Quaternary Research **57**, 334–342 (2002)
doi:10.1006/qres.2002.2330, available online at http://www.idealibrary.com on IDEAL®

Historic Dead Sea Level Fluctuations Calibrated with Geological and Archaeological Evidence

Amos Frumkin[1]

Geography Department, The Hebrew University of Jerusalem, Jerusalem, Israel 91905

and

Yoel Elitzur

Eretz-Israel Studies Department, Herzog College, Alon Shevut, Israel 90433

Received January 31, 2001

The Dead Sea, the Holocene terminal lake of the Jordan River catchment, has fluctuated during its history in response to climatic change. Biblical records, calibrated by radiocarbon-dated geological and archaeological evidence, reinforce and add detail to the chronology of the lake-level fluctuations. There are three historically documented phases of the Dead Sea in the Biblical record: low lake levels ca. 2000–1500 B.C.E. (before common era); high lake levels ca. 1500–1200 B.C.E.; and low lake levels between ca. 1000 and 700 B.C.E. The Biblical evidence indicates that during the dry periods the southern basin of the Dead Sea was completely dry, a fact that was not clear from the geological and archaeological data alone.

Key Words: **Dead Sea; lake levels; radiocarbon dating; archaeology; Biblical chronology; closed lake; Jordan River; Sodom; Mount Sedom; Holocene environment.**

INTRODUCTION

The Dead Sea, at the lowest point on Earth (Fig. 1), has fluctuated during the historic period, bringing about major changes in its shoreline and surface area. As a terminal lake, its fluctuations are due to its high sensitivity to climatic change. Being under extremely arid conditions, and getting most of its water from a moister region, the Dead Sea is an "amplifier lake" (Street-Perrott and Harrison, 1985), serving as an excellent recorder of variations in precipitation/evaporation ratio. The study of past Dead Sea changes is especially important because of water shortage in the region today, and the possibility to infer from the late Holocene fluctuations possible changes in the near future.

Two different approaches may be used to reconstruct lake-level history. One is the field approach, which uses sediments, geomorphic evidence, and archaeological remains associated with the lake level. The second is the historical approach, which looks for ancient documents pertaining to lake levels. The historical approach includes human records prior to instrumentally recorded observations. Instrumental measurements of the Dead Sea started recently, less than 100 yr ago (Klein, 1986), and meteorological observations in the region started only slightly earlier, in the 19th century. The short instrumental record compared to the exceptionally long historical documentation of the region renders the historical approach of special importance for the Dead Sea.

In colder regions, historical records of lakes have been used to infer paleotemperatures using lake-freezing dates of recent centuries (e.g., Arakawa, 1957; Zhang and Gong, 1979). However, historical documentation of lake levels is less common, probably because such long-term fluctuations tend to go unnoticed, being beyond the temporal perspective of an individual observer. In addition, ancient humans showed less interest in lake fluctuations than in events such as river floods and recessions, which are more frequent, or earthquakes (e.g., Ken-Tor *et al*., 2001), which are more significant to society.

The purpose of this article is to explore the possibility of using chronologically imprecise ancient historical documents as a source for lake-level reconstruction and of using geological and archaeological evidence to calibrate the historical record. This approach may allow us to estimate how far back in time history and human memory reflect environmental changes. This question is linked to the debate over the role of climate change in controlling human history. As we go back in time thousands of years, paleoclimatic historical records become scarce. When such historical observations do exist, their significance should be analyzed as rigorously as possible. Pertinent questions include the following: "How reliable is the historical source?" "Was the lake described from firsthand experience or has it been distorted by the passage of time, rumor, and late editing of the text?" "How much time had elapsed between the lake-level observation and the writing, or editing, of the text?" and "How much time did the

[1] To whom correspondence should be addressed. E-mail: msamos@mscc.huji.ac.il.

