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THE GEOLOGY OF TELL GEZER, ISRAEL AND
ITS EXCAVATIONS.

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THE GEOLOGY OF TELL GEZER, ISRAEL
AND ITS EXCAVATIONS

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1969

By
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UNIVERSITY OF CINCINNATI

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I hereby recommend that the thesis prepared under my supervision by Reuben G. Bullard

entitled THE GEOLOGY OF TELL GEZER, ISRAEL, AND ITS EXCAVATIONS

be accepted as fulfilling this part of the requirements for the degree of Doctor of Philosophy

Approved by:

Frank L. Koucky

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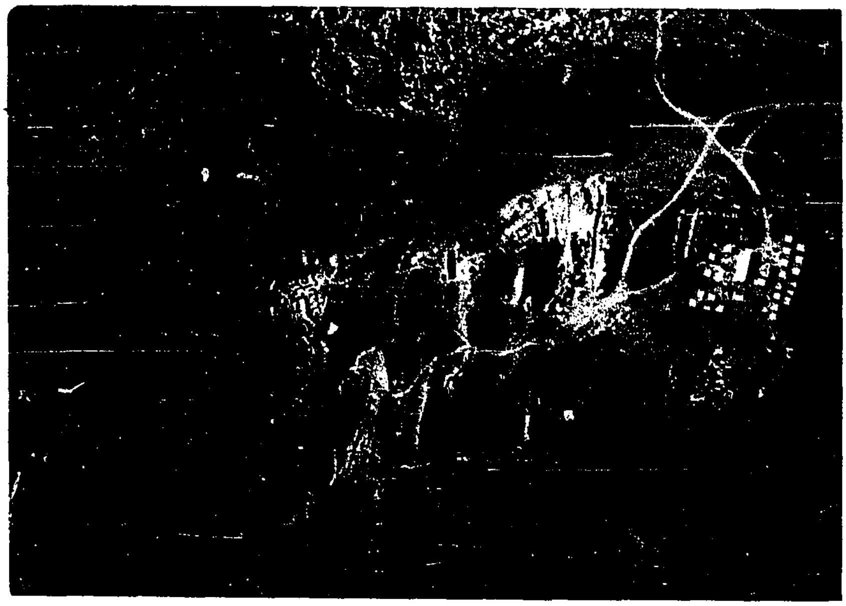

Frontispiece. Aerial view of Tell Gezer from an altitude of 500 meters. The north-to-south orientation of the surface features of Tell Gezer are highlighted by the 8:00 a.m. sun. Fields I-V of the Hebrew Union College-Harvard Semitic Museum's recent excavations (through the summer of 1968) may be seen along with the slit trenches marking the activity of the War of Independence (1948). (Cf. Figure 4 for identification of the excavations, both past and present.)

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ABSTRACT

Tell Gezer is situated on the Eocene chalks of the central Shephelah (Foothills Belt) of Israel. Moderate relief ($\sim$75m) gave Gezer a position which could control the Via Maris in the Coastal Plain and one of the main routes across the Valley of Aijalon up to the Judean Mountains.

Bounded by the Pleistocene sands and soils of the Coastal Plain on the west and moderately folded Upper Cretaceous carbonates of the Judean Mountains on the east, the local stratigraphy ranges from the hard Bi'na Limestone (Turonian) to the soft Maresha chalks with nodular chert (Middle Eocene). The chalk, and to a lesser extent the marls, have given rise to nari, a form of caliche, which was extensively quarried by the Gezer inhabitants. Chert and siliceous chalk occurrences in the Gezer water tunnel were worked in the production of artifacts.

The residual rendzinate soil formed on the carbonate bedrock of the Shephelah is composed mainly of palygorskite with lesser amounts of montmorillonite and illite; eolian silt is a minor constituent. Kaolinite is locally important in the alluvial clays of Nahal Aijalon and the Yarkon River. Local residual, colluvial and alluvial soils were exploited by the Gezer potters and brick makers. Ceramic temper was obtained from the stream-sorted sediments of the local drainage and from the current and wave sorted deposits of the Coastal Plain.

Data obtained from clay mineral, trace element, and heavy mineral analyses form the basis for the erection of eight pottery groups. Type I and II pottery is of local manufacture. Type III ceramics were made

from materials quarried in the Judean Mountains, while Type IV suites show strong affinities for a Galilean provenance. The alluvial clays and sorted silts and sands of the Nahal Aijalon, the Yarkon River, and the Nahal Sorek constitute the probable source for the Type V grouping. Exotic materials from the Emek Yizreel, the Golan, and Aegean areas are placed in categories VI, VII, and VIII respectively.

The deposits of Tell Gezer are classified according to three major modes of origin in a new approach to the examination of sediments of an archaeological site. Considered genetically, all deposits relate to an occupational, a destructional, or an hiatus phase in Gezer history.

Domestic, courtyard, and street depositional agencies contribute sediments of a distinctive nature and are considered as synchronous by the recognition of facies relationships within an archaeological stratum. Destructional deposition, in contrast to the more orderly occupational accumulations, is frequently initiated by shattered pottery and fired debris, followed by rapid chaotic deposition. Hiatus phases are mainly the result of natural agencies such as wind transportation (loess) and weathering (incipient soils).

Artifacts are a distinct aspect of the occupational sediment. Mostly of local origin, many of them are made of nari, siliceous chalk, and chert. Exotic occurrences are basalt, andesite porphyry, pumice, amethyst, and clear quartz. The basalt shows petrographic affinity with Galilee. The provenance of the other exotics is not proposed.

The description and classification of the Gezer deposits is offered as a model for consideration of archaeological "depo-centers".

The aim of this research is a fuller understanding of the agencies of deposition operating within the context of human habitation as a contribution to the broader archaeological and historical frame of reference.

ACKNOWLEDGMENTS

Dr. Nelson Glueck, President of Hebrew Union College/Jewish Institute of Religion recognized initially the value of geologically-oriented research and made possible the writer's participation in excavations in an early stage in Israel. The enthusiastic attitude of Dr. William G. Dever, Director, and Professor H. Darrell Lance, Associate Director of the Gezer Excavations, made the field work a pleasure.

Maximum interest was shown continually by all the members of the staff of the Department of Geology, University of Cincinnati. The writer is especially grateful for the critical assistance of his thesis committee: Dr. Frank Koucky, Professor Richard H. Durrell, and Dr. Warren D. Huff.

Credit is due various members of the Geological Survey of Israel and the staff of the Hebrew University, Jerusalem, for their willingness to discuss the local and regional geology with the writer upon several occasions. Mr. Richard Alexander and Dr. Zeev Reiss gave valuable assistance in confirming the identity of the foraminiferal forms of the local stratigraphy and in the pottery.

This investigation was made possible by assistance from President Walter C. Langsam of the University of Cincinnati, The Nevin Fenneman Fund, The Ford Foundation, and the Renton K. Brodie Fund. The writer is greatly endebted to those who made available this aid.

Mr. Richard L. Bullard assisted in some of the photographic printing. The manuscript was typed in most of its form by Lynn Bullard, without whose untiring labor these results would not have been published.

Reuben G. Bullard
May 1969

INTRODUCTION

> The hill on the summit of which for some three thousand years the city of Gezer stood, lies in the boundary that divides the maritime plain of Philistia from the foothills of the Judean Mountains. It is 16 3/4 miles south-east of Jaffa and 13 miles from the mouth of the Nahr Rubin, which is the nearest point off the sea-coast. To the traveler proceeding to Jerusalem, whether by the ancient valley road or by the modern railway, it is a striking object in the scenery; appearing first as he approaches Ramleh, some five miles away, and remaining in sight almost continually till the view is shut in by the Judean Mountains, through which winds the last stage of his journey. (MacAllister, 1912, p. 1)

LOCATION

R. A. S. MacAllister characterized in this fashion the site where he began his excavations on behalf of the Palestine Exploration Fund in 1902. It is situated at coordinates 1427 1408 on the Palestinian Grid or 34 55' 20" E longitude and 31 51' 30" N latitude (Plate II). The French scholar, Clermont-Ganneau, was the first to suggest the identity of this particular mound, known to the Arabs as Tell el-Jazar, as ancient Gezer in 1874 (Smith, 1931).

Undisputable identification of the site has resulted from the discovery of seven unique boundary inscriptions situated in an arc to the south and east of the tell, actually reading in the Hebrew, "The Boundary of Gezer" (cf. Figures 5a and 5b).

Tell Gezer is located in the Shephelah or Foothills Physiographic Province of Israel (Plate II). Its elevated position on an erosion remnant of deeply weathered Eocene chalk gave it a commanding situation over the maritime highway (the ancient Via Maris) on the inner Coastal Plain. About halfway between Jaffa and Jerusalem, it dominated the ancient route from the Coastal Plain through the Valley of Aijalon up to the Judean Hills (Plate III).

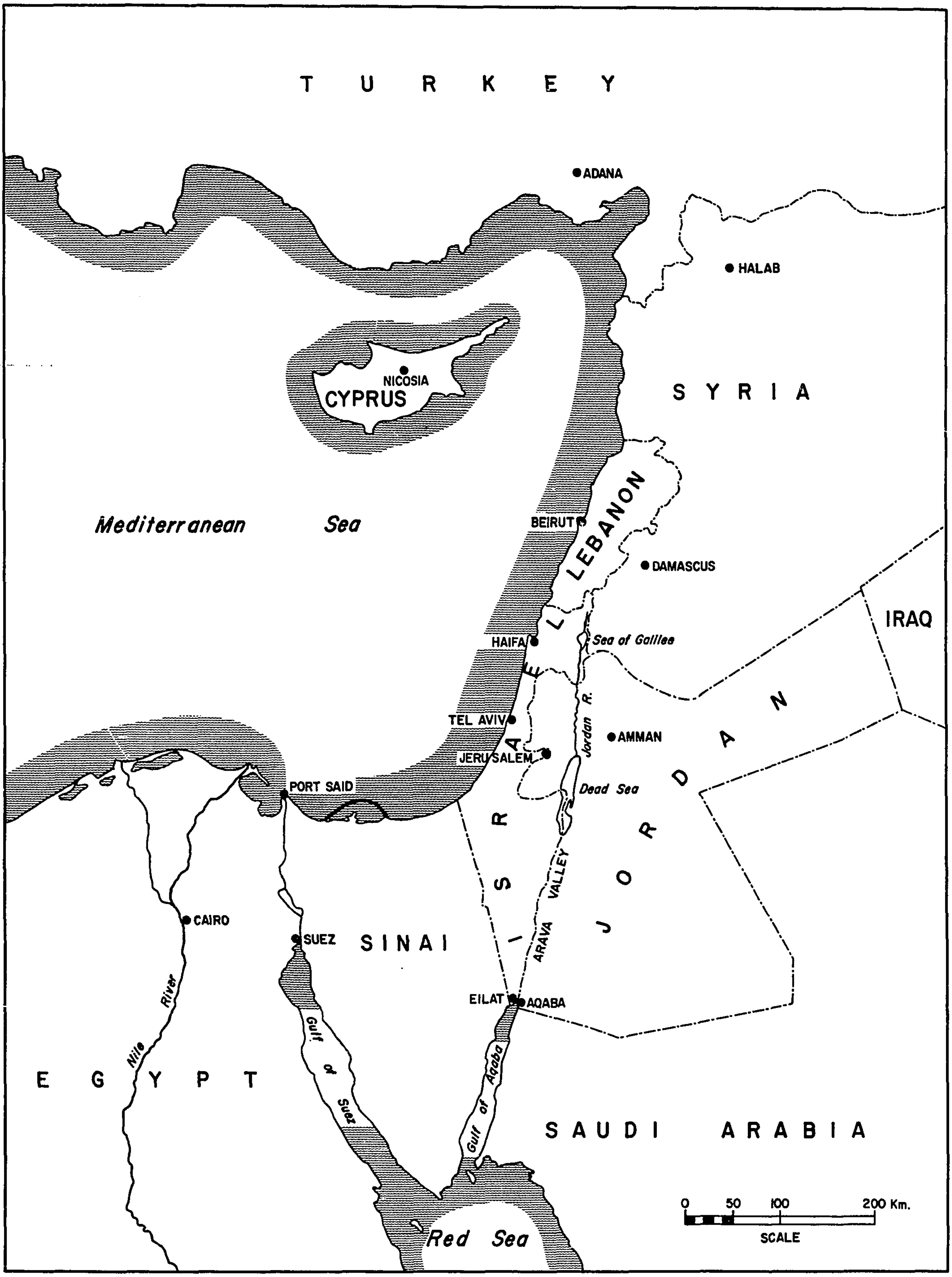


Plate I

The Near East: Geographical Setting

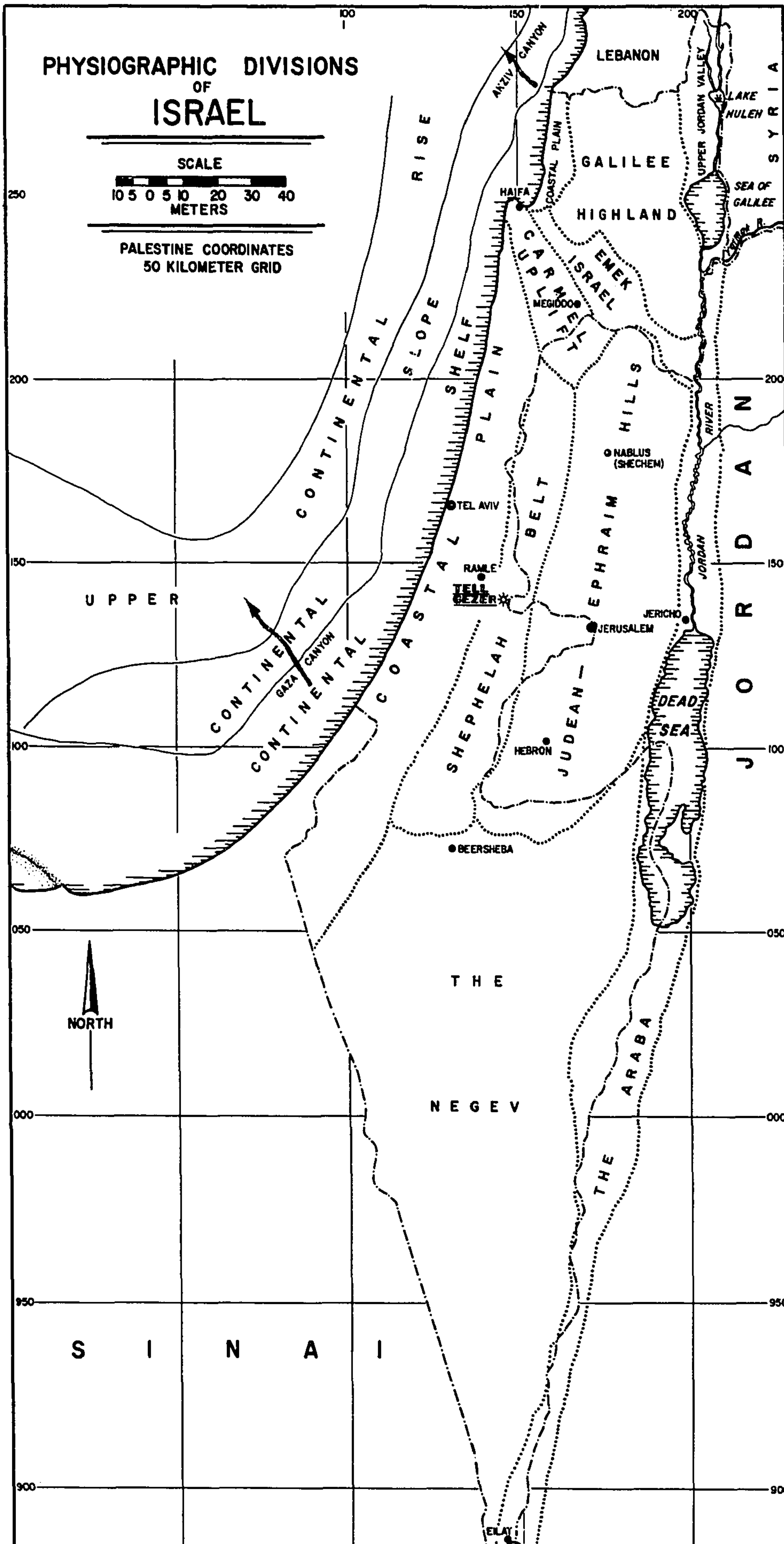
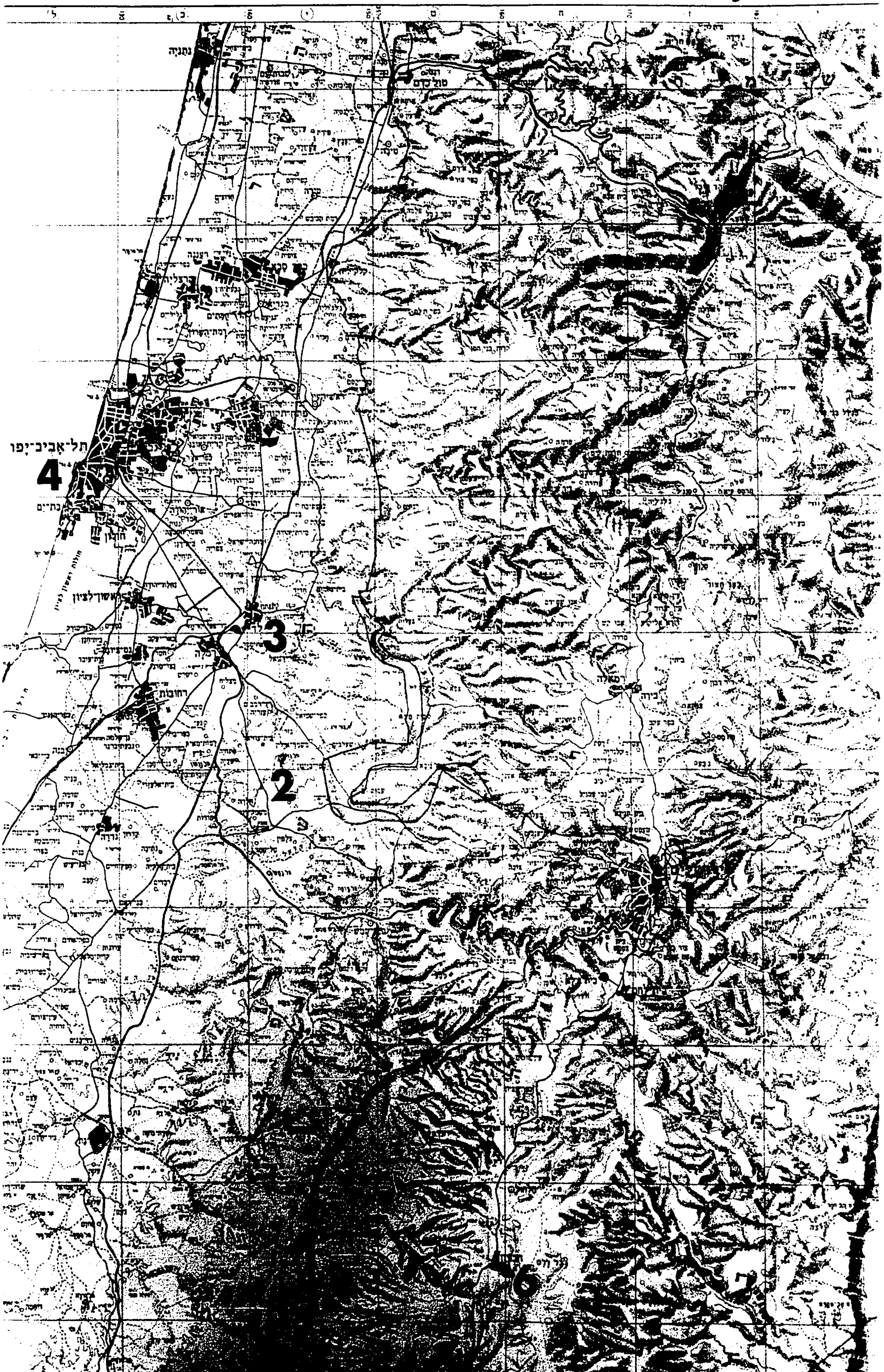


Plate II

Base map modified from Ball and Ball, 1953, and Emery, et al, 1966.

Plate III. Topography of Central Israel and the Central West Bank of Jordan.

1. Jerusalem (~800m)
2. Tell Gezer (227m)
3. Lod (Lydda) (53m)
4. Tel Aviv (Jaffa) (10m)
5. Shechem (550m)
6. Hebron (970m)


נתניה
תל-אביב-יפו
4
רחובות
3
2
6

HISTORY OF THE EXCAVATION

R. A. S. MacAllister began the first excavations at Gezer upon receiving a permit from the Turkish government in 1902. With the aid of an Egyptian foreman and about two hundred men, women, and boys from the Arab village of Abu-Shusheh, located just southeast of the tell, MacAllister's plan "to turn over the whole mound" was implemented by a series of trenches dug 40 feet wide and extending north-south nearly the entire width of the tell. His excavation to bedrock carried him through strata that were locally 42 feet in total thickness (cf. Figure 61). MacAllister continued his work, with some interruption, through 1909, excavating almost two-thirds of the more than 27 acre area of the site. In addition to reports in the Quarterly of the Palestine Exploration Fund, he published the essence of his work in three large volumes, entitled, The Excavation of Gezer, in 1912.

MacAllister's discoveries were significant and abundant. He uncovered parts of four city wall systems, a famous "High Place" with its monolithic stele, notable epigraphic material, and much pottery from Chalcolithic to Roman time (Dever, 1967).

Excavation of the site was resumed again for the Palestine Exploration Fund by Alan Rowe in 1934. His probes on the west end of the mound in search of the ancient acropolis of Gezer were disappointing, yielding bedrock through a shallow cover (Rowe, 1935).

Recent excavations were initiated in 1964 and in 1965 by Hebrew Union College, Biblical and Archaeological School, Jerusalem, and the Harvard Semitic Museum under the directorship of Dr. G. Ernest Wright.

Figure 1. Tell Gezer from the south. Occupying the northernmost extension of a deeply weathered Eocene erosion remnant, the archaeological site of ancient Gezer is seen from the next foothill about 1.2km to the south. Excavation trenches and spill piles of the Hebrew Union College-Harvard Semitic Museum excavations can be seen in the central and western parts of the mound. The saddle between the hills was the area of the threshing floors, the latest use of which was made by the Arabs of the destroyed village of Abu-Shusheh. Beyond Tell Gezer to the northeast lies the Valley of Aijalon and the northern continuation of the foothills belt on Upper Cretaceous deposits.

Figure 2. Tell Gezer from the north. This is the aspect of the ancient city viewed by those traveling the main road from the Coastal Plain through the Valley of Aijalon and up past Lower Upper Beth Huron to Jerusalem and to the Judean Plateau. The ruins of an Arab weli are prominent as an apex on the right-central portion of the mound. Current prevailing wind directions afford a subtle clue concerning the nature of the cultural remains which await the archaeologist when Field I is extended to this area. The position and elevation of this portion of the tell contribute to the probability that this was the site favored by the nobility at various times during the occupation of the tell.

The Middle Eocene strata variously overlain by virgin soil and/or occupational debris of the earliest inhabitants are obscured by the talus and surface float above. Lower Eocene chalk, nodular chert, and siliceous chalk, blanketed by nari, extend down to the limit of the exposed caliche where soils on the Paleocene marls are under cultivation. Maastrichtian argillaceous chalks reveal a subtle lithological difference in the soil coloration in the foreground.

Figure 1

Figure 2

Figure 3. Oblique aerial photograph of Tell Gezer and its geological context at an altitude of 500 meters, viewed from the east. The more resistant Lower Eocene formations visible below the tell debris and above the Paleocene marls show the characteristic resistivity to weathering which the Middle Bronze water tunnel excavators encountered in their quest for an internal water supply. The cultivation to the west is that of the vine, an occupation as old as the site itself.

Awareness of a lack of stratigraphic control on the part of MacAllister prompted renewed interest in the undisturbed part of the tell. The destruction of Abu-Shusheh and the Arab weli on the tell during the War of Independence in 1948 made possible the recent excavations in the previously inaccessible western quarter of the mound (Field I in Fig. 4).

The work assumed a greater momentum in 1966 as the excavations became a full-scale operation under the direction of Dr. William G. Dever with Professor Darrell H. Lance as Associate Director (under the executive leadership of Dr. Nelson Glueck and Dr. G. Ernest Wright). This modern excavation featured the careful stratigraphic control of the Wheeler-Kenyon method (Wheeler, 1954) discussed more fully below (cf. Figure 62). A probe trench reached bedrock in the southern end of the initial trench (Field I) in the latter part of the 1967 season.

PROBLEMS OF A GEOLOGIC NATURE

The primary direction of the geologically related research at Tell Gezer has been the augmentation and clarification of the archaeology. The ultimate goal is a broader comprehension of the ecology of Gezer inhabitation during the course of its human history. This is understood to be an extended project, the intial lines of which study are suggested in the research data of this study.

Experience of the writer early in the 1966 season isolated pertinent areas of fruitful archaeological related geologic study:

1) Stratigraphy and sedimentation. This is the essence of contemporary stratigraphic archaeology (Wheeler, 1954, Kenyon, 1960,

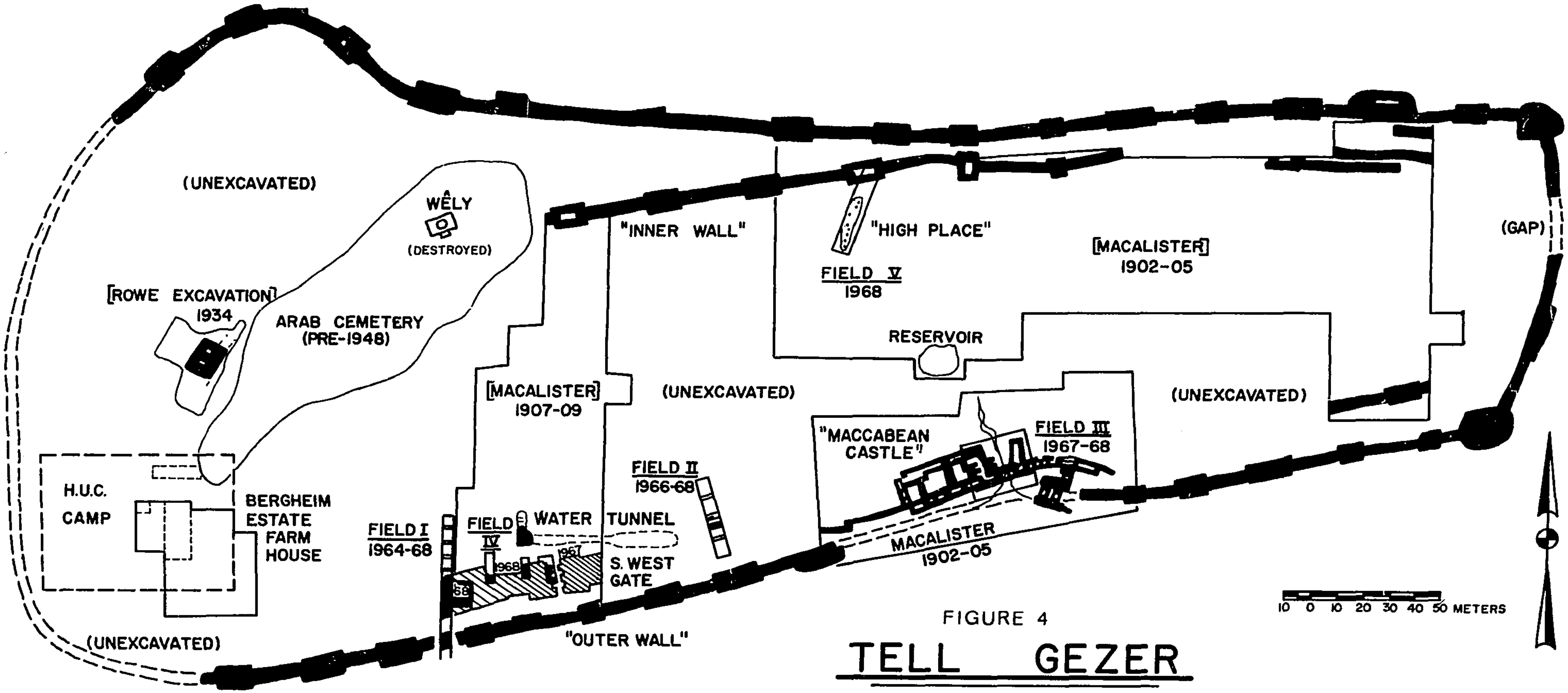


FIGURE 4

TELL GEZER

PLAN OF THE SITE

THE EXCAVATIONS OF
MACALISTER, ROWE, AND HEBREW UNION COLLEGE
ARE ILLUSTRATED

MODIFIED FROM MACALISTER, 1912 AND DEVER, 1967

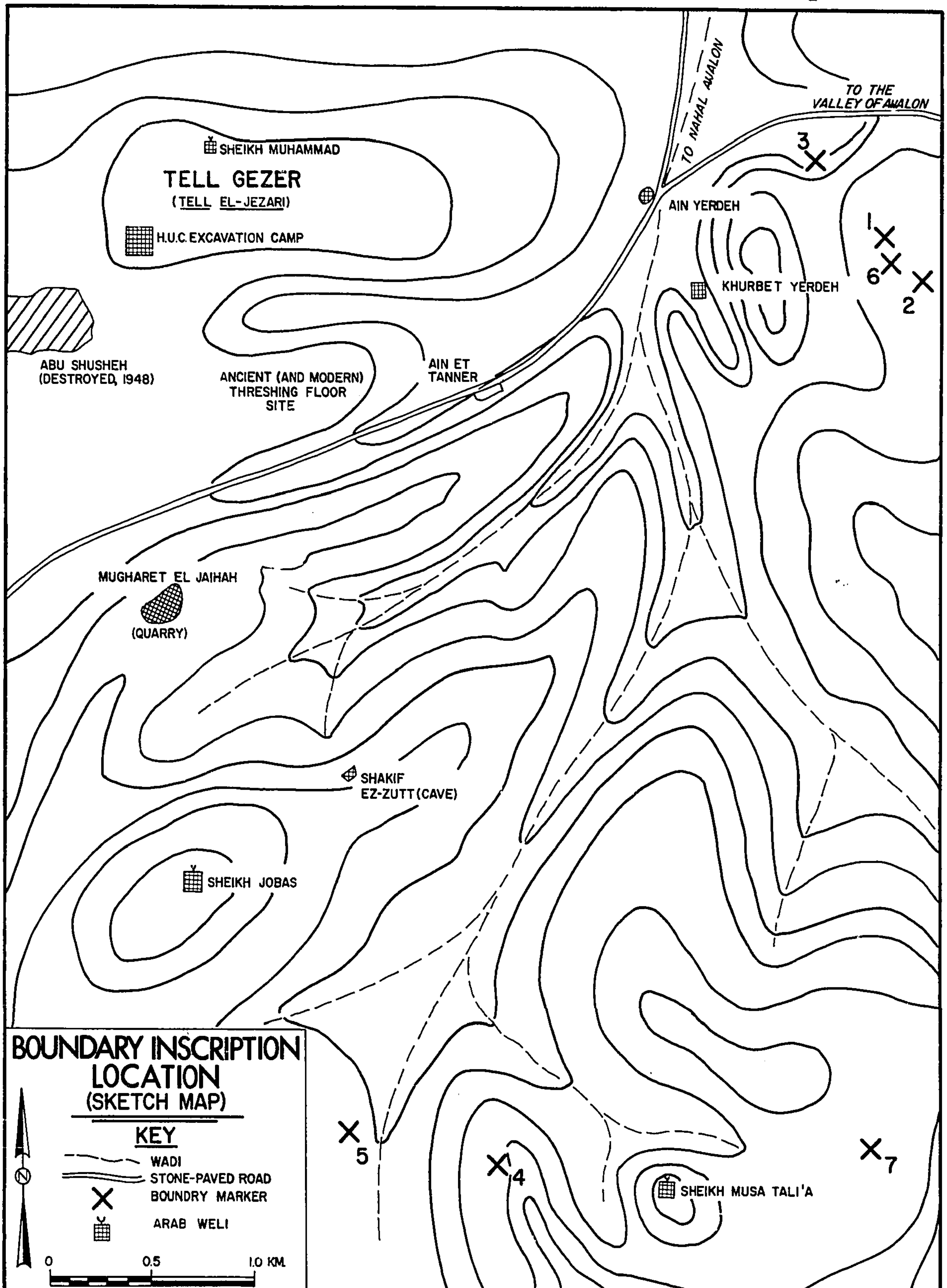


Figure 5a

Location map of the boundary inscriptions in the vicinity of Tell Gezer. The marker stones situated to the east and south of the city establish the virtual certainty of the correct identity of the site. This evidence corroborates that of the Arab name, Tell el-Jazar, which reflects the historical memory of the Arab inhabitants and their predecessors.

Figure 5b. The new boundary inscription (No. 7). This marker was discovered by members of Kibbutz Nahshon in 1964 (cf. Figure 5a for the location). The lithology is that of deeply weathered Middle and Lower Eocene chalk, the caliche residue of which is termed, nari. The resistance of nari to further weathering is illustrated by the preservation of the inscription which dates from the Roman Period of Gezer occupation (to the end of the 1st century A.D.). The Greek word ΑΛΚΙΟΥ means, "of Alkius", perhaps the limit of an estate owned by a man bearing this Greek name. The Hebrew תחם גזר oriented upside down in this view means, "The boundary of Gezer", and was no doubt intended to be read by a traveler approaching the site of Gezer from the differientially eroded Senonian strike valley to the southeast (in the distance).

Figure 6. The Mediterranean Sea from Tell Gezer. The ancient city of Gezer lay 24 km due east of the Mediterranean Sea in the Levantine coastline of Israel. The bright band on the horizon in the distance is the reflection of the sunlight on the breakers along the shores. The lights of a number of communities along the Mediterranean shore shine brightly in the clear night air in full view from the tell, reminiscent to the historically minded of the campfires of the armies which frequently used the Coastal Plain route. It is clearly evident why the early inhabitants of Palestine chose such a place of habitation as this. The geomorphology of the Shephelah with its characteristic topographic highs gave its occupants command of the area to the limit of view. Cf. Plate VI for the structural stratigraphic basis of this expression of relief.

Pydoke, 1961, Dever, 1967). Five stratigraphic sections were studied during the course of 1966 and 1967 excavations involving detailed sedimentological data.

2) Petrology of artifacts and architecture -- description and provenance. The study of regional and local lithologies has provided a preliminary basis for the place of origin of numerous extrusive, metamorphic, and sedimentary artifacts and building materials. The investigation was limited in that only discards could be shipped to the laboratory and sectioned for study. A small comparative basis, however, has been established with a catalogue of 693 samples, of which all representative types were analyzed.

3) Ceramic analysis. This phase of the work began by the collection of all datable discards from the daily field pottery calls. It was augmented by random sampling of the pottery spoil piles of all the excavations conducted on the tell. This material was analyzed for clay mineralogy, differential thermal characteristics, trace and selected elemental chemistry, and temper. The potsherd color was Munsell typed for reference. A catalogue of 1309 samples has been erected, of which 147 specimens were analyzed.

4) Pottery source survey. A systematic sampling of the exposed clays and soils within 5 km to the north, west and south of the tell was undertaken. Survey to the east was not possible (cf. Figure 9b). A minimum representation of the soil catenas on Eocene, Paleocene, and Senonian formations was obtained (cf. Figure 9a). These samples were prepared and analyzed in an identical manner to

the ceramic materials. Potential temper sources from the sediments of the local wadis and from the Pleistocene and Recent sands of the Coastal Plain were taken and studied mineralogically. A catalogue of 15 tempers has been erected. (Cf. Table V)

5) Regional geological survey. As an essential preliminary for the foregoing, the writer attended the International Clay Conference held in Jerusalem, June 1966. Stimulating papers and fieldtrips from one end of the small country to the other provided an unusual introduction to this subject. Fieldtrips with archaeologists and alone in Dr. Nelson Glueck's command car have served to implement the regional study locally. A search of all available literature has been carried on from the time of the conception of this project.

CHAPTER I

GEOLOGY OF THE SOUTHERN LEVANT

> To appreciate more fully the morphological structure of Palestine, one should take into account the country's geology, since morphology is essentially the outward expression of geological changes -- evolutionary or revolutionary -- wrought in the course of time. This examination may have historical value too; for geological conditons not only affect the landscape, but also the quality of the soil, the water supply, and the wealth of mineral resources. They largely affect a country's living conditions, and thus play an important role in determining its historic course. (Avnimelech, 1964)

The geology of the southern Levant has its greatest utility for the archaeologist and the historian when cast in the geomorphological framework of the physiographic provences (Plate II).

PROMINENT WORKERS

The eastern Mediterranean has not had the heritage of a great proliferation of early geological workers which characterized Europe and the United States. Certain outstanding pioneers in the science deserve mention.

The first vague information about the geology of the Levant came from J. Russegger, an Austrian mining engineer in the service of the Viceroy of Egypt (1841-1842), who studied the fossils of the Beirut area. Seven years later an American, W. F. Lynch, led an expedition exploring the mysteries of the Jordan Valley and of the Dead Sea (Lynch, 1849). The first knowledge of Palestinian fossils came from the study by T. A. Conrad of the Paleontological collections of the Lynch expedition.

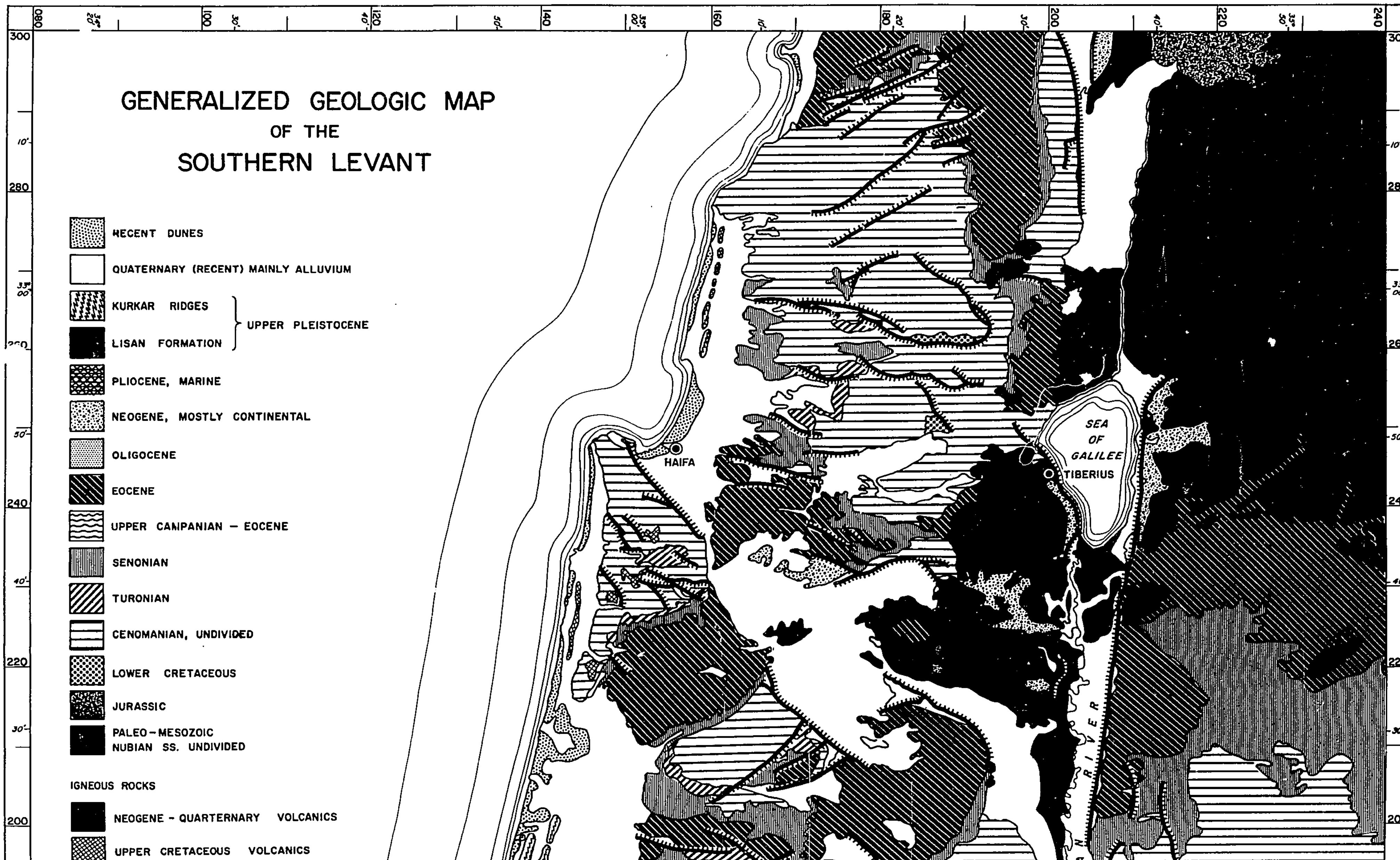
During the years before the end of Turkish occupation (World War I), the German, M. B. Blanckenhorn, was one of the best known geological authorities on the Near East. The giant of Palestinian geology during the years of the British Mandate was G. S. Blake. He mapped all of northern Palestine on a 1:100,000 scale, supporting his work with rich faunal collections (Blake, 1935; 1937).

Especially prominent and well-known is the work of L. Picard, whose research began under the Mandate and continues to the present time. His early work, Structure and Evolution of Palestine (1943), though undergoing modification, is still a reference source. Other prominent Israeli geologists are M. Avnimelech, whose paleontological studies are well-known, and Y. Bentor, an eminent contemporary in the geological sciences. The reports of many other young Israeli geologists were consulted in the course of the research of this study.

REGIONAL FRAMEWORK AND HISTORY

The entirety of the Fertile Crecent from the Nile to the Persian Gulf lies between the Afro-Arabian Shield on the south and the folded mountains of Iran, Armenia, and Turkey on the north. The central western portion of this arc, the Levant, has been a coastal zone between this shield and the Tethyan predecessor of the Mediterranean since Cambrian time. Erosional products have been supplied to the Tethyan geosyncline from this Afro-Arabian foreland.

The littoral zone shifted from the edge of the shield as seas intermittently covered the entire region from the Tethys geosyncline to the Mesopotamian-Persian Gulf geosyncline. The Tethyan seas approached their maximum development in Jurassic time. Concommitantly epeirogenic movements produced periods of emergence permitting shelf sediment erosion and reworking, yielding a dominant clastic eastern facies


GENERALIZED GEOLOGIC MAP
OF THE
SOUTHERN LEVANT
RECENT DUNES
QUATERNARY (RECENT) MAINLY ALLUVIUM
KURKAR RIDGES
LISAN FORMATION
UPPER PLEISTOCENE
PLIOCENE, MARINE
NEOGENE, MOSTLY CONTINENTAL
OLIGOCENE
EOCENE
UPPER CAMPANIAN – EOCENE
SENONIAN
TURONIAN
CENOMANIAN, UNDIVIDED
LOWER CRETACEOUS
JURASSIC
PALEO-MESOZOIC
NUBIAN SS. UNDIVIDED
IGNEOUS ROCKS
NEOGENE - QUARTERNARY VOLCANICS
UPPER CRETACEOUS VOLCANICS
HAIFA
SEA
OF
GALILEE
TIBERIUS
RIVER

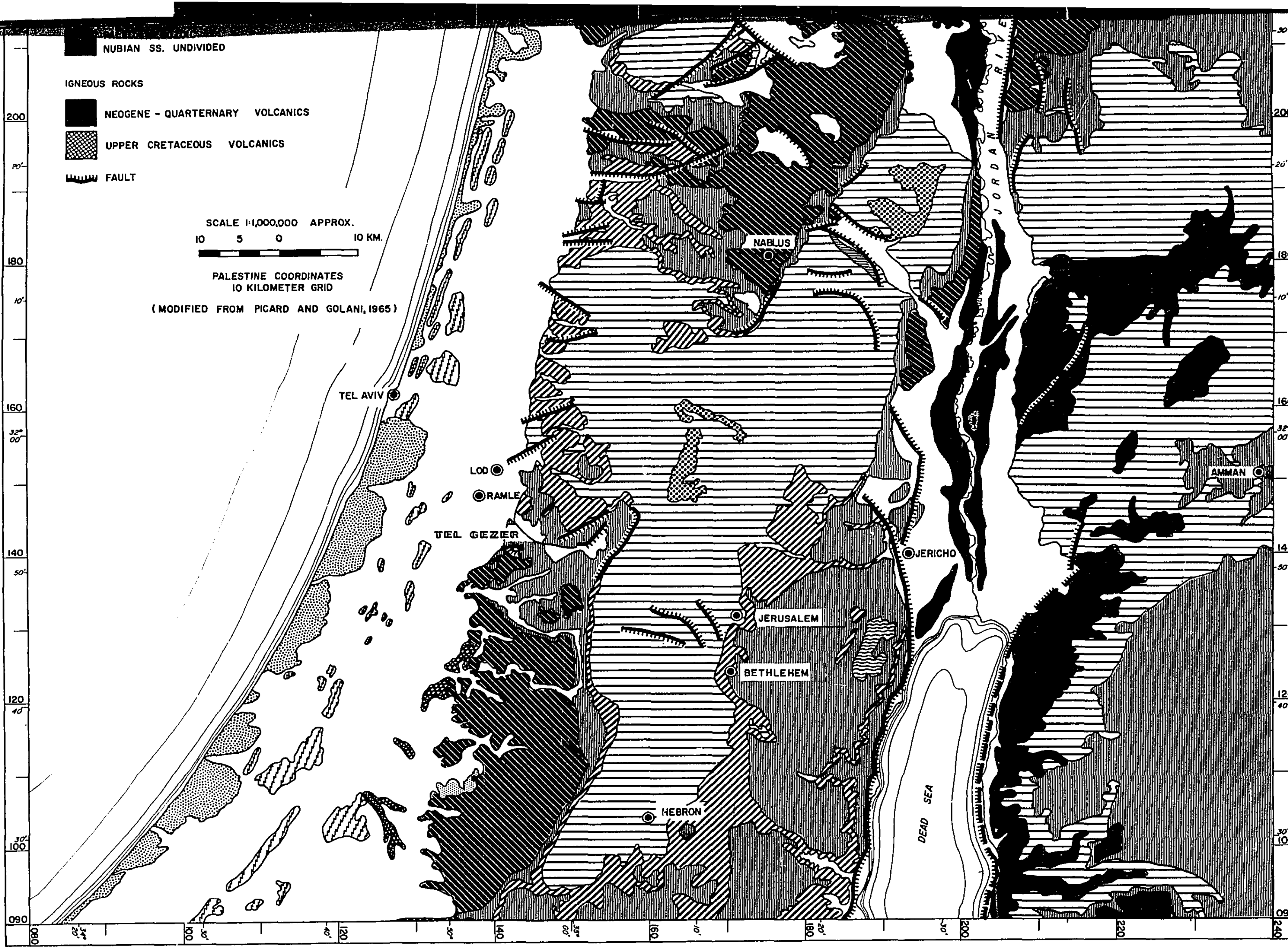
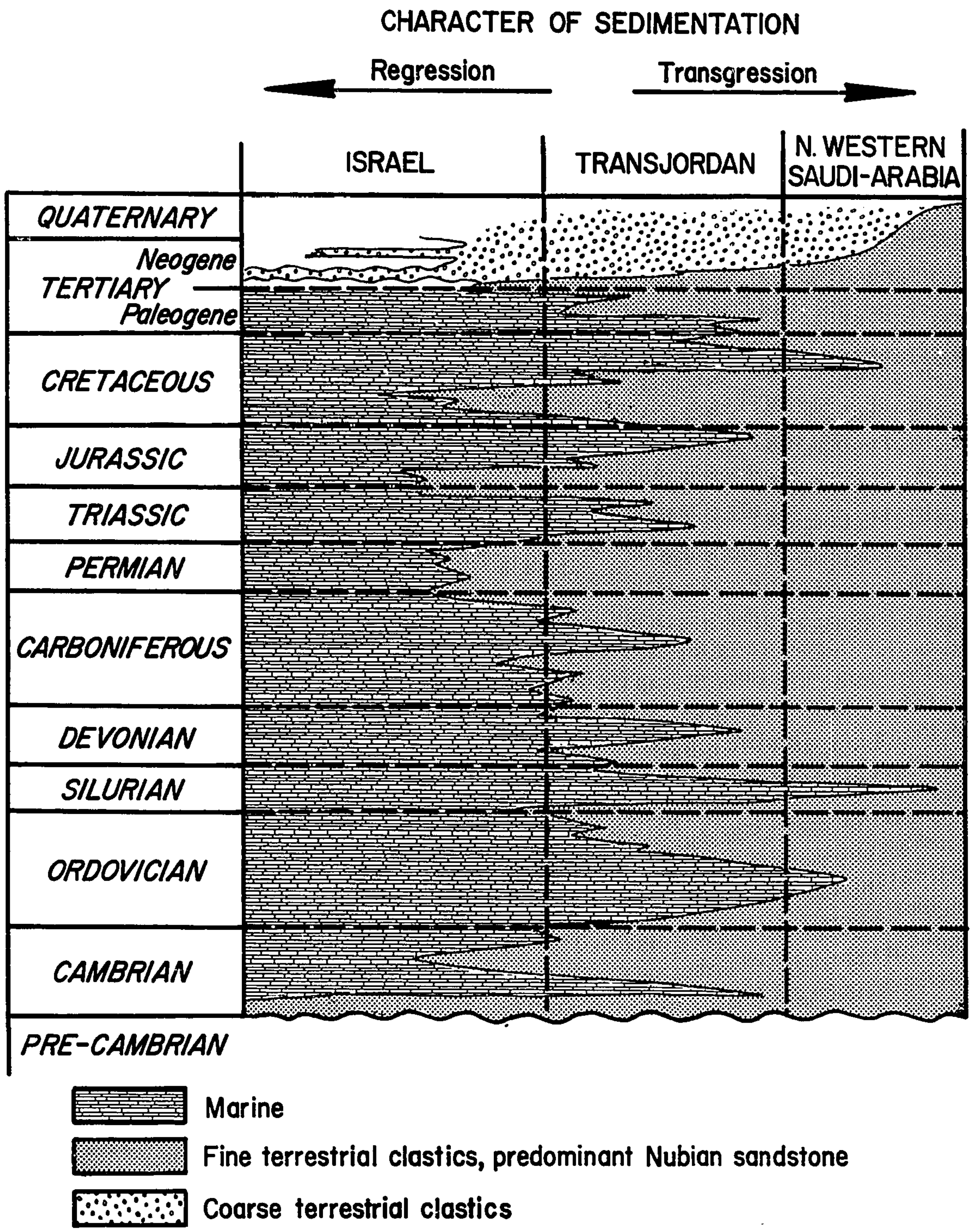

NUBIAN SS. UNDIVIDED
IGNEOUS ROCKS
NEOGENE - QUARTERNARY VOLCANICS
UPPER CRETACEOUS VOLCANICS
FAULT
SCALE 1:1,000,000 APPROX.
10 5 0 10 KM.
PALESTINE COORDINATES
10 KILOMETER GRID
(MODIFIED FROM PICARD AND GOLANI, 1965)
NABLUS
JORDAN RIVER
TEL AVIV
LOD
RAMLE
TEL GEZER
JERICHO
AMMAN
JERUSALEM
BETHLEHEM
HEBRON
DEAD SEA

PLATE IV



DIAGRAMMATIC SKETCH, ILLUSTRATING MARINE AND NON-MARINE FACIES IN SOUTHERN LEVANTINE SEDIMENTS

(Modified from Ball and Ball, 1951 and Picard, 1943)

Plate V

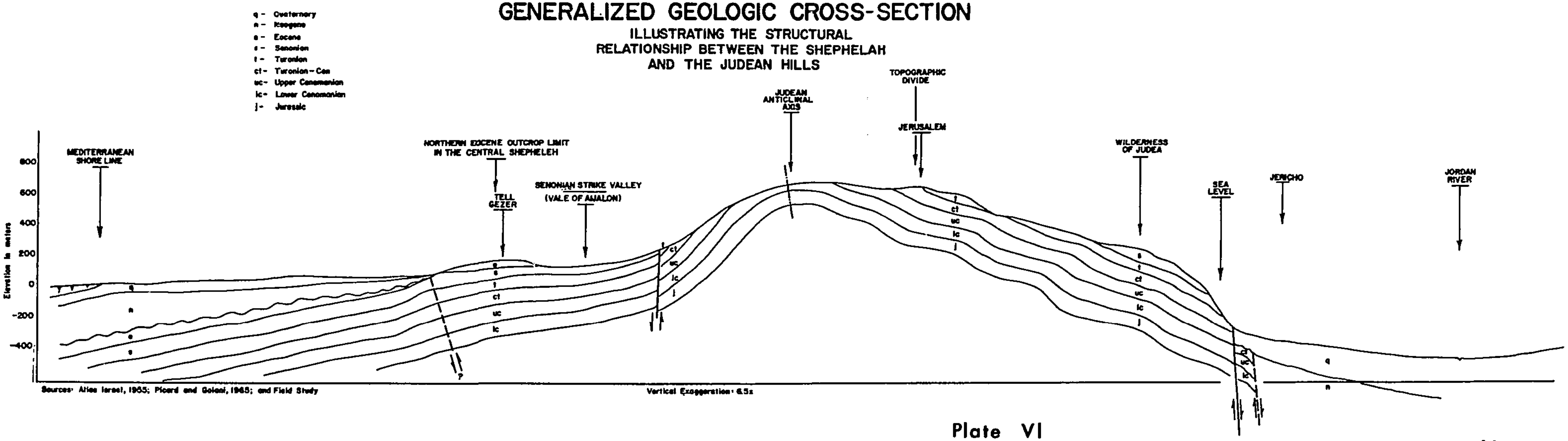
(Plate V) (Picard, 1943, Ball and Ball, 1953).

The Paleogeography of the area is best understood from mid-Mesozoic time. The Nubian Massif was positive then with thick Tethyan Jurassic deposition to the north in Lebanon and Israel. Epeirogenic uplift began in Late Jurassic time; this was accompanied by deep fracturing and volcanism which continued into the Early Cretaceous when there was general emergence in the Levant.

Regional movement began to reverse in the Middle Cretaceous with maximum transgression reached during the Late Cretaceous and Early Paleocene. To the south a general regression took place across the Afro-Arabian Highland. Late Cretaceous volcanism in the Carmel area is evidence of deep-seated fracturing locally. The transgressional maxima of the Late Cretaceous continued in the Levant, Sinai, and northern Egypt into the Tertiary as Early Eocene seas covered the area of the Sinaitic Peninsula, all of Lebanon, Israel, Jordan, and the eastern half of the Arabian Massif (Figure 7).

The end of Early Eocene time marked the beginning of orogenic and epeirogenic activity which produced regional withdrawal of the sea to the vicinity of the present coast. In the Levant, deposition continued through the Middle Eocene after which general emergence took place (Figure 22). Late Eocene shelf incursions on erosional surfaces occurred in northern Egypt and the Levantine Coastal Plain with deposition continuing through a gradual regression into the Miocene. From this time on marine deposition occurred only within the confines of the present coastal provinces (Swartz and Arden, 1960).

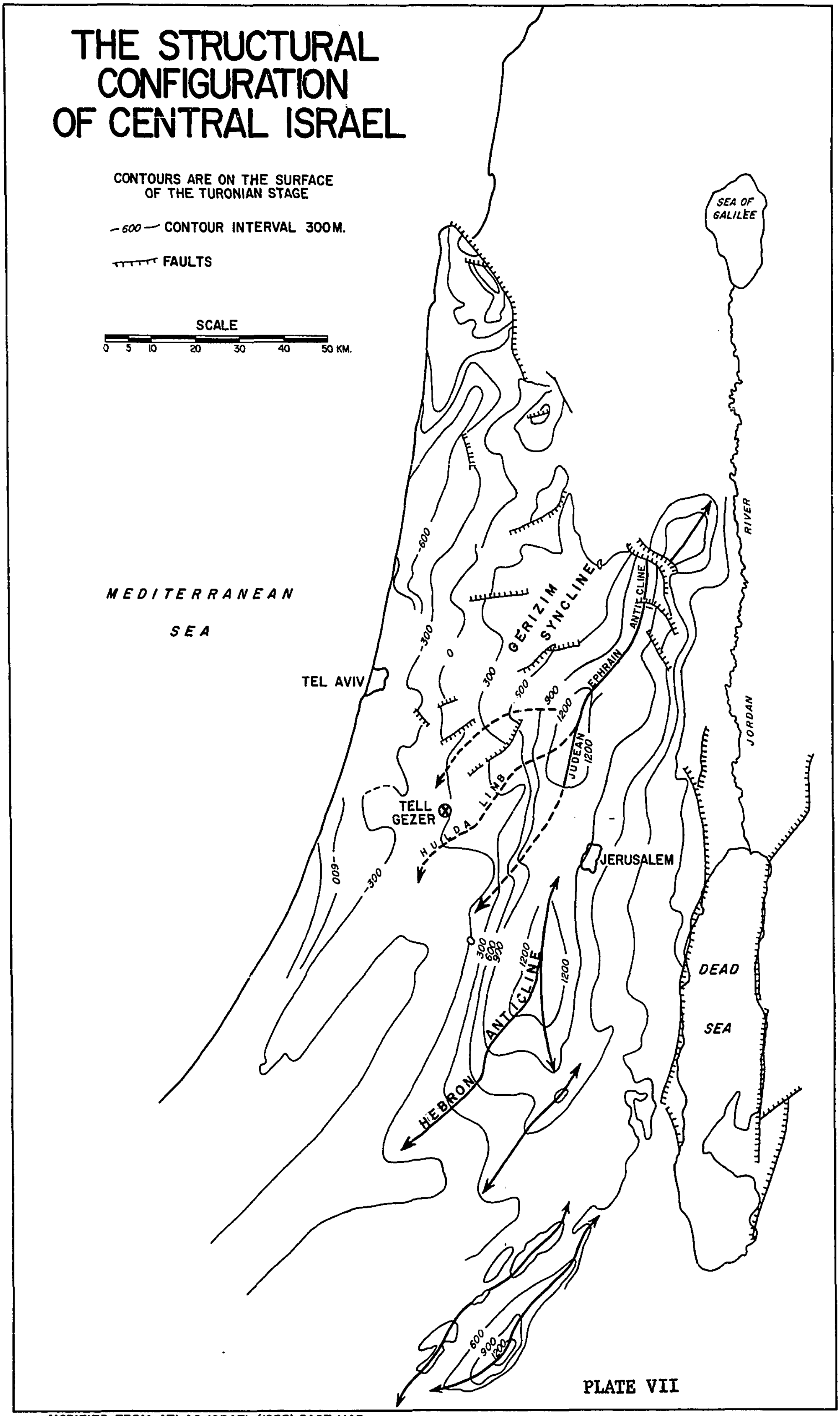
GENERALIZED GEOLOGIC CROSS-SECTION
ILLUSTRATING THE STRUCTURAL RELATIONSHIP BETWEEN THE SHEPHELAH AND THE JUDEAN HILLS



Sources: Atlas Israel, 1965; Picard and Golani, 1965; and Field Study

Vertical Exaggeration: 6.5x

Plate VI



MODIFIED FROM ATLAS ISRAEL (1955) BASE MAP

TECTONIC ASPECTS

The tectonic events which controlled the transgressive-regressive phases from Late Cretaceous to Early Miocene were dominantly epeirogenic in nature. The character of these events underwent a sharp change during the Miocene Epoch. Autochthonous compressional folds develop <u>en echelon</u> beginning in the Late Cretaceous or Early Tertiary time trending through western Syria, Lebanon, and Israel with a western component through northern Sinai and Egypt. In Israel these folds occurred relatively close to the Arabian Shield where the main fold axis is crossed by numerous faults trending east-northeast, west-southwest, and northwest-southeast. Transverse depressions and uplifts (Plate VII) characterize this fault trend in Israel (e.g., the Emek Graben and the Carmel Upwarp) and in Lebanon (the Homs Gap).

The most striking aspect of the tectonic history of the Near East is the northern extension of the African Rift System through the Red Sea, the Gulf of Aqaba, the Valley of the Araba, Dead Sea, the Jordan River, and the valley between the Lebanon and anti-Lebanon Mountains. This is a graben with some transcurrent movement nearly 600 km long overlying the mountain trend which is parallel to the eastern Mediterranean shoreline.

PHYSIOGRAPHIC PROVINCES OF ISRAEL

The character of the sedimentation, dominantly shelf carbonate, in its stratigraphic context together with the structural framework have produced the peculiar geomorphology of Israel.

The Negev

The southern portion of Israel extending from the region of Beersheba where the Judean anticline plunges beneath Quaternary sediments to the Gulf of Aqaba (Eilat) constitutes the Negev. The eastern limit is the depression of the Araba, while the western boundary is political with the structure and morphology extending into eastern Sinai. This triangular area, essentially a rocky desert in which ridges, mesas, buttes, and mountains alternate with dry wadis and canyons, has extremes in elevation from -397m at the southern end of the Dead Sea to 1033m at Har (Mt. Ramon) in the west-central Negev.

The southern Negev features the Eilat Mountains, the northern flank of the Precambrian Afro-Arabian Massif. These, the oldest lithologies exposed in Palestine, constitute an igneous complex of granitic and metamorphic rocks.

North in the vicinity of Timna, the mountains break down into a broad plateau area, the southern Negev Plateau. This region of gentle relief is surfaced by a Plio-Pleistocene Hamada with a desert pavement developed mainly on Upper Cretaceous marine sediments. Below these rocks lie the anomolous Nubian Sandstone sequences with a maximum thickness of 350m, ranging in age from Lower Cambrian to Lower Cretaceous. These sands lie directly on the Precambrian basement (Baly, 1957, p. 18-19).

The Lower Cretaceous Nubian sands are of special interest for their copper mineralization which has been exploited intermittently from the Chalcolithic to the early Iron Age.

