報　文

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Dish Structure Newly Found in the Nichinan Group, Kyushu, Japan

Haruo NAGAHAMA* Ryohei OTA* and Hisatomo AOYAMA**

Introduction

NAGAHAMA and AOYAMA made a geologic investigation for the purpose of studying sedimentary structures in the Nichinan and Miyazaki Groups, Miyazaki Prefecture, Kyushu, in March, 1974. On this occasion, they happened to find dish structure in the Nichinan Group, exposed in the Izaki Peninsula, northeast of Odotsu station in Nichinan City. The dish structure was discussed by WENTWORTH (1967) and STAUFFER (1967) at first. The dish structure, as far as the authors know, has never been reported in Japan. The outline of their study on the dish structure is stated here. Almost all of the contents of this report was written by NAGAHAMA, except the part of microscopic observation which was done by OTA.

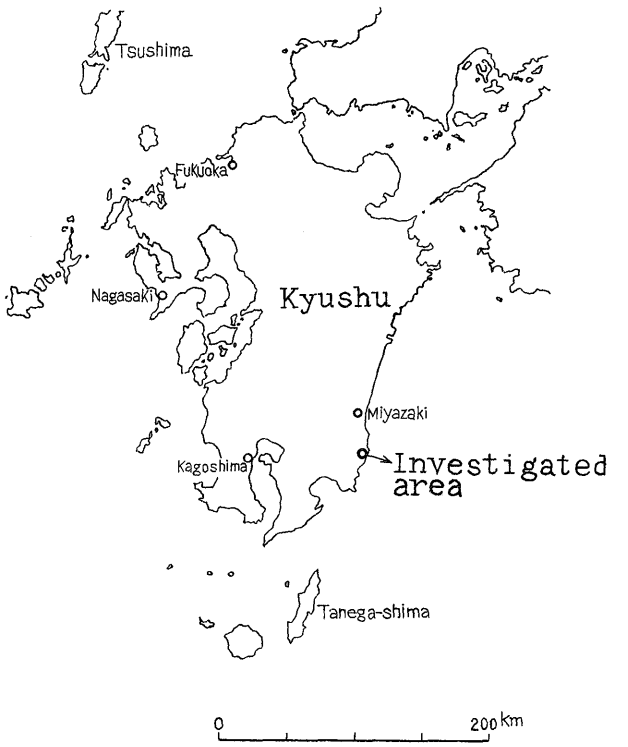

Fig. 1　Locality map.

Geology

The Nichinan Group, widely distributed along the Nichinan seacoast, is well-known for its

* Geology Department
** Miyakonojo Deaf School, Miyazaki Prefecture

complicated geological structure with frequent folds, faults and even overturned folds. The general geology of this Group was studied by KINO (1958, 1959a, 1959b), SHUTO (1963) and AOYAMA (1972). Among them, AOYAMA discussed the paleocurrent of the Group distributed in the Izaki Peninsula.

The Takigahirayama Formation (Oligocene-Miocene), that is, the upper part of the Nichinan Subgroup which is a lower half of the Nichinan Group according to SHUTO (1963), is distributed over the Izaki Peninsula. The mentioned formation, in which the dish structure was newly found, is over 150m in thickness and is composed mainly of alternations of dark grey siltstone and greyish white sandstone in the variable ratios. But the alternations can be roughly classified into two; one is thin-bedded and rich in siltstone, while the other rich in sandstone and often contains massive sandstone. In the former, however, sandstone beds of over 2m thick are rarely intercalated.

Generally, a sandstone bed is below 2m in thickness, while a siltstone bed is below 10 cm in thickness. The sandstone is comparatively well-sorted and is fine- to medium-grained, fine-grained one being predominant. A sandstone bed overlies a siltstone bed with slightly uneven and usually distinct boundary. Referring to the internal structure of the sandstone bed, it is rarely structureless, and in most cases, ripple-cross lamination, convolute lamination, parting lineation, irregular lamination or the dish structure newly found are observable there. Sorting of grain sizes is generally indistinct, that is, it can hardly be recognized by naked eyes, and cross-bedding on a large scale cannot be found at all.

