IX. BOTTOM SEDIMENTS

Seizo Nakao

Method

Three kinds of sediment samples were obtained from the survey area. These include 29 samples of bottom sediments with Okean–70 grab sampler, five core samples with gravity corer having the inside diameter of about six centimeters and the length of six meters, and 60 samples with small cylinder attached to the free-fall grab sampler (FG cylinder).

The samples were treated through the following process;

(1) for the samples obtained with Okean–70,
  (a) to take a photograph showing the surface condition,
  (b) to pick out manganese nodules on or near the surface,
  (c) to scoop up the surface part (two or three centimeters thick) into a cup of 300 cc for the compositional analyses,
  (d) to measure the vane shear strength (by YAMAKADO and HANDA),
  (e) to resample five sediment cores in the cylindrical or square shaped pipes
  (f) to take photographs and X-ray photographs, and make a visual description of the vertical section of sediment core,
  (g) to measure the water content (by HANDA),
  (h) to squeeze interstitial water from each selected segment of sediment cores for chemical analysis (by NOHARA),
  (i) to separate coarser fractions from finer ones of the surface part mentioned above (c) and a few segments cut off from a sediment core, through the sieve of 63 micron openings with water poured on it,
  (j) to measure the volume of coarse fraction on the sieve in the sedimentation tube designed by ARITA (1977), and
  (k) to determine compositions of the coarse fraction under the binocular microscopes, and,

(2) for the core samples with the gravity corer,
  (a) to cut off the cores together with inner tubes usually into each one meter length part,
  (b) to take photographs and X-ray photographs, and make a visual description of the vertical section,
  (c) to separate coaser fraction from finer of the segments about 10 cm thick, taken usually in a rate of five per each one meter length of the core, through the sieve of 63 micron openings with water poured on it,
  (d) the same as (j) of (1), and
  (e) the same as (k) of (1).

The samples obtained with FG cylinder were sieved, pouring water in much the same way as the others.

Composition of the coarse fraction and the types of sediment

The coarse fraction settled in the sedimentation tube consists of one or more layers with dark brown, orange, white and pale brown colors, or colorless (semitransparent). Major compositions under the microscope of each (colored) layer are shown as follows;

(1) dark brown: minute fragments and/or micro-spherules of manganese nodules, silicified radiolarian remains fragments of phosphorite, and zeolite minerals,
(2) orange: silicified radiolarian remains,
(3) white: foraminiferal remains,
(4) pale brown: radiolarian remains, 10–30% of which are stained, and
(5) colorless: radiolarian remains.

Some minor or accessary constituents other than those mentioned above, which are recognizable under the microscope, are ichthyoliths (fish skeletal debris, DOYLE *et al.*, 1974), siliceous sponge spicules, radiolarian spines, volcanic glass, pumice, benthic foraminifera, rock fragments, cosmic dusts and other mineral grains. The term, "mineral" (Min) used in the Figs. IX–3 and 4 includes predominant phosphorite grains, and minor amount of zeolite minerals, rock fragments, pumice, volcanic glass etc.

The following types of sediments (ARITA, 1977) are identified based upon both volumetric ratio of the coarse fraction to bulk sample and composition of the coarse fraction;

(1) deep sea clay: coarse fraction <10%, or >10% and non-biogenic (consists largely of "mineral" and silicified radiolarian remains),
(2) siliceous caly: coarse fraction 10–30%, radiolarian,
(3) calcareous clay: coarse fraction 10–30%, foraminiferal,
(4) calcareous-siliceous clay: coarse fraction 10–30%, foraminiferal-radiolarian,
(5) siliceous ooze: coarse fraction >30%, radiolarian, and
(6) calcareous ooze: coarse fraction >30%, foraminiferal.

Distribution of surface sediment

Fig. IX–1 shows distribution of the surface sediments classified into five types among the six, except the type (3) (calcareous clay), mentioned in the foregoing section. The surface sediment here means the surface part (two or three centimeters thick) of the sample of Okean-70, the uppermost part (about five centimeters thick) of that of gravity corer, or the whole of that of FG cylinder, used only as complementary data.

It seems that the distribution of sediments is controlled by two major topographic factors. One of these is the Magellan Rise situated around the intersection of the meridian 177°W and the parallel of latitude 7°N (St. 715), and the other is a range of seamounts along the parallel of latitude 11°N.

Calcareous ooze is distributed over the Magellan Rise area down to about 4,300 m in water depth where St. 716 is situated. On the other hand, calcareous-siliceous clay (St. 721, WD 4,580 m) or deep sea clay (St. 711, 5,740 m), which has the texture of clayey sand in SHEPARD's nomenclature (PETTIJOHN, 1957, p. 24) as shown in Fig. IX–2 and appears pale yellow dark grey, is distributed on the range mentioned above.

Siliceous clay is distributed in separative three areas. Two of those surround the Rise or the range, and the rest occupies the southeast corner (St. 726) of the survey area.

Siliceous ooze, coarse fraction of which consists almost exclusively of radiolarian remains including stained ones of 10–20%, occurs only in the border (Sts. 731 and 732) of the northern distribution of siliceous clay.

