GEOMORPHOLOGY OF THE NORTHERN COAST OF ISRAEL

BY ISAAC SCHATTNER

Department of Geography, Hebrew University, Jerusalem

ABSTRACT. The northern part of the Mediterranean coast of Israel exhibits many characteristics indicating recent submergence. Its beaches are mostly covered by allochthon sands, whose transport is not yet fully understood. On some parts of them shingles are present, derived from thinly laminated eolianites and from calcareous root encasements of dune plants. Beachrock is widely distributed and appears to be the product of subaerial consolidation processes. Coastal karst phenomena are everywhere present and solution plays an important part in the morphogeny of all coastal features.

Introduction

The Mediterranean coast of Israel—about 180 km long—represents from the genetical and typological point of view the transition-link from the deltaic coast of East-Egypt and Sinai to the mainly tectonically conditioned coast of Lebanon—Syria. Accordingly, depositional processes and resulting features predominate on the southern main-part of the Israel coast, whereas faulting, subsiding and marine erosion are the principal factors affecting the northern division of the coast.

The small coast-inflection at Jaffa, probably conditioned by an inland tectonic line, here coming to an end with the sea, clearly delineates the border of the two divisions (Amiran, 1950–52). Relatively wide sand-beaches are characteristic of the southern main-division, and only in two places do cliffs border the sea. To the east of the beach-zone there extends a belt of dunes several kilometres wide. In the nothern division the shore is bordered by cliffs, relatively high in the southern portion of this unit and progressively lower farther north. Beaches along the northern main division either do not exist at all, or are very small and narrow, often confined to the insides of the minute indentations and coves characteristic of some portions of this coast. Dune-covered areas are here also very sporadic and small, and limited to cliffless portions of the coast. The Bay of Haifa—the terminus of a tectonic valley—flight that traverses the country from the Jordan Rift Valley to the sea marks not only a break in the course of the coastline but also a change in its characteristics. Here a long and continuous beach reappears, eastwards passing over into an extensive area of dune-sands.

Marine agents

Wave activity along the coast of Israel is comparatively very moderate owing to two main groups of factors: A. The small amplitude of the waves approaching the coast. Winds, whose prevailing directions and with regard to the fetch of the waves dominant direction is from SW and W, very infrequently have a force of more than 6 Beaufort. Only on 45 days in a yearly average is the sea stormy (L. Striem, personal communication). B. Insignificance of the tide-amplitudes. Tide amplitudes amount to 25 cm in the mean (L. Striem, personal communication) and very seldom exceed 50 cm. Differences in height between high and low sea-level seldom exceed 70 cm even when strong landwinds are blowing. Thus, waves higher than 2 m are not frequent off the surf-zone, higher ones occurring almost exclusively during the months December–March. Owing to these conditions the longshore currents are rather feeble and indistinctive. Along the southern main division the direction of the longshore current most of the year is S–N; in the northern division its direction is N–S (Emery-Neev, 1960).

The lithological setting

The sands covering the beaches of the southern and of the adjacent beaches of the northern main division, comprise more than 90 % of quartz grains. They are not supplied from inland by the rivers, which drain an almost entirely calcareous mountain region. The sands of the beaches and dunes are primarily allochthon, transported and supplied almost exclusively by the sea. Their source-area sensu stricto is the Nile and its delta, as evidenced also by the analysis of the heavy minerals in the sands along the coasts of Israel (Neev, Nir, Pomeranc-blum, 1963). The episodically water carrying rivers of the Sinai Peninsula are probably another source area, particularly Wadi el Arish whose catchment area comprises more than half the peninsula. Its competence and capacity to supply coarse sediment is evidenced by the vast extent of gravels and coarse sand covering the sea-floor to a great distance all around its exit into the sea (Rosenan, 1937). The 30 m isobath, whose course along the Sinai–Israel coast fairly coincides with the limit of the sand-covered shelf-part, runs at the Sinai coast at a distance three and more times as great as along the Israel coast. Similar are the relative distances of the 10 m isobath which approximately delineates the sea floor, whose sediments are still subject to lifting by the waves.

The quantity of sands at present carried by the Nile into the sea amounts approximately to 2,500 000 m^3 in the yearly average (Shukri, 1950) and naturally only a small percentage of it is deposited along the coasts of Israel. It seems therefore that the current supply depends mainly on the sands accumulated in the past in the subaqeous delta and on the sea floor adjacent to the Sinai coast.

The agents and modes by which the sand is transported to the coast of Israel are not yet sufficiently understood. The greatest difficulty arises from the presence of quartz sands and the rocks formed by their consolidation along the northern coastal division, where the course of the longshore current—the principal sediment transporting agent—is headed towards the source areas. To explain this contrariety, Emery and Neev (1960) assumed that the longshore current is joined by a marginal part of the general Mediterranean current whose course in the Levantine basin is S–N. This current-fringe carries the sands also along those parts of these coast whose longshore current runs in a direction opposite to the general current. The outermost component of the current, deflected into the Bay of Haifa accounts for the sand-accumulations there and for the availability of sands for transport by the N–S longshore current.

