

The Southeastern Dead Sea Plain: Changing Shorelines and their Impact on Settlement Patterns through Historical Periods

Introduction.

Among the many possibilities for GIS mapping of the southeastern Dead Sea area one of the most interesting and feasible to present in a brief study is the impact on the settlement patterns by rising and falling Dead Sea levels through historical periods. Data for the study has been drawn from surveys, excavations and field studies of the Expedition to the south east Dead Sea Plain, low and high level aerial photos and electromagnetic radiation data from the Landsat Thematic Mapper (TM).

Sources and Methods

The sources used for this study include results from surveys and excavations collected by the Dead Sea expedition since 1973. An accurate and comprehensive locational data base listing all of the known archaeological sites for the southeastern Dead Sea region has been recently updated incorporating information from the most recent surveys and excavations, including some unpublished data. Information in the data base (TABLE I) includes exact site locations, utilizing the Palestine grid, elevations, size, type and extensive textual descriptions of the nature of the sites. Geological field studies have documented the natural stratification in the region and recreated the basic changes in wadi profiles through historical times.

Aerial photographs accessible for the study include low level plane and helicopter shots from 1975, 1979 and 1990. We are grateful for the support of the Royal Jordanian Air Force which made it possible for our staff photographers to take these photos. Stereo pairs taken at 10,000 feet for the northern part of the region were made available to us by the Jordanian National Geographic Society.

The Landsat 4 Thematic mapper images for this region were recorded on 9/6/84, a day with 0% cloud cover. The satellite records surface reflectance intensities from visible to thermal infra-red in seven wave length regions (Band 1 = 0.45-0.52 microns, Band 2 = 0.52-0.60, Band 3 = 0.63-0.69, Band 4 = 0.76-0.90, Band 5 = 1.55-1.75, Band 6 = 10.4-12.5, Band 7 = 2.08-2.35). Seven bands, each with different wave length and color, were recorded. The two standard types of images used in this study and

presentation are 'Achromatic Greyscale' and 'Four Component RGB' (Red-Green-Blue). The greyscale makes it easier to see linear and high frequency features than on a color image. In the Four Component RGB bands are combined to emphasize various minerals. The different colors can sometimes be related to different lithologies.

For the studies of site settlement pattern a program was developed to convert site locations and site codes from the database to vector overlay on the image. The Landsat image data was georeferenced to a Universal Transverse Mercator (UTM) projection using real world coordinates (Lat. Long.) of natural and man-made landmarks. Features such as stream tributaries and road intersections are easily identifiable with the 30 m resolution of the image even though the features themselves may have a dimension smaller than 30 m. Contours of the 1969 shoreline, -380 m (not shown in FIG. 1) and -300 m were digitized for two 1:50,000 scale maps and converted to UTM coordinates. A program was then written to overlay the contours on the image.

Dead Sea Levels

A. *Recent changes*

A number of important features may be seen in recent satellite images. The 1984 TM image (FIG. 1) clearly illustrates the fall in the Dead Sea level over the last 20 or more years caused by the removal of fresh water from the Jordan River and numerous wadis on the east and west side of the Dead Sea for use in agricultural irrigation. The straight line features in the South Basin are dikes used to create small evaporating pans for extraction of potash by both the Jordanians and Israelis. The drop in Dead Sea water levels is especially obvious around the al-Lisān Peninsula shoreline. The white interior of the peninsula denotes the 1960's through 1970's higher levels for the Dead Sea while the darker area, especially between the al-Lisān Peninsula and the Israeli coast marks a dry land area separating the North and South basins.

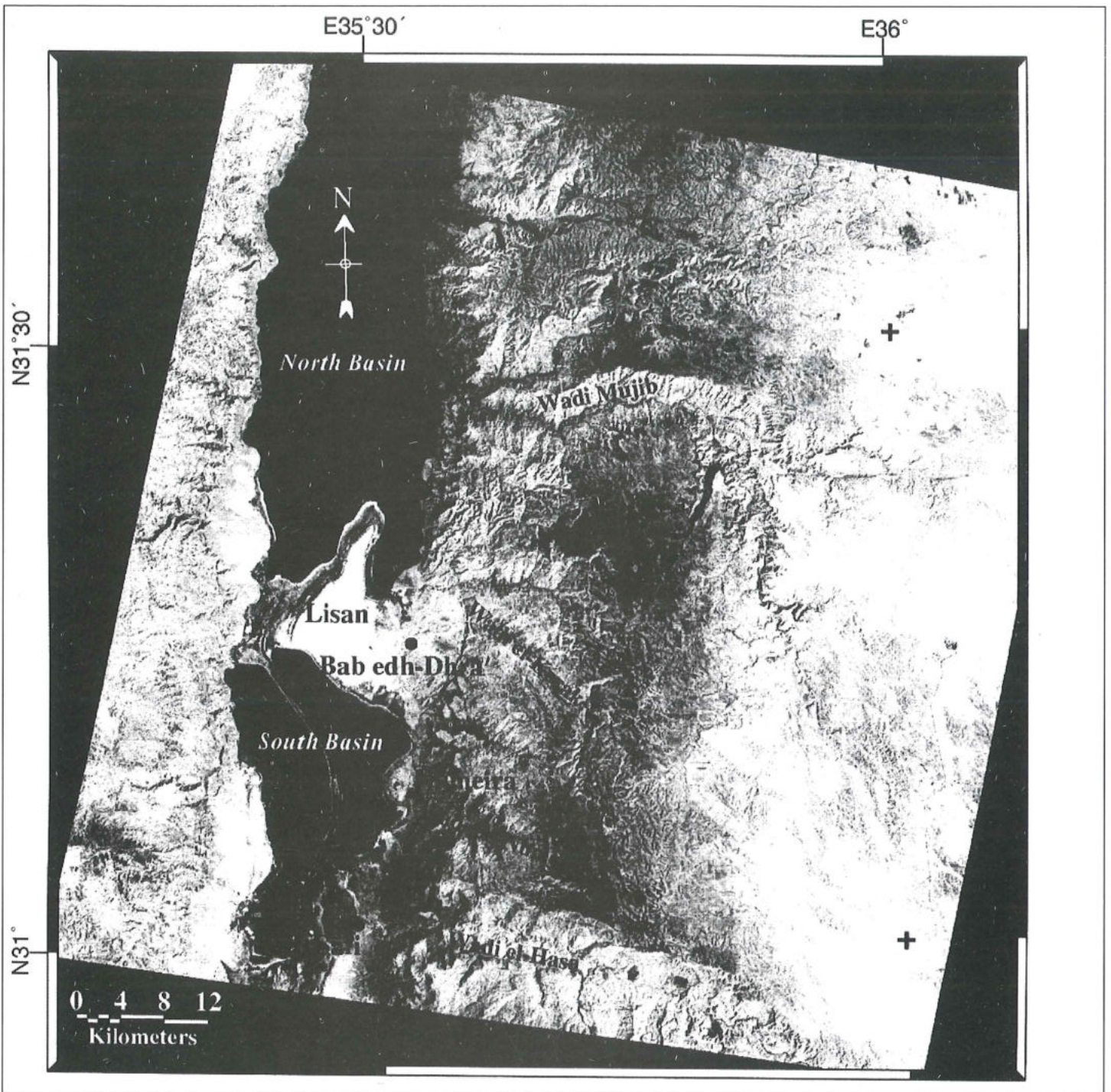
Also indicated on the image is the location of three significant Early Bronze Age sites, Bāb adh-Dhrā' an-Numayra and aṣ-Ṣāfi and four major east to west flowing wadis, al-Mūjib, north of the al-Lisān Peninsula, al-Karak