According to BOUMA (1962), a typically graded flysch type sandstone bed is composed of the following five parts in ascending order; graded interval (A), lower interval of flat (parallel) lamination (B), interval of current ripple lamination (C), upper interval of flat (parallel) lamination (D) and pelitic interval (E). While, in the investigated area, sandstone beds showing the parts

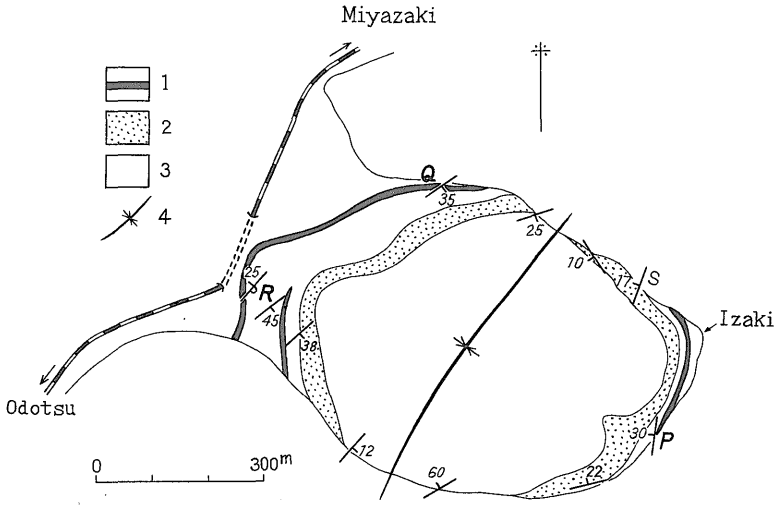

Fig. 2 Idealized geologic map of the Izaki Peninsula with observation spots (P ~ S).
1 Sandstone bed with the thickness of over 1m
2 Sandstone rich alternation of sandstone and siltstone
3 Thin-bedded alternation of sandstone and siltstone
4 Synclinal axis

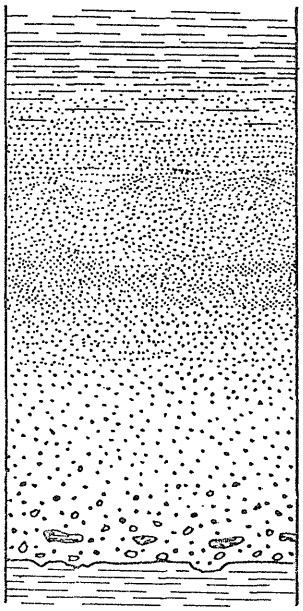

Fig. 3 Feature of idealized turbidite bed (after BOUMA, 1962), modified by STAUFFER (1967).

from A to C are well observable, especially the C part being characteristically predominant. Accordingly not only the upper parts such as D and E, but also even the lower ones such as A and B are often deficient there. That is to say, a sandstone bed having all of the five parts is not found. In short, the sandstone bed is composed mostly of one to three parts.

Flute casts at R spot are conspicuous on its sole with occasional appearances of any other kind of sedimentary structures, e.g., groove cast, prod cast, striation cast or load cast. And also trace fossils such as *Paleodictyon* sp. (of convex hyporelief, nearly hexagonal, reticulated with a diameter of 3.0–6.5 mm and with the thickness of a stripe of 0.9–1.0 mm) and *Helminthoidea* sp. (of convex hyporelief and with the thickness of a stripe of 1.5–4.0 mm and the width of a winding of 6.5–10.0 cm) are found in a rather silty sandstone bed, a horizon about 20 m above the one at which the dish structure is observable (at S spot). Well-developed flute casts and trace fossils, however, never co-exist with each other on sole of a sandstone bed.

Judging from the trace fossils, the sedimentary environment was the bottom of a bathyal, waveless, quiet and of poor oxygen condition, namely, such a place that pelagic sediments interbedded with turbidite in a wide sense were accumulated. The siltstone is dark grey to black, fine- to coarse-grained and mostly stratified.

Geological structure of this area, which shows a synclinal axis in the NE-SW direction with the dip of 20–40° across the central part of the peninsula, is said to be stable, as compared with other distributed area of the Nichinan Group. But the Group is locally overturned in the western part of this area.

