MAJOR RECENT TECTONIC UPLIFT IN ISKENDERUN BAY, TURKEY

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ABSTRACT. Radiocarbon dating was carried out in the sediment profiles of four marine sediment cores taken from Iskenderun Bay, Turkey. The bay is quite shallow in the present day, and a previous tectonic study had considered that the bay floor might have been subsiding. However, this cannot be so, for the ^{14}C ages would thereby lead to the apparent paradox of normal marine sedimentation having taken place during times when glacio-eustatic sea level lowering would have exposed the bay floor. Rather, we conclude that the floor of Iskenderun Bay on the whole has been experiencing rapid uplift since the end of the Last Glacial, due to a combination of tectonic factors linked to the compression between the Anatolian and African plates.

INTRODUCTION

Iskenderun Bay, Turkey, lies along the eastern side of the Levant basin in the Mediterranean Sea. The bay is large, shallow, and tectonically active. It is a region where the African and Anatolian plates are converging. Along the northeastern shore of the bay lies the north–northeast-trending Misis-Kyrenian thrust belt. To the east is the Eastern Anatolian Fault (Figure 1).

Seismic reflection profiling carried in the vicinity, suggests that the shelf of the Anatolian Plate is underlain by a sequence of at least 11 stacked deltas, separated by erosional unconformities (Aksu et al. 1992). This was interpreted as delta formation followed by erosion due to Pleistocene eustatic sea-level fluctuations. It was assumed that during that time the floor of the basin was continuously subsiding. However, delta formation—and its subsequent truncation—is not restricted to a downward sinking basin. Such features can be formed when the sea level rise, or fall, is greater than the movement of the land. During the late Pleistocene when cycles of relatively large and rapid sea level movement occurred, such features could form equally as well by continuous upward movement of the basin.

METHODS AND RESULTS

Four short gravity cores of marine sediment were taken at various depths within Iskenderun Bay (Figure 1). The cores provided material for sedimentological and foraminiferal analyses, as well as for radiocarbon dating. These cores had been taken to supplement a wider sedimentological, geochemical, and foraminiferal study of the sediment surface (provided by 139 grab samples) across the bay. The results of this latter study are provided by Yanko (1994, 1995) and will be presented in detail elsewhere.

The cores are dominantly mud (clay and silt, with minor sand) throughout. Sands are generally restricted near the shore, or locally, to elevated features in the bay (Koral 1996). For the ^{14}C analyses, the bulk carbonate (consistently 30% of the sediment) was dated, except in samples at 18–20 cm and 48–50 cm in Core 16. These two samples contained coral tubules, which were removed before analysis. Two-centimeter-thick sections of the sediment cores were used. The dried samples were treated with hydrochloric acid to decompose the carbonate. The evolved carbon dioxide gas was used for radiometric analysis in a gas proportional counter (Vogel and Marais 1971). The results of

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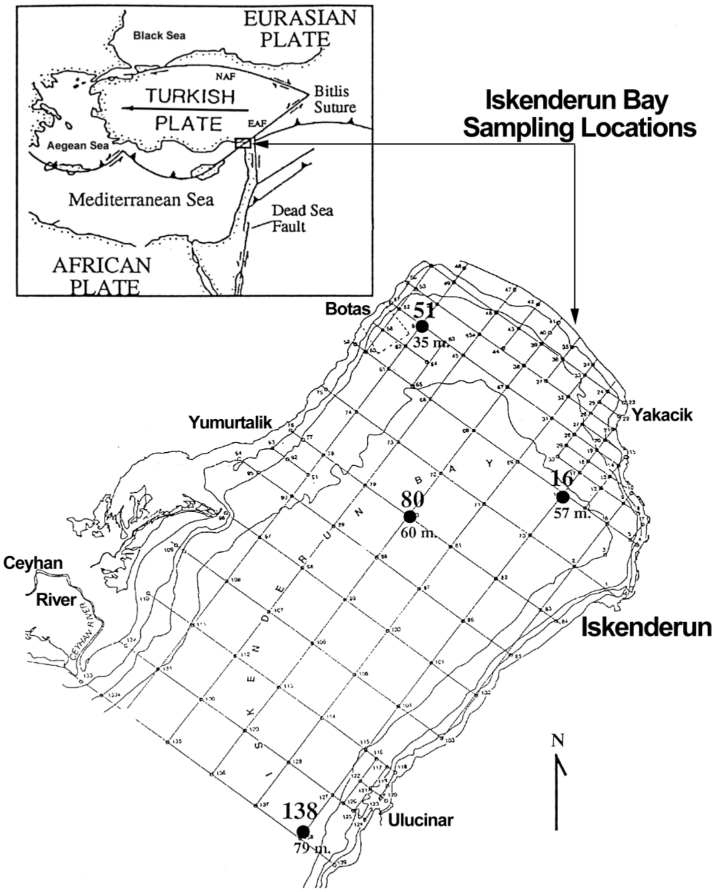

