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HANNAH M. COTTON, JONATHAN J. PRICE, LISA ULLMANN
DAVID J. WASSERSTEIN

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Stone-Balls from Tel Dor and the Artillery of the Hellenistic World*

Israel Shatzman

Since 1980 the Hebrew University of Jerusalem and the Israel Exploration Society have conducted excavations at Tel Dor, ancient Dor, on the Carmel coast, under the directorship of Prof. E. Stern.[1] During these excavations, including the 1991 season, 207 artillery stone-balls have been unearthed, as well as fragmentary balls. All these stones are preserved in the museum of Kibbutz Naḥsholim, which stores ten additional balls removed from the bottom of the bay at Tel Dor (see Fig. 1). More stones may be found in subsequent excavations, but since the material discovered so far is instructive from several points of view, it appears worthwhile to publish a preliminary report of the finds and a discussion of their significance in relation to Hellenistic artillery.

The Employment of Artillery Engines in the Hellenistic Period

To understand the military significance, as well as other aspects, of the artillery stones discovered in Tel Dor, it seems useful to give here a brief account of the use of artillery in the Hellenistic period, particularly in the East.[2] Invented under Dionysius I, during his war preparations against Carthage in 399,[3] artillery engines were subsequently developed, improved and much utilized by Greek states, Philip II, Alexander the Great and his successors. The first engines were used to

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* I would like to thank Prof. E. Stern for letting me study the stone-balls and Mr. I. Sharon for supplying me with information about the excavations. I am grateful to the staff of the museum of Kibbutz Naḥsholim for their kind hospitality. Thanks are also due to Prof. F.W. Walbank and the anonymous reader for helpful comments.

1 For summaries and preliminary reports see E. Stern, "The Excavations at Tel Dor", *The Land of Israel: Cross-Roads of Civilizations*, ed. E.L. Lipinski, 1985, 169-92; E. Stern and I. Sharon, "Tel Dor, 1985", *IEJ* 35, 1985, 101-4; *idem*, "Tel Dor, 1986", *IEJ* 37, 1987, 201-11; E. Stern, A. Gilboa and I. Sharon, "Tel Dor, 1987", *IEJ* 38, 1988, 32-42; E. Stern, J. Berg and I. Sharon, "Tel Dor, 1988-1989", *IEJ* 40, 1990, 46-61; E. Stern, A. Gilboa and I. Sharon, "Tel Dor, 1991", *IEJ* 42, 1992, 34-46, esp. 42-3.

2 For a detailed account see E. Marsden, *Greek and Roman Artillery. Historical Development*, 1969, 48-77.

3 Diod. Sic. 14.41-2, 50-51.

hurl arrows or bolts only, but by the 350s more powerful machines had been constructed and used to shoot stone-balls. Onomarchus, the Phocian general, employed stone-throwers to good effect against the Macedonian army in 353 BCE.[4]. Alexander employed stone-throwers, installed on siege-towers, during the siege of Halicarnassus in 334 and against Tyre in 332.[5] It is instructive that artillery engines were used by the defenders of Halicarnassus, and it is even more significant that Tyre was extensively equipped with catapults and had no difficulty in constructing more engines, thanks to the great number of engineers and artificers it had at its disposal during the siege by Alexander.[6] Gaza, too, had some artillery engines at the same time, as may be inferred from the notice that a catapult bolt passed through Alexander's shield and wounded him during its siege.[7] Evidently knowledge of and expertise in this new form of military technology had spread to the East by that time. Literary and epigraphic evidence indicates that various cities, for example Samos, Rhodes, Ceos and Cyaneae in Lycia, had artillery engines at their disposal.[8] In brief, not only major Hellenistic kingdoms, but also lesser city-states managed to possess and use artillery engines.

Several pieces of evidence refer to the use of artillery in Palestine in the second century. According to the *Letter of Aristeas*, the citadel of Jerusalem was equipped with various pieces of artillery, which may refer to the period of Ptolemaic or Seleucid rule in Jerusalem, or more probably to the Hasmonaean period.[9] The Seleucid army employed various artillery weapons in the campaigns against Judas Maccabaeus and his brother Jonathan, namely Lysias and Antiochus V in 163, or, more probably, 162, and Bacchides in 158.[10] Judas employed artillery engines when he besieged the Acra in 163, or, more probably, 162, and so did his brother Simon during the siege of Beth-Zur.[11] During the recent exca-

4 Polyaen. 2.38.2.

5 Arr. *Anab.* 1.22.2; Diod. Sic. 17.42.7.

6 Diod. Sic. 17.24.6 (Halicarnassus); 41.3 (Tyre).

7 Arr. *Anab.* 2.27.2. Cf. Curtius Rufus 4.6.17.

8 See Marsden (n. 2), 74-5.

9 *Letter of Aristeas* 100-101. Opinions vary about the date of composition of this work, the majority of scholars ascribing it to about 200 BCE. Not a few scholars prefer to date it in the second half of the second century, or even later. For a brief account of opinions and arguments see E. Schürer, *A History of the Jewish People in the Age of Jesus Christ (175 BC-AD 135)*. A New English version, revised by G. Vermes, F. Millar, M. Goodman *et alii*, III, 1, 1986, 679-84. For some reservations on the use of this source as reliable evidence see Shatzman (n. 13), 464-5.

10 Lysias: *I Macc.* 6.51; cf. Joseph. *AJ* 12.377; Bacchides: *I Macc.*9.64-7; Joseph. *AJ* 13.27-9. On the date of Lysias' expedition, which followed the siege of the Acra by Judas, see B. Bar-Kochva, *Judas Maccabaeus. The Jewish Struggle against the Seleucids*, 1989, 543-50.

11 Judas: *I Macc.* 6.18-20; cf. 6.52; Joseph. *AJ* 12.363. Simon: Joseph. *AJ* 13.156. Judas may have captured some artillery engines in his war against Timotheus in Transjordan. See *I Macc.* 5.30-34.

vations at the Tower of David in the Jerusalem citadel about 200 artillery stones were discovered; they may be attributed to the siege of Antiochus VII, *ca.* 134-132 BCE.[12] Thus the artillery stones discovered at Tel Dor belong to a normal context of military activity in Palestine during the Hellenistic period.[13]

Some Technical Characteristics of Hellenistic Artillery

The stone-balls of Tel Dor have to be studied on the basis of what is known about the artillery of the Hellenistic period and of other, relevant archaeological finds.[14] Here no more than a few basic facts need be mentioned. The stone-throwers of the Hellenistic period, usually of the torsion type, were operated by springs made of sinew, horse-hair or women's hair. Every engine had two springs, installed in a wooden frame, and in each spring a wooden arm was inserted. The spring was connected to the wooden frame by iron levers placed over holes made at the top and bottom of the frame. A washer was inserted between the lever and the frame, and thus every artillery engine had two springs, four holes, four levers and four washers. The diameters of the springs, of the holes and of the washers were of the same length; such washers have been found in several places.[15]

The Greek engineers and artificers discovered that the heavier the stone they wanted to discharge, the longer the diameter of the spring they needed. By means of trial and error they found a formula to accommodate the spring-diameter (= hole-diameter) to the weight of the stone, which is described by Heron of Alexandria in the following words: "one must calculate the hole of the stone-throwers thus. Multiply by one hundred the weight in minas of the stone to be discharged; find the cube root of the product; add to the result (whatever the cube root is) its tenth part, and make the diameter of the hole that number of dactyls".[16] This may be expressed by the following equation: $D = 1.1\sqrt[3]{(100xM)}$, where D is the spring-diameter in dactyls (1 dactyl = 1.93 cm.), and M is the weight of the proposed stone in minas (1 Attic mina = 436 gr.).