0033-5894/02 $35.00

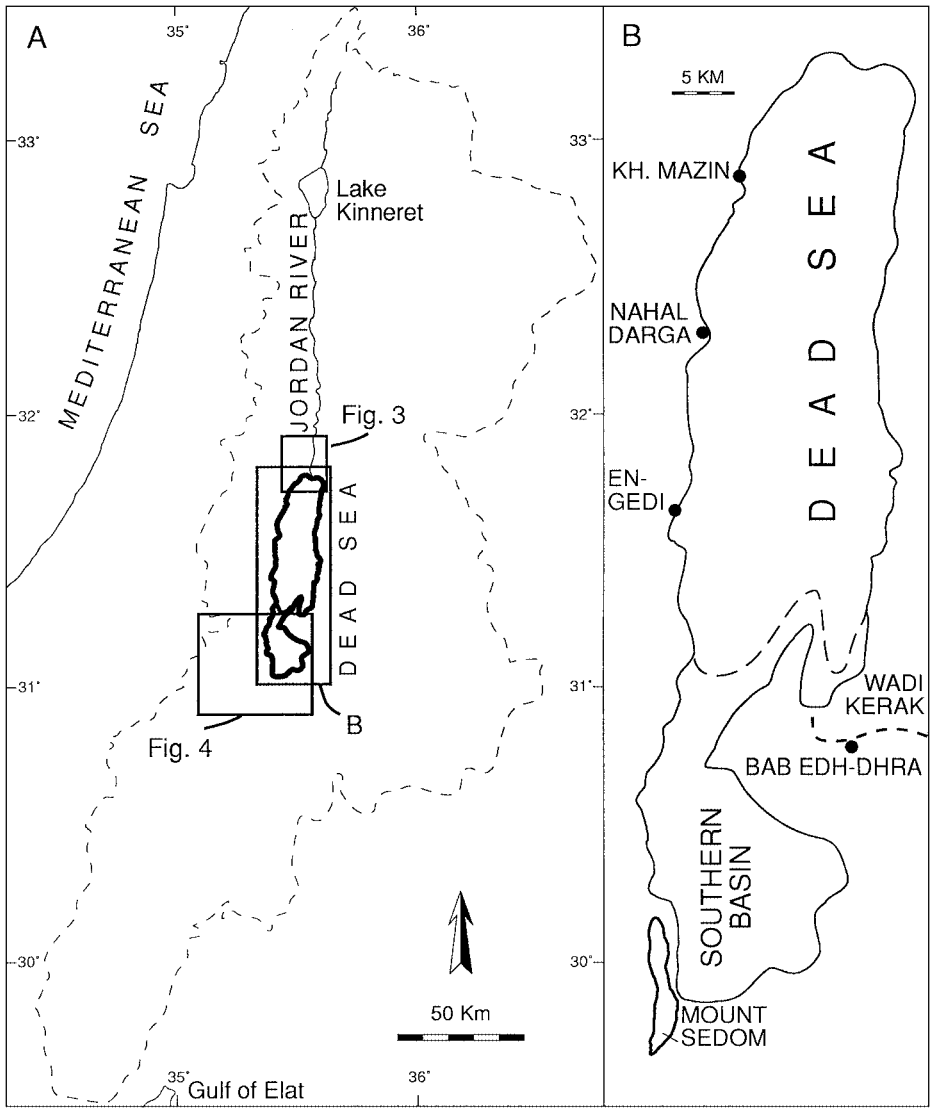

FIG. 1. (A) Location of the Dead Sea and its catchment. (B) The Dead Sea area at its −395 m above mean sea level (amsl) level, as in the mid-20th century. In 2001, the level had dropped to −420 m amsl because of human withdrawal of water.

lake stay in the recorded mode?" Some of these questions are difficult or impossible to answer directly, especially for records dating to thousands of years ago.

Our period of interest, ∼2000–500 B.C.E., is not rich in historical documentation. A unique source of evidence for the Dead Sea region is the Bible, although some scholars debate the historical basis of Biblical passages, and even those who acknowledge the historical basis of Biblical records often debate their chronology. In this article we try to detect the fluctuations of the Dead Sea level as reflected in the Bible. To avoid the vicious circle of debating the historicity of a source while drawing historical conclusions from it, we have, as a point of departure, collected the relevant data from the Bible, and then calibrated the Biblical paleoenvironmental record with independent field evidence. Our approach requires the evaluation of the available field data sets independently, using their own inherent chronology, and then comparison to the relevant Biblical passages.

We first review previously published geological and archaeological evidence pertaining to the period of interest; then we try to extract the Biblical indications for Dead Sea levels and then suggest a chronology for the Biblical record, calibrated by the geological and archaeological evidence. Finally, we reconstruct the history of lake-level fluctuations for the Dead Sea on the basis of all the lines of evidence (Table 1).

GEOLOGICAL EVIDENCE

A major morphologic feature in the southwestern edge of the Dead Sea (Fig. 2) is Mount Sedom (Jebel Usdum), composed of salt that extruded from the depth of the Dead Sea Depression

TABLE 1
Comparison of Dead Sea Level Indicators from Three Disciplines

Age years B.C.E.	Level m amsl (geology)	Level m amsl (archeology)	Level m amsl (Bible)	Biblical expression	Source[a]
2000–1500 (Mid Bronze Age)	−390 or lower		≤−400	"the vale of *Siddim*"	Gen. 14
1500–1200 (Late Bronze Age)	−375 to >−390		≥−400	"which is the *Salt Sea*"	Gen. 14
			ca. −375	"the tongue of the *Salt Sea*, the edge of the *Jordan*"	Josh. 15 + 18,
			−370 to −380	"from the tongue that turns to the south"	Josh. 15
			−370 to −380	"the eastern edge of the *Salt Sea*"	Num. 34
			ca. −375	Borders of Reuben and Beth Jeshimoth	Josh. 12 + 13
1200–700 (Iron Age and later)	fall of lake level	<−388 (1100−900 B.C.E.) −395 to −400 (800–600 B.C.E.)	≤−400	"the *vale of salt*"	II Sam. 8 II Kings 14 II Chron. 25 Ps. 60

[a] Gen., Genesis; Josh., Joshua; Num., Numbers; II Sam., II Samuel; II Chron., II Chronicles; Ps., Psalms.

late in the Quaternary Period (Frumkin, 1996a). The extremely soluble halite is highly susceptible to dissolution during the rare rainfall events of this hyperarid region. The largest known salt cave in the world has developed in this unique environment (Frumkin, 1994). Caves act as underground channels conveying water from subaerial catchments to the Dead Sea, which serves as the regional base level. The downcutting rate of one cave channel, measured over 10 yr, is 23 mm/yr (Frumkin, 1998). This rate indicates that the level of the channels rapidly adapts to base-level changes (Frumkin and Ford, 1995). Today, the active cave

FIG. 2. Mount Sedom (center) at the shore of the southern basin of the Dead Sea, presently occupied by potash extraction ponds.

