
The Climate of the Ancient near East. The Early Third Millennium BC in the Northern Negev of Israel (Das Klima des dritten vorchristlichen Jahrtausends im Nahen Osten. Die nördliche Negevwüste Israels)
Author(s): David H. K. Amiran
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THE CLIMATE OF THE ANCIENT NEAR EAST. THE EARLY THIRD MILLENNIUM BC IN THE NORTHERN NEGEV OF ISRAEL

With 4 figures and 5 tables

DAVID H. K. AMIRAN

Zusammenfassung: Das Klima des dritten vorchristlichen Jahrtausends im Nahen Osten. Die nördliche Negevwüste Israels

Im frühen dritten vorchristlichen Jahrtausend gab es im Negev nur eine Stadt, die keine Oasensiedlung war, aber trotzdem einige tausend Einwohner hatte. Das Gebiet hat heute eine jährliche Regenmenge von weniger als 200 mm. Die Bedingungen, die damals die Existenz einer städtischen Siedlung ermöglichten, bedürfen somit der Aufklärung. Die vorliegende Arbeit untersucht die Niederschlagsschwankungen dieser Gegend in der Gegenwart. Auf der positiven Seite war in den letzten Jahrzehnten in mindestens drei Jahren normaler Regenfeldbau möglich. Die Annahme, daß solche Bedingungen zu Beginn des dritten Jahrtausends, d.h. zur Zeit des „Atlantischen Optimums“, fast regelmäßig vorherrschten, würde die Existenz der alten Stadt Arad erklären. Daß eine solche Annahme berechtigt ist, wird an Hand einer umfangreichen Literatur über den Nahen und Mittleren Osten belegt. Dieselben Quellen deuten auch auf eine ausgesprochene und ziemlich plötzliche Aridisierung im 27. Jahrhundert v. Chr. hin, die das Ende der Stadt Arad erklären könnte.

The significance of the semi-arid climate of ancient Arad

Tel Arad is located in the south of Israel, at the border between the Negev desert to the south and the Judean Mountains with their Mediterranean-type climate to the north. Tel Arad is nearly halfway between Beersheba (today the largest town of the Negev) and the Dead Sea (present level 410 m *below* sea level). Before the steep descent to the Dead Sea, the ground rises gradually to an elevation of slightly over 600 m (maximum 637 m) near the modern town of Arad, located 9 km to the east of the ancient site.

Excavation and research at Tel Arad since 1962 suggest that this city of the Early Bronze II period (c. 3000–2650 BC) had a population of c. 2500 (ROSENAN 1978) within the city walls enclosing an area of about ten hectares (25 acres). This raises the question of the city's functioning and basis of subsistence.

Early Bronze Arad was an important and flourishing city. At its time it was the *only* urban place in this area between the Mediterranean to the west, the Dead Sea to the east, and southern Sinai to the south. There were many small settlements in this area, but no city but Arad. Arad developed into an important market center, trading copper utensils from Sinai, and bitumen and probably salt from the Dead Sea area. It had a resource base of local agriculture, documented by large quantities of carbonized seeds of barley, wheat, peas, lentils, chickpeas, and of grapes. Olive pips were found, but there is no evidence to show whether olives were grown at Arad or imported from the Judean Mountains nearby. The many bones of donkeys recovered by the excavation attest to its importance as a trade center, donkeys being the only vehicle of transportation in that period. In assessing the agricultural potential of the Arad region one has to consider the superior quality of the soil with its high loess component.

Tel Arad – 31° 17′ N, 35° 07′ E, altitude 540–570 m, i. e., c. 940 m above the present level of the Dead Sea – has a distinct semi-arid climate. The *Atlas of Israel* (1970, sheet IV/3, maps E, F) grades it BShs climate of the „steppe“ type according to the Koeppen classification, or type E, with moisture index –40 to –60 according to Thornthwaite. Average annual rainfall for 1951–80 was c. 225 mm (RUBIN 1985).

Climate of this degree of aridity is distinguished by a sizeable inter-annual fluctuation of rainfall. The modern town of Arad had an average rainfall of 133 mm for the 29 years beginning 1961/62 (Table 1). These years included one with 277 mm (a deviation of +108 percent from average) and one with 45 mm (a deviation of –66 percent from average). Both these extreme values were recorded within two years from one the other, which is by no means exceptional in an arid climate. Table 1 shows the range of deviation from average annual rainfall. For obvious reasons strong negative deviations are particularly serious for the population, the more so if they occur in a series of consecutive years.

