Ancient wells and their geoarchaeological significance in detecting tectonics of the Israel Mediterranean coastline region

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Now in the digging of wells we must not disdain reflection, but must devote much acuteness and skill to the consideration of the natural principles of things.
Vitruvius Pollio, *Architectura*, Book VIII, Chapter VI (25 B.C.)

ABSTRACT

Eight ancient water wells, representing the late Bronze Age to the Crusades period (ca. 3100–700 B.P.), have recently been excavated (six by the authors) and reopened at archaeological sites (tels) along the southern and central Mediterranean coast of Israel. Evidence of ancient freshwater levels directly reflects on possible neotectonics of the region and on eustatic changes of sea level. There is substantial disagreement about the tectonic stability of the Israel Mediterranean coastal region during the past 3500 yr, whether there was a large-magnitude tectonic event (one of the largest known for recent times) during the period in discussion or whether the region was tectonically quiet. We tested the instability hypothesis by using geoarchaeological data from the wells and found no evidence for significant tectonic deformation of the central and southern Israel coast in the past 3100 yr. The "ancient water-well" method can, with appropriate modifications, be used all around the Mediterranean and other coasts elsewhere in the world where ground-water–sea-level relations are alike.

INTRODUCTION

The coastal plain of Israel (Fig. 1) is known to have been inhabited for the past 7000 yr (since the Neolithic). Due to the lack of natural water sources such as springs or rivers, the inhabitants were totally dependent on eventual floods, rains, or on artificial sources such as wells and cisterns. The existence of ground water at a relatively shallow depth below the surface in the nearshore region permitted water exploitation through well digging as early as the late Bronze Age (ca. 3100 B.P.; "present" refers to A.D. 1950; Raban, 1983). Apparently, man started in much earlier periods to exploit shallow ground water by primitive methods that later developed into well digging and construction.

In the Pleshet and Sharon coastal plains, the aquifer and overlying strata are friable, being composed of loose sand, sandy loams, and kurkar sandstone ("kurkar" is a local term for carbonate-cemented quartz sandstone of Pleistocene age); most wells required reinforced walls to prevent collapse (Fig. 2). Specially dressed kurkar stones, the only local building stone available in the coastal plain, were therefore used at every stage of the well construction. As excavators descended the wells, they reinforced each successive level with a row of kurkar stones; only if the bedrock itself was of solid kurkar did this prove unnecessary. These kurkar stones were strengthened by cement plaster, which has preserved the wells in relatively good condition (Fig. 2). Most wells are cylinder shaped, and their inner diameters vary from 90 to 140 cm. They were located within the old site for economic or security reasons; they are therefore quite deep because