This notion, not so far corroborated by any evidence, appears rather problematic in view of the small velocity of the general current measured far offshore (900 m/h). This velocity must appreciably decrease close to the shore, thus still more reducing the current's ability to carry coarse sediments. It seems more plausible to assume that the transport of sands as far as Haifa Bay and beyond, is effectuated in the not-infrequent periods when, as has been established, the longshore current with the appropriate change of the wind direction changes to a northward course. Another possible factor is the dismembered abrasion platform. Its remnants, submerged and above sealevel are strung out along the coast of the northern division up to a distance of several kilometres from the coastline and are very probably also the cause of strong local currents and other kindred water movements whose direction does not coincide with that of the longshore current in the strict sense of the term. The remnants of the platform are most certainly effective in sand-trapping as may be also inferred from the sand-buried submarine ridges at considerable distance from the coast (Bentor-Emery, 1960). Another minor agent for transporting sand northward with cumulative effect, may be the rip-currents, respectively their feeders, here very strongly developed. The wearing-down of the coastal cliffs and of the abrasion platform, also contributes a not negligible amount of quartz-sands, especially of the coarser sort.

To the N from the Bay of Haifa the composition of the beach material changes completely and rather abruptly. The very few and embryonic beaches here consist of more than 90 % coarse-grained calcareous sands (Neev, Nir and Pomerancblum, 1963), chiefly aggregates of shell-fragments and other organogenic matter. The rivers here, coming from the mountainous area not far from the sea play an important part in sediment supply, made very conspicuous by cobble accumulations at the exits of some rivers.

Quartz grains are also the main constituent of the calcareous sandstone of the cliffs and of the abrasion platform along almost the whole extent of the northern division. It is vernacularly termed here "kurkar" and is characteristic also of the coasts of Egypt, Sinai, Lebanon and Cyprus. It is very variegated in its origin and subsequently in its lithofacies (10 subdivisions according to Issar, 1961) with eolianites making up the bulk of it and of greatest importance as to the morphology of the coast. Kurkar of preponderantly eolian origin consists mainly of consolidated dune sands as outwardly evidenced by its very intensive cross-bedding. The cementing component is $CaCO_3$ and the induration was probably effected by capillary rise of interstice moisture with consequent precipitation of its calcium content. Another possibility is induration by infiltrating rainwater (Picard, 1943) as made probable by hard top-beds of kurkar and particularly by the abundance of calcified root-encasements, dealt with later. The kurkar is very variegated in the ratio of quartz to calcium carbonate, in the degree of induration and in the mode of layering. These seem to be closely connected with the relative age of the three dune ridge-alignments along, but not parallel to the present coast (Nir, 1959). Their material was probably deposited during the successive Pleistocene (post-Sicilian) regression stages. The three alignements are still preserved as such in some southern parts of the division, but the farther north the more complete their destruction by abrasion subsequent to faulting and subsidence. Thus the cliff-face of the southern part of the division is cut into the still preserved westernmost i.e. youngest ridge (Nir, 1959), whose bedrock consequently exhibits the least degree of compactness and homogeneity. Here extremely thin, laminated, intensively crossbedded kurkar (Fig. 1) is to a great extent intercalated with red sandy loam (vernacularly termed hamra) and with layers and lenses of loose sands. In the following part to the N the cliff is established in the median, more easterly ridge. The kurkar here is far more compact and fairly homogeneous in bedrock. The cliff north of the Haifa-Bay is established in the kurkar of the third, easternmost i.e. oldest alignement and accordingly consists of relatively very strongly indurated, homogeneous and prevailingly thick-banked kurkar. There exists naturally a direct relation between the various degrees of compactness of the kurkar and the other rock outcrops along the coast, and its configuration. The more indurated they are, the wider the range and elaboration of the major and minor erosion features. The more poorly consolidated and inhomogeneous the coastal bedrock, the less developed are these features. This is not a result of lesser strength or efficiency of the solution and abrasive processes active here. The forms initiated here by the above mentioned agents do not mature and are not preserved either. They are effaced very soon after their initiation and rather rapid development. Accordingly, the cliffs along these parts of the coast are generally straight, despite or rather because of the rapid and relatively uniform rate of retreat of their fronts. This is in con-

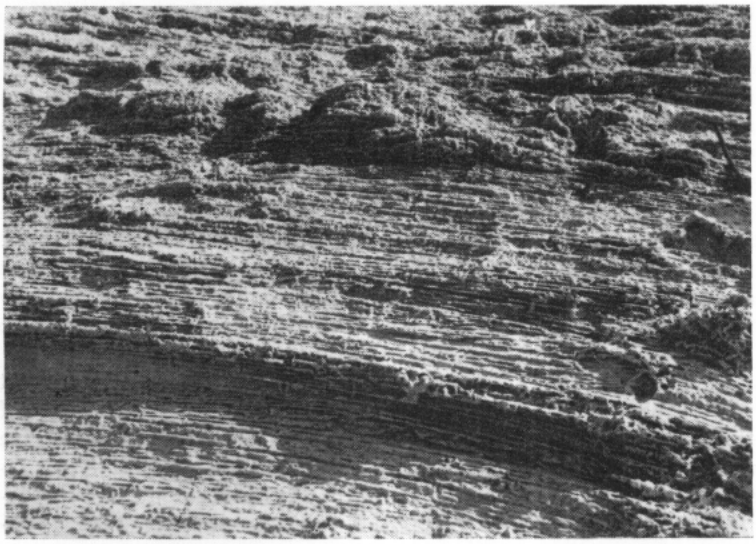

Fig. 1. Crossbedded kurkar, whose lamellae are intensively differentiated according to their resistance, in particular to solution processes.

trast to some cliffs farther north, whose strainghtness is largely conditioned by the very hardness of the kurkar which considerably slows down their regrading while at the same time preserving the configuration once arrived at for a long time.