Table. 1

NAME	PGE	PGN	ELV	SZ	TP	OCC	OTHER
BILAYDAII	204.4	076.6	-60	SM	CM	EB	MANY DIAGNOSTIC, PROBABLY BECAUSE TOMBS
ER-RISHI 1	205.9	075.4	-140	ME	WA	EB	80 X 60 M. DESTRUCTION LEVELS, EBI-III
NWAK-37.1	203.6	078.9	-165	SM	BG	EB1	LATE CHALCO/EBI- HOUSE FOUNDATIONS
KHAN CEM.	191.8	032.6	-175	LG	CM	EB4	LARGE EBIV CEMETERY WITH RECT. BLDGS.
BDSUR77-11	203.1	070.6	-200	SM	CS	EB	ALSO PAL. HAND AXE 50 M. AWAY
NUMSUR24	201.4	061.4	-200	SM	CS	EB	NATURAL CLEARING NEAR ROCK SHELTER
NWAK 43	203.2	076.5	-200	SM	CS	EB	NO WALL REMAINS
NUMSUR13	201.4	062.0	-220	SM	RG	EB	RING STRUC., 23 M. IN DIAM.
NUMSUR28	201.7	066.8	-220	SM	RG	EB	NAB/LR/BYZ/MAM 18 M. DIAM. RECT PLATFORM
BABEDHDHRA	200.6	073.4	-245	LG	WA	EB	EBI-IV, LG SETTLEMENT 330 X 110 M.
BDSUR77-5	200.7	074.1	-250	SM	FM	EB	FARMSTEAD, UPPER FAN, 3 X 7 M. HUT FOUNDATION
BDCEM	200.3	073.0	-260	LG	CM	EB	EBI-IV, CEMETERY USED THROUGHOUT TOWN OCCUPATION
NWAK.-37.2	202.5	079.8	-260	SM	CV	EB	CAVE WITH TERRACE COVERED WITH LARGE STONES
NUMSUR12	201.0	062.0	-270	SM	RG	EB	RING ENCLOSURE, 13 M. DIAM. LOCATION UNCERTAIN
NUMSUR11	201.0	062.0	-270	SM	RG	EB	TWO STONE CIRCLES, JOINED 38 M. X 19 M.
NUMSUR10	201.0	062.0	-270	SM	RG	EB	STONE CIRCLE, 30 M. DIAM., STONES ON EDGE
SGNAS3	195.9	047.3	-280	SM	TO	EB	ROBBED TOMB, EB1, IR1A, MAM, OTT
NUMSUR22	200.8	060.3	-280	ME	BG	EB	LARGE ENCLOSURE, WALLS ON N. AND S.; ASH
NUMEIRATWN	200.4	060.1	-280	ME	WA	EB	WALLED TOWN SITE
FEIFACEM	193.8	038.9	-280	LG	CM	EB	LARGE CIST TOMB CEM CHALIEB
SGNAS78	194.5	038.1	-280	SM	CS	EB	BYZ, OTT, UD, SHERD SCATTER
SGNAS2	195.0	047.4	-285	LG	CM	EB1	EBIB, EBII-III (?), MAM,
SGNAS79A-H	197.2	049.9	-300	LG	CM	EB	TOMB AREAS, EB4, IR2, NAB, ROM, BYZ, MAM
SGNAS67	195.2	040.8	-300	SM	CS	EB	POTBUST, 7 X 5 M. AREA
NUMSUR17	200.7	057.0	-300	SM	RG	EB	SEMI CIRCULAR RING, 12 X 7 M.
NUMSUR21	199.3	054.9	-300	SM	RG	EB	2 RING STRUCT. ONE 22 M., OTHER 3 X 8 M.
BDSUR77-4	200.3	074.9	-305	SM	FM	EB	FARMSTEAD ON UPPER FAN
NUMSUR16	201.4	057.2	-310	SM	RG	EB	2 RINGS, ABOUT 10 M. IN DIAM EACH
BDSUR77-19	198.9	072.9	-330	SM	CM	EB	EBI SHERDS - TOMBS?
BDSUR77-17	199.0	073.4	-335	SM	FM	EB	FARMSTEAD ON LOWER FAN
BDSUR77-20	198.9	072.7	-335	SM	CM	EB	EBI SHERDS-TOMBS?
BDSUR77-18	198.3	073.4	-360	SM	CS	EB	FARMSTEAD LOWER FAN
NUMSUR2	200.9	059.8	-200	ME	VI	CHA	POSSIBLE VILLAGE CHALCO-EBIB
NUMSUR7	201.3	062.5	-225	LG	VI	CHA	FOUNDATIONS, SQ. RECT. DOLMENS
BDTWNSHIP	200.5	072.5	-255	LG	CM	CHA	STONE CIRCLE TOMBS OVER LARGE AREA
SGNAS80	197.3	049.1	-275	SM	CS	CHA	CAMPSITE, 22 X 6 M. AREA
NUMSUR8	201.2	061.8	-290	ME	VI	CHA	ASH PITS, SOME WALL REMAINS
AINSIKKIN2	200.7	075.4	-310	MD	VI	CHA	CHAL/EB- 50 M. SOUTH OF SPRING
BDTWNSHIP3	199.6	072.6	-310	SM	BG	CHA	BUILDING, CHALCOIEB
DHIRA-NEOL	204.9	072.5	-30	ME	CS	NEO	1979-POTTERY NEO A
FEIFAEAST	193.9	038.9	-270	LG	VI	NEO	APPEARS TO BE LARGE NEOLITHIC VILLAGE
AINSIKKIN1	200.8	075.5	-300	SM	CS	NEO	CLOSE TO SPRING
BDSUR77-3	201.7	074.4	-200	SM	CS	LPA	PAL. SITE BUT PROBABLY SECONDARY
BDSUR77-21	201.7	069.4	-280	SM	CS	MPA	2 LEVALLOIS POINTS - ON BEACH LINES
BDSUR77-10	202.2	070.1	-220	SM	BG	PAL	2 CIRC. AND 1 RECT. STRUCT., UD.
BDSUR77-2	201.5	074.6	-225	SM	CS	PAL	COBBLES, FLINTS
BDSUR77-9	202.1	070.3	-230	SM	CS	PAL	
BDSUR77-1	201.5	074.5	-235	SM	BG	PAL	CIRCULAR HUT- ONLY FLINT TOOLS
BDSUR77-15	201.4	072.8	-240	SM	CS	PAL	
BDSUR77-8	202.1	070.6	-240	SM	CS	PAL	
BDSUR77-16	201.3	073.0	-240	SM	CS	PAL	ALSO BYZ.
BDSUR77-6	199.0	072.4	-260	SM	CS	PAL	
BDSUR77-7	201.7	070.1	-260	SM	CS	PAL	
BDTWNSHIP2	199.5	072.1	-330	SM	CS	PAL	LARGE COLLECTION(92) FLINTS
NUMSUR19	201.0	056.5	-150	SM	RG	UD	SMALL, 9M. DIAM CIRCLE
NUMSUR29	202.1	066.5	-200	SM	RG	UD	13 M. DIAM. RING ENCLOSURE
NUMSUR14	201.4	062.1	-220	SM	RG	UD	COMPLETE RING STRUC. OUTER, INNER, ROOF
SGNAS17	196.8	044.9	-240	SM	CM	UD	UD, CAIRNS, CAMPSITE
NUMSUR31	201.8	066.3	-250	LG	CS	UD	RINGS, CRUDE WALLS, MANY LITHIC, NEOLITHIC?
SGNAS19	196.4	043.8	-270	SM	CS	UD	MIDDEN, NO OBJECTS
SGNAS22	196.3	044.4	-285	SM	CS	UD	UD, SMALL CLEARING, NO OBJECTS
SGNAS68A-C	195.7	040.3	-290	SM	TO	UD	SERIES OF GRAVES, SOME CAIRNS
SGNAS64	196.7	047.8	-290	SM	CS	UD	CAMPSITE
SGNAS81	196.7	048.6	-310	SM	AQ	UD	CONDUIT REMNANTS, 100 M. AREA
SGNAS63	196.6	047.9	-310	SM	TO	UD	ROCK PILES, GRAVES, 20 X 10 M.
SGNAS26	196.0	044.9	-320	SM	TO	UD	EB? A TOMB, FIVE OTHER TOMBS LOCATED NEARBY
SGNAS25	195.9	044.6	-320	SM	CS	UD	GRAVES, OVEN, HOUSE, SHERD SCATTER
SGNAS8	195.2	043.2	-330	ME	CM	UD	UD, GRAVES OVER LARGE AREA, NO OBJECTS
BIRKETL2	199.6	070.2	-380	LG	BI	UD	MAN MADE WATER TANK, ANCIENT BUT REFUBISHED

Table 1. cont.

