EPHEMERAL TRACES OF ANIMAL ACTIVITY ON THE BEACH SAND FROM MAMAIA

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Abstract: Numerous ephemeral traces of animal activity, made by invertebrate and vertebrate on Mamaia beach sand, partially investigated in this work, contain elements which permit us to include them to *Psilonichnus* ichnocoenosis. Predominantly terrestrial, but maritime feature, *Psilonichnus* ichnocoenosis can support the interpretation of rich paleoichnological content of Lower Miocene molasse from Subcarpathians, the obtained data could be used, besides other information (sedimentological, lithofacial etc.) to paleoambiental reconstructions.

Key words: ephemeral traces, fossile traces, ichnocoenosis, ichnofacies, paleoambiental reconstruction.

Introduction

The recent paleogeographical evolution of the Dobrudgean Black Sea coast has determined the appearance of a relief characterized by two distinct types: an accumulation relief and a cliff relief. Between the two types there exist a limit separating the two fields: the northern field, situated between the Chilia branch of the River Danube and Constanta (143 km), it presents an accumulation relief formed by strandwalls and sand banks, and the southern field, situated between Constanta and Vama Veche (85 km), having a high relief, formed by cliff constituted by a thick layer of loess placed on sarmatian limestone deposit.

The different types of submersed substrata and the creatures associated to it have made up the subject of many studies undertaken by a lot of collective researches coordinated by Acad. M. Bacescu and published in the series of volumes "Marine Ecology" as well as in other speciality publications. If these studies have mainly been concerned with learning the life conditions, ecology and dinamics of the animal and vegetal populations from the sandy zones situated under the sea level, the data reffering to the way of forming and preserving the animal activity traces on the beach sand belonging the supralittoral floor, are less known. From this point of view, the study carried out by Marinescu (1973) on the taphocoenoses on the Romanian coast of the Black Sea remains an exception.

Morphologic background

The beaches of the Romanian shore of the Black Sea are sandy beaches, usually made up of three berms remitted from the accumulation of the shells and of the detritical material. Marinescu's opinion is that the beaches belong to two categories: cliff beaches and "free" beaches. Some observations upon the beach deposits (Panin, 1967) show that their structure is closely related to the granulometric and the mineralogic nature of the sand as well as to the amplitude, the type of sea level oscillations and the characteristics of the waves. The present beach deposits belong on the whole to two categories: the northern field contains the quartz sands, with a fine granulation (about 70% comes back to the fraction placed between 0.045 and 0.1 mm) and the southern field is characterized by coarse organogene limestone (0.3-0.6 mm).

Table 1. Sand fractions for "Rex" beach sector (acc.to Mares & Mares, 1971)

Fractions	%
0.06-0.1 mm	10
0.1-0.2 mm	78-82
0.2-0.5 mm	3-14

Granulometric and mineralogic characteristics of the Mamaia beach sand

The Mamaia beach occupies the zone of the offshore bar between the sea and the Siutghiol lake being placed between the ex Mamaia village in the north and the Tabacaria lake in the south. The offshore bar shows a low relief having dunnes from place to place which do not overtake 2-3 m in height and portions occupied by bushy vegetation.

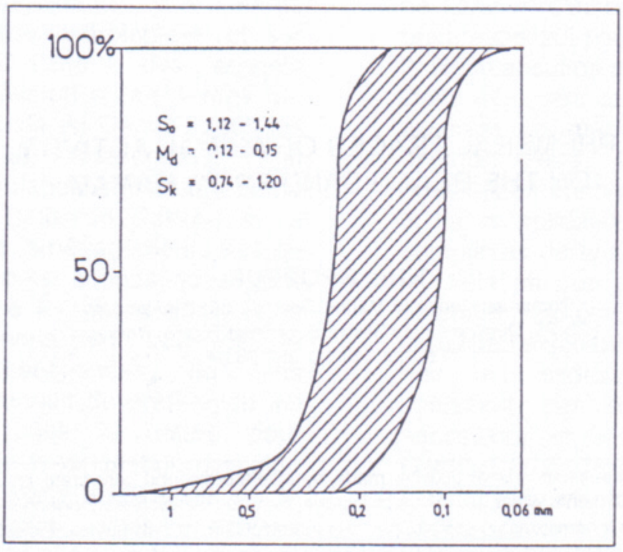


Fig.1. Grain size variation of the sands from the "Rex" beach sector (acc.to Mares & Mares, 1971). S_0= standard deviation; M_d= median; S_k= standard skewness.

According to Mares & Mares (1971) the sand of Mamaia beach are characterized by the domination of the fine fraction of 0.1-0.2 mm which can reach more than 95%. The sorting is very good, this fact results from the shape of the curve whose slope is close of the vertical and median one, with small values of 0.14 mm at Mamaia and 0.15 mm at Constanta. The granulometric characteristics of the Mamaia beach sand drawn from 11 samples originating in an alignment placed right in front of the "Rex" hotel show the values in Table 1, and Fig. 1.

From a mineralogic point of view the sands from "Rex" are homogenous, contain quartz, are rich in calcit, muscovite, feldspar and heavy minerals. The medium mineralogic composition indicated on classes and dimensions is reproduced in Table 2.

In all the granulometric fractions can be observed that calcit, quartz, feldspar and muscovite have a higher persistance and frequency. The other components are representated bv heavy minerals which appear more often in the fraction of 0.06 mm. The silt character of those sands has a consequence the appearance of granules covered by a clayish-ferruginous coating. The granules of the sand present various aspects, from semirounded to angular and subangular, reflecting the conditions of a marine transport. The Mamaia beach sands are practically maintaining the granulometric characteristics and the mineralogic composition under the sea level, up to the depth of about 22 m, the fineness degree increasing with the depth maintaining its silt character, fact which is emphasized by the illiophilic fauna (Gomoiu, 1969).