Figure 1 Sample location map. Iskenderun Bay is situated in an area of high tectonic activity related to the compression caused by the collision between the Anatolian and African Plates.The floor of this bay is relatively quite shallow. The station position and the depth from which the four sediment cores have been collected are shown.

17 sediment analyses are reported in Table 1, along with the core depth and location. The ^{14}C dates increase in a remarkably consistent manner as a function of depth (Figure 2), except for the top of Core 51. This core, situated in the northern corner of the bay, was taken at the base of a local topographic high. The samples from the top of the core gave an older age than the underlying samples, which all subsequently increase in age as a function of increased depth in the core. This must be explained as being slumped material from the adjacent high spot.

The basal ages of all four cores are pre-Holocene. It should be noted that the reservoir age of surface ocean water is about 400 years. The reservoir age must be subtracted from all of the ^{14}C dates to obtain the actual ^{14}C age of the sample. This correction would only engender a small percentage change in the ages reported in Table 1.

The ages of the coral fragments that were separated out from the sediment at 18–20 cm depth in Core 16 are also reported in Table 1. The age of the measured coral sample of 8300 BP (Pta-7412) is some 700 years younger than the remaining bulk carbonate (Pta-6941). This concordance in ages between the two sediment fractions demonstrates that the shell in the bulk carbonate is not of secondary origin, for the coral material, which consisted mainly of rodlets with a diameter of 2–3 mm, would not have survived transport on the floor of the bay. This suggests that the coral fragments sank down onto the slowly accumulating bottom sediment at a slightly later date than that of the dead for-

Table 1 Radiocarbon ages of sediments in Iskenderun Bay

Analysis nr (PTA-)	Sample depth (cm)	^{14}C age (BP)	δ^{13}C (‰)
Core 51 (36°52′21″N, 35°58′54″E) Water depth –35 m, core length 140 cm			
6946	0–2	11,310 ± 130	−2.7
6905	32–34	8,860 ± 90	−1.3
6930	52–54	9,530 ± 80	−1.2
6933	70–72	10,520 ± 90	−2.0
6902	92–94	10,810 ± 110	−1.6
6935	112–114	11,430 ± 100	−1.5
6910	138–140	12,080 ± 90	−1.6
Core 16 (36°41′58″N, 36°07′42″E) Water depth –58 m, core length 50 cm			
6945	0–2	4,890 ± 60	−0.2
6941	18–20	8,990 ± 80	−1.7
7412 (coral)	18–20	8,300 ± 70	−3.8
6940	48–50	10,510 ± 80	−1.5
Core 80 (36°41′3″N, 35°57′0″E) Water depth –61.5 m, core length 120 cm			
6887	0–2	7,750 ± 70	−2.1
6888	42–44	11,310 ± 100	−2.6
6889	72–74	11,090 ± 110	−2.7
6891	120–122	12,170 ± 110	−2.4
Core 138 (36°23′64″N, 35°47′76″E) Water depth –80 m, core length 70 cm			
6911	2–4	7,570 ± 60	−1.7
6912	32–34	9,080 ± 90	−1.3
6913	62–64	13,500 ± 140	−2.2

aminifera tests. The percentage age difference is small, so that the ^{14}C dates of the sediment can be accepted as correct to within 1000 years at most.