The central Negev is a striking region of breeched asymmetrically folded mountains trending east-northeast. They are separated by prominent strike-slip faults. This is the southern part of an area of large bowl-shaped erosional depressions called Makteshim (mortars, literally in the Hebrew). Here the Maktesh Ramon, the largest of the makteshim, has a relief of ca. 500m, exposing lithologies from Middle Triassic to Middle Eocene. The monotonous Nubian Sandstone is interwoven locally with Upper Triassic limestones and evaporites and Lower Cretaceous basalts.

Northward from the Nahal (Hebrew for wadi or stream) Zin (the Wilderness of Zin of Biblical literature) to the plunging Judean anticline, lies the northern Negev fold area. Large asymmetric arcuate anticlinal folds trending northeast are prominent in the southern half. In the east these folds are developed parallel to the Araba Rift with makteshim occurring in the erosional breeches. A single wadi drains each maktesh. The denudational process is principally that of Lester King's scarp retreat: pedimentation. Strata exposed in the northern Negev range from Upper Jurassic marine limestones, and marls, Lower Cretaceous Nubian sandstone, Upper Cretaceous limestones and dolomites, and Eocene chalks to Neogene deposits. The lowest strata are exposed only in the makteshim. Pleistocene to Recent loess is extensively deposited in the Beersheba Valley where it blankets Turonian to Eocene limestones and chalks, Neogene sediments, and alluvial hamra (Bentor, 1966).

THE ARABA-DEAD SEA-JORDAN VALLEY

The rift valley between Transjordan and Israel is a long (400km) and narrow (10-30 km) tectonic depression extending from the Gulf of

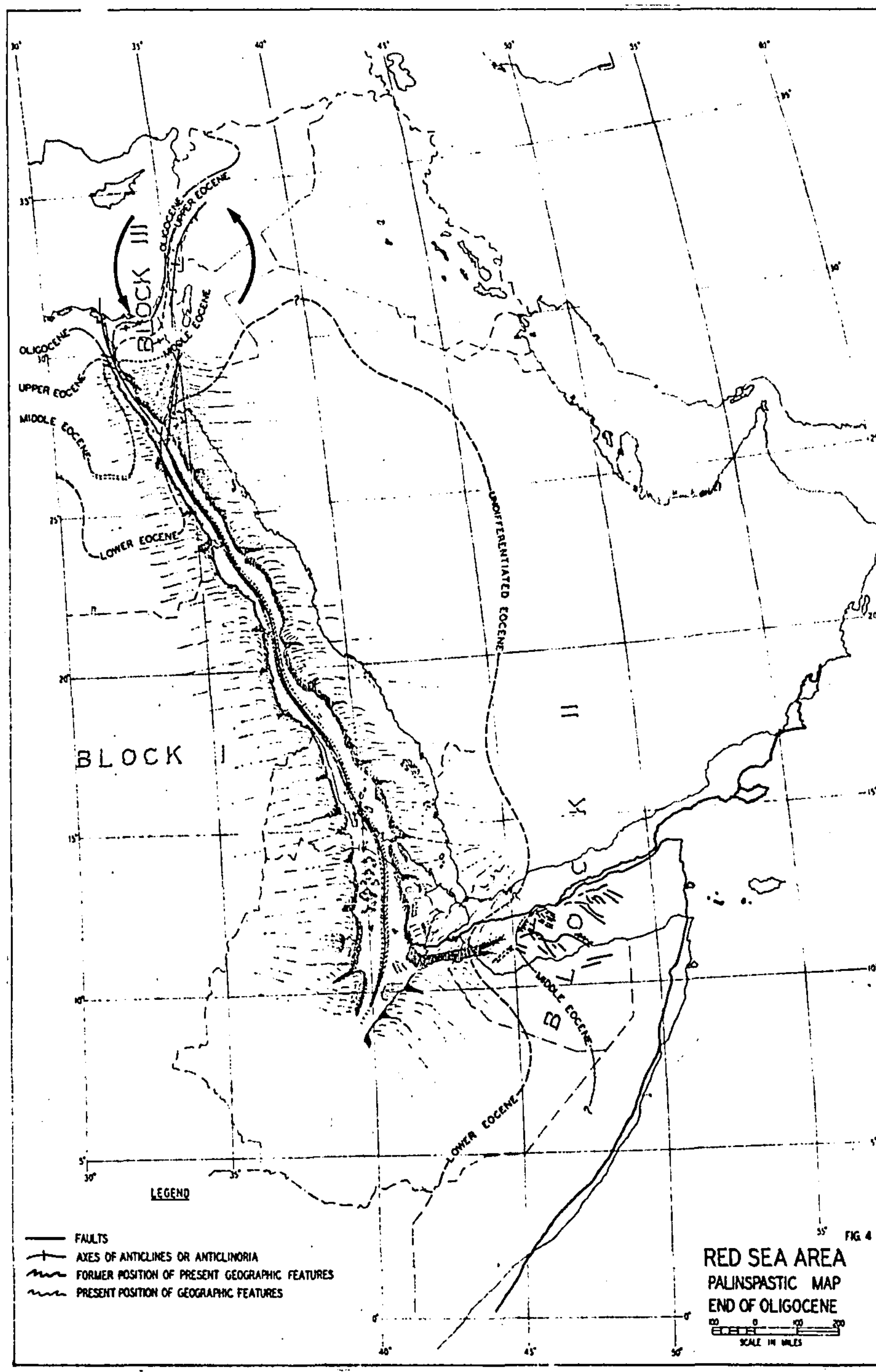


Figure 7. Palinspastic map of the Red Sea area at the end of the Oligocene (Swartz and Arden, 1960, p. 1628). The tectonic interpretation is that there is a counter-clockwise rotation of the Arabian Peninsula with a northern translation of this area to produce the graben structures of the Araba-Jordan Rift with concomitant transcurrent faulting. The retreat of Early Tertiary seas is illustrated by the indicated strand lines. Note that the Middle Eocene is the last major marine depositional environment over the principal part of the southern Levant.

Aqaba (Eilat) on the south to the slopes of Mt. Hermon on the north. It is an area, down-dropped to considerable depth, between the two mountain massifs and between Cis- and Transjordan. Its eastern border is marked by a "large geosuture" which started in Triassic time (Bentor, 1966). Downwarping is regarded as commencing as early as the Lower Cretaceous with the movements attaining a maximum in the Miocene when the western marginal down-folding was faulted transforming the depression into a rift valley in the sense of Carey's Modified Extension Hypothesis (Carey, 1958).

The regional tectonic aspect of the nature and development of this graben have been discussed by Picard (1943, 1954, and 1966), Vroman (1961), Quennell (1956 and 1958), Carey (1958), Freund (1965) and Knopoff and Belshe (1965). The amount of strike-slip movement (very little to 108 km) is under discussion. Geophysical data is accummulating to clarify the issue. Holmes (1965) has summarized the pertinant data and regards the Dead Sea depression as a rhombochasm, an expression of crustal separation. Studies of a geomorphological nature leave no doubt as regards Recent strike-slip movements. Sinistral translations leaving dislocations of about 600m are recorded on the alluvial fans of the Araba Valley (Zak and Freund, 1966).

The view of Freund (1965) parallels that of Quennell and Carey. He postulated a counter-clockwise rotation of the Arabian block of about 3 [paleo-magnetic data gives 6 -7 (C. M. A. Powell, pers. comm.)] with folding developing since the Late Cretaceous from the Zagros-Taurus range southward throughout the Levant. Extension

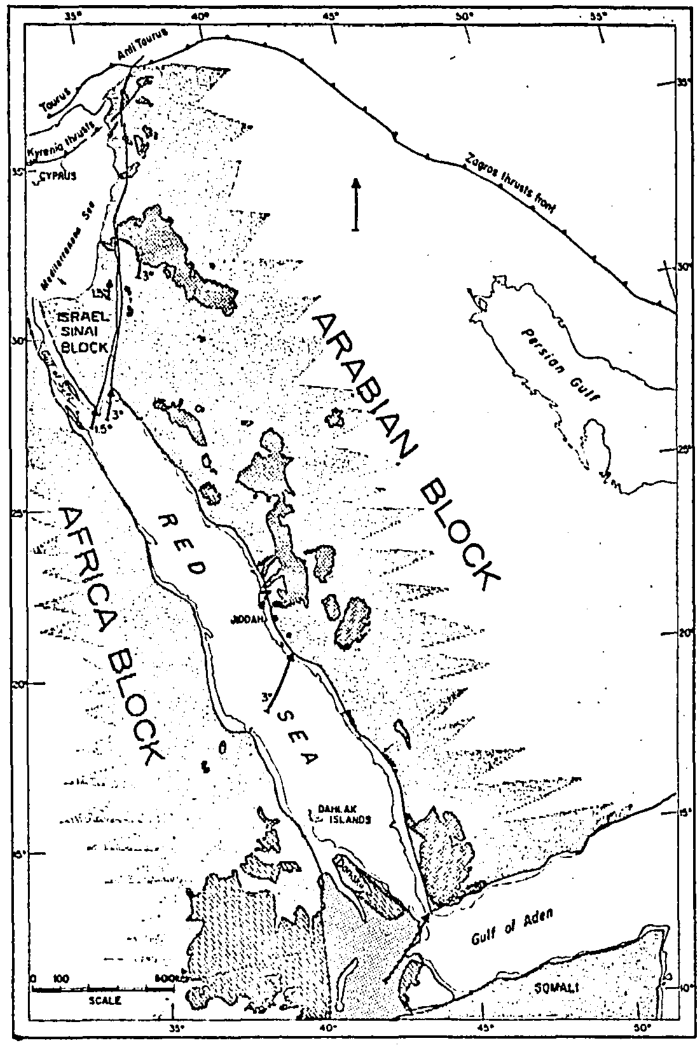


Figure 8. The northward rotation and movement of the Arabian Block with concomitant transverse faulting parallel to the eastern coast of the Mediterranean Sea (Freund, 1965, p. 201). A movement of the Arabian Block about 60-80 km northward along the Dead Sea Fault since Late Cretaceous time is postulated by Freund. The folds of the Zagros-Taurus Mountain System may represent the resultant compression and release.

faulting is suggested in the Red Sea, Gulf of Suez, and in northern Israel with concomitant movement of the Arabian block some 60-80 km northward along a sinistral strike-slip fault. A "rift valley" was opened up from the Gulf of Aqaba to the upper Jordan depression having its greatest width along the Gulf of Aqaba, the Dead Sea, and the Sea of Galilee. Volcanism was associated with some east-west normal faults and secondary sinistral transcurrent faults east of the Dead Sea and west of the upper Jordan depression (cf. Figure 8).

The first sedimentation is limited only to the main depression of the graben, the Dead Sea. A unit of salt (3500m) was deposited during the Plio-Pleistocene transition, after which the depression became separated from the ocean. Early to Middle Pleistocene deposition was local, but Late Pleistocene Lisan deposits (chalk, gypsum, tufa, and fanglomerates) record a flood stage (18m below sea level) extending from 30 km south of the Dead Sea to the Sea of Galilee (Neev and Emory, 1967).

Subsequent evaporation of this inland lake has left three major basins which characterize the graben in recent time, Lake Hula (100m), Sea of Galilee (-209m), and the Dead Sea (-395m).

The "rift valley" is accordingly divided into five mutually differing segments: the Araba Valley, the Dead Sea, the Central Jordan Valley, the Sea of Galilee, and the Upper Jordan Depression. The Araba Valley section, 175 km long, rises gradually northward from the Gulf of Aqaba for about 75 km to a watershed at 220m from which it slopes gently into the Dead Sea depression. It is essentially a bajada characterized by enormous alluvial fans extending from the wadis of the Transjordanian Plateau on the east and the Negev on the west.

The Dead Sea is a basin 80 km long which bottoms at approximately 800m below sea-level, making it deeper than any continental segment of the East African Rift System. Geophysical evidence points to a considerable depression fill which extends to a depth of more than 7000m (Bentor, 1966, and Emory, 1967). The Dead Sea has a very high salinity (32 percent) with a magnesium component that makes the waters bitter. A salt diapir (or wedge, its exact structure is not determined) forms Mt. Sdom (11 km by 2 km and rising to 240m above the level of the Dead Sea) along the southwestern border of the basin. Blocks of asphalt occasionally rise to the surface from seeps within the basin.

Climatic fluctuations during the Pleistocene produced several changes in the level of Lake Lisan. The last major event to precede the present limnic regime attained a level of 180m below sea level, attested by deltas proximal to the fault zones. Several hundred meters vertical displacement mark the post-Lake Lisan faulting (Nir, 1967).

The Central Jordan Valley segment of the rift extends from the Dead Sea with a gradual rise for about 50 km to a sill south of Bethshean (Beisan) at ca. -250m. From this point it extends northward for another 50 km to the Sea of Galilee. Through this section the Jordan River meanders in a very sinuous course with a total distance of 270 km. The central valley is largely covered by sediments of Lake Lisan of the Late Pleistocene. These brackish-limnic stream deposits are dominantly chalky, finely laminated marls.

The Sea of Galilee occupies a 20 km by 12 km depression, the bottom of which reaches a level of 252m below sea level (Oren, 1962). This intermediate lake, dating after the initial recession of Lake Lisan, is contained on the south by a partial basaltic barrier and the Yarmuk River delta (Ben-Arieh, 1964).

The northernmost Rift Valley segment in Israel, the Upper Jordan Depression, is separated from the Sea of Galilee by a barrier of basalt flows extending into the graben and bordering the Sea of Galilee on the north. This basin formerly occupied by an enlarged Lake Hula is filled mostly by Pleistocene swamp deposits featuring alternating sequences of clastics and peat. The sources of the Jordan River are in the northern part of this valley. They arise in the lower reaches of the Jurassic carbonates which make up the foothills of Mt. Hermon. At the southern end of this section, the Jordan River has cut a deep canyon into the basalt flows along the faulted eastern border of the rift.

The Emek Yizreel (Biblical Esdraelon)

The Emek (valley) Yizreel is a graben structure trending northwest from the central Jordan Valley in the region of Bethshean (Beisan) about 30 km long. This feature exhibits a parallelism between the Carmel upwarp on the south and the northwest fault components of eastern Galilee. A transcurrent fault movement in response to the sinistral transverse faulting of the principal rift valley is suggested by deSitter (1962) as the tectonic origin of the depression. Tensional stress resulting from a northwest movement of Galilee is estimated at 10 km.

The Emek has three segments: the Bethshean (Beisan) Plain on the southeast, the narrow Harod Valley, and the Plain of Esdraelon on the northwest. The Eocene hills and plateau basalts of lower Galilee and the Carmel and Gilboa Mountains mark out the northern and southern limits of the depression. The area is blanketed with Quaternary-Recent alluvium and deeply weathered Neogene basalts yielding the most fertile soil of Israel (Plates IV and XI).

Galilee Highland

Galilee is situated between the Emek Yizreel on the south and the Lebanon border on the north. Its eastern border is sharply demarcated by the abrupt sheer face of the Naftali Mountains which border the upper Jordan Valley on the northeast and plateau basalts on the southeast. The western border is the northern Coastal Plain.

Galilean stratigraphy is characterized by sediments which range from Early Cretaceous to Recent age.

After Nubian sandstone deposition, an Aptian (Lower Cretaceous) transgression covered the region and continued through the Albian and Cenomanian-Turonian (Upper Cretaceous). Fine clastics and clays are increasingly replaced by limestone sequences in the Aptian and Albian. By Early Cenomanian time dolomitization dominated the carbonate lithologies reflecting warm shallow seas. The Cenomanian marked the beginning of an extensive regional transgression over much of the Middle East and North Africa. During the Cenomanian and Turonian, a considerable thickness (locally 1000m) of hard dolomites, limestone, and chalk was deposited over the entire Middle East area. In western

Galilee two successive reef complexes develop from Upper Cenomanian to Upper Turonian time (Freund, 1965b).

Tectonic movements of the Upper Cenomanian ended conditions of deposition in central Galilee. The Upper Cenomanian seas were enriched with silica which was deposited as abundant nodules and layers. Turonian deposition shows a shallow water microfauna for much of the ca. 300m of its dominantly lithographic sequence (Gouliani, 1961).

Deeper marine conditions which prevailed from Cenomanian time into the Middle Eocene are marked by uniform chalk deposition with abundant planktonic foraminifera.

Marine deposition was terminated in the area by uplift and related tectonic activity during Late Eocene time. A general tilting toward the southeast structurally initiated the formation of the Neogene inland basin, the northeastern limits of which extended to the region of Damascus.

Volcanism was initiated in the subsiding basins during a post-Middle Eocene and pre-Miocene interval, with one of the centers of extrusion remaining as the Horns of Hattin. This activity was the beginning of extensive lava floods which occurred intermittently throughout the Neogene period as indicated by thermoremanent magnetization (Freund, Oppenheim, and Shulman, 1965). These sheet lavas, composed of alkaline olivine-basalts are intimately associated with Neogene sedimentation which was finally terminated by the inundations of the Plio-Pleistocene basalt sheet cover. These fissure flows which covered the entire area of southeastern Galilee were a part of regional volcanic activity extending east of the Rift Valley into the Hauran of southern Syria.

The fold structure of Galilee reflecting Late Cretaceous and Early Tertiary tectonic adjustments was modified by intensive Neogene block faulting with dominant east-west major trends (Bentor, 1966).

The fault block mountains of Galilee extend from Mt. Tabor (588m) to Mt. Meron (1288m) in the north and on into the region of Lebanon. Quaternary-Recent alluvium covers the basin between the fault block highs.

The Carmel Uplift

Mt. Carmel is a folded upwarp which is a structural continuity with the Megiddo syncline (the Ramot Menashe synclinorium of Arad, 1965) and the Umm El Fahm anticline which extends into Cis-Jordan. The Carmel Uplift is bordered on the northeast by a major fault zone separating it from the northern Coastal Plain (the Zebulon Plain) and the Emek Yizrell. Mt. Carmel (546m) is the only portion of the central mountain system of Israel extending to the Mediterranean.

The principal surface lithologies are Cenomanian and Turonian, a part of a larger sequence ranging from Early Cretaceous to Recent. Faunal assemblages suggest a shallow, warm water marine depositional environment for the Upper Cretaceous sediments. Intermittent submarine volcanism produced hyaloclastics and agglomerates locally with rare basic spillitic flows (Bentor, 1966).

Two gentle northerly trending anticlines are cut by two prominent east-west faults which are contemporaneous with the graben formation of the Emek on the north.

The Megiddo syncline with its northeast trending axis is the subjacent southeastern component of the Carmel upwarp (Mt. Carmel is not a true horst). This is the result of a post-Cenomanian folding phase, a response to regional tectonic activity up to Middle Eocene time. Senonian to Early Eocene sediments have been preserved in this synclinal area.

THE JUDEAN EPHRAIM MOUNTAINS

"The backbone of central Palestine" is the northward trending anticlinal mountain belt with three north-northeast en echelon structural components: the Hebron anticline on the south, the Judean anticline in the central area, and the Ephraim anticline on the north. This mountain system is bounded on the east by the "rift valley" fault system and on the west by the dip of the western limb (ca 30) under the Shephelah or Foothills.

The watershed is located about 14 km east of the anticlinal hinge suggesting an eastward shift of the divide by this amount since Early Tertiary emergence. In general the topography is that of a deeply dissected plateau, with maximum elevations of slightly over 1000m. Late Tertiary and Quaternary uplift yielded erosional rejuvenation resulting in the dramatically rugged relief of the mountain belt.

The sediments exposed in the Judean anticline are largely continental shelf carbonates of an extensive epeiric sea transgressing on a land surface of low and undulating relief (dinosaur imprints have been found in the Cenomanian dolomite strata in the vicinity of Jerusalem). The presence of corals and rudists further suggests shallow depths along with tropical temperatures.

Marls in the Cenomanian strata constitute the initiation of an important stratigraphic-tectonic event. The clay and subsequent limestone deposition reflect an abrupt down-warping of the shelf area marking epeirogenic subsidence and the major transgression of the Upper Cenomanian with its characteristic planktonic fauna. The environmental conditions are accordingly established for the mode of sedimentation which continues through the remainder of the Upper Cretaceous time and into the Early Tertiary (considered below) (Arkin, Braun, and Starinky, 1965; Sass and Oppenheim, 1965).

THE SHEPHELAH

> Over the Plain, as you come up from the coast, you see a sloping morrland /sic/ break into scalps and ridges of rock, and over these a loose gathering of chalk and limestone hills, round and featureless, with an occasional bastion flung out in front of them. This is the Shephelah -- a famous theatre of the history of Palestine -- debatable ground between Israel and the Philistines, the Maccabees and the Syrians, Saladin and the Crusaders. (Smith, 1931)

Shephelah means lowland, or the subtle rolling foothill area bordered on the east by the Judean and Ephraim Mountains and on the west by the Coastal Plain. Morphologically the foothills province extends from the Carmel Uplift in the north on Cretaceous lithology to the vicinity of Tell Gezer from which it extends southward on dominantly Eocene deposits to the northern Negev.

The area is relatively inactive tectonically, with a very slight upward flexure of the sediments where characteristic topographic highs persist under a protective armor of a caliche-like weathering residue termed nari.

The marine deposits which constitute the Shephelah contain paleo-ecological indicators, e.g. planktonic foraminifera reflecting bathyal conditions generally, punctuated locally with neritic forms reflecting an irregular continental slope and shelf margin. After an earlier phase of transgression which extended from Senonian time to the end of the Oligocene, a second less significant transgression extended east to the Shephelah during Upper Middle Miocene (Tortonian time) (Ball and Ball, 1953; Orni and Efrat, 1966).

COASTAL PLAIN

The Coastal Plain province extends along the eastern shore of the Mediterranean Sea from the borders of Sinai on the south to the Lebanon border near Rosh Ha-Niqra. It is punctuated only by the cape which is the result of the Carmel Uplift. Below the Carmel promentory, the coastal area is subdivided in the Philistine (Pleshet) Plain on the south and the Plain of Sharon on the north. North of Mt. Carmel the Zebulon Plain borders Haifa Bay beyond which the Galilean Coastal Plain makes up the northern-most segment.

A more geologically relevant division of this province would be the significant topographical units which run the entire length of the Coastal Plain. A littoral and beach belt of arid sand dunes and ridges which is being renewed constantly is on the west. East of the sand dunes is a central plain area surfaced mostly by red sands (Hamra). Locally Kurkar ridges (fossilized or cemented sand dunes) demarcate an eastern plain which stretches up to the foothills and is underlain by dark, heavy alluvial soils (see Figures 21b, 29) (Orni and Efrat, 1966).

The contact above the Cretaceous and Paleogene formations initiates the geological setting for the Neogene-Quaternary units of the Coastal Plain. Silty, pyritic, black shales, a bathyal facies rich in Globigerinoids, Miocene age in its lower part, unconformably blanket the older deposits. Eastward brackish, lagoonal deposits with abundant transparent ostracods and shells of Cardium edule mark the Miocene-Early Pliocene prelude to the final chapter of Coastal Plain sedimentation (Issar, 1968).

A dramatic change took place in the character of the Coastal Plain deposits in Late Pliocene-Early Pleistocene time. An abundance of quartz clastic deposits began to flood the Coastal Plain area at this time. There is no Levantine source sufficient in any sense to account for this deposition:

> Contributions of sand by rivers draining to the shores of Israel are probably also relatively unimportant, owing to the small number of rivers and to the fact that at least the larger ones have such low gradients near their mouths that they can transport little sand. Contribution of sand by wind is also insignificant, because of a prevailingly onshore wind direction. (Emory and Neev, 1960)

This unique change in the character of sedimentation is undoubtedly the manifestation of the beginning of the Nile. This flavial system was the principal source of the detrital fraction of the beach sands of Israel from Late Pliocene-Early Pleistocene time.

The expression of these sandstones cemented by calcite is the Kurkar which abounds in eolian-reworked microfossils such as foraminifera and ostracods (Said, 1962; Issar, 1968). The reddish to brown silts and sandly loams of the central plain constitute Pleistocene weathering (the near-lateritic end product) of the eolian deposits from the shores and the alluvial sediments from the mountains and foothills.

The sesquioxide-stained angular coarse silt to fine sand-sized quartz grains characterize much of the terrestrial facies of this deposit.

A limnic facies occurring as black to brown loamy clay occurs locally and is a reflection of the Recent swamp conditions which forced the Via Maris to run proximal to the Foothills Belt. Draining of the Coastal Plain swamps was initiated in Roman times and continues in the present. A series of Quaternary transgressive cycles range from the Early Pleistocene Calabrain and Sicilian (Villafranchian) time through Tyrrhenian Early Flandrian time (Upper Paleolithic-Lower Mesolithic) into the Late Flandrian (Neolithic-Roman) (Avnimelech, 1952, 1960, 1962; Itzhaki, Reiss, and Issar, 1961).

THE CONTINENTAL SHELF

The Continental Shelf Province marginal to the eastern Mediterranean has a maximum width of about 15 km. This shelf area, punctuated by numerous rock outcrops, regarded as submarine Kurkar, extends westward to the shelf-break point at about the 110m depth west of the coast of Israel. Two prominent submarine canyons cross the shelf, the Gaza Canyon emanating from the city near its head, and the Akiz Canyon, named for the twon lying just south of the Lebanon border.

Bedrock occurrences along the edge suggest an erosional origin for the shelf. Erosion took place during a stage of lower sea level during the Pleistocene Epoch: "Virtually all the shelf and the upper slope were alternatively submerged and subaerially exposed during the Pleistocene" (Neev, etal., 1966).

Influence of the Nile River becomes apparent as there is a greater rate of sedimentary deposition on the continental shelf in the south than in the north. The 57 million tons average annual discharge of suspended sediments with the concomitant eastern movement of offshore currents passing the delta toward Israel supplies the sediment. The present gradient (1:10,000) of a Roman aqueduct draining southeasterly to Caesarea indicates the downwarping of the coast and shelf has been negligible during the past 2,000 years (Emory and Neev, 1960).

TABLE I COMPARATIVE DATES OF ARCHAEOLOGICAL PERIODS

DATE ACCORDING TO:	Wright & Filson, 1956	Harding, 1959	Van Beek, 1962	Wright, 1964
Paleolithic	100,000-8000	2000,000-8000	omits	omits
Mesolithic	8000-5500	omits	"Natufian" 8000-6000	omits
Neolithic	5500-4000	8000-4500	"Pre-Pottery" 6000-5000 "Pottery" 5000-4000	ca. 7000-4000
Chalcolithic	4000-3300	4500-3000	4000-3200 "Esdraelon" 3200-3000	ca. 4000-33d cent.
Early Bronze	3000-2100	3300-2000	I 3000-2800 II 2800-2600 III 2600-2300 IIIB or IV 2300-2100	ca. 33d-24th cents.
Dark Age	omits	omits	omits	24th-21st cents.
Middle Bronze	2000-1500	2000-1500	I 2100-1900 IIA 1900-1700 IIB 1700-1600 IIC 1600-1550	I ca.20th-19th cents IIA ca.1850-1750 IIB ca.1750-1650 IIC ca.1650-1550
Dark Age	omits	omits	omits	ca. 1550-1500
Late Bronze	1500-1200	1500-1200	I 1550-1400 IIA 1400-1300 IIB 1300-1200	I ca. 15th cent. IIA ca. 14th cent. IIB ca. 13th cent.
Dark Age	omits	omits	omits	ca. 1230-1150
Early Iron or Iron I	1200-1000	"Iron Age" 1200-330	IA 1200-1150 IB 1150-1025 IC 1025- 950 ID 950- 900	IA ca. 12th cent. IB ca. 11th cent. IC ca. 10th cent.
Iron II	1000-600	see above	IIA 900- 800 IIB 800- 700 IIC 700- 600	IIA ca. 9th cent. IIB ca. 8th cent. IIC ca. 7th-early 6th C.
Iron III	600-330	see above	"Iron III, Late Iron or Persian" 600-300	omits
Hellenistic	333-63	331-63	300-63	omits
Roman	63BC-AD325	"Rome and Byzantium"	63BC - AD 323	omits
Byzantine	omits	63BC - AD636	AD 323-636	omits
Islamic	omits	AD 636	AD 636 to present	omits

-Modified from Williams, 1965

CHAPTER II

THE GEOLOGY OF THE CENTRAL SHEPHELAH: THE ENVIRONMENT OF TELL GEZER

Geological study of the central Shephelah in the region of Tell Gezer was undertaken for two primary purposes: 1) the relatively low economic potential of the central Shephelah has made it geologically uninteresting for scientists whose work has been concentrated in areas of greater promise such as the oil fields of the southern Coastal Plain and Shephelah and the mineral-rich Negev. The Gezer area geology needed to be described, mapped, and related to those areas to the north and to the south where detailed work has been done. 2) It is the conception of the writer that geological methods of research, when applied to an archaeological excavation, must take into consideration the larger context of the geology of the immediate neighborhood and ultimately the geology of the region in any attempt to understand how man historically related himself to his environment. The ultimate goal of this research concerns the relationship of man to his environment. This is illustrated by the close dependence man has had historically upon the economic aspects of the geology of his environment, sometimes near, sometimes far: his weapons, his tools, his building materials, the raw materials for his various enterprises, and commodities. The nature of this dependence is that which this research aims to elucidate in the archaeological excavation of Tell Gezer.

METHODS OF STUDY

The remoteness of the area under consideration necessitated initial systematic approach to the research. A plane table and alidade

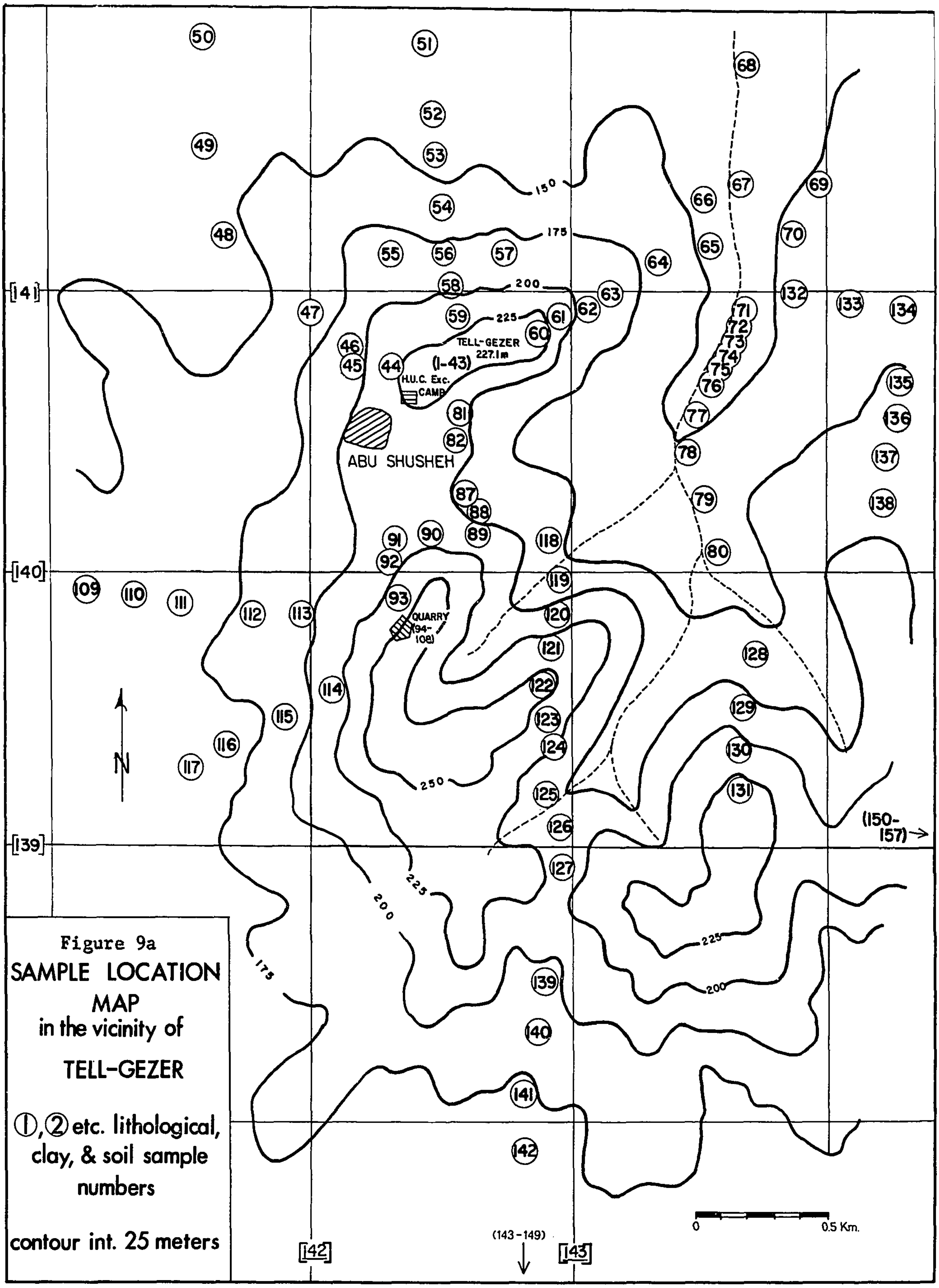


Figure 9a
SAMPLE LOCATION MAP
in the vicinity of
TELL-GEZER

①,② etc. lithological, clay, & soil sample numbers

contour int. 25 meters

Figure 9b. "Beware of the Mines", evidence of the hazardous limitations and demarcations of a regional geological survey in the vicinity to the east of Tell Gezer. No-man's-land lay about 1 km due east of the tell and precluded stratigraphic research in the area to the east and south of this site.

were taken for the purpose of geological mapping, but it became apparent early in this work that the topographic mapping was locally inaccurate (see Figure 5a, MacAllister's boundary marker map, and compare with Figure 9). This topographically corrected base map was construeted on a 1:20,000 scale for reasonable resolution of the lithostratigraphic outcrop pattern.

Geologic mapping was carried out systematically but the presence of the Cca horizon, the relatively insoluble "caliche" residue of the local carbonate bedrock made the stratigraphic sampling very difficult. A sampling grid was laid out, therefore, along lines which crossed excavated tomb, cistern, cave areas, and stream channels, i.e., wadis where the erosive action of wet weather run-off had cut into the unweathered bedrock below. Two notable sources of unaltered bedrock samples were 1) an Arab quarry (Mugharet el Jaihah) just south of Tell Gezer and 2) the fresh bedrock of the Middle Bronze II (Table I) water tunnel cut below the west central area of the tell (Figure 4).

SAMPLING

The field samples collected on the excavation site and from the area mapped were shipped to the University of Cincinnati for analysis. Sampling on fieldtrips with the Geological Survey of Israel and with the International Clay Conference, Jerusalem, 1966, added to the regional geological data. In this way, initial representation of characteristic lithologies from the ores and economic materials of the Negev, the building stone materials of the Judean Mountains, and the basalts of Galilee with their soils were sampled.

ANALYTICAL PROCEDURES

Megascopic and micrscopic examination and description of the sediments were carried out in the field and continued in the Cincinnati laboratories. A portion of the analytical work was performed by the writer in an industrial laboratory. The chalk, marls, and limestones in the sands and soils were studied not only to understand characteristic petrology, but also to determine potential parameters by which it could be detected in the artifactual use of the inhabitants of Gezer.

While the Lower Middle Eocene chalks, freshly exposed in the water tunnel, are easily disassociated in an aqueous solution, the faunal tests are not sufficiently indurated to be removed for diagnostic study. Therefore, the low silica chalks and marls were impregnated with low viscosity epoxy, mounted on glass, and hand worked down to 0.03mm thickness for micrscopic paleontological and petrographical examination. Frequently, siliceous chalk units yielded the best preservation of fauna for study.

Determinations of floral content were further aided by the use of an RCA EMU-1 electron microscope at the Department of Geology, University of Cincinnati. The samples were prepared for electron microscopy by sedimenting very dilute aqueous suspensions onto a mica substrate. After drying, these were shadowed with a platinum-palladium alloy at 30^{o} and then carbon replicated. Dilute HF flotation, was followed by dilute HCl and distilled water washing. The replicas were then implaced on a 200 mesh screen for microscopic study.

All carbonates were analyzed for (1) calcite-dolomite ratios by X-ray diffraction, (2) insoluble residues in dilute acetic acid 1:6, and (3) boron content. A number of Ca^{++} estimations were made by a conventional acid-oxalate wet chemical method. CO_2 was estimated on the same samples by an Orsat gas analysis apparatus. The insoluble residues were examined microscopically and were further investigated for (a) clay mineralogy, (b) trace element chemistry, and (3) heavy mineral content.

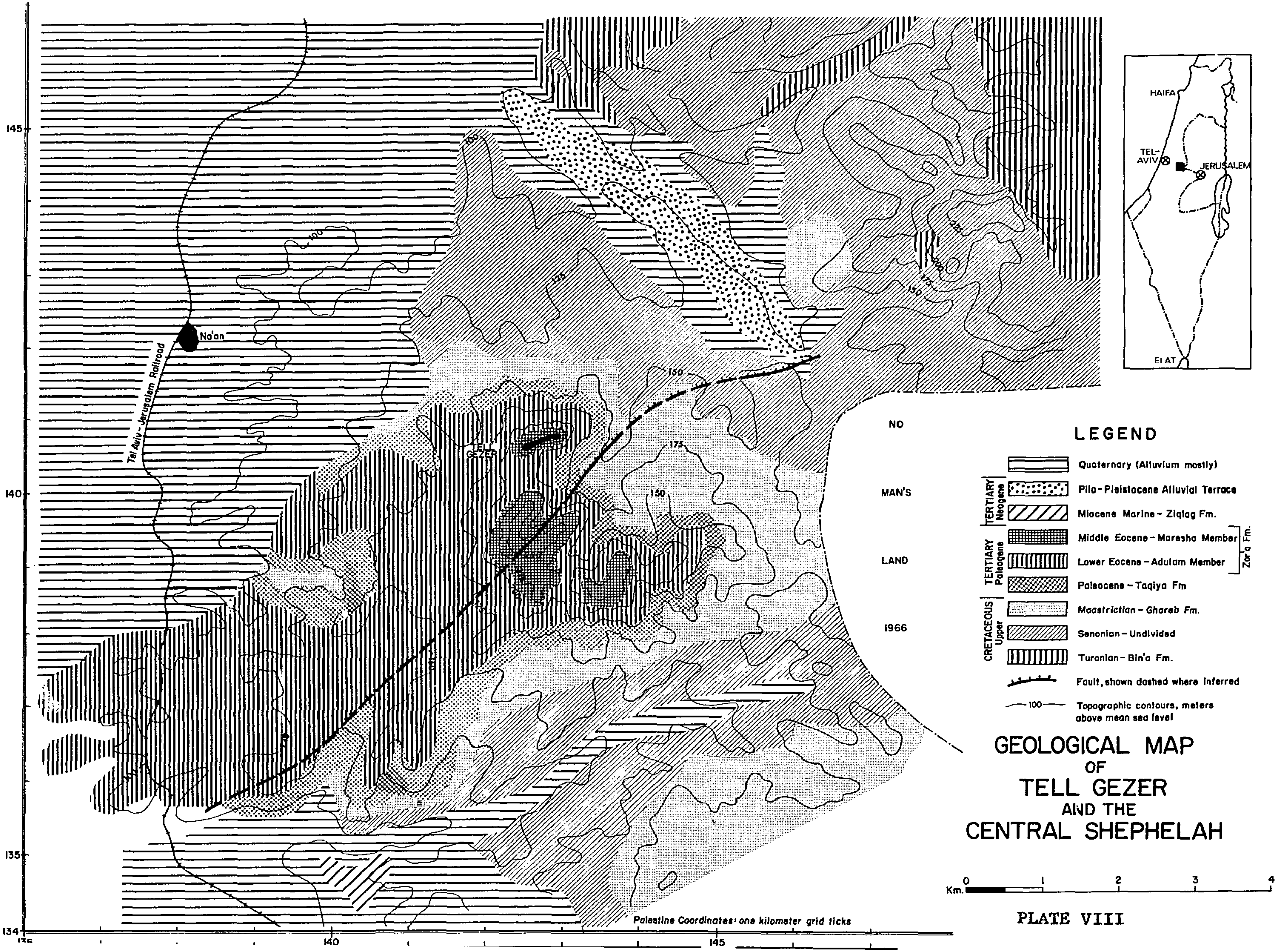
PREVIOUS WORK

Most of the lithological units in the central Shephelah have been described from various other places along the Shephelah strike in Israel (Avnimelech, 1936, 1949, 1950; Bentor, 1956; Gritzer, 1960; Golan, 1960; Arad, 1965; Gvirtzman and Reiss, 1965). No new lithostratigraphic units are introduced here, but the local expression of these units is recognized along with a careful study of their areal distribution (Plates VIII and X).

STRATIGRAPHY

The lithostratigraphic character of the local sediments was determined on the basis of the megascopic sedimentary petrological characteristics observed in the field. Biostratigraphic studies were made on the basis of the 1) microscopic fauna, 2) megascopic fauna, 3) microscopic flora. Mr. Richard Alexander of the University of Cincinnati and Dr. Zeev Reiss of the Hebrew University, Jerusalem, offered valuable assistance in the determination of foraminiffera in thin sections.

The lithological sequence consists mainly of limestones and chalks, locally siliceous, which range from Upper Cretaceous to Middle Eocene in age. Units of marine Miocene and alluvial Plio-Pleistocene have minor



GEOLOGICAL MAP OF TELL GEZER AND THE CENTRAL SHEPHELAH
LEGEND
Quaternary (Alluvium mostly)
TERTIARY Neogene
Plio-Pleistocene Alluvial Terrace
Miocene Marine – Ziqlag Fm.
TERTIARY Paleogene
Middle Eocene – Maresha Member
Lower Eocene – Adulam Member
Zor'a Fm.
Paleocene – Taqiya Fm
CRETACEOUS Upper
Maastrictian – Ghareb Fm.
Senonian – Undivided
Turonian – Bin'a Fm.
Fault, shown dashed where inferred
Topographic contours, meters above mean sea level
NO MAN'S LAND 1966
Na'an
Tel Aviv - Jerusalem Railroad
TELL GEZER
HAIFA
TEL-AVIV
JERUSALEM
ELAT
Km. 0 1 2 3 4
Palestine Coordinates: one kilometer grid ticks
145
140
135
134

PLATE VIII

Figure 10. The Turonian-Senonian contact exposed in the northern face of the Nesher-Ramle Cement Quarry. The physical appearance of the overlying Senonian stratum is striking evidence of the drastic change which characterized eastern Tethyan sedimentation at the end of the Turonian and the beginning of the Senonian Epoch. The lithological change observed above is characteristically distinct. Faunal changes are sudden across the contact: Milliolidae limestones to globigerinal biomicrites. This unconformity is regional (Gvirtzman and Reiss, 1965).

Figure 11a Photomicrograph (150x). Turonian (Bi'na limestone) a formainiferal biomicrite. This white crystalline limestone shows advanced calcite replacement and alteration of many of the foraminiferal remains. A still identifiable form, Gaudryina sp., very characteristic of the Upper Cretaceous is shown. Angular clear quartz grains are seen at (x). The presence of quartz grains is a manifestation of Upper Cretaceous clastic sedimentation originating from clear Nubian sandstone deposition in the area of the Negev. The Turonian is the oldest sediment exposed in the vicinity of Tell Gezer and consequently the lowest carbonate stratigraphically to contribute in any significant way to the ecology of the city.

Figure 11b Photomicrograph (150x). Turonian (Bi'na limestone) a foraminiferal biosparite facies. The form Valvulammina picardi is a biostratigraphic index faunal representative of the Bi'na Formation.

Figure 11c Photomicrograph (150x), Turonian (Bi'na limestone) a foraminiferal biomicritic facies. A representative example of Hedbergella sp. is illustrated together with foraminiferal debris.

Figure 10

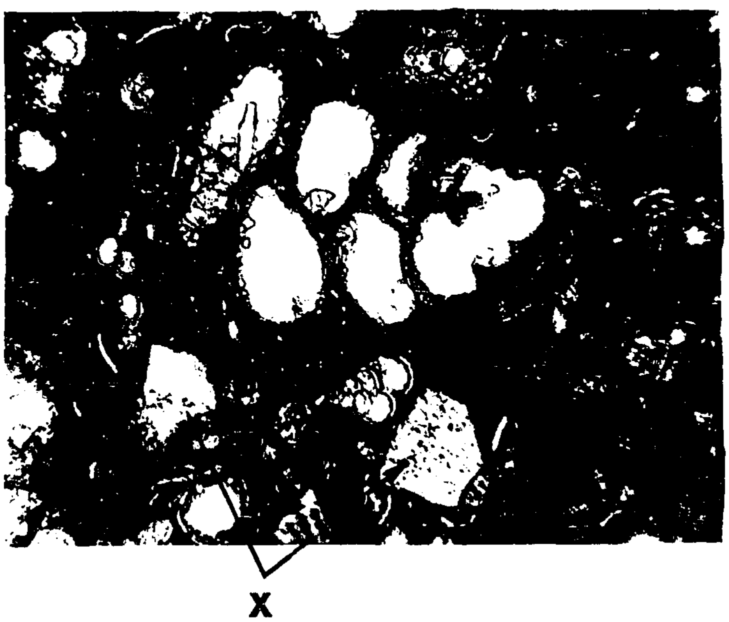


Figure 11a

Figure 11b (left)

Figure 11c (right)

occurrences locally, and predominate to the west.

Two reported occurrences of igneous plugs (Avnimelech, 1935, 1953) were not found by the writer after many traverses were taken across the areas of supposed surface distribution. Two members of the Israel Geological Survey, Y. Arkin and J. Brenner, accompanied the writer to areas in question and supported the conclusion that no surface occurrences of extrusive igneous rocks occur in the area mapped.

UPPER CRETACEOUS

The Bi'na Limestone (18m)

The type and reference sections occur in the Judean Mountains (Shadman, 1959; Arkin, Braun, and Starinsky, 1965).

The Bi'na limestone occurs on the surface north of the Valley of Aijalon where it has been uplifted and exposed by faulting. Modern and ancient quarrying operations have produced a number of unweathered outcrops in the area to the north of Gezer.

The 18m of this formation exposed in quarry of the Nesher-Ramle Cement Company (Figure 10) is composed of finely crystalline and micro-crystalline foraminiferal, sublithographic limestone with minor lenses of illitic shale and sand-sized angular quartz grains (Figures 11b, c, d).

The fossil assemblages of this unit have been catalogued by Reiss (in Shadman, 1959) and Hamaoui (1964). Some of the characteristic fossils noted in this study and verified by Reiss are Valvulammina picardi, Hedbergella sp., Gaudoryina sp., and Praeglobotruncana sp.

The age of this section of the Bi'na limestone is Turonian. Locally this unit is mostly a foraminiferal biosparite partly micritic

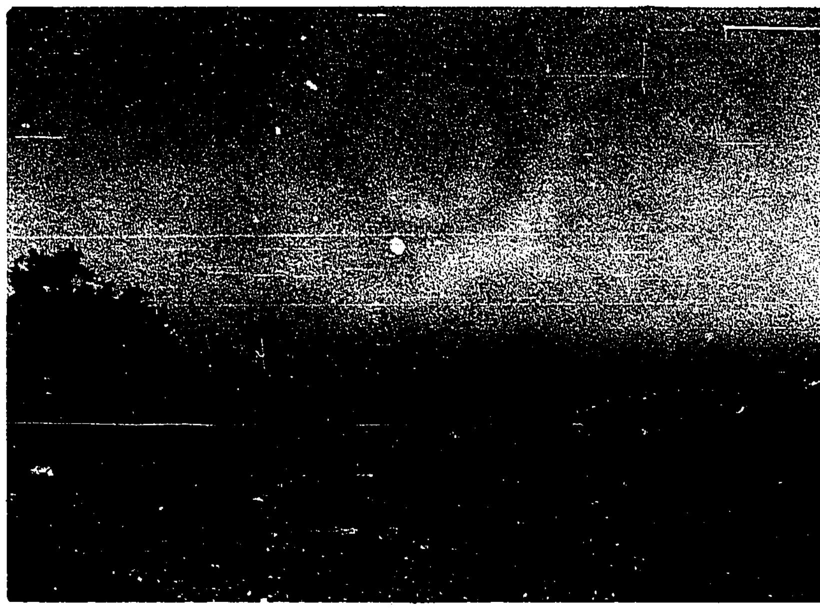


Figure 12. A strike valley on the Senonian marls and chalks. View from the southwestern end of Tell Gezer across the narrow saddle and the hill just south of the tell beyond which lies the strike valley, a feature parallel to the general trend of the Judean anticline. The differentially lower resistance of marls and the absence of a firm nari crust in the soil profile yields topographic lows everywhere this distinctive lithology has surface distribution. The Judean Mountains are seen in the remote background, with the general position of the moon approximately in line with the town of Bethlehem.

The effect of the topographic expression of this valley on the history of the area can be understood in light of the fact that it furnished an alternate north-south route parallel to the one on the Coastal Plain.

Figure 13a. Photomicrograph (150x) of the foraminiferal biomicrite which characterizes the local marls of the Menuha Formation (Senonian). In the region of Tell Gezer, the Senonian Menuha marls are "cleaner" calcilutites (insoluble residue 23.73%) than are the Paleocene marls (insoluble residue 34.22%). The former exhibit higher energy in terms of the faunal disintegration and in terms of the detrital content.

Figure 13b. Photomicrograph (150x) illustrating the quartz which locally constitutes 5% of the sediment. The presence of quartz suggests a second or even multicycle redistribution of Nubian sandstone sources which were uplifted and were furnishing sediments on the southeastern margins of the Tethyan Basin (Upper Cretaceous Senonian sands blanket the southeastern regions of the Negev).

Figure 13c. Photomicrograph (150x) showing the relatively rapid burial and consequent entrapment of organic material as illustrated by the hydrocarbon "shows" in this thin section. The subsurface Menuha is in part bituminous, but this aspect is largely oxidized in surface occurrences. Kiln heating, however, darkens the lithology. Electron microscopic preparations yielded no coccolith content suitable for diagnostic recognition.

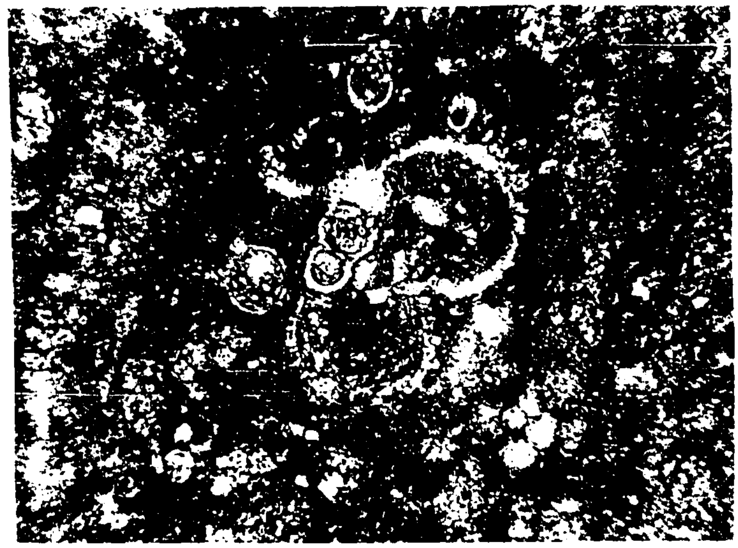


Figure 13a.

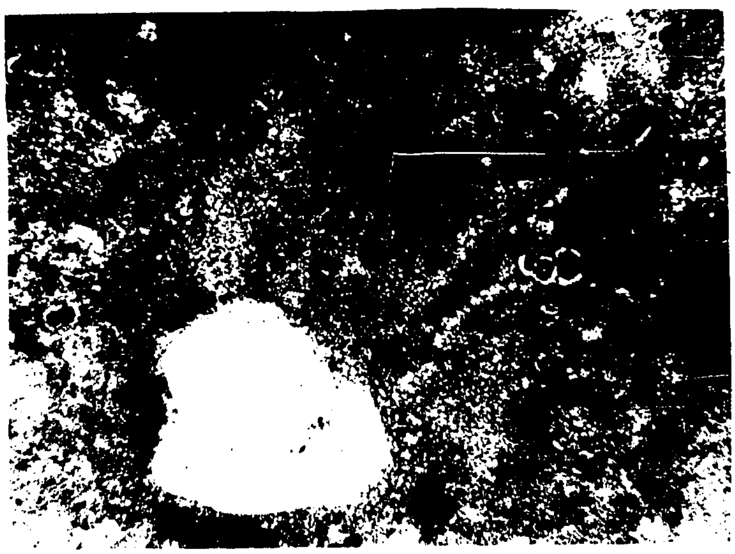


Figure 13b.

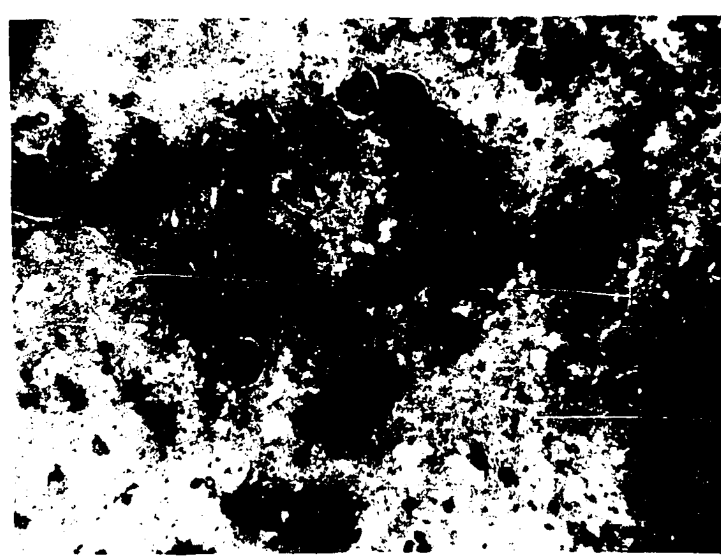


Figure 13c.

and pellety, generally abundant in shallow water foraminifera, e. g., Miliolidae (Reiss, pers. comm.).

An angular unconformity between the Turonian and Lower Senonian exists locally, the result of a major folding phase at this time. After this event, the nature of the sedimentation changes abruptly to a deeper water facies with a higher argillaceous content.

The Menuha Formation (250^{+}m)

Type section: Jebel Meliha in the Negev (coordinates 160/970) S. H. Shaw, 1947.

This formation consists mostly of massive argillaceous chalks and marls occasionally slightly phosphatic and detrital (abundant intraclasts were noted in the thin sections). North of Gezer important outcrops occur mainly on areas of Turonian relative highs where a lower percentage of bituminous content is characteristic (Figure 10). Figure 13c illustrates the planktonic foraminifera which are abundant in the lower part of the Menuha Formation with Globotruncana convacata (Brotzen), G. fornicata Plummer, Globigerinelloides spp., Heterohelix spp., and Guembelina sp. (Reiss pers. comm.).

The prevelance of planktonic foraminfera existing at the base of the Senonian constitutes an abrupt change in faunal composition and suggests subsidence, deepening of the sea floor, and the incursion of open marine waters.

The Menuha Formation is Lower Senonian (Santonian and Early Campanian).

No complete section was available for observation in the Gezer area where most of the upper portion of the formation is covered with alluvium or regolithic materials. Wadi exposures west of No-Man's-Land were sampled in addition to the Ramle quarry section.

Mishash Formation

Type section: Be'er Mishash (coordinates 1448/0892) S. H. Shaw 1947.

Described originally in the Negev, this formation is represented in the Gezer area by a restricted facies known as the "mottled zone". The surface distribution of this lithology was not sufficient for mapping purposes, but its presence was observed in minor outcrops exposed on the northern bank of the wadi Aijalon, 11 km southeast of Ramle.

The unit consists of carbonates and argillaceous carbonates locally siliceous. Owing to the peculiar constitution of these sediments which have their largest distribution in the northeastern Negev, they have received considerable attention by Israeli petrologists. The "mottled zone" is regarded as reconstituted carbonates derived by a diagenetic process, the reducing and highly alkaline conditions of which have yielded a unique mineral assemblage which includes ettringite, volchonskoite, spurrite, afwillite, portlandite, vaterite, and tobermorite (Gross, et. al., 1967).

The planktonic foraminifera preserved in the carbonate portions of this zone occur in a pelitomorphic (micritic) chalk matrix.

The age of this deposit is Upper Senonian.

Ghareb Formation (38m)

Type locality and section: Ma'avar Zin (Nagb el Ghareb) (coordinates 129/028) S. H. Shaw, 1947.

Figure 14 Photomicrograph (50x) of Maastrichtian (uppermost Cretaceous) foraminiferal biomicrite which floors the Aijalon Valley to the north of Tell Gezer (cf. Figure 26 and Plate VIII). Designated elsewhere in the Shephelah as the Ghareb Formation, the Maastrichtian deposition is essentially a continuation of the sedimentary facies established in the Senonian. It is maintained until the onset of Paleocene time when a marked increase argillaceous content is introduced in the sediment of the eastern Tethyan Basin. Together with the Menuha marly chalks, the Ghareb chalks and marls characterize the sedimentary sequences which changes from the indurated carbonates of the Judea Group to the relatively soft chalks and marls of the uppermost Cretaceous and Lower Tertiary deposition in this area of the Shephelah.

Figure 15a. Wadi-waterfall at the Eocene-Paleocene contact, wadi Ain Yerdeh. This is graphic erosional evidence of the weathering differential between chalk and marl occurring on the lower flanks of the local Shephelah. The disequilibrium in the stream profile bears out the variation in the mineralogical character of this deposit. The high clay content (34.22%) of the calcilutite which underlies the chalks drastically reduces the rate of the nari-forming process. Topographic lows characterize the surface expression of this series throughout the area.

Figure 15b. Photomicrograph (330x) foraminiferal biomicrite from the upper Taqiye Formation (Paleocene age). The Morozorella sp. fauna dominates this argillaceous calcilutite (Reiss). The lack of siliceous cementation in this sediment permits it to exhibit a greater permeability to vadose waters, the leaching affects of which have partially dissolved the faunal content. Electron microscopic examination of this sediment revealed a considerable deterioration of the coccolith content, the poor representation of which is seen in Plates XVIII-XXI.

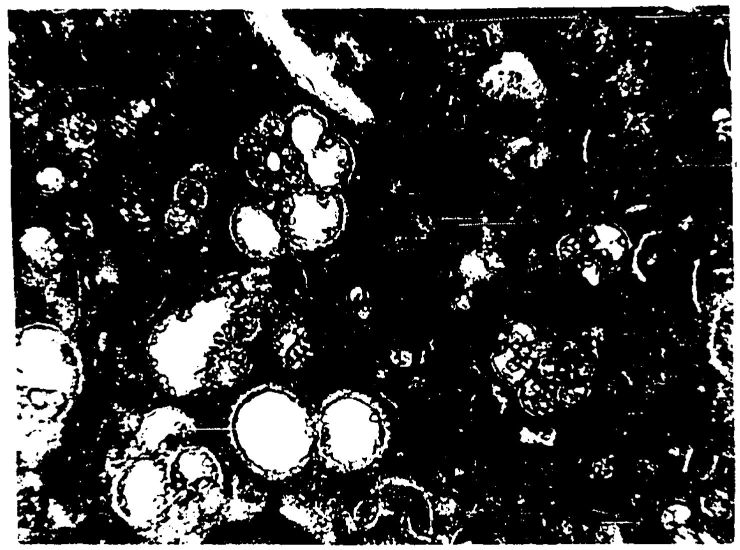


Figure 14.

Figure 15a.

Figure 15b.

Locally this unit is comprised of grayish-yellow (5Y 8/4) argillaceous chalks with minor gypsum, glauconitic, and limonitic accessory mineral content. Wells to the southwest in the Coastal Plain show a bituminous character in subsurface expression. Individual beds have a thickness of about 5cm and alternate in the lower section with thin beds of calcareous shales. The formation attains a thickness of 35m in the Gezer area (cf. Figure 32).

The Ghareb Formation does not have a distinct lithostratigraphic demarcation in the Gezer area and its boundary therefore has been determined on the basis of soil coloration (the calcareous shales characterize its areal distribution under the regolith (Figure 2), lithological change in the wadi outcrop, and on the basis of the Maastrichtian fauna Bolivina incrassata Reuss, Globotruncana contusa (Cushman), and Bolivinoides sp. (Reiss, pers. comm.) (see Figure 14). The mapping of the formation has, therefore, in part, a biostratigraphic basis.

PALEOGENE

Taqiye Formation (23m)

Type locality and type section: Har Kippa (Jebel adu Taqiye) (coordinates 152/973) S. H. Shaw, 1947.

The characteristic lithology is composed of grayish, yellow-green (5GY 7/2), light bluish-gray (5B 7/1) fissile to massive marls locally limonitic (concretions up to 3cm) (Figure 15a). It contains Marcasite spherulites inpart altered to the oxide and is locally Gypsiferous.

This unit, dominantly a biomicrite (Figure 15b) contains the following assemblage of microfauna: Heterolepa scania (Brotzen), Truncorotalia aequea (Renz), Globigerina triloculinoides Plummer, Globigerina compressa Plummer, Globeconusa sp., It is of Paleocene age (Reiss, pers. comm.). This is further documented by the following coccolith representatives (Plate XX and Addenda I):

Heliolithus riedeli Bramlette and Sullivan

Cyclolithus robustus Bramlette and Sullivan

Ericsonia superbtus Hay and Mohler

Coccolithus marismontium Black

The dominantly planktonic character of the fauna of the Taqiye implies deposition in an open marine environment. The relatively high argillaceous content (Table III) is an indication of probable uplift and erosion to the east beyond the margin of the Tethyan Basin.