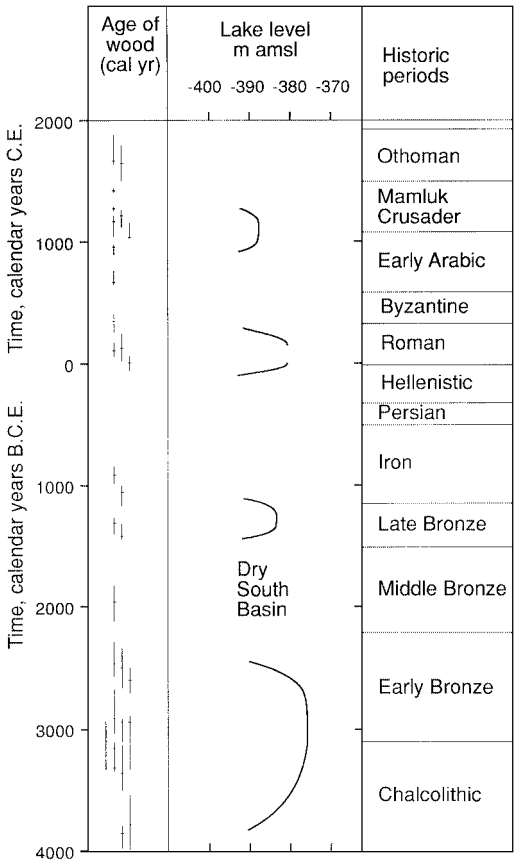

FIG. 3. Dead Sea level according to Mount Sedom caves, taking account of a diapir uplift rate of 6 mm/yr. Calibrated ^{14}C dates on wood, used for constructing the curve, are given and assumed to be equivalent to calendar years for comparison to the historical record. Error bars are ± 1 SD (σ). The gaps in the curve correspond mostly to periods when the Dead Sea level was low and did not reach Mount Sedom. B.C.E., before common era; C.E., common era; amsl, above mean sea level.

channels drain to the base of the eastern escarpment of Mount Sedom, which has been the base level throughout the 20th century as well as in earlier times. High stands of the Dead Sea have resulted in alluvial deposition within the cave channels and in subsequent rising of the cave passages. Dead Sea levels were thus recorded by coeval cave passage levels (Fig. 3). For evaluating the paleo-lake levels we took into account the 6-mm/yr mean uplift rate of Mount Sedom (Frumkin, 1996b).

Plant fragments from the surface of Mount Sedom were carried by floodwater and deposited within the alluvium inside cave passages. Twenty-nine samples of such organic material from 11 caves have been radiocarbon dated to the last 6000 cal yr B.P., providing a chronological framework for lake-level changes (Frumkin *et al*., 1991). Throughout this article we use "calendar" dates, calculated from the distribution of calibrated (Stuiver *et al*., 1998) radiocarbon dates.

The well-developed caves of the lower eastern escarpment of Mount Sedom indicate that ca. −400 m above mean sea level (amsl; i.e., 400 m below mean sea level) was a common level of the Dead Sea during the last 4000 yr. This may be attributed to the buffering effect of the southern basin (Fig. 1): below this level the south basin of the lake is dry, and the Dead Sea is confined to its northern basin, as it is today. When the water rises above −400 m amsl, it inundates the south basin, increasing the lake area almost instantaneously by ∼30%. Evaporation increases abruptly at this stage, reducing the probability of still higher levels, which would require a considerably higher precipitation/evaporation ratio. Similarly, when the level drops below −400 m, the southern basin dries up, reducing the surface area and evaporation significantly, consequently reducing the probability of still-lower levels.

The most dramatic high-level period since the early Holocene occurred during the mid-Holocene (Chalcolithic–Early Bronze Age) (Fig. 3), which corresponds to the largest high and dry cave levels in Mount Sedom, dated by 12 radiocarbon ages and discussed in detail elsewhere (Frumkin *et al*., 1994). This high stand predates the period of interest of this article, because we found no reference to this stage of the Dead Sea in any historical document.

After the Early Bronze Age, cave passages became narrower and deeply incised. One wood sample, jammed in such a narrow canyon at Sedom Cave, is dated to 2110–1820 cal yr B.C.E. (1-σ range, Lab no. RT-810D; 3580 ± 80 ^{14}C yr B.P.; Frumkin *et al*., 1994), fixing the time of incision. Thus, the Dead Sea must have fallen dramatically around 2100–1800 B.C.E.

Rapid canyon downcutting also occurred along the eastern Dead Sea shore in surface channels such as Wadi Kerak (Fig. 1B), causing partial erosion of the Early Bronze Age city of Bab edh-Dhra (Donahue, 1985). A rapid fall of Dead Sea level could have caused the incision on both sides of the lake. Cores drilled in the center of the southern Dead Sea basin indicate that during this stage a salt layer was deposited, indicating this part of the lake dried out (Neev, 1964). The combined evidence suggests that the Dead Sea level was falling, and the south basin was probably dry until ∼1500 B.C.E.

The Dead Sea level was high again between ∼1440 and 1260 B.C.E. (Frumkin, 1997), as indicated by a high cave passage in Mount Sedom, dated by two wood twigs (RT-982G, 3100 ± 55 ^{14}C yr B.P.; RT-982E; 3030 ± 50 ^{14}C yr B.P.; Frumkin *et al*., 1994). The cave evidence suggests that the Dead Sea level rose above −390 m amsl, possibly up to ca. −380 m amsl. In an independent study, undated morphological features along the western shore of the lake led Klein (1982) to postulate that a high level of −375 m amsl was attained during the same period.

Another study, in the fan-delta of Nahal Darga (Fig. 1B), implies similar conclusions (Kadan, 1997; Enzel *et al*., 2000). These researchers based their work on variations in the type of deposit, dated by ^{14}C of organic material found therein. Altogether, the field evidence suggests that the Dead Sea was high between ca. 1440 and 1260 B.C.E., submerging the south basin, and possibly rising to between −375 and −380 m amsl.