Deep sea clay which appears yellowish brown or brown is distributed widely on the sea floor at about 5,500–6,000 m depth. The coarse fraction of deep sea clay is composed dominantly of radiolarian remains at half the stations, i.e. Sts. 708, 709, 712, 718, 719, 725, 728, 729, 730 and 738. In this report, such deep sea clay is included in the term, siliceous sediment as well as siliceous ooze and siliceous clay.

Fig. IX–2 shows grain size of some surface sediments by the combination of hydrometer method and sieve analysis. Although the number of samples is not sufficient, it may be said that most sediments of deep sea clay or siliceous clay types have the texture of silty clay in SHEPARD's (1954) nomenclature. Siliceous ooze (P100), which involves the coarse fraction of 42.1 vol.%, is also named as silty clay having just 19.4 wt.% of sand size fraction. All the samples of calcareous ooze are named as sand-silt-clay.

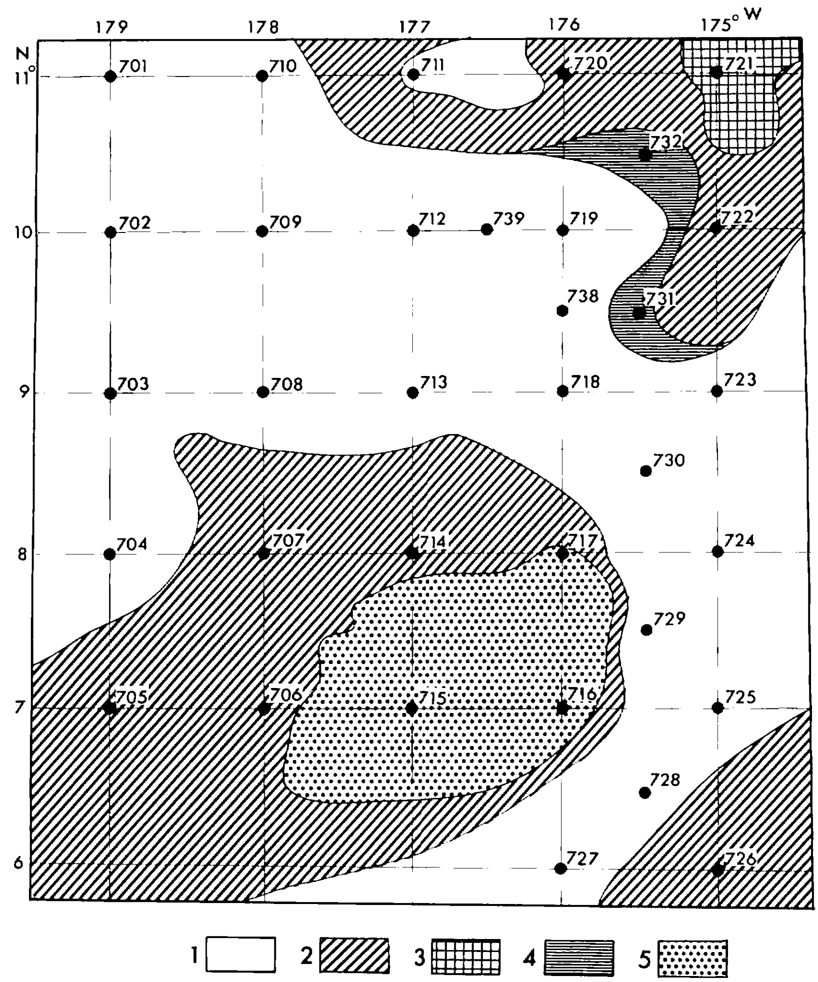


Fig. IX–1 Distribution of the surface sediments. 1. Deep sea clay, 2. Siliceous clay, 3. Calcareous-siliceous clay, 4. Siliceous ooze, 5. Calcareous ooze.