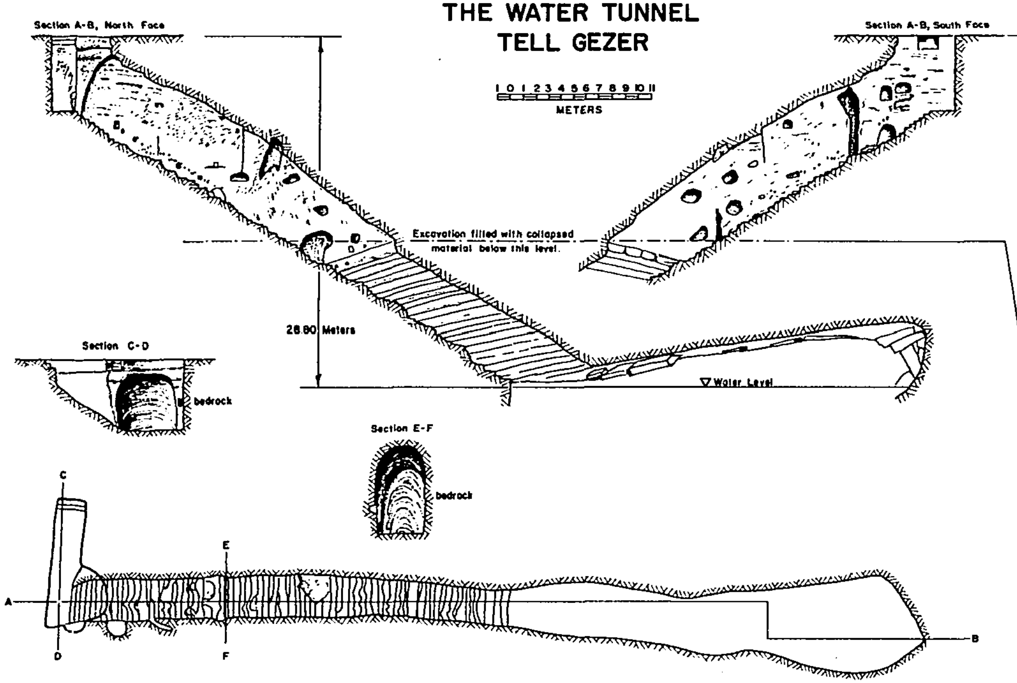
Zor'a Formation

Adulam Member. Type locality and type section: near Kubbutz Zor'a (coordinates 149/132 approximately) Avnimelch, 1936; Reiss, 1962.

Light brown (5YR 6/4) to white (10YR 8/2) silicified chalk and limestones and chalk with interbedded chert nodules up to 0.85m in longest dimension compose this member in the lower part. It constitutes a marked lithologic change with respect to weathering resistance (cf. Figure 3).

Among significant faunal representatives are Truncorotalia simulatilis (Schwager), T. Aragonensis caucasica (Glaessner), Acarinina sp., Subbotina sp., Globogerina spp., Cassidulina sp., and Acarinina (cf. Crassata) (Reiss, pers. comm.). The fossil assemblages are typical of an open marine environment. The abundance of radiolaria and porifera parts constitute a probable source for the high chert-silica content of this unit.

THE WATER TUNNEL
TELL GEZER



THICKNESS (meters)	LITHOLOGIC DESCRIPTION	INSOLUBLE RESIDUES %	INSOLUBLE RESIDUES COARSE FRACTION	INSOLUBLE RESIDUES <2μ CLAYS	CLAY BORON (ppm)
0.66	Buff. 10YR 8/2 dense, lithographic limestone. Nari penetration total depth. Locally jointed and fractured.	5.0	Quartz Amorphous Silica	Illite Palygorskite	60
7.62	Light buff 10YR 7/3 indurated lithographic limestone and chalk. Cross-bedded (dip 22°N) and jointed. Locally siliceous.	1 5.9 2 2.6 3 4.2 4 6.9	Minor Quartz (63) Amorphous Silica	Illite Montmorillonite Palygorskite	42
	Buff 10YR 3/4 very fine grain, moderately indurated massive chalk $CaSO_4$ encrusted surface.	7.0	Quartz (105) $CaSO_4$ Xtls	Montmorillonite Palygorskite	40
1.22	Buff to brown 10YR 6/2 - 10YR 2/2 vitreous siliceous limestone (strike N9°E, dip 4.5°W).	40.2	Amorphous Silica		
0.13	Light to dark brown 10YR 5/2 - 10YR 2/2 siliceous chalk. Chert nodules with siliceous chalk inclusions.	7.5	Quartz (150-250) fish parts	Montmorillonite Palygorskite	36
2.54	Light to dark brown 10YR 5/2 - 10YR 2/2 siliceous chalk. Chert nodules with siliceous chalk inclusions.	58.3	Siliceous foraminiferal tests and Amorphous Silica		
0.10	Buff 10YR 7/2 very fine grain moderately indurated chalk, large vitreous siliceous chalk nodules (nim).	8.1	Quartz fish parts phosphate pellets	Montmorillonite Palygorskite	39
1.73					
0.25	Dark brown 10YR 2/2 chert nodules (nim) with vitreous siliceous chalk rims. Not uniformly bedded.	99.1	Siliceous foraminiferal tests Amorphous Silica		
3.28	Buff 10YR 8/2 fine grain non-indurated massive chalk	9.9	fish teeth Quartz. $BaSO_4$ Xtls, PO_4 pellets Apatite Xtls	Montmorillonite Palygorskite	41
0.15	Dark brown 10YR 2/2 bedded chert nodules with vitreous siliceous rims.	99.9	Amorphous Silica	No residue	
2.84	Buff 10YR 8/2 fine grain non-indurated (friable) massive chalk.	13.5	$BaSO_4$ & Apatite Xtls, Quartz, fish teeth, PO_4 pellets	Montmorillonite Palygorskite	33

EXCAVATED BY MACALISTER

Plate IX

Maresha Member. This member is composed mainly of soft, light buff to very pale brown, slightly limonitic chalk (see Plate IX for a detailed stratigraphic section of the Gezer water tunnel; also see Figures 16a, b, and c.

Characteristic Middle Eocene coccolith forms (Plates XVIII and XIX) of the non-indurated beds of this unit are

Discolithus distinctus Bramlette and Sullivan

Discolithus fimbriatus Bramlette and Sullivan

Discolithus punctosus Bramlette and Sullivan

Chiphragmalithus dubius Deflandre

Discolithus exillis Bramlette and Sullivan

Discolithus solidus Deflandre

Cyclococcolithus luninis Sullivan

Toweius craticulus Hay and Mohler

Discolithus gezerensis n. sp.

Zygolithus crux Deflandre

Discoaster elegans Bramlette and Sullivan

Micrantholithus attenuatus Bramlette and Sullivan

Discoaster falcatus Bramlette and Sullivan

Coccolithus cavus Hay and Mohler

This is the first reported occurrence of coccolith forms in the chalk sediments of the central Shephelah. The stratigraphy of the Tell Gezer area now appears to be firmly established.

A 4m section of the Middle Eocene exposed in an Arab quarry 0.8 km south of Tell Gezer (coordinates 1433/1400), 17m higher than the uppermost Middle Eocene strata of Tell Gezer continues the Middle Eocene record of

Figure 16a. Photomicrograph (150x): Middle Eocene sediment exposed by the excavation of the Middle Bronze water tunnel. The globigerinal biomicrite surface is slightly siliceous 0.6m below the upper bedrock. Replacement of the fauna has prevented deterioration by the generation of nari. The composition of the micritic material is now better understood from the electron micrographs showing a rich coccolithic content (cf. Plates XVIII, XIX).

Figure 16b. Photomicrograph (150x): formainiferal biomicrite illustrating the moderately high concentration of the planktonic Middle Eocene Truncorotaloides sp. Local voids are characteristic of this stratum of the water tunnel 3.5m below the upper bedrock surface. This section shows a very thin powdery film on the smooth chalk surface. Some of the voids may have been the loci of minor concentrations of moderately soluble salts which have subsequently been leached out by vadose-water action.

Figure 16c. Photomicrograph (150x): biomicrite 14.5m below the bedrock surface of the water tunnel entrance. This soft, poorly indurated, massive unit of buff-to-cream colored chalk shows an increase in clay mineral content over that of the Zor'a sediments. This influx of clays along with the echinoid spicule suggests that currents from the shelf area to the east were active in delivering sediment to this portion of the Tethyan Basin.

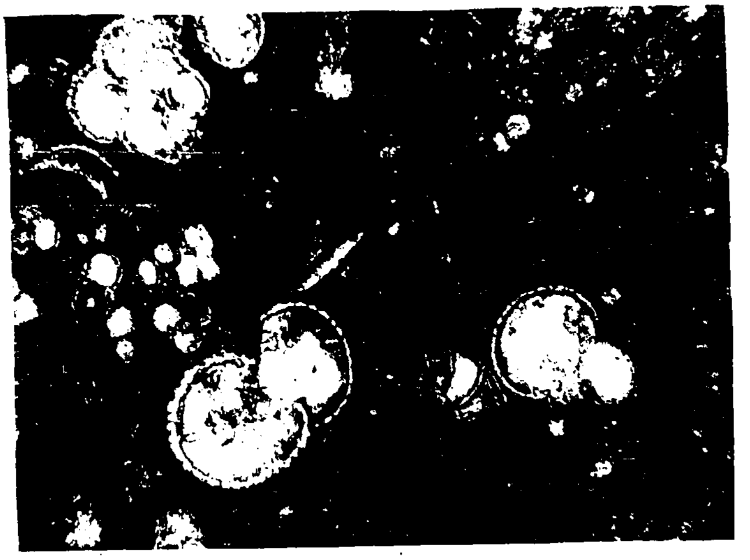


Figure 16a

Figure 16b

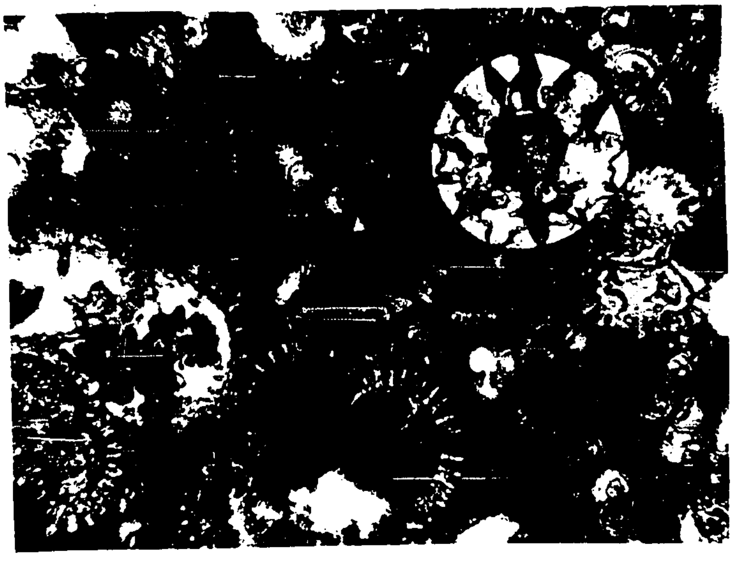


Figure 16c

Figure 17a. Maresha Formation: Arab quarry (Mugharet el Jaihah) outcrop, 17m above the highest bedrock level (216m) of Tell Gezer. Section of a chert nodule deposited in a lensate channel fill of calcirudite composed of the debris of benthonic foraminiferal tests. An interruption of predominantly planktonic foraminiferal and coccolith sediment deposition occurs locally. Chemical analysis of the silica indicates a high percentage (93.68%) of silica comprising the chert. Minor quantities of foraminifera were incorporated into the silica, in which the $CaCO_3$ was chemically replaced by the SiO_2.

Figure 17b. Photomicrograph (150x): siliceous chalk at (x), Figure 17a; pelagic foraminiferal test ca. 50% replaced by silica in a biomicritic matrix. This replacement of calcite tests shows minor crystallographic discontinuity with the ground mass when it too is replaced by silica.

It is this carbonate replacement by silica which produces the pronounced resistance to weathering exhibited by intermittant beds of siliceous carbonate sediment. Except for this partial silicification, any form of bedding in the nari-covered surface expression of this formation would be largely obscurred.

Figure 17c and 17d. (plain light 150x and cross nicols 150x, respectively). The crystallographic discontinuity of the replaced foraminiferal test by chert, the principal constituent of this portion of the sediment (chert nodule at (y), Figure 17a). This is the material economically exploited by the inhabitants of Tell Gezer from the Chalcolithic Period down to and including Iron Age. (Cf. Figures 101a and 101b)

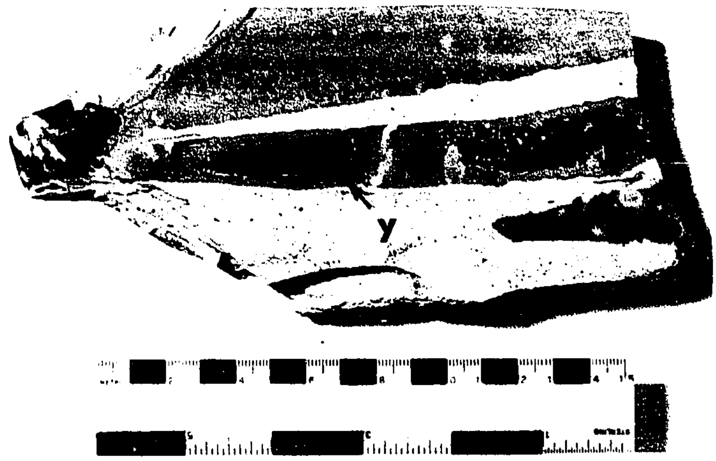


Figure 17a

Figure 17b

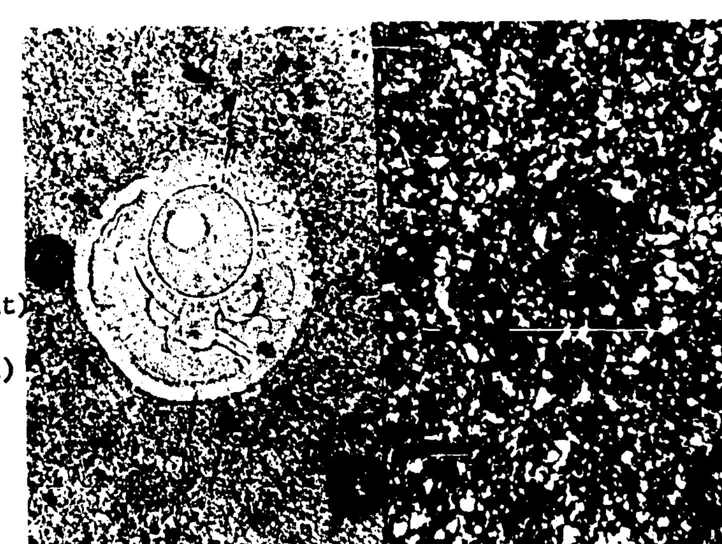


Figure 17c (right)

Figure 17d (left)

Figure 18a. Photomicrograph (150x) Maresha Formation, Arab Quarry section. Interface between planktonic Globigerinal biomicrite and a lens of thanatocoenocic benthonic foraminiferal forms at (z), Figure 17a. Periodic currents sweeping across the eastern continental shelf areas of the Middle Eocene Tethys swept concentrations of these fauna into local lensate deposits. Some fill vertical syneresis cracks in the homogeneous biomicrite chalk matrix.

Figure 18b. Photomicrograph (150x) Maresha Formation, Arab Quarry section (at 235.5m elevation). Fine calcirudite composed of thanatocoenocic benthonic foraminifera or a syneresis crack filling of the chalk sediment. The benthonic representatives are Oberculina sp. and Pararotalia sp. This fauna elsewhere characterizes the Lower-Middle Eocene Zor'a Formation in its benthonic facies.

Figure 18c. Photomicrograph (150x) Maresha Formation, Arab Quarry section (at 236m elevation). Thanatocoenocic deposit of Middle Eocene foraminiferal tests (Nummulites sp. and Pararotalia sp.). The allochthonous character of this detrital biomicrite is shown by the abraided nummulites test and the debris of various foraminifera. Typical benthonic sedimentation was occurring to the east in the area of the Ephraim-Gilboa Mountains synchronous with the deeper water deposits of the central Shephelah.

Figure 18a

Figure 18b

Figure 18c

marine sedimentation (cf. Figures 17a, b, c). The physical weathering of the surface of the fresh chalk (Figure 19) has differentially exposed joint fillings (syneresis cracks). Sub-horizontal lenses of thanatocoenocic benthonic foraminiferal deposits occur in the chalk otherwise characterized by planktonic forms such as Globorotalia crassata (Cushman), and Globigerinoides sp. (Figures 18a, b, c) suggesting submarine current transport of shelf benthonic forms to bathyal sites of accumulation.

Locally, nodules of chert occur in the bioclastic lenses with chalcedony-calcite transition rims, containing various degrees of foraminiferal test replacement (cf. Figures 17c and d).

The chert nodules consist of cryptocrystalline to microcrystalline chalcedony. Fossil tests in them have been replaced by microquartz having a C-axis crystal size up to 200μ. The crystals are generally elongated perpendicular to the replaced test walls. Examples of internal filling are made up of radial chalcedony (Figure 17b).

Middle Eocene chert has a typical conchoidal fracture showing a waxy lustre with the absence of any visible grain. In every instance, the chert of the nodules observed in the water tunnel and in the tombs, cisterns, and the Arab quarry grades into the containing chalk through a brown (10YR 4/3) to a very pale brown (10YR 8/3) transitional zone having a fine grained porcelanous texture. The prgressive silicification of the calcite microfaunal tests indicates that the chert nodules grew from the center outward into a zone of partial silicification (as shown in Figure 17b). Carozzi (1960) regards the genesis of the transitional zone as a final phase in the development of the nodule occurring in the submarine environment during the time interval between the chalk deposition

Figure 19. Relatively unweathered chalk exposed along the walls of a quarry cut into the hill just south of Tell Gezer. The characteristic whiteness of the nearly pure Middle Eocene chalk dominates this view. In the lower part of the outcrop are contorted beds which contain folded zones of benthonic foraminifera in the dominantly planktonic foraminiferal composition of the massive chalk. Both here and in the Gezer water tunnel exposure thin lenses and syneresis fillings of benthonic foraminifera occur. Some of these benthonic faunal deposits occur in connection with the chert deposits. An explanation is suggested in the text.

and diagenesis. Krauskopf (1967) maintains that geologic evidence supports a coherent gel phase for chert nodules during the formative process. The Middle Eocene cherts of the Gezer area, therefore, were probably the result of biochemical precipitation and diagenetic differentiation.

NEOGENE

Ziqlag Formation

Type locality: Ziqim 1 Well (coordinates 1048/1142) G. Gvirtzman and Buchbinder, 1965.

A hard light red (5R 6/6) foraminferal biosparite which occurs in an erosional remnant of about 1 sq. km 6.5 miles south of Tell Gezer just north of the Nahal Sorek (coordinates 134/140).

The characteristic foraminiferal assemblages are Bolivina sp., Borelis melo, Dendritina rangei, Spiroloculina sp., Quinqueloculina sp., and Miliolidae typical of the Middle Eocene of the eastern Tethys (Reiss, pers. comm.) (Figure 20a). The Middle Miocene is a manifestation of the second major Tertiary cycle of sedimentation. The maximum transgression occurred in Late Middle Miocene time. The faunal assemblage is characteristic of shallow water marine environment (Figure 20a).

Ahuzam Formation

Type locality and type section: a series of outcrops near Ahuzam, Southern Shephelah, Issar, 1960.

Conglomerate beds mostly of Eocene and Campanian chert and resistant Upper Cretaceous carbonate rocks exposed on the western flank of the Judean anticline and in the valleys of the Shephelah make up this formation (Figure 21a). These Plio-Pleistocene deposits now remain topographically

Figure 20. Photomicrograph (48x) of the foraminiferal biosparite of the Ziqlag Formation. The fauna are (A) Borelis melo, (B) Dendritina rangei (Reiss, pers. comm.), biostratigraphic index representatives of this formation. The reddish pink crystalline limestone occurs frequently in the composition of stone artifacts uncovered in the excavations. The faunal criteria render the decision concerning the provenance of these artifacts as exotic. The closest outcrop of this lithology is 7.5 km to the south on the central Shephelah.

Figure 21a. Plio-Pleistocene terrace gravels of the Ahuzam Formation above the entrenched recent drainage of Nahal Nahshon, a tributary of Nahal Aijalon. The village of Kefar Shemu'el is in the background. These sediments consist almost entirely of the more resistant lithologies from the Judea Group. The conglomeratic sedimentation is composed principally of rounded, small pebble to boulder size Bi'na limestone and bedded Cenomanian cherts These sediments represent a broad channel deposit by a stream having competence and capacity far in excess of the wadi Aijalon, the drainage net of which may be seen in Plate XII.

Figure 21b. Photomicrograph: calcareous sandstone of the Pleshet Formation (33x). Rounded quartz 58%, shell fragments 14%, feldspar 4%, hornblende 2.5%, pyroxene 1%, calcite cement (and voids) 8.5%.

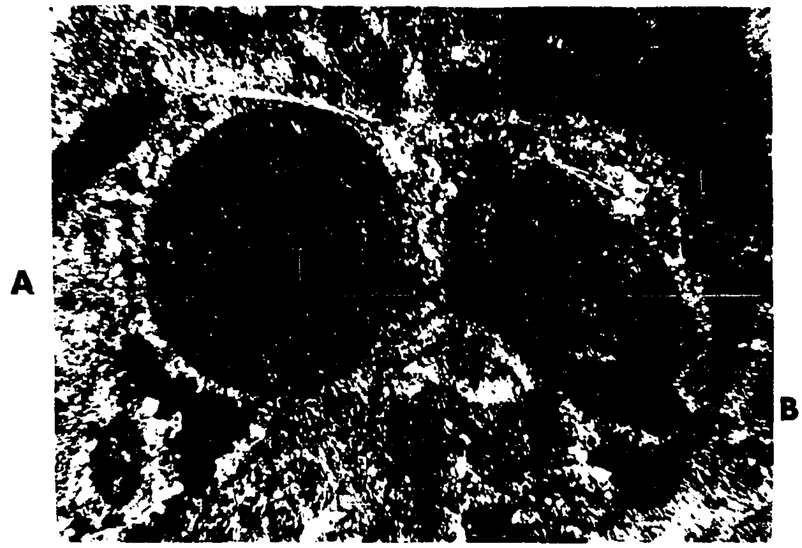


Figure 20.

Figure 21a.

Figure 21b.

as terraces, a consequence of the repeated rejuvenation of the Wadi Aijalon. Subsurface evidence in the southern Coastal Plain shows these conglomerates to be a facies of the dominantly sand-size quartz clastic Pleshet Formation which ranges from Pliocene to Mid-Pleistocene time (Gvirtzman and Reiss, 1965).

<u>Pleshet Formation</u>

Type locality and type section: Ashqelon well No. 5A, Issar, 1961.

Fossilized sand dunes, known as Kurkar, make up the calcareous quartz clastics of this formation (out of the area mapped in this study). The formation consists of calcareous quartz sandstones and calcarenite, the product of a littoral and beach environment, in part reworked by eolian processes (Figure 20c). Entrained foraminfera show a Pleistocene age for the samples available (Reiss, pers. comm.).

<u>Rehovot Formation</u>

Type locality and type section: a well near Rehovot (coordinates 132/145) Issar, 1960.

This lithology occurs principally as red (2.5YR 4/8) to reddish brown (2.5YR 4/4) to dark reddish brown (2.5YR 2/4) silts and sands. Issar (1960) also includes loams in soils (quartz, silts, and sands) stained and in part cemented by the sesquioxides of iron and aluminum. Subsurface evidence (Issar, 1965) shows a stratigraphic facies relationship with the Pleshet Formation and the Ahuzam Formation. Vertibrate fauna and human artifacts imply a Villfranchian to Recent Age (cf. Figure 21).

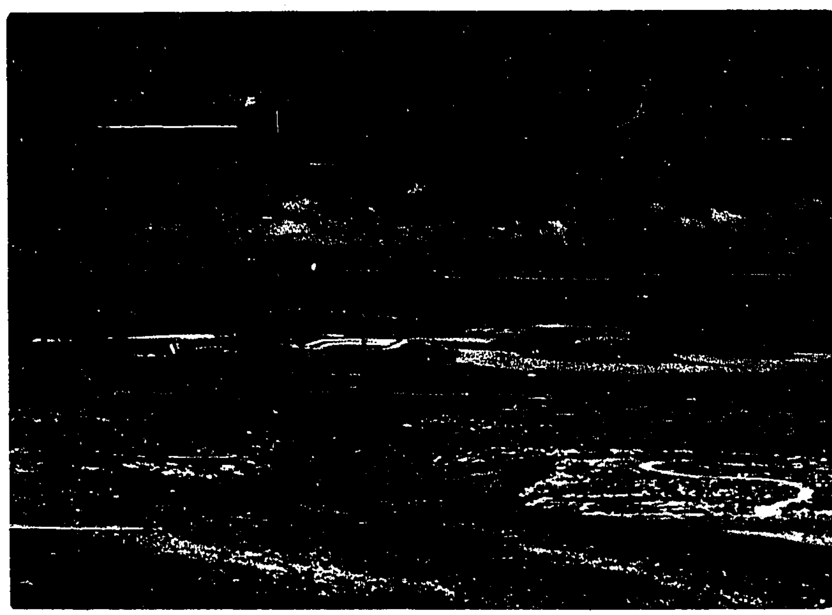


Figure 21c. The Coastal Plain from Tell Gezer. Remnants of Lower Eocene chalk may be seen as the westernmost aspect of the Foothill relief. Beyond the first definite treeline lies the easternmost limit of the Pleistocene marine and continental deposit known as Hamra, beyond this and inland from the line of white sand dunes seen on the horizon is a nearly north-south trending belt of calcified dunal ridges, termed Kurkar. The bright sands of Recent dunes mark the present day coastline, the southern part of which is constantly receiving sediments, the ultimate source of which is the Nile River and the Siniatic Peninsula (see Plate IV).

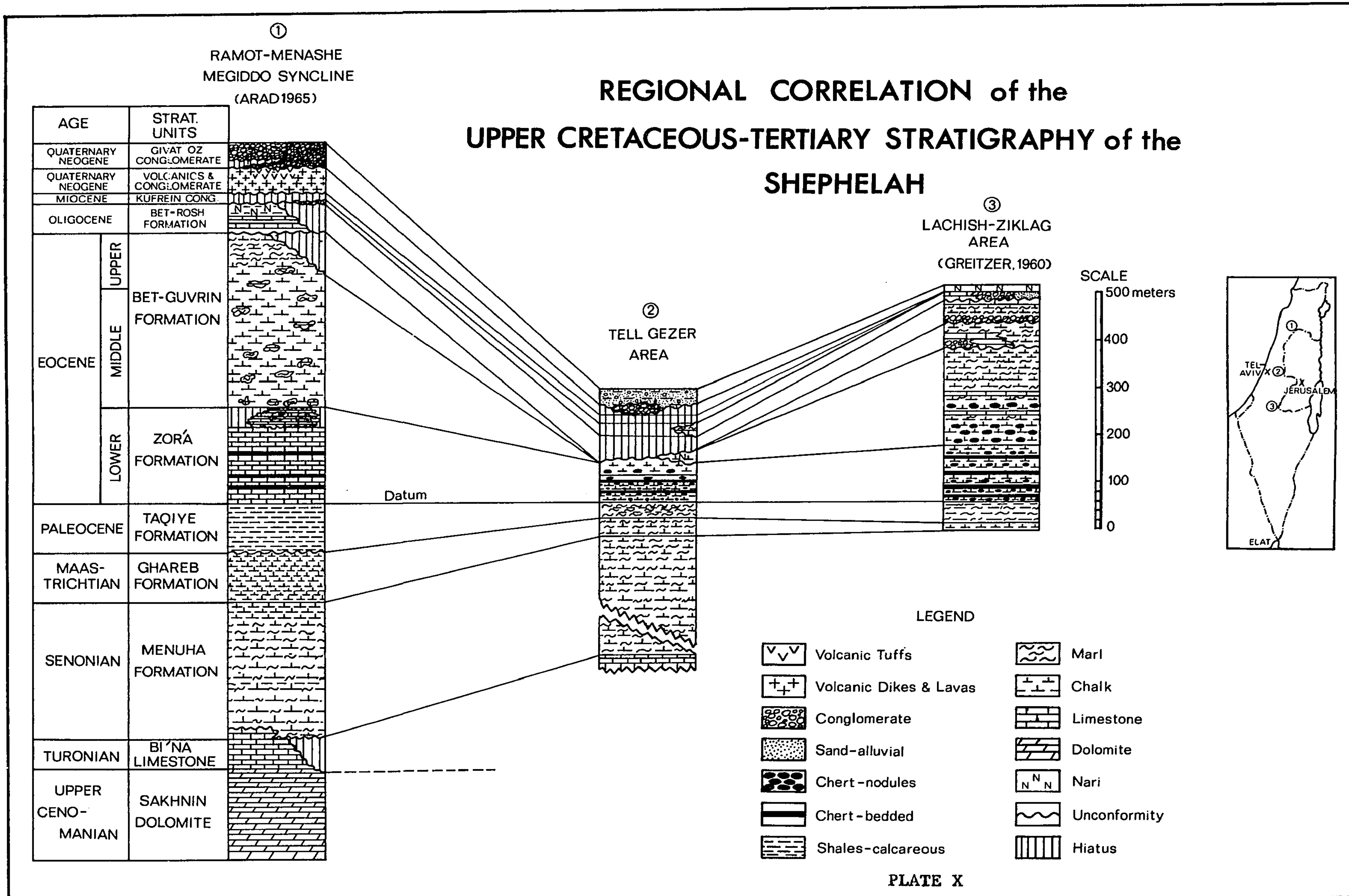

REGIONAL CORRELATION of the
UPPER CRETACEOUS-TERTIARY STRATIGRAPHY of the
SHEPHELAH
①
RAMOT-MENASHE
MEGIDDO SYNCLINE
(ARAD 1965)
AGE
STRAT. UNITS
QUATERNARY NEOGENE
GIVAT OZ CONGLOMERATE
QUATERNARY NEOGENE
VOLCANICS & CONGLOMERATE
MIOCENE
KUFREIN CONG.
OLIGOCENE
BET-ROSH FORMATION
EOCENE
UPPER
MIDDLE
BET-GUVRIN FORMATION
LOWER
ZORÁ FORMATION
Datum
PALEOCENE
TAQIYE FORMATION
MAAS-TRICHTIAN
GHAREB FORMATION
SENONIAN
MENUHA FORMATION
TURONIAN
BI'NA LIMESTONE
UPPER CENO-MANIAN
SAKHNIN DOLOMITE
②
TELL GEZER
AREA
③
LACHISH-ZIKLAG
AREA
(GREITZER, 1960)
SCALE
500 meters
400
300
200
100
0
TEL-AVIV
JERUSALEM
ELAT
LEGEND
Volcanic Tuffs
Volcanic Dikes & Lavas
Conglomerate
Sand-alluvial
Chert-nodules
Chert-bedded
Shales-calcareous
Marl
Chalk
Limestone
Dolomite
Nari
Unconformity
Hiatus

PLATE X

THE STRUCTURE OF THE SHEPHELAH

The earliest deformation in the area of the Shephelah is a Late Turonian to Early Senonian folding, the evidence of which may be observed in the wadi Aijalon 4.5 km N8°E of Tell Gezer (coordinates 143/145) where the following dips were measured on the Bi'na Formation:

	Strike	Dip		Strike	Dip
1)	N32°E	28°NW	3)	N28°E	30°NW
2)	N36°E	25°NW	4)	N31°E	23°NW

Senonian strata overlie the dipping Turonian units unconformably.

Following this Upper Cretaceous deformation, epeirogenic subsidence initiated normal open marine conditions until minor uplift occurs in Early Maastrichtian time (evidence to the north in the Carmel Uplift). Middle Eocene events are punctuated by unconformities (Figure 22) locally, and a spectacular transgression in the Negev where sediments deposited during this time overlie older formations on which deep red lateritic paleo-soils have developed (Bentor and Vroman, 1957). Near the northern limit of the Shephelah, reef facies deposits (Sanin Lentil) are partly unconformable on the Lower Eocene sequence (Arad, 1965), indicating shallow platform stability.

Post Middle Eocene sediments are almost entirely missing from the Gezer area. Local joint patterns in the Lower Eocene exhibit a microstructure which indicates a post-Middle Eocene strain resulting from the northwest-southeast compression component (Figure 23). It is the same direction of deformation which produced the Neogene-Quaternary folded uplift of the central mountain belt.

GEOLOGIC HISTORY OF THE SHEPHELAH

The lithology and fauna of the Cenomanian of the Shephelah are similar to the deposits of this time uplifted and exposed in the Judean Mountains. The presence of reef builders and dinosaur tracks in a partially dolomitic sequence indicate that the sediments were deposited in a shallow neritic to intertidal, warm marine environment, trending toward hypersaline waters as suggested by the prevalance of dolomitic rocks (Wells, 1962; Friedman, 1964). Upper Cenomanian volcanism marks the Umm el Fahm syncline of the Carmel Uplift as the only area of Late Mesozoic extrusive activity. Tectonic adjustment with minor folding and faulting, constitutes the initial orogenic phase of that province.

Turonian age deposits in the Shephelah and the Judean Mountains exhibit a change of sedimentation from mostly dolomite to mostly limestone. Structural adjustment initiated conditions of circulation with the open marine waters and a cessation of the hypersaline conditions which deposited the dolomitic rocks. The Turonian fossils (Bi'na Formation) are essentially benthonic (cf. Figure 11a).

Following a folding event, the sediments of Lower Senonian time include predominantly pelagic formainifera (Globigerinella and Guembelina) which suggest marine transgression and a deepening of the waters in the area of the Shephelah.

The Senonian-Maastrichtian transition reflects the tectonic activity which was most intense during Late Turonian-Early Senonian time. The minor, local unconformities between the sediments of the former stages attest to continued adjustment. Moreover, Upper Cenomanian sediments show a decrease

Figure 22. Angular unconformity within the Middle Eocene of the Shephelah 2 km south of Tell Gezer. This angular relationship illustrates the positive movements which were occurring intermittently to the east since Late Crètaceous time resulting in the uplift of the Judean anticlinorium. The unconformity illustrates one of the regressive phases of the Eocene flooding of the eastern margins of the Tethyan Basin - final phases of full marine flooding of the western margins of the Arabian Massif. A cave of unknown date is cut just beneath the on-lapping chalk sequences.

The general barren character of the central Shephelah is due to the absence of any substantial soil cover. Historical and stratigraphic evidence (see below) suggests that this condition is only a late historical feature of Israel.

in the number of pelagic foraminifera with a corresponding increase in the benthonic forms (Issar, 1938). The conditions established in Early Maastrichtian time continue essentially unaltered to the onset of the Paleocene Epoch when the area became flooded with clays and fine carbonates rich in planktonic foraminifera. Conditions of the Paleocene continued but with marked changes of the character of the sediment.

Lower Eocene foraminiferal assemblages are mainly pelagic and marked out by an abundance of silica, perhaps derived from the skeletal material of the silicious fauna (see Figure 17a). A major transgression has been observed in the Megiddo Syncline at the beginning of the Eocene locally producing a deeper water environment (Arad, 1965; Issar, 1958; Sass, 1968).

The most significant tectonic event in the Gezer area occurred during Middle Eocene time when the Lower-Middle Eocene chalks were mildly folded and faulted and uplifted (Figures 22 and 23). During this time submarine currents from the eastern neritic area carried bioclastic sediment into deeper water depositional sites. The Middle Eocene is the last major flooding, yielding deeper marine cratonic shelf deposition in the eastern Tathys. Regional uplift and regression mark the end of the Middle Eocene. Local and marginal transgression of shallow marine waters occurred throughout the Late Eocene and Oligocene.

Differential tectonic adjustment later resulted in the incursion of marginal seas locally from Upper Middle Miocene time when denudation, faulting, and volcanic activity persisted in the southern Coastal Plain area. This volcanism was only a minor expression of the extrusive activity

Figure 23. Dominant joint trends in the Lower Eocene strata flanking Tell Gezer on the east at the 186m level. Strain elipsoid resolution of these joint matrices suggest a N60W orientation of maximum stresses during Eocene time. The deformational joint cracks are filled with Middle Eocene thanatacoenocic benthonic foraminiferal detritus. This together with the angular unconformity as illustrated in Figure 22 provides a basis for partial understanding of the forces at work which eventually led to the retreat of the Eocene Tehtyan seas and the initial uplift of the Judean highlands and the structural warping of the Shephelah region (cf. Plate VI).

TABLE II LITHOLOGIES USED HISTORICALLY AS BUILDING STONES

Traditional Terminology	Lithologic Description and Provenance
KURKAR	S. Lowengart (1928). Zur Geologie der Kuestenebene Palaestinas. Centralbl. f. Miner, etc., Abt. B. A local name adopted by S. Loewengart for cross-bedded calcareous sandstones deposited under continental or marine conditions and widely distributed in the Coastal Plain. Kurkar is the main component of several ridges of hills running parallel to the Mediterranean Coast line, showing by their steep landward slopes their origin from dunes.
MELEKE	O. Fraas (1897). Aus dem Orient I Teil: Geologische Beobachtungen am Nil, auf der Sinai Halbinsel and in Syrien. Stuttgart. The term, Meleke (Arabic: Royal), originally a stone masons' term, was introduced into geologic literature by O. Fraas to denote a stratigraphic horizon of late Cenomanian or Turonian age. The term has since been used repeatedly to denote various stratigraphic horizons; thus L. Picard (1938) called his horizon 12c near the base of the Upper Cenomanian in the Jerusalem area, "Meleke of the Upper Cenomanian". The term is now generally used to denote a white, coarse grained, granular to spathic limestone. These rocks represent partly re-crystallized rudist limestones, partly re-crystallized reef breccias, or simply coarse grained diagenetic limestones. This rock type, which is readily dolomitized, appears in all parts of the country at various stratagraphic horizons, and particularly in strata of late Cenomanian and Turonian age.
MIZZI (MISSI, MISSIH)	O. Fraas (1867). Aus dem Orient, I. Teil: Geologische Beobachtungen am Nil, auf der Sinai Halbinsel und in Syrien, Stuttgart. The term, Mizzi (from the Arabic: excellent building stone) was adopted by O. Fraas from the stone masons' language, to designate a sequence of smooth, dense limestones of Turonian age. This rock type, generally referred to as Mizzi Helu is widely distributed in the country in strata of Cenomanian, Turonian, and Eocene age. Various other types of Mizzi, e.g., Mizzi Ahmar, Mizzi Yehudi, Mizzi Ahdar, are mentioned in the literature.
MIZZI AHDAR	Picard (1938). Synopsis of Stratigraphic Terms in Palestinian Geology, Bull. Geol. Dept. Hebrew Univeristy, Vol. 2, No. 2. A local stone masons' term (Arabic: green hard stone) used for a green apatitic, crystalline limestone occurring at Beit Sahur near Bethlehem, in the phosphatic limestone sequence overlying the flint beds of the Mishash Formation. G. S. Blake (1935) describes a bed of red marble, 3m thick, overlying flint beds and followed by 2m of green marble (Mizzi Ahdar). Regarding the flint of Maestrichtian age, G. S. Blake attributed the same age, though with reservations, also to the overlying phosphatic crystalline limestones, including the Mizzi Ahdar. The phosphatic sequence at the top of the Mishash Formation is according is Z. Reiss (1955) and A. Parnes (1956) of Campanian age.

MIZZI AHMAR	M. Blanckenhorn (1905). Geologie der naheren Umgebung von Jerusalem. Zeitschr d. Deutsch. Palast. Ver. vol. 28, Leipzig. Under local stone masons' term (Arabic: red hard rock) Blanckenhorn describes two distinct rock types: a red spotted limestone (Fleckenmarmor) occurring together with Der Jasini platy limestone; and a red, crystalline limestone underlying immediately the Meleke crystalline limestones. Picard (1938) however, applied this term exclusively to the sequence of reddish-colored dolomitic limestone underlying the Meleke and overlying the dolomites and dolomitic limestones called Mizzi-Yehudi. The thickness of these beds is approx. 35m. Picard (op. cit.) placed the Mizzi Ahmar into the Cenomanian.
MIZZI HELU	See Mizzi
MIZZI YEHUDI (JEHUDI, YAHUDI)	M. Blanckenhorn (1905). Geologie der naheren Umgebung von Jerusalem. Zeitschr. d. Deutsch. Palast. Ver., vol. 28, Leipzig. This name was adopted from a local stone masons' term by M. Blanckenhorn to disignate part of the sequence called by him Unterer Mizzi in the neighborhood of Jerusalem. M. Shalem (1925) pointed out that the M.Y. is a rock sequence of well defined stratigraphic position overlying the Der Jasini of the Jerusalem area. He placed it into the Upper Cenomanian and determined the following fauna: *Pileolus* cf. *sphaeruliticum* Blanck., *Nerinae cochleaeformis* Conr., *Hastula frassi* Boehm., *Voluta* cf. *algira* Coq., *Cerithium elias* Boehm., *Cytherea* (*Coryatis*) aff. *turgidula* Stol., *Pecten* (*Neithea*) shawi Perv. G. S. Blake (1935) rejected the name of M.Y. as a stratigraphic term and stated that rocks of the M.Y. type are also quarried from higher layers, such as the Mizzi Ahmar. Picard (1938) called his Horizon 9 of the geological section of New Jerusalem "Mizzi-Yahudi of the uppermost Cenomanian" and gave its thickness as 100m. The term, M.Y., as now generally used, designates a hard, granular, gray to dark gray dolomite. Rocks of this type occur all over the country in different parts of the Cretaceous sequence, and locally also in strata of Jurassic age.
NARI	M. Blanckenhorn (1905). Geologie der naeheren Umgebung von Jerusalem. Zitschr. Deutsch. Pal. Ver., Vol. 28. The term, Nari (Arabic: nar-fire, alluding to its use in lime-kilns), was first introduced by M. Blanckenhorn to designate a calcareous surface caliche. The nari is a surface, or near-surface, alteration of permeable calcareous rocks, developing in the dryer parts of the Mediterranean climatic region, through the combined effects of dissolution and redeposition of calcium carbonate. The rock is distinguished by a fine network of veins, surrounding frequently unreplaced remnants of the original rock. The nari often contains clastic rock particles such as flint, hard limestone or dolomite and locally shells of sub-recent terrestrial gastropods. The nari crust, which reaches a maximum thickness of at least 6m developes preferentially on Cretaceous and Tertiary chalks including the chalky cementing material of conglomerates. It is thus widespread in Galilee, Mt. Carmel, the Shephelah, the

	Judean and Shomron Mountains. The nari cover is absent in the Negev, except over limited areas west of Metsada, and near Rosh Ramon. Both these areas have now a highly arid climate.
NUBIAN SANDSTONE	J. Russeger (1845-1849). Reisen in Europa, Asien und Afrika, Stutgart, 4 Vol. A thick predominantly sandy sequence, mainly of terrestrial origin characterized by its intensive and variable colours and composed mainly of fine to coarse grained, sometimes gritty and conglomeratic, frequently cross-bedded, mainly soft but occasionally very hard, sandstones, mostly imperfectly cemented by small amounts of argillaceous, ferruginous or quartzitic material. The sequence also includes layers and lenses of silt, sericitic sandy shales and white, predominately kaolinitic, clays. Ferruginous dikes, incrustations, etc., are frequent. The sequence may reach a thickness exceeding 600m and is widely exposed along the northern and western margins of the Arabian Shield in Israel and the neighbouring countries; it occurs also in the breached cores of the anticlines in the Central Negev and, in small outcrops farther north, up to the Lebanese border near Ramin (Manara). The N.S. interfingers repeatedly with marine sediments which become progressively more prominent with increasing distance from the Precambrian basement. The Geological Survey of Israel uses the term N.S. as a rock-type name for sandstones showing the characteristics mentioned above. In this definition most Nubian Sandstones are of fluviatile to aeolian origin, some are lacustrine, and a few represent continental sandstones redeposited in the area near the shores during the various Paleozoic and Mesozoic transgressions. These show frequently calcareous cement. Otherwise they are undistinguishable from Nubian Sandstones of continental origin. The age of most Nubian Sandstones in Israel ranges from Lowermost Cambrian to Cenomanian. Nubian Sandstone of continental origin are unfossiliferous, except for frequent plant remains not yet determined.

Modified from Bentor, 1956

activity which continued on into Recent time to the northeast of the Shephelah area. Plio-Pleistocene folding renewed earlier deformational trends and structurally elevated the central foothills area. Intense Pleistocene degradational processes continued into the Holocene. Present erosional activity is going on at a considerably lower rate.

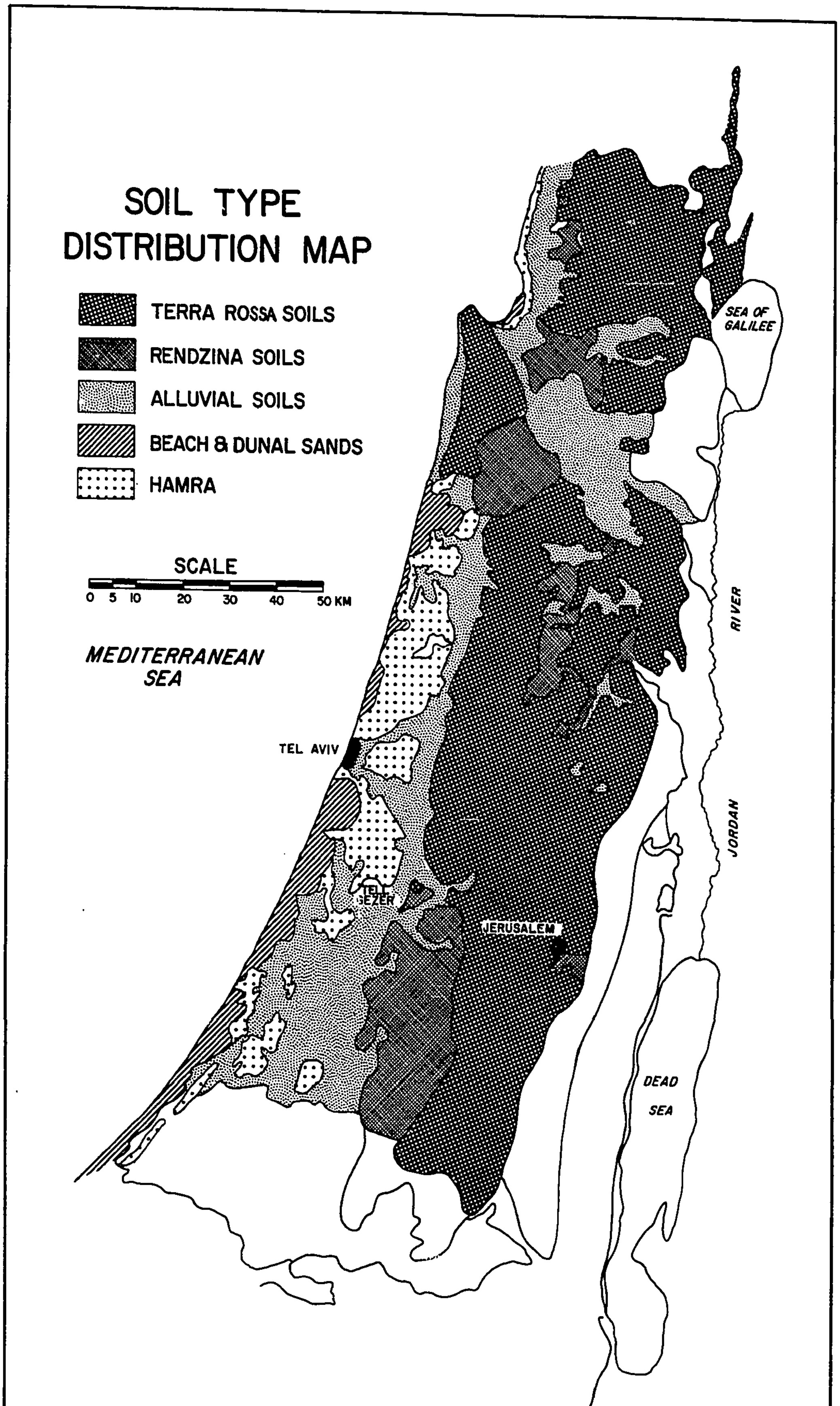
CHAPTER III

THE GEOCHEMISTRY OF THE SOILS AND SOIL CLAY MINERALOGY OF THE GEZER ENVIRONMENT

> Soils, therefore, are rocks or rather they are rocks which have been altered due to exposure at the earth's surface. They are records of the minor cycles of erosion and stability between the larger geologic cycles, and also of the environment during the periods of stability when soil formation took place. They are formed on hard rocks and on unconsolidated sediments, and they are the source material for other sediments and soils formed during the subsequent cycles of erosion and stability. (Brewer, 1964)

The term, soil, usually has a considerably varied meaning when it is used by an archaeologist, by a civil engineer, by a farmer, and by a geologist. A pedologist regards the soil as that earth material which has been altered and acted upon by physical, chemical, and biological agents to the extent that it will support rooted plants. The archaeologist may use the term soil to mean any very fine grained sediment or horizon in the excavation which has color as its only distinguishing feature (and when removed by excavation it becomes spoil! Kenyon, 1962, p. 111). In this study a soil constitutes the weathered material on or at the earth's surface representing the altered parent material. A soil may be residual or transported.

The interaction between the atmosphere and the bedrock of the southern Levant produces a more or less unique weathered material. A Cca zone analogous to the caliche typical of the semi-arid western United States blankets much of the soft carbonate bedrock of Israel. The amount and thickness of this weathered zone depend upon the nature of the bedrock upon which it is formed (Figure 24a).



MODIFIED FROM ATLAS ISRAEL (1955)
BASE MAP

Plate XI

The role of mutually independent pedogenic factors is critical in the generation of nari: 1) the soil climate, 2) the soil relief, 3) the soil biological regime, 4) the initial parent material, and 5) the time involved (Rim, 1954). Parent rock plays an important role in the soil formation of the Levant. Experiments by Ben-Yair (1960) have laid the foundation for an understanding of the reddish-brown "terra rossa" soils which formed mostly on compact and nonporous carbonates. Grayish-brown calcareous soils, the rendzinates, on the other hand, form with a very pronounced Cca transition zone upon the soft bedrock lithology.

Nari

Nari develops by terrestrial weathering under conditions of the Mediterranean climate (Figures 24a and b).

While there is no significant difference in the solubilities of hard and soft carbonates, the low permeability and high water capacity of the soft calcareous rocks, e.g., chalks, permits these rock types to retain a portion of the moisture received during the winter time. During the relatively arid summer, this moisture is released through capillary action and evaporation, promoting the upward movement of water saturated with calcium carbonate which is deposited in the upper portion of the bedrock. The thickness of the nari crust, therefore, is directly related to the permeability of the underlying base rock.

Nari may in part be produced by a biological agency. Krumbein (1968) has found in initial experiments that a well-developed microflora exists on desert caliches and may be involved in increasing

Figure 24a. Nari - a caliche-like $CaCO_3$ concentration which blankets much of the soft, porous carbonate deposits in Israel. Nari is the peculiar surface expression of the Eocene chalk formations of the central Shephelah. This weathering phenomenon represents the solution and precipitation of as much as three times its thickness in fresh rock material (cf. insoluble residue values of nari and the parent chalk below). The hardness and durability of the nari residue blanketing the softer chalk horizons beneath is illustrated in this doline (solution collapse pit) on the northern slope of the highest hill of the Eocene outlier north of the wadi (nahal) Sorek. Most of the local caves form at the nari-bedrock contact.

Man's extensive use of this indurated chalk material was observed throughout the Gezer archaeological stratigraphy from the Early Bronze to the Roman habitation. It was the structural material of the modern village of Abu-Shusheh prior to its destruction in 1948. The use of nari is understandable in the light of the absence of more durable lithologies in the Shephelah area. The Shephelah is flanked by the soft Senonian chalks and marls on the east and the friable coastal sands on the west. Even the fossilized dunes of the coastal Kurkar do not match the durability of quarried and dressed nari.

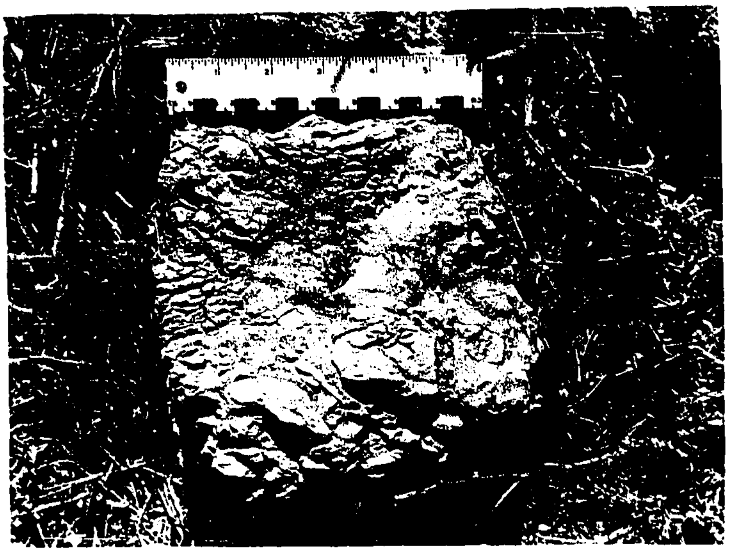


Figure 24b. Weathered block of nari in the talus apron of mass-wasting debris on the southern slope of Tell Gezer. Note the pronounced effect of the solution-concentration of relatively insoluble components of the parent chalk material. The more siliceous fractions of the parent material remain as a quasi-insoluble residue, while the more soluble carbonate materials are removed in the process of "caliche" formation. The nari frequently takes on an appearance of a highly disturbed and brecciated lithology. But the formation of a high concentration of insoluble components can be observed to grade downward imperceptably into the unaltered chalk levels below in the many man-made cuttings which penetrate this hard crust: the Gezer water tunnel, Hellenistic and Roman tombs, and a number of artifactual and natural caves.

the $CaCO_3$ concentration. The migration of the Ca^{++} may result from chelating substances generated by algae, lichen, and bacteria. Thin section studies of nari have shown the presence of such flora which may in part be responsible for its formation.

Results from chemical analysis show that the clay component, i.e., the insoluble residue, first decreases from the base rock upwards and then increases in the secondary compact crust; the percentage of carbonate increases in the nari, but again decreases in the compact crust. The nari, while having a characteristic structure, lacks a typical chemical composition (cf. Table VI).

A cyclic solution - precipitation process yields an upper horizon enriched in clay. Compact encrustation develops by pore filling and cementation in the soft carbonate. Below this crust the crystals become enlarged and interwoven composing the lower nari. The same weathering cycle, when acting on non-permeable rocks promotes the formation of terra rossa soil and of the fissured rocks characteristic of karstic areas. The more indurated carbonates weather along joints and bedding planes, and are unable to store quantities of water sufficient to give rise to nari formation. Thus "the distribution of nari and terra rossa or karst are mutually restrictive." (Goldberg, 1959)

A similar phenomenon is considered the basis of the formation of Kurkar, or eolionites ("fossilized" or fixed sand dunes). Previously regarded as formed under Pleistocene pluvial conditions, recent research (Yaalon, 1967) shows that fixation of the coastal sand dunes is controlled by the calcium carbonate content (must be at least 8%) (cf. Table VI). The amount of solution is determined by relief and by microclimatic conditions that operate on the dune itself.

The semi-arid conditions of the southern Levant yield a high rate of evaporation from open bodies of water during the summer months (75mm per day, Stanhill, 1963). The annual precipitation at Lod near Gezer is only 105mm annual average, (Amiran and Gilead, 1954). The imprint of climatic conditions on the mineralogical content of the alluvial soil load of streams has been shown by Ehlmann (1968). Areas of high rainfall with resultant high leaching yield halloysite or kaolinite mineralogy, while areas of low rainfall and partial leaching yield montmorillonite mineralogy. The local climate, therefore, has had a dominant role in the formation of nari and in the soil mineralogy.

Rates of weathering yield useful data in the archaeological context. In the absence of controlled ceramic evidence, incipient soil formation may give information for the estimation of an occupational hiatus (Plate XIV-C, diagram E). Yaalon (1963) argues that the rate of weathering of limestone in Israel is of the magnitude of 10mm per 1000 years. He cites a rate of 6-10mm/10^3 years for similar bedrock in southern France and in North Africa; and a rate of 60mm/10^3 years in the humid karst of Yugoslavia. If this rate is, in fact, a close approximation to actual occurrences, it has considerable implication in the study of the non-occupational strata of an archaeological site.

The role of topography is seen in the relict soils or those formed under situations which have since been altered. Among numerous examples, the pseudogley swampy soils found on erosional remnants of the Coastal Plain north of the Yarkon River are typical. The swamps have been drained since Roman time but the soils retain a composition indicative of their origin (Dan, 1964).

Analytical Procedures

Immediately superjacent to the nari of the central Shephelah is the B soil zone, typically rendzinate in character (Figure 25a and b). Research on this soil and the associated soil clays of the Gezer area yielded X-ray diffraction maxima which were intially unfamiliar to the writer. The familiar illite, montmorillonite, kaolinite, and chlorite reflections were found, but new maxima occurred at 10.58, 6.44, 4.49, 3.23, and 2.62A. This data corresponds to palygorskite values (Brown, 1961). Standard curves subsequently prepared indicate palygorskite occurrences equaling about one-half the total clay composition of the soils and alluvial clays in the central Shephelah area (Plate XIV-C).

X-ray diffractograms of the clay fraction of the bedrock, of the clays of the alluvial, colluvial, and residual soils were analysed using a General Electric X.R.D.5 Diffractometer, with FeK α (Mn-filtered) radiation (λ = 1.93597A). The high calcium carbonate content of many of the samples examined in this report necessitated special retreatment to facilitate identification. Duplicate samples were analysed one with and one without the following treatment: very

Figure 25a. The first bedrock encountered in the modern Tell Gezer excavations under undisturbed or virgin soil (Field I, Area 10). This lithologic section shows the interface between nari and the rendzinate soil which is generated above (tan-to-brown zone). This interface is of particular interest because of the ubiquitous deflation of virgin soil from the nari-bedrock surface throughout the central Shephelah.

dilute (1:10) HCl was slowly added to a suspension of the finely divided sample in deionized water with continuous agitation. The pH was held at a level above 5.8 to preclude partial solution of the moderately soluble palygorskite. The residues were washed by decantation to the point of no flocculation and were then sedimented onto glass slides which were run on the diffractometer at a rate of $2^{o}\ \theta$ per minute. Estimated amounts were based on diffraction-peak height ratios in parts per 10 determined from mixtures of American Petroleum Institute standards prepared from illite, attapulgite, keolinite, and montmorillonite obtained from Wards Scientific Supply Co. Standard mixtures were used to obtain the relative reflection intensities for an estimation of approximate mineral content. The result are summarized in Plate XIV-C.

Soil, clay, and ceramic analyses were also carried out by means of X-ray fluorescence spectrometry, wet chemical and optical absorption techniques, differential thermal analysis, and by use of the petrological microscope. This study was conducted along a number of lines which might yield data concerning the origin of the ceramic material.

The X-ray fluorescence spectrometry utilized the techniques of Price and Angell (1968) who had demonstrated the operational feasibility of the determination of minor elements in powdered rock samples by thin film techniques. Rock samples and standards were ground in mullite to pass 200 mesh sieve. The powder was uniformly brushed onto the adhesive side of Scotch-brand "Magic Transparent Tape", which was then pressed into the adhesive between two lucite blocks at 5000 lbs per sq. inch.

The sample was subsequently mounted on a 1/4" lucite block and inserted in the sample holder with its adhesive side up. The analysis was performed on a General Electric XRF-5 spectrometer using platinum-λ radiation at the 35KV, 25MA level with a lithium fluoride analyzing crystal in air. Blank readings (by counting for given time intervals) were measured on unmounted adhesive strips at the selected characteristic radiation for each element. A 1:2.5 talc to kaoline matrix was prepared to which the metallic exides were added in the preparation of standards.

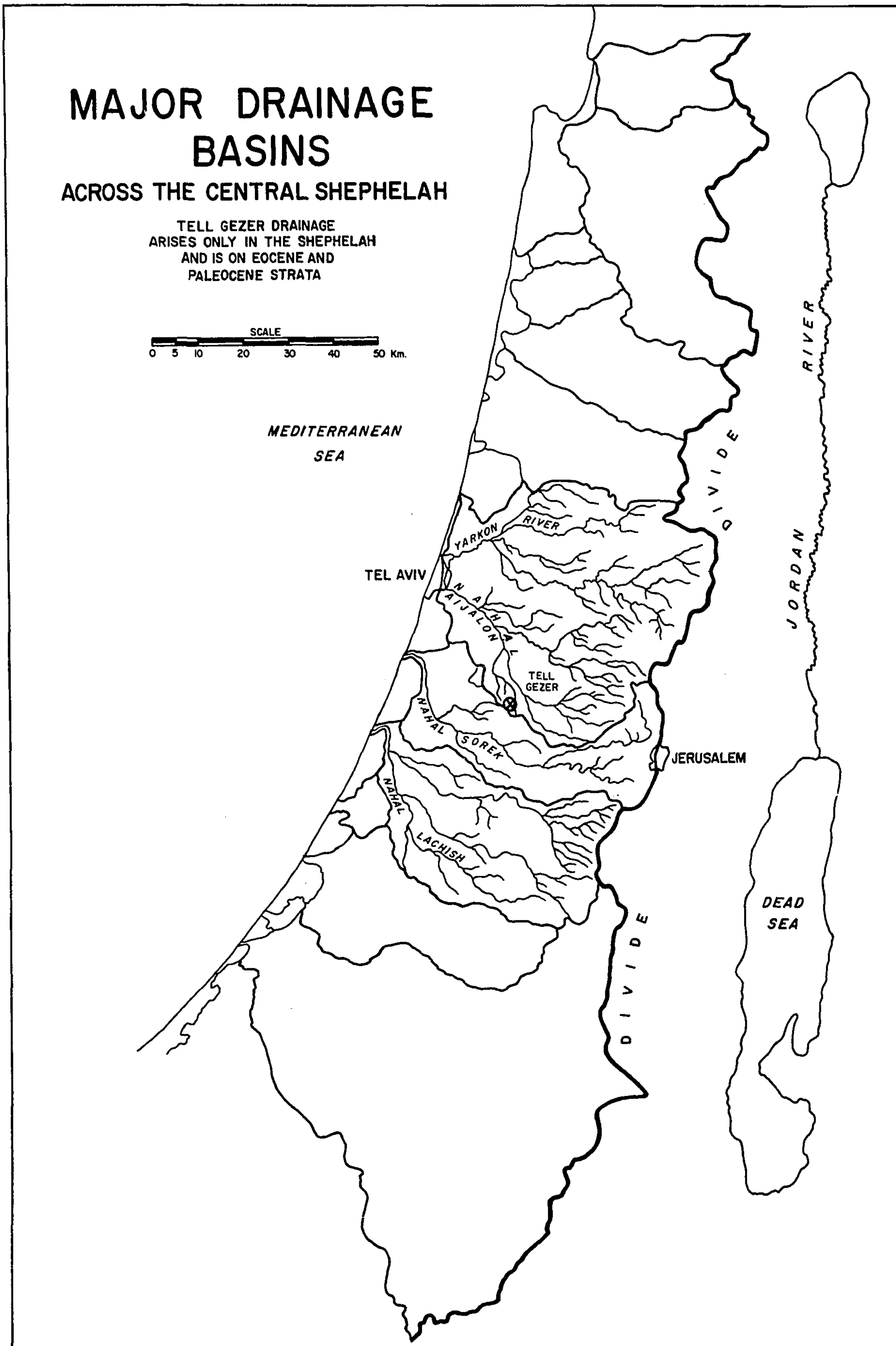
Elements were estimated at the following radiation:

	Zr $K\alpha$	Sr $K\alpha$	Cu $K\alpha$	Fe $K\beta$	Mn $K\alpha$	Ti $K\alpha$	Ca $K\alpha$	Ni $K\alpha$
Lif-2θ=	22.6	25.15	45.2	51.78	63.45	86.2	113.15	48.65
Pulse hgt.	El-15	El-5	El-1	El-1	El-0.3	El-0.2	El-0.2	El-1
Selection	Eu-3	Eu-12	Eu-7	Eu-8	Eu-5	Eu-8	Eu-2	Eu-8

Geochemical analysis data is summarized in Plate XIV-A.