This latter point is well illustrated by the rainfall record of Beersheba, located 32 km west of Tel Arad and 40 km west of Arad town (Table 2). It has the same climate as Arad with a somewhat higher rainfall, 204 mm for the International Standard Period 1931–1960 (*Climatological Standard Normals of Rainfall* 1967), and 208 mm for the years 1961/62–1989/90. Observations began in 1921/22. They include one year with 339 mm (a deviation of +63 percent) and

Table 1: Annual rainfall and deviation from average[1]

Jahresniederschläge und Abweichungen vom Mittelwert

Rainfall year	Arad		Beersheba		Qiryat Gat[2]		Jerusalem[3]	
	mm	deviation (%)	mm	deviation (%)	mm	deviation (%)	mm	deviation (%)
1961/62	110	- 17	145	- 30	266	- 36	447	- 20
1962/63	45	- 66	42	- 80	138	- 67	227	- 60
1963/64	193	+ 45	318	+ 53	483	+ 16	689	+ 23
1964/65	277	+ 108	339	+ 63	542	+ 31	639	+ 14
1965/66	119	- 10	188	- 10	220	- 47	359	- 37
1966/67	188	+ 41	249	+ 20	536	+ 29	783	+ 39
1967/68	165	+ 24	221	+ 6	424	+ 2	660	+ 17
1968/69	127	- 4	163	- 22	357	- 14	575	+ 2
1969/70	88	- 34	129	- 38	281	- 32	489	- 13
1970/71	167	+ 26	233	+ 12	455	+ 10	590	+ 5
1971/72	225	+ 69	330	+ 59	517	+ 25	618	+ 10
1972/73	94	- 29	166	- 20	332	- 20	453	- 19
1973/74	186	+ 40	289	+ 39	602	+ 45	849	+ 51
1974/75	107	- 19	199	- 4	429	+ 3	496	- 12
1975/76	122	- 8	154	- 26	283	- 32	485	- 14
1976/77	82	- 38	171	- 22	433	+ 4	568	+ 1
1977/78	54	- 59	109	- 46	349	- 16	458	- 18
1978/79	72	- 46	154	- 26	331	- 20	427	- 24
1979/80	207	+ 56	309	+ 48	577	+ 39	819	+ 46
1980/81	141	+ 6	223	+ 7	365	- 12	545	- 3
1981/82	95	- 29	218	- 5	346	- 17	462	- 18
1982/83	146	+ 10	274	+ 32	780	+ 88	873	+ 55
1983/84	65	- 51	144	- 31	294	- 29	412	- 27
1984/85	97	- 27	192	- 8	394	- 5	524	- 7
1985/86	103	- 26	185	- 11	308	- 26	371	- 34
1986/87	125	- 6	205	- 1	625	+ 51	678	+ 21
1987/88	192	+ 44	262	+ 26	530	+ 28	667	+ 19
1988/89	101	- 24	185	- 11	393	- 5	472	- 16
1989/90	175	+ 32	226	+ 9	442	+ 6	505	- 10

[1] Table 1 lists all 29 years for which rainfall records for Arad town are available. Station data:

	N Latitude	E Longitude	Altitude m	Average for 1961/62–1989/90 mm
Arad	31°15′	35°12′	610	133
Beersheba	31°14′	34°47′	270	208
Qiryat Gat	31°37′	34°46′	110	415
Jerusalem	31°47′	35°13′	810	557

[2] Data for 1961/62 and 1962/63 are for Qiryat Gat town, those for 1963/64–1989/90 for Mivhor Agricultural Station at the northern fringe of Qiryat Gat.

[3] Data are for Jerusalem Central station (Assicurazione Generali building, Jaffa and Shlomzion road corner).

one with but 42 mm (a deviation of -79.8 percent from average), again both having occurred within but two years from one the other (Table 1) (Orev 1968). Both in Arad and Beersheba the wettest year on record is 1964/65, the driest one 1962/63.

Jerusalem outside the semi-arid area has Mediterranean-type climate. It is the station in the Eastern Mediterranean region with the longest rainfall record. Its record begins in 1846/47 and through 1989/90 includes, therefore, 142 years – allowing for

Table 2: Beersheba: deviation from average annual rainfall of 208 mm for 1921/22–1989/90 in excess of 30 percent

Beersheba: Niederschläge mit einer Abweichung von mehr als 30% vom Mittelwert der Jahre 1921/22–1989/90

Rainfall year	mm	Deviation (%)
1962/63	42	– 80
1959/60	85	– 59
1957/58	102	– 51
1946/47	108	– 48
1977/78	109	– 48
1969/70	129	– 38
1926/27	130	– 37
1928/29	130	– 37
1923/24	130	– 37
1935/36	130	– 37
1940/41	131	– 37
1950/51	132	– 36
1952/53	132	– 36
*	*	
1982/83	274	+ 32
1973/74	289	+ 39
1944/45	291	+ 40
1956/57	293	+ 41
1931/32	301	+ 45
1979/80	309	+ 49
1963/64	318	+ 53
1971/72	330	+ 59
1933/34	336	+ 62
1964/65	339	+ 63

Table 3: Comparison of annual rainfall at Tel Arad and Arad town (mm)