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12 R. Sivan and G. Solar, "Excavations in the Jerusalem Citadel, 1980-1988", *Ancient Jerusalem Revealed*, ed. H. Geva, 1994, 168-76.

13 Cf. I. Shatzman, "Artillery in Judaea from Hasmonaean to Roman Times", *The Eastern Frontier of the Roman Empire. Proceedings of a Colloquium Held at Ankara in September 1988*, edd. D.H. French and C.S. Lightfoot, BAR International Series 553 (ii), 1989, 461-5.

14 See the detailed account in Marsden (n. 2), 1-47.

15 E. Schramm, *Die Antike Geschütze der Saalburg*, 1918 (reprinted, with an introduction by D. Baatz, in 1980), 40-46; D. Baatz, "Recent Finds of Ancient Artillery", *Britannia* 9, 1978, 13-7; *idem*, "Teile hellenistischer Geschütze aus Griechenland", *AA* 1979, 68-75; *idem*, "Katapultteile aus dem Schiffswrack von Mahdia (Tunisien)", *AA* 1985, 679-91.

16 Heron, *Bel.* 113, translated in E.W. Marsden, *Greek and Roman Artillery. Technical Treatises*, 1971, 39. See also Philo, *Bel.* 51.

For example, a stone- thrower constructed to hurl a shot weighing ten minas had to be equipped with a spring of eleven-dactyl diameter ($1.1\sqrt[3]{(100x10)} = 1.1x10 = 11$ dactyls = 21.23 cm.).

All the other parts of the artillery engines were determined proportionally to the spring-diameter, as the ancient technical writers report.[17] The overall length and width of a stone-thrower amounted to about twenty-five and fifteen times, respectively, the spring-diameter. Hence, one may prepare the following table which represents the essential features of stone-throwers, determined by the weight of the stones to be discharged:

Weight		Spring-Diameter		Length (m.)	Width (m.)
minas	kg.	dactyls	cm.		
3	1.30	7.35	14.20	3.55	2.13
5	2.18	8.73	16.85	4.21	2.52
10	4.36	11.00	21.23	5.30	3.18
15	6.54	12.59	24.29	6.07	3.64
20	8.72	13.86	26.75	6.68	4.01
25	10.90	14.93	28.81	7.20	4.32
30	13.08	15.86	30.61	7.65	4.59
40	17.44	17.46	33.69	8.42	5.05
50	21.80	18.80	36.28	9.07	5.44
60	26.16	19.98	38.56	9.64	5.78

The Greek and Roman technical writers classified the stone-throwers by weight of the stones intended to be shot, and not by the spring-diameter or the stone-diameter (the stones were worked in the form of balls). The stone-diameter of a proposed weight varied to some extent according to the type of the stone material used for the preparation of the shot. Such variations did not trouble the artificers, for the ancient stone-thrower did not have a barrel like that of a modern gun. Even so, modern scholars use the term calibre, which does not designate a diameter but the optimal weight of a stone-shot to be discharged by a given stone-thrower. It stands to reason that, for example, a stone-thrower constructed to discharge a stone-shot weighing 25 minas could be employed to hurl a stone-shot weighing 20 minas, but in this case the engine would not attain the best effect. In practice, however, stone-throwers were not constructed to fit all possible weights. Philon of Byzantium (probably late third century BCE) specifies as examples the spring-diameters of stone-throwers of 10, 15, 20, 30, 50 minas and one talent (60 minas), and the Roman Vitruvius (late first century BCE) lists the weights on the basis of the Roman *libra* (about 325 gr.): 2, 4, 6, 10, 20, 40, 60, 80, 120, 160, 180 and 200.[18] In conclusion, it is clear that finds of artillery stones can help determine the sizes of the stone-throwers employed to hurl them.

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17 See Philo, *Bel.* 51-55; Vitruvius 10.10-11 with Marsden (n. 16), 157-61, 194-205. Fur summarizing tables see Marsden (n. 2), 44-7; *idem.* (n 16), 266-9.

18 Philo, *Bel.* 51; Vitruvius 10.11.3.

Characteristics of Some Finds of Artillery Stones

Four finds of artillery stones are particularly relevant for the present inquiry. During the excavations of the northern part of the acropolis of Pergamum, in the years 1927-1936, five magazines of the royal arsenal were investigated. Of the stone-shot found there, 961 balls were collected and examined.[19] All these balls were found near, not inside, the buildings. It appears that the officials in charge of the arsenal were satisfied to keep this type of ammunition in an open area. The stones were carefully worked and dressed, having a fine spherical shape. They were classified by weight and diameter. The stones weighing 22.8-25.8 kg. were included in one group, considered to belong to stone-throwers of the sixty-mina calibre. It is interesting to notice that there is no total conformity between weight and diameter in these stones, that is to say a larger diameter does not necessarily indicate a heavier stone. Thus several stones weighing 23.7 kg. had a diameter of 29.23 cm., whereas other stones weighing 25.7 kg. had a diameter of only 26.32 cm. The German excavators of Pergamum suggested that the stones found belonged to stone-throwers of fourteen different calibres: 10, 13, 15, 18, 20, 30, 37.5, 40, 60, 65, 90, 105, 120 and 180.[20] Stone-throwers of the 60-mina calibre were evidently the most popular with the artillery corps of Pergamum (353 balls), then came the 37.5-mina calibre (166 balls), the 40-mina calibre (126 balls) and in the fourth place the 30-mina calibre (118 balls), comprising together almost eighty percent of the balls found. Stone-throwers of low calibres (15 minas and less) were hardly represented.[21]

Another relevant ammunition pile was unearthed in Rhodes in 1938. The 353 artillery stones excavated there were carefully worked and refined, the level of craftsmanship achieved surpassing that of the stones of Pergamum.[22] Inscribed letters marked the weight, in minas, of the stones, and were painted in red to ease the reading and the use of the ammunition. Many of the letters still preserved the red paint when the balls were unearthed. The letters thus tell precisely the calibres of the stone-throwers employed to discharge those stones:

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19 A. Von Szalay und F. Böhringer, "Die Artillerie von Pergamon", *Altertümer von Pergamon* X, 1937, 48-54.

20 Marsden (n. 16), 83 suggests that groups 7 and 8 represent one calibre only. As will be seen later on, the finds from Tel Dor do not support this suggestion.

21 It was suggested that the stone-throwers and ammunition of low calibres were seized and taken away by the Romans. See Szalay and Böhringer (n. 19), 52.

22 L. Laurenzi, "Projettili dell'artiglieria scoperti a Rodi", in *Memorie... dell'istituto storici-archeologico* 2, 1938, 33-6, Tav. XXVII-XXX.

