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THREE OSCILLATORY TECTONIC MOVEMENTS AT CAESAREA – ONE BYZANTINE AND TWO POST BYZANTINE –

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ONE BYZANTINE AND TWO POST-BYZANTINE

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This report is an updated version of the text (invited paper) which appeared in: The Harbours of Caesaria: Results of the Caesaria Ancient Harbour Excavation Project, 1980-1985, Volume I, Part i., BAR International Series 491, 1989, edited by A. Raban (with permission of the publisher). The interpretations expressed herein are the responsibility of the authors.

ABSTRACT

A 2.5 m oscillatory (down and up) tectonic movement occurred along the coast of Caesarea during Late Roman and Byzantine times, as indicated by changes in the gradients and elevations of aqueducts on land, as well as by the subsidence of the harbor. A similar oscillatory movement, but of greater magnitude (10-15 m), occurred in Caeserea between early Moslem and post Crusader times. The latter is indicated by the changes of the environmental regimens that occurred on land, from a man-made constructed subaerial environment to an overlying aquatic-transgressive (lagoons and swamps) environment. Variations noticed within the sedimentary sequence of the latter suggest the occurrence of two sea-level oscillations (secondary regressions and transgressions) resulting from two tectonic sub-phases: one in pre-Crusader times and the other afterward. A disastrous flood on the Sharon Plain that should have affected Caesarea as well, is inferred from a Hebrew poem, to have occurred sometime between the 8th and 10th centuries A.D.

INTRODUCTION

The evolution of the geological structure at Caesarea and its tectonic history during the Holocene was discussed by Neev et al (1978). One of their specific conclusions, namely the occurrence of a post-Roman oscillatory tectonic movement, provoked a bitter controversy. The mechanism and origin of that movement, as well as a review and discussion of the contradictory concepts, are discussed by Neev et al. (1987, pp. 97-102). Since then, several relevant new data were noted and analyzed. As they corroborate the earlier conclusions, it is the purpose of the present report to discuss them and to protray a more comprehensive tectonic history of Caesarea during the post-Roman period. The following is a short review of some of the earleir data and conclusions.

The structural high of Caesarea is at the junction of three tectonic elements: (i) a NE-SW trending folded structure, formed mostly after Early Cretaceous, and in which folding activity continued until Late Pleistocene; (ii) a NNE-SSW trending post-Jurassic - pre-Cretaceous normal fault that roughly corresponds with the Recent coastline as well as with the present coastal fault system; (iii) the Or-Akiva E-W (transverse) trending fault (or graben) (Gvirtzman and Klang, 1981; Neev and Greenfield, 1981).

Rejuvenated activities in the Recent along these tectonic elements have resulted in the formation of a tilted fault block that is uplifted in the north (at the Caesarea harbor) and dips to the south. Similar structural features of analogous origin were also formed at other sites along the coast of Israel, such as at the Akhziv harbor (Neev et al., 1987, p.39).

Three coast-parallel faults are postulated along the littoral zone off Caesarea (Neev et al., 1978). Two of these faults (the two nearest the coastline, Fig. 1) were identified on the basis of onshore and offshore studies that included detailed stratigraphic analyses of boreholes (including precise elevations of the Pliocene-Pleistocene boundary) and detailed underwater archaeological excavations (Raban et al., 1976). Cumulative throws during the Holocene across these two faults total nearly 20 m within a distance of about 400 m. The Herodian harbor subsided about 6 m across the easternmost (F-1) fault, that corresponds with the submarine cliff along the western margin of the abraded terrace (Fig. 2). This Post-Roman faulting occurred in two phases: one during Byzantine times, and the other since then (perhaps during Mamlukian times, just a few hundred years ago). During both of these tectonic phases, the downthrown block, on which the Herodian

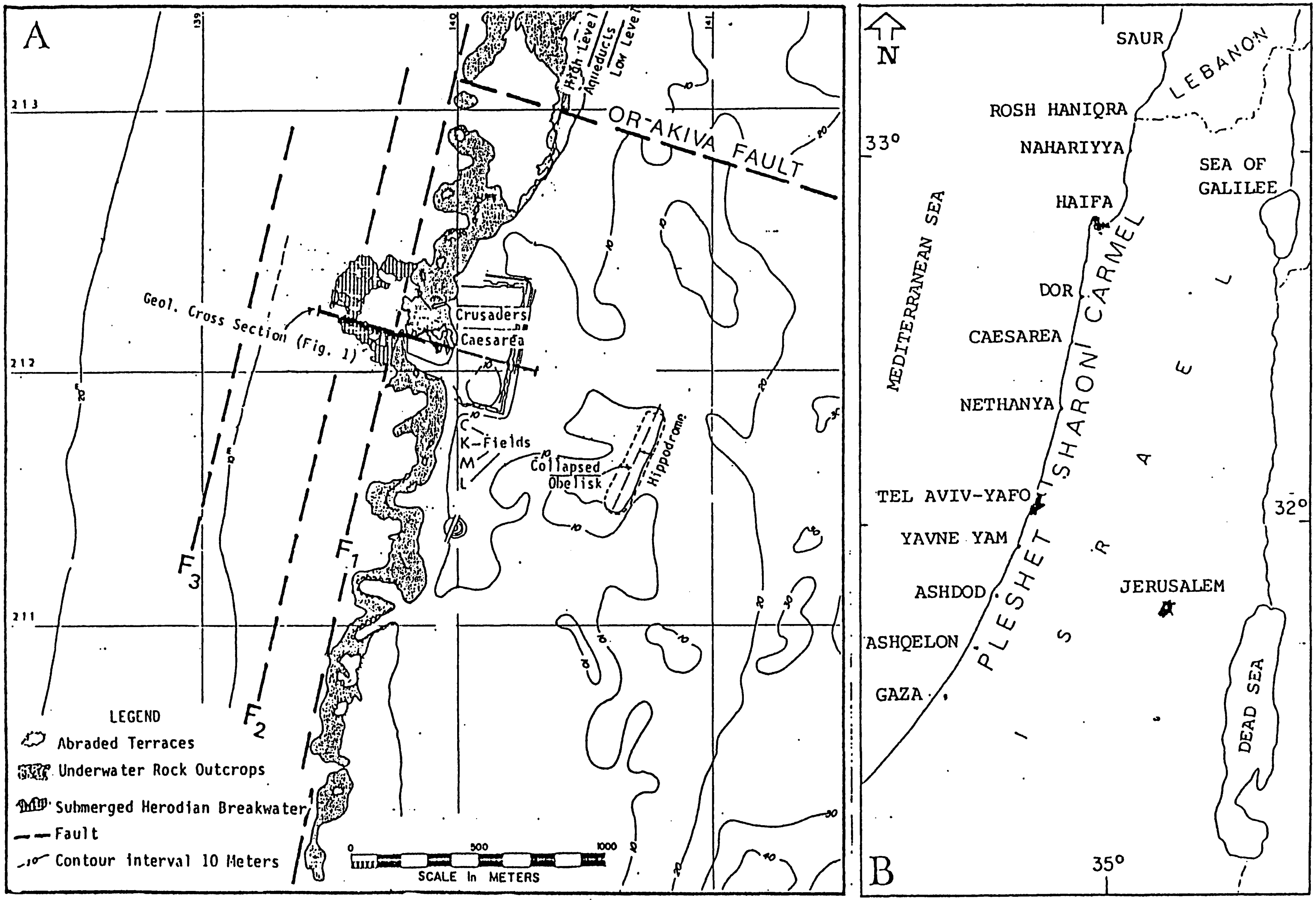


Figure 1. Location maps: (A) Sites at and close to Caesarea discussed in text (after Neev et al., 1978). Note locations of fields C, K, L and M as well as the point of abrupt termination of the high- and low-level acqueducts; (B) Regional map - note the limits of the administrative districts along the coast: Carmel, Sharon and Pleshet (Yehudah).

