Memoirs of the College of Science, University of Kyoto, Series B,
Vol. XXXII, No. 2 Geology and Mineralogy, Article 4, 1965

Some Directional Structures in the Flysch-like Beds of the Shimanto Terrain in the Kii Peninsura, Southwest Japan

By

Tetsuro Harata

Geological and Mineralogical Institute, University of Kyoto

(Received Aug. 26, 1965)

ABSTRACT

The paper deals with the directional sole markings of the Shimanto Terrain. The features of several sole markings, which indicate the strike of the current line or the sense of current flow, are described, and the method of measurement and the method of correcting are described and discussed.

The four main directions of supply are observed in the Yomurakawa Muro Subgroup (Oligocene). One of these directions indicates that the current of supply came from the south or southeast, and from this fact, it may be concluded that the clastics of the Muro Group were sometimes supplied from the area situated to the south of the Shimanto Terrain, although it is now submerged by the Pacific Ocean.

Introduction

In the 1950's great interest was aroused in the various directional structures with the remarkable development in the modern methods of analysis of sedimentary rocks and the rapidly spreading popularity of the turbidity current hypothesis among geologists. Especially in the latter half of this period and in the 1960's, the directional structures have become useful as the most common and most useful criteria of current direction in flysch facies.

Recently, Dzulynski (1963; 1965), and Dzulynski and Walton (1963) have made some attempts to explain their origin in view of the known data concerning the dynamics of transportation and experimental data.

The term "directional structure" of sedimentary rocks refers to all the structures which may give any information on the direction of transportation of rock particles before their final deposition and burial.

Although directional structures have long been known in Japan, little systematic study has been made of them until recent years. KATTO (1952, 1959, 1961, 1964) described a part of these structures, mainly of the Shimanto complex in Shikoku, Southwest Japan, and ARAI (1957, 1959, 1960) described the structures of the Tertiary system of the Chichibu Basin, Northeast Japan. More recently, maps of sole markings and other structures of the Upper Cretaceous Izumi Group of the Honshu Major Belt of Shikoku, have been made by SUYARI (1965), and maps of those of the Mesozoic strata of the Northern Belt of the Shimanto Major Belt of South Kyushu, by NAGAHAMA and ISOMI (1965).

The purpose of this paper is to lay the beginning for a paleocurrent analysis, based mainly on the sole markings of the Flysch-like sediments of the Shimanto complex. The descriptions are based on the Paleogene to Lower Miocene Muro Group, but a few examples from other rocks are also included. The number of collection of data and errors resulting from the correction of data are discussed. Although the number of measurements is still not enough, the directions of supply of the Muro Group are also discussed.

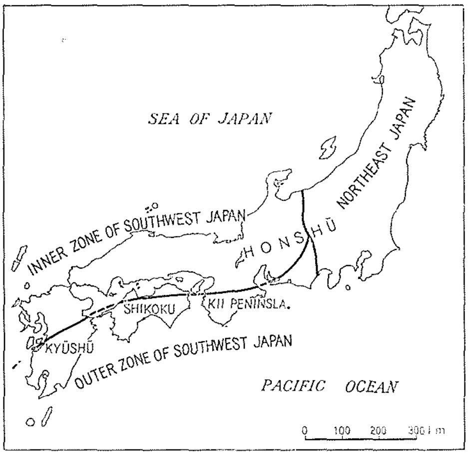


Fig. 1. Index map.

The author wishes to express his sincere thanks to Professor K. NAKAZAWA for valuable instructions and suggestions and to Dr. S. ISHIDA and Dr. T. SHIKI for the helpful discussions and to Emeritus Prof. J. MAKIYAMA for valuable suggestion and to Mr. T. TOKUOKA for the helpful discussions and the use of photographs. Particular thanks are due to the Kishu Shimanto Research Group for the cooperation of field survey. This investigation was supported partly by the Grant in Aid for Fundamental Scientific Research of the Ministry of Education.

CHAPTER I. SOLE MARKINGS

Some markings of various scales on the undersides of many sandstone and siltstone beds are among the most noticeable features of the Flysch-like rocks of the Muro Belt (HARATA, 1964). The bottom surfaces of the beds are characterized by curious int.icate patterns where soft shale has weathered away. These sculpturing are in reality casts*

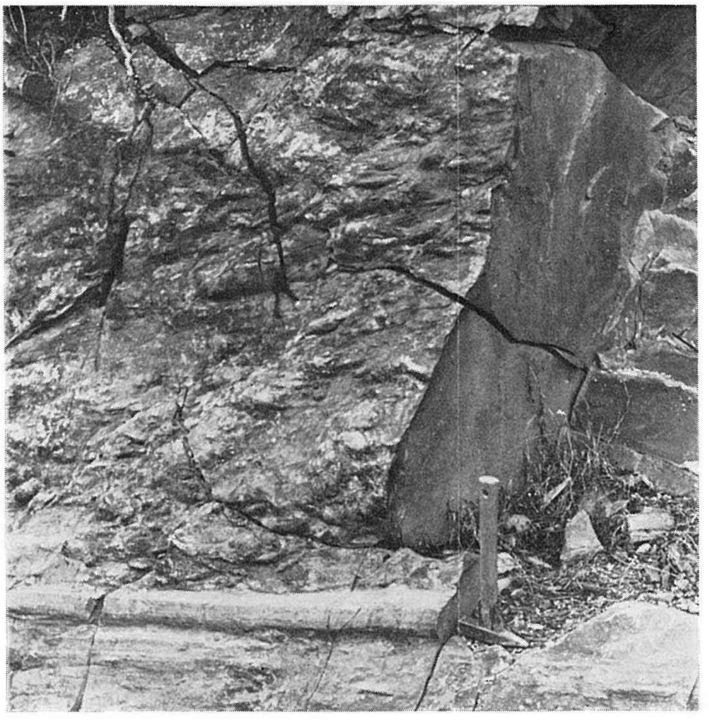


Fig. 2. Tool markings on base of graded sandstone in the Yomurakawa Muro Subgroup. Current from left to right. Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

of structures formed by various processes in the mud below and now filled by cemented sandstone. These structures are commonly referred to as "sole markings" (KUENEN, 1957) or "substratal lineations" because of their striking orientation (POTTER and PETTIJOHN, 1963). Detailed patterns are rarely found on bed tops because of the

* The sole markings themselves are not casts but molds. Common usage, however, refers the sole markings to casts.

gradual grading from sandstone to shale. Many beds also display internal structures such as current and convolute bedding.

Such substratal lineations were reproduced experimentally by FUCHS (1895), RÜCKLIN (1938), KUENEN and MENARD (1952), DZULYNSKI and WALTON (1963) and DZULYNSKI (1965).

Many investigators have observed and measured the orientation of lineations in the Flysch facies and other sedimentary facies over the various ages. Because most substratal lineations are arranged in lines or have elongated symmetrical shapes, they display a marked linearity on bedding planes, which makes their measurement possible. Most features with linearity indicate the strike of the current line or the sense of current flow along this line. Especially, current crescent, flute, brush, some of the bounce and prod and frondescent casts often give the sense as well as the direction of current flow. Almost all other structures described here are parallel to the current direction. Some rocks may show two or more lineations superimposed on each other, as, for example, where the primary current lineation is associated with a secondary lineation owing to the intersection of very closely spaced joints with the bedding plane.

1) Classification of sole markings

The directional current structures were classified in various ways by many authors (VASSOEVIĆ, 1953; KSIAZKIEWICZ, 1962; CROWELL, 1955; KUENEN, 1957; KELLING and WALTON, 1957; DZULYNSKI, 1963, 1965; DZULYNSKI and SANDERS, 1962a; POTTER and PETTIJOHN, 1963, 1964; DZULYNSKI and WALTON, 1963; TEN HAAF, 1959).

The classification accepted in this paper is based on genetic principles already used by Polish writers. According to them, directional structures may be arranged into two groups, namely external and internal structures, and the external structures are divided into sole and top markings.

A classification of sole markings under consideration based on the time of formation of the structure was proposed by VASSOEVIĆ (1953, 1954). They are divided into three categories, namely pre-depositional, post-depositional and syn-depositional sole markings.

a) Sole markings made prior to the arrival of the current which deposited the covering bed (pre-depositional)

b) Sole markings made at the interface between the mud and covering bed after deposition of the covering bed. (post-depositional)

c) Sole markings formed by the passage over the mud of the current which carried the sediment that forms the covering bed. (syn-depositional)

This division cannot be made so easily because it is impossible to designate the structures clearly in term of their time of formation *vis-a-vis* the time of deposition. However, it may be convenient to adopt this division, where possible, because making clear the genetic process of the sole markings is one of the important purposes of recent investigations of sole markings.

In this chapter, the sole markings are mainly described. Sole markings made by the current may be subdivided into scour markings, for the marking of which the scouring of the bottom was responsible, and tool markings, which represent the result of contact between individual objects, the tools, and the bottom.

Table 1. Classification of directional structure.

Directional structure	External structure	Top marking	Biohieroglyphs, ripple mark etc.				
	External structure, Internal structure	Sole marking	Biohieroglyphs				
			Current marking	Scour marking	Flute cast	Pre-depositional	Syn-depositional
					Current crescent cast		
					Frondescent cast		
				Tool marking	Groove cast		
					Bounce cast		
					Bruch cast		
					Prod cast		
			Deformational marking		Load cast, etc.	Post-depositional	

2) Scour markings

Scour markings occur in a large variety of shapes and sizes. The detailed morphology of scour markings is controled not only by the pattern of flow within the current but also by any surface irregularity is and/or heterogeneities that may be encountered within the bottom layer as scouring proceeds.

a) Flute cast

The term "flute cast" is generally attributed to CROWELL (1955, p. 1359), although it appears to have been first used by RICH (1951, pl. 3) in a plate caption. Under this term are embraced structures called "Kegelwülste (FUGGER, 1899), "Fliesswülste" (HÄNTZOCHEL, 1935), "Zaphenwülste" (RÜCKLIN, 1938, p. 96, fig. 1), "lobate rill mark" (SHROCK, 1948, p. 131), "flow mark" (RICH, 1950, p. 72)," scour finger" (BOKMAN, 1953, p. 158, pl. 1c), "turboglyph" (VASSOEVIĆ, 1953, p. 436, 65), "scour cast" (KINGMA, 1958, p. 12, fig. 12), "voltex cast" (WOOD and SMITH, 1958, p. 192), etc..

As described by CROWELL, "flute casts are sharp, subconical welts, one end of which is rounded or bulbous whereas the other end flares out and merges gradually with the surface of the sandstone layer."

Flute casts in the Muro Group show features more or less similar to those described by CROWELL, and have great variety of size, shape and arrangement. Both sides of the raised subconical ridge merge, not gradually, to the bottom surface of the sandstone layers (Fig. 3). There are, in some cases, narrow and shallow furrows along the margin at both sides.

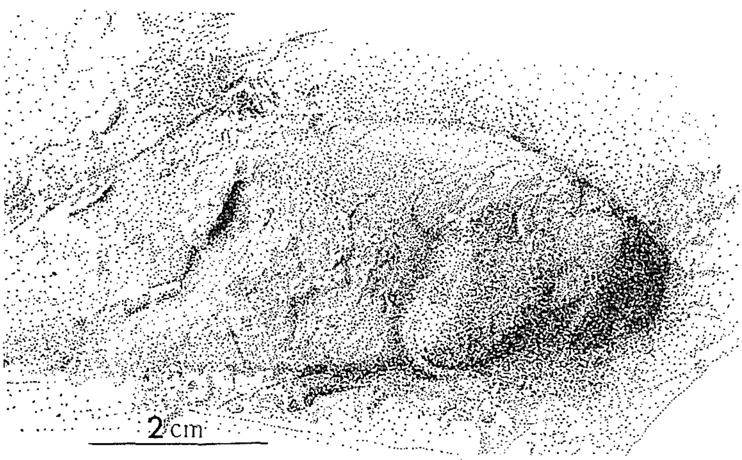


Fig. 3. Flute cast, a simple and somewhat highly raised subconical form with the rounded top. Current flowed from right to left. In the Yomurakawa Muro Subgroup (Paleogene) of the Muro Group. Sample number O-62. (After a photograph).

Variety in shape is as shown in the following types;

i) Flute cast (type 1), a simple and somewhat highly raised subconical form with comparatively rounded top, whose up-current end is rounded or bulbous. (Plate 1B; 8A) This type bears a superficial resemblance to "einfachen Zapfenwülste (simple conical form)" (RÜCKLIN 1938).

ii) Flute cast (type 2), a slightly raised subconical form with comparatively flat top, whose up-current end is narrow and sharp (Plate 1A; 2A, B; 3). This type bears a superficial resemblance to "Flachzapfen (flat triangular flute cast)" of RÜCKLIN (1938).

iii) Flute cast (type 3), a narrow elongated form; the ridge is flat on the lower surface, with rather steep sides; the length of the ridge is more than 15 cm, varying in width from 2 cm to 3 cm (Plate 4; 5). This type bears a superficial resemblance to "delicate flute cast" (KUENEN, 1957, fig. 9), "sludge cast" (WOOD and SMITH, 1958, p. 169), "furrow flute cast" (McBRIDE, 1962, p. 57), "rill mark" (SHROCK, 1948, p. 123) and "ribs and narrow creases" (DZULYNSKI, 1963, pl. XVIII-C).

iv) Flute cast (type 4), a raised finger-like form, both of the marginal side lines of which are nearly parallel (Plate 6; 17). This type bears a superficial resemblance to "longitudinal sand ridge" (DZULYNSKI, 1963, pl. IV, fig. A), the flute casts of TEN HAAF (1959, p. 44, fig. 28) and Pettijohn & Potter (1964, pl. 57B).

In general, the flute casts on a given sole tend to form a group and to be of the same size and much alike in shape. The features of each group may be closely related with the types of shape mentioned above. The occurrences of each type are summarized as following.

i) Flute casts (type 1), some of which overlap each other, are sporadically arranged on a given sole. (Plate 1B; 8A)

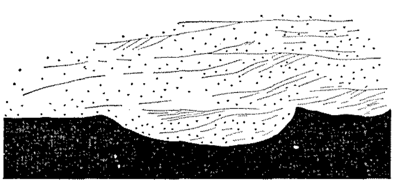
ii) Flute casts (type 2), which are generally abundant, are arranged at brief intervals partly overlapping on a given sole. (plate 1A; 2A, B; 3).

iii) Flute casts (type 3), having subparallel ridges, closely spaced, rather similar in size and somewhat wavy in outline. (Plate 4;5)

iv) Flute casts (type 4), which show a rather regular arrangement, crowding closely together, in bunches with smooth surface in between, overlapping.

The flute casts may be distributed in some orientated pattern on a given sole. In the Shimanto Complex of the Kii Peninsula are observed the "longitudinal pattern" and the "diagnoal or oblique pattern" of the orientated patterns recognized by DZULYNSKI (1963, p. 41, fig. 21). (Plate 1A; 3; 7)

It was found in many cases that the flute casts and the other sole markings coexist with each other on the same sole. The most common coexistence is that of flute casts and organic sole markings (biohieroglyphs), some of which cross the surface of flute casts. In rare cases, the flute casts and groove casts constitute somewhat contrasting assemblages. An example, in which the flute cast (type 4 mentioned above) crowding closely on the bottom surface of the sandstone beds coexists with large groove casts, was found in the Hidakagawa Group (Plate 17). The features of this coexistence bear a superficial resemblance to those described by WOOD and SMITH (1959, p. 169) or shown by TEN HAAF (1959, p. 44, fig. 28). In the assemblages, the orientation of each cast is generally slightly oblique. The oblique azimuths are less than 30°, and coincide approximately



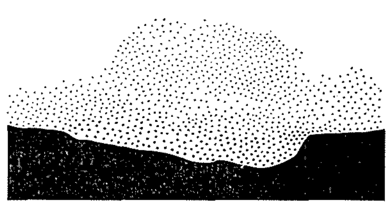


Fig. 4-A 0 5cm Fig. 4-B

In Fig. 4-A is shown the small cross-stratification. Sample number O-62. In Fig. 4-B is shown the coarsest material in section of flute filling. Sample number O-2-1.

with the oblique azimuths between the respective vector mean azimuths of many flute and groove casts which were collected in a successive rock unit. (see Chap. II)

The flute casts themselves may appear structureless, but, if sectioned carefully, many show a small cross-stratification and the coarsest materials of which a bed is composed are commonly collected in the flute casts. Usually on the surface of flute casts some minor sole-markings are found, which are parallel to the current and the orientation of the flute casts.

b) Current crescent casts

The term "current crescent" has been applied by PEABODY (1947) to the cast of crescentic depressions which is scoured in front and at the side by various obstacles. This structure has been described by several writers (FIEGE, 1942; PEABODY, 1947; RICH, 1950; RADOMSKI, 1958; DZULYNSKI and SLACZKA; 1958, 1959; RÜCKLIN, 1938; McKEE, 1954; KSIAZKIEWICZ, 1961). For this structure has been used the term "crescent scour cast" or "Hufeisenwülste" (RÜCKLIN, 1938).

As described by PEABODY, it is a small crescentic rounded ridge, commonly with pit in center; crescent convex up-current. The cast of a horse-shoe shaped moat eroded on the up-current side of an obstacle such as a pebble, shell, etc.

Current crescent casts in the Muro Group show a similarity but are greatly varied in size and shape (Plate 8B; 9; 10). They are horse-shoe shaped or semicircular ridges,

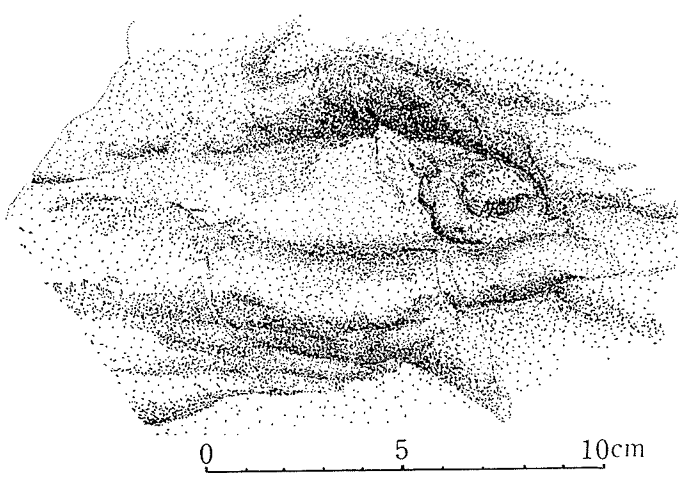


Fig. 5. Current crescent cast with an cast of tool. Current flowed from right to left. On the bottom surface of sandstone of the Yomurakawa Muro Subgroup (Oligocene), west shore of Ōtō River, near Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture. (After a photograph.).

each bifurcated ridge of which vanishes toward the lee side. The inside moat or depression of the ridges is commonly excavated more deeply than the bottom surface, in which are generally small ridges on the up-current side. On some soles, the up-current end of the ridges have one or more shale patches. In rare cases observed, there are "multiple crescent casts*", having double ridges, which are joined together in a part of the up-cu rent side (Plate 8B). One sample of such multiple crescent casts have a tube-like biohieroglyphs on the surface of the inside depression (Plate 8B). On a given sole, the current crescent casts are closely crowded in some cases and tend to be approximately of the same size, shape and orientation and are much alike (Plate 9A); they vary from sole to sole. In some cases, there are asymmetrical current crescent casts (Plate 10A). Their asymmetry is represented by the different length of the bifurcated side ridges, one of which is shorter and broader than the other and shows a bulbous end. This shorter ridge is clearly superimposed by a groove cast at the down-current end. There is an example of a current crescent cast that is more developed than the others and forms a flute cast on the lee side (Plate 10D; Fig. 6).