Table 2. Mean mineralogical composition (%) of the sands from "Rex" beach sector (acc.to Mares & Mares, 1971)

Minerals	Fractions		
	0.06 mm	0.10 mm	0.20 mm
Apatite	2.06	3.40	1.30
Actinolite	1.90	2.80	-
Calcite	25.9	22.6	34.6
Quartz	37.5	45.7	31.4
Chlorite	2.50	3.80	-
Disten	2.16	3.50	3.80
Epidote	3.10	2.10	1.20
Feldspar	6.80	7.26	6.74
Garnet	5.42	5.70	-
Hornblende	6.27	4.48	7.40
Muscovite	7.02	12.62	15.90
Pyroxenes	1.38	2.00	-
Staurolite	1.17	1.00	8.70
Rutile	1.17	-	-
Tourmaline	0.60	-	-
Zircon	1.00	-	-
Zoizite	1.00	-	-
Opaque minerals	3.21	3.43	4.88
Lithoclasts	6.52	8.83	12.58

Ephemeral traces of animal activity

We carried out some researches during 5 years (1985-1990) in July-August, regarding the animal activity traces, belonging mainly to the invertebrates. These observations were mainly done in the morning, between 6.30-7.30 when the human activity on the beach was very reduced. Different types of traces have been photographed, the animals have been rarely surprised in their full activity. Sometimes there were made observations in the evening too, before sunset, when the oblique and less intense light, the same as in the morning, offers the possibility of overtaking some details which can not be observed midday. These observations have been accomplished in two fields of Mamaia beach, relatively close by: one in "Hanul Piratilor" and the other one at the camping "Popasul Mamaia " (Fig.2).

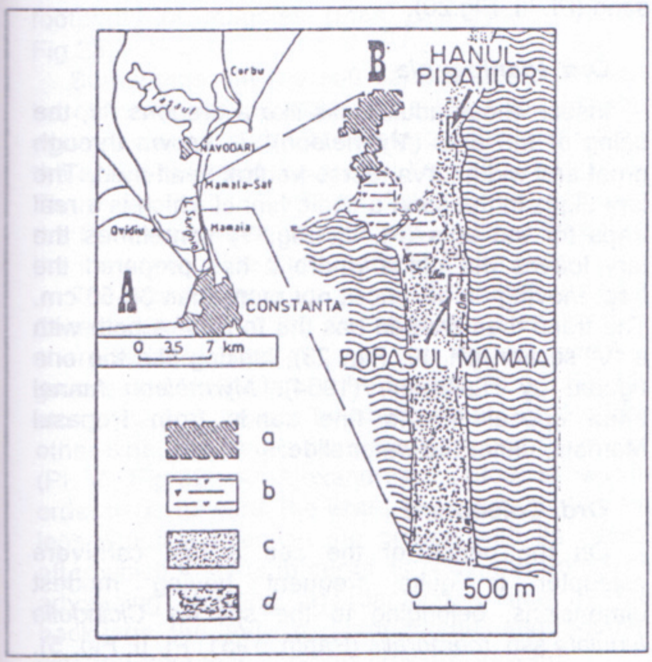
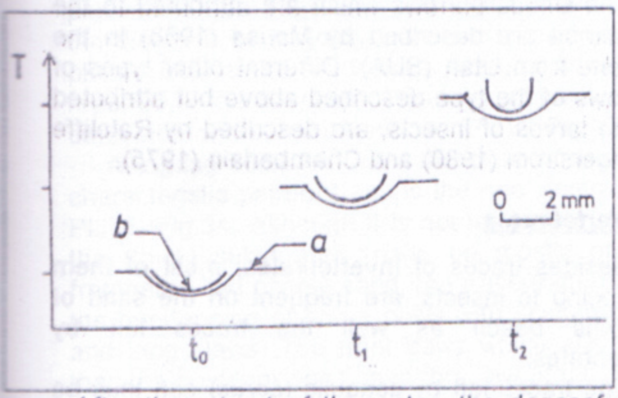


Fig. 2. Location of the beach sector (A) and position of the zones with ephemeral traces (B - acc.to Breier, 1976). a = previous location of the Mamaia village; b = macrophytic vegetation; c = offshore bar with 0 m isohypse; d= neoichnologic investigation area.

Before introducing you to the traces of animal activity we would like to illustrate some mechanical traces produced either by the movement of the water or by the action of the wind. Thus, right in the neighbourhood of the sea shore, the retreat of the "swash-marks" waves on the fine sand can give birth to sinous ridges, more or less continuous, marked by the alignment of the sand granules (Pl.I, Fig.1) or of false vermiculations produced by the chaotic movement of the coarse sand granules in a thin water film (Pl. I, Fig.2). Other times the drawing of an alga fragment by the water stream produced a linear "groove mark" (Pl. I, Fig. 6), as the turning of a *Salix* branch can produce semicircular traces (Pl. I, Fig.4) looking like the "eolian circles" described by Marinescu (1973).



After the retreat of the water, the degasefying of the wet sand is frequently produced, the exit of the air, sometimes with enough power, generating circular traces with an hemispheric aspect, isolated or grouped (Pl. I, Fig. 5), looking like the raindrops traces. In the neighbourhood of the sea bushes of *Elymus sabulosus* there can often be observed cvasiparalel traces produced by the swinging of the spear-shaped leaves, under the influence of the wind (Pl. I, Fig. 3). Not a few times the waves push jellyfish on the beach (*Aurelia aurita*), whose soft, gelatinous body leave a circular or oval mark on the soft sand (Pl. I, Fig. 7) which is soon destroyed by the next wave. Marinescu (1973) described a few interesting cases of producing jellyfish traces at the north of Nāvodari, where the wind had a decisive role, by the quick dehydration of the gelatinous body, upon which the fine sand was fixed.

Fig.3. *Helicella candicans* Pf.: progressive mucus bending related to time (t_0-t_1) and temperature (T). a= fine sand; b= mucus.

Invertebrates

The Gastropoda Class

An interesting case is revealed by the trace a small gastropode *Helicella candicans* leaves on the sand (Pl. V, Fig. 24), which hangs *Zebrina varnensis*, on different types of steppe mugwort (*Artemisia)* like clusters (Calinescu, 1946). On the sand the trace looks like a semicircular groove with outstanding edges (Pl. IV, Fig. 22).

The lining made out of the mucus is very interesting, mucus which agglutinating the fine sand particles quickly curves (Pl. IV, Fig. 22) finally, becoming like a semicylindrical "thread" covered by sand. When this modification of the curve of the mucus when graphically ressed takes place in a very short period of time, with the air temperature increase. This extremely fine film is easily destroyed by the vibration of the air or by a simple strike.

The Crustacea Class

Ord. Isopoda

Very frequent on the fine sand are the traces having the form of displaced trails with linear direction (Pl. II, Fig.13; Pl. III, Fig.15) or sinous route (Pl. IV, Fig. 21). The axle of the trail, lightly engrossed, is limited by short prints, disposed perpendicularly on the median groove at an equal distance one from the other. This trace might belong to an isopod *Idothea* present in a large number in the seaside area, from 0 to 5 m depth, rarely to 30 m (Manoleli & Nalbant, 1976).