harbor is situated, subsided, whereas the upthrown block was subjected to oscillatory (downward followed by upward) movements. The mechanism and origin of the oscillatory movements are discussed by Neev et al. (1987, p. 97-99). Both phases of faulting are believed to be associated with the renewal of massive supplies of quartz-sand from the Nile River. The net amount of vertical shift across the second fault (F-2, Figs. 1 and 2) is about 13 m, most of which occurred in pre-Roman times, probably during the Iron Age. A third offshore fault (F-3, Fig. 1, beyond the western limit of Fig. 2) was identified on the basis of shallow-penetration seismic profiles and geomorphic considerations.

A. THE BYZANTINE PHASE

The occurrence of a vertical tectonic movement at Caesarea during Byzantine times is inferred from the analysis of two sets of data: (i) Changes made in the gradients and elevations of the water supply system to Caesarea, namely the high-level and low-level aqueducts at the north of the city during Late Roman, Byzantine and Early Moslem times. These changes were deduced on the basis of data from Reifenberg (1950-51), Negev (1964), Olami and Peleg (1977) and Nir (1985) as well as our own observations. As shown below, it is suggested that during the Byzantine period, the upthrown block east of the coastal fault, tectonically subsided by 2.5 m and was then uplifted again by the same amount. (ii) Shipwrecks found and an additional rampart built on top of the Roman breakwater (Raban et al., 1976; Raban, 1985). These data indicate that the harbor (i.e., the downthrown block) subsided twice since it was built; once during the Byzantine period and once again since then. The subsidence during each of these phases amounted to approximately 3 m.

(1) Aqueducts

During Roman and Byzantine times, the high-level aqueduct carried fresh water to Caesarea from the southeastern flank of Mount Carmel. Upon approaching Caesarea from the north the exact point where the Or-Akiva E-W transverse fault intersects the coastline, the coast parallel segment of that aqueduct abruptly terminates (Figs. 1A and 3). It is concluded by Nir (1985) that the coastal abrasion of the segment to the south of that point occurred due to the new wave diffraction pattern induced by the construction of the Herodian Harbor. However, the correspondence of that point with the intersection of the Or-Akiva and the coastal faults suggest the involvement of a tectonic factor as well.

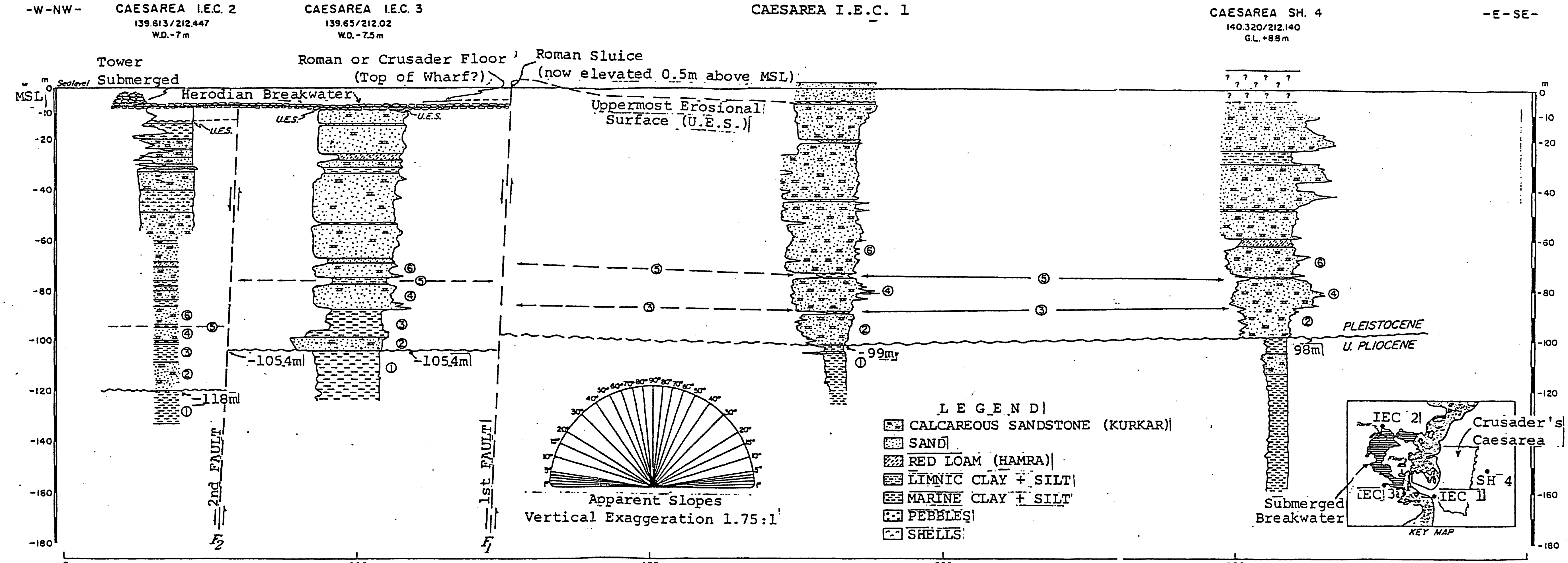


Figure 2. Transverse east-west geological cross-section through the late Pliocene to Recent sedimentary sequence at Caesarea. The section extends from west of the sunken Herodian breakwater to east of the Crusader city wall (after Neev et al., 1978). The Pre-Roman (F-2) and Post Roman (F-1) faults were identified (13 and 6 m throws respectively) from precise age analysis of stratigraphic contacts in drilling and present elevations of the now submerged man-made structures (breakwater, floor and sluice). By permission of the Israel Journal of Earth-Sciences.

