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PIOTR RONIEWICZ

The Tasman Sea coastal-zone sedimentary model, N.S.W., Australia

ABSTRACT: Bottom forms and sedimentary structures investigated through direct scuba diver observations, and an examination of bedding, grain-size distribution and trace fossils in the undisturbed-structure samples taken at Kioloa Bay and several smaller bays along the Tasman Sea coast, allowed to recognize the sedimentary model resulting from the actually prevailing hydrodynamic conditions and depths characteristic for high-energy clastic and tidal coastal zone of the Australian seashores. Moreover, an estuary model has been distinguished at Batemans Bay. The distinguished models were compared with those of the tideless coastal zones of the southern Baltic in Poland, and of the Black Sea in Bulgaria (Kamchiya region). All the discussed models are regarded as an interpretation key for many clastic sequences of the ancient sedimentary environments.

INTRODUCTION

Sedimentological research in the coastal zone of the Tasman Sea was undertaken by the Author during the expedition organized by the Polish Society of the Earth Science Fellows, Warsaw Branch, in collaboration with the Australian National University (A.N.U.), Canberra, over a time from January till April, 1981. The research team included geologists: D. Karp, M. Sc., Dr. H. Bieniaszewska, Dr J. Grodzicki acting as diver, A. Wygralak, M. Sc., Dr. J. Bednarek; and Mr J. Witkowski, as diver, Z. Rajewski, M. Sc. as diver, Mr B. Wojcieszonek — technitian. Mr K. Woźniak as physician.

The Edith and Joy London Foundation of the Australian National University served for the research team as a base, field camp and laboratory. The coastal zone of Australia with its well diversified hydrodynamic conditions offers an excellent opportunity for research of the sedimentary processes. From publications and personal information from Australian colleagues it became evident that in the previous research of the Austrialian clastic coastal zone the stress had primarily been laid on relations between hydrodynamics and the development of beaches and onshore sediments (Short 1978, 1979; Chappell & Elliot 1979; Chappell & Wright 1978; Wright, Tom & Chappell 1978). In a much smaller degree, the research was aimed to investigate the sedimentary structures (bottom forms and beddings) by involvement of the scuba divers and examination of the undistrubed-structure samples.

While having a certain amount ef experience from the research into coastal environments of the southern Baltic, Poland, and of the Black Sea, Bulgaria, a research team of the Institute of Geology, headed by the Author, proposed a very similar programme of investigations for the shoreline of the Tasman Sea. The purpose of research was to determine types of the sedimentary structures and character of the deposits as a key model for the interpretation of many ancient sedimentary environments. In publications concerned with the subject *(cf.* Reineck & Singh 1975) any coastalzone model acceptable for the Australian Pacific (New South Wales) shores has never been distinguished.

Acknowledgements. Both the Author and all members of the sedimentological research team wish to thank the Polish Society of the Earth Science Fellows for having enabled them to organize the Expedition „Australia 80". To the staff of the Australian National University, Canbera, and to the Management Committee of The Edith and Joy Foundation of the Australian National University, thanks are extended for lodgings and laboratory accommodation at Kioloa. A special gratitude is owed to Miss J. London, Dr. R. E. Barwick and to Mr M. Young for their kindness and help in various technical problems during the research time at Kioloa.

Dr. J. Chappell was kind enough to furnish some details on the geological structure, hydrodynamic conditions in the research area, numerous practical hints and personal help in tying up first contacts with the A.N.U. and the Sydney University. Professor J.N. Jennings is especially acknowledged for getting in touch with the Australian researchers, and for his interest in the progress of the field research.

Thanks are also extended to John and Agnes Wesołowski of Sydney, to. J. Krzyżanowski of Melbourne, and to Dr. S. Skwarko of Canberra (now Perth) for the life and research facilities, for advice and assistance, whenever necessary.

The Author wishes also to express his gratitude to K. Zakrzewska, M. Sc., and to Miss I. Tuszyńska, for making grain-size analyses; B. Drozd, M. Sc., for making photographs of the samples, and to Mr. W. Roszczynko and M. Nawrocka, M. Sc., for graphical contributions.

Many thanks deserve also colleagues from the Institute of Geology, University of Warsaw, for their discussions, and Professor A. Radwański for his comments on the first draft of the typescript.

METHODOLOGY OF FIELD RESEARCH

Underwater research was conducted by scuba divers down to a depth of 30 m at Kioloa and a depth of 15 m in the Merry Beach area. The research programme included measurements of the bottom forms; drawings and photographs of the sea bottom; as well as undisturbed-structure and loose-structure sampling of some selected bottom forms and/or their parts. The undisturbed-structure samples (25 cm deep, 15 cm wide, 8 cm thick) were taken with the Reineck-type box sampler constructed at the Institute of Geology, University of Warsaw. The collected samples were cemented with the epoxide resin. With taken off peels, the rest of the sediment was left for grain-size analysis, and divided into portions varying in their type of bedding and in other features as noted

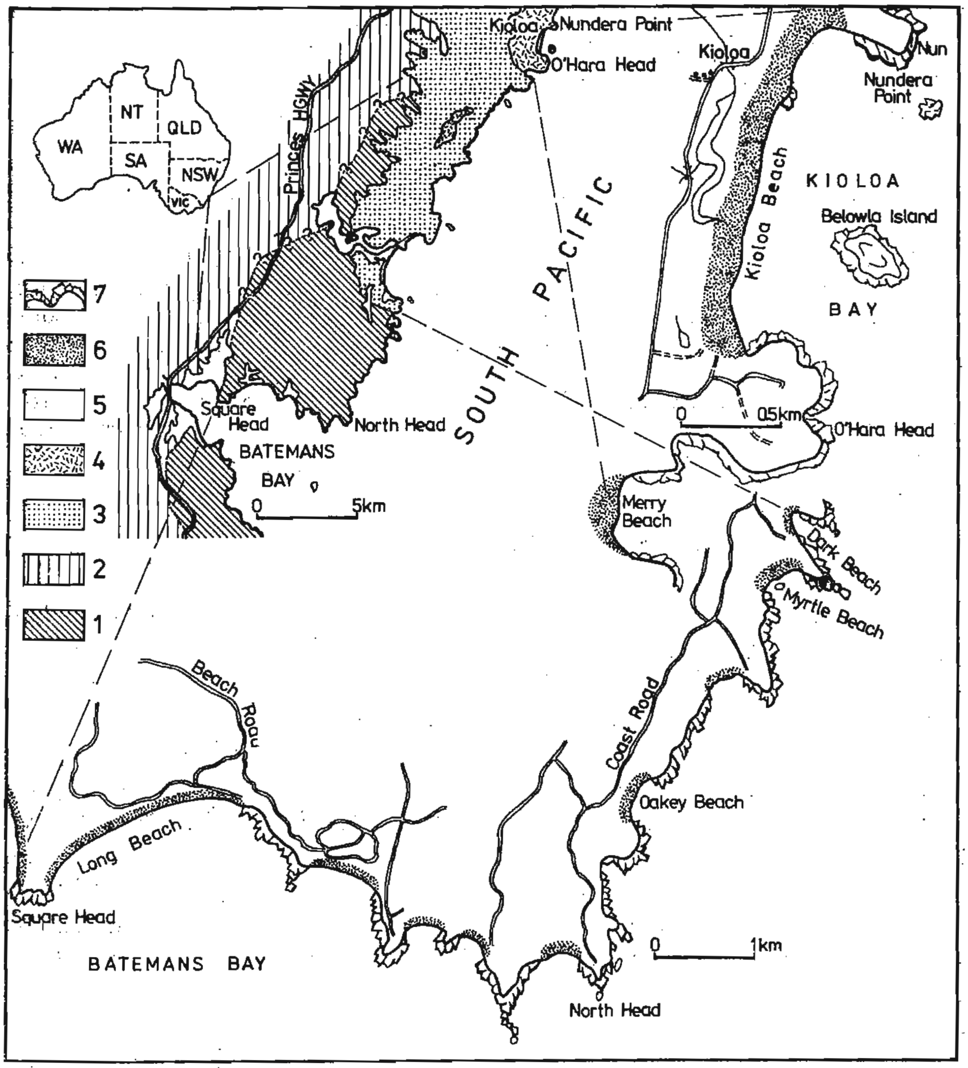


Fig. 1. Sketch-maps showing geology of the investigated area in Australia (*after*: map 1:250 000, sheet S1 56 13 Ulladulla, N.S.W.; *simplified*) and configuration of the shoreline

1 — chert, conglomerate, slate, sandstone, phyllite; Wagoonga Beds, ?Cambrian; 2 — siltstone, claystone, sandstone, quartzite, chert, ?Ordovician; 3 — conglomerate, sandstone, silty sandstone; Conjola Formation, Shoalhaven Group, Permian; 4 — Mesozoic essexite; 5 — Holocene alluvial sand; 6 — beach; 7 — rocky cliff

on the surface. Research was carried o ut from an three-meter dinghy fitted out with 25HP engine, crew of which received samples and observation data from the scuba divers. The divers made drawings and notes on plastic plates, under water. Location of the observation plots and sampling sites proceeded from the shore, by means of two geodetic instruments located on the concrete A.N.U. bench-marks in the coastal dune.

A similar research was carried out at Kioloa Beach, Myrtle Beach, Dark Beach, Oaky Beach, and Long Beach in the Batemans Bay (Text-fig. 1).

GENERAL PHYSIOGRAPHY OF THE STUDIED AREA

The area under study has a warm and relatively arid climate. Apart from all the rainy seasons there is practically no flow in the numerous creek ravines and beds of seasonal rivers, which normally carry their waters to the near-shore lakes and small lagoons. Under such circumstances there is no permanent supply of the material from the mainland into the coastal zone. An exception to this is the Clyde River flowing right into Batemans Bay. Morphologically, the coastal region resembles, in its character, block mountains and this is especially true with regard to Permian rocks in this area.

GEOLOGY

The area adjacent to the coastal zone under investigation has a relatively simple but varied geological background (Text-fig. 1). In its northern part, in the direct vicinity of Kioloa, there are exposed clastic Permian rocks of the Shoalhaven Group consisting of lithologically diversified formations. The Clyde Formation, the oldest among them, carries coal. These Permian formations, belonging to the southern part of the Sydney Basin, are predominantly of marine and glacio-marine origin, and they include marine fossils — occurring *i.a.* at Snapper Point (Text-fig 1) — as well as the shallow water trace fossils (Cavey 1978). The Permian layers, almost horizontal, overlie discordantly the lithologicaly diversified, heavily folded and faulted Old Palaeozoic strata. The whole of Palaeozoic complex is cut by dikes of the Mesozoic essexite, more seldom basalt, of which the Belowla Island, O'Hara Head and the small promontories of Kioloa Beach are built. Underwater exploration proved their presence right on the see bottom or under a thin clay and sand cover (Pl. 23) in the southern part of Kioloa Bay. The youngest formations include the Holocene sand dunes, aged no more than a few thousand years BP (J. Chappell, *personal information*).

Geology of the region, primarily the lithology, contributes to the far-advanced diversification of the shoreline. It consists of major bays as *e.g.* Kioloa and Durras and some smaller ones separated by rocky peninsulas and promontories built of the Permian rocks and Mesozoic essexite, in the northern part of the area, and of the Old Palaeozoic rocks in the southern part. Numerous faults in the Permian formations when combined with the Older Palaeozoic tectonics still add to the shoreline dismembering and this not without consequences for the present-day sedimentary conditions in the coastal zone.

Beaches develop exclusively within bays. Sea bottom in their vicinity is almost plain apart from some changing sedimentary bottom forms, whereas its inclination is uniform, as in the case of Kioloa Bay and Merry Beach. Rocky parts of the shoreline and the nearby sea bottom appear to be more varied in their surface and depth. If there is a deposit, it will be very thin and composed of shell detritus and other organic remnants. The character of the shoreline and wave climate is controlled by islands and rocklets which affect the sedimentary environment.

Beaches and shore-zone deposits are composed of quartz sands with an admixture of shell detritus, in some places as high as thirty per cent. There are but a few beaches, as for instance Dark Beach, which are built of the well-rounded pebbles and gravels of Old Palaeozoic rocks abraded from the nearby cliff. Flat pebbles, often oriented, of black cherts and quartzites from the Wagoonga Formation (?Cambrian) are the most important element (Pls 39-41).

At a depth of 25 m at Kioloa Bay known are the coarse-grained Pleistocene sands thought to have originated when the shoreline of the Pacific was more than a hundred meters below the present-day sea level (J. Chappell, *personal information*). No such deposits could have however been recognized during the exploration in spring of 1981.

HYDRODYNAMIC REGIME AND WAVE CLIMATE

Because of the lack of suitable instrumentation no routine continuous recording of both waving und currents was possible during the sedimentological research.

Wave climate data are systematically recorded some 220 km north of Kioloa (wave rider buoy and telemetry recorder), to be next distributed throughout the entire central part of the N.S.W. coast. There are, moreover, observations carried out sporadically at Kioloa by research students and the staff at the A.N.U. Both those data, received from Mr J. Chappell, when taken together inform that an average height of the wave is likely to be about two metres with 10s period; that storm waves ranging from 8 to 10 m in height occur during about 1% of the time; that the dominant direction of wave propagation is from SE, occurring 60% of the time; that in summer, coastal thermal sea breeze blowing at about 10m/s is common from 11 a.m. till nightfall, causing choppy inshore seas up to 1 m in height with a period of about 7 s. These sea breeze choppy waves superimpose on the regional waves, near the shore, and are predominantly easternly to north--easternly. Average wave base is about 25 m, on unprotected coasts. At Kioloa

Bay, the southern protected beach experiences low waves, usually less than 1 m, and often less than 0.5 m, while the central and northern beaches get waves about 60% to 80% of the heights that occur on the completely exposed N.S.W. beaches.

There were no heavy storms during the time of exploration. Winds used to blow from south-east and so was also the usual direction of the regional wave propagation. In the first decade of February sea breeze was observed to keep on intensifying, likewise on the 16th, 17th, and 27th of February, in the time from 9th to 12th March, and also for a few days in the beginning of April, all the time blowing from the E and NE directions.

Tides during the time of exploration, according to the 1980/1981 commercial tide chart, were within the range of 1.5 m maximum and resulted in a change of the water line up to sixty, seventy metres or so, depending on the actual inclination of the sea bottom and beach, and on the width of the latter. That is why no tidal flats so characteristic, say, for the Dutch and German coast of the Northern Sea do exist in the region under investigation.

BOTTOM FORMS AND BEDDING IN THE KIOLOA BAY DEPOSITS

As shown by underwater observations, sediment down to a depth of 30 m at Kioloa Bay is almost continuously subjected to the action of wind-generated, regional and also local waving at smaller depths, and in the onshore areas also to currents generated by waving, the rip currents in particular. This causes the sediment to move and to give rise to several bottom forms, such as sand ridges, megaripples, ripples and other forms arranged into several bottom patterns (*see* Text-fig. 3 and Pls 1—48). Thus, the bottom patterns and the bedding recorded and seen in peels are a sort of natural record of water movements on the deposit, likely to be found on the surface of layers (bottom forms) and their cross-sections (bedding) in the clastic sedimentary sequences of ancient epochs as well.

This natural record as found in a sample fails to be complete for it takes place only during deposition. Any breaks in the deposition and erosion of the former sediment, seen in the sections as non depositional boundaries, embrace time spans of unknown duration. Both the bottom forms and the bedding depend on the wave climate, depth, and on the character of sediment. With the fairly uniform type of sediment in the area under investigation, and with the movement of water resulting from wind-generated waving, both the bottom forms and the beddings may be assumed as primarily dependent on changes in the intensity and in the directions of waving, and on the depth.

Relationship between bedding as seen in the samples and forms as observed at the sea bottom is evident for the uppermost part of the sample (Pl. 18), especially when the bedding remains identical throughout the entire sample, or undergoes a gradual change only. Erosional boundary in a sample denotes that the underlying bedding has been linked with another type of bottom pattern than observed during the sampling

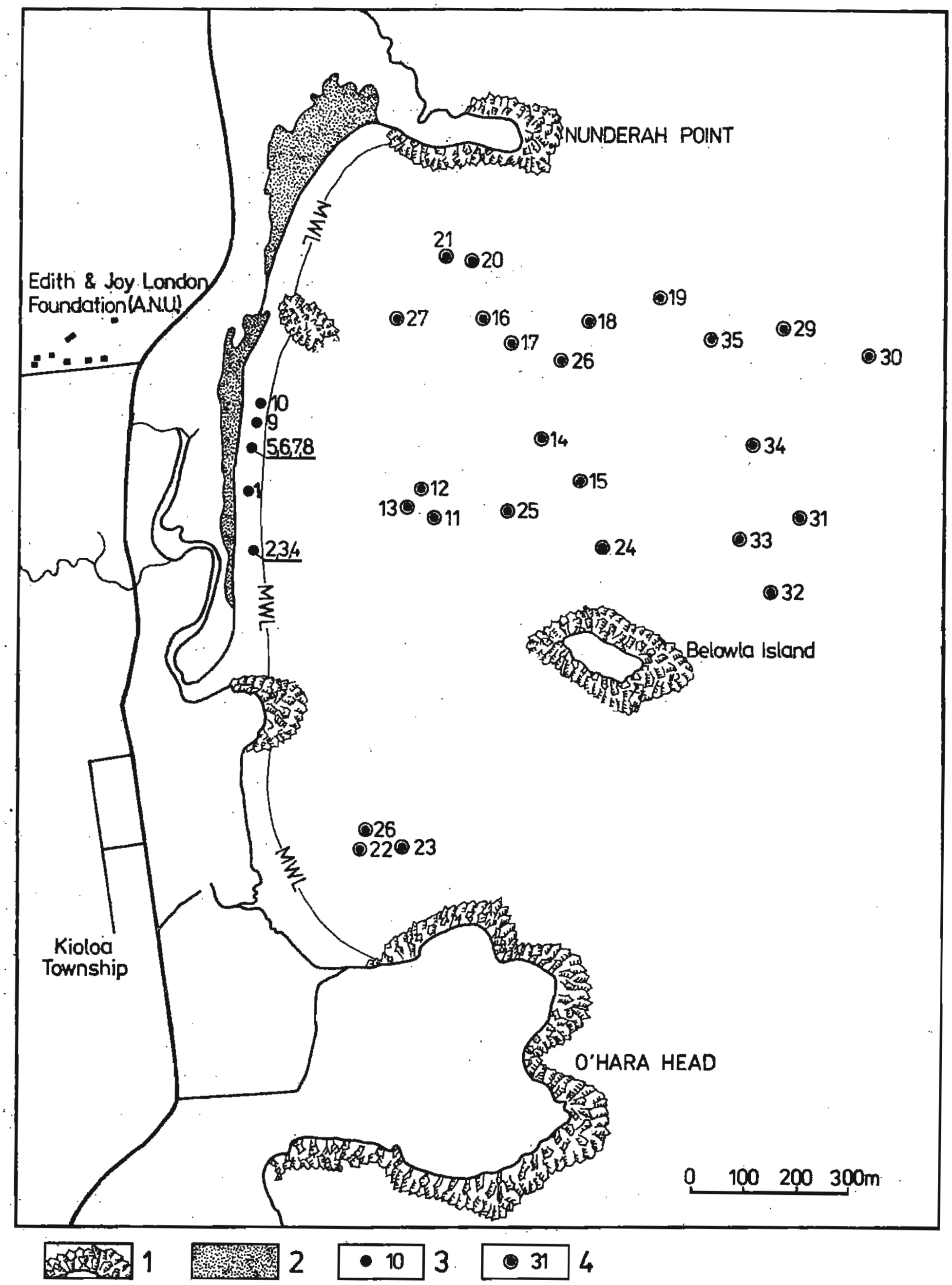


Fig. 2. Location of the illustrated samples (Pls 1—35) in the Kioloa Bay

1 — essexite; 2 — dune; 3 — samples with undisturbed structure, taken from the beach; 4 — underwater samples with undisturbed structure

procedure. Its type can, with a certain approximation, be assesed from the relation between the type of bedding and the bottom forms recognized in other samples and known from the reference data concerning the relationship between hydrodynamics, sediment, bottom forms and bedding, both under natural as well as experimental conditions.

Analysis of more than fifty bottom patterns and samples with undisturbed structure from Kioloa Bay (see Text-Fig. 2) leads to the following more general conclusions. In the sea bottom, outside the shallowest zone not exceeding four metres in depth, there are generally several megaripples and ripples varying in their form, size, continuity, symmetry of crests, and the crest-to-crest spacings. In the course of underwater observations, which for technical reasons were conducted under weak and moderate waving conditions, the sediment in the sea bottom was changing its place due to waving, accompanied by the formation of the youngest-generation ripples conforming to the wave propagation at the given moment and place. This youngest ripple pattern was featured by smaller size and an unstable changing symmetry of crests, the form and orienta-

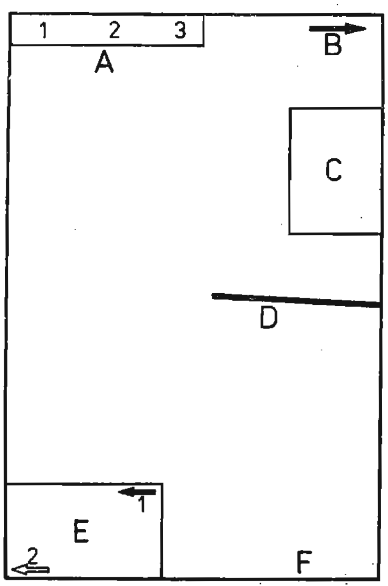


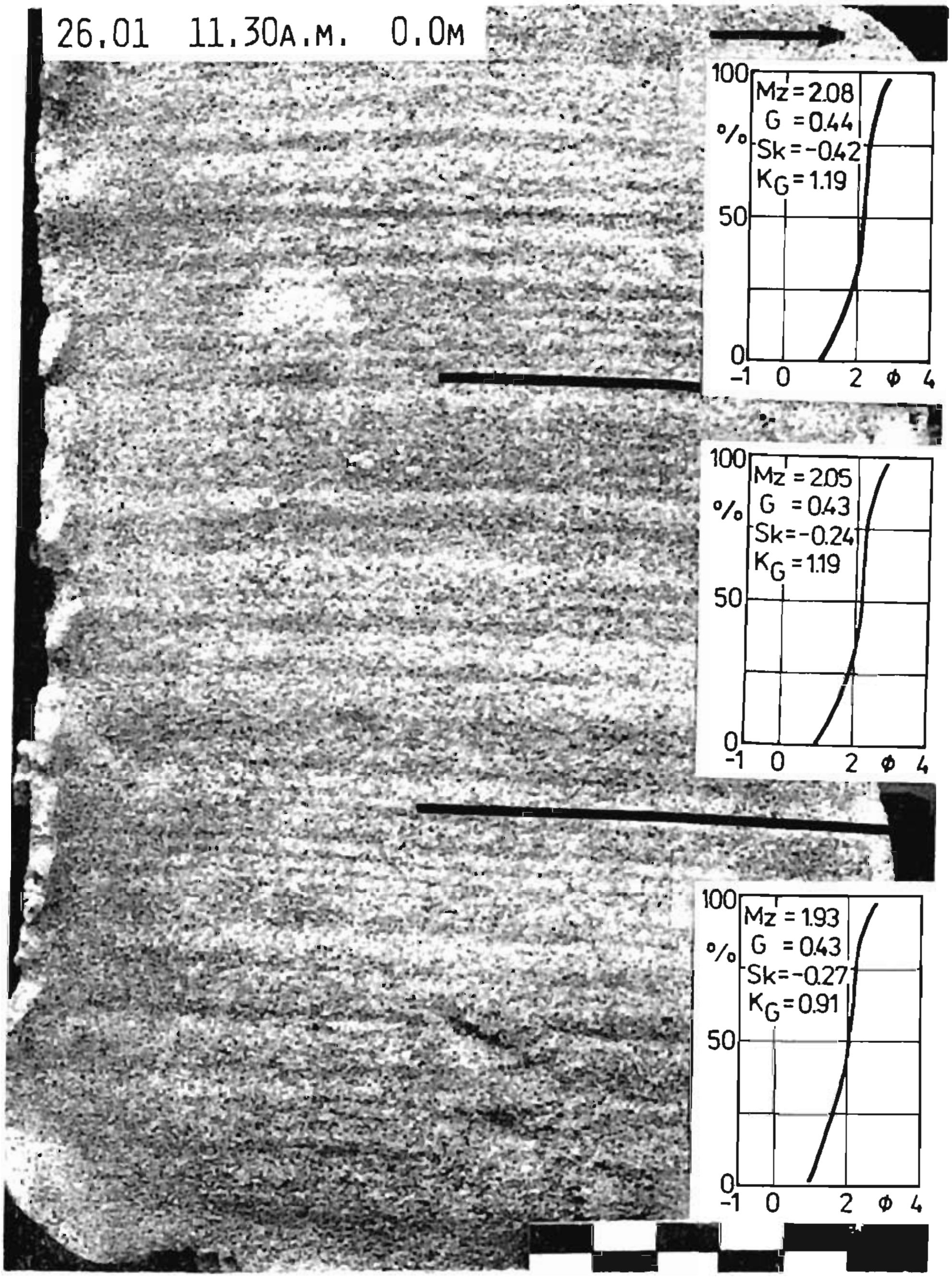
Fig. 3

Scheme of informations given in Plates 1—48

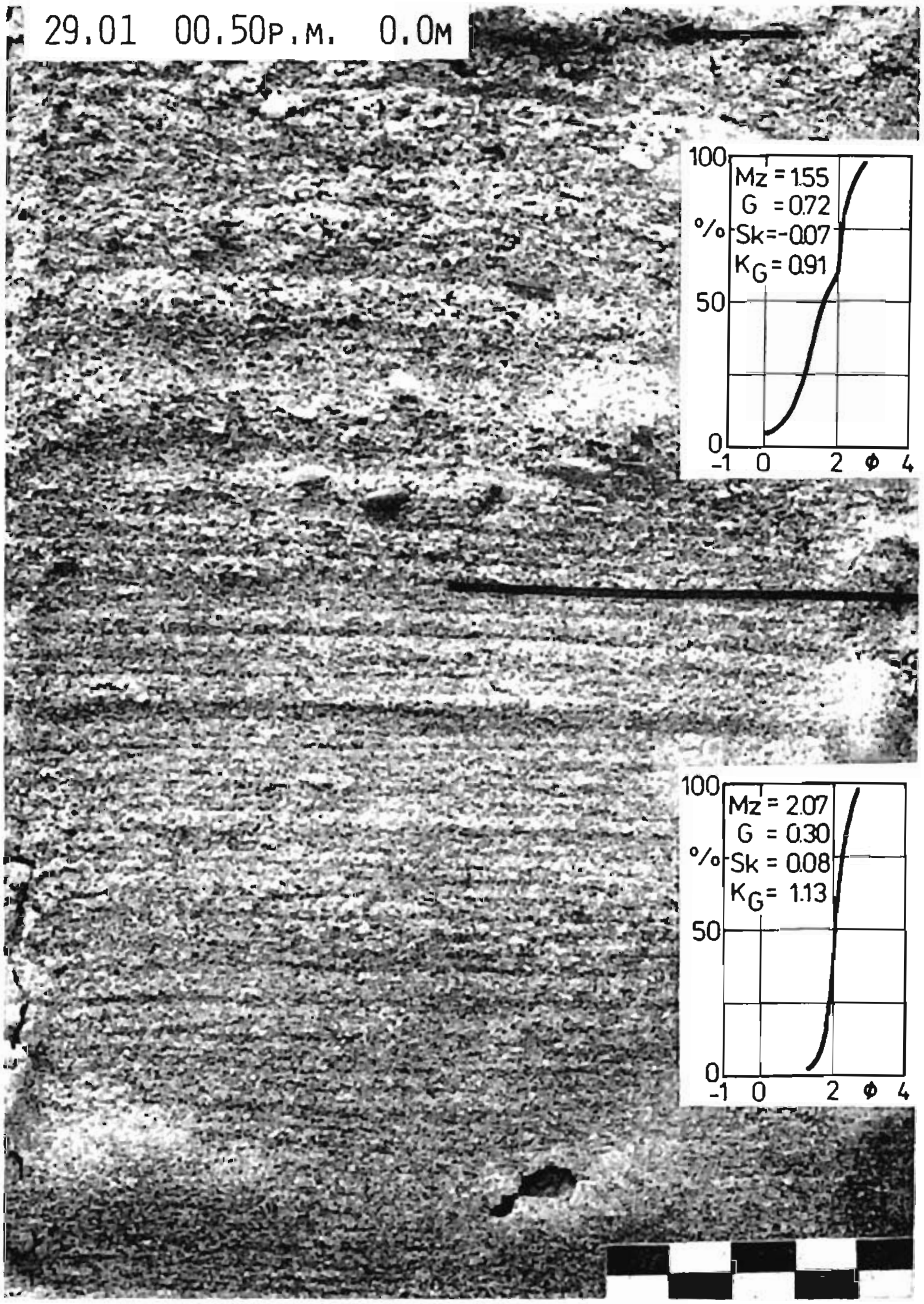
A: 1 — date, 2 — time, 3 — depth
B — direction of shoreline
C — lognormal cumulative curve of sand-grain distribution, and graphic grain parameters (cf. Folk & Ward 1975): Mz — median diameter, G — standard deviation, Sk — skewness, K_G — kurtosis
D — Boundary of the sample to which the data given in C concern
E — scheme of bottom pattern, as observed; numbers denote the height of crests (in centimetres); 1 — direction of wave progagation, as observed, 2 — direction of the shoreline
F — scale of photo (in centimetres)
Location of sampling sites is given in Text-figs 1—2 and partly in Pl. 45

tion of which were influenced by the older-generation ripples and megaripples, and in particular by the angle at which they were developing in relation to crests of the older and larger forms.