Observation spots

The dish structure was first found at a point (P spot) in an outcrop successively exposed for

about 250m below a lighthouse at the eastern tip of the peninsula, about 1,540m NEE of Odotsu station. Afterwards dish structure was found again in another horizon, 4.80m below, at the same spot. It is exposed for 10m at least. The spot falls on the southeastern wing of the syncline in the NE-SW direction across the Izaki Peninsula. A sedimentary structure similar to the dish structure, about 3 cm in thickness, is found on the surface of a polished specimen, obtained at 5 cm above the base of an outcrop (Q spot) at the opposite northwestern wing of the syncline, in other words, at seashore about 1,250m NE of Odotsu station. They are presumably of nearly the same horizon.

Horizon of the dish structure found in a sandstone bed

The dish structure is observable in the lower part of a comparatively thick sandstone bed, 200–230 cm in thickness, which is intercalated in a thin-bedded alternation of sandstone and siltstone. As is shown in Fig. 4, the sandstone bed is classified into the following four parts, based on their characteristics of internal sedimentary structure, in ascending order; the massive part, the lower flat (parallel) lamination part, the dish structure part and the convolute lamination part.

Well-developed flute casts are crowded on sole of the sandstone which forms the massive part. The mentioned part lies on the uneven erosion surface of the underlying siltstone bed with a sharp boundary. The massive part is very fine- to fine-grained, being medium-grained at the most, and it shows well-grading but poor-sorting as compared with that of ordinary turbidite.

The overlying lower flat (parallel) lamination part is either deficient or very thin, if any. It is several centimeters in thickness and transitional to the underlying sandstone in the case of

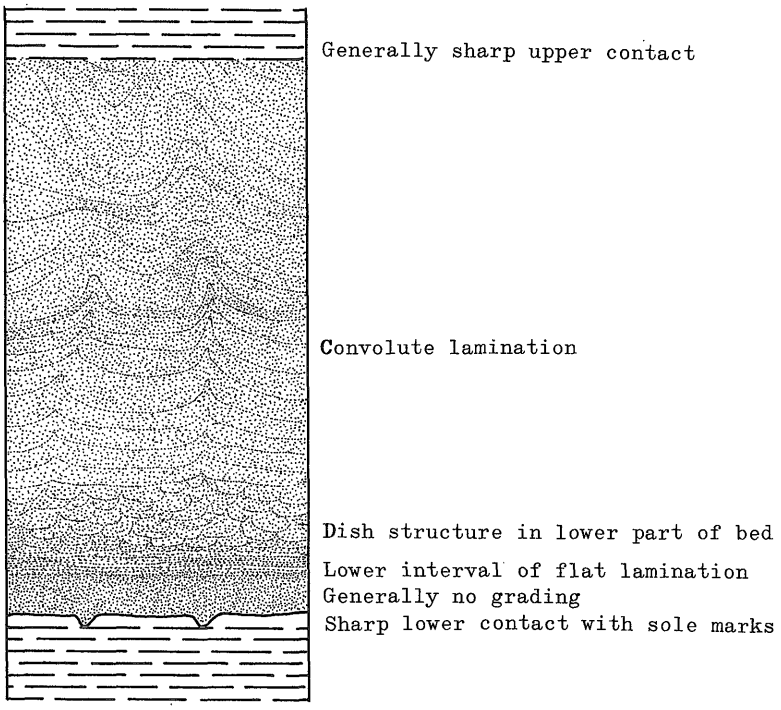

Fig. 4 Feature of idealized dish structure bearing sandstone bed (after NAGAHAMA, 1974).

presence.

The dish structure part is mostly transitional to the both of the underlying flat (parallel) lamination part and the overlying convolute lamination pat, though it is partially distinctly bounded to the latter.

The lower part of convolute lamination part, where dish structure cannot be found any more, is nearly horizontally laminated, but it is rarely a little undulatedly laminated. The undulation lines are partly just like a series of gentle foldings. The undulation, in most cases, becomes more and more remarkable to form convolute lamination in accordance with going upward. This fact may be one of valid clues to clarify the genesis of the convolute lamination.

Dish structure

Megascopic and microscopic observations on the dish structure are as follows.