Vergleich der Jahresniederschläge in Tel Arad und Arad town (mm)

	Tel Arad	Arad town
N Latitude	31°17′	31°15′
E Longitude	35°07′	35°12′
Altitude m	530	610
1964/65	354	277
1965/66	145	119
1970/71	219.9	167
1971/72	297.5	225
1972/73	108.6	94
1974/75	166.9	107
Average of 6 years	215	165

two years missing early in the series (ROSENAN 1955, *Statistical Yearbook of Jerusalem* 1984, p. 82). The overall average of this series is 557 mm, the average for 1961–1990 being 554 mm (*Climatological Standard Normals of Rainfall* 1961–1990). Table 4 lists the largest negative and positive deviations at Jerusalem, reaching extremes of –61.7 and +98.6 percent respectively. Both the Jerusalem and the Beersheba series' show distinct concentrations of extreme years. The greater aridity at Beersheba vs. Jerusalem is expressed by the maximum deviation of the driest year. The driest year at Beersheba recorded 20 percent of the average only, vs. 38 percent at Jerusalem; the wettest year at Beersheba recorded 166 percent of the average, vs. nearly twice the average (198.6 percent) at Jerusalem. Both stations experience wet and dry spells (SHANAN et. al 1967). Two examples from Jerusalem may illustrate this. 79 percent of the years 1873/74–1897/98 had above average rainfall, beginning with the second-moistest year on record (1003.6 mm), and including four years later in 1877/78 the moistest year so far, with 1090.6 mm, 98.6 percent above average. The six years 1957/58 through 1962/63 had deficient rainfall, including the two driest years of its 142-year record. For conventional agriculture, without modern irrigation, this can be a critical experience.

These figures have been quoted in some detail to illustrate that even at present, favorably wet periods (around 300 mm at Beersheba in the early 1970s) alternate with others, dry to the extent of drought, as the years around 1960 with but half the long-year average and reaching a minimum of 42 mm, or 21 percent of the average only. More serious than a year of extreme deficiency in rainfall are *series'* of dry years. E. g., in 1957/58 began a sequence of six years with severe negative deviations: –50.0, –25.0, –58.3, –9.3, –28.9 and –79.4 respectively, the last one being the driest year on record for Beersheba. The influence of such a series of years of deficient rainfall can easily be imagined; it reminds of the "seven lean years" of the Bible!

Within a wider regional frame of climate, Arad is located in the border (or transition) zone from the Mediterranean to Desert climate. This climatic border undergoes changes of both short- and long-time dimensions. Movements of the border of aridity are of particular significance concerning the possibility of human settlement and of at least some type of agriculture in the region, which might find itself not only in a border location, but during certain periods within either the favorable Mediterranean climate zone or the harsh arid one.

A latitudinal shift of rainfall of the order of 170 mm should not be impossible, equivalent in our case to the difference between Tel Arad and Qiryat Gat. An analysis of latitudinal fluctuations of rainfall in the

Table 4: Jerusalem Normal Station: deviations from average annual rainfall of 549 mm for 1846/47–1982/83 in excess of 30 percent

Jerusalem: Niederschläge mit einer Abweichung von mehr als 30% vom Mittelwert der Jahre 1846/47–1982/83

Rainfall year	mm	Deviation (%)
1959/60	210.1	−61.7
1962/63	225.0	−59.0
1950/51	250.3	−54.4
1932/33	262.0	−52.3
1946/47	282.9	−48.5
1924/25	283.0	−48.4
1869/70	318.5	−42.0
1931/32	319.0	−41.9
1954/55	330.0	−39.9
1965/66	335.0	−39.0
1900/01	339.1	−38.2
1957/58	348.0	−36.6
1935/36	349.5	−36.3
1876/77	352.9	−35.7
1852/53	355.9	−35.2
1978/79	373.0	−32.0
1933/34	375.0	−31.7
1927/28	375.9	−31.5
*	*	
1942/43	717.9	+30.8
1883/84	718.1	+30.8
1888/89	730.5	+33.1
1890/91	741.7	+35.1
1941/42	742.1	+35.2
1944/45	750.1	+36.6
1948/49	756.5	+37.8
1895/96	770.2	+40.3
1979/80	775.0	+41.2
1910/11	785.8	+43.1
1919/20	787.0	+43.3
1904/05	793.8	+44.6
1856/57	794.9	+44.8
1896/97	795.9	+45.0
1973/74	818.0	+49.0
1892/93	825.3	+50.3
1905/06	828.3	+50.9
1982/83	840.0	+53.0
1873/74	1003.6	+82.8
1877/78	1090.6	+98.6

Years deviating from 549-mm average (% of 140 years)