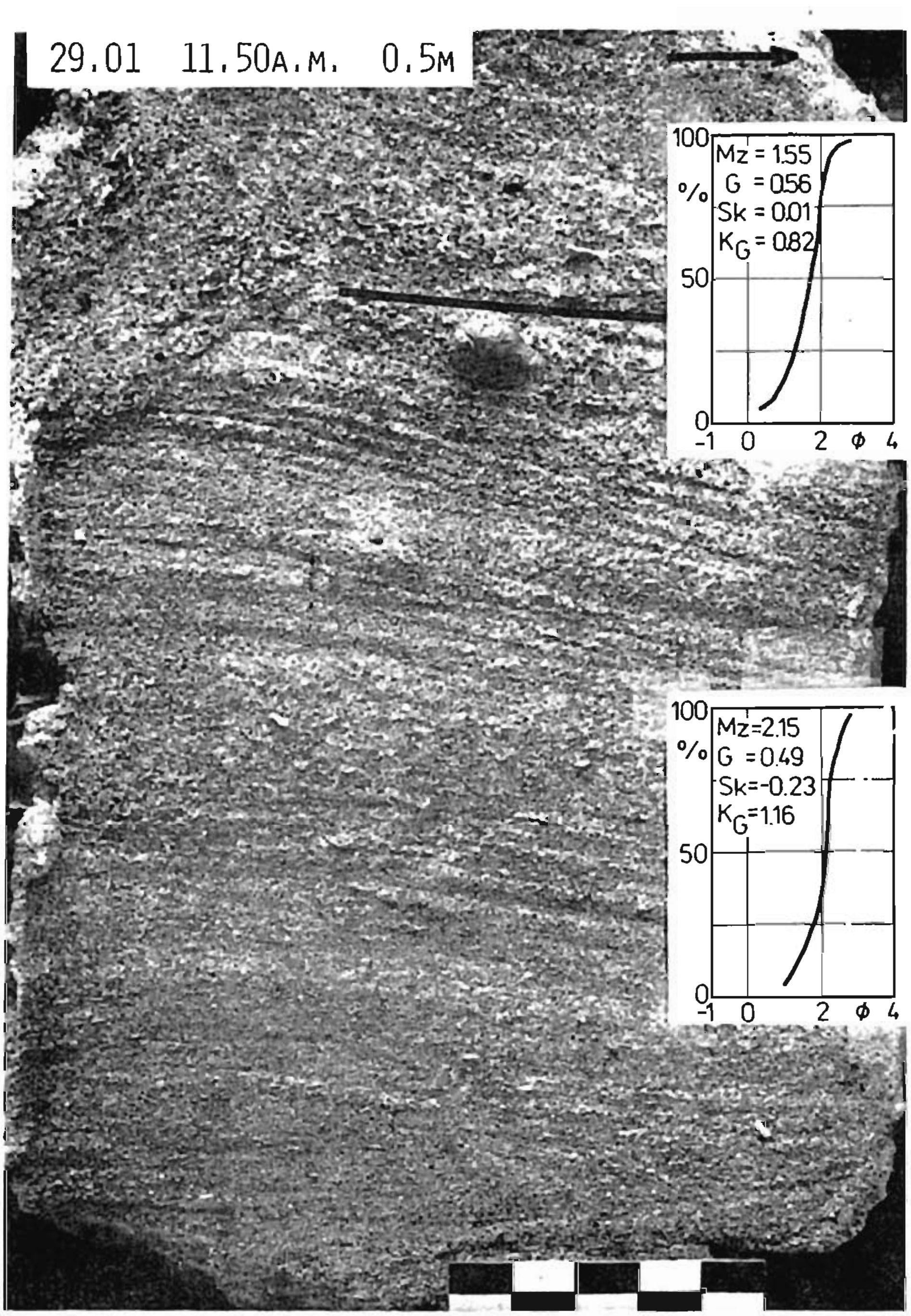
The most diversified bottom patterns were revealed at depths ranging from 4 do 15 m. Deeper, bottom patterns became less complex although there were certain exceptions too. After a stronger waving the bottom patterns characteristic of the shallower zone appeared at greater



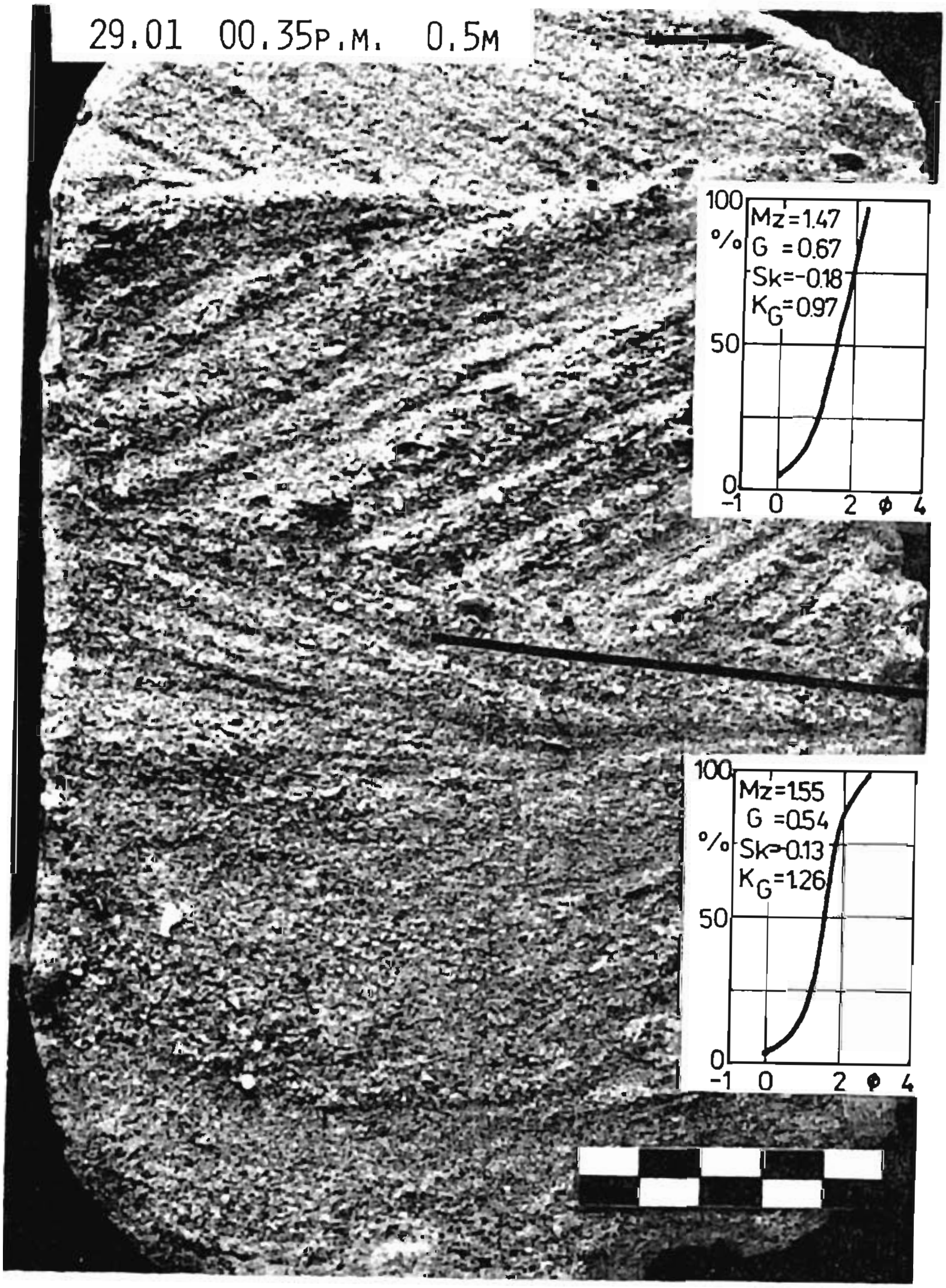
Nearly horizontal bedding in fine-grained well-selected sand; lower part of the slightly inclined beach slope, close to the water line



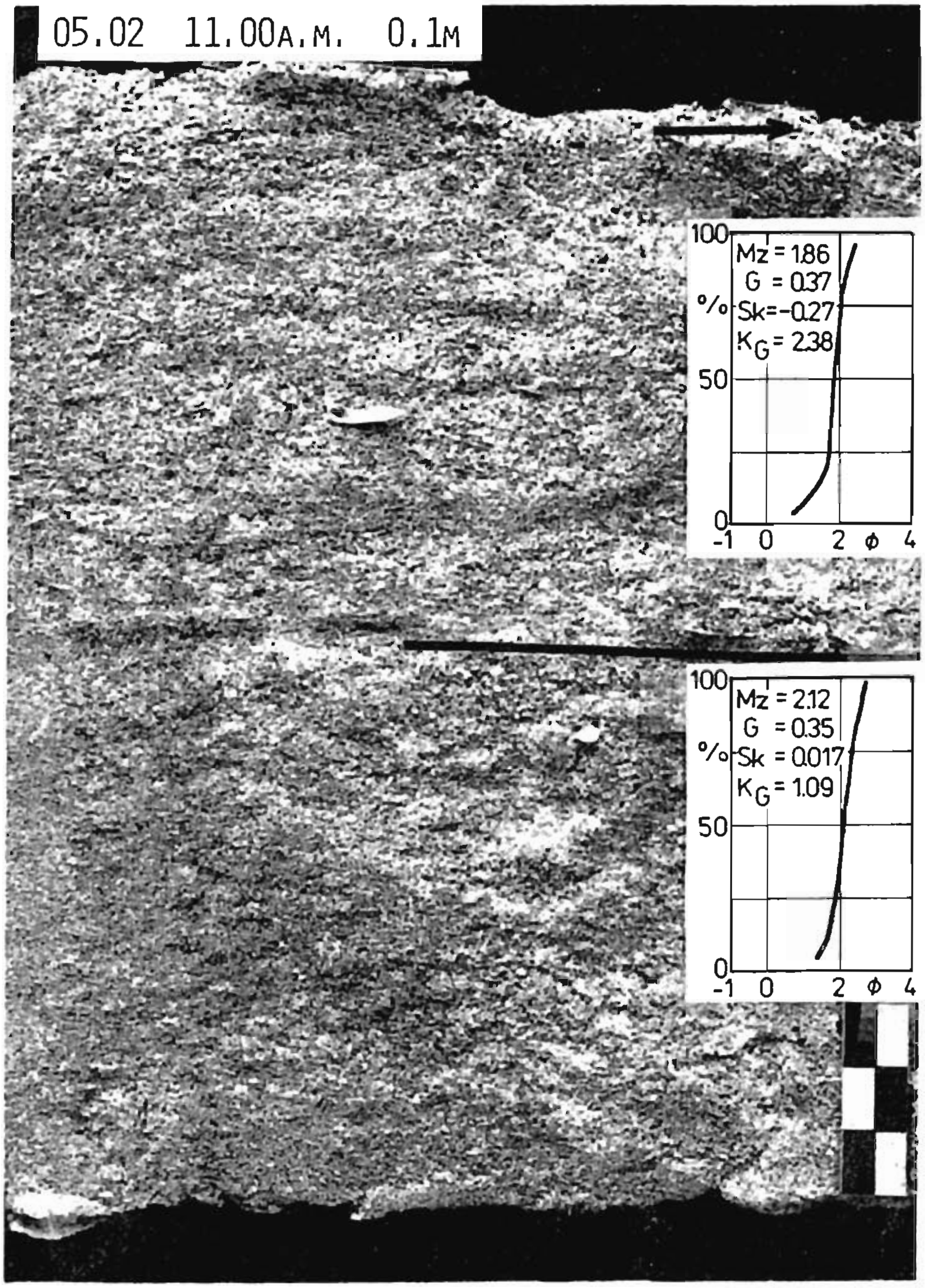
Top part of the horizontal and slightly convex cross laminae, developed in a low--inclined beach slope, sampled just above the water line



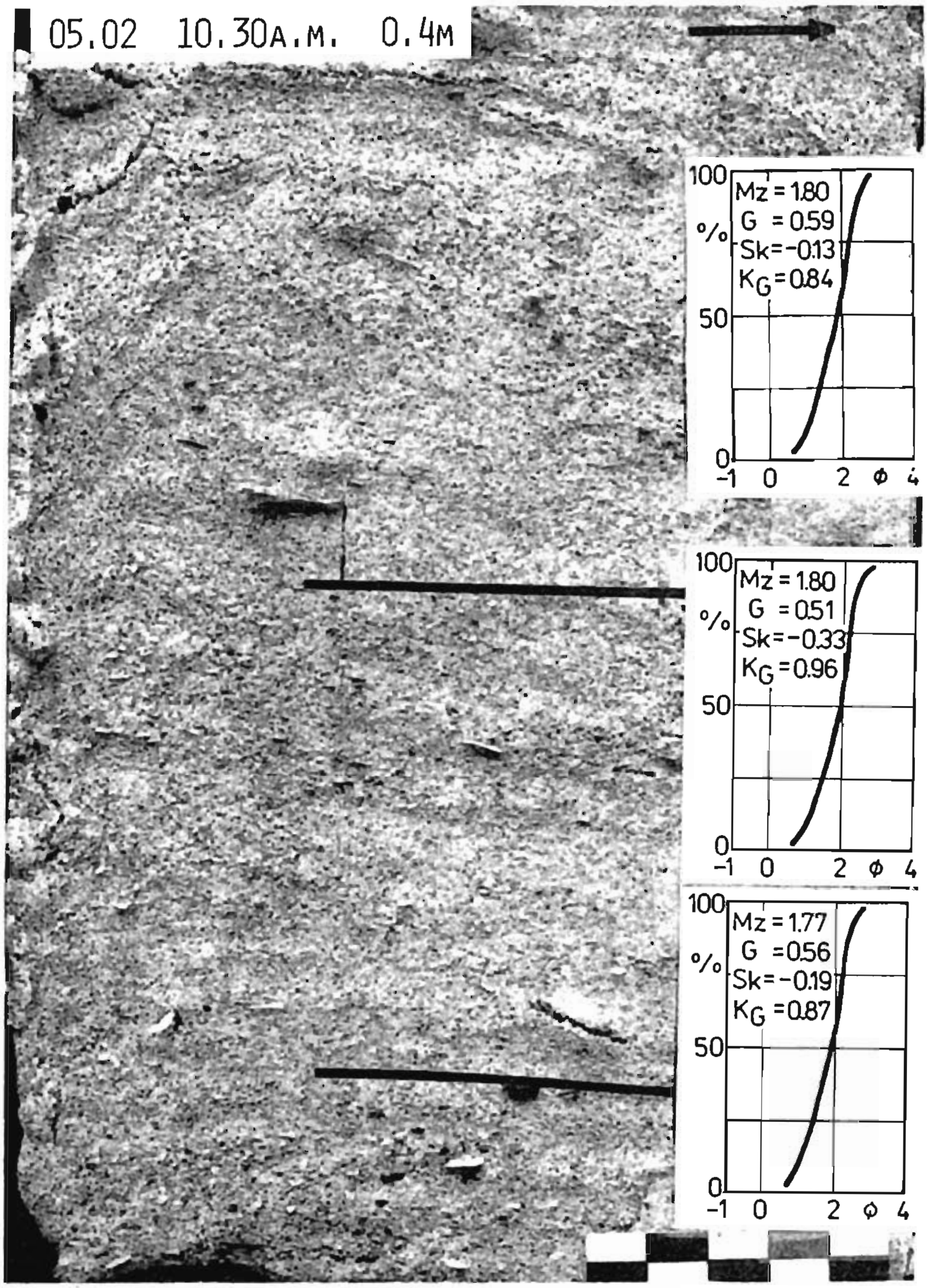
Cross bedding, large- or medium-scale, with increasing inclination of cross laminae, and ending with an erosional boundary, developed in the landward of the rising first sand ridge; overlying is a cross set with an opposite inclination, corresponding to the topmost part of the first sand ridge; orientation of shell detritus consistent with the cross bedding



Several small- and medium-scale cross sets with erosional boundaries, developed in the topmost part of same sand ridge (*see* Pl. 3); the uppermost cross set corresponds to the landward slope of the ridge

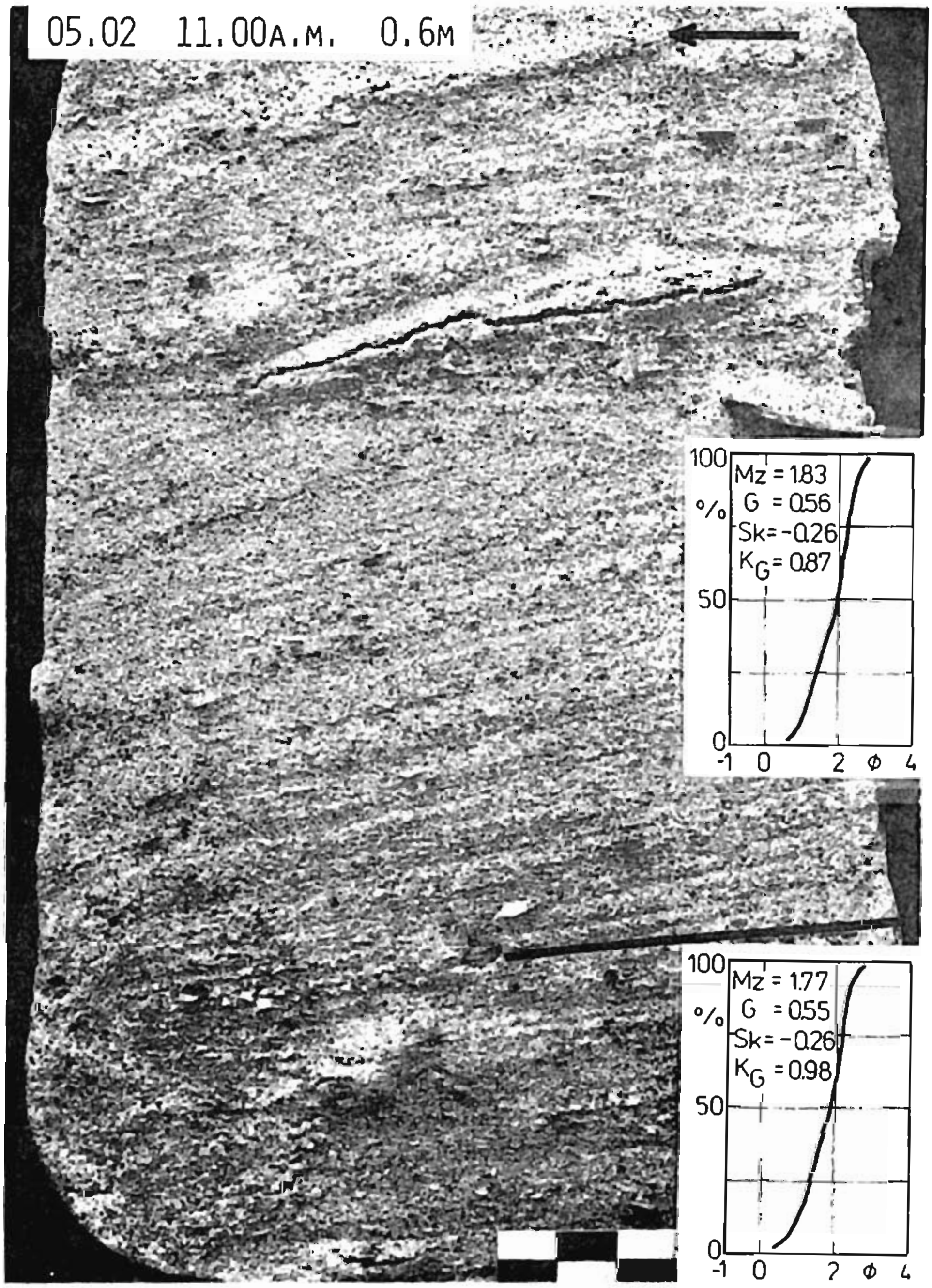


Indistinct horizontal and cross beddings, accentuated by shell detritus; lower part of the beach slope

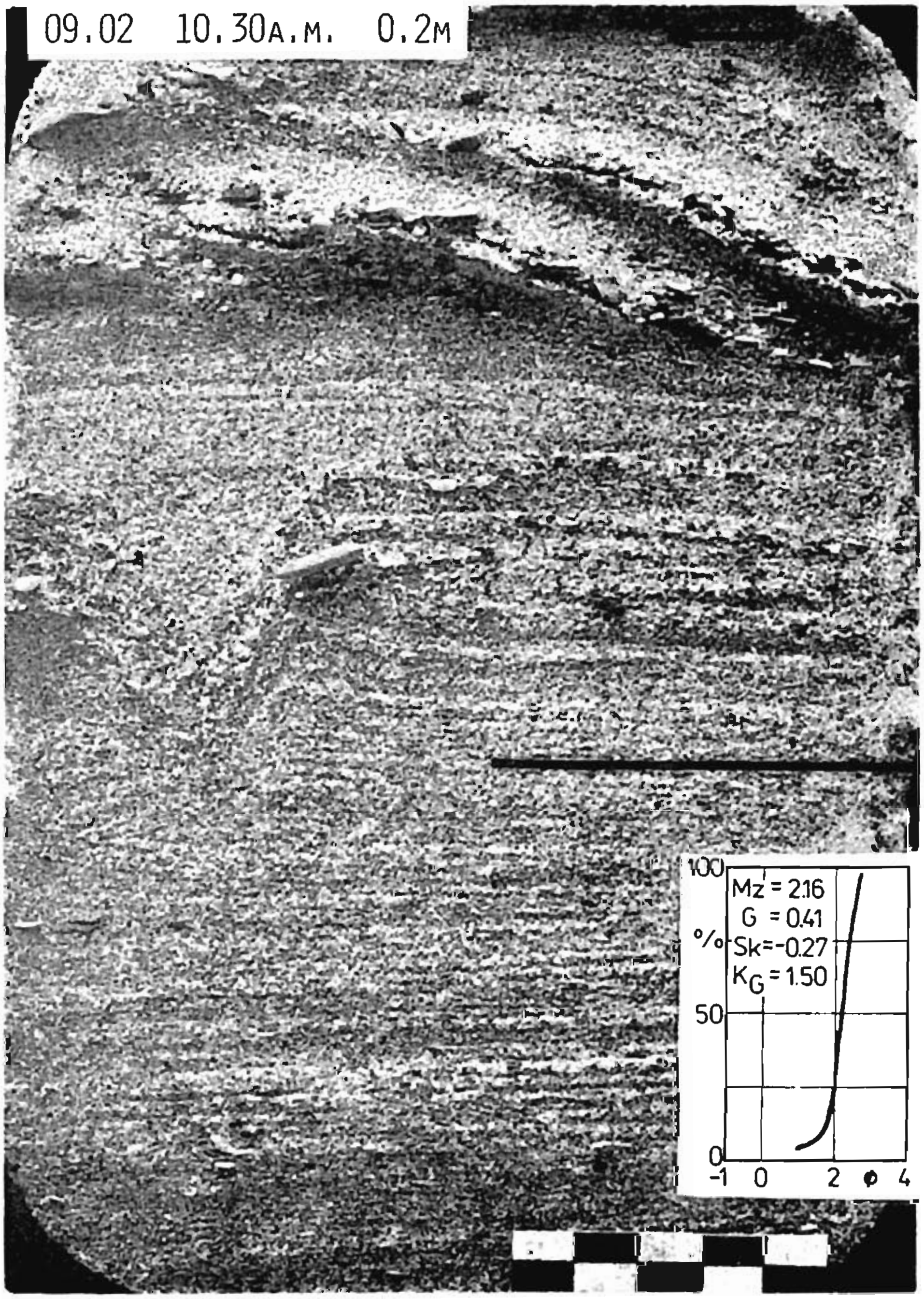


Medium- or large-scale cross bedding with increasing inclination of cross laminae in the successive sets with erosional boundaries; landward slope of the first sand ridge

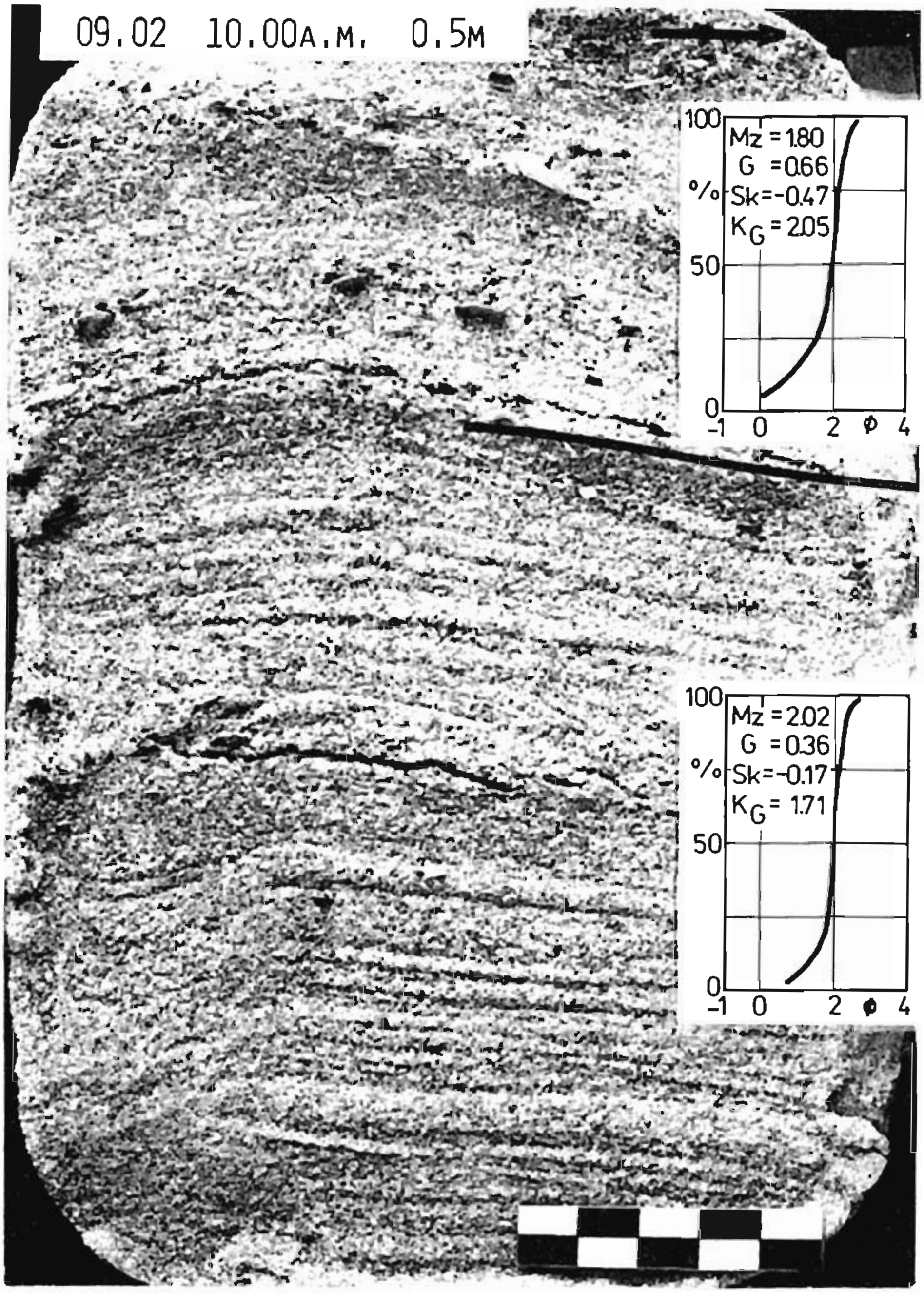
Medium- or large-scale cross bedding with various directions and inclinations of cross laminae, accentuated by the arrangement of detritus and flat pebbles; beginnings of development of the first sand ridge; sample from the axial part of the sand ridge



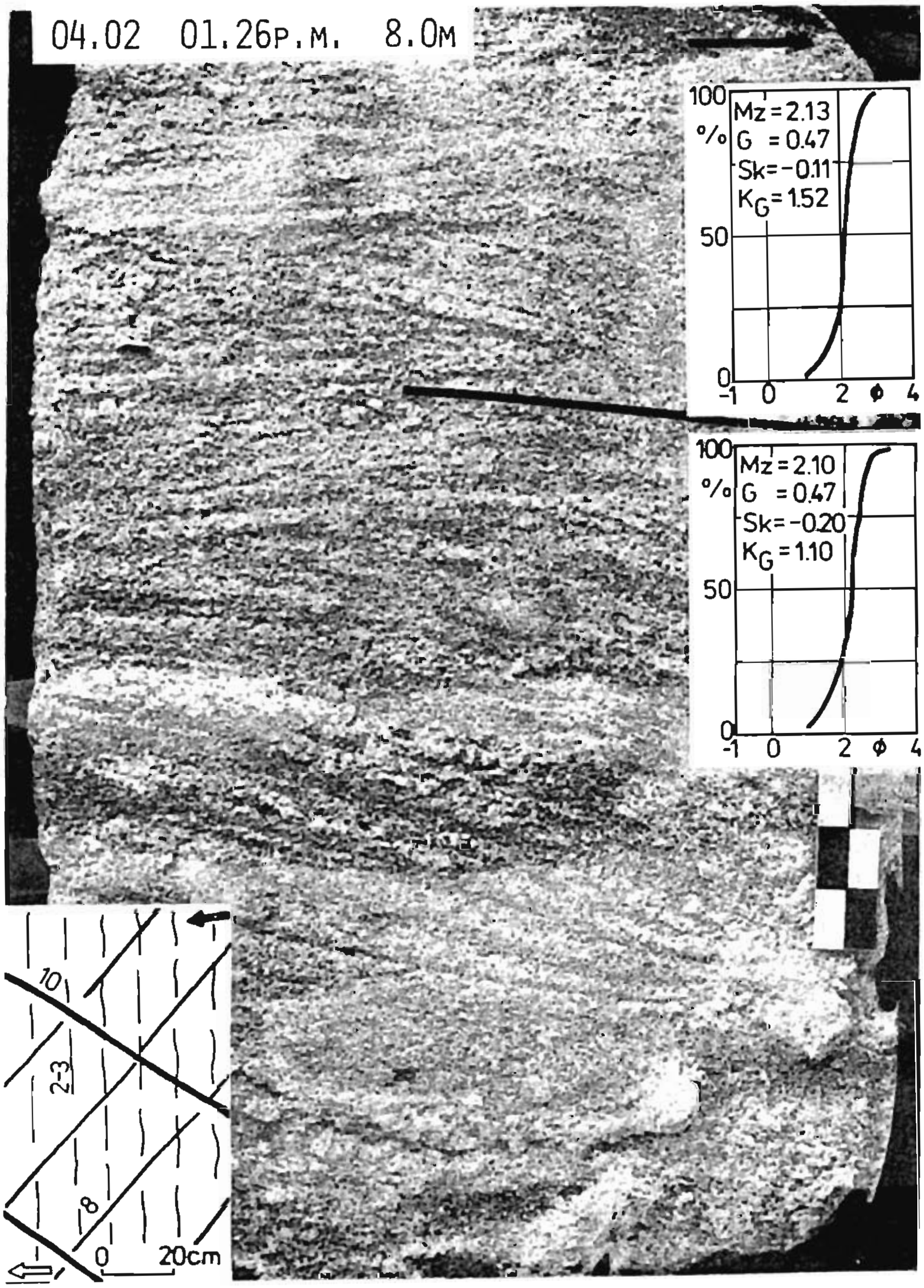
Large- or medium-scale cross bedding with increasing inclination of cross laminae; landward slope of the first sand ridge