During the next period, from ca. 1200 to 500 B.C.E. (and also a few hundred years later) Mount Sedom caves developed

high-gradient narrow passages, associated with falling Dead Sea level, which dropped below −390 m amsl. Two wood samples date to this period (RT-943B, 2880 ± 50 ^{14}C yr B.P.; RT-943A, 2750 ± 50 ^{14}C yr B.P.; Frumkin *et al*., 1994).

Thus, geological evidence indicates a major drop of Dead Sea level ca. 2100–1800 B.C.E., remaining below −390 m amsl until ca. 1500 B.C.E. This was followed between ca. 1500 and 1200 B.C.E. by a high stand above −390 m amsl. Then, between ca. 1200 and 500 B.C.E., the lake level fell once again, to *below* −390 m amsl, a limit close to but slightly above the floor of the southern basin. Thus, during the two low stands, the the Dead Sea was close to its threshold level, but it is not clear whether the southern basin was completely dry.

ARCHAEOLOGICAL EVIDENCE

Three sites are significant for the periods discussed here. All three are Iron Age sites, which were flooded at times of high water level and reappeared when the water level receded. One is Mesad Gozal, in the southern basin near Mount Sedom (Fig. 4). Pottery found there was dated by Aharoni (1964) to ca. 1100–900 B.C.E. The level of the floor is −388 m amsl; thus the Dead Sea level at that time was obviously lower than that, and likely considerably lower, since the site was apparently a fortress. The other two sites appear to be both docks for boats, dated by Bar-Adon (1989) ca. 800–600 B.C.E.: Rujm el-Bahr on the northern shore of the Dead Sea (Fig. 5) and Khirbet Mazin (Figs. 1B, 6), which Bar-Adon (1989) identified with Biblical Midin. The effective water level for the anchoring of boats is −400 m amsl in the former and −395 m amsl for the latter. Klein (1986) concluded from these data that the Dead Sea level fluctuated about 5 m, from −400 to −395 m amsl, during those two centuries.

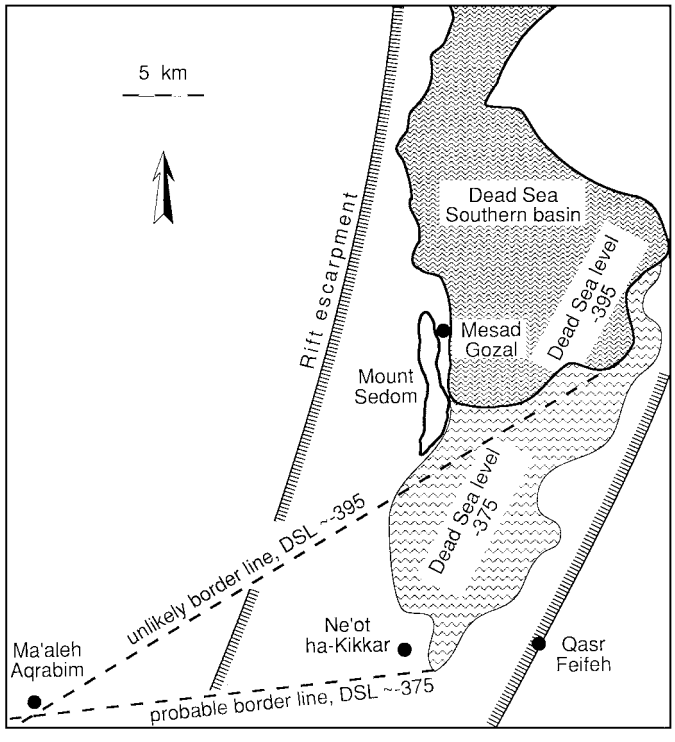

FIG. 4. The southern basin of the Dead Sea during high lake level, and the northern Negev with the suggested southern border according to Numbers 34 and Joshua 15. A southern bay associated with a Dead Sea level (DSL) of ca. −375 m amsl fits the Biblical record best (see text).

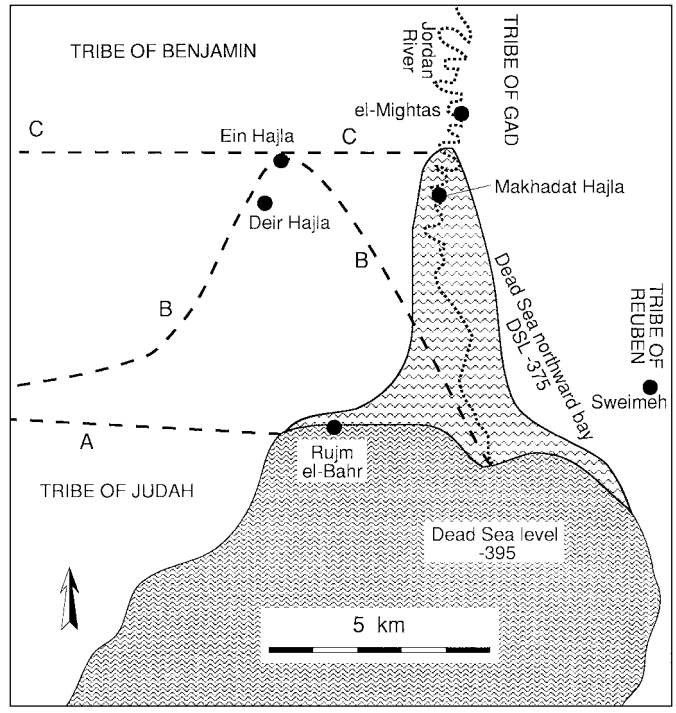

FIG. 5. Possible tribal borders (dashed lines) at the northern end of the Dead Sea, according to Joshua 15. (A) The expected border line if the Dead Sea level was ca. −400 m above mean sea level. This line does not agree with the text which delineates the border line through the southern end of the Jordan River. (B) A possible border line emerging at the current mouth of the Jordan and going through Ein Hajla region includes a loop which is hard to explain. (C) The suggested borderline, emerging from a high-level (ca. −375 m) Dead Sea.