Boron estimation was run by a sodium carbonate fusion, sulphuric acid digestion procedure, to which a measured quantity of dilute HF was added. After overnight digestion, the BF_4 was complexed with methylene blue and extracted with 1,2 dichloroethane. Absorbance was read at 660mu using a Beckman Model DU Spectrophotometer. Boron estimations are summarized in Plate XIII.

Heavy mineral determinations were made on the ceramic materials from material collected on a 230 mesh sieve for optical and oil immersion study. Most of the ceramic temper studies were carried out on thin sections made from available potsherds. The results are summarized on Table V.



MODIFIED FROM ATLAS ISRAEL (1955) BASE MAP.

Plate XII

Rendzinate Soil

The origin of the palygorskite component of the renzinate soils of the Shephelah may be inferred from other sedimentalogical data. The possibility of neoformed palygorskite derived pedogenically has been raised by Heuvel (1966). He argues that thin section relationships and soil zone isolation are reasonable evidence to conclude that sepiolite and attapulgite (=palygorskite) crystallize in the soil during a period of caliche formation in the calcareous zone of soil formed on a relict basin-fill plain in Dona Ana County, New Mexico. He considers that the absence of sepiolite below the carbonate zone and its strict association with the calcite make it improbably that the sepiolite was inherited from a soil parent material.

The concensus of pedologists is that soils produced from limestones or dolomites are the result of the accumulation of their non-carbonate fraction. There is no agreement, however, about the degree of change which may occur in this insoluble residue during soil formation. Reifenburg (1936) regarded rendzinate soils as essentially the insoluble residue from the parent material. He considered terra rossa soils to represent considerable modification of the non-carbonate fraction with a neoformed clay mineralogy not inherited from the parent bedrock. Yaalon et al. (1966) pointedly state,

> It can be shown that soils originating from limestone essentially represent the non-carbonate portion of the parent rocks. The differences between such soils can be attributed to the nature of non-carbonate residue of the limestones . . . Furthermore; it appears that in the Mediterranean climate the non-carbonate residue undergoes only minor changes during soil formation.

The data in the present research confirms this contention. The rendzinate soils appear to be essentially the insoluble residues of the carbonate parent material (Plate XIV-A,B,C).

Considerable proofs for the authogenic character of the palygorskite and sepiolite in marine or brackish sedimentation have been set forth by Parham (1966). He argues for a sedimentary facies transition of the clay mineralogy from kaolinite as a nearshore deposition grading laterally into illite and chlorite with parallel montmorillonite and/or expandable mixed/layered day concentration reaching a maximum at the outer limits of kaolinite and illite deposition. Attapulgite (palygorskite) and then sepiolite dominate the clay mineral populations basinward. Nathan (1966) suggests the following origin for the clay mineralogy of the Upper Cretaceous-Lower Tertiary sediments of Israel: kaolinite - detrital; montmorillonite - partly detrital, partly neoformed; palygorskite and sepiolite - entirely neoformed. Gal (1966) states,

> The composition of rendzina soils, whose soft parent rocks are rich in clay and do not permit free leaching of carbonate, frequently closely resembles that of the parent rocks.

Bentor, et. al. (1963) consider the clay mineralogy of Senonian to Eocene formations as:

> A striking . . . occurrence of palygorskite in brackish-base sediments . . . . It is found in the regressive sediments of the uppermost Jurassic, and is widespread in the Senonian sediments and again in the Tertiary Sakie Formation. Although little is known about the conditions favoring the formation of palygorskite, this mode of occurrence, observed also in other parts of the world, indicates neoformation.

Figure 25b. Renzinate nari interface exposed along the military road cut near the eastern flank of the Eocene Shephelah to the southwest of the valley of Aijalon. This abrupt interface is everywhere characteristic of the bedrock-caliche-soil transition series in the portion of the Eocene strata of the central Shephelah observed. That this soil is not primarily a generation of new clay minerals can be understood from the fact that the clay mineralogy of the rendzinate soils generated on Eocene parent rock is dominantly palygorskite. While the subject of the origin of sepiolite is not finally settled, the palygorskite content of the insoluble residues of the Eocene parent rock strongly suggests that it is this residue which the nari yields upon the final solution of its siliceous components providing the source of these particular soils.

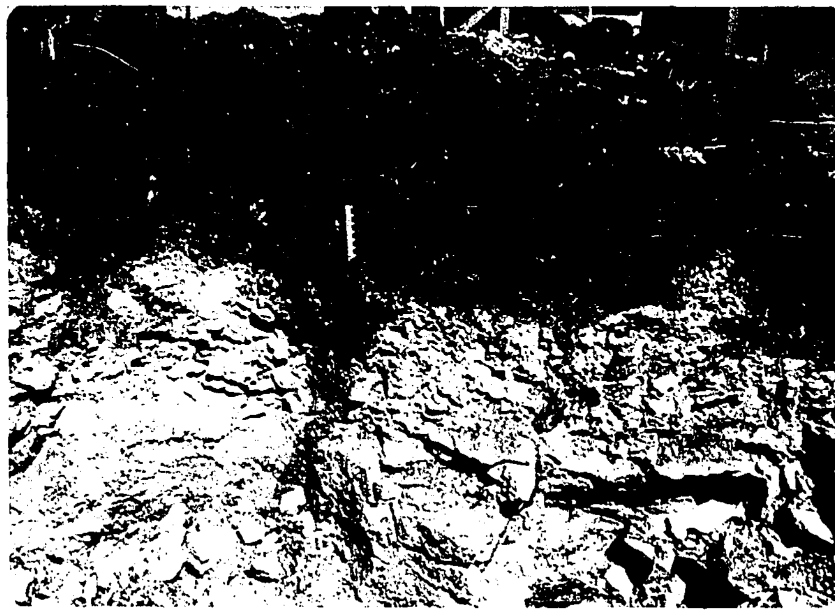


Figure 26. Maastrichtian chalk (in part marl) with its accompanying residual soil. This represents another phase of rendzinate soil formation. The demarcation between the parent bedrock and the soil product is not as abrupt as that observed on the Eocene chalk formations. It is not as gradational as that which occurs under the different climatic regime of the central temperate United States. The significant difference between the Eocene chalk and the Maastrichtian chalk and marl is that gradation from the parent rock material to the soil product is more subtle. More striking, however, is the absence of a caliche phase between the parent material and its soil. This characteristic is usually typical of the marl facies of the Senonian, Maastrichtian, and the Paleocene Series. It accounts for the topographic lows which the surface morphology of these sediments commonly exhibits.

Figure 27. Incipient rendzinate soil formation on the alluvial deposits on the floodplain of the wadi immediately east of Tell Gezer. The boron content of these soils suggests that much of the parent material is Paleocene marl. The partially altered or unaltered coarse aggregate of these floodplain deposits is nari derived from the hills of the Shephelah to the south in which the drainage net arises. Any utilization of the clay fraction of these alluvial soils would necessitate levigation to yield a usable clay. Miniature point bar deposits along the dry wadi bed were sectioned, revealing a pronounced sorting ranging from silt and very fine sand-sizes to very coarse sand-size particles. These sorted deposits provided the Gezer potters with abundant temper material as is illustrated by the "salt and pepper" temper of pottery suites ranging from Early Iron to Roman in age. (See Table VII for precise particle size designations.)

X

Figure 28. Artifactual dating of wadi Ain Yerdah floodplain deposits. The in situ occurrence of an Iron I jug handle (x) sets the depositional limit post quem for the overlying sediment. Subsequent deforestation of the Shephelah area initiated a period of rapid soil removal by water and wind. The thickness of the alluvium overlying the Paleocene bedrock of the floodplain very pointedly illustrates this fact. The marls underlie the jug handle at a depth of 0.21m, while the overlying alluvium has a thickness of 0.52m. Thus the post-floral denudation of the Shephelah has produced a greater sediment load for the wadi than all its pre-denudation erosional history, at least in this instance.

Pottery and Mud-Brick Source Material

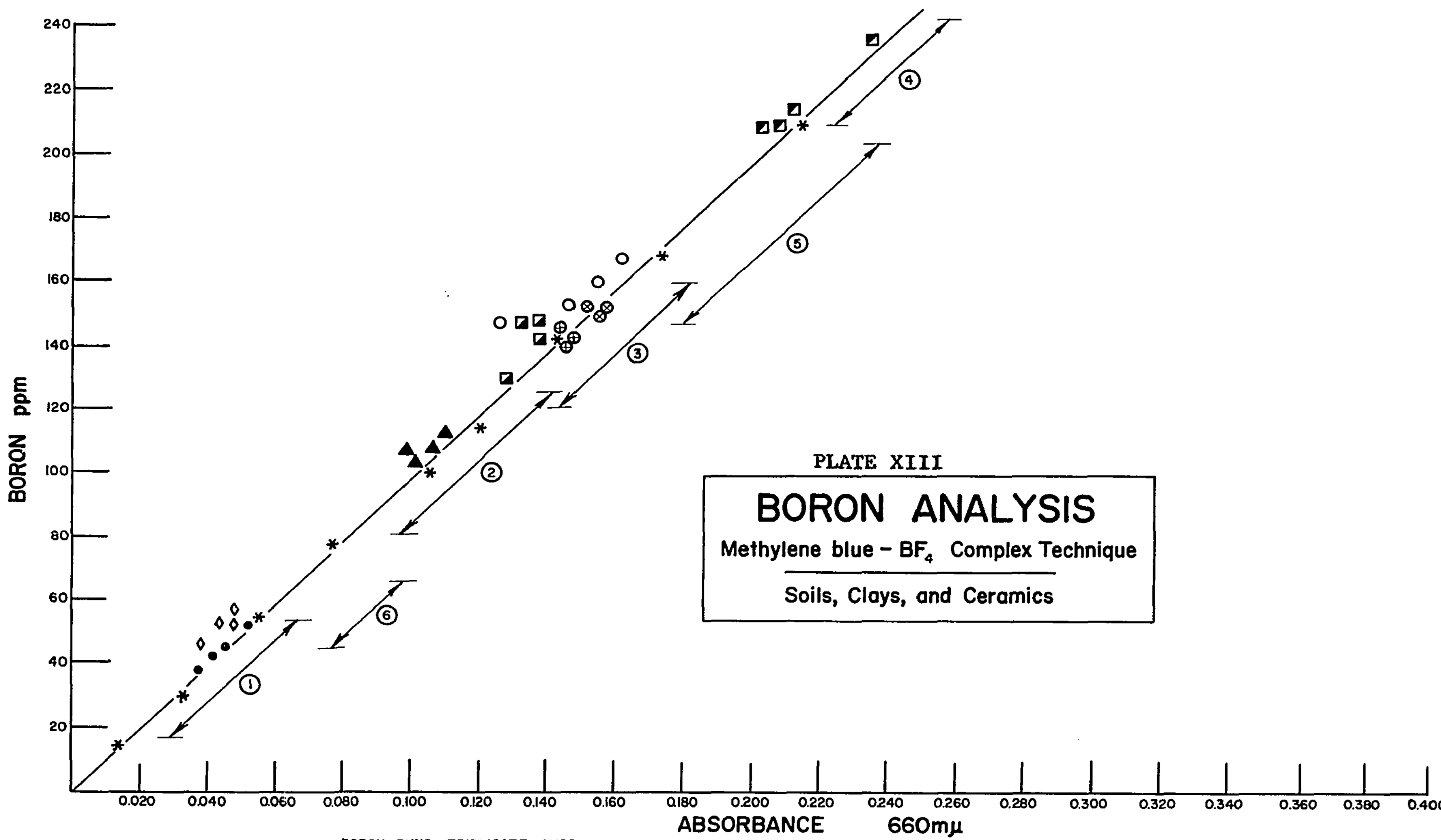
The character of the nari-rendzinate soil interface is abrupt and quite sharp (Figure 25b). The clays originating in the soil occur in the Gezer ceramics and mud bricks.

The marls, however, do not lend themselves to the same capillary action which occurs in the soft chalks of the Middle Eocene and the result is that soil-parent rock material interface areas are not as sharp (Figure 26). The clay mineralogy also appears in local ceramics and mud bricks.

As a part of the search for other potential pottery and brick material sites throughout the Gezer area in the central Shephelah, the alluvial soils and clays of the wadis were also sampled. A wet weather stream (Wadi Ain Yerdeh) arises in the Zor'a formation and flows northward, passes Gezer on the east, cutting into the Taqiye sediments (Figure 28). Its mineralogy shows surprising diversity in trace element content (cf. Plate XIV-A). Geochemical evidence supports the view that this deposit and that of the Nahal Aijalon were potential clay quarrying areas exploited by the inhabitants of Tell Gezer and their neighbors (Figure 29). A very extensive population of potsherds (1/5th of those studied) and mud bricks (1/2) have compositions which suggest these local sources. The analytical results of these and other source areas are tabulated in Plate XIV-A.

CERAMIC ANALYSIS

Pottery was the universal packaging medium of antiquity. In one sense, it is a man-made metamorphic rock. The essential nature of



BORON RUNS– TRIPLICATE AVGS.

- * CALIBRATION DETERMINATION (GRDC REF. STDS.)
- ⊕ BELLVUE SHALE, UNFIRED
- ⊗ BELLVUE SHALE, FIRED (945°–1190°C.)

GEZER STUDIES

- ● RENDZINATE SOIL CLAY – ZOR'A FM.
- ▲ RENDZINATE SOIL CLAY – TAQIYE FM.
- ◪ TERRA-ROSSA SOIL CLAY – BI'NA FM.
- ◩ TERRA-ROSSA SOIL CLAY – S.E. GALILEE BASALTS
- ◊ INSOLUBLE RESIDUE – ZOR'A FM.
- ○ INSOLUBLE RESIDUE – BI'NA FM.

CERAMICS

- ① TYPE I POTTERY + MUD BRICK
- ② TYPE II POTTERY + MUD BRICK
- ③ TYPE III POTTERY
- ④ TYPE IV POTTERY
- ⑤ TYPE V POTTERY
- ⑥ TYPE VI POTTERY

Figure 29. Soil formation on the Pleistocene alluvial clays and sands of the wadi (nahal) Aijalon 3.2 km north of Tell Gezer. The floodplain of the wadi Aijalon in this area is bordered on the north by a Pliocene alluvial conglomerate. While these soils and their clays were only very locally exposed prior to the quarry operation observed here, they do represent a potential source of pottery clay raw material for the Gezer potters. The alluvial clays afford an aluminum source for the cement industry. They are concentrated by the carbonate rich soil formation (Pedocal) observed in the soil profile above. These clays and sands are not characterized by a high $CaCO_3$ (9.6%). The subtle caliche zone is, however, apparent at the base of the rendzinate soil column and is marked by the typically stippled expression of the zone beneath the brown and overlying the red horizon.

Clay and ceramic study: Figures 30a and 30b. A ceramics firing study program in which the results of a particular thermal history of a ceramic raw material were investigated by differential thermal analysis, X-ray diffraction analysis, and for boron fugacity. The color variations are more faithfully reproduced in Figure a than in b, although the oxidation-color alteration is evident for each temperature level.

Figure 30a. Firing data: Bellevue shale quarried from 3.2m below the lowest C zone material in the garage excavation just east of the DAA building on the University of Cincinnati campus. This sample was used as a reference standard for the behavior of other marine clays from the Levant whose thermal character was studied. All samples were air dried prior to ignitions.

K .... room temperature, unfired
A .... 945°C
B .... 993°C
C .... 1040°C
D (J). 1115°C
E .... 1149°C
F .... 1190°C

Note that vitrification begins to occur at approximately 1040°C. All firings were conducted in an exidizing atmosphere.

Figure 30b. Rendzinate residual soil from the Shephelah immediately south of the Gezer threshing floor, sample locations 121, 122. All temperatures are degrees centigrade. Firing was carried on in an oxidizing atmosphere. Specimens in the 400 and 900°C ignition range bracket the temperatures used by most potters in the Gezer area prior to the Roman period (cf. text for analytical data). Low-fired pottery 400-550°C, medium fired pottery 550-750°C, high-fired pottery 750-950°C, very high fired 950°C, is the terminology of the writer.

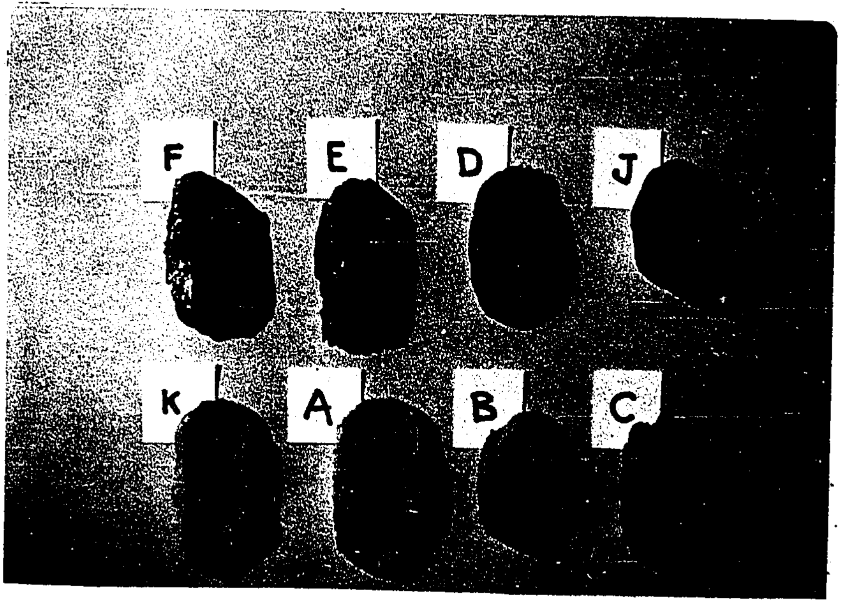


Figure 30a.

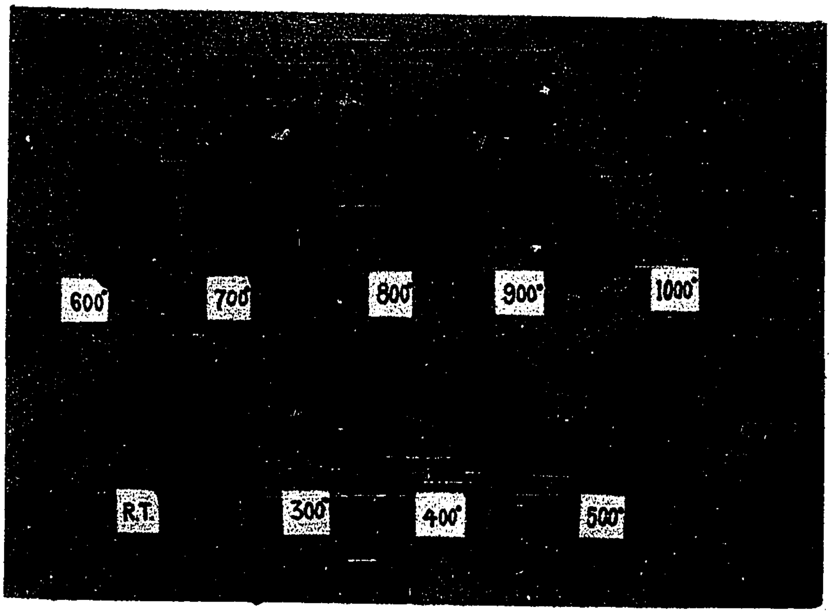
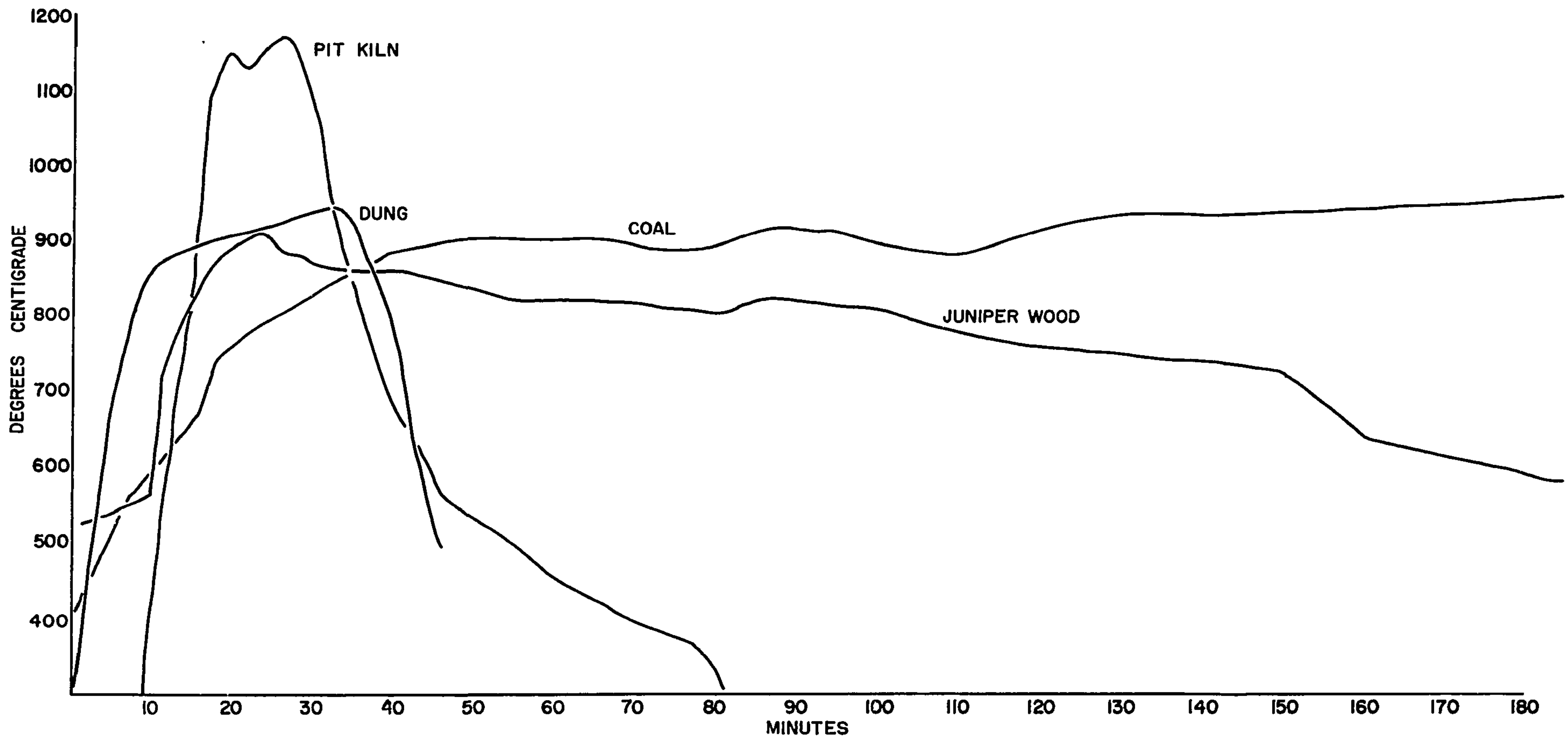


Figure 30b.



EXPERIMENTAL TEMPERATURE CURVES
FOR POTTERY KILN FUELS

(AFTER SHEPARD, 1965)

FIGURE 31

pottery readily lends itself to petrologic examination.

Preparatory Study

Preparatory to laboratory analysis, the question of physical and chemical mineralogical properties of unfired versus fired material was raised. A sample of shale from the Bellevue Formation was obtained from a University of Cincinnati campus construction site for the Brodie Science Center. The clay of this material was fired at different levels for purpose of ascertaining: 1) clay mineral alteration, 2) boron fugacity, and 3) vitrification level (mullite phase) (Figure 30a).

The firing studies indicate that there was no significant boron fugacity at any of the temperatures within the experimental range (Plate XIII).

A second firing sequence was carried out to obtain similar data from raw material immediately available to the Gezer inhabitants: rendzinate residual, colluvial, and alluvial soils. In addition to the visible color changes occurring through the temperature range, the water loss observed between 400-500°C produced a diffusion of the 10.58A reflection with similar modification of the other lines. This peak was still detectable until 800°C, after which it completely collapsed. The boron changes were low (Plate XIII). The increase was 2-7ppm throughout the range. The firings also revealed that ceramic quality meterial is available locally.

Extremes in ware contraction were often countered by the profuse use of temper. Initial calcium carbonate decomposition was

was noted between 600-700°, with all the entrained calcium carbonate particles decomposed between 900-1000°. Gas analysis showed no further CO_2 evolution from carbonate samples heated in this temperature range.

From the data obtained in the firing runs, it was possible to predict that palygorskite, illite, and montmorillonite peaks, however weak, would still be identifiable above the 550° level where kaolinite collapses and below 800° (ca. 770°) above which the mineral peaks no longer are characteristic. Thus only low to medium fired pottery yielded useful clay mineral data.

Stratigraphic studies conducted so far throughout the excavation of Tell Gezer have shown (cf. below) that the dominant fuels were in order of importance: dung and wood. On the basis of primitive American pottery making study, it has been demonstrated that dung can yield as successfully a ceramic product as any other fuel, and its high incidence in domestic occupational sediment ash suggests that it, too, was used by the potters. Figure 31 illustrates the temperatures available and times of burning for three different fuels, compiled from Shephard's data (1965). These results demonstrate essential heat available from this source of fuel.

<u>Sampling</u>

The primary aim of this research is to test the applicability of the analytical procedures of the geologist and geochemists to a definite archaeological context.

The area of ceramics is an excellent one in which to test the application of these methods. This is especially true inasmuch as

Figure 32a. Ceramic analysis: some examples of pertinent Late Bronze II potsherds bearing significant morphological identity. Note that these are examples of either rim or base portions of the original ceramic entity. Typological modifications through time impart a time-stratigraphical significance to pottery remains. Both Sir Flanders Petrie and William F. Albright (later) were successful in erecting a pottery morphology succession which has been the standard for Palestinian archeologists since. This is the ceramic evidence upon which archaeological time-stratigraphy rests (Kenyon, 1960, Wheeler, 1954, and Williams, 1965).

Figure 32b. Ceramic analysis: examples of ceramic morphology characteristic of the Iron I period.

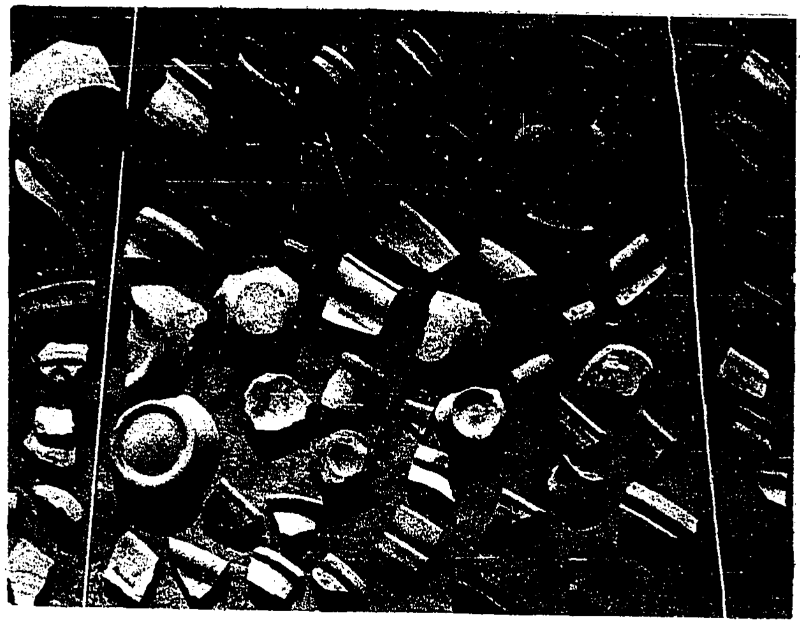


Figure 32a

Figure 32b

Contribution of a Contemporary Potter

An attempt was made to understand the nature of the activity of traditional pottery makers in the southern Levant. The activity of an obliging refugee potter was observed (Figure 33a). He obtained his clay from the Motsa marl beds (Upper Cretaceous, Judea Group) in the vicinity of El Jib (ancient Gibeon). The temper he used came from the coastal sands of the Mediterranean. His pottery making enterprise was carried on in the refugee village in the Plain of Shechem near Nablus. Rubber tires, rags, and dried grass constituted the fuel for the crudely built kiln (reducing atmosphere firing)!

Thin section studies of the ware of the refugee potter revealed the nature of the temper fabric and its wheel parallel alignment. Straw temper was still available in abundance from a threshing floor not far from the potter's quarters (Figure 33b).

Proposed Provenance for the Gezer Ceramics

The erection of pottery type assemblages was done on the basis of the summarized analytical data derived from the study of trace element composition. Calcium content was recorded and plotted with the realization that this component of the ceramics was largely affected by the prolific use of temper having a calcium carbonate composition. Primary consideration was given to the temper composition inasmuch as there are known variations, however subtle, in the drainage net deposits of those streams crossing the Shephelah, e.g., the Nahal Sorek, the Nahal Aijalon, the Yarkon River, and the Quishon River (not plotted). A suite of tempers having a high incidence of local occurrence was

Figure 33a. Ceramic analysis: the study of contemporary pottery manufacture among the Arabs of the west bank territories has yielded fruitful insight into the ancient techniques of clay preparation and pottery manufacture. Wheel-turned ceramic materials begin to make their appearance in Palestine after 1850 B.C. (Anita Fruschpan, personal communication). The use of the wheel in producing ceramic material is illustrated in this view and characterizes techniques used to produce the material so vital to archaeological chronology.

Figure 33b. Ceramic analysis: an a-temporal function of man which has not changed in more than 4,000 years. The threshing floors of the city of Gezer, since its inception, have provided a readily available source for the straw temper that was used not only in mudbrick manufacture but also the making of pottery (cf. Figure 42).

Figure 33a.

Figure 33b.

ceramics are used for primary chronological data by the archaeologist (see Figures 32a and b) in the dating of strata. This commodity was abundant, and was practically non-destructable after its primary purpose was met. An understanding of the local pottery material promises to be instructive in ascertaining those local modifications of the general morphology which have time-stratigraphic significance. Provenance, in the majority of cases, can be determined only on the basis of composition since ceramic morphological convention followed contemporary models used over wide areas.

Geochemical data in the form of trace element studies, therefore, has been assembled to ascertain the nature of the local environment and the breadth of its variation. Identical complete analytic operations were performed on 147 randomly sampled potsherds. The sampling was done without reference to dating, so that a deliberate time-stratigraphic bias could be avoided in the analysis.

The gross character of the ceramic material and its temper content was determined at the site upon 872 potsherds. These results were added to the analytical data obtained on the samples shipped to Cincinnati for microscopic study in the laboratory. Effort was made to obtain a representative sampling of all the specimens available for destructive analysis. Chronologic data were taken from morphological considerations where this was known (Figures 32a and b). Certain trends in the data suggest that potters preferred one or two sources as over against others during various periods of the city's occupation.

Figure 34. Ceramic analysis: section of a Late Bronze jar handle showing 1) the coarse sand size chalk temper (see Figure 58), and 2) straw temper (molds only - see Figure 33b).

The vessel was first prepared with clay containing both straw and coarse sand-size chalk temper. After the wheel turned vessel was shaped, it was then covered with the same clay, but containing only the chalk temper as a surfacing feature which was designed to lower its permeability (a minor permeability was considered desirable). The clay composition of the medium-fired vessel is dominantly that of the rendzinate soils formed on the Eocene chalks of the central Shephelah. The foregoing evidence warrants the conclusion that this pottery very probably originated at Tell Gezer and is a local product. (Type I-A Pottery)

Figure 35. Ceramic analysis: sections illustrating alluvial soils from the wadi east of Tell Gezer. The temper and clay mineralogy reflect a co-mingling of the Eocene and Paleocene weathered, masswasted, and stream-deposited materials. A minor amount of grass was added to the temper of this pottery material. Some deposits of this wadi reflect a character which is an almost natural combination of clays and temper. If the potter used this source, he needed only to add grass as a binder to his clay material.

Another example of a similar clay and temper combination is illustrated in (2). The trace element content of both examples is characteristic of the rendzinate soils formed on the Eocene chalk. The temper is local, similar to that presently found in the wadi Ain Yerdeh. Type I-A Pottery.

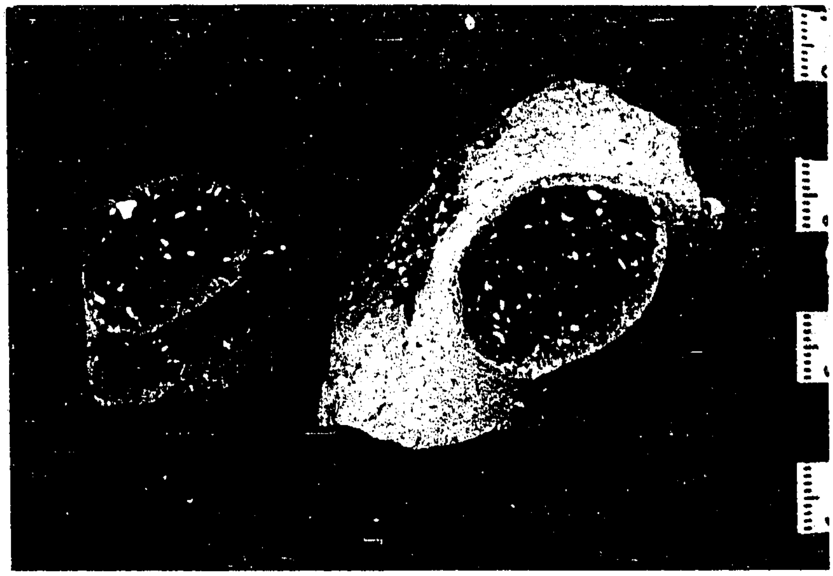


Figure 34.

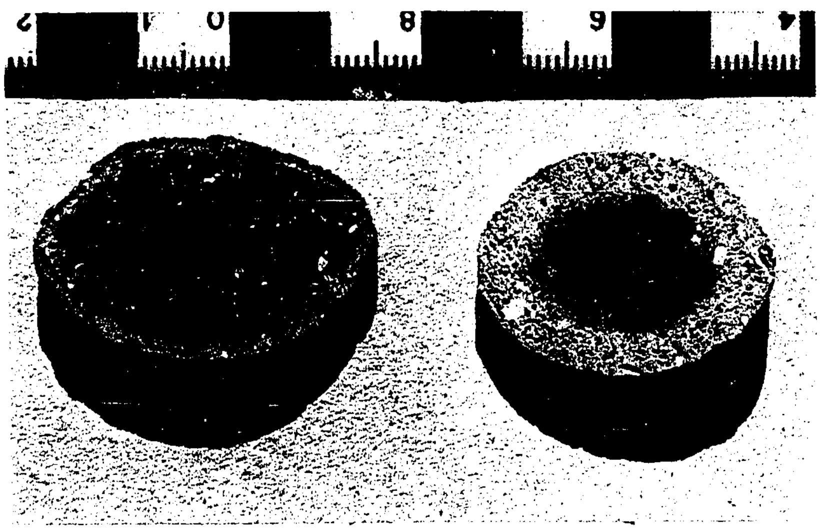


Figure 35.

Figure 36. Ceramic analysis: well-sorted, fine sand size "salt and pepper" temper from a point bar in the floodplain of the wadi just east of Tell Gezer. The local ceramic material shows evidence of the use of this temper source through at least two periods of the history of pottery making at Tell Gezer.

Figure 37. Section of a jug handle showing the "salt and pepper" temper characteristic of the well-sorted find sand size point bar deposits in the channel of the wadi whose floodplain is east of Tell Gezer. The firing history of this ceramic may be observed from the color rings which have migrated inward from the surface during the firing cycle. This was characteristically an initial reducing phase followed by a high temper oxidation phase, followed by a final reducing phase.

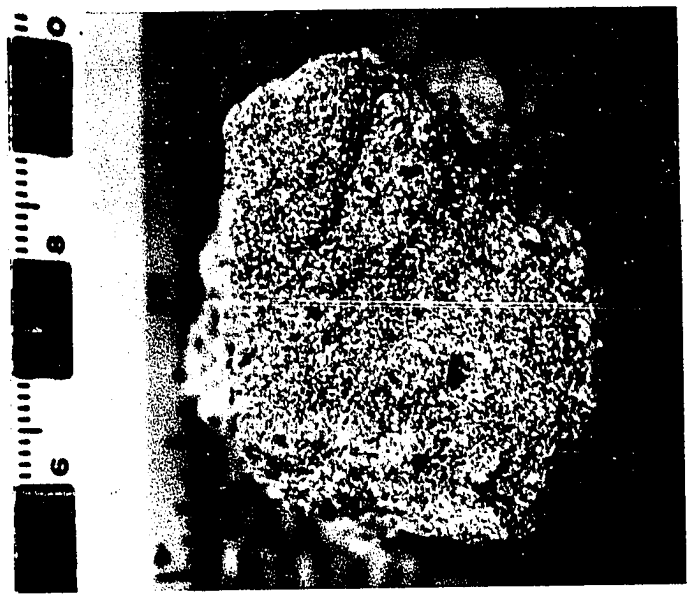


Figure 36.

Figure 37.

drawn up and plotted against the trace element concentrations. Clay mineralogy, were available (low to medium fired ceramics - cf. Figures 30a, b), was added as a corollary to the trace element concentration pattern.

Fairly substantial agreement exists within each type grouping with the exception of certain temper suites. On this basis, pottery type populations were subdivided according to 1) temper which is local to the area where the pottery may have been made (or the materials quarried). 2) Temper which is not known to occur in the vicinity of the proposed quarry areas. Pottery type population groups are illustrated in Table IV.

The application of these techniques is illustrated in a series of figures accompanying the text. Characteristic Type I-A pottery is illustrated in Figures 34 and 35. The clay mineralogy and trace element chemistry is typical of the rendzinate soils of the Eocene of the central Shephelah. Chalk temper further attests to this designation (Figure 58). The firing levels have been sufficiently low to preserve foraminiferal which according to Dr. Zeev Reiss are identifiable on the genus level and in some cases on the species level (Figures 56, 57, 59 and 60).

The addition of straw temper is apparent in Figure 34 and 35 with the high carbon level still evident in the specimens. The straw temper may have been added to the paste to prevent critical shrinkage loss such as would characterize especially the montmorillonite clays. A temper source (megascopic view) available to the Gezer potter from the immediate neighborhood is illustrated in Figure 36. Point bar sedimentation in the wadi Ain Yerdeh presently affords particle size distribution which is the exact complement of that of the "salt and pepper" pottery of Roman and Hellenistic usage (see Figures 38-39).

A temper used frequently by the Gezer potters is the Hamra sands. This sediment is typically shows the presence of a sesquioxide coating on the sand grains, the result of lateritic weathering of the Coastal Plain area. The size distribution of the hamra was found to be fairly constant in the areas sampled. Three traverses were made from Gezer through the Coastal Plain to the Mediterranean between north-south coordinates 135 and 145 along which a series of 18 samples was taken.

Size distribution of the hamra is summarized on Plate XXII, diagram E. The physical character of the hamra is illustrated in Figure 40. The use of this temper in a ceramic is illustrated in Figure 41 where the quartz concentration from the hamra is an amazing 60%. This is an illustration of Type I-B pottery.

A unique occurrence of local raw materials is illustrated in Figure 44. In this instance Type I-A and Type II data are combined in different components of the same vessel! The handle portion of the jug yields values belonging to the Type I-A category, while the body of the vessel yields data characteristic of the Type II-A suite. The pottery material of the body was apparently quarried from raw material sources in the immediate neighborhood to the north or east of the city while the handle material was obtained from suitable material available as close as the topographic saddle between Gezer and the hill to the south.

Type II-B pottery is illustrated in Figure 45. This ceramic material probably was obtained from the local neighborhood to the north or east of the city, but was combined with a temper observed in the sediment load of partially stream-sorted material from wadi Aijalon. The high incidence of kiln dross sediment, in part angular, suggests kiln activity along a tributary not far from the source of this temper. Kiln dross is the carbonized chalk and limestone which did not decompose during the firing of limestone to make lime.

The beginning of lime manufacture. It is possible that the appearance of kiln dross in pottery tempers may serve as an indication of the beginning of the firing of carbonate rocks to make lime. Some ancient kilns were built along streams whose natural cutting propensities would make available outcrop areas of lithology suitable for firing. The dross which results from such lime-making operations would be carried by mass-wasting processes to the streams themselves where the activity of water as a transporting, rounding, and sorting agent would be impressed upon the sediment.

An uninhabited valley occurs just west of the pre-1967 No-Man's-land where 22 remnants of kilns of various ages were counted (Figure 46). Some of the kilns consisted of nothing more than mass-wasted piles of rubble. A few had apparently been used up to the time of the Arab-Jewish war in 1948 (one modern oil burning example was discovered). Along the wadi which drains this "kiln valley" outcrops of Turonian limestone were observed which had been expolited by the kiln operators.

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Figure 38. Ceramic analysis: section cut perpendicular to the potter's wheel on a body sherd from Roman context. This single cycle medium-fired potsherd shows examples of the temper characteristic of the wadi just east of Tell Gezer. Only a slight modification has occurred in the composition of this fine sediment, especially in the partially silicified microfauna which it contains. There appears for the first time in the pottery evidence fine sand-sized calcite rhombs. These may reflect local deforestation with the concomitant soil erosions and deflations sufficient to enable streams to cut into the solution cavities of the local bedrock with a competence sufficient to erosion of the solution deposits there.

Figure 39. Ceramic analysis: section cut perpendicular to the direction of the potter's wheel. This body sherd from a Roman context shows no diffraction pattern, but the trace element distribution is characteristic of the Paleocene soils to the east along with the wadi temper found in the same environment. It is exceptional in that it shows an inverted firing cycle, which was initiated by oxidizing firing, followed by a brief reduction period, to be in turn followed by a final oxidation phase.

Figure 38.

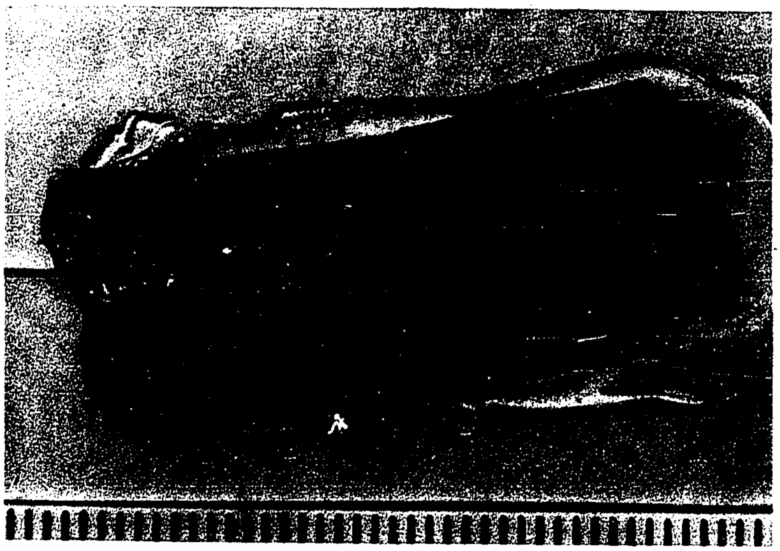


Figure 39.

Figure 40. Sand size hamra from the highest Pleistocene transgressive deposits 5 km due west of Tell Gezer (sample location site no. 201). The hamra sands are composed of sand-sized quartz grains coated with the sesquioxides of iron and aluminum and have the appearance of terra rossa. This provided a common source for pottery temper especially after Late Bronze time in the examples studied thus far from the Gezer stratigraphy.

Figure 41. Ceramic analysis: jug handle section showing a maximum hamra temper, the bonding agent of which was clays having mineralogical characteristics similar to that of the Maresha regolith. This vessel may have been made by a potter who drew part of his raw material from sources to the west of Tell Gezer, and may not represent an entirely local product. Type I-B Pottery

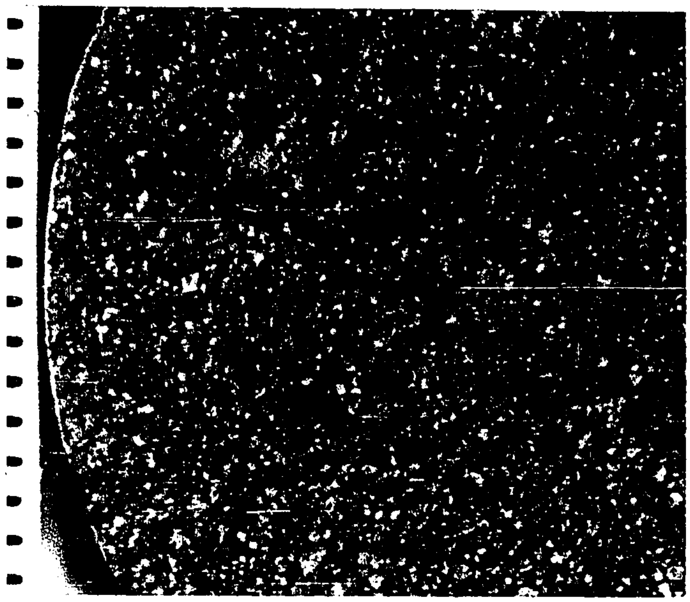


Figure 40.

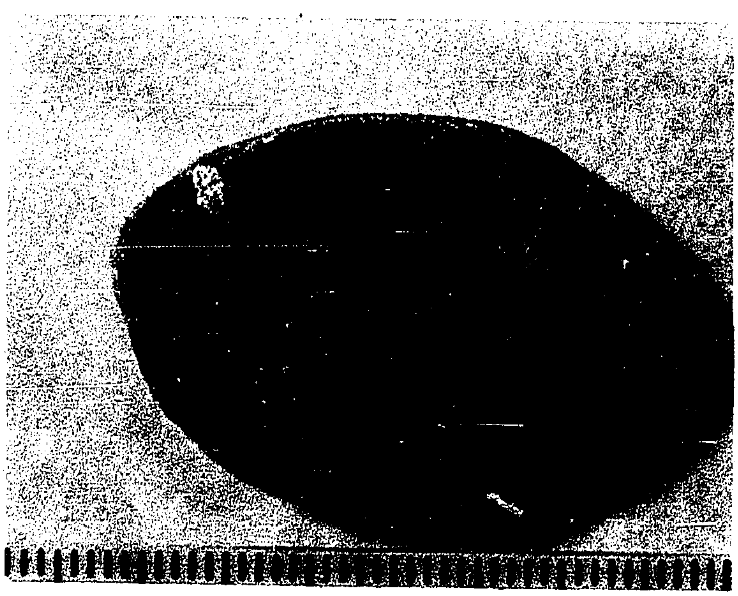


Figure 41.

Figure 42. Ceramic analysis: section cut parallel to the direction of the wheel. Late Iron I context specimen illustrating the coarse sand size temper characteristic of the wadi Ain Yerdeh drainage. To this, however, has been added the unusual addition of the hamra sands from the Coastal Plain. The clay mineralogy and trace element data place this pottery in the Type II category with the hamra sand as not strictly local suggesting the B occurrence.

Figure 43. Section cut perpendicular to the direction of the wheel through a Hellenistic jar rim. This specimen shows the use of the hamra temper, but its trace element chemistry suggests Type V- provenance. The coarse fraction is in part kiln dross sediment from the mass-wasting activity upstream from this area along such tributaries as the Nahel Aijalon.

Figure 42

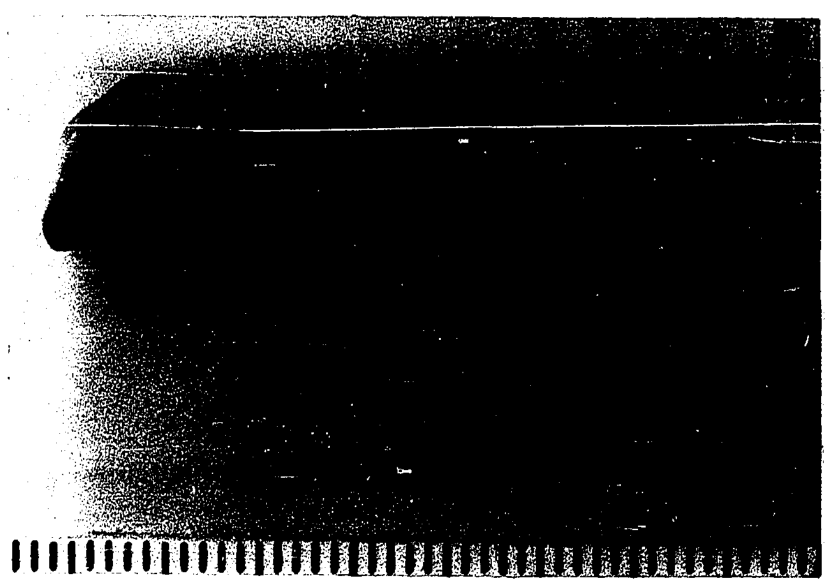


Figure 43

Figure 44. Ceramic analysis: a unique example of a combination of temper technique and clay mineral variation to produce this Late Bronze vessel. (a) Is a clay exhibiting clay mineral and trace element content characteristic of the Paleocene marls which outcrop in the wadi just east of Tell Gezer in quantities suitable for economic utilization. The temper of this clay is characteristic of the sediment of the wadi just east of Tell Gezer which contains partially silicified Eocene faunal assemblages. (b) Is an illustration of the usage of straw temper added to the temper from the wadi east of Tell Gezer. The striking difference, however, is found in the clay mineral and trace element content of this portion of the potsherd: it is low and within the limits of that observed for the rendzinate soil formed on the Eocene chalks higher in the local stratigraphy in the Gezer neighborhood.

Figure 45. Ceramic analysis: section cut in a plane parallel to the direction of the wheel yielding a maximum cut through the temper which characteristically shows an alignment tangent to the wheel direction. This LB II ceramic is composed of medium reduced clay, the mineralogy of which is within the limits of the soil clays derived from the Paleocene marls. In addition to the partially fired limestone, the temper also contains minor chert, siliceous chalk, and sediment. (a) Is an illustration of the permeation of carbon migrating from a seed or grain which was included in the pottery mixture.

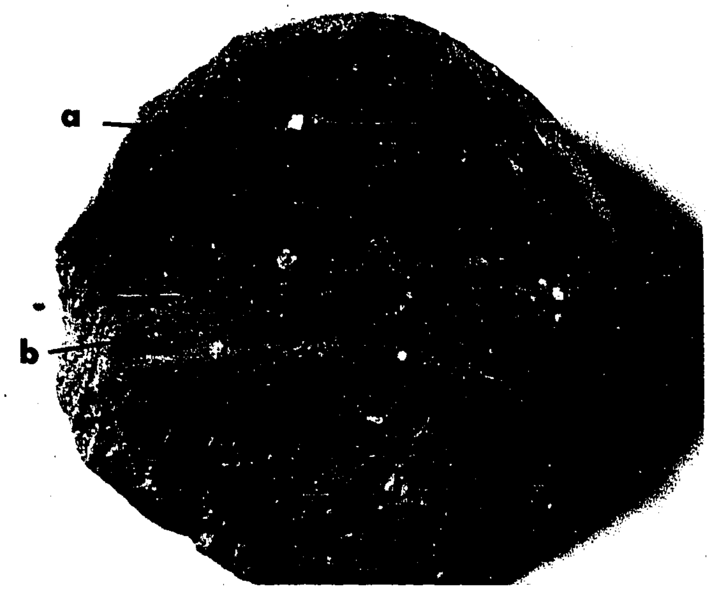


Figure 44.

Figure 45.

Moreover, the channel of the wadi was choked almost to its banks with considerable quantities of fine sand-sized to angular pebble-sized kiln dross fragments. Further study is necessary before any degree of certainty can be maintained in this theory. Future research will have to determine whether pottery can in fact date the first use of lime mortar.

Characteristic Type V-A pottery is illustrated in Figure 47. The trace element distribution, temper composition, and microfauna contribute to this assignment (Plate XIV-B). Another example of this category is seen in Figure 48 where the incidence of angular kiln dross suggests that lime-burning activity is not far away.

Type III-A pottery with its distinctive composition is illustrated in Figure 49. The example is typical of its category, but optical study of the temper shows it to be hamra and not the sediment of the Nahal Aijalon nor that of the wadi Ain Yerdeh. The gibbsite and hematite concentration is that observed in the hamra lateritic soil locally. The large chalk inclusion (6mm maximum dimension) is typical of pastes made from poorly levigated raw material.

The use of grog (ground up pottery fragments) was a general practice of ancient potters from various times. An example from the Persian Period of occupation is shown in Figure 50. The "salt and pepper" temper and trace element content point to a Type I provenance; the clay mineralogy has been largely destroyed in this medium-to-high fired specimen.

Type IV-A pottery (Figure 51) illustrates the surface rock and

Figure 46. Abandoned "kiln valley" cut through the Senonian and into Turonian horizons exposing available raw material for lime burners throughout post-Early Bronze time. This wadi 6.5 km N35°E of Tell Gezer is a tributary of wadi Aijalon to the south. The kiln dross which choked the wadis after man began to burn the limestone and chalk for lime-making purposes appears in the pottery temper. While there are minor Early Bronze occurrences of this temper in the pottery, a marked increase continues to a climax in Late Bronze illustrating a potential proliferation of this artifact in the ecology of the inhabitants of the central Shephelah.

The highlands in the background illustrate the northern continuation of the central Shephelah on uplifted Upper Cretaceous sediments, Tell Gezer being on the northernmost outlier of Middle and Lower Eocene sedimentation of the central Shephelah (cf. Plate IV).

Figure 47. Ceramic analysis: section of pottery (EB) containing temper representative of the sediment characteristic of the wadi Aijalon to the north of Tell Gezer. The temper is composed of chalk, brown-gray and black chert, dark siliceous limestone, and microfauna characteristic of Upper Cretaceous sediments. The clay mineralogy shows kaolin percentages only observed locally in the alluvial clays bordering the wadi Aijalon floodplain.

Figure 48. Ceramic analysis: pottery section cut in a plane parallel to the wheel direction. Late Bronze II material showing a high incidence of kiln dross temper, limestone particles bearing microfauna characteristic of the Upper Cretaceous formations but by the wadi Aijalon and its eastward tributaries. The incidence of kaolin in the low-fired ceramic is typical of the content of the alluvial clays of the floodplain of the wadi Aijalon. Boron content is characteristic of the Type V range.

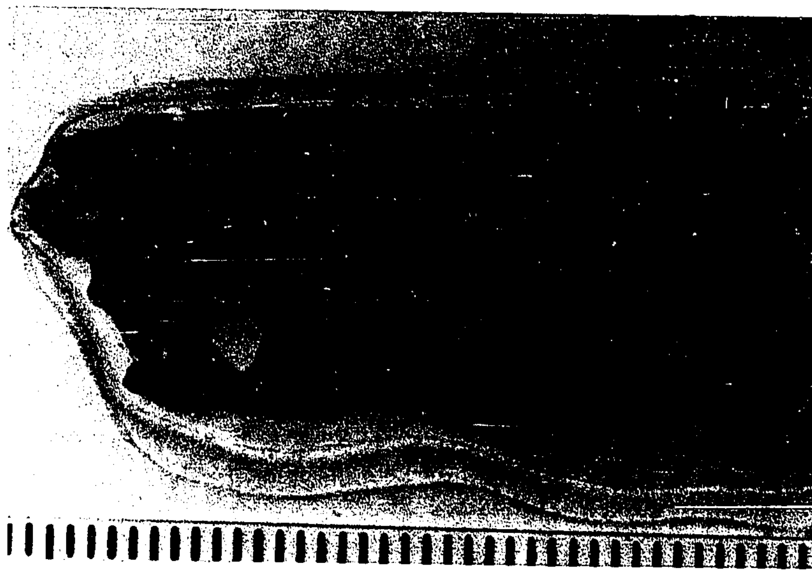


Figure 47.

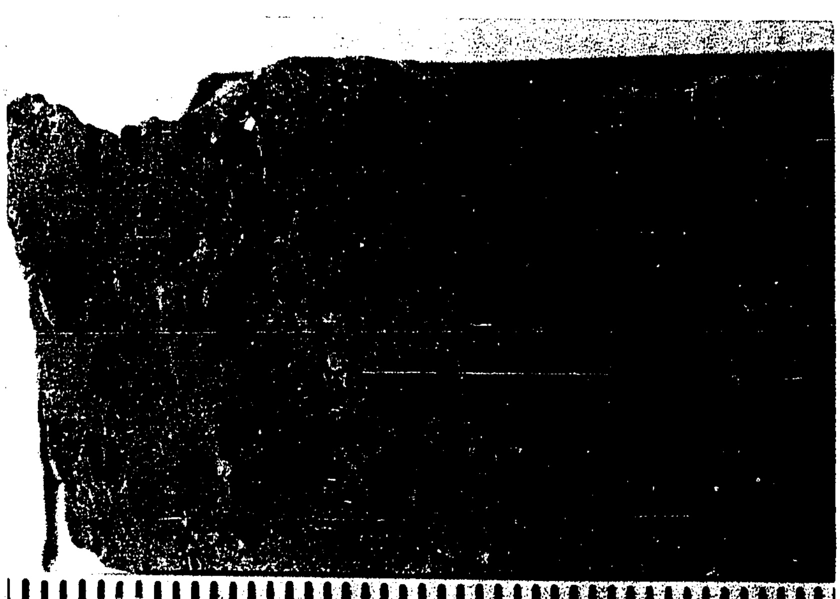


Figure 48.

mineral differentiation which characterizes the relatively small geographical area of Palestine. Alkaline olivine basalt flows with montmorillonite soils predominate in southern and southeastern Galilee (Plate IV). A minor incidence of medium fired pottery derived from the alluvial and colluvial soils of this region occurs in the Gezer pottery. Its provenance is further determined on the basis of its temper: angular to semi-rounded, coarse to fine sand-sized particles of alkaline olivine basalt.

The exotic temper of crushed calcite (Figures 52, 53) suggests an abundance of vein-calcite which is known to occur in the Judean Hills (12cm veins of calcite were observed in the Cenomanian of the Ephraim Mountains). These samples show the mineral and trace element distribution of Type III-B provenance. The example in Figure 53 is typical of initial intensive reduction firing with a final hot exidizing phase. The red margin is not slip since the temper distribution penetrates it undisturbed. It is an exidation feature.

Minor incidences of ceramics have occurred which did not fall into any of the proposed classes. No further attempt to characterize the provenance of these specimens is made except on the basis of generalizations which are derived from very inadequate sampling. Figure 54 illustrates an example, the temper of which has been observed in sand sized sediments in the lower course of the Qishon River which drains into Haifa Bay. The occurrence of basalt demands a drainage net which cuts such surface flows. The jasper may be derived from the Carmel Uplift to the south while fauna observed in the specimen are typical of siliceous Cretaceous forms which could be derived from

Figure 49. Ceramic analysis: section cut perpendicular to the direction of the wheel. This ceramic example of a Late Iron I context has the following temper characteristics: 1) a high incidence of sand with sesquioxide coating on the grains, 2) hematitic ironstone temper admixtures, 3) Upper Cretaceous limestone fragments notably characteristic of Mizzi Ahmar (cf. Figure 74). The clays are similar to those formed on the slightly argillaceous Senonian chalks and marls.

The data make possible the inference that this pottery could have originated from sources where streams have partially concentrated the Fe heavies from the Pleistocene weathering of the hamra sands along with clays formed in the residual soil process and deposited by streams making their way across the Coastal Plain toward the Mediterranean. This would suggest a near but not necessarily local origin for this ceramic and that of 21 other specimens of similar temper and mineralogical suites (Type V-A or B).

Figure 50. Ceramic analysis: sections cut perpendicular to the direction of the wheel. This moderately well fired representative of a body sherd coming from a Persian locus in the excavation illustrates two dominant physical characteristics. (1) The use of grog which is the fragments of crushed pottery used as a temper to make the clay more workable. Only intermediate and smallest diameters are observable in this section cut perpendicular to the direction of the wheel. The addition of fine sand-sized, well-sorted sediment typical of that of the point bars of the wadi just east of Tell Gezer was also added to the clay. Weak diffraction responses bear resemblance to those of soils formed on the Paleocene marls which have surface expression east of Tell Gezer. The Boron content is also typical of this residual soil (Plate XIII) Type II-A pottery.

