ence Rise were located in similar shallow marine depositional environment, but during the late Pliocene and the Quaternary Cyprus was uplifted while Florence Rise subsided to bathyal depths. These displacements suggest extensional tectonic regime off western Cyprus. Comparison of these and similar findings with the tectonic regime of the Tyrrhenian and Alboran Seas in the western Mediterranean, as well as the results of recent experiments in analog models, suggest that the prime tectonic process in the eastern Mediterranean is the Ionian subduction and its seawards roll-back. That migration of the Ionian Arc system presumably causes the extensional opening of the Aegean Sea since the middle Miocene and the westward motion of the Anatolian microplate. The ascent of Cyprus since the late Miocene is its structural response to westwards extension and the consequent structural detachment of Florence Rise and the uplift of Cyprus.

Yossi Mart and William Ryan

GEOMORPHOLOGICAL RESEARCH — ONGOING PROJECTS

Research being carried out in this field focuses on two main subjects: reconstruction of paleoenvironmental conditions along the northern coast of Israel; indications of paleo sea levels over the last thousand years. The first project presented below deals with environmental changes and their effect on human settlement along the northern Israeli coast, while the second and third projects deal with evidence relating to sea level changes along the Israeli coast.

The Paleogeography of the Taninim river mouth and the Kebara swamps in the Holocene

This research is part of the Ph.D. thesis being prepared by Ronit Cohen, supervised by Dorit Sivan of the Leon Recanati Institute for Maritime Studies (RIMS) and the Department of Maritime Civilizations, Moshe Inbar and Noam Greenbaum, both of the Department of Geography, all of the University of Haifa. Ahuva Almogi-Labin and Amnon Rosenfeld, both of the Geological Survey (GSI), Jerusalem, acted as scientific advisors.

The aim of this research is to reconstruct the environmental conditions of the southern Carmel coastal plain during a period of fundamental sea level and climatic change. These changes brought about sedimentary changes and landscape alterations, which influenced human settlement patterns. The area investigated extends from the Daliya River mouth in the north to the Taninim River mouth in the south, and from Mount Carmel in the east to the Hayonim Island

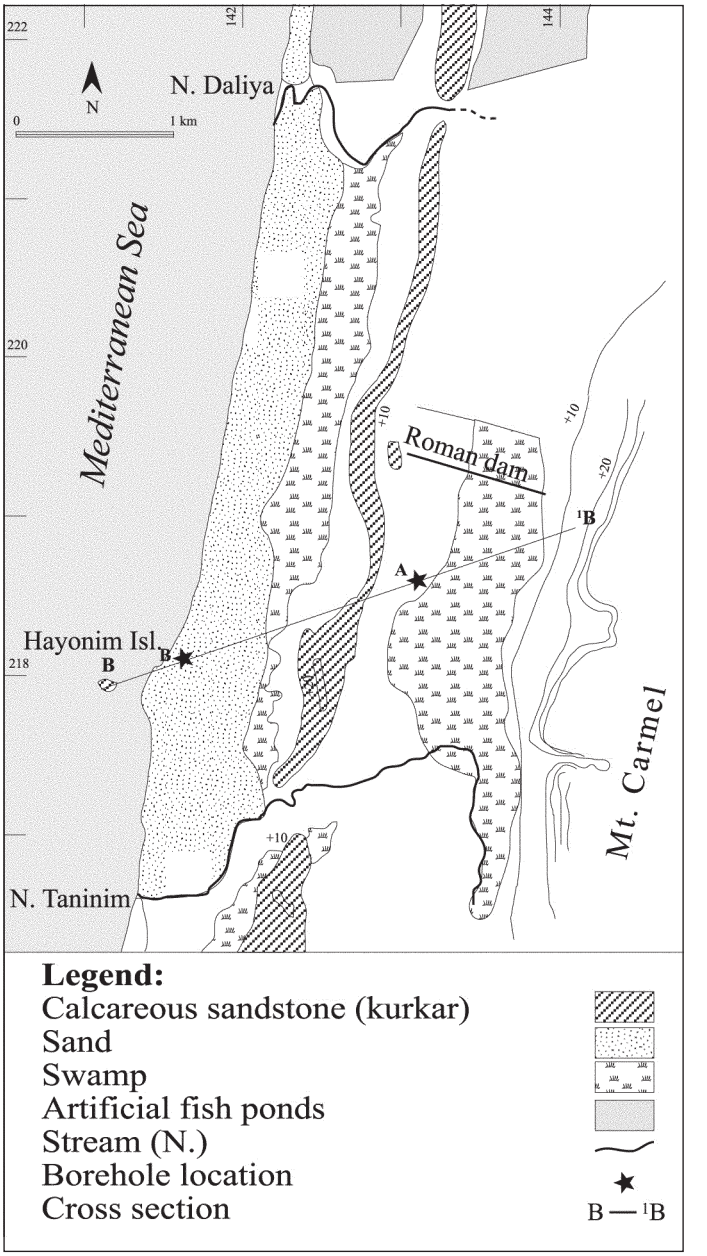

Fig. 1. Map of study area (Drawing: N. Yoselevich)

and the submerged ridge on the shallow shelf (Fig. 1).

