‘He Went Down to Joppa and Found a Ship Going to Tarshish’ (Jonah 1:3): Landscape Reconstruction at Jaffa and a Potential Early Harbour

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Complete List of Authors:	Wachsmann, Shelley; Texas A&M University, Anthropology; Institue of Nautical Archaelogy, Burke, Aaron; University of California, Los Angeles, Near Eastern Languages and Culture Dunn, Rick; Norwich University, Department of Earth and Environmental Sciences Avnaim-Katav, Simona; Israel Oceanographic and Limnological Research Institute Kinneret Limnological Laboratory
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'He Went Down to Joppa and Found a Ship Going to Tarshish' (Jonah 1:3): Landscape Reconstruction at Jaffa and a Potential Early Harbour

Shelley Wachsmann

Institute of Nautical Archaeology at Texas A&M University, Anthropology, Room 121, College Station, TX 77843-4352, USA, swachsmann@tamu.edu

Aaron A. Burke

Near Eastern Languages and Cultures, 382 Kaplan Hall, University of California, Los Angeles, Los Angeles, CA 90095-1511, USA, aaburke@humnet.ucla.edu

Richard K. Dunn

Department of Earth and Environmental Sciences, 158 Harmon Drive, Norwich University, Northfield VT 05663-1035, USA, rdunn@norwich.edu

Simona Avnaim-Katav

Israel Oceanographic & Limnological Research, P.O.B. 9753 Haifa 3109701, Israel, simonaav@ocean.org.il

Abstract

In 2014, the Ioppa Maritima Project took a two-pronged approach, on land and sea, to examine maritime aspects of Jaffa's past. This report supplies the context for the terrestrial work and presents the results of a geological investigation of the hypothesis that, prior to the Hellenistic period, the physical setting near Jaffa provided a protected inland anchorage. Our study reveals that from circa 5000 to 2000 years before present a small estuarine system existed east and north of Tel Yafo that could have served as a harbour facility, a conclusion supported by archaeological and historical data.

Keywords

Geoarchaeology, maritime archaeology, nautical archaeology, harbours, palaeogeography, ports, Bronze Age anchorages

Introduction

Recent terrestrial excavations on, and surrounding, Tel Yafo (Jaffa), Israel have led to a renewed interest in this ancient maritime city (Fig. 1) (*History and Archaeology of Jaffa* 1-2; Avramovitch and Grinberg, 2015; Haddad *et al.,* 2020). Jaffa or Joppa (Hebrew: *Yafo*; Arabic: *Yafa*) has always been indelibly connected to the Mediterranean Sea as an important port city situated on a long and straight coastline now notably lacking in bays and inlets suitable for use as natural harbours (Fig. 2).[1]

Jaffa today nestles within the greater Tel Aviv metropolis. In 2007, under the aegis of The Jaffa Cultural Heritage Project (JCHP), Aaron Burke (University of California, Los Angeles) and Martin Peilstöcker (Johannes Gutenberg University, Mainz) initiated renewed excavations at Tel Yafo. This work centred on Ramesses II's monumental city gate, originally discovered by J. Kaplan (Fig. 3) (Williams and Burke, 2016). In 2013, Burke invited Shelley Wachsmann (Institute of Nautical Archaeology at Texas A&M University) to add a maritime/nautical dimension to the JCHP's terrestrial excavations. The 2014 Ioppa Maritima Project, which resulted from these conversations, took a two-fold approach. On land, the expedition carried out a geoarchaeological study examining the hypothesis that a nearby, but now lost, estuary could have served as an inner harbour to the east of Tel Yafo. At sea, it carried out an underwater survey for shipwrecks in the vicinity of Jaffa (to ~250 m) (Wachsmann, 2014; 2015; Wachsmann et *al.,* 2014).). In this article we discuss the terrestrial study, including the rationale for the land survey, and report on the final results of this research.

A concise maritime history of Jaffa

A few sherds dating to the Early Bronze Age I (circa 3800/3600-3050 BC) represent the earliest evidence for settlement at Tel Yafo (Gophna, 2002: 419, 420 n. 1; A.A. Burke, 2011: 64).[2] There followed an extended hiatus during the Early Bronze II-III (circa 3050-2500/2400 BC) and Early Bronze IV (circa 2500-2000 BC) periods, although it is difficult to imagine that the Egyptians would not have utilized Jaffa's environs as a stopover for their voyages to Byblos during the Old Kingdom (Wachsmann 1998: 9-16, 18). Nevertheless, to date no evidence of this has come to light. This interlude is typical of southern Levantine coastal sites and may have been the result of climatic shifts (Faust and Ashkenazy, 2007; 2009).

The Middle Bronze Age (2000-1550 BC) witnessed a dramatic increase in sites located along the southeastern Mediterranean coast (Mazar, 1990: 39 fig. 2.2, 61 fig. 3.1, 95 fig. 4.1, 153 fig. 5.1, 177 fig. 6.1). Also, beginning in this period we can identify the local culture as Canaanite (A.A. Burke, 2011: 65). Ceramics from Cyprus found at Tel Yafo testify to its maritime importance beginning in the Middle Bronze Age (circa 2000-1550 BC). Jaffa was likely one of a series of nautical waypoints located at major settlements along the Levantine coast (A.A. Burke, 2011A: 64-67). Indeed, its West Semitic name, *Yapu,* means 'Beautiful (Place?).'[3] The scant evidence of maritime trade at other Middle Bronze Age coastal sites that could have served as alternate maritime hubs argues for Jaffa's central role as Canaan's leading entrepôt during this period (A.A. Burke, 2011: 64, 65 fig. 6.1).

Jaffa fell under Egyptian control in the defeat of the Canaanite coalition at Megiddo during Thutmose III's first campaign (year 23). His annals list Jaffa but provide no details regarding its conquest (Simons, 1937: 112, 117 no. 62; Morris 2005: 138 n. 89).).[4]

Apparently, after Jaffa's capture, the ruler of Jaffa rebelled but the city was then recaptured by the Egyptians, as related in Papyrus Harris 500 (BM 10060; *ANET*[3:] 22-23; Goedicke, 1968; Wente, 2002; Allen, 2001). Subsequently, Jaffa became an Egyptian garrison city and its fortifications were rebuilt in the classical Egyptian style (*History and Archaeology of Jaffa* 2: 105-107; Williams and Burke 2016). E.F. Morris (2005: 138-139, n. 90) concludes that Jaffa should be identified among the *Ḫtm*-bases, which monitored transit and communications while also serving as storage depots. While no New Kingdom texts directly reference Jaffa's role as a moorage during this period, its coastal location, as well as its distance from the north-south road through the coastal plain, makes clear its continued role as an Egyptian port.

Jaffa would have been impacted by nautical issues described in the annals regarding Thutmose III's fifth campaign (year 29). That expedition captured two Syro-Canaanite merchant ships that were reportedly loaded to the gunnels with all manner of trade items (Säve-Söderbergh 1946: 35). Since maritime transport of Egyptian troops was not a new idea, whether this event served as the impetus for Thutmose III's subsequent introduction of ship transport of troops to and from the Levant—saving them the arduous march across the northern Sinai and up the coast—requires clarification (*ANET*[3]: 227-228; Säve-Soderbergh 1946: 35; Wachsmann, 1998: 10). Clearly, Thutmose III gained a new appreciation for the value of shipping in support of his campaigns. His annals first document the systematic organization and stockpiling of harbors along the Levantine coast during his seventh campaign (year 31) (*BAR* II: §472).[5]

Given Thutmose III's conquest of Jaffa, there can be little doubt that he would have included it in his maritime-military reorganization (Morris 2005: 138 n. 89, 232 n. 53). Although the annals never mention the names of these maritime bastions, based on the Amarna Tablets, Morris (138 n. 90, 229), proposes that this list would have included at a bare minimum the settlements of

Gaza, Jaffa, perhaps Akko, Yarimuta, Byblos, Sumur and Ullaza. She (4) further notes the references (EA 294: 18-24) to Jaffa regarding storage of foodstuffs during the Amarna period in *šu-nu-ti,* apparently an Akkadian transliteration of the Egyptian term for granary, *šnwt*, and later, the repair of chariots there (Papyrus Anastasi I, 26: 3-9; Gardiner, 1911: 28*, 74-77). These may indicate the continuation of Thutmose III's program of stockpiling harbours into the Ramesside era. Similarly, this hypothesis finds support in ships' names dating to the reign of Seti I stamped on potsherds found along the Sinai coast, the Egyptian 'Way of Horus' (Goldwasser and Oren, 2015). In the 13th century BC, the evidence for Jaffa having served as an Egyptian military base becomes overwhelming and includes a monumental gate with Ramesses II's names on the doorjambs (Fig. 3) (A.A. Burke, 2011: 69-70; *History and Archaeology of Jaffa* 2).

Despite the appearance of Philistine ceramics at the site, the question of the presence there of Sea Peoples in general, or Philistines in particular, also remains unclear (A.A. Burke, 2011: 70-71, fig. 6.5).[6] In the Iron Age and the Persian period, Jaffa, although never identified as a Judean or Israelite settlement, appears in the Bible as the port of choice for the importation of Lebanese cedar for construction projects in Jerusalem.

The cedar timber used in Solomon's construction projects during the tenth century in Jerusalem are said to have been supplied by Hiram, the king of Tyre (2 Chronicles 2:16): 'We will cut whatever timber you need from Lebanon, bring it to you as rafts by sea to Joppa; you will take it up to Jerusalem.' [7] An earlier parallel reference to these activities does not mention Jaffa specifically, but there can be no doubt that it is the intended port of entry. (1 Kings 5:8). The later biblical reference to Jaffa is explicit, however, when it is mentioned as the port of entry for Lebanese cedars for the construction of the Second Temple in Jerusalem in the sixth-century BC (Ezra 3:7):

> So they gave money to the masons and the carpenters, and food, drink, and oil to the Sidonians and Tyrians to bring cedar trees from Lebanon to the sea, to Joppa, according to the grant that they had from King Cyrus of Persia.

A relief from Sargon II's (721-705 BC) palace at Khorsabad, now in the Louvre, depicts Phoenician ships towing logs behind them thus supplying an evocative visual confirmation of the biblical description of Phoenician transport of timber in rafts (Fig. 4) (Botta and Flandin, 1849-1850: pls. 32-34; Basch 1987: 306-307, 308-309 fig. 650).

Jaffa's importance as a major maritime transport hub is also evident in Jonah's (1:3) attempted escape to Tarshish:

> But Jonah set out to flee to Tarshish from the presence of the Lord. He went down to Joppa and found a ship going to Tarshish; so he paid his fare and went on board, to go with them to Tarshish, away from the presence of the Lord.

Jonah's seeking a ship on the route to Tarshish, along with other references to this destination are meaningful because together they demonstrate Jaffa's role as a primary entrepôt for its Israelite/Judean hinterland, able to accommodate even large, long-haul ships on the Tarshish run, a vessel type termed 'Tarshish ships' elsewhere in the Bible (1 Kings 22:48; 2 Chronicles 9:21; Wachsmann, 1990A: 78, 80; 1998: 159, 299).[8]

The myth of Andromeda, Perseus, and the sea monster Cetus has for over two millennia been indelibly entwined with Jaffa's rocky western harbour, the northwestern part of which is still known as ‘Andromeda’s Rock’ (Fig. 5) (Kaizer, 2011). The myth is first linked to Jaffa by Pseudo-Skylax in the fourth-century BC (Shipley, 2019: 78 §104 no. 3). Numerous later ancient authors refer to the connection between the Andromeda cycle and Jaffa (*Geography* 16.2.28; *Natural History* 5.69, 9.11; Stern, 1974: 370-372; Romer, 2001: 53 no. 64; *War* 3.420; *Guide* 4.35.9), while coins minted in Jaffa during the early third century AD bear motifs related to the Andromeda legend (Hill, 1914: XXIV-XXV, 44, pl. 5: 7; Meshorer, 1985: 24, 111).

During the Hasmonaean revolt, Judah, Jonathan, and Simon led attacks against pagan Jaffa, eventually conquering the city (Aharoni *et al.,* 1993: 145 map 192; Notley, 2011: 188-189). The first of these offensives, in which Judah ‘set fire to the harbor by night’ and ‘burned the boats’ took place in 163 BC (2 Maccabees 12:3-7). One can only speculate if the burning of the harbour refers—in addition to land structures—to wooden piers similar to those that existed in Jaffa’s harbour in the recent past (Mirkin, 2017: 145, 147, 148 fig. 6.37). The author of 2 Maccabees employs the term σκάφη (‘boat’) to describe the vessels burnt by Judah. If this is a technical term for a specific boat type, it may refer to small craft similar to the Kinneret Boat.[9]

The early Hasmonaean leaders clearly saw Jaffa as an important portal to the sea for their fledgling Jewish national entity. Apart from the repeated campaigns that the sons of Mattathias waged against Jaffa, leading to its eventual conquest in 142 BC by Simon’s forces (1 Maccabees 13:11; 14:34), there are additional indications of Jaffa’s unique significance to the Hasmonaean cause. In building Jonathan’s tomb at Modi’in, Simon ‘carved ships so that they could be seen by all who sail the sea’ (1 Maccabees 13:29). Given the proximity of Jaffa to the region of Modi’in it is difficult not to see this as an allusion to Hasmonaean interest in Jaffa (1 Maccabees 10:75-76; 12:33-34; 13:11; *Antiquities* 13.91-92, 180, 202). Simon also fortified Jaffa and settled Jews there among other coastal enclaves (1 Maccabees 14:33-34). Similarly, the importance of Jaffa finds voice in the eulogy to Simon (1 Maccabees 14:5):

> To crown all his honors he took Joppa for a harbor,
>
> and opened a way to the isles of the sea.

Several later Hasmonean rulers also minted coins bearing nautical symbols.[10] While there existed multiple considerations for the choice of these motifs, one among them must have been the importance of Jaffa and other maritime sites held by the Judean state (Meshorer, 1982A: 61; Jacobson, 2000; Hoover, 2003; Notley, 2011: 189).[11]

Jason's Tomb, a Hasmonaean-era sepulchre located in the Rechavia district of Jerusalem, contains a charcoal graffito of three ships: two galleys with typical Hellenistic-period tripart waterline rams, as well as a ship under sail bearing armed men (Fig. 6).[12] L.Y. Rahmani (1967: 73, 97), the tomb's excavator, concluded that the scene references piratical activity by the owner of the tomb circa 100-64 BC.

Indeed, throughout the early Roman period Jaffa is repeatedly connected with Jewish piracy. In 63 BC Pompey divested the Hasmonaean state of a number of cities in an attempt to restructure and limit it (*Antiquities* 14.76; *War* 1.156-157; Rainey and Notley, 2006: 336; Notley, 2011: 101-102). One outcome of this reorganization was a loss of access to all seaports, an act on the part of Pompey that may have resulted from complaints of piracy brought by Hyrcanus II (63-40 BC) against his brother Aristobolus II (67-63 BC) (*Antiquities* 14.43). A pre-imperial autonomous city coin of Jaffa depicting a galley dates to this period (Fig. 7) (de Saulcy, 1874: 174-175, pl. IX: 4; Hill, 1914: xxiv; Tolkowsky, 1924: 58 fig. 6). Strabo alludes to Jaffa's use as a centre for piracy during the Hellenistic period (*Geography* 16.2.28). Josephus, at the outset of hostilities during the Jewish War, also describes Jaffa in AD 67 as a pirate den (*War* 3.414-416). The Jews may have been trying to cut off the grain supply to Rome and disrupt their communications (Tolkowsky, 1924: 68; Patai, 1998: 80).

Jewish legend links Jaffa's harbour with the Second Temple in Jerusalem. Several Egyptian Jews from Alexandria contributed to the Temple's construction (Levine, 2002: 236-237). Nicanor had doors for an inner gate of the Temple made of Corinthian bronze in Alexandria and then accompanied their—reportedly miraculous—shipment to Jaffa (Jerusalem Talmud, *Yoma* 3:8 41a; Tosefta Yoma 2:4; Guggenheimer, 2013: 479).[13] For our purposes the story of Nicanor's doors once again illustrates the importance of Jaffa at that time as a maritime hub for its hinterland (Notley, 2011: 103).

During the Early Roman period, Josephus identifies Jaffa and Dor as important harbour towns along an otherwise open coastline, thus explaining the reasoning behind Herod the Great's construction of the great harbour at Caesarea (*War* 1.409:[14]

> For the whole sea-board from Dora to Joppa, midway between which the city (Strato's Tower) lies, was without a harbour, so that vessels bound for Egypt along the coast of Phoenicia had to ride at anchor in the open when menaced by the south-west wind…

In his account of the Roman recapture of Jaffa in AD 67, which included the loss of a Jewish fleet to a storm, Josephus describes Jaffa's rocky western harbour as small, cramped and particularly dangerous due to the perils of Andromeda's Rock at the harbour's entrance (*War* 3.417-427:

> Nature has not provided Joppa with a port. It terminates in a rugged shore, which runs for nearly its whole length in a straight line, but is slightly curved at its two extremities in crescent fashion; these horns consist of steep cliffs and reefs jutting far out into the deep; here are still shown the impressions of Andromeda's chains, to attest the antiquity of that legend. The north wind, beating full upon the coast, dashes the waves high against the face of the rocks and renders this roadstead more perilous to sailors than the watery waste.[15] It was here that the people of Joppa were tossing, when, towards dawn, a furious blast burst upon them, the wind called by navigators in those parts the 'Black Norther.'

The Flavian emperors later minted coins with the inscription *Judea Capta* to commemorate their victory over Judea (Madden, 1881: 207-229; Meshorer, 1982B: 190-197). A small subset of these carry the declaration *Iudaea Navalis* or *Victoria Navalis,* and one type, dating to AD 73, shows Titus with his foot resting on a ship's prow while holding a winged Victory(?) (Madden, 1881: 222-223; Tolkowsky, 1924: 70-71; Meshorer, 1982B: 190-193, pl. 35).[16] The coins marking a naval victory have long been connected to the destruction of the fleet at Jaffa (Madden, 1881: 222), but that outcome was not the result of an actual sea battle and neither Vespasian nor Titus, both of whom were hardened battle commanders, actually took part in the conquest of Jaffa.[17]

During the Byzantine period Jaffa became a place of Christian pilgrimage due to the stories of Jonah and Tabitha (Acts 9:36-43; Foran 2011: 109). The mid sixth-century AD Madaba map, unfortunately, is damaged in the area that might have depicted Jaffa. A small domed structure captioned 'of Saint Jonah' appears, however, beneath a quote from the Song of Deborah regarding the Tribe of Dan and slightly south of where Jaffa would have been located (Avi-Yonah, 1954: 62-63, pl. 7). In the small surviving patch of sea below it is a fragmentary circular object, which M. Avi-Yonah (63) identifies as 'part of a ship or of a monster.'

In the tenth century, the Arab geographer Muqaddasi (Abu Mohammed Abdallah ibn Ahmed) describes Jaffa's harbour as 'excellent' (Le Strange, 1886*:* 54), which is difficult to explain as it contradicts virtually all other descriptions.[18] With the Crusades at the end of the 11th century, the textual evidence about Jaffa increases dramatically (Tolkowsky, 1924: 85-125). The Holy Land continued to be a draw for both Christian and Jewish pilgrims.[19] Jaffa played a crucial role at the beginning of the Crusader kingdom and at first served as its only available port (Runciman, 1992: 307-310). With the assistance of Pisan sailors in 1100 Godfrey improved the harbour, employing Jaffa as a base for blockading the Fatimid ports along the coast and encouraged neighbouring rulers to the east, now cut off from the coast by the Frankish state, to use Jaffa as a port.

Because larger ships could not enter Jaffa's harbour, having instead to ride at anchor with commodities and people transported to land by lighters, disembarking was inherently dangerous. Storms could lead to disaster, as happened on October 13th, 1102 when Saewulf, a Christian pilgrim, describes in vivid terms the catastrophic wrecking of some 30 ships in a storm that caught a fleet anchoring off Jaffa's poor rocky harbour (*Saewulf:* 6-8). This event may have been an impetus for the subsequent preeminence of Acre (Akko) as a Crusader port despite its distance from Jerusalem (Boas 2011: 122), after Baldwin recognized a need to replace Jaffa if immigration were to be encouraged. Despite this, throughout the Crusader period Jaffa saw mercantile ship traffic, as well as naval blockades and attacks (Tolkowsky, 1924: 86-125; Boas, 2011).

Under Mamluk rule, Jaffa again served as an access point to Christian pilgrims (K.S. Burke, 2011). The Arab geographer Abu-l Fida describes Jaffa in 1321, and like Muqaddasi, curiously praises its harbour: ‘Yâfâ, in Filastîn, is a small but very pleasant town lying on the sea-shore. It has a celebrated …. large harbour frequented by all the ships coming to Filastîn, and from it they set sail to all lands’ (Le Strange, 1890: 551).

In 1332, Philip VI of France began planning a crusade, but this came to naught (Tolkowsky, 1924: 128-129). These plans, however, had a direct effect on Jaffa’s waterfront for, when the Mamluk sultan an-Nasir Muhammad got word of them, he demolished Jaffa’s breakwater and quay and prohibited its use by pilgrims as an entryway to the Holy Land (Stewart, 2013: 49).