Letters	Calibre in Minas	Calibre in Kg.	Number of Stones	Average Weight
Π	5	2.18	1	2.40
Δ	10	4.36	46	4.35
ΔΠ	15	6.54	56	6.50
ΔΔ	20	8.72	36	8.75
ΔΔΠ	25	10.90	85	10.25
ΔΔΔ	30	13.08	83	13.00
ΔΔΔΔ	40	17.44	7	16.80
⚑	50	21.80	7	21.00
T	60	26.16	7	24.50
TΔ	70	30.52	5	29.50
TΔΔ	80	34.88	7	33.00
TΔΔΔ	90	39.24	2	37.50
H	100	43.60	4	43.50
TTΔΔΔ	150	65.40	1	67.80
TTT	180	78.48	1	78.40

It appears that stone-throwers of 10- to 30-mina calibres were preferred in Rhodes. The average actual weight of the stones in several of the calibres is close to that of the theoretical weight. Still, even in these stones, which are worked more carefully than any other artillery shot excavated to date, one can notice weight differences among stones belonging to the same calibre. The 10-mina calibre stones show 0.7 kg. difference between the heaviest and the lightest stones; in the 15-mina calibre the difference is 0.8 kg. and in the 20- and 30-mina calibres the difference is 1 kg. Furthermore, the average actual weight of several calibres (25, 40, 50, 60, 70, 80, 90) is smaller by 0.64 to 1.80 kg. than the theoretical weight. These differences testify to the difficulties the ancient stonecutters faced in working stones to fit a given weight.

An important find of artillery balls was excavated in the fill of a tumulus in the necropolis of Salamis in Cyprus in the mid 60s.[23] The mound was constructed over the cenotaph of Nicocreon, the last king of Salamis, who met his death in 311/310.[24] This supplies a *terminus ante quem* for the production of these stones, which are the earliest dated artillery balls found to date. Most of the balls are made of soft limestone, and thirty three of them have inscribed letters, which apparently indicate their calibres. It is the same system that was used to indicate the calibres of the Rhodian stone-balls. Despite some oddities, it is clear that the Salaminian shot were intended to be used by stone-throwers of

23 See V. Karageorghis, *Excavations in the Necropolis of Salamis* 3, 1973, 188-91; E.W. Marsden, "Artillery Balls Found in the Tumulus over Nicocreon's Cenotaph", *ibid.*, 222-8.

24 Karageorghis (n. 23), 138, 200-202, who refers to Diod. Sic. 20.21, where Diodorus confused Nicocreon of Salamis with Nicocles of Paphos.

eight different calibres: 10, 15, 20, 30, 50, 60, 70 and 80 minas. In most cases the actual weight of the stones differs from the theoretical one, and there is a wide variety among the balls belonging to the same calibre. For instance, those marked ΔΔΔΔ (= forty minas) show three kg. difference between the heaviest and the lightest stones.[25] In one exceptional case, the actual weight of the stone (80.17 minas) corresponds very closely to the weight marked on it. Generally, however, the difficulty involved in working stones to fit a given weight is revealed in this find as well.[26]

The area of ancient Carthage yielded an exceptionally large quantity of shot, of which 5600 have been examined.[27] These stone-balls probably belonged to the artillery of the city before its capture by Rome in 146 BCE. The working and dressing of these stones were far below the level of craftsmanship achieved by the stonecutters of Rhodes and Pergamum. The stones were divided into four groups according to their weight:

Size	Weight in Kg.	Weight in Minas	Number of Stones
light	2.5-4.5	5.7-10.3	900
medium	5.0-7.5	11.5-17.2	3500
heavy	9.0-14.0	20.6-32.1	550
heaviest	16.0-40.5	36.7-92.1	650

This classification, however, says nothing concerning the calibres of the stone-throwers employed in Carthage. One might suggest that all 3500 stones of the medium group were to be employed by 15-mina engines. It is no less reasonable to suggest that they belonged to stone-throwers of two calibres (13, 17) or even three calibres (12, 15, 17).[28] It should be borne in mind that the engineers responsible for the construction of stone-throwers had to take into account the width of the walls and the size of the towers, which generally served as emplacements for the artillery. These put some limitations on the calibres the engineers could use. At any rate, the majority of the stone-throwers in Carthage (78%) were in the range of 10- to 20-mina calibres, in contrast to the heavier calibres preferred in Pergamum.

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25 I ignore item no.216 which weighs 30.91 minas, probably a mistake of the stonecutter who added a superfluous Δ.

26 It is hazardous to draw conclusions with regard to other characteristics of the balls found at Salamis, for Karageorghis supplied details of a selection of only 38 balls out of the total found (230?).

27 B. Rathegen, "Die Punischen Geschosse des Arsenals von Karthago", *Zeitschrift für historische Waffenkunde* 5, 1909-1911, 236-43. The circumference, from which the diameter can be calculated, and the weight of a considerable number of these stones were estimated, and not actually taken by measuring and weighing.

28 For other suggestions see Marsden (n. 2), 80-82.

The Distribution of the Stone-Shot at Tel Dor (Map 1)

The majority of the stone-balls were found in area B2 within a short distance south and south-east of the gate on the eastern wall of the city (see Fig. 1). Altogether about 125 balls were found in this area, most of them concentrated in two piles. North of the gate, and again close to the Hellenistic wall, some 20 stones were found indicating another place of concentration of this ammunition. Several stray balls were unearthed in areas A and C. Two stones were found on top of the northern and southern towers which were excavated in these two areas. Since these stones were found close to the surface, they cannot be definitely associated with the towers. A few stones were found in this part of the city area, as far as 45 meters west of the eastern wall. At least three balls were discovered in secondary use in walls of houses of the Hellenistic period. Several stones were unearthed in area E, in the north-west corner of the city. Finally a small number of stones were found in area D2, in a site adjacent to the ancient port of Dor.[29]

The relatively great quantity of stone-shot found close to the east gate of the city, on both the southern and the northern sides, seems to indicate that stone-throwers were placed here to strengthen the defence of the gate. It is quite possible that in Dor as in Pergamum the stone-shot were stored in an open area and not in a storage room. This probably holds true of the large piles of stones found south of the gate. The stones discovered scattered in areas A and D, some certainly in a secondary use, do not contribute much to understanding the defensive system of Dor. True, towers were frequently equipped with stone-throwers in the Hellenistic period, but the stones discovered here cannot be shown to be related to the towers excavated on the east wall of the city. Conversely, the stone-balls found in area D2 may indicate that artillery engines were placed in this sensitive part of the city. As a result of an earth collapse in this area, a number of stones may have been swept in to the bay, from which ten balls have indeed been retrieved. The stones found in area E could hardly have been brought there from other parts of the city for a secondary use. Possibly here, too, some stone-throwers were placed.