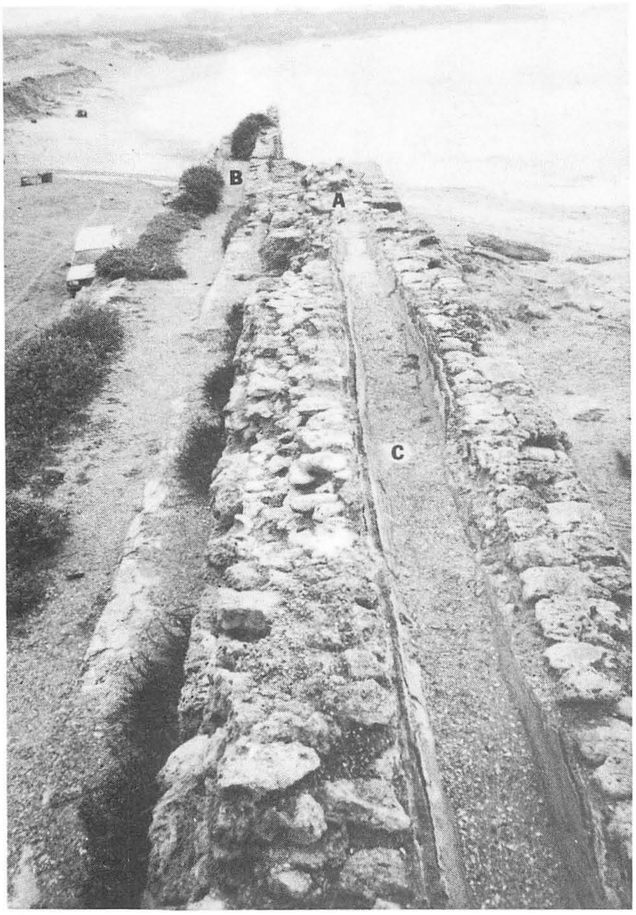


Figure 3. The Caesarean aqueducts: (A) high-level aqueduct; southward view from its top close to the point of its abrupt termination due to the combined effect of sea abrasion and of rejuvenated tectonic movements. At that point, the coastal and Or-Akiva faults cross each other. Aqueduct c was built on top of aqueduct b. Both a and b were gradually filled with layers of rubble and cement to raise their level by 2.5 m; (B) low-level aqueduct; northward view of the vaulted (to avoid clogging by the encroaching sand of the coastal dunes) aqueduct (photographed from a point about 200 m east of the 3A). It was built in the 6th century A.D. to replace the high-level aqueduct (seen on the left as a coast-parallel feature) following damages caused by the Byzantine oscillatory tectonic movement.

At its point of termination, the high-level aqueduct contains three separate channels (a, b and c, Fig. 3A). Channel a, the eastern one, was built by King Herod (late first century B.C.); Channel b was constructed and attached to Channel a on its west, during Hadrian's time (137-138 A.D.) to double the water supply to the city as well as to support and repair damages to Channel a, caused by small tectonic movements or earth compaction processes. Subsequently, both channels were repeatedly filled with layers of rubble cemented with mortar to raise their level. The much smaller Channel c (10% of the capacity of a and b) was then built atop the rubble-filled Channel b, so that the cumulative raised level reached 2.5 m (Fig. 3A). The same sequence of events is also noted farther south, at the northern entrance to the Roman city of Caesarea, where a small relic of the high-level aqueduct was found. The repeated efforts within such a short time (3rd-6th centuries A.D.) to raise the level of that aqueduct by 2.5 m all along its coastal segment, suggest the effects of a tectonic subsidence process due to which the water supply to Caesarea was disturbed. Apparently, these troubles culminated during the 6th century (during the reign of Justinian) when .... "the Caesarea aqueduct..... stopped because of negligence to allow a free passage of the running water..... (although) the springs continued to flow".... (Reifenberg, 1950-51, p.27, quoting the Christian writer Chorikios). The above interpretation is in agreement with one of the rationales suggested by Nir (1985, p. 187) for raising of aqueduct's level by 2.5 m, i.e., the tectonic subsidence of the whole area. It is also in agreement with Raban's (1989b) description of the results of the onland excavations of Caesarea in Area J-3, a few hundred meters north of the Crusader wall along the coastal cliff next to the synagogue: "The main architectural feature....exposed was a series of drainage systems from the Roman and Byzantine eras. The complex consists of three separate drains, which were laid at different heights, along parallel, but not overlapping courses...The successive raising of the sewer floors by about one meter increments over the course of several centuries corresponds to the raising of the synagogue floor levels. These two phenomena suggest that the builders were concerned with potential water damage from the nearby sea." Based on the above, it is interpreted that the sewer floors were raised by three meters in three stages during about the same period that the high-level aqueduct subsided by 2.5 meters.

On the other hand, the above conlusion is in apparent disagreement with an observation made by Rim (1950-51, p. 35), who calculated that the hydraulic gradient of the high-level aqueduct between the foot of Mount Carmel and the coastline. Since he found this gradient to be very low (1:10,000), he concluded that there had been practically no subsidence of the shoreline or any other vertical tectonic movement of the coastal zone during the last two millena. The contradiction between his conclusion and ours may be resolved if we assume the following: (i) Rim's data refers just to the upthrown block (the on-land area) so that there should be no conflict with the offshore data (the Herodian Harbor-see below), indicating the subsidence of the downthrown (offshore) block; (ii) the subsidence part of the Byzantine oscillatory tectonic phase was followed by a rebound movement, due to which the upthrown block was again tectonically uplifted in the late 6th century A.D. Consequently, that block reached its original structural elevation and even slightly higher (at least along its western rim, see Fig. 2 and Neev et al., 1978). The implied range of that oscillatory movement is therefore 2.5 m.

The low-level aqueduct runs along the coastline and most of it parallels the coastal segment of the high-level aqueduct, about 200 m to its east (Fig. 3B). It carried a large amount (2500 cu m/hr) of brackish water to Caesarea from the Taninim spring (Krokodilon River), located some 5 km north-northeast of the harbor. Its age, however, is not really known. Following indirect indications such as architectural analogies, Reifenberg (1950-51) conjectured that it was built during the 3rd century A.D., whereas Olami and Peleg (1977) thought it was built during the 4th century A.D. Nevertheless, the above cited data suggests that the low-level (vaulted) aqueduct was built during the 6th century A.D. to replace the high-level one that by then was not functioning (see above) and apparently could no longer be repaired due to the repeated damages caused by the oscillatory movement. Such a scenario is corroborated by the following data: (i) The Moslems penetrated into the fortified Byzantine Caesarea in 640 A.D. through the low-level aqeduct (Reifenberg 1950-51, p. 29, quoting Al-Baladari and Yakut). This indicates that by then the aqueduct already functioned; (ii) According to the 10th century Moslem geographer Muqqadasi (as cited by Reifenberg, 1950-51, p. 29) Caesarea of his time was a beautiful and flourishing town but its drinking water was drawn from wells and cisterns located mostly in the swamps east of the city. This implies that high-level aqueduct, which carried fresh water, no longer functioned; (iii) The 11'th century Persian writer Nasir-i-Khusrau praises Caesarea as being "a fine city with running waters.... and with fountains that gush out within the city" (Reifenberg, 1950-51, p. 29-30). As a relatively high dynamic head was needed to operate the fountains, it is implied that the low-level aqueduct was still functioning.