Megascopic observation; The dish structure part is 30–60 cm in thickness. The shape of its vertical section looks like a dish-form showing a sedimentary structure with a dent downward. However, it is variable in its section ranging from nearly flat to just like a U letter. The width, that is, the distance from a brim to another brim, is generally 2.5–3.5 cm, rarely reaching about 10 cm, and the height is 1–3 cm. Even though the specimens obtained in the field by NAGAHAMA are only two pieces, the observation on them are as follows: In thin sections with ordinary thickness, about 0.03 mm, "dishes" of the dish structure do not appear when observed through in the air by naked eyes. When the thickness of thin section comes to about 0.08 mm, the patterns look the most distinct in dark grey coarse-grained siltstone to very fine-grained sandstone. The grain sizes become larger and larger to fine-grained sandstone in accordance with going upward within a dish. That is to say, it indicates inverted grading. The sorting tends to become better in accordance with going upward.

Microscopic observation of the dish structure in ordinary-thick sections is as follows; The minerals seen at the part of dark grey coarse-grained siltstone to very fine-grained sandstone are quartz, considerably sericitized or kaolinized felspar, biotite, iron ores and such secondary colored minerals as chlorite and epidote. CHIPPING (1972) recognized the presence of chlorite and iron ores at the dark grey border line which makes up the bottom of the dish structure under the microscope as well. On the other hand, the comparatively coarse and greyish whity sand grains at the upper part are composed mostly of angular quartz accompanied by a small quantity of felspar and are poor in muddy matrix.

As is clarified by the above observation, the pattern of the dish structure is represented by dish-like lines, which were caused by difference in grading and presence of colored minerals.

Dish structure was first reported by WENTWORTH (1967) from the upper Cretaceous flysch sequence in western California, and by STAUFFER (1967) from the lower Tertiary proximal flysch sequence in southern California.

WENTWORTH (1967) attributes the formation of dish structure to antidune migration in a turbidity current as follows; "Antidunes may produce simple dish structure by alternate scour, and by breaking and deposition in the troughs during aggrading suspension flow in a turbidity current that has declined from dispersion flow". STAUFFER (1967, p. 493–502) interprets dish structure as being due to disruption and modification of primary flat lamination formed by

pseudo-lamina movement in a mass-flow or grain-flow which were thought to be maintained by the dispersive pressure of grain collisions. He suggested "the agency of modification may be inhomogeneous shearing just before the moving mass 'jells', internal load deformation, localized water expulsion, or some combination of these".

Thus, two different mechanisms have been suggested for the formation of dish structure, but it is noticeable that the both mechanisms are primary in origin. Accordingly, the dish structure might be a sediment caused by grain flows as STAUFFER (1967) states, presumed from the fact that elements of turbidity currents and traction currents are excluded in the sandstone bed which contains the dish structure. Further detailed investigation on the under- and over-lying beds of the sandstone bed in question is desirable.

Comparison between the dish structure-bearing bed in the Nichinan Group and that stated by STAUFFER (1967)

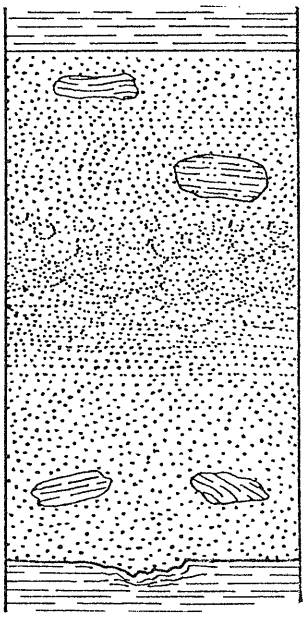

Fig. 5 Feature of idealized grain-flow bed (after STAUFFER, 1967).

The both beds show some similalities as follows:

(1) The upper surface and the base of the sandstone bed are abrupt.

(2) Grading of grain sizes is generally unobservable in sandstone of the massive part.

(3) Dish structures appear between the underlying flat (parallel) lamination part and the overlying convolute or swirled lamination part with transitional boundaries to them.

(4) The upper flat (parallel) lamination part is hardly observable.