A detailed study of the foraminiferal populations was carried out down the core. The foraminiferal tests were well preserved. There is no sign that they represent reworked material. A presentation of the detailed study of the foraminifera is beyond the scope of this work and will be presented elsewhere (Avsar and Yanko, in preparation). It is pertinent to note that the study of the benthic foraminifera does not support the contention that the floor of the basin has subsided.

By comparing the fossil foraminiferal populations in the core to living benthic populations collected from grab samples at various depths around Iskenderun Bay and elsewhere along the eastern Mediterranean coast (off of the Israeli coast), we were able to determine the relative paleo-water depths at which the sediment had been deposited. The benthic foraminiferal populations could be classified into three broad groupings based upon approximate water depth, of "shallow" (<30 m), "relatively deep" (30–60 m) and "deep" (>60 m).

Thirty-two species have been encountered that comprise the "deep" dwelling group in the cores. Of these, 15 (e.g., *Globocassidulina subglosa, Lagena laevis, Lagena nebulosa*, *Lenticulina gibba*) are found in the cores but are not found in the living assemblages anywhere today in Iskenderun Bay. On the other hand, species that are known to be restricted to very shallow depths are generally absent within the core material. In the absence of a clearly definable "shallow" water species, *Ammonia tepida* (Cushman) is taken for this purpose. *A. Tepida* has been shown to represent the shallow

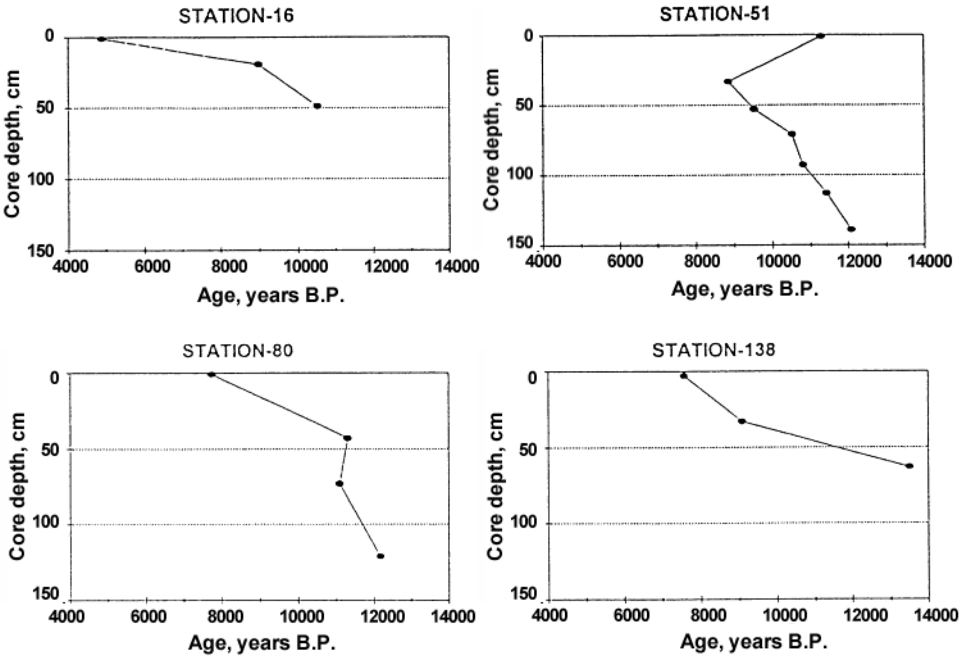

Figure 2 The radiocarbon ages of the four cores are plotted as a function of depth in the cores. The anomalously older age at the top of core 51 is believed to be caused by slumping from the adjacent topographic high.