Ord. Amphipoda

We attribute to the amphipodas the compound trace from Pl. II, Fig.9, probably produced by *Pontogammarus maeoticus.* One can notice the lower part of the trace created by the passive movement of the shell fish by the water stream and the upper part produced by the active movement of the animal, marked by the punctiform tracks from the left side of the groove. These tracks are visible as well at the trace specimen from Pl. II, Fig.8.

Ord. Decapoda

Close by the line of the shore the agony trace of the sand shrimp has been surprised (*Crangon crangon)* in the very wet and fine sand. The shell fish brought on the land by the wave has struggeed (to the right and to the left) until it was caught by the moving sand, remaining captive (Pl. III, Fig.18).

An interesting trace is the one shown in Pl. II, Fig.14 too. It might be the moving path of shell fish (the sand crab - *Macropipus holstatus*) the four parallel rows of the cvasipunctiform tracks may represent the print of the ending of the pareiopod (the right of the image). In the left side, the same rows of tracks, less visible are traced on the less wet sand.

The Insecta Class

Ord. Dermaptera

A very clearly expuned trace is made up of two rows of tracks having the form of a pipe, perfectly parallel, placed at a distance of about 8 mm one from the other. At exterior of the two parallel rows semilunar tracks are displaced, easily alternate. It is not excluded that the described trace should be produced by the great ear wig (*Labidura riparia*), an insect with a long body, ended in two strong extensions (Pl. III, Figs.19,20). The different sort of printing the trace is remarkable, is very clear on the dry sand (Pl. III, Fig.19) and less visible on the wet sand (Pl. III, Fig.20).

Ord. Planipennia

Insect whose adult looks like a dragons fly, the being of the ants (*Myrmeleon*) is known through great and width larva, dorso-ventral yealtened. The larv diggs in the sand a conic funnel which is a real traps for the ants (Pl. III, Fig.17) sometimes the larv leaves the place where it has prepared the trap, moving on distances not more than 30-50 cm. The trace thus created has the form of a path with a "V" section (Pl. IV, Fig. 23), looking like the one figured by Halifmann (1964). *Myrmeleon* funnel often appear in the fine sands from Popasul Mamaia, under the water slide.

Ord. Coleoptera

On the beach of the sea a fast carnivore coleopter is quite frequent having modest dimensions, belonging to the species *Cicindella lunulata* ssp. *memoralis* (Panin, 1951, Pl. II, Fig. 5). Judging after the massive presence of those coleopteres, the traces shown at Pl. III, Fig.16, characterized the prolonged punctiform tracks on one and the other part of the axis of the track might belong to this species. It is not excluded that numerous burrows, having various forms (straight, meandered, sinous) digged in the sands should belong to the leaves *Cicindella*, hiding by day in such shelters where from they catch the prey (Panin, 1951).

On the surface of the sand often appear traces representing long cylindrical burrows, with circular-oval section, winding and meandering (Pl. II, Fig. 10), slightly meandering (Pl. II, Fig.11) or sinous (Pl. II, Fig.12), many times combined (Pl. VI, Fig.33).

The sinous burrows which are attributed to the nematoda are described by Mousa (1968) in the Eocene from Utah (SUA). Different other types of burrows of the type described above but attributed to the larves of insects, are described by Ratcliffe & Fagerstrom (1980) and Chamberlain (1975).

Vertebrates

Besides traces of invertebrates, most of them belonging to insects, are frequent on the sand of Mamaia beach as well the traces left by vertebrates.

The traces left by seagulls (*Larus*) can thus be noticed, as they are well printed on the partly wet sand (Pl. V, Figs.25,27) sometimes the traces of the strongly curved beak being visible while looking for food (Pl. V, Fig.29) and of tern (*Chlidonias*) whose traces on the soft sand leave the print of the interdigital membrane (Pl. V, Fig.26). Besides these traces there can very often be recognised footprints of magpies (*Pica pica pica* - Pl. V, Fig.28).

Sometimes, on the soft sand dunes there can be observed traces made by small frogs (*Rana*), whose leap reach about twice larger the length than the actual length of the animal body (Pl.VI, Fig.30). There can quite clearly be distinguished prints of the front legs, which remote toes, in the moment of the impact with the sand at the end of a jump.

The quick movement of the lizard (maybe *Lacerta taurica*) on the dry sand is materialised in characteristical traces with a narrow winding groove, left by the tail of the animal (Pl. VI, Fig.31) along which there can be observed at one and the other side, the traces from the front and back feet (Pl. VI, Fig.32). As Alexandrescu (1969) shows, in order to go forward, the lizard first leans on its front legs which it fixes on the ground with its claws, after which it starts to curve its body, the front legs advancing crawling, approaching a little by the back legs, the body than stringhtenes and together with the front legs it moves crawling forward.

On the beach there are not missing traces left by different mammals, the most frequent are the traces of a dog (*Canis familiaris*) with its characteristic pattern-trace (Pl. VI, Fig.35). According to Rosetti-Balanescu (1961) the trace of the dog, differing from the one of the wolf, shows scattered toes, the traces left by the side toes reaching up to a third of the high of the middle toes.

More rarely there have been observed traces which reveal a succession of small leaps which could belong to some small animals (probably rodents), with a pretty clear pattern-trace of about 9 mm length. These pattern-traces are grouped in, what Rosetti-Balanescu (1961) names path-traces "rabbit-like". At this sort of traces, the animal places the front legs one behind the other one in the direction he is going to and the back legs are placed beside the front ones, being a bit oblique reported to the direction of walking, at one and the other side of the movement line (Pl. VI, Fig.33).

A zigzag footprint, with the print of the very characteristic pattern trace is the one illustrated at Pl. VI, Fig.34. Although it is not very clear, due to the (thick) substratum made up mostly of shell fragments and coarse sand, the trace-pattern show the overlapping of some paws with scattered toes and long claws. The front paws which are longer than the posterior ones have the claw of the middle toe a bit longer than the surrounding toes. The traces thus described and figured, having the length of the stride of about 10 cm seem to belong to a young hedgehog (*Erinaceus europaeus*).