On the other hand, the two show some differencies as follows:

	NAGAHAMA (1974)	STAUFFER (1967)
sole marks on sole of the massive sandstone	abundant flute casts	load casts
appearing horizon of dish structure within the sandstone bed	the lower part	the middle part
soft pebbles such as mudstone in the sandstone bed	scarce	many
sedimentary structures above the dish structure	Well-developed convolute lamination	swirled lamination

Comparison between the dish structure-bearing bed in the Nichinan Group and the turbidite bed by BOUMA (1962)

The both characteristics are compared with each other as follows: The similarities are that the boundary to the underlying siltstone bed is distinct and that sedimentary structures indicating its current direction, such as sole marks, on sole of the sandstone bed are well observed.

However, there are some differences between them as tabulated below.

	NAGAHAMA (1974)	BOUMA (1962)
grading	hardly observable	distinct
sorting	very good as compared with turbidite	bad
dish structure	observable	none
relation to the overlying siltstone bed	distinctly bounded	transitional
upper flat lamination part	none	present

Another sedimentary structures

Another kind of sedimentary structure observed on the surface of a sandstone boulder is shown in Pl. 9. It is probably a vertical section of convolution or sand volcano. The cylindrical shape of its section is just like that of a chewing rubber for baby. However, it is different in the respect that it has an opening just like a trumpet, instead of being spherically closed at the tip. From the detailed observation on the arrangement of sand grains at the mentioned cylindrical patterns, they seem to have moved vertically upward. That is to say, the "cylindrical patterns" seem to have originated in the compaction of sediments and the escape of water along columnar flow paths. The above-mentioned sedimentary structure may be a kind of "ruptured structure" named by DAVIS (1965).

Also there is a boulder, on which surface such sedimentary structure as is shown in Pl. 10 is observable. The shape is an oval with a dent just like a crater on the surface of a sandstone bed. The major diameter is 1.3–3.5 cm, the minor diameter being 1.3–3.5 cm, and the depth of the dent is 0.9–1.1 cm. The above-mentioned sedimentary structure is presumably a kind of "crater-

like structure".

Summary

(1) The sandstone bed, in which dish structure is observable, at an outcrop exposed at the Izaki seashore can be classified into the following in ascending order; the massive part, the lower flat (parallel) lamination part, dish structure part and the convolute lamination part. That is to say, the dish structure is observable in the part between the lower flat (parallel) lamination part and the convolute lamination part.

(2) The sandstone bed in question is different from the turbidite bed stated by BOUMA (1962). It rather resembles the grain-flow bed stated by STAUFFER (1967), but detailed inspection proves a little difference between the two.

(3) The genesis of the dish structure is not fixed yet, but it seems to be closely related to the genesis of convolute lamination and ruptured structure from the detailed observation on its mode of occurrence in the field.

Only one example found in the Nichinan Group was discussed in this report and NAGAHAMA spent only one day for it in the field. Accordingly there leaves room to be desired. In conclusion, the authors sincerely hope that further studies on the genesis of dish structure will be done on other examples, which are to be found in many formations of various ages in other districts.

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日南層群からみいだされた皿状構造

長浜 春夫・太田 良平・青山 尚友

要 旨

1974年3月，日南海岸地域の地質概査を行ったさい，日南市猪崎半島の滝ガ平山層の一部にあたる砂岩淤泥岩互層から皿状構造をみいだした．みいだされた皿状構造は，この地域についての1例にすぎないが，その産状・肉眼および顕微鏡観察などについて記載した．まとめとして次の結論を得た．

① 皿状構造を有する砂岩層の内部構造は，基底部から頂部に向かい，塊状部→下部平行葉理部→皿状構造発達部→斜交葉理部に区分される．

② 皿状構造を有する砂岩単層内部の堆積構造は BOUMA (1962) の turbidite bed の内部構造とは著しく相違し，むしろ STAUFFER (1967) の grain flow bed に類似する．しかしながら細部にわたり検討すると多少の相違点は認められる．