Characteristic of the kurkar formations are calcified tube—or pipe-like encasements of roots of dune plants—scrubs of considerable size, to judge from the length, thickness and ramification of the encasements (Fig. 2). Their overall length frequently amounts to several metres, their diameter ranging according to their order (main root—capillary root) from 10 cm and more to few milimetres. The fill-in of the tubes varies considerably. Many of them are entirely or partly hollow, others contain fine-grained sand in various degrees of cementation; relatively few of them—still protruding from the cliff-face contain little or no sand and are completely solid with calcium carbonate.

The tubes usually consist of one thick and rather long main stem which cuts through the kurkar laminae almost perpendicularly. It branches off into several secondary stems which ramify in progressively thinner roots. Most of the secondary roots and their appendices are encased between the bedding planes of the kurkar causing them to bulge out and produce considerable local irregularities and discontinuities in the layering pattern. Many tubes are connected with minor irregularly running cracks, evidently syngenetically initiated by them when the sand material consolidated. Outwardly, the tubes, especially when detached from the inframing rock, exhibit a sort of articulation due to the adhering lamellae of the kurkar and thus somewhat resemble portions of a vertebral column or of a throat pipe. From the above mentioned cliff-faces of poorly consolidated kurkar, frequently intercalated with hamra and sands, they protrude markedly, clearly indicating their greater resistance ability to solution and other processes affecting the cliff. Even more conspicuous is their relatively greater durability if fully mineralized, where they appear in the far more consolidated kurkar farther north. Here they particularly affect the shape and the surfaces of disjointed blocks, forming, when single, a sort of horizontal central axis, and when ramified determine the confines of the block, which usually breaks off where the tubes peter out. When hollow, they form minute channels across the surface, greatly influencing the pattern of its pitting and rilling by solution.

Next to kurkar beachrock plays from a morphological point of view the most important role. It crops out rather frequently on the coast of the northern division, notwithstanding the paucity and smallness of its beaches, subject almost everywhere with the exception of the Haifa Bay to overrunning by waves up to the bases of the cliffs. Very characteristic of them are the extreme differences in their composition sometimes at very short distances apart. Beachrock consisting of unbroken shells and coarse sand is the most widely distributed type,

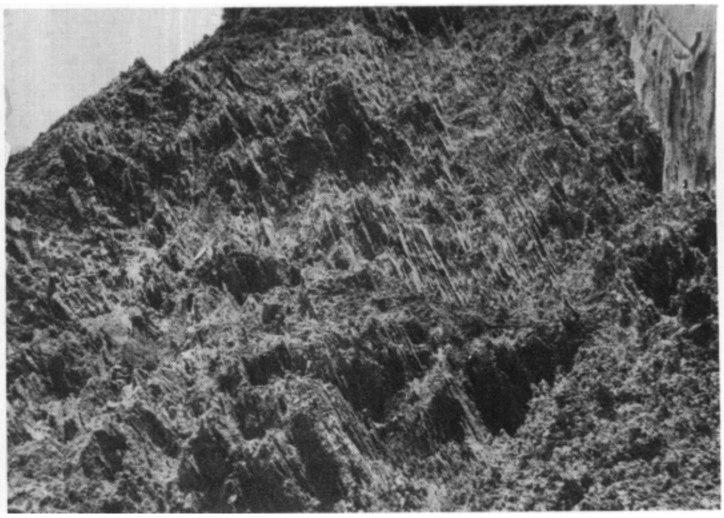

Fig. 2. Cliff-face with root encasements. In the upper right corner the slope is covered by washed-down incrusted hamra.

but nearby at the exit of a river there exists beachrock consisting almost entirely of cobbles with diameters of 10 cm and more—a very conglomerate but consolidated in an environment and by processes specific for the formation of beachrock in the strict sense. Other kinds of beachrock consist mainly of well assorted shell-fragments and coarse sand, or wholly of sand (Fig. 3).

The beachrock, whose thickness averages 40–50 cm, is generally double layered, i.e. consists of two layers of material mostly very different from each other in the kind and size of their respective constituents. On beaches where the supply of shells is abundant at present, the top-layer usually consists of unbroken shells with their convex side upwards, whereas the bottom layer most frequently consists of shell fragments and sand different in size from that of upper layer. The interfaces of the two layers are cemented to one another without any transition in material. The interfaces appear to be relatively smooth. The contact of the interfaces is outwardly made conspicuous by a minute notch along all or most of the periphery of the beachrock slab.