The next data on the city comes from the French nobleman the Baron d’Anglure, who visited it in 1395 (Tolkowsky, 1924: 129). By then, Christian pilgrims were allowed to land but Jaffa itself lay in ruins. In 1586, the Belgian Jean Zvallaert described the harbour thus (Tolkowsky, 1924: 133): ‘The haven was, in times bygone, walled all around, except towards the north, where was the entrance: the remains of the said walls can be seen to the present day emerging slightly out of the water, like reefs.’ From the late 15th century, representations of Jaffa with its rocky harbour begin to appear (Mirkin, 2017: 130-139).

Reports from the 18th-19th centuries consistently describe the poor quality of Jaffa’s harbour (Pocock, 1745: 2; Light, 1818: 138-139; MacGregor, 1870: 109-110; Baedeker, 1876: 127-128; Rogers, 1881: 118; Twain, 1899: 605-606). Nothing improved with the coming of the 20th century (Barton (1904: 92). The lack of a good harbour during the 19th and early 20th centuries resulted in economic and political disadvantages for Jaffa (Kark 1990: 230-238). Studies reveal the limits of Jaffa’s harbour facilities (Mirkin, 2017; Mirkin and Goren 2012). Jaffa’s resurrection as a port at this time resulted from increased pilgrimage by Jews, Christians and, to a lesser degree, Muslims. Beginning in the late 19th century, the Zionist revival also contributed to the port's maritime activity. Weather, and even moderate surf, regularly wreaked havoc on the lighters ferrying passengers and cargo from larger vessels moored offshore. Writing in the early 20th century, G. Smith (1920: 130–131) notes: 'Everyone knows the open roadstead at Jaffa, with the reefs that are more dangerous in foul weather than they are useful in fair.' During the winter, which brought heavy storms, most of the boats moored less than 6 km north of Jaffa within the estuary of the Yarkon River, while smaller vessels lay beached upon the shore (Hanauer 1903A: 260-261; Avitsur 1965: 30). The Reverend J.F. Hanauer (1903A: 262) describes rock cuttings on the offshore ridge at Jaffa, perhaps indications of earlier efforts to improve the harbour's meagre viability.[20]

Even today, Jaffa's harbour leaves much to be desired. The situation was, however, far worse prior to the major harbour works carried out during the British Mandatory period (1920-1948), which removed some of the more hazardous obstructions at the harbour's mouth (Figs. 5, 8). Dredging of Jaffa's harbour in the 1980s, tracked by S. Wachsmann during his tenure as Inspector of Underwater Antiquities for the Israel Department of Antiquities and Museums (now the Israel Antiquities Authority), removed almost entirely sterile sand. One suspects that this might at least partially result from past dredging, although earlier records are lacking (Haddad *et al.*, 2020: 40): harbours were dredged in antiquity, but Jaffa seems an unlikely candidate for it (Marriner and Morhange, 2006; 2007: 179 fig. 33, 184). Underwater surveys of the harbour and its environs revealed little: a Persian-period basket handle attributed to the fourth-century BC, together with a potpourri of other sherds and artefacts spanning the Roman to Ottoman periods (Sharvit and Galili, 2002).

The poor quality of Jaffa's rocky western harbour—documented from its earliest descriptions until today—raises the question: why did the city rise to such prominence as a port during the Bronze and Iron Ages, when the nearby Yarkon River could have provided a safer estuarine harbour? The answer may lie in Jaffa's particular physical setting.

The Physical Setting, Jaffa and the Bassa

The southeastern Mediterranean coast is marked by discontinuous on-and-offshore north-south *kurkar* ridges (cemented aeolianite of coastal dunes) oriented parallel to the coastline but separated by longitudinal depressions (Fig. 9: A) (Raban and Galili 1985; Sade *et al.* 2006; Sneh and Rosensaft, 2008). On land the ridges attain a height of at least 30 metres and Jaffa is located upon a prominent ridge astride the modern coastline (Fig. 10). Extensive weathering of the dune ridges and the sandy inter-dune areas has produced a clay-rich *hamra* soil at the surface. Stream valleys are also dominated by clay-rich sediments and soils. While large streams like the Yarkon and Ayalon originate in uplands to the east, spring-fed wetlands and small streams are found along the coastal plain (Avnaim-Katav *et al.* 2016). Streams often flow parallel to the coast, behind one or more kurkar ridges, before finding a topographic break for their exit to the sea. Additionally, Lichter *et al.* 2010 and Lichter *et al.* 2011 have demonstrated that in areas of constant slope to the sea, stream mouths are often deflected by a barrier beach and flow parallel to the shore before finding an exit through the sand body. Conversely, streams that flow overland in a funnel-like topography are deflected less at their mouth but tend to shift position within their funnel-like setting. In most cases, natural stream mouths are protected from the open sea by a barrier beach and offshore sand bars.

Today most of Israel's coastline lies beneath sand dunes, but until two to three millennia ago it consisted of sediments deposited by wetlands that accumulated in the coastal and eastern bedrock troughs (Sivan *et al.,* 2004A: 1046; Sivan *et al.* 2011). Shorelines of the region have generally retreated in response to sea-level rise and coastal erosion (e.g., Raban and Galili 1985; Sivan *et al.* 2001; Sivan *et al.* 2004A; Cohen-Seffer *et al*. 2005). Cores from Tel Dor, located on the Carmel coast about 60 kilometres north of Jaffa, reveal that coastal marshes receded prior to the Pre-pottery Neolithic period (circa 8,000 BC) while freshwater wetlands continued to thrive on the coast in the troughs, surviving into historical periods (Sivan *et al.,* 2004A: 1046; Cohen-Seffer *et al.,* 2005: 117-118). At Tel Michal, situated about 10 km north of Jaffa, wetlands were drained in the Byzantine period: valley bottoms along the coast lay beneath the water table and remained wetlands into the early 20th century (Karmon, 1959: I; Grossmann, 2001: 13).

At Jaffa, artificial fills mostly camouflage the earlier geomorphology and bury geological units (Fig. 11). The Jaffa ridge ends abruptly to the north, but a small bedrock ridge that is nearly completely buried by artificial fill can be found a few hundred metres to the northeast and slightly offset to the east (Fig. 9: A). Between these bedrock exposures the land surface is the lowest along this stretch of coast and any drainage east of Tel Yafo would have passed through this position (Fig. 10). The bedrock offset and the low ground between the ridges can be explained by tectonic activity in this position, as it is a down-dropped crustal block produced by motion on two parallel, east-west trending normal faults near Tel Yafo (Fig. 9: B).

With an awareness of Jaffa's physical setting in mind, might that city have utilized a now-lost adjacent stream outlet, small estuary, or lagoon as a harbour during the Bronze and Iron ages? Although its importance as a port in those periods can be teased out of textual references, these reveal nothing regarding the actual location, or the nature, of Jaffa's moorings. The earliest reference to its harbour is remarkably late, considering the site's long history as a port: Judah's punitive action in 163 BC (2 Maccabees 12:3-7) describes a single harbour. Clearly, even if an estuary or a lagoon had served Jaffa's needs previously, by the mid-second century BC it was no longer in use. Judah had attacked the rocky western harbour. Similarly, in explaining the economic impetus for Herod's construction of Caesarea Maritima in the first-century BC Josephus makes no mention of a second harbour at Jaffa.

Recent geoarchaeological studies reveal, however, that early harbours along the Levantine coast could be buried by silting and anthropogenic processes. As G.A. Smith (1920: 131) wrote over a century ago, 'while the cruelty of many another wild coast is known by wrecks of ships, the Syrian shore south of Carmel is strewn with the fiercer wreckage of harbours.'

Although modern Levantine cities—such as Beirut, Sidon and Tyre—still have active harbours, their ancient harbours now lie buried (Marriner *et al*., 2005; Marriner *et al*., 2006A: 2006B; Marriner and Morhange 2007: 152; Marriner *et al*., 2008A; 2008B). Bronze Age mariners favoured pocket beaches and protected embayments (Marriner and Morhange 2007: 175; Marriner *et al*., 2014: 5-6). With natural harbours, these sites, and perhaps Jaffa among them, flourished as seafaring hubs. While marine re-entrant and estuarine harbours supplied natural havens for watercraft in antiquity, over time these low-energy settings progressively all but disappeared under sedimentary deposits. N. Marriner and C. Morhange (2007: 159) note that although estuaries would have been shallow, they could have accommodated even large Bronze and Iron Age vessels.[21]

The recognition that such processes have been at work in obscuring the location of early harbours raises the possibility that a similar situation existed at Jaffa in high antiquity. Beginning in the late 18th century until the founding of the modern city of Tel Aviv in 1909, an assortment of accounts, maps, and illustrations document the existence of a shallow lake and wetland termed *el Bassa* in Arabic, located east of Jaffa.[22] The former center of this feature today lies approximately 800 metres from the shoreline. Since the early 20th century scholars have tentatively identified the Bassa as a remnant of an ancient marine embayment that could have served as a harbour during Jaffa's pre-classical period, the so called 'Solomonic' harbour of local tradition (Hanauer, 1903A; 1903B). By 1873, the Bassa was a seasonal lake (Clermont-Ganneau 1896: 158-159). This situation continued into the early 20th century. Interestingly, it has been recently recognized that Tel Yafo's Ramesside gate appears to align with the southern limits of the Bassa, perhaps suggesting a certain 'awareness' of this area as a harbour (Figs. 3, 12).

A.F. Rainey and R.S. Notley (2006: 37) propose that the Ayalon River (Heb. *Nahal Ayalon*; Arab. *Wadi Musrara*) flowed from the Ayalon Valley, traversing the Sharon (coastal plain) in the direction of Jaffa, but that 'in geological antiquity it had debouched in the sea where the port of Joppa was formed, but prior to human habitation it was deflected northward by the intrusion of sand and had to flow behind a sandstone ridge until it joined Nahr el-'Auja [the Yarkon River].' A. Raban (1985: 27) describes river pebbles recovered from an undated core taken off Jaffa's headland that in his opinion illustrate 'the existence of an ancient outlet of the N. Ayalon at this part of the shore.'

Contra this view, north-south trending kurkar ridges and relative high ground (15+ metres) lie between the present Ayalon River and the coast and essentially eliminate the possibility that the Ayalon River flowed toward Jaffa in the Holocene (Fig. 10). Indeed, a map created by Napoleon Bonaparte's cartographer, M. Jacotin, in 1798 shows the Ayalon flowing north to join the Yarkon River (Fig. 13: A).

The valley-like topography just east of Jaffa, however, suggests that a stream may have once flowed to the north here before debouching on the north end of the ridge upon which Jaffa sits, through the topographic low point there (Fig. 10). This stream, like many modern coastal wetlands, may have been spring-fed, and passed through wetlands before ending in a small estuarine or lagoon system. The river gravel reported by Raban (1985) can be attributed to this stream.

North of Jaffa, swamps existed near the Tel Aviv Exhibition Grounds. Kaplan mentions marshy soil and an ancient wadi with settlement remains dating to the Chalcolithic period, as well as to the Early Bronze and Middle Bronze II Ages (Golan, 2009). During the late 19th century, a push to promote settlement and agriculture led to the clearance of swamps around Jaffa (Kark 1990: 9, 207). Tolkowsky (1924: 2) suggests that, prior to their conversion into orange orchards, these wetlands may have served as a natural defence against enemy attack. Given the geomorphology and historical/archaeological evidence, it is likely that a stream and associated wetlands (at times with open water) and coastal marshes, and perhaps seasonal streams (wadis) dominated the coastal plain in the region immediately to the east of Jaffa. The precise position of the ancient shoreline is not known and may have been located more seaward than present, as has been demonstrated for other coastal sites (e.g., Sivan *et al*., 2001), and the stream mouth could have been partially inundated creating a shallow marine embayment.

Thus, while *direct* textual references to Jaffa's harbour situation only emerge in the Hellenistic period, given the physical setting and documented geomorphological change in similar settings, we postulated that Jaffa may have utilized as a harbour some form of coastal re-entrant, like those described by Marriner and Morhange (2007), which would have been substantially preferable to Jaffa's rocky western harbour. Subsequently, the familiar process on this coast of infilling by transported sediments and anthropogenic activities would have suffocated this inner basin, eventually making it unusable as a harbour, sometime prior to the mid-second century BC. Similar processes of sedimentation and relocation have been documented at other ancient harbours (Brückner *et al.,* 2005; Kraft *et al.,* 2007; Marriner and Morhange, 2005; 2006; 2007; Marriner *et al.,* 2005; 2006A; 2006B; 2008A; 2008B). Our work in 2014 represents the first systematic effort to examine the possibility of a similar estuarine harbour alternative at Jaffa.

The biblical scholar J.E. Hanauer (1903A; 1903B) appears to be the first to have proposed in print that the Bassa might represent the remnants of a harbour (Fig. 14). Hanauer (1903A: 258) recorded that it was 'covered by a shallow lake or swamp after heavy rains, and local tradition asserts that it marks the site of the ancient harbour of the time of Solomon.' A particularly rainy winter in 1892-1893 filled the Bassa with water causing an outbreak of malaria the following summer that required the digging of a ditch to empty it (259; Kark 1990: 207). Hanauer (1903A: 260) also notes that 'a great many years ago old people had related that they had heard of boat anchors having been dug up in the 'Baasah', as the lowest part of the hollow is called' and that wells sunk here 'had at various points struck upon portions of what was supposed to have been a massive sea wall built with somewhat of a curve as if intended to surround or limit a large pool or sheet of water.'

G. Barton's 1902 excavation northeast of Tel Yafo originally led to claims of 'the existence of an ancient inner harbour at Jaffa, used in the Maccabaean period and in the time of Saladin, and perhaps also in the time of Solomon' (Moore and Barton, 1903: 41). Subsequently, Barton (1903: 186) changed his mind, concluding that the wall he uncovered was not related to an inland harbour.

Tolkowsky (1924: 27) reports on ‘a piece of iron looking like a ship’s anchor’ from the Bassa. Clearly, even if this were part of an iron anchor, it would have been deposited long after the Bassa could have served as a harbour as iron anchors only came into use in the Roman period (Kapitän, 1984: 42-43; Votruba, 2014). Conversely, Barton (1903: 185) relates how the contemporaneous owner of the land containing the Bassa described that two decades earlier, while ‘making some incidental excavations, some rocks were found, which contained holes and rope-marks, as though they had been used for the anchorage of ships.’ Needless to say, rocks with ‘holes and rope-marks’ *could* refer to the ubiquitous stone anchors used during the Bronze and Iron Ages along this coast or to later mooring stones (Nun, 1988: 10, 15, 21; Wachsmann, 1998: 255-293; 2000: 815-817).

During the rule of Ibraham Pasha in the early 19th century a plan was put forward to excavate a harbour in the Bassa (Avitsur, 1965: 32-33; Kark, 1990: 25; 2011: 132; Mirkin, 2017: 147). Nothing came of this, but in 1847 the American naval officer W.F. Lynch (1850: 440) examined the Bassa with this proposal in mind. A much-diminished body of water, presumably seasonal in nature, appears in the region of the Bassa on a Palestine Exploration Fund map, published in 1880, but based on an 1872-1877 survey (Fig. 15) (Shacham, 2011: 139, 156 fig. 13.17).

Maps represent an important source of information for this study. The earliest of these, detailing the 1799 siege of Jaffa by Napoleon Bonaparte’s *Armée d’Orient*, were created by his cartographers P. Jacotin and A.J. Denain. These maps serve as an important modern starting point for localizing and contextualizing the Bassa at the end of the 18th century.

The maps show a body of water at times termed *flaque d’eau* (Eng. ‘pool of water’) or *etang* (Eng. ‘pond’) (Figs. 13B, 16-17) (Jacotin, 1826: Flle 44 [Jérusalem et Jaffa]; Shacham, 2011:137-138, figs. 1, 2-4, 7). Both terms indicate that the Bassa still existed as a shallow body of water at that time.

A scant four decades after Bonaparte's cartographers created their maps, David Robert's 1839 painting of Jaffa depicts the city as viewed from the north with a flat plain to its east separated from the sea by a low ridge (Fig. 18). A gap through the ridge would have allowed the Bassa to drain to the sea. Although Roberts did not illustrate any opening in the ridge, Jacotin's 1799 maps, as well as an one published later by A.-J. Denain and Delamare, shows lower areas where the Bassa could have emptied to the sea directly north of Jaffa (Fig. 16-17; Shacham, 2011: 144 fig. 13.2, 146 fig.13.4, 147 fig. 13.5, 148 fig. 13.7, 149 fig. 13.8). Moreover, georeferencing Jacotin's maps, together with the obvious valley axis in this position present in the 1950s, and a study of digital elevation models and geological coring during the 20th century, also support this hypothesis (Fig. 10; *History and Archaeology of Jaffa* 2: 101-104).

If Jacotin's flaque d'eau/etang, and later the Bassa, indeed represent the final watery remnants of a natural harbour, then Tell Mashuk, a potential candidate for the site of Paleo-Tyre on the coast opposite ancient Tyre, serves as a useful analogy (Marriner *et al.,* 2008A: 1304 fig. 21, 1305-1306). Sedimentological studies indicate that the coastal environment of Tell Mashuk flooded 6,000 years ago creating a lagoon with access to the sea that could have served as a likely haven for Bronze and Iron Age ships. After seaward growth of a barrier beach separated the lagoon from the sea, the area became marshland, a situation that persisted till the 19th century. Marriner (*et al.,* 2008A: 1306) and his colleagues note that 'in the absence of a fluvial flushing system, any inlet would gradually have been blocked by beach ridge accumulation.'

Thus, various streams of evidence—archaeology, cartography, illustrations, texts and topography—all converge in supporting a natural coastal re-entrant that could have served as an inland harbour for Tel Yafo during the Bronze and Iron Ages. To test this hypothesis we undertook a drilling campaign in the Bassa area so that we could determine its subsurface geology and reconstruct its palaeo-environmental setting.

The Geological Study

Employing a Geoprobe, the expedition drilled six continuous cores—designated Yafo 01, Yafo 04, Yafo 06, Yafo 10, Yafo 16 and Yafo 18—to a maximum depth of 13 metres (Fig. 19; Table A).[23] Core locations and elevations were determined in the Israeli Geodetic Datum (IGD) 05-12 coordinate system by the means of Real-Time Kinematic (RTK) Global Positioning System (GPS) placement. The cores span about 180 metres in the east-west direction in the only area available within the urban development, and they are centered about 900 metres from the present shoreline. All cores reached Pleistocene sandstone, which occurs in this area from ~2 metres below, to 3 metres above, present sea level (Fig. 20; Table A). The sedimentological characteristics were determined for 84 representative samples from cores Yafo 04 and Yafo 16 (Appendix). Sixty-eight sediment samples from the same boreholes underwent semi-quantitative micropalaeontological analysis (Appendix).

<<INSERT TABLE A>>

Table A. The locations, elevations and lengths (m) of the sediment cores. Elevations have a ~2-centimetre precision.

Chronology

Age analysis was performed on six samples by optically stimulated luminescence (OSL), and on one sample by radiocarbon method. For OSL dating, we drilled two duplicate boreholes, which we termed Yafo 204 and Yafo 216, immediately adjacent to boreholes Yafo 04 and Yafo 16. The oldest OSL ages come from sandy-silty clay sediments from depths of 5.25 metres in core Yafo 204 (representing Yafo 04) and 8.3 metres in Yafo 216 (representing Yafo 16) dated to 9400 ± 500 and 14,300 ± 900 BP, respectively (Fig. 20, Table B). Thus, the sediments that accumulated overlying these depths represent the Holocene sedimentary sequence. The youngest ages obtained derived from a depth of ~3.3 metres in core Yafo 204 and ranged between 360 ± 20 and 290 ± 30 BP (Fig. 20; Tables B and C). Ages are stratigraphically consistent within each core. We apply a transgressive-depositional model in which coastal environments migrated landward and upward with rising sea level, and therefore, we expect the age of units to get younger to the southeast.

<<INSERT TABLE B>>

Table B. Optically stimulated luminescence (OSL) data for Yafo cores. Grain size for all samples: 125-150µm. Water content estimated at 50% of saturation values (with an error of ±25%), based on grain size distribution. Error on burial depth – 10 cm. O-D — over-dispersion, a measure of the internal sample scatter. No. aliquots —the number of aliquots used to calculate the De and age out of those measured. CAM — central age model.

<<INSERT TABLE C>>

Table C. AMS ^{14}C dating results. Calibration via Calib 702 (Stuiver and Reimer, 1993; Reimer *et al.*, 2013).

Lithology/sedimentology

The cores revealed nine sedimentary units, including an artificial fill (Fig. 20):

The Pleistocene sequence (Units I-V).— Core Yafo 10 typifies the stratigraphic sequence found across most of Groningen Park (Fig. 21), and the units found in this core appear in all other cores. In the case of Core 10, the Pleistocene-Holocene transition lies approximately 6 metres below the present surface, or at present sea level; however, this transition varies laterally due to the transgressive nature of the deposits.