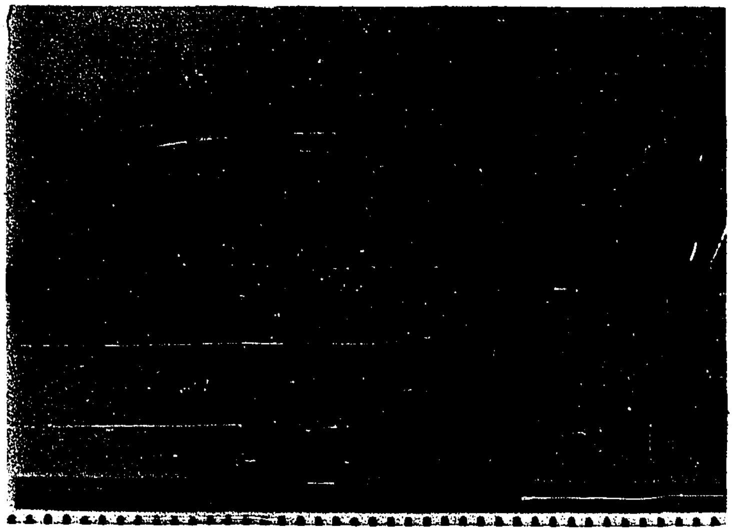


Figure 49.

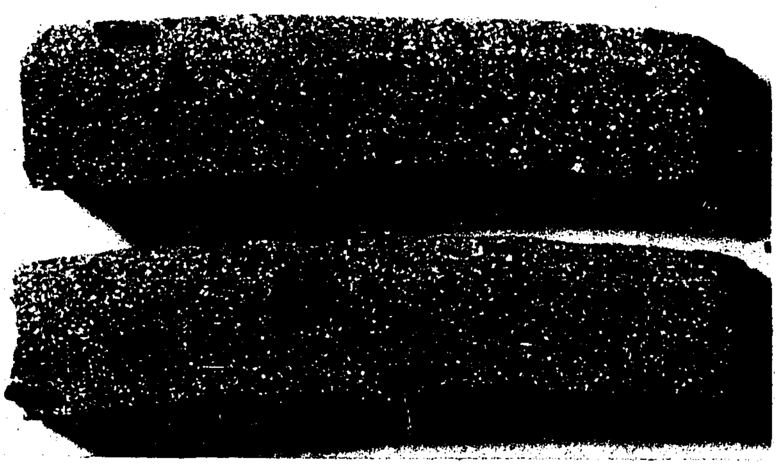


Figure 50.

Figure 51. Ceramic analysis: section cut perpendicular to the direction of the potter's wheel on an exotic rim from Late Bronze context. Coarse to fine sand-sized angular basalt temper. The petrography of the basalt temper is identical in every way to that of the massive basalt samples sectioned for study from southeastern Galilee and the artifact specimen from the context of the excavations. The altered olivine phenocrysts are evident in this megascopic view. The high montmorillonite content of the clay together with the minor silicified foraminiferal tests suggests that it is derived from stream acitivity cutting both weathered basalt and marine carbonate regalithic environments. A possible context for this would be southern Galilee between Beisan and Afula.

Figure 52. Ceramic analysis: section cut perpendicular to the circular direction of the lower side and base of an Early Bronze jar. This moderately low-fired example is typical of 31 specimens studied containing coarse, angular (frequently broken along cleavage surfaces) calcite which is the dominant temper component (97% with minor siliceous limestone). The absence of foraminiferal tests characterize this medium fired clay. Boron values are low, typical of clays formed in soils on marine carbonates. Inference drawn from this data suggests that the pottery is the product of the Judean-Ephraim Highlands and is not that of local manufacture.

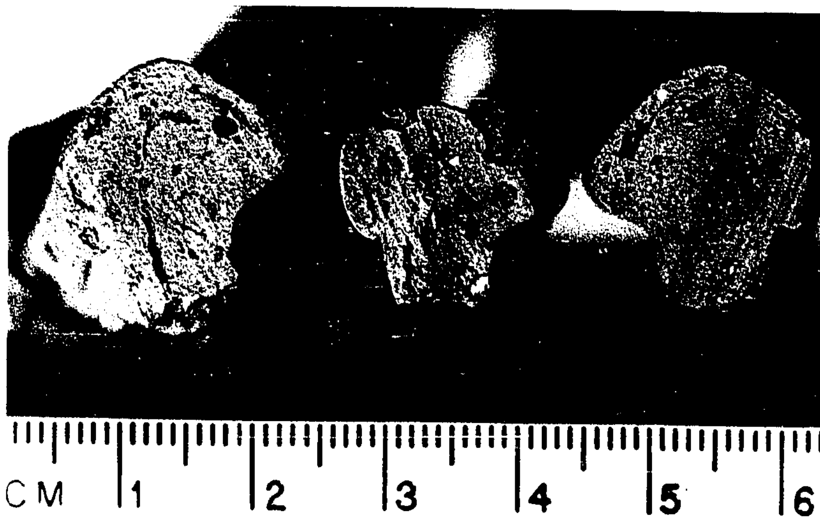


Figure 51.

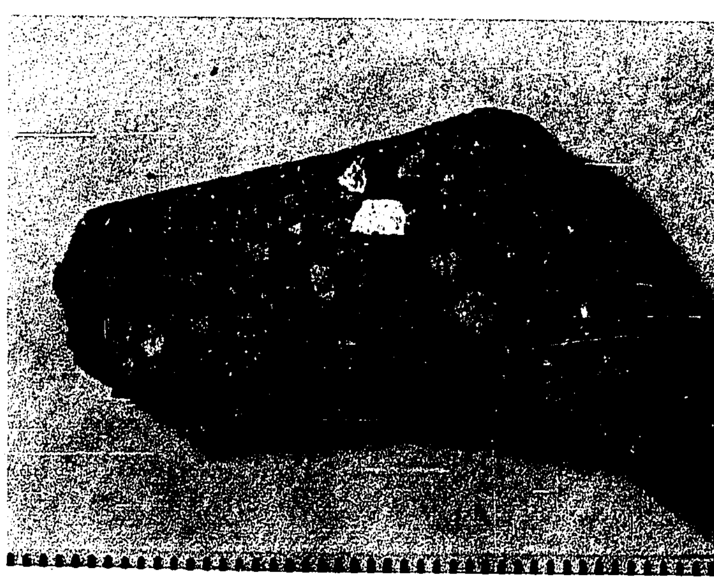


Figure 52.

Figure 53. Ceramic analysis: section cut perpendicular to the arc of curvature of a pre-wheel body sherd. The temper is composed of very angular, sand-sized calcite with minor chert, atypical of stream transported sediments. The temper is similar to that prepared by the crushing of vein calcite having minor chert incidence. The clay is largely that of an unweathered marl material with a high carbonaceous content. This pottery has been subject to a moderately high temperature reducing kiln environment with a very short oxidation history. The red (10R 4/8) outer surface of the vessel represents a brief final oxidation phase to the firing rather than a red slip. A primary criteria for this conclusion is the interpenetration of the temper between the reduced and oxidized phases of the ceramic specimen.

Calcite temper appears to be exotic to the Shephelah environment where no vein calcite was observed on any of the extensive field surveys conducted in the area mapped on Plate VIII. Vein calcite was observed in extensive occurrences in the Lower Cenomanian carbonate in the Ephraim Hills bounding the Plain of Shechem on the south and east, and closer west bank occurrences probably occur but were not accessable for political reasons. On the basis of temper considerations primarily, it is concluded that the raw material source for this specimen is exotic and is probably derived from the Judean-Ephraim Hills.

Figure 54. Ceramic analysis: ceramic section cut perpendicular to the direction of the wheel of a body sherd from Hellenistic context. The temper mineralogy of this specimen is unique and exotic, consisting of 1) well-rounded sand-sized particles of basalt, 2) well-rounded sand-sized jasper and minor brown chert, minor angular to rounded siliceous limestone, minor sand-sized fragments of partially burned limestone and chalk, and 3) planktonic foraminferal debris. The clay minerals consist of montmorillonite, illite, and minor kaolinite. A tentative proposal is that the materials quarried for this ceramic came from the Qishon River valley to the north of Mt. Carmel, the drainage net of which cuts the basalts of the Emek Yizreel, the Eocene litholgies on the north and south central peripheries of the valley and the northern slopes of Mt. Carmel.

Figure 53.

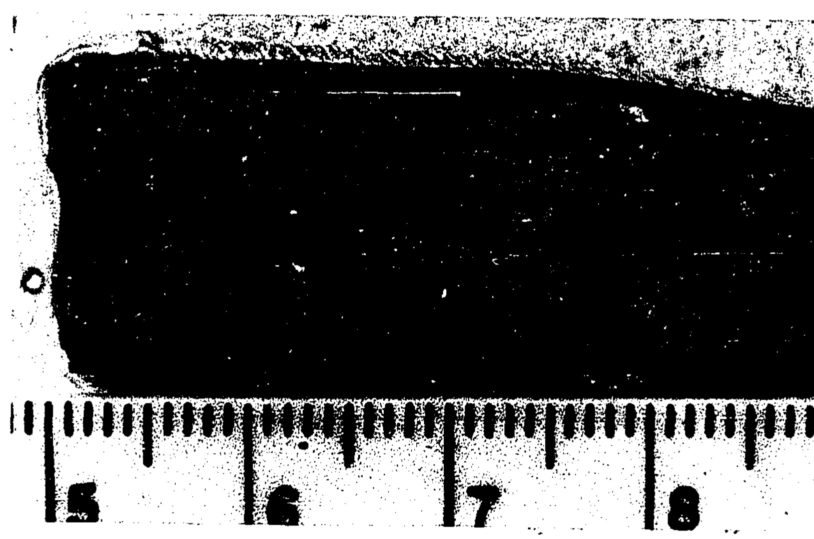


Figure 54.

Figure 55. Ceramic analysis: potsherd cut perpendicular to the direction of the wheel. Showing high-temperature firing decomposition reaction of the calcite-rhomb temper (48X) Type III-B Pottery (C-30).

Figure 56. Photomicrograph of the silicified foraminiferal tests (Sub fam. Hastigerininae) which are residual in the rendzinate soil of the Zer'a Formation (38X) (cf. Figure 25b). These appear in the ceramics of Type I-A pottery.

Figure 57. Ceramic analysis: potsherd cut perpendicular to the direction of the wheel (48X). Clay with Globigerina sp. with hamra temper. Type I-B pottery (C-37).

Figure 55

Figure 56

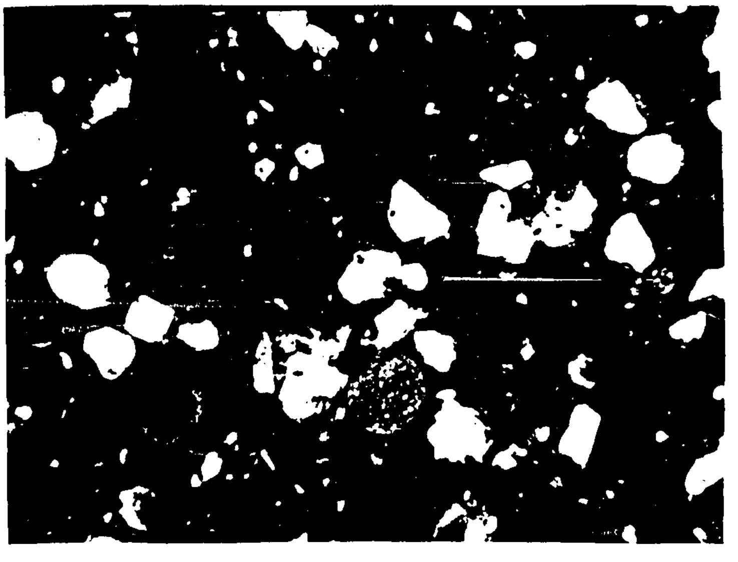


Figure 57

Figure 58. Photomicrograph: sorted sediment from the wadi Ain Yerdeh (2.3x). This temper was that which was most frequently used by the Gezer potters in Type I-A and Type II-A pottery groups. The incidence of this temper in these two ceramic types taken together is 68%. The temper is composed of white chalk fragments, silicified chalk fragments, terrestrial gastropod shells (aragonite), small aggregates of caliche-bonded rendzinate soil particles, and minor silicified foraminiferal tests.

Figure 59. Ceramic analysis: photomicrograph of a thin section of Type II-A Hellenstic pottery (reflected light, 16x). This potsherd was cut fortuitously as an equatorial section of the species Rotalia trochidiformis Lamarc, known from the Middle Eocene of the area. There is a high degree of certainty that this specimen was manufactured by a Gezer potter from the local rendzinate raw material.

Figure 60. Ceramic analysis: photomicrograph (48x) of Type IV-B pottery. The trace element chemistry of this ceramic shows affinity with soils that are produced upon basalt parent rock (see Plate XIV-A). The temper is not typical of the Galilean materials studied, it is composed of coarse silt-sized quartz with minor foraminferal tests (Globigerina sp.). The occurrence of early Tertiary carbonate bedrock in Galilee could be the basis of the presence of foraminifera in minor assemblages of this pottery category.

Figure 58

Figure 59

Figure 60

the rocks on the north or the south of this valley. Such placement is very tenuous and is characteristic of this category, Type VIII. Other exotic representatives having a supposed Aegean provenance are also included in this group.

SUMMARY OF POTTERY TYPES

The ceramic categories erected in this study are outlined in Table IV. They are tentative and subject to revision on the basis of future research. These populations, however, are established on an objective basis and it is expected that they may stand without considerable modification.

Type I and II pottery designations rest upon a rather firm basis inasmuch as mud brick (82% unfired samples) data were plotted with that of the ceramic material. Mud bricks were without exception made of local raw materials, a foregone conclusion which applies to wall construction in general.

Type IV pottery cannot be local since the data relate with a very high degree of certainty to areas of igneous extrusive activity and the indigenous regolithic material. Galilee is proposed on the basis of data obtained on samples of that area.

One of the surprising results of this study has been the recognition of the existence of identifiable microfauna existing within the ceramic body. The use of faunal perameters adds another line of evidence for the nature of these demarcations.

Serious limitations for this research have arisen from the political environment which existed in the field when a major portion of the study was conducted. These limitations no longer exist, consequently new avenues for additional extended research now are available.

Resumé of temper analysis: Tables III, IV, V

VH=very high
H=high
M=medium
L=low

TABLE III

LIGHT AND HEAVY MINERAL INCIDENCE IN THE LOCAL DRAINAGE NETS

LIGHT MINERALS	Wadi Ain Yerdeh	Nahal Aijalon	Nahal Sorek	Yarken River	Coastal Plain Hamra	Recent dunes & beach sand	Galilean	Aegean
Calcite (rounded)		L	M					
Chert (Chalcedony)	H	VH	VH	H				
Jasper			L					
Quartz 0.25-2.0mm (medium rounded)					L	VH		
Quartz 0.1-0.25mm (stained, angular)	L	L			VH			
Limestone sparry/siliceous		M	H	L			L	
Mizzi Ahmar			H	M				
Dolomite		L	H				L	
Kiln dross		VH						
Gypsum	M	M						
Albite			L	L		L		
Plagioclase							M	
Muscovite								X
Shell fragments (Calcite)					L	VH		
HEAVY MINERALS								
Goethite/"Limonite"	L	H	H	H	M	L	L	
Apatite	L	M	L					
Hypersthene						L		X
Epidote					L	VH		
Basalt							VH	
Olivine							M	
Magnetite							L	
Hornblende					LM	H		
Rutile		L	M	H		L		
Tourmaline		M		H	L	L		
Barite/Celestite	M	L	VH	M		L		
Augite/Pyroxene						M	M	
Hematite					M	L	L	X
Garnet						L		X
Zircon	M	L	VH	M				
Kyanite						L		X
Arogonite shells	VH	L						

TABLE IV

POTTERY TYPE DESIGNATION
ACCORDING TO PROVENANCE

The erection of the Pottery Types is based upon data summarized on Plates XIII, XIV-A, XIV-B, XIV-C and Tables III and V. All assignments are tenative.

Type I Pottery (and mud bricks)

The immediate area of Tell Gezer (residual, colluvial, and alluvial soil clays originating from the Zor'a Formation. Materials available today on the saddle just south of Tell Gezer and on the Shephelah to the south (Figures 34, 35, 36, 37, 44).

Type I-B Pottery

Essentially the same raw material constituents with the exception of tempers that are unavailable in the immediate neighborghood (Figures 40, 41, 44).

Type I-C Pottery

Alluvial soil and clays and associated tempers derived from total regolith of the Shephelah. Essentially the floodplain sediments of wadi Ain Yerdeh.

Type II-A Pottery (and mud bricks)

Residual, colluvial, and alluvial soils derived from the Taqiye, Ghareb, and Menuha Formations. Ceramic raw materials available within a half-hour walk of the city. These materials were available to the east and north of Gezer (Figures 38, 39).

Type II-B Pottery (and mud bricks)

The same as Type II-A with the exception that the temper is not that of the immediate local stream regimes (Figures 42, 45, 49, 50).

Type III-A Pottery

Trace elements, clay mineralogy, temper composition, and fauna suggest raw materials derived from residual, colluvial, and alluvial soils on Turonian and Cenomanian (i.e., the Judea Group) lithologies with local temper.

Type III-B Pottery

Same as A, but with an incidence of temper known only to be available in the Judean Hills (Figures 52, 53).

Type IV-A Pottery

Residual, colluvial, and alluvial soils derived from the Neogene basalt flow in Galilee. Crushed basalt or stream sorted temper is characteristic (Figure 51).

Type IV-B Pottery

Same as above with different types of temper, e.g., limestone temper from Galilee, Qishon River alluvial sands, N. Harod alluvial sands, and tempers showing affinity with the sand-sized sediment available from Mt. Gilboa (Figure 54).

Type V Pottery

A category at present somewhat general but initial data suggests the following: A) alluvial soils and clays from the Nahal Aijalon with associated temper (Figures 47, 48); B) alluvial soils and clays from the Yarkon River and the associated limnic deposits through which the river cuts the Coastal Plain in its course through to the Mediterranean (Figure 43); C) alluvial soils and clays from the Nahal Sorek with associated temper.

Type VI-A Pottery

The Coastal Plain with its deep "terra rossa" type weathering of Pleistocene deposits, the soluble mineralogy of which has been largely leached out, but the temper suggests derivation from the immediate neighborhood such as is available in the Hamra and Holocene sand dunes. Some brackish water and limnic clays have also been used..

Type VI-B Pottery

Same as A, but showing temper suites which reflect unweathered shoreline deposits in terms of such relatively unstable minerals as hornblende and augite.

Type VII Pottery

Possibly the Golan, as the clays show relict shards in the ceramic paste. Pyroclastic deposits from the Late Neogene cinder cones observed on the Golan are a possible source. Political conditions not withstanding, more documentation is needed here.

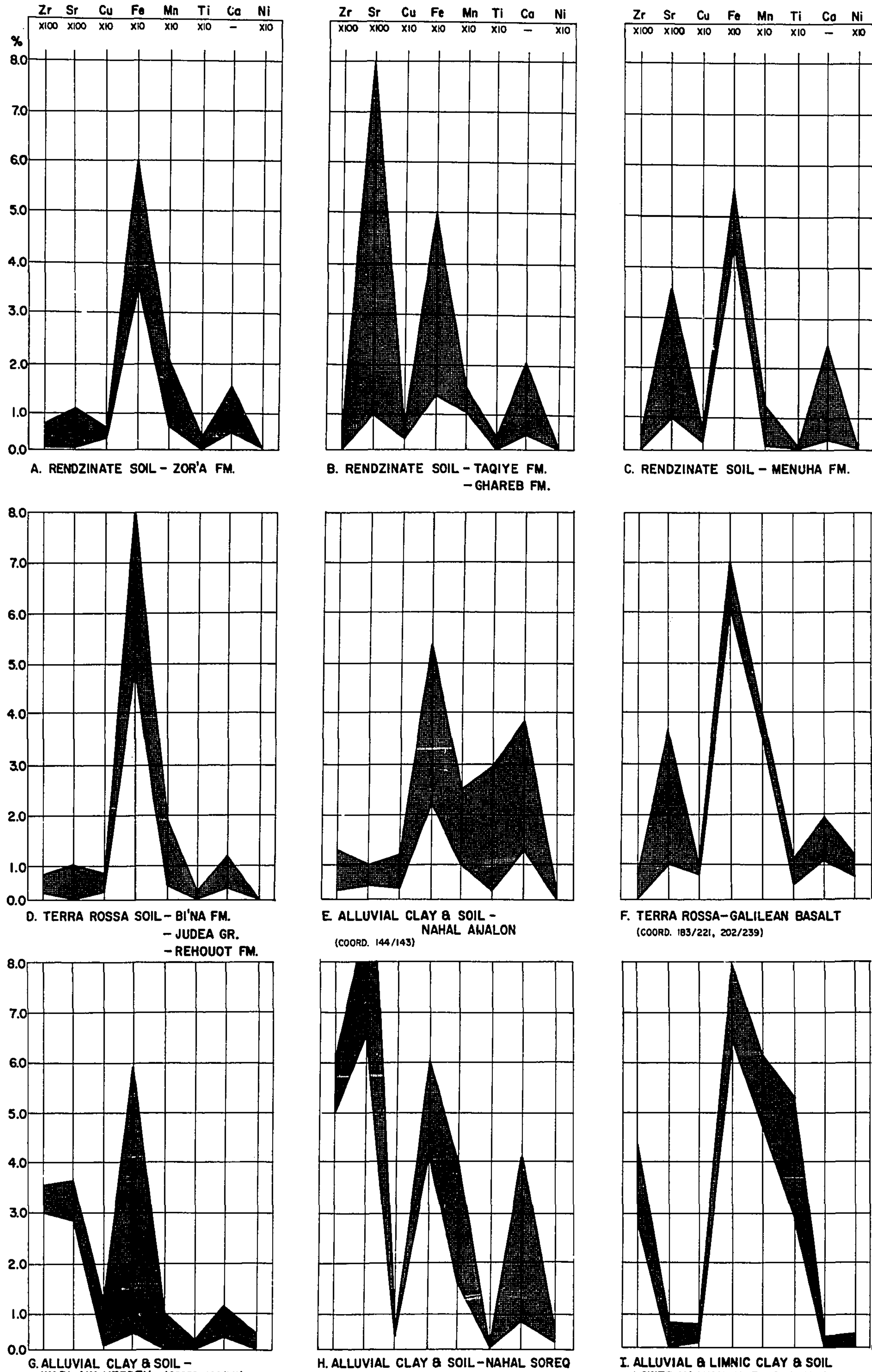
Type VIII Pottery

Exotic, Physical appearance, clays and tempers, mineral, and trace element chemistry of which are totally unrelated to that which was found locally and from that which is known in the literature. Could be Aegean in part.

TABLE V

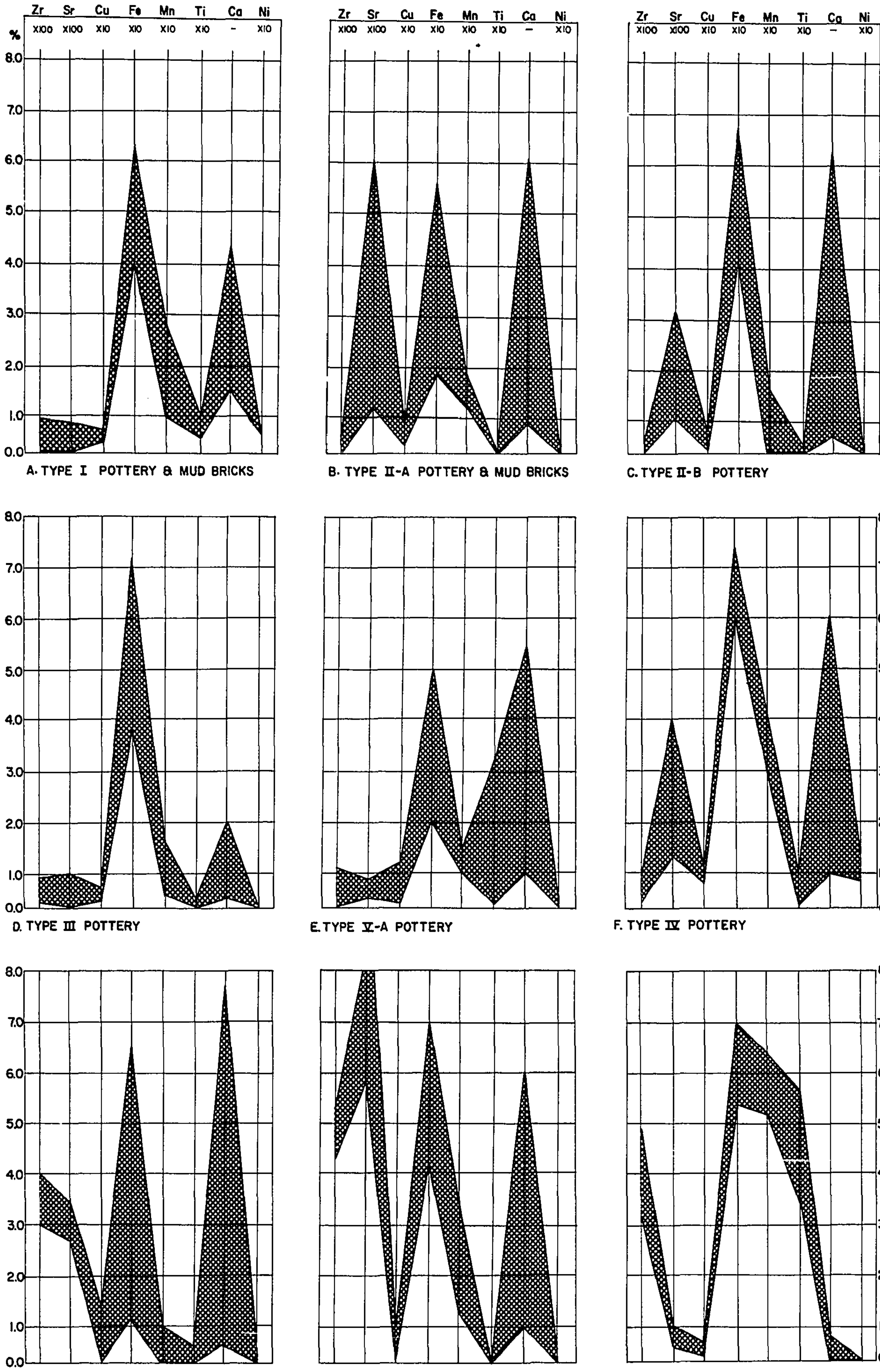
TEMPERS USED IN THE GEZER CERAMICS
(Size range: 0.01mm-2.0mm)

Temper	Pottery Type														
	I A	I B	II A	II B	III A	III B	IV A	IV B	V A	V B	V C	VI A	VI B	VII	VIII
Chalk 0.10-2.0	X		X					X							
Foraminifera															
Pelagic	X		X												
Benthonic	X							X					X		
Calcite (rhombs)						X					X				
Calcite (rounded)															
Aragonite (terres. gastropod shells)	X		X												
Limestone (sparry/ siliceous)					X			X							
Chert (Chalcedony)	X		X							X	X				
Jasper								X			X				X
Quartz 0.25-2.00mm (clr, med. rnded)		X		X				X		X			X		
Quartz 0.1-0.25mm (stained, angular Hamra)		X		X					X			X			
Mizzi Ahmar									X	X	X				
Basalt							X							X	
Geothite/"Limonite"	X		X						X	X	X				
Lapilli 0.1-0.3mm														X	
Dolomite								X							
Kiln dross									X						
Albite									X	X			X		
Gypsum	X		X						X						
Apatite	X		X								X				
Rutile									X	X	X		X		
Tourmaline									X	X		X	X		
Barite		X		X		X					X				
Mica (Muscovite)															X
Hornblende												X	X		
Augite							X								
Magnetite							X								
Hematite							X					X	X		X
Garnet													X		X
Zircon		X		X					X	X	X				
Lithic 0.1-2.0mm	X	X	X	X											X
Kyanite													X		
Straw	X		X												



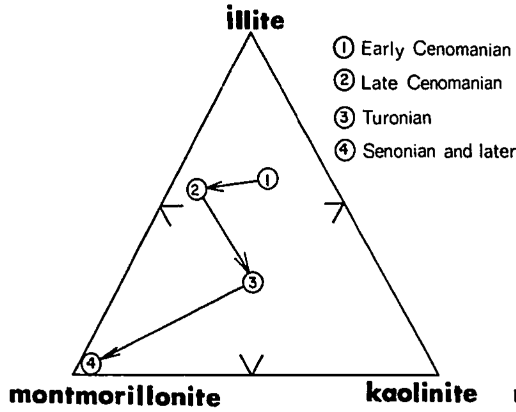
METALLIC ELEMENT DISTRIBUTION/SELECTED CLAYS AND SOILS

PLATE XIV-A

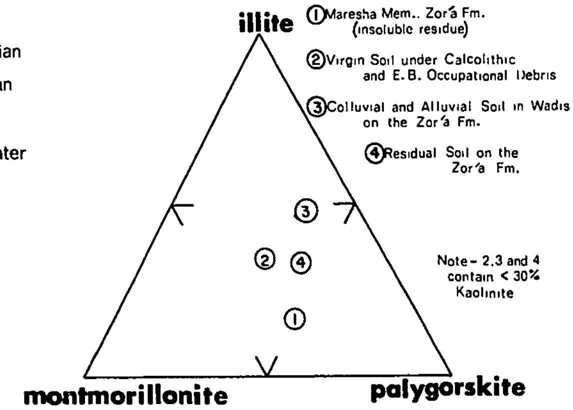


METALLIC ELEMENT DISTRIBUTION IN SELECTED POTTERY TYPE POPULATIONS

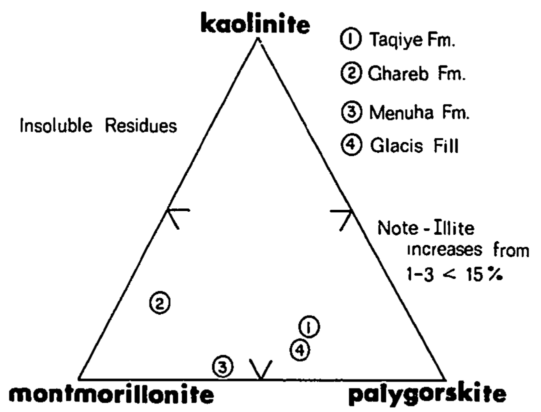
PLATE XIV-B



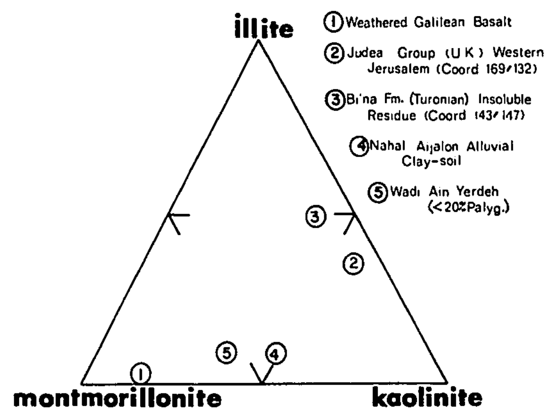
A. CHANGES IN MARINE SHALE DEPOSITION IN SOUTHERN ISREAL FROM THE UPPER CRETACEOUS TO THE LOWER TERTIARY
(After BENTOR et al., 1966)



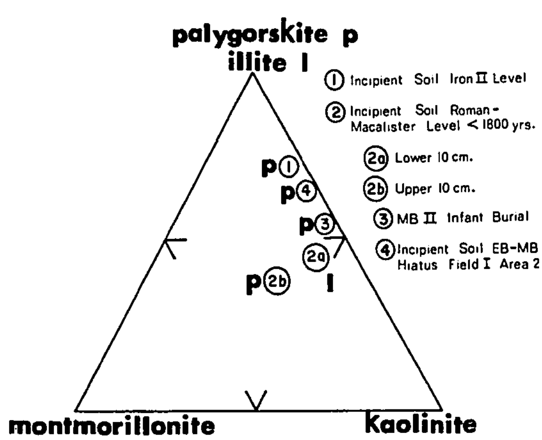
B. ESSENTIAL CLAY MINERALOGY IN THE ZOR'A FM. (LOWER-MIDDLE EOCENE), THE CENTRAL SHEPHELAH



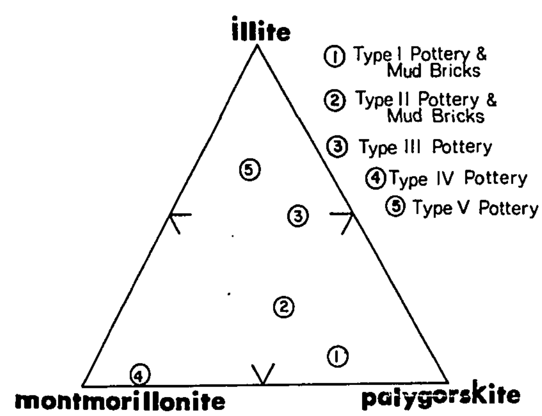
C. ESSENTIAL CLAY MINERALOGY IN THE TAQIYE, GHAREB, & MENUHA FMS. THE CENTRAL SHEPHELAH



D. THE CLAY MINERALOGY OF SELECTED SOIL CLAY SITES



E. CLAY MINERAL STUDIES IN THE GEZER EXCAVATIONS



F. CLAY MINERAL STUDIES ON SELECTED POTTERY TYPE POPULATIONS

CLAY MINERAL DISTRIBUTION

(QUANTITATIVE ESTIMATION-PARTS PER 10)

PLATE XIV-C

CHAPTER IV

THE STRATIGRAPHY AND SEDIMENTARY PETROLOGY OF TELL GEZER

> So, over some 6,000 years, there grew up a tell-mound covering 6-8 acres; within it are buried the remains of many successive city walls. Eventually this city, as it had become, was destroyed and abandoned; according to the Biblical record: '. . . and they burned the city with fire . . . and Joshua adjured them at the time saying, Cursed be the man before the Lord, that riseth up and buildest this city Jericho.'
>
> The city was never fully reoccupied, no more building materials were accumulated or refuse thrown out of doorways; the mound no longer grew and no one repaired the ravages of the elements. . . . (Pyddoke, 1961, p. 111)

The task of interpreting the history of stratified archaeological remains is considerably more than the interpretation of the ceramic evidence. It goes beyond the recognition of the layered or stratified levels and the careful delineation of their geometry. In the mind of the writer there is a vital and highly important facet to the understanding of the history of a city which is undergoing excavation.

"Digging is destruction." Even the casual observer of the glaring, grey-white dust which comes up under the archaeologist's trowel is accutely aware of the fact that these deposits can tell their story only once. Afterwards, they become refuse or "spoil" in the true sense of the word. The writer has not viewed his task as that of a laboratory technician whose work is that of merely analyzing in the confines of research quarters those curiosities brought to him by the archaeologists from the field. His concern is essentailly a new way of looking at that which may be "dry as dust" for those who have not concerned themselves with the information at hand.

This new way of trying to understand the history of an accumulation of ancient cities is none other than that which has traditionally concerned the sedimentologist. It is as broad as Vatan has said:

> Le domaine de la sedimentologie est notablement plus vaste que celui de la petrographie sedimentaire. Le premier est a l'echelle du bassin, le second a celle de l'echantillon de roche. A vrai dire, la petrographie n'est qu'une partie de la sedimentologie, son aspect technique de laboratoire. Des progres tres notables ont ete accomplis dans ces deux directions, ces dernieres annees. (Milner, 1962, p. 19)

Even as students of sedimentary rocks have turned in recent years from the process of rock description i.e., sedimentary petrography, to the more difficult task of understanding the geologic history of a stratigraphic unit; so also has the student of archaeology the need to turn from description to genetic factors.

The writer seeks to direct attention to <u>those processes</u> in the of the regime of human activity <u>which produced</u> the sedimentation of the archaeological context. He seeks no other goal than that which has been adequately outlined by Pettijohn:

> The history of any given bed involves determination of the source rocks and the source area from which the sediment came, or in a word, its <u>provenance</u>, It involves also an understanding of the mechanism of <u>dispersal</u> of the residues formed in the source regions and the direction and distance of the transport and the area of petrologic provenance over which these materials were spread. Germain to the history of a sediment is a reconstruction of the <u>environment</u> of the deposition - the physical and chemical milieu in which the materials accumulated. Finally, the history involves those changes or modifications which the sediment underwent after deposition including internal physical and chemical rearrangements and the resultant <u>lithification</u> (1957, p. 1, 2).

The primary aim or purpose of this research is an elucidation of the human history by means of those methods proven successful by students of earth history. The ultimate goal is an understanding of the ecology controlling the life of the Gezer inhabitant and his dependency upon the environment in which he lived.

Those questions directed in the course of this research were: 1) the origin of the sediment, 2) the primary composition of this sediment, and 3) the agency which was responsible for the occurrence of the sediment in the context in which it was found. In this fashion, the products of the activities of man may serve to contribute to a knowledge and understanding of his history.

It is important to emphasize that this mode of research can be carried out only when the geologist observes the sediments in their stratigraphic position. Facies relationships exist within each stratigraphic entity in the same real sense that they do in the sedimentary basins within the geological regime of sedimentary environments, whether continental or marine. These facies relationships are totally marred and obscured if the geologist is handed merely a grab-sample of material about which the archaeologist was a bit curious at the moment it came up under his trowel. Once the sediment is disturbed, vital information may be lost apart from its content relationships. The loss is no less significant than that which has been stated by archaeologists viewing their science in retrospect: vital stratigraphy has been lost because of the lack of stratigraphic controls, especially at the hands of those who were mere treasure hunters, *e.g.*, "the gold of Troy".

The nature of the study is not chronological elucidation but rather it is a summary of examples of sedimentation which occurred throughout the history of the tell. Each example is not necessarily peculiar to the

Chalcolithic, Early Bronze, Late Bronze, or the Iron Age. The study concerns those patterns of sedimentation which have been observed to be general. Certain exceptions are applied in specific cases as the data came up in research, but no deliberate effort is made in this report to isolate these incidences in their chronological order. That must await the final archaeological reports of the excavation with a total integration of all the material in its stratigraphic association (see Figures 61 and 62).

SAMPLING AND ANALYTICAL PROCEDURES

There are many ways to study sediments. The central concern of this research is 1) to draw attention to the data inherently available to the archaeologist and historian in the sediments of a tell, 2) to present the data in such a meaningful and significant way that it is useful to the archaeologist and historian in the integrated synopsis of the primary material, and 3) to outline the potential problems which future research must consider if the destruction of digging is not to produce irreparable loss in its quest for discovery.

The investigation of the strata of Tell Gezer as sedimentary units involves procedures well known to sedimentologists. The writer made arrangements to obtain his own samples. This was greatly facilitated by the intercom system which is in use in the archaeological operation at this site. As new loci came up, the writer endeavored to be present and to observe the lateral and vertical relationships of that which was being cleared.

Samples were taken in plastic containers to prevent contamination. Identification logs were kept and were annotated with the archaeological location numbers on each sample. When feasible, photographic recording was

Figure 61. 1966 excavation photograph of Field I north, west baulk. The stratigraphic section assumes a major role in contemporary scientific archaeology. The technique of carefully reading the stratigraphy from the trench walls was introduced into Palestinian archaeology by Wheeler (1954) and Kenyon (1960). This north-south trench was laid out immediately to the west of the area excavated by R. A. S. MacAllister. A primary goal was the possible salvaging of the MacAllister stratigraphy by means of modern control, but his lack of stratigraphic detail has made this aim nearly fruitless (Dever, 1967). An entirely new concept of Gezer history is unfolding.

Figure 62. 1966 excavation photograph of the trench cut of Field I. Close and exacting stratigraphic control is maintained in squares or "areas" 3x5m dimension. The excavation of these areas is carefully monitored by the assignment of locus numbers to each stratigraphic entity occurring in the area. Levels are taken on each locus and its lateral equivalent is keyed into the stratigraphic configuration portrayed on the west (right) baulk. Field I originally was laid out in ten areas in the 3m wide trench seen above. Some areas were abandoned when they came down upon large architectural structures such as the Great Wall (locus 5017).

at the moment of excavation as part of the documentation.

A field laboratory was set up by the writer in the dig house at Tell Gezer. This consisted of a work bench with north light in the staff room, a binocular sedimentary petrology microscope, and a full set of standard sieves. A suite of reagents was prepared for special treatment such as the solution of carbonates, spot and stain tests for dolomite, copper,nickel, silver, potassium, and phosphorous. Other tools considered as basic to mineralogists were also included in the equipment.

The study of the sediments of Tell Gezer involved the documentation and recording of the texture in which particle size, shape and roundness, surface texture, porosity and permeability, and the packing and fabric of the sediment were considered. Mineralogical composition was also determined. As a part of the history of the sediment, a structural analysis was carried out. Primary and secondary mechanical structures were noted such as bedding, bedding planes, irregularities, deformation, disruption, and distortion.

CLASSIFICATION OF THE ARCHAEOLOGICAL SEDIMENT

Inasmuch as human history is the ultimate goal of the study of these materials, the primary objective and determining principle in this classification is a genetically meaningful designation of the sediments studied. The information derived from the geological research is channeled in such a way as to be available for this purpose.

The following classification is therefore proposed by the writer for the sediments studied at Tell Gezer:

I. Occupational sedimentation

A. primary material left in situ as the result of the orderly human activity in the course of the daily life of the city.

B. occupational debris - mixtures and aggregates of (A) which have been used as fill or as a deliberate leveling to prepare for a new structure.

C. structures cut or hewn into the bedrock in such a way as to leave evidence of their primary usage:

1) cisterns, water tunnels, wine presses, rooms, or dwelling places excavated into the bedrock,drainage channels.

D. primary structures raised within the strata of the successive cities:

1) city walls, gates, steets, and drains.

2) structures and sediment which are associated with the courtyards of houses, e.g., cisterns made of plastered rock materials, plaster, wine presses, cooking ovens, quarters for livestock, and refuse pits.

3) primary structures and sediment associated with the interior houses typical of the Near East and observable even today among the Fellahin Arabs: walls, roofs, doorways, floor sequences, ovens, hearths, cooking stoves, - all made of clay - refuse pits, infant burials, and the debris that normally pertains to human activity within the confines of such dwellings.

4) structures associated with crafts and with industrial activities such as pottery manufacture, tools, and weapon manufacture with typical sediment.

5) structures built for cultic practices and associated sediment.

6) buildings serving man's aesthetic propensities such as the arts: theatres and circuses.

II. Destructional deposition

A. debris caused in the visible collapse of structures which have been fired (perhaps by man):

1) house roofs, the beams of which have burned with resultant structural failure.

2) carbonate fortifications such as gate areas which have been breached by use of fire (Figure 99).

B. debris resulting from the pulling down of structures by an enemy attempting to make the city uninhabitable.

1) the collapse of walls, the filling of cisterns and water supplies, the destruction of cooking facilities, and the occasional slaying of domestic animals that were not taken as booty.

III. The occupational hiatus

A. a minor occupational lapse within the city (may be explained on the basis of a plague or a migration of a city's population or a destruction of the city which was locally incomplete - more data needed).

B. a major occupational gap in which an incipient soil has developed upon the destructional debris by the process of weathering.

1) an occupational layer may be deposited after the soil formation has begun.

IV. The processes of erosion which may remove any one or all of the above:

A. mass wasting

B. running water

C. deflation by wind

V. Naturally induced destructive agencies

A. earthquake

B. volcanic eruptions with ash falls, mudflows, nuees ardentes, caldera explosions (such as in the case of Thera).

C. tsunamis or tidal waves

D. floods

VI. "Erratics" - non local sedimentary fragments brought in by trade, travelers, etc.

Figure 63. Saddle between Tell Gezer and the next topographic high of the Shephelah to the south. Floored on the Lower Eocene, the saddle abounds with circular areas (in the background behind the Bedouin tent) which mark out threshing floors used by the inhabitants of Abu-Shusheh prior to 1948. Their antiquity extends back much beyond this; it was the nearest suitable area for threshing for the inhabitants of the city of Gezer. It is penetrated in more than twelve places by the excavation of cisterns, the deepest one of which was measured at 27.2m.

The nari-encrusted chalk strata constituting the hill on the south have been excavated in a number of places. A quarry and numerous man-made caves abound on this northern slope; seventeen tombs were also counted in a survey of this area. The soft rounded relief of the weathered Eocene chalks is typical of the region. The Shephelah has suffered denudation of its flora, especially during late historic time.

Figure 64. Bedrock survey: a cistern drilled through the nari into the softer chalk below where the main water storage chamber is located. Fresh bedrock material is available for sampling in such cisterns as this located on the western end of Tell Gezer in an area excavated by the Rowe Expedition of 1934.

Figure 65 Bedrock survey: specific use of <u>in situ</u> nari. A wine press cut into the sub-solum nari of the Shephelah immediately south of the threshing floor area (Figure 63). This special use of the local lithology characterizes Hellenistic and Roman activity especially during the time when the countryside was relatively secure from the threat of surprise invasion. The geometry of this structure features a drain hole along the axis of which a scale is placed (1), an overflow channel (2), and surface sheet wash drainage channel cut into the bedrock above and behind the press basin to prevent soil contamination of the press basin during the wet season.

Figure 63

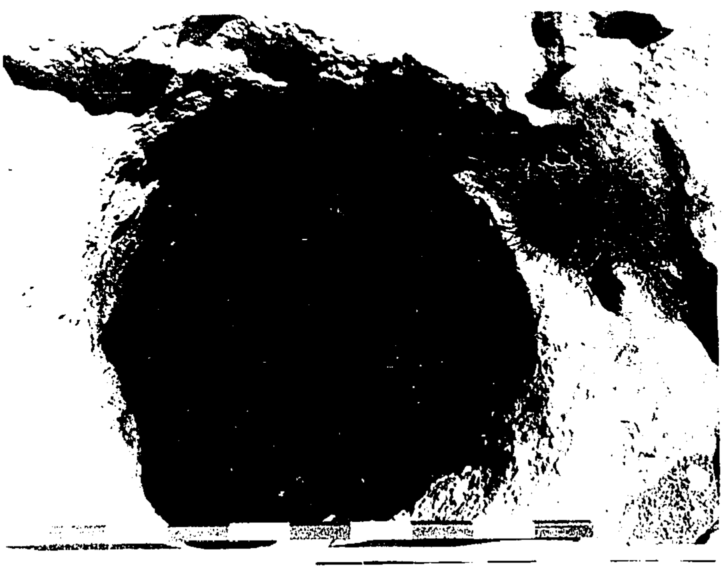


Figure 64

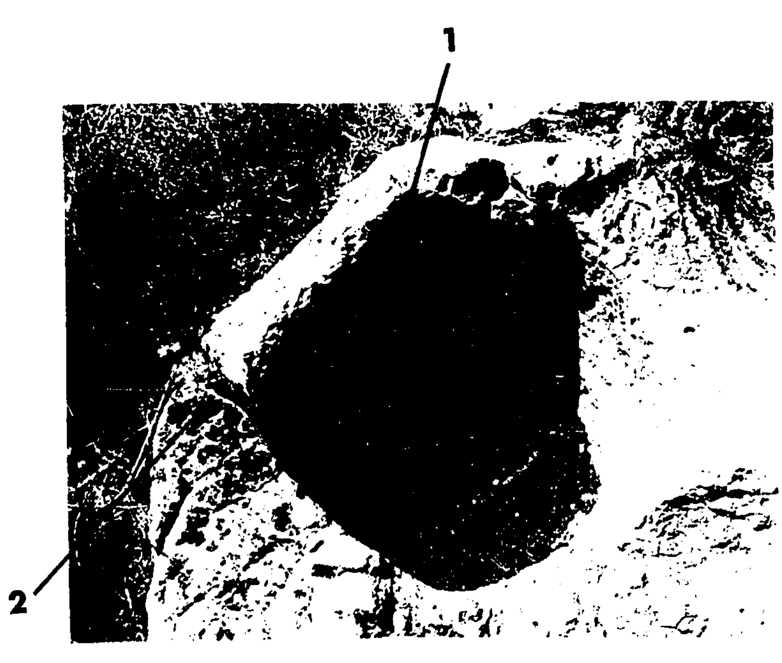


Figure 65

SEDIMENTARY STRUCTURES

Models Cut into the Bedrock

In the study of those structures which man considered vital and essential to his existence, it is useful to examine the work of his hands in stone. The typical morphology and geometry of the manufactured contents of the houses and courts of the city may be recognized from their sculptured counterparts observed in the bedrock structures themselves.

An area of semi-arid climate is one which historically demands conservation of the water supply. This is observed in the numerous attempts by the inhabitants of the Gezer area to manufacture water storage facilities. Figure 64 illustrates a cistern which was in use by inhabitants of the western end of the tell.

The activities of man often involved the manufacturing of food commodities. An example of a wine press very well preserved in the nari bedrock in the immediate neighborhood of Tell Gezer may be seen in Figure 65. This artifact was equipped with a drain below which a niche was carved in the rock to receive the vessel into which the pressed out fruit of the vine would flow. While one might tolerate the dust of the road on the feet which trod out the vintage, he nevertheless was cautious to prevent sheet wash from contaminating his operation as the channeled rock above the press illustrates.

The contribution of nari to the ecology of the inhabitants of Tell Gezer is quite evident in Figure 63. Beyond the Bedouin tent in the foreground is the area of a threshing floor in which cisterns have been excavated. The hillslope of the Shephelah immediately to the south contains numerous other excavations. These were not only used as corrals for domesticated animals, but also as dwelling places. Some of the hewn rooms bear evidence of lamp niches and water jar stands carved into the nari bedrock. In numerous other places there are tombs (see Figure 66). The use of this form of tomb characterizes the Hellenistic and Roman Periods. The caliche surface of the bedrock had lost its soil cover and thus provided an indurated crust through which man's structures penetrated. The loose and friable chalk underneath the nari was readily excavated and used in various domestic applications (see below).

Some of the tombs were cut with considerable care (Figure 66), having steps leading down to a door around the opening of which was cut a channel to receive the stone serving as the seal. The tomb illustrated is one which has a room 10x12' with loculi drilled laterally into the chalk to receive the bodies of those being buried.

Frequently the nari was utilized in the excavation of domestic structures. Figure 67 is an illustration of a large room sufficiently high for a man standing erect. The walls of this room show very careful special preparation. The roughly hewn chalk surfaces were coated with a crude plaster which was coated with a very fine grained pink plaster (dating from the Roman Period on the basis of fragments of sealed pottery). It is not known how frequently and to what extent the area outside the extra city walls was inhabited by the ancient population, but these structures suggest that it was secured by military and political conditions so that man need not necessarily depend upon the fortification of the city for his survival.

Figure 66. Bedrock survey; one of the sources of unweathered bedrock. A tomb hewn into the unaltered chalk through nari. Unweatherd bedrock exposures are found in the Hellenistic and Roman tombs previously excavated by MacAllister in the neighborhood of Tell Gezer. This tomb is located on the north slope of the hill just south of Tell Gezer.

Figure 67. Bedrock survey: entrance to a large livingroom cut through the nari into the underlying chalk in the saddle between Tell Gezer and the hill to the south. This room and its entrance, perhaps part of a house which was built above it, show evidence of human occupation (see text).

Figure 66

Figure 67

The Gezer Water Tunnel

One of the most lucid illustrations of the quest of Near Eastern man for his water supply may be observed in the Gezer water tunnel (Plate IX). Like the water tunnel at Megiddo, the water fountain at Athens, and the water supply at Mycenae, the Gezer water tunnel represents an attempt by man to obtain this necessary commodity even during times of seige and attack. For the Middle Bronze inhabitants of Tell Gezer, this was a relatively easy task. The nari overlying the soft chalk interior had merely to be pentrated, after which the digging was relatively easy even with bronze picks and mattocks.

The thick nari on the tell surface is evident. The keyhole (plan) entrance (Figure 68) to this structure is essentially a penetration of the nari some 2.5m thick. The faint remains of steps which have been cut into the soft chalk are evident immediately below the nari. Figure 69 is a view of the uppermost chalk levels immediately below the nari of the Tell Gezer strata. The soluble salt (potassium, sodium, and calcium) incrustations on the tunnel walls are visible where the nari penetration ceases and the softer chalk bedrock sequence begins.

The water tunnel afforded an unweathered bedrock source for study of the sedimentary petrology of Middle Eocene chalk (Chapter II). (Well samples were unavailable for the local area.) Within the tunnel itself, large chert nodules were a source of flint for the inhabitants of the city (cf. Figures 101a, b). All those exposed in the tunnel were extensively quarried back into the surface of the walls.

Figure 68. Oblique view of the Gezer water tunnel entrance, 180° clockwise from the view in Figure 69. The steps were cut by the Middle Bronze workers (see Plate IX).

Figure 69. The partially filled water tunnel as viewed from the entrance. The tunnel slopes downward due east at an angle of about 38.5°. Note the upper level strata whose lithological character differs somewhat from that of the upper central portion of the tunnel. The actual pick-marks of the Middle Bronze workers are still visible on the vaults of the tunnel arch.

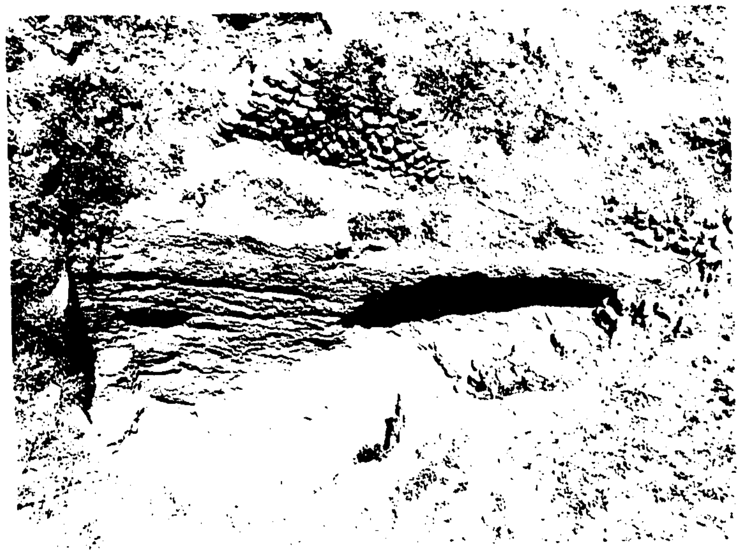


Figure 68

Figure 69

GEZER SEIMENTATION

Virgin Soil Preservation

An illustration of the sequences of Gezer sedimentation may be observed in Figure 70. The significance of this portion of the Field I excavation trench (Area 8) is that locally 1m of virgin soil was found on the nari-bedrock below. The position of this quantity of soil undisturbed by man points to the fact that this was the actual soil thickness when the Late Bronze wall was constructed on top of an area ideally situated for mass-wasting processes. Such soil retention, virtually absent elsewhere in the immediate Shephelah alludes to the presence of some manner of plant anchoring of the regolith. If climatic conditions were very little different from that of today, the inference may be advanced that this soil was held in place by arboreal retention. Deforestation of the Shephelah, therefore, was post-Late Bronze.

Defensive Occupational Sedimentation

The Late Bronze Wall. This section concerns the type of rock construction which characterized the Early Bronze outer wall. The occupational sedimentation in view (Figure 70) is that of the inner face of the wall which abutted against a trench wall cut into the glacis (observable on the right and on the left sides of the cut). The wall structure was strengthened by intermittant lateral courses of axially elongate blocks of nari in between which were placed the pebble, cobble, and boulder-sized material. That this type of orientation and fabric gave strength to the wall is evident by the free standing face visible in the photograph.

Figure 70. Virgin soil (x) overlying bedrock at the bottom of the trench and sealed in place by Late Middle Bronze II and Early Late Bronze I fortification structures, Field I, Area 8, south end. Note the sectioned glacis structures (Plate XV) on the west and east baulk. The glacis had fallen out of use during LB-I time as is signified by the erection of an outer wall (y), the undressed interface of which was placed against the southern face of the trench cut into the glacis. The presence of a meter of compact and undisturbed virgin soil (with minor surface intrusion) under the outer wall is a revealing feature of the soil preservation of the Shephelah prior to this time.

The high palygorskite mineralogy of this undisturbed soil also implies its residual character (Chapter III). As observed in soil-nari interface contacts elsewhere, the demarcation is typical of contacts observed throughout the Shephelah area (Figures 24 and 25).

Figure 71. Dressed southern face of the outer Late Bronze I wall (the outside surface of the wall shown in Figure 70). This defensive structure was founded directly upon the bedrock (nari) surface to prevent undermining by an enemy. The wall is composed entirely of nari, the face of which has been dressed.

The cutting into bedrock below the meter scale is Chalcolithic activity on the tell. The symmetry, concentric abrasion rings, and tool marks on the upper rim of the hole are hallmarks of its artifactual character. The nari bedrock surface is illustrated in Figure 25 and was sampled at the point (x).

Figure 70

Figure 71

The outer face of the wall presented an entirely different type of occupational sedimentary arrangement. Close and very careful trimming and fitting of the rock gave the wall uniform resistance against battering rams and prevented scaling by an enemy. The founding of the wall on the bedrock was an additional defensive measure. Wall sedimentation beginning on soil could be easily undermined by those desiring to penetrate the city's defenses (Figure 71).

The Southcentral Gate. One of the phases of the Gezer excavations has been the uncovering of a special form of wall composition known as Ashlar masonry. This structure is that which constituted the facade about the entrance to the gate. Figure 72 shows carefully hewn Ashlar blocks cut to fit closely together in the facing on both sides of the entrance. The building stone is nari, which has been quarried locally /insoluble residues (Table VI) and textural character/. This portion of the occupational structures has a chronological significance because the long axis dimension of these stones is 51cm, the royal cubit in use in the time of the reign of King Solomon.

The aesthetical utility of this bedrock commodity is demonstrated in the southcentral gate construction. Cultic utilization is considered below. Many cities of antiquity were located in areas where the immediate environment provided all their specific building needs. Only the most wealthy cities could afford to bring exotic building stones long distances.

As a part of the research to understand the trimming process used in antiquity to produce Ashlar masonry, observation was carried out on those building sites where Arab workmen are using techniques which have

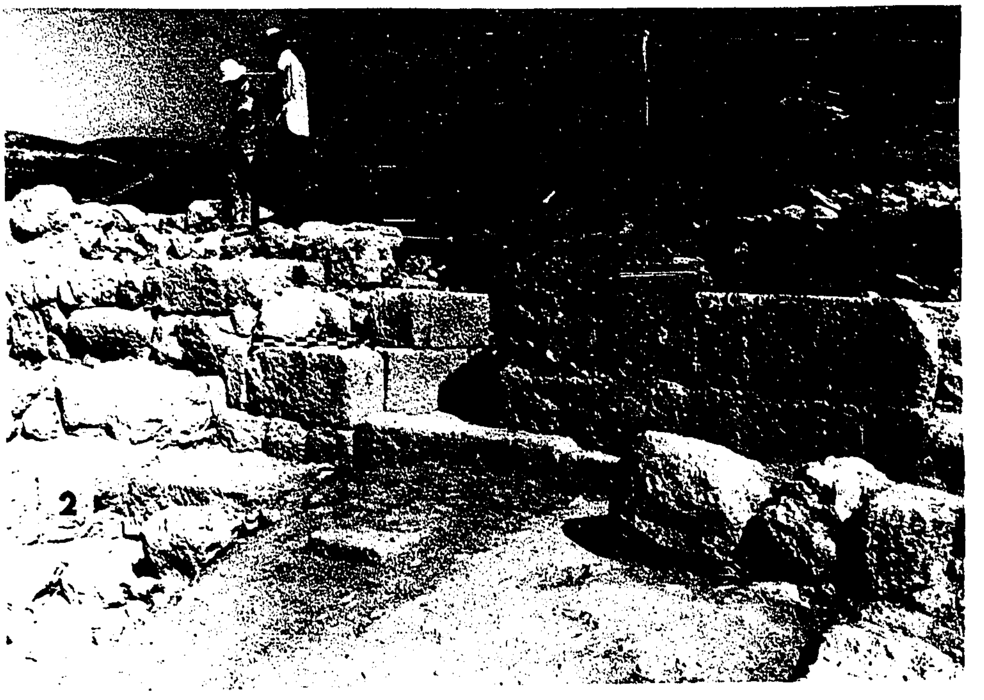


Figure 72. Petrologic analysis: Ashlar blocks veneering the surface of the Solomonic gate structure. Analysis of these very carefully cut materials gave results within the range of variation found for the local nari bedrock transition zone (Plate IX). The Ashlar masonry which has as it longest axis the dimension of the royal cubit (51cm) as one of the hallmarks of the constructions of the period (1). Evidence of a Hellenistic rebuild of this gate structure is present at (2) on which a marginal trim to the block facing is wrought by the tongue chiselled geometry. Analytical values for these lithologies were also in the range of variation for the local nari bedrock material (Cf. Table VI)

not changed in millenia. Figure 73 illustrates the tedious and very slow trimming process necessary to produce a smooth face on a block of stone. Only those whose way of life exhibits considerable patience (e.g., Near Eastern people) tend to produce this form of building material. This is an essential concept for the understanding of the nature of the occupational sedimentation of Tell Gezer.

A different source for building stone outcrops on the crest of the Judean anticline. Figure 74 shows the conchoidal fracture of trimmed Mizzi Ahmar (Table II) a much harder construction material. Only four samples were found scattered in isolated contexts in the Gezer strata. It is not an essential sedimentary commodity in the Gezer excavation. Mizzi Ahmar represents an exotic. The stone attracted ancient builders in the Jerusalem area where it was used by Herodian (Roman), Arab, Crusader, and Turkish builders.

The Late Middle Bronze Glacis. The section exposed by the Field I trench (Areas 8, 9) is illustrated in Figures 83a and b and Plate XV. The glacis had its widest use as a defensive structure during the Hyksos Period of Egyptian history (Middle Bronze II-B and C). This carefully prepared structure has a representation at Gezer which may prove to be classic. Its location between the inner massive wall (locus 5017 and No. 4 on Plate XV) and the outer Late Bronze structure (locus 9011) has prevented significant deterioration in its stratigraphy by mass wasting.