Characteristics of the Stone-Balls

The stones found were not uniformly worked and dressed. It looks as if some stonecutters made a great effort to produce balls with a smoothed, well-dressed surface and a fine spherical shape. In contrast, other stones convey the impression that they were worked carelessly, having a coarse surface and a few a shape more similar to a cube than to a ball. But these two apparently different levels of craftmanship have much to do with the stone material used. Most if not all of the imperfectly worked stones were made of *Kurkar* (calcareous sandstone), whereas

29 The excavators of Tel Dor marked on each stone-ball the number of its *locus*. Unfortunately since the marks of 29 balls had disappeared by the time I began this study, I have not been able to ascertain their exact provenance.

the refined stones were made of limestone (see below). Presumably it was more difficult to refine the easily breakable *kurkar* rocks. It is evident that several stones were damaged and lost some parts of the form they had been given by the stonecutters. But one cannot decide whether this damage was caused by the discharge of the stones and their landing on hard material or by the collapse of a pile of ammunition. At any rate, the number of the damaged stones is less than 25% of the total shot found. This can be compared to the number of the damaged stone-balls found in Masada, which may have equalled the number of those found complete. There is no doubt that most of the stone-balls found in Masada were hurled by the Roman army during the famous siege of 73 CE.[30]

All the stone-balls, 217 in total, were measured and weighed. Each stone was measured twice, once along a longitude circumference, so to speak, and once along a latitude circumference, for, as has been mentioned, the stonecutters were not able to work the stones to the shape of a perfect sphere. The circumference of 38 stones was almost identical in the two measurements taken. A difference of no more than 1 cm. was noticed in 116 stone-balls, 52 stones had a difference of 1.1 to 3 cm., and in 11 stones the difference ranged from 3 to 6 cm. The excavators of Carthage and Rhodes did not mention such differences, reporting one diameter or circumference only, as if the stones had a perfect spherical shape. The excavators of Pergamum, however, reported differences between maximum and minimum diameter, which were sometimes bigger than those noticed in the stones of Tel Dor. Such differences were also noticed in the artillery balls of Salamis.

Several stones deserve special attention, for they have letters inscribed upon them (see Fig. 3-6). Assuming that these letters represent numerals, I suggest that they indicate the weight of the stone-balls in minas, that is to say, the calibre of the stone-throwers. The details are presented in the following table:

Letters	Numeral	Weight in kg.	Weight in minas	Theoretical weight in kg.
IE	15	6.3	14.40	6.54
IH	18	7.7	17.60	7.86
KB	22	9.5	21.75	9.60
KΔ	24	10.1	23.16	10.47
Λ	30	13.1	30.04	13.08
M	40	16.8	38.55	17.44
M	40	17.5	40.11	17.44

Red paint is still preserved on one of the stones, that inscribed with the letters IH. Two stones have upon them the letter M. and the weight difference between them is 0.7 kg., or 1.62 minas. The actual weight of the stone-balls is very

30 See Joseph. *BJ* 7.304-9; Y. Yadin, "The Excavations of Masada, 1963/4. Preliminary Report", *IEJ* 15, 1965, 76, 80. For the finds from Masada see A.Holley, "The *Ballista* Balls from Masada", *Masada IV. The Yigael Yadin Excavations 1963-1965. Final Reports*, edd. J. Aviram, G. Foerster and E. Netzer, 1994, 349-65.

close to that indicated by the letters. If this interpretation is correct, this is the first time that the alphabetic numerical system is attested on stone-shot. At Rhodes and Salamis, as explained above, the weight of the stones was indicated by the acrophonic numerical system.[31]

Considering this and other finds of artillery stones from the Hellenistic period, as well as the weights proposed by the ancient technical writers, the stone-balls found in Tel Dor may be divided into 14 groups, whose characteristics are summarised in the following table:

Calibre		Stones	Average	Weight	Min.	Weight	Max.	Weight	Diameter	(cm.)
Minas	Kg.		Kg.	Minas	Kg.	Minas	Kg.	Minas	Minim.	Max.
3	1.30	6	1.55	3.56	1.29	2.69	1.82	4.17	10.6	11.1
5	2.18	18	2.41	5.53	1.96	4.49	2.80	6.41	10.6	13.5
8	3.49	11	3.64	8.35	3.10	7.19	3.80	8.71	13.2	15.8
10	4.36	30	4.34	9.97	3.90	9.06	4.80	11.00	14.6	16.5
13	5.68	15	5.33	12.27	4.90	11.23	6.10	13.99	16.0	19.5
15	6.54	23	6.78	15.54	6.30	14.44	7.40	16.97	17.2	20.0
18	7.86	9	8.03	18.41	7.70	17.60	8.30	19.03	18.8	21.6
20	8.72	9	9.07	20.80	8.60	19.12	9.10	20.87	20.0	21.9
22	9.60	10	9.70	22.24	9.30	21.33	10.00	22.93	19.3	22.7
24	10.46	19	11.07	25.38	10.10	23.16	12.00	27.52	19.9	23.2
30	13.08	23	13.58	31.14	12.30	28.21	14.80	33.94	21.0	24.8
40	17.44	28	16.92	38.80	14.90	34.17	19.50	44.72	22.6	27.5
50	21.80	12	21.69	49.74	20.20	46.33	23.20	53.61	25.7	27.6
60	26.10	4	25.70	58.86	23.70	54.35	27.20	62.29	27.2	29.0

Comparison of the Finds of Tel Dor, Rhodes and Pergamum

To date the only finds that have been studied in detail are those of Rhodes and Pergamum; of the Salaminian shot only a selection of 38 balls were examined. According to the division proposed above of the stone-shot of Tel Dor, the difference between the average weight and the theoretical weight in each calibre is slight, ranging from twenty grams (calibre 10) to 610 grams (calibre 24), or less than one mina in ten calibres (3, 5, 8, 10, 13, 15, 18, 20, 22, 50) and only slightly more than one mina in four calibres (24, 30, 40, 60). The difference between the lightest stone-ball and the theoretical weight in each calibre ranges from ten grams in calibre 3 to 2.54 kg. in calibre 40, or less than one mina in eight calibres (3, 5, 8, 15, 18, 20, 22, 24), more than one mina in three calibres (10, 13, 30), more than three minas in one calibre (50) and more than five minas in two calibres (40, 60). The difference between the heaviest stone-ball and the theoretical weight in each calibre ranges between 310 grams in calibre 8 to 2.06 kg. in calibre 40, or less than one mina in five calibres (8, 10, 13, 20, 22), more than one mina in four calibres (3, 5, 15, 18), more than two minas in one calibre (60), more than three minas in three calibres (24, 30, 50) and more than four minas in one calibre (40).The difference between the heaviest and lightest balls in

31 For a convenient summary of these two systems see A.G. Woodhead, *The Study of Greek Inscriptions*, 1981, 108-112.

each calibre is obviously greater, ranging from 0.5 kg. in calibre 20 to 4.6 kg. in calibre 40.

Compared to the artillery stones from Rhodes, the weight difference between the heaviest and lightest balls of the Tel Dor finds is greater in six groups (in kg.): 1.2, 1.1, 2.5, 4.6, 3.0, 3.9 (calibres 13, 15, 30, 40, 50, 60). The corresponding difference in weight in the Rhodes finds is less than 1 kg. in every single calibre. Conversely, the difference between the average and the theoretical weight is higher in the Rhodes finds in eight calibres (25, 40, 50, 60, 70, 80, 90, 150): 0.64 to 2.4 kg.; the highest difference in the Tel Dor stones is 0.52 kg. The stone-balls of Pergamum show the following weight difference between the lightest and heaviest shot (in kg.): 0.3, 0.8, 1.15, 2.7, 3.0 (calibres 18, 20, 30, 40, 60), and in this respect the finds of Tel Dor do not differ significantly from those of Pergamum.