The beach rock along the northern coast-division seems at present to be subject to progressive destruction by the rise of the sealevel relative to land for several centuries at least. There exist few portions of the coast with continuous strips of beachrock; in many places the typically tiered outcrops are to their full width permanently covered by waves and separated from the beach by runnels. Their persistent wearing down is evidenced not only by their jagged general outline but even more by that of the individual slabs separated from each other by continually widening cracks. Further evidence is the great number of giant boulder-like cobbles–remnants of beachrock slabs (Fig. 3). No beach exists (not even in the coves) lined to even half their extent by beachrock, although shells may here entirely cover the sand. There are many indications that anthropogene interference-directly by sand mining indirectly by channelling sewage into the sea greatly promotes the disintegration of beach rock.

Kurkar surfaces at times several metres above M.S.L. and also kurkar blocks broken off from the cliff face and resting on the beaches exhibit shells and small pebbles strongly cemented to the rock. This is particularly frequent with the various-sized cavities in the kurkar surface (Fig. 4). Shells and shingles strongly cemented to the surface and particularly to the cavity-insides were found on kurkar-blocks tumbled down to the beach from the cliff face only a few years ago. All this seems to indicate that the genesis of beach rock and kindred rocks in coastal environment is not necessarily connected with precipitation from subsurface water (Russell, 1963) or seawater in the interstices of beach material (Emery and Cox, 1956). The submerged and periodically

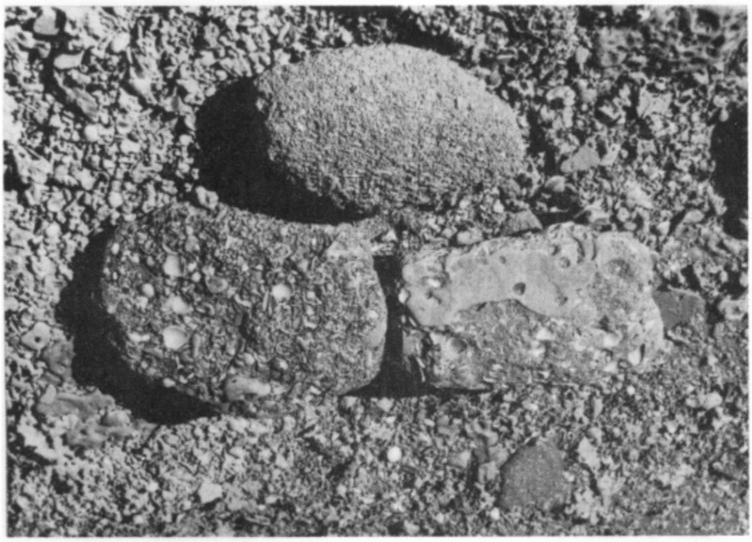

Fig. 3. Three types of beachrock, turned into giant pebbles. A. (to the left): Relatively old, strongly indurated b. r. with partly preserved surface-crust affected by solution. B.: b. r. consisting to about 70 % of shells (Glycymeris) and shell fragments. C: b. r. composed almost entirely of small shell fragments and very coarse sand.

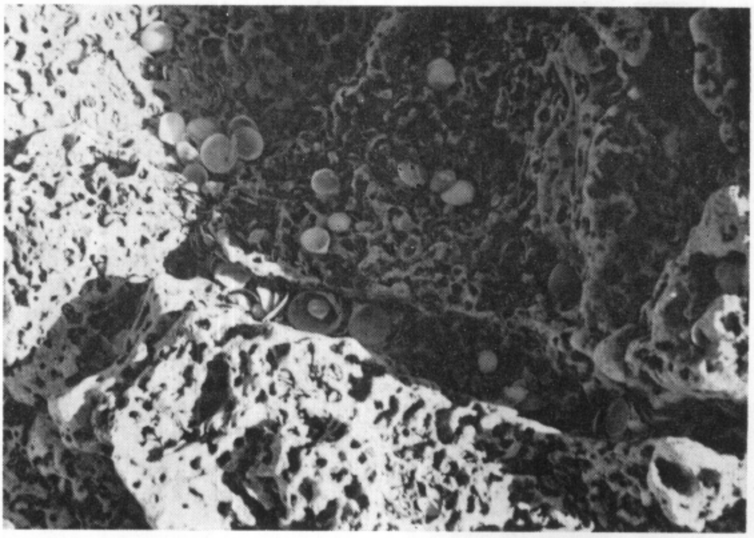

Fig. 4. Kurkar surface, about 5—4 m above MSL pitted by solution. In the solution basin, Glycymeris shells directly and strongly cemented to the rock.

wetted rockfaces near the shoreline are thickly populated with algae and other organisms, which probably play an important part in creating the conditions for intensive chemical precipitation resulting also in formation of beachrock.

The possibility of subaerial diagenesis of beach material is corroborated by the abundant presence of strongly consolidated conglomerates and breccia derived from magmatic and metamorphic rocks besides beachrock consisting mainly of coral fragments at the fully arid coast of Eilath (Red Sea).

As to the palaeogeographical importance of the beachrock, not only its location, composition and relation to the present coast-line are relevant, but also—at least along the northern coast of Israel—the presence of beach-conglomerates at some distance from the present river exits. On the coast near the northern border of Israel, they clearly evidence migration to the N of two river mouths (Baumann, 1965).