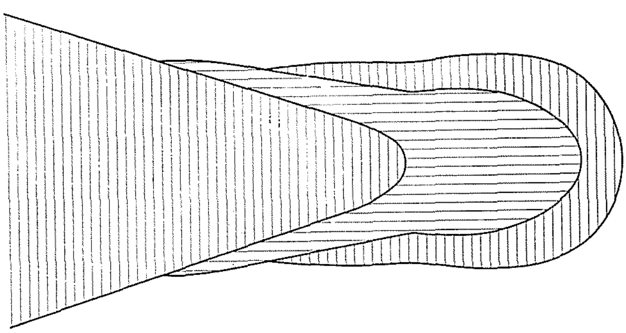


Fig. 6. Schematic representation of the assemblage of the current crescent and the flute casts. ||| ridge; ≡ depression.

They range in size from 5 cm to 100 cm in length; most commonly they are 7 to 10 cm long. The soles yielding crescent structures are comparatively smooth because of the scanty existence of other sole markings. In rare cases, the current crescent casts and the other sole markings constitute some assemblages. The sole markings assembled on a given sole are the bounce, groove and flute casts and the very few problematic hieroglyphs. The current crescent and the flute cast coexist only in the manner mentioned above. Current crescent is usually observed on the sole of the sandstone layers

* DZULYNSKI and SANDERS 1962, Table XIV, 3

in the sand rich alternation of well laminated sandstones and shales. In the rock units, which are represented by similar features and include these structures, there are a great number of tool markings and parting structures* and the so-called Paleodictyon. (Plate 11; 12)

c) Frondescent cast**

The term "frondescent cast" was proposed by TEN HAAF (1959, pp. 30-31, fig. 15), although this structure was first mentioned briefly by KUENEN (1957, pp. 255-256, pl. 2A), who called it "cabbage leaves". Under this term are embraced structures called "deltoidal cast" (BIRKENMÄJER, 1958, Fig. 8.9, Pl. 21, p. 143), "feather-like hieroglyphs" (KSIAZKIEWICZ, 1958, Pl. 5, fig. 1), "frondescent 'furrow flute casting'" (McIVER, 1961, p. 168).

As described by TEN HAAF, "the flat casts are usually several decimeters long, resembling certain shrubs or large cabbage leaves. They tend to occur in large crowded groups, often constituting a distinct level of their own a few centimeters lower than the rest of the fluted or grooved bedding plane. Frondescent casts may also overrun an entire sole as far as exposed. The spreading "foliage" is always directed down-current. The ends of many casts are slightly undercut, and separated from the bedding plane proper by a wedge of mudstone."

As described by Kuenen, "It recalls a massive, large cabbage leaf or an aerial photograph of soil erosion (as cast). Although the edges are separated from the sole itself by a film of shale, the major central part is indivisibly attached and forms an integral part of the graywacke bed. The "stem" of the cabbage leaf points up-current, the free edges down-current, as if they were pushed by the current into the underlying mud. The leaves have been found isolated or in great numbers, entirely covering a sole with large fans."

An example of the frondescent cast was observed in the Muro Group. It bears a supperficial resemblance to the structure mentioned above. This sample has the mud ball at the "stem" side of the foliage (Plate 13).

3) Tool markings

The term "tool mark" was proposed as a general term for all the marks which were made by the contact of some object (the tool) and the bottom. (DZULYNSKI and SANDERS, 1962a, p. 72)

* Parting structures are not sole marking but internal structures. They were first described by SORBY (1856, p. 114) and called by the term "primary current lineation" (STOKES, 1947, p.21) or "parting lineation" (CROWELL, 1955, p. 1361).

** The origin of this structure is problematic. It is mentioned here under scour marks with some doubt.

a) Bounce cast

The term "bounce casts" has been proposed by WOOD and SMITH (1957) for rather short ridges widest and deepest in middle and fading out at either end. Structures of the kind under consideration, have been described by many writers; HALL (1843), DZULYNSKI and RADMSKI (1955) and DZULYNSKI, KSIAZKIEWICZ and KUENEN (1959).

As described by WOOD and SMITH (1957, p. 168); "Bounce casts commonly occur in myriads all over the base of a single bed; groove-casts may occur with them, but strong flute casts rarely do so. They are fine discontinuous parallel ridges usually difficult to see other than with inclined lighting. The deepest and widest parts always coincide, and the mark fades away in both directions. There is a tendency for the deepest part to be at one end, and though these marks are frequently parallel to flute-casts on adjacent beds the steep end usually points in the opposite direction. In some instances there is a transition from these marks to groove casts."

In the Muro Group, bounce casts belong to the most common sole markings on the bottom surface of sandstone layers (Plate 14; 15; Fig. 6). It is generally impossible to tell whether the current came from one end or the others. However, the details of

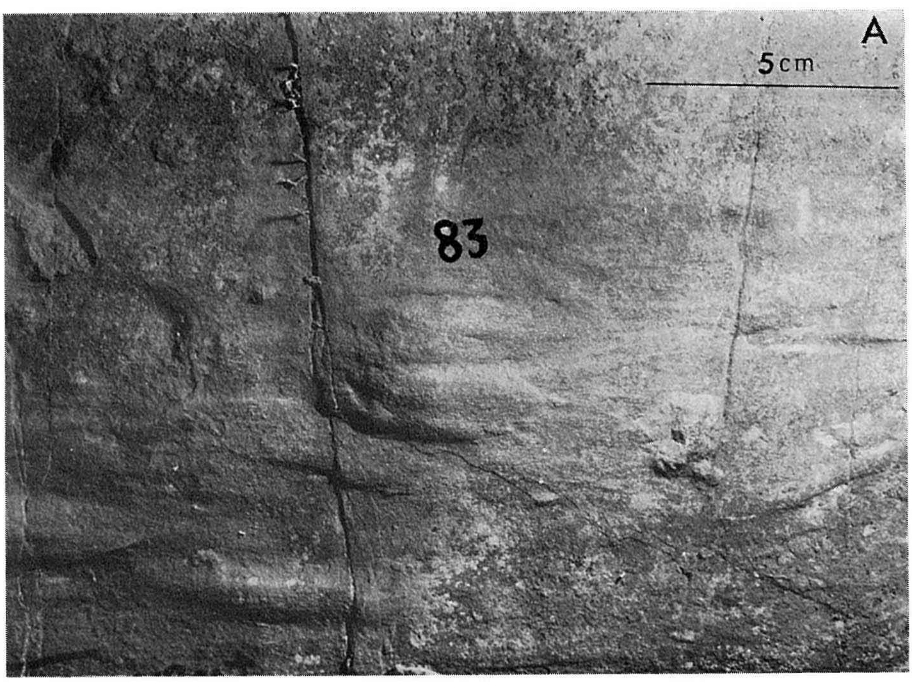


Fig. 7. Bounce casts on base of sandstone in the Yomurakawa Muro Subgroup. Current from right to left. Kawayu, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

their feature show that the down-current end fade out more steeply than the up-current end. On the surface of this ridges there are one or more strains parallel to their orientation. They are various in size, 7 cm to 30 cm in length and 2 cm to 10 cm in width. They are commonly assembled with groove, prod and brush casts but not with scour markings (Plate 14: 15).

b) Brush Cast

The term "brush cast" was applied by DZULYNSKI and SLACZKA (1958, p. 231) to bounce casts with crescent depressions at one end. DZULYNSKI and SANDERS (1962a) used the term "brush mark", which refer to imapct marks (RADOMSKI, 1958), whose longitudinal profile is gently curved, concave upward, and whose down current end always shows one or more characteristic bulge(s) that formed in the mud and which generally overhangs somewhat in the down current direction.

In the Muro Group brush casts belong to the most common sole markings (Plate 16). The undersides of many sandstone and siltstone beds of the Muro Group are characterized by these structures. A semicircular depression or moat is excavated on the down-current side being the cast of a mud ridge heaped up in front of the object as it momentarily slid along the bottom. The crescent depression cast, therefore, points down current. The depression of moat is not only at the up-current side but also continues to either side of the ridge, narrowing and shallowing up-current. The side depression is the counterpart of the mud ridge, which is heaped at the side of objects brushing against the bottom while carried by the current. The ridge of brush casts is commonly longitudinal in shape, narrowing and sloping up-current, and various in size. They range in size from 5 cm to 20 cm in length; most commonly they are from

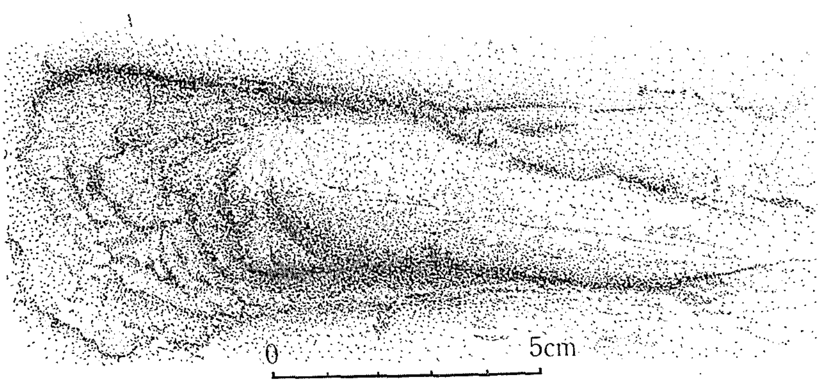


Fig. 8. Brush cast with a semicircular depression. Kawayu Formation of Yomurakawa Muro Subgroup (Oligocene). Current flowed from right to left. Sample number O-83. (After a photograph.)

7 cm to 8 cm long, and from 2 cm to more than 10 cm wide. The ridge which is longer in length or width, is commonly larger in its depression than the shorter ridge. In a rock unit showing a uniform lithofacies, the brush cast and the other sole markings show common assemblages. On a given sole, the brush casts are sporadic and commonly coexist with tool markings but not with scour markings.

c) Groove cast

The term "groove cast" is generally attributed to SHROCK (1948). Under this term are embraced structures called "mud furrow" (HALL, 1843), "drag mark" or "slide mark" (KUENEN, 1957), "Schleifmarken" (SEILACHER, 1960) and "striation cast" (PETTIJOHN, 1957).

The general explanation suggested by HALL (1843) that they are due to the action of current flowing over the surface upon which the subsequent deposits were laid down, holds true for most cases.

As described by SHROCK (1948), "groove casts are rounded or sharp-crested rectilinear ridges a few millimeters high and many centimeters long. The ridges are striking because of their marked parallelism and constant size and particularly because they are confined to the under surfaces of sandstone layers lying on mudstone. Two or three sets usually differing somewhat in size and transecting one another, may be present on the same surface."

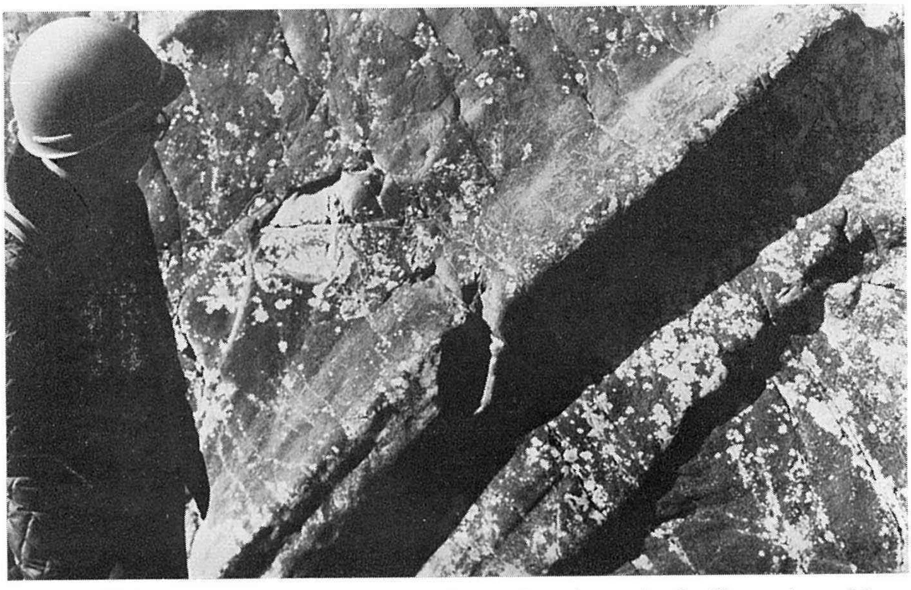


Fig. 9. Triangular large groove cast on base of sandstone in the Yomurakawa Muro Subgroup. Taira, Hongū-cho, Higashimuro-gun. Wakayama Prefecture.

Plate 1A: Flute casts on underside of sandstone of the Yomurakawa Muro Subgroup (Oligocene). Note orientated pattern and overlapping character. Current from bottom to top of picture. West of Wabuka Bay, Kushimoto-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 1B: Simple subconical flute casts on underside of sandstone in the Hitakagawa Group (Upper Cretaceous ?). Current from right to left on picture. Komatagawa, Ryuzin-mura, Hitaka-gun, Wakayama Prefecture.


A
0
10CM


B
0
30CM

Plate 2A, B: Flute casts on underside of sandstone of the Yomurakawa Muro Subgroup (Oligocene).. Current from lower right to upper left. West of Wabuka, Kushimoto-cho, Higashimuro-gun, Wakayama Prefecture.


A

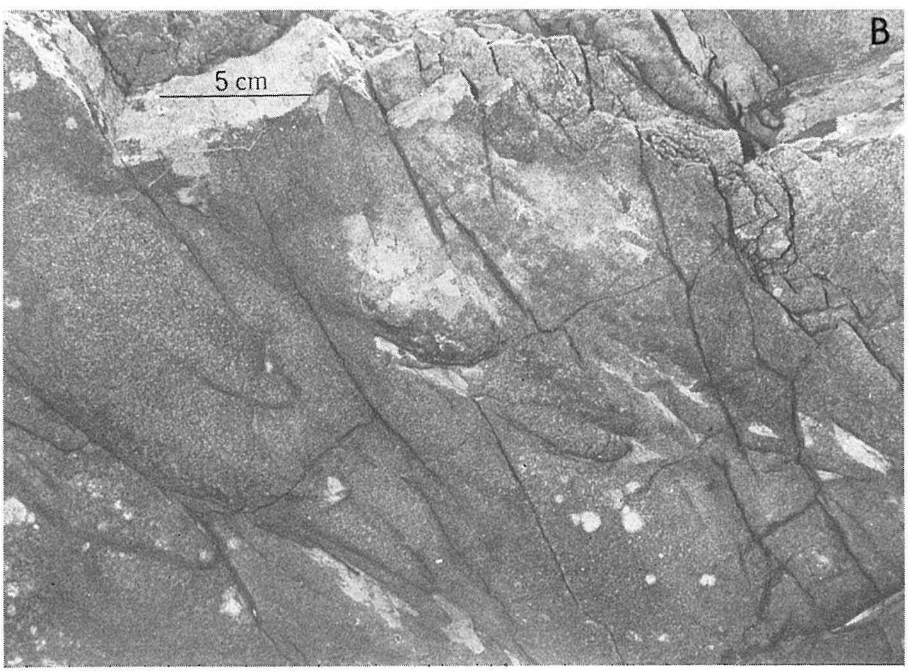

B
5 cm

Plate 3: Flute casts on underside of graded sandstone in the Yomurakawa Muro Subgroup (Oligocene). Note arrangement showing diagnoal or oblique pattern. Current Bottom to *top*. Wabuka, Kushimoto-cho, Higashimuro-gun, Wakayama Prefecture.


1 m

Plate 4: Fine-texture flute casts on underside of sandstone of the Yomurakawa Muro Subgroup (Oligocene). Current from upper right to lower left. Fukuidani, Kozagawa-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 5: Fine-texture flute casts. Fukuidani, Kozagawa-cho, Higashimuro-gun, Wakayama Prefecture.


5cm

Plate 6: Flute casts on underside of sandstone in the Hitakagawa Group (Upper Cretaceous ?). Current from upper right to lower left. Yumoto, Ryuzin-mura, Hitaka-gun, Wakayama Prefecture.