Two core drillings were carried out, one on the coastline (core B), the second (core A) east of the *kurkar* ridge, at the center of the wetland area. The east borehole (A) was drilled down to 16 m; the west one (B), down to 12 m. Both cores present continuous sequences. The coastal drilling sequence consists of 7.5 m of sand, overlying 4.5 m of dark clay, which becomes brown at the bottom. To the east of the ridge, the 16 m sequence consists of clays from top to bottom, becoming red towards the bottom. It appears that the brown clay represents a paleosol, while the dark clay was deposited in a wetland environment.

The sedimentological analyses, which were performed at the Department of Radiography, Bnei Zion Medical Center,

Haifa, as a combined research project together with Elisha Barmeir (MD) and Simona Croitoru (MD), include x-ray radiography and computerized tomographic scanning (CT). Both the CT images and the x-ray radiographs were analyzed using ENVI processing software (Fig.2). The detailed stratigraphic examination is based on conventional parameters, such as color, stiffness and structure, water and organic content, and on granulometry, as well as on the analysis of the radiographs and CT images.

Core A was divided into 103 sub-units, which were combined into 25 main stratigraphic units. The clay sequence from core B was divided into 35 sub-units which were combined into 11 units. Ten dates, obtained through ^{14}C dating, provide a general time framework, but more dating is needed to obtain accurate environmental reconstruction. Detailed paleontological research, carried out at almost every 10 cm along the clay sequences of both cores, provides preliminary conclusions about the character of the water in which the clay and the fauna were deposited (meteoric or brackish water).

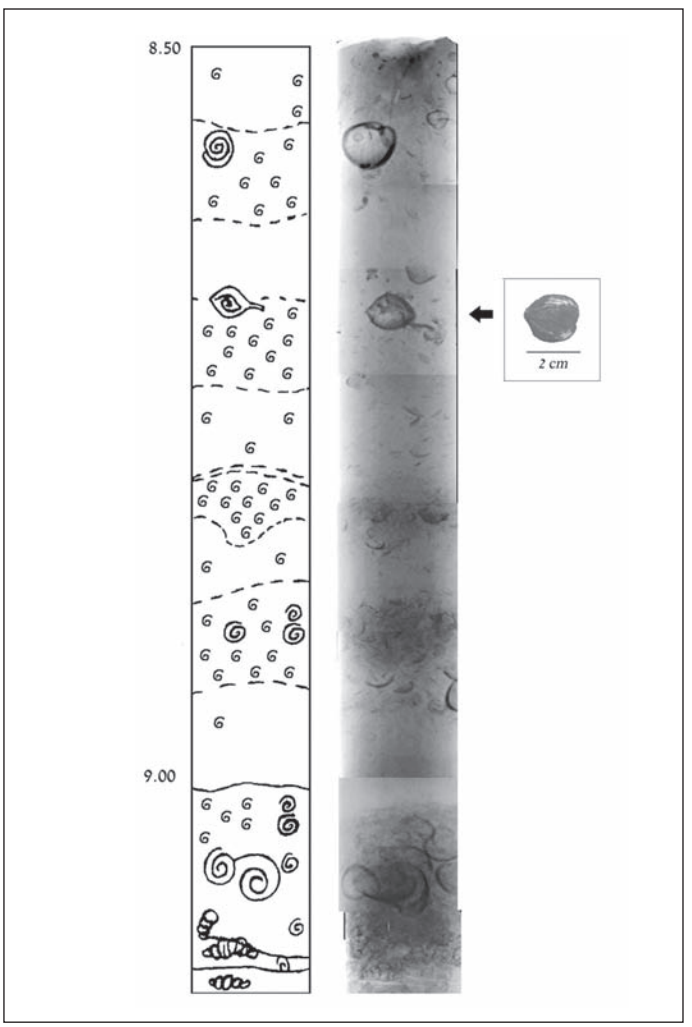

Fig. 2. Detailed stratigraphy based on X-ray radiography, an example from core A.

At this stage of research it can be concluded that in both cores, the lower sequence is constructed of mainly thick brown units, which become dark grey to black towards the top. In general, the bottom units represent a mainly dry landscape covered by red paleosol. The upper dark units indicate changing wetland conditions. Core A contains a relatively large variety of Foraminifera and Ostracoda, most of which indicate the presence of fresh to brackish water, while core B contains a smaller number of species, all indicating a brackish deposition environment.