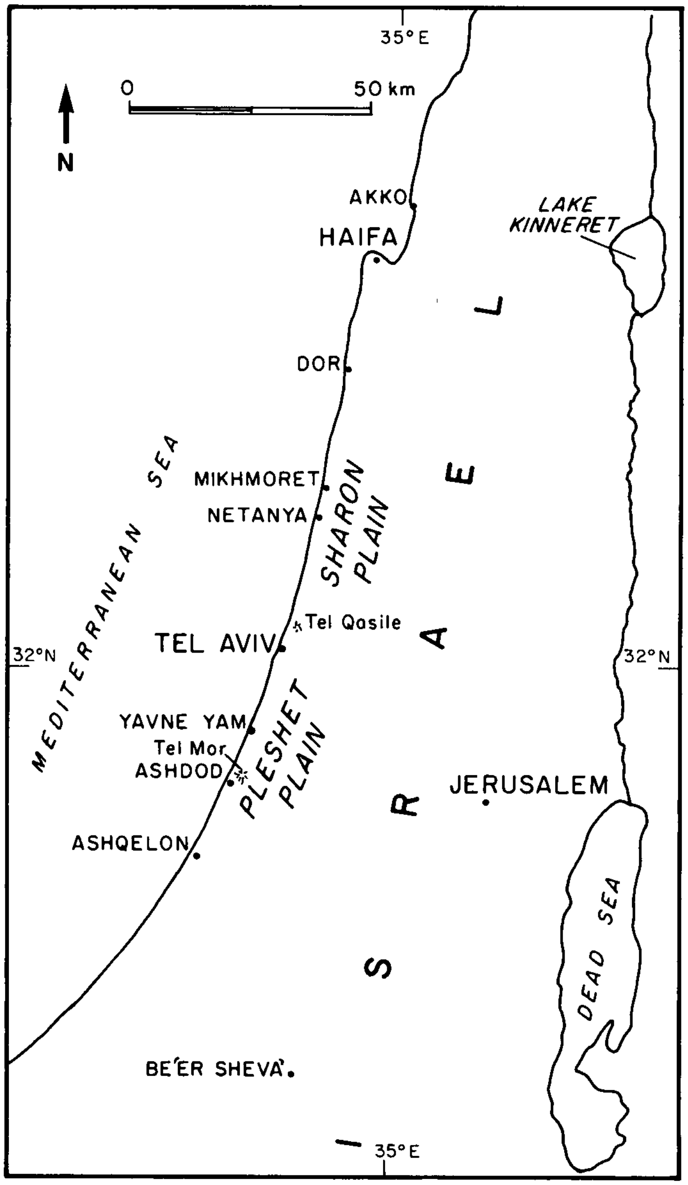

Figure 1. Map showing locations of eight ancient well sites and their geographic relation to modern Israeli cities.

Figure 2. Well-preserved dressed kurkar stones forming upper rows of Roman period well at Tel Mor, Ashdod.

Figure 3. Imported Hellenistic period Greek amphora 80 cm long, found at Yavneh Yam well (ca. second century B.C.).

they were almost always sunk from the top of the kurkar ridge and not, as one might expect, in the adjacent lows where ground water is much closer and easier to reach. As a result of technical difficulties of digging under water, further progress could not proceed, and the wells therefore terminated some 0.5–1.0 m below the water table. This permitted the drawing and hauling of water by all the conventional methods of those days. There is no doubt that the ancient water level was usually stable, only small possible fluctuations occurring because of seasonal changes (summer and winter), long periods of droughts, or rainy years that are very characteristic of this part of the Levant. Because tides in this part of the Mediterranean are of minor amplitude (about 30–40 cm), the ground-water level near the shore is steady. Because of the large quantity of ground water in this region, in that time there were no problems with wells becoming saline due to over pumping, such as occurs at present (Dror Gile'ad, Hydrological Service, 1986, personal commun.).

In some of the wells the ancient water-table mark is a clear and an easily identified, brown-black horizontal strip, 3–6 cm wide, which encircles the well's interior. This strip usually occurs between 40 and 60 cm above the bottom of the well. When the well became inoperative, either because of technical problems or for political reasons, it was generally turned into a garbage pit and subsequently filled with pottery shards, stones, animal bones, coins, ash, soil, and sand. We removed this fill material from six wells in order to expose the bottom of the well and the water-table mark. The material from the bottom of the wells yielded large quantities of pottery that allowed us to date accurately the period of the well's operation. In certain cases it was even possible to reconstruct entire jars from the shards (Fig. 3). All the wells that we cleared had been completely covered by overburden and were just recently discovered.

Fresh ground water in the Pleistocene aquifer of the coastal plain of Israel, from the shore to about 8–10 km eastward, flows from the foothills in the east toward the drainage basin of the Mediterranean Sea, to the west. This ground-water flow has an average slope of about 1/1000, and its surface is almost linear (Kafri and Arad, 1978; 'Amos Ecker, 1985, personal commun.). Its level is fully controlled by sea level, and it fluctuates with changes in sea level (Fig. 4). Therefore, the ground-water level in the coastal plain can be predicted accurately if the regional sea level is known.

DISCUSSION

More than a decade ago Neev et al. (1973) proposed that the Israel Mediterranean coastal region was tectonically unstable. This hypothesis was later reinforced by Neev and Bakler (1978), Neev et al. (1978a, 1978b), and more recently by Bakler et al. (1985) and Levy et al. (1986). Bakler et al. (1985, p. 223) stated that "the late Holocene movements involved the downwarping of the entire coastal zone, with a brief inundation (by seawater) of the landward side, after which the latter rebounded to its former position." These movements were also judged to have occurred within the past 3500 yr. This hypothesis is based mainly on the age of strata found along the coastal cliffs, as deduced by shallow-penetration offshore seismic reflection profiles, *Glycymeris*-shell accumulations, swamp deposits, and elevated beachrocks. While proposing their theory, Neev et al. (1973, p. 255) suggested that the uplift of 20–30 m is a "part of a more regional process, due to which the coastal plain, shelf and slope of Israel were arched and the coastal zone was submerged" in post-Mamluk time; i.e., during the past 700 yr. In their more recent work, Bakler et al. (1985) suggested that the elevated +28-m terrace of Tel Haraz is younger than 3500 B.P. Such an uplift rate, if assumed correct, averages about 8 m/1000 yr, perhaps the highest in the world.