Discussions

Situated between the marine realm and the continent, the littoral zone represents a transition region, an ecoton where the interconnection of the biotic communities of two ecosystems takes place. In ichnologic terms, this ecoton shows a mixture of marine and continental traces recently named by Frey & Pemberton (1987) as "*Psilonichnus* ichnocoenosis". From a sedimentological point of view, the mentioned ecoton generally correspond to the beach.

According to Frey & Pemberton (1987), the *Psilonichnus* ichnocoenosis is mainly terrestrial, having a maritime aspect, including a mixture of marine animals and plants, cvasimarine and terrestrial, the eolian processes being dominant. This ichnocoenosis, typical of the coast, contains sheltering structures with the form of tunnels, mostly vertical, with a form like an "J", "Y" and "U" as the structures of fossils of *Psilonichnus upsilon,* made by crabs: superficial traces and tunnels for feeding or movement of the vertebrates and invertebrates; footprints of vertebrates. The traces including vertical tunnels made by insects and arachnide are prevailing, the horizontal systems and tunnels of insects and tetrapods as well as the traces, the footprints, the faecal pellets or the coprolits of different insects, reptiles, birds and mammals.

This ichnofacies passes over gradual towards offshore in *Skolithos* ichnocoenosis, and near the shore it mixes not only with *Skoyenia* ichnocoenosis but also with other nonmarine ichnocoenoses (lakes, marshes, rivers, flooded plains, forests etc.).

It is obvious that the majority of traces of invertebrates and of vertebrates are destroyed before the lithification of the host sediment. The taphonomic and toponomic aspects of the ichnofauna being as important as the etologic and ecologic aspects (Frey & Pemberton, 1986, 1987).

The preserving potential of the traces of invertebrates is practically controlled by the critical factors of the stability of the sediments; imposed by granulometry, the cohesion, the water content and by the degree of strengthening (Crimes, 1975), the modification of one ore more of these leading to the variation of the morphology of the trace (Knox & Miller, 1985). Generally, the ideal situation leading to the preserving of the traces is given by the fine granular sediment, coherent and moistened under conditions of law energy by turbid water (Panin, 1965; Sarjeant, 1975).

The researches made upon the present traces of animal activity made by invertebrates are, on the whole very advanced, starting with those initiated by the German school of ichnology, remarkably synthethized in a valuable monograph belonging to

Schafer (1962) and going on up to now, in different mediums, and regions of the world: the Atlantic coast of the SUA, the macrotidal plain of Ichnon from the western coast of the peninsula of Korea (Frey et al., 1987) and even on the beaches (Mason, 1987).

Although the traces of invertebrates and vertebrates are ephemeral they are extremely important when trying to elucidate their forming and preserving as well as when establishing the importance they have for the paleoambiental rebuilding. The fact that they constitute testimonies of the behaviour of the producers in different circumstances (feeding, sheltering, resting, movement etc.) is already known.

Thus, the accidental presence of traces of amphipodes on the surface of the sand (Pl. II, Figs.8,9) show that these little shell fish are present in the substratum, where they can produce an intense cryptoturbation, proper for the meiofauna which homogenisates the sediment at a low scale. It is worth being known that, at north of Constanta, characteristic to the biocenosis of the fine and medium sands from the mediolittoral zone, there exist *Pontogammarus maeoticus* (Gomoiu, 1969). Frey & Pemberton (1987) consider this type of bioturbation be specific to the *Psilonichnus* ichnocoenosis.

The high frequency of the traces resulted from the movement of the coleoptera (*Cicindella* - Pl. III, Fig.16), of the burrows probably produced by the larves of those insects (Pl. II, Figs.10,11,12; PL. VI, Fig.33), of the funnels and the traces from the movement of the lion of ants (*Myrmeleon* - Pl. III, Fig.17; Pl. IV, Fig.23) and of the traces of crabs (Pl. II, Fig.14), are elements of diagnosis for the *Psilonichnus* ichnocoenosis, especially for the backshore zone (Frey & Pemberton, 1987).

The way of manifesting of the mucus caused by the gastropod *Helicella* which agglutinating the fine sand and then curve rapidly showing an increased temperature represents a novelty (Pl. IV, Fig.22; Fig.3-text). As it is already known, the mucus makes the advancing of the animal in or on the sediment easier, due to the elastic film which it forms. The mucus consists in a complex of macromolecule of the polyzaharidic type, sometimes it is lightly biodegradable or it has different longevity and chemism from one organism to another (Bromley, 1990). By bioturbation, animals which produce mucus modify the physical and chemical properties of the substratum by dislocating the mineral particles and by introducing the organic material as metabolic products which are sometimes extremely reactive (Bromley, 1990). The role of the mucousin the preserving of one trace may sometimes be very important. Yochelson & Fedonkin (1991) recently described fossile paleozoic traces, attributed to the ichnogenus *Climactihnites* which show a purple colour contrasting with the dark yellowish colou of the sandstone support. This chromatic contrast is explained by the degradation of the mucous secreted by the animal during its movement on the wet sand of the tidal zone. In the same time, the consolidated mucus has protected the created trace conferring an invariable flat aspect.

The rich inventory of fossile traces of vertebrates and invertebrates existent in the Lower Miocene molasse from the Subcarpathians, precisely in Vrancea district, which is well known (Grozescu, 1918; Pauca, 1942; Panin, 1961, 1965: Panin & Avram, 1962; Panin & Stefanescu, 1968; Alexandrescu et al., 1986) may offer extremely useful data at the specification of some depositional systems existent at a certain moment, depending on the abundance and the prevalence of certain types of traces of animal activity (Brustur & Alexandrescu, 1993).

It remains for the future researches, focused upon the study of the so-known nonmarine deposits and of the traces of actual animal activity to identify the biogene sedimentary structures proper to the *Skoyenia* ichnocoenosis or of the *Psilonichnus* ichnocoenosis, as Frey et al. (1984) suggest, the field of Miocene molasse from Vrancea, one of the few regions in the world very rich in traces of vertebrates (Panin, 1961), has to be the object of some systematical paleoichnologic investigations, especially because the future prospects in this field are practically unlimited (Panin & Avram, 1962).

Within this context, the protection of the zones of paleoichnologic interest appears as absolutely necessary (Brustur, 1992) as well as as the continuation of the neoichnologic observations not only on the coast of the Black Sea but also in different other environments (lacustrian, fluviatil, etc.), the obtained information being to be used, besides the data of other nature (sedimentologic, lithofacial, etc.) at the paleoambiental reconstruction.