The bottoms of both cores A and B were dated by ^{14}C. Core A was dated to 9,770± 130 BP (uncalibrated) and core B to 9,705± 70 BP (uncalibrated). The top of the clay unit in core B, which is overlaid by sand, is dated to 7,968± 51 BP. In core A the clay was deposited up to modern times.

Preliminary conclusions suggest that the two sequences represent alternating dry and wet cycles, both originating at the beginning of the Holocene. At the west trough (B), the marsh dried up at about 8,000 BP (uncalibrated). A similar reconstruction appears in Dor, north of the Taninim area, where at around 8,700 BP wet conditions prevailed, and then the wetland dried up. The sand that now covers the present coastal zone began accumulating approximately 5,000-4,500 years ago. At the east trough, wet conditions prevail up to the present, with indications of changing salinity and dispersion of the marsh.

Research is still in progress, and paleontological data is to be analyzed; the results of which will assist in identifying the water characteristics, thus giving a better understanding of the local and regional environmental conditions that affected the landscape.

This research is supported mainly by a Sir Maurice and Lady Irene Hatter research grant of $6,000.

Ancient coastal wells of Caesarea Maritima, Israel — an indication of sea level changes during the last 2000 years

This is a joint research project carried out by Dorit Sivan, Roni Toueg and Avner Raban, all of RIMS and the Department of Maritime Civilizations, University of Haifa, in cooperation with Yosef Porath, of the Israel Antiquities Authority (IAA), Boris Shirman, of The Survey of Israel, and Kurt Lambeck, of the Research School of Earth Sciences, The Australian National University, Canberra, Australia.

During the extensive archaeological excavations carried out over a period of more that 20 years at the ancient city of Caesarea Maritima, 64 wells were exposed and cleaned down to their base. Most of the inner harbor wells were excavated by Roni Toueg as part of his M.A. thesis, supervised by Avner Raban. These wells are dated to various occupational phases,

from the Early Roman period in the 1st century CE, to the Crusader period at mid-13th century CE. It was found that most contemporaneous well bases had been cut down to around the same elevation, differing from the well base elevations from other periods. The working hypothesis of this research states that the well base elevations indicate different water table elevations during different periods, and coastal well water table changes are the result of sea level changes. This hypothesis is based on the assumption that the base level can be used as a tool for reconstructing the ancient paleo sea levels, as there were no vertical movements along the coast of Caesarea over the last few thousand years. Modern seasonal water table data, obtained during the last 50 years, together with the present-day daily measurements of the water table in one ancient well, are compared with the daily present-day sea level. The modern data concerning water table fluctuations indicate an almost one-to-one correlation between sea level and the coastal water table. Thus, it can be concluded that the reconstructed paleo water table, based on data derived from ancient coastal wells, allows the reconstruction of paleo sea levels during the relevant historical periods.

At this stage, it can be concluded that the sea level during the 1st century CE was similar to that of the present day. During the 3rd to 4th centuries CE, and again during the 5th to 7th centuries CE, and possibly even up to the 8th century CE, sea level was higher than today. The sea started to regress to approximately its present level during the 9th century CE. There is insufficient data available for the 10th to the 11th centuries CE, but it seems that the sea regressed to its lowest level, lower than at present, during the 12th and 13th centuries CE.

Bio-structural indicators for paleo sea level changes

This research is a joint research project being carried out in association with Christoph Morhange of Aix en Provence, France, and Maoz Fine of Tel Aviv University. The research deals with indications of ancient sea level markers that can be dated using ^{14}C and uranium series dating methods. Anat Shmueli is carrying out part of this research for her M.A. thesis, supervised by Dorit Sivan and Ehud Spanier, both of RIMS and the Department of Maritime Civilizations, University of Haifa.

Within the framework of this research, core drillings at the edge of the abrasive platform along the coast between Caesarea and Rosh Haniqra were carried out (Fig. 3). The edge of the abrasive platform consists mainly of *Dendropoma petraeum* (Vermetidae), which is considered to be a relatively accurate sea level indicator. Various analyses, will be carried out on the cores in order to date the first settlement

Fig 3. Drilling cores at the edge of the abrasive platform at Habonim (Photo: D. Sivan)

of this fauna, thus indicating the last phase of sea level stabilization. Both underwater and land surveying will be carried out to look for sunken and/or uplifted bio-constructions in order to obtain information regarding paleo sea level indicators that can be accurately dated.