The Pleistocene stratigraphy consists of five units. The base of the sedimentary sequence encountered, Unit I, contains pale brown to white, moderately-well cemented calcareous fine-medium grained quartz-rich sandstone. Above this, Unit II contains silty-fine to medium sand, of a pale brown color, which typically darkens up section. Subunit IIIa, found in cores Yafo 04, Yafo 06, and Yafo 10, consists of a thin, very pale brown, fine to medium grained foraminifera-bearing quartz sand. Overlying this sand, Unit III is a thick, very pale orange-brown homogenous well-sorted and rounded quartz-rich fine-medium grained sand. Up section, in Unit IV, the sand darkens, exhibiting homogenous orange-brown oxidation colors and becoming finer in texture. Unit V consists of pale brownish-gray to medium-gray silty fine-medium sand, exhibiting color mottling and some rooting, with plant remains commonly appearing as vertical roots, but also as horizontal laminae, as if they had been washed in during deposition. This unit exhibits redoximorphic features, including localized iron-oxide staining, usually as spots and lineaments, possibly surrounding degraded organic matter, and black spots that appear to be manganese oxide. Unit V spans the Pleistocene-Holocene transition.

The Holocene sequence (Units VI-IX).—The base of the Holocene sequence likely occurs within Unit V of core Yafo 04 and in the lower portion of Unit VI of core Yafo 16. Unit VI is a silty clay to clay with an up-section color darkening gradation from a brownish-gray to dark gray. Horizons rich in fine degraded organics occur. Analysis of our selected cores, Yafo 04 and Yafo 16, reveals that Unit VI sediments in core Yafo 04 are generally finer-grained and composed mostly of clay (>95 percent), but with silty horizons, compared to the silty clay sediments characterizing this unit in core Yafo 16, which contains ~5-50 percent silt throughout (Figs. 22-23). Total organic matter (%TOM) values are rather similar at ~5-8 percent in both cores.

Unit VII is predominately olive-gray silty clay to clayey silt with plant remains, particularly small roots, as well as abundant pedogenic carbonate as nodules. Locally, this unit contains up to 25 percent sand (Figs. 22-23). Grain size fluctuates in Yafo 04 while in Yafo 16 the grain size generally coarsens upward. The %TOM is greater in Core 16 but the range within both cores is approximately 3-8 percent. In some locations the top of Unit VII may have been truncated by dredging and filling making any trend interpretation tentative. Unit VIII appears only in cores Yafo 06 and Yafo 10 and consists of a light gray, well-sorted, rounded, homogenous quartz sand. Pedogenic textures are minimal (Fig. 20). Above this lies Unit IX, an artificial fill composed of a wide variety of grain sizes, broken ceramic, rock fragments of various lithology, plastic and rubber fragments and weakly-developed granular soil characteristics.

Lithological data from previous work. —To the west of our study area, approximately 300 metres west of core Yafo 16, core 3729 Yafo-Migdal Hamayim, recovered by the Yafo Municipality in 1933, included a thick dark-gray sandy silty clay unit extending to a depth of 13 metres below sea level and deposited on what is likely hamra above calcareous sandstone (Fig. 19). The other municipality cores in the area contain deposits with thicknesses and depths similar to our cores. Core 3729 Yafo-Migdal Hamayim is located on the trend of the lowest topography between our study area and the coastline.

Palaeontology

The palaeontological results for the Holocene section show several similarities between the two cores analyzed. Autochthonous well-preserved fossils, including ostracods, molluscs and alga, appear predominantly in units VI and VII in core Yafo 04 and core Yafo 16, respectively (Figs. 22-23). The detailed faunal record is divided into three (A-C) distinct biofacies, that is, the sum of the faunal and floral characteristics of a sedimentary horizon. Due to transgressive deposition, the biofacies are not necessarily found in the same sedimentary units in different cores.

Biofacies A occurs in the lower part of unit VII in core Yafo 16 and Biofacies B encompasses the lower part of unit VI in core Yafo 04. These biofacies are characterized by a more continuous frequent-to-abundant occurrence of ostracod shells in both cores. We observed, however, lateral differences between the cores in the distribution pattern of the ostracod composition of the four species encountered, as well as among the accompanying gastropods and flora. The dominant ostracod in Biofacies B (Yafo 04) is *Sarscypridopsis aculeata*, accompanied by a rather low abundance of *Heterocypris reptans* and *Ilyocypris gibba*, a low concentration of gastropods, and a high abundance of *Chara* macrofossils (Fig. 22). In contrast, in Biofacies A (Yafo 16)

Cyprideis torosa is the dominant ostracod species together with a fluctuating abundance of *G. piscinarum* and rarely *Chara* sp. (Fig. 23).

The uppermost biofacies (C) is found in both cores, but in core Yafo 16 it appears in the upper half of unit VII, while in core Yafo 04 it comprises the upper part of unit VI. This biofacies is characterized by a rare occurrence of ostracods, while *Chara* sp. is frequent in both cores but more abundant in core Yafo 04. The gastropod *Gyraulus piscinarum* makes a rare to frequent appearance (Figs. 22-23).

Discussion

Figure 24 presents a lithological cross section illustrating the continuity of sedimentary units, the slope of the Pleistocene transgression surface to the northwest, and the general transgressive nature of coastal depositional environments in the Holocene sequence. Sedimentary units dip gently to the northwest and this, coupled with regional sea-level rise (Sivan *et al.,* 2001) and the chronology established by OSL and ^{14}C, reveals that deposition was transgressive in nature and progressed southeastward during sea-level rise.

Pleistocene to early Holocene depositional environments

For the Pleistocene sequence, we interpret Units I – IV as aeolian to coastal sandstones (Units I and III) and their associated paleosols (Units II and IV). These units occur on the coastal plain of Israel and date to the Late Pleistocene (e.g. Sivan *et al*., 2004A: 1038; Avnaim-Katav *et al*., 2017; Shtienberg *et al*., 2017). Unit V, which has sedimentary indicators for a rooted and saturated surface, appears to represent stream deposition across the area followed by rising water table levels during the approximate transition into the Holocene. The early Holocene record is poorly represented. The onset of mid-Holocene deposition reflects sea-level rise and initial coastal environmental transgression across the study area, with sea level reaching 1-2 metres below its present level by circa 5000 BP (Sivan *et al*., 2001). This rising base level created an increase in the water table, indicated by the redoximorphic features of Unit V, while also influencing stream conditions. Additionally, the appearance of marine allochthonous foraminifera (mostly reworked and polished), although in low numbers, in both analyzed cores, may reflect increasing proximity to the coastline.

*Mid Holocene to recent depositional environment*s

Multi-proxy data enabled us to decipher the depositional environments forming the Yafo sedimentary record during the Holocene, which is of most interest to the current discussion. Integrating sedimentological properties with analyses of several floral and faunal assemblages (ostracods, molluscs and foraminifera) enabled us to produce a detailed palaeoenvironmental reconstruction (i.e., aquatic environments) for the middle and late Holocene that is transgressive in nature and follows other Mediterranean studies (e.g., Frenzel and Boomer, 2005; Elyashiv *et al*., 2016; Sivan *et al*., 2016; Avnaim-Katav *et al*., 2017). For our palaeontological studies we focused on a detailed taxonomic framework, ecological data, and natural taphonomic processes.

The sum of the properties of the Holocene sedimentary units indicates three main depositional environments:

1) *Fluvial (stream) to head of estuary (Biofacies A)*

In core Yafo 16 (Fig. 23), Unit VI and the lower half of Unit VII, classified as Biofacies A, comprise olive-gray silty clay that generally coarsens upward, contain alternating horizons of silt and clay, and are overall coarser than the same units in core Yafo 04. Organic matter is 7-8 percent. Grain size indicates moderately low energy conditions. *Cyprideis torosa,* which dominates the Biofacies A ostracod assemblage, inhabit various aquatic environments within a wide range of salinities, but it prefers oligo-to-mesohaline waters (e.g., Mischke *et al*., 2014: 102; Avnaim-Katav *et al*., 2016). The occurrence of a population composed of merely adult shells of this species indicates a relative high-energy environment, typical of tidal channels (Frenzel and Boomer, 2005; Penney, 1987: 240). Biofacies A also contains other fresh-to-brackish water ostracods and fluctuating quantities of badly preserved, reworked, and occasionally broken, mollusc specimens of *G. piscinarum*. Scarce allochthonous elements, such as reworked *Ammonia parkinsoniana*, were probably transported inland from their habitat on the shallow shelf (e.g., Avnaim-Katav *et al*., 2013; 2015; 2016), indicating some proximity and connection to the sea. The state of preservation of the brackish ostracods points to their allochthonous nature and, along with the lack of *Chara* sp., indicates a fluvial source (Frenzel and Boomer 2005: 72). The occurrence of the badly preserved freshwater gastropod *G. piscinarum* may indicate transportation by floods from inland. The characteristics stated above indicate a brackish, moderately low energy environment with episodes of high energy, and are indicative of a fluvial system that is subjected to marine incursion or a fluvial-estuarine transitional setting ('head of estuary' environment). While fossils are not preserved in Unit VI of Yafo 16, sedimentary characteristics suggest that it was initially deposited under fluvial conditions beginning in the early Holocene. With increasing marine influence from sea-level rise, the onset of Biofacies A brackish conditions began at least as early and likely earlier than

4400 BP (Fig. 23). This shift in the depositional environment is contemporaneous with landscape evolution of other coastal areas, such as the Zevulun Plain (Haifa Bay), Israel (Elyashiv *et al.,* 2016). At this point, the position of Yafo 16 was located at the head of a small estuary, or perhaps slightly farther upstream in a reach that was inundated by marine waters during storms. The thick and deep, -13 metres relative to sea level, sandy silty clay in Core 3729 Yafo-Migdal Hamayim, located west of core Yafo 16 (Fig. 19), is a likely extension of the head of estuary deposits in our study area and the deeper occurrence suggests a buried palaeovalley that extends west-northwest to the coast.

2) *Inland brackish and fresh wetlands (Biofacies B & C)*

In core Yafo 04, the lower half of Unit VI, classified as Biofacies B, is a dark gray clay with moderate concentrations of organic matter (4-8 percent) (Fig. 22). Grain size indicates very low energy conditions. This sedimentary unit, as indicated above, is likely associated with a fluvial or head of estuarine system, but Yafo 04's position is farther from the coast and as a result of transgressive environmental evolution, palaeo-conditions lagged in time compared to Yafo 16 units. Thus, longer freshwater influence is expected. *Sarscypridopsis aculeata* dominates the ostracod assemblage, which suggests a fresh-to pleio-mesohaline habitat (Mischke *et al*., 2006: 62). Preserved shells of this species include different sizes representing varied larval stages. The biofacies also contains *Heterocypris reptans* and low numbers of *Cyprideis torosa*. Today in estuaries along the coast of Israel these three species represent the most common brackish taxa that dominate the live ostracod assemblage (Avnaim-Katav *et al*., 2016: 40, fig. 6). The ostracod *Ilyocypris gibba*, which also occurs sporadically in Biofacies B in low concentrations, is a common species from the hyperarid regions of Israel and Jordan, but also tolerates almost freshwater to mesohaline environments (Mischke *et al*., 2012: 92, fig. 3). The ostracod assemblage in Biofacies B comes with a high abundance of *Chara* sp., and seeds of *Najas minor* and *Zannichellia palustris* – both seeds plants are submerged/floating aquatic macrophytes found in the lower part of these sediments. *Najas* species are abundant in freshwater wetland habitats (Gophen *et al*., 2003: 807) whereas *Z. palustris* is a high marsh plant associated with higher salinities as a result of dry conditions (Hilgartner and Brush, 2006: 490) and its ephemeral occurrence is typical of periodically shallow water habitats (Wasylikow, 2005: 723). The land snail *Xeropicta vestalis* occurs almost continuously throughout this biofacies but in low numbers. The fine grain size and all organic aspects of this biofacies, including the preservation, the population structure of the ostracods (Frenzel and Boomer, 2005: 72), and the absence of foraminifera, indicate a shallow, low energy, wetland environment with fresh to oligohaline (<3psu) water, as expected at the head of an estuary or more landward. These environmental conditions existed in the study area from 5600 BP to ~1700 BP, and possibly later (Fig. 22).

Biofacies C is found in both cores analyzed: in core Yafo 04 this biofacies is present in the upper part of Unit VI and may be in Unit VII but the latter unit was not analyzed for this core. In Yafo 16 the upper part of Unit VII contains this biofacies (Figs. 22-23). Sedimentologically, the upper part of Unit VI in Yafo 04 and Unit VII in both cores consist of silty clay with horizons of silt that indicate fluctuating moderately low to low energy, and sand in Unit VII of both cores reveals an increase in energy with time. The occasional occurrence of gypsum in the upper part of Biofacies C in core Yafo 16 reveals episodes of drying.

Biofacies C is similar to Biofacies B, with somewhat different palaeontology. Both cores analyzed contained well-preserved autochthonous macro-fauna and flora, including *Gyraulus piscinarum* and *Chara* sp. The latter belongs to Charophyte plants (submerged macro-algae) represented by an abundance of brown oospores with organic walls and calcareous gyrogonites—both of which serve as reproductive structures. These plants grow in a wide range of non-marine environments, from fresh to hypersaline waters and, although their reproduction conditions are not fully understood it seems that they usually reproduce in shallow perennial water bodies under stressful conditions and under threat of desiccation (Soulie-Marsche and Garcia, 2015: 15). The gastropod *G. piscinarum* belongs to the family Planorbidae, which usually lives in slow-flowing freshwater aquatic habitats rich in macrophytes (Mienis and Ashkenazi, 2011: 334). This species inhabits lakeshores, marshes, swamps and other shallow-water environments in Asia and the Near East (Germain, 1921-1922). For Biofacies C and the associated sedimentary units, the low species diversity and the fluctuating abundances of *Gyraulus piscinarum* and *Chara* sp., along with the low abundance of ostracods and absence of foraminifera, when coupled also with the sedimentological characteristics, indicate a shallow freshwater wetland environment that experienced aerial shrinkage, stressful conditions and occasional desiccation. A slight increase in depositional energy up the section probably marks the approaching marine setting with continued shoreline retreat. Age analysis reveals that freshwater wetlands were well established in the study area 3.5 centuries ago, and very likely existed several centuries earlier, thus, in summary, given our present data, we conclude that the setting of the Bassa transitioned from a fluvial-estuary transitional environment to a freshwater wetland between 1700 and 350 years ago (Fig. 24).

3) *Channel, shoal and shoreline*

In core Yafo 10, Unit VIII is a ~35 centimetre thick, light-gray moderately well sorted medium-grained sand of limited lateral extent and is found above Unit VII (Figs. 20, 24). In core Yafo 06, this same unit is present as a light gray, very well sorted, medium-grained sand and is found unconformably above the Pleistocene sandstone of Unit III. These appear to be deposits of a shallow channel or sand shoal, likely for Yafo 10, and a shoreline, likely for Yafo 06. The deposition of well-sorted sands indicates the continued occurrence of moderate energy in the system, at least sporadically, until fairly recently. In both cases the sand is overlain by artificial fill (Unit IX), indicating sandy conditions prior to recent human activity.

In summary, the pattern of Holocene depositional environments of the study area is marked by relatively open(?), brackish water conditions and moderately low energy to the northwest (core Yafo 16) and more restricted, fresher water conditions and low energy with pulses of moderate energy in the southeast (core Yafo 04). With sea-level rise, higher energy conditions generally shifted southeast with time, locally creating shallow sand deposition in the southeast, while water became fresher across the entire area over time. We interpret these conditions as indicating an initial fluvial setting (Unit V) that transitioned to the uppermost head of an estuarine setting with sea-level rise and coastal environmental transgression. Brackish and then freshwater wetlands developed and expanded due to sediment aggradation. Pulses of higher energy deposition across the area occurred as the marine shoreline shifted southeast.

Holocene palaeogeography in the vicinity of Tel Yafo.—Global sea-level initially rose rapidly during the post-glacial period (Lambeck *et al*., 2004: 1591; Peltier and Fairbanks, 2006: 3334), but then slowed in the early Holocene, and by ~6000 BP was within two metres of its present level. Regional sea level was likely within two metres of present by 5000 BP (Sivan *et al.* 2001; Cohen-Seffer *et al*., 2005: 118; Sivan *et al*., 2016), and by 3600 BP was at its present level (Porat *et al.* 2008). Before sediment from stream and longshore current systems could dominate coastal deposition, continued sea-level rise and concomitant environmental transgression resulted in flooded palaeo-valleys and an embayed shoreline along many Mediterranean coasts (Marriner and Morhange, 2007: 156; Marriner *et al*., 2014). The late Holocene slowdown and stabilization of sea-level rise accompanied by a high sediment supply resulted in enhanced coastal progradation, which damaged or buried many ancient harbours (Marriner and Morhange, 2007: 156).

Details remain elusive for these phenomena along the Sharon coastal plain, but with the slowing of sea-level rise, stream mouth bars and shoaling stream mouths probably dominated the sandy coastal plain. The topography in the study area favours the reconstruction of an embayment associated with a small estuary. We have illustrated a tentative location for a small estuary headed by wetlands circa 5000-2500 BP (Fig. 25). In doing so, we make the assumption that the modern topography is similar, though subdued by depositional filling, to the Pleistocene flooding surface, and thus low areas in the present topography indicate possible embayed areas during the early-middle Holocene. The proposed stream-estuary is oriented in the natural topographic swale that was previously present here, striking northwest directly from our core site to the present coastline (Fig. 10). The deep nature of deposits in Core 3729 Yafo-Migdal Hamayim to the west of the study area supports the existence of a palaeovalley.

Along the coastal plain of Israel, wetlands typically formed along streams as sediment transportation by longshore currents resulted in the accumulation of sand bars that blocked palaeo-stream mouths (Sivan *et al.,* 2011: 89–90; Elyashiv *et al.,* 2016: 259). Wetlands in the vicinity of Jaffa may have originated from springs or by the partial blocking of stream mouths, or both. The early-to-middle Holocene sediments in the study area contain macro charcoal (>1 millimetre) suggesting transportation by water (Scott, 2010), and these sediments lack faunal remains, which probably indicates arrival under terrestrial conditions (Units V and VI, Fig. 24). We interpret the early-middle Holocene deposits as having undergone transgression with sea-level rise, transitioning from a fluvial setting that was largely a sediment bypass zone to a micro-tidal uppermost estuary and associated wetlands influenced by a rising water table and sediment aggradation. The brackish conditions indicated by Biofacies B reveal a limited marine influence in the southeast study area (core Yafo 04) by ~5600 BP, as is expected based on the regional sea level record (Sivan *et al.,* 2004B: 327; Cohen-Seffer *et al.,* 2005: 116).

Above this sequence our sedimentological and microfossil interpretations, along with deposits in core 3729 Yafo-Migdal Hamayim, suggest a more open upper estuary setting to the northwest with moderate marine influence in the study area beginning no later than circa 4400 BP (Fig. 24). We believe that a narrow, restricted estuary existed northwest of the study area, with its head and transition to a fluvial environment found in our study area. The water bodies were probably surrounded by wetlands, and channel and beach sands (Unit VIII) are evidence for open fluvial-estuarine flow at this time (Fig. 24). Estuarine conditions, though diminishing in area over time, existed from the middle Holocene to 1700 BP or later. The low concentrations of marine fossils in these deposits could be due to a partial blockage of the palaeo-stream mouth by aeolian dunes or inshore sand bars derived from longshore transport, creating a protected and narrow estuarine setting. Sources of sand include the Nile littoral cell (e.g., Zviely *et al.,* 2007) and erosion at the Yafo headland by the transgressive shoreline. The present-day rate of relative sea-level change along the coast of Israel is -0.1 mm/yr according to glacial isostatic adjustment (GIA) models (Dean *et al.,* 2019: fig. 7), suggesting a maximum of ~50 centimetres of uplift in the region since the Mid-Holocene. The head of estuary deposits in the immediate study area lie 1.5-3 metres above present sea level and, therefore, marine influence at this point in the fluvial system may have been limited to storm surge.

Our palaeogeographic reconstruction raises the possibility that at Jaffa there existed a small estuary and stream, that could have served as a harbor, beginning no later than 4400 BP and continuing for, at present, an undetermined period. The width of such an embayment is unknown, and its mouth was likely protected by sand bars fed by longshore current. The fluvial system may have been over-widened due to blockage at its mouth, and ships could have anchored behind the sand beach or along the small estuary shoreline. The main harbour was likely located to the northwest of our immediate study area.

The probable shoreline deposit covered by artificial fill in core Yafo 06 (Unit VIII) reveals the possibility of an estuary or stream shoreline, or some type of moderate current energy until relatively recently. The harbour hypothesis must be explored, however, by additional work to the northwest of our study site and additional dating aimed at revealing the specific timing of environmental change.

Following the transgressive deposition of middle-late Holocene sediments, the freshwater wetlands represented by Biofacies C underwent aggradation and existed in the area at least as early as ~350 years ago. We recognize the potential for unconformities in the Holocene sequence, but without better chronological control we do not attempt to pinpoint these hiatuses. The final stage of wetlands represents the *Bassa* swamp known from historical maps from the end of the 18th century CE.

Conclusions

A review of the available historical evidence for the location of Jaffa's pre-Hellenistic era harbour and the record of coastal geomorphological change across the Mediterranean suggests the existence of a small marine re-entrant that could have served as an ancient harbour located to the east of Tel Yafo, including the general area of Bloomfield Stadium and Groningen Park. Multi-proxy analyses—sedimentology, palaeontology and dating—of the Holocene subsurface sequence in the study area enable deciphering of the evolving depositional environments. By circa 5000 BP the lower end of a small stream valley had been flooded by rising sea level and the partial blockage of the mouth by a sandy shoreline and nearshore bars. This small estuarine setting may have served as a protected harbour during pre-Hellenistic times. If such an estuarine harbour existed, it had gone out of use prior to the mid-second century BC and perhaps several centuries prior to this. Natural coastal processes and possibly human activity resulted in siltation of the embayment and concomitant aggradation and progradation of freshwater wetlands, leading to its eventual disappearance, a process common to natural harbors across the Mediterranean. The surface remains of the embayment consisted of the *Bassa* swamps known form historical maps and illustrations from the end of the 18th century AD.