NAME	PGE	PGN	ELV	SZ	TP	OCC	OTHER
SGNAS5	196.5	047.1	-270	SM	CS	MOD	BEDOUIN, IR1A, NAB, MAM
SGNAS70	195.7	040.5	-270	SM	CS	MOD	
SGNAS59	194.8	048.5	-355	SM	FM	MOD	3 ROOM FARM HOUSE, 25 X 6 M.
NUMSUR20	201.5	065.2	-290	SM	BG	OTT	ENCLOSURE WALL, VAT, STONE HOUSE, MAM ALSO
EL-QASR	200.1	077.3	-350	SM	TR	OTT	SHERDS FROM LOWER SLOPES-IRON, ROM, OTT
ISALF3-3	201.5	066.5	-290	ME	MD	MAM	90 X 30M. MOUND, MOD TOMBS ON TOP, LROM-BYZ, IR11 SHERDS
T.SUKKAR2	200.1	073.6	-300	LG	VI	MAM	SOME EB, LARGEST MAMLUK, BYZ
QAL'AT HAD	201.2	078.0	-309	ME	BG	MAM	TO EAST OF POLICE POST, BYZ, OTT ALSO
T.SUKKARI	195.3	047.9	-330	ME	SM	MAM	
BDSUR77-12	198.8	073.6	-340	SM	CS	MAM	
SGNAS1	195.3	047.6	-340	SM	SM	MAM	EB2-3(?), NAB, BYZ, LBYZ-UM, LABB/FAT, MOD
el-HADITHA	201.1	077.8	-340	LG	VI	MAM	SOME BRONZE, MORE BYZ, OTTOMAN
QASRFAYFA	192.3	039.1	-350	LG	MD	MAM	SOME BYZ, MOSTLY OTT TO MAM. MILL STONE
SHEIKH'ISA	195.1	048.0	-350	LG	VI	MAM	EB, NAB, ROM/NAB, LATE BYZ, FATIMID
NUMSUR5	199.8	060.3	-360	LG	MD	MAM	WEST OF RUJM, SOME NAB, BYZ, UMM, ASH, STONE
SGNAS77	194.9	038.4	-270	SM	AQ	ISL	EB, UD, 2 SQ. BLDS, AQUEDUCT
SGNAS58	194.9	048.8	-355	SM	CS	ISL	UD., SHERD SCATTER
BIRKET,L1	197.1	073.9	-360	LG	BI	ISL	WATER TANK FOR ISLAMIC PILGRIMAGE
AL-RUJOUH	194.9	049.9	-370	LG	MD	ISL	MOUND + CEM., 100 X 200 M. ROM? ABB, FAT, AYY, MAM
ALTHIAHEM	196.2	051.3	-375	SM	BG	ISL	FARM BLDG. 21 X 6 M., UD, PROB. ISL.
SGNAS74	197.3	039.4	-200	SM	FM	BYZ	SOME ROCK ALIGNMENTS
SGNAS18	196.8	044.4	-260	SM	CS	BYZ	HEARTH, STONELINES
ISALF3-2	201.6	066.8	-275	SM	TR	BYZ	IRON II, LATE ROM -16 M.SQ
NUMSUR27	201.5	066.8	-280	SM	MD	BYZ	STONE BLDG. 15 X 8 M., NAB, LR, MAM REBUILT
AIN-ABATA	197.9	052.8	-290	LG	CH	BYZ	MON. CH. HAB, ROM, UMM?, ABB, OTT, UD
SGNAS7	196.9	047.4	-300	SM	CV	BYZ	BYZ HERMITAGE, ROCK-CUT CHAMBERS, CISTERN
ISALF3-1	201.6	067.0	-300	SM	BI	BYZ	35 X 35 M. WALLS, 3 M. HIGH, 2.5 M. THICK, STYLE BYZ
ISALF3-4	201.5	066.4	-300	SM	TR	BYZ	EARLY ROM TO LATE BYZ. TOWER 22 X 12 M.
FEIFA WEST	193.3	038.8	-310	ME	CS	BYZ	ALSO EB/IRON--PLOWED FIELD, MASONRY, SHERD
NUMSUR4	200.2	059.7	-320	MD	VI	BYZ	BETWEEN TOWN AND RUJM BYZ, UMM, MAM REBUILT
QASRETTUBA	195.3	047.9	-320	ME	TR	BYZ	SHERDS NO LATER THAN POST-UMMAYYAD
BDSUR77-14	199.2	073.2	-330	SM	CS	BYZ	ALSO ROMAN, SOME EB?
BDSUR77-13	199.3	073.4	-330	SM	CS	BYZ	
SGNAS61	197.2	049.9	-335	SM	BG	BYZ	ISL, UD, 2 STRUCTURES, GRAVES NEARBY
AINSIKKIN3	200.6	075.8	-340	LG	BG	BYZ	MUTRABA EAST AND WEST, NAB, ROM, ARABIC
DYKE,LISAN	195.5	073.5	-340	LG	DM	BYZ	100 M. LONG RAISED CAUSEWAY OR DYKE
SGNAS65	194.9	048.4	-350	SM	CS	BYZ	ISL, UD SHERD SCATTER, 15 X 10 M. AREA
SGNAS66	195.0	047.5	-355	SM	CS	BYZ	NAB, ROM, UM, ABB, ISL, MOD. SHERD SCATTER
DEIR,LISAN	196.1	075.2	-360	SM	BG	BYZ	RUINS OF MONASTERY/HERMITAGE
BIRKETSAFI	194.9	049.5	-360	ME	BI	BYZ	FEW SHERDS BYZ, MAM, 60 M. SQ., CUT STONE
ISALKINGII	201.2	066.1	-370	SM	MD	BYZ	SOME MAM, 2 UMM, 1 FAT, SOME IRON I
ISALKINGI	201.0	066.1	-380	SM	TR	BYZ	SOME LATE ISLAMIC, FALLEN MASS SANDSTONE
BILAYDA I	204.5	076.5	-60	ME	BG	ROM	ROM/NAB, BYZ, ISL, MANY GRAVES
NUMSUR30	202.1	066.1	-180	SM	RD	ROM	LROM/BYZ/ ISL/ ROMAN ROAD
SGNAS24	196.3	043.0	-255	SM	CS	ROM	POTBUST
SGNAS23	196.3	043.9	-290	SM	CS	ROM	CAMP, GRAVE, STONE LINES
FEIFATELW	193.6	038.9	-306	SM	TR	ROM	ROM/NAB/BYZ/ OTTOMAN TO MAMLUK
T.SUKKAR2W	199.6	073.6	-320	ME	VI	ROM	ROM/BYZ, LOW MOUND, SOME NAB, ISL, EB
KH.el QUNE	201.9	082.3	-385	SM	BG	ROM	21 X 50 M. BUILDING, ER, LR
ER-RISHI 2	206.0	075.4	-140	SM	BG	NAB	BLDG. 30 X 25 M., ALSO TOWER ER/LR/BYZ
NUMSUR23	202.0	062.3	-150	SM	RG	NAB	RING 5 M. IN DIAM. LATER SHERDS ALSO
ET TAWABIN	196.9	046.7	-165	LG	WA	NAB	ROM/NAB (MOST), BYZ, POST UMM, MAM. TOWERS
NUMSUR9	201.0	062.1	-270	SM	CS	NAB	WATCH STATION? SMALL PILE OF STONES
RUJMNUMEIR	199.9	059.8	-355	SM	TR	NAB	NABATEAN WATCH TOWER, DAMS TO N. AND W.
NUMSUR26	200.9	066.6	-355	ME	MD	NAB	ER/BYZ/ UMM TO MAM, ASH, BLDG. FOUNDATIONS
NUMSUR25	200.8	066.6	-360	SM	TR	NAB	EARLY ROM. LOW MOUND, BLDG., 5 COURSE
NUMSUR15	200.2	058.6	-390	LG	CS	NAB	HELLENISTIC? ASH, SHERDS
SGNAS60	196.6	039.5	-200	SM	CS	IR	BYZ, UD SHERD SCATTER, 20 X 20 M. AREA
SGNAS62	196.5	048.9	-315	SM	CM	IR	6 ROCK BUILT TOMBS, 50 X 20 M. AREA, OTT
SGNAS71	196.6	039.5	-210	SM	CS	IR1	EB, UD, SHERD SCATT., POTBUST?, 10 X 6 M. AREA
UMJUFNA	198.5	039.4	-180	SM	TR	IR2	HELL. TOWER 15 M. IN DIAM
SGNAS72	196.8	039.4	-190	SM	CS	IR2	NAB, TOMB, SHERD SCAT.
SGNAS69	195.6	040.5	-270	SM	TO	IR2	2 GRAVES, TOWER, 20X10 M.
KH.KHANAZI	191.5	033.8	-270	ME	WA	IR2	ALSO EB? NAB/ROM, BYZ
FEIFA-TELE	193.6	038.9	-300	ME	WA	IR2	WALLED AREA IRON
QASR UMRUQ	194.3	035.8	-320	SM	TR	IR2	POSSIBLE, ALSO ROM/BYZ, BYZ, MANY POST-UM
NUMSUR6	200.3	059.5	-345	SM	BG	IR?	DATE UNCERTAIN, ALSO HAS STONE CIRCLES
DHRAWAIDHA	205.2	072.3	-30	ME	CU	EB	HIGH PLACE WITH LONG WALL OR STAIRCASE



