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Late Quaternary marine terraces in the Mediterranean coastal area of Syria: Geochronology and neotectonics

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Abstract

In order to provide new data on the neotectonics and geodynamic properties of western Syria, studies of marine terraces have been carried out. The most attention was paid to the lower terraces in the range of 3–5 to 30–35 m above sea level, because they have more complete distributions along the shore. The lower terraces were examined along the coastal area from Tartus to Latakia, and along the carbonate cliff on Arwad Island. Seven ^{230}Th/U dates for these terraces are in the range of 85–130 ka, suggesting the age interval of the last interglacial (MIS 5). New dates on the lower terraces provide a basis for stratigraphical and geomorphological interpretation as well as neotectonic reconstruction. According to the geomorphological data and lithological composition of those terraces, two main uplifted blocks can be established. One coincides with the Latakia block, and another corresponds to the western margin of the Banias volcanic plateau. These blocks are divided by a subsided structure corresponding to the Nahr el Kebir graben. The amplitude of neotectonic uplifting in the Latakia and Banias blocks reaches 15–20 m for the Late Pleistocene.

1. Introduction

Quaternary studies in the Mediterranean usually place particular emphasis on the geological development of the coastal area due to its vital importance for the population (Fig. 1). In the Eastern Mediterranean, the Syrian shore provides geologic and geomorphologic evidence of major changes of Quaternary sea-level fluctuations and regional neotectonic properties. The Syrian Coastal Plain is a relatively narrow strip which extends from the Iben Hani area (Nahr el Arab) in the north to the Syrian–Lebanese border in the south. Previous investigations, especially in the Latakia region and the Nahr el Kebir Valley, have described the marine and fluvial deposits at archaeological sites (Copeland and Hours, 1978; Besançon, 1981; Copeland, 1981; Sanlaville, 1981; Muhesen, 1985). Four marine formations associated with terraces have been established: the Mchairfet Formation at 180–190 m above sea level (asl), the Baqsa Formation at 120–130 m, the Hennadi/Khellale Formation at 80–90 m, and the sediments forming the Tyrrhenian terrace from 30–35 m down to 5–10 m asl. These formations have analogues in the Lebanese coastal area, corresponding to the Chaabien Formation, Zakrounian Formation, Jbalian Formation, and Enfeen Formation, respectively (Table 1).

In the publications, *Strombus bubonius*, a typical Tyrrhenian thermophilic mollusc, was mentioned from the sediments of the lower marine terrace near Banias as well as in the Enfeen Formation of the Lebanese coastline. A relative stratigraphy of the marine terraces was suggested on the basis of elevation and archaeological evidence. The highest terrace, Mchairfet, was assigned to the late Early Pleistocene (pre-Günz). The Baqsa and Hennadi/Khellale terraces were considered to be Middle Pleistocene, taking into account the presence of the Acheulean industry in the fluvial gravels (the Roudo alluvial terrace) corresponding to marine sediments. However, direct correlation between

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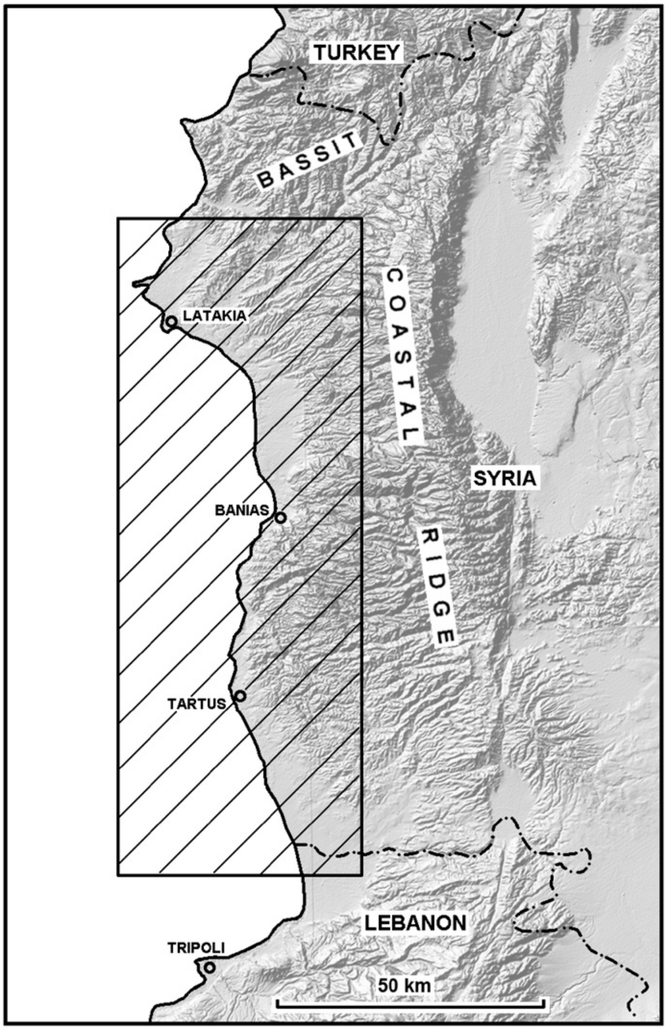

Fig. 1. Studied area along the coastline of Western Syria.

the fluvial terraces and marine formations is thought to be questionable or rather complicated. A suggested model correlates the fluvial accumulations with the glacial/pluvial epochs accompanied by regressive marine phases, whereas the marine transgressions should correspond to interglacial/arid epochs (Butzer, 1958; Besançon, 1981; Copeland, 1981; Sanlaville, 1981). Due to the poorly represented geochronological data from the Middle Pleistocene terraces and their fragmentary preserved forms along the shore area, the correlation of the marine and fluvial terraces as well as the paleoclimatic aspects remain uncertain.

Research on the Tyrrhenian terrace can provide more accurate data for a geochronological and paleoclimatic approach. Earlier publications reported an age of 90 ka for the Enfeen Formation in the Lebanese coastal area (Sanlaville, 1981), and the thermoluminescence date of 100 ka for the 20–25 m sand terrace near the settlement of Snoubar in Syria (Devyatkin and Dodonov, 2000).

In order to provide new information on the neotectonics and geodynamic properties of the western part of Syria, studies of marine terraces have been carried out during field campaigns in 2005–2006. Most attention was paid to the lower terraces in the range of 3–5 to 30–35 m asl. The studies aimed at two targets. First, it was important to describe the geological and geomorphologic features of the Late Pleistocene and Holocene marine terraces, emphasizing their structural and neotectonic properties. Secondly, it was important to provide an age control for the lower marine terraces using Th/U geochronology.