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PLATE I

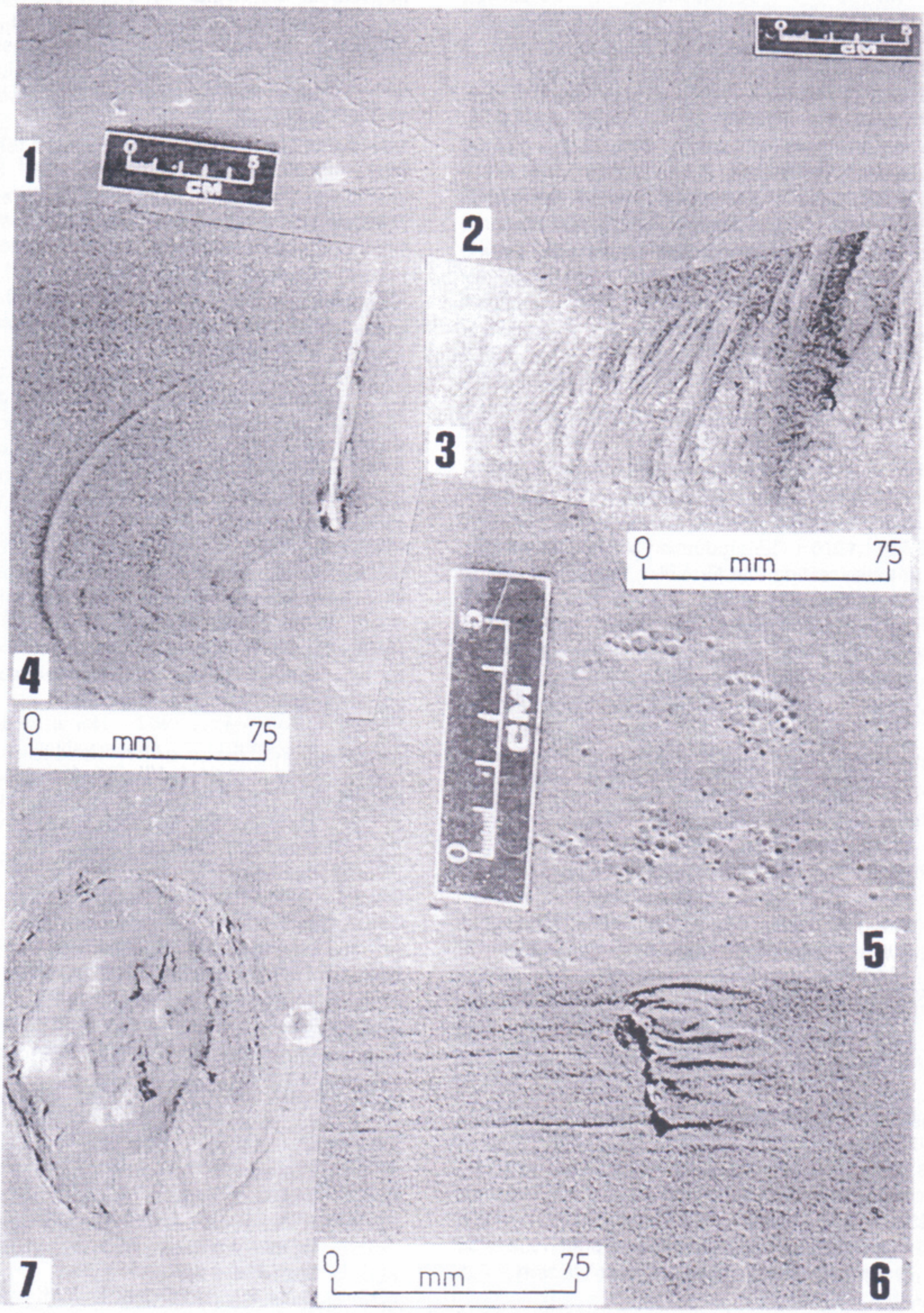
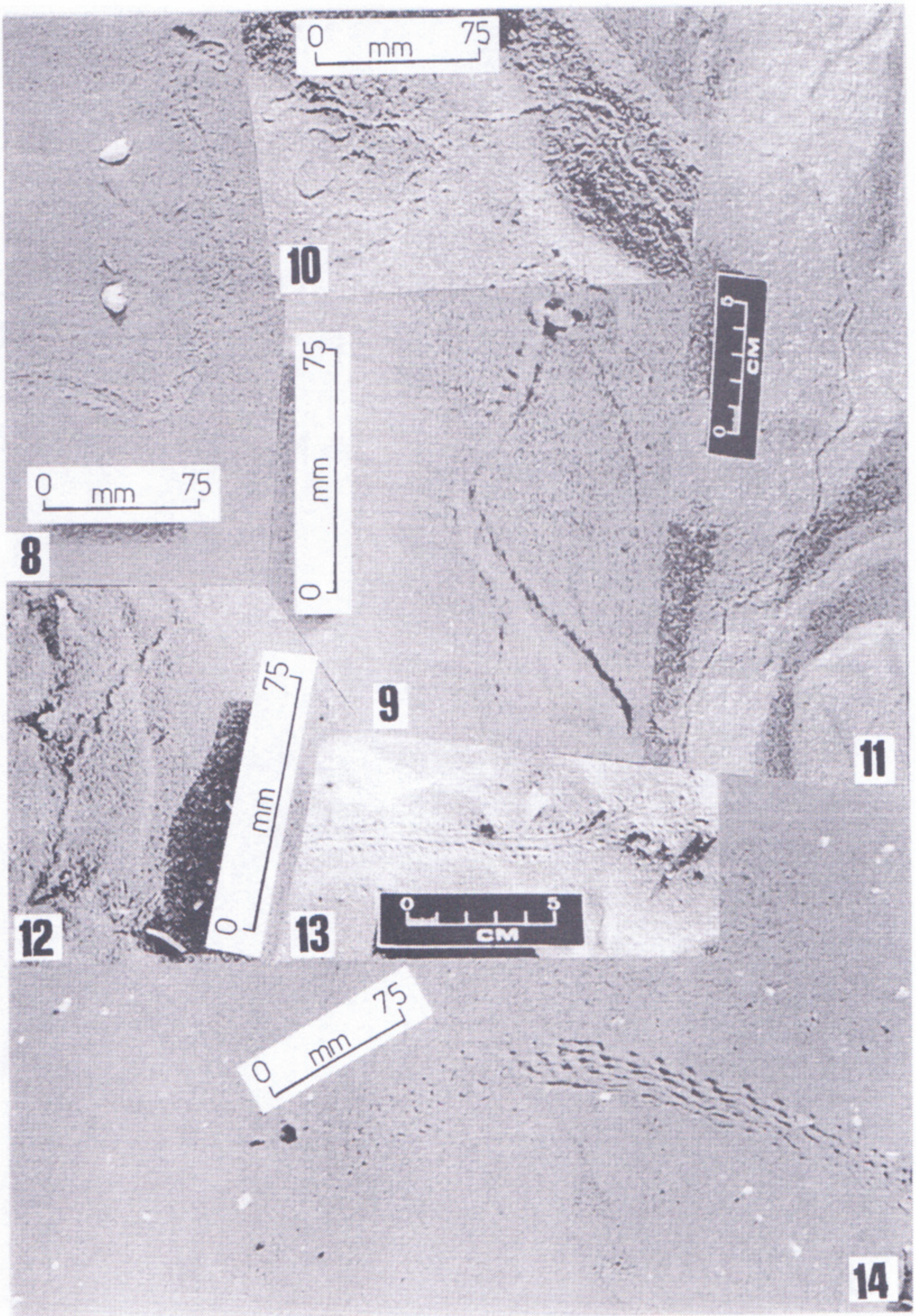