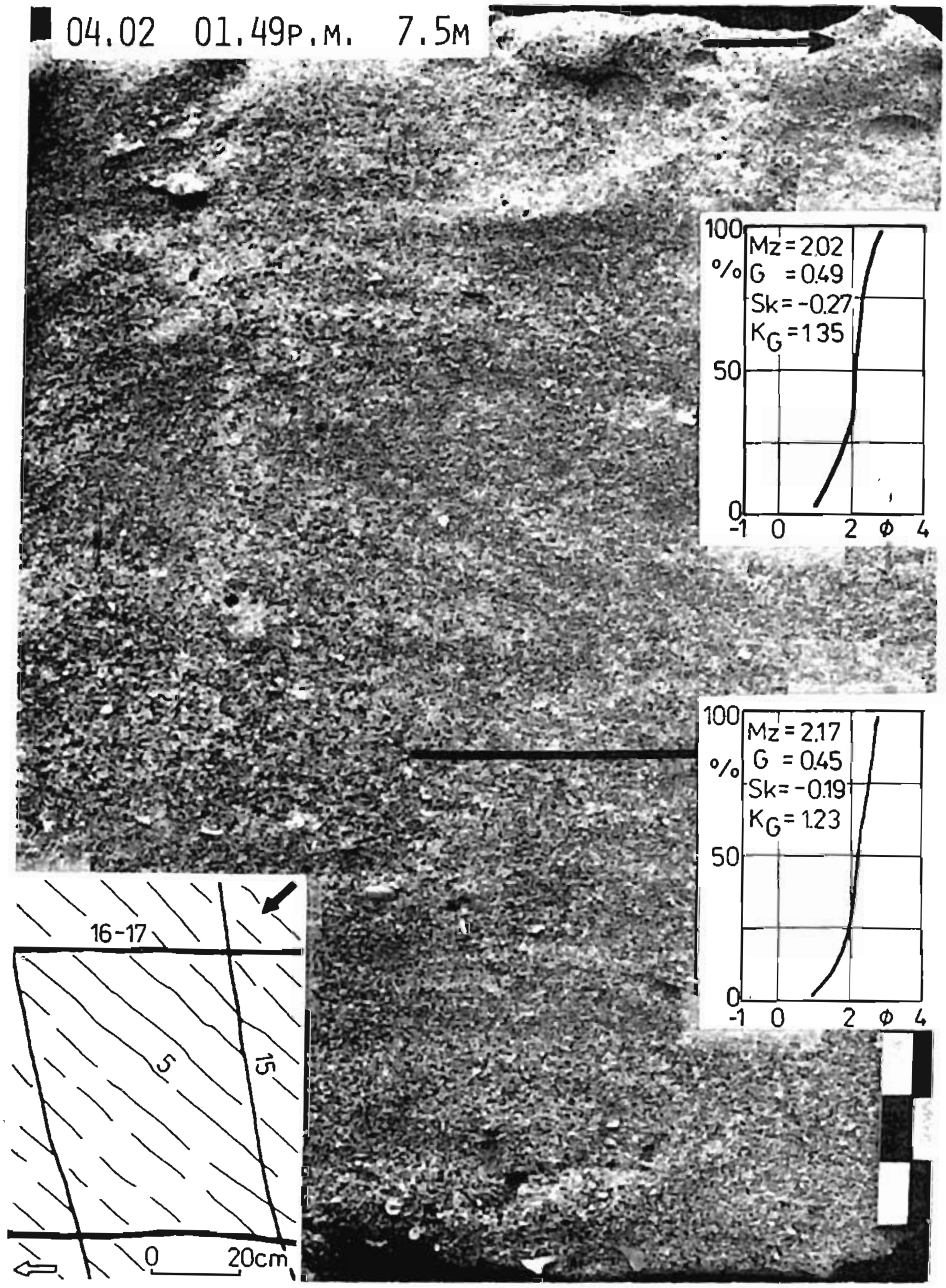
Cross bedding *(top)* in the lowermost part of the developing beach slope; underlying is horizontal bedding formed prior to the development of the beach slope; a burrow produced by a bivalve (?) is visible *(at left)*



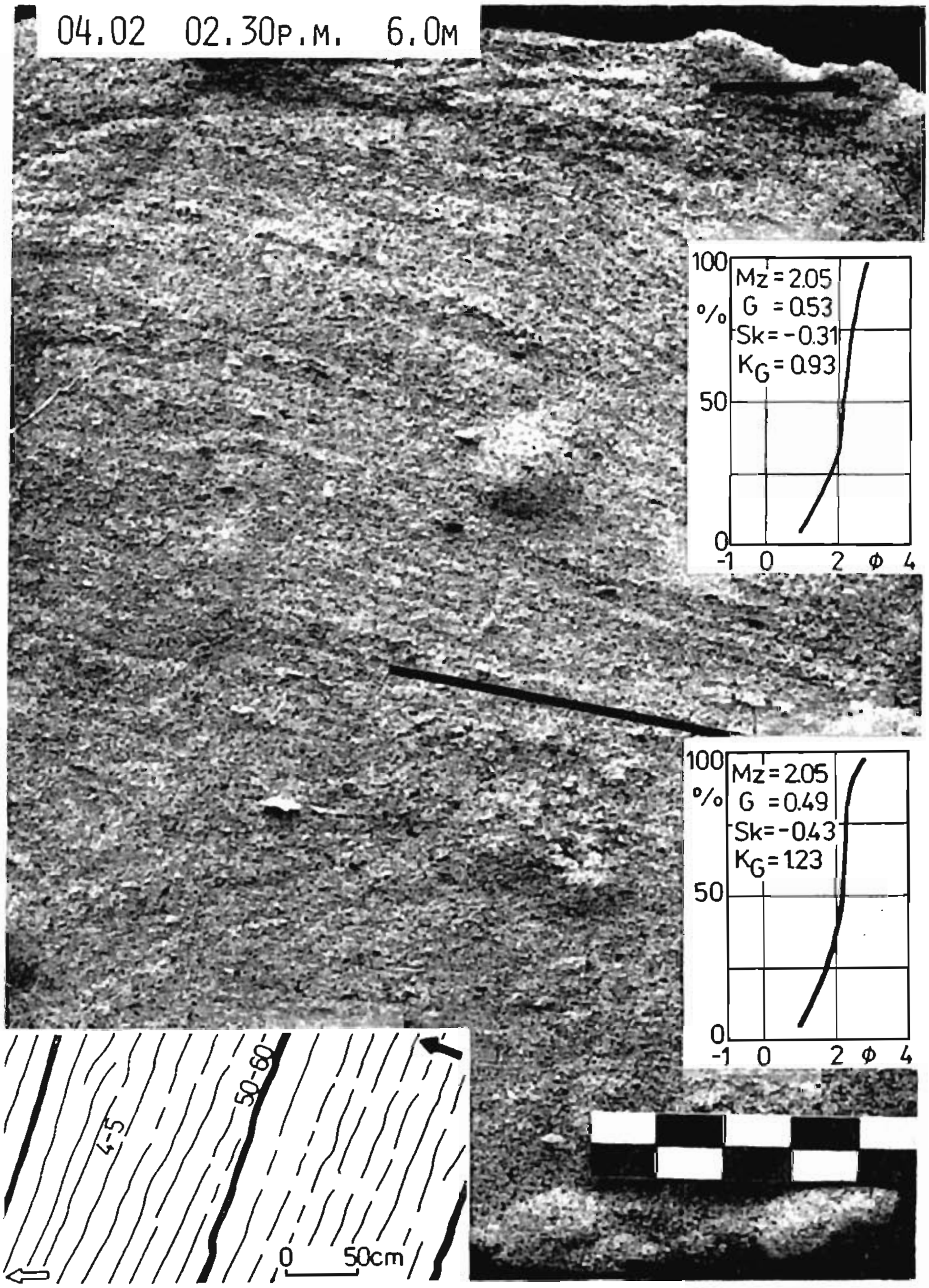
Medium- or large-scale cross bedding from the uppermost part of the beach slope; convex cross laminae with an upwardly-increasing inclination develop on the flat bottom



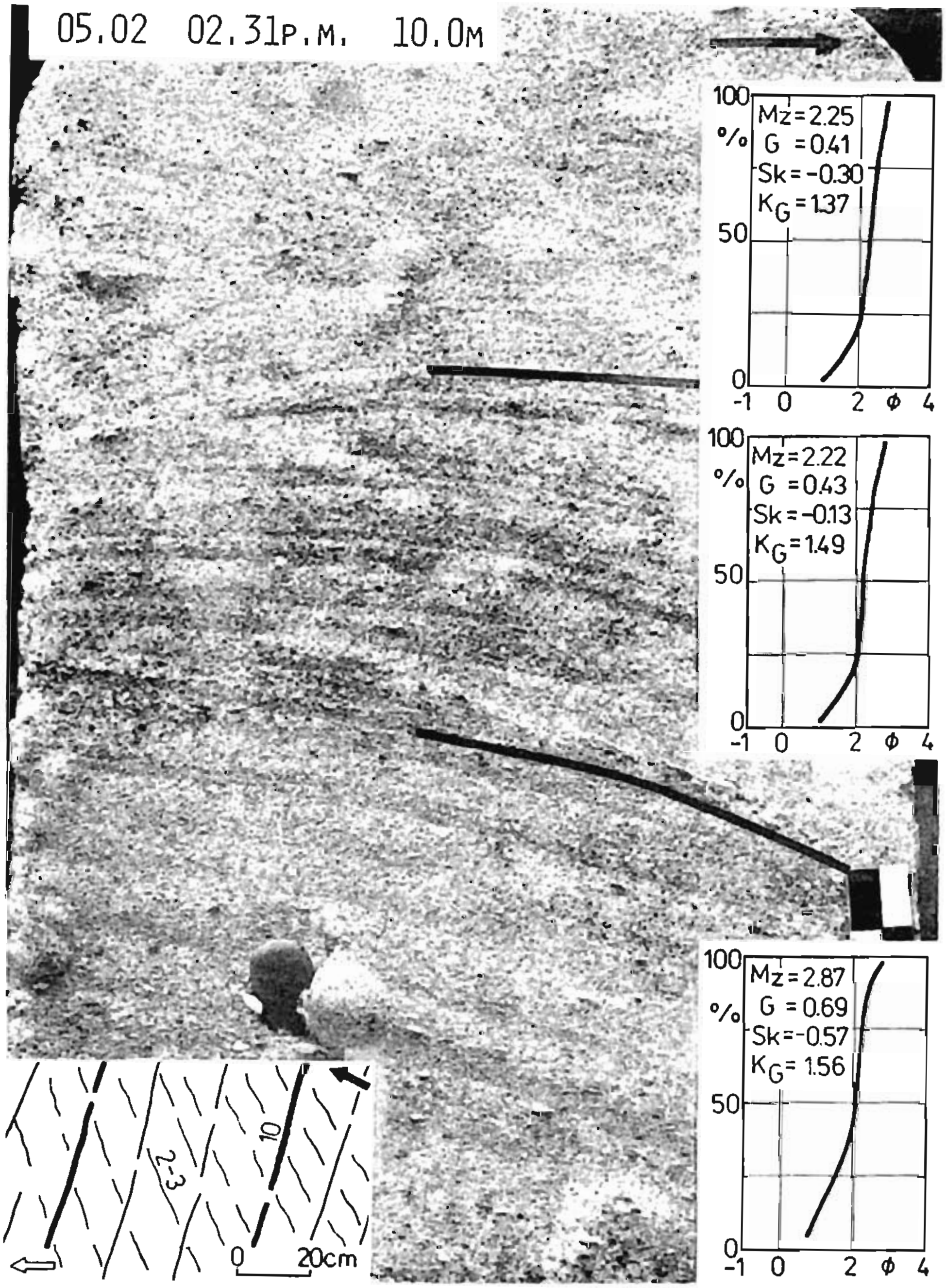
Medium- or large-scale megaripple cross bedding overlain by small-scale ripple cross bedding



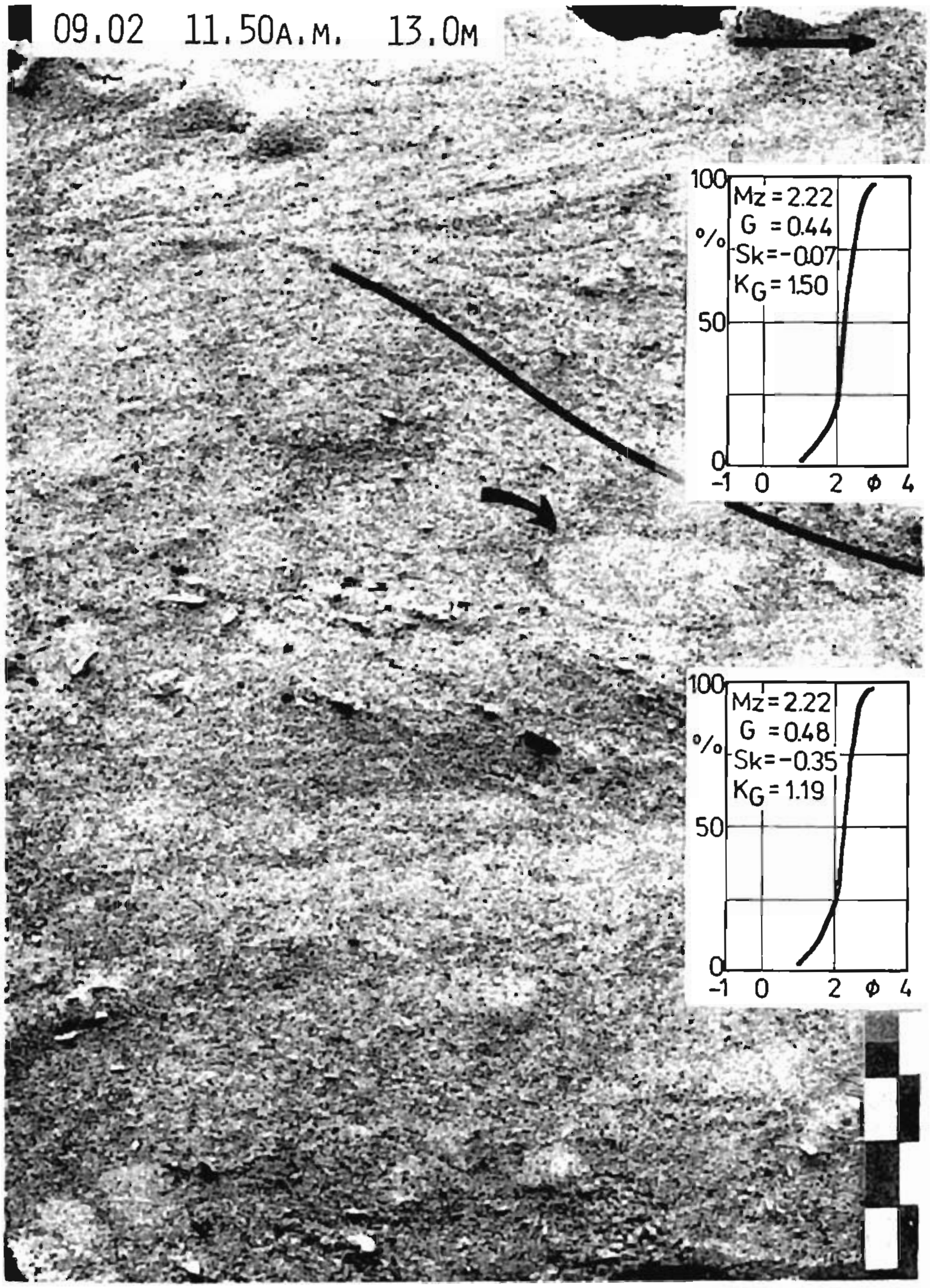
Vague contours of the medium- or large-scale cross bedding, indistinct due to bioturbations; a larger burrow visible at left



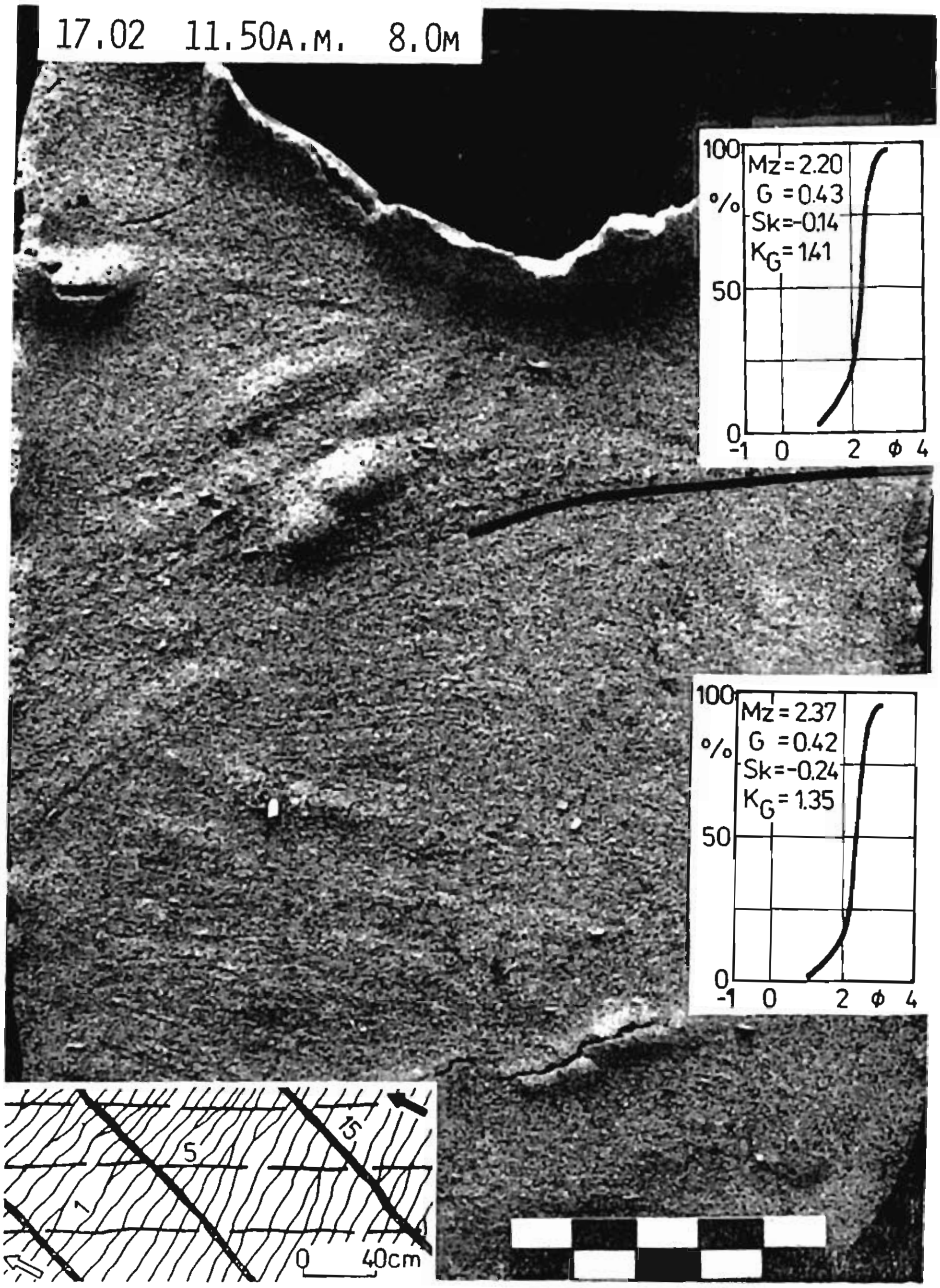
Small-scale ripple cross bedding (*bottom and top*), the latter of which is connected with ripples recorded in the pattern scheme; large- or medium-scale cross bedding (*center*), with an increasing inclination of cross laminae, connected with the crests of megaripples (as recorded in the pattern scheme)



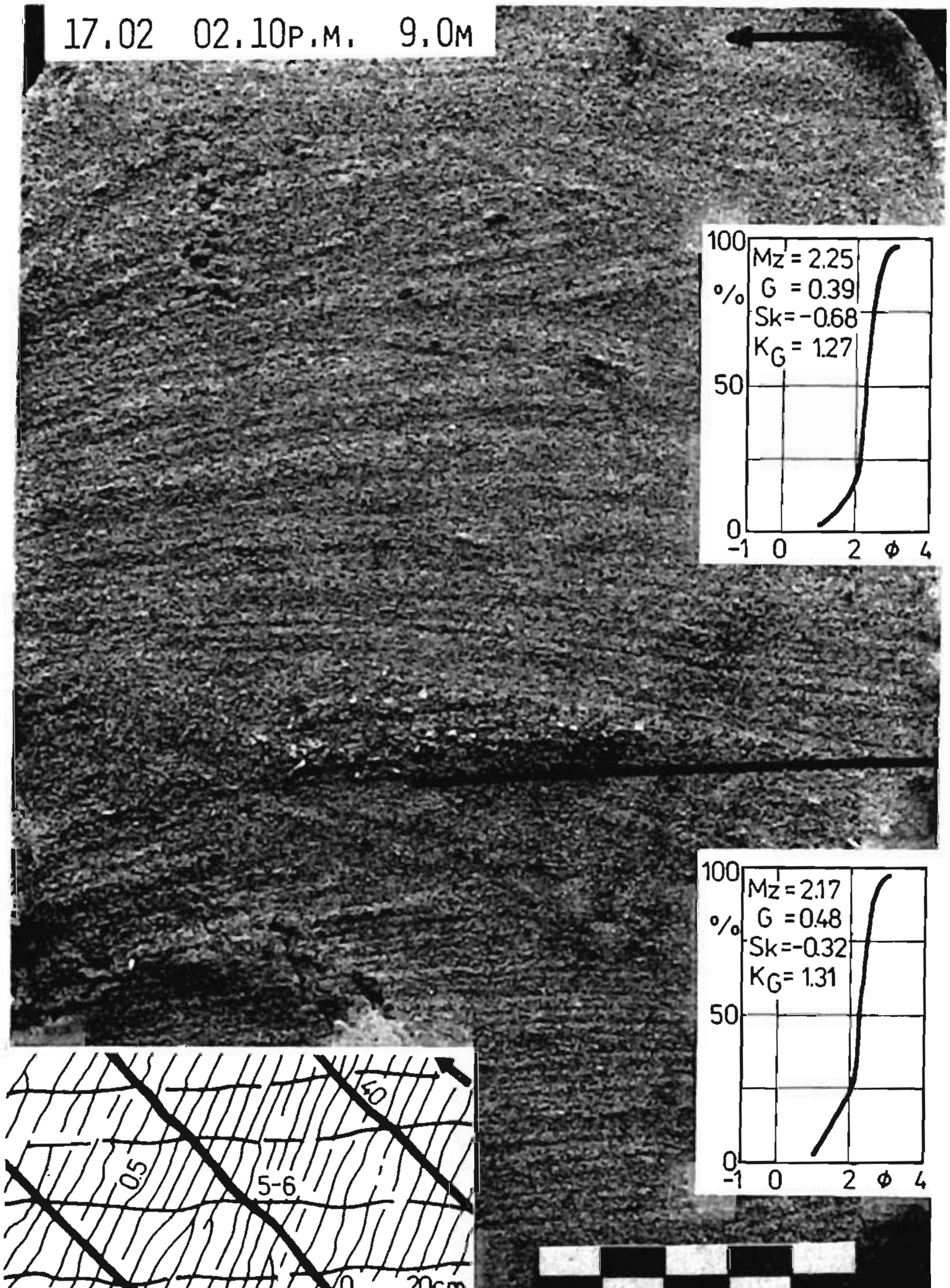
Medium- or large-scale megaripple cross bedding with increasing inclination of convex cross laminae, and small-scale ripple cross bedding *(top)*, corresponding to ripples recorded in the pattern scheme



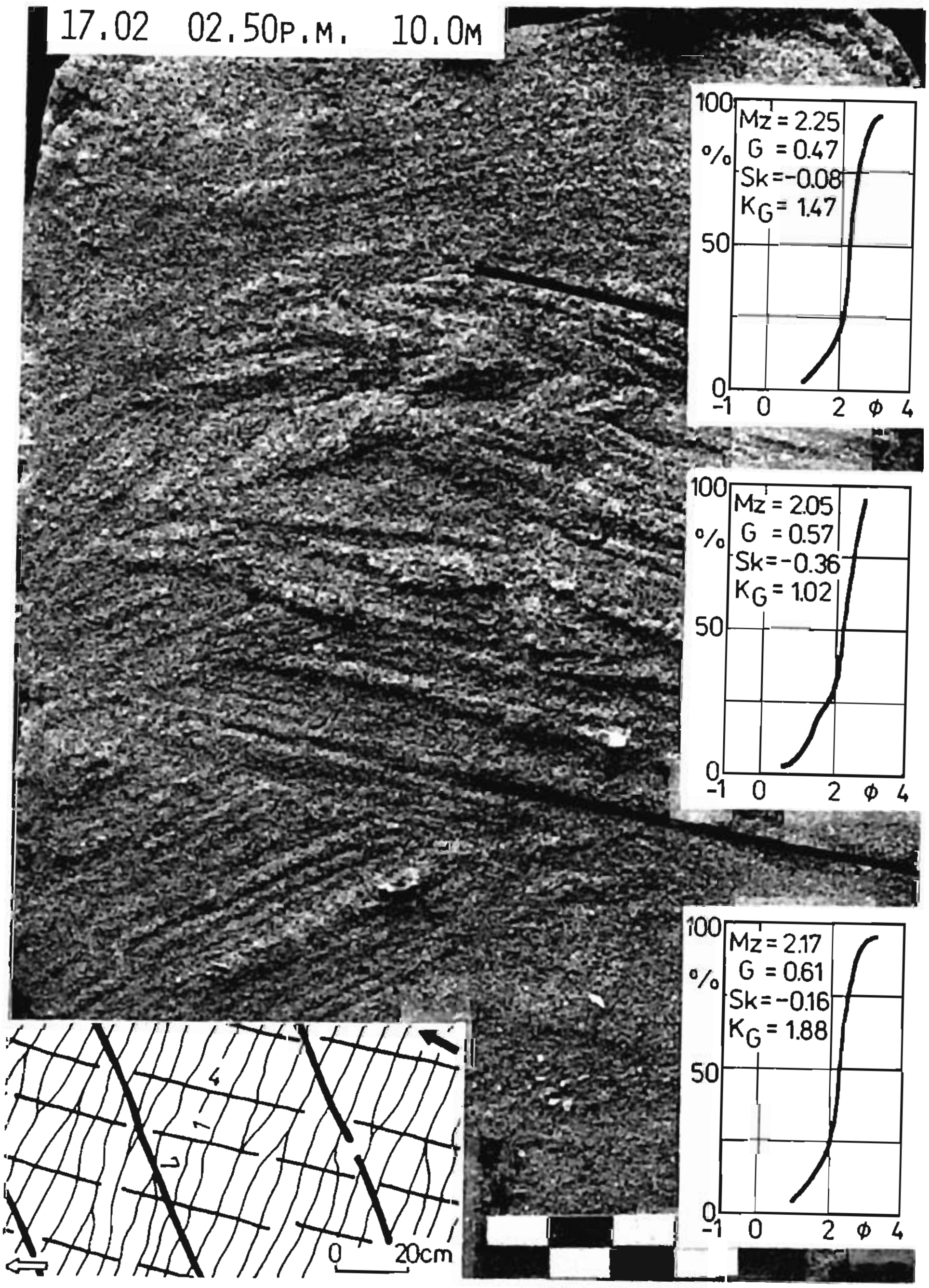
Sets of the medium-scale cross bedding and ripple cross bedding accentuated by shell detritus and small pebbles; visible is a burrow (*arrowed*) produced supposedly by an echinoid, and filled with finer material and lined with a darker sediment



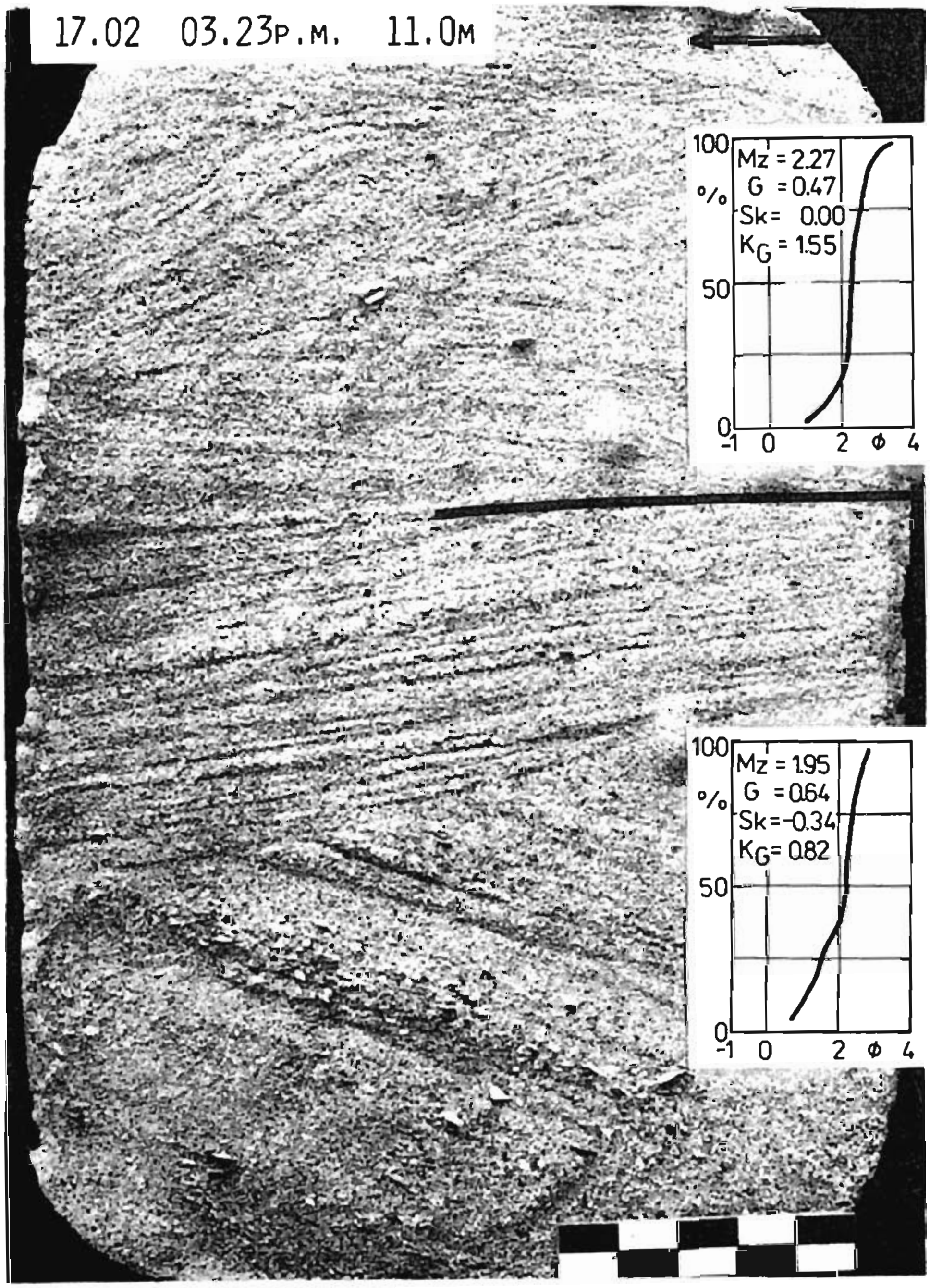
Ripple cross bedding *(bottom)* and overlying megaripple cross beddnig with erosional lower boundary, the convex cross laminae of which contain coarser material