Four calibres (3, 8, 22, 24) that do not appear in the tables proposed for the artillery of Rhodes and Pergamum and are not marked in the Salaminian shot call for an explanation. The excavators of Pergamum ascribed a 2.8 kg. ball, i.e. 6.42 minas, to calibre 10. If so, the calibre is 1.5 heavier than the actual weight, which is hardly plausible. It seems that the excavators were too much influenced by the examples cited by Philo, whose lowest calibre is ten minas. It is more plausible to ascribe the 2.8 kg. ball of Pergamum to calibre 5. The employment of this calibre has been proved by the finds of Rhodes, which were not known to the excavators of Pergamum. Now the excavators of Pergamum did suggest calibres of 13,15 and 18 minas, that is to say, they regarded as possible a difference of less than five minas between the lower calibres. Furthermore, Vitruvius cited stone-throwers of four and ten Roman *librae,* that is to say, 1.3 and 3.25 kg. For these examples he relied, *inter alia*, on Greek writers. These two examples are identical or almost identical with calibres of three and eight minas. Finally, if calibres 3 and 8 are not assumed to have been employed in Tel Dor, all their stone-balls will have to be ascribed to calibres 5 and 10. This will result in having in these two calibres stones 1.5 times heavier than others in the same calibre, which is implausible.[32]

Calibres 22 and 24 are proposed because they are clearly indicated by the letters inscribed upon two of the stone-balls. These two calibres are not mentioned by any of the ancient technical writers, nor are they known from any other finds of artillery stones. But for these stone-balls, it would be more reasonable to propose a calibre of 25 minas and to divide the balls attributed to calibres 24 and 22 between calibres 20 and 25. Still, this evidence cannot be disregarded, and perhaps the lesson to be inferred from the finds of Tel Dor is that the ancient ar-

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32 One of the stone-balls of Salamis was marked ΔΙΙ (=12 minas), but its actual weight was 19.5 minas. This mistake, probably of the stonecutter, may point to the use of calibre 12 at Salamis, which indicates a difference of less than five minas in the lower calibres. Marsden's suggestion that 'there should be a horizontal line across the top of the two vertical ones: Π' (n. 22, p. 225), i.e. calibre 15, is not persuasive. A 19.5-mina ball probably belonged to calibre 20, not 15.

tificers employed a wider variety of stone-throwers than that proposed by the ancient writers and modern scholars.

The employment of balls of low calibres, that is to say, ten minas and less, amounted to 29.95% of the finds in Tel Dor, compared to 16% in Carthage, 13.3% in Rhodes and 0.1% in Pergamum. This preference for low calibres is also known from two finds of Roman artillery: all the stone-shot found at Numantia and the vast majority of those found in Masada belonged to calibres of ten minas and less.[33] Conversely, 78% of the balls of Pergamum belonged to calibres of thirty to sixty minas. We may also note that 63% of the balls found in Carthage belonged to calibres in the range of eleven to seventeen minas, and that 86% of the stone-shot of Rhodes were in the range of ten to thirty minas, compared to 64% of the balls of Tel Dor in the same range. The selected shot of the Salaminian find might indicate that the 20- 30- and 40-mina calibres were preferred there.

Another noteworthy feature of the artillery balls of Tel Dor is the lack of conformity between weight and diameter. In almost all the calibres (three to forty) are included balls whose diameter is longer than that of some of the balls of the next higher calibre. This is particularly conspicuous in calibres 20 and 22: the majority of the balls of the higher calibre, whose weight is heavier, have a diameter shorter than that of the balls belonging to the lower calibre. Such a phenomenon has also been noticed in some of the stone-balls of Pergamum (above, at n. 19). As will be explained presently, this feature of the Tel Dor finds has much to do with the use of three types of rock for the manufacturing of the artillery balls.

Petrographic Examination of the Stone-Balls of Tel Dor

Since it seemed that the shot were not all made of the same type of stone, samples from twenty five of the balls were given to geologists for petrographic examination in order to determine the rocks which were used as raw material. Twelve samples of the local rocks of Tel Dor were also analysed for comparative checking.[34] The results demonstrated that the objects under discussion were made from three different types of rock: *kurkar* (calcareous sandstone), limestone and basalt. Each of these three types has its own petrographic characteristics.

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33 For Numantia see A. Schulten, *Numantia* 3, 1927, 165, 211, 215, 218-20, 264-5, and for Masada see A. Holley (n. 30), 355-9. See also Shatzman, *art.cit.* (n. 13), 472.

34 The samples were given to and examined by Dr. A. Almog, Dr. A. Bein, Dr. B. Buchbinder, Prof. G. Gewirtzman and Miss D. Sivan of the Geological Institute of Jerusalem and by Dr. Sh. Shuval of the Open University of Israel. I should like to thank all of them for their cooperation, and in particular Dr. Shuval who willingly undertook to summarize the results in a language that can be understood by lay people.

Kurkar rocks are divided into two main groups: the common *kurkar* that is rich in quartz grains, and the *kurkar* that is rich in limestone or in lime fossil (calcarenite type). The first group is abundant along the Mediterranean shore of Israel *south* of the Gulf of Haifa. Rocks of the second group are found along the shore *north* of the Gulf of Haifa. Of the samples analysed, five belong to the first group, but another five belong to the second group. Of the dozen samples taken from the local rocks of Tel Dor, nine belong to the first group, the remaining three to a different type of coastal rock and none to the second group.

Limestone rocks are divided into several petrographic groups. The main group is characterized by micrite (microcrystalline calcite) with sparaite patches (crystalline calcite), and contains Cenomanian-Turonian foraminiferal fossils. Another group is characterized by nummulite fossils. Of the samples taken, eight belong to the first group, one to the second and five more to other groups of limestone rocks. Mount Carmel, located a few km. east of Tel Dor, is abundant in limestone rocks, notably of the first and second groups.

The petrographic examination has shown that one of the samples taken was made of basalitic rock, of the olivine-basalt type. Volcanic rocks are abundant in Mount Carmel, but on its eastern range, quite far from the coastal plain, and most of them are tuff and weathered basalt. Outcrops of basalitic rock are abundant in eastern Galilee and Golan, but it is less likely that the material for the basalitic stone-ball found at Tel Dor originated from such far away regions. It is more reasonable to suppose that a basalitic stone ballast from some ship was used for this particular ball. At any rate, this basalitic stone-ball is probably unique in the finds of Tel Dor, for it is visibly different from all the other stones in its dark colour.[35]

To judge by the results of the petrographic examination of the twenty five examples, more than half of the stone-balls were made of limestone rocks of Mount Carmel. Other stone-balls were made of the local *kurkar* of Tel Dor. A third group of stones was manufactured from *kurkar* rocks located north of the Gulf of Haifa, some seventy km. north of Tel Dor, which is rather surprising and calls for explanation.

The Employment of Artillery in Tel Dor

It follows from the table of calibres proposed above, based on the weight of the stone-shot, that in Tel Dor stone-throwers operated whose length ranged between *ca.* 3.5 m. and 9.7 m. (above, at n. 17), and their width between 2.1 m. and 5.8 m. In certain, not common circumstances, artillery engines were placed on platforms in front of the curtain-walls, protected by ditches and palisades.[36] It is possible, though unlikely, that some engines were placed in front of the walls in Tel Dor.

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35 The shot found in the Jerusalem Citadel, about 200, include two basalitic stone-balls (Sivan and Solar [n. 12], 173), which I find harder to explain.

36 Philo, *Par.* 82.4-6. See the discussion in Marsden (n. 2), 117-21.

Low calibre engines may have been set up on the rampart. True, the width of the Hellenistic wall of Tel Dor was only about two meters, but it was possible to extend it rearwards in certain points by means of wooden staging, thus procuring the extra length needed to place a three- or five-mina calibre stone-thrower.[37] It must be admitted, though, that so far no physical evidence has been discovered to indicate that such a device was employed in Tel Dor.