Deviation (%)	Total No.	Total %	Negative No.	Negative %	Positive No.	Positive %
30 or more	38	27	18	12.9	20	14.3
50 or more	9	6.4	4	2.8	5	3.6
70 or more	2	1.4	0	0	2	1.4

Table 5: Latitudinal location of 400- and 200-mm rainfall isopleths for selected years

Lage der 400- und 200-mm-Niederschlagsisoplethen für ausgewählte Jahre

Rainfall mm	Average 1951–80	Very wet year 1937/38	Very dry year 1932/33
400	31°28′ Yutta	31°16′ 'Ein haBesor	32°18′ Netanya
200	31°12′ Nevatim	30°14′ Har Karkom	31°25′ Dhahiriya

present century shows fluctuations of much greater order[1]. Table 5 gives the latitudinal location of the 400- and the 200-mm rainfall lines respectively for the average of the period 1951–80 (Rubin 1985), for the exceptionally wet year 1937/38 and the exceptionally dry year 1932/33. For the 1951–80 average, the latitudinal distance between the 400-mm and the 200-mm rainfall lines in this area is 22′ or 40 km. By comparison, the latitudinal distance of the 400-mm rainfall lines of 1937/38 and of 1932/33 is 1° 11′ or 130 km, that of the 200-mm rainfall lines for the same years 1° 02′ or 111 km.

Such parallel shifts of rainfall lines are supported by the large spatial coherence of the station records. The correlation coefficients between the four station records listed in Table 1 vary only between 0.65 and 0.91 (= Arad vs. Beersheba), all significant at the 99 percent level. For a 41-year period (1935/36–1975/76) we may mention the correlations Beersheba vs. Jerusalem (0.67) and vs. Amman (0.68), both also highly significant. As long as the water balance of the Dead Sea remained undisturbed by man, its fluctuations were highly correlated with representative rainfall records in its catchment area (for 1930/31–1962/63 correlation with Jerusalem rainfall = 0.80, with Amman = 0.81; cf. Klein a. Flohn 1987). This is especially true in the winter rain belt, where the dry summer season is accompanied with remarkable inter-annual constancy by high global radiation responsible for a quasi-constant evaporation. During the last 40–50 years no significant trend in rainfall could be found in all these records. It appears, therefore, that even in the short span of the present

[1] Maps K, L, M on sheet IV/2 of the *Atlas of Israel* (1970) provide composite plots of isohyetic lines of 200, 300 and 400 mm of rainfall respectively for the rainfall-years 1931/32 through 1960/61. Sheet 13 of the 1985 edition of the same atlas presents 44 annual rainfall maps for the years 1932/33–1975/76.

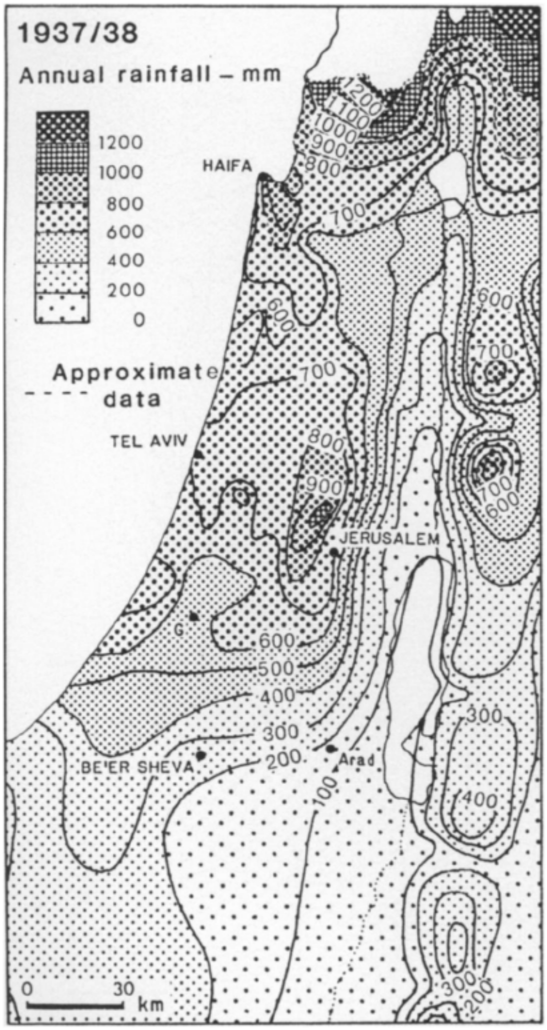

Fig. 1: Annual rainfall (mm) 1937/38. G = Qiryat Gat
Source: Atlas of Israel 1985
Jahresniederschlag (mm) 1937/38