1. Georeferenced Landsat Quarterscene (1984) of the Dead Sea region. Achromatic Greyscale image was produced using bands 2,3,4, and 5.

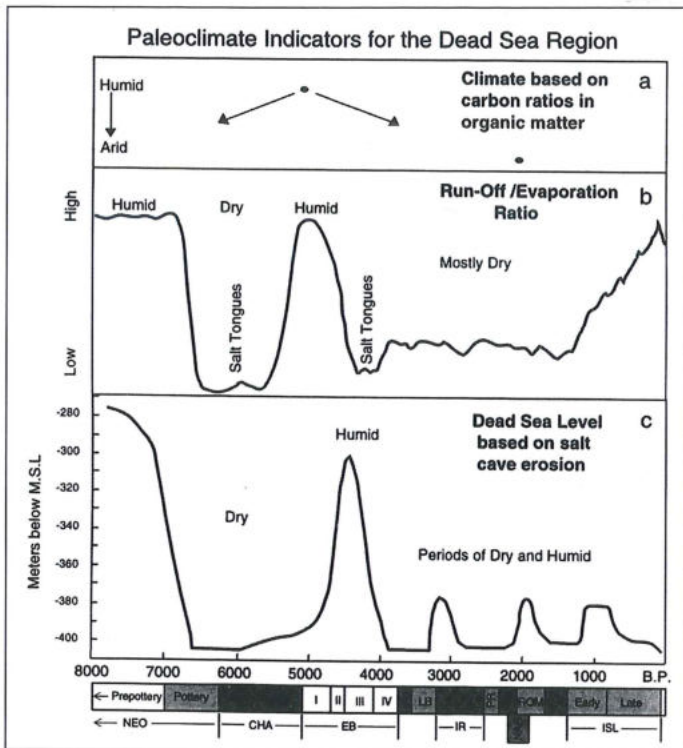
located immediately north of Bāb adh-Dhrā', an-Numayra situated just north of an-Numayra and al-Ḥasa which occurs adjacent to aṣ-Ṣāfi.

B. Estimates of Past Dead Sea Levels.

Three different estimates of changes in the Dead Sea climate are presented in FIG. 2. Both BP and the cultural sequence are shown along the bottom horizontal axis with the calendrical time scale for the latter reflecting calibrated

Radio Carbon dates.

FIG. 2a (Margaritz *et al.* 1991) is based on carbon ratios in organic matter with only four rather widely spaced data points. This suggests the most humid conditions during Early Bronze I. More arid conditions occur during the Early Chalcolithic and Middle Bronze periods while the most arid conditions happen during the Hellenistic/Nabatean periods. Only four data points are used in this proposal making it too generalized to provid-



2. a) Cilate aridity based on $12C/13C$ rations in organic matter collected from cores in alluvial sediments of the western shore of the Dead Sea (adapted from Margaritz *et al.* 1991). b) Cilamate aridity based on run-off of clastic versus precipitated (salt) material found in the south basin of the Dead Sea (adapted from Neev and Emery 1967). c) Dead Sea level based on salt cave development in the diapir of Mount Sedom, Israel(adapted from Frumkin *et al.* 1991).

ed good estimates.

FIG. 2b (Neev and Emery 1967) is based on a run-off evaporation ratio estimate derived in part on dated sediments and sedimentary rock units during their study of the Dead Sea. The figure presents their estimates of humidity in the Dead Sea valley over the last 8000 years. They suggest humid conditions during Neolithic, Early Bronze and Islamic Ages, with relatively arid conditions during the other cultural periods.

In FIG. 2c (Frumkin *et al.* 1991) the Dead Sea level curve is based on the morphology of well-dated salt caves located in the subsurface of Jabal Usdum on the south west shore of the Dead Sea. Thirty two Carbon 14 dates, with tree-ring calibration, were used in the study including eight for the Early Bronze Age. This is a quantitative curve with the highest sea level stand (-280 m bsl) during the Neolithic period. The next highest stand (-300 m bsl) occurs in the first half of the Early Bronze Age. The BP dates range from 4580 +90 to 4050 +75 and the corresponding adjusted calendrical dates are 3350 (+450,-150) BCE to 2590 (+390,-270) BCE. The widest cave width is dated by a wood sample to 2930 +180,-160, ranging from 3110 to 2730 BCE. It is important to note that both the rise and fall of the Dead Sea to and from -300 mm was quite rapid. Three lower high stands (-380 bsl) occur in Iron I, Nabataean/ Roman and Early Islamic periods. The

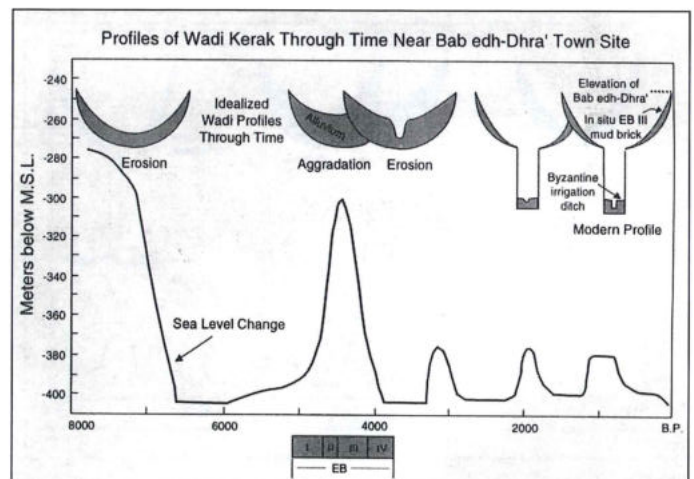
Frumkin hypothesis estimates rather rapid changes in the Dead Sea level in all cases.