The archaeological evidence suggests that the Dead Sea level was significantly lower than −388 m amsl ca. 1100–900 B.C.E. During ca. 800–600 B.C.E. the level was from −395 to −400 m amsl. Thus, during the first interval, the southern basin may have been shallowly filled by the Dead Sea, and during the second interval it may have been dry, or nearly so, but on this point the evidence is inconclusive.

BIBLICAL EVIDENCE

Any attempt to deal historically with events described in the Bible, especially in its more ancient parts, depends on the credibility of the sources and on the question of when they were written and/or edited. Since the most ancient manuscript copies that include significant parts of Bible known to us are most probably from the last few centuries B.C.E. (e.g., Vermes, 1977), one might attribute the composing of these Biblical sources to any

FIG. 6. Kh. Mazin, an 8th–7th century (800–600) B.C.E. dock for boats (Bar-Adon, 1989) at −395 m amsl, on the north/western shore of the Dead Sea. The Dead Sea has recently retreated to the level of −420 m amsl (background, right).

date prior to that period. Indeed, a wide spectrum of chronologies has been suggested for the writing and editing periods of various parts of the Bible. Although this article is not an appropriate place to assess the traditional scholarly efforts to establish a reliable chronology, the dating of the events in our investigation is compatible with the conclusions of prominent authorities of Biblical and historical research. Below, we discuss five Biblical passages and their proposed relevance to the Dead Sea level.

Genesis

Geographical descriptions in Genesis (Gen.) 14 bear on the low, but rising, level of the Dead Sea early in the Biblical record. For the antiquity and originality of Gen. 14 see Albright (1926, 1935, 1963) and Glueck (1934); for the relatively early date of the composition of this chapter see Speiser (1964) and Grintz (1983). The Biblical account of the primeval battle of "the four kings against the five" in Gen. 14 mentions archaic geographical terms, four of which are identified within the text with terms that were familiar at the time of writing or editing: "*Bela* which is Zoar" (verses [v.] 2, 8), "the *vale of Siddim* which is the Salt Sea" (v. 3), "*En Mishpat* which is Kadesh" (v. 7), "*the vale of Shaweh* which is the vale of the King" (v. 17; Elitzur, 1990). Note that, except in Gen. 14, these archaic names do not occur elsewhere in the Bible, and even the description of the destruction of Sodom (Gen. 19) uses Zoar exclusively rather than Bela. On the other hand, the four *new* names (Zoar, the Salt Sea, Kadesh, the vale of the King) are known in the books of the Bible. Gen. 14 lists the five cities twice, in both cases noting the change from Bela to Zoar, while the other four cities, which were destroyed afterward—Sodom, Gomorrah, Admah, and Zeboim—have only one name. This is an indication of the authenticity of the change of names, as well as the remoteness of the period in which it took place. The names of the ethnic groups mentioned here—Rephaim, Zuzim, Emim, and Horri—also testify to the archaic atmosphere of the chapter (cf. the "updating" identification of Deuteronomy [Deut.] 2:9–22 for these nations).

Accordingly, the phrase "the vale of Siddim which is the Salt Sea" (Gen. 14:3) is significant. The text describes a battle, which took place before the destruction of Sodom and Gomorrah, in a wide valley or plain (Hebrew *emeq*; cf. Brown *et al*., 1966, pp. 770–771) which, at the time of writing or editing, was no longer a valley but had become the *Salt Sea*. The most obvious candidate to fit this description is the southern basin of the Dead Sea (Fig. 1).

Moreover, Gen. 14:10 apparently provides an interesting characterization of the geology of this valley: "And the vale of Siddim was full of *be'eroth hemar*." *Be'eroth hemar* should be interpreted "pits of slime," rather than "wells of asphalt" (Frumkin and Raz, 2001; *be'eroth* has here a unique vocalization; cf. Elitzur, 1987). This is consistent with a feature known today

along the receding Dead Sea shore: pits are being formed continuously, and people have fallen into them due to their collapse, just as described in Gen. 14:10: "and the vale of Siddim was full of *be'eroth hemar* and the king of Sodom and the king of Gomorrah fled and fell into them."

Whether Sodom and Gomorrah should be located on the southern shore of the Dead Sea or in the northern or central shore (cf. Smith, 1974, pp. 324–328; Mulder, 1992), the implication of Gen. 14 is that in the time of the described war, the southern part of the lake was completely dry, so that the Dead Sea level must have been below −400 m amsl.On the other hand, when the chapter was written or edited, the plain was completely inundated. The Dead Sea level would have been higher than −400 m amsl at that time.

Political Boundaries

According to Kaufmann (1985) and Aharoni (1979, pp. 248–255), boundary delineations in the Book of Joshua (Josh.) date to a period shortly after the conquest of the Dead Sea region by the Israelites.The boundaries between the Tribes of Judah and Benjamin suggest that the Dead Sea was low at that time.

The easternmost point of the boundary between the Tribes of Judah and Benjamin as defined in the Book of Joshua is "the northern tongue of the Salt Sea at the southern end of the Jordan" (Josh. 18:19; similarly Josh. 15:5). The next point to the west is "the shoulder of Beth Hoglah to the north." The name of Beth Hoglah is undoubtedly preserved in Ein Hajla and Deir Hajla (Fig. 5), located about 5–6 km north of the current shore of the Dead Sea. Although no pertinent archaeological finds have as yet been found in this area, it is quite reasonable to assume that the Biblical site of Beth Hoglah was located close to Ein Hajla and Deir Hajla.