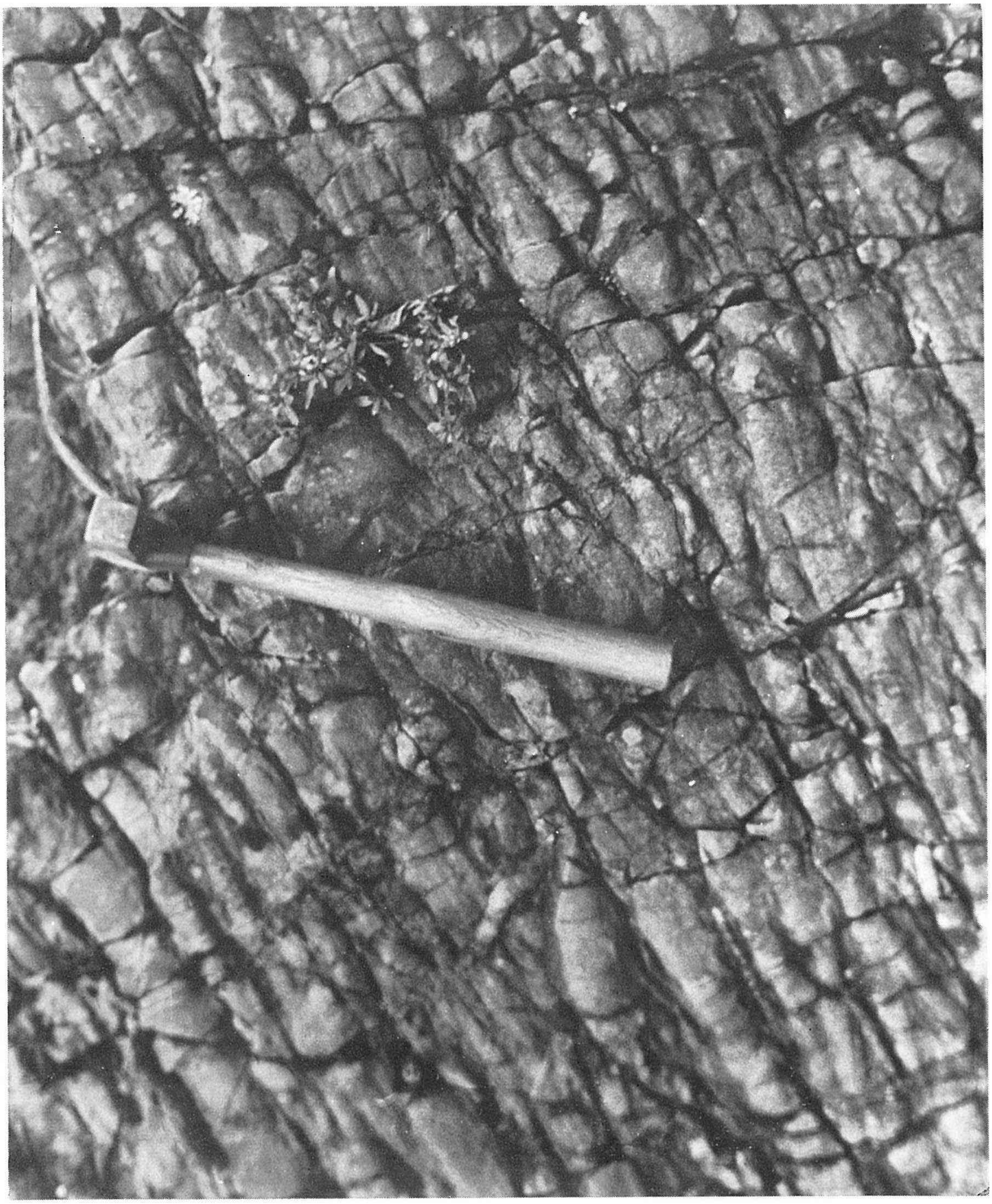
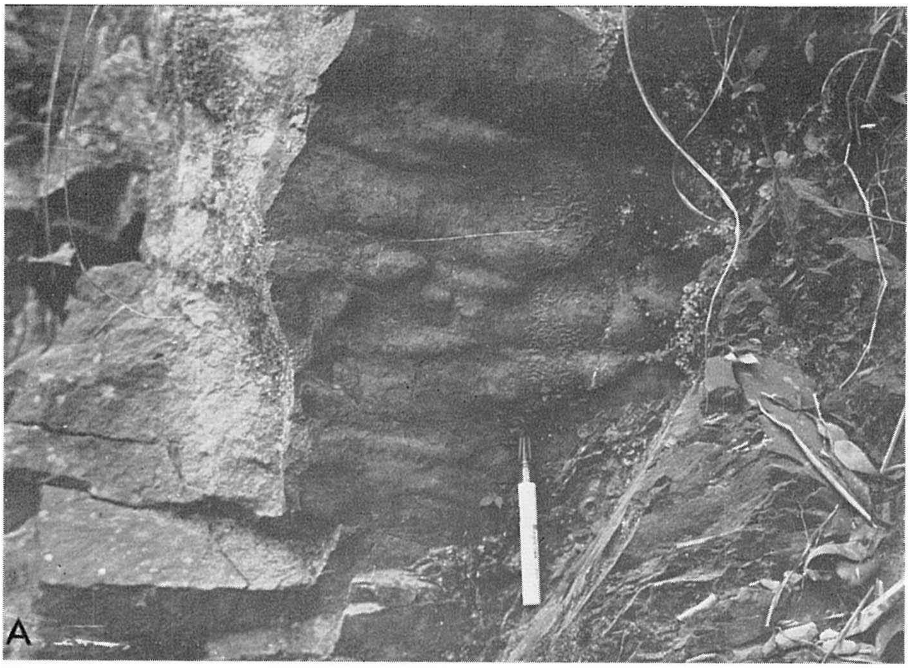


Plate 7A, B: Flute casts on underside in the Yomurakawa Muro Subgroup (Oligocene). Current from top to bottom. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefectures.


A
50cm
B
10cm

Plate 8A: Simple subconical flute casts on underside of sandstone in the Ukekawa Muro Subgroup (Upper Oligocene—Lower Miocene). Current right to left. Maenokawa, Mikawa-cho, Higashimuro-gun, Wakayama Prefecture. (Photograph by T. Tokuoka).

Plate 8B: Multiple current crescent casts with shale patches. Note tube-like "biohieroglyphs" in the inside furrow. Current left to right. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.



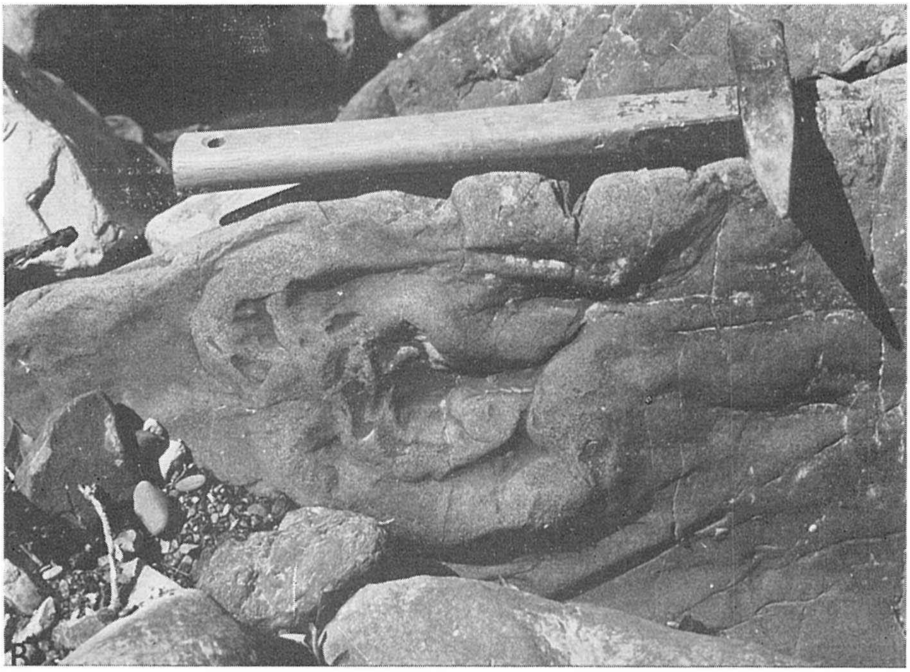


Plate 9: Current crescent casts on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from lower left to upper right. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

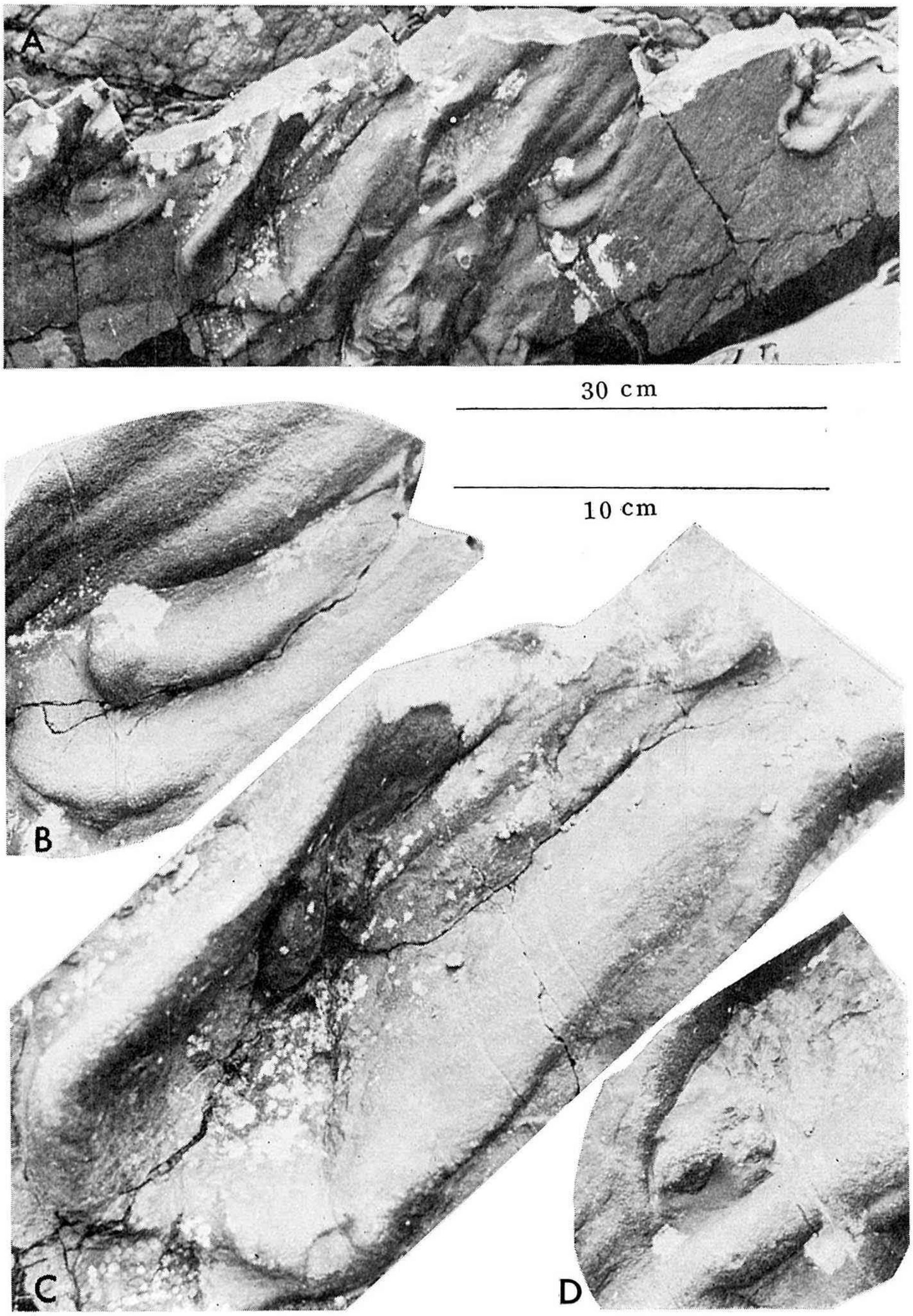

A
30 cm
10 cm
B
C
D

Plate 10A: Asymmetrical current crescent casts and small flute cast on undeside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from top to bottom. Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 10B: Current crescent cast on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from top to bottom. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 10C: Large current crescent cast on underside of sandstone in the Yomurakawa Muro Subgorup (Oligocene). Note the asymmetry. Current from top to bottom. Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 10D: Current crescent casts with flute cast. On underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

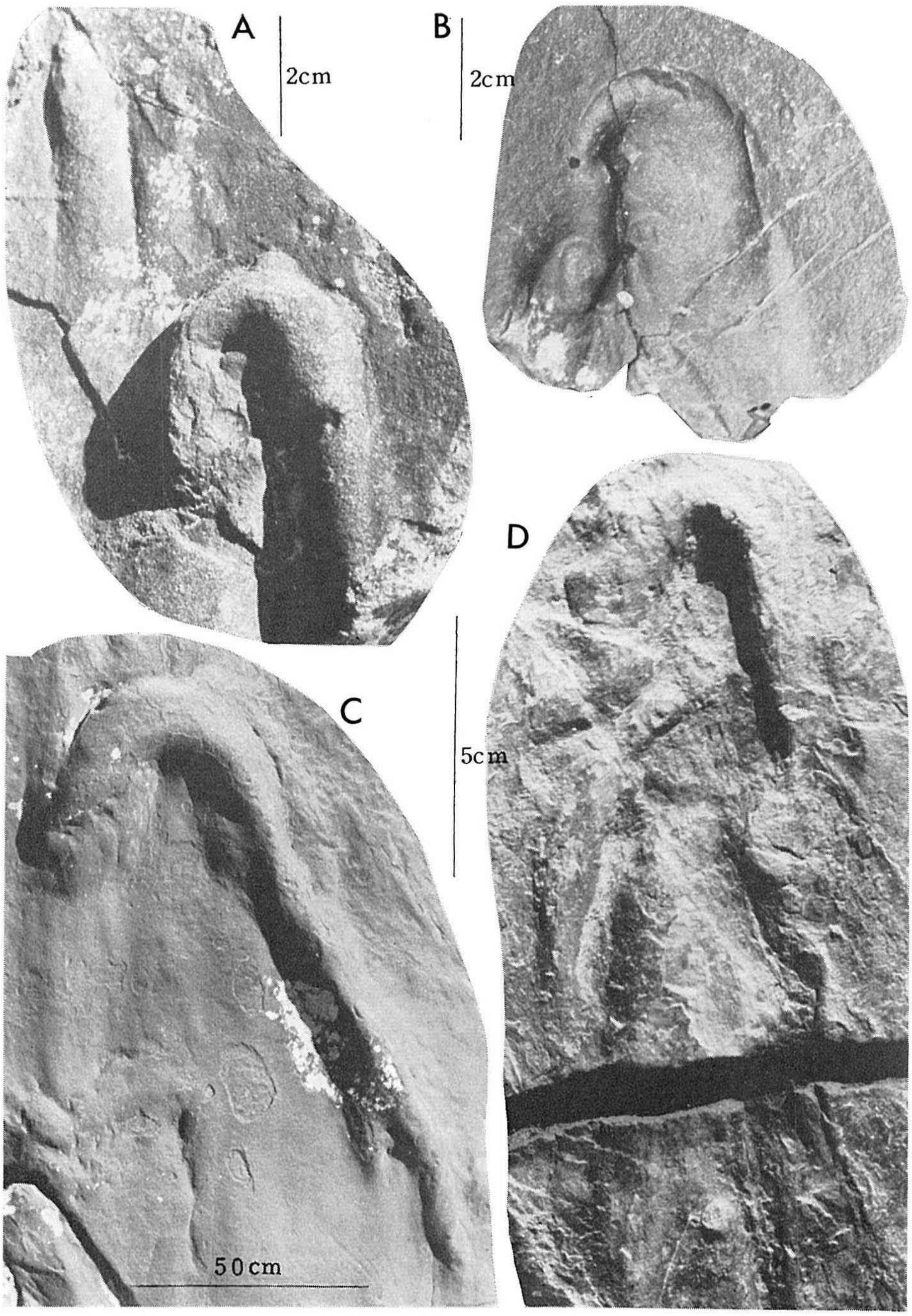

A
2cm
B
2cm
D
5cm
C
50cm

Plate 11: Parting stracture in laminated sandstone in the Yomurakawa Muro Subgroup (Oligocene). Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 12: *Paleodictyon* on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Taira, Hongū-cho, Higashimuro-gun Wakayama Prefecture.

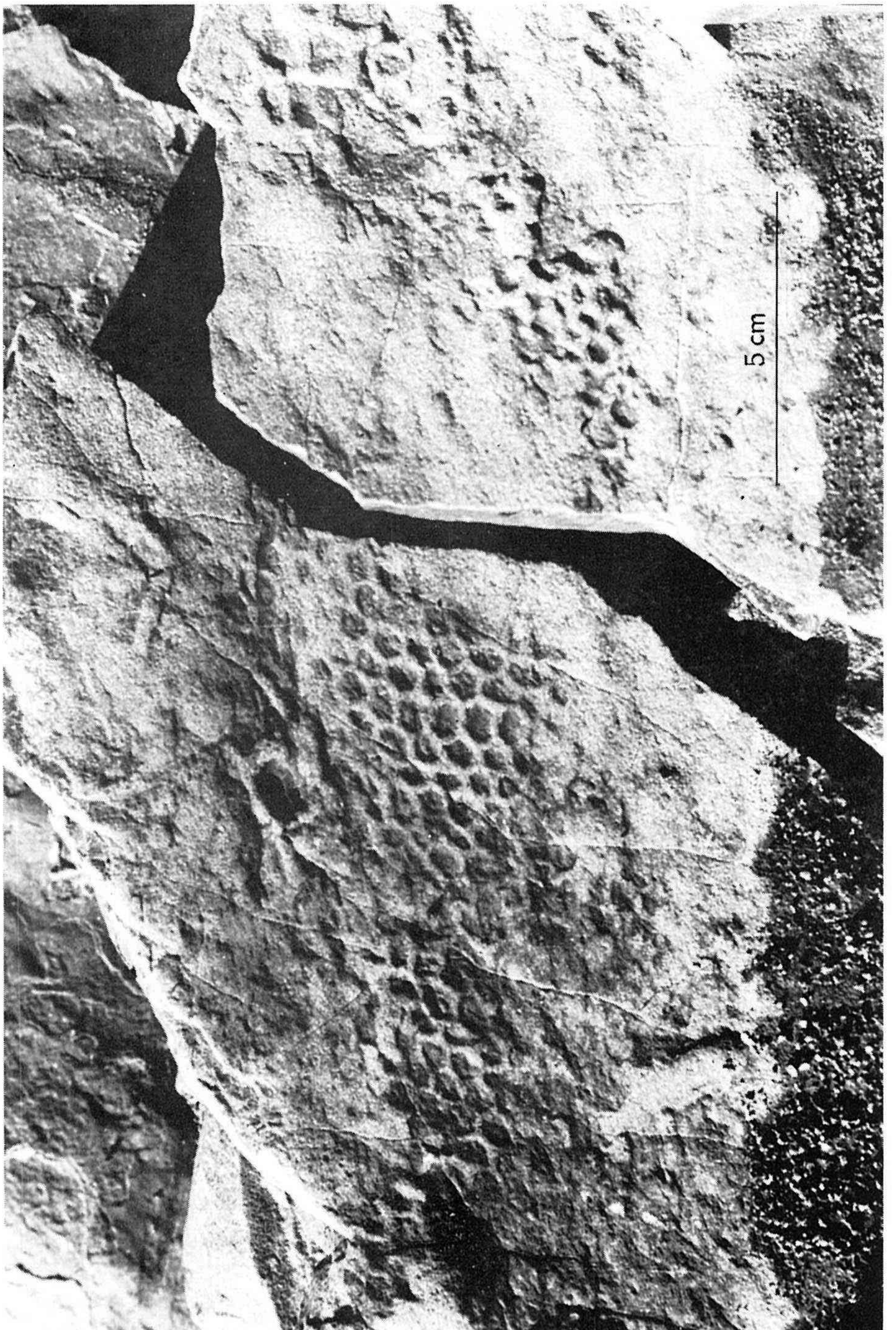

5 cm

Plate 13; Frondescent cast on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from lower left to upper right. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.


5 CM

Plate 14: Groove casts (A), bounce casts (B) and brush casts (C) Note asymmetry of bounce casts. Current from left to right of picture. Yomurakawa Muro Subgroup (Oligocene). Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture. Sample number O-17.