Stone-throwers, especially of the high calibres, were usually set up in chambers of towers.[38] It seems that the eastern gate complex as well as the other towers that have been excavated in Tel Dor could have accommodated even stone-throwers of high calibres. The stone-balls found south of the eastern gate indicate that stone-throwers of eleven different calibres were probably employed in that section: 5, 8, 10, 13, 15, 20, 22, 24, 30, 40, 50. North of the gate the following calibres were probably used: 10, 13, 20, 24, 30, 60. There is no way to tell how many engines were set up, but it is well to remember that three-story towers could accommodate at least three, possibly six, engines apiece. A word of caution is in order, though. One cannot be certain that all the balls found really represent the calibres used by the artillery of Tel Dor, for some of the shot were originally hurled by besieging armies (see below). It might be that the defensive artillery of Tel Dor did not include all the calibres of the heavier type of machines, say of the 50-mina calibre.[39] Notwithstanding this reservation, the variety of calibres may be taken as evidence for the efforts made to provide efficient defence for the gate, which served as the main entrance to the city from the mainland.

There is no information in any literary source concerning the supply of the defences of Dor with artillery. As explained above (at n. 5), Tyre had numerous artillery engines at the time of its siege by Alexander, and Gaza, too, had some catapults at its disposal in 332; it is quite possible that other Phoenician cities had aquired such engines by that time. The recent excavations of Tel Dor have shown that a new, Hellenistic wall was constructed in the first third of the third century, probably under Ptolemy II, replacing a Persian wall of the fourth century.[40] It stands to reason that on that occasion, when better and stronger fortifi-

37 See Marsden (n. 2), 122-6.

38 See Marsden (n. 2), 126-63.

39 Marsden maintains that there were 'very few points indeed anywhere in and near fortifications in which a 1-talent engine could have been placed' (n. 23), 227. He refers to the examples given by Philo in his recommendations about the employment of artillery in defence, the largest being a 30-mina engine (*Par.* 95, 67). But the validity of Marsden's conclusion is questionable. As we have seen, actual finds have shown that the calibres cited by Philo are no more than examples that do not list all the calibres used by the ancient artillerymen. Moreover, there is no reason to doubt that the stone-balls of Pergamum and Rhodes were intended to be used by the defensive artillery of these cities; they included 50- to 180- mina shot.

40 E. Stern, "The Walls of Tel Dor", *IEJ* 38, 1988, 6-14.

cations were constructed, the city was also provided with stone-throwers, if it did not have such engines before.[41]

The new defensive system of Dor was tested and functioned well when Antiochus III put the city under siege in 219 BCE, the first siege of the city reported during the Hellenistic period. Having defeated the Ptolemaic forces which tried to block his way to the south in Phoenicia, Antiochus succeeded in winning several cities, including Tyre and Ptolemais/Acre, whose Ptolemaic commanders went over to him. Several other cities that remained loyal to Ptolemaic rule were then besieged, but only one of them is mentioned by name, Dor. In that campaign the Seleucid land forces were supported by a fleet, and although Polybius, our source, does not mention it specifically, the siege may well have been conducted from the sea as well. But Dor succeeded in withstanding the enemy thanks to its strength and the support given by Nicolaus, the Ptolemaic commander in Coele-Syria.[42]

Dor was put under siege again in 138/7 BCE. At that time Antiochus VII landed in Seleucia in Syria to regain the Seleucid kingdom from Tryphon, the claimant to the throne who had killed Antiochus VI. Antiochus VII conquered the capital city Antioch, defeated his rival and pursued him southward. For unknown reasons, Tryphon preferred to find shelter in Dor and not in Ptolemais, the bigger city which remained loyal to him. Antiochus was supported by a fleet and carried on the siege vigorously both by land and by sea. Tryphon apparently lost hope of defending himself for he managed to escape on board a ship, but later on he committed suicide in Apameia in Cilicia.[43]

During the excavations of Tel Dor finds relating to a siege operation have been unearthed including sling bullets, arrow-heads and, we may add, artillery balls. Among the interesting finds at Tel Dor are "rolling stones", that is to say, large stones worked and prepared in order to be rolled down at an enemy as he approached the wall. Such stones were found at Masada and at Herodium as well.[44] Clearly these stones belonged to the defenders of the city. The same probably holds true of the sling bullets, including one with an inscription that

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41 On the new type of fortifications see I. Sharon, 'The Fortifications of Dor and the Transition from the Israelite-Syrian Concept of Defence to the Greek Concept", *Qadmoniot* 95-6, 1991, 105-12 (Hebrew).

42 See Polyb. 5.62-6. In 5.66.1 the reading Δουρα is obviously a corruption of Δωρα. See F.W. Walbank, *A Historical Commentary on Polybius* 2, 1957, 592. For cooperation between land and naval forces in the next season's campaign see Polyb. 5.68-69.

43 See *I Macc.* 15.10-14, 25, 37; Joseph. *AJ* 13.223-4; Charax in Steph. Byz. s.v. Δῶρος =*F.Gr.Hist.* 103 F 29; Strabo 14.5, 2; App. *Syr.* 68.

44 For Masada see Y. Yadin, *art.cit.* (n. 30), 80 and for Herodium V.C. Corbo, "L'Herodion di Giabel Fureidis", *Liber Annuus Studii Biblici Franciscani* 31, 1963, 226. Cf. E. Schramm, *Heerwesen und Kriegführung der Griechen und Römer*, edd. J. Kromayer and G. Veith, 1928, 237 with Taf. 24 Abb. 79.

has been interpreted to mean "for the victory of Tryphon".[45] These have obviously to be ascribed to the siege of Dor by Antiochus VII.

As explained above, the source of the raw material for part of the artillery balls found at Tel Dor must be located in the coastal plain north of the Gulf of Haifa. It is extremely improbable that the defenders of Dor should have taken the trouble to go as far as north of Ptolemais to find quarries for their artillery stones. Things are different for the sieges of Dor by Antiochus III and Antiochus VII (see Map 2). They most likely passed through the area where those stone-balls were quarried. Antiochus VII certainly and Antiochus III probably attacked the city from the sea. Hellenistic fleets operated arrow-firers and stone-throwers, emplaced on ships, to bombard besieged cities.[46] Antiochus VII almost certainly employed artillery in his siege of Dor,[47] and so probably did Antiochus III.[48] These pieces of information help us understand how stones from north of Ptolemais arrived at Tel Dor. Since the fleet had to be supplied with ammunition in the port where it took off for the attack, it is only natural that the fleets of these two kings were supplied with balls worked from the coastal rocks of western Galilee. The balls shot by the attacking forces on these two occasions were presumably collected and stored in the local arsenals of the defenders of the city.

The limestone balls found in Tel Dor clearly indicate that the artillerymen were not satisfied with local *kurkar* as raw material for stone-shot. They evidently preferred a harder type of stone, and it was not too difficult to find it on Mount Carmel. The defenders could have prepared a stock of ammunition made of this raw material well before the start of a siege, and the attacking armies probably soon realized that it was better to operate with balls made of Mount Carmel stone.