Charles Clermont-Ganneau investigated this part of the boundary in 1902 (Clermont-Ganneau, 1902; Simons, 1959). He pointed out that if the border had issued from the current mouth of the Jordan, moving northward to Beth Hoglah and then again to the west, it would have formed a meaningless loop, which could rather be replaced by a simple straight line. Moreover, this argument does not depend on the identification of Beth Hoglah. Namely, since the shoreline in that area runs east–west for about 8 km, the border should have begun from the northwest corner of the lake, near Rujm el-Bahr (Fig. 5).

If one assumes that the Dead Sea had a northward bay extension toward the region of el-Mightas (Fig. 5), however, the line becomes logical and is also quite compatible with the identification of Ein/Deir Hajla. Such a bay was indeed suggested by Clermont-Ganneau, who also observed—correctly—that *lashon* ("tongue") in the Bible, unlike the Arabic *lisan*, has the meaning of a narrow, tapering *bay*, rather than a *peninsula*. In Isaiah 11:15, for example, "the tongue of the Egyptian sea" clearly seems to refer not to a marsh or a shallow lake, but to the Gulf of Suez (cf. Brown *et al*., 1966, p. 546; Skinner, 1954, p. 110).

Clermont-Ganneau (1902) was not yet aware of the intermittent rising and falling of the Dead Sea level throughout historical times. Nowadays, his theory should be adapted to currently available data of the fluctuations of the Dead Sea. The course of the boundary would be quite logical if one assumes a lake level of −380 to −370 m amsl for the period described in the book of Joshua, with a bay, or tongue, extending northward, toward el-Mightas.

The Southern Border of Judah

If *lashon* means "a bay" and not "a marsh," one does not have to associate the southeast corner of Judah "from the edge of the Salt Sea, from the tongue that turns to the south" (Josh. 15:2), with the Sabkha marshes, as did Clermont-Ganneau (1902). Rather, this southern *lashon* should be explained simply as the southern shore of the Dead Sea, so called because of the long, narrow shape of the sea. If one again assumes a sea level of approximately −370 to −380 m amsl and relies on the contours as they appear in Israeli topographical maps (scale 1:50,000), one obtains an acute-angled triangle of water in the eastern part of the southern plain, between Ne'ot ha-Kikkar and Qasr Feifeh (Fig. 4), with the apex to the south.

The above suggestion might provide a satisfactory explanation to an apparently difficult geographical indication in Num. 34:3, which Aharoni (1979, p. 183) regarded as reflecting pre-Israelite reality. In that chapter the borders of "the Land of Canaan" are delineated, the southern boundary being almost exactly the same as the southern border of the tribe of Judah in Josh. 15, with some marginal differences. One of these differences is the definition of the southeast angle; as against "from the edge of the Salt Sea, from the tongue that turns to the south," of Josh. 15:2, Num. 34:3 has "from the *eastern* edge of the Salt Sea." The question is how the southern border could have begun from the eastern shore of the sea if the sea itself was part of the eastern border (cf. v. 5). The most common solution is to interpret *eastern* here as "southeast"; again, however, as seen above in connection with the northern border of Judah, the reference to this point is geographically meaningless—unless a line drawn westward from there enclosed some district within the borders. This, in turn, would be the case if the Dead Sea had been approximately −375 m amsl at that time. The term "*eastern* edge" may be associated with the fact that in this level the southern edge of the Dead Sea is closer to the eastern escarpment bordering the rift, rather than to the western escarpment (Fig. 4).

It is noteworthy that the southernmost latitude for the edge of the southern part of the Dead Sea, as concluded from the above discussion, may be compatible with the delineation of the entire southern border of Num. 34 and Josh. 15. The next point of the boundary after the edge of the Dead Sea is Ma'aleh Aqrabim (Fig. 4) (commonly identified with Naqb es-Safa, although it has never been conclusively proved). The latter lies at almost the same latitude as Ne'ot ha-Kikkar and Qasr Feifeh, resulting in a reasonable east–west borderline (Fig. 4).

The Eastern Jordan River Valley

According to the book of Joshua, the eastern Jordan River Valley from Lake Kinneret (Fig. 1A) to the Salt Sea (Dead Sea) was

given to the tribe of Gad (Josh. 13:27) almost in its entirety. Only one city in the plain found its way to the tribe of Reuben—the southernmost city of Beth Jeshimoth (Josh. 13:20), commonly identified with Sweimeh or some nearby site (Fig. 5). What reason could there be for this exception?

In the light of our previous discussion, one might suggest that this discrepancy, too, reflects a change in the level of the Dead Sea. If the level was high, as suggested above, Sweimeh and its environs would have been located east of the *sea* but not east of the *river.* The boundaries of Reuben then become logical, since the western border follows the shore of the Dead Sea up to its northern edge.

The Vale of Salt

The term *gai ha-melah*—"the Vale of Salt"—occurs five times in the Bible, as the battlefield in which King David, and later King Amaziah, defeated thousands of Edomite warriors (II Samuel (Sam.) 8:13; II Kings 14:7; Psalms (Ps.) 60:2; I Chronicles (Chron.) 18:12; II Chron. 25:11). In Biblical Hebrew, the word *gai* means both a narrow ravine (as in Josh. 8:11; I Sam. 17:3) and a wide plain (as in Devt. 3:29, 34:6). In our case, the context apparently dictates the second sense. Moreover, the term "vale of salt" most probably denotes the southern basin of the Dead Sea, or at least a significant part of it, at a time when that area was dry. This is indicated by the association with Edom, as well as the fact that nowhere else in the Holy Land is there a geographical feature that fits this term. In addition, as there is no "updating comment" for the term "vale of salt" in any of the passages in which it occurs, we may perhaps assume that the lake did not inundate the "vale of salt" until the time of writing and editing of the Books of Samuel, Kings, Psalms, and Chronicles.