(2) The Herodian Harbor

The Herodian Harbor (located on the downthrown block, Figs. 1, 2), gradually subsided sometime between the 3rd and 6th centuries A.D., as evidenced by the following: (i) 17 shipwrecks were found on top of the breakwater, ranging in age from the 3-4th to the 5th centuries A.D. (Raban et al., 1976, p. 51; Raban, 1985, p. 158); (ii) A complaint made in an early 6th century letter from the theologist Procopius of Gaza to Caesar Anastasius regarding the malfunctioning of the Caesarea Harbor as a protected anchorage (Raban et al., 1976, p. 20; Oleson et al., 1984, p. 294). Therefore ships could have sunk on top of the submerged breakwater during storms; (iii) An additional rampart was built on top of the Herodian breakwater, apparently to improve its functioning. That rampart is now submerged, its top being a few meters below sea level - "Being post 5th century A.D. the rampart might well be part of the Byzantine Caesar Anastasius's effort to repair the Sebastos already in ruins....." (Raban, 1985, p. 158). As the top of the now submerged rampart originally protruded close to 2 m above sea level (Fig. 7A), it is assumed that it tectonically subsided a few meters since then. This implies that the 6 m of tectonic subsidence of the downthrown block took place in two phases since Herodian times: 2.5 m during Byzantine times and 3.5 m since then.

(3) Caesaria Maritima

During Roman-Byzantine times, Caesarea Maritima went through three major stages of construction. The first occurred during the reign of Herod (first century B.C.) when the infrastructure of the city and its harbor was built. The second stage took place during late Roman or early Byzantine times (3rd or 4th century A.D.). The third stage occurred during late Byzantine times (late 6th century A.D.) when a dramatic level of building activity and street repairs are inferred based on the results of archaeological excavations (Vann, 1983). We suggest that the second stage followed a very destructive event during which most of the Roman city was virtually destroyed (Bull and Toombe, 1972). Apparently, that event corresponds to the first (2.5-3 m downward) movement of the Byzantine oscillatory phase. The third stage of construction and repairs followed the last (upward) movement of that oscillatory phase, i.e. the rebound of the upthrown block. Accordingly, the duration of the entire Byzantine oscillatory phase is estimated to have been close to 300 years.

(4) Evidence from Other Coastal Sites for the Byzantine Phase

The occurrence of an oscillatory movement during Byzantine times is not limited to Caesarea. Similar indications suggest the occurrence of 4 m down and up movements across the coastline of Yavneh Yam (south of Tel Aviv, Fig. 1B), sometime between Late Roman and Late Byzantine times (Neev et al.,1987, p. 65-66). Other indications were noted in two sites on the coastal cliff at Tel Ashqelon (Neev, in prep.), suggesting the occurrence of an oscillatory movement of about 8 m during the same period. These two sites are in addition to that described by Neev et al. (1987, p. 73-75), located along the same segment of coastline, several hundred meters further north. However, the time of occurrence of the latter one, whether Byzantine or Mamlukian, is still unclear. Another event of the Late Roman to Late Byzantine period is described by Lewy et al. (1986) from the Akhziv-Nahariya coastal area close to the Israel-Lebanon border (see also Neev et al., 1987, p. 39-41).

Pirazzoli (1988) reports on the occurrence of sudden vertical displacements across several coasts in the northeastern part of the Eastern Mediterranean during the 5th and 6th centuries AD (but mostly around 1530 y.B.P.). He called this phase "The Early Byzantine Tectonic Paroxysm" and correlates it with several great earthquakes in the Eastern Mediterranean that occurred during the period from the middle of the 4th century to the middle of the 6th century AD. The movements reported included mostly emergence of the land (up to +10 m) but some cases of submergence (up to -4.5 m) were also mentioned. Nevertheless, oscillatory type ~~of movements are not specified in the above paper. The~~ discussed tectonic paroxysm is ascribed by Pirazzoli (1988) to a subduction-thrust movement of the Ionian crust under the Helleneic Arc which caused the sudden narrowing of the Eastern Mediterranean Sea, and also to necessary readjustments of various blocks of the lithosphere. This mechanism is similar to that suggested by Neev et al. (1987, p.99) to explain the oscillatory movements along the coasts of Israel.

B. THE TWO POST-BYZANTINE PHASES (early Moslem and Mamlukian)

The occurrence of post-Byzantine vertical differential tectonic movements across the coast of Caesarea is largely inferred from sedimentological evidence. A succession of man-made structures almost uninterruptedly developed as an urban complex in Caesarea during the period extending between Hellenistic and early Moslem times (i.e., for about 1,000 years). That period of artificial construction terminated rather abruptly when the sea transgressed the coastal zone and at least the segment south of the Crusader fortress was onlapped by a few meter thick sequence of lagoonal and swamp sediments. Such a change of regime could only have occurred due to tectonic subsidence of the upthrown block and the transgression of the sea. Apparently, the transgressive regime prevailed several hundreds of years, though with some fluctuations. It terminated when the coastal zone was gradually uplifted again and returned to its pre-movement structural elevation sometime since the end of Crusader rule.

The occurrence of post-early Moslem swamps along the coast-parallel topographic trough, south of the Crusader fortress of Caesarea, was described by Neev et al. (1978, p. 56-60). At present, the elevation of that trough is about + 10 m msl (Fig. 1). It is separated from the sea by a +15 m msl high ridge that extends southward as far as the Roman Theatre (Van, 1983, Fig. 1). Large early Roman to Byzantine public structures were excavated by Bull and Toombe (1972) at the northwestern end of that ridge. The tops of these relics are now exposed at about +10 m msl, where they are onlapped by a few meter thick unit of beach or dune sand (Bull, 1973, 1974). Patches up to 20 cm thick of loose shell lenses are locally exposed due to wind winnowing of the sandy apexes of that ridge. That sandy unit interfingers eastward with sandy clay sediments of lagoonal or swamp origin, with which shell lenses are interbedded (mostly *Glycymeris violacescens* (Lamark)). It was argued by Neev et al. (1978) that under present-day physiographic conditions, a swamp along the coast-parallel trough would not hold water; these swamp sediments are located just a few tens of meters east of the coastline, in places hanging on top of the sea cliff at an elevation of up to +10 m msl, where the subsoil (the ruins of the Byzantine to Roman structures) is very permeable down to present day sea level. It is therefore assumed that when these swamps first formed, the sea level (or base level of erosion) had to be relatively (although appreciably) higher than it is today and that the water of the swamp was in hydraulic equilibrium with that of the nearby sea.