2. Geological setting

The Syrian Coastal Plain is limited in the north by the Bassit Mountains, containing ophiolites, and in the east by the Coastal Ridge composed of Jurassic, Cretaceous and, to a lesser extent, Paleogene carbonate rocks forming a westerly tilted monocline. The Nahr el Kebir Valley is situated between the two mountain areas of Bassit and the northern margin of the Coastal Ridge, and coincides with the El Kebir Graben. The Nahr el Kebir is strongly incised into the Neogene marine sediments filling the graben. Pliocene marly clays are intensively eroded in the lower part of the Nahr el Kebir Valley. The active erosional processes along the western side of the Coastal Ridge formed deeply incised valleys in carbonate rocks of the ridge, as well as the accumulation of proluvial (colluvial) deposits at its base. The heavy erosion resulted in the destruction of the Pleistocene terraces along the slope of the Coastal Ridge. Only small areas of the Middle Pleistocene terraces still exist on its western side. The Late Quaternary terraces are better preserved and form an almost continuous belt along the modern coastline, with width varying from a few hundred meters to 7–8 km (Fig. 2).

3. Methodological approach

The Mediterranean coastal area of Syria has a very dense population and the natural terraces were subjected to intensive recultivation and urban construction in many places, strongly hindering the research. The sea cliffs, quarries and artificial trenches along the roads were examined to collect lithological, geomorphologic and paleontological information, and the altitudes of terraces were measured (using GPS). One of the important purposes was to search for mollusc shells suitable for ^{230}Th/U dating, especially in the lower terraces in the range of 3–5 to 30–35 m asl. Cross-sections normal to the coastline were used. The question about how many terraces are present in the altimetric range from 3–5 to 30–35 m is not easy since the surface of the lower topographic level is not clearly subdivided into separate steps with individual geomorphologic properties. In the area between the Nahr el Kebir and Snoubar, three sub-levels have been observed at the altitudes of 10, 20–25 and 30–35 m asl The 10 m level is very local. Two other levels seemingly belong to the same terrace with the surface arising to its inner edge.

According to the previous investigations, it was suggested that the Late Pleistocene terrace (Tyrrhenian

Table 1
Scheme of stratigraphic position and correlation of marine and alluvial terraces in Western Syria

Stratigraphy		Age (Ma)	Archaeology		Lebanon	Western Syria	
					Terraces, Formations	Marine terraces	Alluvial terraces
Holocene			Neolithic				
Pleistocene	Upper	0.01	Mesolithic				
			Paleolithic	Upper	Enfeen Th/U (90–100 ka)	Snoubar 25–30 m (TL 101 + −20 ka)	Ech Chir 30–35 m
				Middle			
		0.13			Jbalian	Hennadi 80–90 m	Roudo 80–90 m Jinndiriye 100–120 m
	Middle						
				Lower			
					Zaqrounien	Baqsa 120–130 m	Sitt Markho 130 m
					Chaabien	Mchairfet Es Samok 180–190 m	

The scheme was compiled after Besançon (1981), Sanlaville (1981), Muhesen (1985), with additional data from Devyatkin and Dodonov (2000).

terrace) is widely represented along the coastal area of Western Syria (Copeland, 1981; Sanlaville, 1981; Devyatkin and Dodonov, 2000), although the Geological Map of Syria, scale 1:200, 000 (1964) shows only terraces with indexes Q_{1-2} (Lower–Middle Pleistocene) and Q_4 (Holocene). It seems that occurrences of *Strombus bubonius* are very rare, which accounts for the lack of new occurrences of this mollusc in the sediments of the lower marine terrace near Banias. Intense anthropogenic changes in the Banias region hamper location of the sites of the earlier findings.

The lower terraces were examined along the coastal area from Nahr el Arab in the north to the Syrian–Lebanese border in the south, as well as along the carbonate cliff on Arwad Island and the unpopulated small island of El Abbas, situated 3–4 km off-shore southwest of Tartus. The macroscopic and microscopic descriptions were used to get a more representative picture about the marine sediments forming the lower terraces.

The marine sediments of the lower terraces contain a very sparse mollusc fauna, especially shells suitable for Th/U dating. Nevertheless, eleven sites with shells were found. Shells of *Ostrea*, *Taxodonta*, Pectinidae and other remains of bivalves were used for dating. One site with clays where ^{230}Th/U dates have been obtained was used for palynological sampling.

To get more data for chronological evidence of the lower terraces along the coastline, attention was given to the archaeological aspect. Stone artifacts have been rarely found on the surface of the lower terraces, and only in the Snoubar area were some artifacts collected on the surface of the 30 m terrace. According to N.J. Conard, the collected material in the Snoubar area belongs to the Middle–Upper Paleolithic mixed assemblage. The lower terraces up to 30–35 m asl do not contain stone artifacts older than the Middle Paleolithic. An archaeological survey undertaken in 1999 by Conard and Kandel along the coastal area of Western Syria yielded Early Paleolithic finds, mostly from the surface of highland settings above the 30–35 m terrace (Conard and Kandel, 2006).

4. Geological structure and litho-mineralogical features of the lower terraces

The map of the coastal area of Syria (Fig. 2) schematically illustrates the main geological and geomorphologic properties, which are characteristic for this territory during the Late Quaternary. This map was compiled on the basis of the Geological Map of Syria, scale 1:200,000 (1964).

The altitude of the Holocene terrace is not higher than 2–3 m asl. It is composed of sands with gravel, sandstones with minor carbonate, and conglomerates. The Holocene terrace was dated by ^{230}Th/U at one site, located approximately 20 km to the south of Tartus (Fig. 2B). The age of 7.8 ± 1.3 ka of the 3 m high terrace formation fits well with the Holocene time interval. The Holocene sand beach with a length of 15–17 km and a width of about 1 km is widespread to the south of Latakia (Fig. 3). Another widespread Holocene sand belt extends southward of Tartus.

The terrace 20–30 m asl is widely developed in the northern part of the Syrian coastal area. This terrace has an erosional origin in the Latakia region, being basically not higher than 25–35 m (at one site an altitude of 41 m was measured). Only scattered well-rounded marine gravel has been found on the surface of this terrace. The erosional