To summarize, the Biblical sources at our disposal indicate that at the time of the war described in Gen. 14, the southern part of the Dead Sea was dry (i.e., its level was lower than −400 m amsl), but by the time Gen. 14 was written or edited, the southern basin was inundated and defined as a *sea* (i.e., its level was therefore higher than −400 m amsl). Some data in the book of Joshua seem to reflect a level of approximately −370 to −380 m amsl (possibly around 1300 B.C.E.), which appears to be compatible with geographical data in the book of Numbers. The Books of Samuel, Kings, Psalms, and Chronicles, referring to David and Amaziah (kings commonly attributed to ca. 1000–900 and 800–700 B.C.E., respectively), again testify to a low lake level, indicating that the southern basin of the Dead Sea—or at least a significant part of it—was a dry salt plain then. Apparently, when these four books were written and/or edited, the level was still lower than −400 m amsl.

DISCUSSION

Geological data suggest that the level of the Dead Sea fluctuated during the last two millennia B.C.E. In particular, during the first centuries of the second millenium B.C.E. it was lower than −390 m amsl and the southern basin must have been dry or shallowly filled (period 1). Then, from 1500–1200 B.C.E., the level rose to ca. −375 to −380 m amsl, filling the southern basin to a depth of 20–25 m (period 2). From ca. 1200–1000 up to 500 B.C.E. (and also a few hundred years later) the Dead Sea was again lower, no higher than −390 m amsl (period 3).

Archaeological data compatible with period 3 have come to light in three sites along the shore, where buildings from ca. 1100 to 600 B.C.E. indicate lake levels lower than −388 m amsl and around −395 and −400 m amsl. During period 3, then, the southern basin appears to have been dry or very nearly so, especially in its latter part (Table 1).

Biblical passages associated with Dead Sea levels may be attributed to the certain periods discerned above, as follows: The war in the Vale of Siddim (Gen. 14) agrees with period 1, whereas the editing remark "which is the Salt Sea" seems to be in agreement with period 2. The geographical descriptions of "the Land of Canaan" (Num. 34) and the tribal borders of Judah, Benjamin, and Reuben (Josh. 13–18) also indicate a high level, again consistent with period 2. The designation "The Vale of Salt" (II Sam., II Kings, Ps., I–II Chron.) indicates that the southern basin of the Dead Sea was at least partly dry during the reigns of David and Amaziah and at the time the relevant books were written/edited, apparently in agreement with period 3. The historic Biblical record thus appears to span all or part of the three periods of lake-level history recognized from geological and archaeological evidence. It indicates that, during period 3, the southern basin probably was completely dry, information that was not available from the geological and archaeoloogical records alone. Historical information therefore can be used to reinforce and amplify the geological and archaeological evidence of Dead Sea fluctuations, although it does not appear to be robust enough to stand alone, without supporting evidence.

The main contribution of the Biblical record to the lake-level history is that it shows that the southern basin of the Dead Sea was dry or at least partly dry during the first centiuries of the second millennium B.C.E., and again between 1200 and 700 B.C.E., so that it could serve as a battleground. This suggests that the lake level dropped below −400 m amsl during these periods.

CONCLUSIONS

Ancient historical evidence can be used to confirm and elaborate chronologies deduced from geological or archaeological evidence, and scientific evidence can be used to calibrate ancient historical records, both provided that naturally changing phenomena, such as lake fluctuations, can be identified in the various records. We have attempted this method in calibrating Biblical verses associated with the Dead Sea level. We have shown that the Biblical sources were sensitive to the fluctuations of the Dead Sea throughout the various periods and have added to our understanding of the history of fluctuations of the Dead Sea by demonstrating that its southern basin dried completely during low stands during the first centiuries of the second millennium B.C.E. and ca. 1000–700 B.C.E. Our findings suggest that ancient historic texts should be evaluated in other regions as well to extract late Holocene paleoenvironmental records.

Such an approach would be more difficult in regions such as parts of the Americas, where many ancient sources of historical information are limited to oral legends.

REFERENCES

Aharoni, Y. (1964). Mesad Gozal, *Israel Exploration Journal* **14,** 112–113.

Aharoni, Y. (1979). "The Land of the Bible—A Historical Geography." Translated and edited by A. F. Rainey. Westminster Press, Philadelphia.

Albright, W. F. (1926). The Historical Background of Genesis XIV. *Journal of the Society of Oriental Research* **10,** 231–269.

Albright, W. F. (1935). "The Archaeology of Palestine and the Bible." Fleming Revell, New York.

Albright, W. F. (1963). "The Biblical Period from Abraham to Ezra." Harper, New York.

Arakawa, H. (1957). Climatic change as revealed by the data from the Far East. *Weather* **12,** 46–51.

Brown, F., Driver, S. R., and Briggs, C. A. (1966). "Hebrew and English Lexicon of the Old Testament," 6th ed. (BDB). Clarendon, Oxford.

Bar-Adon, P. (1989). "Excavations in the Judean Desert." The Department of Antiquities and Museums, Jerusalem. [in Hebrew]

Clermont-Ganneau, C. (1902). Où était l'embouchure du Jourdain à l'époque de Josué? *Recueil d'archéologie Orientale* **5,** 267–280.