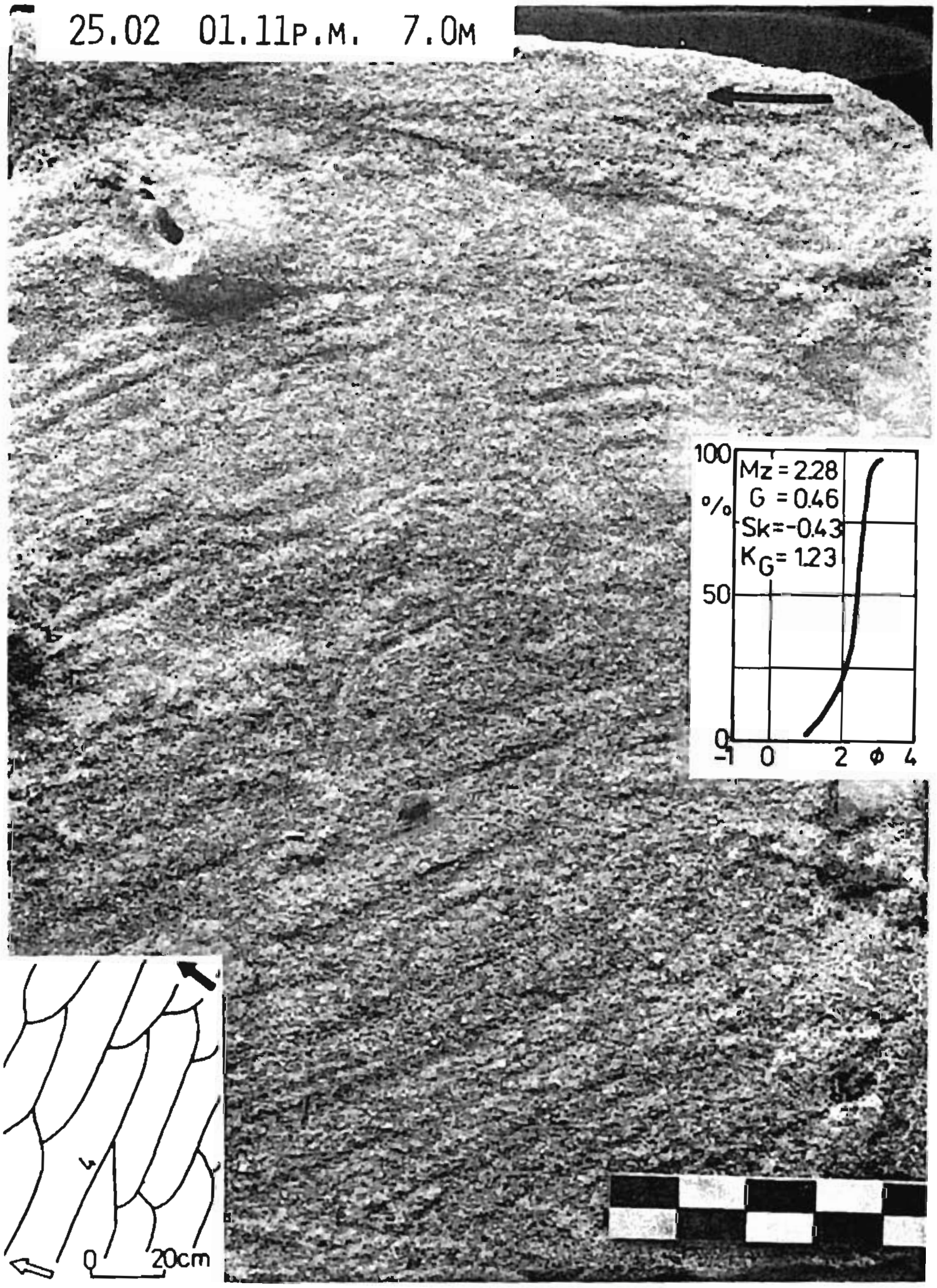
Several medium- or large-scale megaripple and small-scale ripple cross beddings with erosional boundaries, an effect of several successive generations of ripples and megaripples



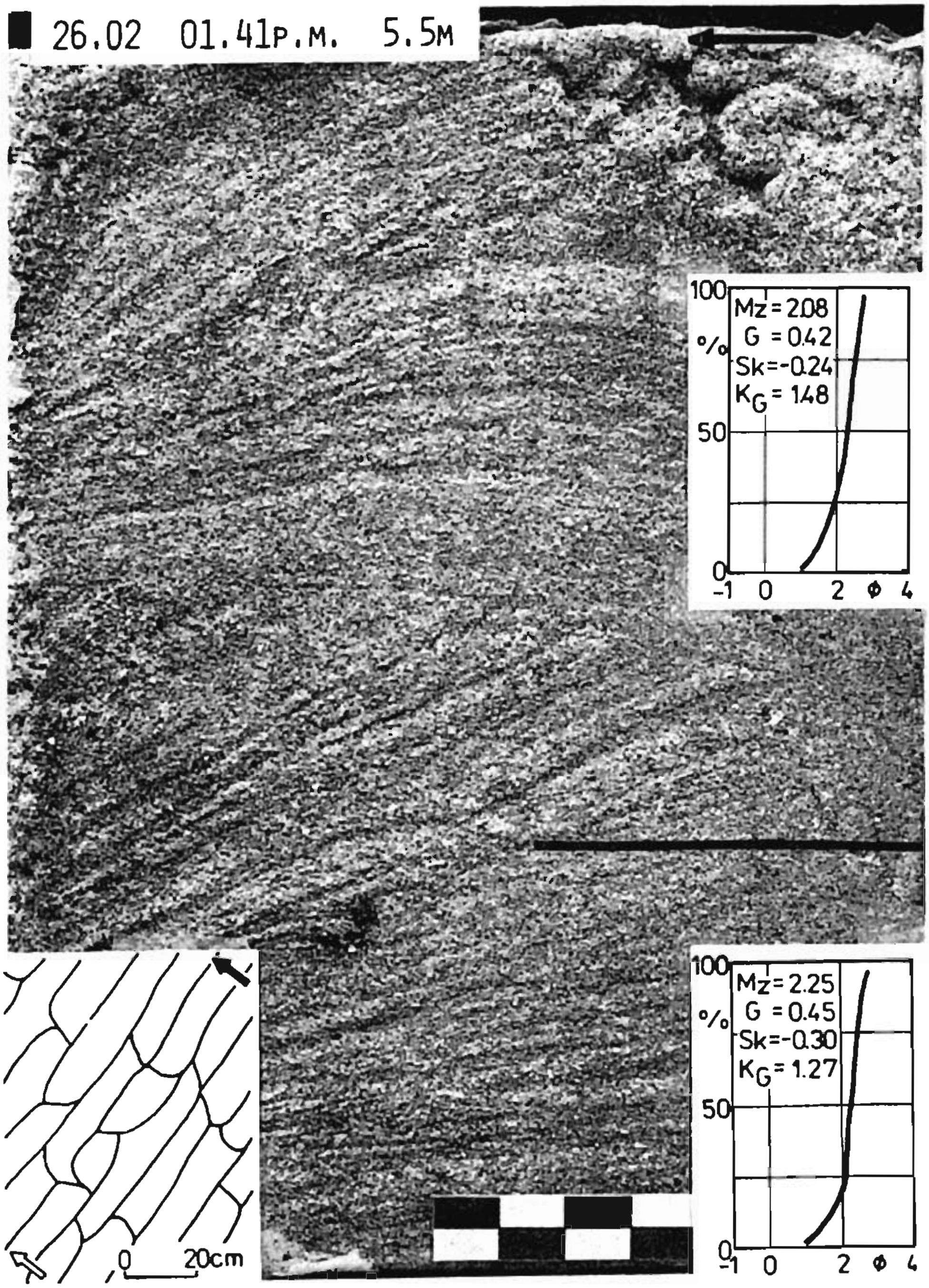
Large-scale megaripple cross bedding *(bottom)*, erosionally truncated and overlain by sets of small-scale ripple cross bedding; a ripple crest, corresponding to the smallest forms reported in the pattern scheme is visible *(top)*



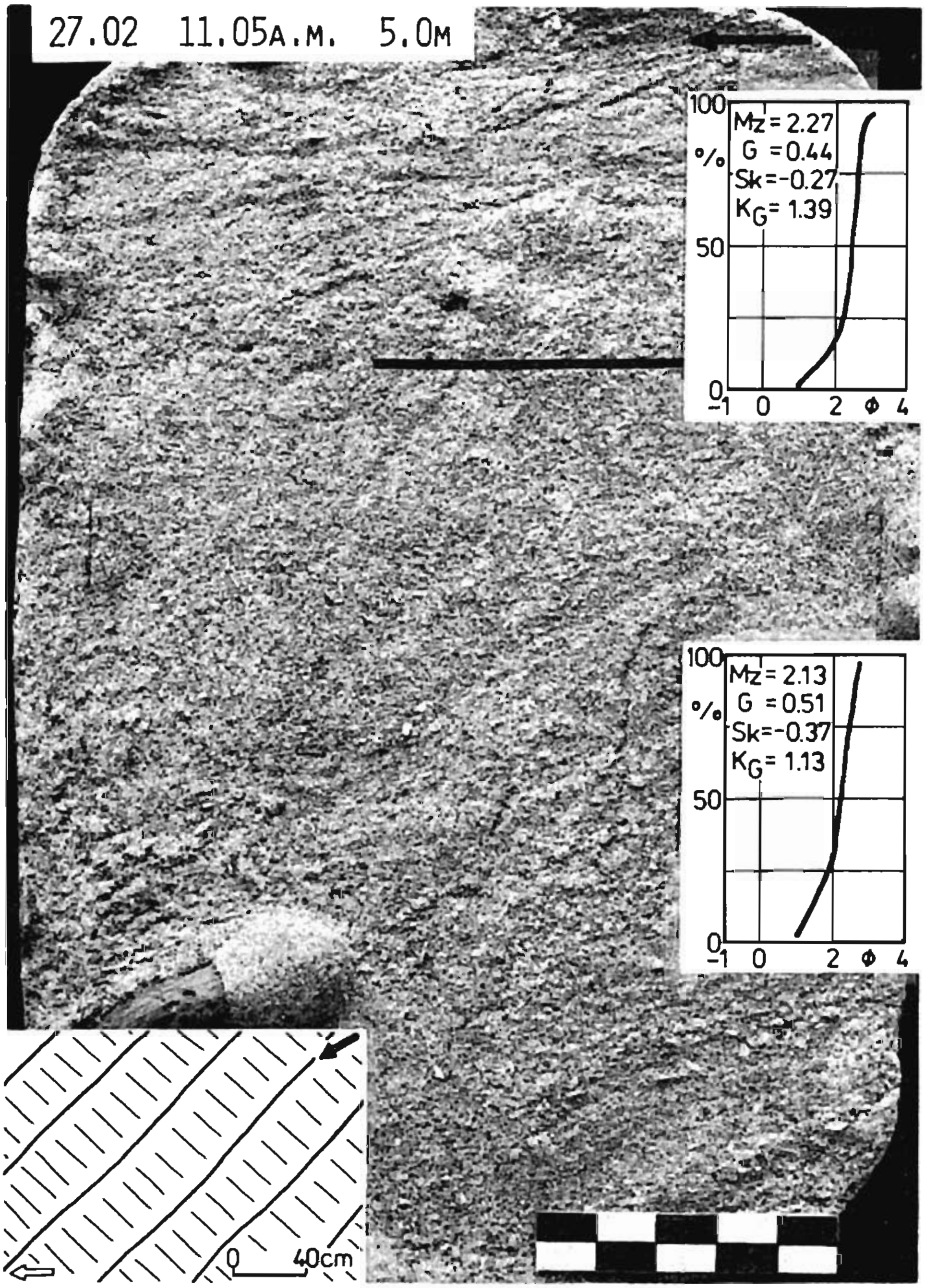
Large-scale cross sets with an erosional boundary, and small-scale ripple cross bedding with the less distinct erosional boundaries (*top*)



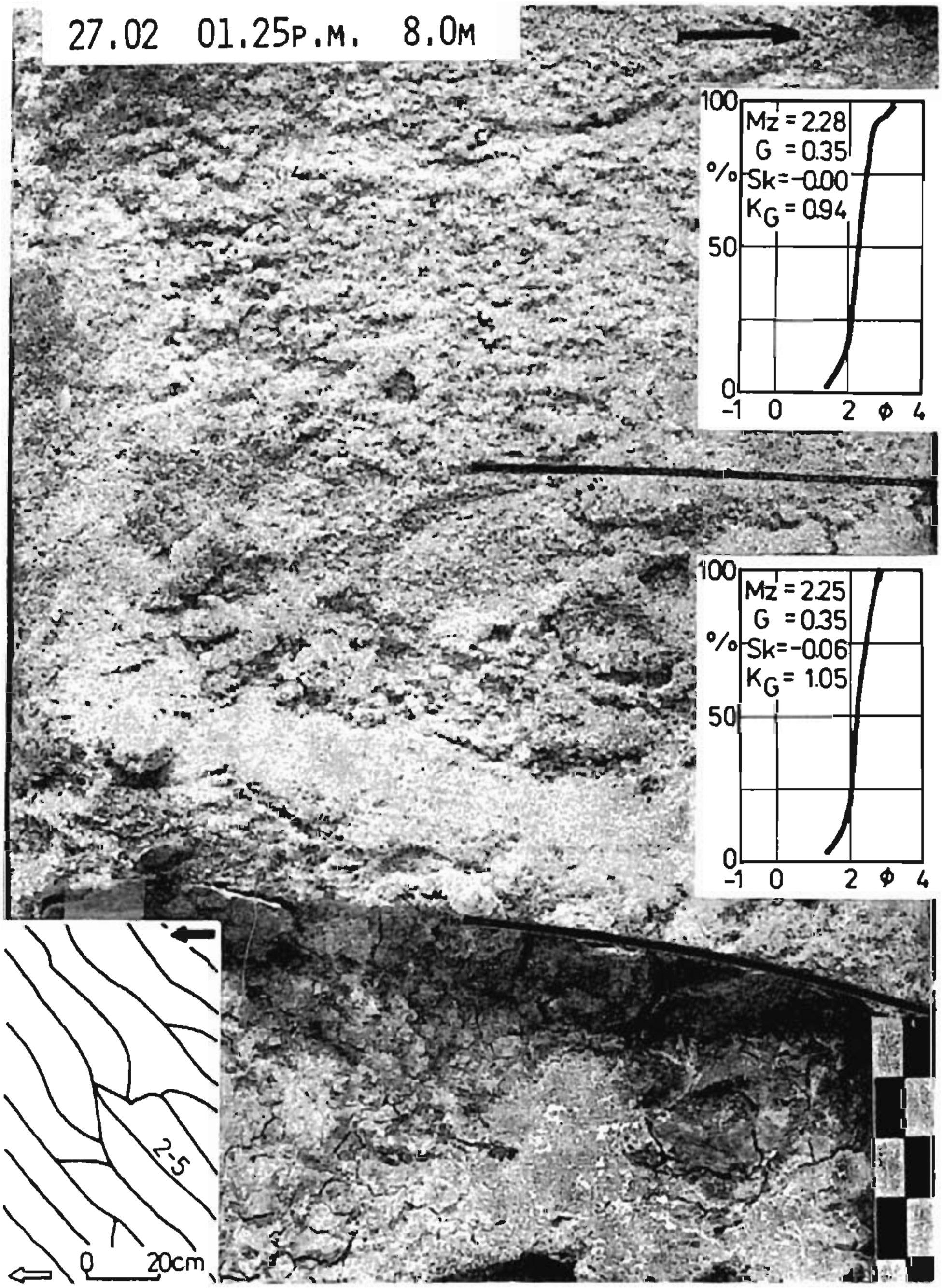
Large-scale cross bedding with escape burrows penetrating from the boundaries of cross sets



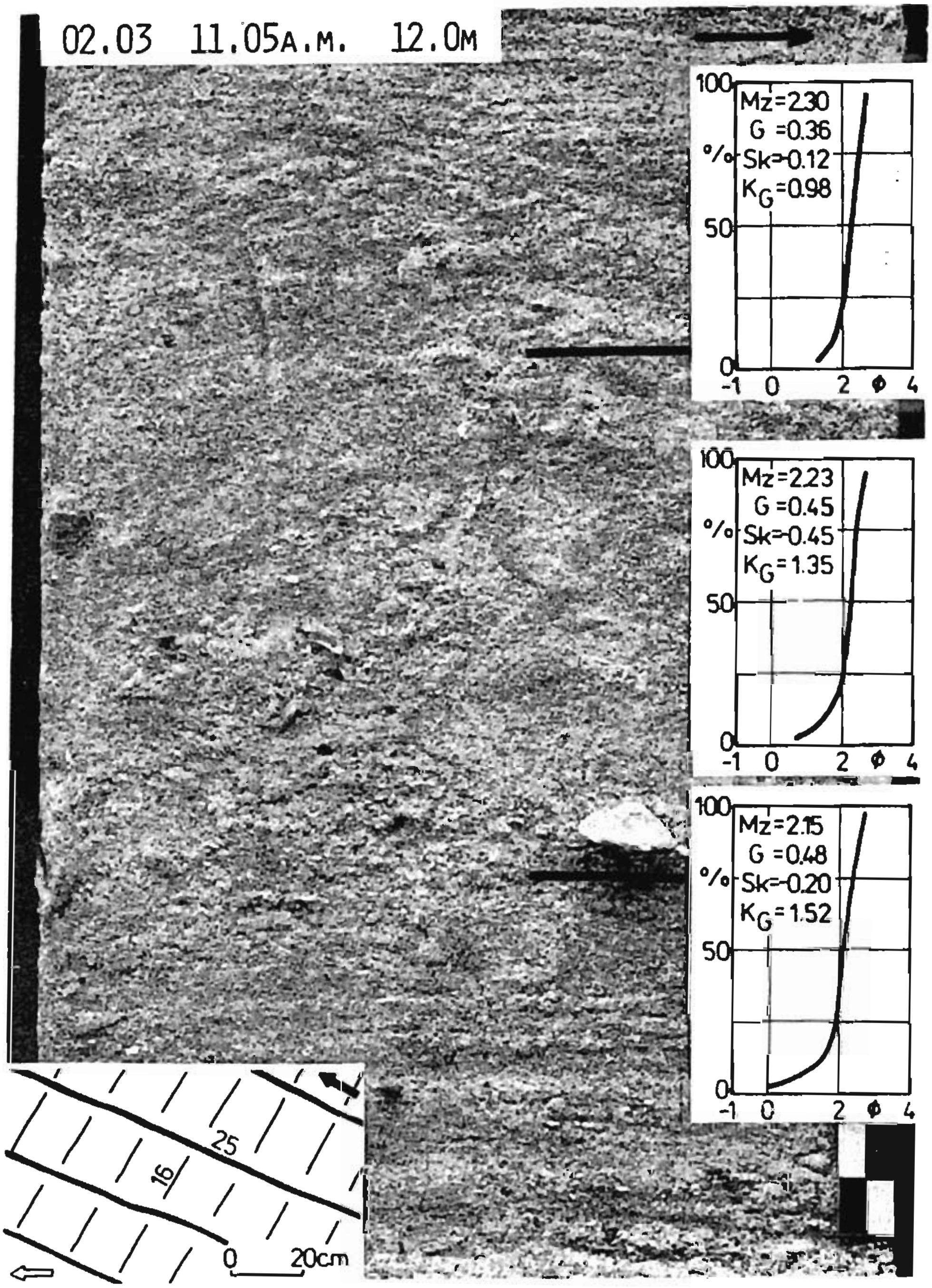
Large- or medium-scale megaripple cross bedding with increasing inclination (*lower set*), and convex cross laminae (*upper set*) corresponding to the slope and to the axial part of the megaripple



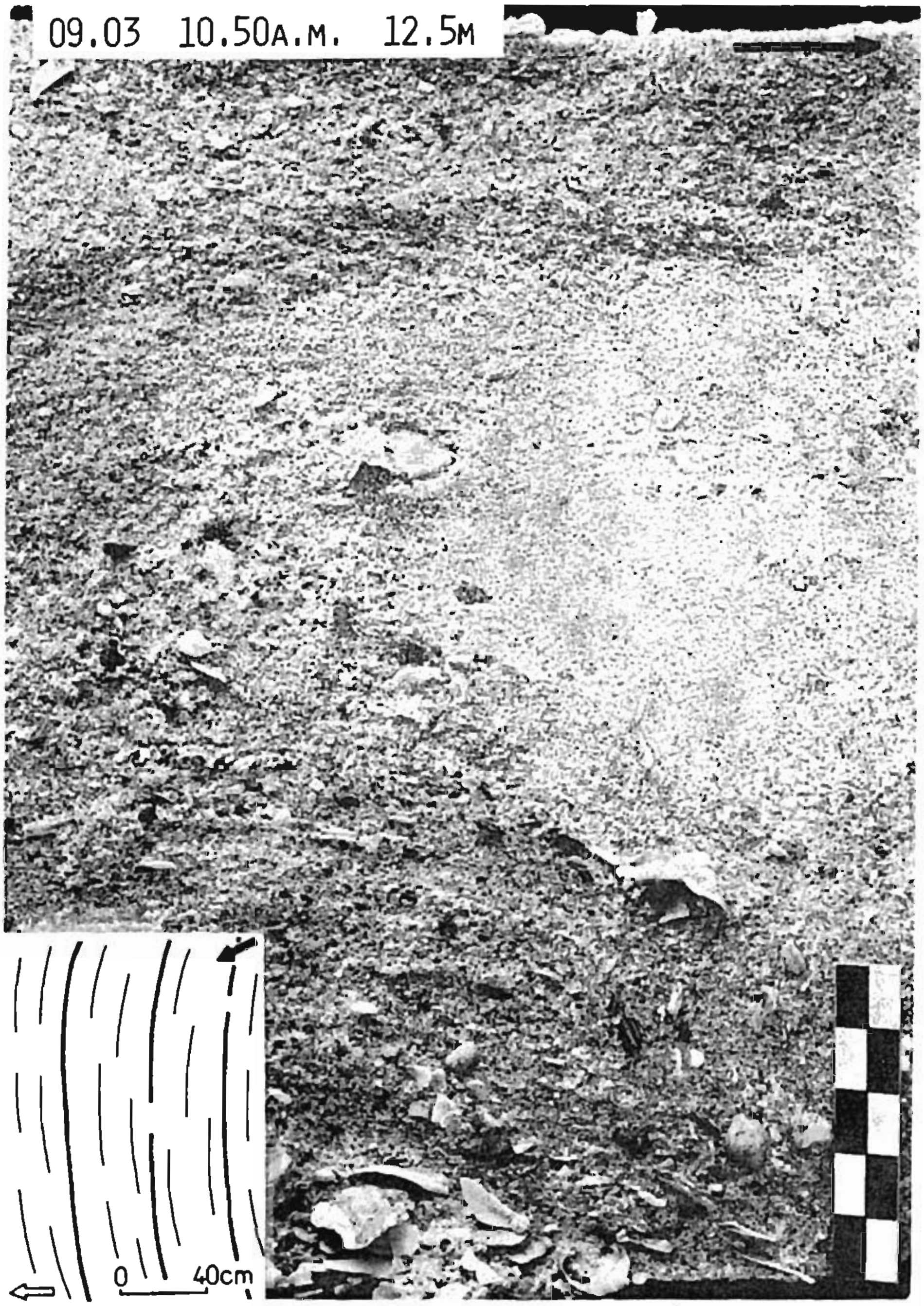
Large-scale megaripple cross bedding accentuated by the position of a flat pebble, and heavily obliterated by bioturbations (*center*); small-scale ripple cross bedding (*top*) corresponds to minor crests in the pattern scheme



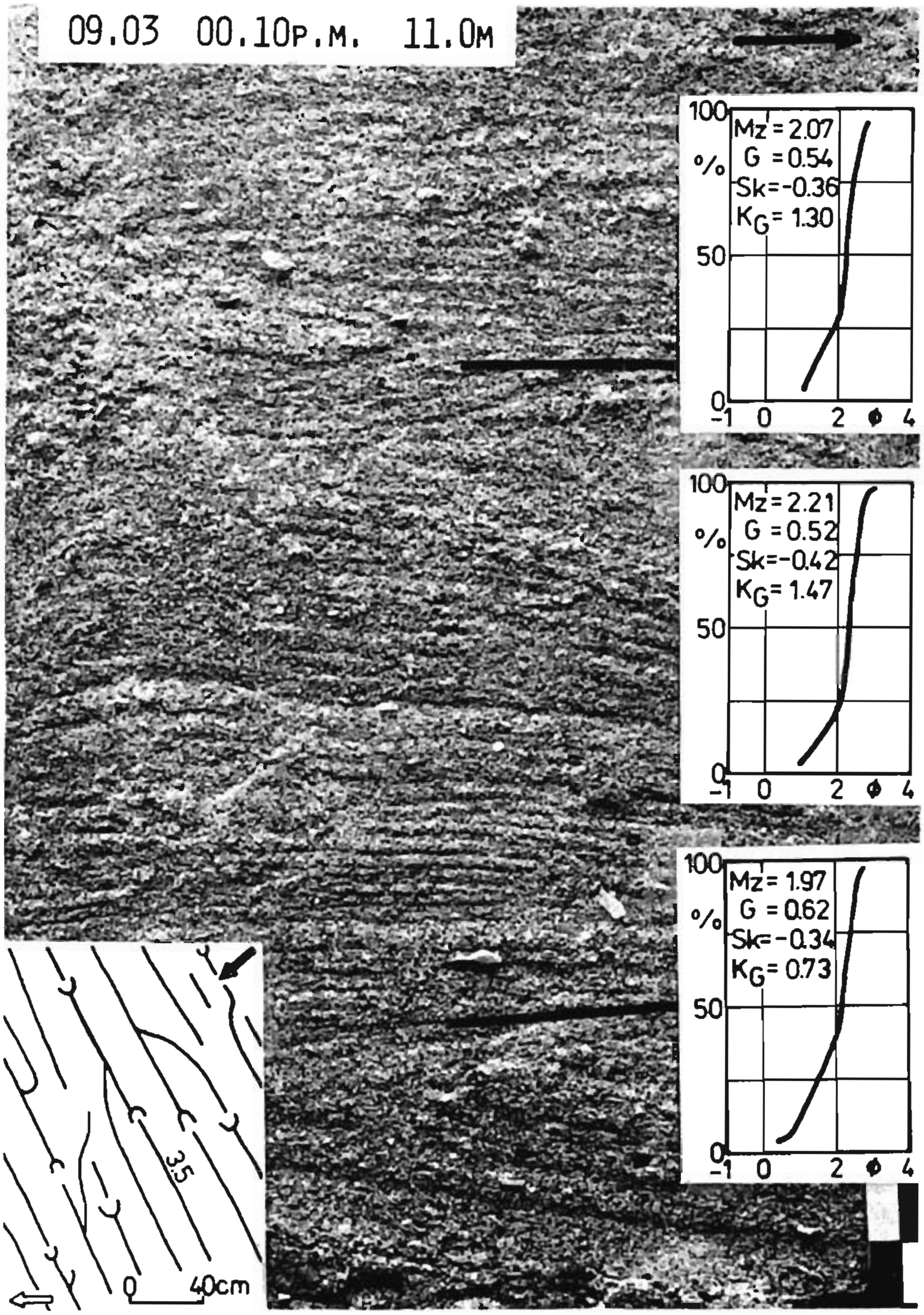
Sand cover with indistinct stratification, resting on clay composed of illite, smectite, montmorillonite, beidelite, ?siderite and organic substance