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Appendix: Materials and Methods

We opened, photographed and thoroughly described all of the cores. We used five percent HCl to qualitatively determine carbonate content and defined colors with Munsell®, selecting Cores Yafo 04 and Yafo 16 as representative of the Holocene sedimentary sequence. These two cores underwent detailed sedimentological and micropalaeontological analyses at 10-centimetre resolution. The cores' chronologies derive from samples submitted for optically stimulated luminescence (OSL) at the Geological Survey of Israel (GSI) and by the accelerated mass-spectrometre (AMS) ^{14}C- technique at the Keck-Carbon Cycle AMS Facility, University of California, Irvine.

OSL samples were obtained from two duplicate boreholes, Yafo 204 and Yafo 216, representing Yafo 04 and Yafo 16, respectively. Duplicate cores were taken within two metres of the originals. To prevent any light affecting the OSL results, we first wrapped the Perspex tubes of these cores with opaque black tape prior to their insertion into the Geoprobe collection tube: upon retrieval we capped and sealed the tubes' extremities. Standard laboratory procedures served to extract and purify quartz (Porat, 2007). We determined equivalent doses (De) using the single-aliquot regenerative (SAR) dose protocol (Murray and Wintle, 2000; Wintle and Murray, 2006). For each sample, 17-24 aliquots were measured and averaged for age calculations using both the un-weighted mean and the central age model (Table B).

The single AMS ^{14}C dating derives from the carbonate of a terrestrial gastropod. Leaching with ~30% HCl (concentration determined by sample mass) at 70°C for 25 minutes removed potentially anachronistic secondary carbonates. Adding ~0.8 mL phosphoric acid (85 percent) and warming the sample at 70°C for 20 minutes allowed for the sample's evacuation and hydrolyzation.

Following conversion of the sample to graphite it was manually pressed into a target for the ^{14}C AMS measurement. The calibrated calendar age derives from applying the IntCal13 curve to the raw radiocarbon date via Calib 702 (Stuiver and Reimer, 1993; Reimer *et al*., 2013). The results have a statistical error of 2σ, or 95% confidence level (Table C).

To remove biogenic silica from cores Yafo 04 and Yafo 16, samples for particle-size analysis first received a 35 percent hydrogen-peroxide solution bath until reactions ceased (3-7 days), followed by being centrifuged, decanted, and leached for an hour in 0.1M NaOH at 85C. A 3 percent sodium hexametaphosphate solution coupled with a sonicating bath achieved deflocculation. To measure grain-size distribution we employed a Horiba LA-950 laser particle-size analyzer, which reports on a volume basis and has an effective range from 50 nanometres to 3 millimetres. For calculations, we employed a refractive index of 1.54 with an imaginary component of 0.1i. Samples were processed to remove pedogenic carbonate using acetic acid following the methods outlined in Poppe *et al*. (2001). Ten percent of the samples received duplicate runs.

For micropalaeontological analysis samples of approximately 20 g dry weight each were washed over a 63 μm sieve, dried, and reweighed. We identified benthic foraminifera, ostracods, and floral parts in the >63μm fraction, as well as molluscs >1000μm employing a six-point scale of relative abundance: absent (0); rare (1, <5 specimens); common (2, 5–10 specimens); frequent (3, 10–50 specimens); abundant (4, > 50 specimens); very abundant (5, > 200 specimens). We based our identification of taxa, to the species when possible or genera level, as well as their habitats, primarily on Cimerman and Langer (1991) for benthic foraminifera and on Martens

(1996) and Mischke *et al.* (2011) for ostracods. We identified and classified molluscs based mainly on Mienis (2012), Barash and Danin (1992), and Milstein *et al.* (2012) and evaluated the state of fossil preservation with a binocular microscope.

References

Aharoni, Y., Avi-Yonah, M., Rainey, A. F. and Safrai, Z. 1993, *The Macmillan Bible Atlas.* New York.

Albright, W. F., 1941, New Light on the Early History of Phoenician Colonization. *Bulletin of the American Schools of Oriental Research* **83,** 14-22.

Allen, J., 2001, Taking of Joppa, in D. Redford (ed.), *The Oxford Encyclopedia of Ancient Egypt*, vol. 3, 347-348, New York.

ANET³ = Ancient Near Eastern Texts Relating to the Old Testament. (Third ed. with supp.). J. B. Pritchard, (ed.), Princeton. 1969.

Anonymous, 1922, Reviving an Ancient Port. *Steam Shovel and Dredge* **32**, 25.

Antiquities = Josephus Flavius, *Jewish Antiquities*

Avi-Yonah, M., 1954, *The Madaba Map: With Introduction and Commentary.* Jerusalem.

Avigad, N., 1967, Jewish Rock-Cut Tombs in Jerusalem and in the Judaean Hill-Country. *Eretz Israel* **8,** 119-125, 172*. (Hebrew with English summary)

Avitsur, S., 1965, Earliest Projects for Improved Harbour Facilities at Jaffa. *Bulletin of the Museum Haaretz* **7**, 30-39.

Avnaim-Katav, S., Almogi-Labin, A., Sandler, A., Sivan, D., 2013, Benthic Foraminifera as Paleoenvironmental Indicators during the Last Million Years in the Eastern Mediterranean Inner Shelf. *Palaeogeography, Palaeoclimatology, Palaeoecology* **386**, 512–530.

Avnaim-Katav, S., Hyams-Kaphzan, O., Milker, Y., Almogi-Labin, A., 2015, Bathymetric Zonation of Modern Shelf Benthic Foraminifera in the Levantine Basin, Eastern Mediterranean Sea. *Journal of Sea Research* **99**, 97–106.

Avnaim-Katav, S., Sivan, D., Agnon, A., Almogi-Labin, A., 2016, Calcareous Assemblages of the Southeastern Mediterranean Low-tide Estuaries – Seasonal Dynamics and Paleo-environmental Implications**.** *Journal of Sea Research*, **108**, 30–49.

Avnaim-Katav, S., Almogi-Labin, A., Agnon, A., Porat, N., Sivan, D. 2017, Holocene Hydrological Events and Human Induced Environmental Changes Reflected in a Southeastern Mediterranean Fluvial Archive. *Palaeogeography, Palaeoclimatology, Palaeoecology* **468**, 263-275.

Avramovitch, R. and Grinberg, A., 2015, *Yafo - Home Port.* (Hebrew)

Baedeker, K., (ed.), 1876, *Palestine and Syria Handbook for Travellers*. London.

BAR = Ancient Records of Egypt I-V. J.H. Breasted, ed. London. 1988.

Barash, A. and Danin, Z., 1992, Fauna Palaestina: Mollusca 1 — Annotated List of Mediterranean Molluscs of Israel and Sinai. Israel Academy of Sciences and Humanities, Jerusalem.

Barton, G., 1903, Researches of the American School in Palestine. *Journal of Biblical Literature* **22** 2, 164-186.

Barton, G., 1904, *A Year's Wandering in Bible Lands*. Philadelphia.

Basch, L., 1987, *Le musée imaginaire de la marine antique*. Athens.

Boas, A. J., 2011, Frankish Jaffa, in *History and Archaeology of Jaffa* 1, 121-126.

Botta, P. and Flanding, E., 1849-1850, *Monument de Ninive* I. Paris.

Brückner, H., Vött, A., Schriever, A. and Handl, M., 2005, Holocene Delta Progradation in the Eastern Mediterranean –Case Studies in Their Historical Context. *Méditerranée* **104**, 95-106.

Büchler, A., 1899, The Nicanor Gate and the Brass Gate. *Jewish Quarterly Review* **11**, 46-63.

Burke, A. A., 2011, Early Jaffa: From the Bronze Age to the Persian Period, in *History and Archaeology of Jaffa* 1**,** 63-78.

Burke, K. S. 2011, Mamluk Jaffa: A Note, in *History and Archaeology of Jaffa* 1, 127-128.

CAD = The Assyrian Dictionary of the Oriental Institute of the University of Chicago

Casson, L., 1995, *Ships and Seamanship in the Ancient World.* Baltimore and London.

Cimerman, F. and Langer, M. R., 1991, *Mediterranean Foraminifera. Academia Scientarium et Aritium Slovenica, Dela, Opera 30, Classis IV: Historia Naturalis.*

Clermont-Ganneau, C., 1896, *Archaeological Researches in Palestine during the Years 1873-1874. Vol. 2.* John Macfarlane (trans.). London.

Clermont-Ganneau, C., 1903, Archeological and Epigraphic Notes on Palestine. *Palestine Exploration Fund Quarterly Statement* **36**, 125-131.

Cohen-Seffer, R., Greenbaum, N., Sivan, D., Jull, T., Barmeir, E., Croitoru, S. and Inbar, M., 2005, Late Pleistocene-Holocene Marsh Episodes along the Carmel Coast, Israel. *Quaternary International* **140/141**, 103-120.

de Saulcy, F. L., 1874, *Numismatique De La Terre Sainte.* Paris.

Dean, S. Horton, B.P. Evelpidou, N., Cahill, N., Spada, G., Sivan, D., 2019, Can We Detect Centennial Sea-level Variations over the Last Three Thousand Years in Israeli Archaeological Records? *Quaternary Science Reviews* **210**, 125–135.

Dickson, G., 1903, The Tomb of Nicanor of Alexandria. *Palestine Exploration Fund Quarterly Statement* **36**, 326-332.

EA = El Amarna

Elyashiv, H., Bookman, R., Zviely, D., Avnaim-Katav, S., Sandler, A., and Sivan, D., 2016, The Interplay between Relative Sea-level Rise and Sediment Supply at the Distal Part of the Nile Littoral Cell. *The Holocene* **26**, 248-264.

Faust, A. and Ashkenazy, Y., 2007, Excess in Precipitation as a Cause for Settlement Decline along the Israeli Coastal Plain during the Third Millennium BC. *Quaternary Research* **68**.1, 37-44.

Foran, D. 2011. Byzantine and Early Islamic Jaffa, in *History and Archaeology of Jaffa* 1*,* 109-120.

Frenzel, P., Boomer, I., 2005. The Use of Ostracods from Marginal Marine, Brackish Waters as Bioindicators of Modern and Quaternary Environmental Change. *Palaeogeography, Palaeoclimatology, Palaeoecology* **225**, 68-92.

Gardiner, A. H., 1911, *Egyptian Hieratic Texts Transcribed, Translated and Annotated:* Series I: *Literary Texts of the New Kingdom.* Part I. *The Papyrus Anastasi I and the Papyrus Koller, Together with the Parallel Texts.* Leipzig.

Geography = Strabo, 1930, *The Geography.* Vol 8: Books 15-16. H.L. Jones, trans. Cambridge.

Germain, L. 1921-1922, *Mollusques terrestres et fluviatiles de Syrie. Voyage zoologique d'Henri Gadeau de Kerville en Syrie*. Vols. 1-2. Paris.

Glanville, S. R. K., 1931, Records of a Royal Dockyard of the Time of Thutmose III: Papyrus Museum 10056: Part I. *Zeitschrift für Agyptische Sprache und Altertumskund* **66**, 105-121.

Glanville, S. R. K., 1932, Records of a Royal Dockyard of the Time of Thutmose III: Papyrus Museum 10056: Part II. Commentary. *Zeitschrift für Agyptische Sprache und Altertumskund* **68**, 7-41.

Goedicke, H., 1968, The Capture of Joppa. *Chronique d'Égypt* **86**, 219-233.

Golan, S., 2009, Tel Aviv, the Exhibition Grounds: Final Report. *Hadashot Arkheologiyot: Excavations and Surveys in Israel* **121**, 1187-1189.

Goldwasser, O. and Oren, E. D., 2015, Marine Units on the 'Ways of Horus' in the Days of Seti I. *Journal of Ancient Egyptian Interconnections* **7**.1, 25-38.

Gophen, M., Tsipris, Y., Meron, M. and Bar-Ilan, I., 2003, The Management of Lake Agmon Wetlands (Hula Valley, Israel). *Hydrobiologia*, **506**, 803–809.

Gophna, R., 2002, Elusive Anchorage Points Along the Israel Littoral and the Egyptian-Canaanite Maritime Route During Early Bronze Age I, in E. van den Brink and T. Levy (eds), *Egypt and the Levant: Interrelations from the 4th through the Early 3rd Millenium B.C.E.*, 418-421. London.

Grossmann, E., 2001, *Maritime Tel Michal and Apollonia: Results of the Underwater Survey 1989-1966*. BAR 915, Oxford.

Guggenheimer, H. W. (ed.) 2013, *The Jerusalem Talmud: Second Order: Mo'ed: Tractates* Pesahim *and* Yoma*. Edition Translation and Commentary.* Berlin.

Guide = Pausanias, *Guide to Greece:Central Greece*

Haddad, E., Goren, H., Artzy, M. and Sivan, D., 2020, The Appearance and Disappearance of Birket el-Kamar, Jaffa, Israel. *Palestine Exploration Journal* **152**.1, 27-43.

Hanauer, J., 1903A, The Traditional 'Harbour of Solomon' and the Crusading Castle at Jaffa. *Palestine Exploration Fund Quarterly Statement* **35**.3, 258-264.

Hanauer, J., 1903B, The Traditional 'Harbour of Solomon' at Jaffa. *Palestine Exploration Fund Quarterly Statement* **35**.4, 355-356.

Hilgartner, W.B. and Brush G. S., 2006, Prehistoric Habitat Stability and Post-settlement Habitat Change in a Chesapeake Bay Freshwater Tidal Wetland, USA. *The Holocene* **16**, 479-494.

Hill, G. F. H., 1914, *Catalogue of the Greek Coins of Palestine (Galilee, Samaria, and Judaea).* London.

History and Archaeology of Jaffa 1 = *The History and Archaeology of Jaffa* 1. M. Peilstöcker and A. A. Burke (eds). Los Angeles. 2011.

History and Archaeology of Jaffa 2 = 2017, *The History and Archaeology of Jaffa* 2. A. A. Burke, K. Strange Burke and M. Peilstöcker, (eds). Los Angeles. 2017.

Hoover, O. D., 2003, Seleucid Coinage of John Hyrcanus I: The Transformation of a Dynastic Symbol in Hellenistic Judaea. *American Journal of Numismatics* **15**, 29-39.

Jacobson, D. M., 2000, The Anchor on the Coins of Judaea. *Bulletin of the Anglo-Israel Archaeological Society* **18**, 73-79.

Jacotin, M., 1826, Carte topographique de l'Égypte et de plusieurs parties des pays limitrophes, levée pendant l'expédition de l'armée française, in *Description de l'Égypte, ou rescueil des observations et des recherches que ont été faites en Égypte pendant l'expedition de l'armée française* 8.) Paris.

Kaizer, T., 2011, Interpretations of the Myth of Andromeda at Iope. *Syria* **88**, 323-339.

Kapitän, G., 1984, Ancient Anchors–Technology and Classification. *International Journal of Nautical Archaeology* **13**, 33-44.

Kark, R., 1990, *Jaffa: A City in Evolution (1799-1917)*. G. Brand (trans.). Jerusalem.

Karmon, Y., 1959, Geographical Conditions in the Sharon Plain and Their Impact on Its Settlement. *Studies in the Geography of Eretz-Israel* **1**: I-III, {3-25}. (in Hebrew with English Summary).

Kindler, A., 1954, The Jaffa Hoard of Alexander Jannaeus. *Israel Exploration Society* **4**.3/4, 170-185.

Kindler, A., 1966, Maritime Emblems on Ancient Jewish Coins. *Sefunim* **1**, 15-20.

Kinneret Boat = S. Wachsmann (ed.) *The Excavations of an Ancient Boat in the Sea of Galilee (Lake Kinneret)*. *Atiqot* 19. Jerusalem.

Kloner, A. and Zissu, B., 2007, *The Necropolis of Jerusalem in the Second Temple Period.* Leuven.

Kraft, J., Brückner, H., Kayan, I. and Engelmann, H., 2007, The Geographies of Ancient Ephesus and the Artemision in Anatolia. *Geoarchaeology* **22**.1, 121-149.

Lambeck, K., Antonioli, F., Purcell, A., Sergio, S., 2004, Sea-level Change along the Italian Coast for the Past 10,000 yr. *Quaternary Science Reviews* 23, 1567–1598.

Le Strange, G. (trans.), 1886, *Description of Syria, Including Palestine by Mukaddasi (Circ. 985 A.D.).* London.

Levine, L., 2002, *Jerusalem: Portrait of the City in the Second Temple Period (538 B.C.E.-70 C.E.).* Philadelphia.

Lichter, M., Zviely, D., Klein, M., 2010. Morphological Patterns of Southeastern Mediterranean River mouths: The Topographic Setting of the Beach as a Forcing Factor. *Geomorphology* **123,** 1–12.

Lichter, M., Klein, M., Zviely, D., 2011. Dynamic Morphology of Small South Eastern Mediterranean River Mouths: A Conceptual Model. *Earth Surface Processes and Landforms* **36**.4, 547–562.

Light, H. (ed.), 1818, *Travels in Egypt, Nubia, Holy Land, Mount Libanon and Cyprus in the Year 1814.* London.

Lin, S.-H. S., 2003, Lading of the Late Bronze Age Ship at Uluburun, *Texas A&M University.*

Lipiński, E., 2004, *Itineraria Phoenicia.* Studia Phoenicia 18. Leuven.

Lynch, W. F., 1850, *Narrative of the United States' Expedition to the River Jordan and the Dead Sea.* Philadelphia.

MacGregor, J., 1870, *The Rob Roy on the Jordan, Nile, Red Sea, and Gennesareth, &C.: A Canoe Cruise in Palestine and Egypt, and the Waters of Damascus.* New York.

Madden, F. W., 1881, *Coins of the Jews.* London.

Marriner, N. and Morhange, C., 2005, Under the City Centre, the Ancient Harbor. Tyre and Sidon. *Journal of Cultural Heritage* **6**, 183-189.

Marriner, N. and Morhange, C., 2006, Geoarchaeological Evidence for Dredging in Tyre's Ancient Harbour, Levant. *Quaternary Research* **65**, 164-171.

Marriner, N. and Morhange, C., 2007, Geoscience of Ancient Mediterranean Harbours. *Earth-Science Reviews* **80**, 137-194.

Marriner, N., C. Morhange, M. Boudagher-Fadel, M. Bourcier, and P. Carbonel, 2005, Geoarchaeology of Tyre's Ancient Northern Harbour, Phoenicia. *Journal of Archaeological Science* **32**, 1302-1327.

Marriner, N., Morhange, C. and Doumet-Serhal, C., 2006A, Geoarchaeology of Sidon's Ancient Harbours, Phoenicia. *Journal of Archaeological Science* **33**, 1514-1535.

Marriner, N., Morhange, C., Doumet-Serhal, C. and Carbonel, P., 2006B, Geoscience Rediscovers Phoenicia's Buried Harbors. *Geology* **34**, 1-4.

Marriner, N., Morhange, C. and Carayon, N., 2008A, Ancient Tyre and Its Harbours: 5000 Years of Human-Environment Interactions. *Journal of Archaeological Science* **35**, 1281-1310.

Marriner, N., Morhange, C. and Saghieh-Beydoun, M., 2008B, Geoarchaeology of Beirut's ancient harbour, Phoenicia. *Journal of Archaeological Science* **35**, 2495-2516.

Marriner, N., Morhange, C., Kaniewski, D. and Carayon, N., 2014, Ancient Harbour Infrastructure in the Levant: Tracking the Birth and Rise of New Forms of Anthropogenic Pressure: *Scientific Reports*, **4**, no. 5554. (June 2021, https://doi.org/10.1038/srep05554)

Martens, K., 1996, On Heterocypris reptans (Kaufmann, 1900) (Ostracoda) Cyprididae, a New Record of Israel. *Israel Journal of Zoology* **42**, 287-291.

Mazar, A., 1990, *Archaeology of the Land of the Bible: 10,000-586 B.C.E.* New York.

Meshorer, Y., 1982A, *Ancient Jewish Coinage* I: *Persian Period through Hashmonaeans.* Dix Hills, NY.

Meshorer, Y., 1982B, *Ancient Jewish Coinage* II: *Herod the Great through Bar Cochba.* Dix Hills, NY.

Meshorer, Y., 1985, *City Coins of Eretz Israel and the Decapolis in the Roman Period.* Tel Aviv.

Mienis, H. K. and Ashkenazi, S., 2011, Lentic Basommatophora Molluscs and Hygrophilous Land Snails as Indicators of Habitat and Climate in the Early-Middle Pleistocene (0.78 Ma) at the Site of Gesher Benot Ya'aqov (GBY), Israel. *Journal of Human Evolution* **60**, 328-340.

Mienis, H.K., 2012, Inland Water Molluscs of Israel. June 2020, http://www.nature-of-oz.com/freshwater.htm

Milstein, D., Mienis, H. K. and Rittner, O., 2012, *A Field Guide to the Mollusks of Inland Waters of the Land of Israel.* Nature and Parks Authority, Jerusalem (Hebrew).