The major coastal elements (Fig. 5)

A. The abrasion platform

A very considerable part of the northern division is fringed by an abrasion platform cut into the coastal bedrock. It differentiates into three distinct zones, each of them exhibiting some particular features. The offshore zone consists of small reefs, few of which attain the size of islets. They usually appear in wide-spaced groups, and represent residuals of kurkar ridges that ran in the past farther west than the present coast. The second zone comprises the near-shore reefs, often separated from the shore only by a narrow and shallow extent of water. They often are two–three storied, i.e. above a broader platform at a depth of 5–3 m rises a smaller one, separated from the lower by slopes high and steep towards the sea and less so landwards. Their outline is rather irregular, with numerous angular salients and recesses. At flood-tides and even when winds of moderate force are blowing, this platform is fully submerged. Above it, there rises in the form of short serrated ridges or small buttes the highest reef-part, even more irregular in outline than the lower platform. The notches at their base cut-in very deeply, caving-in is strongly developed with not infrequent blow-holes, and some of these reefs are reduced to stacks (Fig. 6).

The third zone comprises the platform connected with the shore and forms its fore-part. It is continuous for considerable stretches and may attain a width of 30 m and more, particularly at the outsides of the coves and lesser indentations. Its width is influenced by their exposure to prevailing winds. The platforms are broader on the S—and SW side of an indentation than on its N side which is more affected by wave activity. The surface of the platform adjacent to the shore contains many erosive, solution and organogene features. It is