The glacis represented enormous movements of earth. It was constructed as a rampart against the base of the outer wall of the city to provide: 1) surface which an enemy would scale with great difficulty, 2) a defensive device to deflect the battering ram which was being

Figure 73. Petrologic analysis: artifactual surface feature study. Skilled Arab masons and surfacing blocks of Cenomanian lithology from quarries in the Judean Mountains known as "Melike" (the historic royal building stone), using a technique that produced the Gezer architecture since Middle Bronze time.

Figure 74. Petrologic analysis: indurated Cenomanian Mizzi Ahmar used in both ancient and modern (Arab and British Mandate) architecture. This lithology is distinctive in the deeper water, Late Mesozoic fauna, and especially in the yellow and red color which other carbonate formations do not exhibit.

Figure 73

Figure 74

introduced throughout the Middle East during this period (D. Lance, pers. comm.).

The glacis illustrates the economic value of certain constructional materials. Referring to Plate XV, the stratigraphic and sedimentary relationships show a dark brown (10YR 3/2) virgin soil (with shallow cultural intrusion (7.5YR 4/2) 2.8cm at 3) (see also Plate XIV-C, diagram B). Above this is a lens of the Taqiye marl (6a) in which Globoconusa sp. occurs. A light gray-green color (5Y 6/2) and "limonite concretions" pseudomorphic after goethite are other characteristics of this formation. Lenses 7a and b are surface rendzinate soil derivations of the Eocene mingled with occupational debris. After another lens of Taqiye marl, local surface soil materials (8-10d) were used to back fill in front of the massive nari wall (4) (locus 5017).

The glacis surface is composed of unweathered nari quarried from the Maresha Formation. (It contains Middle Eocene coccoliths and foraminifera, cf. Chapter II). The chalk was worked into a paste in its initial depositional phase. The compaction is texturally illustrated by the impermeable nature of the glacis surface (11). Vadose water has deposited a 4.0-9.2cm sesquioxide concentration (12) immediately above the compacted chalk.

Although the upper portion of the glacis which is still preserved was constructed with a 45^{o} angle to its slope, there is no evidence of mass-wasting down the face of the surface. Experiments conducted during the excavations by the writer showed that fresh chalk excavated from the 28m depth of the water tunnel could be worked into a paste with the addition of only 5% water. The resultant plaster was sufficiently

STRATIGRAPHIC SECTION of WEST BALK (face)

FIELD I, AREA 8, TELL GEZER
1966 & 1967 EXCAVATIONS

LEGEND (See text description)

18. Macalister excavation spill (1902-09)
17. Field rock
16. Soil (weathered Tell debris)
15. Fill on wall 14
14. Early Late Bronze wall (Hewn Nari)
13. Nari rubble - angular boulders, cobbles & pebbles
12. Sesquioxide deposition zone
11. Indurated impermeable compacted chalk paste
10. Brown lenses of rendzinate soil and occupational debris
9. Brown lens of rendzinate. soil with minor grey-green marl and occupational debris
8. Brown lens of rendzinate soil, angular Nari cobbles and occupational debris
7. Brown horizons of rendzinate soil, packed with large potsherds, and Nari pebbles and debris
6. Grey-green angular marl slabs and conglomerate.
5. Indurated Nari chalk lenses
4. Middle Bronze II A ? Massive wall (15.5 M thick) hewn (face only) Nari
3. Soil-occupational debris - mingled zone - Paleo "A" zone relict
2. Virgin rendzina soil with minor occupation debris intrusions (upper 10 cm.)
1. Nari bedrock, jointed and irregular

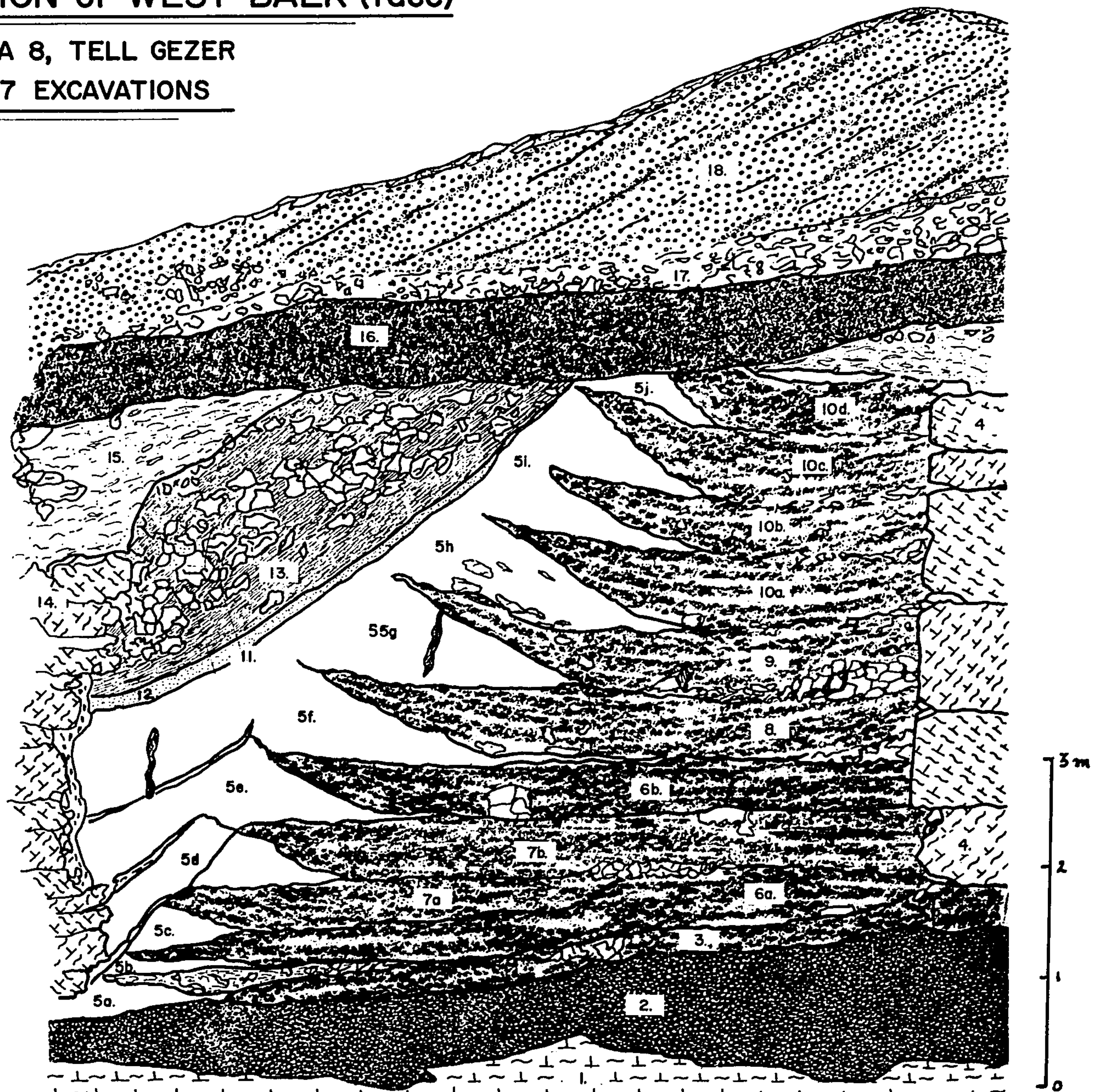


PLATE XV

Figure 75a. Middle Bronze II-C glacis protecting the south face of the Early Middle Bronze II wall. Although this massive wall (out of view to the right) has a local thickness of 15.5m (in the area intercepted by the Field I trench) the glacis was constructed to further enchance its defensive purposes.

Figure 75b. Undistorted glacis section at the 219m datum level. The interfingering of relatively clean unweathered chalk with that of occupational and destructional debris and quarried bedrock represents a pertinent chapter in the ecology of Tell Gezer.

The surface at the head of the meter stick is evidence of the care used in the preparation of this structure. The freshly quarried chalk is so tightly packed that the degree of induration achieved has been sufficient to deflect percolating ground water down its surface since the structure fell into disuse. In the debris lying immediately above the surface a high concentration of sesquioxides occurs. This degree of impermeability could be attained only with the use of unweathered chalk materials, always in short supply. Construction could not involve siliceous chalk since it would not become indurated and would easily be scaled by assaulting enemy troups.

Figure 75a

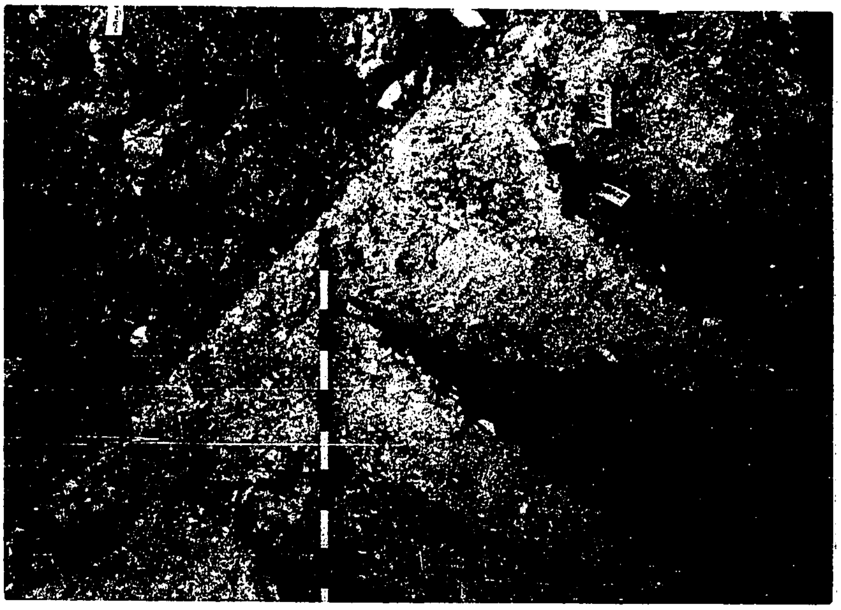


Figure 75b

competent upon drying to withstand breakage from 1 kg weight placed upon it.

The Gezer glacis is an example of the economic utilization of the local geology. The builders went to the base of the Shephelah to quarry the Paleocene marl for a portion of the support material to conserve the relatively scarce unweathered chalk. The glacis surface could be prepared only from this source. This material was available only in the excavation of such structures as tombs, cisterns, and rooms cut in below the nari surface. It is the contention of the writer that the amount of material necessary for the construction of the glacis necessitated a nearby quarrying source of sufficient quantity to provide an apron about the city. This quantity would be available in material excavated from the construction of the Gezer water tunnel. While the archaeological evidence of the date of the water tunnel is unclear from MacAllister's results and must await excavations of the lower water tunnel pool area, the hypothesis concerning the origin of the material for this structure is credible.

THE STRATIGRAPHIC HIATUS

Criteria by which sedimentary processes other than those of occupational accumulation or destructional sedimentation are distinguished as follows: 1) sediment of a clearly loessic character, 2) sediment in which there is gradational enrichment of clay mineral content vertically. These deposits are devoid of facies showing an occupational or destructional sedimentary character in its inherent fabric.

Weathering and Soil Zones

The origin of occupational hiatus sedimentation is a natural process which is at work on the local environment generally. The rate of weathering suggested in Chapter III may be applied to the alternative of tell debris. If weathering proceeds in the eastern Mediterranean area at the rate of 10cm in 1000 years, one might expect to see such changes in abandoned cultural contents. It is not surprising, therefore, to observe soils in the true pedogenic sense of the word in an incipient state within the local stratigraphy.

One such horizon with known vertical control exists in the confines of the strata of Tell Gezer. Figure 76 (cf. Plate XV, sediment 16) illustrates a case in point. The latest pottery found sealed in the surfaces on top of wall 5017 (Plate XV, No. 4) upon which the brush is lying were Roman. No further sealed ceramic contexts were found above this level. MacAllister dump (Plate XV, sediments 17 and 18) is seen above the "soil" with the sorted tip lines. Samples were taken at 5cm levels throughout the sediment. Minor yet significant increases of clay mineral content occur upward in this stratum. The mineralogical shift is toward palygorskite concentration from a predominance of illite and kaolinite in the lower level (cf. Plate XIV-C, diagram E). In addition to the shift from illite to palygorskite there is a minor increase in montmorillonite content.

This differential may be explained by 1) nari and Middle Eocene chalk debris in the upper zone releasing palygorskite with its minor montmorillonite content. 2) The illite content of the lower zone may be due to the presence of mudbricks quarried from the wadi Aijalon

(Plate XIV-C, diagram D) a clay source which has over 50% of this mineral. The illite is present but new yields of clay from the weathered bedrock debris have produced the enrichment and differential increase of palygorskite in the upper levels. The lower levels still reflect the mineral concentrations of mudbrick, the pottery type mineralogy of which includes wadi Aijalon sources.

The study of this "paleosoil" is intended as a model designed to serve as the basis for understanding stratified sediment of this nature.

Another buried soil in the excavation was analyzed to test the conclusions concerning the incipient soil observed in Field I, all areas. Figure 77 illustrates the angular truncation of a section of Iron II sediments, the upper part of which features an incipient soil in the definition of the writer. This "soil" may have been forming during a period of 2700 years, if ceramic evidence is correct. This "soil" also showed a clay mineral enrichment in the direction of montmorillonite and palygorskite.

The Occurrence of Loess

No better place may be found to observe the cessation of normal occupational activity in a city than in the street environment. Figure 78 is a view southward through the entrance of the southcentral gate. The street surfaces have been delineated in the step-like surfaces proceeding toward the gate exit. Archaeologists have made this distinction on the basis of the relative hardness or resistance to the trowel of the street sediment.

Figure 76. Field I, Area 8, west baulk. The trimmed baulk contains a geologically significant stratigraphic entity: an incipient soil profile (horizon (A)= locus 8005 of the excavation record). The incipient soil essentially represents an occupational hiatus between the last time of Roman habitation and the time when MacAllister's workers covered it with the excavational debris from the adjacent trench to the east.

Figure 77. Stratigraphic analysis: a span of approximately 2700 years separates the principal phases of this stratigraphy. Sediment (A) (10YR 7/3) is dated from ceramic evidence as Iron II. Sediment (B) (2.5Y 5/2) is an incipient residual soil, buried by MacAllister dump sediment (C) with the graded bedding of tip lines. The clay size particle content of (B) is 24.3%, (A) is 14.8%. The palygorskite content of (B) shows a reflection intensity of slightly more than twice that of the clay fraction of (A).

The gross textural fabric of (B) is similar to that of (A) to the extent that (A) could only be regarded as residual and not transported in character. The distribution of large particle sizes in the coarse sand to pebble size range precludes the possibility of this sediment having a purely loessic origin. Weathering processes have partially leached the carbonate content of the incipient soil (17.2% less) yielding an increase of the clay residue. Clay mineralogy has shifted in the direction of a small montmorillonite increase (10%) and a 2-fold palygorskite increase (30%).

The existence of incipient soil seems probable in this area. It constitutes evidence of an hiatus in the occupational sedimentary accretion above the soil level in this area for several hundred years. The understanding of the correct nature of this sediment is a vital aid in the stratigraphic interpretation of the occupation of this portion of the central gate area in the south wall of the city.

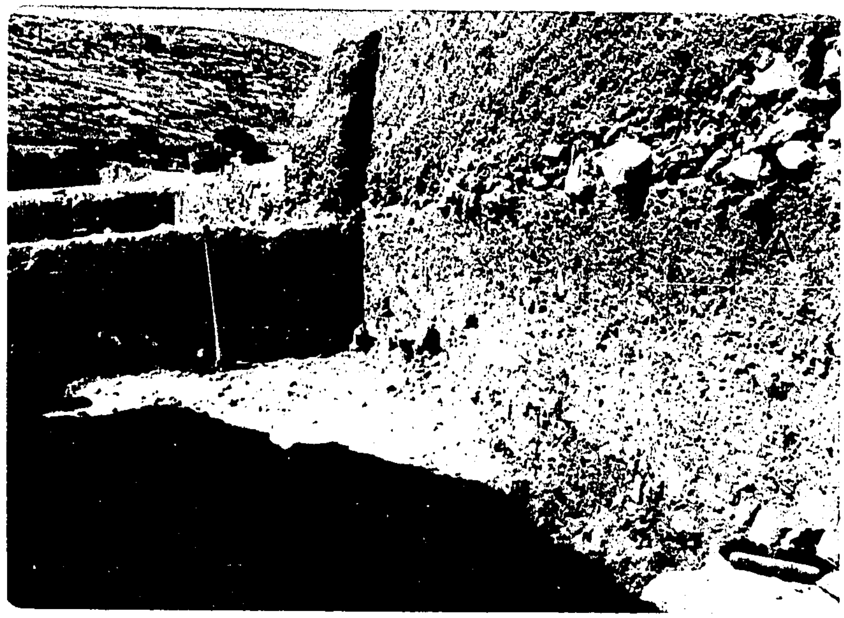


Figure 76

Figure 77

A sediment of unusual nature turned up in the excavation of the surfaces: a 16.0cm thickness of finely divided sèdiment in the silt size range of .03-.06mm was uniformly deposited across the area observed. Sieved portions of this stratum revealed the absence of the usual occupational fines: charcoal flecks, unweathered chalk particles, pottery fragments of various sizes, and the field mud and soil which is usually co-mingled with the street surface material.

This loessic material is described for the purpose of establishing parameters by which this form of occupational hiatus may be recognized. It is quite subtle and can be readily missed by anyone who is merely scraping for "hard surfaces".

Meteoric Water Runoff

While surface water drainage is a familiar subject to every student of elementary geology, its effects may not be discernable to those who are unfamiliar with the processes. This form of sedimentation was observed in a number of stratigraphic contexts. Figures 79a and b are a record of an incident in which the nature of the placement of Ashlar blocks was deduced. Beneath the block in the upper position and elsewhere in this are (Figure 79a) the deposit illustrated in Figure 79b was found. This sediment has the texture of graded bedding. Cyclic water runoff with high competence flow into a ponded area where low competence flow conditions follow yields a coarse to fine particle deposition.

The data show particle sizes in concentration ranges which are close to that found for loess from the Beersheba area (taken on Clay Conference fieldtrips); see Plate XXII, diagrams A-D. The writer knows

Figure 78. Stratigraphic analysis: accumulation of separate surfaces in the occupational history of the southcentral gate area (view south along successive street levels through the southcentral gate of the city). These surfaces are usually recognized by the archaeologist on the basis of relative hardness of layers; other criteria, however, contribute to the validity of these conclusions. Street surfaces generally show a distinctive convex upward orientation of curved sedimentary particles which range from pelecypod shells to body sherds.

Local lenses of sorted silt and sand occur on the streets in ruts and low places. These are deposits of meteoric water run-off (see Figure 79a). The successive street levels are divided into two series: the arrow indicates a stratum of sediment unusual for its isolation in a street context. Analytic data shows a loess composition for this sediment (16.0cm average thickness) (70% of the sediment was in the 0.03-0.08 size range, Plate XXII). The loess blanketed the entrance to the city constituting an occupational hiatus in the habitation sequences. This sediment together with that of incipient soil profile formations constitute two of the major categories of non-occupational or occupational hiatus stratigraphic record.

The composition of the loess is quartz 58.2%, carbonate silts 26.4%, aggregates or clusters of soil particles 15.1%, feldspars 5%. It is similar to that which is deposited near Beersheba (Aisenstein, 1959) and may originate from the same source.

of no human activity nor any other natural process which would produce this sediment.

This sediment may be explained on the basis of an open trench in which meteoric surface water carried the sediment to the ponded conditions of the trench. Cycles of graded bedding imply repeated rainstorms which are known to occur from present conditions in the Shephelah during the winter time. Graded sediment was distorted under the Ashlar masonry suggesting that blocks fell into an open trench.

THE PYROTECHNOLOGY OF THE GEZER SEDIMENTATION: ASSOCIATED STRUCTURES

Sedimentary structures produced by man in his use of fire are diverse. These range from early campfire configurations of semi-nomadic people to very complex structures built for cooking. Figure 80 illustrates a Chalcolithic/Early Bronze campfire area. This stratum was uncovered in Field I under a succession of levels consisting of Early Bronze, Middle Bronze, and Late Bronze contexts above it. The absence of building or wall structures in this stratum indicates a context in which facies relationship shows no local sedentary sediment.

This is not a forest fire remnant. A Chalcolithic cooking vessel with its blackened outer walls is located in the same stratum. The fire was intense enough to produce calcination of the bedrock material in the immediate vicinity. A thin layer of rendzinate soil covered the charcoal twigs, possibly an attempt to extinguish the fire.

Two marks characteristic of the presence of fire in this area in addition to the charcoal are 1) the change of the soil color which represents a dehydration of the hydrous iron oxides and with the consequent formation of hematite and 2) the calcination of the limestone which

Figure 79a. Ashlar blocks resting on open trench sediment Field I, Area 9-10. The presence of Ashlar blocks (typical of Solomonic architecture) at this location on the southern perimeter of the city raised speculation concerning existence of fortification structures from this period in this area. The character of the sediments underlying these blocks, however, precludes the existence of such structures at this level. A lens of graded but distorted sediment immediately underlies the block above the scale (cf. Figure 79b). The "curly bedding" has resulted from the fall of these Ashlar blocks into an open trench, the bottom of which was receiving intermittent sedimentation from winter season precipitation runoff.

Figure 79b. Graded bedding from the trench containing the Ashlar blocks (Figure 79a). The graded character of this sediment is an example of the cyclic sedimentation typical of rainstorm runoff occurring during the rainy season. At least six cycles of sedimentation are preserved in this section, two of which show continued high velocity flow resulting from a heavy precipitation rate. In light of the known frequency of winter rains (Baly, 1957), this series of graded bedding need not require more than one season for deposition. The late trenching into which the Ashlar blocks fell was probably open for a sort time - about one year. The graded bedding distorted by impact, was found only under these blocks.

The coarse sand-size fraction is composed of chalk, chert, bone, and siliceous chalk particles. The fine bedding is composed of clay and silt size particles of chalk, soil, clays, and charcoal flecks. A very minor silicified foraminiferal residue is present, derived from the attrition of the chalk used in the city. The charcoal occurs in the uppermost layers indicating evaporation of the ponded water upon which they floated.

Figure 79a

Figure 79b

involves temperatures in excess of 900°C.

By way of contrast, Figure 81 is an illustration of a pyrotechnic structure of Early Iron I origin (Stratum 10). This domestic oven context (locus 1129) shows a circular geometry (analogous to that of a beehive). It was erected by the use of terra cotta material (the field soil made plastic by wetting) and by the outward placement of potsherd remnants along the circumference for insulation. The use of this technique was observed in a number of situations within the excavations ranging from Late Bronze down to the Roman time. The general geometry of these structures changed very little through time (Figure 82).

Pyrotechnical Study: Fuels and Ash

One significant aspect of tannur sedimentation is the type of fuel generally used in the domestic environment. Figure 83 illustrates the gross fabric and texture of ash from dung fuel. This commodity had wide and general application, especially in Middle Bronze time and continued through the Roman period. The fuel was a product of the keeping of flocks. (Modern Bedouin have been observed using this fuel along with that obtained from camels in the preparation of coffee, the boiling and roasting of meats, and the heating of washwater.)

Shephard (1965) observes that American Indians used it for another purpose:

> Dung, a fuel widely used by potters who had domestic animals, has both advantages and disadvantages. It burns easily and rapidly because it is open in texture and is composed of fine material. It also retains its form after the more combustable material has been burned out, thus maintains a warm blanket around the pottery, but it gives a short firing because it burns out quickly [Figure 31] . . .
>
> The Zia potter . . . used thick slabs from the sheep corral instead of chips, by the time she had laid the fuel, a temperature

Figure 80. Sediment analysis: pyrotechnic studies. A Chalcolithic campfire site - the earliest evidence of the use of fire in the stratigraphic history of the tell. The context of this record is on a thin rendzinate soil cover (4.8-7.1cm thick) immediately overlying the nari bedrock surface (Field I, Area 3). A number of nearly complete charred branches lay buried in the soil - perhaps an ancient extinguishing technique - evidence of the use of arboreal fuels. The temperature levels achieved may be observed from the decarbonation of the rendzinate soil (b) in the light orange (7.5YR 7/8) and from the decomposed nari patch (a). A broken piece of cooking pottery lies at (c). A momentary glimpse into the non-sedentary activity of the Chalcolithic inhabitants of the central Shephelah. (d) is the west baulk face.

of 415°C was reached. The slabs burned more slowly than chips; consequently the rate of heat increased to the first peak was less than half that of the other 3 Pueblo firings. Since there was more fuel, the high temperature was maintained much longer.

A variety of fuels was used by the inhabitants of Gezer. Evidence in the archaeological sedimentation shows various kinds of woods ranging from coniferous to deciduous sources (evidence is bark material present in some of the facies relationships with the tannur deposits). The length of time a fuel burns depends upon the amount of volatile material it contains, the denisity of the carbon and the nature of the ash it forms.

Certain kinds of wood were chosen because the ash acts as an insulating blanket over the charcoal and thereby induces a slower rate of consumption and a prolonged burning. Occasionally, fuels such as coarse grasses, straw, and chaff were used because of their ability to produce a very quick heat. Frequent renewals, however, were required. Other sources such as hardwood tend to burn more slowly and need not be replaced or replenished.

While no coal has been found in the recent Gezer excavations, three incidences of bitumin have occurred. Bitumin occurs in the vicinity of the Dead Sea where submarine seepage and flotation have produced a littoral accumulation. This material provided ancient man in the Near East with a source of this potential fuel. Although the bitumin observed came from facies relationships unconnected with the use of fire, it remains a potential fuel.

There is evidence that abundant supplies of wood were available as late as the Roman period. A commodity is shown in Figure 84 which demanded considerable quantities of fuel. While portland cement is unknown in this period of the Levantine history, mortar was produced by

Figure 81. Sedimentological analysis: pyrotehcnic study. Sectioned tannur (baking oven) from Iron I levels of occupation. Two principal use strata are in evidence. The lowest (a) is on the founding level of the tannur and constitutes the ash sediment during this initial phase. Analytic data on the sediment corresponds to that of dung ash. After a phase of disuse (b) and the accumulation of as much as 17cm of occupational debris fill, the tannur was again used for about half the duration of the first, if the rate of ash accumulation was similar.

Figure 82. Sedimentary structure analysis: pyrotechnic study: Moderately well preserved tannur in use during Late Iron or Persian times. The smooth ceramic interior was the surface upon which flour cakes were placed to bake in the residual heat. Modern Arab practice of baking in this fashion was observed in the vicinity of Nablus.

Figure 83. Sediment analysis: pyrotechnic study - photomicrograph of dung ash. Identical physical characteristics were observed in dung ash produced by a fire in a corral in the large cave (Figure 5b) on the hill just south of Tell Gezer. Chemical analysis for potassium and for residual carbon is comparable.

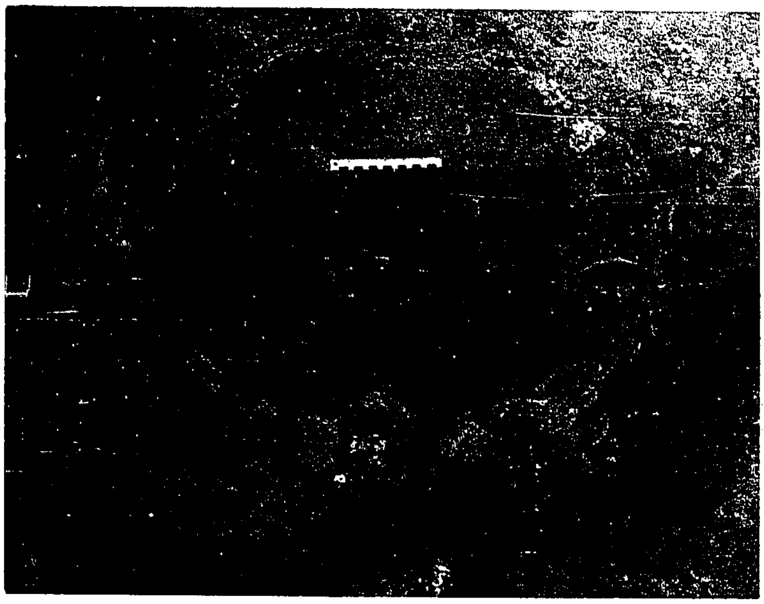


Figure 81

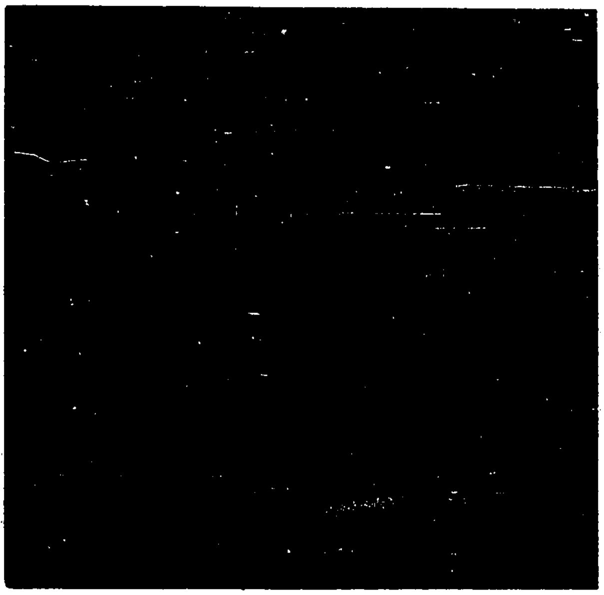


Figure 82

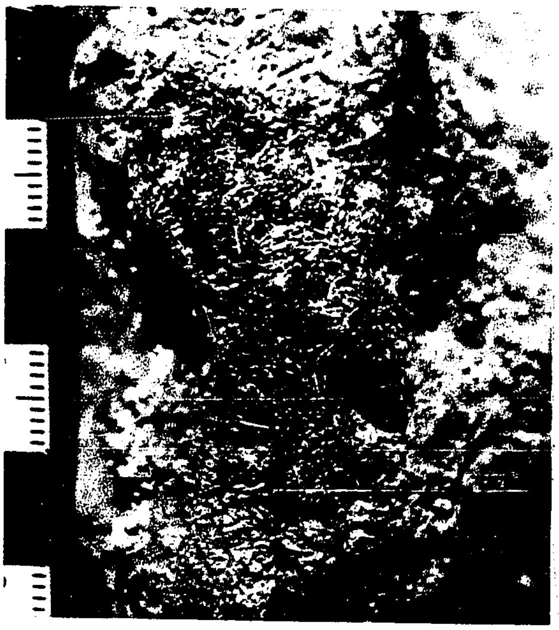


Figure 83

erecting a slio-shaped structure in which alternating layers of fuel and limestone were placed until the silo was nearly filled. It was then lighted off and allowed to burn to effect the decomposition of the carbonates (observation notes made in "kiln valley"). After cooling, this material was shoveled out of the kiln and used in various building contexts.

Mortar from the occupational structure sediment of Roman buildings is illustrated. It was observed in the construction of the Hadrianic temple on Mt. Gerazim above the Plain of Shechem in the Ephraim Hills. Isolated examples of mortar have occurred in the Gezer excavations to date, none have been demonstrated by facies relationships to be a part of a remaining structure.

Occupational Sedimentation

Mudbrick Debris. Although ceramic materials were considered in Chapter III of this report, the evidence of mudbrick sediment is reserved for this section. Mudbricks were observed in various states of preparation. Figure 85 illustrates the three most common states of use: 1) unfired mudbrick with as much as 35% vug area constituting the molds of straw and chaff used as a binder in the brick manufacture, 2) reduction fired mudbrick, and 3) mudbrick fired above 900°C (no endothermic reaction peaks remain).

Examples of (3) were observed in the Middle Bronze II gate structure (Figure 4) in the southwestern wall area (Field IV), a massive construction of prepared bricks. Trace element chemistry shows that pottery type sources I and II were used for these materials (Plate XIV-A).

The history of the use of mudbricks in further documented in Figure 86. This section cut through the Middle Bronze gate structure (Field IV) illustrates a chapter of the history of the southern fortification.

The sediment is compositionally different in the various types of mudbricks used for the construction of the defensive wall and its gate. The frequency and distribution of the bricks shows that certain compositions played a key role in the structural stability of the walls.

The higher clay content of the wadi Aijalon floodplain colluvial, alluvial, and residual soils provided a product of greater competence structurally than the residual rendzinate raw materials close by. The wall, however, is an illustration of structural failure; for the inhabitants of the Bronze age city found it necessary to add to the fired brick structure, materials of far less competent composition: occupational debris. Three different compositions of debris bricks are visible in Figure 81.

The familiar effects of mass wasting and slump may be observed not only in the crecentic slip-plane scar observable in plan view above the wall, but also in the lobate flow structures at the toe of the slip. Whether this represents a tragic failure in the fortification structures of the city during the time of occupation or whether it is a subsequent failure of the wall, it took place before internal destruction affored a buttress to prevent the inward slumping of the wall structure. The use of occupational debris in the construction of the brick wall may have been a last resort to bolster a failing structure. The inhabitants of the city had to use materials internally available within the confines

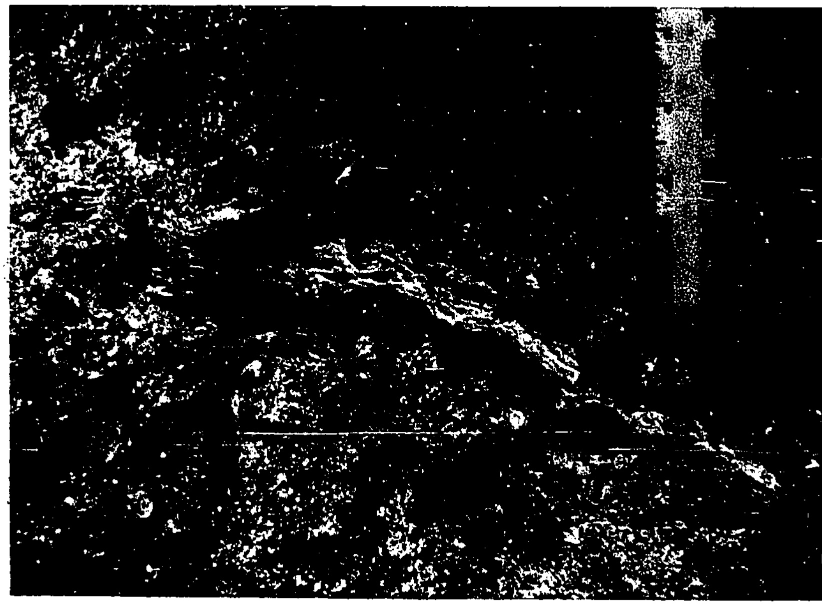


Figure 84. Sedimentary analysis: pyrotechnic studies. Late Roman lime mortar construction. Calcium hydroxide ($Ca(OH)_2$) leaching has resulted in a travertine-like deposit in a vug. Note the dispersion of charcoal throughout the mortar matrix. This is also characteristic of mortar when its use appears earlier - the fuel and the product are inseparably mixed. The more highly siliceous components of the original $CaCO_3$ source are observed as coarse sand and fine pebble size aggregates in the mortar matrix. The temperature never reached sufficient level to form significant quantities of tricalcium silicate, one component of portland cement.

The study of abandoned Arab kilns (kiln valley), some of which may go back to much earlier times, indicates that the tehcnique used to produce mortar has not changed appreciably since the Roman period. Circular kilns with basal diameters of up to 2.5m were stacked with fuel, limestone or chalk or nari, another layer of fuel, another layer of rock, another layer of fuel, and so on until the silo-like structure (remains of which still show vertical dimensions of 3.5m) was nearly filled to the top. It was lighted off and allowed to burn until the cool residue could be removed and prepared for use. Since no lime storage bins have been reported in the archaeological literature, it can be inferred that the lime-firing operation generally took place upon demand.

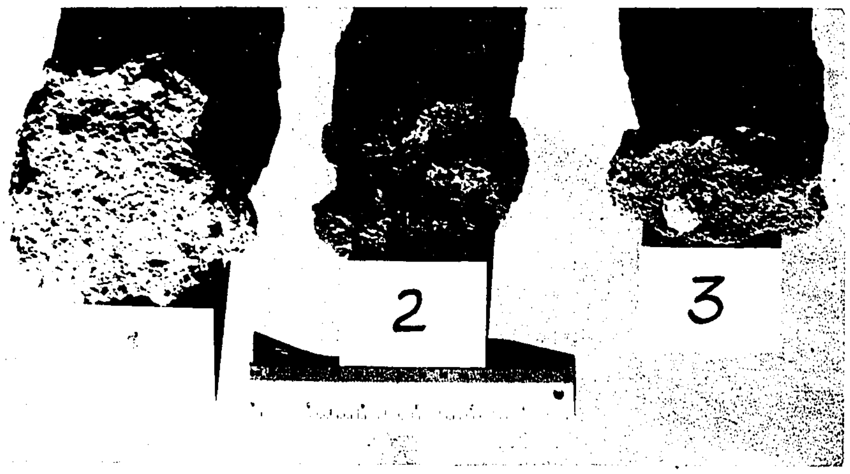


Figure 85. Sedimentary structure analysis: three types of mudbricks used in the architecture of Tell Gezer. 1) Unfired and non-levigated alluvial soils from wadi floodplain contexts draining Eocene strata. The brick was originally indurated with straw/grass binder (color, 10YR 7/4). 2) Mudbrick of nearly identical composition with reducing firing history. Firing temperatures have exceeded the endothermic reaction at 550°C, but palygorskite reflections persist in the clay mineral fraction (color, 5YR 2/2). 3) Mudbrick of similar composition but with an oxidizing firing history (color 10R 4/8). The stratigraphic studies thus far have revealed that brick types (2) and (3) are used almost exclusively in wall fortification structure, while bricks of (1) are used throughout domestic architecture. It should be added, however, that most of the mudbrick superstructure of stone wall foundations has been lost throughout destructional activities and by the process of mass wasting.

Mudbrick structures were observed in a number of locations, and especially at Jericho where houses were built exclusively of this material except for the supports and roofs. This material has durability useful to the semi-arid regions of the world.

of their defenses. The occupational debris bricks were demonstrated to have a competence less than half of that of the mudbrick counterparts.

Sedimentary Processes: Domestic Occupation

A Wine Press. A circular depression representing the bottom of some sort of basin (similar to Figure 65 truncated by overlying strata was observed in Field II, Area 1 (Figures 87a and b). The geometry of this basin suggested a sediment container for some commodity of man.

Analysis of the sediment contained in this area yielded data detailed in the explanation accompanying the illustration. A wine press context for the origin of this sediment seems credible. The nature of the deposit differs drastically from that of sedimentary basins observed elsewhere (cf. Figures 79a and b). Cistern contexts typically show graded bedding composed of a coarse silt to fine sand alternating with clay-sized sediment. Deposition is the result of meteoric water runoff. The data imply the proposed genesis - a wine press.

Prepared House Surfaces. A well-prepared floor surface is classic occupational sedimentation. One constructional sediment of this type consisted of nari aggregate in a matrix of chalk paste and ranged in thickness from 5-12cm (Figure 88a).

Another prepared occupational sediment (Figure 88b) is a roof plaster found in the context of a destroyed dwelling (Field I, Area 3, Late Bronze I). The important distinction between these two constructional sediments is that one is designed as a floor surface while the other is designed to have sufficient structural competence to exist as a roof plaster. This was the purpose of the binder, the molds of which

Figure 86. Stratigraphic and structural analysis: section of slumped Middle Bronze brick wall structure near the southwest gate in that fortification (cf. Figure 4). The subtle nuances of color differientation essential to analysis are perceived only by means of color photography. Compositional variation reveals two distinct building phases connected to the history of that portion of the wall preserved. (A) is a primary section of the wall composed of levigated alluvial clays (free of coarse sediment) indurated with straw binder and subject to a firing in excess of the first kaoline endothermic peak (550°C) (type I-A ceramic group). These bricks of darker color (7.5YR 5/6) (A^1) show the greatest competence as a constructural material.

The other bricks of wall portion (A^2) are composed of non-levigated alluvial clays typical of those found in the wadi just east of Tell Gezer, and show evidence of similar firing levels. Wall segement (B) illustrates a dramatic change in the raw material source for mudbrick construction. This section is composed of unfired bricks made up of occupational debris from within the tell. The clay mineral DTA traces show typical kaolinite and palygorskite endothermic reactions across the temperature range (240°C-360°C, 480°C-560°C, 760°C-780°C). The wall was interlaced with a few bricks of rendzinate soil indurated with straw binder, which were fired above the minimal levels indicated above.

The structural weakness and incompetence of defensive ramparts prepared from occupational debris is evident in this section. Serious slumping has occurred along a slippage plane at (1), the drag component of which is evident in the distortion of the normal geometry of the bricks. Additional illustration of the incompetence of the occupational debris brick structure is observed in the lobate flow of the light-colored bricks at (C) (color 5YR 7/2). The distortion of these bricks is most accute along the slippage plane at (2).

The phases of wall construction signify two different types of fortification activity (1) an orderly construction of a defensive wall built of the best materials available and prepared carefully to producé a durable structure. (2) Hasty additions to this well-conceived preparation from intra-city sources to repair or strengthen the construction. (An alternative to (2) is that the occupational debris materials were used as a substrate and backing for the more resistant wall fronting.) Whether contemporary or later, the use of the far less competent sediments for defensive purposes was ill-conceived. The section illustrates a potentially tragic incident in the history of the wall near the southwestern gate. Structural failure has resulted in an inward collapse of this section of the wall.

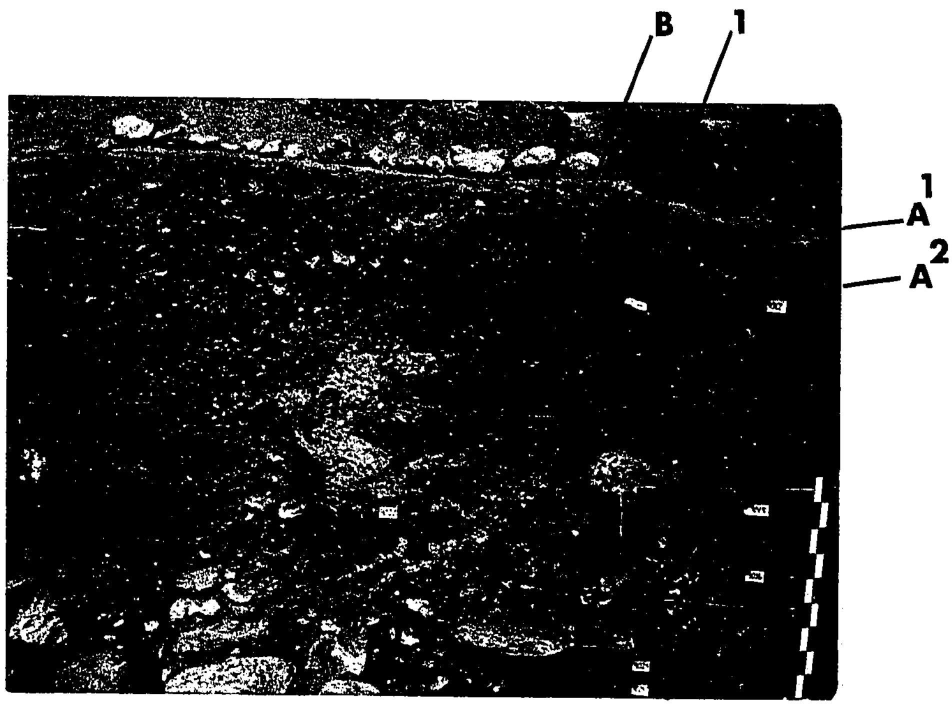


Figure 86

are yet in evidence in the illustration. It is important to recognize this distinction in the analysis of destructional debris where occupational and destructional sediments are frequently co-mingled.

During times of continuous occupational sedimentation in houses which exist as structural entities through long periods of time, a thick sequence would be expected to accumulate. This would take the form of the slow accretionary floor surfaces in the domestic quarters.

Two cycles of mutually independent sedimentary accumulation in a domestic context may be observed in Figure 89. The data revealing the origin of this sediment is easy to discern from the photograph of the freshly exposed occupational horizons. Important differences in the nature of the occupational sediment exist as it is laid down in the dwelling floor context. The significant features to be noted are: 1) specially prepared flooring which may be composed of field soil or chalk-nari layers, 2) ash layers which are a facies continuum from a cooking or baking area, 3) the dust and sediment associated from the human activity in the area which would represent an essential blending of the sediments mentioned with particles of pottery, bones, and artifacts such as pins, buttons, weapons (points) and tools (chert blades).

Another example of a domestic structure and its associated sedimentation may be observed in Figure 90. The subtle outlines of a pithos base may be observed in the red hamra lenses which are marginal to its upper lip and sides. This was a hole excavated into the floor of a domestic environment so that large pointed-base water storage jars could rest in it securely without breakage loss. It is evident from the surface (Figure 88a) that level floors were not a common feature of the

Figure 87a. Sedimentary structure analysis: bottom sediment probably from a wine press context in a basin or circular receptacle. The desiccation cracks are non-typical of cistern sediments observed elsewhere (in the topographic saddle proximal to the threshing floor area just south of Tell Gezer and in large cisterns excavated on Mt. Gerizim).

Figure 87b. Sedimentary analysis: stratigraphic cross-section of the sediment contained in the structure observed in Figure 87a. The evidence in the texture and the analysis of the sediment itself strongly suggests a wine press deposit on the basis of the following data: 1) the convoluted and distorted bedding which can only rarely be traced entirely across the basin, 2) a residual carbon content of 19.2% - analytical variation +/- 4.1% - on the basis of ignition residues at 800°C, and 3) the worm burrowing activity, the incidence of which exceeds by more than 50% that observed in closed basin deposits in other contexts. While no model of wine press sedimentation has been available for study, the inference that wine press activity would yield a sediment and alteration of this character is credible. The absence of graded bedding which is typical of cisterns and basins receiving meteoric water runoff is significant.

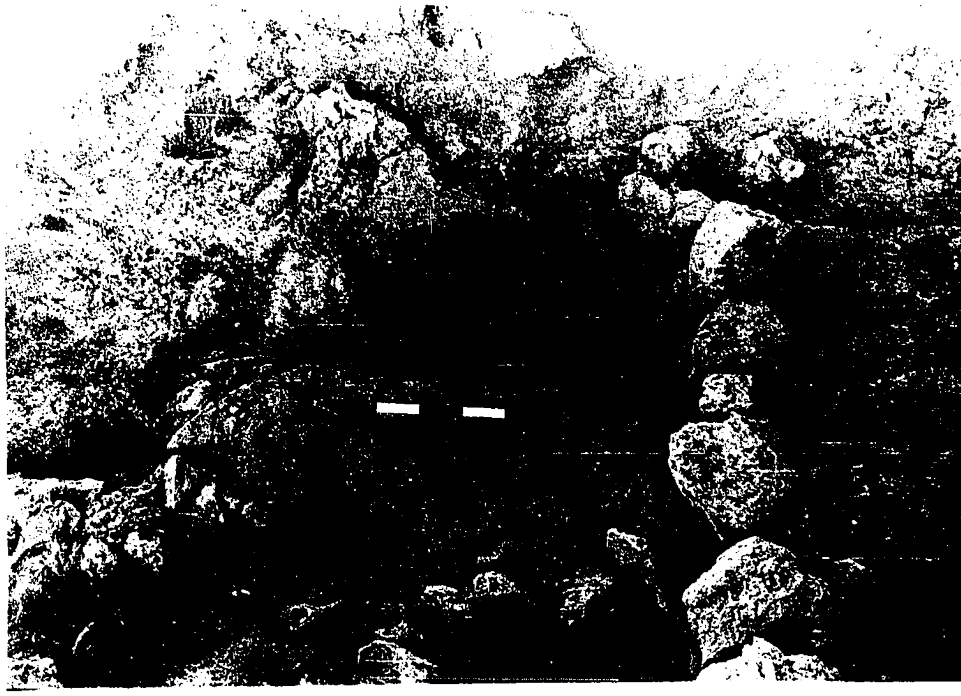


Figure 87a

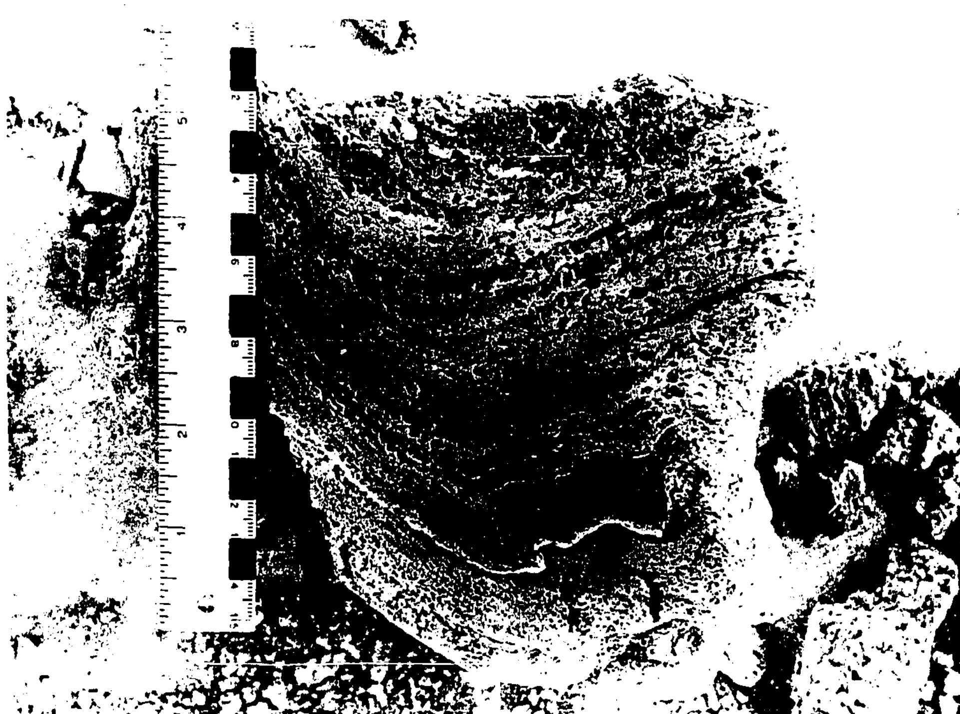


Figure 87b

dwellings of the inhabitants of Gezer, even granting stratigraphic compaction with time. Consequently the provision of receptacles for the pithoi in the flooring of the houses would be an expected feature.

Destructional Sedimentation

The nature of destructional sediment is illustrated in Figures 89, 91, 91b, 92, 93. A different process is at work in the origin of these deposits. The agency may be that of human or natural causes (cf. Table VII).

One of the most thorough destructions recorded in the stratigraphy unearthed during the recent Gezer excavations is that of Thutmoses II (1465 B.C.) (Figure 91a). This destruction phase is composed of a lower layer consisting of wood ash covering most of the tell in the area penetrated by Field I. This ash horizon records the initial phases of the destruction. Afterward, buildings sustained by wooden supports collapsed, smothering the fire and preserving the charred material beneath. The upper phase is debris of the fallen structures. It shows a chaotic orientation of the sediment overlying the carbon horizon. A section through a collapsed wall structure is at (2) in the illustration. During excavation this wall exhibited a distinct imbricate layering of the nari stone components. The interstitial areas retain the yellow mud "mortar" which bound them in the erect position.

A third dimensional view of this deposit on the domestic surface upon which it occurred may be observed in Figure 91b. The nari chalk-paste floor surface has been swept clean of the charcoal in the excavation. Two slightly damaged juglets lie on the floor where they fell at the moment

Figure 88a

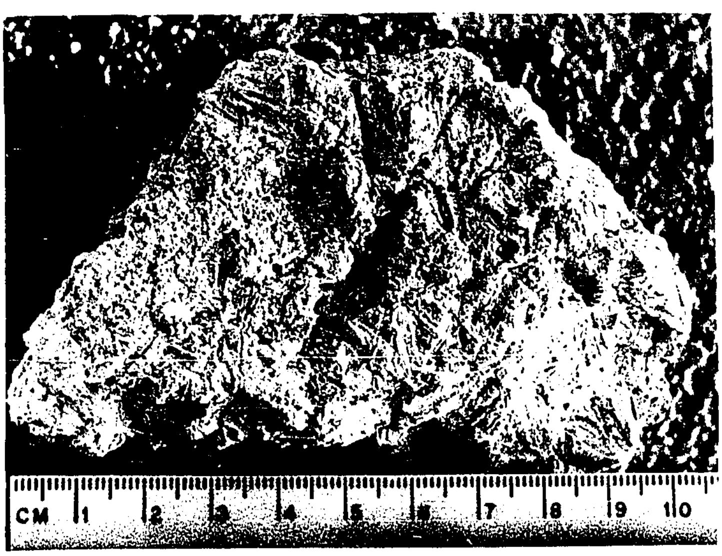


Figure 88b

Figure 88a. Stratigraphic analysis: view of domestic occupational sedimentation. This is the best example of an intentionally prepared floor surface observed in the excavations. The constructional material is composed of nari chips (57%), siliceous chalk (21%), and unweathered chalk paste as a binder. The floor surface was used in connection with the dwelling wall against which it was laid down.

Figure 88b. Stratigraphic analysis: specially prepared roof plaster preserved still attached to charred thatching and a charred roofing beam (Field I, Area 3, L.B.-II destruction phase). Analysis of this plaster showed that it was composed of unfired, unweathered chalk paste thoroughly co-mingled with straw and grass binder, the molds of which are still visible. The cohesive properties of unfired chalk paste (also observed in the glacis construction) are evident. $CaCO_3$ analysis: 89.6% (on the basis of gas evolution).

Figure 89. Stratigraphic analysis: occupational sedimentation showing various phases of domestic activity. Rates of sedimentation in domestic context are sufficiently slow so that occupational activities deposit thin beds of sediment ranging from less than .10cm to as much as 5.0cm. The nature of the depositional activity, in general, tends to determine the thickness of each stratum.

The lower phase of occupation (A) begins with a fill and leveling operation which resulted in a heterogeneous sediment ranging from small cobble down to clay-sized particles. The palygorskite content of this stratum (locus 3047) is identical to the residual soils found under the city and in thin lenses yet remaining on the nearby Shephelah (color 5YR 4/8).

The overlying 15cm of the domestic sedimentation (B) features types of sediment which could be considered classic. Locus 3044 is a series of thin lensate beds ranging from .50-3.0cm in thickness. Three common types of sediment typify this unit: tannur ash mingled with chalk, nari dust, charcoal, and unweathered chalk distributed to fill depressions or to cover ash (the alkalinity would prompt local resurfacing). Chalk dust is mingled with soil brought in from the fields by man, vehicles, and animals. A number of flat lying potsherds further attest to the use-function of the accretion; an illustration of the most common orientation of plano-convex fragments is seen in (1) in its most stable postion.

The lower occupational sedimentation ceases after a deposition of domestic ash above which lies 28cm of occupational debris fill (C) with a random orientation of all particles of planar or near-planar geometry. Domestic occupational series (D) is initiated by an obvious leveling of this debris fill. This sequence is finely laminated interfingering lenses of ash, soil, chalk, and various mixtures thereof. This very slow sedimentation ceases at (2) with the deposition of mudbrick material (non-levigated clays thoroughly mingled with straw binder (color 7.5YR 4/4).

The ash at (3) is mute evidence of the end of this domestic occupational sequence. The heat from the fire gave rise to the ash sediment and partially baked the mudbrick with temperatures above the characteristic 600°C endothermic DTA reaction level.

Figure 89

Figure 90. Stratigraphic analysis: support hole for pithos penetrating the fill beneath an occupational or use level. Reddish (2.5YR 5/4) lenses accentuate the stratigraphic nuances which reveal the essential features of a cutting made into the floor surface of a dwelling for the purpose of supporting a water vessel of pithos design.

In addition to the asethetic value, Hamra sand shoulders of this support provided a cushion against the ever-present possibility of breakage. That breakage, in fact, has occurred can be noted from the crushed pottery at the base of the depression. A use phase of this surface continued after the pithos support fell into disuse. Laminae of occupational accretions (field soil and charcoal) are depressed into the upper levels of its filling (Field I, west baulk between Areas 3 and 4, Middle Bronze occupation).

of destruction. The heterogeneous nature of the destruction debris is seen above these juglets in the east baulk, the base of which is on a line with the juglets.

A chaotic display of large quantities of ceramic sediment in a destructional context is observed in Figure 92. The Iron II cooking pot geometries are evident in the disarray of the broken pottery whether of natural or human origin.

Not all the destructional contexts give direct evidence of human activity. Since the Levant is an area of relatively high seismic frequency, occasional destruction - the failure and collapse of man-made structures - was brought about by earthquake tremors. It is self-evident that ceramic material would suffer in any event.

Destructional Sediment: Defense Structure Failure

Among the means used to breach defensive structures was a form of attack which was quite effective against carbonate lithologies. This was the breaching fire. An example of the measure of the destruction which can be accomplished by this method is presented in Figure 93. Since the gate structures were the most assailable of all the defensive fortifications of the ancient city, an enemy frequently directed his attack to this area. Such an incident is recorded in the archaeological stratigraphy of Tell Gezer in the area of the southcentral gate. The assault was unquestionably effective. The decomposition of the nari gatehouse structure resulted in which the carbonate lithology was reduced to calcium oxide producing a failure of the wall. Ceramic evidence sealed in charcoal beneath the calcined wall rock material enables the date of deposition to be assigned to the period of the Assyrian invasions during the latter part of the 8th century B.C. (perhaps Sennacherib in 701).

Cultic Practice Sedimentation

R. A. S. MacAllister had excavated the High Place area (Figure 4) in his campaigns early in this century. Very little of the original sediment of this interesting area was left for the modern excavator to examine. MacAllister did, however, leave the stratigraphy immediately underlying the pillars (stele or massēbôth) untouched. This offered an excellent opportunity for the application of the critical analysis of modern stratigraphic technique. These small remnants of the original stratigraphy held the only remaining information which might tell a more accurate story concerning man's activity in this place. The sediment of this area received very special attention. All of it was carefully sorted on a 5mm, a 250μ, and a 74μ sieve sequence so that the fines might be studied according to their size category and composition.

It became apparent in the intial phases of the excavation that any altars that may have been connected with the use of this area had been destroyed. Generalizations about the purpose of this area range from that of a burial and mortuary center in the city to that of an area of sacrifice (the nature of which ranges according to the viewpoint of the commentator from animal to human sacrifice).

Analysis of the sediment of the area gave results which were of a unique character. Deposits of this nature were not observed by the writer in any other context of the Gezer excavations. Nor was it observed in the context of the other excavations in which the writer has taken part (Shechem 1968). Analytical details are presented in Figures 94a and b. The conclusion is that an unusual occupational

Figure 91a. Stratigraphic analysis: view of the west baulk and trench floor at the base of the 50.0cm stick (showing the ash layer (1) which underlies the destruction debris of a fallen mudbrick and stone wall (2)). The imbrication of the stones mingled with a yellow-brown (2.5Y 7/8) mudplaster residue of the higher kaolinite content of the wadi Aijalon was deposited with a characteristic imbrication of a nearly fallen wall of mud adobe. This debris sediment yields stratigraphic evidence of one of the most violent and thorough of the wide-ranging destructions of the city.

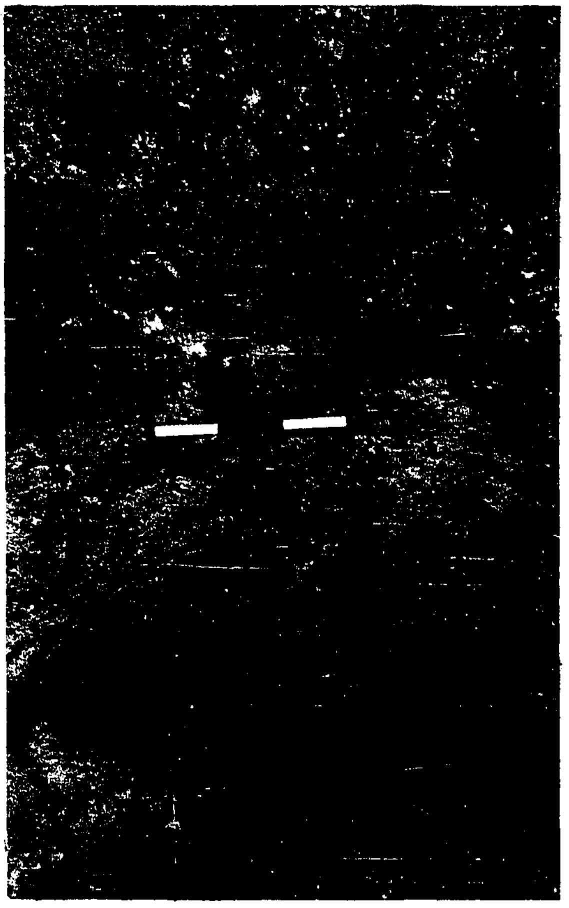


Figure 91b. Stratigraphic analysis: occupation-destruction sediment. Oblique view of the surface 3031 (3) of the previous figure showing the floor of a domestic dwelling which was inhabited at the moment of the destruction (Pharoah Thutmoses III, Palestinian invasion of 1465B.C.). The chalk surface of the floor on which the walls of the house collapsed has been exposed. Dramatic evidence of the destruction is seen in the small hearth (1) containing charred grain (quarter-sectioned in the foreground). The small juglets (2) lying partly shattered on the chalk surfaced floor are at the base of the heterogeneous conglomeration of the destruction debris.