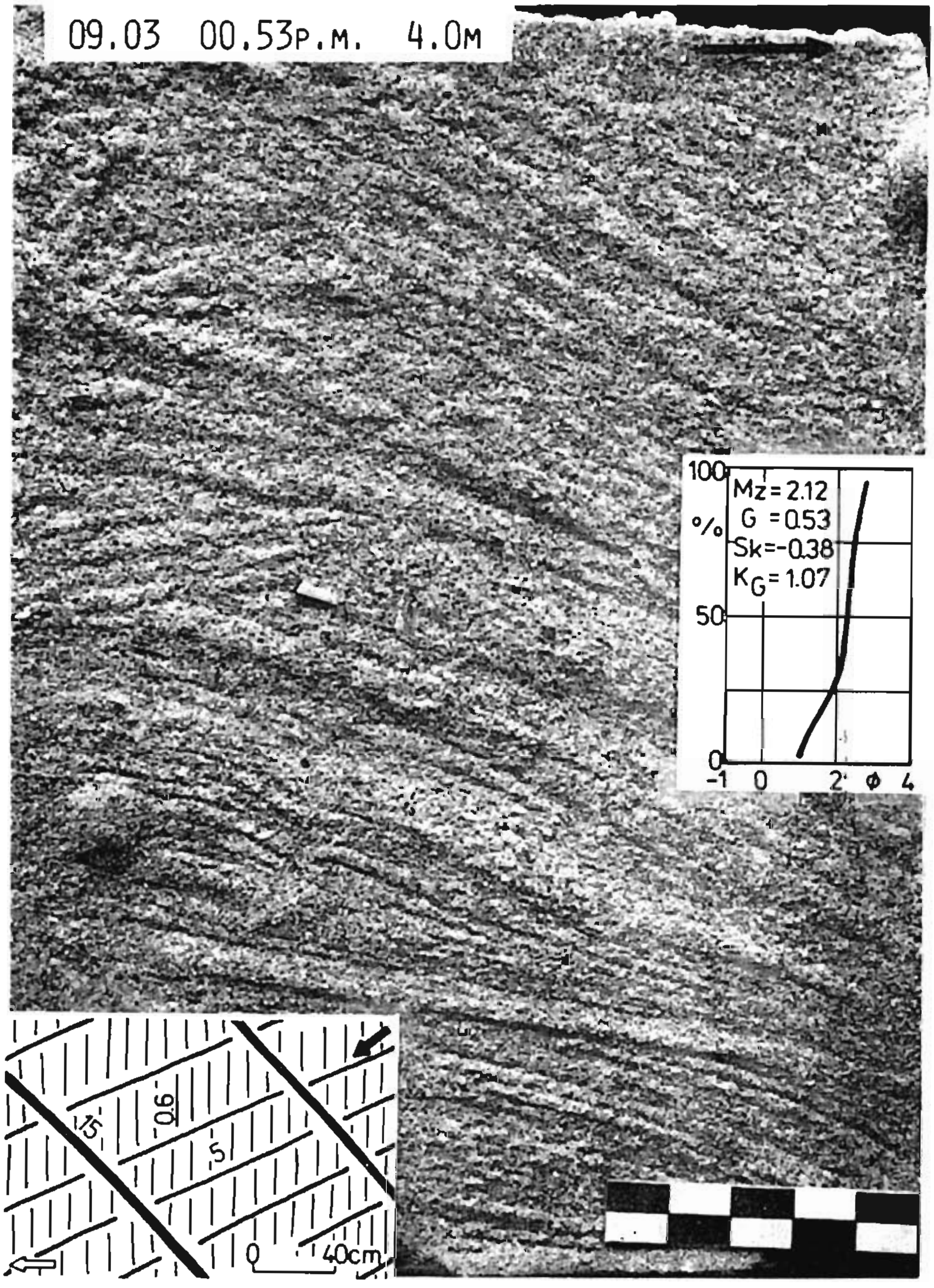
Horizontal (*bottom*), and small-scale ripple cross bedding heavily bioturbated (*center*); long escape burrow (*left*), and ?echinoid burrows (*right center*) are visible



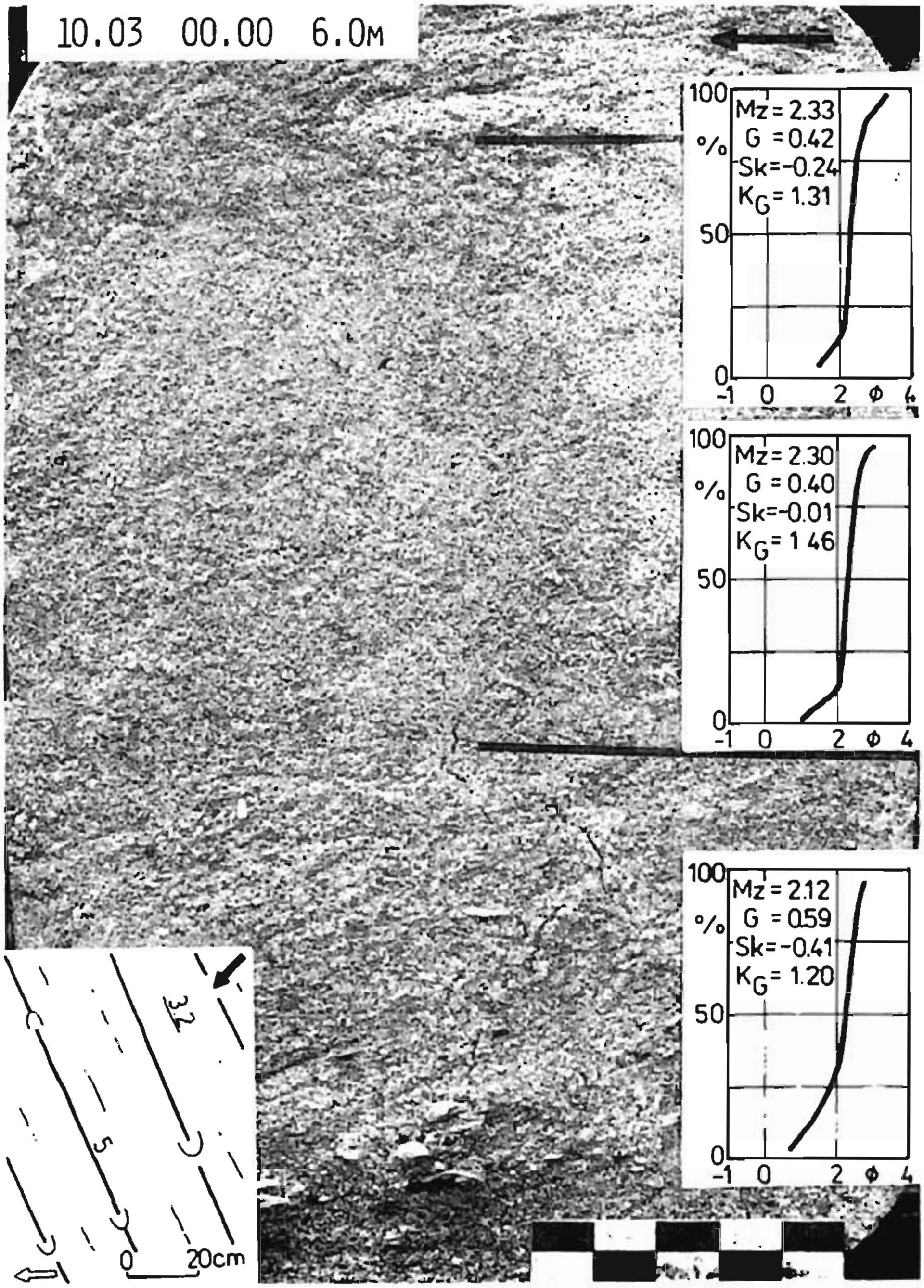
Heavily bioturbated cross-bedded sediment containing coarse grains, pebbles and shell detritus; a long escape burrow is visible (*at center*) and vague ripple cross bedding (*top*) linked with some minor crests recorded in the pattern scheme



Thin sets of the medium- or large-scale cross laminae with erosional boundaries and changing angles and directions of inclination, and small-scale ripple cross bedding *(top)*



Large- or medium-scale megaripple cross bedding with increasing inclination of cross laminae within the cross sets separated by erosional boundaries (*left center*); burrows disturb the bedding locally



Large- or medium-scale cross bedding, almost entirely bioturbated (*center*); small-scale cross bedding (*top*) corresponds to small ripples recorded in the pattern scheme depths, and vice versa. Similary in the zones protected from waving by the specific contour of the shoreline, bottom patterns characteristic of the deeper ones with a normal intensity of waving, and thus less complex in their drawing, were observed to come up.

In the northern part of Kioloa Bay where SE waving predominates, waving fails to be controlled by the shoreline, except for the area adjacent to Belowla Island; one could distinguish there the theer depth zones varying in their bottom patterns and bedding.

SHALLOW ZONE, 0-4 METRES DEEP *(PLS 1—10)*

This zone encompasses the area situated in the direct vicinity of the shoreline, in which bottom pattern includes beach bars and sand ridges and also vast shoals in places with rip currents, as well as sea bottom sloping down to 4 metres, lacking any clearcontoured bottom forms. The material here may be intensively entrained and relocated when passing along successive surfs, with some part remaining almost continuously in suspension.

Within the beach bars and the first sand ridge, which usually fails to be continuous near the shore, the large-scale cross bedding appear. They often vary in the inclination of cross laminae consistant with the inclination of the beach slope (Pls 1—2, 5, and 9—10) and slopes of the sand ridges (Pls 3—4 and 6—8). An increase in the inclination of cross laminae, as often observed, corresponds to the sand ridge an to the development of its slope (Pls 3, 6, and 9). Different angles of inclination can be observed for cross laminae in particular beach slopes, from almost horizontal (Pls 1—2, and 5) to much inclined (Pls 9—10), according to the stage of beach development, reflective or dissipative, and according to the place from which a sample was collcted. Convex cross lamina were present in the uppermost part of the beach slope, near the beach--bar top (Pl. 10), or at its bottom (Pl. 2), and also within the first sand ridge (Pls 3, 6, and 8). In its top part, characteristic are the cross sets with variable directions of inclination (Pls 3—4 and 7), often separated by erosional boundaries. Cross bedding is normally accentuated by the position of shell fragments and pebbles (Pls 2—4 and 6—10).

When advancing towards the sea from the first sand ridge the bottom often becomes flat with the water moving at a speed exceeding the limits decisive for the development of ripples, and the sand being transported in large quantities from place to place, thus forming horizontal laminae corresponding in their process of development to the second smooth phase.

Neither ripples as a bottom form, nor small-scale ripple cross bedding as observed in the samples, are characteristic of this entire coastal zone, in contrast to a similar zone of the lower-energy shores, like *e.g.* those of the tideless seas, to quote the southern Baltic (Rudowski 1963, 1970; Giżejewski & *al.* 1980), or the Bulgarian shoreline zone of the Black Sea (Giżejewski & *al.* 1982) as an example, in which ripples and the ripple cross bedding prove to be te distinguishing features.

Rip currents generally in the high-energy Australian coasts (Wright & *al.* 1978) have a far-reaching effect on the development of cross bedding and specific bottom form in the area under consideration. Observations carried out in the northern Kioloa Beach on 26[th] March have shown that the rip current speed in its axial part exceeds 1.7. m/sec. and that this has resulted in a wide erosional trough having developed 1.5 m deep in relation to the adjacent bottom. The trough serves as a channel for transporting sedimentary matter also in suspension with short-lasting irregular sand waves produced at time intervals. In the distal zone of the current extinction, the sedimentary matter was swallowed by the surf and carried towards the shore to develop there into extensive shoals, on both sides of the current. Their slopes grew quickly up towards the trough, and a little slowlier towards the shore. Large-scale cross beddings, with predominantly straightline cross laminae, developed on the slopes. When the slopes were approaching the zone of the rip current action, sedimentary material was again entrained by the current and this gave circulation of the matter symmetrical on both sides of the current, and reaching areas (several metres deep) over 150 m in width and more than 100 m longshore. Samples collected at the seaward end of the current-action zone hardly had any features differing from those in samples collected at the same depth, but in places where the rip currents were absent. The entrained sedimentary material might have been brought in its majority back to the shore where it produced the discussed shoals, and when deposited at the sea bottom it accumulated into the waving--generated bottom forms. It is hardly possible to identify sedimentary material carried by rip currents to the zone of their extinction, and by the same to identify ancient deposits developed in such places. The inclination of the cross laminae along the slopes of the trough produced by rip currents will be more or less perpendicular in relation to the current flow. The area in which the discussed rip-current mechanism operates, undergoes some shift during the tides, and so the sedimentary complex as described herein may be preserved no otherwise as only in residual forms.

MEDIUM ZONE, 4-15 METRES DEEP *(PLS 11—28)*

Among bottom patterns of this zone two megaripple systems dominate; mostly symmetrical, with somewhat rounded crests, crossing each other at an acute angle (Text-fig. 4b, c, d). Usually of the systems has larger crests, with greater crest-to-crest spacing. This is overlaid by smaller ripples, their orientation being consistent with the direction of wave propagation as observed. A pattern consisting of only one system of large crests with smaller ripples overlying them (*see* Text-fig. 4a), usual for the deeper zones, comes more seldom. Bottom patterns of that type were found to be present rather after longer periods of weak waving, or in the better protected zones (Pls 22—23 and 25—26). From the orientation of megaripple and ripple crests one could conclude that they had developed as a result of regional direction of waving superimposed on other waving due to local thermal breeze and other local factors, such as *e.g.* configuration of shoreline influencing wave climate and the direction of wave propagation.

Differentiation of bottom patterns in the zone leads to greater diversification of cross-bedding and its vertical sequence. In samples medium- or large-scale cross bedding and small-scale ripple cross bedding dominate

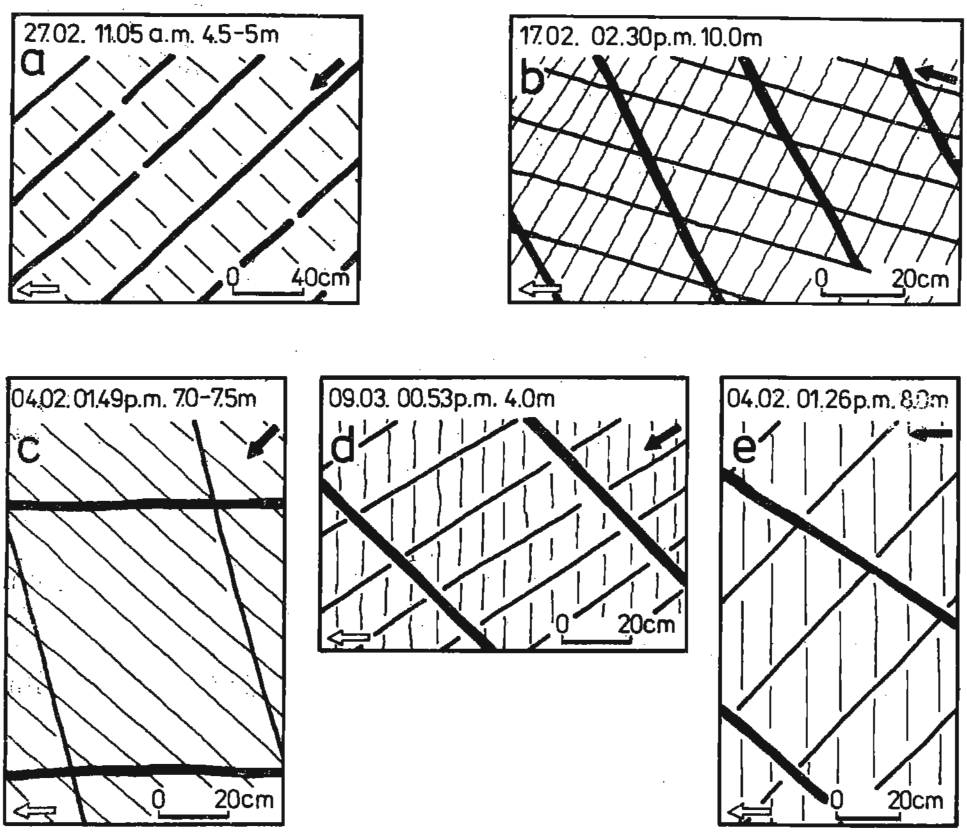


Fig. 4. Typical bottom patterns *(a-e)* for medium depths (4—15 m)

Top: data, time, depth. Solid arrow: direction of wave propagation, as observed. Blank arrow: direction of the shoreline

(Pls 11, 14, 17—18). Generally, angles of inclination of cross laminae tend to increase gradually within a cross set, thus developing into megaripple slopes (Pls 13, 16, 21, 27); the same process in the convex laminae leads to the build-up of uppermost parts of megaripples (Pls 14, 16, 21). More seldom, than in shallow zone, erosional boundaries (Pls 17, 19, 21) and marked differentiation in the material grain-size come up. A sample taken from a depth of 12.5 m (Pl. 25) and containing abnormally high percentage of shell fragments and pebbles, in all probability an example of the tempestite, is an exception to this rule. Occasionally, also disturbances due to material sliding the steep slopes of the megaripples could be observed. Universal is the presence of various burrows (Pls 13, 20, 24—27) and bioturbations obliterating contours of bedding (Pls 12, 22, 24—25, 28).

In a sample collected from a depth of 8 m (Pl. 23), in the northern part of Kioloa Bay (see Text-fig. 2), clay layer overlying essexite rests

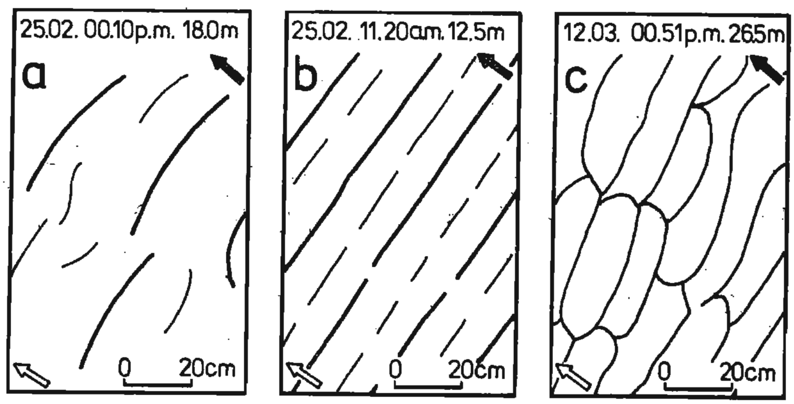


Fig. 5. Typical bottom patterns (*a—c*) for greater depths (15—30 m)
Top: data, time, depth. Solid arrow: direction of wave propagation, as observed. Blank arrow: direction of the shoreline

under a thin cover of sand. In the direction of Belowla Island there extends a zone free from sediment, containing essexites in form of rocky outcrops forming the sea bed. According to derivatographic analysis (*DTA* and *DTG*), the clay has been found to consist of illite, smectite, montmorillonite, beidelite, some ?siderite and an admixture of organic matter. They seem to be remnants of older deposits having little in common with the present-day conditions of sedimentation.

DEEP ZONE, 15-30 METRES DEEP (*PLS 29—35*)

Bottom patterns typical of these depths are featured by (Text-fig. 5a, b, c) usually symmetrical, hardly ever asymmetrical crests, frequently dismemberd, up to seventeen centimetres in height maximum, and with crest-to-crest spacing well below one metre. Their orientation indicates that they developed affected by regional SE direction of wave propagation. The ripples crossing each other are a proof that waving due to thermal breeze and local wave propagation phenomena must have been rather ineffective. The array of ripple crests varies from slightly curved larger crets (Pl. 29), accompanied by smaller and weak contoured younger forms (Pl. 32, and Text-fig. 5a), through a system of two-generation rectilinear crests (Pl. 31), both smaller and larger and smaller ones developing while in observation, up to a system of crests forming a kind of grid from the splitting and inflecting crests (Pls 29, 33—35; and Text-fig. 5c). The latter pattern was seen at smaller depths, after longer periods of weaker waving, stable in its direction.

From grain-size analysis it is evident that material is well selected with only a small percentage of coarser grains and pebbles. The shell detritus is smaller than in the shallower zones, although coarser shell fragments happen to occur within large-scale cross bedding (Pl. 31) with erosional boundaries connected in all probability with megaripples developed under heavy waving conditions. This zone is featured by the presence of small-scale ripple cross bedding overlying the large or medium-scale cross bedding (Pls 31, 33), and this corresponds to changing from a formation of megaripples to that of ripples, *i.e.* conditions of the fading-down waving. Relatively common is the presence of burrows (Pls 32—33), polychaete in particular, with the tracer marker sometimes preserved (Pl. 34).

Diversity of bottom patterns and the scale of cross bedding decreases with the depth, which fact seems to be a normal outcome of the relatively weaker wind-generated waving and propensity towards regional waving, more stable in its direction.

MERRY BEACH *(PLS 36—38)*

Merry Beach is situated in a bay right to the south of Kioloa Bay, opening to south-east and separated from Kioloa Bay by O'Hara Head with steep rock-face essexite shores, bounded from the south by rocky promontory Snapper Point and built of Permian clastic rock referred to as the Shoalhaven Group. The Beach (*see* Text-fig. 1) is comparatively short, narrow and confined to the mostinland shoreline of the bay. Observations were conducted along the profile at right angle to the shoreline, in the northern part of the bay, under relatively wavy conditions.

In the course of observations on March 11th a clear-contoured beach bar with steep slopes was found in the beach with a first sand ridge, discontinuous and undergoing constant transformations, due to being right in the state of development. From it the sea bottom kept on lowering. Down to a depth of some seventeen metres or so the sedimentary material continually changed its place, due to waving, and developed ripples with bifurcating crests consistent in their orientation with the direction of waving (Pls 36—38). There were moreover two systems of megaripples crossing each other at an acute angle (Pls 37—38), and yet another one located in the shallower zone (Pl. 34). In the well-selected sandy material one could hardly notice any pebbles, despite close presence of the abrasive rocky shores, or larger shell fragments.

In samples large-scale cross beddings with increasing inclination (Pls 36—37) as well as convex laminae (Pl. 36) of the developing megaripple slopes were dominating. A small-scale ripple bedding connected with ripples developing in the bottom and separated by an erosional boundary from the underlying large-scale cross bedding with slightly impressed burrows was revealed only in a sample collected from the depth of 8 m (Pl. 38).

As proved, bottom forms and beddings are here similar to those from Kioloa Bay, observed at similar depths despite another configuration of the shoreline.

DARK BEACH (*PLS 39—41*)

Dark Beach is a small sickle-shaped beach at the end of a narrow bay, opening towards south-east, with abrasive shores built of the Permian Shoalhaven Group and heavily folded and faulted Old Palaeozoic rocks. During observations on February 10th, under moderate waving conditions, a well-developed steep beach bar and a few ridges, constantly changing their shape and consisting chiefly of the Palaeozoic-rock pebbles from the nearby cliffs, were the main feature. In samples there were slightly marked, nearly horizontal, large-scale cross beddings corresponding to the upper part (Pl. 39), lower part (Pl. 40) and the base part Pl. 41) of the beach bar. Orientation of flat pebbles, at the base of slope in particular (Pl. 41, *bottom*), was noticeable in all samples. Domination of local material, similarly to adjacent Myrthle Beach, with no such material identified in other beaches showing similar configuration of the shoreline, as *e.g.* Oaky Beach, is one of the distinctive features of the Dark Beach sedimentary environment.

OAKY BEACH (*PLS 42—44*)

Oaky Beach is situated in a small bay opening towards the east and contoured by small promontories with cliffy shores built of folded and faulted Old Palaeozoic rocks (Cambrian?, Waggoonga Beds; Text-fig. 1).

Exploration of the Beach was conducted on 13[th] February under heavy waving.

A steep beach bar and a flat sand ridge (changing its shape when every new wave was passing over) were formed in this area. The bottom itself has a steep profile, sedimentary material undergoes a process of intensive relocation and no clear-cut bottom form can be revealed.

Sedimentary material proved to be well selected and deprived of any shell fragments or pebbles, despite close vicinity of the abrasive cliffs. Nearly horizontal beddings, corresponding to the flat beach slope, and the large-scale cross beddings developed on each slope in a way characteristic for the high-energy shoreline.

LONG BEACH *(PLS 45—48)*

Long Beach is situated in the southern coast of Batemans Bay (Text--fig. 1), its axis of extension being more or less perpendicular to the directon of regional waving. However the effects of this waving prove be rather limited due the specific configuration of the shoreline, due to the presence of various promontories, small islands and shallows. Clyde River is one of the factors infuencing the character of the local sedimentary environments, as it supplies certain quantities of material, mainly in suspension.

Exploration took place on February 13[th]; its beginnings happened during an ebb-time (Pl. 45). Waving was low, while in the beaches outside the Bay (in the North Head region) it was much stronger. At a depth of 2 m, under *LTL* conditions, the bottom consisted of fine-grained material with an admixture of mud and other substances easily passing into suspension, including organic matter chiefly resulted from life processes of numerous bottom dwellers, whose traces are preserved in the samples.

The Long Beach had mild slope with well-developed beach bars and beach lagoons behind, whose bottom was covered with ripples similar to those on the Baltic coast and not revealed in the investigated N.S.W. oceanic beaches. Ripples in the bottom were consistent in their orientation with the direction of waving (Pl. 45). Except fo weak-contoured sand ridges, parallel to the shoreline, neither ripples nor megaripples of an older generation could have been found here.

The presence of horizontal bedding was confirmed according to samples, with large-scale cross bedding revealed in the beach slope (Pl. 46) and in the slopes of sand ridges only. Small-scale-ripple cross bedding (Pl. 45) was also present. Generally, the bedding was obliterated by highly numerous bioturbations (Pls 45, 47—48), with the clearly perceivable trace fossils formed by the polychaetes (Pl. 46) and echinoids (Pl. 47). In two samples (Pls 47 and 48) an attention was focused on a layer with a large amount of bivalve shells and shell detritus, well different from the horizontally bedded fine-grain sediment, deposited in all probability at an increased energy of waving.

GENERAL CHARACTERISTICS OF THE GRAIN-SIZE DISTRIBUTION

Grain-size analysis was made using sieve set in which each sieve varied from the preceding one by about 0.5 phi. Findings cover analysis of the material from undistrurbed-structure samples are presented in the from of lognormal curves and four (Folk & Ward 1957) graphic grain parameters with indication to what part of the sample particular findings refer (*see* Text-fig. 3).

From analytical data it results that all sediments analysed, except for that coming from Dark Beach (Pls 39—41), represent a well or very well selected sand. Only the material from Long Beach (Pls 45—48) included an admixture of finer material. Grain-size distribution was effected by the admixture of shells and shell detritus present in the material, sometimes even quite significant and increasing the share of coarser fractions. Should the latter component be omitted, the sediment might have appeared more homogeneous in its grain size and better selected.

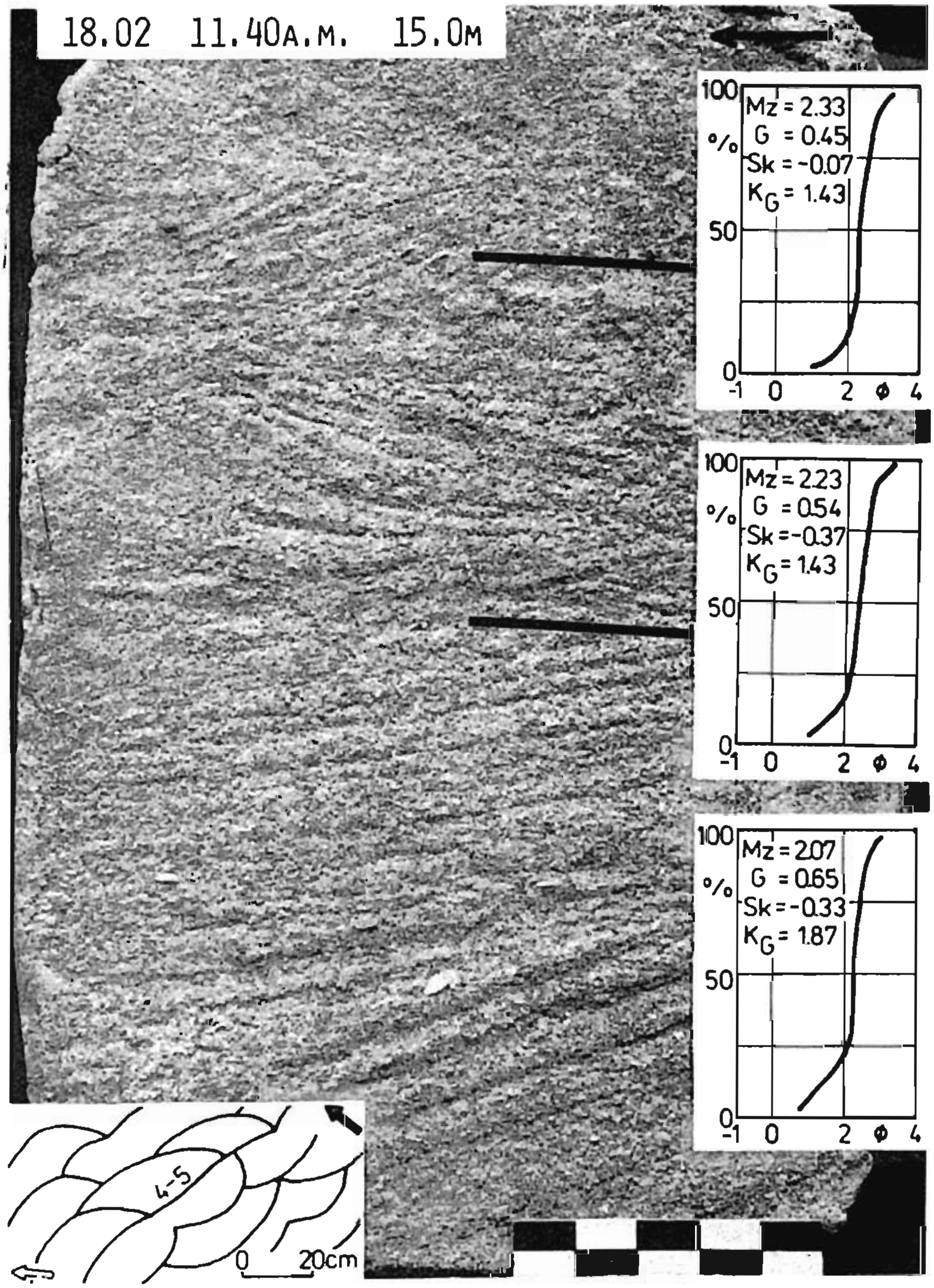
Median diameters (*Mz*) range from —0.33 to 3.17 phi without showing any more general tendency towards a change with depths. Median diameters for small-scale ripple cross bedding are included within a somewhat narrower interval than those of the large- or medium-scale cross beddings, in which *Mz* exhibits a slight decline in value with an increase in depth. The *Mz* for ripple cross bedding from greater depths are a little higher in their value than those for large-scale cross bedding of identical depth.

The standard deviation (*G*) values indicate that the sediments featured with very good or good selection, with no changes observed in the *G* value at an increase in the depth. For the ripple cross bedding these values are included within a somewhat narrower interval, compared with the large-scale cross bedding.