C. Geomorphological Studies at Bāb adh-Dhrā' and an-Numayra.

Extensive and detailed field work at the Early Bronze Age sites of Bāb adh-Dhrā' and an-Numayra and their adjacent wadis demonstrates a consistent pattern of erosion, deposition and then rapid erosion at both the sites and wadis. Additional field studies at two additional Early Bronze sites, Feifeh and al-Khanazir, further south in the al-Ghawr, document the same sequence of events.

The wadi profiles in FIG. 3 illustrate the proposed relationship between the development of Wādī al-Karak and the changes in the Dead Sea level proposed by Frumkin, *et al.* (1991; see also Frumkin 1994). During the Neolithic period, a stable high stand of the Dead Sea and resultant slow erosion caused the gentle bowl-shaped profile for the upper half of the Wādī al-Karak. The low stand during Chalcolithic and EBI undoubtedly caused some rapid downcutting in the Wādī al-Karak and at Bāb adh-Dhrā' but no record of that is preserved.

The middle profile corresponds to Early Bronze II-III, during which there is a rising Dead Sea level and a corresponding rise in the base level for the Wādī al-Karak and even more so, its tributaries. Aggradation or deposition of sediments occurred during this period. This is quite obvious within the interior of the site of Bāb adh-Dhrā' where active sedimentation caused development of cultural feature sequence up to more than three meters in thickness. Finally the rapid drop in the Dead Sea level during EB IV caused extensive erosion, particularly within the two tributaries of Wādī al-Karak which breach the interior of Bāb adh-Dhrā'. This erosion also removed most of the northern portion of the stone and mudbrick wall line which originally encircled the site. The subse-



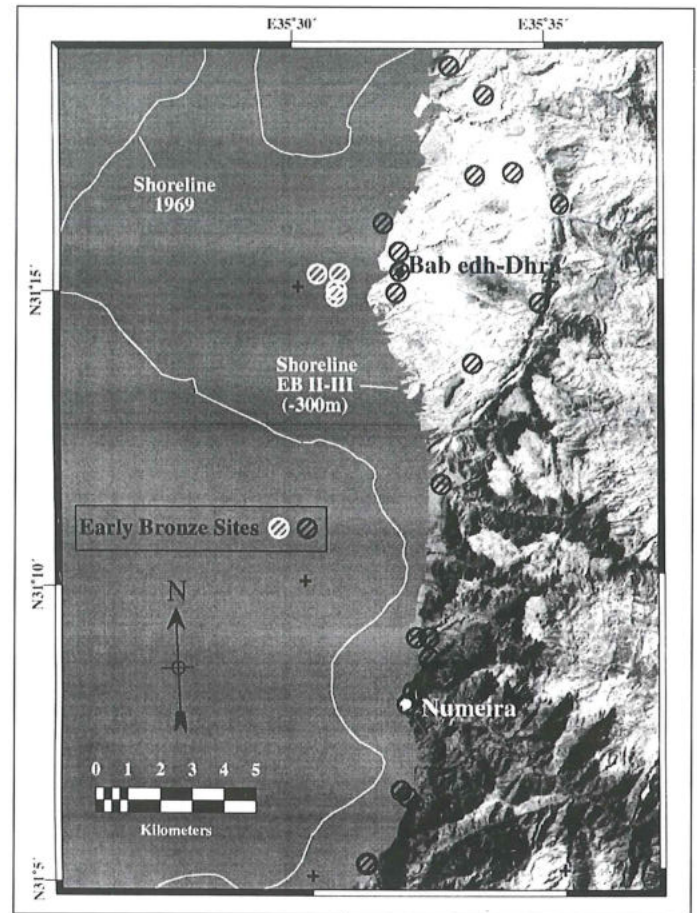
3. Relationship of idealized profiles of Wādī al-Karak through time (adapted from Donhaue 1985) and the changes in the Dead Sea level (adapted from Frumkin *et al.* 1991). Extrapolation of profiles back through time was determined from cultural material found within the wadis, and erosional and depositional features found at Bāb adh-Dhrā'.

quent downcutting of the Wādī al-Karak, is reflected in the steep sides (diagrammatic) of the lower, narrow, vertically sided "stem" on the third profile.

FIG. 4 compares the Wādī an-Numayra profile with the Frumkin (1991) Dead Sea level curve. The periods of erosion at an-Numayra were more extensive than at Bāb adh-Dhrā'. Both the upper bowl-shaped profile and the lower "stem" are narrower and deeper than within the Wādī al-Karak profile at Bāb adh-Dhrā'. The Early Bronze site an-Numayra is quite small while the stream emerging from the narrow, deeply entrenched Wādī an-Numayra has apparently eroded a large volume of sediment from a previously more extensive alluvial fan terrace. There is a distinct possibility that the Early Bronze III site of an-Numayra was far larger than the erosional remnant which remains preserved today. In contrast to Bāb adh-Dhrā', there is no indication of sediment deposition at the preserved remnant of an-Numayra during EB III. The differences between Bāb adh-Dhrā' and an-Numayra may have been caused by less fault movement in the area of the al-Lisān Peninsula where Bāb adh-Dhrā', is located and more movement along the South basin of the Dead Sea where an-Numayra is located. Additional field work and data analysis will be necessary to confirm or deny this hypothesis.

D. Reconstructed EB II-III Shoreline

FIG. 5 shows the proposed location of the Dead Sea shore line during EB II-III, assuming that Frumkin's (1991) interpretation of salt cave data from Jabal Usdum is correct. The 100 m rise in the Dead Sea level would place the shore much closer to Bāb adh-Dhrā' and an-Numayra. Both sites have a steep slope on their western edge which strongly resembles a wave-cut bluff generated during an Early Bronze III high Dead Sea level stand. The 1969 shore line for the Dead Sea which outlines the al-Lisān Peninsula is

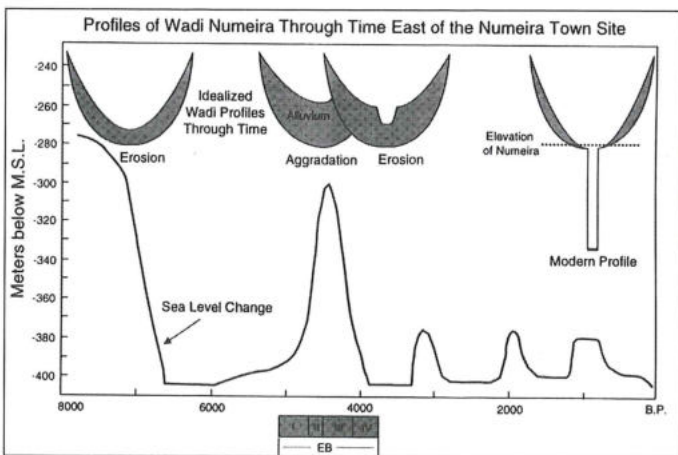


5. Reconstruction of the Dead Sea highstand during late EB II and EB III. EB sites represented by light grey circles are EB I sites which would have been occupied before the highstand.