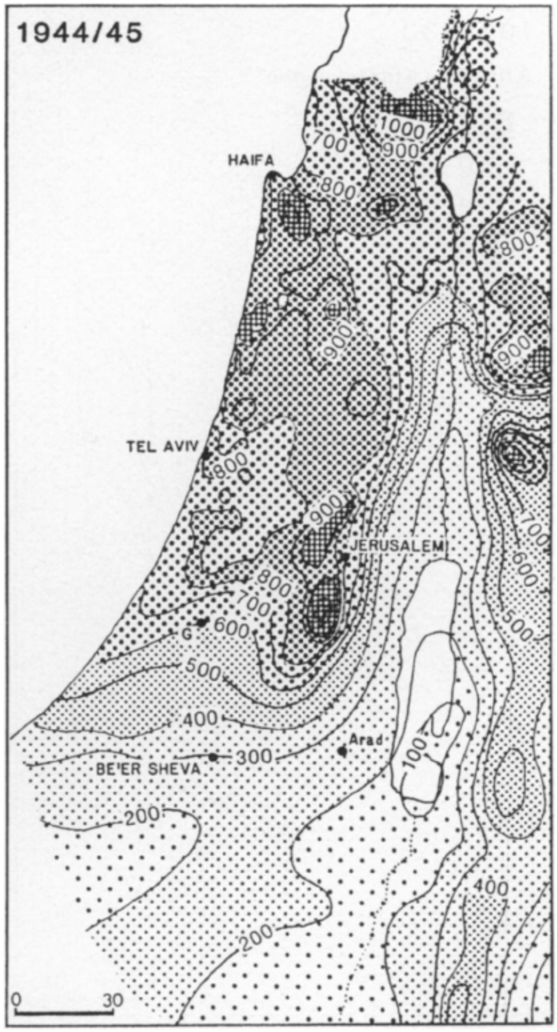

Fig. 2: Annual rainfall (mm) 1944/45. G = Qiryat Gat
Source: Atlas of Israel 1985
Jahresniederschlag (mm) 1944/45

century, and even in the six-year period 1932/33–1937/38 latitudinal fluctuations were 3 to 3.5 times the distance required to shift average rainfall from conditions at Tel Arad to those at Qiryat Gat.

The range of present-day climatic fluctuations at the border of the semi-arid and the arid area is illustrated when noting that the shift of 200-mm rainfall to Har Karkom 30° 14′ N in 1937/38 and the similar shift to 30° 21′ N in 1944/45 brought 200 mm of rainfall right into the normally fully arid area, compared with c. 55 mm according to the 1951–80 map (Rubin 1985).

The impact and consequences of a long-range change in semi-arid climate, especially its moister part, are of particular significance. The greater the annual average amount of rainfall, the lower generally is the inter-annual variability. A southward shift of the border of aridity in the northern Negev, increasing average annual rainfall in the Arad area from the present c. 220 mm to 300 or even 400 mm, a latitudinal shift of c. 37 km, would significantly increase its reliability and decrease the frequency and severity of series' of dry years, making the area much more habitable. Figures 1 and 2 illustrate such situations. Whereas in 1932/33, the driest year on record, Galilee still received some 450 mm of rainfall, Arad had 150 mm (Fig. 3). More extreme even for the Negev were conditions in 1962/63 (Fig. 4) when Beersheba recorded 42 mm of rainfall only and Arad town 50 mm, whereas 200 mm were recorded only from

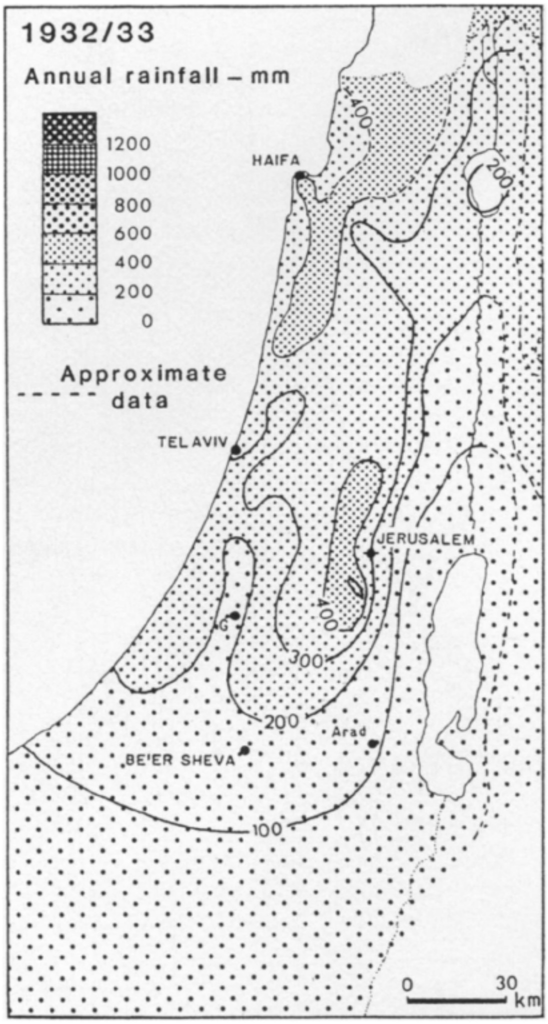

Fig. 3: Annual rainfall (mm) 1932/33. G = Qiryat Gat
Source: Atlas of Israel 1985
Jahresniederschlag (mm) 1932/33