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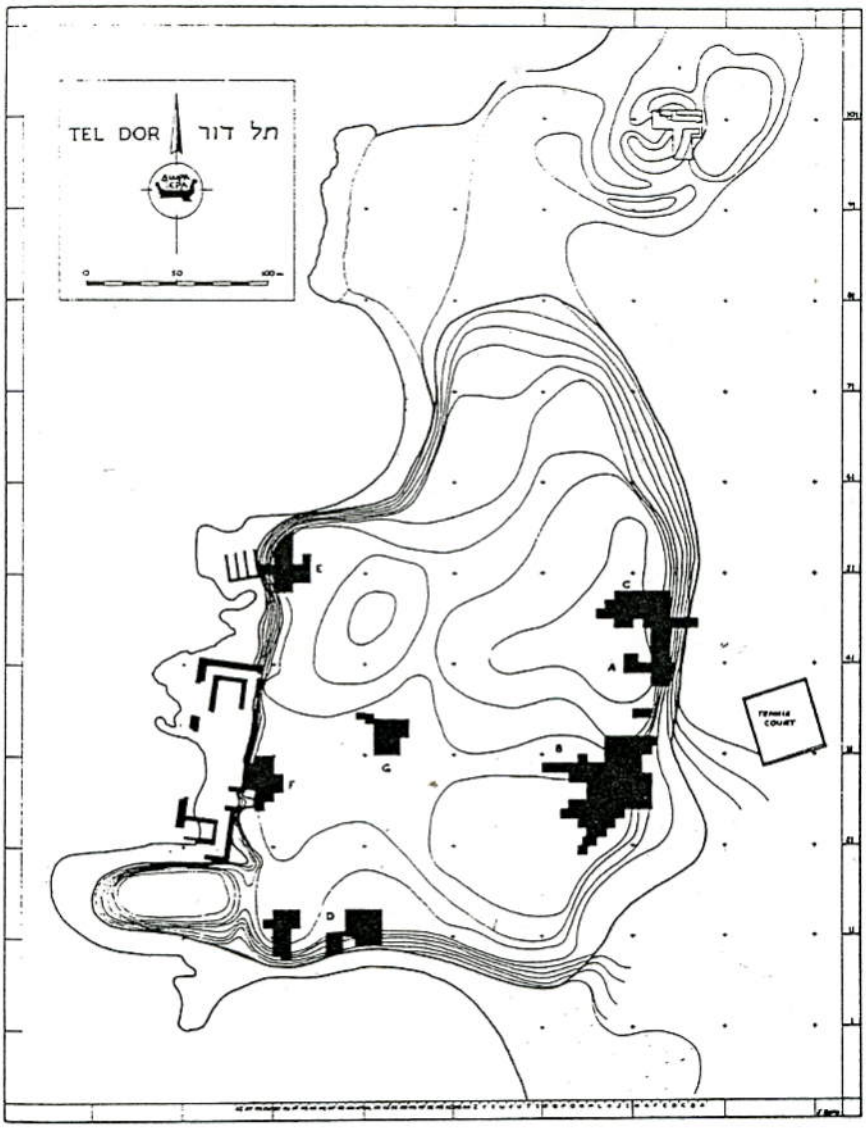
45 See D. Gera, "Tryphon's Sling from Dor", *IEJ* 35, 1985, 153-63. For a different reading see Th. Fischer, "Tryphons verfehlter Sieg von Dor?", *ZPE* 93, 1992, 29-30.

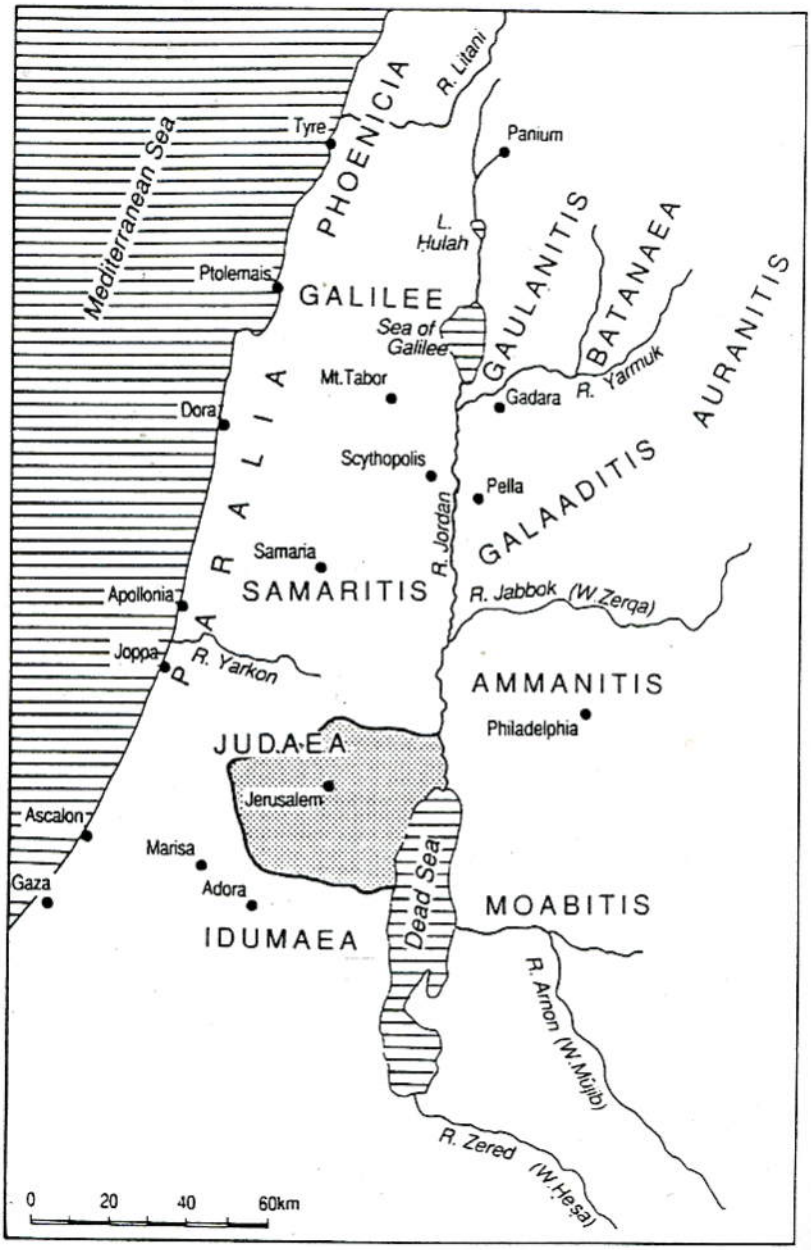
46 See Arr. *Anab.* 2.21; Diod. Sic. 20.85.3; Philon, *Bel.* 57, and the discussion in Marsden (n. 2), 169-73.

47 *I Macc.* 15.25: καὶ μηχανὰς ποιούμενος.

48 Antiochus used ἔργα and μηχανήματα to capture Gadara and Philadelphia in Transjordan in 218 (Polyb. 5.71). These terms may mean various types of siege machines, including artillery. There is no reason to assume that it was only during the siege of those two cities and in the compaign of these years that Antiochus' army employed those machines .



MAP 1. Tel Dor, 1991.