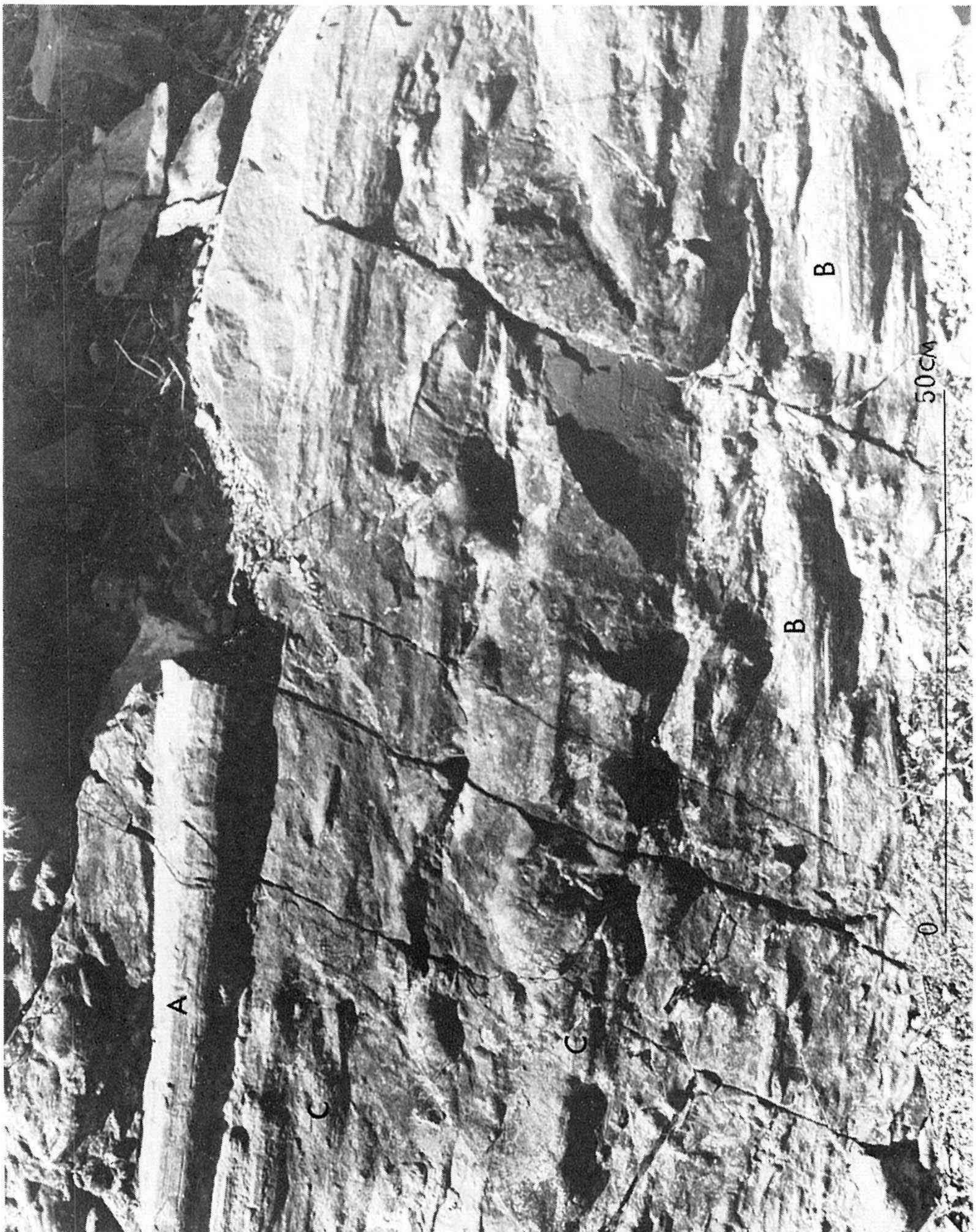
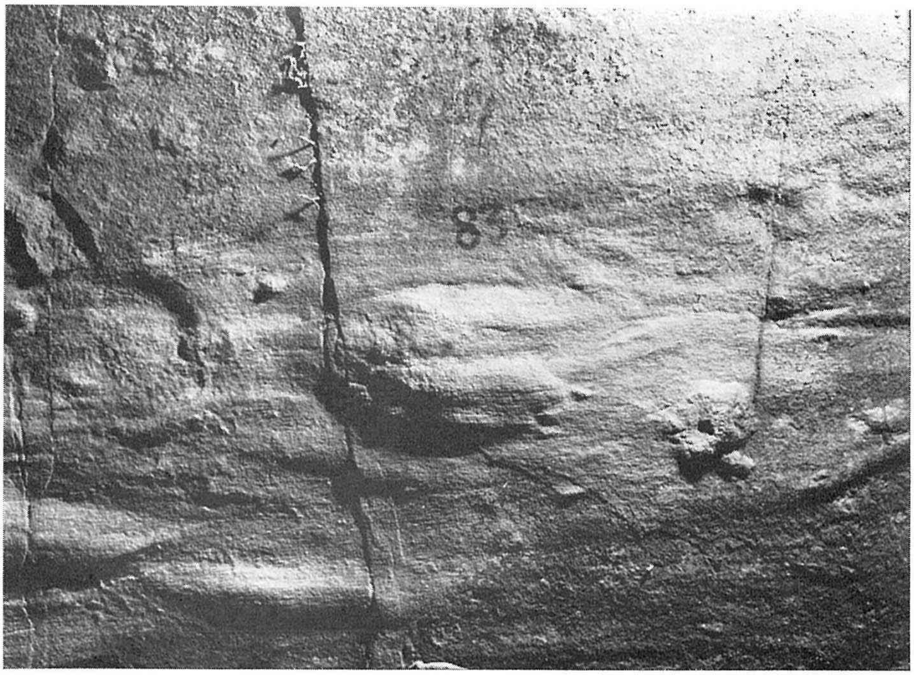

A
B
B
C
C
50CM
0

Plate 15A, B: Bounce casts on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from right to left. Kawayu, Hongū-cho, Higashimuro-gun, Wakayama Prefecture. Sample number O-83.


83

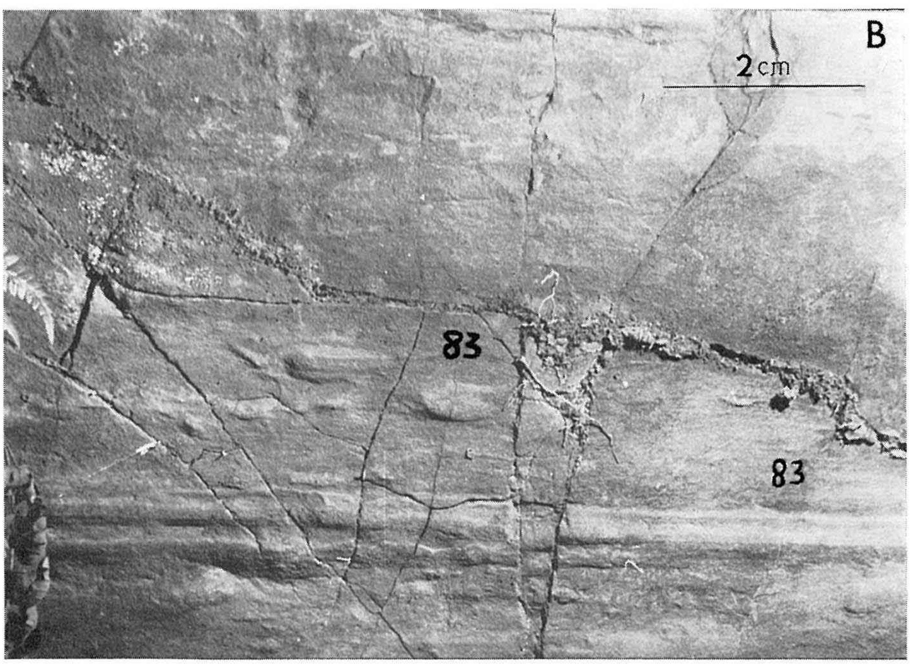

B
2cm
83
83

Plate 16: Brush casts on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Curroent right to left. Fig. A, B and C; Kawayu, Hongū-cho, Higashimuro-gun, Wakayama Prefecture. Sample number O-83. Fig. D; Hikigawa Section, sample number H-23.

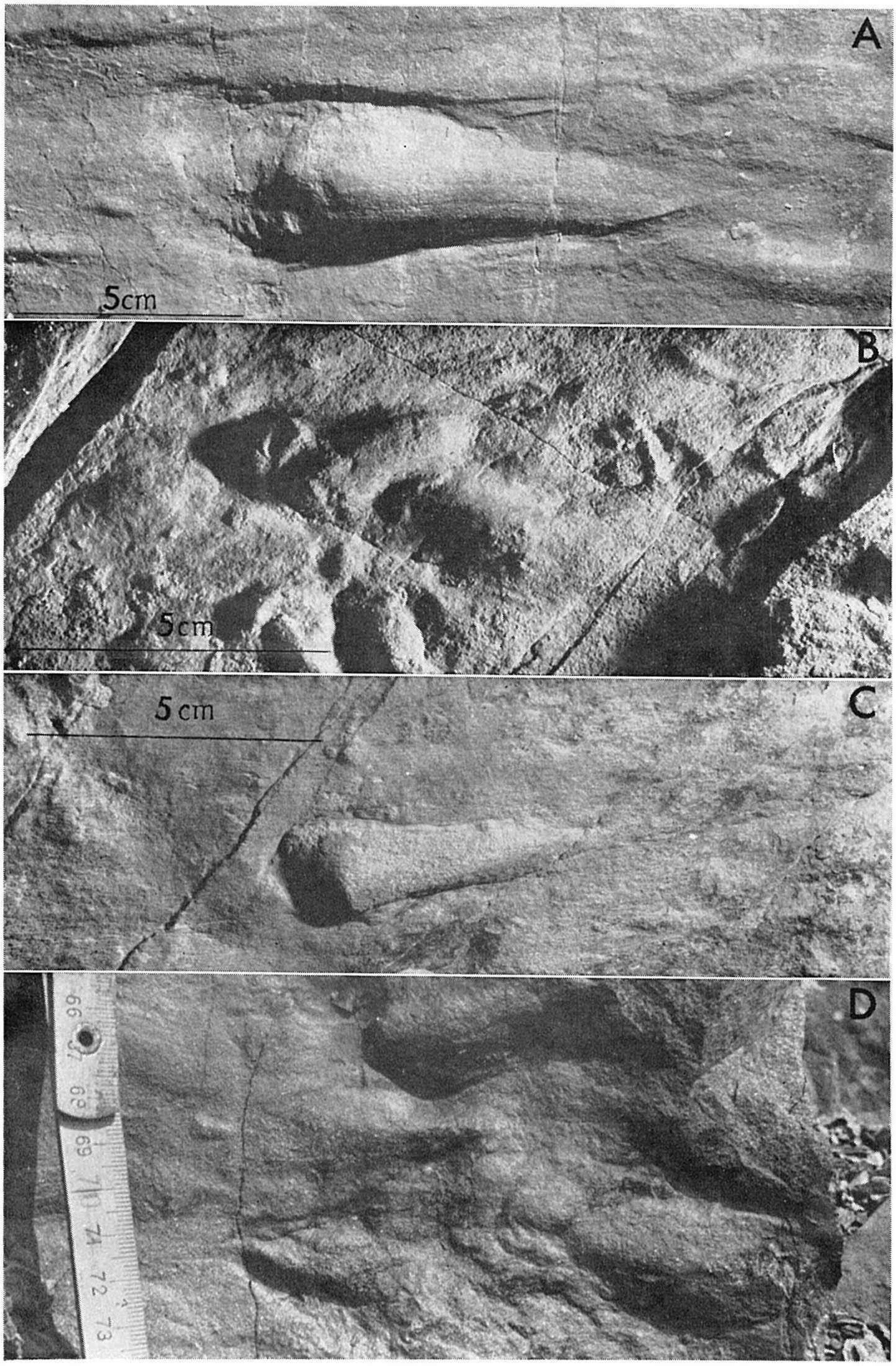

A
5cm
B
5cm
C
5 cm
D

Plate 17: Large groove cast and flute casts (longitudinal sand ridges) on base of sandstone in the Hitakagawa Group (Upper Cretaceous?). Current from right to left. West shore of Hitaka River, Yumoto, Ryuzin-mura, Hitaka-gun, Wakayama Prefecture. (Photograph by T. Tokuoka).

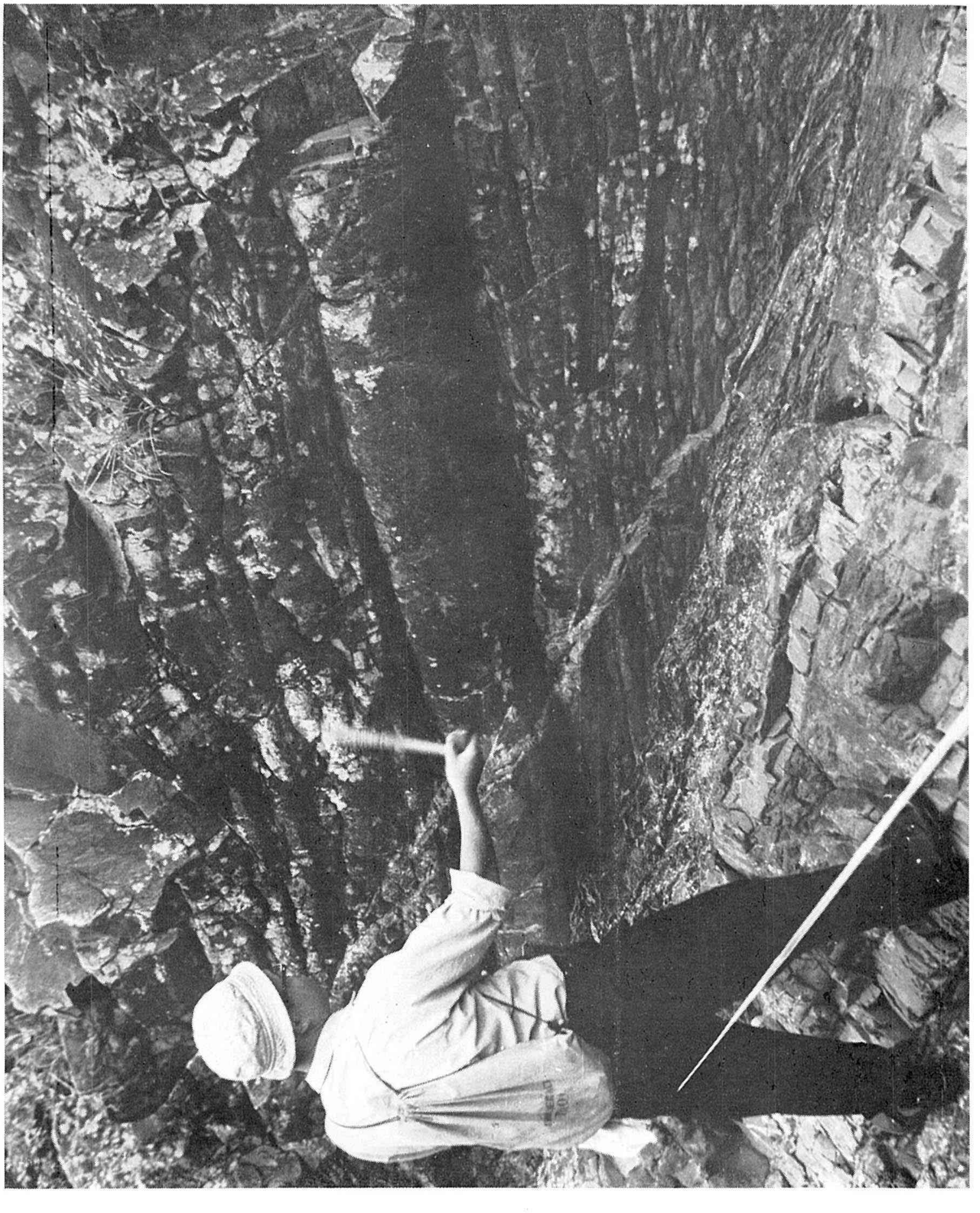
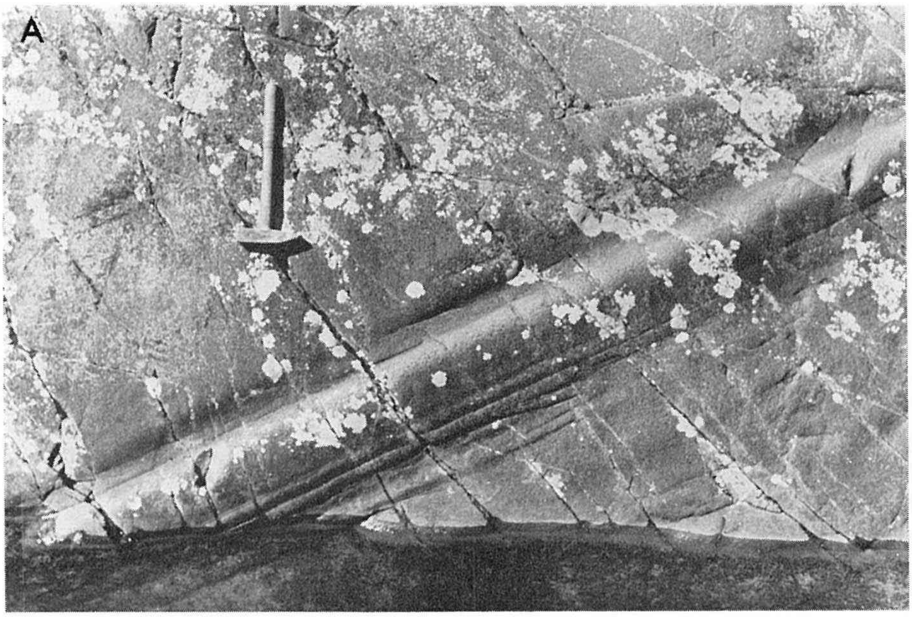


Plate 18A: Large groove cast on base of graded bed in the Yomurakawa Muro Subgroup (Oligocene). Note side furrow. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 18B; Two large groove casts on base of graded bed in the Yomurakawa Muro Subgroup (Oligocene). Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.


A

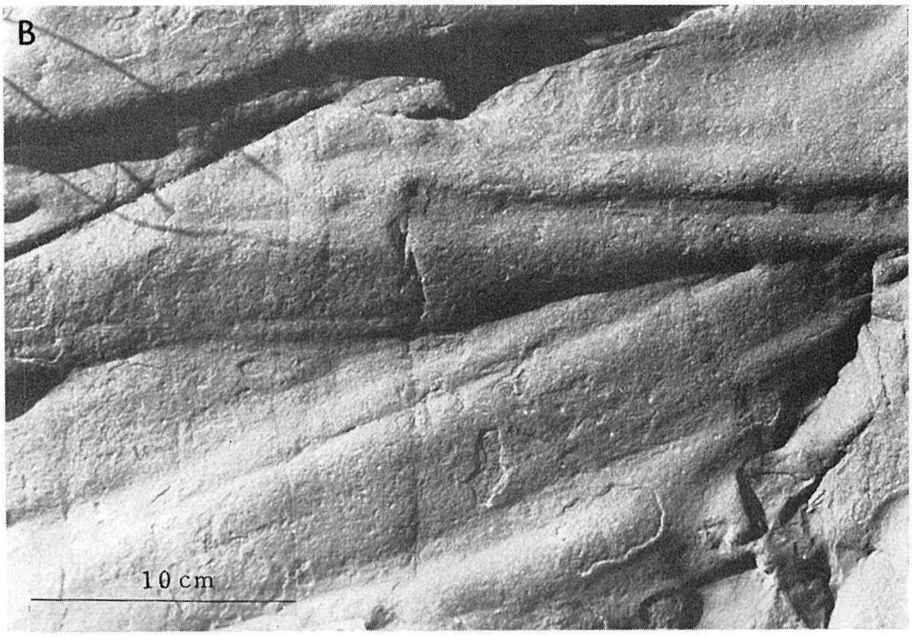

B
10 cm

Plate 19A: Groove casts and bounce casts on base of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Current from left to right. Shizukawa, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

Plate 19B: Groove casts on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Onachizaki of Esumi, Susami-cho, Nishimuro-gun, Wakayama Prefecture.

Plate 19C: Groove casts on underside of sandstone in the Yomurakawa Muro Subgroup (Oligocene). Fukuidani, Kozagawa-cho, Higashimuro-gun, Wakayayama Prefecture.