Mirkin, D., 2017, The Ottoman Port of Jaffa: A Port without a Harbor, in *The History and Archaeology of Jaffa 2*, 121-156.

Mirkin, D. and Goren, H., 2012, Jaffa: A Port Without a Port: Failure of Nineteenth-Century Plans to Build a Modern Deep-Water Port. *Cathedra* **143**, 133-152, 209, 212. (Hebrew)

Mischke, S., Herzschuh, U., Sun, Z., Qiao, Z., Sun, N. and Zander, A. M., 2006, Middle Pleistocene Ostracoda from a Large Freshwater Lake in the Presently Dry Qaidam Basin (NW China). *Journal of Micropalaeontology*, **25**, 57-64.

Mischke, S. and Zhang, C., 2011, Ostracod Distribution in Ulungur Lake (Xinjiang, China) and a Reassessed Holocene Record. *Ecological Research* **26**, 133-145.

Mischke, S., Ginat, H., Al-Saqarat, B., Almogi-Labin, A., 2012, Ostracods from Water Bodies in Hyperarid Israel and Jordan as Habitat and Water Chemistry Indicators. *Ecological Indicators* **14,** 87–99.

Mischke, M., Almogi-Labin, A., Al-Saqarat, B., Rosenfeld, A., Elyashiv, H., Boomer, I., Stein, M., Lev, L.and Ito, E., 2014, An Expanded Ostracod-based Conductivity Transfer Function for Climate Reconstruction in the Levant. *Quaternary Science Reviews* **93**, 91-105.

Moore, G. and Barton, G., 1903, Second Annual Report of the Managing Committee of the American School for Oriental Study and Research in Palestine. *American Journal of Archaeology* **7**, 33-44.

Morris, E.F., 2005, *The Architecture of Imperialism: Military Bases and the Evolution of Foreign Policy in Egypt's New Kingdom*. Problem der Ägyptologie 22. Leiden.

Murray, A. and Wintle, A.G., 2000, Luminescence Dating of Quartz Using an Improved Single-aliquot Regenerative-dose Protocol. *Radiation Measurements* **32**, 57-73.

Nadich, J., 1983, *Jewish Legends of the Second Commonwealth.* Philadelphia.

Natural History = Pliny, *Natural History,* Volume I: Books 1-2. Translated by H. Rackham. Cambridge, MA. 1997.

Notley, R. S., 2011, Graeco-Roman Jaffa and Its Historical Background, in *History and Archaeology of Jaffa* 1, 95-107.

Nun, M., 1988, *Ancient Anchorages and Harbours around the Sea of Galilee.* Ein Gev.

Ormerod, H., 1987, *Piracy in the Ancient World: An Essay on Mediterranean History.* Liverpool.

Patai, R., 1998, *The Children of Noah: Jewish Seafaring in Ancient Times.* With contributions from James Hornell and John M. Lundquist. Princeton.

Peltier, W. R. and Fairbanks, R.G., 2006, Global Glacial Ice Volume and Last Glacial Maximum Duration from an Extended Barbados Sea Level Record. *Quaternary Science Reviews* **25**, 3322-3337.

Penney, D.N., 1987, Application of Ostracoda to Sea-Level Studies. *Boreas* **16**, 237–247.

Pococke, R., 1745. *A Description of the East and Some Other Countries. Vol. II. Part I. Observations on Palæstine or the Holy Land, Syria, Mesopotamia, Cyprus and Candia.* London, W. Bowyer. (June 2021, https://archive.org/details/gri_33125009339611).

Poppe, L. J., Paskevich, V. F., Hathaway, J. C., Blackwood, D.S., 2001, A Laboratory Manual for X-ray Powder Diffraction. U. S. Geological Survey Open-File Report 01-041.

Porat, N., 2007, Analytical Procedures in the Luminescence Dating Laboratory. Geological Survey of Israel. Report TR-GSI/08/2007. (Hebrew)

Porat, N., Sivan, D., Zviely, D. 2008, Late Holocene Embayment Infill and Shoreline Migration, Haifa Bay, Eastern Mediterranean. *Israel Journal of Earth Sciences* **57**: 21-31.

Raban, A., 1985, The Ancient Harbors of Israel in Biblical Times (from the Neolithic Period to the End of the Iron Age), in A. Raban (ed.), *Harbor Archaeology*. BAR **257**, 11-44. Oxford.

Raban, A. and Galili, E., 1985, Recent Maritime Archaeological Research in Israel–A Preliminary Report. *International Journal of Nautical Archaeology* **14**, 321-356.

Rahmani, L. Y., 1967, Jason's Tomb. *Israel Exploration Journal* **17**, 61-100.

Rainey, A. and Notley, R., 2006, *The Sacred Bridge: Carta's Atlas of the Biblical World*. Jerusalem.

Reimer, P. J., Bard, E., Bayliss, A., Beck, J. W., Blackwell, P. G., Bronk Ramsey, C., Grootes, P. M., Guilderson, T. P., Haflidason, H., Hajdas, I., Hattž, C., Heaton, T. J., Hoffmann, D. L., Hogg, A. G., Hughen, K. A., Kaiser, K. F., Kromer, B., Manning, S. W., Niu, M., Reimer, R. W., Richards, D. A., Scott, E. M., Southon, J. R., Staff, R. A., Turney, C. S. M. and van der Plicht, J., 2013, IntCal13 and Marine13 Radiocarbon Age Calibration Curves 0-50,000 Years cal BP. *Radiocarbon* **55**, 1869-1887.

Rogers, M. E., 1881, Maritime Cities and Plains of Palestine, in C. W. Wilson (ed.) *Picturesque Palestine, Sinai and Egypt*, 109-144. London.

Romer, F. E., 2001, *Pomponius Mela's Description of the World.* Ann Arbor.

Runciman, S., 1992, *A History of the Crusades* I: *The First Crusade and the Kingdom of Jerusalem.* Cambridge.

Sade, A., Hall, J.K., Golan, A., Amit, G., Gur-Arie, L., Tibor, G., Ben-Avraham, Z., Ben-Dor, E., Fonseca, L., Calder, B.R., Mayer, L.A., de Moustier, C.P., 2006, Acoustic Backscatter at 95 kHz from the Mediterranean Seafloor off Northern Israel. Geological Survey of Israel.

Saewulf = Lord Bishop of Clifton, (trans.), *Saewulf (1102, 1103 A.D.).* London. 1896.

Säve-Söderbergh, T., 1946, *The Navy of the Eighteenth Dynasty*. Uppsala.

Scott A.C., 2010, Charcoal Recognition, Taphonomy and Uses in Palaeoenvironmental Analysis. *Palaeogeography, Palaeoclimatology, Palaeoecology* **291**, 11–39.

Shacham, T., 2011, Jaffa in Historical Maps (1799-1948), in *History and Archaeology of Jaffa* 1, 137-174.

Sharvit, J. and Galili, E., 2002, Yafo Harbor, Underwater Surveys. *Hadashot Arkheologiyot – Excavations and Surveys in Israel* **114**, 54-55.

Shipley, G. (ed.), 2019, *Pseudo-Skylax's Periplous: The Circumnavigation of the Inhabited World: Text, Translation and Commentary.* Liverpool. Second Edition.

Shtienberg, G., Dix, J.K., Roskin, J., Waldmann, N., Bookman, R., Bialik, O.M., Porat, N., Taha, N., Sivan, D. 2017, New Perspectives on Coastal Landscape Reconstruction during the Late Quaternary: A Test Case from Central Israel. *Palaeogeography, Palaeoclimatology, Palaeoecology* **468**, 503–519.

Simons, J. J., 1937, *Handbook for the Study of Egyptian Topographical Lists Relating to Western Asia.* Leiden.

Sivan, D., Wdowinski, S., Lambeck, K., Galili, E. and Raban, A., 2001, Holocene Sea-Level Changes along the Mediterranean Coast of Israel, Based on Archaeological Observations and Numerical Model. *Palaeogeography, Palaeoclimatology, Palaeoecology* **167**, 101-117.

Sivan, D., Eliyahu, D. and Raban, A., 2004A, Late Pleistocene to Holocene Wetlands Now Covered by Sand, along the Carmel Coast, Israel, and their Relation to Human Settlement: An Example from Dor. *Journal of Coastal Research* **204,** 1035–1048.

Sivan, D., Lambeck, K., Toueg, R., Raban, A., Porat, Y., Shirman, B., 2004B, Ancient Coastal Wells of Caesarea Maritima, Israel, an Indicator for Sea-level Changes during the last 2000 years. *Earth and Planetary Science Letters* **222,** 315–330.

Sivan, D., Greenbaum, N., Cohen-Seffer, R., Sisma-Ventura, G., Almogi-Labin, A., 2011, The Origin and Disappearance of the Late Pleistocene–Early Holocene Short-lived Coastal Wetlands along the Carmel Coast, Israel. *Quaternary Research* **76,** 83–92.

Sivan, D., Greenbaum, N., Cohen-Seffer, R., Sisma-Ventura, G., Almogi-Labin, A., Porat, N., Melamed, Y., Boaretto, E. and Avnaim-Katav, S., 2016, Palaeo-environmental Archive of Groundwater–surface Water Interaction Zone, the Kebara Wetlands, Carmel. *Quartenary Journal* **396,** 138-149.

Smith, G. A., 1920, *The Historical Geography of the Holy Land: Especially in Relation to the History of Israel and of the Early Church.* New York.

Sneh, A. and Rosensaft, M., 2008, Geological Map of Israel, Tel Aviv Sheet 7-II: Geological Survey, State of Israel, Ministry of National Infrastructures. Jerusalem, 1:50,000.

Soulie-Marsche, I. and Garcia, A., 2015, Gyrogonites and Oospores, Complementary Viewpoints to Improve the Study of the Charophytes (Charales). *Aquatic Botany* **120**, 7-17.

Stager, L. E., 1989, The Song of Deborah: Why Some Tribes Answered the Call and Others Did Not. *Biblical Archaeology Review* **15**.1, 50-64.

Steffy, J. R., 1990, The Boat: A Preliminary Study of Its Construction, in *Kinneret Boat*, 29-47.

Steffy, J. R., 1994, *Wooden Ship Building and the Interpretation of Shipwrecks.* College Station.

Stern, M., 1974, *Greek and Latin Authors on Jews and Judaism.* Jerusalem.

Stewart, A., (ed. & trans.), 2013, *Ludolph von Suchem's Description of the Holy Land and of the Way Thither: Written in the Year A.D. 1350.* Cambridge.

Stuiver, M. and Reimer, P.J., 1993, Extended 14C Database and Revised CALIB Radiocarbon Calibration Program. *Radiocarbon* **35**, 215-230.

Thackeray, H. S. J. (Translator), 1961A, *Josephus: With an English Translation by H. St. J. Thackeray, in Nine Volumes* II: *The Jewish War, Books* I-III. London and Cambridge MA

Thackeray, H. S. J. (Translator), 1961B, *Josephus: With an English Translation by H. St. J. Thackeray, in Nine Volumes* III: *The Jewish War, Books* IV-VII. London and Cambridge MA.

Tolkowsky, S., 1924, *The Gateway of Palestine: A History of Jaffa*. London.

Twain, M., 1899, *The Innocents Abroad, or, The New Pilgrims' Progress: Being Some Account of the Steamship Quaker City's Pleasure Excursion to Europe and the Holy Land.* New York.

Votruba, G. F., 2014, Iron Anchors and Mooring in the Ancient World (Until ca. 1500 CE), *Wolfson College*.

Wachsmann, S., 1990A, Ships of Tarshish to the Land of Ophir: Seafaring in Biblical Times. *Oceanus* **33**.1, 70-82.

Wachsmann, S., 1990B, Literary Sources on Kinneret Seafaring in the Roman-Byzantine Period, in *Kinneret Boat*, 111-114.

Wachsmann, S., 1990C, First Century CE Kinneret Boat Classes, in *Kinneret Boat*, 119-124.

Wachsmann, S., 1998, *Seagoing Ships & Seamanship in the Bronze Age Levant*. College Station.

Wachsmann, S., 2000, Some Notes on Mediterranean Seafaring During the Second Millennium B.C., in S.Sherratt, (ed.), *Proceedings of the First International Symposium, The Wall Paintings of Thera.* (*Petros M. Nomikos Conference Centre, Thera, Hellas, 30 August - 4 September 1997*). Vol. 2, 803-824. Athens.

Wachsmann, S., 2009, *The Sea of Galilee Boat.* College Station.

Wachsmann, S., 2014, The 2014 Ioppa Maritima Project: The Land Survey. An INA Team Searches for Shipwrecks in Israel without Setting Foot in Water. *INA Quarterly* **41**.3, 20-25.

Wachsmann, S., 2015, 'Rafts by Sea to Jaffa' (2 Chronicles 2, 16): The 2014 Ioppa Maritima Project. *Skyllis (Deutsche Gesellschaft zur Förderung der Unterwasserarchäeologie e.V.)* **15**.1: 40-45.

Wachsmann, S., Inglis, D., Lickliter-Mundon, M., Morriss, V. and Perdue, H., 2014, 2014 Ioppa Maritima Project: The Deep-Sea Survey, An INA Team Searches for Shipwrecks in Israel Using Multibeam Sonar and an ROV. *INA Quarterly* **41**.4, 16-19.

War = Josephus, *The Jewish War.*

Wasylikowa, K., 2005, Palaeoecology of Lake Zeribar, Iran, in the Pleniglacial, Lateglacial and Holocene, Reconstructed from Plant Macrofossils. *The Holocene* **15**, 720-735.

Wente, E.F. 2002. The Capture of Jaffa, in *The Literature of Ancient Egypt: An Anthology of Stories, Instructions, and Poetry,* Simpson, W. K. (ed.), 72-74. New Haven.

Williams, J. I. and Burke, A. A., 2016, 'You Have Entered Joppa:' 3D Modeling of Jaffa's New Kingdom Egyptian Gate. *Near Eastern Archaeology* **79**.4, 260-270.

Wintle, A.G. and Murray, A. S., 2006, Review of Quartz Optically Stimulated Luminescence Characteristics and their Relevance in Single-aliquot Regeneration Dating Protocols. *Radiation Measurements* **41**, 369-391.

Zviely, D., Kit, E., Klein, M., 2007, Longshore sand transport estimates along the Mediterranean coast of Israel in the Holocene. *Marine Geology* **238**, 61–73.

Tables

Borehole	Coordinates (Israel transverse Mercator [ITM])		Elevation (m)	Core Length (m)
	Longitude (E)	Latitude (N)		
Yafo 01	177859.979	662143.83	6.576	10.8
Yafo 04	177872.874	662067.062	7.784	10.25
Yafo 06	177832.979	662000.276	7.418	10.8
Yafo 10	177755.335	662019.373	6.413	13.2
Yafo 16	177737.449	662130.292	6.327	12.0
Yafo 18	177788.536	662124.471	6.319	12.0

Table A. The locations, elevations and lengths (m) of the sediment cores. Elevations have a ~2-centimetre precision.

<<NOTE TO EDITOR: Insert here Table B.docx>>

<<The png below of Table B is meant as a place holder>>

CORE	DEPTH (CM)	LAB CODE	WATER (%)	K (%)	U (PPM)	TH (PPM)	ALPHA (μGy/a)	BETA (μGy/a)	GAMMA (μGy/a)	COSMIC (μGy/a)	DOSE RATE (μGy/a)	O-D (%)	NO. ALIQUOTS	DE (GY)	AGE (KA)	CAM AGE (KA)
204C	335-345	JAF-1	20	0.41	1.1	2.9	3	399	295	139	836±31	52	24/25	0.26±0.13	0.31±0.16	0.29±0.03
204D	370-380	JAF-2	20	0.89	2.7	5.9	7	892	653	133	1685±65	18	18/18	0.61±0.12	0.36±0.07	0.36±0.02
204E	495-505	JAF-3	20	0.68	1.8	5.1	5	665	498	116	1285±51	16	18/18	7.2±1.3	5.6±1.0	5.6±0.3
204E	520-530	JAF-4	15	0.76	1.6	4.8	5	719	507	114	1346±48	19	17/18	12.9±1.8	9.6±1.4	9.4±0.5
216D	445-460	JAF-6	25	1.03	2	9.7	8	924	730	121	1783±82	10	18/18	7.9±0.9	4.4±0.5	4.4±0.2
216G	825-835	JAF-7	20	0.61	1.1	5.6	5	565	440	82	1092±45	21	18/18	16.0±3.9	14.6±3.6	14.3±0.9

Table B. Optically stimulated luminescence (OSL) data for Yafo cores. Grain size for all samples: 125-150µm. Water content estimated at 50% of saturation values (with an error of ±25%), based on grain size distribution. Error on burial depth – 10 cm. O-D — over-dispersion, a measure of the internal sample scatter. No. aliquots —the number of aliquots used to calculate the De and age out of those measured. CAM — central age model.

					^{14}C Age (BP)			
UCIAMS Lab No.	Borehole	Depth (m)	Elevation (m)	Dated Material	Uncalibrated Age	Calibrated Age Range	Calibrated Age (Median)	Error
168425	Yafo 04D	4.47	3.3	Gastropod*	1820 ± 15	1714-1815	1764.5	50.5

* Land snail (*Xeropicta vestalis*).

Table C. AMS ^{14}C dating results. Calibration via Calib 702 (Stuiver and Reimer, 1993; Reimer *et al.*, 2013).

Captions

1 Map of the eastern Mediterranean (Map: D. Davis).

2 Map of the central and southern Levantine coast. On the location of Yarimuta, in the vicinity of Beirut, see Morris, 2005: 228-229 (Map: D. Davis).

3 Reconstruction of the Ramesses II fortress gateway, which faces east towards el-Bassa (Photo: A. Burke).

4 A relief from Sargon II's palace at Khorsabad depicts Phoenician ships towing logs (Courtesy: Louvre. Photo: Shelley Wachsmann).

5 Andromeda's Rock as the feature survives today at the entrance to Jaffa's rocky western harbour (Photo: A. Burke).

6 Ship graffiti in Jason's Tomb in the Rechavia district of Jerusalem. Hellenistic period (Courtesy *Israel Exploration Journal* **Vol. 17**: 70 fig. 5a, 71 fig. 5b, from Rahmani, 1967).

7 Autonomous city coin of Jaffa portraying a galley. The coin was minted after Pompey removed Jaffa, together with the other coastal cities, from Hashmonaean rule (From de Saulcy, 1874: pl. IX: 4).

8 World War I-era photo of Jaffa harbour showing Andromeda's Rock, prior to the Mandatory period removal of some of the more dangerous obstructions (Courtesy State Library of New South Wales. Photo: Frank Hurley).

9 A) Geological map of the southern Sharon and the continental shelf including the study area. The yellow line represents the present coastline. The arrow points to the gap between the *kurkar* ridge forming Tel Yafo and the lower-lying rocky element north of the tell, which corresponds to the small valley outlet found in this location prior to urban development. B) Structural map of the southern Sharon and the continental shelf. Faults are shown as solid lines with tick marks indicating the down-thrown (down-faulted) side. Note that el-Bassa and the former small valley (of A, above), located east and northeast of Jaffa, respectively, are situated above a structural graben, or a down-dropped basin (after Gvirtzman, 1990: 20, 46).

10 Topography in the vicinity of Jaffa, which is dominated by NNE-SSW trending bedrock ridges. The natural drainage to the sea is just north of Jaffa and the potential stream system, prior to extensive urbanization, is indicated with a blue dashed line. 'GG' indicates the location of modern Groningen Gardens (GG), which is the location of sediment cores taken for this study. The former position of a lake/wetland, known from the late 18th century, can be seen in the southeast corner of the map (Base map: U.S. Army Corps of Engineers, 1958).

11 The modern artificial fill covering the view from Jaffa, facing north (Photo: S. Wachsmann).

12 Georectified version of one of M. Jacotin's maps above an orthophoto of modern Jaffa. The outline of the fortified city of Jaffa in Jacotin's map appears highlighted in red. The yellow line indicates the orientation of Ramesses II's gate (Fig. 3) on Tel Yafo and its

correlation with the southern limits of the *flaque d'eau* on Jacotin's map (After Shacham, 2011: 148 fig. 13.7. Georectification: K. Kowalski).

13 A) Map of the Jaffa region by M. Jacotin, 1798. Note that in this map the Ayalon River drains north to the Yarkon River. A stream drains north from an unnamed lake east of the Bassa and into the Yarkon. The location of this lake appears in Fig. 10, where a large flat plain existed in the 1950s (see also Fig. 16 [lower left]). There appears to be a spatial error in the 1798 map, with greater distance between the lake and the Ayalon River than is physically possible. B) Detail of the environs of Jaffa (After Jacotin, 1826: Flle 44 [Jérusalem et Jaffa]).

14 The location of el-Bassa, marked as 'Ancient Harbour' to the east of Jaffa on a map published by the Reverend J. Hanauer (From Hanauer 1903A: 258).

15 A) A greatly shrunken pool appears on this map of Jaffa and its environs published by the Palestine Exploration Fund in 1880. B) Detail (From Shacham, 2011: 156 fig. 13.17).

16 Map of Jaffa and its environs prepared by M Jacotin in 1799. Note the ancient drainage outlet through a gap in the bedrock ridge or dune line (From Shacham 2011: 146 fig. 13.4).

17 Map of the 1799 French assault on Jaffa published by A.-J. Denain & Delamare, 1830–1831, showing an ancient drainage outlet through a gap in the bedrock ridge or dune line (After Shacham, 2011: 144 fig. 13.2).