Since 1978 archaeological investigations have been expanded within the trough, some 100 m further east of the coastal ridge, where an extensive complex of Byzantine structures topped by early Moslem ones was excavated and studied (Fields and Vann, 1983). Top elevations of these Byzantine to early Moslem relict structures in Fields C and K, range from close to +6 m to about +8 m. Therefore, the respective thickness of the overlying swamp and shell bed sequence, ranges from 4 to 2 m. The fresh outcrops exposed by the excavation enabled us to better observe the details of the sedimentary structures and textures within the overlying sedimentary sequence. As stated above, most of this sequence is composed of lenticular shells, rounded and angular pottery shards and rubbles, which are interbedded in sandy-clay layers. Two prominent bands of more uniform dark gray to brown sandy clay deposits, 20 to 40 cm thick each, occur at about the middle of the outcrop and close to its top (Fig. 4). Traces of horizontal fine lamination as well as burrower tunnels (Fig. 5) were noticed within these two bands, indicating the alternation of stagnant and aerated (bioturbated) environments. These two bands are therefore assumed to have been deposited within low energy lagoonal or swamp environments that were in hydraulic equilibrium with the nearby sea. Occasionally, these swamps dried out completely, enabling restricted human activities as indicated by the presence of a horizontal layer of neatly carved building stones that is interbedded within the lower swamp bed (Figs. 4 and 5A).

The interbedding of shell lenses and swamp beds within that post-Byzantine sedimentary sequence suggests the occurrence of appreciable changes in the hydraulic energies of the environments of deposition. Most of these shells are oriented concave downward and densely packed with local "nestling textures" (see Neev et al., 1987, p. 31). In some cases, the chains of the nestled shells form circular patterns and in others weak bedding is noted (Figs. 6A and 6B). Smaller lenses of broken shells and granules with graded bedding, in places associated with imbricated patterns, are also interbedded within the discussed sequence (Fig. 6C). All of the above features suggest the involvement of strong and persistent currents in the depositional process of the shell beds.

The distribution pattern of these shell beds suggest their genetic relationship to the nearby strand line. The shell accumulations are found within and along the coast-parallel trough between the Crusader fortress and the Roman Theatre (Fig.1). They become rarer eastward and disappear completely about 300 east of the coastline.

The massive accumulations of these shells within the post-Byzantine sequence along the belt discussed, are in themselves supporting evidence for their natural marine (beach) origin. The ratio of shells to the other coarse detrital components within that sedimentary sequence is estimated to range between one quarter and one half. Other shell accumulations of similar extensive dimensions and dense concentrations are also found in different sites along the coastal cliff (Neev et al., 1973; Neev et al., 1987), one of which is located north of Tel Dor. At the Dor site, however, well-cemented beachrock layers dominate the lower part of the shell beds sequence. At present, this sequence is situated

Figure 4. 2-4 m thick sedimentary sequence overlying Byzantine and early Moslem structures some 100 m east of the coastline. The presence of shell lenses with nestled packing structures as well as the inter-bedded swamp sediments (a lower one close to the middle part of the sequence and an upper one close to its top) indicates the prevalence of marine-lagoonal environments, and thus the successive occurrence of two subsidence-transgression-uplift events. The early Moslem structure found within the mid-sequence swamp bed suggest the complete desic-cation of that swamp. The occurrences of two successive tectonic oscillations is therefore implied. 12th century coins found within the upper part of the sequenece suggest its post-Crusader age;

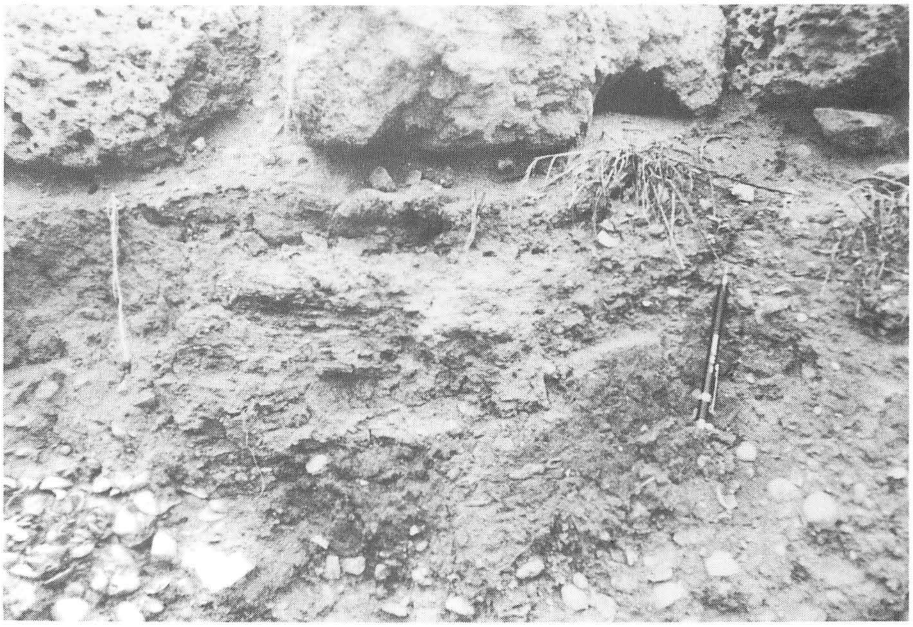
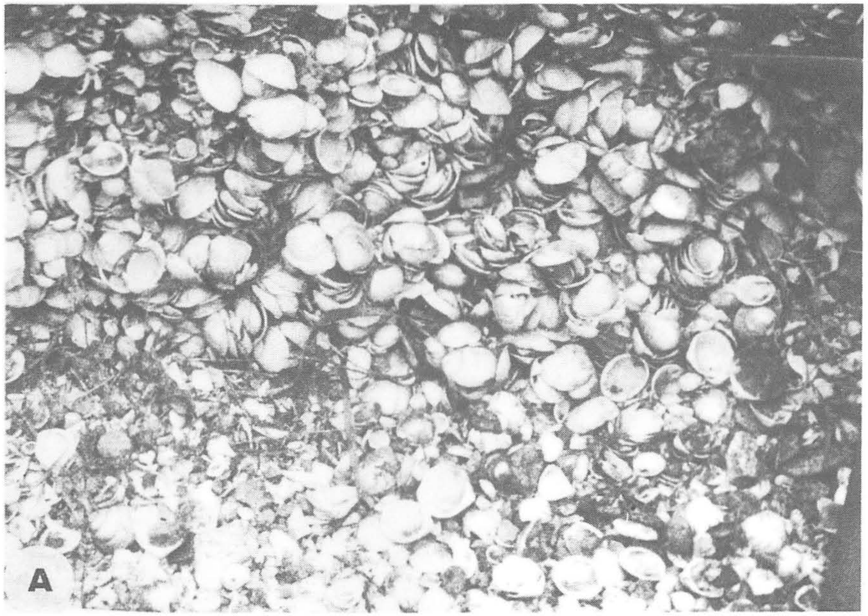


Figure 5. Swamp sediments - alternations of anaerobic and aerobic environments. (A) Horizontal lamination within the mid-sequence swamp layer suggesting stagnant conditions; (B) burrower's tunnels indicating bioturbation or aerobic conditions within the same bed as (A).