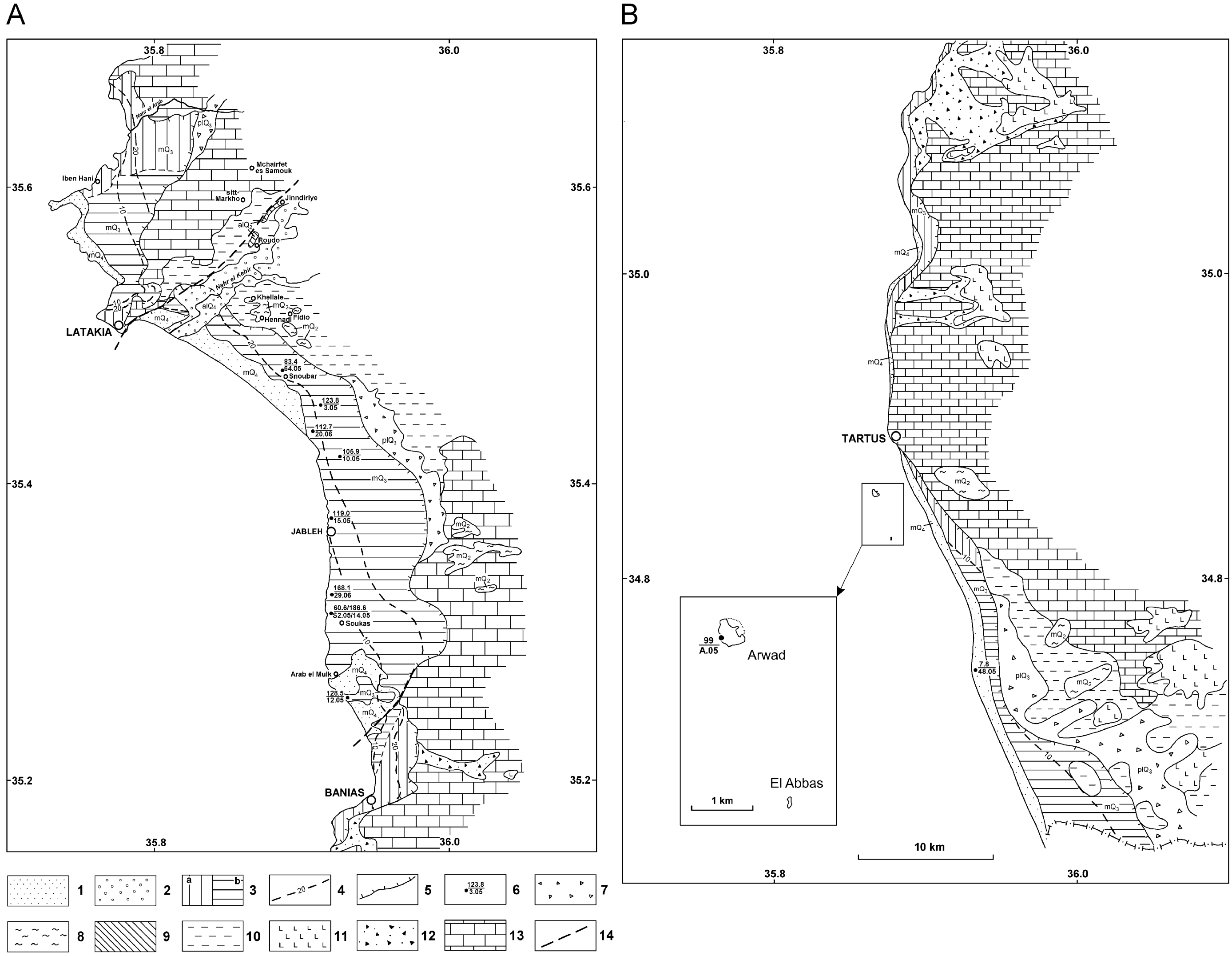

Fig. 2. Geological–geomorphological map of the coastal area of Syria: (A) northern part of studied area, (B) continuation, southern part. (1) Holocene marine terrace (mQ_4); (2) Holocene alluvium (alQ_4); (3) marine Late Pleistocene (Tyrrhenian) terrace (mQ_3): (a) abrasion, (b) accumulative; (4) isobase (m) of the surface of the Late Pleistocene terrace; (5) inner edge of the Late Pleistocene terrace; (6) site of dating: uranium–thorium age (above), site number (below); (7) Late Pleistocene proluvial (colluvial) deposits (plQ_3); (8) Middle Pleistocene marine terrace (mQ_2); (9) Middle Pleistocene alluvial terrace (alQ_2); (10) marine Pliocene deposits; Pliocene volcanic rocks: (11) basalts; (12) tuff-breccias; (13) Late Mesozoic and Cenozoic carbonate rocks; (14) proposed fault.

type of terrace occurs to the north of Latakia as well, approaching the Nahr el Arab Valley. Cemented marine gravels 1.5–2 m thick are observed at 33–35 m altitude in the road cut to the south of this valley.

Between Latakia and Jableh, the 25–30 m terrace is well represented. It decreases in elevation to the south and generally demonstrates a depositional origin. In the Jableh area, the height of this terrace is not more than 10–12 m asl. This terrace is composed of clays, sands, gravels and carbonates, and limestones are recognizable in the sections as well. Different types of sections are observed from north to south (Fig. 4). For example, sands with gravels predominate in the lower part of the sections in the Snoubar area and to the north of it, whereas the upper parts of the same sections are mostly calcareous. Sands are well sorted, horizontally and cross-bedded, with well-rounded gravel and very rare inclusions of thin-wall marine shells. Sand grains are unevenly rounded and composed of flint, quartzite, green schists, igneous rocks, quartz, feldspars, glauconite, and gypsum clasts. The calcareous part of the section, with the thickness observed up to 5–6 m, consists of detrital cavernous limestones, rarely containing poorly preserved and partially dissolved mollusc shells (Fig. 5). In these outcrops along the road to Latakia, 15–16 km to the southeast, the detrital sandy limestone contains badly preserved shells of *Cerastoderma glaucum* Poirr., *Acanthocardia* sp., and *Ostrea edulus* L. Two to three km south of Snoubar, in the sand section of the 25–30 m terrace, shells of *Acanthocardia tuberculata* (Poirr.), *Cerastoderma* sp., and *Glycymeris* sp. were recognized (determinations by A.L. Tchepalyga). This mollusc fauna is characteristic of shallow water conditions.

Fig. 3. Holocene marine sand beach to south of Latakia. The view is from south to north.