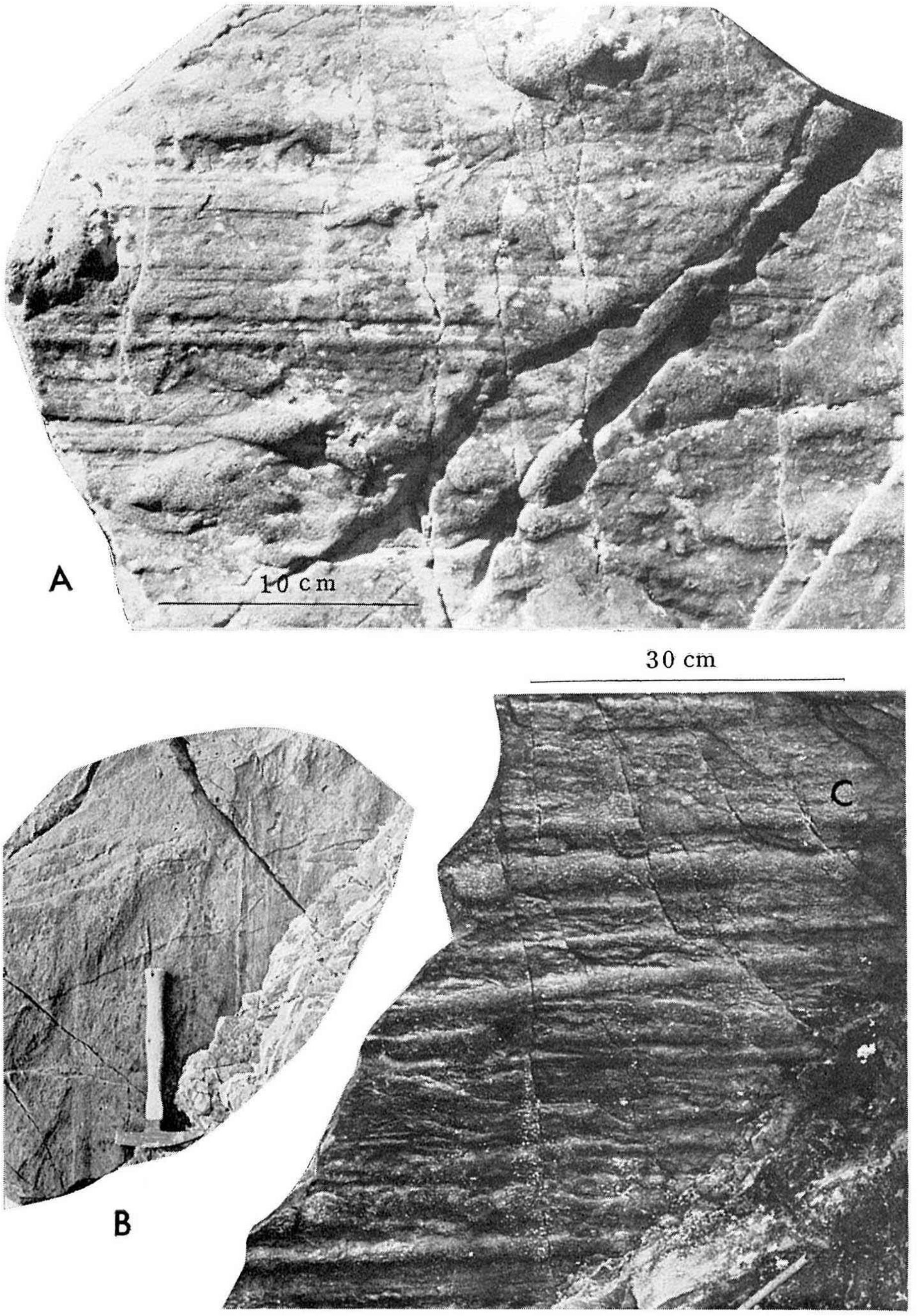
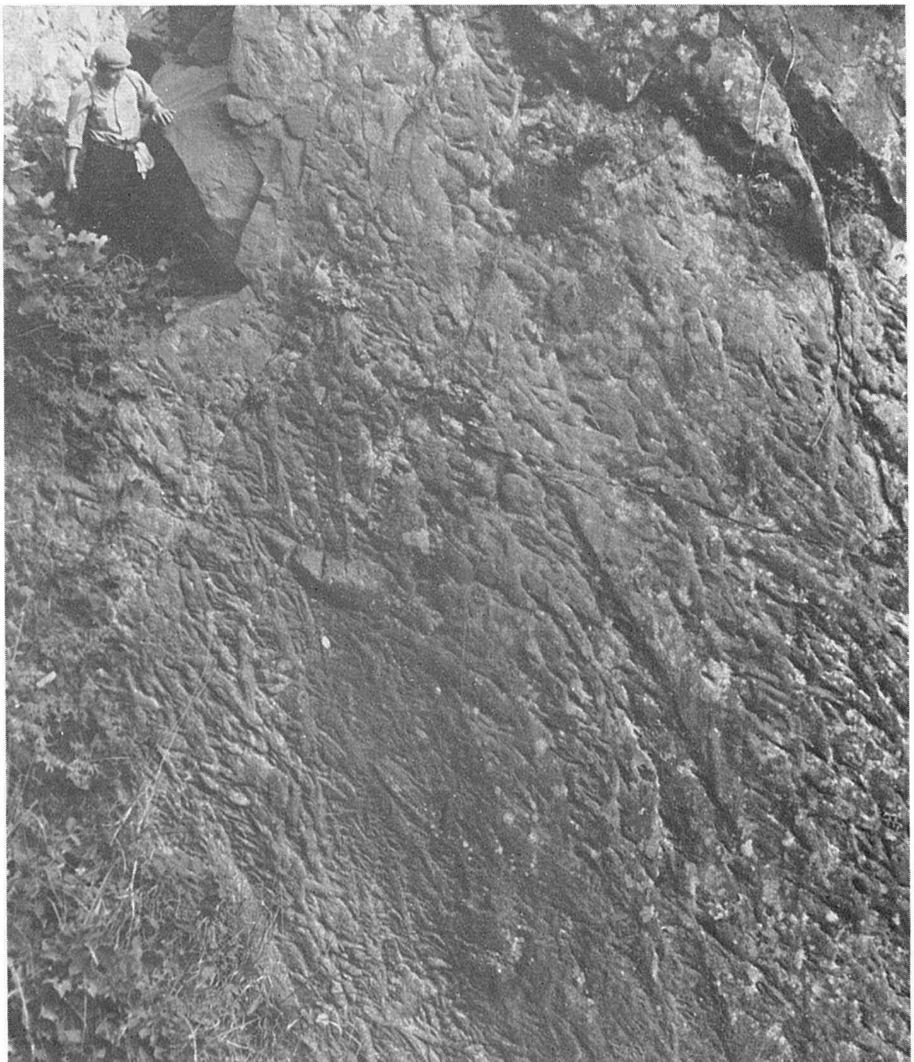

A
10 cm
30 cm
C
B

Plate 20: Tool marking, groove and bounce casts, on base of graded sandstone in the Yomurakawa Muro Subgroup (Oligocene). Note three sets of orientation and overlapping character. Sample number H-24. Hikigawa Section.



KUENEN (1957) proposed to use the term "groove cast" in a general meaning only, and the term "drag mark" for this structure. As described by KUENEN (1957), "drag marks are long, even ridges on graywacke soles. In cross section they are rounded or flat-topped or sharply crested, usually with many minor crenulations on the profile. The profile in many cases is not symmetrical. The minor sculpturings normally persist a as longitudinal striation over the whole length of the ridge."

In the Muro Group groove casts are one of the common sole markings. They show a similarity to the structures described by SHROCK (1948) and KUENEN (1957). They range in size from a few millimeters to 15 cm in height. Although the length of groove casts is usually not estimated, the longest one of them is more than 20 m long. In one case, a groove cast was gently curved. The side furrows are usually observed at either side of the groove cast (Plate 18A, B). The longitudinal striations are side of the groove cast (Plate 18A, B). The longitudinal striations are usually observed over the whole length of the ridges, being parallel to the orientation of the ridges and the current (Plate 14; 18A). There are assemblages with other sets of groove casts and brush, bounce, prod casts, in rare cases, with flute and current crescent casts on a given sole (Plate 14; 15B; 19A; 20). On several soles, the relation between the flute and groove casts shows that the fluting was earlier than the grooving, because the flute casts were superimposed by the groove casts (Plate 17). The general parallelism of groove and flute casts will be described in Chapter II or III.

CHAPTER II. ORIENTATION OF SOLE MARKINGS

It has become apparent to many investigators that sole markings are the most common and most useful criteria of current direction in Flysch facies. One of the purposes of the present study, in addition to describing the sole markings and inquiring into their origin, was to see whether the results of observations of some rock units were consistent in the direction of supply. If the observations of each rock unit taken as a whole gave a significantly uniform direction, then conclusions might be drawn concerning the bottom slope of the sea at the time of deposition, and the direction of supply (CROWELL, 1955).

1) Method of measurement

Substratal lineations include those which indicate the line of movement as well as the direction of movement. The measuring, recording and mapping of linear features, especially of sole markings, are less troublesome than of other directional structures*. The general orientation of sole markings that have a plane of symmetry is

* Internal structures.

easily determined by inspection and only one compass reading per bed is required. Almost all of the groove, bounce and brush casts and a part of flute casts observed have the plane of symmetry. Moreover, groove, bounce and brush casts are more or less elongate ridges with longitudinal, parallel strains and side furrows. In this case, the strains, the crest line, the marginal line of the side furrows and their flanks were measured. On the other hand, the measurement of some flute casts is rather troublesome. In general, the crest line of the flute cast, which is not superimposed, conincides with its axis of symmetry in plan, but many overlapped flute casts forming a group are more or less asymmetrical in shape. In the latter case, less deformed ones were selected for measurement. In rare cases, the symmetrical ridge of corrected typical form was measured, although the resultant error might be negligible.

In making field observation, the rake or pitch (the angle between the line of strike and the lineation in the plane of the bedding) of the structure was measured rather than the plunge because rotating the observations back to the horizontal state is much simpler with the pitch than with plunge.

2) Determination of direction

The direction of substratal lineations with the asymmetrical features in form was easily determined. The up-current end of the flute cast is rounded bulbous, and the down-current end flares out to merge gradually with the straited bottom surfce of the sandstone bed. The up-current end of the current crescent is a horse shoe-shaped ridge, and a little narrowing and sloping depression is on the down-current side. The down-current end of the brush cast is shown by a slight crescentic depression. The down-current end of the bounce cast fade out more steeply than the up-current end.

3) Correction of data in tectonic tilted strata

As for the problem of direction from which the sediments have come, it is necessary to correct the present attitude of substratal lineation suffered from tectonic shift and to restore them to their original position. The directional structure may have rotated about one or more of the three mutually perpendicular axes. The rotation given in the Table 2 is the rotation about the horizontal axis only, that is, by rotating about the strike of the strata. The resultant errors by the rotation about vertical axes and due to the plunge of folding axes will be stated in the chapter "Consideration".

The directional measurements made in the field, which amount to 243, are listed in Table 2 and plotted as current roses in Figures 11 through 14.

4) Measured data

The four sections of the Paleogene~Lowest Neogene Flysch-like sediments studied for this paper are exposed in the Northern and the Southern Subbelts of the Muro Belt (HARATA, 1964).

The sections I and II are situated in the Northern Subbelt, and the other sections in the Southern subbelt.

Large-scale geological map and route maps of the four sections are shown in Figures 10 and 13 and 14.

The Flysch-like rocks of the Muro Belt which reach a thickness of about 10,000 m, consist of three main stratigraphic units; the Otonashigawa lower, the Yomurakawa middle and the Ukekawa upper subgroups. Their lithological features have been stated in previous papers (HARATA, TOKUOKA, MATSUMOTO, 1961; HARATA, 1964). Recently, the auther and the other members of the Kishu Shimanto Research Group have been investigated the Flysch-like rocks of the Shimanto Terrain, above all the Muro Belt.

The litho-stratigraphic and paleontological data obtained by them will be published in the near future. In this paper, the description of the Muro Group is followed as stated in the previous papers (HARATA *et. al.* 1961; HARATA, 1964). Our recent studies require to correct the our previous conclusions which have been published.

Table 2. Field Measurements of Directional Current Structures.

I: Section
II: Observation number
III: Strike and dip of bedding (Ov=Overturned; Nr=Normal)
IV: Pitch (rake) of substratal lineations (Clockwise)
V: Bearing of lineation, rotated into horizontal, where sense from which flow came is unknown.
VI: Bearing to source of current, rotated into horizontal, where sense from which flow came is known.
VII: ↖ ; line of flow and pointing distinct (SE to NW), ; line of flow distinct, pointing doubtful (SE to NW)
VIII: Type of directional current structure.

I	II	III	IV	V	VI	VII	VIII
ESUMI	E-1						Load cast
	E-2	N14E, 65W (Ov)	142	N52E			Groove cast
	E-3	N 4W,35E (Ov)	37	N41W			Groove cast
	E-4-1	N84E, 11N (Ov)	120	N36W			Groove cast
	E-4-2	N84E, 11N (Ov)	110	N26W			Groove cast
	E-4-3	N84E, 11N (Ov)	107	N23W			Groove cast
	E-4-4	N84E, 11N (Ov)	100	N16W			Groove cast
	E-4-5	N84E, 11N (Ov)	95	N11W			Groove cast
	E-4-6	N84E, 11N (Ov)	100	N16W			Groove cast
	E-4-7	N84E, 11N (Ov)	115	N31W			Groove cast
FUKUIDANI	F-1	N79W,45N (Nr)	0	N79W			Groove cast
	F-2	N80E, 40N (Nr)	0		N80E		Brush cast
	F-3	N79E, 40N (Nr)	0		N79E		Flute cast
	F-4-1	N74E, 40N (Nr)	37		N37E		Brush cast
	F-4-2	N74E, 40N (Nr)	30		N44E		Brush cast
	F-4-3	N74E, 40N (Nr)	40		N34E		Brush cast
	F-5	N84E, 45N (Nr)	70	N14E			Groove cast
	F-6	N84E, 45N (Nr)	65		N19E		Brush cast

(continued)

I	II	III	IV	V	VI	VII	VIII
	M-1	N54E, 45W (Nr)	20	N34E			Ripple crest line
	S -1	N84E, 55N (Nr)	30		N54E		Load cast
	S -2	N86W,50N (Nr)	58		N36E		Linguoid ripple mark
WABUKA	W-1	NS,15E (Nr)	75		N75W		Load casted flute cast
	W-2	NS,15E (Nr)	30		N30W		Flute cast
	W-3	NS,15E (Nr)	90	EW			Groove cast
	W-4	N14W,20N (Nr)	15		N29W		Flute cast
	W-5	N14W,20N (Nr)	50		N64W		Flute cast
	W-6	N39W,18N (Nr)	20		N59W		Flute cast
	W-7	N39W,18N (Nr)	14		N53W		Flute cast
	W-8	N40W,20N (Nr)	45		N85W		Flute cast
HIKIGAWA	H-1	N85W,60N (Ov)	6	N89E			Groove cast
	H-3-1	N85W,60N (Ov)	0		N85W		Prod and load cast
	H-3-2	N70W,70N (Ov)	0		N70W		Scour cast
	H-3-3	N80E, 70N (Ov)	14	N66E			Scour cast -
	H-3-4	EW,70N (Ov)	13	N77E			Scour cast
	H-4-1	N60E, 55N (Ov)	100		N40W		Load casted flute cast
	H-4-2	N60E, 55N (Ov)	100		N40W		Load casted flute cast
	H-4-3	N60E, 55N (Ov)	120		N60W		Load casted flute cast
	H-4-4	N60E, 55N (Ov)	95		N35W		Load casted flute cast
	H-4-5	N60E, 55N (Ov)	105		N45W		Load casted flute cast
	H-5	N60E, 55N (Ov)	110		N50W		Flute cast
	H-6	N20W,40S (Nr)	140		N20E		Flute cast
	H-7-1	N25E, 45W (Nr)	175		N30E		Load casted flute cast
	H-7-2	N25E, 45W (Nr)	15		N10E		Load casted flute cast
	H-8	N50W,50S (Nr)	90		N40E		Load casted flute cast
	H-9-1	N50W,50S (Nr)	116		N20E		Load, flute and groove casts
	H-9-2	N50W,50S (Nr)	120		N10E		Load, flute and groove casts
	H-10	N50W,50S (Nr)	100		N30E		Load casted flute and groove cast
	H-11-1	N20W,45S (Nr)	50		N70W		Flute and groove casts
	H-11-2	N20W,45S (Nr)	80		N80E		Flute and groove casts
	H-12	N20W,40S (Nr)	140		N20E		Flute cast
	H-13	N70E, 60N (Ov)	92		N22W		Flute cast
	H-13′-1	N35E, 47N (Ov)	137		N78E		Flute cast
	H-13′-2	N35E, 47N (Ov)	135		N80E		Flute cast
	H-13′-3	N35E, 47N (Ov)	145		N70E		Flute cast
	H-13′-4	N35E, 47N (Ov)	135		N80E		Flute cast
	H-13′-5	N35E, 47N (Ov)	140		N75E		Flute cast
	H-13′-6	N35E, 47N (Ov)	146		N69E		Flute cast
	H-13′-7	N35E, 47N (Ov)	130		N85E		Flute cast
	H-14-1	N30E, 40N (Ov)	155	N55E			Groove cast
	H-14-2	N30E, 40N (Ov)	155	N55E			Groove cast
	H-14-3	N30E, 40N (Ov)	148	N62E			Groove cast
	H-14-4	N30E, 40N (Ov)	147	N63E			Groove cast
	H-14-5	N30E, 40N (Ov)	165	N45E			Groove cast
	H-14-6	N30E, 40N (Ov)	147	N63E			Groove cast
	H-14-7	N30E, 40N (Ov)	148	N62E			Groove cast
	H-14-8	N30E, 40N (Ov)	147	N63E			Groove cast
	H-14-9	N30E, 40N (Ov)	139	N71E			Groove cast
	H-14-10	N30E, 40N (Ov)	148	N62E			Groove cast
	H-14-11	N30E, 40N (Ov)	160	N50E			Groove cast
	H-14-12	N30E, 40N (Ov)	147		N63E		Flute cast
	H-14-13	N30E, 40N (Ov)	160		N50E		Flute cast
	H-15	N55E, 70N (Ov)	115		N65W		Load casted flute cast
	H-16	N25E, 45N (Ov)	160		N45E		Brush and flute casts
	H-17						Load cast

(continued)