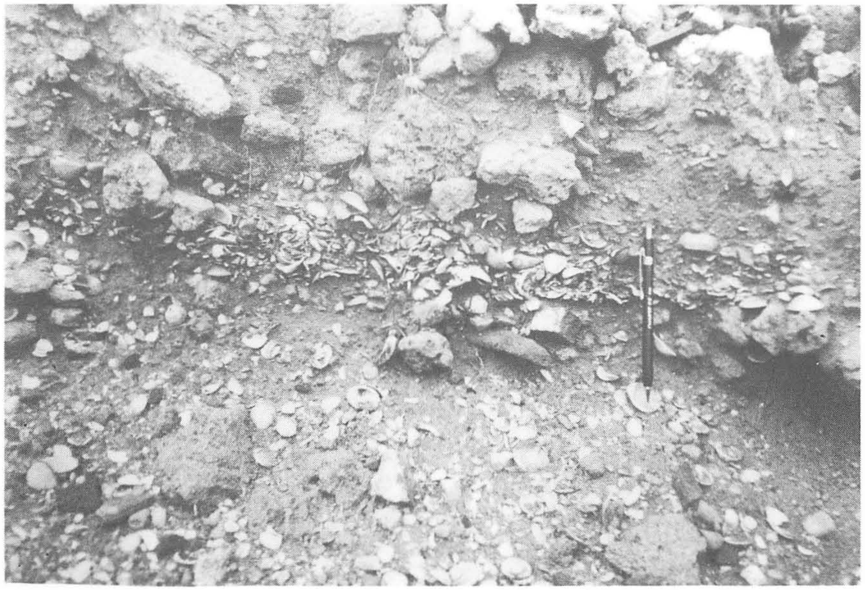


Figure 6. Shell lenses within the post-Byzantine sedimentary sequence indicating natural marine (beach) environment of deposition. (A) Nestled packing of shells; (B) Dominant concave downward orientation; (C) Lenticular layer of imbricated fragmented shells and pebbles.

both above and below the high tide level (up to +4 m). The occurrence of the beachrock facies at Dor also supports our interpretation of the natural beach origin of the overlying uncemented part of this shell bed, and thus our conclusion of the natural beach environment of the uncemented shell beds at Caesarea is also indirectly supported.

Nevertheless, doubts have already been expressed respecting the origin of the Caesarea shell beds and alternative mechanisms were offered to explain their presence at such a high elevation above msl. For example, a man-made mechanism was suggested by Y. Porath (pers. com.) involving an early Moslem dredging operation at the bottom of the Caesarea harbour. According to that hypothesis, the discussed shells were then artificially dumped along the trough of Fields C, K, and farther on to the south (see Fig. 1). However, such an explanation does not stand to reason since no shell accumulations of appreciable quantities were noted during the submarine archaeological excavations that were carried out at the bottom of the nearby Herodian harbour (A. Raban, pers. com.). Another contradicting hypothesis along the same line is that the shells could have been artificially brought to that place as raw material to be mixed with mortar for building purposes (A. Raban, pers. com.). ~~This should also be ruled out based on the following two~~ considertions: (i) Systematic differences are found between the orientation and packing patterns within naturally deposited shell beds and man-made accumulations (Neev et al., 1967, pp. 29-31; Neev and Emery, 1990, pp. 299-304). When applied to the present case, these criteria clearly support the natural deposition origin of these shells; (ii) The fact that no cement was found to encrust the shells in the discussed post-Byzantine sequence. Relics of such artificial crusts are abundantly found in man-made accumulations located, for example, at the foot of the Crusader southern wall of Ashqelon to where the disintegrated shells fell and accumulated, whereas the sand and dust were winnowed out.

The specific sedimentary facies within the discussed 2-4 m thick post Byzantine sedimentary sequence at Caesaria indicates that it was deposited and accumulated by natural beach and swamp processes and is not the product of an instantaneous catastrophic event such as a tsunami. In other words, this coast-parallel trough was transgressed by the sea and remained submerged for a relatively long time. As a result, the environments of deposition fluctuated from open beach to lagoon and swamp. Considering the postulated vertical dimensions of that transgression (10-15 m) and its duration (a few hundred years), as well as the estimated range of eustatic sea level change during the past 1500 years (less than 1 m), it is suggested that this change in the land and sea level relationship should be related to an oscillatory tectonic movement and not to other factors.

The following review of the data is presented in an attempt to further clarify and decipher the nature and timing of the post-Byzantine tectonic history at Caesarea. The succession of Roman, Byzantine and early Moslem man-made structures was transgressed by the sea sometimes during the 7th or 8th centuries A.D. Relicts of early Moslem structures that are also interbedded within the overlying sedimentary sequence, may indicate temporary regressions. Most of the pottery shards found within that overlying sedimentary sequence are of early Moslem age or 7th to 9th centuries A.D. (I. Rol, pers. com.) although some medieval ones were also occur (Y. Porath, pers. com.). Coins of different ages were found within the upper part of that sequence, the youngest of which is from Crusader times (12th century A.D.) (Y. Porath, pers. com.).

Bull and Toombe (1972) and Y. Porath (pers. com.) state that the area of Field C was a cemetery during Crusader and Moslem times. However as neither the exact ages of the Moslem graves nor a detailed stratigraphic order within the post-Byzantine sedimentary sequence were specified there, the graves may range from early Moslem through Mamluk to Bosnian times (Moslems settled by the Turks during the 19th century). Likewise, it is suprising that no mention was made of the presence or absence of tombstones on the reported Crusaders' graves at Caesarea, although they are in abundance at the well-preserved and organized Crusader's cemetery at Atlit (some 25 Km north of Caesarea, Fig. 1B). Moreover, we suspect that some of the few complete human skeletons and most of the many dismantled bones scattered within the sediments of the post-Byzantine sequence in Field C, were drifted to their present location by the same natural hydraulic processes that transported and buried the other coarse detrital components of the sequences (such as shells, pebbles and rubble). In examining a complete skeleton that is horizontally interbedded within the post Byzantine sedimentary sequence in Field C, the first author did not notice any relict feature or other sign that could testify to the burial of this corpse in an artificially dug grave. For example, vertical breaks disturbing the fine sedimentary bedding would be expected just above the skeleton, if it was buried in an organized graveyard; feebly undisturbed horizontal depositional lamination was was noted both above and below as well as beyond the horizontal limits of the above-mentioned complete skeleton. Nor were vertically oriented plate-like stones, that usually mark the graves limits in Moslem cemeteries, were found there.