Fig. 1 - Sinous trace left by the recession of a swash wave.
Fig. 2 - Vermiculations produced by the rolling of the floating sand grains in a thin water film.
Fig. 3 - Eolian traces of the oscilation of *Elymus sabulosus* lanceolate leaf.
Fig. 4 - Semicircular trace left by pivoting of *Salix* branch (scale as in Fig.3).
Fig. 5 - Traces left by the degazification of the wet sand.
Fig. 6 - Dragged mark produced by the traction of *Enteromorpha* fragment.
Fig. 7 - Jellyfish impression (? *Aurelia aurita*).

PLATE II



Figs. 8,9 - Trace of a gammaride crustacean *(Pontogammarus maeoticus)*.
Figs. 10,12 - Trails of insects (or nematoda).
Fig. 13 - Isopoda trace (? *Idothea)*.
Fig. 14 - Trace of a brachiure crustacean

PLATE III

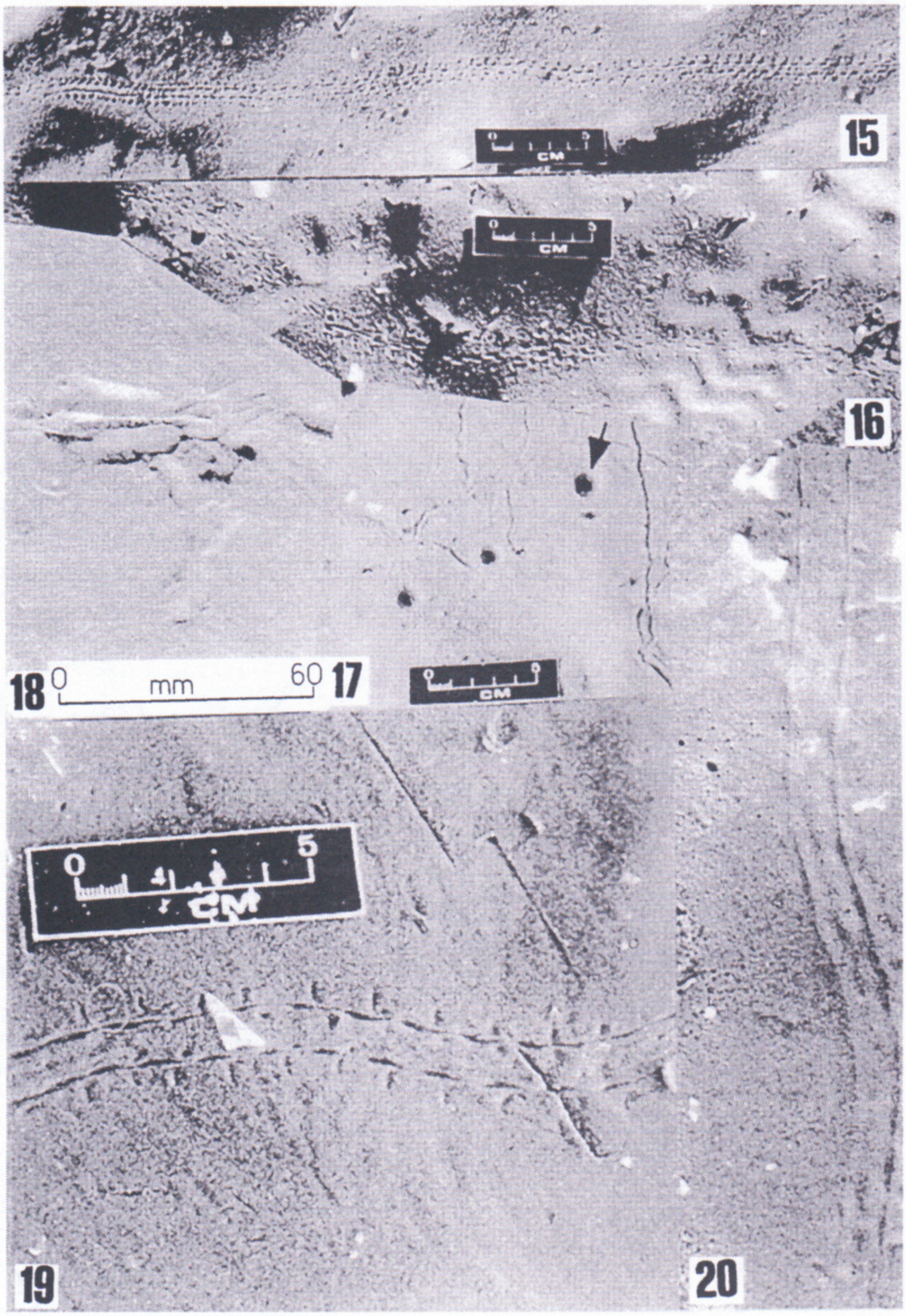


Fig. 15 - *Labidura* trail.
Fig. 16 - *Cicindella* trail.
Fig. 17 - Funnels of *Myrmeleon* (black arrow) and insects or nematoda burrows.
Fig. 18 - Agony trace produced by the sand shrimp (*Crangon crangon*).
Figs. 19,20 - Trails of *Idothea* isopod.