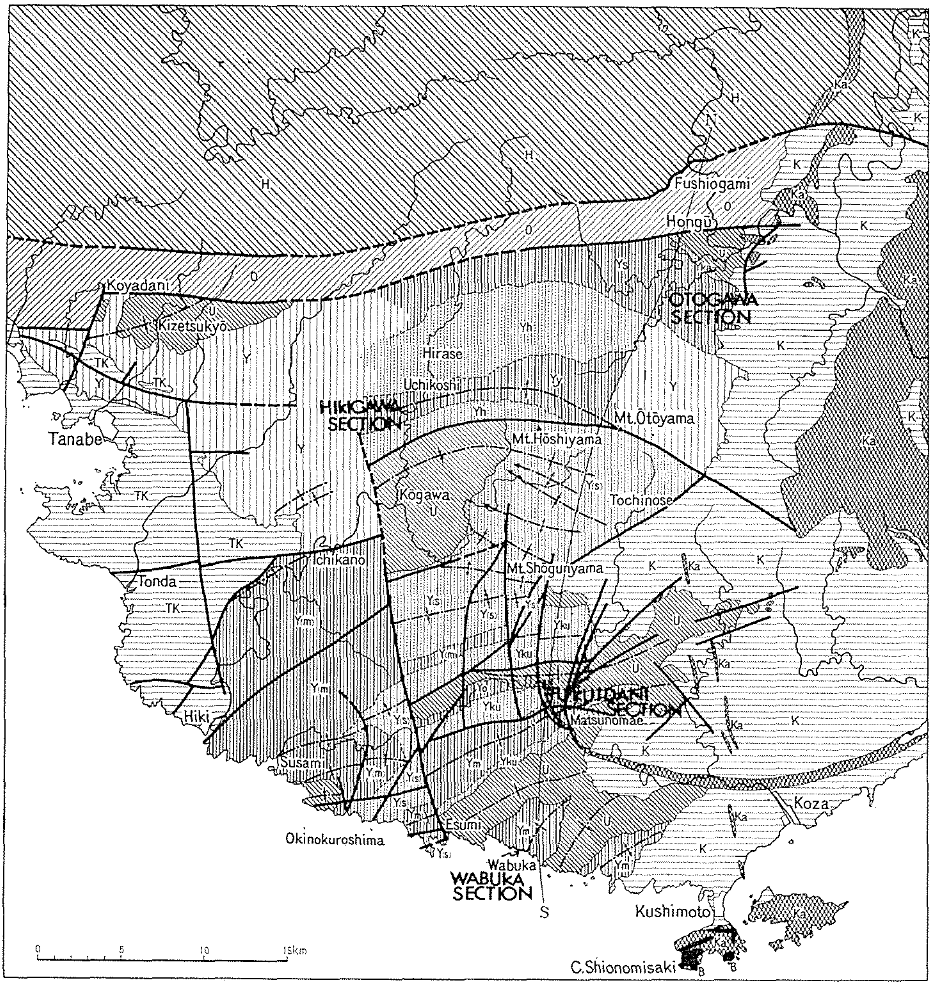
I	II	III	IV	V	VI	VII	VIII
HIKIGAWA	H-18						Ball-and-pillow structure
	H-19-1	N30E, 50N (Ov)	163	N47E			Groove cast
	H-19-2	N30E, 50N (Ov)	135	N75E			Groove cast
	H-20	N30E, 50N (Ov)	47	N17W			Bounce cast
	H-21	N70E, 70S (Nr)	135		N25W		Flute cast
	H-22	N60E, 75N (Ov)	175		N65E		Brush, groove and flute casts
	H-23-1	N60E, 75N (Ov)	175		N65E		Flute, brush and bounce casts
	H-23-2	N60E, 75N (Ov)	180		N60E		Flute, brush and bounce casts
	H-24-1	N70E, 60N (Ov)	40	N30E			Groove and prod cats
	H-24-2	N70E, 60N (Ov)	43	N27E			Groove cast
	H-24-3	N70E, 60N (Ov)	25	N45E			Groove cast
	H-24-4	N70E, 60N (Ov)	74	N 4W			Groove cast
	H-24-5	N70E, 60N (Ov)	185	N75E			Groove cast
	H-25	N40E, 75N (Ov)	140		N80E		Prod cast
	H-27-1	N65E, 85N (Ov)	82	N17W			Bounce cast
	H-27-2	N65E, 85N (Ov)	85	N20W			Bounce cast
	H-27-3	N65E, 85N (Ov)	80	N15W			Bounce cast
	H-28	N60E, 75N (Ov)	55		N 5E		Flute cast
	H-29	N60E, 75N (Ov)	55		N 5E		Load casted flute cast
	H-30	N65E, 80N (Ov)	90		N25W		Scour mark
	H-31-1	N60E, 80N (Ov)	80		N20W		Flute cast
	H-31-2	N60E, 80N (Ov)	90		N30W		Flute cast
	H-31-3	N60E, 80N (Ov)	100		N40W		Flute cast
	H-32-1	N60E, 60N (Nr)	70		N10W		Load casted flute cast
	H-32-2	N60E, 60N (Nr)	80		N20W		Load casted flute cast
ŌTŌGAWA	O-2-1	N54W,60N (Nr)	160		N34W		Flute cast
	O-2-2	N54W,60N (Nr)	157		N31W		Flute cast
	O-2-3	N54W,60N (Nr)	162		N36W		Flute cast
	O-2-4	N54W,60N (Nr)	164		N38W		Flute cast
	O-2-5	N54W,60N (Nr)	160		N34W		Flute cast
	O-3-1	N55W,38N (Nr)	159		N34W		Scour cast
	O-3-2	N55W,38N (Nr)	157		N32W		Scour cast
	O-3-3	N55W,38N (Nr)	171		N46W		Scour cast
	O-3-4	N55W,38N (Nr)	144		N19W		Scour cast
	O-3-5	N55W,38N (Nr)	165		N40W		Scour cast
	O-3-6	N55W,38N (Nr)	161		N36W		Scour cast
	O-3-7	N55W,38N (Nr)	140		N15W		Scour cast
	O-3-8	N55W,38N (Nr)	156		N31W		Scour cast
	O-3-9	N55W,38N (Nr)	165		N40W		Scour cast
	O-3-10	N55W,38N (Nr)	153		N28W		Scour cast
	O-3-11	N55W,38N (Nr)	160		N35W		Scour cast
	O-3-12	N55W,38N (Nr)	158		N33W		Scour cast
	O-3-13	N55W,38N (Nr)	157		N32W		Scour cast
	O-3-14	N55W,38N (Nr)	156		N31W		Scour cast
	O-6	N68W,68E (Nr)	150		N38W		Flute cast
	O-7-1	EW,55N (Nr)	151		N61W		Flute cast
	O-7-2	EW,55N (Nr)	152		N62W		Flute cast
	O-7-3	EW,55N (Nr)	156		N66W		Flute cast
	O-7-4	EW,55N (Nr)	156		N66W		Flute cast
	O-7-5	EW,55N (Nr)	151		N61W		Flute cast
	O-7-6	EW,55N (Nr)	157		N67W		Flute cast
	O-8-1	EW,55N (Nr)	125		N35W		Scour cast
	O-8-2	EW,55N (Nr)	164		N74W		Flute cast
	O-8-3	EW,55N (Nr)	155		N65W		Flute cast
	O-8-4	EW,55N (Nr)	151		N61W		Current crescent
	O-9	N47W,42N (Nr)	150		N17W		Flute cast
	O-10	N47W,42N (Nr)	146		N13W		Flute cast

(continued)

I	II	III	IV	V	VI	VII	VIII
ŌTŌGAWA	O-11	N85E, 85N (Nr)	117		N32W		Flute cast
	O-12	N82E, 62S (Ov)	114	N32W			Groove cast
	O-13	N43W,62N (Nr)	24		N67W		Flute cast
	O-14						Load cast
	O-15-1	N60W,55N (Ov)	5	N65W			Groove cast
	O-15-2	N60W,55N (Ov)	166	N46W			Groove cast
	O-16	N60W,43N (Ov)	11	N71W			Groove cast
	O-17-1	N70W,52N (Ov)	0	N70W			Groove cast
	O-17-2	N70W,52N (Ov)	176	N66W			Groove cast
	O-17-3	N70W,52N (Ov)	177	N67W			Groove cast
	O-17-4	N70W,52N (Ov)	179	N69W			Groove cast
	O-17-5	N70W,52N (Ov)	1		N71W		Brush cast
	O-17-6	N70W,52N (Ov)	167		N57W		Brush cast
	O-17-7	N70W,52N (Ov)	165		N55W		Bounce cast
	O-17-8	N70W,52N (Ov)	165		N55W		Bounce cast
	O-17-9	N70W,52N (Ov)	168		N58W		Bounce cast
	O-17-10	N70W,52N (Ov)	0		N70W		Bounce cast
	O-18	N55W,60N (Ov)	170		N45W		Current crescent
	O-19-1	N54W,80N (Ov)	166		N40W		Current crescent
	O-19-2	N54W,80N (Ov)	166		N40W		Bounce cast
	O-19-3	N54W,80N (Ov)	170		N44W		Current crescent
	O-19-4	N54W,80N (Ov)	160		N34W		Current crescent
	O-21-1	N50W,45N (Ov)	174		N44W		Current crescent
	O-21-2	N50W,45N (Ov)	174	N44W			Groove cast
	O-21-3	N50W,45N (Ov)	155	N25W			Groove cast
	O-21-4	N50W,45N (Ov)	153	N23W			Groove cast
	O-21-5	N50W,45N (Ov)	134	N 4W			Groove cast
	O-21-6	N50W,45N (Ov)	166	N36W			Groove cast
	O-21-7	N50W,45N (Ov)	178	N48W			Groove cast
	O-22	N50W,45N (Ov)	155		N25W		Flute cast
	O-23-1	N50W,45N (Ov)	175	N45W			Groove cast
	O-23-2	N50W,45N (Ov)	178	N48W			Groove cast
	O-24	N55W,45N (Ov)	153		N28W		Flute cast
	O-26	N55W,45N (Ov)	157		N32W		Scour cast
	O-27	N55W,45N (Ov)	156		N31W		Scour cast
	O-28	N55W,45N (Ov)	155	N30W			Scour cast
	O-29	N55W,45N (Ov)	165	N40W			Parting structure
	O-30	N55W,45N (Ov)	144		N19W		Scour cast
	O-31	N55W,45N (Ov)	160		N35W		Scour cast
	O-32	N55W,45N (Ov)	160		N35W		Flute cast
	O-33	N55W,45N (Ov)	164	N39W			Groove cast
	O-35	N75W,55N (Ov)	30	N75E			Parting structure
	O-36	N75W,55N (Ov)	27		N78E		Scour cast
	O-37	N75W,55N (Ov)	140		N35W		Flute cast
	O-38	N75W,55N (Ov)	34	N41W			Groove cast
	O-39	N75W,55N (Ov)	134		N29W		Bounce and groove casts
	O-40	N75W,55N (Ov)	17		N88E		Scour cast
	O-41	N75W,55N (Ov)	168	N63W			Groove cast
	O-43	N40W,45N (Ov)	149	N 9W			Parting structure
	O-44	N40W,45N (Ov)	151	N11W			Parting structure
	O-45	N40W,45N (Ov)	160	N20W			Scour cast
	O-46-1	N40W,45N (Ov)	155		N15W		Flute cast
	O-46-2	N40W,45N (Ov)	157	N17W			Parting structure
	O-46-3	N40W,45N (Ov)	169	N29W			Parting structure
	O-46-4	N40W,45N (Ov)	145	N 5W			Parting structure
	O-46-5	N40W,45N (Ov)	150	N10W			Parting structure
	O-46-6	N40W,45N (Ov)	147	N 7W			Parting structure
	O-47-1	N40W,56N (Ov)	144		N 4W		Current crescent

(*continued*)

I	II	III	IV	V	VI	VII	VIII
ŌTOGAWA	O-47-2	N40W,56N (Ov)	165		N25W		Current crescent
	O-47-3	N40W,56N (Ov)	154		N14W		Current crescent
	O-47-4	N40W,56N (Ov)	154		N14W		Current crescent
	O-47-5	N40W,56N (Ov)	154		N14W		Current crescent
	O-47-6	N40W,56N (Ov)	165		N25W		Current crescent
	O-48	N40W,56N (Ov)	162		N22W		Frondescent cast
	O-51	N25W,40N (Nr)	41	N66W			Parting structure
	O-52-1	N50W,60N (Ov)	144		N14W		Flute cast
	O-52-2	N50W,60N (Ov)	145		N15W		Flute cast
	O-53	N50W,60N (Ov)	150		N20W		Scour cast
	O-54-1	N50W,60N (Ov)	148		N18W		Bounce cast
	O-54-2	N50W,60N (Ov)	125		N 5E		Bounce cast
	O-54-3	N50W,60N (Ov)	133		N 3W		Bounce cast
	O-54-4	N50W,60N (Ov)	116		N14E		Bounce cast
	O-54-5	N50W,60N (Ov)	132		N 2W		Bounce cast
	O-55	N25W,30N (Ov)	94		N61E		Flute cast
	O-56	N25W,30N (Ov)	95		N60E		Flute cast
	O-57	N25W,30N (Ov)	90	N65E			Groove cast
	O-59	N35W,50N (Ov)	130	N15E			Groove cast
	O-60	N45W,45N (Ov)	113		N22E		Flute cast
	O-61	N75W,35N (Ov)	109		N 4W		Flute cast
	O-62	N10W,40N (Nr)	58		N68W		Flute cast
	O-63	N10W,40N (Nr)	68		N78W		Brush cast
	O-65-1	N15W,30N (Nr)	120		N45E		Scour cast
	O-65-2	N15W,30N (Nr)	111		N54E		Scour cast
	O-66	N15W,30N (Nr)	116		N49E		Scour cast
	O-67	N15W,30N (Nr)	94		N71E		Flute cast
	O-69	N15W,30N (Nr)	105		N60E		Brush and flute casts
	O-70	N15W,30N (Nr)	110	N55E			Groove cast
	O-71	N40W,25N (Nr)	79	N61E			Groove and scour casts
	O-73	N30W,90	152	N 2W			Parting structure
	O-74	N30W,90	74		N86E		Flute cast
	O-75	N30W,90	43		N73W		Scour cast
	O-76	N30W,90	47		N77W		Bounce cast
	O-77	N30W,90	39		N69W		Flute cast
	O-78	N30W,90	50		N80W		Scour cast
	O-79	N30W,90	38		N68W		Flute cast
	O-80	N30W,90	45		N75W		Flute cast
	O-81	N30W,90	34	N64W			Groove cast
	O-82	N30W,50N (Nr)	28		N58W		Flute cast
	O-83	N40W,50N (Nr)	178		N38W		Groove, bounce and brush casts
	O-84-1	N78W,38N (Nr)	17	N85E			Groove cast
	O-84-2	N78W,38N (Nr)	6		N84W		Bounce and brush catsts
	O-85-1	N77W,40N (Nr)	36	N67E			Groove cast
	O-85-2	N77W,40N (Nr)	30		N73E		Brush cast
	O-86	N77W,40N (Nr)	37		N66E		Brush cast
	O-87	N77W,40N (Nr)	36		N67E		Brush cast
	O-88	N10E, 20N (Nr)	86	N76W			Bounce cast
	O-89	N18W,30N (Nr)	54	N72W			Groove cast
	O-90	N18W,30N (Nr)	46		N64W		Bounce cast
	O-91	N18W,30N (Nr)	15		N33W		Brush and bounce casts
	O-92	N40W,20N (Nr)	62		N78E		Groove, bounce and brush casts
	O-93	N40W,20N (Nr)	67	N73E			Groove cast
	O-94	N40W,20N (Nr)	67	N73E			Groove cast
	O-95	N65W,25N (Nr)	45	N70E			Groove cast
	O-96	N65W,25N (Nr)	40		N75E		Bounce cast
	O-97	N65W,25N (Nr)	54	N29E			Groove cast
	O-98	N50W,70N (Nr)	20	N70W			Parting structure



Basic rocks — B — Gabbro and Diabase

Kumano acidic igneous rocks — Ka — Granophyre, Biotite granite porphyry and Persemic biotite rhyolite

Kumano, Tanabe and Kanayama groups — K, TK — K; Kumano Group, TK; Tanabe and Kanayama Groups

Muro group
- Ukekawa-Muro subgroup — U — Yunomine, Ukekawa, Masago and Hisohara Formations
- Yomurakawa-Muro subgroup
  - Y — Undivided Formation of the Yomurakawa-Muro Subgroup
  - Ys, Yy, Yo, Ym, Y(m) — Ys; Shizukawa Formation, Yy; Yasukawa Formation, Ym; Matsunomae Formation, Yo; Oikawa Formation, Y(m); Muddy Formation of the Yomurakawa-Muro Subgroup
  - Yka, Yh, Yku, Y(s) — Yka; Kawayu Formation, Yh; Hirase Formation, Yku; Kurumi Formation, Y(s); Sandy Formation of the Yomurakawa-Muro Subgroup
- Otonashigawa-Muro subgroup — O — Otonashigawa Formation and the correlatives

Hitakagawa group — H — Undivided Mesozoic strata

Fig. 10. Figure shows the situations of each section (Geological map by T. Harata, 1964).

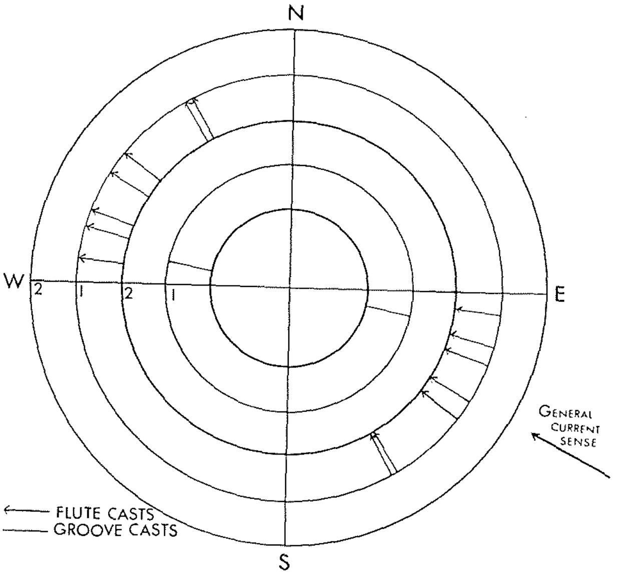


Fig. 11. CURRENT ROSE DIAGRAM, WABUKA SECTION (Section I).

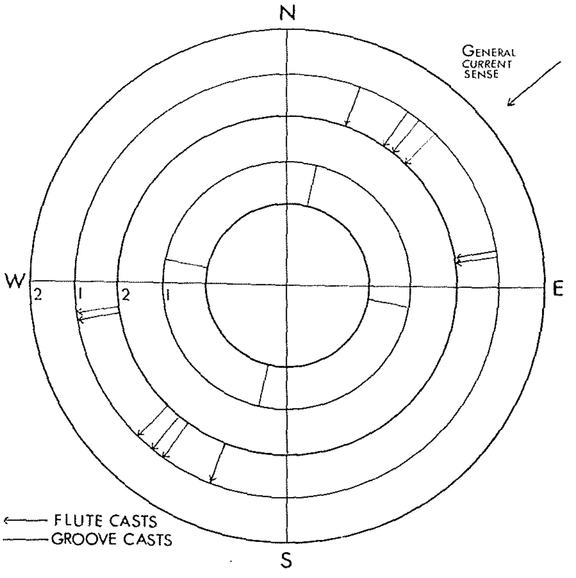


Fig. 12. CURRENT ROSE DIAGRAM, FUKUIDANI SECTION. (Section II).