On the other hand, virtually no vertical uplift of the shoreline area has been postulated by Mazor (1974), Arad et al. (1978), Garfunkel et al.

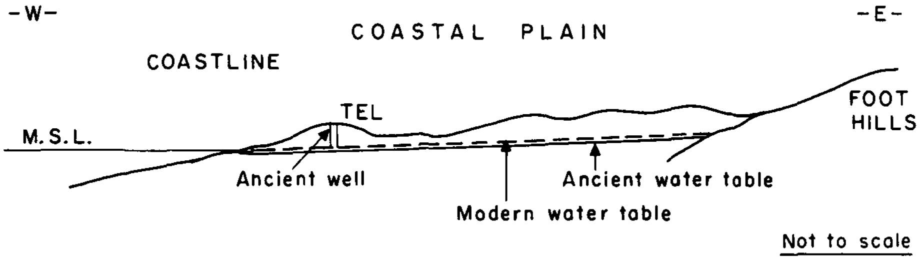

Figure 4. Schematic east-west profile along coastal plain of Israel showing ancient and present water tables in relation to sea level.

TABLE 1. STATISTICAL DATA ON 8 WELLS ON THE COAST OF ISRAEL, FROM DOR IN THE NORTH TO ASHQELON IN THE SOUTH

Location	Period	Age (B.P.)	Distance from present shore (m)	Elevation of top of well above msl (m)	Elevation of old water table (m)
1 Dor*	Late Bronze	3500-3200	5	4.0	-1.0
2 Dor	Byzantine	2000-1400	400	3.0	0.0
3 Mikhmoret	Persian	2550-2300	25	3.3	-1.4
4 Tel Qasile+	Persian	2550-2300	1800	14.0	+1.8
5 Yavneh Yam	Hellenistic	2300-2000	25	1.5	-0.7
6 Ashdod (Tel Mor)	Hellenistic	2300-2000	1000	23	+2.0
7 Tel Ashqelon**	Byzantine	2000-1400	200	17.3	+1.0
8 Tel Ashqelon	Crusader	850-700	200	17.0	+0.5

*Dug by Raban (1983); estimated to be 3100 B.P.
+Dug by Mazar (1983); estimated to be 2400 B.P.
**Because of collapse at the bottom, digging of this well was stopped at 14-m depth, but another 2 m of debris was present; therefore, its water mark could not have been much higher than the present ground-water table.