Research is in its preliminary stages, and so far two *Dendropoma* samples from the abrasion platform edge at Sedot Yam (south of Caesarea), on the southern Carmel coastal plain, and from Achziv, on the coastal Galilee plain, were dated at Lion, France. The sample from Sedot Yam was dated to about 840 BP, and the sample from Achziv to 645 BP. To date four cores have been drilled at Sedot Yam and three at Habonim, north of Dor, on the Carmel coast. Thin sections were taken from one core and samples sent for ^{14}C dating.

The results will be compared with sea level curves based on archaeological and hydro isostatic models obtained from the Israeli coast, and to the morphological and biological coastal measurements obtained in Lebanon and Egypt. These data will assist in attaining high-resolution regional data on Holocene sea level changes, thus facilitating the reconstruction of the eastern Mediterranean coastal sea levels.

Assemblages of live and/or fossil *Glycymeris* in archaeological coastal sites and selected sites on the Israeli coast and shelf

This research is being carried out as an M.A. thesis by Mina Potasman, under the supervision of Dorit Sivan and Ehud Spanier, both of RIMS and the Department of Maritime Civilizations, University of Haifa, and Ahuva Almogi-Labin, of the Geological Survey of Israel, Jerusalem.

As reported previously, the research aims to answer the question of the disproportion that exists along the Israeli

coast, between the amounts of *Glycymeris* fossils found today at the waterline and embedded in archaeological sites, and the almost total absence of live specimens on the shallow shelf.

The research aims to answer the main question regarding the origin of the *Glycymeris*: where and when they live, and why they accumulate along the Israeli coast. The research will attempt to reveal if the phenomenon is the result of extinction, due to environmental or ecological changes, or possibly that the *Glycymeris* today live in deeper or more distant areas and are swept towards the Israeli coast by currents.

Samples were taken from 13 coastal sites (Fig. 4). Assemblages from different historical periods, at different archaeological layers, from three ancient coastal sites, and 7 samples representing different depths along 13 intersect cross-sections (91 samples) along the shelf were also sampled systematically, taxonomically identified and analyzed statistically.

Fig. 4. Sampling Glycymeris assemblages in one of the study areas (Photo: I. Potasman)

Preliminary results indicate:

1. South of Haifa bay, from Ashkelon to Dor, *Glycymeris* comprise 89% to 100% of the total fossil mollusks, while north of Haifa bay, only 0 to 4.5% (with an exception of 19.5% at Betzet, north of Nahariyya). In Shikmona, located between these two sectors, 71% of the total mollusk assemblages are *Glycymeris*.
2. The proportion of the *Glycymeris* in archaeological layers from the Middle Bronze age to the Byzantine period is similar to that of the present along the coastline. At Ashkelon and Dor the *Glycymeris* are 75-90% of the total mollusk assemblages, while on the present coastline they are 100% of the total.
3. All shells in the southern sector, up to and including Haifa bay, were identified as *Glycymeris insubrica* (the common species) while in the northern sector most are *Glycymeris pilosa*. At Shavei Zion and Nahariyya they are 46-66% of the total, while at Achziv they are 100% of the total.
4. Although, up to Haifa bay the majority of the total species are *Glycymeris*, they are in the minority at the shallow shelf at depths from 3 m up to 30 m.
5. The few live specimens found were all *Glycymeris pilosa*, and no *Glycymeris insubrica*, (the common species that makes up almost 100% of the total assemblages, from Ashqelon to Haifa bay) were found alive.

The results of ^{14}C dating from six samples were incorporated with data previously obtained from 5 samples. The dates obtained in this research are all earlier than 2,300 BP (uncalibrated). In previous research they were revealed to be more than 1,150-1,500 years old. These dates substantiate the theory that the *Glycymeris insubrica* is probably extinct.

This research project is supported by a Recanati research grant of $4,500.

Dorit Sivan

THE UNDERWATER EXCAVATIONS AT CAESAREA MARITIMA 2002

The 2002 Caesarea underwater research field season took place between June 2nd and June 13th. Although there were only 8 underwater working days, work kept to schedule and the majority of the pre-planned tasks were properly completed (Fig. 1).

The expedition, whose base was the 'Old Caesarea Dive Shop', consisted mostly of staff from the Recanati Institute for Maritime Studies, with a total of 16 volunteers offering additional assistance, among whom were students from the University of Haifa (mostly from the Graduate Department of Maritime Civilizations).

The following staff participated in the 2002 excavations: Director — Avner Raban, Recanati Institute for Maritime Studies, University of Haifa (RIMS); Co-director — Eduard G. Reinhardt, McMaster University, Canada; Field Director — Areas CO, K and G — Gregory Votruba, RIMS; Field Director — Areas W1-4, Beverly Goodman, McMaster University; Survey Architect — Christopher Brandon, London, RIMS; Geomorphological studies — Krista Chomicki, McMaster University; Registrar — Karen Shokar, McMaster University; Operations Manager — Stephen Breitstein, RIMS; underwater