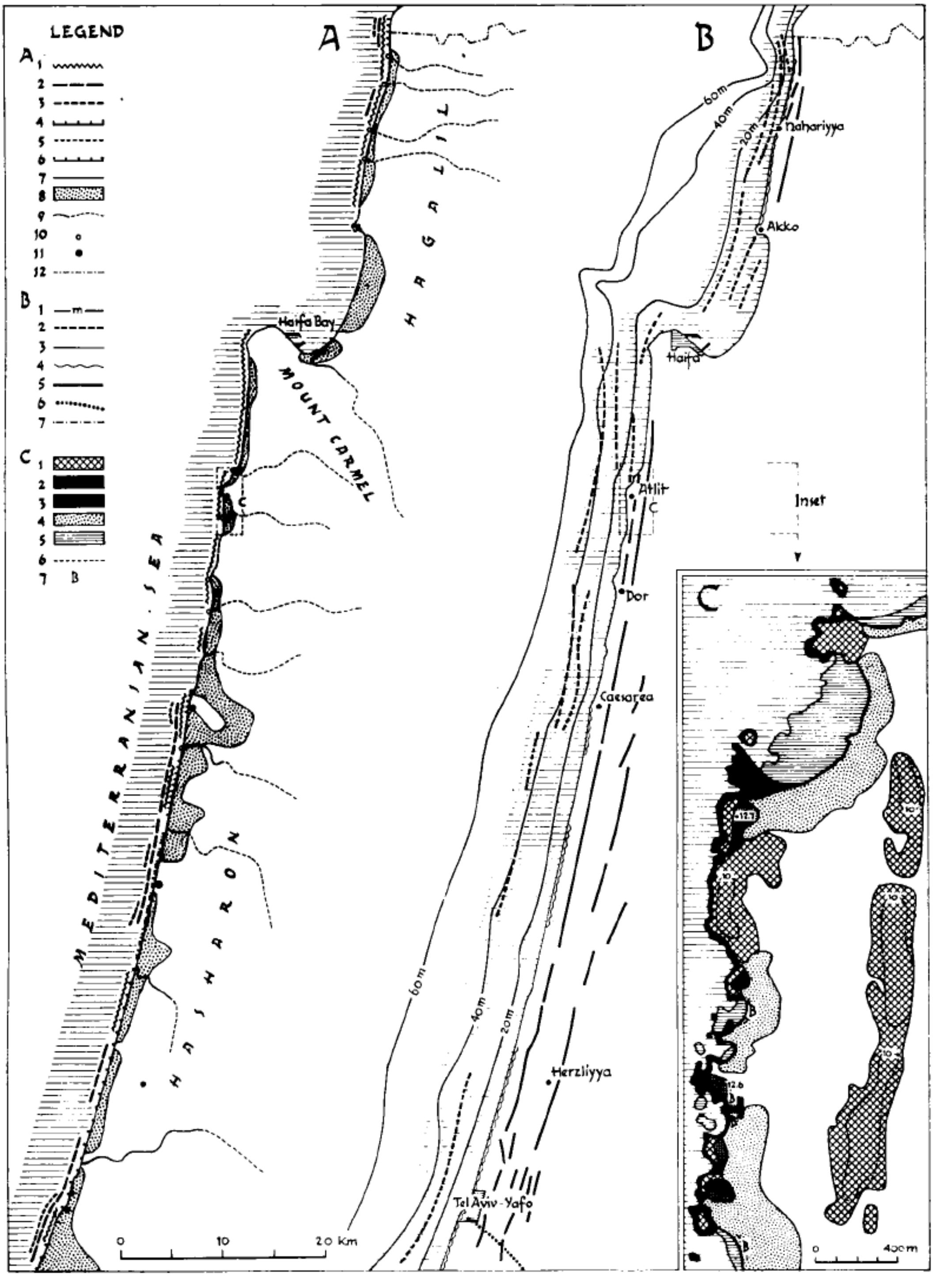

Fig. 5

A.
1. Abrasion platform, adjacent to the shoreline.
2. Reef of the second zone.
3. Outlying reef.
4. Coastal cliff higher than 10 m.
5. Coastal cliff lower than 10 m.
6. Coastal cliff of intercalated material.
7. Beaches.
8. Sand area.
9. River course (mostly carrying water periodically).
10. Pebble deposit.
11. Shingle originating in root encasement.
12. Border between Israel and Lebanon.

B.
1. Isobath.
2. Submerged kurkar ridge.
3. Coastline.
4. Beachrock outcrop.
5. Inland kurkar ridge.
6. Supposed tectonic line.
7. Border between Israel and Lebanon.

C.
1. Kurkar ridge.
2. Abrasion platform adjacent to the shoreline.
3. Abrasion platform covered by sand.
4. Sand area.
5. Sand-covered floor of the Athlit-cove.
6. Height contour line.
7. Beachrock outcrop.

Based on Atlas of Israel (sheet VI/2), Emery-Neev (1960), Emery-Bentor (1960), Almog (1965), Rosenau (1937), aerial photographs and field observations. The inset: Z. Ron (1962; with minor additions). Drawing: N. Z. Baer, Department of Geography, Hebrew University, Jerusalem.

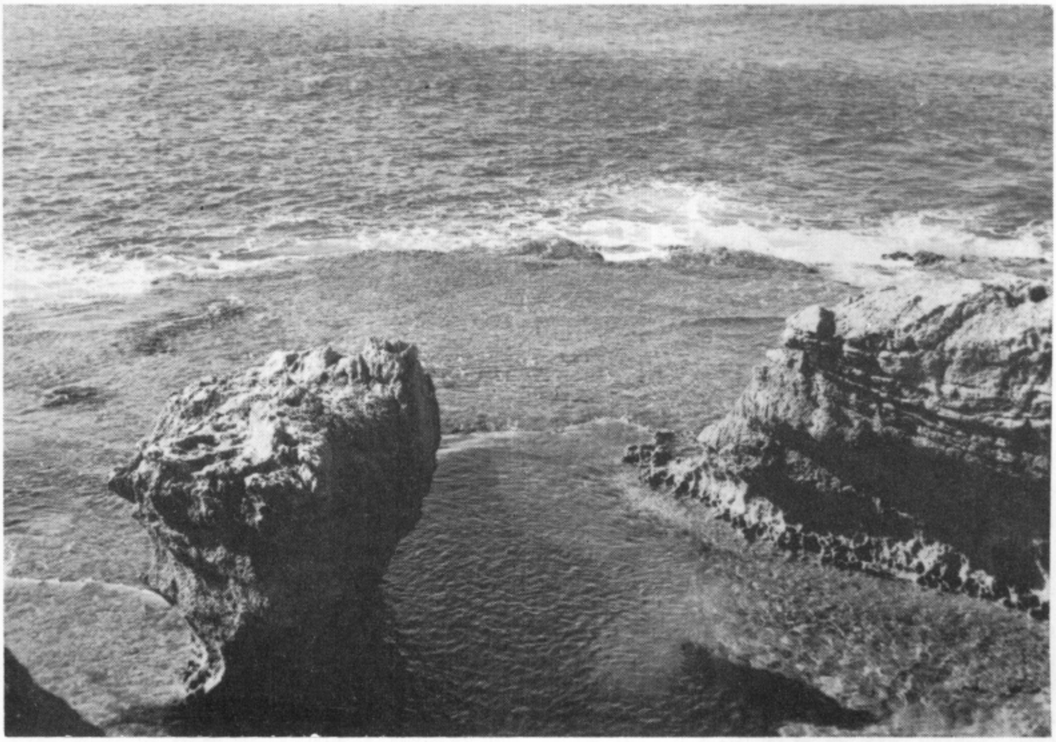

Fig. 6. Portion of the abrasion platform (2nd zone) with a part of the upper storey reduced to a stack.

pitted by many potholes which exhibit distinct linear patterning both parallel to the coast and approximately at right angles to it, indicating the influence of reticulation of cracks and particularly of their intersections. Many potholes originated from small solution basins which abound in the higher parts of the platform. Rilling due partly to solution, partly to corrosion, and producing lapies-like ridgelets, appears particularly on platform surfaces which cut the bedding planes of the kurkar layers at a relatively acute angle. The platform usually contains several surface levels separated by minute scarps. Where the platform is wider there appear at the top-edge of these scarplets minute dam-like structures consisting of fossilized organic matter (algae, Vermetus and other molluscs). From these top-edges, secondary structures branch off, usually at almost right angles, resulting in a division of the pertinent level into a number of small flat-floored basins covered mainly with algae and framed-in by the elevated rims (Safra, 1962).