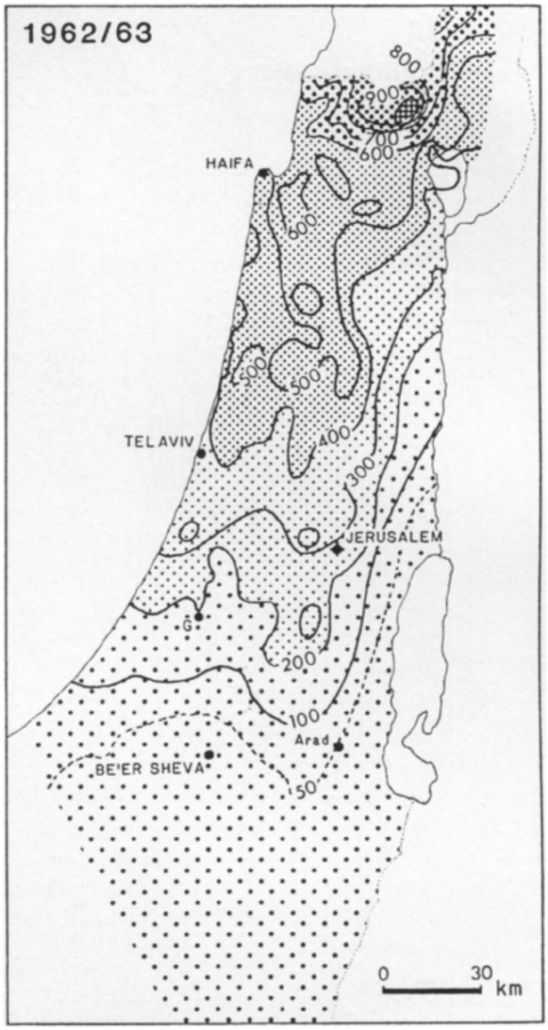

Fig. 4: Annual rainfall (mm) 1962/63. G = Qiryat Gat
Source: Atlas of Israel 1985
Jahresniederschlag (mm) 1962/63

Hebron to the north. But 400 mm were recorded already at the latitude of Tel Aviv, and Galilee recorded normal amounts of rainfall. If rainfall in the south would decrease by another 70–100 mm, the Negev should be on the verge of catastrophe. It is, therefore, important to assess the probability of a lesser aridity in the Arad area in the early third millennium BC.

There are two types of proof to substantiate such an assumption. The first is provided by Early Bronze Arad itself. The existence of a town of 2000 or even 3000 inhabitants on a pre-modern level of water technology would be impossible under climatic conditions prevailing there at present. There are no local water resources at the site. There were no cisterns for storing rainwater either, as the Early Bronze Age predates the introduction of impervious lining enabling the construction of cisterns in Israel. The existence of a settlement of 2–3000 inhabitants must, therefore, have been dependent on a more ample rainfall at the site.

A further argument to this effect is provided by the large amount of carbonized seeds of a variety of plants which have been found in the excavations at Tel Arad. The amount and the type of these plant remains prove that they were grown near the town and are not imports from other areas. They have been analyzed and their climatic significance evaluated by MARIA HOPF (1978).

The second group of proofs for a moister climate at Tel Arad close to five thousand years Before Present is provided by climate indicators for that time from Israel or from a wider regional context which is climatologically comparable.

Regional evidence of climate in the Early Third Millennium BC

The climate and its changes in every region, including that of Arad, is part of the general pattern of climate at any particular time, and has to fit into it. Our knowledge of the wider regional climate of any given period provides, therefore, a general frame of information for a specific area. This applies to our case, the climate of Arad in the Early Third Millennium BC. We shall survey the references to climate indicators for the early third millennium BC in two parts, the first concerning Israel (including Jordan for this purpose), the second concerning North Africa and the Near and Middle East.

Climate indicators for Israel

In accordance with data from North Africa and the Near and Middle East, palaeoclimatic indicators from Israel point to a climate moister than the present one for about 3500–2600 BC, i. e., roughly the Early Bronze Age. ROSEN (1986 a, b, c; GOLDBERG a. ROSEN 1987) bases such evidence on the analysis of sediments in the Lachish and Shiqma valleys; GOODFRIEND (1986) bases his evaluation on fossil land snails. VALERIE FARGO (1979) who bases her evidence on Tel el-Hesi and other sites confirms a moist interval in the Early Bronze Age. She reports about large agricultural and pastoral villages "producing sizable crops of grains, olives, grapes and pulses, and raising ... sheep, goat and cattle". There was a reliable water supply and sufficient land for grazing.