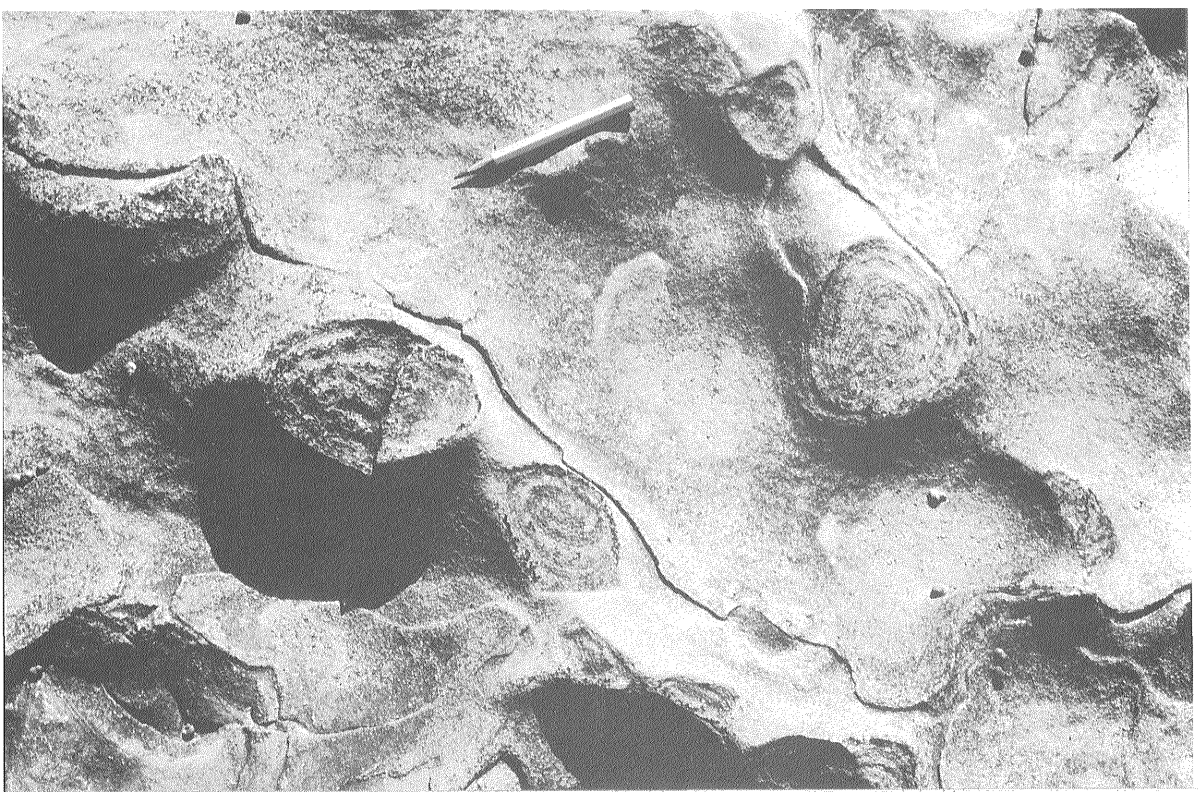
③ 皿状構造の成因に関しては現在のところ定説はないが，露頭でその産状を詳細に観察すると，convolute lamination や ruptured structure などの成因と密接な関係があると推定される．

PLATES

(With 2-8)