Unexpected support for the above interpretation could be found in a few expressions included within three different sentences extracted from

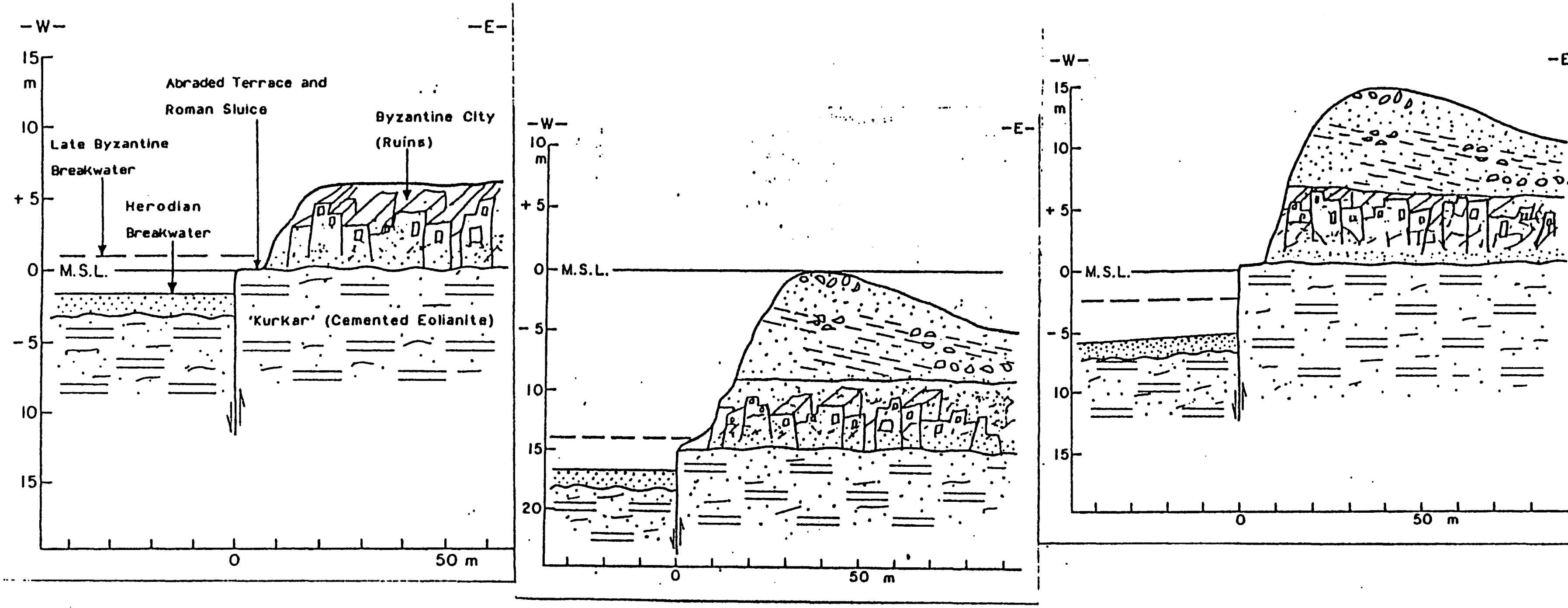


Figure 7. Sketch diagrams of the 3 stages of a post-Byzantine tectonic oscillatory movement across the coastline at Caesarea (south of the harbor): (A) Pre-movement stage - the top of the repaired breakwater (by adding a rampart on its top) is arbitrarily marked at +2 m m.s.l. The coastal fault (F-1) separates between the harbor and the Roman-Byzantine - early Moslem city. (B) Post- subsidence stage - both the upthrown and the downthrown blocks subsided 10-15 m. Berm-like sand body accumulated on top of the ridge-forming Roman-Byzantine coastal structures whereas lagoonal sediments were deposited along the trough to its east. Mostly sands and debris accumulated in the offshore on top of the downthrown side of the fault; (C) Post-rebound movement stage - both the upthrown and downthrown blocks were tectonically uplifted again. The first returned to its pre-subsidence structural elevation whereas the downthrown block lagged and stabilized 3.5 m below its pre-oscillatory movement structural elevation.

a Hebrew poem written by an anonymous author sometime between the mid-8th and mid-10th centuries A.D. (Zulay, 1936, p. 158 and E. Fleischer, pers. com.). In "free" translation from the Hebrew - (i) "Multitudes drowned violently, those dwellers in the Shefela (coastal lowlands of Israel - Authors) and in the Sharon Valley". (ii) "A current appeared.... strangers were stormed angrily..." , (iii) "... women and children were drowned along with preachers of the Bible and Mishnah...". Apparently, the above citations reflect a disastrous event that occurred sometime during the early Moslem period along the coastal zone of the Sharon Plain. Caesarea is situated at the northern part of the Sharon Plain (Fig. 1B). Shalem (1956) considered the horrors described in the above poem to be related to the 746 AD earthquake and tsunami. However, as explained above, the facies of sediments involved in the post-Byzantine sequence suggest that the water body from which they were deposited was not a tsunami, but had to be associated with a relatively long-term transgression of the sea. The above citations also corroborate the interpretation that the discussed skeletons and bones could have drifted to their present place of burial by the trasgressive currents.

The facies distribution within the lower half of the post-early Moslem sedimentary sequence (Fig. 4) represents a full sedimentary cycle that started with a high-energy environment (turbidites composed of shells and rubble) and ended with a low-energy environment (swamp deposits), i.e., deepening and shoaling of the sea or a transgression and regression caused by a tectonic oscillatory movement. The overlying half of the sequence is a replica of the lower one (another cycle of shells and swamp deposits that represents a second cycle of transgression-regression or another oscillatory movement that occurred after the Crusader times).

A reflection of the post-Byzantine to pre-Crusader tectonically induced environmental fluctuations that affected the Caesarea area, can be found in a script from that period. Mua'wiya, the Moslem Caliph who reigned in the late seventh century, commanded his secretary in the District of Filastin to purchase agricultural estates, but instructed him that "They should not be in arid al-Dharum and not in swamply Caesarea (El'ad, 1982, p. 151, quoting al-Jahshiyari, 1938). It is therefore suggested that during the late 7th and 8th centuries, the lands close to Caesarea were swampy and unfertile. Apparently, these swamps were in hydraulic equilibrium with the nearby sea

On the other hand, an entirely different agricultural environment and hydraulic regime prevailed in the same area just three centuries later - Caesarea of the 10th and 11th centuries was described as an affluent society cultivating fertile and lush fields and gardens (see above citations after Reifenberg, 1950-51, regarding the low-level aqueduct).

It is speculated that the peaks of the two post-Byzantine oscillatory movements could have occurred during the 7th-8th centuries A.D. and during the 14th century A.D., respectively. There are practically no Moslem documents left from the 7th to 8th centuries A.D. that can testify to civil or natural activities along the coastal zone of Israel during that period (I. Rol, pers. com.). On the other hand, during the 10th century, that region and especially the harbors at Acco and Ashqelon, underwent an intensive phase of building and reconstruction, which is related by Frenkel (in press) to an important phase of economic prosperity and revival of trading ties in the Eastern Mediterranean. A time of tectonic quiet could be one of the prerequists for the existence of such a phase.