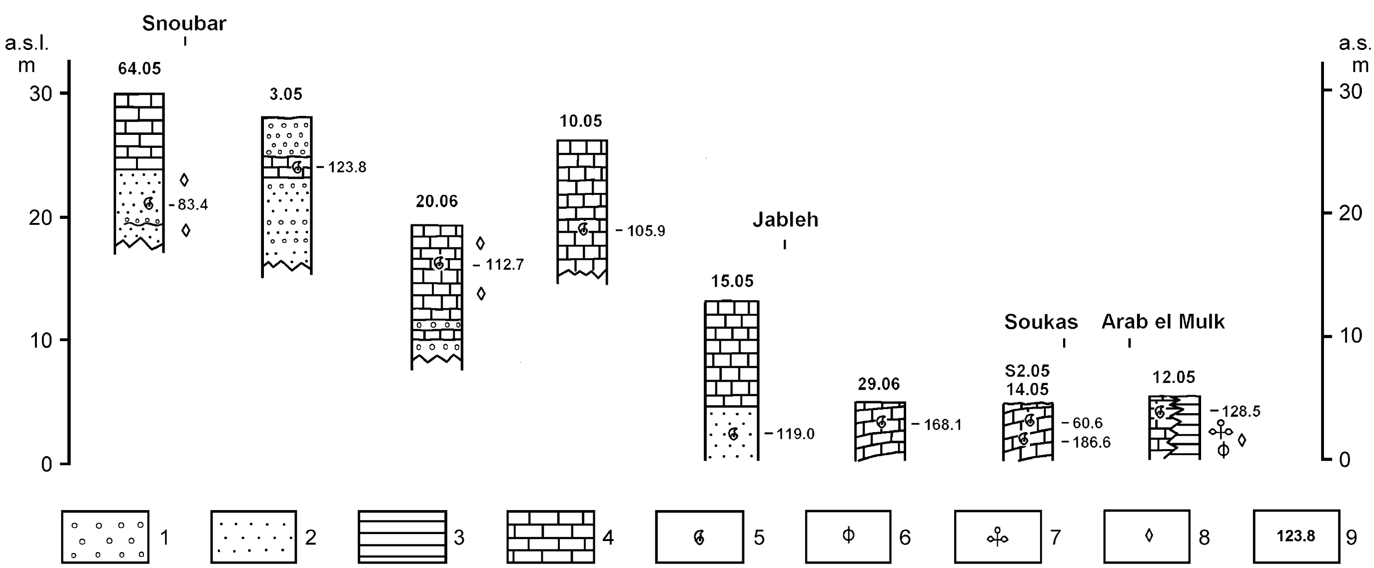

Fig. 4. Lithological columns of the Late Pleistocene terrace studied along coastal area between Latakia and Banias. Numbers of the columns correspond to the sites on the map Fig. 2A. (1) gravel; (2) sand; (3) clay; (4) limestone; (5) mollusc shells; (6) foraminifers; (7) palynological sampling; (8) mineralogical sampling; (9) Th/U age.

Between Snoubar and Jableh, the terrace section becomes more calcareous, and gravel is represented in the basal part of limestone strata, as was observed in the quarry 5 km south of Snoubar (Fig. 6a–c). In the thin section, the limestone contains detrital material of mollusc shells, foraminifers, and ostracods cemented by pelithomorphic or thin crystalline calcite (Fig. 7a, b). Authigenic glauconite is recognized in thin sections as well. This limestone consisting of numerous fragments of organogenic carbonates can be considered as a stratum formed in coastal or beach conditions. On Arwad Island, the 5–7 m asl. Cliff consists of fine sandy carbonate detritus originated from relict accumulative forms such as marine bars or dunes (Fig. 8a–c). Detrital material in thin sections of limestones of Arwad and El Abbas islands (Fig. 7c, d) is very similar to that from the coastal area near Snoubar.

To the south of Jableh, the lowering of the terrace is remarkable. For example, 2 km southward of the village of Arab el Mulk, the altitude of this terrace does not reach more than 5–6 m asl. Here, the sediments of the terrace are

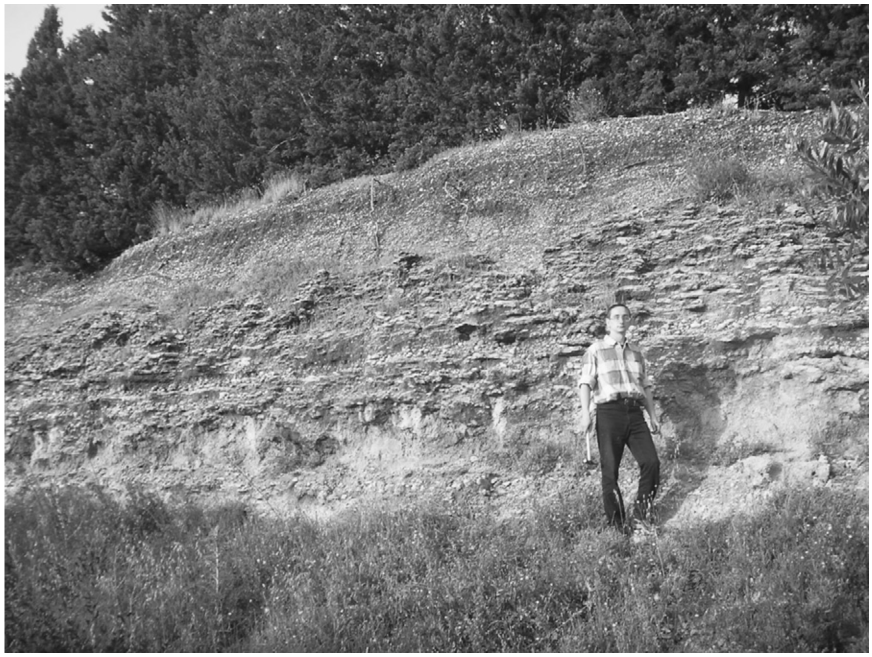

Fig. 5. Section of marine 28 m height terrace in the road cut composed of sands, gravels and limestones, containing rare poor preserved mollusc shells; 15–16 km to southeast of Latakia.

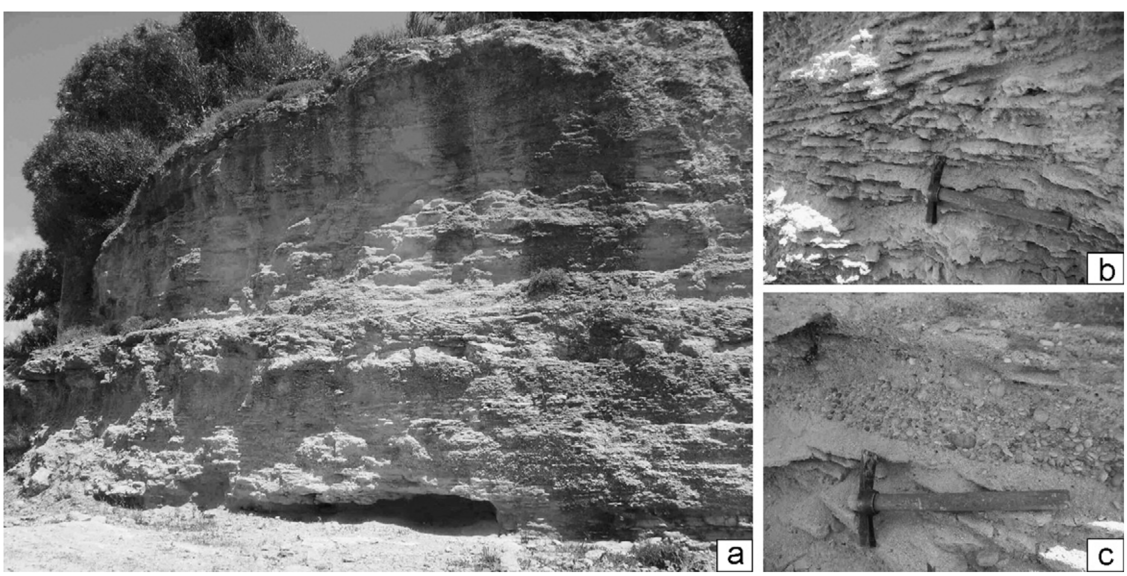

Fig. 6. Carbonate strata of 18–20 m terrace in the quarry, 5 km to south of the Snoubar settlement (a); details of the same section: detrital carbonates with traces of lamination (b), detrital carbonates with lenses of well-rolled gravels (c).

represented by clays with a facies transition to limestones; clays include numerous carbonate concretions (Fig. 9a, b). The color of clay is brownish-gray with brown patterns of iron oxides, fragments of foraminifers and traces of lamination seen in thin sections (Fig. 7e, f). In the basal part of the clay strata, foraminifers have been identified: planktonic—*Orbulina universa, Globigerinoides ruber, G. trilobus, Globorotalia scitula, Globigerinita glutinata*, and benthonic—*Ammonia* sp. and *Elphidium* sp. (determinations by M.E. Bylinskaya). This foraminifer assemblage is undoubtedly Quaternary. Benthonic forms are characteristic of shallow water conditions. In general, the clayey and marly-clay type of section capped by carbonates is widely represented from Jableh to Banias.