GERSON (1981) investigating the Be'er Resisim area in the Central Negev, located 77 km south-west of Ancient Arad (or 30' latitude south of it), stated that the "Early Bronze period was still within the less arid climate mode of the 'Atlantic Optimum'".... Shrub vegetation was more abundant in the region ... "before its further deterioration through continuing aridity and overgrazing in later periods."

NEEV a. EMERY (1967) analyzing sediments of the Dead Sea found evidence of a humid period about 3090 ± 680 BC, followed by a rapid drop in humidity with a sequence of dry sediments, indicating severe desiccation in c. 2600–1700 BC. W. E. RAST (personal communication, 1983) found archaeological evidence of a moist period during c. 4000–2500 BC at Bab edh-Dhra on the east side of the Dead Sea. Finally, LAUSTRUP (1984) analyzing the palaeobotanical finds of Tel Lahav, located 27 km WNW of Tel Arad, found remnants of olives in 74 percent of all Early Bronze samples, vs. 20 percent of samples from the Late Bronze Age and 22 percent of those from the Iron Age, a clear indication that the Early Bronze Age was succeeded by times with drier climate.

The moister than present climate of the Early Bronze Age was followed by a significant change to drier climate. This change which according to some sources was rather abrupt occurred according to various authors between 2800 and 2300 BC. ROSEN (1986 b, 1989), CROWN (1972) and FARGO (1979) find evidence for the onset of a dry period in the Negev about 2300 BC. According to GOODFRIEND (1986) the evidence of fossil land snails points to a drier climate in the northern Negev during 2800–1200 BC. VAN ZEIST (1985, p. 201) states, mainly on geomorphological evidence, that after 3000 BC the climate became drier.

Finally, HARLAN (1981, 1982, 1985) finds a critical change to greater aridity during 2300–2100 BC. Within a relatively short time one urban settlement after the other was abandoned bringing about the collapse of the urban system not only in Israel and Jordan but in Egypt and elsewhere in the Near East as well. According to HARLAN, cities so affected were, i. a., Jericho, Bab edh-Dhra, Numeira, Beth Shan, Kh. Kerak, Ai and others.

Climate indicators from North Africa and the Near and Middle East

In order to complement the palaeoclimatic evidence for Israel and to ascertain whether it conforms to the development of climate in the third millennium BC in a wider regional frame, the following section surveys climate indicators from North Africa to the Indus Valley. North Africa, and the Sahara in particular, are of special interest in this respect. The beginning of the third millennium BC was the end of the last moist period in this area; according to BUTZER (1966) it terminated "in stages" between 2900 and 2350 BC. At its peak there were sizeable lakes and a fauna attesting to much moister conditions. Apart of palaeontological finds, the neolithic rock-drawings depicting elephants, giraffes, rhinoceri, etc. in the Central Saharan mountain massifs are unequivocal evidence of this. They are generally dated to 4000–2500 BC (LAMB 1968/69, p. 107; LAUER a. FRANKEN-

BERG 1979, p. 24). NICHOLSON (1980, p. 174) evaluated various sources indicating that both the northern and the southern fringes of the Sahara were between 4000 and 3000 BC considerably moister than at present. The Sahara at that time, therefore, provides evidence of a contraction of the desert and not of a unilateral shift in latitude. "Sub-fossil groundwater" apparently generated at least in part during this moist period persisted until close to the beginning of the Christian era (LAMB 1968/69, p. 105/6). Similar reports refer to East Africa stating that from 8300-3000 BC "the regional climate was much wetter, with higher lake levels and extensions of rivers into many lake basins which at present have no outlet" (HARVEY a. GROVE 1982, p. 328). BUTZER a. HANSEN (1968) too state that in the "Neolithic Wet Phase" c. 3100-3000 BC there occurred distinctly higher Nile floods than at present. According to FUERST (1982, pp. 51, 54) the climate of the western Libyan Desert from 5000 or 4000 to 2000 BC was moist enough to permit pastoral nomads to raise cattle.