The partially broken pottery lying on the chalk floor of a Late Bronze I house is mute evidence of the destruction which the sediment above this floor records (Field I, Area 3). The time-stratigraphic significance of this pottery of known date is underscored by the fact that this distinctive destruction is contemporaneous with a military campaign of Pharoah Thutmoses III into Palestine about 1465 B.C. His campaign is known from accepted literary sources (Lance, 1967).

activity did take place in the Gezer High Place area. Origin postulated for this type of sediment does not leave much latitude for the agency of deposition. A typical excerpt from the writer's notebook follows:

> G68 7/31 (soil under plaster surface next to basin)
> V.7.188
> Loc. 7006 - 556 gm sample
>
> This material is composed of fine pebble to fine sand size nari, burned nari, scorched and burned bone splinters and fragments, burned teeth fragments, pottery fragments, terrestrial gastropod fragments, chert fragments, fine and sand size clear quartz grains, calcite cleavage rhomb.
>
> | | |
> |---|---|
> | unburned nari and chalk - | 50% |
> | burned and blackened nari | 30% |
> | burned bone and teeth fragments - | 15% |
> | pottery and misc. - | 5% |
>
> The nature of the sediment on this plaster surface connects the use of that level with the following activity: (1) burning in which there has been free ash and fire fall in the production of burned nari and burned and scorched bones. The fire was such that its coals fell away from the point of burning before the nari was calcined and the bone material consumed. The teeth show strong burning incidence: 4 fragments showing enamel and dentine suggesting (2) that the animal material involved in the burning included the head part of a (the) carcass(es). (3) The pavement was made up of a chalk and nari pebble chip aggregate in a probable chalk paste.
>
> The burned nari and bone incidence in this chip pavement surface is atypical of any paved surfaces observed including all the streets of Field III, the floor and court paving surfaces in the makeup of Field I including MB and EB levels. The conclusion is indisputable that there is a different kind of activity yielding the sediment of this peculiar stratum.

The writer concludes that a cultic sacrificial context is probable.

As a further commentary on the cultic sediment of the Gezer High Place area, the associated structures are illustrated in Figures 95a and b. From the standpoint of sedimentary analysis, the composition of these materials is nari, the bedrock material of which was amply available to the Gezer inhabitants on the flanks of the Shephelah about Tell

Figure 92. Stratigraphic analysis: an array of ceramic sediment from the Iron Age levels near the southcentral gate (Field III). The orientation and distribution of the potsherds illustrate a mode of destructional sediment accumulation. The random orientation together with the convex-down position of the pottery is evidence of a rapid accumulation and burial. Perhaps the result of the raid of Pharaoh Shishak, ca. 918B.C. during the reign of King Rehoboam successor to Solomon.

Figure 93. Stratigraphic analysis: destructional sedimentation on the west flank of the southcentral gate. The effect of a deliberate and considerable conflagration is in evidence, the result of an assault upon a critical point in the city's defenses in the white calcined lime deposit (x). $CaCO_3$ is the dominant constituent of nari (analysis shows carbonate decomposition to occur slightly above 900°C, depending upon the CO_2 vapor pressure). A considerable and continuous fuel supply would be essential to affect sufficient destructional decomposition of the gate architecture to achieve breeching. Additional evidence of the availability of fuels not now in supply in the Shephelah is a foregone conclusion. CaO-$CaCO_3$ ratios, 2:1, show that decomposition was sufficient to affect structural failure of the gate in this area. One of the best examples of fortification breeching by fire in Palestinian excavation history is recorded here.

Note the affect of fire on the nari blocks adjacent to the CaO deposit. This is the identical affect that was observed in and about the kilns observed in "kiln valley" in the dross remaining from the lime-making operation.

Figure 92

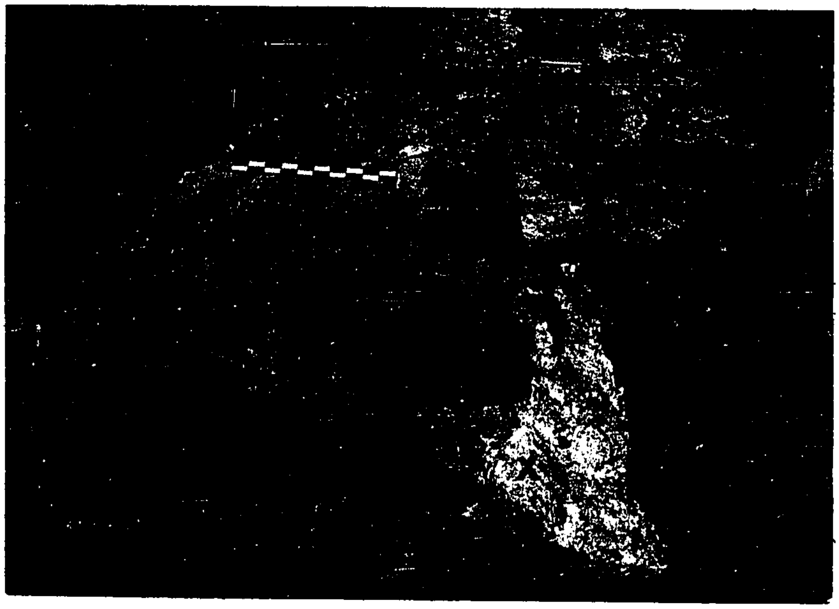


Figure 93

Gezer. One unusual aspect of these monoliths is the nature of No. 7. The faunal content of this lithology is exotic, inasmuch as it contains Upper Cretaceous, Campanian, or Turonian megascopic shallow marine fauna. This facies of Upper Cretaceous sedimentation is not locally expressed in the Turonian exposed in the Nesher Cement Quarry to the north of Tell Gezer. The closest available source is the western flank of the Judean anticline where these sediments outcrop.

A peculiar channeling has been chiseled into this pillar. It is that which could give hold to a rope by which the stone was dragged to its present location.

The sedimentology of the Gezer High Place may serve as a standard for the excavation of cultic sites in terms of its sedimentary petrology.

Occupational Sedimentation: Exotic Composition in Occupational Use Surfaces

An exotic sediment was used in the flooring of one of the guardhouse rooms in the gatehouse structure of the southcentral gate area (Figure 96). It is a bimodal sand which has an origin known on in the Mediterranean littoral. The motives behind the selection of this sediment for a surfacing of this area are unknown. It has been observed in other contexts throughout the excavations but not with use as a flooring.

Occupational Sedimentation: Ceramic Accretion

A very special moment occurs in the history of any excavation when a complete ceramic piece is uncovered from its stratigraphic context (Figure 97a). Not only does the complete ceramic give nearly unquestionable chronological fixation to the stratigraphy in which it occurs but it also affords some tangible (and publishable) material from the excavation: it is that which will find its way into museums.

Figure 94a. Sedimentary analysis: coarse-fraction (> 250μ), sieved sediment from the Middle Bronze II occupational use levels in the area of the G$_e$zer "High Place" (see Figures 95a and b). The sediment represents a 43.9% weight fraction of the total sediment (Field V, Area 7, locus 7006). This material is composed of nari, burned nari, scorched and burned bone splinters and fragments, pottery fragments, terrestrial gastropod fragments, chert fragments, burned tooth fragments, clear angular quartz sand grains, and one calcite cleavage rhomb.

Figure 94b. Sedimentary analysis: occupational use phase of the area of the Gezer "High Place". The sample constitutes 69% of the total and represents the > 250μ fraction. The sediment contains chert chip and blade fragments, coarse sand to pebble size pottery fragments, sand to pebble size nari, burned nari, sand size to small pebble burned and partially burned bone fragments and splinters, charcoal, terrestrial gastropods, and sand size clear quartz grains.

This represents Field V, Area 7, locus 7041, an area of an activity found nowhere else in domestic or public contexts throughout the various levels of excavation in the tell (see text for explanation).

Figure 94a

Figure 94b

Too frequently, however, the ceramic evidence consists of the less fortunate but nevertheless important find as illustrated in Figure 97b. The chronologic significance of this ceramic sediment is pertinent and meaningful to the archaeologist. The telltale Early Bronze character of the ledge handle potsherd is a significant stratigraphic marker.

Sedimentary Structures and Facies Relationships

Lateral variation within each stratum must be explained from the standpoint of facies relationships: lateral change within a given strata of sediment is caused by synchronous deposition by polygenetic agencies.

Foundation trenches - excavations cut preparational for the construction of wall footing -- must be observed in connection with wall structures in order to provide the proper facies relationships throughout the stratum. It is important to understand that foundation trenches are later than the sediment into which they are cut. The walls constructed in the trenches, therefore, are also later. An interruption of the sedimentary facies characteristic of foundation structures is shown in Figure 98. A foundation trench is cut into Middle Bronze occupational horizons.

The subtle color relationships seen in this illustration (arrow) are discernable only while the baulk facing is damp immediately after excavation. This underscores the critical necessity of the presence of the geologist to observe these relationships at the moment of excavation. Examination of sediment torn from the stratigraphic context to the right and left of this foundational trench interface would have revealed material, the sedimentary petrography of which is very similar.

Figure 95a. Petrologic analysis: Field V, the Gezer "High Place" viewed from the north. Of the original ten massebot, seven now remain standing, the eighth was tipped by the bulldozer used in removing MacAllister fill around the High Place area.

The lithologic material of the ten massebot and the "laver" were analyzed for composition and fossil content. Monoliths 1-6 and 8-10 along with the "laver" are all composed of the altered bedrock material known as nari. Numbers 1, 3, 4, 6 are oriented with their soil-nari interface areas to the east. Numbers 5, 9 have been trimmed so that orientation evidence is gone. The "laver" is oriented upside down with respect to its bedrock position. Comparative study shows insoluble residue averages, clay mineral residue analysis, and general physical character to be identical to that of the nari zone in the immediate vicinity of Tell Gezer.

Figure 95b Monoliths of the Gezer High Place, viewed from the south. One outstanding anomoly among the ten massebot occurs in the nature and composition of No. 7. The stone is oriented with its upright bedding plane to the west and contains megascopic marine fauna characteristic of the pre-Senonian Cretaceous seas (Exogyra columba Lamark, Neolobites sp., Nerinea sp.). This fauna precludes the possibility that it was quarried from the Turonian lithologies which have surface expression in the upwarpted (horst) area immediately north of the Aijalon Valley.

There is a very peculiar abrasion line about Monolith 7. It has no counterpart in the patterns of solution weathering and it is a channel produced by chiseling action. Such cutting would provide a rope hole for the dragging essential to transport this stone to its present location.

Evidence for fire against the Massebot and on the western margin of the "laver" is visibile at (F). These fires were not of sufficient intensity at the contact with the lithologies to induce calcination, with the possible exception of Monolith 3.

The valley of the wadi Aijalon lies in the distance along the upper margin.

Figure 95a

Figure 95b

Summary: Sedimentary Description

Sedimentary analysis in an archaeological excavation is a critical feature of the historical elucidation of the data. The writer strongly contends that this is valid. Figure 99 is an illustration of a common practice among some contemporary archaeologists. The stratified relationships are clear; certain facies changes are evident. The genetic significance of the sedimentary entities, however, is almost completely lost. The use of such terms as "sticky black burnt", "green bricky", and "dark brown stony" are not only imprecise but unacceptable. Each sedimentary entity should be carefully studied and analyzed to record not only the composition of its material, but also the probable agency by which it was deposited.

TABLE VI INSOLUBLE RESIDUES OF THE LOCAL BEDROCK (%)

Turonian ls ...	5.39, 5.70, 5.21 (lensate bed of Illite 94.18)
Menuha Fm	23.73, 22.44, 17.58, 21.70
Ghareb Fm	6.55, 12.78, 16.21
Taqiye Fm	4.24, 34.22, 34.15, 34.64
Zor'a Fm	3.93, 5.87, 2.64, 4.61, 4.18, 6.91, 7.50, 13.49 (siliceous)
Kiln dross	5.79, 5.48, 5.20
Nari	2.61, 3.04, 2.16, 2.90
Kurkar	91.79, 90.83, 90.01, 91.94

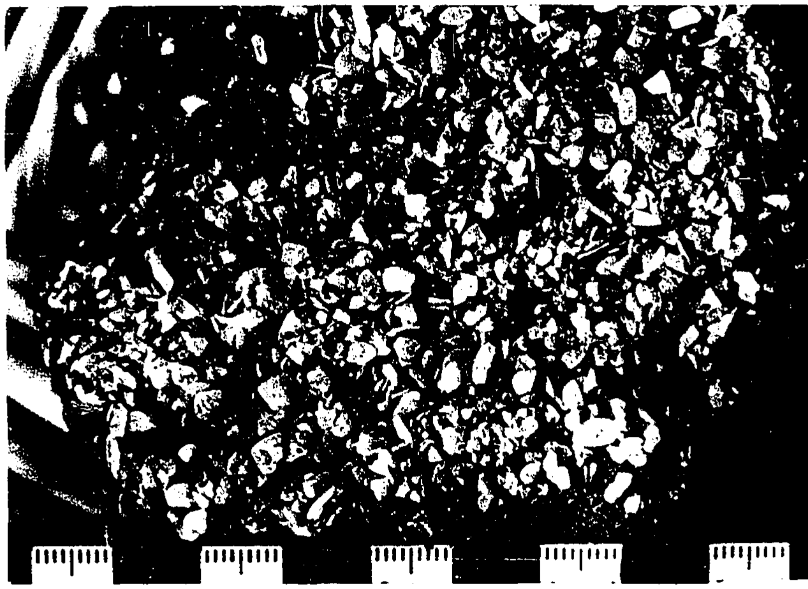


Figure 96. Sedimentary analysis: bimodal beach sands from the Mediterranean littoral. This sediment deposited in the occupational levels just above the founding stratum of the west guardhouse of the southcentral gate, was a floor surface for a short period of time; it is not co-mingled with the normal occupational debris of the Gezer environment.

The bimodality of the beach sands of Israel has been a characteristic of the littoral environment since the beginnings of the Nile River during the Late Pliocene and early Pleistocene time (Said, 1962). The quartz sands (cf. text discussion) are, in part, of multicycle origin, having an eolian history prior to Nile transport, and partly originating from the weathering and erosion of the intrusive acid igneous lithologies in the vicinity of the 1st cataract of the Nile. Longshore current activity has operated to convey the fine fraction portion of this sediment to its Levantine depositional site. The coarse fraction is derived from the fauna inhabiting the neritic zone of the continental shelf of Israel and consists of the wave-worn bioclastic detritus of such pelycopod representatives as Glycimeris sp. and Cardium sp.

In other contexts in the history of Tell Gezer, quantities of whole-shell individuals of these genera have been carried to the city of Gezer, a minimum distance of 24 km from the Mediterranean coast.

Figure 97a. Middle Bronze II-A trifoil juglet, Field 5, the High Place. This whole pottery piece represents the primary means of archaeological dating. Morphological, decorative, and compositional variations through time representing the aesthetic mood and utilitarian necessity of its day, all contributed to the subtle but continuous modification of pottery themes. This evolution of design is now sufficiently understood to provide critical chronological control for the stratigraphical sequences in which these time-markers occur (cf. Figures 32a and b).

Figure 97b. Early Bronze ledge handle jar fragment on the fill earth under the glacis from which it was taken. This artifact typical of its period, sets a post-quem time limit for any structures which contain it or lie above it. Such ceramic fragments are as useful stratigraphically as the whole entity of Figure 97a. The time stratigraphic significance of such material is similar to the role of fauna and flora in historical geologic contexts.

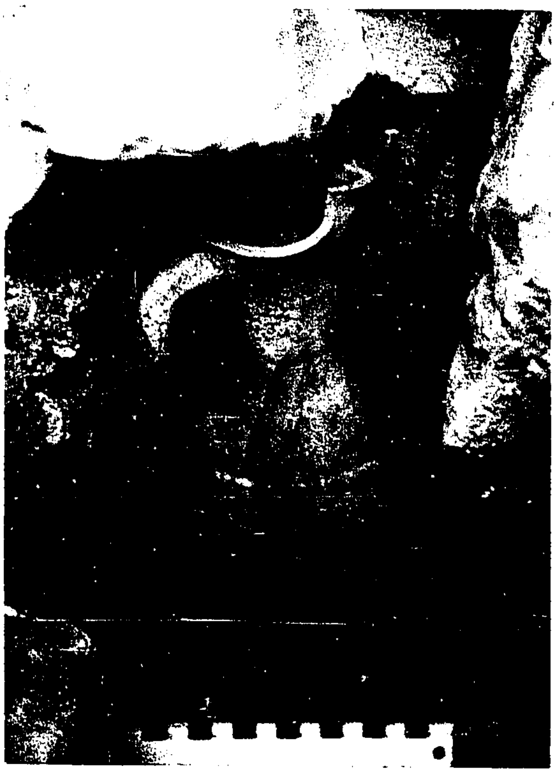
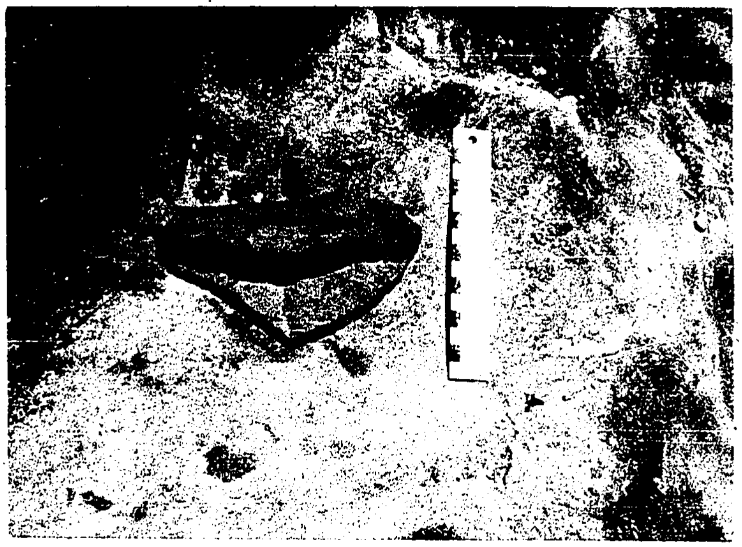


Figure 97a



·Figure 97b

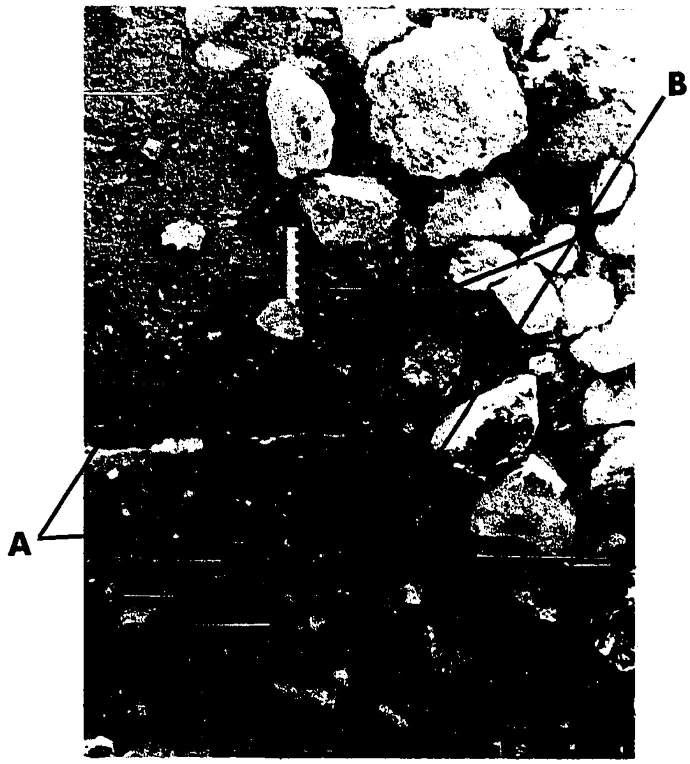


Figure 98. Stratigraphic study: foundation trench for an M.B. wall dug into earlier M.B. occupational horizons. The recognition of the existence of foundation trenches is critical to the dating of any of the structures erected in such excavations. This foundation trench clearly illustrates it (B) and the wall are later than the adjacent occupational deposits (A). Ceramic evidence in the trench must be carefully isolated from that of the surrounding sediments. The particle orientation of the pebble and cobble-sized pottery, siliceous limestone, and nari fragments in the occupational accumulations contribute to the evidence that this is a sediment slowly deposited by the agency of orderly human activity on these surfaces. Particles in the larger size ranges having a curvature in their geometry showed an 83% convex upward orientation in these sediments. For additional evidence of occupational sedimentation see Figure 94 and its commentary.

TABLE VII

GRAIN SIZE SCALES FOR SEDIMENTS

Wentworth Size Class	U.S. Standard Sieve Mesh #		Millimeters	Microns	Phi (Ø)
			4096		-12
Boulder			1024		-10
			256		- 8
Cobble			64		- 6
Pebble			16		- 4
	5		4		- 2
	6		3.36		- 1.75
Granule	7		2.83		- 1.50
	8		2.38		- 1.25
	10		2.00		- 1.00
	12		1.68		- 0.75
Very coarse sand	14		1.41		- 0.50
	16		1.19		- 0.25
	18		1.00		- 0.00
	20		0.84		0.25
Coarse sand	25		0.71		0.50
	30		0.59		0.75
	35	½	0.50	500	1.00
	40		0.42	420	1.25
Medium sand	45		0.35	350	1.50
	50		0.30	300	1.75
	60	¼	0.25	250	2.00
	70		0.21	210	2.25
Fine sand	80		0.177	177	2.50
	100		0.149	149	2.75
	120	1/8	0.125	125	3.00
	140		0.105	105	3.25
Very fine sand	170		0.088	88	3.50
	200		0.074	74	3.75
	230	1/16	0.0625	62.5	4.00
	270		0.053	53	4.25
Coarse silt	325		0.044	44	4.50
	↑		0.037	37	4.75
		1/32	0.031	31	5.00
Medium silt		1/64	0.0156	15.6	6.00
Fine silt		1/128	0.0078	7.8	7.00
Very fine silt		1/256	0.0039	3.9	8.00
	Analyzed		0.0020	2.0	9.00
	by		0.00098	0.98	10.00
Clay	Pipette		0.00049	0.49	11.00
	or		0.00024	0.24	12.00
	Hydrometer		0.00012	0.12	13.00
	↓		0.00006	0.06	14.00

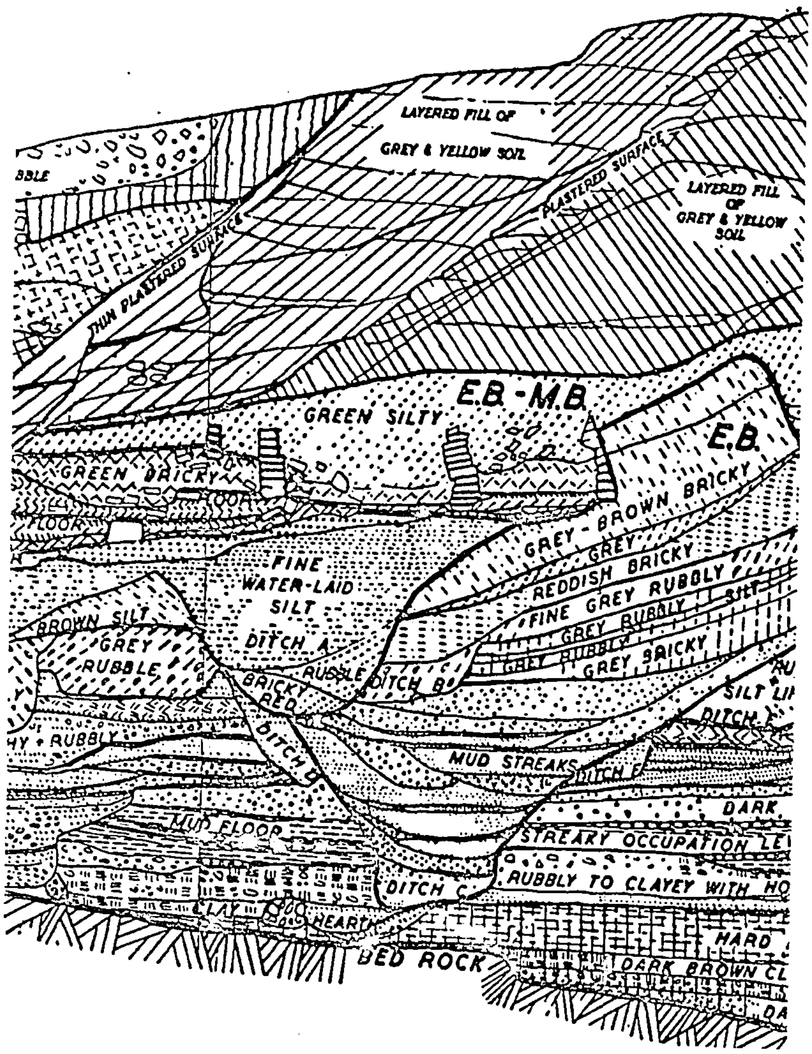


Figure 99. Stratigraphic analysis: a portion of the stratigraphy recorded by Kathleen Kenyon in her excavations at Jericho. The careful and exacting stratigraphic work by Miss Kenyon deserves proper credit for her worthy achievement. The issue at hand, however, is the lack of a definitive sedimentological description of the different phases of the stratigraphy. Such imprecise terminology as "gray brown bricky", "dark brown stony", "green silty", "yellow soil and bricks", "brown ashy", "black burnt", "sticky, black burnt", "ashy, rubbly", "green bricky", etc., illustrates the case in point. All genetic significance is lost in such sedimentological notation. Even if the origin is discernable from the stratigraphic relationships, the precise agency is frequently lost. It is the purpose of this study to set forth certain definite sedimentological parameters by which the agency of each sedimentary entity can be noted and recorded for future students of archaeology whose perception may be greater than that of the present generation. (Pyddoke, 1961)

CHAPTER V

THE PETROLOGY OF ARTIFACTS

The role of tools and weapons in the occupational activity of the inhabitants of Tell Gezer is one of considerable significance. It shows the extent of man's utilization of the raw material of the immediate and remote environment. It is a reflection of his dependence upon areas sometimes near, sometimes far in the immediate context of his way of life.

This phase of the writer's research concerns the petrography of artifacts to aid in the understanding of their provenance. Petrographic study, the purely descriptive facet of petrology, is also relevant in understanding the reason why a particular rock material functioned specifically as a tool or a weapon, i.e., the essence of physical properties, its hardness, its lustre, its fracture, its color, and its ability to take a polish.

Consideration of the grinding stones used by the inhabitants of Gezer constitutes a case in point. The unsuitableness of the local bedrock is a critical issue. Chalk has neither the hardness (induration) or cohesiveness necessary for this purpose. Chert is far too brittle and unmanageable to be shaped into a suitable grinding vessel. One of the frequent uses of the exotic alkaline olivine basalt found within the excavations has been grinding stones. Both bottom and top sections of the grinding stones tools have been taken from the Gezer strata. It is the physical character of this lithology which distinguishes it as a utility and as an economic necessity for the inhabitants of Tell Gezer in their domestic activities.

The study of artifact suites unearthed in the Tell Gezer excavations was carried beyond the limits circumscribed by petrographic investigation. Trace element analysis was prepared where the rock from certain areas was in question. The lithological provenance of an artifact must involve its petrologic character, i.e., the genetic aspect of the original rock source. Genetic implication is considered essential to a comprehensive understanding of the origin and migration of artifact suites. It provides the basis of erecting probable limits of compositional and textural variations of a given source material.

Petrographic Classification of the Gezer Artifacts

A catalogue of all rock entities occurring in the excavations at Gezer was initiated from the start by the writer. A large table was erected for classification and exhibition purposes in the dig house in the Hebrew Union College excavation camp. Figure 100 shows an area (about 1/3) of the table with some typical stone artifacts. It illustrates the diverse nature of only a small portion of the total representatives among the Gezer lithic artifacts.

The provenance of the lithic entities (Figure 100) range from the chert available in the nodules occurring in the Gezer water tunnel to important exotic materials such as acid pumice (which may have floated from an Aegean explosive source to the shores of Israel). The text which follows is a summary of a few of the more important finds and their petrographical character.

Figure 100. Petrologic study: part of the lithic variation (less than 1/3) observed in the tools and rock materials brought by man to the site of Tell Gezer.

All the examples in this view, except the chert blades, are exotic. The closest occurrence of basic igneous surface flows is that of southern Galilee (cf Plate IV). The visicular basalt lithologies were used as hand mills or grinding stones in the preparation of grain.

The brecciated chert pebbles used as tools (pounders) or weapons (balista) have the closest occurrence in the Pleistocene terrace deposits that flank the Aijalon Valley 3 km to the north-east. They are Plio-Pleistocene alluvial clastics of the Ahusam Formation derived by stream action on the western flanks in the Upper Cretaceous (Cenomanian) strata of the Judean Arch. The marine sandstones are representatives of Miocene and Pliocene formations still remaining on the central and southern Shephelah but not present in the vicinity of Tell Gezer. The singe representative of arkosic sandstone has no occurrence known any closer than the central Negev.

Figure 101a. Petrologic analysis: chert and siliceous limestone (1) blade from Bronze and Iron Age contexts. The chert is typical of Eocene nodular occurrence. The siliceous limestone is frequently found in lenses which have a stratigraphic association with the chert nodules (cf. Figure 17a) and represent a partial replacement of the carbonate sediment. Faunal investigations show Middle Eocene Globigerinal representatives.

Figure 101b. Petrologic analysis: a delicately wrought chert blade with serrated edges. The deep brown coloration (5YR 3/3) is characteristic of the local chert. The homogeneous chert of the nodules found in Eocene strata is distinctive from the brecciated chert and the bedded black cherts of the Upper Cretaceous of the Judean Hills and the Negev.

This artifact cannot be dated after the Middle Bronze II-C, as it came from the fill used in the construction of the glacis. It may be much earlier.

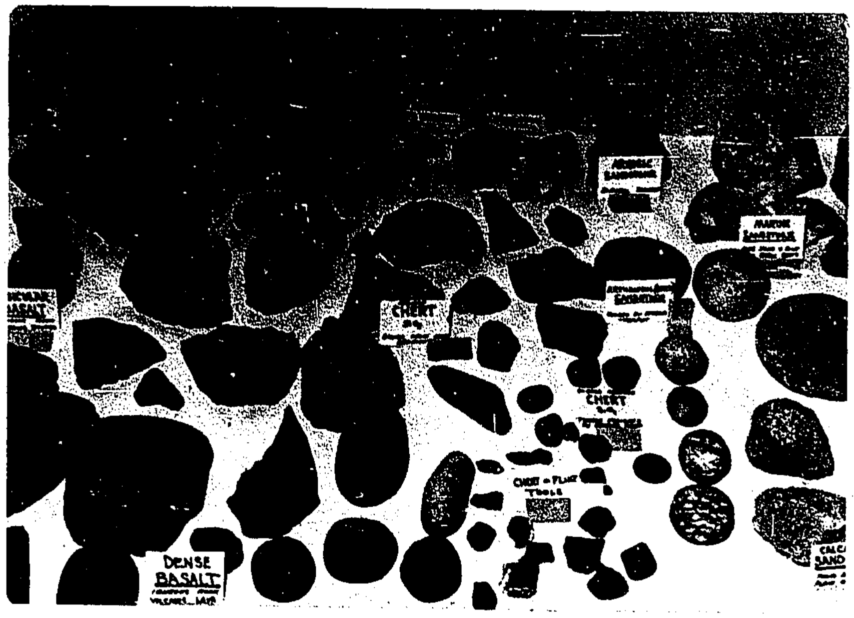


Figure 100

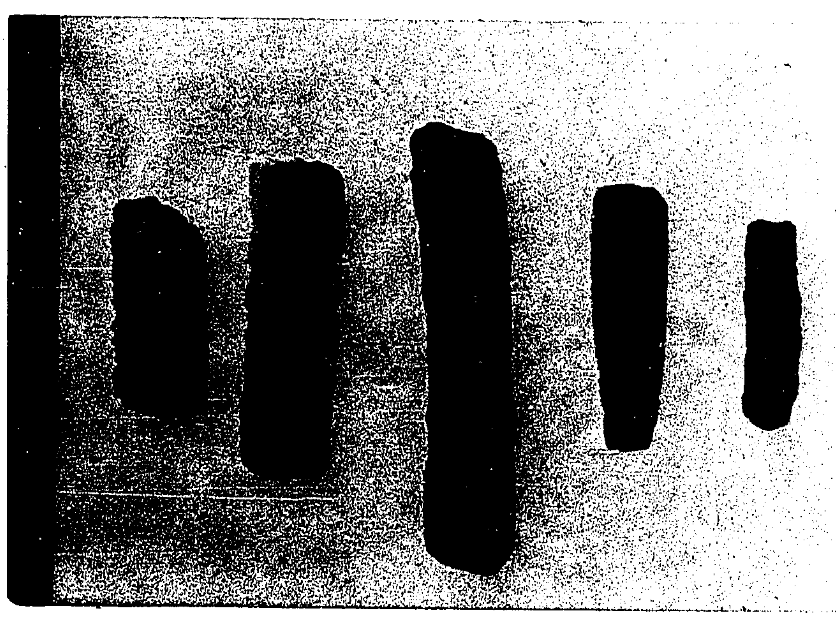


Figure 101a

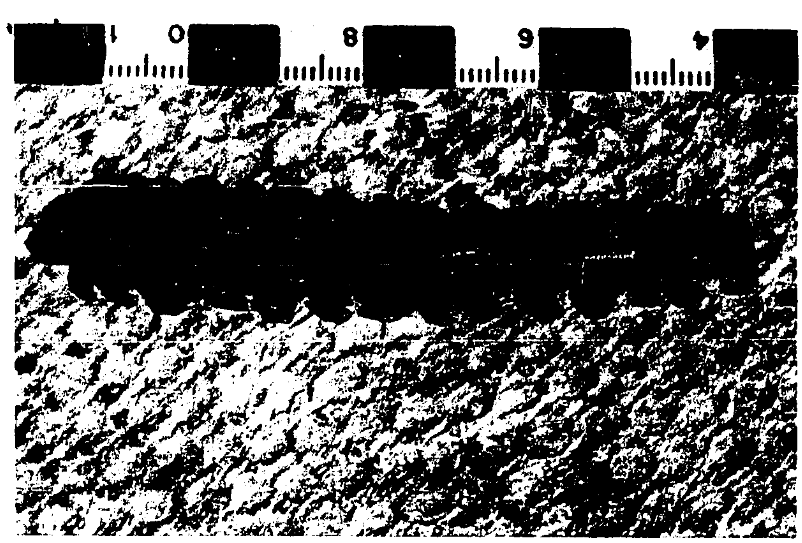


Figure 101b

Petrographic Analysis: Artifacts Composed of Local Lithologies

In addition to the general utilization of the local commodity known as nari, the use of local chert and siliceous limestone is also important.

Chert and Siliceous Chalk. Considerable quantities of chert blades were found in the excavation. The geometry of the chert ranges from crude chips (used to cut flesh or to be fitted into the cutting bars of scythes) to exquisitely trimmed blades (Figure 101a). Excellent artistry was needed to manufacture blades with serrated edges (Figure 101b). These chert artifacts are probably local to the Shephelah. Siliceous chalk and limestone artifacts are media in which the silicified remains of foraminifera may be observed (cf. Figure 17c, d).

Petrographic Analysis: Artifacts Made from Exotic Lithologies

Basalt. The use of basalt was not restricted to grinding stones. Massive basalt was frequently used in carved vessels such as bowls and vases by the Gezer inhabitants. Although MacAllister (1912) found a large quantity of these entities, the current excavations have uncovered only fragments. One example is a portion of the large bowl shown in Figure 102a. This bowl was composed of alkaline olivine basalt of ophitic texture with olivine phenocrysts. Its closest known surface occurrence is in the region of Galilee in northern Israel.

The basalt samples uncovered in the Gezer excavations were examined petrographically. Figure 102b is representative of the crystalline nature of the basalt bowl fragment in Figure 102a. While known occurrences of basalt exist in Jordan and Syria, these have not been available for study by the writer. The use of Occam's principle (simplist explanation)

Figure 102a. Petrologic study: exotic alkaline olivine basalt. The nearest surface occurrence of this lithologic commodity is known to occur only in Galilee and in the Transjordanian area (cf. Plate IV). The geometry of this specimen is that of a leg support for a large bowl.

Figure 102b. Petrologic analysis: microscopic thin section of dense alkaline olivine basalt (48x). The partially altered olivine occurs in a matrix of plagioclase An_{50}-An_{70} and hornblende. The trace element chemistry of the dense basalt samples studied shows a 3-fold titanium increase from those of the vasicular artifacts and suggests a different magmatic origin either with respect to time or place.

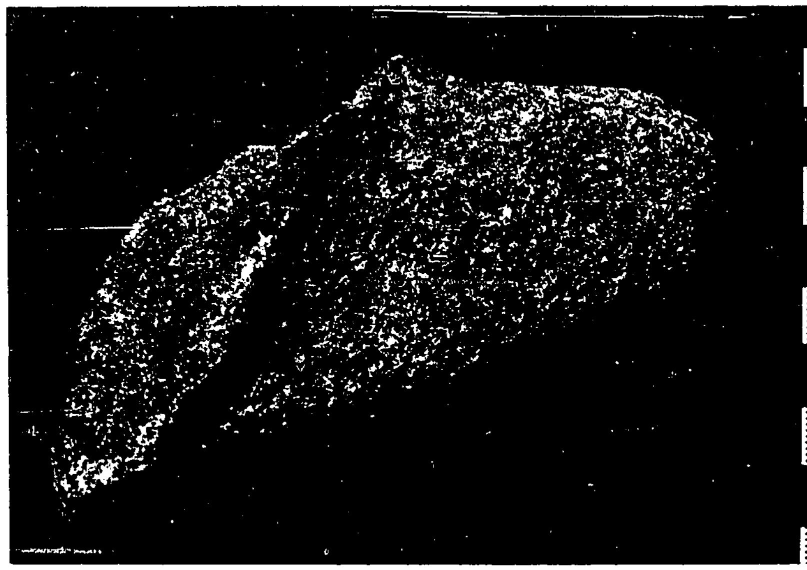


Figure 102a

Figure 102b

in a decision about provenance is the basis for this discussion. The composition of the basalts of Galilee fall within a narrow range of variation of that which is shown in Figure 102b. The exceptions are certain occurrences of nepheline basalt peridotite dikes which are of minor importance.

The latest edition (1965) of the geologic map of Israel shows two igneous plugs which are mapped along the Jerusalem-Tel Aviv Railway within 5 km of Tell Gezer. The writer conducted an extensive field survey across these areas and throughout the drainage nets which crossed them. No indication of a surface expression of these plugs was observed. It is the conclusion of the writer that they have been erroneously mapped and do not constitute in any way a potential igneous extrusive lithic source for the inhabitants of Tell Gezer.

Pumice. One of the most unusual lithic materials to be uncovered in the Gezer excavations has been pumice, clearly exotic to the Levantine area. The sample occurring in an L.B. II level is illustrated in Figure 103b. Pumice with sanidine phenocrysts is an igneous extrusive in this portion of the Levant. The density of pumice (Sp. Gr. less than 1.00) enables it to float upon water. A possible source for the pumice is the caldera explosion of the island of Thera. Fragments from this explosion could be driven by prevailing winds to various areas of the eastern Mediterranean. It is not inconceivable that the pumice occurring in the Gezer excavation originated from an explosion of the Aegean island.

Andesite Porphyry. A number of other exotic lithic artifacts

Figure 103a

Figure 103b

Figure 103a. Petrologic analysis: exotic andesite porphyry rubbing stone. Zoned intermediate feldspars occur in a matrix of hornblende crystals. Surface occurrence of shallow or near surface intrusions of andesitic composition are not known to exist in the central Levant.

Figure 103b. Petrologic analysis: one of two exotic pumice specimens (from an LB-II level). Sanidine crystals occur in the volcanic glass matrix (arrow). The closest known occurrence of surface igneous material of this physical and chemical composition is that of the island of Thera in the Cyclades.

have occurred in the Gezer excavations, the provenance of which is presently unknown to the writer. A rubbing stone that may have been used as a grinder or as a tool in the preparation of animal hides. Andesite porphyry lithology may occur in the rugged terrain bordering the Araba near Eilat in the south, but it was not observed on the fieldtrips to that area in connection with the International Clay Conference of 1966.

Amethyst. Another member of the lithic suite discovered at Gezer is shown in Figure 104a. A beautiful uncut amethyst fragment from an outer portion of the original crystal. The characteristic 120° interfacial angle is observable. The gemstone has no known occurrence in this part of the Near East (Paul Desauntel, personal communication) and may represent a bartered item from areas to the northeast in Armenia.

Cut Quartz Gemstone. A sensational discovery of the excavations is that shown in Figure 104b. A small lens cut from clear quartz was uncovered in the Iron II levels in the vicinity of the southcentral gate (Field III). The lens has a magnification of 1.5x. While it is not the writer's contention that this artifact was used as a lens, this property is most interesting. Used as a gemstone, cut to be fitted in an appropriate setting is a possible function. The provenance of this quality of clear quartz may be the Judean Mountains, although workable quantities of this mineral are unknown to the writer.

The contribution of the geologist to the success of any archaeological excavation is proportional to his awareness of the petrology of the region in which the archaeological context exists. Study in this area is far from complete, but an initial foundation has been laid upon which future research may be structured.

Figure 104a. Exotic lithologies: uncut amethyst fragment. The characteristic 120° angle of the hexagonal system is preserved in this unique specimen.

Figure 104b. Petrological analysis: unique Early Iron II cut and polisted plano-convex quartz lens capable of 1.5x magnification. This lens has been cut from an unstrained quartz crystal and prior to its partial fracturing may have had a history as a gem stone in a setting which featured its magnifying properties. This occurrence considerably antedates the first historical references to lenses, although Pliny and other ancient writers indicate that burning glasses in the form of glass spheres filled with water were known to them. The earliest historical reference concerning the use of deliberately fashioned lenses is that of Miesner (A.D. 1260-80) (Key, 1955).

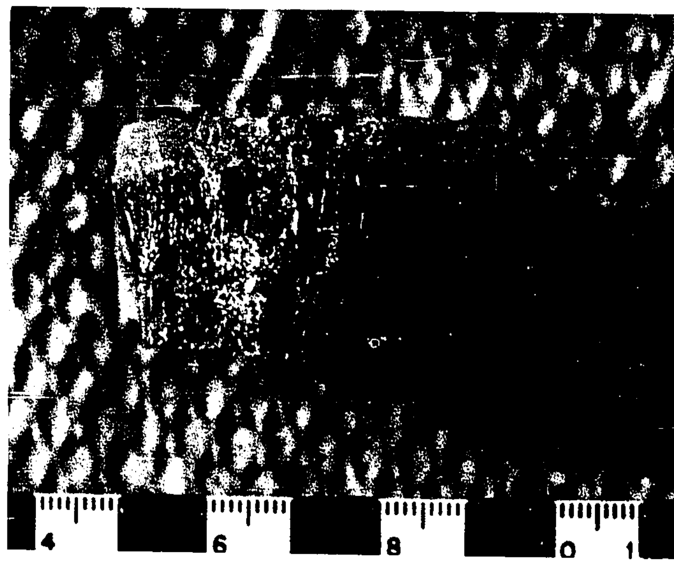


Figure 104a

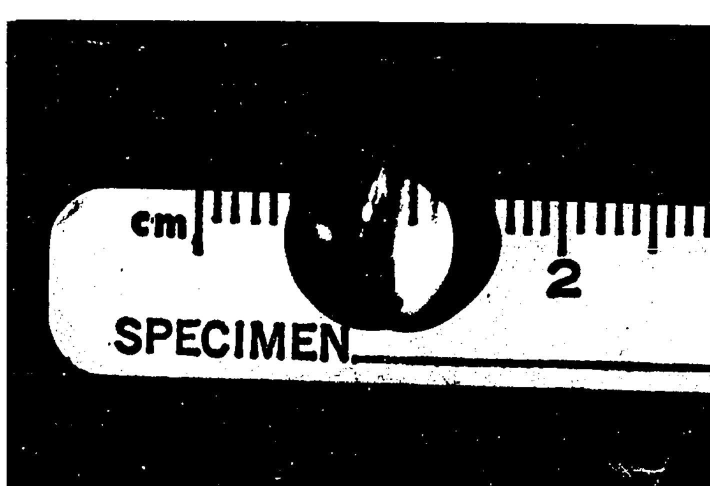


Figure 104b

CHAPTER VI

CONCLUSIONS

The stratigraphy and structure of the southern Levant has given rise to nine physiographic divisions ranging in elevation from more than 800 m below sea level to more than 900 m above. In between these extremes lies the Shephelah (or Foothills) Belt (200-400+ m).

Bounded by the Coastal Plain on the west and the sharply rising Judean Anticlinal Mountains on the east, the Shephelah gave its inhabitants a strategic locale in the command of the marine highway and of access routes to the high plateau to the east.

Although the Shephelah is founded mainly on Eocene chalk, the striking resistance of the rolling foothills to erosion is a result of a caliche-type of $CaCO_3$ accumulation and the insoluble residues of the largely eroded regolith. The ancient city of Gezer was founded on deep soil which has elsewhere long since been deflated from its deforested surroundings.

Gezer, like the other cities of Palestine, was built from the bedrock upon which its defensive walls were raised. Nari was a universal construction material. Almost without exception the city was fabricated from this common source.

Gentle structural flexure along with local faulting have brought the harder crystalline carbonate lithologies to the surface north and east of Gezer. In addition to the varied bedrock materials available, a weathering residue of a varied chemistry and mineralogy occurred in the form of soil.

The residual, colluvial, and alluvial soils and clays of the Gezer environment became the raw material source for local potters. The ceramic evidence of their ware-making abounds in the strata of the city imparting a time-stratigraphic significance to the context in which it occurs.

Mudbrick composition strengthened the evidence for the erection of local pottery types since this was one material which would require a local soil-clay source. Two dominant local ceramic types persist in acceptable agreement ranges with raw materials sampled on and marginal to the local Shephelah.

Geochemical evidence extends the basis of the inference that some of the Gezer pottery was not of local manufacture. Agreement with temper suites available in igneous extrusive areas or in regions of uplifted crystalline carbonates is within permissable limits. Both the Judean Hills and the southern part of Galilee probably were centers of origin for a part of the non-local ceramics. Two pottery types have been erected for these areas on the basis of preliminary data.

Coastal Plain manufacture also contributed to the ceramic assemblages of Gezer. Broad lines around possible centers of origin have been suggested. Both the Nahal Soreq and the Yarkon River cross this area with their sediments yielding distinctive temper sources.

Since pottery played an important packaging role in antiquity, it is not surprising to observe ceramic material with data of unknown or exotic affinities. If the average vessel existed for eight to ten years (Anita Furschpan, personal communication), it is natural to conclude that pottery would also migrate with those who possessed it as they moved from place to place.

A most surprising aspect to the ceramic thin section study was the realization that some partially silicified foraminiferal tests remained in the regolith as residues from the parent rock material. Thus the locale of the soil-clay mineral generation yielded its identity even after its soluble components were chemically weathered away.

Unlike some of the metamorphically altered carbonates of certain archaeological sites in Greece and the Aegean, the geological context of a city on the Shephelah is distinctive. Considerable progress has been made by Israeli micropaleontologists in the study of the characteristic microfauna of Cretaceous and Tertiary sediments. Foraminifera may now serve a unique role in the determination of the provenance of carbonate artifacts.

The recognition of exotic lithological entities in the tell structures may result from recognition of megascopic faunal content. One of the Gezer High Place monoliths cannot be local since it bears the fauna of a biostratigraphic context which is not found in the younger units of the Shephelah.

Aside from merely perfunctory analytical chores of a petrographical nature, the writer sees a special role for the geologist who seeks to contribute to the historical elucidation of the archaeological record. Even as he pursues the genetic significance of sedimentary rock bodies in their natural context in his traditional vocation, the geologist may also find application for uniformitarian insights in the genesis of the sediment of a tell. Certain sedimentary environments of Tell Gezer were analyzed utilizing those parameters which have yielded fruitful results in earth science.

The results of a sedimentological approach to the stratigraphic phases of occupational accretion are contributory to the historical understanding of the successive cities which existed on the Gezer site. While the data collected in the course of this research are only preliminary, they are recorded as a part of a catalogue of sediments which have a distinctive origin with limited contexts.

The distinct dependence of man upon his local environment is evident from the economic exploitation of the local geology. His needs were met from materials quarried within the hill, upon which Gezer was built and rebuilt, from the soil, clays, and sediments of the fields and wadis nearby, and from the sands of the Coastal Plain. The structures he erected, the artifacts he designed, and the commodities he consumed were nearly all critically determined by the geological context of his way of life.

The cities of Tell Gezer fluorished, and left sedimentary records of their prosperity, their worship, their defensive measures, and their tragic destruction: - a story written boldly in the stratigraphic account.

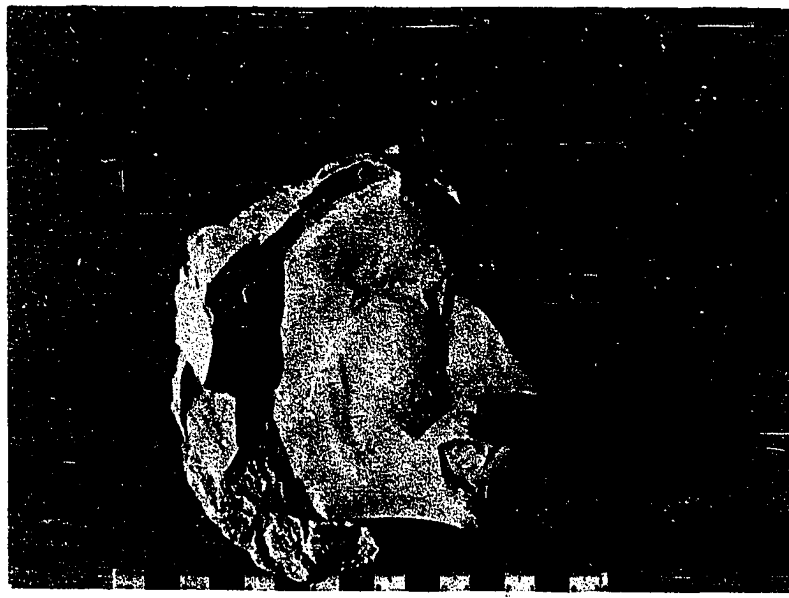


Figure 105. Petrologic study: non-artifactual artifact. The unusual fracture pattern of this siliceous limestone concretion imparts to it a very peculiar homonoid resemblance. It was removed from object registry channels after study of its typical concoidal fracture pattern suggested it to have a natural fracturing affinity. It cannot be identified with any deliberate artifactual sculpturing.

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CERAMIC STUDIES

C-1 Body sherd, E. B., 1.1cm, tan grading outward to medium pinkish tan, 7.5YR 8/2, coarse sand size temper, very minor vugs.

C-2 Body sherd, E. B., 1.7cm, uniform tan with dark red slip, 7.5YR 8/2, sand size temper, tight ceramic.

C-3 Body sherd, UD, 1.4cm grayish tan grading outward to pinkish tan, 10YR 7/3, in part shell fragment temper, kiln dross?, numerous elongate vugs subparallel to the circular section.

C-4 Body sherd, UD, 1.6cm, gray grading outward to pinkish tan, 10YR 6/1, kiln dross temper, linear vugs, subparallel to great circle of vessel.

C-5 Base with hole drilled, M.B. II-B, 1.6cm, grading outward from gray to pinkish tan, 7.5YR 7/0, coarse to medium sand size temper, minor pore spaces.

C-6 Rim, MB II-B, 1.1cm, light orange brown uniform, 5YR 7/6, coarse sand to fine silt size temper, no slip.

C-7 Body sherd, MB II-B, 1.1cm, light orange brown uniform, 5YR 7/6, coarse sand to fine silt size temper, no slip.

C-8 Body sherd, Hellenistic, 0.8cm, medium tan 7YR 8/2, coarse to fine sand size temper.

C-9 Rim, Hellenistic, 0.8cm, light orange brown uniform, 5YR 7/4, fine sand size temper.

C-10 Rim, Hellenistic, 0.7cm, dark grayish tan grading outward to orange grayish tan, 7.5YR 7/2, coarse to fine sand size temper.

C-11 Body sherd, Hellenistic, 0.6cm, light grayish brown to light orange brown 7.5YR 7/0, "salt and pepper" temper, minor grog.

C-12 Rim, Hellenistic, 0.9cm, light brown grading outward to light orange brown, 7.5YR 7/4, fine sand size temper, very minor elongate vugs.

C-13 Body sherd, Hellenistic, 0.9cm, light grayish tan, 10YR 7/1, coarse to fine sand size temper, local vugs, irregular and frequent carbonization.

C-14 Body sherd, Hellenistic, 0.9cm, tan uniform 7.5YR 8/2, coarse to fine sand size temper, minor small vugs.

C-15 Body sherd, Hellenistic, 0.6cm, tan uniform, 7.5YR 8/2, coarse to fine sand size temper, very minor vugs.

C-16. Rim, UD(Seger), Galilee basalt temper, weathered basalt clay, ceramic?

C-17 Sherd rim (Seger), UD, heavy calcite temper.

C-18 Body sherd, Greek, 2.1cm, 5YR 7/6.

C-19 Body sherd, Hellenistic, greenish-tan matrix, yellow outside slip, coarse dark temper.

C-20 Sherd handle section, Hellenistic, greenish-gray pottery, 10YR 8/1, silty clay.

C-21 Body sherd, Hellenistic, 0.3cm, black, thin, section cut parallel to wheel.

C-22 Body sherd, Hellenistic 0.4cm, tannish gray with pink slip, 7.5YR 8/2.

C-23 Body sherd, Hellenistic, 0.6cm, brown matrix, tan slip over red, 7.5YR 7/2, shell material.

C-24 Body sherd, Hellenistic, 0.9cm, light tan, high silt, vuggy, 7.5YR 7/4.

C-25 Body sherd, Hellenistic, 0.6cm, light tan, 7.5YR 8/4, dark brown temper, slightly silty.

C-26 Body sherd, Hellenistic, 0.4cm, grayish-tan, yellow-tan slip, slightly silty.

C-27 Body sherd, Hellenistic, 0.9cm, yellowish, tannish, greenish, 2.5Y 8/4, fine dark brown temper, low silt content.

C-28 Body sherd, Hellenistic, 0.9cm, grayish, dark tan, 10YR 7/1, fine temper, slightly silty, shells.

C-29 Handle, Hellenistic, brown, red slip, 5YR 5/3, sand size chalk temper, fine pores.

C-30 Body sherd, Hellenistic, 0.6cm, brown, red outside slip, light orange inside slip, 5YR 6/3, fine sand size chalk, minor dark temper, minor vugs.

C-31 Body sherd, Hellenistic, 0.6cm, red clay (high fired?), light brown slip, sand size chalk temper, tight.

C-32 Body sherd, Hellenistic, 0.6cm, light brown, red slip, 7.5YR 6/4, silt size temper, silty matrix, minor vugs.

C-33 Body sherd, Hellenistic, 0.9cm, gray clay, red slip firing surfaces, 10YR 6/2, minor fine chalk temper, minor vugs.

C-34 Body sherd, Hellenistic, 0.6cm, tannish brown, 5YR 7/3, fine sand size temper, high silt clay, minor vugs.

C-35 Jug rim, Hellenistic, tan, 10YR 8/2, coarse brown temper, minor vugs, silty.

C-36 Rim, E.B., 1.8cm, dark grayish brown clay, light brown slip, 10YR 4/1, coarse sand size temper.

C-37 Rim, L.B.-I, light gray grading to tan outward, tan slip 7.5YR 7/10 (o.s. 5YR 8/4), fine sand and silt temper, rusty brown major and minor temper.

C-38 Rim, L.B.-I, gray grading to grayish-tan outward, light orange pink outside slip, light greenish-tan inside, minor sand size grog, silty, minor vugs.

C-39 Carinated bowl rim, L.B.-I/II, gray grading to pink-orange outward 7.5YR 6/10 (o.s. 5YR 7/6), fine sand temper, silty.

C-40 Body sherd, L.B.-I/II, tan, pinkish-tan outside slip, 10YR 8/2, coarse sand size light temper.

C-41 Bowl rim, L.B.-I/II, tan with light brown slip (slightly pinkish), 10YR 4/1 (o.s. 5YR 6/6), coarse sand size chalk-limestone temper, minor vugs.

C-42 Body sherd, L.B.-I/II, light brown grading to rusty brown, pinkish-tan slip, 7YR 7/4, sandy temper with much silt.

C-43 Body sherd, L.B-I/II (resembles C-40), grayish tan, tan slip, 10YR 7/3, coarse sand size temper, light colored temper, tight.

C-44 Body sherd, L.B.-I/II, gray grading to tannish brown, light tan slip, light sand size temper, silty.

C-45 Body sherd, L.B.-I/II, tannish gray grading to light brown, light brown slip, 10YR 6/1, sand size rusty temper.

C-46 Jug rim, Chalco/E.B-I, 10YR 6/2, minor sand size light temper, vuggy, tight, pressed ring around outside rim.

C-47 Body sherd, L.B.-I/II, 1.2cm (similar to C-27 and C-19), greenish gray, 2.5Y 7/2, sand sized varigated dark temper, slightly silty, minor vugs.

C-48 Body sherd, L.B.-I/II, 1.2cm, brown outside, red inside slip, 10YR 4/1, black with white sand size angular temper, vugs.

C-49 Body sherd, L.B.-I/II, 0.9cm, grades outward to dark tan, brown slip, 10YR 5/1, dark gray with white angular temper, vugs.

C-50 Rim, L.B.-I/II, 0.6cm, tan, slip same color, 10YR 7/4, high silt.

C-51 Carinated rim at shoulder, L.B.-I/II, grades outward to dark tan, dark tan slip 10YR 6/1, gray fine silt size light and dark temper.

C-52 Body sherd, UD, tan to orange tan, 10YR 7/2 (o.s. 10YR 8/6), sand size temper.

C-53 Body sherd, Roman, 0.5cm, tan slip, 10YR 6/2 (o.s. 2.5YR 6/8), silt size chalk temper, minor dark coarse temper.

C-54 Body sherd, Hellenistic, 0.7cm, light brown, dark tan slip, 7.5YR 7/4, fine sand size chalk temper, minor vugs.

C-55 Body sherd, UD, light brown, 7.5YR 7/4 (o.s. 2.5YR 6/6), sand size lithic temper.

C-56 Jug handle, UD, black inner zone with tan to orange outer firing ring, dark tan-brown slip, 10YR 3/1, fine sand sized temper with coarse lithic temper, straw binder leaving considerable vugs.

C-57 Jug rim, Roman, (cf. C-82), red fired interior, brown-tan outer zone, chalk silt sized temper, minor grog and lithic temper, coarse.

C-58 Jug handle, Hellenistic, inner red-fired zone, outer dark fired with outer most red fired, 2.5YR 6/6 (o.s. 5YR 6/1-5YR 7/6), chalk size temper.

C-59 Body sherd, Hellenistic, 0.7cm, rusty brown with dark red outer zone, salmon slip, 2.5YR 5/4 (o.s. 2.5YR 6/8), coarse silt size white chalk temper, abundant gray temper.

C-60 Handle, UD, inner dark tan, outer ring of orange-brown, light orange-tan slip, very silty, porous.

C-61 Jar handle, Hellenistic ("Rhodian") 7.5YR 6/4, no apparent temper, minor vugs, tight, fine clay.

C-62 Body sherd, Hellenistic, (cf. C-64) 5YR 7/6, sand size temper.

C-63 Base, Hellenistic, 0.6-1.4cm, black surface paint, 7.5YR 7/4, light brown, fine sand lithic temper, small minor vugs.

C-64 Body sherd, Hellenistic, 0.6cm, light brown, light brown slip, 7.5YR 6/4, coarse silt size temper, minor sand size temper, silty feel.

C-65 Body sherd, Hellenistic, 0.6cm, light reddish-brown with tan slip, minor lithic temper, abundant silt size temper.

C-66 Body sherd, Roman, 1.0cm, orange brown, orange tan slip, firing gradient from brown to orange-brown, 5YR 7/6, silt size temper, minor vugs.

C-67 Body sherd, Hellenistic, 0.6cm, greenish-tan, 2.5Y 8/2, varigated temper, medium fine sand size.

C-68 Body sherd, Hellenistic, 0.8cm, red-fired, light orange-tan slip, 5YR 7/6, coarse sand size lithic temper, minor vugs, tight.

C-69 Body sherd, Roman, 0.6cm, red-fired, 5YR 7/6, minor silt size grog, tight.

C-70 Jug rim, Hellenistic, 1.3cm, tan throughout, slip same as body, 10YR 8/3, coarse sand size dark brown grog temper, minor vugs.

C-71 Body sherd, Hellenistic, rusty-orange brown, brown to orange brown firing gradient, silt size temper, mica surface flakes, tight, probably exotic.

C-72 Body sherd, Roman, 0.8cm, brown, tannish-green slip, 7.5YR 6/4, minor silt sand sized temper, silty.

C-73 Body sherd, Roman, 0.5cm, brown with orange slip 7.5YR 5/2 (o.s. 5YR 7/6), black and dark brown coarse temper, silt size chalk,

C-74 Body sherd, Hellenistic, 0.8cm, orange-brown slip, 7.5YR 7/2, light brown varigated temper, minor fine vugs.

C-75 Jug rim, Roman, 0.6cm, gray with light orange-tan slip, 10YR 7/1, (o.s. 5YR 7/6), silty.

C-76 Body sherd, Hellenistic, 0.5cm, brownish brick-red, 2.5YR 7/6, minor chalk silt temper, silty, minor large grog.

C-77 Body sherd, Roman, 0.7cm, grayish-brown, light brown slip, 5YR 6/1 (o.s. 5YR 7/4), tight silt size chalk temper, minor vugs.

C-78 Body sherd, Hellenistic, 0.8cm, very light tan, light tan slip, 7.5YR 8/4, chert temper, fine sand size, minor small vugs.

C-79 Body sherd, Roman, 0.6cm, red-fired, light tan slip, 10R 6/8, minor silt size chalk temper, grog temper, minor vugs.

C-80 Body sherd, Hellenistic, 0.6cm, tan with pink-orange firing gradient, pink-orange slip, lithic fragments, coarse sand size temper, silty.

C-81 Body sherd, Hellenistic, 0.9cm, tan to orange, tan slip, 10YR 8/3, sand sized grog temper, minor firing differientation.

C-82 Jug rim, Roman, red-fired interior, brown-tan outer zone, chalk silt size temper, minor grog and lithic temper, coarse.

C-83 Body sherd, Roman, 0.6cm, red fired, 2.5YR 4/2 (o.s. 2.5YR 6/8), silt size chalk temper, coarse grog temper, minor vugs.