In Banias and to the south, a shoreline of the lower terrace is uplifted up to 15–25 m asl, mostly of erosional origin with a thin 1–2 m cover of marine sandy gravel. The terrace is narrow, not more than a few hundred meters in width. Southward of Tartus, the terrace is not higher than 10–15 m, with a general lowering trend to the south.

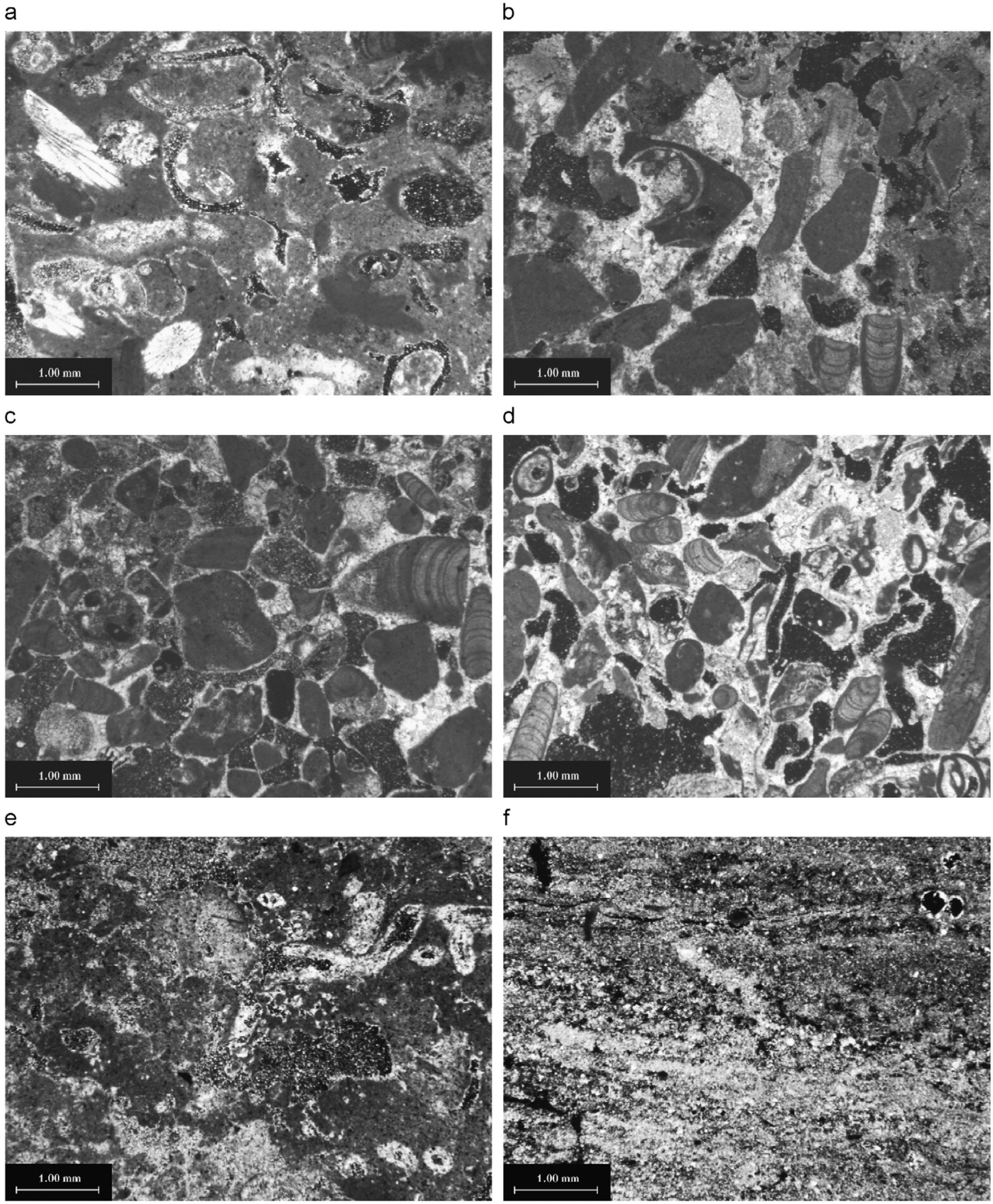

Fig. 7. Composition and microstructure of sediments composing the lower terrace in the coastal area of Western Syria: (a, b) detrital limestones from Snoubar area—(a) micro-remains of marine shells are cemented by pelithomorphic and crystalline calcite; (b) unevenly rounded micro fragments of marine shells; (c) detrital limestone from the Arwad Island; (d) detrital limestone from El Abbas Island; (e, f) carbonated clays from site 12.05, located 2 km to south from the village of Arab el Mulk: (e) clays with inclusions of foraminifers, (f) clays with traces of lamination.

Fig. 8. Carbonates in the 5–7 m cliff of western part of the Arwad Island (a); structural details of the limestone clasts bearing layers: cross-bedded detrital carbonates (b); horizontally laminated detrital carbonates (c).

5. Palynological data

Section 12.05 situated 2 km to the south of the village Arab el Mulk was palynologically characterized (Fig. 10). Thirteen samples have been processed. Marine clay sediments outcrop in this section, and partially eroded red soil is represented at the top of the section (Fig. 9a). Samples from the lower part of the section, 3.5–3.0 m depth, contain rare grains of *Picea, Pinus, Quercus, Artemisia*, Chenopodiaceae, and Cyperaceae.

The pollen spectra from the interval at 3.0–2.5 m depth contain less than 20% pollen grains of trees (*Pinus,* Betulaceae, *Quercus ilex, Carpinus, Celtis, Morus*), whereas in the herb group Asteraceae (up to 70%) and Brassicaceae (45%) predominate. Isolated pollen grains of Chenopodiaceae, Poaceae, Liliaceae, Cannabaceae, and *Thalictrum* have been found. The composition of the spectra points to the development of an open meadow-steppe landscape with small portions of xerophytic forests and bushes.

The interval of 2.2–0.8 m depth is characterized by relatively increasing role of arboreal pollen (sum from 20% to 70%) with the presence of *Picea, Corylus, Ulmus, Juglans, Oleaceae, Cotinus, Alnus, Quercus* and the domination of *Pinus* (30%). In the upper part of this interval, the presence of *Alnus, Tilia, Quercus* and Betulaceae is more prominent. In the nonarboreal group, pollen of Chenopodiaceae (30%), Asteraceae (70%), Brassicaceae (15%), and Cyperaceae (20%) predominate. A few pollen grains of *Rumex, Thalictrum, Draba*, *Artemisia*, and Poaceae have been observed. This spectrum illustrates a forest-steppe landscape. Coniferous and broad-leaved forests with xerophytic shrubs were represented in the forest coenoses, whereas the open areas were occupied by meadow-steppe assemblages.