marine environment in the Black Sea (Yanko 1990a, 1990b) and is noted from very shallow depths in the eastern Mediterranean (Yanko et al. 1994). It is found that there is a high abundance of *A. Tepida* throughout the shallowest core, Station 51. Conversely, the group of relatively "deep" benthic species replaces *A. tepida* in cores taken at the deeper stations. It is also noted that there is a general trend for the "deep" species to increase down-core in all the cores. This would suggest that the top of the core 51 (which contains representatives of "deep" species only in the uppermost samples and which is anomalously old for its stratigraphic position) is indeed out of sequence (Figure 2), presumably having slumped from an adjacent uplifted block. At least four species of planktic foraminifera *Globigerinoides ruber* (d'Orbigny), *Globigerinoides trilobus trilobus* (Reuss), *Globoquadrina dehiscens* (Chapman, Parr, and Collins), and *Globorotailia obesa* (Bolli) are encountered throughout all cores, with the richest abundance in Core 38, taken from the deepest water nearest to the entrance of the bay.

DISCUSSION AND CONCLUSIONS

The investigated cores extend over a large chronological interval, going back into the late Pleistocene. The sedimentation rate is low as would be expected for a basin lacking significant river borne detrital inputs. The Ceyhan River is the only major sources that discharges to the bay. Other inputs are small and ephemeral. The Ceyhan River itself has changed course and outlets several times. Ptolomey (Skelton 1969) indicated that during Classical times the river drained directly into the Mediterranean. At present, it enters the sea near the mouth of the bay. The lack of sources for transporting sediments also strengthens our belief that the foraminiferal populations have not been reworked, nor do they represent sediment mixtures containing older transported foraminifera.

There is a continuity of marine sediments down the cores going back in time to over 13.5 ka BP. This stands in contradiction to the global sea level curve for this time (Fairbanks 1989). Eustatic sea level at 13.5 ka BP was approximately 104 m lower than today. The sea level rose to within approximately –70 m at 11.0 ka BP, continuing onto –10 m at 6.0 ka BP. Therefore, if the floor of the bay, whose maximum depth is barely greater than 80 m, had remained at its present elevation, no marine sedimentation would be possible for the times recorded. Indeed, at 13.5 ka BP, when sea level would have been expected to be eustatically lowered by 104 m, Core 138 records the greatest abundance of deep dwelling benthic foraminifera.

To illustrate the problem, the age and depth of the shallowest core, 51, and the deepest core, 138, are plotted against the global sea level curve (Figure 3). All of the sampled intervals of core 51 are older than 8.0 ka BP. Its present water depth is 35 m, yet all of the ^{14}C ages fall to the right side of the sea-level curve. This would imply that the normal marine sediments that were studied were depositing at times when the floor of the bay should have stood 60–70 m above sea level. This is not possible. Likewise, assuming that the present depth of station 138 is representative of its absolute elevation in the past, the floor of the bay would have been above sea level for the early part of its depositional history (Figure 3). All of the four cores exhibit the same conflicting evidence of normal marine sedimentation occurring at times when greatly lowered sea levels would have placed the floor of the basin well above the then existing level of the sea. The difference in elevation between the present basin floor and that of the previously lowered sea surface would have been even greater still if it is assumed that the basin has been undergoing subsidence, as has been suggested by Aksu et al. (1992).