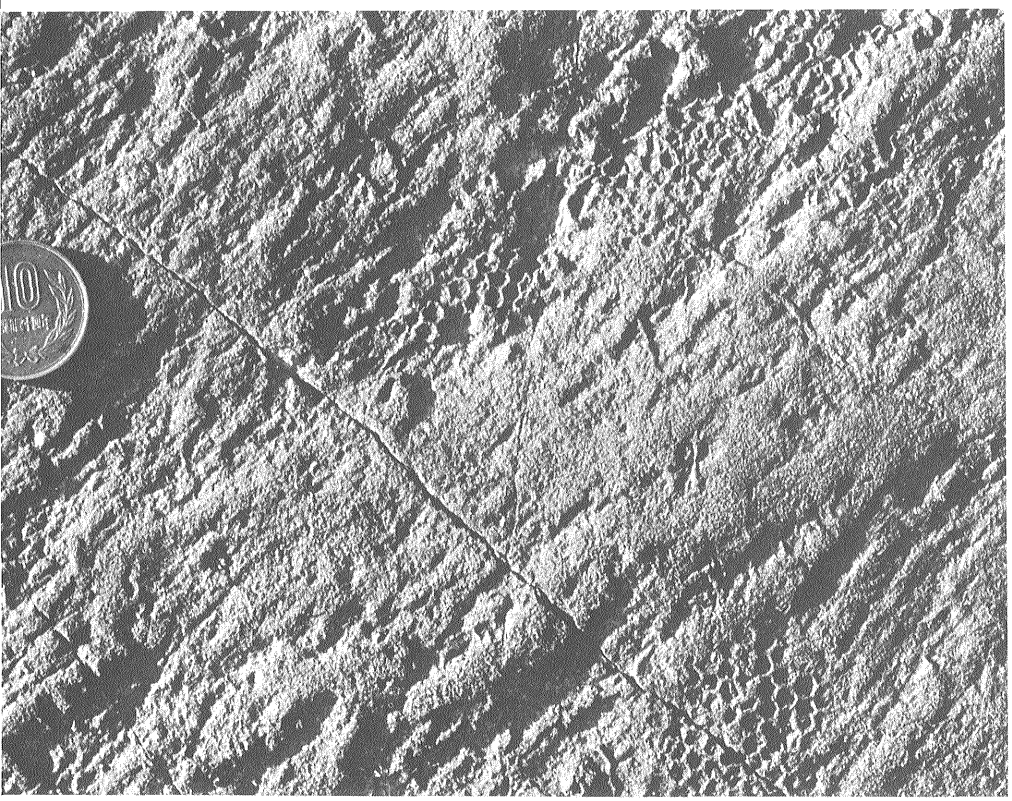
1 Convolutions in sandstone beds of the thick-bedded alternation of sandstone and siltstone (Loc.: P spot in Fig. 2).

2 Crests of convolutions in transverse in a sandstone bed (Loc.: north of P spot in Fig. 2).



Flute casts on sole of a sandstone bed (Loc.: R spot in Fig. 2).

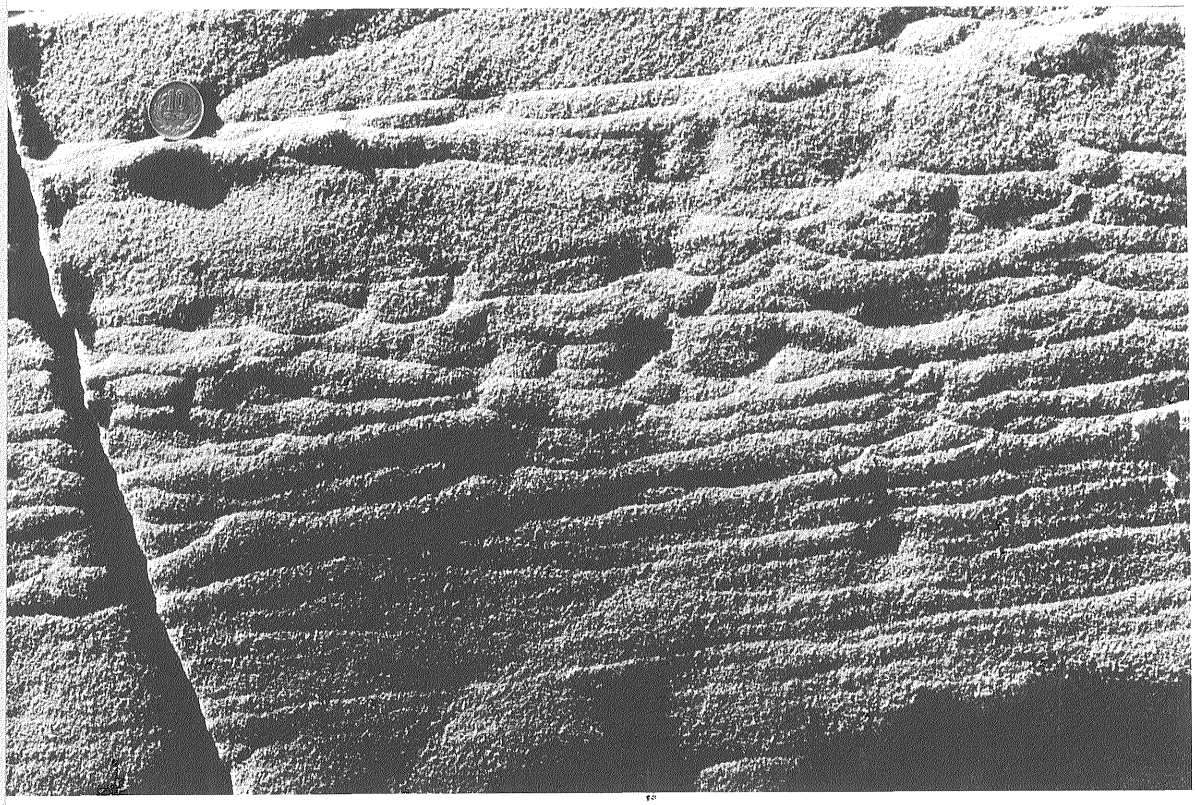
Current from top to bottom.