B. Beaches

There are many indications that in the northern division beaches were wider, even in the near past, than at present. Characteristically, they chiefly exist on portions of this coast where tiered strips of exposed beachrock form a kind of barrier against wave onrush.

The beaches up to the N-end of the Haifa Bay are covered by quartz sands whose grain size generally diminishes the farther N. Another cover material, very irregularly distributed is formed by shells, deposited on the beach-face in larger quantities. Where they are sparser and the beach widens and slopes very gently they tend to originate very poorly-defined and short-lived cusps. Where berms develop they frequently form their top-layer.

In the southern part of the division, where the cliff is built of laminated kurkar often interbedded with hamra, the shore—here no more than 20–10 m wide—is covered in various degrees of density and thickness by shingles.

Fig. 7. Tabloid shingle with characteristic perforations not yet affected by wave action.

The bulk of them are very thin, tabloid fragments of kurkar laminæ. Most of them are rectangular, not having been worked on sufficiently by the breakers. Their length may attain 20 cm, their width 15 cm. Almost all of them exhibit one or more perforations as a result of alveolation by solution or of root growth (Fig. 7). When reworked by the surf their shape becomes perfectly elliptical, their size decreases very rapidly and they very soon are reduced to sand.

Where the cliff contains root-encasements, fragments of tubes appear, intermingled with the former kind of shingles and extremely variegated in shape. Many of them are still trunklike and somewhat curved, with sides still articulated by their having been embedded in the laminated kurkar. In most of them—particularly when recently broken out of the cliff face—the fill-in is still preserved and so are the secondary, inner pipes. Under the impact of the waves they break up at the minute grooves ringing them into segments progressively shorter; their sides become smoother and the

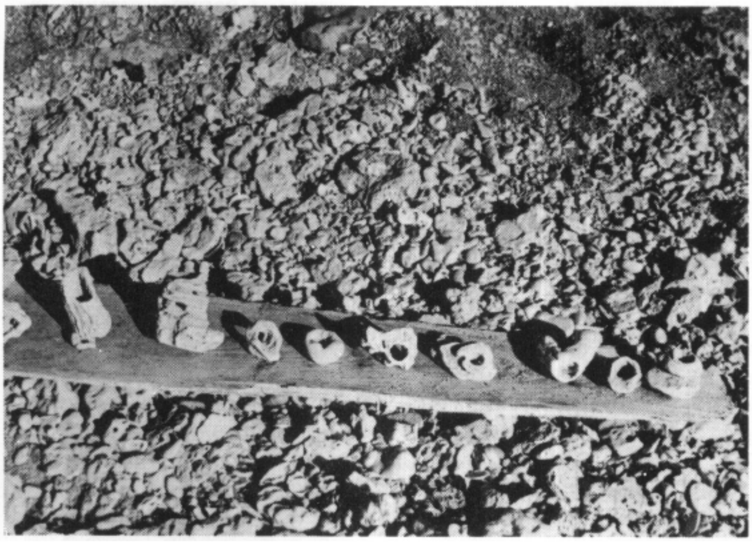

Fig. 8. Shingle, originating from calcified root encasements. On the board some typical forms of tube fragments in various degrees of disintegration and smoothness.

fill-in, if composed of indurated sand, disappears. The resulting shingles still exhibit two of more edges but their hollow interior is almost perfectly annular in shape. Where the fill-in has been thoroughly calcified the breaking up is much slower and imperfect. The end products are solid, smooth, elongated pebbles usually thicker at one end than at the other. There exists a great variety of in-between shapes according to the parent tube. Shingles formed from tube parts where branching off took place are knoblike in appearance; where only partly calcified, they will have a filigree appearance, etc. (Fig. 8).

The shingles originating both from kurkar and from encasements build up steeply sloped berms, and besides naturally functioning as a very efficient erosion tool for the waves impinging upon the cliff-faces, conversely form a sort of temporary protection against their impact. Thrown up against the base of the cliff they pile up there in such quantities as to form a kind of ramp which greatly diminishes the energy of the onrushing breakers and particularly deprives them of the possibility of acting upon the base notch, filled as it is with densely and strongly compacted shingles. There exists a sort of zoning in the relative location of the shingles, mainly conditioned by their respective shapes: The discoid kurkar shingles, more easily carried by the waves, are usually piled up at the base of the cliffs, whereas the spheroidal ones rest near the sea.