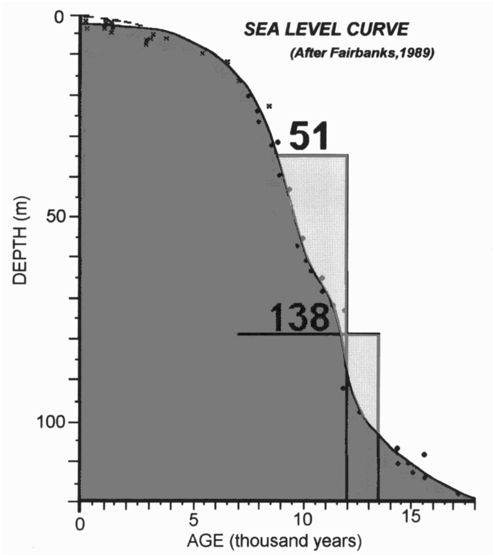

Figure 3 The sediment ages and present water depth from cores 51 and 138, plotted on the global sea level curve (Fairbanks 1989). In the area to the left of the curve are those elevations that have always been beneath the sea. The area to the right of the curve represented the times when sea level lowering had exposed the sea floor. For example, for the period of time represented by the sediment ages in Core 51, the floor of the bay floor should have been above sea level for the entire period recorded. The deeper core 138 would have been beneath water only during the later times. The fact that normal marine environments are recorded in the sediments demonstrates that the current sea floor must have once been situated at greater depths than today.

Our data shows that Iskenderun Bay must have been continuously rising. The floor of the basin stood at a much lower elevation in the past and has risen to its present position. This would explain why "deep" dwelling foraminifera occur at the oldest intervals in the cores, which are synchronous to low sea level stands. It can also explain the presence of planktic foraminifera throughout the core.

There may be several mechanisms, working alone, or in tandem, responsible for the rapid uplift of Iskenderun Bay. Up to 4.5 km of Neogene sediments are present under the bay (Schmidt 1961; Yalçin and Gorur 1984; Gorur 1985; Uffenorde et al. 1990). A gravimetric survey suggests that these sediments are gravimetrically undercompensated. While the eastern Levant basin is characterized by generally broad and positive Bouger gravity anomalies, only a broad negative Bouger anomaly is found (Woodside 1977) across much of the bay (Figure 4). The compressional forces acting sub-perpendicular to the axis of the bay are squeezing the sedimentary mass, which includes the mobile Messinian evaporite sequence, upwards. This would lead to uplift of the bay as a whole. Another consideration is the continuous process of the closing of the southern branch of the Neotethys. This has been ongoing since the middle Miocene due to the compression between the Anatolian and African plates (Yilmaz and Gürer 1996). GPS measurements of the region suggest that the descent of the African plate beneath the Anatolian plate is occurring at the rate of 2 cm/yr. This motion is accommodated by the westerly rotation of the Anatolian plate along the East and North Anatolian Faults at the rate of 1–1.5 cm/yr, respectively (Oral et al. 1995). Though the specific mechanism and the exact amount of vertical movement can be debated, the end-result has been an upward movement of the basin. Since late Pleistocene time, a minimum average vertical uplift on the order of 0.5–1.5 cm/yr is deduced from our study. Thus, from the late Pleistocene to the present, a total vertical uplift of nearly 100 m can be considered to have taken place in Iskenderun Bay.

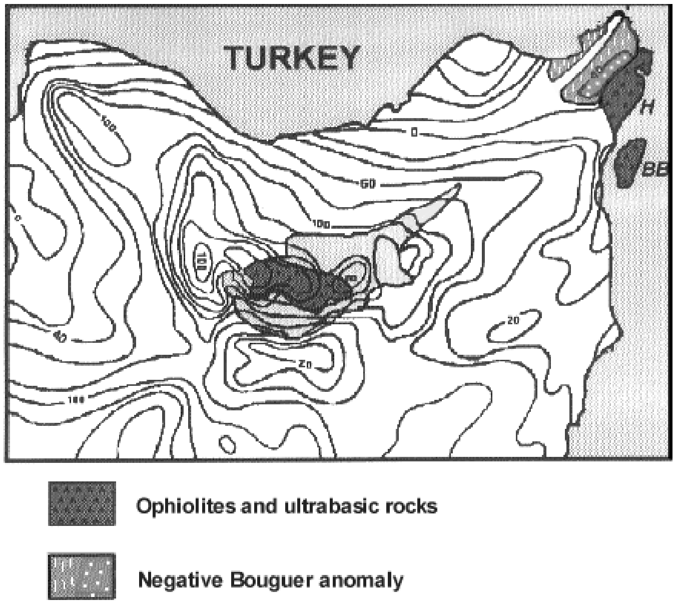

Figure 4 The floor of the eastern Mediterranean Sea is denoted by positive Bouger gravity anomalies. The area of Iskenderun Bay, on the other hand, is characterized by a broad negative Bouger (gravimetrically undercompensated) anomaly. The floor of the bay should thus continue to rise, driven by the ascending thick and less dense sedimentary mass that underlies the bay.

