 0.5 to 1.2 mm/year. Our results confirm the necessity to take into account the tectonic impact in palaeoenvironmental studies and sea level reconstructions in the Black Sea for the late Holocene.

The consequences for archaeological investigations are very important. Most coastal archaeological vestiges are underwater on the peninsula, but not at the same altitude according to their position on the peninsula. Our results highlight the interest of an underwater survey which would take our information into account. It also seems that global eustatic variations like the “Phanagorian regression” should be reconsidered. Perhaps apparent rapid regressions and transgressions in the Black Sea, indicated by archaeologists, are a consequence of neo-tectonic movements. It is too early to renounce to the climatic and eustatic effect hypothesis to explain these variations, but we have yet to continue our work in the Taman Peninsula and to extend our exploration to the different places around the Black Sea.

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