Two samples from soil show the predominance of pollen grains of herbs and shrubs; significant numbers of Chenopodiaceae (85%) and Asteraceae (12%) were documented. Cichoriaceae, Cyperaceae, Poaceae, and *Tribulus* grains are present. The pollen spectrum from the upper part of the soil contains few grains of Betulaceae, Asteraceae, Cichoriaceae, and Chenopodiaceae. The pollen assemblage from the soil indicates an arid landscape with predominant steppe vegetation.

In general, according to the pollen data available for the Late Pleistocene and Holocene of Eastern Mediterranean, the increase of forest-steppe coenoses occurred under warm climatic conditions, while the steppe and desert associations were characteristic of the cool climatic intervals (Niklewski and Zeist, 1970; Leroi-Gourhan, 1973; Emery-Barbier, 1988; Issar, 1995). As shown in the pollen diagram (Fig. 10), the forest–steppe associations were recorded for the upper part of the marine sequence, tentatively attributed to interglacial/interstadial climatic conditions of the Late Pleistocene.

6. ^{230}Th/U dating of mollusc shells from the lower terrace and its geochronology

Detailed radiochemical research of the possibilities and limitations of the ^{230}Th/U-dating have shown that only the inner fraction of mollusc shells for most samples behaves as a closed geochemical system in regard to the isotopes (Arslanov et al., 1976, 2002). Based on this conclusion, radiochemical analyses of 11 mollusc shells from the lower terraces of the eastern Mediterranean coast of Syria were carried out. The surface and outer layers, about 2/3 of the sample weight, were removed by nitric acid and the residual part of the sample was analyzed. The protocol of the analytical procedures to extract the uranium and thorium from the mollusc shells was described earlier (Arslanov et al., 2002).

Seven mollusc samples give ages in the range from 83 ± 4.6/4.4 to 128.5 ± 10.4/9.2 ka, which corresponds to the time interval of MIS5 (Table 2). These dates provide geochronological control for correlation of the studied terrace.

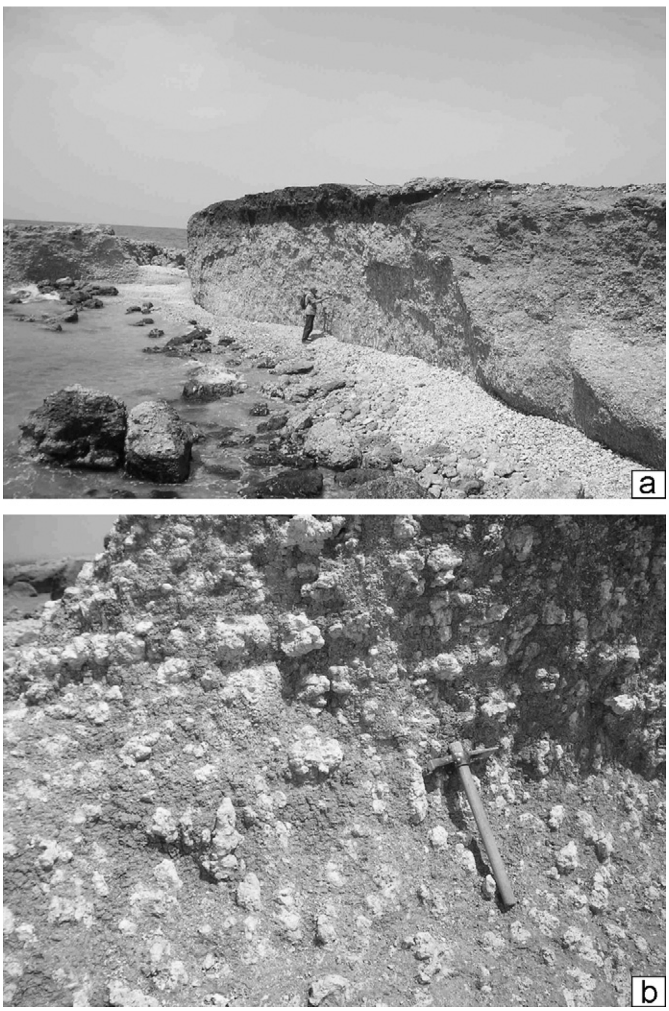

Fig. 9. Cliff of 5–6 m terrace composed of clays, 2 km to south of the Arab el Mulk village (a); the detail of the same section—numerous carbonated concretions in the clays (b).

Two dates from the Soukas site, 186.6 ± 23.9/19.1 and 168.1 ± 18.2/15.0 ka from limestones forming the abrasion terrace of 3–4 m asl, correspond to pre-MIS5. These dates obviously do not fit the existing chronological model, because they belong to the regression time interval. Perhaps the apparent age of both samples was caused by a recrystallization of shells. Another date from Soukas (S2)—60.6 ± 6.2/5.6 ka, is not comparable to the latter two dates perhaps due to partial contamination by ^{232}Th in the mineral material of shells. In these cases, some distortion of the age could not be excluded from the final results.

To interpret the geochronology of the lower terraces in the coastal area of Western Syria, it is impossible to follow the restricted approach of the term "Tyrrhenian" according to its original definition, i.e. to the *Strombus bubonius*-bearing marine units, as there are almost no *Strombus bubonius* in the sediments of the lower marine terraces. Only a few finds of *Strombus bubonius* have been ascribed to the lower terrace in the vicinity of Banias without any precise documentation. This suggests acceptance of the age control approach, using geochronological data for the determination of the Tyrrhenian terrace. In this case the Tyrrhenian terrace is considered to be MIS5 age equivalent, with the sediments formed during the interval of 130–70 ka (Fig. 11). The three-fold subdivision was employed for Tyrrhenian transgression: Paleotyrrhenian, Eutyrrhenian, and Neotyrrhenian (Ambrosetti et al., 1972), consequently correlated with MIS 7, 5 and 3.