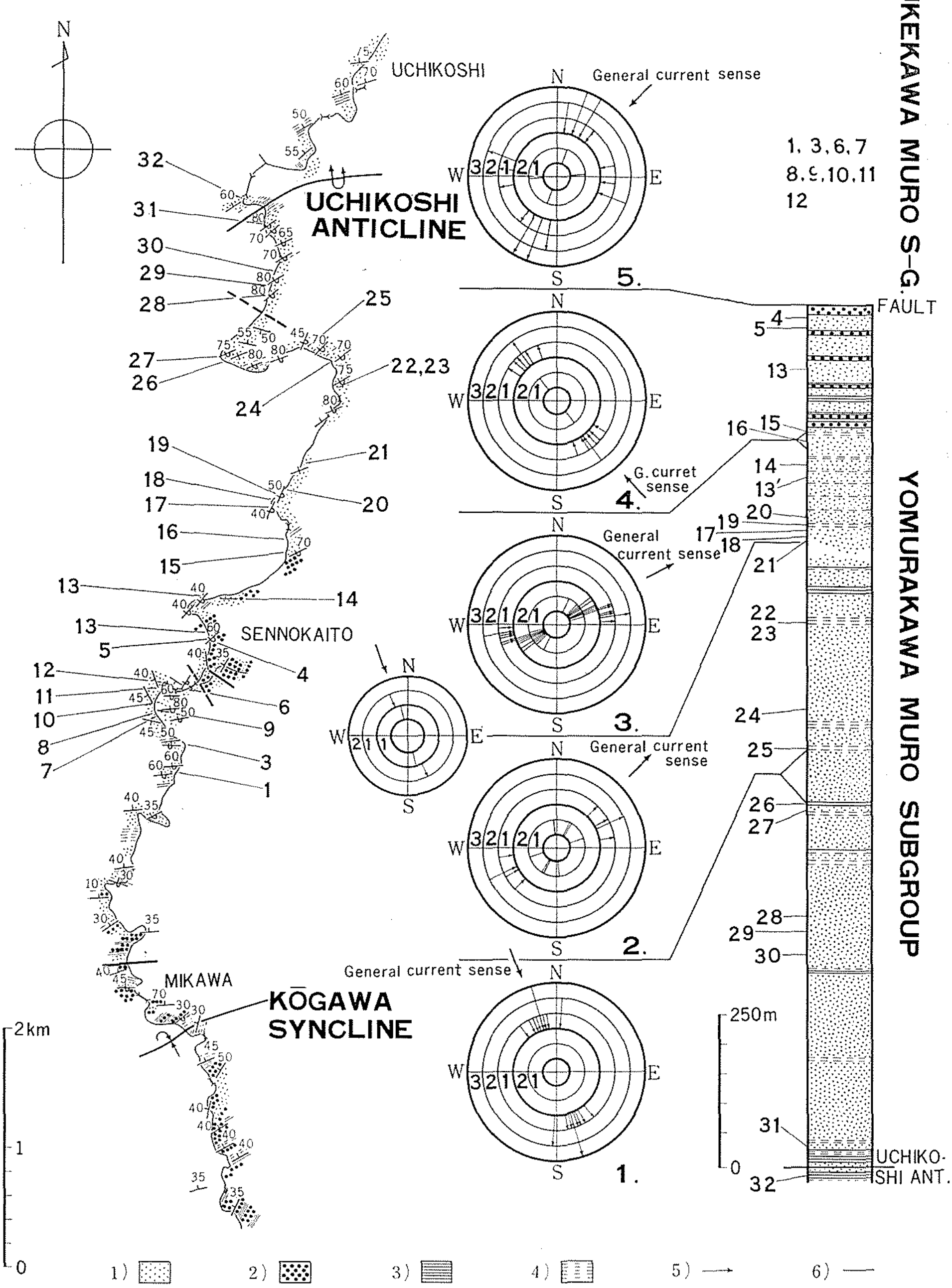


Fig. 13. CURRENT ROSE DIAGRAM, HIKIGAWA SECTION (Section III).

1) Massive sand stones and sandy flisch-like alternations, 2) Conglomerates, 3) Mud stones, 4) Muddy flisch-like alternations, 5) Line of flow and pointing distinct, 6) Line of flow distinct, pointing doubtful, (Route map by T. Tokuoka).

CHAPTER III. CONSIDERATION

1) Origin of current marks

J. HALL (1843a; 1843b) attributed the features listed here to the effect of current action on the bottom, but he did not determine the kinds of currents involved and the mechanics of the origin of the marks.

We agree with DZULYNSKI and SANDERS (1962, pp. 84-85) that the type of bottom plays a passive but important role in the origin of current marks, largely influencing preservation and only secondarily influencing the shape of marks formed, and that the flow conditions and sediment load constitute the main active causes that determine the kinds of marks.

The present research is not enough for considering the origin of sole marks, and the experimental results will be needed, but several facts, which are stated in the following sections, may suggest something of the origin of sole marks.

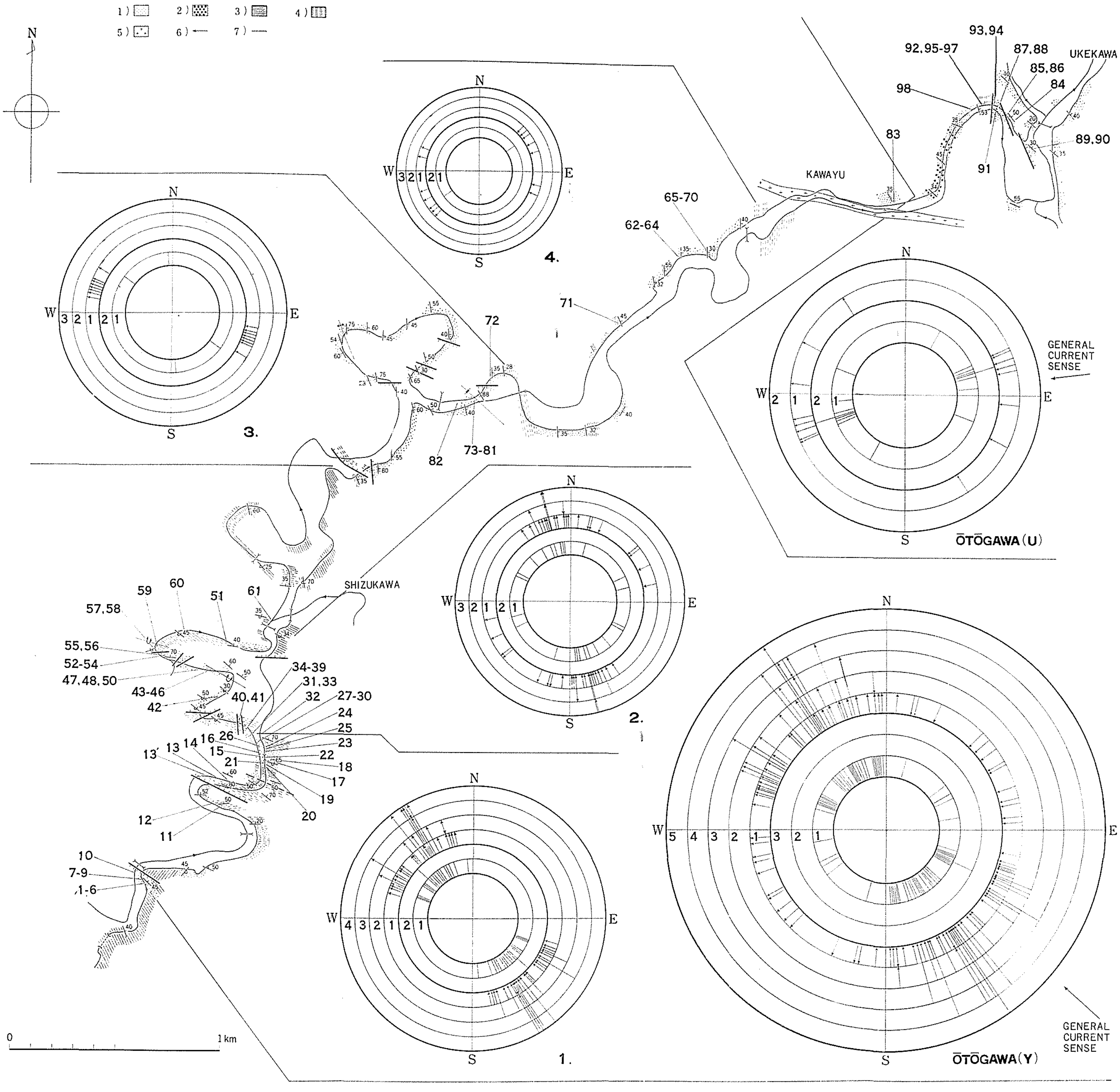
a) Mixed assemblages of sole markings in successive sequence

It is of interest that the directional structures in the same rock units point approximately in the same direction and nearly all the types of sole markings listed here coexist in the same rock units. The similarity between the rock units is represented by the thickness of alternations, the mineralogic composition and the type of transition from sandstone to the coverlying shale. The mixed assemblages of various sole markings in any sequence are represented by the following three cases; the predominance of tool markings in some sequences, the predominance of scour markings in other sequences, and their being mixed in still other sequences. This may demonstrate the fact that the condition of the current flow, which produced various types of current marks on cohesive mud bottoms, had been essentially unchanged through the sedimentation of the rock unit and such a current had made various current marks on the same bottom. Although on a given sole the current markings (cast) tend to be of the same type and are much alike, they vary from sole to sole, and we contend that the "partial" flow conditions (velocity, density, composition of load, thickness, direction) consititute the main active cause of the kinds of marks.

b) Mixed assemblages of sole markings on a given sole

The previous sections describing tool markings and scour markings have indicated the contrast between these two extreme types. Scour marks by their overall shape and detailed morphology suggest scouring of the bottom by the collective effect of sediment-laden turbulent eddies.

TEN HAAF (1959, p. 37) suggested that grooves are the first bottom marks made by a



Fig, 14. CURRENT ROSE DIAGRAM, ŌTŌGAWA SECTION (Section IV).

1) Sandy flisch-like alternations, 2) Conglomerates, 3) Mud stones, 4) Muddy flisch-like alternations, 5) Line of flow and pointing distinct, 6) Line of flow distinct porinting doubtful.

turbidity current "in the earliest stage of erosion" for "excavation of flutings by fluid erosion takes some little time".

In the Shimanto Major Belt, the relation between the flute and groove casts shows that fluting was earlier than the grooving. Our investigation into this problem has been influenced by he attempts of GLAESSNER (1958), HSU (1959) and DZULYNSKI and SANDERS (1962a) to apply mechanics of flow to the different aspects of the marks produced. DZULYNSKI and SANDERS (1962a) concluded that the linear marks are the result of transportation of grains in the traction mechanism (in this case, the dominant activity is saltation).

We consider only scour marks to be the effect of direct erosion by the current. Tool marks are due to the traction. Large-scale traction transportation of sand may occurs only when the flow is turbulent (DZULYNSKI and SANDERS, 1962a).

c) Overlapping feature of flute casts

In general, the flute casts tend to form a group, and to overlap each other on a given sole. The flute cast on the up-current side is overlapped by the flute cast on the down-current side. The above fact demonstrates that the scouring condition was shifted successively toward the lee side on the cohesive mud bottom. According our experimental observation, we consider that the materials eroded on the up-current side influence secondarily the formation of this overlapping feature.

d) Time of origin

As mentioned in the previous section, it is important to make clear the genetic process of the sole markins.

The coexistence of "biohieroglyphs" is the most common and most useful criteria. In the Muro Group, there are some soles, on which the sole markings are assembled with the biohieroglyphs. The feature of these assemblages shows clearly that the sole marks were former prior to the arrival of the current which deposited the covering bed.

On the other hand, there are other soles, on which the sole markings are not assembled with the biohieroglyphs, in the Muro Group. In this case, it is hardly possible to decide whether the sole markings were of pre-depositional or not.

As stated in the previous section, there is another criterion to permit a decision on the time of origin. It is the mixed assemblage of the sole marking on a given sole. This assemblage is represented by two or three sets of groove casts or the flute and groove casts. The preceedings sets of the former assemblage and the flute cast of the latter are of pre-depositional.

From these data, it is considered that the tool marks and the scour marks could be made not only by the passage over the mud of the current which carried the sediment that forms the covering bed, but prior to the arrival of the current which deposited the covering bed.

The further observations must be required on the time of origin, when the sole markings were formed, as the above phenomena are related with the mechanism of formation of turbidites.

e) The change of current direction

In the Chapter II, it is shown that the current direction in the successive beds changed in the order of member. Fig. 15 shows that there is a passage portion where the current direction changed alternatively between the two members of different directions. It is of interest that each direction indicate exactly the same direction of each member.

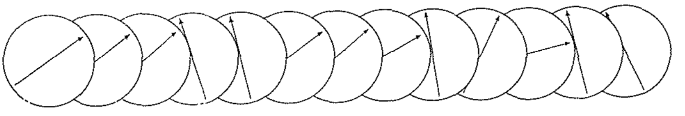


Fig. 15. A passage portion where the current direction changed alternatively between the two members of defferent directions. Taira, Hongū-cho, Higashimuro-gun, Wakayama Prefecture.

As the change of directions is assumed to suggest the difference of source area and or the tectonic movement in the geosynclinal basin, the further observations should be established in the future.

2) Collecting data

A close identity may be assumed between the general orientation of a sole marking in outcrop is considered to coincide with the orientation of that not available for measurement.

For testing the relation between the number of measurements and the accuracy, the orientations of sole markings and parting structures available for measurement were collected from each section as far as possible. The number of orientations of substratal lineations measured was plural in nearly all cases and singular in rare cases. The orientation on a bottom surface was given as a vector mean azimuth. However, for a bed on which several sets were superimposed on each other were given a number of vector mean azimuths.

In the case of one bottom surface and one rock unit, variability was measured quantitatively by variance:

$$\sigma^2 = \sum_{i=1}^{n} (x_i - \bar{x})^2 / n$$

where x_i is the individual azimuth, $\bar{x}$ is the vector mean of all measurements and n the number of measurements (Table 3;4). The accuracy of the estimate of current direction was measured by standard deviation (Table 3;4).

Table 3. Consistency of Sample (one bottom surface).

Sample number	n	σ^2	σ	R	L	Sole marking
O-2	5	7.16	2.68	4.995	99.85	Flute casts
O-7	6	6.50	2.55	5.994	99.90	Flute casts
H-13′	7	28.03	5.29	6.970	99.57	Flute casts
O-17	10	40.56	6.37	9.940	99.40	Groove, brush and bounce
H-14	13	48.02	6.93	12.905	99 27	Groove casts
O-3	14	58.60	7.66	13.875	99.11	Flute casts

Table 4. Consistency of Sample (one successive sequence).

Section	n	σ^2	σ	R	L	Vecter mean azimuth
Fukuidani	8	881.80	29.70	6.966	87.07	50°27′(NE)
Wakuba	8	494.24	22.25	7.452	93.15	60°40′(SE)
Hikigawa (1)	11	164.00	12.81	10.727	97.52	17°02′(NW)
Hikigawa (2)	9	604.85	24.59	8.133	90.37	49°54′(SW)
Hikigawa (3)	23	134.98	11.63	22.535	97.55	63°50′(SW)
Hikigawa (4)	8	165.98	12.49	7.799	97.49	47°50′(SE)
Hikigawa (5)	15	1142.93	33.81	12.214	81.43	53°04′(NE)
Ōtōgawa (Y)	93	1626.77	40.33	75.233	80.90	47°31′(NE)
Ōtōgawa (U)	17	675.55	25.64	15.358	90.34	84°11′(NE)

According to Reiche (1938, p. 913), the consistency ratio in per cent (L), which is the magnitude of the resultant vector in terms of per cent, and the vector magnitude (R), which is the magnitude or length of the resultant vector, are shown in Table 3;4.

$$R = (V^2 + W^2)^{1/2} \qquad \left[\begin{array}{ll} V = \sum_{i=1}^{n} n_i \cos x_i & \bar{x} = \arctan W/V \\ W = \sum_{i=1}^{n} n_i \sin x_i & \end{array} \right]$$

$$L = (R/n) \times 100$$

Where x is the mid-point azimuth of the ith class interval, $\bar{x}$ is the azimuth of the resultant vector, n_i the number of observations in each class, n the total number of observations.

The results are follows:

i) The consistency ratio of each bottom surface is more than 99 per cent. This indicates that $\bar{x}$ is extremely reliable. (Table 3).

ii) In the Hikigawa section, the grouped directions of each sequence show the high consistency ratio; more than 90 per cent (See Table 3, Fig. 13). From this data, it is concluded that the current direction is highly concentrated in a line, in each successive sequence.

iii) On Table 4, the consistency ratio of the Ōtōgawa (Y), all measurements in the Yomurakawa Muro Subgroup of the Ōtōgawa Section, is 80-90 per cent, although the data is not grouped. The well-grouped directions of the Ōtōgawa Section are shown with the high consistency ratio (Fig. 14).

iv) The directions of the Ukekawa Muro Subgroup, in the Hikigawa Section and the Ōtōgawa Section, may be divided into two general current senses.

3) Orientation

In this section, errors resulting from the correction of data are discussed. Before the sedimentary direction can be measured as it prevailed when a bed was laid down, the pretectonic situation must be reconstructed. Rotatory movements do affect the primary directions. In sharply stratified formations such as the Muro Group, three kinds of rotation can be considered; the shearing of the plane of stratification, disjunctive rotation in the same plane, and vertical tilting or folding.

The importance of shearing and disjunctive rotation in the plane of stratification, at any given locality in the Muro Group, is difficult or impossible to evaluate. The pretectonic position, and therefore the original current direction, cannot be reconstructed. In the tectonics of the Muro Group, however, shearing and disjunctive sliding may not have been so strong in general. In this paper, the above two kinds of rotation have been disregarded entirely.

As for the tilted and folded strata, the initial geographical orientation as well as the pre-tectonic subhorizontal position can be inferred from the visible tectonic situation.

In Chapter II, the observed actual directions are turned back to horizontal position by rotating about the strike axis. In this case, the azimuth of autochthonous bottom slope is disregarded. Errors resulting from regarding the horizontal plane to be the autochthonous slope; the azimuths up to 20°, causing a maximal error of less than 2°, can be disregarded for our purpose.

It is generally known that, in areas where fold axes are plunging, rotation about the strike may lead to considerable errors. Table and curves have been published, showing the amount of these errors for different angles of dip and plunge (HAAF, 1959, p. 75; NORMAN, 1960, p. 339; RAMSAY, 1961, p. 89). The assumption underlying these corrections is that "non-plunging folds attained a plunge by rotation about a horizontal axis at right angles to the fold axis. CUMINS examined errors resulting from plunge correction on this assumption, if it is mistaken. (1964, p. 167-173).

In this section, the amount of axial inclinations and the errors introduced by rotating about a horizontal axis at right angles to the fold axis will be stated.