18 David Roberts’1839 painting of Jaffa as viewed from the northeast. Note the flat area (dry alluvial plain?) to the left of the city. Jaffa lies on a *kurkar* ridge, the continuation of which forms the ridge in the foreground (From Wikimedia commons, June 2021, https://upload.wikimedia.org/wikipedia/commons/c/cc/Jaffa_ancient_Joppa_April_16th_1839_-_David_Roberts%2C_R.A._LCCN2002717506.jpg).

19 Locations of cores taken by the Jaffa Municipality in 1933 and 1964 within el-Bassa basin together with the location of cores recovered in 2014 by the Ioppa Maritima Project. The NW-SE cross section shown in Fig. 24 is indicated by the red line, with yellow lines showing projection of cores into the line of section. (Map: K. Kowalski).

20 Lithologic logs plotted relative to present mean sea level, with ages of OSL and ^{14}C samples (Diagram: R. Dunn and S. Avnaim-Katav).

21 Photograph of core Yafo 10; top is upper left, base is lower right. Geoprobe tubes, most at 1.2 m length, have been split open and both halves are shown. Depth below the surface, in metres, is shown above each tube. The top 2.4 m (tubes A & B) are not shown and consisted of artificial fill, which is seen in tube C to a total depth of 3.0 m (Photo: R. Dunn).

22 Sedimentological and faunal characteristics of borehole Yafo 04. See Fig. 20 for lithological symbols. Vertical scale in centimetres (Diagram: S. Avnaim-Katav).

23 Sedimentological and faunal characteristics of borehole Yafo 16. See Fig. 20 for lithological symbols. Vertical scale in centimetres (Diagram: S. Avnaim-Katav).

24 Lithological cross section with Pleistocene units grouped for simplicity. Cores have been projected into a NW-SE trending section (see Fig. 19 for locations). Biofacies were established in cores Yafo 04 and Yafo 16 and are overprinted here. Paleoenvironmental interpretations are based on sedimentology, paleontology, and geometry of units. See Fig. 20 for lithological symbols (Diagram: R. Dunn and S. Avnaim-Katav).

25 Paleogeographic reconstruction for the late second millennium BC, which occurs in the time of maximum estuarine expansion, between approximately 5500 to 1700 BP (see Fig. 24) . The topography of the study area is based on Fig. 10 (Map: R. Dunn).

Endnotes

[1] For the purposes of this discussion the terms *port* and *harbour* distinguish between a settlement's role as a location frequented by shipping (a *port*) as opposed to a protected location where ships could shelter, irrespective of their natural, manmade, or combined origins (a *harbour*). This distinction recognizes that a port can lack a proper harbour. Anchorages could allow ships to anchor offshore while employing lighters, or similar vessels, to transfer cargoes despite a difficult coastline. A single port city may have multiple contemporaneous harbours serving different functions as is the case today, for example, with Haifa and Athens. Also, a port might relocate harbour facilities over time due to natural or human causes, as we propose here regarding Jaffa.

[2] On the city's general history, see Tolkowsky, 1924; Kark, 1990; Rainey and Notley, 2006; *History and Archaeology of Jaffa* 1.

[3] Compare 'Fair Havens' on Crete where St. Paul's merchantman anchored on his way to Rome (*CAD:* 325; Acts 27:8).

[4] A.F. Rainey and R.S. Notely (2006: 66) suggest that the city was taken during the march to Megiddo from Gaza. Alternately, E.F. Morris (2005: 138 n. 89) proposes that the conquest of Jaffa took place during the seven-month siege of Megiddo noting, 'A battle on the march from Gaza to Megiddo would have been pressed for time and should have been mentioned in the annals, while subsequent to the first campaign, the southern coast of Canaan was firmly in the hands of the Egyptians.'

[5] This must be seen in relation to contemporaneous activity at the Egyptian shipyard of *Prw nfr*, eight months of records from which survive in Papyrus BM 10056 (Glanville 1931; 1932; Säve-Soderbergh 1946: 37; Wachsmann 1998: 223-224). *Prw nfr* was under the direct control of the crown prince (Amenhotep II), making it likely that the work there was military in nature.

[6] In the Song of Deborah, considered one of the earliest parts of the Bible, the prophetess chastises the tribe of Dan for its absence at the battle of Mt. Tabor (Judges 5:17): 'And Dan, why did he abide with the ships?' Scholars generally concur that Dan never inherited the coastal region in the *vicinity* of Jaffa originally assigned to them: the tribe is said to have eventually moved north, conquering the city of Laish, which they renamed Dan (Joshua19:40-48; Judges 18:1). Some scholars see the nautical connection in the Song of Deborah as a reference to the involvement of Danites working for others in seafaring activity in Jaffa and its region prior to the tribe's northward peregrinations (Stager, 1989: 63-64; Aharoni *et al.,* 1993: 56 map 64).

[7] All quoted texts from the Bible and Apocrypha use the New Revised Standard Version (NRSV) translations.

[8] W.F. Albright (1941: 22) denied the geographical meaning of the term, considering the reference to Tarshish as indicative of a 'refinery' ship, which 'brought the smelted metal home from the colonial mines.' This does not fit the narrative, however, in the Book of Jonah in which Tarshish appears as a destination. Ezekiel (27:12) emphasizes the importance of metals—'silver, iron, tin and lead'—from Tarshish, a location which most likely equates with the contemporaneous Iberian Tartessian culture (Lipiński, 2004: 225-265). If this identification is correct then, for Jonah, Tarshish would have represented a quite literal 'end of the earth'—an

Ultima Thule—making it an eminently reasonable travel destination for someone desperately trying to escape the wrath of an all-seeing Deity (Lipiński, 2004: 228).

[9] Over two centuries later, Josephus used the same term for boats on the Sea of Galilee during the Jewish War (AD 66-70) in the context of the nautical battle of Migdal (AD 69) (*War* 2.635; Wachsmann 1990C: 120). Josephus recounts that these vessels were 'small and built for piracy' (*War* 3:325). This is a decidedly odd comment given that the Sea of Galilee is only 12 by 24 kilometres, making it much too small for pirates to avoid detection. Josephus does not, however, state that they were *used* in that manner: he presumably meant that this inland type of craft had characteristics common with those coastal vessels used by pirates, who in antiquity often carried out their nefarious activities near shore in small craft (Ormerod, 1987: 26-28). In such cases, a shallow draft became vital to facilitate beaching as well as to allow escape into waterways inaccessible to larger pursuing craft. The Kinneret Boat, which had been about 9 metres long before the removal in antiquity of her bow assembly and sternpost, has a flat-bottomed profile amidships with a remarkably hard turn of the bilge suitable for just such purposes (Steffy, 1990: 40, 42 fig. 5.13; 1994: 65, 67 fig. 3-53).

[10] The nautical symbols include both wooden and iron anchors, the *aphlaston*, a galley, a galley's prow and a galley lacking a ram. See Meshorer, 1982A: 49 Group A, 61-62, 80; John Hyrcanus I: Meshorer, 1982A: 39 fig. 1; Jacobson 2000: 74-75; Alexander Yannai: [anchor] 118-122, pls. 4: Aa1-6, Aa1P, Ab1-7, 5-7; Meshorer, 1982B: Herod the Great: [*aphlaston*] 18, 235, pl. 1: 5-6, [anchor] 26, 237-238, pls. 2: 17aFBS, 17b-h, 3: 18-18a. 19, 19a-b 20, 20a, 21-22, 22a-b, [galley] 28, 238, pl. 3: 22, 22a-b; Herod Archelaus [galley] 31-32, 239-240, pls. 4: 3, 3a-h, 5: 4, 4a-d**,** [anchor] 239, pls. 4:1, 1a-f, 2, 2a-c, [galley's prow] 240-241, pls. 5: 5, 5a-g; Agrippa II [anchor]

250, 253 pls. 11: 4, 4a, 5, 13: 21 [galley] 253, pls. 13: 18, 18a, [galley lacking ram] 253, pl. 13: 20, 20a. On the identity of the merchantman, see Kindler, 1966: 17, pl. IV: 4. For a possible comparison to Agrippa II's ram-less galley, see Casson, 1995: 160-162 (κέλησ), fig. 139.

[11] John Hyrcanus I (134-104 BC), the first Jewish ruler to mint a coin type with a nautical symbol, is believed to have struck his coins bearing an upside-down anchor, a Seleucid symbol, as part of his tribute to Antiochus VII Sedetes (Meshorer, 1982A: 39 fig. 1; Jacobson, 2000: 74-75). Alexander Jannaeus (103-76 BC), who included a nautical motif, an anchor, on his coinage, held the coastal cities of Strato's Tower, Apollonia, Jaffa, Jamnia, Ashdod, Gaza, Anthedon, Raphia, and Rhinocolura (*Antiquities* 13.395). He may have copied the anchor design from earlier Seleucid coins and/or have used the anchor to commemorate his conquest of these coastal cities in 95 BC (Madden, 1881: 86; Meshorer, 1982A: 61-62). Of a hoard of 851 coins of Alexander Jannaeus found in Jaffa, all but one bear the anchor symbol (Kindler, 1954: 170-171).

[12] Rahmani, 1967: 69-73, pls. 20, 21:A. Compare Basch, 1987: 351 figs. 737-739; Casson, 1995: fig. 115. On the tomb, most recently see Kloner and Zissu, 2007: 389-391 no. 23-3, figs. 22, 282-284.

[13] Ptolemais, present day Akko, is given as Nicanor's arrival city in a parallel reference in the Babylonian Talmud, (*Yoma* 38a; Nadich, 1983: 108-109 n. 33). As Notley (2011: 103) observes, however, 'the geography supports the variant reading of Joppa found in the Tosefta and the Jerusalem Talmud. Shipments from Alexandria would not have travelled to Ptolemais if the intended destination were Jerusalem.'

Nicanor's Doors, also referred to as the 'bronze gate,' appear repeatedly in Rabbinic literature, as well as being mentioned by Josephus, and have been proposed as the identification of the

'Beautiful Gate' mentioned in Acts (3:2, 10; Mishnas: Middot 1:4, 2:3, 2:6; Shekalim 6:3; Sotah 1:5; Nega'im 14:8; *War* 2.411, 5: 201, 204; Büchler, 1899; Thackeray, 1961A: 484-485 n. a;1961B: 261 n. d).

Nicanor was a real person. In 1902 his tomb—one of the most elaborate from that period in Jerusalem—was discovered on Mount Scopus (Dickson, 1903; Avigad, 1967: 119-125; Kloner and Zissu, 2007:179-181 no. 2-[5-9], figs. 74-76). The tomb contained an ossuary with the following Greek and Hebrew inscription: 'The bones of the (sons *or* descendants?) of Nicanor, the Alexandrian who made the doors.— NICANOR ALEKSA' (Clermont-Ganneau, 1903: 126). The tomb dates to the mid first-century BC (Kloner and Zissu, 2007: 181).

[14] Quotes from *War* from Thackeray 1961A.

[15] Literally 'than a desert' (Thackeray, 1961A: 695 n. b).

[16] Vespasian and Titus in AD 71 also celebrated the conquest of Judea with a triumph, memorialized on the Arch of Titus, in which 'many ships' (πολλαὶ δὲ καὶ νῆες) were also staged (*War* 7.147).

[17] Josephus records two other naval engagements during the Jewish War: one appears to have been a minor mopping-up operation on the Dead Sea (*War* 4.439), but the other saw the destruction of a Jewish fleet—consisting largely of non-combatant refugees—on the Sea of Galilee following the investiture of the walled city of Tarichaeae (Migdal) by the Romans (*War* 3.462-505, 522-531). Both Vespasian and Titus directed the Battle of Migdal. It seems probable, therefore, that the coins relate to that battle, or to a Roman perception of a general naval victory

as part of the conquest of Judea, rather than specifically to the Jewish losses in Jaffa (Thackeray, 1961B: 548 n. a; Patai, 1998: 81 fig. fig. 18; Wachsmann, 1990B: 112-114; 2009: 169-194).

[18] Muqaddasi also relates that Jaffa, along with other coastal cities, were centres for the redemption of Muslim captives from the Christians (Le Strange, 1886*:* 61-62).

[19] Those who came by ship on the fleets of merchantmen that sailed from Amalfi, Genoa, and Pisa usually disembarked at Jaffa, due to its proximity to Jerusalem. Ingulf, who later became the Abbot of Croyland, was one of these Christian pilgrims: he records returning to Europe from Jaffa in 1065, taking ship with a fleet of Genoese merchant fleet sailing for Italy (Tolkowsky, 1924: 82). The arrival of one such fleet in Jaffa proved pivotal to the Crusader conquest of Jerusalem (Tolkowsky, 1924: 85-86; Runciman, 1992: 281-282). At the behest of a hermit the Crusaders carried out their first attack on the city on June 13th, 1099, but lacking the proper resources, they were badly beaten back. Five days later a fleet of six Genoese ships arrived at Jaffa with supplies, including those needed to construct the necessary siege equipment.

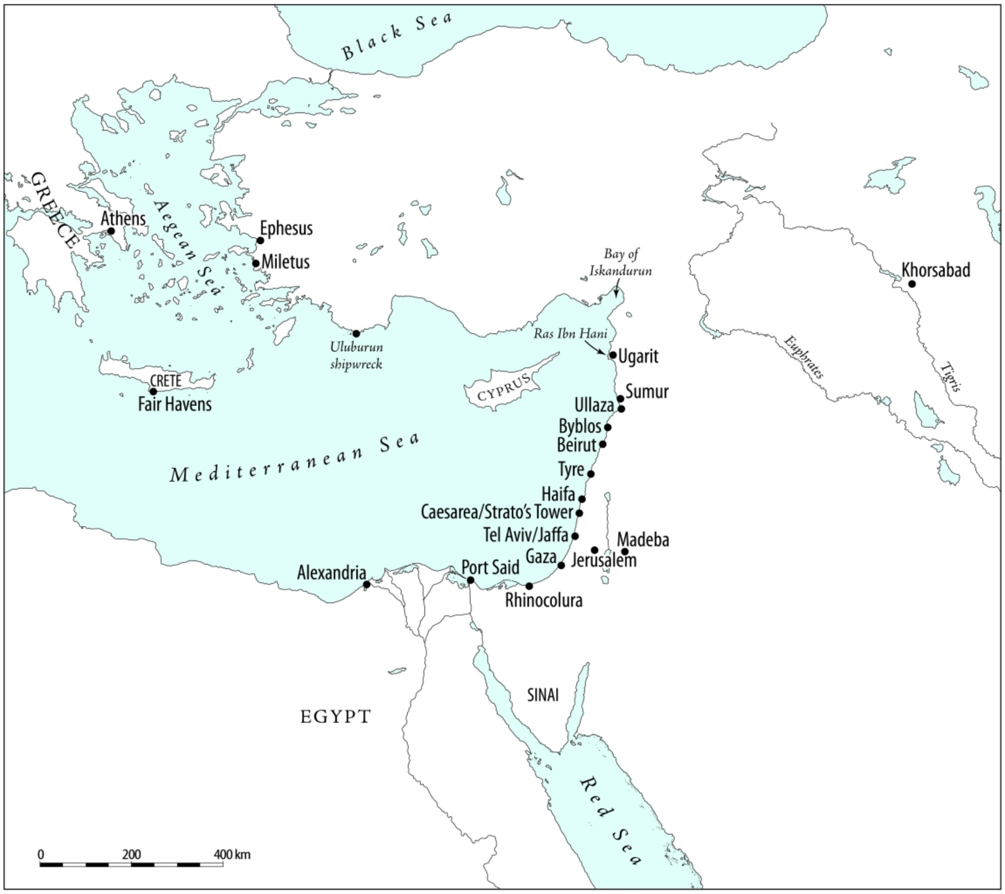
[20] Beginning in the mid-19th century various proposals aimed at permitting the harbour's use by larger steamships included the construction of breakwaters and connecting the quay to railroads (Shacham 2011: 140-141, 168 fig. 13.29, 169 fig. 13.30, 170 fig. 13.31, 171 fig. 13.32). An Italian syndicate floated a scheme to improve the harbour: the brief comment in *Steam Shovel and Dredge* notes, with unwarranted optimism, that 'commensurate with harbor improvement, the city of Jaffa itself is making plans to come out of its lethargy and reap rich rewards' (Anonymous 1922). These included improving the waterfront by the construction of warehouses, restaurants, hotels and private housing. Such plans only materialized in the late 1990s and consisted mainly of revitalizing older structures.

[21] The ship that sank at Uluburun circa 1300 BC, for example, has an estimated draft of 0.48 metres empty and a maximum estimated draft of 1.3 metres fully burdened (Lin, 2003: 65, 192).

[22] C. Clermont-Ganneau (1896: 158-159) connected the Arabic term ‘Bassa’ to the Hebrew word בצה, which appears repeatedly in the Bible connoting a lake, swamp or marsh (Job 8:11, 40:21; Ezekiel 47:11 [בצאת]).

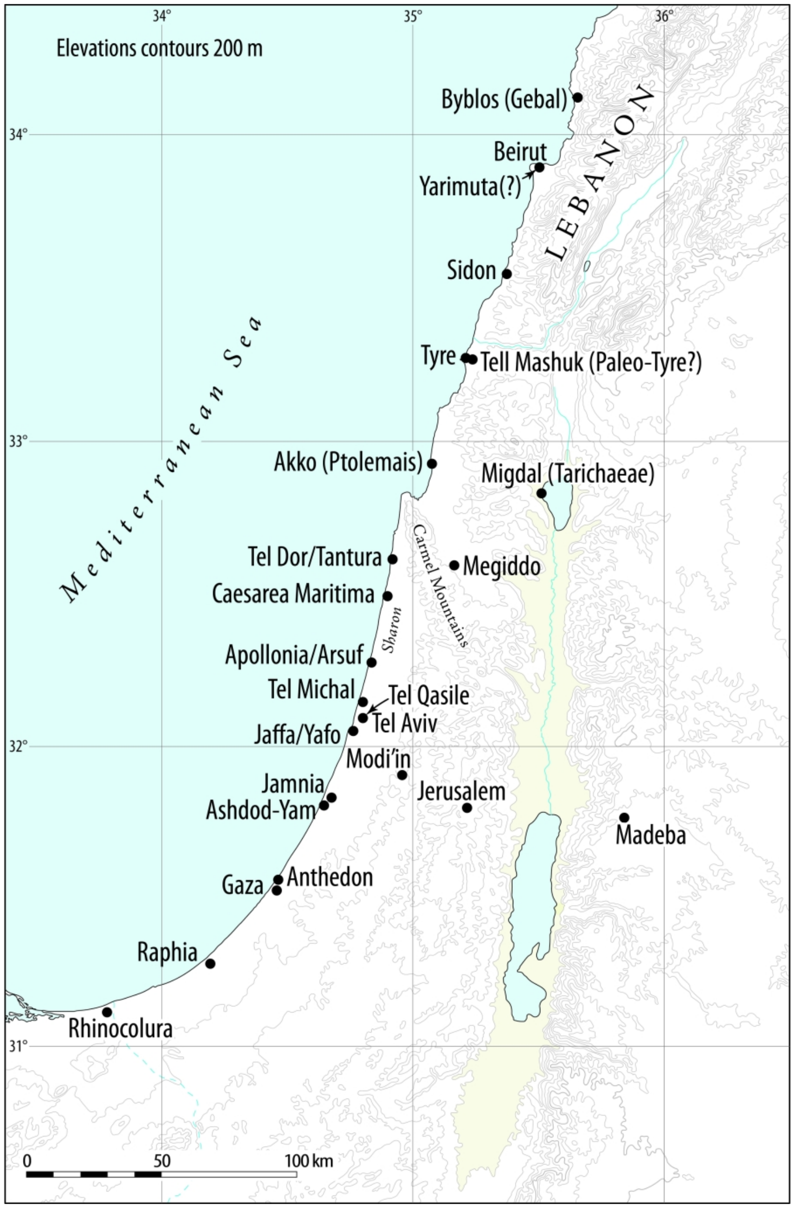
[23] See below, Appendix: Materials and Methods, pp. __-__.

[NOTE TO EDITOR: Page numbers to be added in proofs.]



1 Map of the eastern Mediterranean (Map: D. Davis).

165x146mm (600 x 600 DPI)



2 Map of the central and southern Levantine coast. On the location of Yarimuta, in the vicinity of Beirut, see Morris, 2005: 228-229 (Map: D. Davis).