PLATE IV

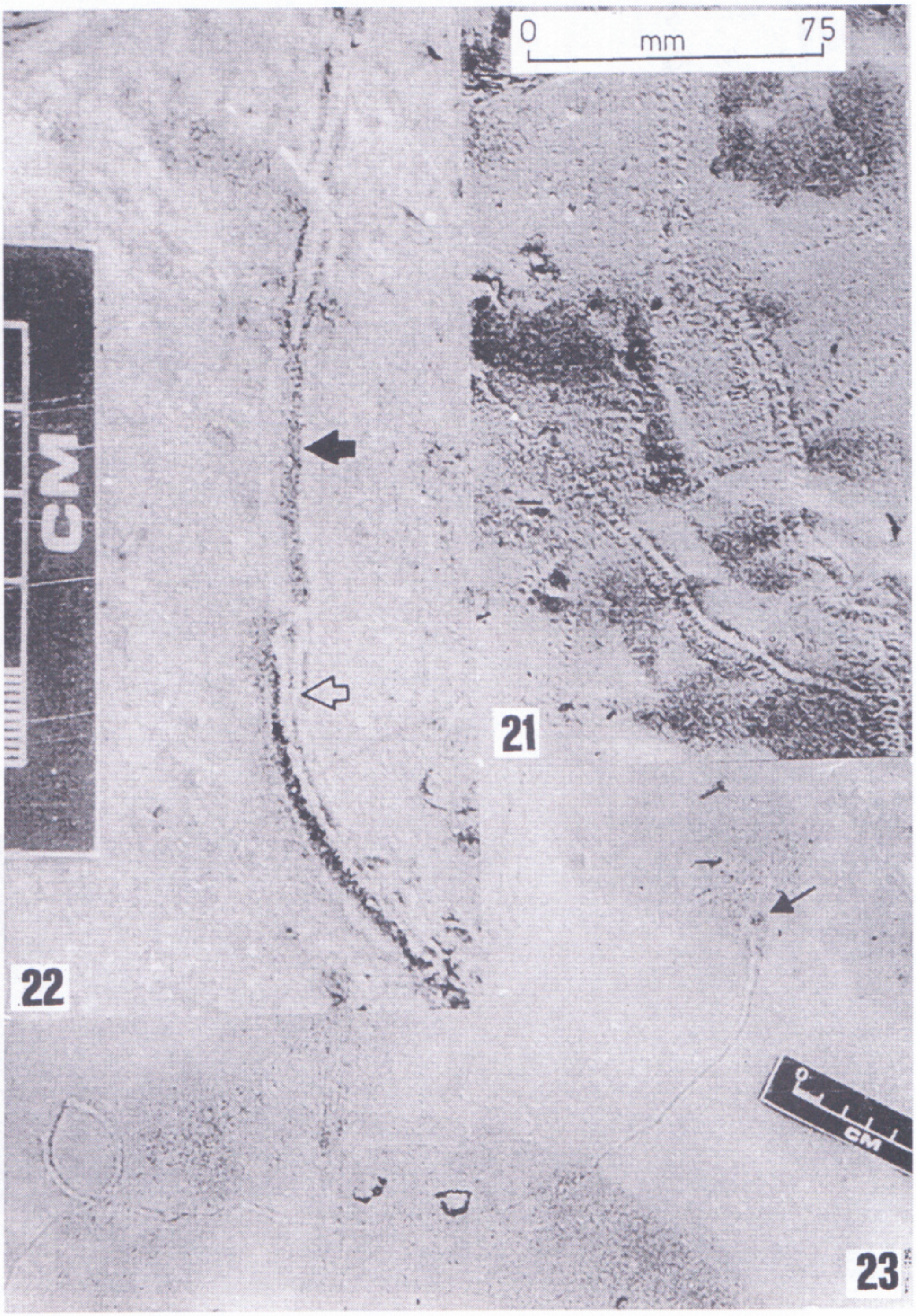


Fig. 21 - Isopoda trails.
Fig. 22 - *Helicella candicans* trail (black arrow) and mucus lined with fine sand (white arrow).
Fig. 23 - Conical funnel (arrow) and shifting traces produced by the ants lion (*Myrmeleon*).