A second period of cultural decline followed the intentional destruction of vital installations carried out by the Mamluk sultans Bibars and al Ashraf along the coastal zone of Palestine, as a defensive measure against another (potential) Crusader invasion (Reifenberg, 1950-51). Based on descriptions made by various travellers and pilgrims, Elad and Schiller (1981) conclude that between the end of Crusader time and the late 19th Century, Caesarea and its vicinity were practically deserted. However, the evidence for the occurrence of a post-Crusader transgressive cycle at Caesarea lead us to suggest that this desertion was caused, at least partly, by a natural, physical change. Thus, the re-occurrence of the great swamp just to the east of Caesarea and the intensification of the inland sand dune encroachment in post-Crusader times, are natural processes that should not be related to the man-made destructive operations along the coastal zone (see above and Neev et al., 1987). The several devastating earthquakes that occurred during the same period (early 14th century AD) all around the eastern Mediterranean fit in well with our interpretation.

It is possible that the two post-Byzantine oscillatory movements constitute a multiple type of tectonic phase through which the coastal zone fluctuated downward and upward several times. Such a scenario is analogous to the two oscillatory movements that occurred along the Pacific coast of Japan during the past 100 years. That interpretation is based on the analysis of continuous tide measurement records made by Thatcher (1985, see also Neev et al., 1987, p. 99). Each of these two movements lasted 30 years with amplitudes of 2 m. The analogy from Japan indicates that oscillatory tectonic movements are not just an "imaginary phantom" but actually occur even at present. The tectonic model suggested by Neev et al. (1987) to explain the origin and mechanism of the oscillatory type of movement, is also in agreement with that suggested by Thatcher (1985). The common denominator of the two tectonic models is the downwarping of continental margins after collision with oceanic crusts (direct collision off Jappan and oblique collision off Israel) and the rebound of the continental crust that followed (apparently due to isostatic adjustment).

Results of measurements made by the use of various methods across the northeast segment of the Aleutian Islands (Beaven et al., 1984) indicate the occurrence of a ten-years period of a steady tilt-down movement towards the trench. This downwarping was interrupted during 1978-1980 by a rapid episode of reverse tilt. The amplitude of the vertical down and up movements, as measured at the surface (or sea bottom) across the Shumagin Islands some 100 to 200 Km to the north of the trench, was a few tens of centimeters. Though small, these vertical shifts suggest the occurrence of oscillatory movements also in that region where the Pacific plate collides with the North American plate.

The magnitude of the post-Byzantine oscillatory movements at Caesarea had to be appreciably larger than the Byzantine one. The total amount of post-early Roman displacement across the coastal fault (F-1; Figs. 1 and 2) is close to 6 m, of which the net amount of subsidence of the Herodian harbor (on the downthrown side), which occurred during the Byzantine phase, is 2.5 m. Therefore the net amount of subsidence that occurred during the post-Byzantine multiple phase is 3.5 m. Nevertheless, the vertical dimension of the oscillatory movement during that phase is postulated to range between 10 and 15 m. The implied discrepency can be bridged assuming that the downthrown block participated in the downward movement of the upthrown block all through the first stage of the oscillatory movement. The downthrown block also participated in the second part of the oscillatory movement, i.e., in the upward moving phase. However, on its way up, during the rebound stage, the downthrown block lagged behind the upthrown block by 3 to 3.5 m. The net amount of total displacement since Roman time was therefore 6 m (see Fig. 7). Such a mechanism is somewhat more complicated than that described by Neev et al. (1987, Fig. 35) but it is implied from the data.

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Front Cover: The inner (natural) port of Caesarea, engraved by W.H. Bartlett (1841). Courtesy of the Ariel Publishing House, P.O. Box 3328, Jerusalem. Left-center background: Relicts of Crusader citadel built on a Roman breakwater extending from the coastline to an offshore abraded terrace island. The breakwater formed the southern limit of the inner harbor; Foreground: northern limit of the Herodian inner harbor is marked by the landward segment of a Crusader pier. That pier made of Roman granite and marble pillars, was laid down from the coastline across the abraded terrace. The now-submerged Herodian breakwaters that sheltered the man-made outer harbor extend to westward of the coast-parallel fault (F-1).

Back Cover: Part of a map published in 1651 by Ph. De La Rue, Paris. Courtesy of the Ancient Maps Division, National Library, Hebrew University, Jerusalem. The illustration shows the segment of the southeastern Mediterranean coastline extending between the Bardawil Lagoon (Ostracina in NW Sinai) to Sidon (Lebanon-Phoenicia). The original title says (translated from Latin): "Geographical Map of the Patriachate of Jerusalem. It is based upon ancient notes stored at the Florentine Council from the Year 553 to its end in 1250". Jaffa, Caesarea and Tyre are illustrated as sheltered harbors. The configuration of the Caesarea harbor very much resembles that of the now-submerged Herodian outer harbor, suggesting that until sometime between 553 and 1250 it was still functioning.

MARE
SYRI
ACVM
Sidon
Sarepta
Paneas et Cæsarea Philippi
PHOENICIÆ
TYRVS Metropolis sub Antiocheno Patri
PRIMÆ
PARS
Petra q. Petra
Acrabates Joseph et
sub Cæsariensi
Heraclea
Gadæ
Kedes. ol.
Acco et Ptolemais
Album Prom.
Sycaminum
Zabulon
PALES
Diocæsarea
NAZARETH
Montis Tabor
Sync
Tyberias
Carmeli pro.
Porphyrion
Come
Nais quæ Comanas
Dora
Legio
Pella
CÆSAREA Metropolis. I. Antea sub Antiocheno
Caparcotia
SCYTOPOLIS Antea Maximianopolis
Metropolis sub Antiocheno
SECVNDA
PALES
TINA
Sozusa et Assur
Apollonias. ol.
Sebaste Syncellus
Antipatris
Areopolis Aroer ol.
Lydda Diospolis et S. Georgius Sync.
Neapolis Syncellus
Ioppe Sync.
Regium Gadarorum
Archelais
Vadum Iordanis
Nicopolis
Ierico
Onus
Libias
Iamnia
Azotus Paralia
HIERVSALEM Seu ÆLIA
Ascalon Syncellus
Bethlehem
Eleutheropolis
Baschat quæ et Diocletianopolis
Bethylium
Hebron et Sti. Abraham
Gaza
PRIMA
Estomazon
Rhinocolura Episc
Berosabbon
Toexus
Sodoma quæ Ciuitas Salis
Maiuma
Arad
Triscomia
Ostracina Episc
Anthedon
Raphia
Saltus Ioraticus et Constantini Nices
Carmelus minor mons
Petra Amasiæ
Elusa
Mampsis et Mapsis
HATVS
Torrens Ægypti
Iarapolis seu Hierapolis Heiram. ol.
Zoaron
Karach
Carcaa Syncellus
Carcaria D. Hier.
Phenon et Phunon
PALES
Mesrocomia
Moseroth. ol.
TINA