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REFERENCES

Aksu AE, Ulug A, Piper DYP, Konuk YT, Turgut S. 1992. Quaternary sedimentary history of Adana, Cilicia and Iskenderun basins: northeast Mediterranean Sea. *Marine Geology* 104:55–71.

Fairbanks RG. 1989. A 17,000-year glacio-eustatic sea-level record: influence of glacial melting rates on the Younger Dryas event and deep-ocean circulation. *Nature* 42:637–42.

Gorur N. 1985. Depositional history of Miocene sediments of the NW flank of the Adana Basin. In: Izdar E, Nakoman E, editors. *Sixth colloquium of geology of the Aegean region*. Dokuz Eylul University: Piri Reis Institute Contribution Series. p 185–208.

Koral H. 1996. Sedimentological study of the cores in Iskenderun Bay: evidence of depositional conditions during the Holocene. In: Yanko V, editor. *Annual Report, Benthic foraminifera as indicators of heavy metal pollution-a new kind of biological monitoring for the Mediterranean Sea*. p 101–14.

Oral MB, Reilinger RE, Toksoz MN, King RW, Barka AA, Kinik I, Lenk O. 1995. Global positioning system offers evidence of plate motions in Eastern Mediterranean. *EOS, Transactions, American Geophysical Union* 76:9–11.

Schmidt GC. 1961. Stratigraphic nomenclature for the Adana region: Petroleum District VII. *Petroleum Administration Bulletin* 24:39–50.

Skelton RA. 1969. Claudius Ptolemacas, Geographica, Venice, 1511. *Theatrvm Orbis Terrarvm*. Amsterdam MCMLXIX.

Uffenorde H, Lund JJ, Georgi, K-H. 1990. Biostratigraphy of the Neogene in the Iskenderun Basin. 8th Petroleum Congress of Turkey, Turkish Association of Petroleum Geologists, UCTEA Chamber of Petroleum Engineers. p 363–70.

Vogel JC, Marais M. 1971. Pretoria radiocarbon dates I. *Radiocarbon* 13(3): 378–94.

Woodside JM. 1977. Tectonic elements and the crust of the eastern Mediterranean Sea. *Marine Geophysical Researches* 5:317–54.

Yalçin MN, Gorur N. 1984. Sedimentological evolution of the Adana Basin. In: Tekeli O, Goncuoglu MC, editors. *Geology of the Taurus Belt.* MTA Ensititusu. p 165–72.

Yanko V. 1990a Quaternary, foraminifera of the genus *Ammonia* of the Pontian- Caspian region. *Paleontological Journal* 1:18–26.

Yanko V. 1990b Stratigraphy and paleogeography of the marine Pleistocene and Holocene deposits of the southern seas of the USSR. *Memorie della Societa Geologica Italiana* 44:167–87.

Yanko V. 1994. Benthic foraminifera as indicators of heavy metals pollution – a new kind of biological monitoring for the Mediterranean Sea. *AVICENNE Annual Report*. 42 p.

Yanko V. 1995. Benthic foraminifera as indicators of heavy metals pollution – a new kind of biological monitoring for the Mediterranean Sea. *AVICENNE Annual Report.* 270 p. Contract Number AVI CT92-0007.

Yanko V, Kronfeld J, Flexer A. 1994. The response of benthic foraminifera to various pollution sources: implications for pollution monitoring. *Journal of Foraminiferal Research* 24:1–17.

Yilmaz Y, Gurer F. 1996. The geology and evolution of the Misis-Andirin Belt, around Andirin (Kahramanmaras). *Turkish Journal of Earth Sciences* 5:39–56.