C-83b Body sherd, Roman, 0.5-0.6cm, orange-tan with tan inner surface, pink-tan slip, 2.5YR 6/4 (o.s. 10YR 8/4), minor sand size grog temper.

C-84 Body sherd, Roman, 0.6cm, tan slip outside, orange slip inside, 2.5YR 6/8, chalk silt, occasional larger temper, grog?, tight, 3 heating phases.

C-85 Jug rim, Roman, 0.6cm, gray with light orange-tan slip, 10YR 7/1, silty.

C-86 Body sherd, M.B.-II, B.C/L.B., 1.3cm, grades from grayish tan to red-orange, orange tan slip, sand and silt size chalk temper, minor vugs, wheel parallel block mounted.

C-87 Body sherd, M.B. II, B.C./L.B., 0.7cm, gray grading to orange tan with orange tan slip, brownish-tan inside slip, coarse sand lithic and chalk temper, minor vugs, section cut parallel to wheel 1/2 thickness of sherd.

C-88 Body sherd, M.B.-II B.C./L.B., 0.9cm, gray dark orange tan slip, varigated lithic temper, minor vugs, section cut wheel parallel through 1/2 sherd.

C-89 Body sherd, M.B.-II F.C./L.B., 1.1cm, brownish-tan grading to orange tan outer surface, dark lithic temper, tight, cut wheel parallel.

C-90 Body sherd, M.B.-II B.C./L.B., (cf. C-87) section cut wheel parallel within slip.

C-91 Body sherd, M.B.-II B.C./L.B., 0.8cm, dark gray grading to tan with orange-tan slip, light and dark coarse sand size temper, tight, section cut wheel parallel.

C-92 Rim, M.B.-II B.C./L.B., 1.0cm, brownish-tan uniform, varigated dark sand size temper, minor vugs.

C-93 Rim, M.B.-II B.C./L.B., 0.9cm, gray varigated tan, white-gray, black coarse sand temper, section cut wheel parallel.

C-94 Rim, E.B., greenish-tan, orange-tan slip, 2.5Y 7/2, low density, temper almost absent.

C-95 Body sherd, E.B., 1.1cm, gray grading to orange-pink outside, chalk and dark mineral sand size temper, vugs from binder, dense.

C-96 Body sherd, E.B., 1.2cm, light brown grading to tan fired surface.

C-97 Body sherd, E.B., 1cm, light brown, sand size varigated lithic temper, medium density.

C-98 Body sherd, E.B., 0.7cm, greenish-gray brown, light grading outward to gray brown, 10YR 7/3, sand and silt size calcite temper.

C-99 Body sherd, E.B., 0.9cm, brown-orange-tan, grades outward to rusty-tan brown, 7.5YR 7/4, varigated lithic temper, temper size grog or clay slugs in body.

C-100 Body sherd, E.B., 1cm, light brown grading outward to orange brown and inward to gray brown, 7.5YR 7/4, curious elongate rusty-brown clay slug temper, tight.

C-101 Body sherd, E.B., 0.8cm, tan-brown, grades outward to same color with same color slip, 7.5YR 7/4, minor sand size temper, minor vugs, tight, good clay.

C-102 Body sherd, E.B., 1.2cm, dark tan grading outward to lighter tan and inward to darker tan, 10YR 7/2, extremely varigated sand and coarse sand size temper, basalt in part?.

C-103 Body sherd, E.B., 1.2cm, gray grading outward to light rusty brown and inward to tan brown, 5YR 6/1 (o.s. 7/5YR 7/4), profuse 1-2mm sand size calcite temper, minor large vugs.

C-104 Body sherd, E.B., 0.7cm, internal gray zone, thin, grading outward to light brown, internal thin brown horizon, 7.5YR 6/10 (o.s. 7.5YR 7/4), coarse sand size temper composed of calcite and lithic material, extremely varigated.

C-105 Body sherd, E.B., 0.9cm, light gray brown grading outward to dark gray brown, 7.5YR 7/2, carbon burning, abundant calcite temper, coarse sand size.

C-106 Body sherd, 1cm, E.B. dark tan gray grading to light rusty brown, 10YR 6/2 (o.s. 7/5YR 8/6), varigated tan and brown coarse and fine lithic temper, elongate flat vugs (grass?), tight clay.

C-107 Body sherd, E.B., 0.7cm, dark tan, rusty brown slip, 10YR 8/3, varigated lithic temper, tight.

C-108 Rim, M.B.-II, 0.9cm, gray, varigated tan, white, gray, black coarse sand temper, section cut wheel parallel.

C-109 Body sherd, M.B.-IIA, grayish-tan, orange tan slip, sand and silt size temper, minor vugs.

C-110 Body sherd, M.B.-IIA, gray grading outward to pinkish tan, coarse to medium sand size temper.

C-111 Body sherd, 10th,11th century, 1.1cm, gray grading to tan outward with orange tan slip, 10YR 6/1 (o.s. 10YR 7/3), coarse sand size temper, one very large pebble.

C-112 Body sherd, 10th-11th century, 9cm, light brown grading to brown outward, brown slip, 7.5YR 7/2, silt size temper, minor vugs.

C-113 Handle, 7th century Iron Age, gray grading to red, 7.5YR 6/0, sand size light lithic temper.

C-114 Rim, Iron II, brown, burnished surface, 7.5YR 6/2, fine temper.

C-115 Rim, 10th-11th century, 0.7cm, gray grading to dark brown outer light brown inner surfaces, 5YR 6/1, white sand size angular temper.

C-116 Body sherd, 10th century, 0.6cm, dark tan with coarse silt size temper, dark tan grades outward to tan, 7.5YR 7/2, coarse silt size temper, gritty or silty feel.

C-117 Body sherd, 10th-11th century, 0.7cm, gray-tan, 10YR 7/1, tan lithic temper, tight, silty feel to tan inside/outside slip.

C-118 Body sherd, 10th-11th century, 0.8cm, dark tan uniform color, dark tan, silty slip, 10YR 7/3, temper coarse to medium sand size.

C-119 Body sherd, 10th-11th century, 1.3cm, gray grading to dark tan, dark tan slip, 10YR 7/2 (o.s. 10YR 8/3), coarse light lithic temper, dark sand size temper.

C-120 Body sherd, 10th-11th century, 0.8cm, brown grading brown slip outwardly, inwardly gray to light brown, 2.5YR 6/6, fine silt temper.

C-121 Body sherd, L.B.-I, 0.6cm, gray grading outward to tan, 2.5YR 5/p (o.s. 5YR 8/4), painted outer surface, varigated fine sand temper.

C-122 UD bottle neck, 1.5cm, dark gray grading outward to dark tan, 7.5YR 5/0, coarse sand size lithic temper, small vugs.

C-123 Jar handle, UD, dark brown grading to orange red, 2.5YR 5/2 (o.s. 10R 6/6), fine silt and grog temper.

C-124 Jar handle UD, light gray grading through gray-tan to tan slip 10YR 6/2, fine sand size varigated temper.

C-125 Rim, U.D., dark tan grading through tan to dark tan, 10YR 6/2, varigated sand size lithic temper.

C-126 Handle, UD, reddish brown grading to rusty brown, 2.5YR 6/4 (o.s. 2.5YR 6/8), coarse silt temper, minor vugs.

C-127 Handle UD, gray grading through gray-tan to light brown, sand size lithic temper.

C-128 Handle, UD, black grading to light tan to orange pink, 5YR 5/1 (o.s. 5YR 6/4), considerable grass binder.

C-129 Rim, Iron II, light brown, no variation, silt temper, minor vugs.

C-130 Rim, Iron II, dark purple red with light red brown outer surface 7.5YR 3/2 (o.s. 2.5YR 6/6).

C-131 Rim, Iron II, dark gray grading through light brown to dark brown, dark brown slip, calcite temper.

C-132 Rim, Iron II, dark tan grading to rusty brown, red-brown slip, 7.5YR 7/2 (o.s. 2.5YR 6/4), minor vugs, tight.

C-133 Body sherd, Hellenistic-Early Roman, 1.2cm, blackish dark brown grading to brick-red, 2.5YR 5/0 (o.s. 2.5YR 6/6), abundant small vugs.

C-134 Body sherd, Roman, Persian context, 2.5YR 5/2 (o.s. 2.5YR 6/8).

C-135 Body sherd, Roman, 4.5cm, brown grading to light dark red, minor silt, no vugs, tight.

C-136 Rim, M.B.-IIC, 1cm, gray tan to orange tan, 7.5YR 7/4, tan and brown sand size lithic temper, minor small vugs.

C-137 Body sherd, L. B.?, 1.1cm, has appearance of Hellenistic, greenish-tan to greenish-tan slip, 2.5Y 7/2, white and brown sand size temper, slightly silty, tight.

C-138 Jar rim, Hellenistic, 0.9cm, tannish green, 2.5Y 7/2, sand size varigated temper, no slip, tight.

C-139 Rim, Hellenistic, 0.9-1.5cm, light brown, 5YR 7/6, bimodal, coarse silt size temper, probably exotic source, minor vugs, tight.

C-140 Body handle, M.B./L.B., 6.5cm, body gray, interior fired dark tan-orange, light orange brown firing hole 2cm thick on external handle, handle black with numerous binder molds, vuggy, tan and gray coarse sand size lithic temper, mineralogy appears different.

C-141 Carinated? bowl, M.B./L.B., gray grading outward to tan, orange-tan firing ring, 7.5YR 4/0 (o.s. 7.5YR 8/4), silt size coarse sand size, bimodal temper, numerous small vugs.

C-142 Body sherd, M.B.-IIC, 1.2cm, gray grading to orange-tan, dark orange tan slip, 7.5YR 5/0 (o.s. 7.5YR 8/6), coarse sand size lithic temper, silty, small vugs.

C-143 Body sherd, Persian, 0.6cm, inner light brick red grading to brown, light brown-tan slip, 10R 6/6 (o.s. 7.5YR 5/0-5YR 7/3), silt chalk temper, minor vugs.

C-144 Body sherd, Persian, 0.1cm, grayish brown grading to brown with tan slip, inner light orange-brown surface, fine sand size chalk temper with minor varigated material, minor grog, minor small vugs.

C-145 Body sherd, Persian?, 0.7-1.2cm, brown with orange-brown slip, silt size lithic temper, minor vugs.

C-146 Rim, L.B., 0.6-1.5cm, light brown, silty silt-sand bimodal temper, tight.

C-147 Rim, Chalco., tan with gray-tan grading outward to light orange tan slip, rusty brown burnish, varigated lithic temper, sand size.

C-148 Body sherd, M.B.-II B/C, Minyon ware?, blue gray grading outward to chocolate brown slip, coarse silt size varigated temper.

APPENDIX II

SOME OF THE FORAMINIFERAL REPRESENTATIVES

IN THE CENTRAL SHEPHELAH STRATIGRAPHY

PLATE XVI

1. Morozorella gr. dimulatilis rex, Taqiye Fm., Paleocene
2. Morozorella gr. dimulatilis rex, Taqiye Fm., Paleocene
3. Cibicordis sp., Taqiye Fm., Paleocene
4. Heterolepa scania Brotzen, Taqiye Fm., Paleocene
5. Cibicides pachecoensis, Taqiye Fm., Paleocene

6. Acarinina sp., Taqiye Fm., Paleocene
7. Globoconusa, Taqiye Fm., Paleocene
8. Globoconusa, Taqiye Fm., Paleocene
9. Pseudoguembelina sp., Ghareb Fm., Maastrichtian
10. Heterohelix sp., Ghareb Fm., Maastrichtian

11. Bolivinoides sp., Ghareb Fm., Maastrichtian
12. Hedbergella sp., Ghareb Fm., Maastrichtian
13. Hedbergella sp., Ghareb Fm., Maastrichtian
14. Subbotina sp., Menuha Fm., Senonian
15. Subbotina sp., Menuha Fm., Senonian

16. Subbotina sp., Menuha Fm., Senonian
17. Gaudryina sp., Bi'na Fm., Turonian
18. Heterohelix sp., Bi'na Fm., Turonian
19. Gardinella sp., Bi'na Fm., Turonian
20. Hedbergella sp., Bi'na Fm., Turonian

21. Gardinella sp., Bi'na Fm., Turonian
22. Valvulammini picardi, Bi'na Fm., Turonian

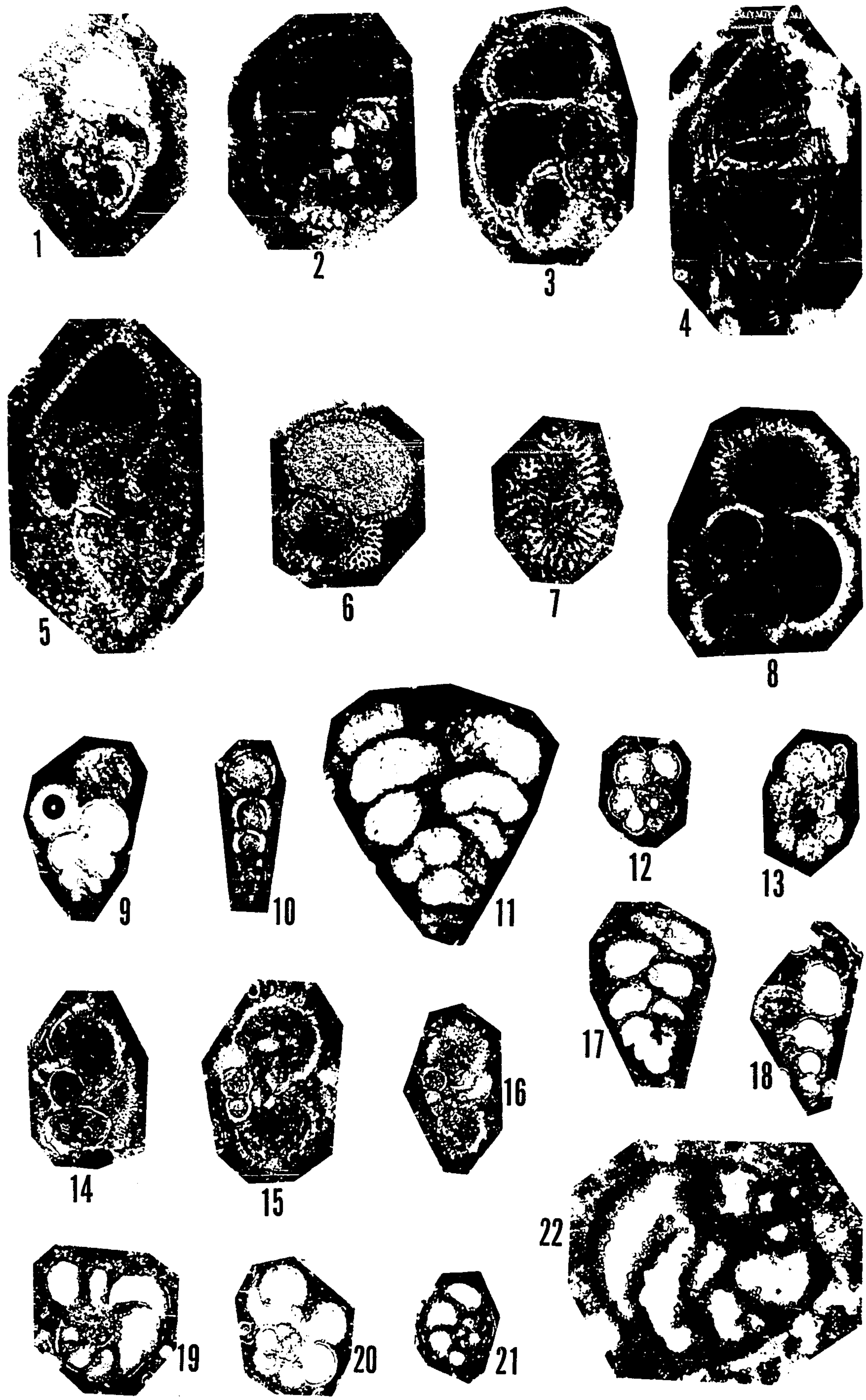

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Plate XVI

PLATE XVII

1. Acarinina sp., Zor'a Fm., Lower Middle Eocene
2. Acarinina sp., Zor'a Fm., Lower Middle Eocene
3. Acarinina sp., Zor'a Fm., Lower Middle Eocene
4. Chiloguembelina sp., Zor'a Fm., Lower Middle Eocene
5. Globorotaloides sp., Zor'a Fm., Lower Middle Eocene

6. Abicides sp., Zor'a Fm., Lower Middle Eocene
7. Bolivina sp., Ziqlag Fm., Miocene
8. Laterostomella sp., Ziqlag Fm., Miocene
9. Operculina sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
10. Pararotalia sp., Zor'a Fm., Maresha Member, Lower Middle Eocene

11. Nummulites sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
12. Pararotalia sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
13. Nummulites sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
14. Guembelina sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
15. Protelphidium sp., Zor'a Fm., Maresha Member, Lower Middle Eocene

16. Pararotalia sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
17. Pararotalia sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
18. Operculina sp., Zor'a Fm., Maresha Member, Lower Middle Eocene
19. Spiroloculina sp., Ziqlag Fm., Miocene
20. Elphidiononion sp., Ziqlag Fm., Miocene

21. Borelis melo, Ziqlag Fm., Miocene
22. Qumqueloculina sp., Ziqlag Fm., Miocene
23. Spiroloculina sp., Ziqlag Fm., Miocene
24. Triloculina sp., Ziqlag Fm, Miocene
25. Gaudryina sp., Ziqlag Fm, Miocene

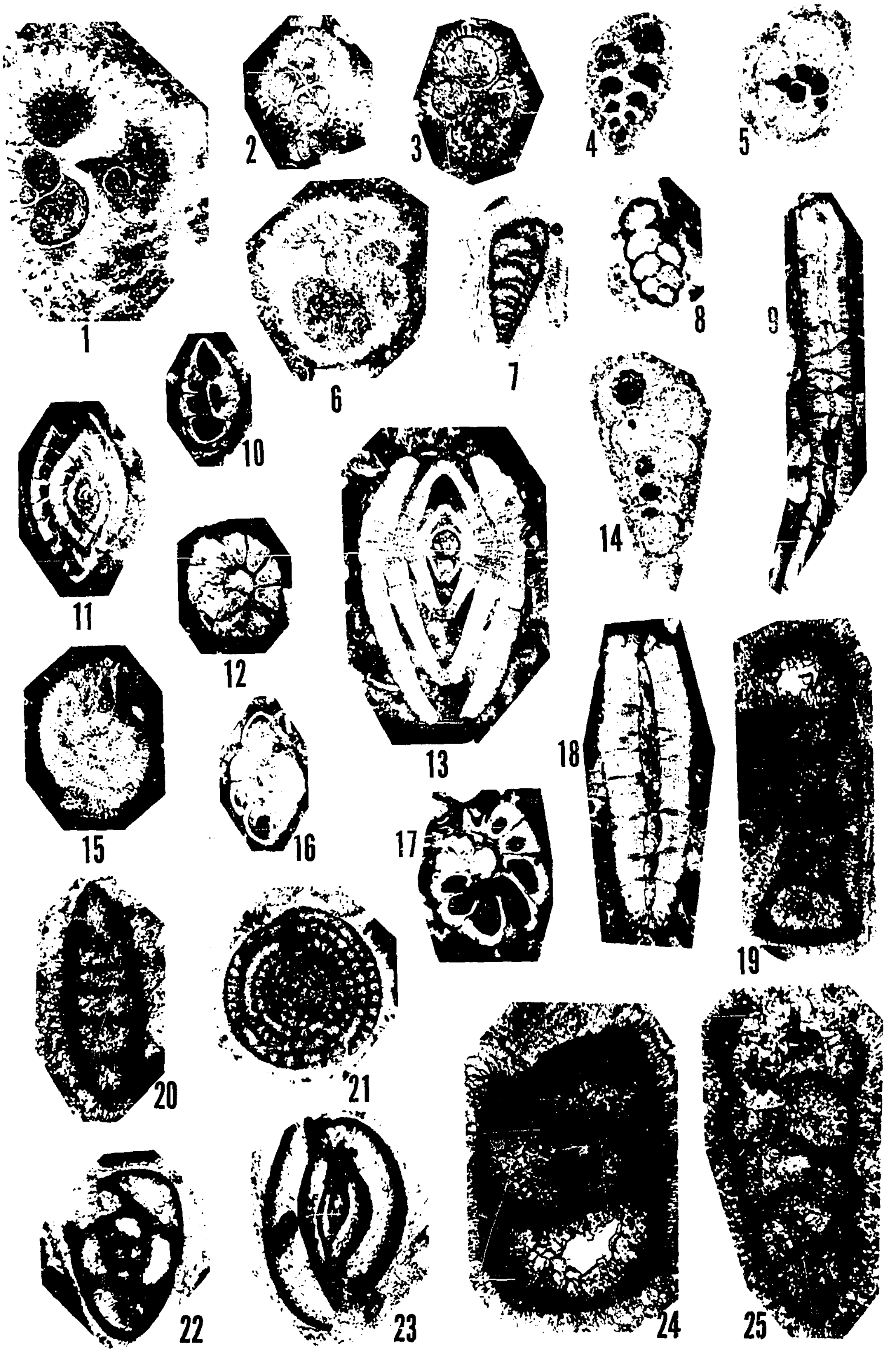


Plate XVII

APPENDIX III

NANNOPLANKTON

Historical Resume

The chalks and marls of the central Shephelah contain, in addition to the foraminiferal constituents, tiny rosettes of calcite crystals from unicellular algae called coccolithophonids. Black (1965) notes that these crystal assemblages

> were first noticed as long ago as 1836 by C. G. Ehrenberg using an ordinary microscope who remarked on their extraordinary abundance in samples of chalk which he got from the island of Rügen in the Baltic; he regarded them as inorganic concretions, similar to the spherulites formed by radial growth of crystals about a nucleus. They came to be known as 'morpholiths' or 'crystalloids', and their inorganic origin was generally accepted until 1861 when H. C. Sorby of Sheffield published the results of his researches on the English chalk. Sorby ...concluded that the chalk crystalloids were more likely to have been formed organically, as part of the external skeleton of a living organism, than purely inorganically.
>
> At about the same time, the first samples of deep-sea ooze were raised from the floor of the Atlantic Ocean and examined by T. H. Huxley and G. C. Wallich [as part of a thorough investigation of the sea floor between Ireland and Newfoundland to discover the properties of the area upon which the first transatlantic telegraph cables were about to be laid]. ...Huxley at first doubted their organic nature, but because their general shape reminded him of the cells of the green algae Protococcus, he called them coccoliths. Wallich found little hollow spheres built out of the coccoliths and he called these coccospheres, and a few years after he was able to announce the discovery of living coccospheres swimming freely near the surface of the ocean.

Living coccosphers are unicellular, biflagellate, golden-brown algae belonging to the class Haptophyceae (Parke and Dixon, 1964) and constituting the family Coccolithophoridaceae (Lohmann, 1902). Together with diatoms and dinoflagellates, the coccolithophorids inhabit the euphotic marine ecozones. While most species are found in the low and middle latitudes, a few representatives occur in great abundance in boreal waters (McIntyre and Be, 1967).

The stratigraphic significance of nannoplankton is underscored by the almost universal extinction of Mesozoic forms at the end of the Cretaceous Period and the appearance of a great number of new species in the Tertiary. Some forms are remarkable for their unusual size or for their bizzare geometry (see PlatesXVIII and XIX). A notable feature of the Tertiary assemblages, however, is the occurrence of an entirely extinct group of fossils regarded as having close affinities with the coccoliths, known as discoasters (Plate XIX, Figures 6-8). Unknown from deposits of any other age, these circular discs composed of various numbers of rays have a unique stratigraphic importance. All the discoasters disappeared at the beginning of the Pleistocene and not a single species is known to survive (Black, 1965).

Certain fundamental pecularities characterize calcareous nannofossils: (1) ubiquity of their occurrence, (2) their distinctive morphology, (3) their occurrence in massive concentrations. Hay and Mohler (1967) submit the following data:

> The numbers of calcareous nannofossils are commonly astronomical. A cubic centimeter of marine shale may contain as many as 10^9 specimens, and a slide prepared for light microscopy will commonly have more than 10^5 specimens.

The stratigraphic relevance of coccoliths and discoasters has been stressed in the investigations of Bramlette and Sullivan (1961), Sullivan (1964, 1965), Black (1964), and Hay and Mohler (1967). A world-wide distribution occurs in Jurassic, Cretaceous, Tertiary, Quaternary, and Recent marine strata. Legitimate time-stratigraphic correlations of Lower Tertiary chalks and marls have been made on the basis of coccolith and discoaster assemblages. While these investigations are initial and tentative, the results appear to be sufficiently reliable as to be of value in this present study.

Sampling and Procedure

The first 20 meters of the Gezer water tunnel, which now remains exposed since the collapse of MacAllister's west balk section, provided relatively fresh rock sample material. Samples were taken at one meter intervals from the present base of the exposed section, except where chert nodules or silicified chalk precluded the possibility of a sample which could be disassociated for electron microscopic viewing. Samples of the marls were also taken where outcrops occur along the northward trending wadi immediately east of Tell Gezer at intervals of one meter. Elevation control was maintained through the use of tape and Brunton compass in the exposures in this area.

Suspensions of these chalk and marl sediments were evaporated onto micaplates, shadowed with platinum carbonate, and replicated by carbon evaporation. The replicas were then released from the mica substrat by dilute HF flotation and washed with dilute HCl. After rinsing with distilled water, the carbon films were lifted onto 200 mesh screens and dried in preparation for microscopic viewing.

Since the wave length of light near the middle of the visible spectrum is approximately 1/2 micron, an electron microscope is of immense advantage in the study of many coccoliths and discoasters having component crystals of smaller dimension than this. The RCA model EMU-2 housed in the Geology-Department, University of Cincinnati, was utilized in the microphotographs in Plates XVIII, XIX, XX, and XXI.

Terminology

The structural terms used in this discussion are based upon the following morphological considerations:

1. Coccolithophorid - the living organism, skeleton and protoplasm.
2. Coccosphere - the skeleton composed of its outer covering of coccoliths.
3. Coccolith - a skeletal element.
4. Central area - an opening about the central axis of the coccolith. Distinctive features such as grilles and transverse bars may be in it.
5. Placolith - a coccolith having a plate-like or shield-like configuration, circular or elliptical when viewed distally.
6. Shield - one of the discs of a placolith, either proximal or distal.
7. Rim - the upper axial margin of the (distal) shield adjacent to the central area.
8. Crystallite - a single regular polyhedral form of calcite.
9. Suture - the edge of separation between crystallites.
10. Grille - a central area with perforations.
11. Pore - circular or polygonal perforations in the grille.
12. Central Column - the ring or collar of crystallites that connects the shields of placoliths.
13. Basal Plate - proximal portion of the proximal shield which

connects the placolith to the coccolithophorid wall.

14. Phabdolith - rod-shaped appendix, some of which are trumpet-shaped (salping form).

15. Pentalith - a five-rayed discoaster, each ray showing a v-shaped crystallite from the adjacent one.

16. Asterolith - a multi-rayed discoaster, each ray made up of a single crystallite.

Systematic Descriptions and Stratigraphic Distribution

Family COCCOLITHOPHORIDACEAE

Genus Chiphragmalithus Bramlette and Sullivan, 1961

Chiphragmalithus dubius (Deflandre)

Plate XVIII, Figure 4

Zygolithus dubius Deflandre, 1954. Bramlette and Sullivan, 1961, p. 150, Pl. 6, Figs. 12, 13, 14.

Chiphragmalithus dubius (Deflandre). Sullivan, 1974, p. 179, Pl. 1, Fig. 2; Sullivan, 1965, p. 30, Pl. 1, Figs. 1, 2.

Description. An elliptical distal shield with an open central area, transversed by an x-shaped structure. Overlapping crystallites slope into the central area on this shield. A proximal shield is also composed of overlapping crystallites.

Distribution. In California, this species is represented in the Lower and Middle Eocene Stages. It is cosmopolitan in the Eocene. It is present in the Middle Eocene of Tell Gezer.

Genus Coccolithus Schwarz 1894

Coccolithus cavus Hay and Mohler

Plate XIX, Figure 9

Coccolithus cavus Hay and Mohler, 1967, Journal of Paleontology, Vol. 41, No. 6, pp. 1524, 1525, Pl. 196, Figs. 1, 2, 3, Pl. 197, Figs. 5, 7, 10, 12.

Description. An elliptical to subcircular distal shield composed of approximately 40 wedge-shaped dextrally imbricate crystallites having straight sutures inclined clockwise. A central concave depression lined with cycles of imbricate crystallite characterizes the distal shield. The crystaliite of the proximal shield occur in the same number as those of the distal shield and have a serrate outer border.

Distribution. The Paleocene and Lower Eocene of Pont Labau, France, and the Middle Eocene of Tell Gezer.

Coccolithus marismontium Black

Plate XXI, Figure 1

Coccolithus marismontium Black, 1964, Palaeontology, Vol. 7, Part 2, p. 309, Pl. 51, Figs. 1-4, Pl. 52, Fig. 3.

Description. Elliptical to nearly circular placolith with the distal shield about 3/4 the diamter of the proximal, each bearing approximately 50 nonimbricate radial crystallites.

Distribution. White chalky Eocene limestone deposits dredged from Galicia Bank off the west coast of Spain and from Middle Eocene specimens present in samples brought up from the Muir Seamount, northeast of Burmuda.

Representatives are unknown in any sediments exposed on land, except these from the Middle Eocene of Tell Gezer.

Genus *Cyclococcolithus* Kamptner, 1954

Cyclococcolithus luninis Sullivan, 1965

Plate XVIII, Figure 8

Cyclococcolithus luninis Sullivan, 1965, University of California Publications in Geological Sciences, Vol. 53, p. 33, Pl. 3, Fig. 9.

Description. Circular placolith with shields, the distal one of which is slightly less than half the total diameter of the proximal one with a small central area.

Distribution. California, Middle to Upper Eocene.

Genus *Cyclolithus* Kamptner, 1948

Cyclolithus? robustus Bramlette and Sullivan

Plate XX, Figures 4 and 5

Cyclolithus? robustus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7, No. 2, p. 141, Pl. 2, Fig. 7; Sullivan, 1964, University of California Publication in Geological Sciences, p. 182, Pl. 3, Fig. 8.

Diagnosis. Placoliths with a large nearly circular shield having a thick peripheral rim which is 1/4 - 1/5 the diameter of the central opening (not too definite in specimens shown). Assignment is tentative inasmuch as published examples feature only optical microscopic views.

Distribution. Common in the Paleocene of California and of Tell Gezer.

Genus *Discolithus* Kamptner 1948

Discolithus distinctus Bramlette and Sullivan 1961

Plate XVIII, Figure 1

Discolithus distinctus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7, No. 2, p. 141, Pl. 2, Figures 8, 9.

Description. A wide, flat distal shield and a proximal shield of about 1/2 the width of the rim. Regular pores occur as conspicuous perforations in the grille.

Distribution. The Lodo Formation (Middle Eocene) of California, Weches Formation (Middle Eocene) of Sabine River, Texas, the Middle Eocene of Trinidad, the Lower Lutetian (Middle Eocene) of Domzacq, France, the Middle Eocene of Carriere de Nousse, France, and the Middle Eocene of Tell Gezer.

Discolithus exillis Bramlette and Sullivan

Plate XVIII, Figures 5 and 6

Discolithus exillis Bramlette and Sullivan, 1961, Micropaleontology, Vol. 7, No. 2, p. 142, Pl. 2, Fig. 10; Sullivan, 1965, p. 33, Pl. 5, Fig. 7.

Description. A thin rim on the distal shield, a proximal shield with central area having two very large openings leaving a narrow transverse connection across it. A widening of the connection occurs at opposite sides near the central column.

Distribution. California, throughout the Middle Eocene, the Cain River Formation (Middle Eocene) of Louisiana, and the Middle Eocene of Tell Gezer.

Discolithus fimbriatus Bramlette and Sullivan

Plate XVIII, Figure 2

Discolithus fimbriatus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7, No. 2, p. 142, Pl. 3, Fig. 1.

Description. A high wide distal shield surrounds a large central area which has a grille with small circular perforations. Two circular openings in the basal plate below the grille are not in evidence in the figured example.

Discolithus gezerensis? n. sp.

Plate XIX, Figures 1, 2, 3

Description. Placoliths consisting of a single elliptical plate or shield with a concave proximal side. A central grille with 10-14 polygonal pores arranged in subparallel rows of 1-4 perforations.

Discussion. This description is similar that given by Cohen, 1964, for his examples of *Discolithus macroporous* Deflandre, two representatives of which he illustrates: Micropaleontology, Vol. 10, No. 2, p. 236, Pl. 3, Fig. 5, Pl. 4, Fig. 6. The geometry of the perforation in his figured examples, however, is clearly circular, while that of this proposed species is distinctly polygonal (square).

Distribution. The Middle Eocene of Tell Gezer. (Representatives of the similar Discolithus macroporous Deflandre are recorded from the Oligocene? of New Zealand (type locality of Deflandre) and the Tertiary of Austria.)

Discolithus punctosus Bramlette and Sullivan

Plate XVIII, Figure 3

Discolithus punctosus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7, No. 2, p. 143, Pl. 3, Fig. 11; Sullivan 1965, Pl. 4, Fig. 7.

Description. Elliptical placolith with a distal shield 1/2 the diameter of the proximal. A central area has many irregular central pores. The grille is dissected by a longitudinal line.

Distribution. The Lodo Formation, California (Lower Eocene) (rare) and the Middle Eocene of Tell Gezer.

Discolithus solidus Deflandre

Plate XVIII, Figure 7

Discolithus solidus Deflandre 1954. Bramlette and Sullivan, 1961, pp. 43-44, Pl. 3, Figs. 14, 15; Sullivan, 1965, p. 34, Pl. 4, Fig. 8.

Description. [Provisionally retained in the genus Discolithus]. A very small, but thick ovoid basal plate with six large holes arranged in the geometry 1-2-2-1 longitudinally.

Distribution. From Plaeocene to Middle Eocene in California; the Weches Formation (Middle Eocene) of Sabine River, Texas; the Lower Lutetian (Middle Eocene) of Donzacq, France; the Middle Eocene of Tell Gezer.

Genus *Rhabdosphaera* Haeckel

Rhabdosphaera vitrea Deflandre

Plate XX, Figures 8, 9

(*Rhabdolithus vitreus* Deflandre 1954), *Rhabdosphaera vitrea* Deflandre 1954. Bramlette and Sullivan, 1961, Micropaleontology, Vol. 7, No. 2, p. 147, Pl. 5, Figs. 15, 16.

Description. Small Rhabdoliths with trumpet-like appearance (the salpingform cyrtolith appendix of McIntyre and Be, 1967). The flaring basal plate of the rhabdolith has a central hole which is continuous with a canal in the stem. A thickened collar is present at the junction with the stem.

Remarks. Modern studies have shown these rhabdoliths to be appendices which are attached to the coccolithophorids. The evidence (McIntyre and Be, 1967, Pl. 1) suggests that on the basis of *Discosphaera tubifera* (Murray and Blackman) Lohmann the trumpet-shaped appendices are attached with their stems in proximal fashion to the coccospheres with the flaring ends oriented distally.

Distribution. The Lower and Middle Eocene of California; the Lower Lutetian (Middle Eocene of Donacz, France); the Cane River Formation (Middle Eocene of Louisiana); and the Middle Eocene of Tell Gezer.

Family BRAARUDOSPHAEROIDACEAE

Genus Micrantholithus Deflandre 1950

Micrantholithus attenuatus (Bramlett and Sullivan)

Plate XIX, Figure 7

Micrantholithus attenuatus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7, No. 2, p. 154, Pl. 8, Figs. 8, 9; Sullivan, 1964, University of California Publications in Geological Sciences, Vol. 44, No. 3, p. 188, Pl. 8, Fig. 8; Levin, 1965, Journal of Paleontology, Vol. 39, No. 2, p. 268, Pl. 42, Fig. 6.

Description. Pentaliths composed of five V-shaped crystallites with adjacent sides forming long tapering rays yielding a star-shape configuration. Crystallite variation ranges from equal adjacent sides to one side three times the length of the other, maintaining internal constancy within any one pentalith. Marginal indentations vary from very sharply angular to moderately rounded.

Distribution. The Lower Eocene of California; the Bashi Formation (Paleocene or Lower Eocene); the Nanafalia Formation (Paleocene of Alabama); the London clay (Lower Eocene of England; the Tuilerie of Gan (Lower Eocene) in France; and the Middle Eocene of Tell Gezer.

Family DISCOASTERACEAE

Genus Discoaster Tan Sin Hok 1927

Discoaster elegans Bramlette and Sullivan

Plate XIX, Figure 6

Discoaster elegans Bramlette and Sullivan, 1961, Micropaleontology, Vol. 7, No. 2, p. 159, Pl. 11, Fig. 16; Sullivan, 1963, University of California Publications in Geological Sciences, Vol. 44, No. 2, p. 1960, Pl. 10, Figs. 5, 6.

Description. Asteroliths with twelve concentrically aligned, pointed rays united throughout most of their length with a pronounced stem on the concave side.

Distribution. The Lower and Middle Eocene of California; the Middle Eocene of Tell Gezer; a cosmopolitan occurrence throughout this Epoch.

Discoaster falcatus Bramlette and Sullivan

Plate XIX, Figure 8

Discoaster falcatus Bramlette and Sullivan 1961, Micropaleontology, Vol. 7 No. 2, p. 159-160, Pl. 11, Figs. 14, 15; Sullivan, 1964, University of California Publications in Geological Sciences, p. 190, Pl. 11, Figs. 10-12.

Description. Asteroliths with eight rays, the thickest portions of which appear curved, joined throughout about half their length, yielding a moderate asymmetry. A prominent boss occurs centrally.

The Gezer examples show a tendency toward attenuation (this could be due to damage occurring during sample preparation) or a slight elongation such that samples rarely show rays of exactly equal length.

Distribution. Cosmopolitan in the Paleocene, rare in the Lower Eocene of California; equally rare in the Middle Eocene of Tell Gezer

Family HELIOLITHACEAE

Genus Heliolithus Bramlette and Sullivan 1961

Heliolithus riedeli Bramlette and Sullivan

Plate XX, Figures 1, 2, 3

Heliolithus riedeli Bramlette and Sullivan, 1961, Micropaleontology, Vol. 7, No. 2, p. 164, Pl. 14, Figs. 9, 10, 11; Sullivan, 1964, University of California Publications in Geological Sciences, Vol. 44, No. 3, p. 193, Pl. 12, Figs. 4, 6, 7, 8; Sullivan, 1965, University of California Publication in Geological Sciences, p. 44, Pl. 11, Figure 6.

Description. "Forms with two conical-shaped parts jointed at truncate apices. Conical ends vary from being similar to having one distinctly appressed and greater in diameter from base thin peripheral part of concave bases showing about twenty petal-like elements" (Bramlette and Sullivan, 1961).

Remarks. The Heliolithid radial arrangement of component crystallites is especially evident in Figure 3. These specimens along with others of the species and with various representatives of the other groups figured all show a marked structural deterioration in the crystallite and shield preservation. This may be evidence of a partial solution of the $CaCO_3$ in the marls of the Shephelah where conditions of a mildly reducing sedimentary environment is indicated by the presence of small amounts of FeO. The solution and deterioration of the Paleocene forms has proceeded to such a marked degree that only remnants of coccolithophorid forms occur throughout as much as 60-70% of all the prepared samples from this Series.

Distribution. The Paleocene of California. The Paleocene of Alabama, England, and Tell Gezer.

Family PRINS'ACEA

Genus Ericsonia Black 1964

Ericsonia cf. superbtus Hay and Mohler

Plate XX, Figures 6, 7

Ericsonia superbtus Hay and Mohler, 1967, Journal of Paleontology, Vol. 41, No. 6, p. 1531, Pl. 198, Fig. 11, 15, 18, Pl. 199, Figs. 1-3.

Description. A complex distal shield made up of four cycles of crystallites arranged in a characteristic herringbone pattern. The proximal shield is slightly more than half the diameter of the distal shield. A central area has about 1/3 the diameter of the placolith.

Distribution. The Paleocene of Pont Labau, France, and the Paleocene marls horizons below the Eocene Chalks of Tell Gezer.

Genus Toweius Hay and Mohler 1967

Toweius craticulus Hay and Mohler

Plate XVIII, Figure 9

Toweius craticulus Hay and Mohler, 1967, Journal of Paleontology, Vol. 41, No. 6, p. 1530-1531, Pl. 196, Figs. 7-9, Pl. 197, Figs 2,3.

Description. A distal shield made up of overlapping tabular crystallites. A rim consisting of 3/4 of the diameter of the total shield area surrounds a central ovate area having a grille with radial perforations.

Distribution. The Lodo Formation of California and the Pont Labau area, France. [In the Shephela of Israel it occurs in the uppermost strata underlying Tell Gezer, containing distinctly Middle Eocene fauna and coccoliths.]

Family ZYGODISCACEAE

Genus *Zygolithus* Kamptner 1955

Zygolithus crux Deflandre

Plate XIX, Figures 4,5

Zygolithus crux Deflandre. Bramlette and Sullivan, 1961, Micropaleontology, Vol. 7, Pl. 6, Figs. 8-10; Levin, 1965, Journal of Paleontology, Vol. 39, No. 2, p. 267, Pl. 41, Fig. 7.

Description. Placoliths consisting of an elliptical shield with a central elliptical opening transversely spanned by two cross-bars corresponding to the direction of the axes of an elipse. Cross-bars may have a slight sigmoidal aspect. This minor variation may be due to distortion in the process of preparation.

Distribution. Europe, North Africa, the Lutetian and the Ypresian Stages (Middle and Lower Eocene); the Jackson Stage (Upper Eocene) of Mississippi; the Lower to Middle Eocene of California.

Specimens of Unknown Affinity

Plate XXI, Figures 2, 3

Discussion. A number of recurrent forms present throughout the marl sections show two types of deterioration. Figure 2 shows evidence of advanced solution of the crystallites to the extent the diagnosis is most improbable even on the genus level. Figure 3 illustrates a common occurrence in the prepared materials from these horizons in which there exists a general masking of the vital diagnostic features of the coccoliths. Whether this masking is partial surface solution of the crystallite rendering the sutures very difficult to recognize, or whether it represents poor preservation from other causes, is not understood. For physical entities less than 30 microns in diameter, the deterioration of the specimens would not be expected from physical abrasion in the currents which affected the distribution of the marls on the continental shelf and slope of the Paleocene Levant.

Summary.

The study of the Early Tertiary coccolithiphorids of the central shephelah has illustrated the utility of these forms in biostratigraphic research. The time-stratigraphic significance of this research has yielded sufficient fruition to warrant the considerable amount of time essential to obtain the results.

The stratigraphy of the Shephelah of the area of Tell Gezer now appears to be firmly established.

PLATE XVIII

1. *Discolithus distinctus* Bramlette and Sullivan
   Electron micrograph (8000x)

2. *Discolithus fimbriatus* Bramlette and Sullivan
   Electron micrograph (6500x)

3. *Discolithus punctosus* Bramlette and Sullivan
   Electron micrograph (6500x)

4. *Chiphragmalithus dubius* Deflandre
   Electron micrograph (4500x)

5. *Discolithus exillis* Bramlette and Sullivan
   Electron micrograph (4500x)

6. *Discolithus exillis* Bramlette and Sullivan
   Electron micrograph (3500x)

7. *Discolithus solidus* Deflandre
   Electron micrograph (4500x)

8. *Cyclococcolithus luninis* Sullivan
   Electron micrograph (3500x)

9. *Toweius craticulus* Hay and Mohler
   Electron micrograph (9000x)

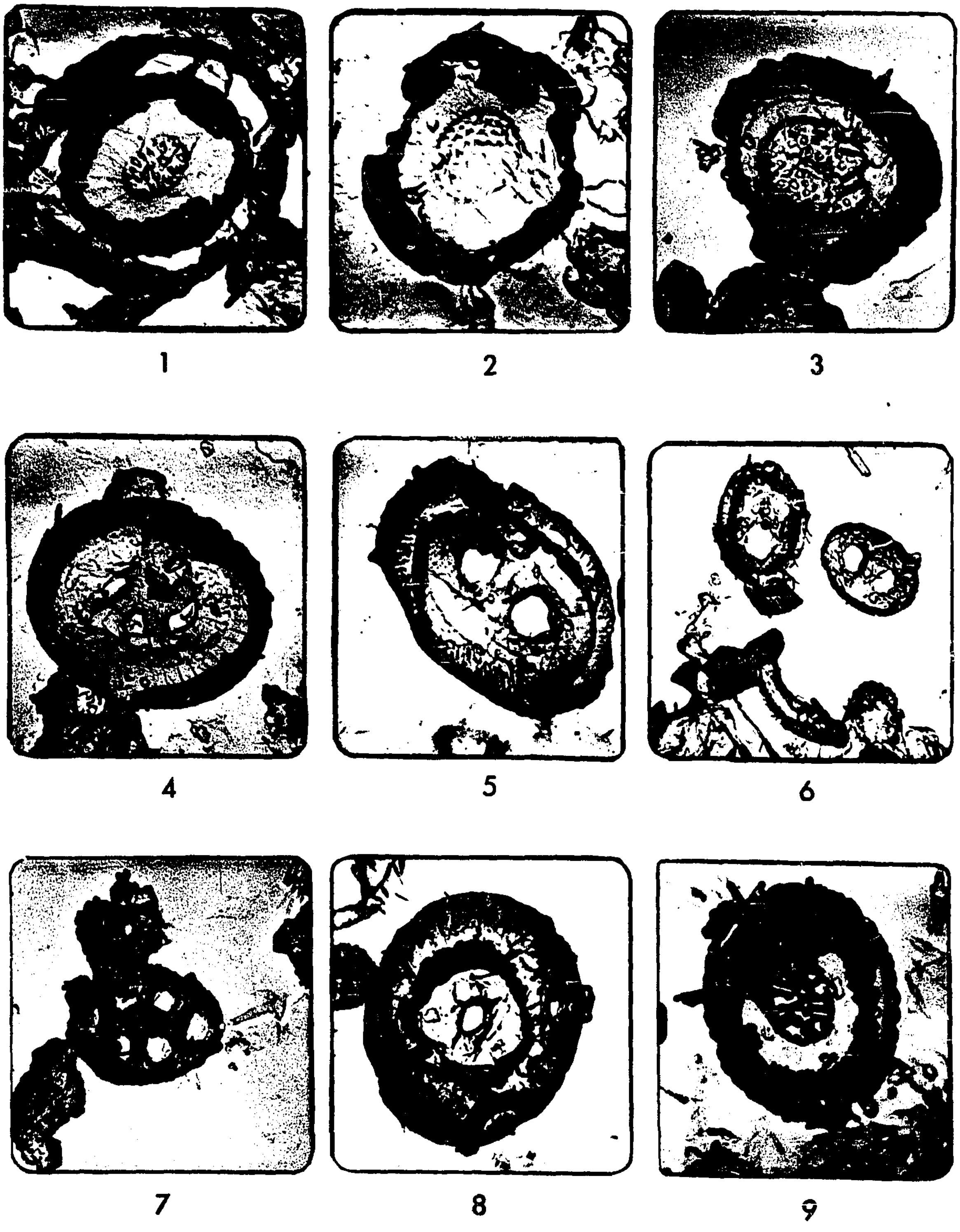


PLATE XVIII

PLATE XIX

1. Discolithus gezerensis n. sp.
   Electron micrograph (6500x)

2. Discolithus gezerensis n. sp.
   Electron micrograph (6500x)

3. Discolithus gezernesis n. sp.
   Electron micrograph (6500x)

4. Zygolithus crux Deflandre
   Electron micrograph (3500x)

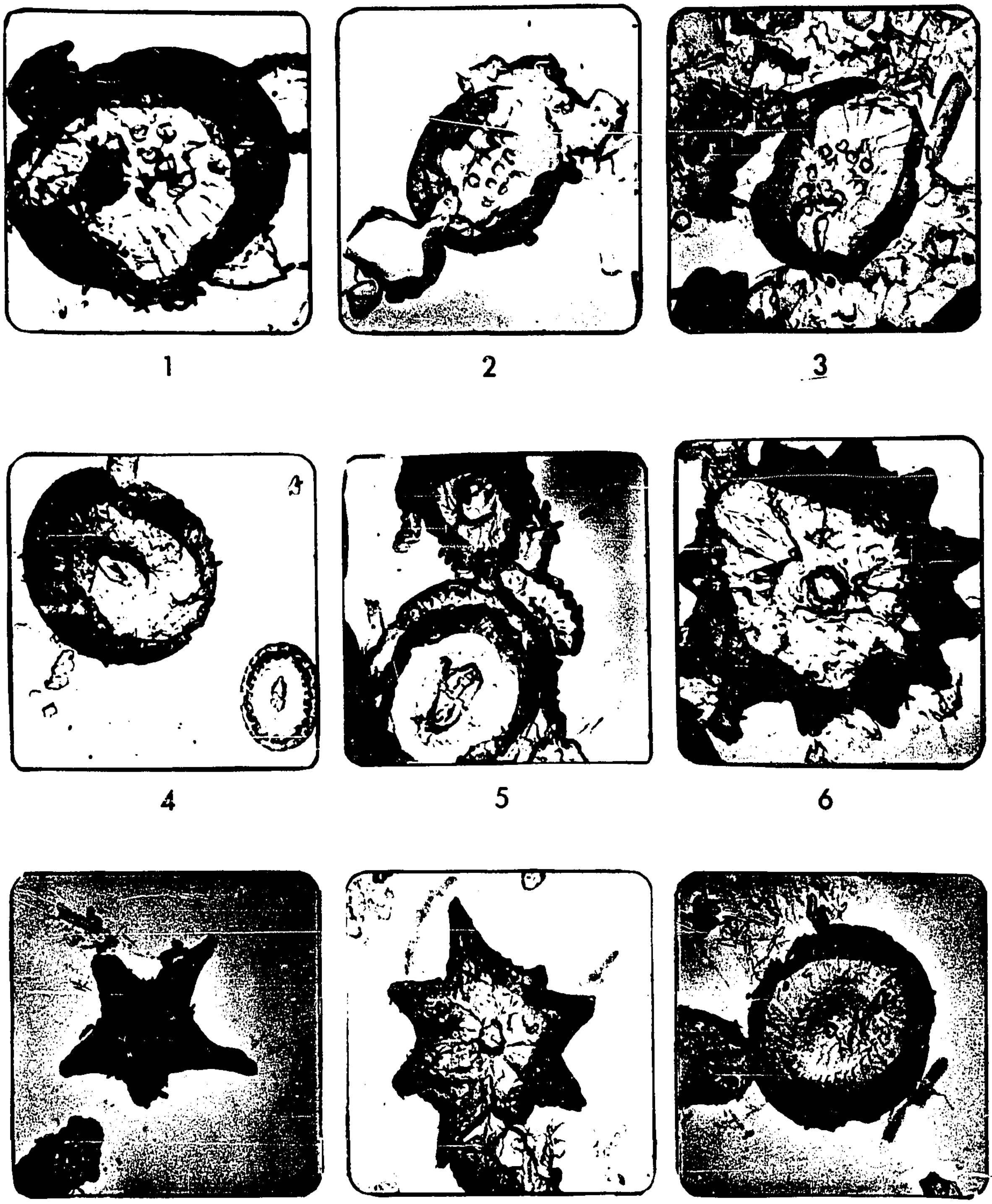
5. Zygolithus crux Deflandre
   Electron micrograph (3500x)

6. Discoaster elegans Bramlette and Sullivan
   Electron micrograph (3500x)

7. Micrantholithus attenuatus Bramlette and Sullivan
   Electron micrograph (3500x)

8. Discoaster falcatus Bramlette and Sullivan
   Electron micrograph (4500x)

9. Coccolithus cavus Hay and Mohler
   Electron micrograph (3500x)



1 2 3

4 5 6

7 8 9

PLATE XIX

PLATE XX

1. *Heliolithus riedeli* Bramlette and Sullivan
   Electron micrograph (5500x)

2. *Heliolithus riedeli* Bramlette and Sullivan
   Electron micrograph (2000x)

3. *Heliolithus riedeli* Bramlette and Sullivan
   Electron micrograph (5500x)

4. *Cyclolithus*? *robustus* Bramlette and Sullivan
   Electron micrograph (3500x)

5. *Cyclolithus*? *robustus* Bramlette and Sullivan
   Electron micrograph (4500x)

6. *Ericsonia superbtus* Hay and Mohler
   Electron micrograph (5500x)

7. *Ericsonia superbtus* Hay and Mohler
   Electron micrograph (5500x)

8. *Rhabdospharea vitrea* Deflandre
   Electron micrograph (4500x)

9. *Rhabdospharea vitrea* Deflandre
   Electron micrograph (2000x)

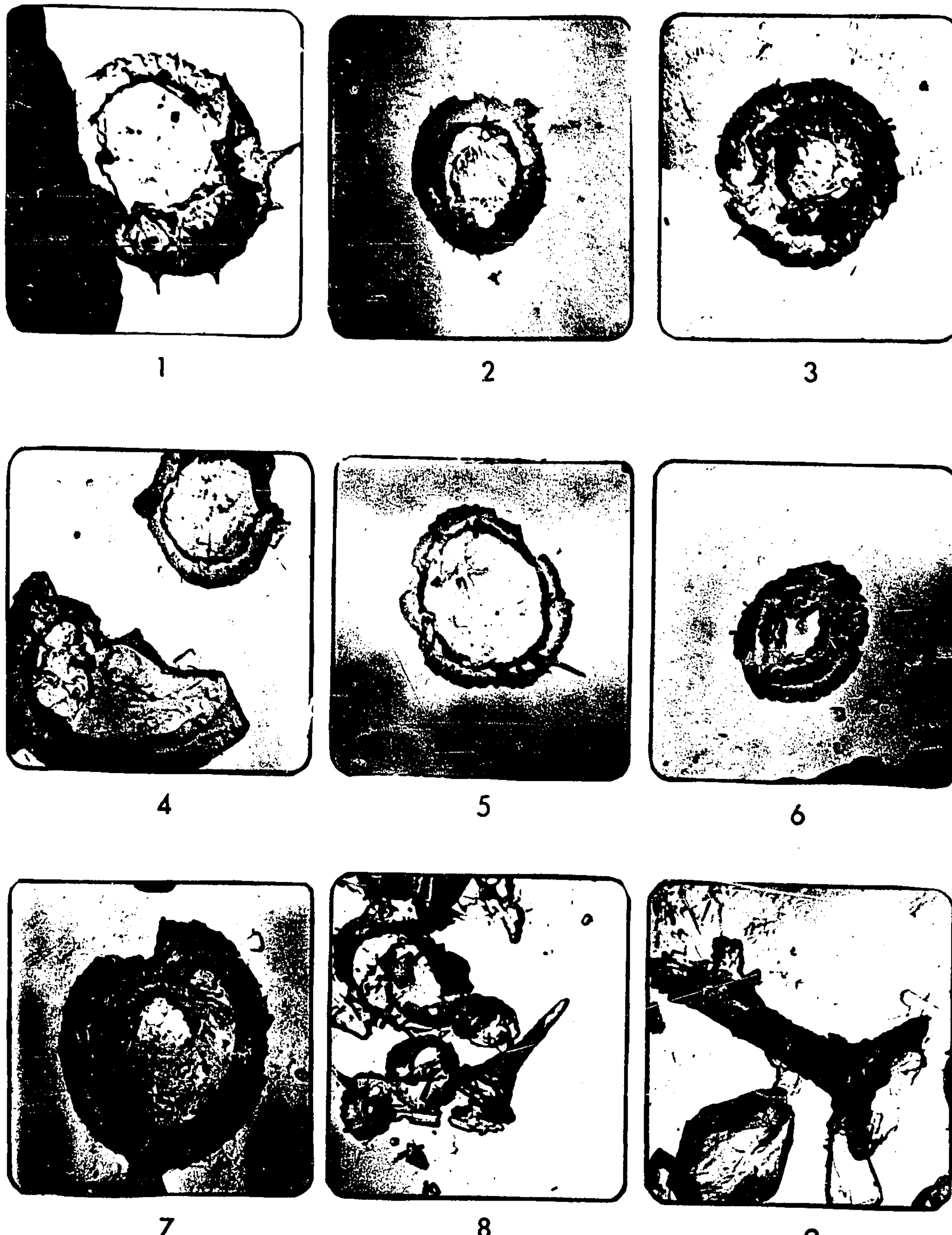


PLATE XX

PLATE XXI

1. _Coccolithus_ _marismontium_ Black
   Electron micrograph (2000x)

2. Coccolithiphoridae of unknown affinity in Paleocene marls
   Electron micrograph (5500x)

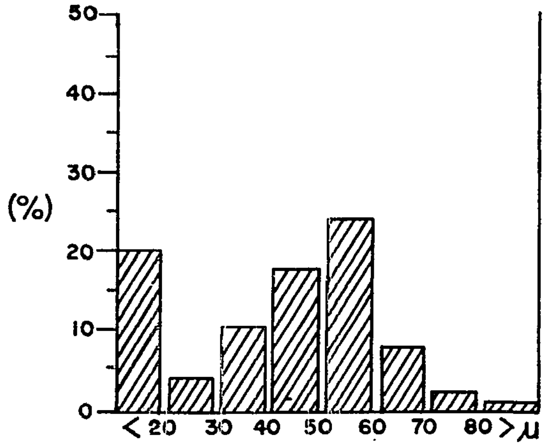
3. Coccolithiphoridae of unknown affinity in Paleocene marls
   Electron micrograph (4500x)

1

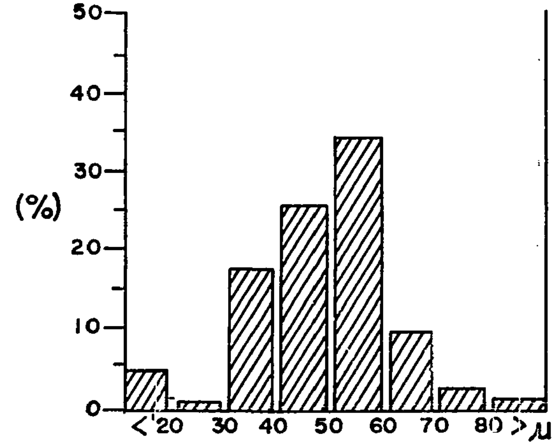
2

3

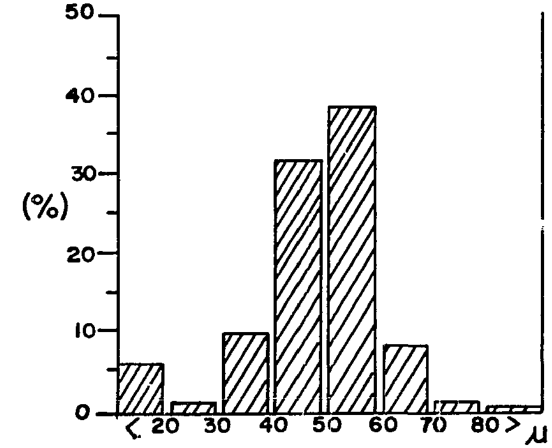
PLATE XXI



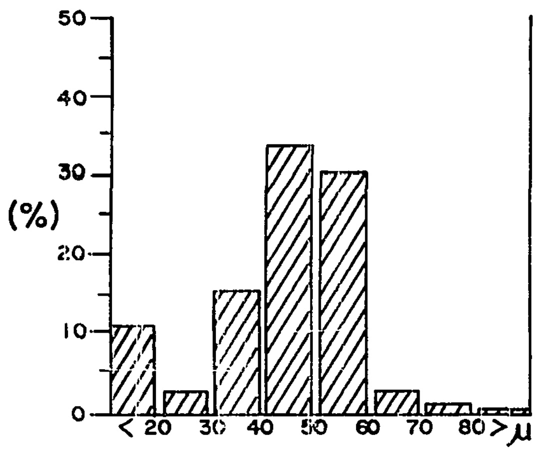
A. BEERSHEBA LOESS



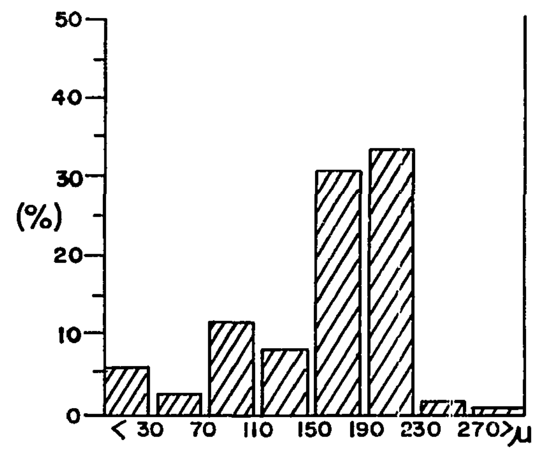
B. LOESS, SOUTHERN SHEPHELAH
(Coord. 120/105)



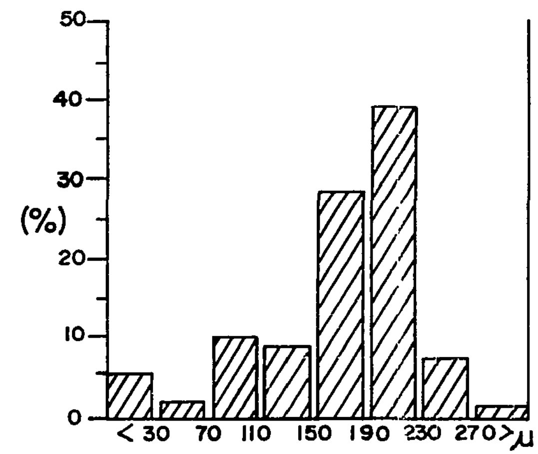
C. LOESS, GEZER, FIELD III STREET
(gate area)



D. LOESS, GEZER, FIELD III STREET
(3.5 m. east of gate area)



E. HAMRA, COASTAL PLAIN
(2.1 km. south of Na'an)



F. HAMRA, GEZER, FIELD III
(Middle Bronze II B)

IV-i

PLATE XXII SIZE DISTRIBUTION OF LOESS AND HAMRA