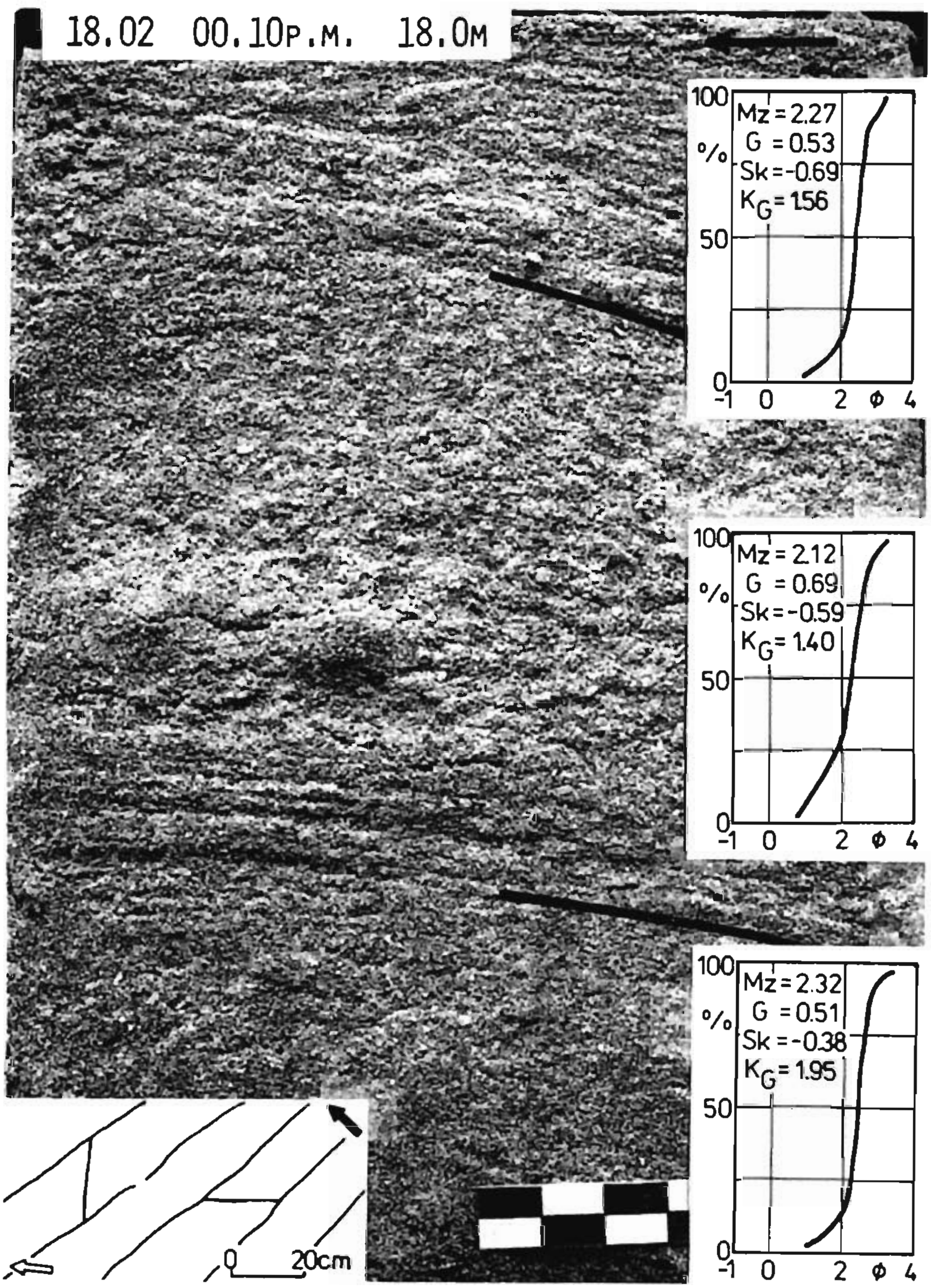
The skewness (*Sk*) values fall within a relatively narrow interval, with a preponderance for negative values, which fact ceases to be odd if an allowance is made for the high admixture of the comparatively coarse shell detritus and scarcity of pebbles. The latter does not apply to the Dark Beach areas.

The kurtosis (K_g) values indicate that the grain-size distribution curve appears more steep than in the case of normal distribution, with a wider interval of quantities for the large-scale cross bedding rather than for the ripple cross bedding, and a weak tendency observed towards a certain growth in their value with an increase of the depth.

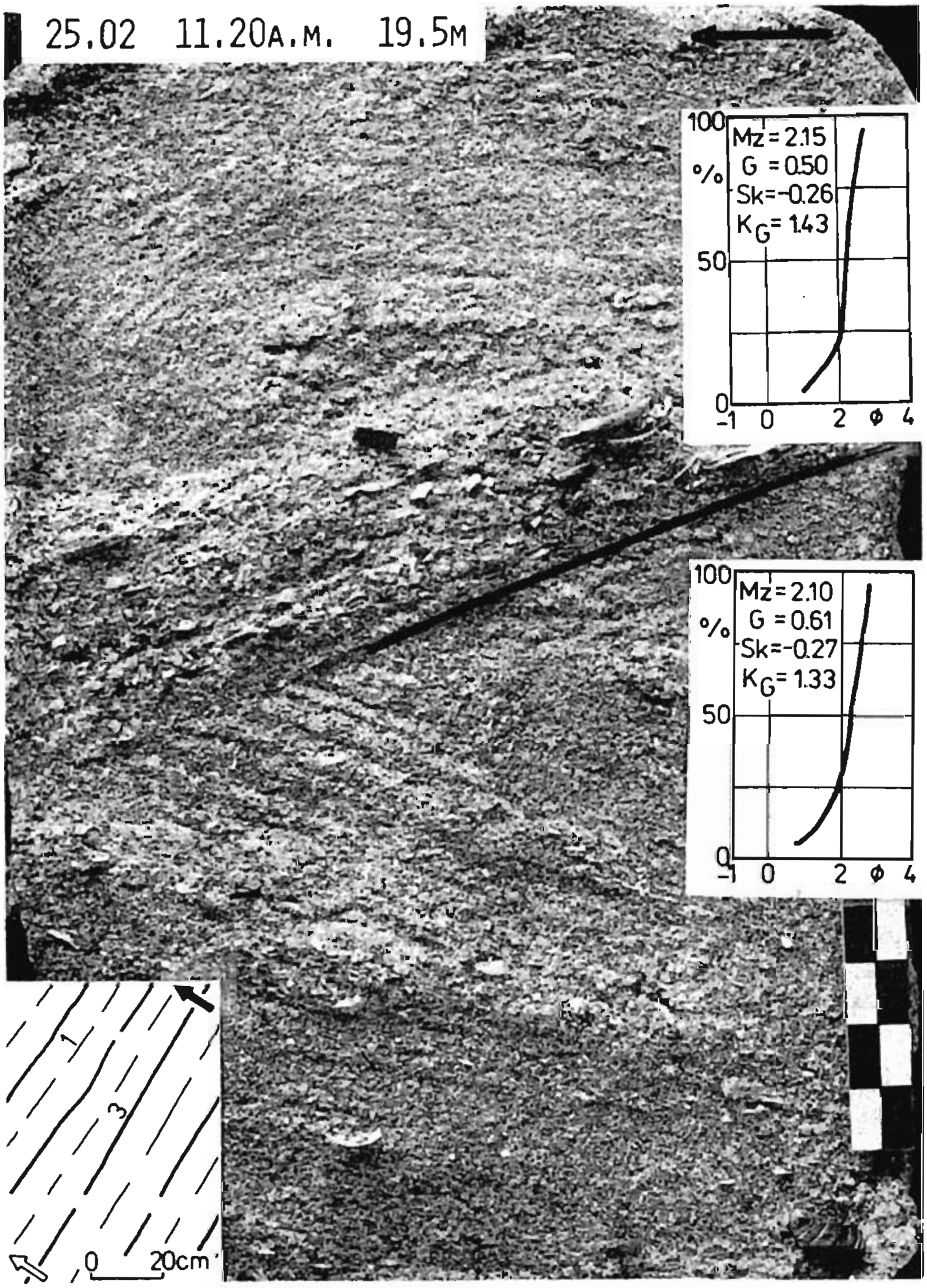
The *Mz*/*G* and *Sk*/*G* relations (Friedman 1961) easily go into the fields of the oceanic beach sediments. As it will be seen, grain-size distribution and grain-size parameters point to their high maturity without representing any substantial or unmistakable indicators of the environment, in a degree recognized for the Southern Baltic and Black Sea shorezones (Czapkowski & *al.* 1980, Merta 1982).



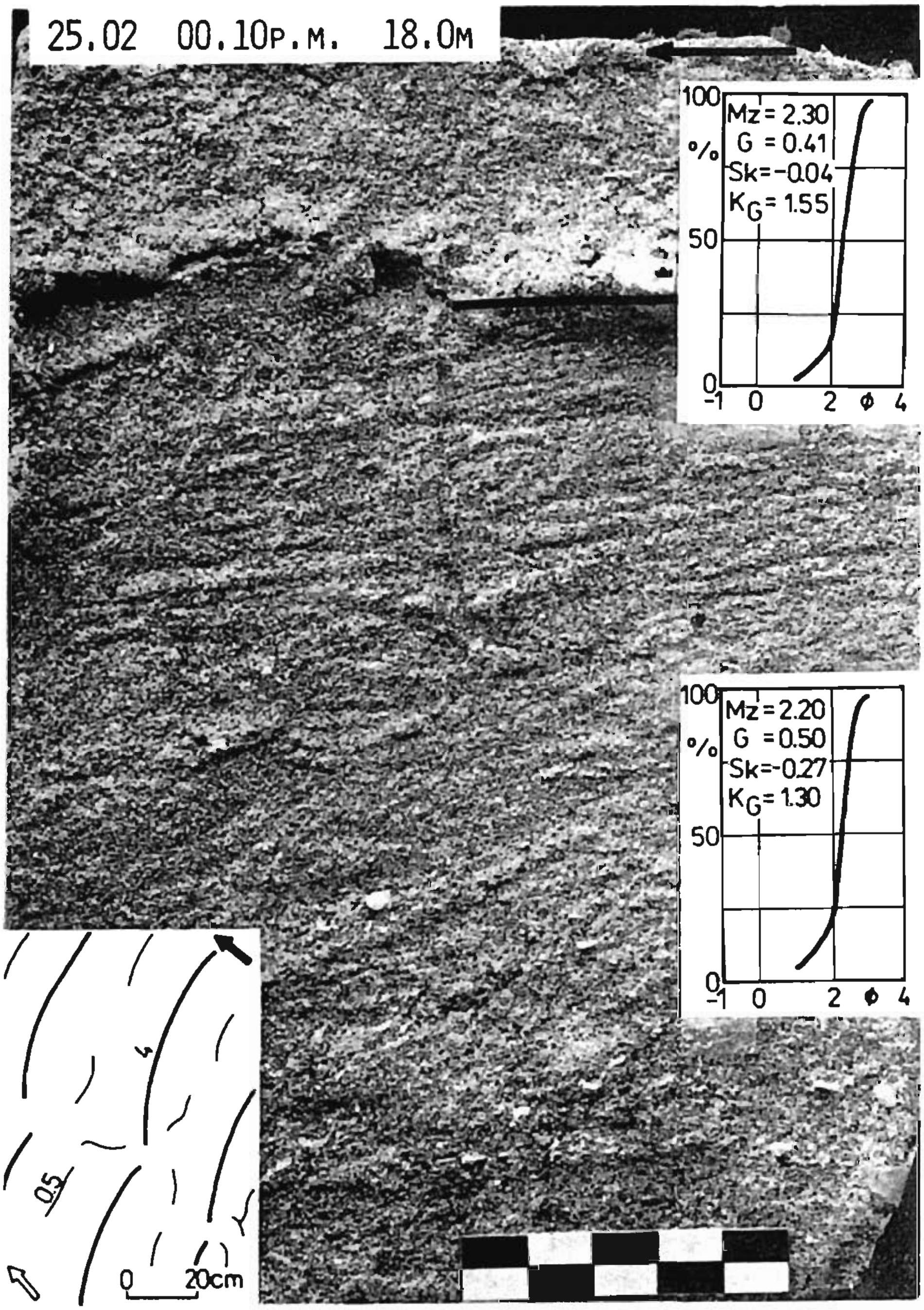
Large- or medium-scale megaripple cross bedding with decreasing inclination of cross laminae, and small-scale ripple cross bedding *(top)* corresponding to the crescentic crests of the ripples recorded in the pattern scheme



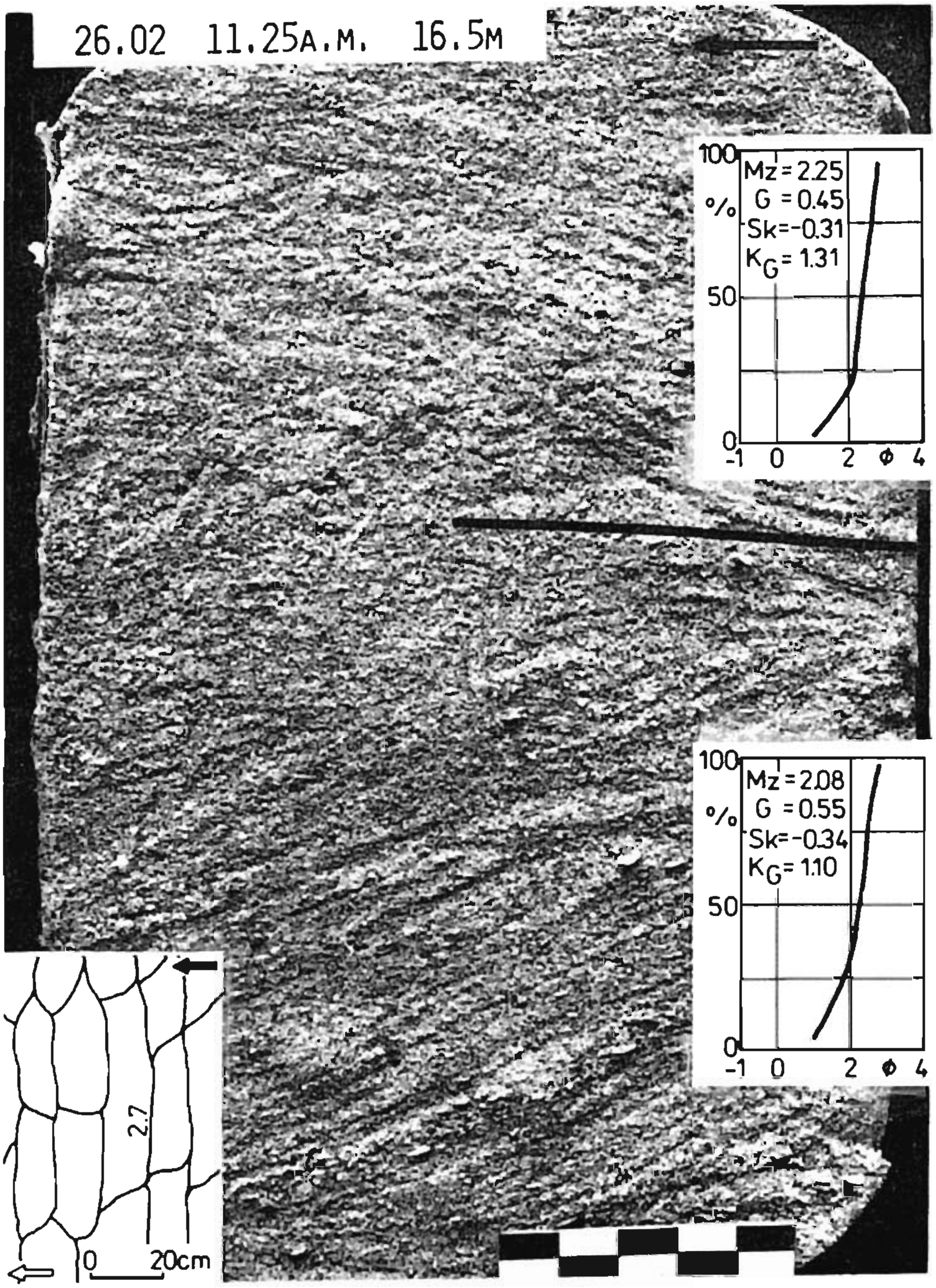
Large- or medium-scale megaripple cross bedding with slowly increasing inclination of cross laminae, heavily bioturbated (*center*), and small-scale ripple cross bedding (*top*) corresponding to ripples recorded in the pattern scheme



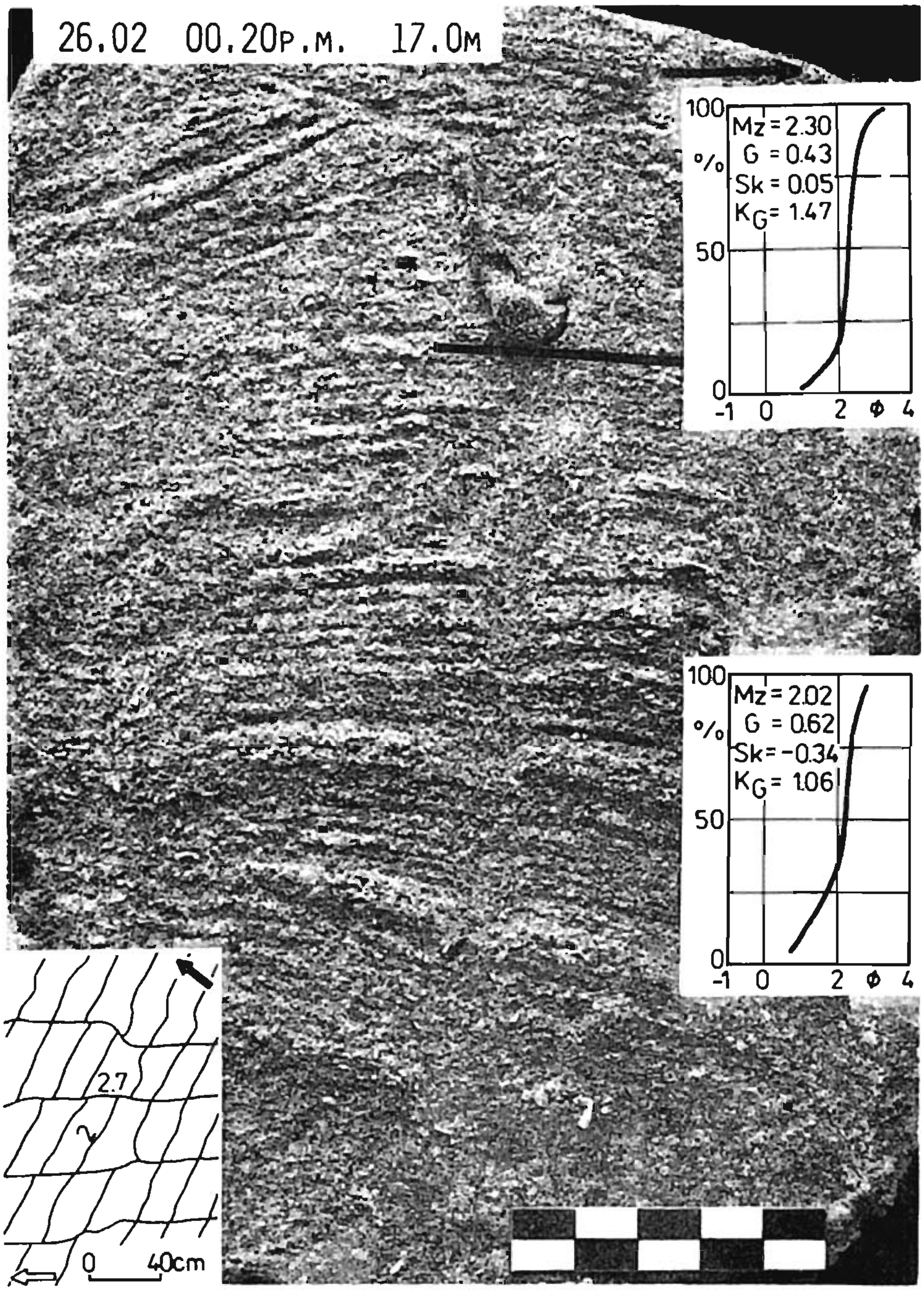
Two cross sets of large- or medium-scale megaripple cross bedding separated by an erosional boundary, and small-scale ripple cross bedding *(top)* corresponding to small ripples on the surface of megaripples (as recorded in the pattern scheme)



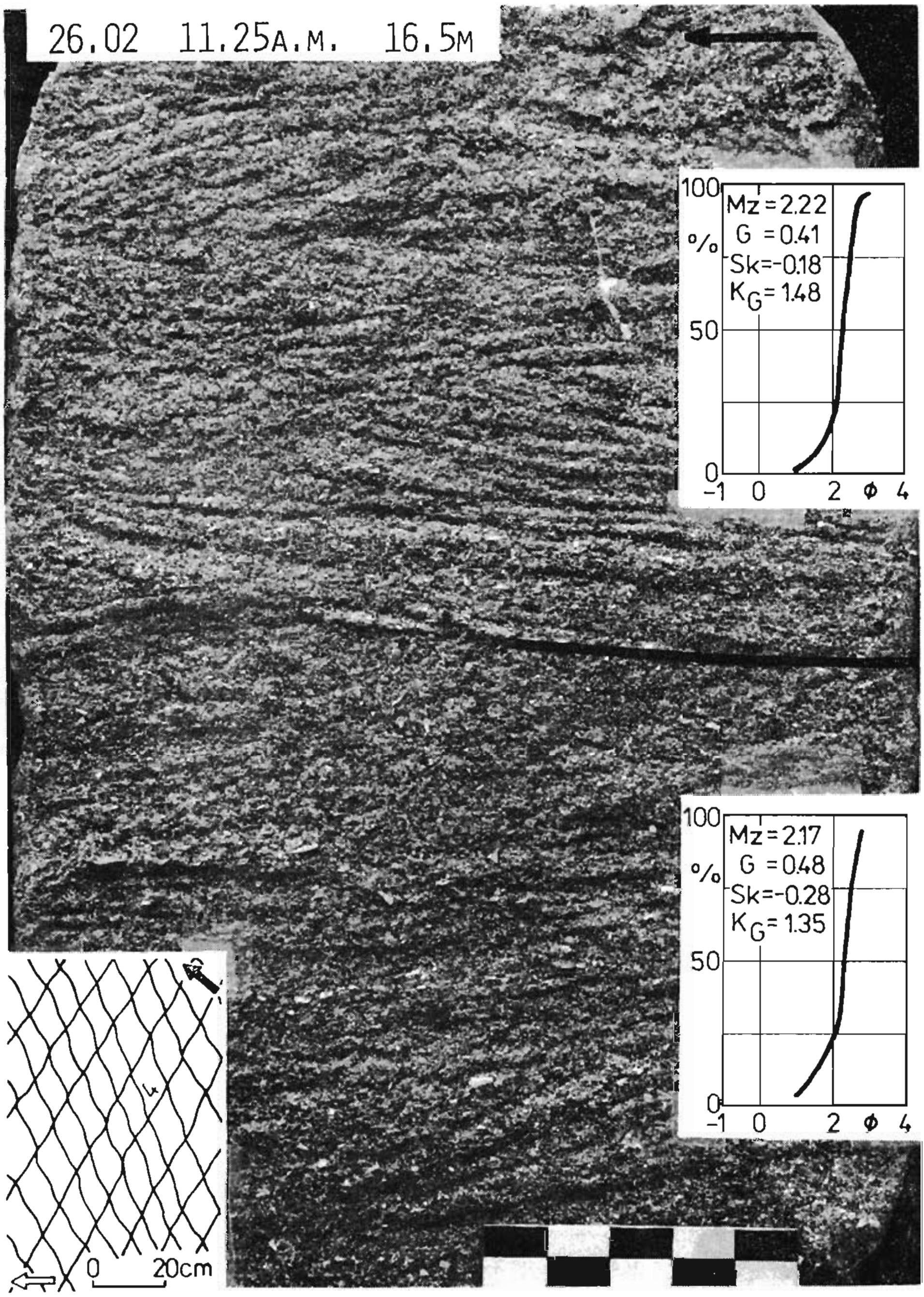
Several small- and medium-scale ripple and megaripple cross bedding and a long escape burrow *(center)* reaching the top surface of the sediment



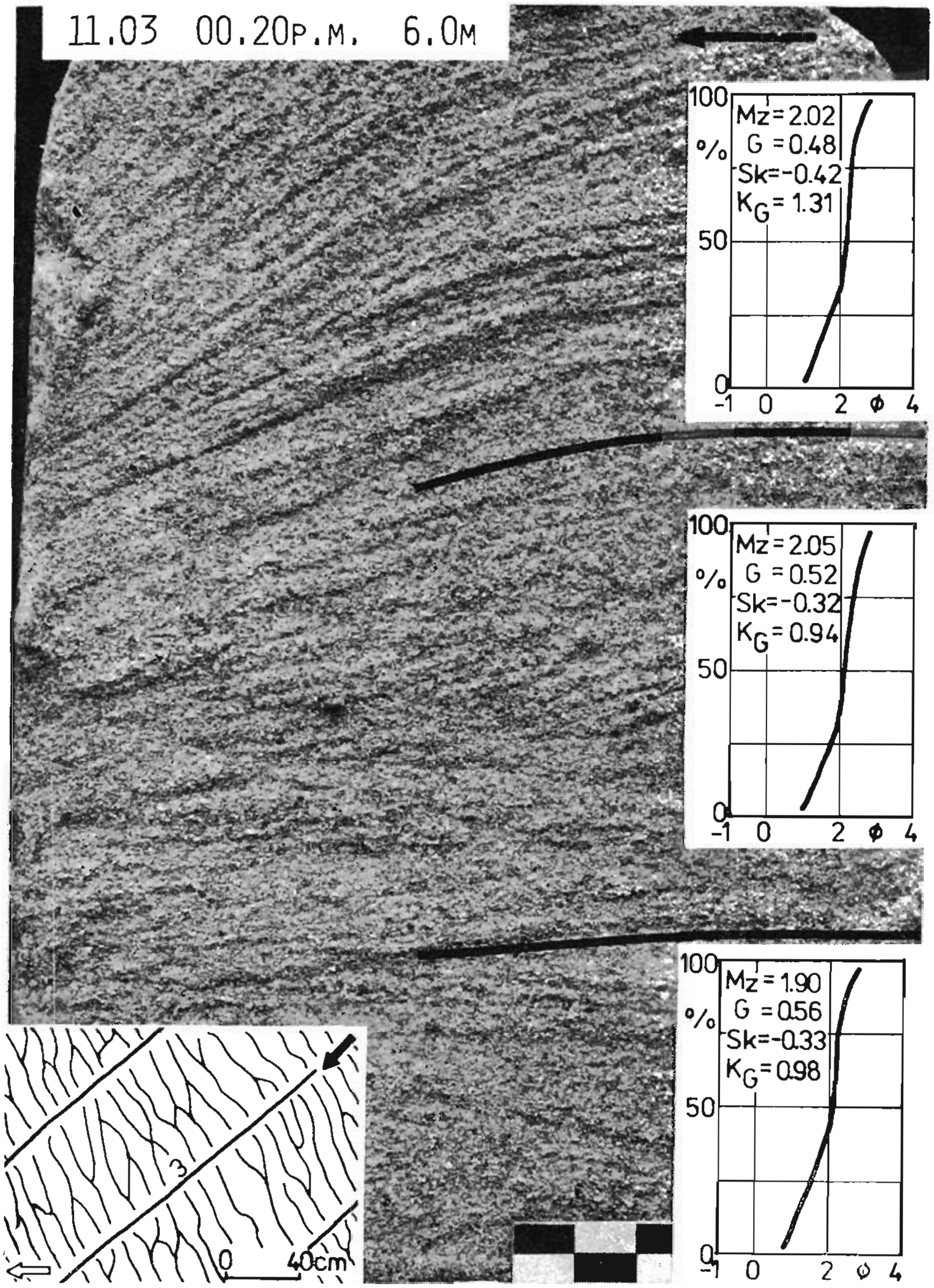
Large- and/or medium-scale cross bedding *(bottom)* and small-scale ripple cross bedding *(top)*; some escape and other burrows visible in the lower part of the sample



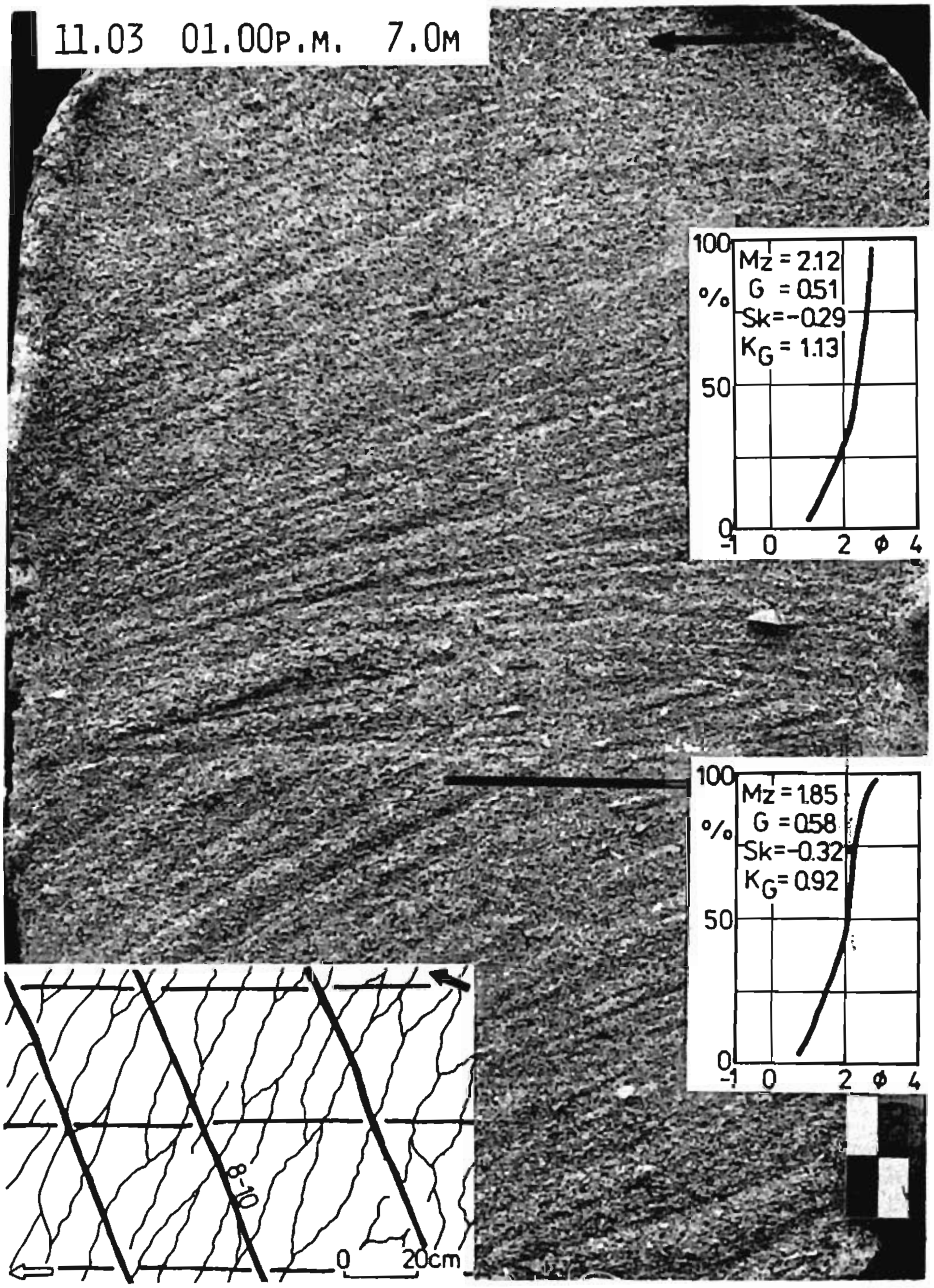
Large- or medium-scale megaripple cross bedding and small-scale ripple cross bedding *(top)*; a long escape burrow with the polychaete preserved is visible