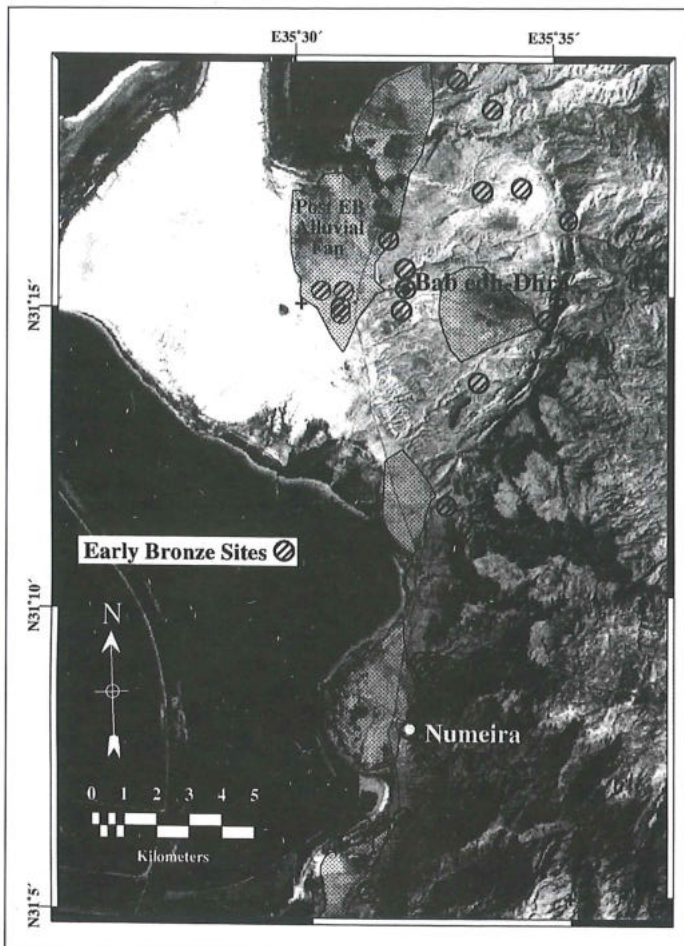
also given in the figure. The Early Bronze sites located in the area of the submerged al-Lisān Peninsula just west of Bāb adh-Dhrā' documented during a 1977 survey (BDSUR77-17,18,19,20 in TABLE 1), appear to challenge this hypothesis. A check of the field notes, however, reveals that two of the sites had only EB I tomb pottery (before the high stand of the Dead Sea) and all four were located on the western edge of the alluvial fan in recent erosional cuts and not on top of the alluvial fan.

Post EB III.

The dotted areas on the satellite image (FIG. 6) show positions where post-Early Bronze III alluvial fan deposition occurred. All of these fans are distinctly different in appearance (color and texture) from the older fans on which Bāb adh-Dhrā' and an-Numayra are situated. The fans immediately west of Bāb adh-Dhrā' and an-Numayra may be interpreted as post EB II-III alluvial fans caused by the down gradient deposition of sediments derived from the down-cutting of the wadis and some erosion of the two sites. If the interpretation is correct, the sediments should contain transported and redeposited cultural materials.



4. Relationship of idealized profiles of Wādī an-Numayra through time (adapted from Donhaue 1985) and the changes in the Dead Sea level (adapted from Frumkin *et. al.* 1991). Extrapolation of the profiles back through time was determined from cultural material found within the wadis, and erosional and depositional features found at an-Numayra.



6. Location of post EB alluvial fans and EB sites. EB I sites emphasized in FIG. 5 are beneath the post-EB Alluvial fan.

Settlement Patterns and Changing Shorelines.

A comparative study of the basic settlement patterns along the south-east shore of the Dead Sea during the major historical periods reveals no major inconsistencies with the hypothesis of Frumkin. In fact, when the corrected calendrical BCE dates are used, the settlement patterns of occupational sites correlate well with the proposed changing shorelines.

Since 1973, a series of intensive and extensive surveys have built up an impressive data base of sites for the south-east Dead Sea area (see TABLE 1). Rast and Schaub (1974) highlighted the Early Bronze Age and King (1987) the Byzantine and later periods over the entire area. Raikes (1980) concentrated on earlier sites. Others have focused on sub-regions, McCreery (1978-79, 1979), Clark (1978), McConaughy (1981) on the Sahl adh-Dhrā' region, Mittmann (1982) and Jacobs (1983) the Wādī Isal, Koucky (1983) the Ghawr an-Numayra, Worschech (1985a,b;1986) the Ard-al Karak and MacDonald (1992) the Southern Ghors, south of aṣ-Ṣāfi.

Excavated sites include Bāb adh-Dhrā' (Lapp 1966, 1968; Schaub and Rast 1989), Bāb adh-Dhrā' and an-Numayra (Rast and Schaub, 1981; Schaub and Rast, 1984; Schaub 1993), Feifa and al-Khanāzīr by the "Expe-

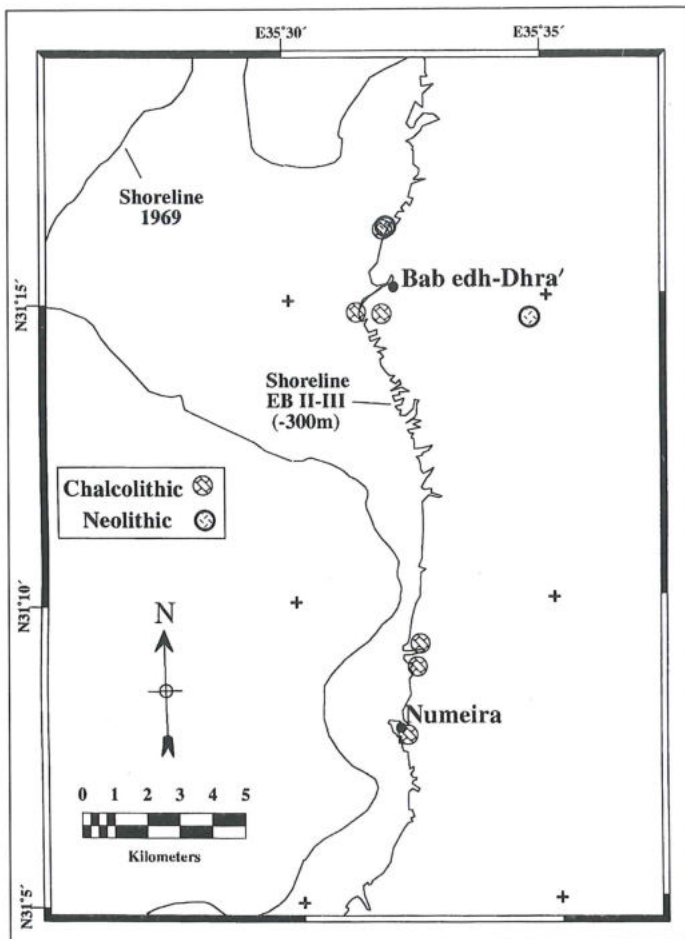
dition to the South-east Dead Sea Plain" (EDSP) in 1989-90, Waidha, near adh-Dhrā' (Korber 1993), Bāb adh-Dhrā' Chalcolithic cemetery (Clark 1979), adh Dhrā Neolithic (Bennett 1980) and 'Ain 'Abata (Politis 1989, 1990, 1992).

The sites in TABLE 1 are listed in sequence by major occupational period (MOD, OTT, MAM etc.) and within each period by decreasing elevation. Only those sites below sea level in this area are included in the Table. Site size is indicated in the table by the terms LG, ME, or SM. Apart from the excavated sites most of the size designations are relative estimates lacking quantitative precision but they do offer some relative sense of the extent of observed ruins. There are actually few "large" sites in the south-east al-Ghawr Bāb adh-Dhrā' with a walled town area of 12 acres and a large cemetery area of over 120 acres is the largest for the earlier periods.