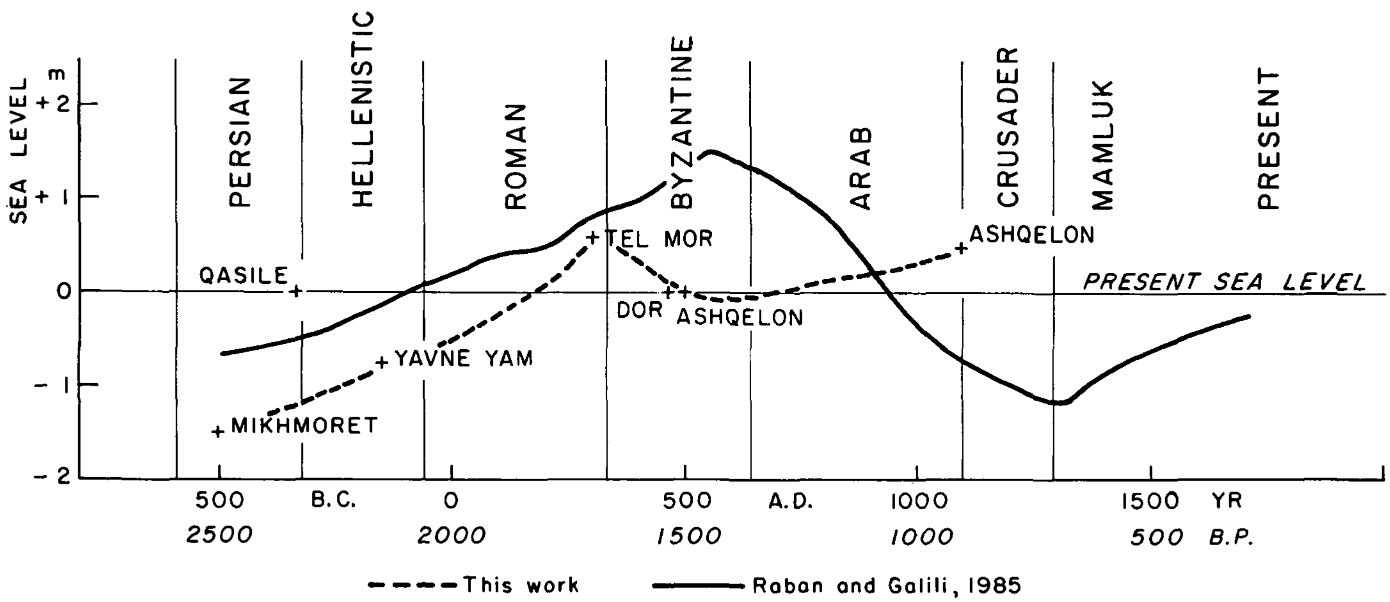

Figure 5. Comparative graph showing elevations of water table marks of different wells reexcavated along coastal plain of Israel and sea levels given by archaeological studies (Raban and Galili, 1985). Relative rise of sea level of about 1 mm/yr since Persian to late Roman period can be seen. Note: Water-mark level of Ashqelon Byzantine well and Tel Qasile well is not precise due to technical difficulties of excavation.

(1977), Ronen (1980), and Nir and Eldar (1986), as deduced from historical, archaeological, and stratigraphic evidence.

On a local and worldwide basis, sea-level changes during the past 3500 yr have not been significant, probably not greater than ±1.5 m (Fairbridge, 1961; Bloom, 1971; Flemming et al., 1978; Sneh, 1981; Mörner, 1982; Frau, 1985). However, for such a large area as the central and southern Israel coast, one would not expect larger changes in ground-water level throughout the period concerned. Therefore, differences of more than about 2 m between the present and ancient water tables may well be an indication of recent neotectonics.

We reexcavated six wells that are all located within 1 km inland from the shoreline, which is a few tens of metres or, at the most, a few hundred metres east of the ancient shoreline (Nir, 1973) (Table 1). Any minor eastward shore migrations could not have caused any dramatic change in the water level of the wells. Therefore, the present ground-water level should approximately correspond to that of the preceding 3.5 milleniums.

Two wells excavated earlier are also included in the study (Table 1), one of the Persian period from Tel Qasile (Mazar, 1983) and the other of the late Bronze Age from Dor (Raban, 1983).

The eight ancient wells that were reexcavated in the Pleshet and Sharon plains occur over a distance of about 110 km along the Israel Mediterranean coastline. Their water marks are at about the same levels as the present water level of the Pleistocene aquifer. We believe that neotectonism of downwarping and subsequent uplifting on the order of 20–30 m, as proposed by Neev et al. (1973) and Bakler et al. (1985), would have been reflected in the ancient wells. During downwarping episodes the water in the wells should have risen, whereas uplifting would have necessitated continuous digging and construction in order to reach the water table. However, the wells studied represent a chronological dispersion of approximately 3100 yr and do not show any signs of such dramatic changes, evincing neither several water marks nor stages of construction. The present data also indicate a gradual rise in sea level of about 1 mm/yr from the Persian to the Crusades period (Fig. 5).

CONCLUSIONS

From archaeological data, the ancient wells span an almost 3100-yr period. Because all the wells show water marks that almost merge with the present freshwater table, we conclude that the central and southern coastal region of Israel, from Dor on the north to Ashqelon on the south, has been tectonically relatively stable for the past 3100 yr (since the late Bronze Age). This conclusion, however, does not necessarily apply to the offshore region, which may have been affected by possible subsidence as suggested by Neev et al. (1973, 1978a). Other ancient wells from this and adjacent regions may well provide additional information about the location and magnitude of subtle tectonic and eustatic problems of the past 3100 yr. We also believe that, with just a few local improvisations, this new geoarchaeological study of ancient wells can be easily adapted to better understand neotectonic and eustatic sea-level changes all around the Mediterranean Sea and perhaps along coasts of other seas where ancient cultures existed.

REFERENCES CITED

Arad, A., Ecker, A., and Olshina, A., 1978, Discussion *of* "The young (post-lower Pliocene) geological history of the Caesarea structure": Israel Journal of Earth-Sciences, v. 27, p. 142–146.

Bakler, N., Neev, D., and Magaritz, M., 1985, Late Holocene tectonic movements at Tel Haraz, southern coast of Israel: Earth and Planetary Science Letters, v. 75, p. 223–230.