1 *Paleodictyon* sp. on sole of a sandstone bed (Loc.: S spot in Fig. 2).

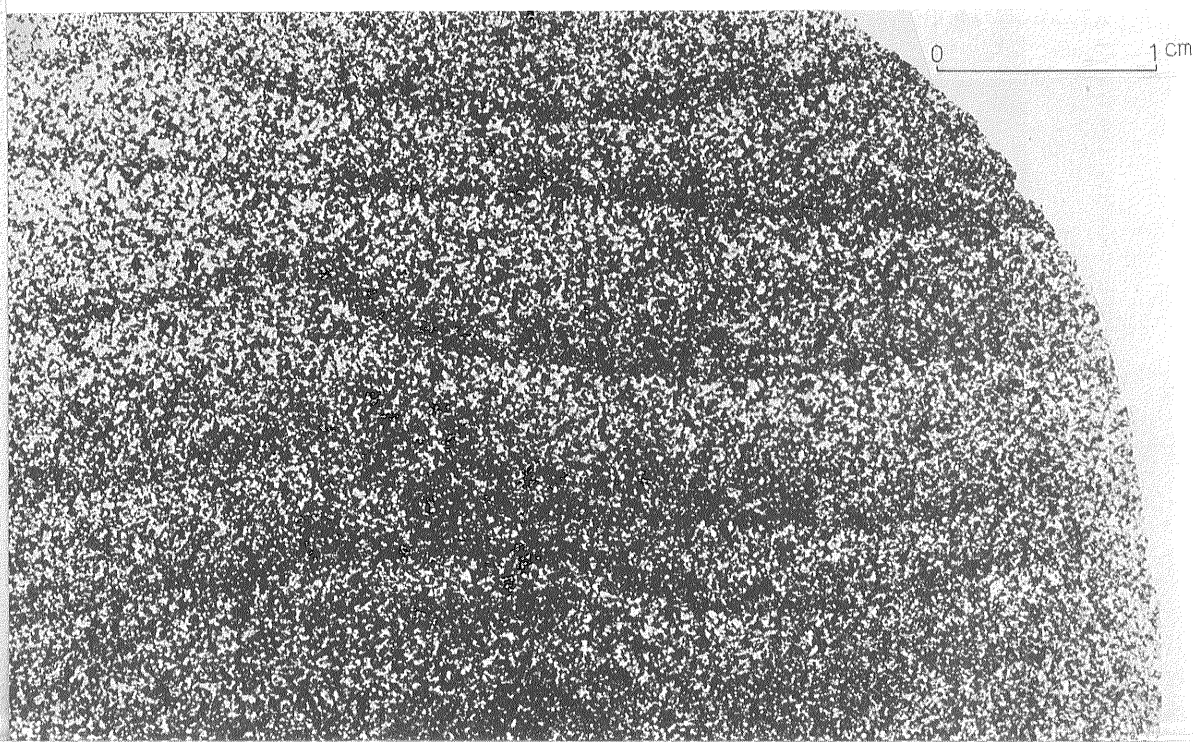
2 *Helminthoida* sp. on sole of a sandstone bed (Loc.: S spot in Fig. 2).

An outcrop of dish structure (lowermost part) and convolute lamination (upper part) (Loc.: P spot in Fig. 2).



1 Dish structure in a sandstone bed (Loc.: P spot in Fig. 2).

2 Magnified photograph of dish structure.



Ruptured structure (?) in a sandstone bed (Loc.: north of P spot in Fig. 2).

Markings of unknown origin (crater-like structure (?)) on a sandstone bed (Loc.: west of S spot in Fig. 2).