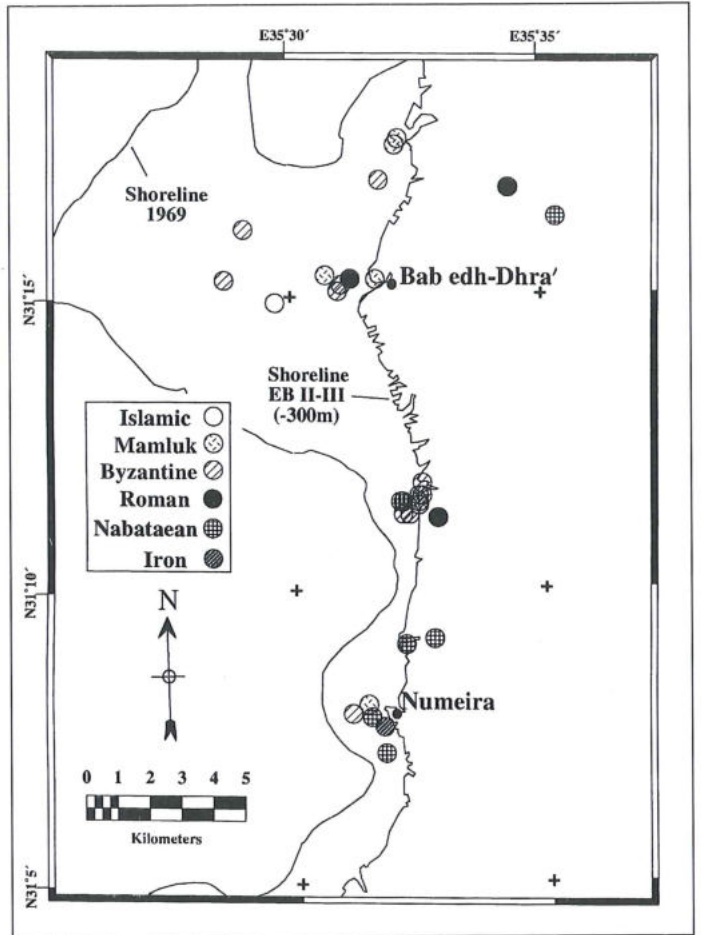
The Palestine Grid coordinates and elevation data listed in TABLE 1 are based, for the most part, on published data from the surveys and excavations listed above. Some unpublished sites from surveys (Koucky 1983 and McCreery 1979) are also included. Most of these surveys used 1:50,000 and 1:10,000 scale topographic maps (see the data in MacDonald 1992: 9). In some instances we have corrected the published data using 1:2500 scale maps provided by the Jordan Valley Authority. In these cases the information varies from that listed in the Jordan Antiquities Database and Information System (JADIS) (Palumbo 1994). Some sites listed in JADIS for the different chronological periods have not been included in this data base because the evidence recorded by the surveys appears inconsequential (a "potbust" or a few body sherds).

The settlement pattern maps (FIGS. 5,7,8) are based on the available satellite data north of the aṣ-Ṣāfi region and are intended to show the impact of changing shorelines on the settlement patterns along the southeastern coast. In general, sites for the earlier periods, the Early Bronze Age, (with the exceptions of the BDSUR 17-20 sites, discussed above), and the Neolithic and Chalcolithic are above the -300 m while the majority of sites for the Byzantine, Mamluk and Islamic periods are below -300m bsl (See also TABLE 1).

The easternmost Neolithic site in FIG. 7 is a flint factory site in the Sahl adh-Dhrā' dated to Pottery Neolithic A. Similar levels were also exposed by the EDSP in the plateau area east of Tall Feifa in the south, also at higher elevations, which could reflect the high stand for the Dead Sea in Frumkin's hypothesis. For the Chalcolithic period both cemeteries (excavated) and settlements (unexcavated) are attested. In the Sahl adh-Dhrā' 17 tombs, constructed of concentric stone circles with monolithic stones in the center, were assigned to the early Chalcolithic period. Similar sites occur all along the slopes and plateaus of the hills from Bāb adh-Dhrā' to aṣ-Ṣāfi. Surveys describe a possible habitation site near the



7. Location of Neolithic (pottery stage) and Chalcolithic sites.



7. Location of Iron through Islamic Age sites.

'Ayn Sikkin spring above Mazra'a, three in the an-Numayra area, and several south of the Wādi Feifa. All of these sites are near or to the east of the -300 m. bsl contour. In Frumkin's hypothesis the Chalcolithic period was dry and the level of the Dead Sea was around -400 m bsl. If the hypothesis is correct there could be Chalcolithic sites buried below the later alluvial fans at Bāb adh-Dhrā' and an-Numayra.

The Early Bronze Age represents the first extensive occupation in the southern Ghawr with 32 sites reported although many of these are small (FIG. 5 and TABLE 1). The major occupational sites during EB II-III, the projected high stand of the Dead Sea, are above the -300 m bsl contour and concentrated in the north, including the excavated walled towns of Bāb adh-Dhrā', an-Numayra and a third site, ar-Rishi, situated on the northern bank of the Wādi al-Karak as it exits from the mountains. Both Feifa and aṣ-Ṣafī have large EB I cemeteries and the southernmost site al-Khanāzīr is a cemetery from the EB IV period.

The one Iron Age site in FIG. 8, near an-Numayra, represents the remnants of a building found during a survey (NUMSUR6) with a question mark on the dating evidence. Two possible Iron II tower sites not on the map, nor listed in TABLE 1, have been noted in the Wādi Isal

(Palumbo, JADIS, 2006.099, 2006.104) and at al-Qaṣr above al-Mazra'a (Palumbo, JADIS, 2007.104). All of the Iron Age sites are above the -370 m. bsl high stand level for this period in Frumkin's hypothesis (see FIG. 2c).

Evidence for Middle and Late Bronze age occupation has been rarely recorded in the Southeast ghors. Nine cairn tombs with MB/LB pottery near the Byzantine site of 'Ayn 'Abāṭa were observed recently by Politis (1993).

The location of Nabataean through Islamic sites are also indicated on FIG. 8. Small Nabataean towers guarded the Wādi al-Karak (ar-Rishi 2) and the Wādi an-Numayra (Rujm an-Numayra). The an-Numayra region has several additional sites including a medium-sized settlement mound with Nabataean and later remains and a possible large camp area (Hellenistic?) at a level below the high stand of -375 m bsl. for this period in Frumkin's hypothesis. The largest Nabataean site in the area is Umm aṭ-Ṭawābīn, located in the south and not indicated in FIG. 8. It is a walled site (2.5 km in circumference) built on a high ledge on the south bank of the Wādi al-Ḥasa. There is a large tower at the south-east corner and many structures, large and small, visible within the enclosure wall.

The Byzantine period has the largest number of sites from after the Early Bronze Age. Several seasons of sur-

vey and excavations at the Byzantine site of Dayr 'Ayn 'Abāta, north of aṣ-Ṣafī, have revealed an impressive reservoir with water catchment and distribution system, and a religious building with mosaic pavement. Surveys have recorded other Byzantine cultural remains throughout the area. In the aṣ-Ṣafī area, a large pottery scatter south-west of Ṭawāhin as-Sukkar, the shrinking mudbrick ruins of the nearby Qaṣr aṭ-Ṭuba, and a large reservoir or *birka*, 60 sq. m, further north, have been interpreted as Byzantine by King.

In the north a large Byzantine complex with several buildings is located near the 'Ayn as-Sikkin spring. Two kilometers to the west Buleida has tombs and a settlement. Both of these sites also have Nabataean and Roman remains. Other Byzantine sites include two on the al-Lisān, a dike and a mud-brick hermitage, Qaṣr aṭ-Ṭuba, and several in the Wādī Isal, including a large *birka*, 35 x 35 m, several towers and a possible settlement mound. Many of the Byzantine sites, especially those on the al-Lisān are located at lower levels which corresponds to a low level of the Dead Sea according to Frumkin's hypothesis.

Arab geographers generally describe the southern al-Ghawr as flourishing during the Mamluk period (Le Strange 1965). Although only ten archaeological sites are listed as primarily Mamluk, seven of these are large or medium (TABLE 1, FIG.8). The major Mamluk sites are al-Ḥaditha and Ṭawāhin as-Sukkar 2 in the Ghawr al-Mazra'a, a mound west of Rujm an-Numayra (NUMSUR5) in the Ghawr an-Numayra, Al-Rujūm, Shaykh 'Isa and Ṭawāhin as-Sukkar 1 in the aṣ-Ṣafī region and Qaṣr Feifa. According to Frumkin's theory there is a high stage of the Dead sea in the early part of the second Millennium followed by a low stage. All of the Mamluk sites, dated from the mid-12th to the 16th century are located at lower levels.