7. Neotectonics

New ^{230}Th/U dates on the lower terrace provide good support for stratigraphical and geomorphological interpretation. On the basis of the geomorphologic observation and neotectonic reconstruction, the following conclusions can be suggested. According to the geomorphological data and lithological composition of the Tyrrhenian terrace, two main uplifted blocks can be recognized. One coincides with

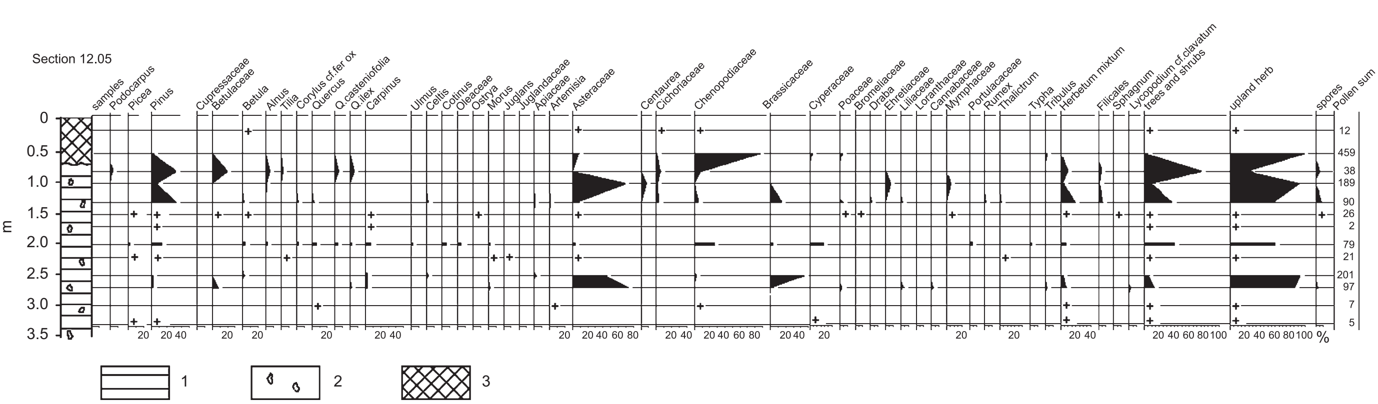

Fig. 10. Pollen diagram from the 3.5 m section (12.05) in which carbonated clays outcrop along the marine terrace, 2 km to the south of the Arab el Mulk (see Fig. 9). The location of this section is depicted in Fig. 2A. (1) clay; (2) carbonate concretion; (3) soil.

Table 2
Results of radiochemical analyses of the mollusc shells of the lower terraces in the Mediterranean coastal area of Syria and their $^{230}Th/U$ ages

No.	Lab. no.	Site sample	Shell material	Latitude N	Longitude E	Altitude (m)	^{238}U (dpm/g)	^{234}U (dpm/g)	^{230}Th (dpm/g)	^{232}Th (dpm/g)	$^{230}Th/^{234}U$	$^{234}U/^{238}U$	$^{230}Th/U$ age (ka)
1	LUU 145	15.05 Ramleh	Pectinidae	35°22′ 44.6″	035° 55′ 11.5″	13	0.359 ± 0.015	0.443 ± 0.017	0.304 ± 0.006	0.015 ± 0.001	0.685 ± 0.030	1.235 ± 0.062	$119.0^{+11.3}_{-9.9}$
2	LUU 157	12.05 Sample 1	Ostrea sp.	35°15′ 20.0″	035° 56′ 02,2″	5	0.374 ± 0.012	0.453 ± 0.014	0.323 ± 0.006	0.005 ± 0.001	0.714 ± 0.026	1.211 ± 0.040	$128.5^{+10.4}_{-9.2}$
3	LUU 158	3.05 Sample 2	Ostrea sp.	35°27′ 04.5″	035° 54′ 40.7″	28	0.168 ± 0.06	0.230 ± 0.007	0.163 ± 0.004	0.070 ± 0.003	0.709 ± 0.028	1.365 ± 0.058	$123.8^{+10.3}_{-9.2}$
4	LUU 159	64.05 SnoubarSample 2	Pelecypoda	35°28′ 28.0″	035° 53′ 10.1″	30	1.369 ± 0.033	1.567 ± 0.037	0.852 ± 0.020	0.006 ± 0.002	0.544 ± 0.018	1.145 ± 0.030	$83.4^{+4.6}_{-4.4}$
5	LUU 160	48.05 Sample 1	Taxodonta	34°44′ 31.1″	035° 55′ 57.5″	3	0.136 ± 0.006	0.190 ± 0.007	0.013 ± 0.002	0.002 ± 0.001	0.070 ± 0.011	1.391 ± 0.067	$7.8^{+1.3}_{-1.3}$
6	LUU 161	10.05 Sample 1	Pectinidae gen.	35°25′ 03.0″	035° 55′ 31.5″	26	0.208 ± 0.006	0.251 ± 0.007	0.160 ± 0.005	0.004 ± 0.001	0.638 ± 0.026	1.206 ± 0.046	$105.9^{+8.2}_{-7.4}$
7	LUU 162	14.05 Soukas 1 Sample 1	Ostrea sp.	35°18′ 56.8″	035° 55′ 37.5″	3	0.630 ± 0.017	0.725 ± 0.009	0.612 ± 0.017	0.006 ± 0.001	0.845 ± 0.032	1.150 ± 0.030	$186.6^{+23.9}_{-19.1}$
8	LUU 163	A.05 Arwad Sample 1	Pelecypoda	36°51′ 19.9″	035° 51′ 28.9″	7	1.433 ± 0.047	1.526 ± 0.050	0.925 ± 0.018	–	0.606 ± 0.023	1.065 ± 0.042	$99.9^{+7.4}_{-6.8}$
9	LUU 170	S2.05 Soukas 2 Sample 1	Ostrea sp.	35°18′ 41.2″	035° 55′ 15.9″	4	0.661 ± 0.039	0.745 ± 0.044	0.322 ± 0.011	0.051 ± 0.004	0.432 ± 0.029	1.128 ± 0.088	$60.6^{+6.2}_{-5.6}$
10	LUU 217	29.06 Soukas 3 Sample 5	Ostrea sp.	35°19′ 00.9″	035° 55′ 21.2″	4	1.450 ± 0.036	1.513 ± 0.037	1.202 ± 0.029	–	0.794 ± 0.028	1.044 ± 0.027	$168.1^{+18.2}_{-15.0}$
11	LUU 218	20.06 Quarry Sample 3	Ostrea sp.	35°25′ 46.0″	035° 54′ 43.0″	19	0.998 ± 0.051	1.169 ± 0.056	0.771 ± 0.037	0.009 ± 0.005	0.660 ± 0.045	1.172 ± 0.074	$112.7^{+15.9}_{-13.5}$

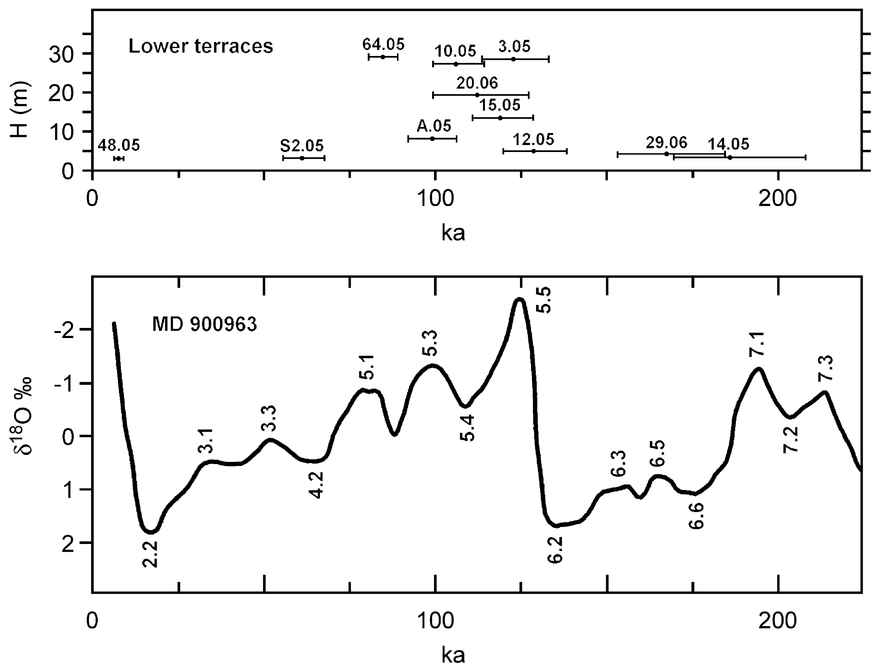

Fig. 11. Uranium–thorium ages and altitudes of dated sites on the lower marine terraces of Western Syria and its connection with the oxygen isotope stages. The oxygen isotope curve MD 900963 after Bassinot et al. (1994).