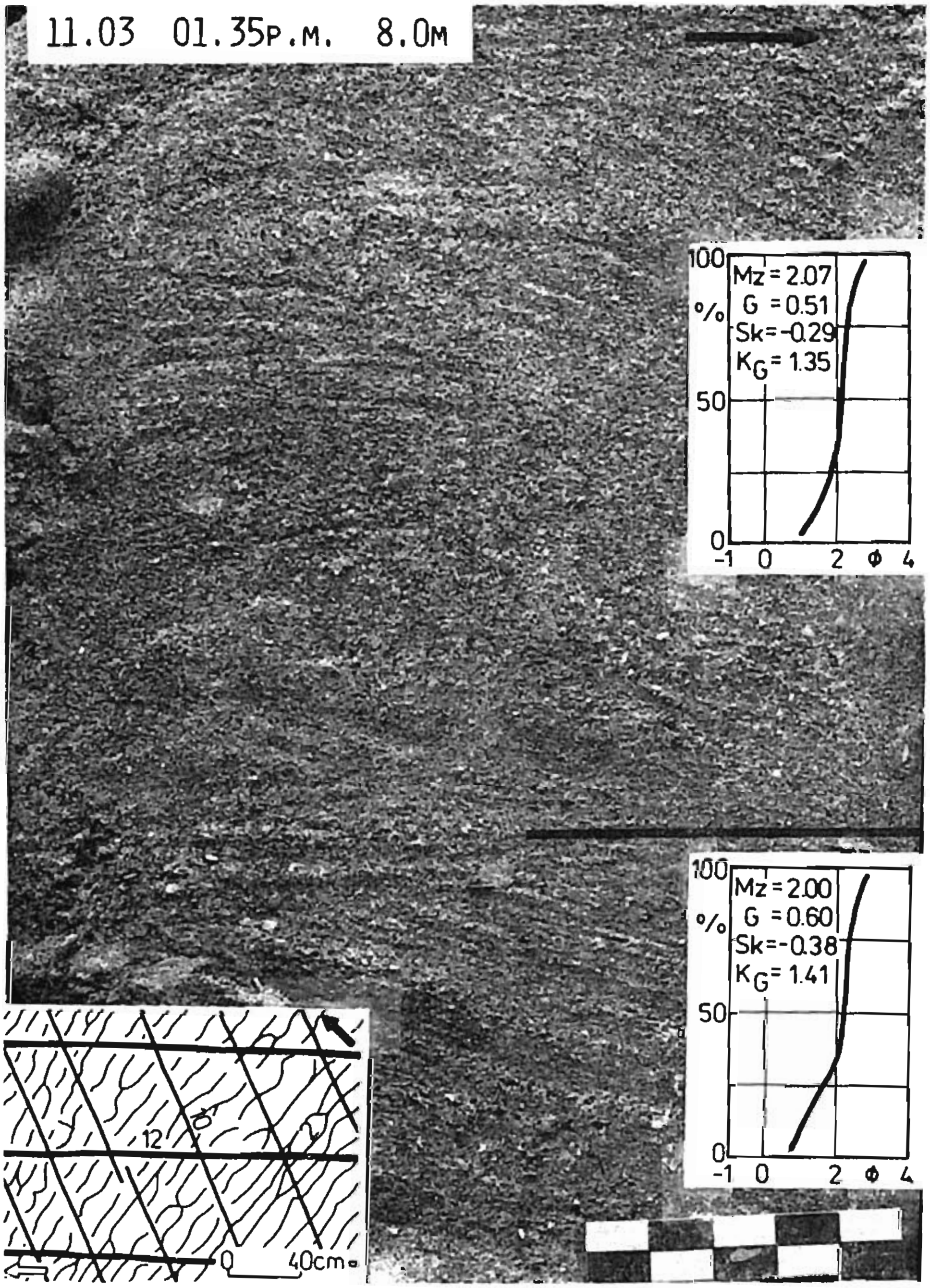
Medium- or large-scale cross bedding with some burrows *(bottom)*, and small-scale ripple cross bedding *(top)*



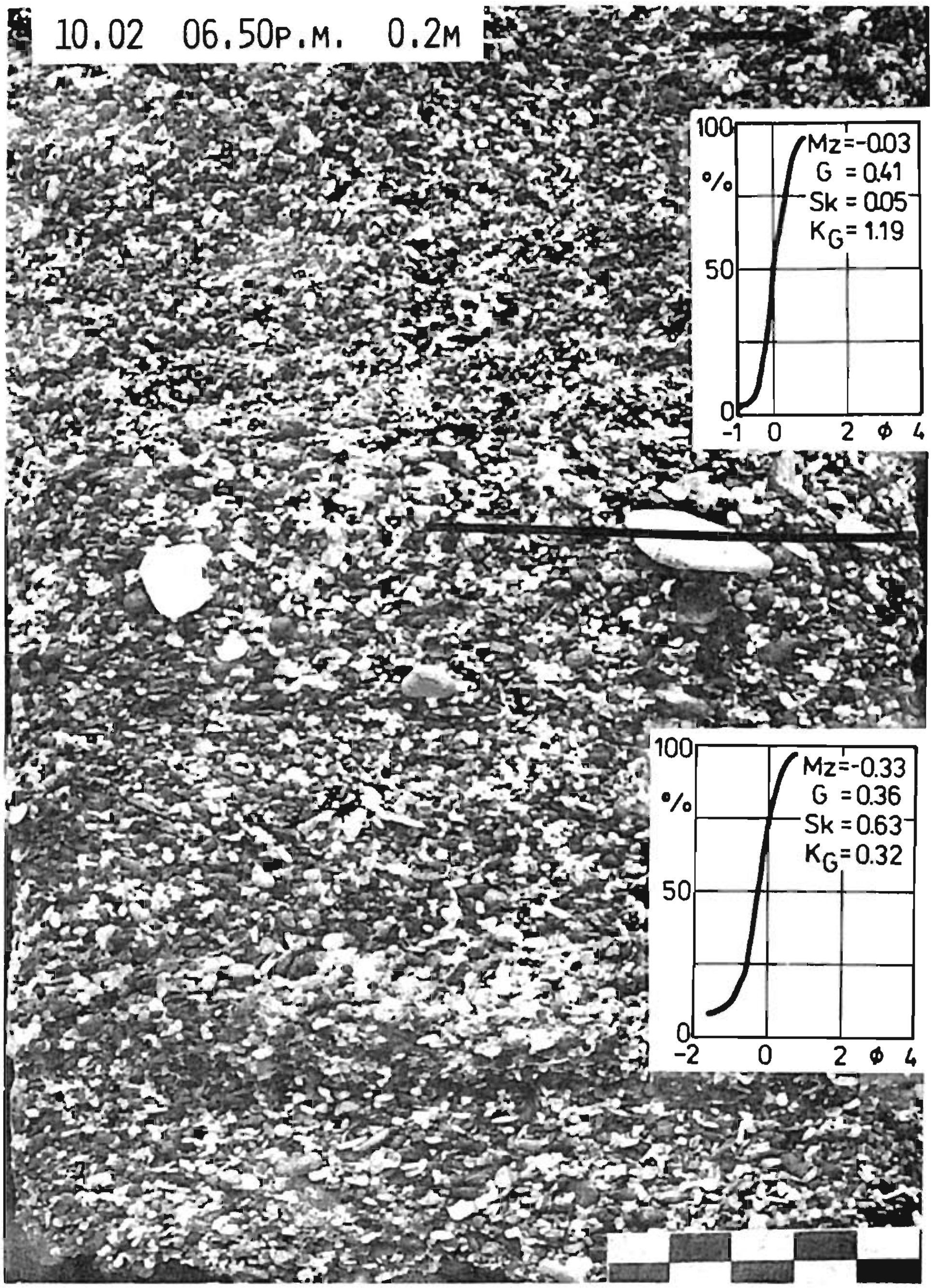
Large- or medium-scale megaripple cross bedding with small and varying inclination and with increasing inclination of convex cross laminae in the upper cross set, corresponding to the rising slope of the megaripple; sample yields no traces of cross bedding connected with the ripples recorded in the pattern scheme



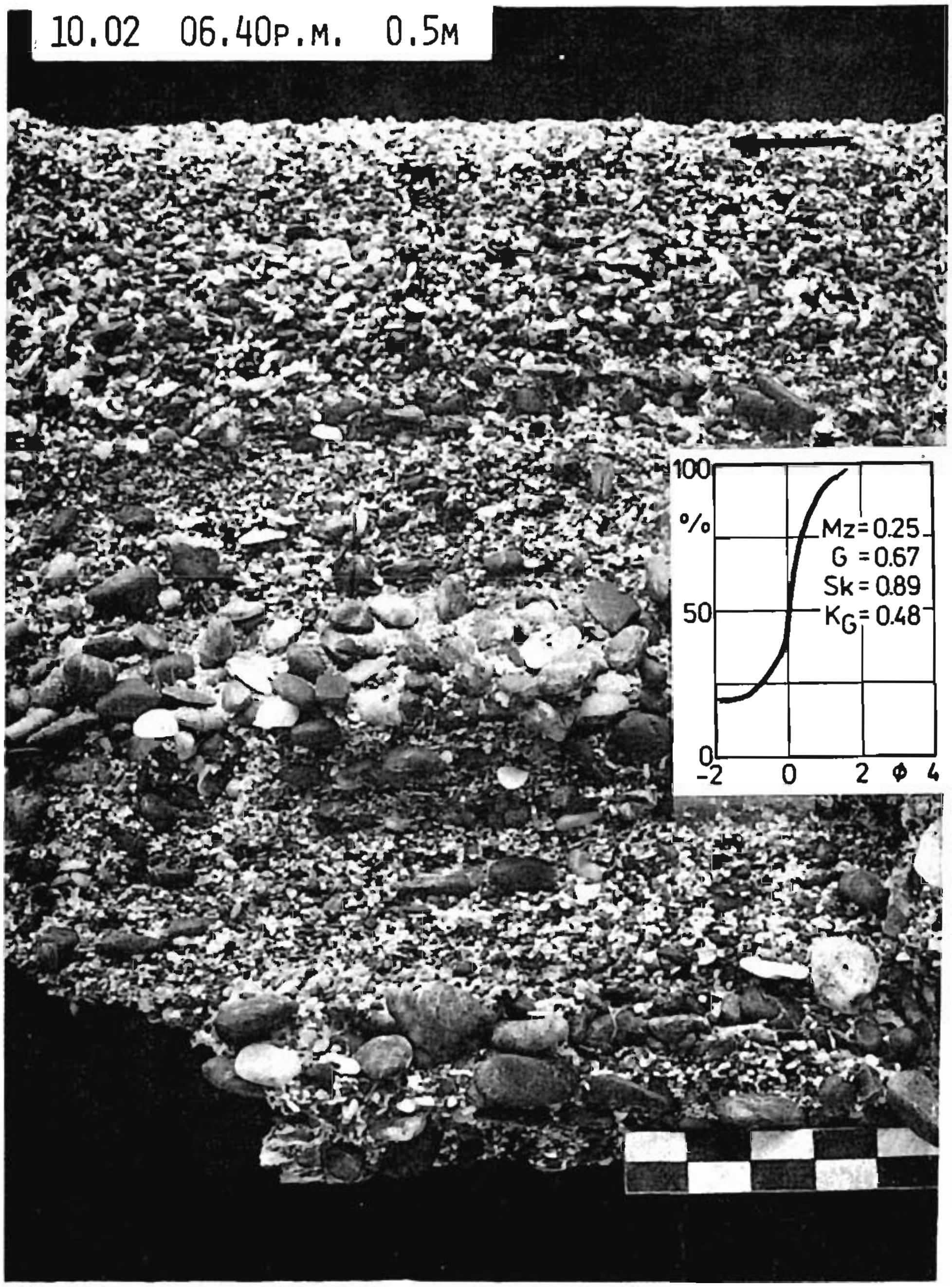
Two cross sets of large-scale megaripple cross bedding separated by an erosional boundary and showing increasing inclination of cross laminae in the upper set, corresponding to the rising slope of the megaripple



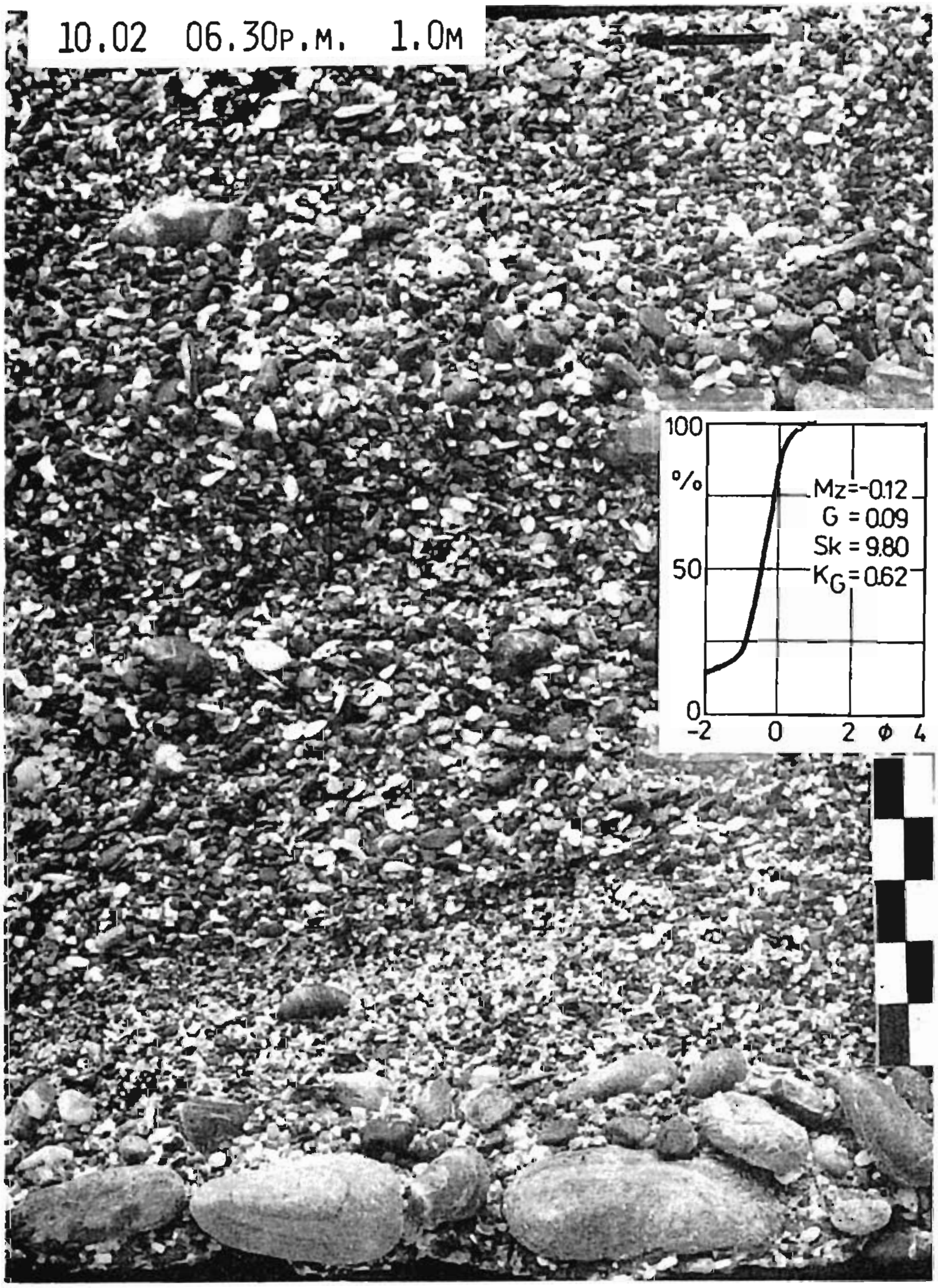
Large- or medium-scale megaripple cross bedding with an erosional boundary (*bottom*), and small-scale ripple cross bedding disturbed by sporadic burrows (*top*)



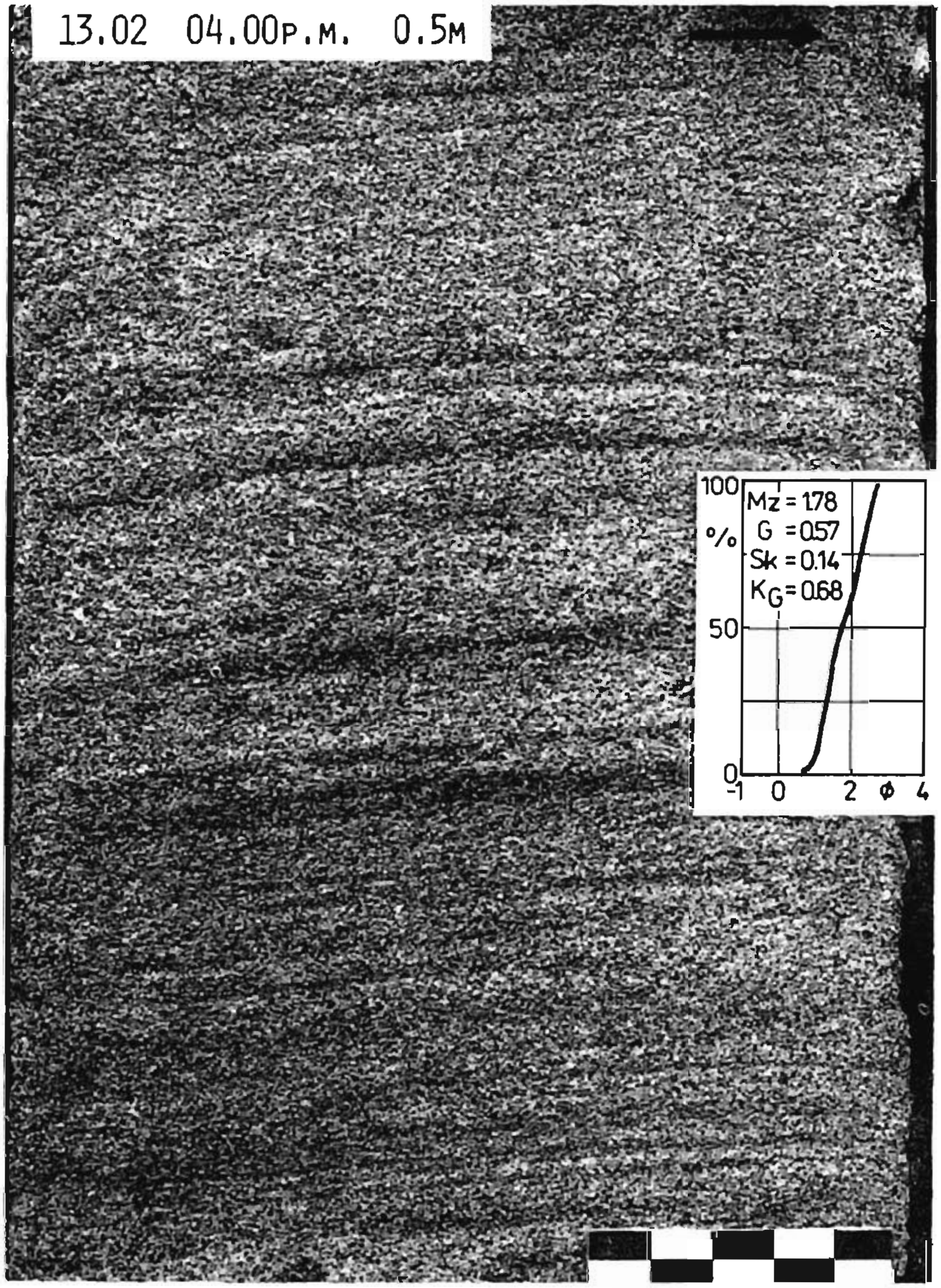
Vague, nearly horizontal or large-scale cross bedding in coarse sediment of the upper part of the low-inclined beach bar



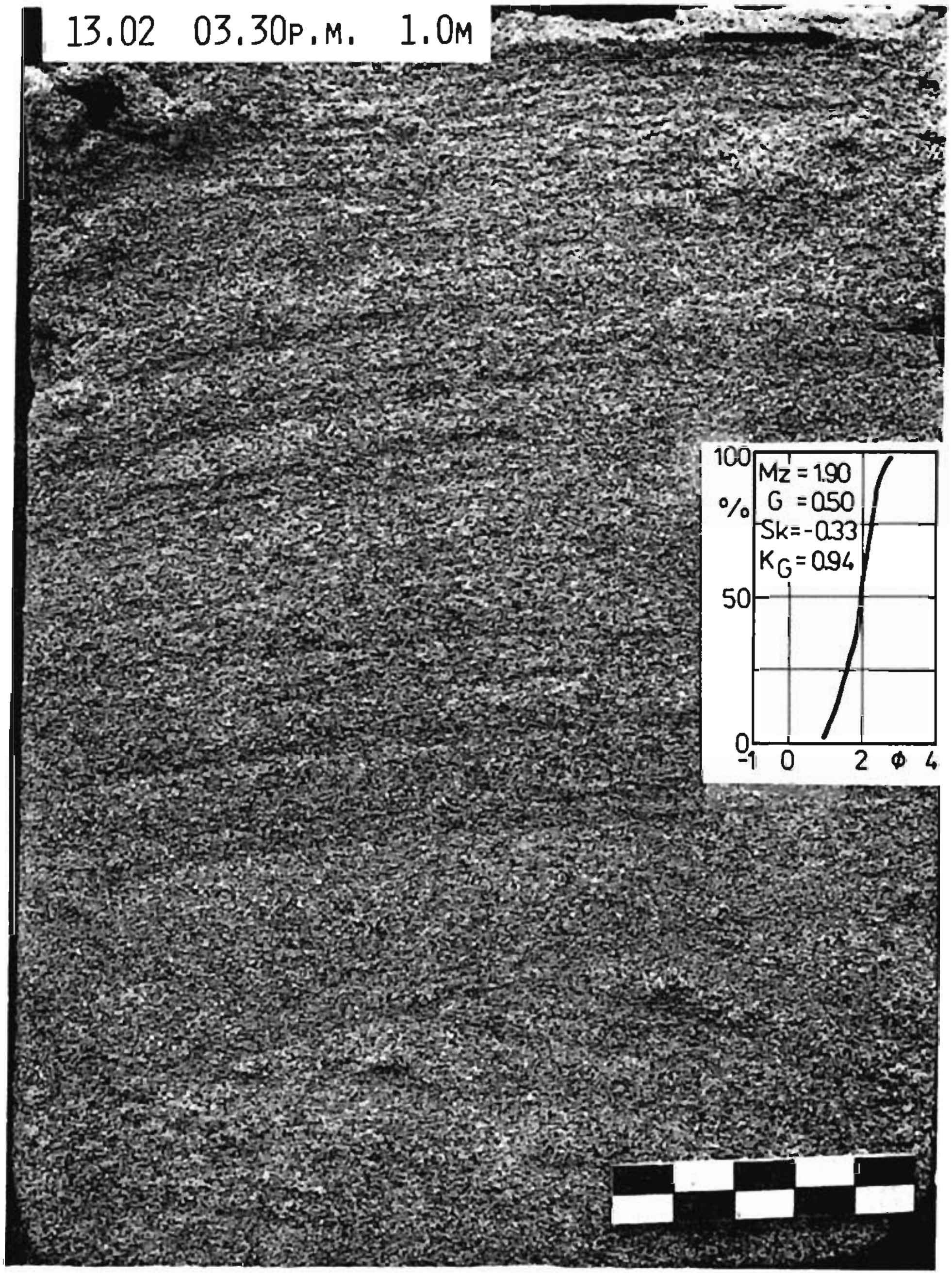
Nearly horizontal or large-scale cross bedding in gravel sediment of the lower part of the beach slope; orientation of pebbles and shell fragments is well visible



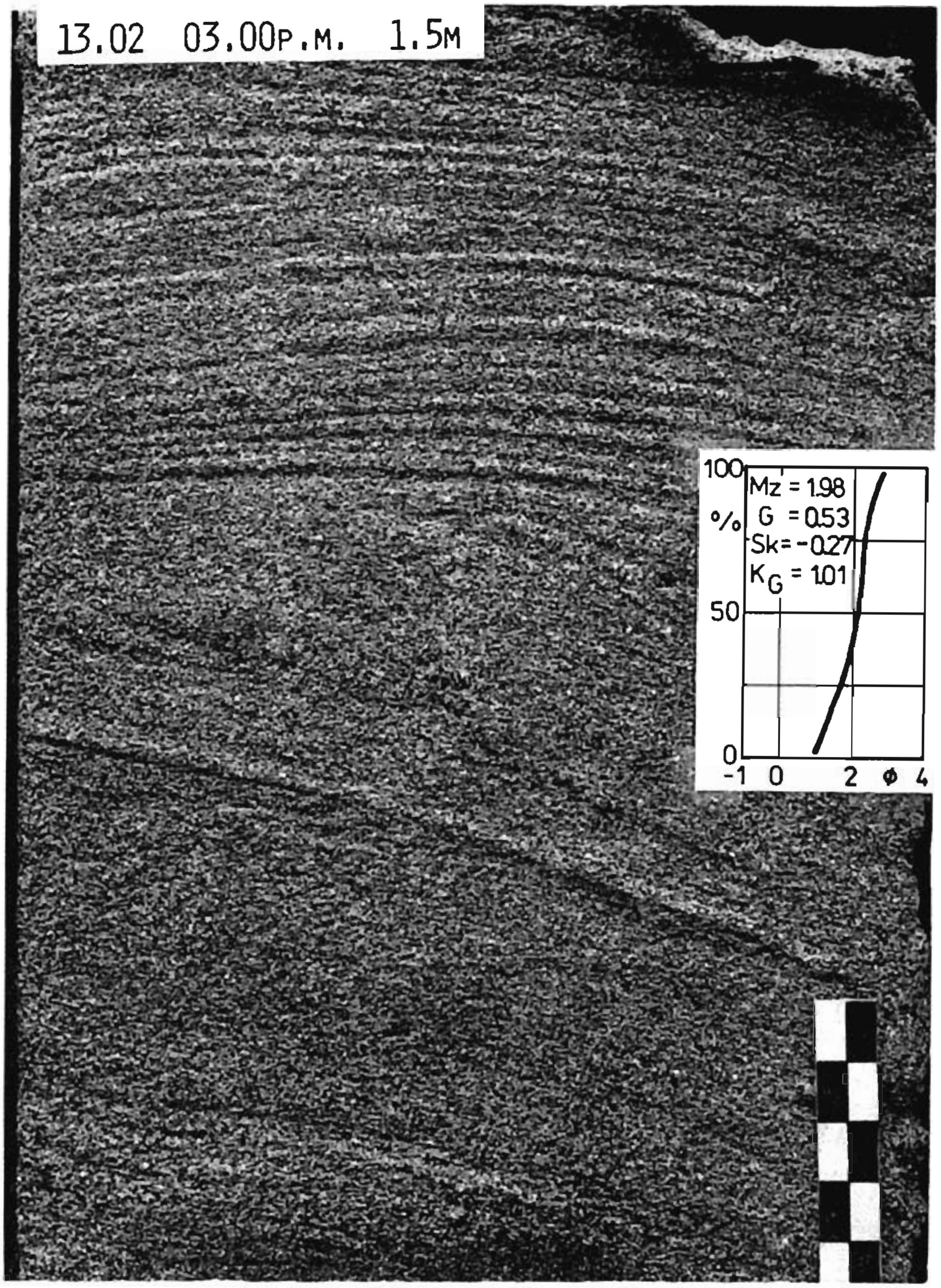
Slightly inclined bedding (flat pebbles are oriented) in the sample collected from the base of the beach slope