Summary

The hypothesis of Frumkin on changing Dead Sea levels of the past that we have examined holds its own in the light of the evidence examined from survey, excavation, geomorphological fields studies and comparison of settlement patterns. The geomorphological studies of the wadi profiles coordinated with excavation of the sites of Bāb adh-Dhrā' and an-Numayra certainly correlate well with the theory. A survey of the settlement patterns of the various cultural periods does not yield any major obstacles to the hypothesis. The study of the satellite images did not reveal traces of ancient shore lines but the outlines of recent alluvial fans show up clearly on these images.

Bibliography

- Abel, F.-M. 1967. Géographie de la Palestine, Tome II Géographie Politique. Les Villes. (3rd ed.) Paris: Etudes Bibliques Series.
- Bennett, C.-M. 1980. Soundings at Dhra', Jordan. *Levant* 12:30-39.
- Clark, V. 1979. Investigations in a Prehistoric Necropolis near Bab edh-Dhra'. *ADAJ* 23:57-77.
- Donahue, J. 1985. Hydrologic and Topographic Change during and after Early Bronze Occupation at Bab edh-Dhra' and Numeira. Pp. 131-140 in *SHAJ* II. Amman: Department of Antiquities.
- Frumkin, A. 1994. Hydrology and Denudation Rates of Halite Karst. *Journal of Hydrology*. 162: 171-189.
- Frumkin, A., Carmi, I, Zak, I. and Margaritz, M. 1991. The Holocene Climatic Record of the Salt Caves of Mount Sedom, Israel. *Holocene* 1:191-200.
- 1994. Middle Holocene Environmental Change Determined from the Salt Caves of Mount Sedom, Israel. In O. Bar Yosef and R. S. Kra (eds), *Late Quaternary Chronology and Paleoclimates of the Eastern Mediterranean*. Tucson: Radiocarbon, Department of Geosciences, University of Arizona.
- Jacobs, L. 1983. Survey of the South Ridge of the Wadi 'Isal, 1981. *ADAJ* 27:245-74, Figs. 1-15.
- King, G.R.D., Lenzen, C.J., Newhall, A., King, J.L. and Deemer, J.D. 1987. Survey of Byzantine and Islamic Sites in Jordan. Third Season Preliminary Report (1982). The Southern Ghor. *ADAJ* 31:439-59.
- Klein, C. 1981. The influence of rainfall over the Catchment Area on the Fluctuations of the Level of the Dead Sea Since the 12th Century. *Israel Meteorological Research Papers* III, Sept: 29-57.
- 1985. Fluctuations of the Level of the Dead Sea and Climatic Fluctuations in the Country during Historical Times. Pp. 197-224 in *International Association of Hydrological Sciences. International Symposium on Scientific Basis for Water Resources Management*. Jerusalem, 19-23 Sept. vol. 2, Additional Papers and Poster Summaries.
- 1982. Morphological Evidence of Lake Level Changes, Western Shore of the Dead Sea. *Israel Journal of Earth-Sciences* 31: 67-94.
- Korber, C. 1993. Edh-Dhra' Survey 1992. *ADAJ* 37: 550-553.
- Koucky, F. 1983. Archaeological Sites of the Numeira Area. (unpublished manuscript).
- Lapp, P. W. 1966. The Cemetery at Bab edh-Dhra' Jordan. *Archaeology* 19:104-111.
- 1968. Bab edh Dhra' Tomb A76 and Early Bronze I in Palestine. *BASOR* 189:12-41.
- Le Strange, G. 1965. *Palestine Under the Moslems. A description of Syria and the Holy Land. From A.D. 650 to 1500*. Translated from the works of Medieval Arab Geographers. Beirut: Khayats. (reprinted from the Original edition of 1890).
- Margaritz, M., Rahner, S. and Yechieli, Y. 1991. C13/C12 Ratio in Organic Matter from the Dead Sea Area: Paleoclimatic Interpretation. *Naturwissenschaften* 78:453-455.
- McConaughy, M. 1981. A Preliminary Report on the Bab

- edh-Dhra Site Survey. Pp. 187-90 in W. E. Rast and R. T. Schaub (eds), *The Southeastern Dead Sea Plain Expedition: An Interim Report of the 1977 Season*. AASOR 46. Cambridge, MA: American Schools of Oriental Research.
- McCreery, D. 1977-78. Preliminary Report of the A.P.C. Township Archaeological Survey. *ADAJ* 22:150-62.
- 1979. Initial Report of the Archaeological Survey of the Southern Ghor and Araba, May 2-16, 1979. (unpublished manuscript).
- MacDonald, B. 1980. The Hermitage of John the Abbot at Hammam 'Afra, Southern Jordan. *LA* 30:351-64 Pls. 59-70.
- 1992. *The Southern Ghors and Northeast 'Arabah Archaeological Survey*. *Sheffield Archaeological Monographs*, 5. Sheffield: J.R. Collis.
- Mittmann, S. 1982. The Ascent of Luhith. Pp. 175-180 in *SHAJ* I. Amman: Department of Antiquities.
- Politis, K. D. 1989. Excavations at Deir 'Ain 'Abata 1988. *ADAJ* 33:227-234.
- 1990. Excavations at Deir 'Ain 'Abata 1990. *ADAJ* 34: 377-385.
- 1992. Excavating Lot's Cave in Jordan: Evidence of a Forgotten Biblical Episode. *Minerva: The International Review of Ancient Art and Archaeology*. July-August 1992: 3(4).
- 1993. Deir 'Ain 'Abata. Pp. 336 in *The New Encyclopedia of Archaeological Excavations in the Holy Land*, I.
- Neev, D. and Emery, K.O. 1967. The Dead Sea: Depositional Processes and Environments of Evaporites. Ministry of Development, Jerusalem: *Geological Survey, Bulletin* 41.
- Palumbo, G. (ed.) 1994. *The Jordan Antiquities Database and Information System (JADIS)*. Amman: Department of Antiquities of Jordan and American Center of Oriental Research.
- Raikes, T.D. 1980. Notes on Some Neolithic and Later Sites in Wadi Araba and the Dead Sea Valley. *Levant* 12:40-60.
- Rast, W.E. and Schaub, R.T. 1974. Survey of the Southeastern Plain of the Dead Sea, 1973. *ADAJ* 19: 5-53, Pls. I-XI.
- 1981 (eds). *The Southeastern Dead Sea Plain Expedition: An Interim Report of the 1977 Season*. AASOR 46. Cambridge, MA: American School of Oriental Research.
- Schaub R.T. 1993. Bab edh Dhra. In *The New Encyclopedia of Archaeological Excavations in the Holy Land*. Vol. 1. New York: Simon and Schuster.
- Schaub, R. T. and Rast, W. E. 1984. Preliminary Report of the 1981 Expedition to the Dead Sea Plain, Jordan. *BASOR* 254:35-60.
- 1989. *Bab edh-Dhra. Excavations in the Cemetery Directed by Paul W. Lapp (1965-67)*. *Reports of the Expedition to the Dead Sea Plain, Jordan*, Vol. 1. Winona Lake: Eisenbrauns.
- Worschech, U. 1986. Die sozio-ökologische Bedeutung frühbronzezeitlicher Ortslagen in der nordwestlichen *Ard el-Kerak*: Ein Vorbericht. *ZDPV* 102:40-52.
- 1985a. Preliminary Report on the Third Survey Season in the North-West *Ard El-Kerak*, 1985. *ADAJ* 29:161-73.
- 1985b. Northwest *Ard El-Kerak* 1983 and 1984. A Preliminary Report. *Biblische Notizen*. Beiheft 2. München: Manfred Gorg.
- Worschech, U., Rosenthal, U. and Zayadine, F. 1986. The Fourth Survey Season in the North-west *Ard el-Kerak*, and Soundings at Balu', 1986. *ADAJ* 30:285-309.
- Worschech, U. and Knauf, E. A. 1986. Alte Strassen in der nordwestlichen *Ard el-Kerak*. Ein Vorbericht. *ZDPV* 101/2 :128-33 .