In North Africa this wet period apparently came to an end between 3500-2500 BC. FLOHN (1985, p. 145) dates the beginning of aridization to about 3500 BC, reaching its extreme c. 2500 BC. ROGNON (1967, p. 119) found evidence of rapid aridization in the Hoggar massif about 3100 BC, and recognizes a definite "step" towards aridization in North Africa in general between 2500 and 2000 BC (ROGNON 1987, p. 214). This was part of a major change in climate which by 2000 BC approached the present one (NICHOLSON 1980, p. 174); according to LAUER a. FRANKENBERG (1979, p. 31) it involved a southward shift of isohyets at the northern fringe of the Sahara of the order of 100-200 km. There is evidence of drying-up lakes in East Africa dated to 3000-2500 BC, which forced pastoralists to abandon traditional grazing areas (HEATHCOTE 1983, p. 35). About 2500 BC increasing desiccation forced nomadic pastoralists out of the Sahara and brought about an invasion of the Nile Valley (BUTZER a. HANSEN 1968; SMITH 1980, p. 463). In c. 2350 BC an arid period began, accompanied by a decrease in Nile floods to very low volumes, lasting until 2180 BC, or even to 1950 BC (BUTZER 1966; 1980, p. 278). BARBARA BELL (1971, pp. 3, 7, 9) evaluating literary historical sources found evidence for two severe droughts, the first 2180-2160 BC or even 2150, the second lasting a few years around 2000 BC. The ensuing famine was of catastrophic dimensions, especially in Upper Egypt where cannibalism occurred, if some inscriptions do not exaggerate. According to ROGNON (1976, p. 273), desertification was rapid and lasted until c. 1500 BC.

HEMPEL (1982, pp. 52/53) evaluating material from southern Greece and the eastern Mediterranean region finds evidence for a phase of aridization in 3500-2000 BC. MAGARITZ a. KAUFMAN (1973) analyzed marine molluscs of the eastern Mediterranean and found evidence of a more humid climate at about 3000 BC.

For Iraq too there are indications that climate during 3500-2500 BC was "unusually wet", definitely moister and cooler than both the preceding and the succeeding millennia (CROWN 1972, pp. 326, 329). ADAMS (personal communication, 1986) stated that the fourth millennium was considerably wetter than the third. Furthermore, compared with the preceding period, irrigation "channels had been sharply reduced (possibly with increasing climatic aridity as a factor)" (ADAMS 1981, p. 245). About 2300 BC there occurred "another sudden secular rise in temperature and a resurgence of the droughts and crop failures" (CROWN, 1972, p. 329); in the Zagros mountains lakes dried out. During 2300-1900 BC Mesopotamia experienced, according to documents referring to Akkad and Sumerian Ur III, a "period of increasing aridity marked by salinization and reduced Tigris-Euphrates streamflow." (NEUMANN a. PARPOLA 1987, p. 177).

These general trends are confirmed for Iran by GANJI (1978, pp. 161/2), who traced a "near-Pluvial period" with rising lake levels beginning about 3500 BC, followed during 2400-850 BC by higher temperatures and decreasing rainfall, which GANJI considers to have been the driest phase in the climate of the Middle East since 6800 BC. Farther east, at Mohenjo Daro in the Indus region of Pakistan, arid conditions prevailed during 2500-2250 BC (BELL 1971, p. 1).

Conclusions

References of climate indicators for Israel and the wider region in which it is located have been quoted in some detail to demonstrate that over the entire area there is considerable agreement of evidence and of opinion that the period preceding 3000 or 2500 BC had a relatively moist and favorable climate. Sometimes between 2600 and 2200 BC there occurred a process of distinct aridization. This change according to certain sources might have been rather abrupt. It affected many areas from Greece in the west to Pakistan in the east and to Egypt in the south. Many cities ceased to exist, e. g., Byblos, Ebla, or Jericho. In Egypt, the First Dark Age known as the "First Intermediate Period" brought critically low Nile floods (BELL 1971, pp. 16/17) with widespread famine.

All this brought about a severe disintegration of settlement structure. The Akkadian Empire fell apart between 2230-2130 BC, Ebla in 2250 BC, so did Byblos, Troy II, Jericho and lesser sites such as Bab edh-Dhra (BELL 1971, p. 1; HARLAN 1985, p. 127). A major catastrophe affected parts of Anatolia at the end of the Early Bronze II period. MELLAART (1971, p. 406/7) considers it the result of a hostile and destructive invasion. But BELL views this event too in a wider regional frame. She is of the opinion that "the concentration in time of so many disasters and the universal absence of prosperity throughout the area strongly suggests a common underlying cause". This apparently was "drought-widespread, severe and prolonged" (BELL 1971, p. 2).

The Early Bronze Age city of Arad - and a city it was - came into existence about 3000 BC, i. e., within a period of favorably moist climate which had prevailed already for some considerable time. The city was deserted about 2650 BC, i. e., at the onset of a time of distinct aridization. The shift in regional climate which this involved would have moved Ancient Arad to beyond the border of aridity, resulting not only in a critical decrease of average rainfall, but no less serious in a decisive increase in inter-annual fluctuations in rainfall increasing the irreliability of its essential resource base. The significance of such a climatic situation has been dealt with in the opening section of this paper.

To sum up, Arad was founded on the fringe of the settlement area during a period of rather favorable climate. Thus the reason for its emergence as a city would have been of an economic nature. By contrast, its abandonment in the 27th century BC might well have been caused by the climatic deterioration which without any modern technology of water supply made the continued occupation of the site impossible.

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