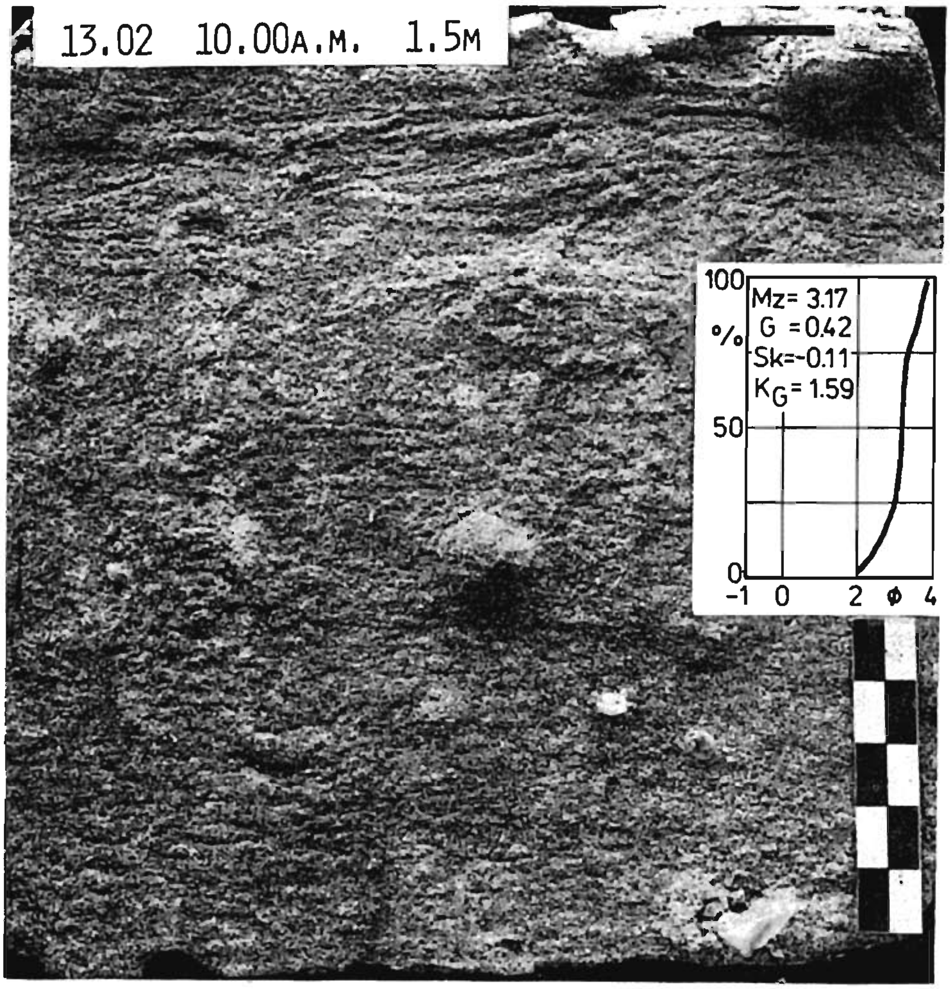
Low-angle cross bedding in a sample collected from the central part of the beach slope

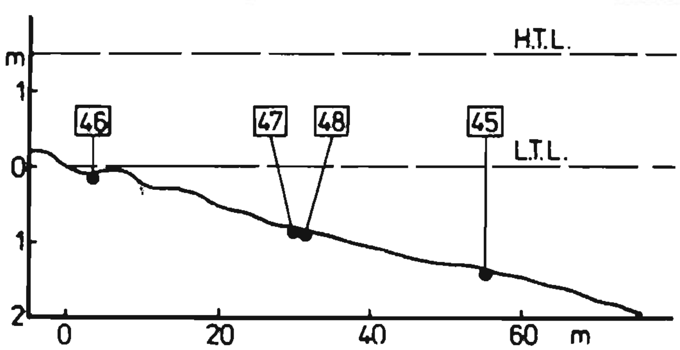


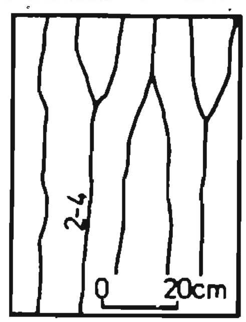
Two sets of large-scale cross bedding; the upper set corresponds to the beach slope



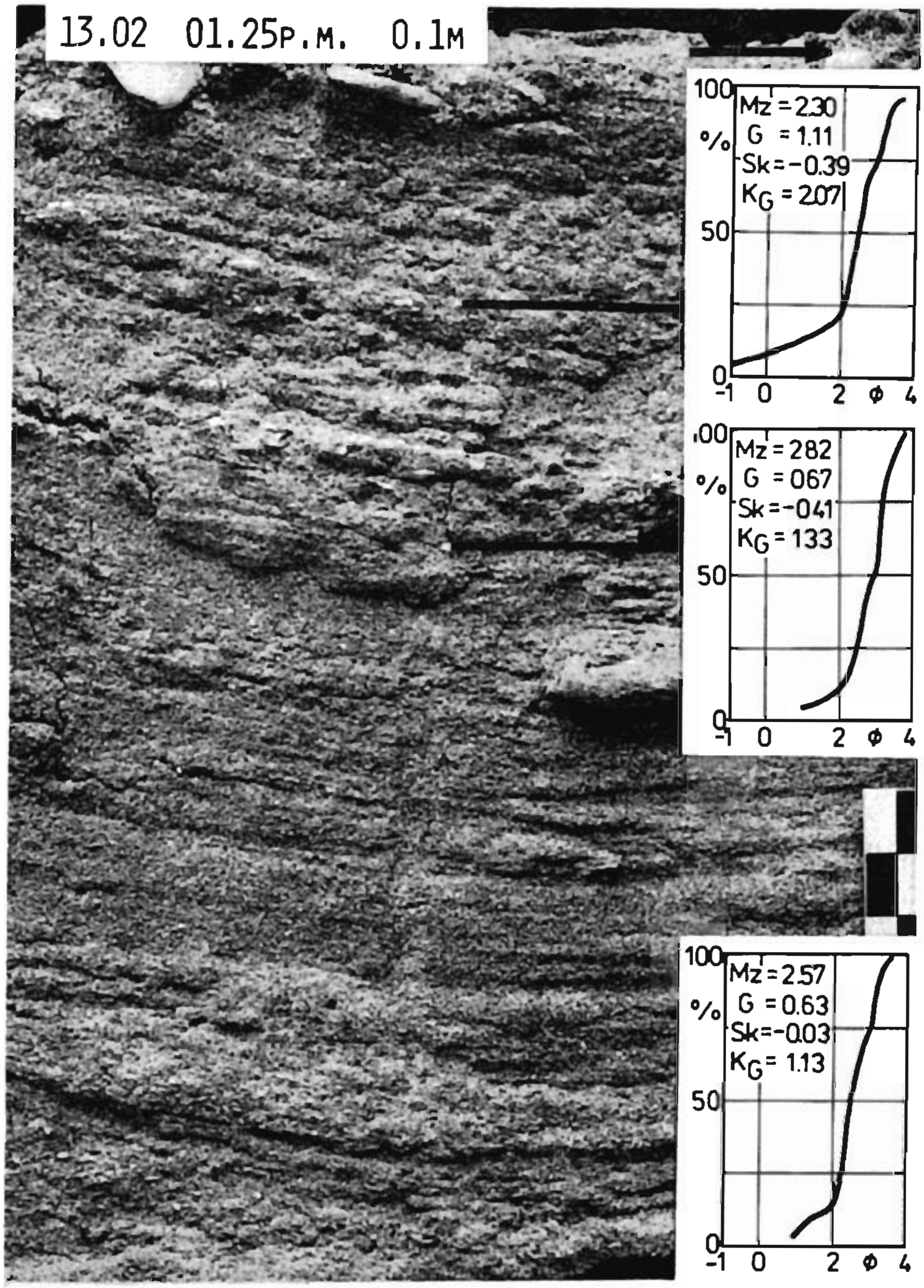
Two large-scale sets with cross bedding; the lower set corresponds to the landward slope of the first sand ridge, and the upper one to an almost flat surface of the landward slope of the successive sand ridge



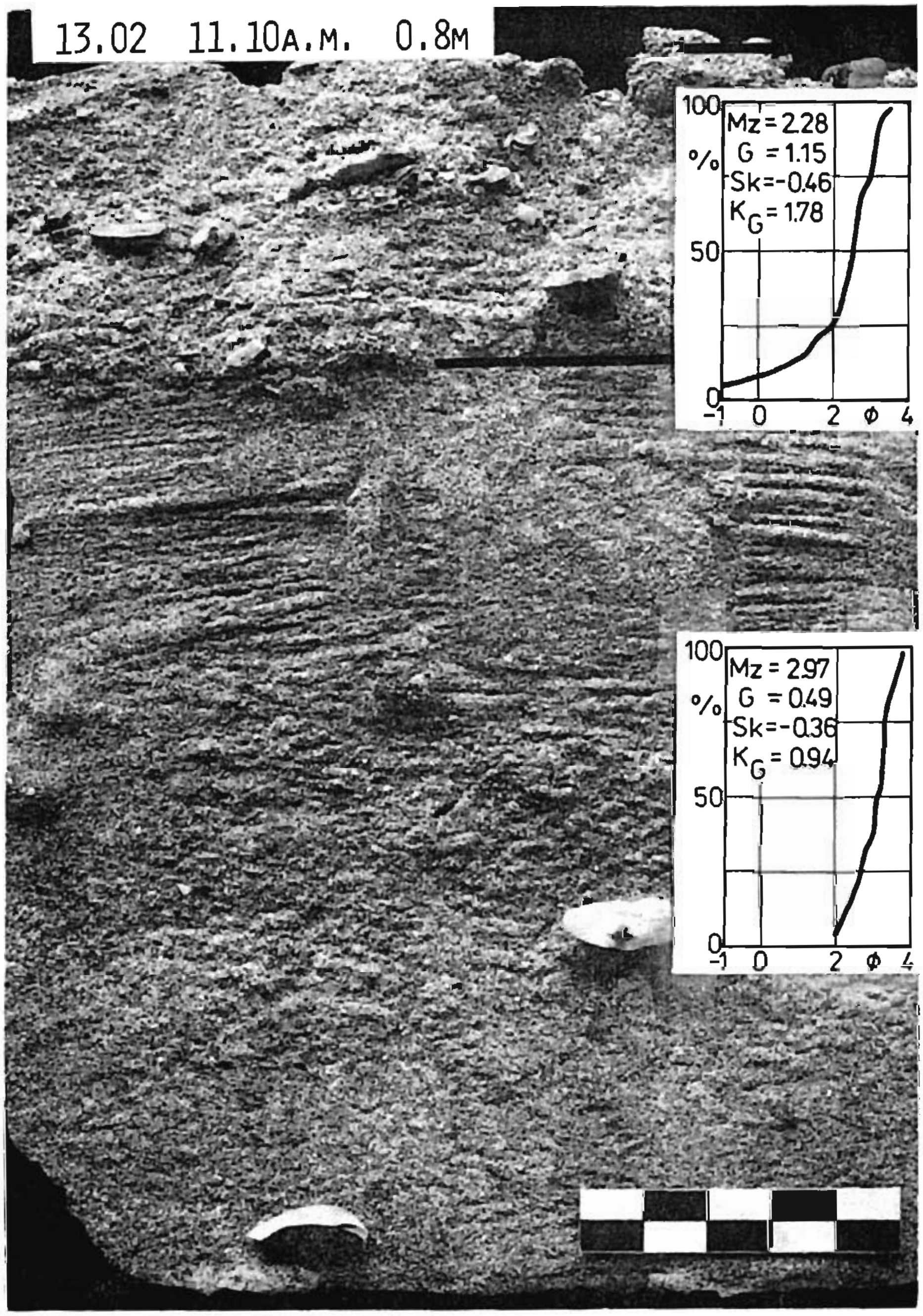




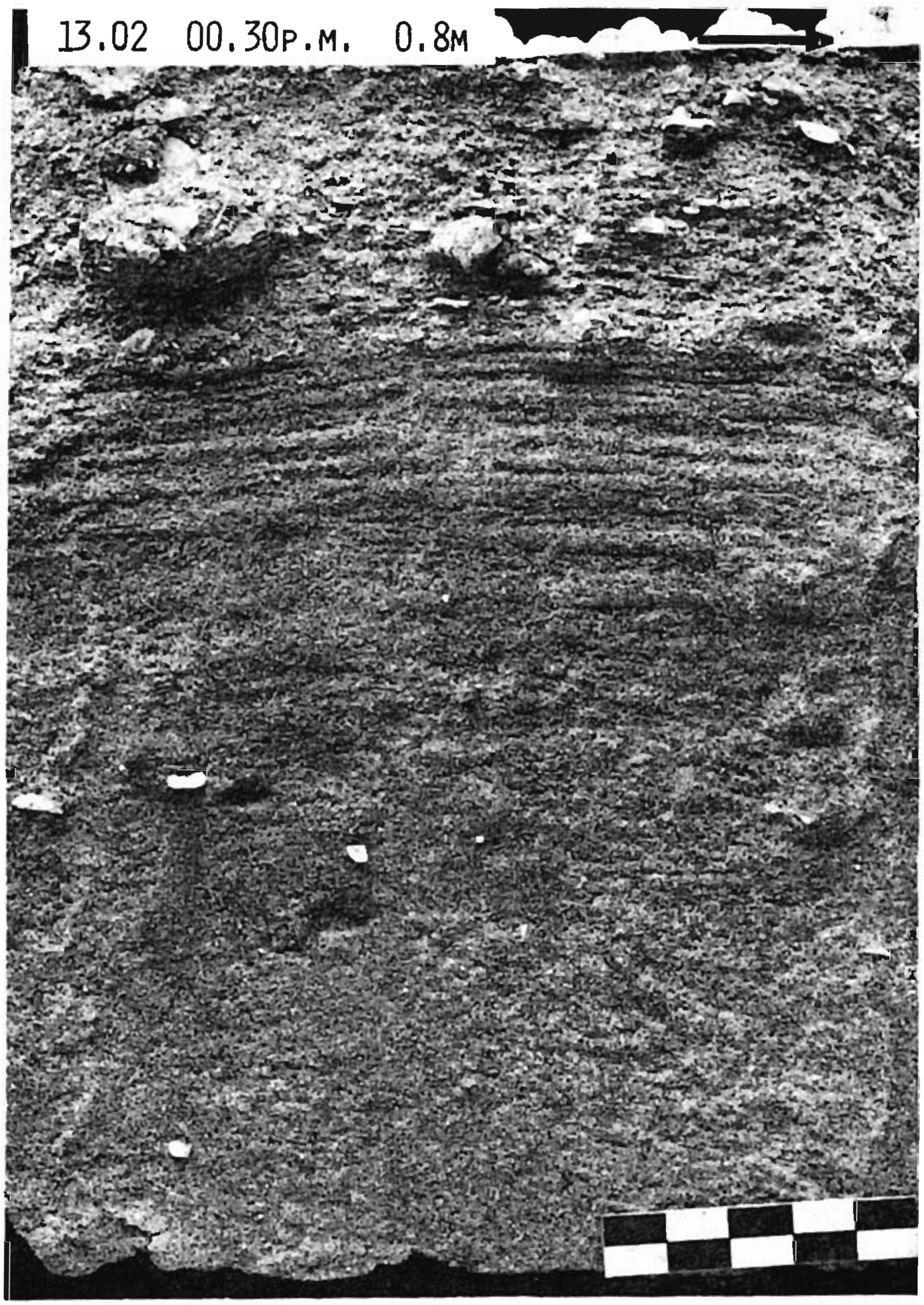
Heavily bioturbated fine-grained sediment with polychaete burrows; small-scale ripple cross bedding particularly distinct in the upper part of the sample; inserted is the bottom profile, to show location of the samples illustrated (Pls 45—48), and the bottom pattern, as observed



Large-scale cross bedding with concave cross laminae in the lower part of the sand ridge slope; a polychaete burrow reaches the upper boundary of a finer sediment



Horizontal bedding in the fine-grained sediment with an echinoid burrow, and ripple cross-bedded coarse sediment *(top)* with pebbles and bivalve shell fragments oriented



Horizontal bedding in the fine-grained sediment, heavily bioturbated *(bottom)*, and coarse sediment *(top)* with pebbles and shell fragments oriented

TRACE FOSSILS

Sandy sediments, continually set in motion by various hydrodynamic factors and free from any fine-grain layers including clay or silt, do not favour the preservation of traces left by living organisms.

The effect of the intensity of waving on the occurrence of organic traces is clearly evident from the samples collected in the Merry Beach and Oaky Beach where waving appears to be exceptionally intense. The same applies to the coarse-grained sedimentary material which does not favour the life of organisms, and still less preservation of their traces, as this has been best illustrated by samples derived from Dark Beach.

Fine-grained material with a larger percentage of suspended matter, as resulting from the lower energy of waving due to a particular configuration of the coastal line, steps up the abundance of traces as this may easily be seen from the Long Beach samples where burrows are identified in all samples (Pls 45—48). However, traces left in this environment have practically no chance to be preserved because of the water and sediment being in a perpetual motion.

Trace fossils revealed on the surface of fresh and wet samples were much more distinct and abundant. In a dry state, and when cemented with epoxide resins, samples lost much of their distinctness, contours of the previously well-visible forms became obliterated while the more subtle ones tended to disappear completely. Despite unfavourable conditions. rendering preservation rather difficult, trace fossils in the sedimentary environments of Kioloa Bay proved to be rather common, appearing in much larger quantities in the Batemans Bay onshore form. These included diverse burrows, *i.e.* traces of life processes left by such organisms living in the sediment as bivalves, polychaetes, and echinoids.

POLYCHAETE BURROWS

The polychaete burrows and an organism leaving its trace are perceivable in the Kioloa Bay sample (Pl. 34). These are mostly isolated vertical traces (0.5 to 1 cm in width), losing distinctness of their stratification in their axial part and often causing downward inflexion of the laminae (Pls 24, 34). Such inflexion speaks for an upward movement of the animal and may be interpreted as an escape trace, *i.e.* of the *fuginichnia* type (Seilacher 1953, 1967), due in all probability to a deposition of the overlying material. No such traces have been found in the Kioloa Bay at a depth not exceeding seven metres or so, their relative frequency showing an upward trend with an increase in depth. Burrows are present in a large variety of beddings and it is often so that burrows occur within a particular set of laminae, or end together with a boundary, and this may be a proof that either the animal had left the environment before some new material settled over the boundary, or that the erosion had destroyed some parts of the burrows.

BIVALVE BURROWS

The not very deep burrows, up to a few centimetres in width, and disturbing the bedding (Pl. 9) are not comparable to the number of bivalves actually living in the sea bottom under observation. The presence of such burrows is noted in samples collected from very small depths. The wide, vertical zones caused by animals changing their place due to material movement or through escape from being buried (Pl. 25) represent another type of bivalve burrows.

ECHINOID BURROWS

The form as in the Long Beach sample (Pl. 47) is to be recognized as a typical echinoid burrow. This is an oval mark disturbing stratification of the sediment and exhibiting a certain amount of concentricity in the configuration of matter filling out the mark at its extremes, no doubt due to animal changing its position in the sediment (Radwański & *al.* 1975, Figs 16—17). Similar marks have also been stated in Kioloa Bay (Pls 15, 24—25).

BIOTURBATIONS

In a lot of samples it was possible to observe a partial or even complete obliteration of the bedding (Pls 12, 22, 24—25, 28, 30, 48): Since also individual burrows are observed in this sedimentary environment (Pls 12, 22, 24), obliteration of the original bedding is considered as a result of life activity of the burrowing animals, polychaetes and bivalves at first.

SEDIMENTARY MODELS

Two models of sedimentation, varying a little from each other, could be outlined on the basis of research findings: a model of the high-energy coastal zone of the open seas, based on data from the Kioloa Bay and Merry Beach and made complete through the addition of findings from the remaining oceanic beaches; and a model of an environment more or less estuary in its character, based on the Batemans Bay data.

OPEN-SEA COASTAL ZONE MODEL

This zone stands out for a very high energy of the wind-generated waving and for the presence of rip currents coming from that waving to an extent making deposition of any fine-grained clastic material impossible. Neither mud nor silt are present in the bedding of the sandy environments as separate strata, and this precludes the possibility of keeping any traces preserved in the bottom and adds to relative scarcity and lack of distinctness in the trace fossils available. This is one of the features that makes this sedimentary environmnt different from other lower-energy coastal zones having extensive tidal flats, as *e.g.* the Watt zone.

No material supplied from inside the mainland renders that sandy material of the coastal environment is circulating within an almost closed cycle of redeposition; from the sea bottom, beaches, and even from the onshore dunes; and is carried away to those places where it undergoes periodically a process of abrasion, as *e.g.* in the northern part of the Kioloa Beach. Some smaller quantities of the clastic material coming from the abrasion of cliffs are of local significance only, as this may be exemplified by the Dark Beach and Myrtle Beach and do not play any important part in the general sedimentary balance-sheet of this zone. This continuous movement of the material, under a closed-cycle regime, is to be blamed for the generally level of its selection and maturity. It is only the shell detritus which as one of the components of the sedimentary environment is supplied in quantities big enough to infuence composition of the sedimentary material and its degree of selection.

Sedimentary structures, bottom forms and beddings constitute an essential feature in diagnosing that model of sedimentation. Some of these forms, at greater depths, are comparable with the hummocky stratifications known from different ancient formations (Dott & *al.* 1982).

To identify such sedimentary environment, it is necessary to recognize circumstances under which sedimentary structures come into effect, and their vertical sequence, thus to assess changes in the energy acting to the bottoms. The types of bottom forms and beddings, as observed for various depth zones, can help to determine changes followed in the depth of a basin. From findings presented it is evident that seedimentary structures in this model remain hardly influenced in their character by tides being responsible for comparatively unimportant horizontal relocations of zones. Vital part play rip currents in the onshore environment whose effects come as large-scale cross beddings with bimodal orientation parallel to the shoreline, Grain-size distribution and grain parameters fail to be unmistakable environment indicators, like in the case of tideless near-shore zones of the Baltic Sea (Czapowski & *al.* 1980) and Black Sea (Merta 1982), and can only fulfil an auxiliary function. Specified categories of organic traces (burrows and bioturbations) may be extremely helpful as facies indicators.

Sedimentary models described vary a lot from models of tideless seas in the same zone, as *e.g.* southern Baltic and the Black Sea. Differences result, above all, from particular hydrodynamic situations and find their expression in a specific distribution of bottom forms and beddings ,and also in their sequence, for sedimentary environments of respective zones appear fairly similar in their character.

One distinctive feature of the southern Baltic near-shore zone is the presence of several, three on an average, underwater longshore sand bars („low-and-balls") together with a multitude of symmetric and asymmetric ripples due to wind-generated wavings (Rudowski 1962, 1970), and in the onshore and in the troughs between bars — also by wave-generated currents. Longshore bars („low-and-balls") represent stable elements of the bottom configuration. They change in their position and shape according to the actual energy of waving, and more precisely according to the actual rate at which energy rises or falls, known as the structure of storm (Giżejewski & *al.* 1980). Whenever the storm is getting more intense, these bars are being washed out and reduced in their height; and each time the storm yields and draws back, and this is a longer process, the bars rebuild their bodies, grow in size and come closer to the shoreline, the first sand bar in particular. At this stage, the bars gain on their overall dimensions, chiefly owing to the material deposited on the landward slopes and this, in turn, renders that large-scale cross beddings oriented towards the land start building-up. On their seaward slopes asymmetric wave ripples , keep on developing a cover of ripple cross bedding overlying another large-scale cross bedding. Sedimentary material is carried through asymmetric ripples to join cross laminae on the landward slope of bars. The presence of underwater longshore sand bars, making up shallower bodies parallel to the shoreline, causes in each of these zones that wind-generated waves tend to transform and thus contribute to the generation of longshore currents in the troughs between bars likely to develop into whole systems of current ripples, especially when the direction of wave propagation is oblique to the shoreline. All these processes lead to highly diversified bottom patterns formed of a variety of ripples and, in a smaller degree, of megaripples which develop into entire fields extending parallelly to the shoreline, as far as the seaward slope of the shore-farthest bar and they form zones several hundret metres in width and several metres in depth. Outside such a zone one can find symmetric ripples on the sea bottom, and it is fine-material horizontal bedding that starts to dominate in the undisturbed-structuce samples.

In a near-shore zone of the Black Sea, in the Kamachiya region of Bulgaria, no regular longshore bars were observed. Bottom patterns, to a depth of some seventeen metres or so, consist of a variety of asymmetric and symmetric wave ripples which, irregular as they were in their size, certained a small percentage of the megaripples only (Giżejewski 1982a), and this found its expression in dominating small-scale ripple cross bedding, except for beach bar and beach slope, where also large-scale cross bedding occurred (Giżejewski & *al.* 1982b). At a depth of some twelve to fifteen metres there began horizontal bedding with an admixture of finer material, and also cross bedding which came up sporadically, only in connection with heavy storms. A certain amount of variability is noticeable in the distribution of bottom forms, to some extent in connection with the structure of storm, and this — like in the case of the Baltic Sea — was symptomatic for no ripples having been present down to a depth of some metres, when the storm was getting more violent, and from retransportation of the sedimentary material to a deeper zone so as to form these chiefly asymmetric ripples again, when the energy of waves was on decline. The ripples while moving towards the shoreline changed into sets of ripple cross beddings which are separated from by erosional boundary. Sedimentary model is less intricate in this case than in coastal zone of the Baltic because of no longshore bars present, and because of the more steep slope of the bottom. All this rendered that the whole zone in question was getting relatively narrow.

BATEMANS BAY COASTAL-ZONE MODEL

The Batemans Bay coastal-zone model is estauary in its character and is based on the Long Beach findings. It differs in the character of sedimentary structures from the oceanic coastal-zone model. Differences come from a much lower energy of waving, as a result of a specific configuration of the shoreline; and, no doubt, also because of material having been transported by Clyde River in suspension, and in other type of transport as well, when rainfalls were more intense.

Both factors have contributed to making sedimentary environment more complex in its character. It is generally featured by somewhat finer sediments, with a large admixture of silt and mud, and organic matter found in the samples.

Like in the tideless shore-zone of the Baltic Sea and Black Sea the oscillation ripples tend to develop in the bottom running from the shoreline. Large-scale cross beddings are much less abundant here as compared to ripple cross beddings; horizontal beddings being rather common in the environment. This environment stands out, on the other hand, for an abundance of trace fossils, such as burrows and bioturbations, both due to more favourbale living conditions as well as more advantageous, than in the oceanic coastal zone, conditions of their preservation in the sedimentary sequence.

FINAL REMARKS

The described models of sedimentation may provoke to a question, having in mind the fact that observations were conducted under moderate and weak waving conditions, whether these models can be regarded as universal enough also when no stormy conditions are in action. Such a reservation may partly be true with regard to bottom patterns. Although, in addition to bottom forms originating in the course of observations, there were also some older forms corresponding to earlier waving conditions, these forms have been tranformed in part by the weaker waving and were lacking the peculiarity of forms strictly corresponding to the storm-waving regime. These changing waving conditions, following each other, are particulary well perceivable in the medium-depth zones.

From observations conducted in the Baltic Sea and Black Sea it is evident that, as the energy of waving in shallow zone increases, the regular bottom forms slowly disappear and the bottom itself is getting more plain, and the material is carried out from the shore towards greater depths. The absence, in the highenergy part of Kioloa Bay (to 4 m in depth) of any bottom forms, either medium or small ones, seems to confirm that rule and it is beyond any doubt that regular bottom forms tend to disappear under heavy-storm waving conditions only in the deeper zones.

The undisturbed-structure samples, taken from somewhat deeper zones in particular, embrace a little longer record of events at the sea bottom, the heavier waving conditions being no exception to this rule. These conditions are responsible for erosional surfaces and for those scarce of samples that contain more pebbles, shells and large shell fragments and other coarse-material. That this material is so scarce comes from the fact that although deposited at sea bottom at high wave, a rather fast process of transformation soon followed, as waving of the sea yielded, and so respective bottom forms and beddings, as they now are, correspond to the latter wave climate.

Typical tempestites are expected to occur in profiles situated well below the average wave base; in the given case, outside the Kioloa Bay region in the open-seas environments. As far as the storm wave base sediments are likely to resemble those described in the Kioloa Bay findings; forming beds within the deep-water sedimentary environments, with horizontal or graded bedding, and containing material settled from suspension, just as it happens in the offshore zone in the Baltic Sea and Black Sea.

From investigations carried out in Durras Bay (Chappell & Eliot 1979, Fig. 2) it is evident that the surf-beach is much more complicated in configuration than the zones under research, chiefly due to the presence of rather regular underwater bars or shoals. Forms in question undergo, under changing waving conditions, a process of perpetual transformation and their presevvation potential is rather limited. In a residual form they may appear in such an environment as a variety of large-scale and medium scale beddings, as it is well expressed in the undisturbed structure samples from Kioloa Beach and other oceanic beaches under investigation.

A final remark is to be offered that it would be highly appreciable to get some undisturbed-structure samples collected from somewhat greater depths, in order to examine their possible tempestite nature; and from the Batemans Bay area, to get a more complete model of estuary sedimentation.

Institute of Geology
of the Warsaw University,
Al. Żwirki i Wigury 93,
02-089 Warszawa, Poland

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P. RONIEWICZ

MODEL SEDYMENTACJI DLA STREFY BRZEGOWEJ MORZA TASMANA

(Streszczenie)

Przedmiotem pracy jest analiza mikro- i mezoform dna piaszczystego (badanych bezpośrednio przez płetwonurków) oraz analiza warstwowań, składu granulometrycznego a także śladów organicznych, określonych z prób o nienaruszonej strukturze, pobranych z dna i plaż próbnikiem skrzynkowym (*patrz* fig. 1—5 oraz 1—48), na obszarze strefy brzegowej morza Tasmana, w Nowej Południowej Walii w Australii *.

Uwzględniając ogólne warunki hydrodynamiczne, określono model sedymentacji dla tej wysokoenergetycznej strefy brzegowej. Oparty on został o badania sięgające do 30 m głębokości w zatoce Kioloa, gdzie wyróżniono trzy strefy głębokościowe różniące się typami struktur sedymentacyjnych i ich następstwem (pl. 1—35). Podobne badania przeprowadzono w płytszych częściach szeregu innych zatok (pl. 36—44), aż do zatoki Batemansa, gdzie wyróżniono specyficzny, niżej energetyczny model sedymentacji o typie estuariowym, wyróżniający się bardziej drob-

* Badania przeprowadzone zostały przez członków wyprawy naukowej „Australia 80", zorganizowanej przez Oddział Warszawski Polskiego Towarzystwa Przyjaciół Nauk o Ziemi, w porozumieniu z *The Australian National University* w Canberze.

noziarnistymi osadami, odmiennym charakterem struktur sedymentacyjnych i obfitością śladów organicznych (pl. 45—48).

Wyróżnione modele porównano z opisanymi wcześniej modelami stref brzegowych mórz bezpływowych — Bałtyku i Morza Czarnego (rejon Kamczji w Bułgarii), gdzie przeprowadzono badania w ramach międzynarodowych ekspedycji „Lubiatowo 76" oraz „Kamczija 78".

Rozważane modele sedymentacji, ze względu na zespół cech jaki stał się podstawą ich wyróżnienia, mogą być szczególnie przydatne przy interpretacji kopalnych środowisk sedymentacyjnych.