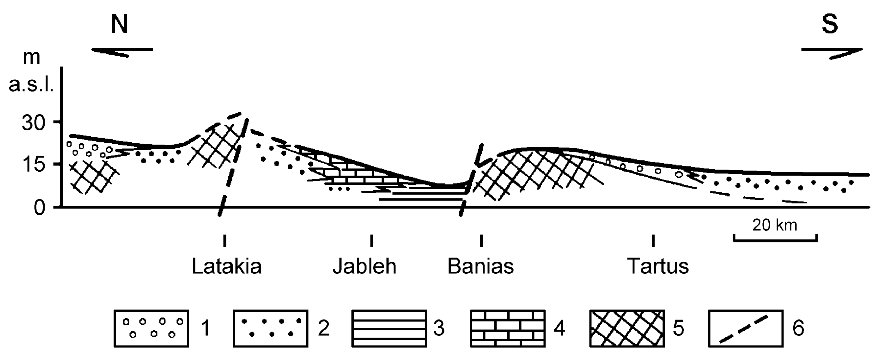

Fig. 12. Schematic geological profile along the Mediterranean coast of Syria showing the neotectonic deformation of the Tyrrhenian terrace and its composition. (1) gravel; (2) sand; (3) clay; (4) carbonate; (5) bedrock; (6) proposed faults.

the Latakia area, and the other corresponds to the western margin of the Banias high volcanic plateau (Fig. 12). In both cases, uplifting of the Tyrrhenian terrace illustrates the active neotectonic development of the Latakia and Banias blocks. These blocks are divided by a subsided structure corresponding to the El Kebir graben. Geomorphologically, the Tyrrhenian terrace has a gradual inclination from the northern flank of the Nahr el Kebir graben to the south. At Banias, the uplifted Tyrrhenian terrace is erosional. The next subsided structure is developed south of Tartus. The amplitude of uplifting in the Latakia and Banias blocks reaches 15–20 m for the Late Pleistocene, if the mean altitude of the paleo-Tyrrhenian coastline is considered at 7–8 m above the modern shoreline. This corresponds to an average rate of deformation of 0.1–0.2 mm/a for the Tyrrhenian terrace. The uplifted parts of the Tyrrhenian terrace are relatively small and a significant portion was subjected to neotectonic subsidence.

In the El Kabir graben, the Pliocene deposits form a surface at about 200–250 m asl (Geological Map..., 1964). According to the stratigraphical data (microfauna, paleomagnetic measurements) obtained at the Mardido and Msharfeh sections, located in the Nahr el Kabir Valley near the villages with corresponding names, the upper part of the Pliocene unit at the altitude 200 m asl is capped by the late Early Pleistocene deposits with age about 1 Ma (Devyatkin and Dodonov, 2000). These data suggest an uplift rate of 0.2 mm/a for the time interval of the last 1 Ma, which fits to the value of the late Pleistocene uplifting. These calculations show an average uplift rate for the Middle and Late Pleistocene for the coastal area between Latakia and Banias. The eustatic factor, involved in estimation of the sea level during Early–Middle Pleistocene transgressions, is partly neglected in these calculations. This result differs from data obtained from Quaternary marine and fluvial terraces in Southern Italy

Fig. 13. Carbonate strata of the lower terrace (10–15 m) tilting 3–5° to the west; the portion of the coastal area at the mouth of the Ramleh River, 2 km to the north of the town of Jableh.

(Bianca and Caputo, 2003; Dumas et al., 2003). The latter authors suggested the continuous uplift rate of 1–2 mm/a for the Late Pleistocene. However, the Reggio Calabria area in southern Italy is one of the most notable raised areas in the world, where a great number of stepped marine terraces were formed during the Quaternary.

The neotectonic movements resulting in the subsidence of the Tyrrhenian terrace should be considered as one of the factors that affected the submergence of the Middle and Late Paleolithic sites, discussed by archaeologists for the Eastern Mediterranean coastal area in connection with regression and transgression phases during the Late Quaternary (Copeland, 1981). In some places, for example 1–2 km to the north of the Jableh and in the Soukas area, a clear 3–5° westward tilting of the sediments of the Tyrrhenian terrace is observed (Fig. 13). The Tyrrhenian coastline was further offshore.

From detailed bathymetric data, the offshore continuation of the Tyrrhenian terrace forms several shallow (up to 30 m below recent sea level) small synclinal basins elongated along the coast between Banias and Tripoli. The synclines are separated from the open sea by an en echelon row of underwater small gentle anticlines which represent a strand of the Roum fault zone (Rukieh et al., 2005) and demonstrate the presence of the sinistral component of motion along the zone. The Tyrrhenian sediments of the two anticlines are partly asl and are exposed on Arwad and El Abbas. Remains of accumulative forms (bars/dunes) on the Island of Arwad, dated to 100 ka, as well as on El Abbas Island point to dramatic changes in the interaction of the sea and land. These islands are situated 3–4 km offshore. The major western part of the Tyrrhenian terrace near Tartus subsided below sea level by Late Pleistocene neotectonic movements, which took place along the Syrian coastal area. The relative lack of Paleolithic sites on the Tyrrhenian terrace along Syria's Mediterranean coast is partly due to neotectonic submergence.

8. Conclusions

The lower terrace with prevailing altitudes of 20–30 m asl is widespread in the coastal area of Syria. This terrace is attributed to the Last Interglacial through Th/U dates. The problem of the Tyrrhenian stage remains uncertain because of the absence of *Strombus bubonius* in the studied horizons and localities. Geomorphologically, the undulation of the Last Interglacial terrace was determined to be in the range of 5–40 m asl. Lithological characteristics of the Last Interglacial terrace document facies changes dependent on the neotectonic structure. In the subsided area more clayey sections predominate, whereas the uplifted area has coarser sections and reduced thickness. According to the geomorphological data and lithological composition of the Last Interglacial terrace, two main uplifted blocks can be recognized along the studied sea shore of Western Syria. One coincides with the Latakia area, and the other corresponds to the western margin of the Banias high volcanic plateau. The estimated average rate of deformation of the Last Interglacial terrace is 0.1–0.2 mm/a.

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