Donahue, J. (1985). Hydrologic and topographic change during and after Early Bronze occupation at Bab edh-Dhra and Numeira. *In* "Studies in the History and Archaeology of Jordan" (A. Hadidi, Ed.), pp. 131–140. Department of Antiquities, Amman.

Elitzur, Y. (1987). Reality, archaeology and linguistic research (Hebrew). *Leshonenu* **51,** 207–229.

Elitzur, Y. (1990). Place names of two words in the Arabic nomenclature and in the Bible. *In* "Tenth World Congress of Jewish Studies," pp. 21–28. Magnes, Jerusalem.

Enzel, Y., Kadan, G., and Eyal, Y. (2000). Holocene earthquakes inferred from a fan-delta sequence in the Dead Sea graben. *Quaternary Research* **53,** 34–48.

Frumkin, A. (1994). Morphology and development of salt caves. *Journal of Caves and Karst Studies (NSS Bulletin)* **56,** 82–95.

Frumkin, A. (1996a). Determining the exposure age of a karst landscape. *Quaternary Research* **46,** 99–106.

Frumkin, A. (1996b). Uplift rate relative to base level of a salt diapir (Dead Sea, Israel), as indicated by cave levels. *In* "Salt Tectonics, Special Publication no. 100" (I. Alsop, D. Blundell, and I. Davison, Eds.), pp. 1–47. Geological Society, London.

Frumkin, A. (1997). The Holocene history of the Dead Sea levels. *In* "The Dead Sea—The Lake and Its Setting" (T. M. Niemi, Z. Ben-Avraham, and Y. Gat, Eds.), pp. 237–248. Oxford Univ. Press, Oxford.

Frumkin, A. (1998). Salt cave cross sections and their paleoenvironmental implications. *Geomorphology* **23,** 183–191.

Frumkin, A., Magaritz, M., Carmi, I., and Zak, I. (1991). The Holocene climatic record of the salt caves of Mount Sedom, Israel. *The Holocene* **1,** 191–200.

Frumkin, A., Carmi, I., Zak, I., and Magaritz, M. (1994). Middle Holocene environmental change determined from the salt caves of Mount Sedom, Israel. *In* "Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean" (O. Bar-Yosef and R. Kra, Eds.), pp. 315–322. Univ. of Arizona Press, Tucson.

Frumkin, A., and Ford, D. C. (1995). Rapid entrenchment of stream profiles in the salt caves of Mount Sedom, Israel. *Earth Surface Processes and Landforms* **20,** 139–152.

Frumkin, A., and Raz, E. (2001). Collapse and subsidence associated with salt karstification along the Dead Sea. *Carbonates and Evaporites* **16,** 117–130.

Glueck, N. (1934), Exploration in Eastern Palestine, I: *Annual of the American Schools of the Oriental Research*, **XIV,** 81–82.

Grintz, Y. M. (1983). "The Book of Genesis, Its Uniqueness and Antiquity." Magnes, Jerusalem. [in Hebrew].

Kadan, G. (1997). "Evidence of Dead-Sea Level Fluctuations and Neotectonic Events in the Holocene Fan-Delta of Nahal Darga." Unpublished M.Sc. thesis, Ben Gurion University.

Kaufmann, Y. (1985). "The Biblical Account of the Conquest of Palestine." Magnes, Jerusalem.

Ken-Tor, Agnon, A., Enzel, Y., Stein, M., Marco, S., and Negendank, J. F. W. (2001). High-resolution geological record of historic earthquakes in the Dead Sea basin. *Journal of Geophysical Research* **106**(B2), 2221–2234.

Klein, C. (1982). Morphological evidence of lake level changes, western shore of the Dead Sea. *Israel Journal of Earth Sciences* **31,** 67–94.

Klein, C. (1986). "Fluctuations of the Level of the Dead Sea and Climatic Fluctuations in Israel During Historical Times" Unpublished Ph.D. dissertation, The Hebrew University of Jerusalem. [in Hebrew, English abstract]

Mulder, M. J. (1992). Sodom and Gomorrah. *In* "The Anchor Bible Dictionary" (D. N. Freedman, Ed.), pp. 101b–103a, Doubleday, New York.

Neev, D. (1964). "The Dead Sea." Geological Survey of Israel (report Q/2/64). Jerusalem.

Simons, J. (1959). "The Geographical and Topographical Texts of the Old Testament." Brill, Leiden.

Skinner, J. (1954). "The Book of the Prophet Isaiah," Chapters I–XXXIX." Cambridge Univ. Press, Cambridge, Cambridge, UK.

Smith, G. A. (1974). "The Historical Geography of the Holy Land." Ariel, Jerusalem.

Speiser, E. A. (1964). *Genesis—Introduction, Translation, and Notes*. *In* "The Anchor Bible Dictionary (D. N. Freedman, Ed.)." Doubleday, New York.

Street-Perrott, F. A., and Harrison, S. P. (1985). Lake levels and climate reconstruction. *In* "Paleoclimate Analysis and Modeling" (A. D. Hecht, Ed.), pp. 291–340. Wiley, New York.

Stuiver, M., Reimer, P. J., Bard, E., Back, J. W., Burr, G. S., Hughen, K. A., Kromer, B. G. M., van der Plicht, J., and Spurk, M. (1998). INTCAL98 radiocarbon age calibration, 24,000-0 cal BP. *Radiocarbon* **40,** 1041–1083.

Vermes, G. (1977). "The Dead Sea Scrolls, Qumran in Perspective." Collins, London.

Zhang, P., and Gong, G. (1979). Some characteristics of climatic fluctuations in China since the 16th century. *Acta Meteorologica Sinica* **34,** 238–247.