Bloom, A.L., 1971, Glacial eustatic and isostatic control of sea level since the last glaciation, *in* Turekian, K., ed., Late Cenozoic glacial ages: New Haven, Connecticut, Yale University Press, p. 355–379.

Fairbridge, R.H., 1961, Eustatic changes in sea levels, *in* Ahrens, L.H., ed., Physics and chemistry of the Earth, Volume 4: New York, Pergamon Press, p. 99–185.

Flemming, N.C., Raban, A., and Goetschel, K., 1978, Tectonic and eustatic changes on the Mediterranean coast of Israel in the last 9,000 years, *in* Progress in underwater science, Volume 3: p. 33–93.

Frau, B., 1985, From the Etruscan ports of Graviscae and Martanum: Elements for a new methodology in the field of maritime archaeological research, *in* Raban, A., ed., Harbour archaeology: British Archaeological Research Institute, ser. 257, p. 93–104.

Garfunkel, Z., Arad, A., and Wachs, D., 1977, Shell deposits in the Tel Haraz area: Geological Survey of Israel Report Hydro/3/77, 12 p.

Kafri, U., and Arad, A., 1978, Paleohydrology and migration of the ground-water divide in regions of tectonic instability in Israel: Geological Society of America Bulletin, v. 89, p. 1723–1732.

Levi, Z., Neev, D., and Prausnitz, M.W., 1986, Late Holocene tectonic movements at Akhziv, Mediterranean coastline of northern Israel: Quaternary Research, v. 25, p. 177–188.

Mazar, 'A., 1983, Tell Qasileh: Tel Aviv, Muzeon Ha'aretz, 67 p. (in Hebrew).

Mazor, E., 1974, On the stability of the Mediterranean coast of Israel since Roman times: A discussion: Israel Journal of Earth-Sciences, v. 23, p. 149–151.

Mörner, N-A., 1982, Sea level curves, *in* Schwartz, M. L., ed., The encyclopedia of beaches and coastal environments: Stroudsburg, Pennsylvania, Hutchinson Ross, p. 729–733.

Neev, D., Bakler, N., Moshkovitz, S., Kaufman, A., Magaritz, M., and Gofna, R., 1973, Recent faulting along the Mediterranean coast of Israel: Nature, v. 245, p. 254–256.

Neev, D., and Bakler, N., 1978, Young tectonic activities along the coast of Israel: Hakibutz Hameukhad, Hof ve Yam, p. 9–30 (in Hebrew).

Neev, D., Schachnai, E., Hall, J.K., Bakler, N., and Ben-Avraham, Z., 1978a, The young (post-lower Pliocene) geological history of the Caesarea structure: Israel Journal of Earth-Sciences, v. 27, p. 43–64.

Neev, D., Schachnai, E., Hall, J.K., Bakler, N., and Ben-Avraham, Z., 1978b, Reply *to* Discussion *of* "The young (post-lower Pliocene) geological history of the Caesarea structure": Israel Journal of Earth-Sciences, v. 27, p. 147–149.

Nir, Y., 1973, Geology of the recent and subrecent sediments of the Israel Mediterranean shelf and slope: Geological Survey of Israel Report, 179 p.

Nir, Y., and Eldar, I., 1986, Ground water levels in post-Persian (ca. 2500 yBP) water levels as indicators of tectonic activity and sea level changes along the Israel Mediterranean coast: Hydrodynamic and Sedimentary Consequences of Sea-level Changes Conference, Cork, Ireland, March 1986, 2 p.

Raban, A., 1983, Recent maritime archaeological research in Israel: International Journal of Nautical Archaeology and Underwater Exploration, v. 12, p. 229–251.

Raban, A., and Galili, E., 1985, Recent maritime archaeological research in Israel—A preliminary report: International Journal of Nautical Archaeology and Underwater Exploration, v. 14, p. 321–356.

Ronen, A., 1980, The origin of the raised pelecypod beds along the Mediterranean coast of Israel: Paleorient, v. 6, p. 163–170.

Sneh, Y., 1981, The paleogeography and the history of the coast of Dor in the Holocene period [M.A. thesis]: Haifa, Israel, University of Haifa, Department of Maritime Civilizations, 126 p. (in Hebrew).

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Reviewer's comment

Develops a technique to assess neotectonics not heretofore used, and most inexpensive, at that! Concludes no apparent uplift in late Holocene time, apparently in great contrast to judgments of previous workers.

Roy J. Shlemon