In Wabuka, Fukuidani and Hikigawa Sections, the amount of axial inclinations measured by the geological mapping are 45° (NE), 25° (NE) and 10° (SW) respectively. The errors induced by disregarding these axial pitches are estimated at less than 1°, less than 10° and less than 30° respectively. If these axial pitches are allowed for, the vector mean azimuths of general current senses or current orientations are as follows;

i)	Fukuidani		50°27′	⟶	51° (±)	[NE]
ii)	Wabuka		60°40′	⟶	61° (±)	[SE]
iii)	Hikigawa	(1)	17°02′	⟶	13° (±)	[NE]
	,,	(2)	49°54′	⟶	80° (±)	[SW]
	,,	(3)	63°50′	⟶	86° (±)	[NW]
	,,	(4)	47°50′	⟶	78° (±)	[SE]
	.,	(5)	53°04′	⟶	83° (±)	[NE]

In Ōtōgawa Section, although the occurrence of plunging structures is not actually obse.ved, it is assumed that the Section is comprised in the northern limb of the Uchikoshi anticline with an easterly pitch, because the tectonics of the Muro Northern Subbelt show the relative depression of the eastern and western parts against the central area as a whole (Harata, 1964, p. 87). The amount of axial inclination may be not larger than that in Hikigawa and hence the errors induced by disregarding the axial pitch may be of the order of 30°.

Chapter IV. Conclusions

1) Uniformity and parallelism of current trends

The observed current trends are recorded in Chapter II; their uniformity and parallelism are remarkable in any sequence and on a given sole. Moreover, it has been shown that the observed trend of tool markings is parallel or subparallel to that of the scour marking. Thus, we have reached the conclusion that in every good exposure there can be found a single, at least excessively dominant direction indicating the path followed by all, or nearly all, of the successive current.

2) Supply of clastic materials

If it is to be assumed that the observed and corrected directions of sole markings indicated the direction of supply, and that non-plunging folds attained a plunge by rotation about a horizontal axis at right angles to the fold axis and that the shearing and disjunctive sliding in any bedding surface of the Muro Group was not so heavy, the results are as follows.

a) The supply of the sediments of the Yomurakawa Muro Subgroup

In Hikigawa section, the measurements made in the lower part* of the Yomurakawa Muro Subgroup indicate three main directions; the directions from the nearly north, from the nea ly west and from the southeast. In Ōtōgawa Section, those of the middle part* of the Yomurakawa Muro Subgroup indicate two directions of supply; from the southeast and the nearly east. In Wabuka Section, those of the upper part* of the Yomurakawa Muro Subgroup indicate the direction of supply from the southeast. In Fukuidani Section, those of the upper part* of Yomurakawa Muro Subgroup indicate the direction of supply from the northeast.

b) The supply of the Ukekawa Muro Subgroup

In both the sections of Hikigawa and Ōtōgawa, the direction of supply of the Ukekawa Muro Subgroup is from the northeast and/or nearly east.

Thus, the observed directions show that the direction of supply changed according to the time when the different sequences of strata had been deposited.

The two directions, the nearly west and the nearly east, observed in some sequences of the Yomurakawa Muro Subgroup are seemed probably to show the so-called 'longitudinal supply' and the other two directions, the nearly north and the southeast, to show the so-called 'lateral supply' (DULYNSKI, KSIAZKIEWICZ and KUENEN, 1959).

It is of interest that the directions assumed to be longitudinal supply are in reverse direction each other and that the directions assumed to be latteral supply are not only from the nearly north but from the southeast.

3) Source area

It is of great interest tht coarse clastics of the Yomurakawa Muro Subgroup, in any sequence, indicate the direction of supply not only from the north, the southwest or the northeast, but from the southeast. From these data, it may be concluded that the clastics of the Muro Group were sometimes supplied from the area situated to the southeast of the Shimanto Terrain, although it is now submerged by the Pacific Ocean.

CHAPTER V. SUMMARY

The purpose of this paper is to lay the beginning for a paleocurrent analysis, based mainly on the sole markings of the Flysch-like sediments of the Shimanto Complex. The descriptions are based on the Paleogene to Lower Miocene Muro Group, but a few examples from other rocks are also included.

1) Several directional sole markings, flute, current crescent, frondescent, bounce, brush and groove casts, are observed in the Shimanto Terrain and described in the Chapter I.

* See T. HARATA (1964).

2) The orientation of sole markings is measured in the four sections, Wabuka, Fukuidani, Hikigawa and Ōtōgawa Sections, and each datum is rotated about the horizontal axis only and recorded in the Chapter II.

3) Some facts which may suggest the origin of sole marks are stated, and the consistency of measured data and the errors resulting from the correction of data are discussed in the Chapter III.

4) It is concluded that in every good exposure there can be found a single, at least excessively dominant direction indicating the path followed by all, or nearly all of the successive current.

5) In the Yomurakawa Muro Subgroup, the current direction of supply is indicated with four main directions; the direction from the nearly north, from the southeast, from the nearly north and the nearly east.

6) In the Ukekawa Muro Subgroup, the current direction of supply is indicated with the direction from the northeast and/or the nearly east.

7) It may be concluded that the clastics of the Muro Group were sometimes supplied from the area situated to the south of the Shimanto Terrain, although it is now submerged by the Pacific Ocean. (4, 5, 6, 7 are stated in the Chapter IV)

References

ARAI, J. 1957: Some load cast structures in the Akahira formation (Oligocene), Chichibu basin, Saitama Prefecture, Japan. Bull. Chichibu Mus. Nat. History, No. 7, 85-88.

ARAI, 1959: Cylindrical structures in the Tertiary sediments of the Chichibu basin, Saitama Prefecture, Japan. Bull. Chichibu Mus. Nat. History, No. 9, 61-68.

ARAI, 1960: The Tertiary system of the Chichibu basin, Saitama Prefecture, Central Japan, Part I, Sedimentology. Tokyo Soc. Promotion of Sic., 122P.

BIRKENMAJER, K., 1958: Orientouane hieroglify splywowe we fliszu Karpackimi i ich stosunek do hieroglifow pradowydh i wleczniowych (Oriented flowage casts and marks in the Carpathian flysch, and their relation to flute and groove casts). Acta Geol. Polon. 8, 118-148 (Polish and Engl. Summ.).

BIRKENMAJER, K., 1959: Systematyka warstwowań w utworach fliszowych i podobynch (Classification of bedding in flysch and similar graded deposits). Studia Geol. Polonica 3, 133p. (Polish; Engl. Summ.).

BOUMA, A.H., 1962: Sedimentology of some flysch deposits. Amsterdam: Elsevier Publishing Co., 168P.

CLARKE, J.M., 1917: Strand and undertow markings of Upper Devonian times as indication of the prevailing climate. New York State Mus., Bull., 196, 199-210.

CLOOS, H., 1938: Primare Richtungen in Sedimenten der Rheinischen Geosynkline: Geol. Rundschau 29, 357-367.

COOPER, J.R., 1943: Flow structures in Gerea sandstone and Bedford shale of central Ohio. Jour. Geol., 51, 190-203.

CROWELL, J.C., 1955: Directional-current structures from the Pre-alpine Elysch, Switzerland. Bull. Geol. Soc. America, 66, 1351-1384.

CUMMINS, W.A., 1958: Some sedimentary structures from the Lower Keuper sandstones. Liverpool Manchester Geol. Jour., 2, 32-43.

CUMMINS, W.A , 1964: Current direction from folded strata. Geol. Mag., 101, 169-173.

DZULYNSKI, St., 1963: Directional structures in Flysch. Studia Geol. Polonica, 12, 136p.

DZULYNSKI, St., 1965: New data on experimental production of sedimentary structures. Jour. Sedimentary Petrology, 35, 1. 196-212.

DZULYNSKI. St., M. Ksiazkiewicz and Ph. H. Kuenen, 1959: Turbidites in flysch of Polish Carpathian Mountains. Bull. Geol. Soc. Am., 70, 1089-1118.

DZULYNSKI, St., and A. RADOMSKI, 1955: Pochodzenie ś ladów wleczenia na tle teroii pra dow zawiesinowych (Origin of groove casts in the light of turbidity current hypothesis). Acta Geol. Polon., 5, 47-56.

DZULYNSKI, St., and J.E. SANDERS, 1959: Bottom marks on firm lutite substratum underlying turbidite beds (Abstract). Bull. Geol. Soc. Am., 70, 1594.

DZILYNSKI. St., and SANDERS, 1962a: Current marks on firm mud bottoms. Trans. Conn. Acad. Arts. Sci., 42, 57-96.

DZULYNSKI, St., and J.E. SANDERS, 1962b: O niektórych hieroglifach prdowych we fliszu (On some current markings in flysh) Roczn. O1. Tow. Geol. (Ann. Soc. Geol. Pologne), XXX, 144-145.

DZULYNSKI, St., and A. SLACZKA, 1958: Sedymentcja i wskaźniki kierunkowe transporta w warstwach Krosniech (Directional structures and sedimentation of the Krosno beds, Carpathian Flysch). Ann. Soc. Geol. Pologne, 28, 205-260 (English; Polish Summ.).

DZULYNSKI, St., and A. SLACZKA, 1959: Przyklak drozji dna basenu fliszowego (An example of large-scale bottom erosion in the flysch basin). Ibid. 29, 327-333.

DZULYNSKI, St., and E.K. WALTON, 1963: Experimental production of sole markings. Geol. Soc. Edinburgh Trans., 19, 279-305.

FIEGE, K., 1942: Hilfsmittel zur Erkinnung normaler und inversen Lagerung in tektonisch stark gestörten Gebieten. Senckenbg., Bd. 25, 292-325.

FUCHS, T., 1895: Studien über Fucoiden und Hieroglyphen. Denskchr. Math.-nat. Kl. Akad. Wiss. Wien, 62, 369-448.

FUGGER, E., 1899: Das Azlzburger Vorland. Jahrb. Kais. Kon. Geol. Reichsanst., 49, 287-428.

GLAESSNER, M.F., 1958: Sedimentary flow structures on bedding planes. Jour. Geol., 66, 1-7.

HAAF, E. TEN., 1956: Significance of convolute lamination. Gwol. en Mijinbouw, 18, 188-194.

HAAF, E. TEN., 1959: Graded beds of the northern Apennines. Ph. D. thesis, Rijks University of Groningen, 102p.

HALL, James, 1843: Geology of New York, Pt. 4, Survey of the fourth district. Albany: Carroll and Cook, 683p.

HALL, J., 1843b: Remarks upon casts of mud furrows, wave lines, and other markings of the New York system: Assoc. Am. Geologists Rept., p. 422-432.

H¨NTZSCHEL, W., 1938: Bau und Bildung von Gross-Rippeln im Wattenmeer. Senckenbergiana, 20, 1-42.

HARATA, T., T. TOKUOKA and E. MATSUMOTO, 1963; Some important new facts from the Muro Group in the South part of the Kii Peninsula. The new occurrence of fossils from the Upper part of the Muro Group. Earth Science, 69, 20-24.

HARATA, T., 1964: The Muro Group in the Kii Peninsula, Southwest Japan. Mem. Coll. Sci. Univ. Kyoto, Ser. B, 31, 2, 71-94.

HSU, K. J., 1959: Flute- and groove-casts in the Pre-Alpine flysch, Switzerland. Am. Jour. Sci., 257, 272-276.

KATTO, J., 1952: Research on the Unknown Mesozoic formations in the Outer Zone of Shikoku. Rep. No. 3-New observations in the vicinity of Misaki-machi and Shimizu-machi in Kochi Prefecture, especially on the features of the bedding surface (in Japanese). Res. Rep. Kochi Univ., Vol. 1, 11, 1-8, 10 pl.s

KATTO, J., 1959: Markings on stratification surface. Res. Rep. Kochi Univ., Vol. 8, 26, 1-9, 3pls.

KATTO, J., 1961: Sedimentary structures from the Shimanto Terrain, Shikoku, South west Japan. Res. Rep. Kochi Univ., Vol. 10, Natural Science I, 6, 135-142, 4pls.

KATTO, J., 1964: Some sedimentary structures and problematica from the Shimanto Terrain of Kochi Prefecture, Japan. Res. Rep. Kochi Univ., Vol. 13, Natural Science I, 6, 45-58, 7 pls.

KELLING, G. and E.K. WALTON, 1957: Load-cast structures their relationship to upper-surface structures and their mode of formation. Geol. Magazine, 94, 481-490.

KINGMA, J.T., 1958: The Tongaporutuan sedimentation in central Hawjes Bay. New Zealand J. Geol. Geophys. 1, 1-30.

KSIAZKIEWICZ, M., 1952: Uwarstwienie frakcjonalne i laminowane we fliszu karpackim (Granded and laminated bedding in the Carpathian Flysch). Roczn. O1. Tow. Geol. (Ann. Soc. Geol. Pologne), 22, 339-449.

KSIAZKIEWICZ, M., 1958: Osuwiska podmorskie we fliszu karpackim (Submarine slumping in the Carpathian flysch). Ann. Soc. geol. Pologne, 28, 123-150. (English with Polish Summ.)

KUENEN, Ph. H., 1950: Marine geology. New York: John Wiley & Sons, 568p.

KUENEN, Ph. H., 1952: Paleogeographic significance of graded bedding and associated features. Koninkl. Ned. Akad. Wetenschap.. Proc., Ser. B, 55, 28-36.

KUENEN., 1953: Significant features of graded bedding. Bull. Am. Assoc. Petrol. Geologists 37, 1044-1066.

KUENEN, Ph. H,. 1957: Sole markings of graded graywacke beds. Jour. Geol., 65, 231-258.

KUENEN, Ph. H., 1958: Experiments in Geology. Trans. Geol. Soc. Glasgow, 23, 2-28.

KUENEN, Ph. H., and J.E. SANDERS, 1956: Sedimentation phenomena in Kulm and Flözleeres graywackes, sauerland and Oberharz, Germany. Am. Jour. Soc., 254, 649-671.

KUENEN, Ph. H., and H.W. MENARD, 1952: Turbidity currents, graded and nongraded deposits. Jour. Sed. Petrol., 22, 83-96.

LYELL, Charles, 1839: Elements of geology, 1st ed. Philadelphia: James Kay, Jun. and Brother, 316p.

MATUSMOTO, E., 1965: The New Occurrence of Fossil from the Muro Group along the Upper Reach of the Hiki River (in Japanese). Jour. Geol. Soci. Japan, 71, 838, 353.

McBRIDE, E.F., 1962: Flysch and associated beds of the Martinsburg Formation (Ordovician), Central Appalachinans. Jour. Sediment. Petrol. 32, 39-91.

McIVER, N.L., 1961: Upper Devonian marine sedimentation in the central Appalachians. Ph. D. thesis, The Johns Hopkins University, 347p.

McKEE, Edwin D., 1938: Original structures in Colorado flood deposits of Grand Canyon. J. Sediment. Petrol., 8, 77-83.

McKEE, E.D., 1954: Stratigraphy and history of the Moenkopi formation of Triassic age. Geol. Soc. Am. Mem., 61, 133p.

MIGLIORINE, C.I., 1950: Data conferma della risedimentazione della arenarie macigno. Atti Soc. toscana sci. nat. Pisa Mem., 57, Ser. A, 3-15.

NAGAHAMA, H. and H. ISOMI, 1955: Paleo-current in the Taisyu Group. Jour. Geol. Soc. Japan, 71. 838, 372p. (in Japanese)

NORMAN, T.N., 1960: Azimuths of Primary Linear Structures in Folded Strata. Geol. Mag., 97, 338.

PEABODY, F.E., 1947: Current crescents in the Triassic Moenkopi formation. Jour. Sedi. Petrol., 17, 73-76.

PETTIJOHN, F.J.: Sedimentary rocks 2nd ed. New York: Harper and Brothers, 718p.

PETTIJOHN, F.J., and P.E. Potter, 1964: Atlas and glossary of primary sedimentary structures, Berlin- Göttingen-Heidelberg: Springer, 370p.

POTTER, P.E., and F.J. Pettijohn, 1963: Paleocurrents and Basin Analysis. Berlin-Göttingen-Heidelberg: Springer, 296P.

PRENTICE, J.E., 1956: The interpretation of flow-markings and load-casts. Geol. Mag., 93, 393-401.

PRENTICE, J.E , 1960: Flow structure in sedimentary rocks. Jour. Geol. 68, 217-225.

RADOMSKI, A., 1958: Charakterystyka sedymentologiczna fliszu podbalanskiego (The sedimentological character of the Podhale flysch). Acta Geol. Polon., 8, 335-409 (Polish; English summ.).

RAMSAY, J.G., 1961: The effects of folding on the orientation of sedimentation structures. Jour. Geol., 69, 84.

REICHE, Perry, 1938: An analysis of lamination; the Coconino sandstone. Jour. Geol. 46, 905-932.

RICH, J.L., 1950: Flow markings, groovings, and intra-stratal crumplings as criteria for recognition of slope deposits with illustrations from Silurian rocks of Wales, Bull. Am. Assoc. Petrol. Geologists, 34, 717-741.

RICH, J.L., 1951: Three critecal enveronments of deposition, and criteria for recognition of rocks deposited in each of them. Bull. Geol. Soc. Am., 62, 1-20.

RÜCKLIN, H., 1938: Strömungsmarken im unteren Muschelkalk des Saarlandes. Senckenbergiana, 20, 94-114.

SEILACHER, A., 1960: Strömugsanzeichen im Hunsrückschiefer. Notezbl. hess. Landesamtes Bodenforsch. 88, 88-106.

SHROCK, R.R., 1948: Sequence in layered rocks. New York: McGraw-Hill Book Co., 507p.

SHROCK, R.R., 1959: Primary structures in sedimentary deposits. Presid. Address Ann. Meet. Am. Ass. Adv. Sci. (Msc.)

SORBY, H.C., 1856: On the physical geography of the Old Red Sandstone sea of the central district of Scotland. Edinburgh New Philos. j., n.s. 3, 112-122.

STOKES, W.L., 1947: Primary lineation in fluvial sandstone: a criterion of current direction. Jour. Geol., 55, 52-54.

STOKES, W.L., 1953: Primary sedimentary trend indicators as applied to ore finding in the Carrizo Mountains, Arizona and New Mexico. U.S. Atomy Energy Comm. RME-3043, 48p.

SUYARI, K., 1965: The sedimentary structures in the Izumi Group of the east of Tokushima Prefecture. Jour. Geol. Soc. Japan, 71. 838, 376. (in Japanese)

TOKUOKA, T., 1965: The conglomerates of the Muro Group. Jour. Geol. Soc. Japan, 71. 838, 353-354. (in Japanese).

TOKUOKA., 1965: The Muro Group along the upper r ach of the Hiki River in Wakayama Prefecture, Japan. Jour. Geol. Soc. Japan, (Im press) (in Japanese).

TWENHOFEL, W.H., 1939: Principles of sedimentation. New York: McGraw-Hill Book Co., 610p.

VASSOEVICH, N.B., 1953: O nekotorykh flishevykh teksturakh (znakakh) (On some flysch textures). Trudy Lvovs. Geol. Obsh., Univ. Ivan Franko, Geol. ser. No. 3, 17-85.

VASSOEVIC, N.B., 1954: Sputnik polevogo geologo neftjanika, v. 1: Leningrad (Geological Field Companion; in Russian).

WOOD, Alan and A.J. SMITH, 1958: The sedimentation and sedimentary history of the Aberystwyth grits (Upper Llandoverian). Quart. Jour. Geol. Soc. London, 114. 163-189.