PLATE V

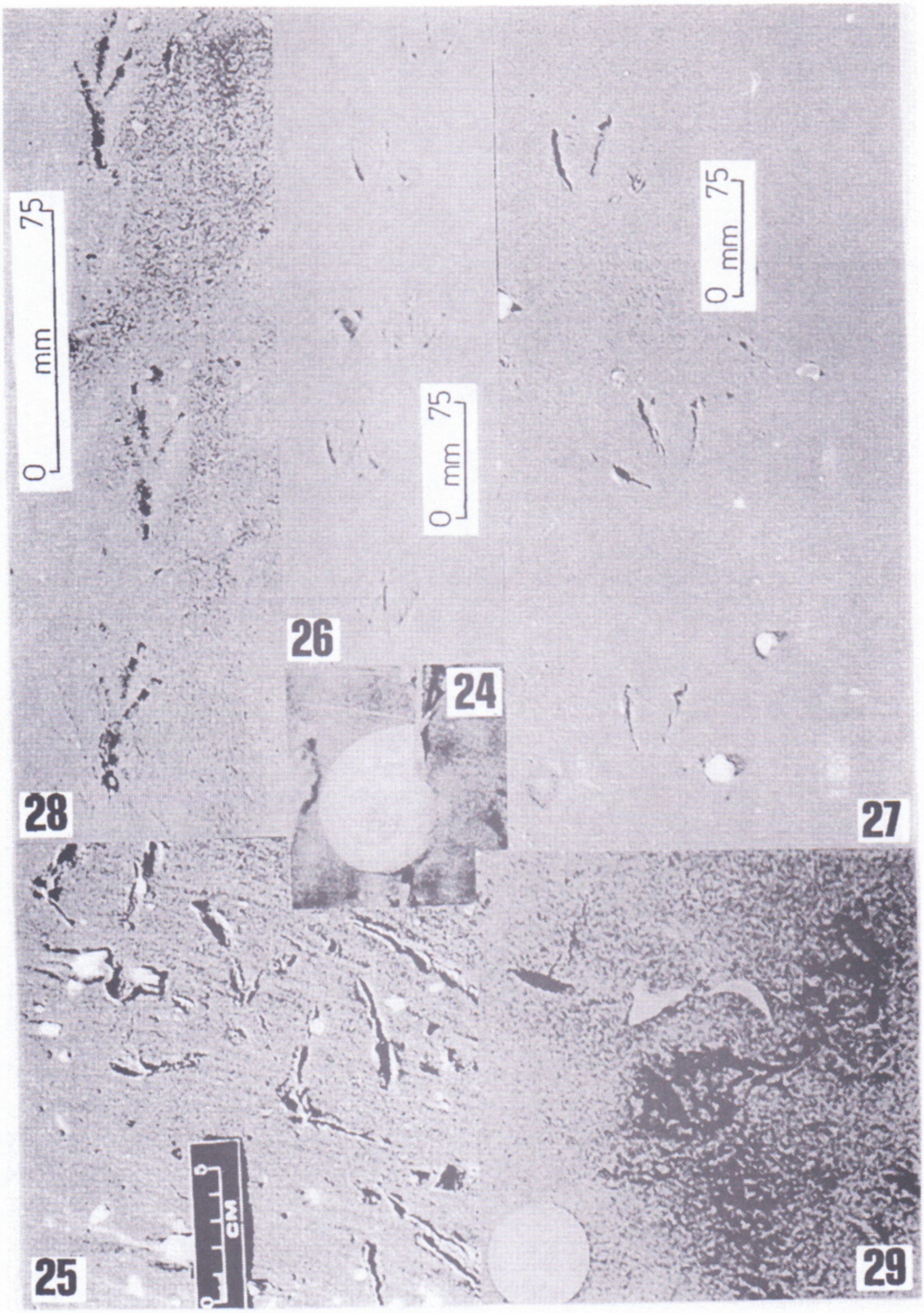


Fig. 24 - *Helicella candicans* Pfeiffer (natural size).
Figs. 25,27 - Footprints of *Larus.*
Fig. 26 - Footprints of tern (*Chlidonias*) with the print of the interdigital membrane.
Fig. 28 - Footprints of *Pica pica pica.*
Fig. 29 - The trace of the curved beak of *Larus.*

PLATE VI

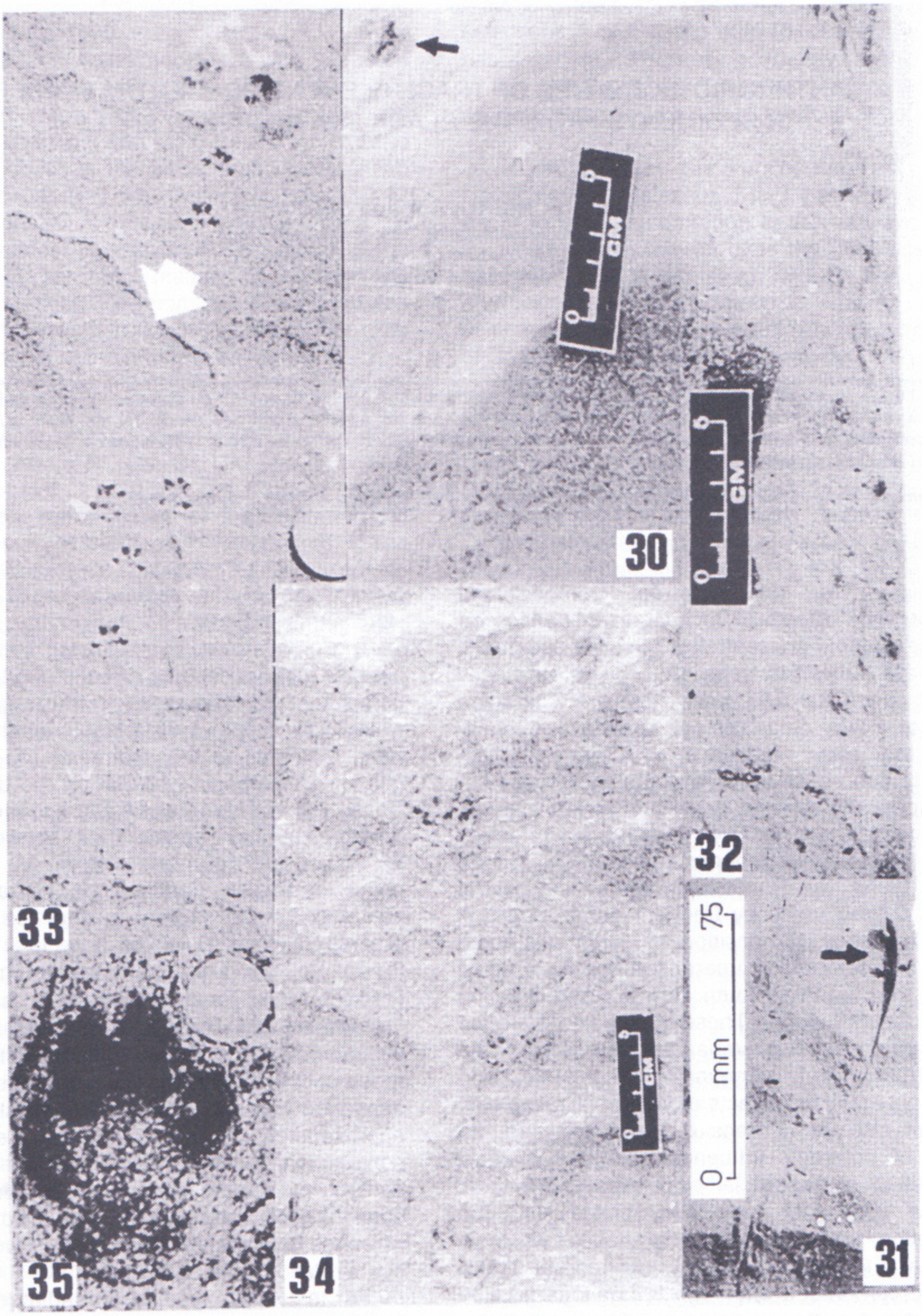


Fig. 30 - The track produced by *Rana sp.*
Figs. 31,32 - *Lacerta* (? *Lacerta taurica*) trails.
Fig. 33 - Footprints of a rodent (?) and larval burrows (arrow). Coin diameter = 24.5 mm.
Fig. 34 - Footprints probably produced by hedgehog (*Erinaceus europaeus*).
Fig. 35 - Footprint of *Canis familiaris* (coin diameter = 24.5 mm).