MAP 2. Seleucid Palestine

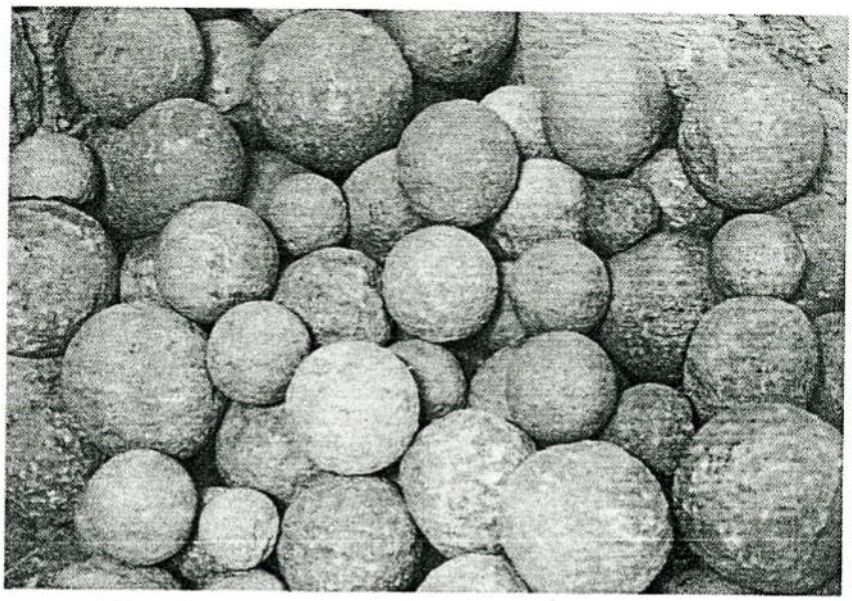


FIGURE 1. Stone-balls in the Museum of Kibbutz Naḥsholim

FIGURE 2. Stone-balls in area B2

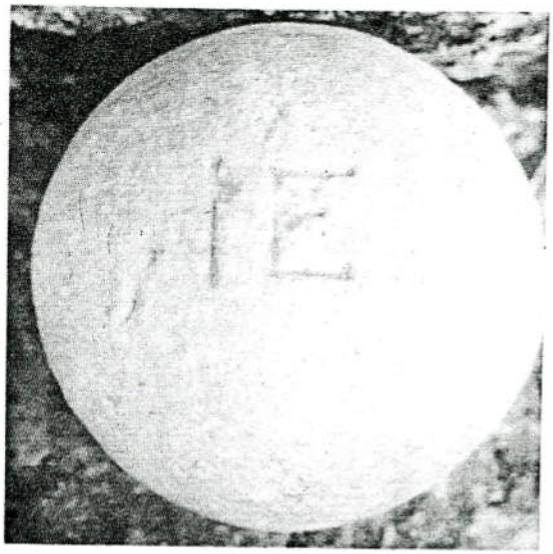


FIGURE 3. Stone-ball inscribed with the letters IE.

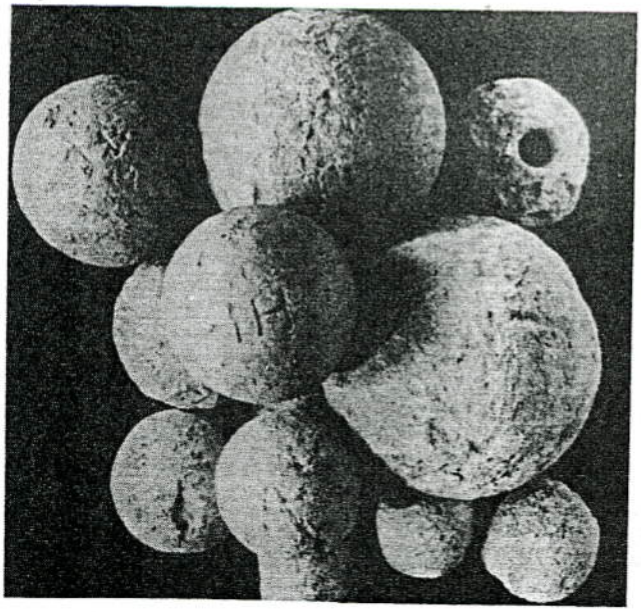


FIGURE 4. Stone-ball inscribed with the letters IH.

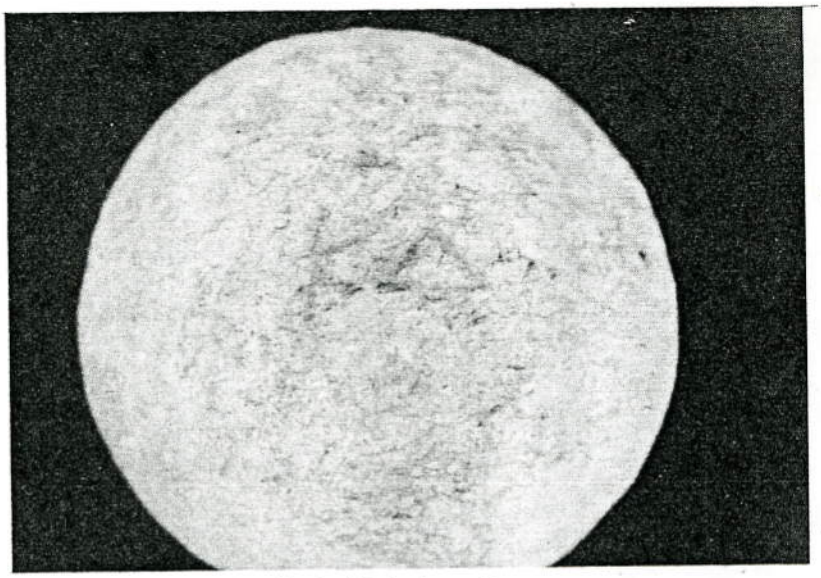


FIGURE 5. Stone-ball inscribed with the letters KΔ.

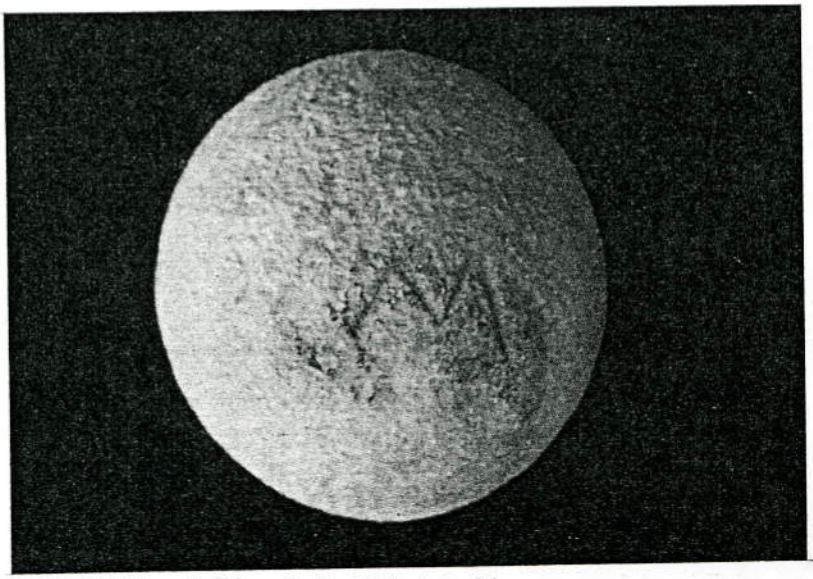


FIGURE 6. Stone-ball inscribed with the letter M.