96x147mm (600 x 600 DPI)

3 Reconstruction of the Ramesses II fortress gateway, which faces east towards el-Bassa (Photo: A. Burke).

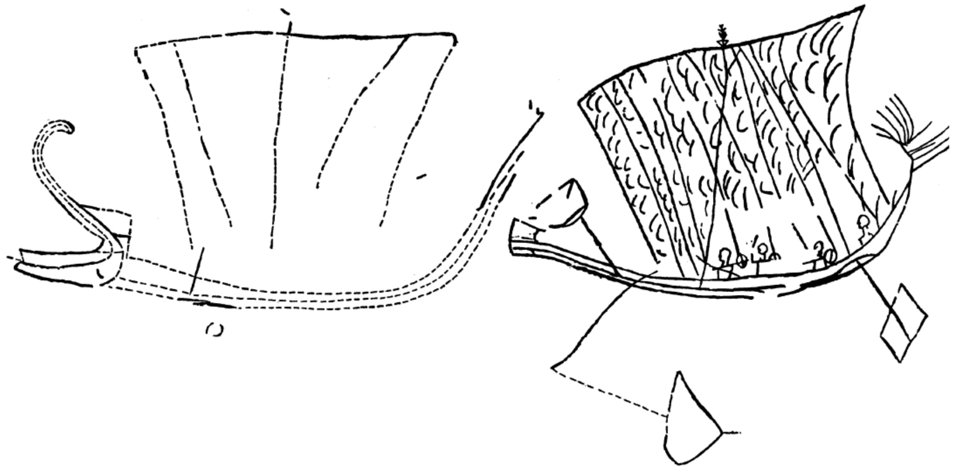
914x682mm (72 x 72 DPI)

4 A relief from Sargon II's palace at Khorsabad depicts Phoenician ships towing logs (Courtesy: Louvre. Photo: Shelley Wachsmann).

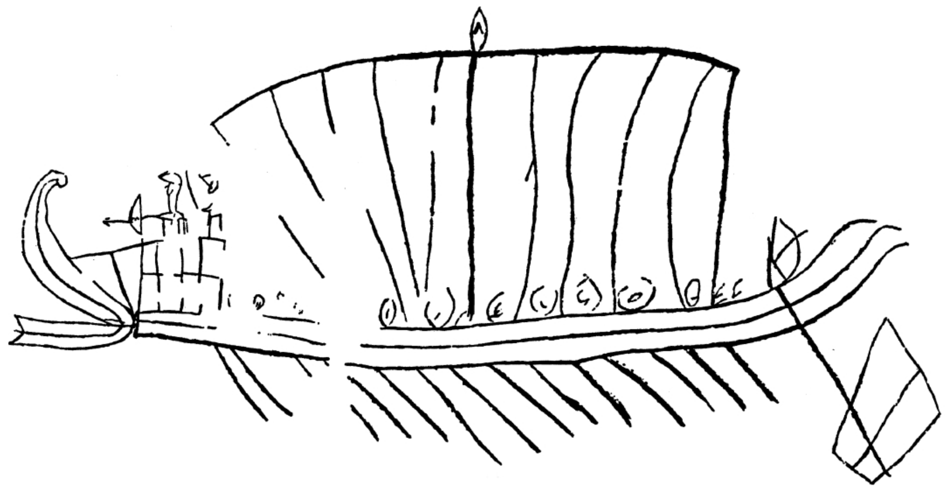
433x289mm (180 x 180 DPI)

5 Andromeda's Rock as the feature survives today at the entrance to Jaffa's rocky western harbour (Photo: A. Burke).

1151x863mm (72 x 72 DPI)



6 Ship graffiti in Jason's Tomb in the Rechavia district of Jerusalem. Hellenistic period (Courtesy Israel Exploration Journal Vol. 17: 70 fig. 5a, 71 fig. 5b, from Rahmani, 1967).

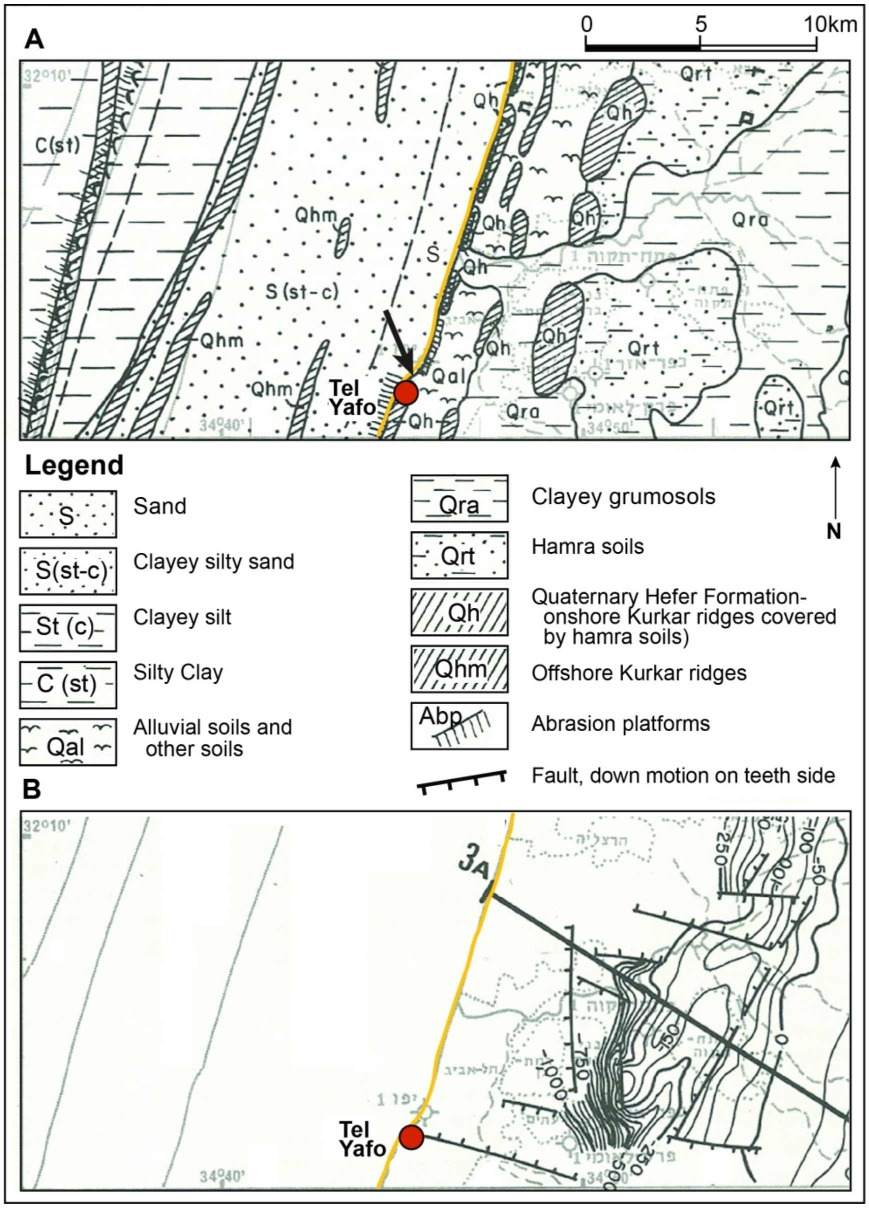


6 Ship graffiti in Jason's Tomb in the Rechavia district of Jerusalem. Hellenistic period (Courtesy Israel Exploration Journal Vol. 17: 70 fig. 5a, 71 fig. 5b, from Rahmani, 1967).

7 Autonomous city coin of Jaffa portraying a galley. The coin was minted after Pompey removed Jaffa, together with the other coastal cities, from Hashmonaean rule (From de Saulcy, 1874: pl. IX: 4).

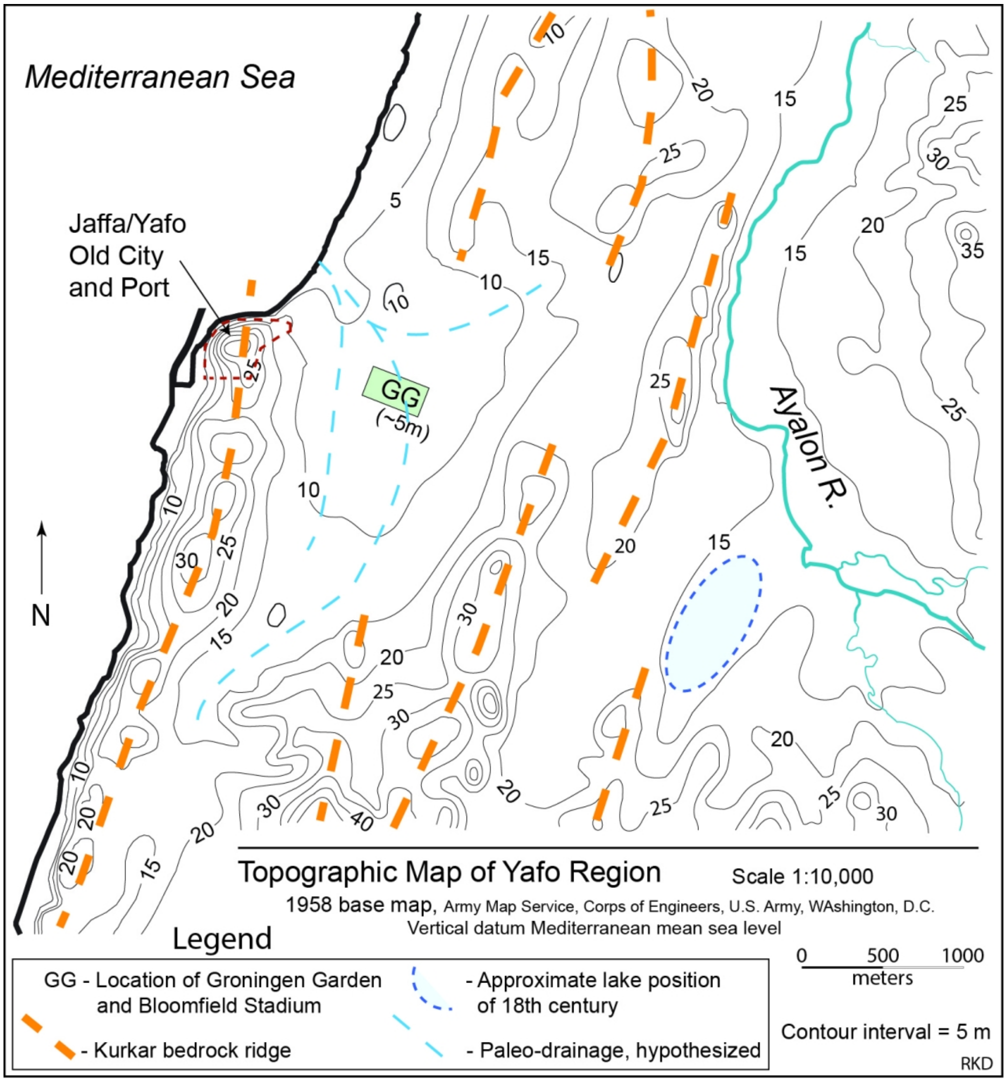
8 World War I-era photo of Jaffa harbour showing Andromeda's Rock, prior to the Mandatory period removal of some of the more dangerous obstructions (Courtesy State Library of New South Wales. Photo: Frank Hurley)

349x243mm (72 x 72 DPI)



9 A) Geological map of the southern Sharon and the continental shelf including the study area. The yellow line represents the present coastline. The arrow points to the gap between the kurkar ridge forming Tel Yafo and the lower-lying rocky element north of the tell, which corresponds to the small valley outlet found in this location prior to urban development. B) Structural map of the southern Sharon and the continental shelf. Faults are shown as solid lines with tick marks indicating the down-thrown (down-faulted) side. Note that el-Bassa and the former small valley (of A, above), located east and northeast of Jaffa, respectively, are situated above a structural graben, or a down-dropped basin (after Gvirtzman, 1990: 20, 46).

165x228mm (300 x 300 DPI)

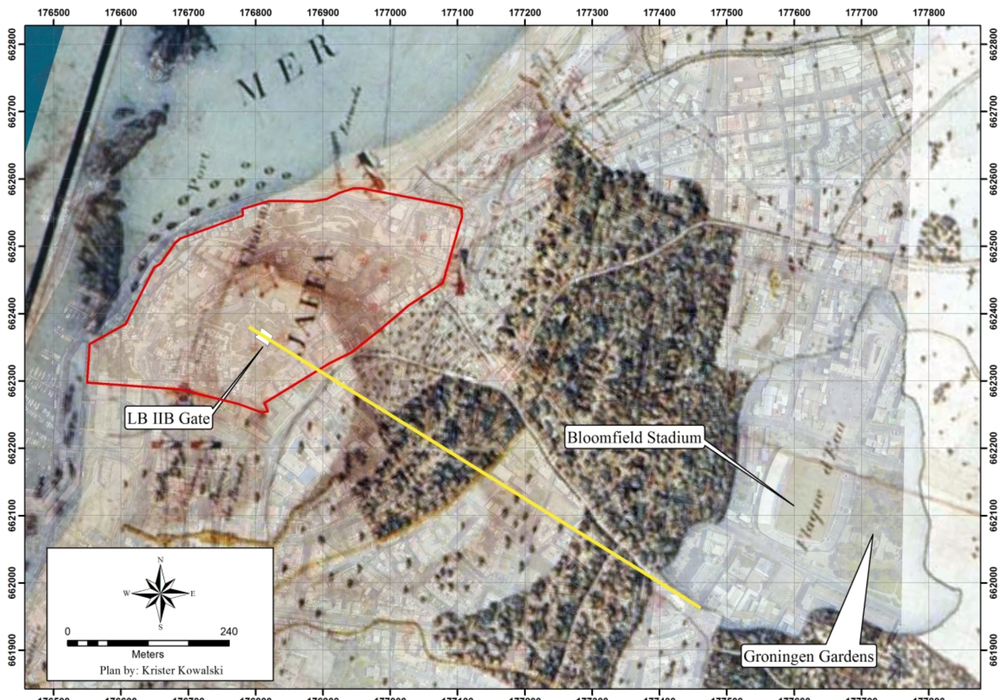


10 Topography in the vicinity of Jaffa, which is dominated by NNE-SSW trending bedrock ridges. The natural drainage to the sea is just north of Jaffa and the potential stream system, prior to extensive urbanization, is indicated with a blue dashed line. 'GG' indicates the location of modern Groningen Gardens (GG), which is the location of sediment cores taken for this study. The former position of a lake/wetland, known from the late 18th century, can be seen in the southeast corner of the map (Base map: U.S. Army Corps of Engineers, 1958).

132x142mm (300 x 300 DPI)

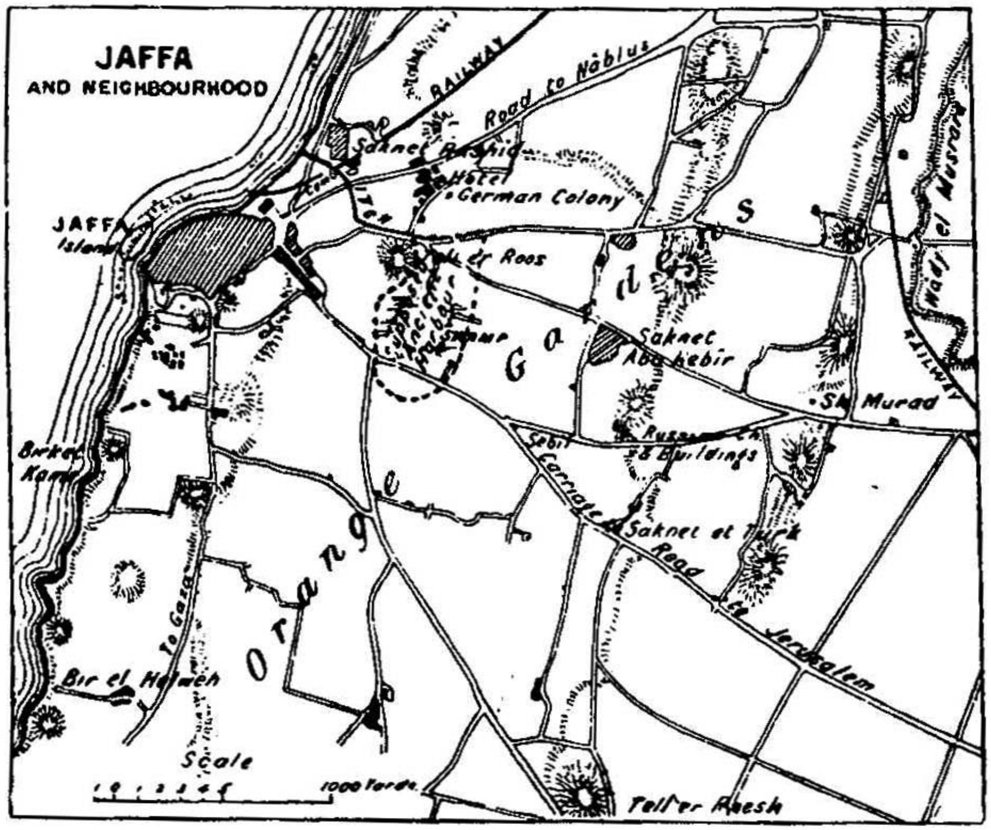
11 The modern artificial fill covering the view from Jaffa, facing north (Photo: S. Wachsmann).

690x518mm (180 x 180 DPI)



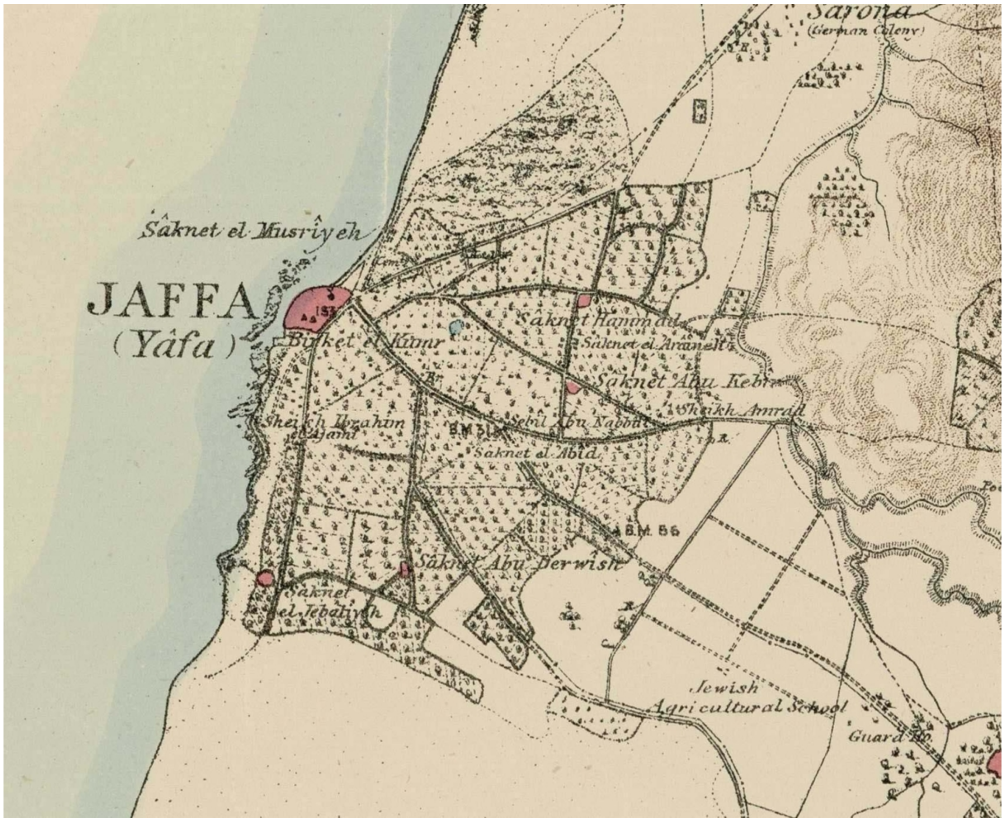
12 Georectified version of one of M. Jacotin's maps above an orthophoto of modern Jaffa. The outline of the fortified city of Jaffa in Jacotin's map appears highlighted in red. The yellow line indicates the orientation of Ramesses II's gate (Fig. 3) on Tel Yafo and its correlation with the southern limits of the flaque d'eau on Jacotin's map (After Shacham, 2011: 148 fig. 13.7. Georectification: K. Kowalski).

297x209mm (300 x 300 DPI)



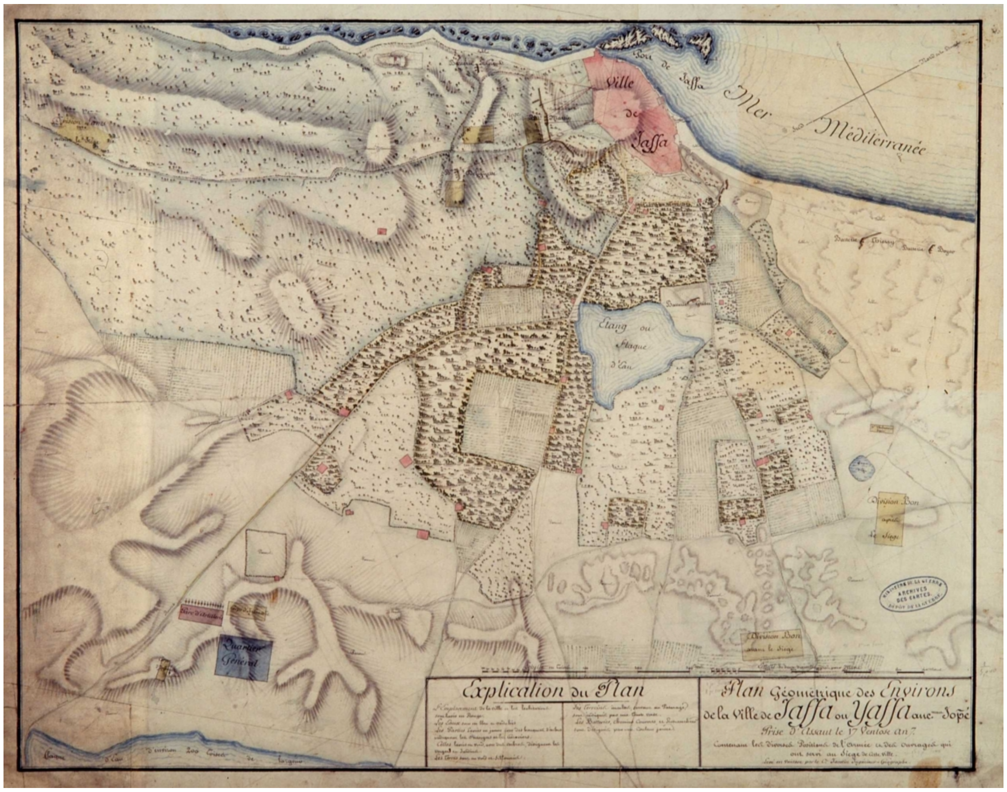
14 The location of el-Bassa, marked as 'Ancient Harbour' to the east of Jaffa on a map published by the Reverend J. Hanauer (From Hanauer 1903A: 258).