C. Cliffs

The cliffs in the northern coast division differ greatly not only in height but also, as has been shown, in bedrock and in distance from the sea. As to the latter one fact is crucial: Whether bordering the sea, or separated from it by beach, they are both subject to the direct impact of the waves. Where the cliffs are relatively high as in the portion established in the westernmost kurkar-ridge, they are worn-back at a rather rapid rate mainly by abrasive activity of the waves on their bases. Where the cliffs are lower, the efficiency of abrasion is smaller because of the generally harder rock composing the cliff, but the influence of the sea extends farther inland affecting the cliff zone from above by very intensive solution processes; these are caused not only by spray but also by humid salt-air. The decisive influence of the cliff-rock is particularly conspicuous at the portion of the coast where the cliff exhibits greatest variety in material composition and structure, as in the southern part of the Sharon-coast where intercalations of kurkar, hamra and sand are frequent and the kurkar is greatly variegated in compactness, thickness of layers and direction of dipping. Where the kurkar preponderates, the cliffs generally attain greater heights and their slope tends to be steep all the way from the base to the top. Where hamra forms the bulk of the cliff material, especially near the base, only this part will exhibit an almost perpendicular slope up to the height subject to the impact of spray; whereas the upper part will slope away at a steep angle if composed of kurkar, its slope will be moderate if hamra is present. Characteristically the highest and steepest slopes appear here when the cliff is topped by massive strongly indurated kurkar, which even forms an out-jutting cornice. The top-bed is very intensively crevassed and the disjointed blocks frequently break away and fall upon the beach, exposing the slope beneath to rainwash and rilling with consequent rapid backwearing.

The influences of difference in rock material is also reflected in the way this type of cliff is receding. Only where kurkar crops out at the base of the cliff, will notches be formed. They never however attain much depth and are produced not so much by the mechanical impact of the waves as by solution in consequence of the almost daily recurring wetting. This is evidenced by the surfaces of the notch which are pockmarked by innumerable minute alveoli alternating with thin long, sometimes intensively intertwined protrusions partly consisting of calcareous matter, which are very breakable and even somewhat friable. The efficiency of solution as the cliff-affecting agent is also conspicuous in the very great number of cavities from minute holes to cavities of taffoni type. The latter particularly abound in the uppermost thick and strongly indurated kurkar-bed. Solution is also the chief cause of the notches developed along the contacts of hamra and kurkar particularly below the top-bed. The alveoli and other cavities tend to develop connecting cracks thus still further diminishing the stability of the cliff-face.

Prime causes of the coast configuration

It is almost generally assumed that tectonics played an important part in determining the course and basic character of the northern coast division. Some geologists recently arrived even to the conclusion that they were active up to the present (Neev, Nir, Pomerancblum, 1963) and that a faultline running along the boundary between the cliffzone and the sea primarily determines the coast configuration. More conservative views attribute the typical characteristics of this coast mainly to the Flandrian transgression (Avnimelech, 1960) and to the recent eustatic rise of sea level. Subsidence in connection with isostatic adjustments of the depositional area of the Nile affecting also neighbouring regions must also be taken into consideration (Emery, Bentor, 1960) and so isostatic compensation to the movements which resulted in considerable uplift of the Lebanese-Syrian coastal regions evidenced there by several marine terraces, and possibly also affected a very small portion of the coast adjacent to the Lebanese border (Baumann, 1965).

References

Almog, Z., 1965: The morphology of the Atlith-coast. (unpubl. MS., Hebrew). *Dept. Geogr. Hebr. Univ. Jerusalem.*

Amiran, D. H. K., 1950—52, A revised earthquake catalogue of Palestine: *Israel Expl. Jour.*, 1:223—246; 2:48—61.

Avnimelech, M., 1960, The latest history of the Mediterranean coast of Israel: *Rapp. Proc.-verb. Comm. Inter. Explor. Sci. Mer. Mediterr.* 15:331—340.

Baumann, D., 1965: Coastal morphology Rosh Haniqra-Akziv. (unpubl. MS. Hebrew). *Dept. Geogr. Hebr. Univ. Jerusalem.*

Emery, K. O., and Cox, D. C., 1956: Beachrock in the Hawaiian Islands. *Pacif. Sci.*, 10: 382—402.

Emery, K.O. and Bentor, Y. K., 1960: The continental shelf of Israel. *Bull. Geol. Surv. Israel*, 26: 28—40.

Emery, K. O. and Neev, D., 1960: Mediterranean beaches of Israel. *Bull. Geol. Surv. Israel*, 26: 1—13.

Issar, A., 1961: Geology of the subterranean water horizons of the Shephela and of the Sharon regions. (Ph. D. thesis, mimeogr. Hebrew). *Geol. Dept. Hebr. Univ. Jerusalem.*

Neev, D., Nir, J., and Pomerancblum, M., 1963: The problems involved in sand-mining on the Mediterranean coast of Israel. (mimeogr. Hebrew). *Develop. Ministry-Geol. Inst. Jerusalem.*

Nir, D., 1959: Étude sur la morphologie littorale d'Israel. *Ann. Géogr.* 68: 424—436.

Picard, L., 1943: Structure and evolution of Palestine with comparative notes on neighbouring countries. Jerusalem.

Ron, Z., 1962: The morphographic configuration of the southern Carmel coast. (Hebrew). *Studies in Geogr. of Eretz Israel*, 26: 31—40.

Rosenan, N., 1937: Fishermen's chart 1: 100 000, in four sheets. *Govt. of Palestine Dept. Agric. and Fisheries.*

Russell, R. J., 1963: Beach rock. *Jour. Trop. Geogr.* 17: 24—27.

Safra, D., 1962: The abrasion platform and the cliff of the southern Carmel-coast. (Hebrew). *Studies in Geogr. of Eretz Israel*, 26: 15—30.

Shukri, N. M., 1950: The mineralogy of some Nile sediments. *Quart. J. Geol. Soc.* London, 105: 511—534.