114x95mm (208 x 208 DPI)



15 A) A greatly shrunken pool appears on this map of Jaffa and its environs published by the Palestine Exploration Fund in 1880. B) Detail (From Shacham, 2011: 156 fig. 13.17).

127x103mm (300 x 300 DPI)



16 Map of Jaffa and its environs prepared by M Jacotin in 1799. Note the ancient drainage outlet through a gap in the bedrock ridge or dune line (From Shacham 2011: 146 fig. 13.4).

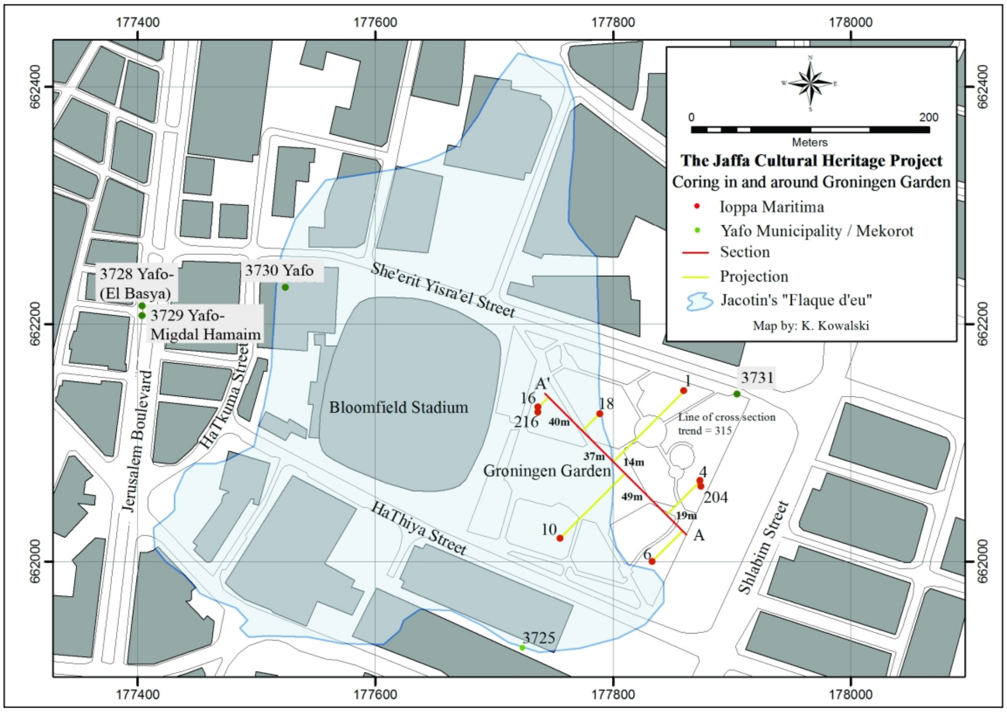
894x701mm (72 x 72 DPI)

17 Map of the 1799 French assault on Jaffa published by A.-J. Denain & Delamare, 1830–1831, showing an ancient drainage outlet through a gap in the bedrock ridge or dune line (After Shacham, 2011: 144 fig. 13.2).

88x63mm (300 x 300 DPI)

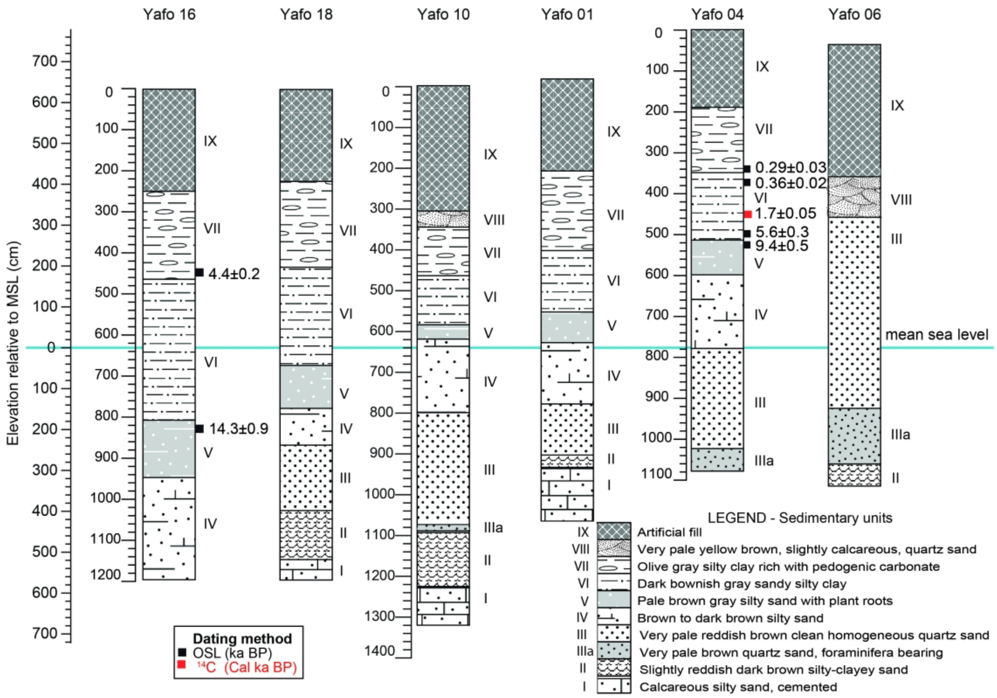
18 David Roberts'1839 painting of Jaffa as viewed from the northeast. Note the flat area (dry alluvial plain?) to the left of the city. Jaffa lies on a kurkar ridge, the continuation of which forms the ridge in the foreground (From Wikimedia commons, June 2021, https://upload.wikimedia.org/wikipedia/commons/c/cc/Jaffa_ancient_Joppa_April_16th_1839_-_David_Roberts%2C_R.A._LCCN2002717506.jpg).

376x265mm (72 x 72 DPI)



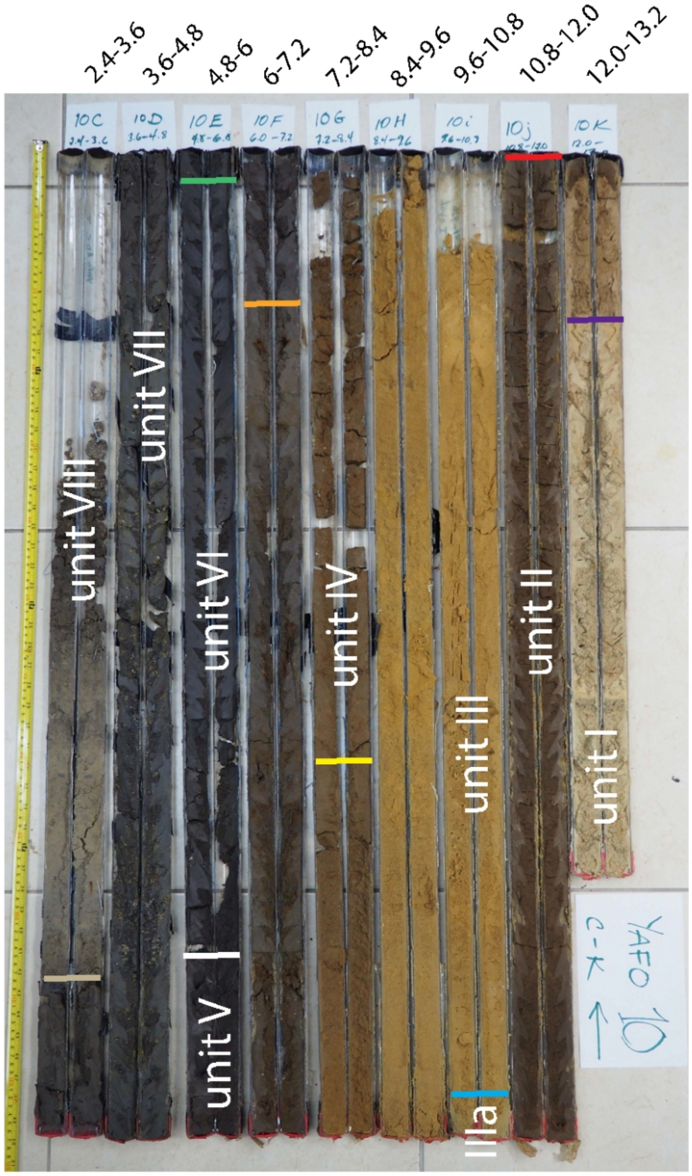
19 Locations of cores taken by the Jaffa Municipality in 1933 and 1964 within el-Bassa basin together with the location of cores recovered in 2014 by the Ioppa Maritima Project. The NW-SE cross section shown in Fig. 24 is indicated by the red line, with yellow lines showing projection of cores into the line of section. (Map: K. Kowalski).

210x148mm (300 x 300 DPI)



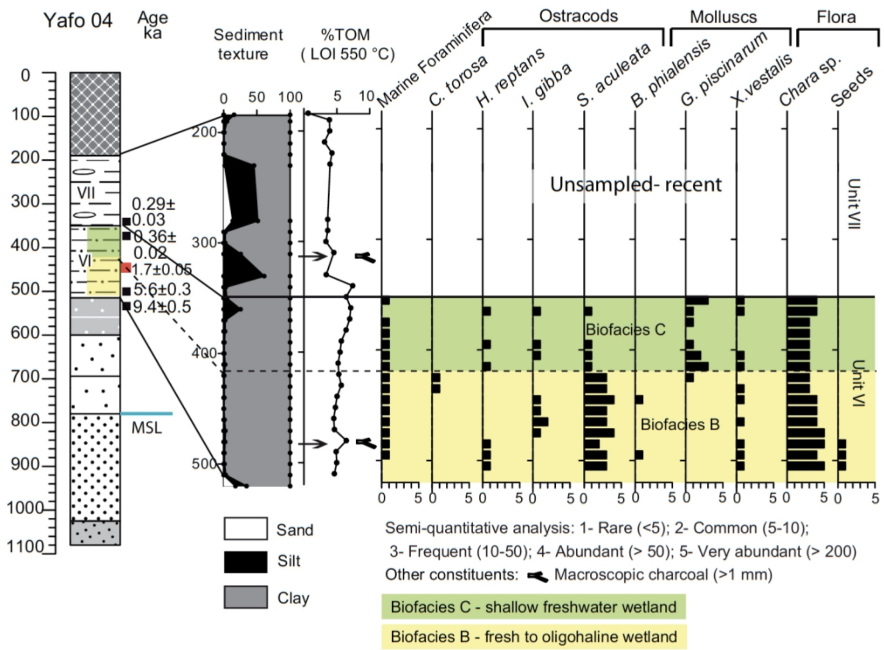
20 Lithologic logs plotted relative to present mean sea level, with ages of OSL and 14C samples (Diagram: R. Dunn and S. Avnaim-Katav).

297x210mm (300 x 300 DPI)



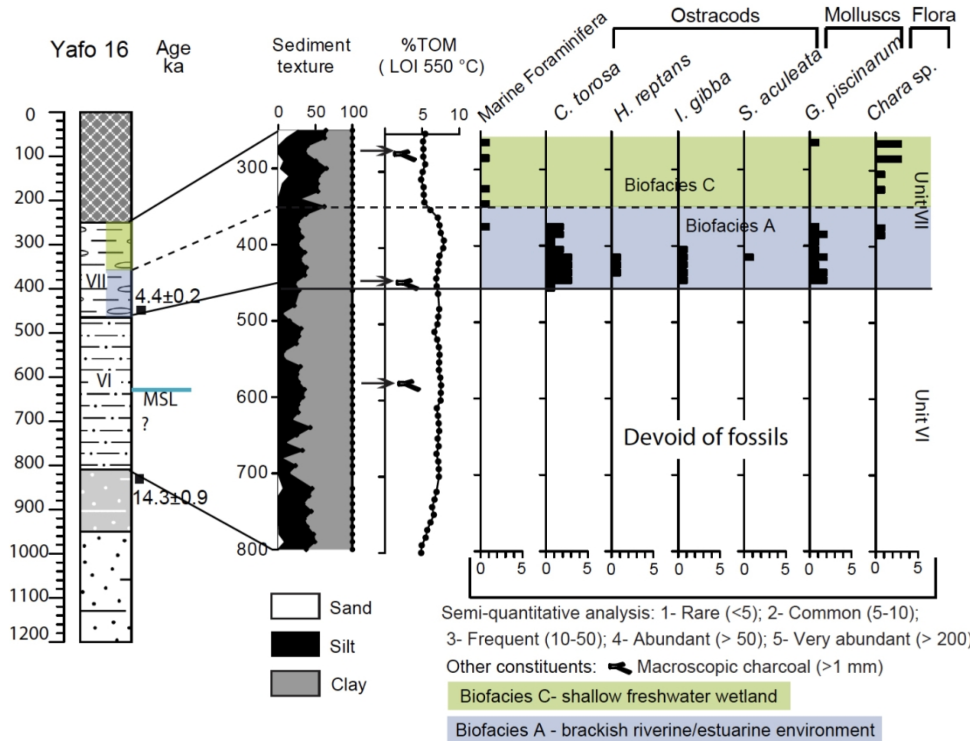
21 Photograph of core Yafo 10; top is upper left, base is lower right. Geoprobe tubes, most at 1.2 m length, have been split open and both halves are shown. Depth below the surface, in metres, is shown above each tube. The top 2.4 m (tubes A & B) are not shown and consisted of artificial fill, which is seen in tube C to a total depth of 3.0 m (Photo: R. Dunn).

240x375mm (96 x 96 DPI)



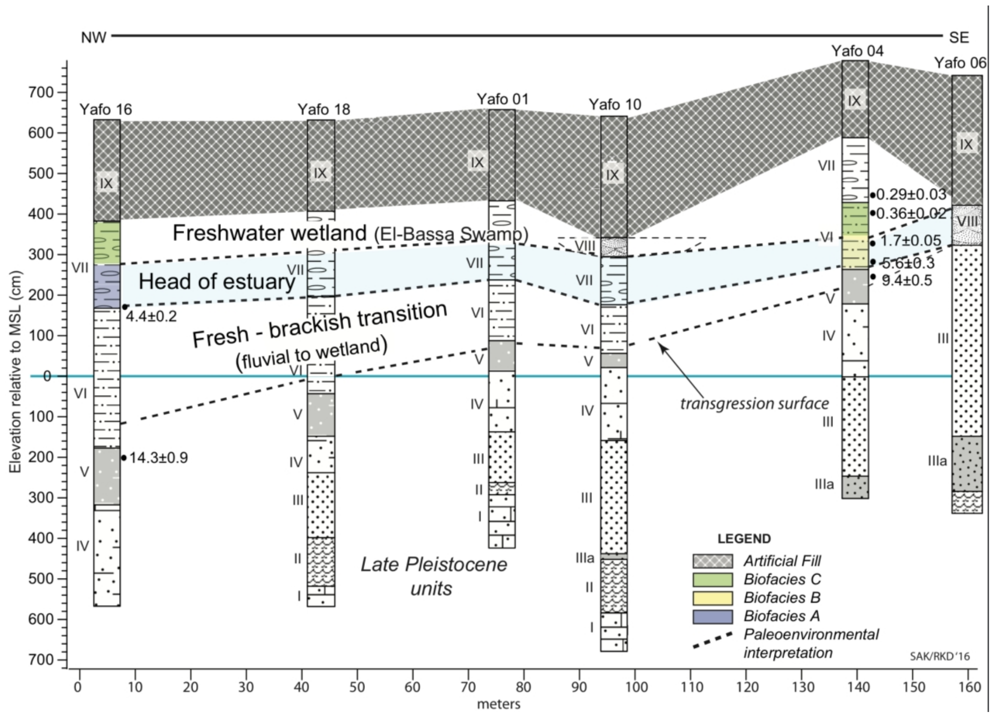
22 Sedimentological and faunal characteristics of borehole Yafo 04. See Fig. 20 for lithological symbols. Vertical scale in centimetres (Diagram: S. Avnaim-Katav).

314x250mm (144 x 144 DPI)

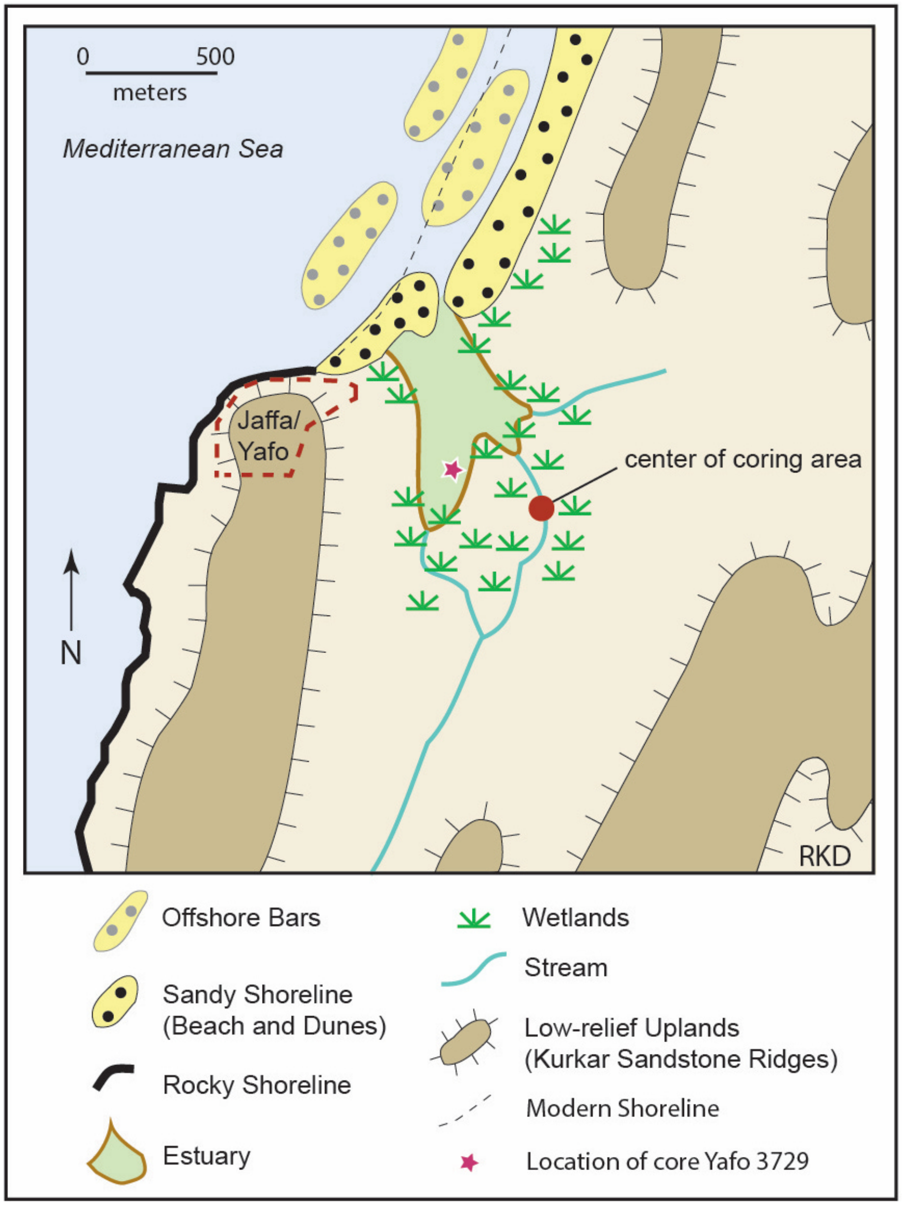


23 Sedimentological and faunal characteristics of borehole Yafo 16. See Fig. 20 for lithological symbols. Vertical scale in centimetres (Diagram: S. Avnaim-Katav).

255x211mm (144 x 144 DPI)



24 Lithological cross section with Pleistocene units grouped for simplicity. Cores have been projected into a NW-SE trending section (see Fig. 19 for locations). Biofacies were established in cores Yafo 04 and Yafo 16 and are overprinted here. Paleoenvironmental interpretations are based on sedimentology, paleontology, and geometry of units. See Fig. 20 for lithological symbols (Diagram: R. Dunn and S. Avnaim-Katav).



25 Paleogeographic reconstruction for the late second millennium BC, which occurs in the time of maximum estuarine expansion, between approximately 5500 to 1700 BP (see Fig. 24) . The topography of the study area is based on Fig. 10 (Map: R. Dunn).

304x407mm (72 x 72 DPI)