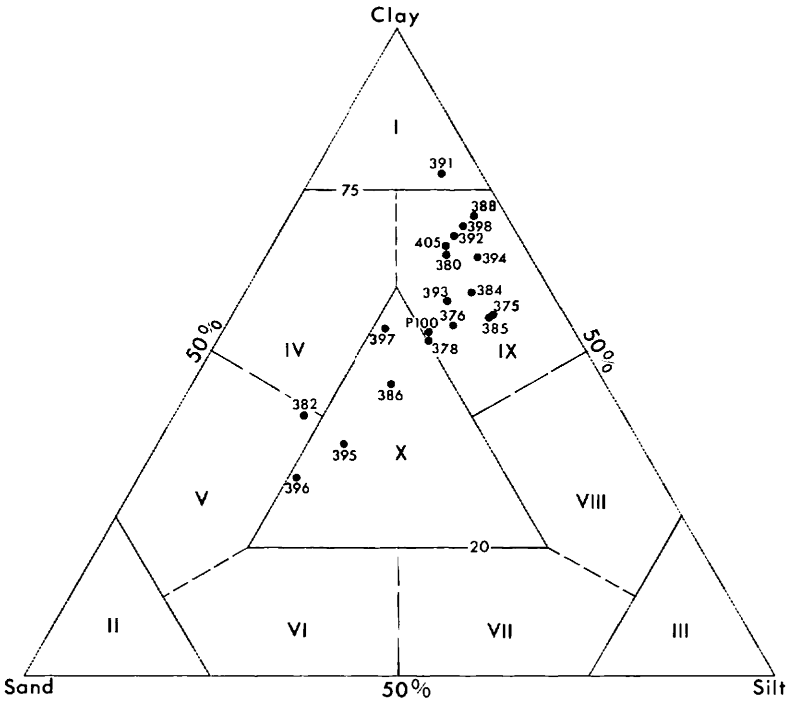


Fig. IX–2 Grain size of some surface sediments obtained with Okean-70 grab, except P100, plotted on the diagram by SHEPARD (1954) (PETTIJOHN, 1957). I. Clay, II. Sand, III. Silt, IV. Sandy clay, V. Clayey sand, VI. Silty sand, VII. Sandy silt, VIII. Clayey silt, IX. Silty clay, X. Sand-silt-clay.

Sequence in sediment cores

Observation of vertical section

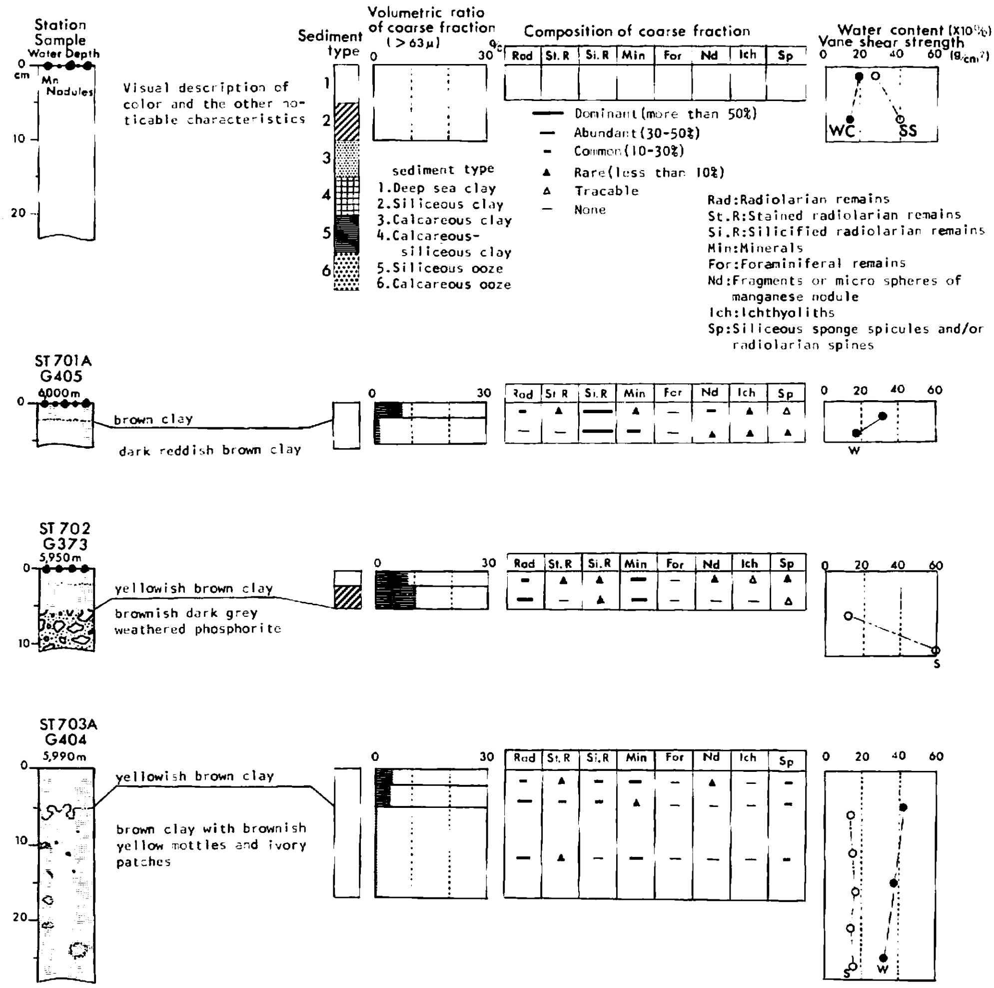
Fig. IX–3 shows vertical section, type of sediment, composition of the coarse fraction etc. of the cores from Okean-70, and Fig. IX–4 represents those from the gravity corer.

Most of the profiles of brown or yellowish brown sediments from Okean-70 show a part having mottles usually colored in the same as the color of the overlying part (Fig. IX–5, G394 and G398). The similar evidences are found in the sediments partially colored with ivory (Fig. IX–5, G385 and G390). Some profiles have numerous mottles complicated in shape (Fig. IX–5, G383), and some are apparently structureless or homogeneous (Fig. IX–5, G402).

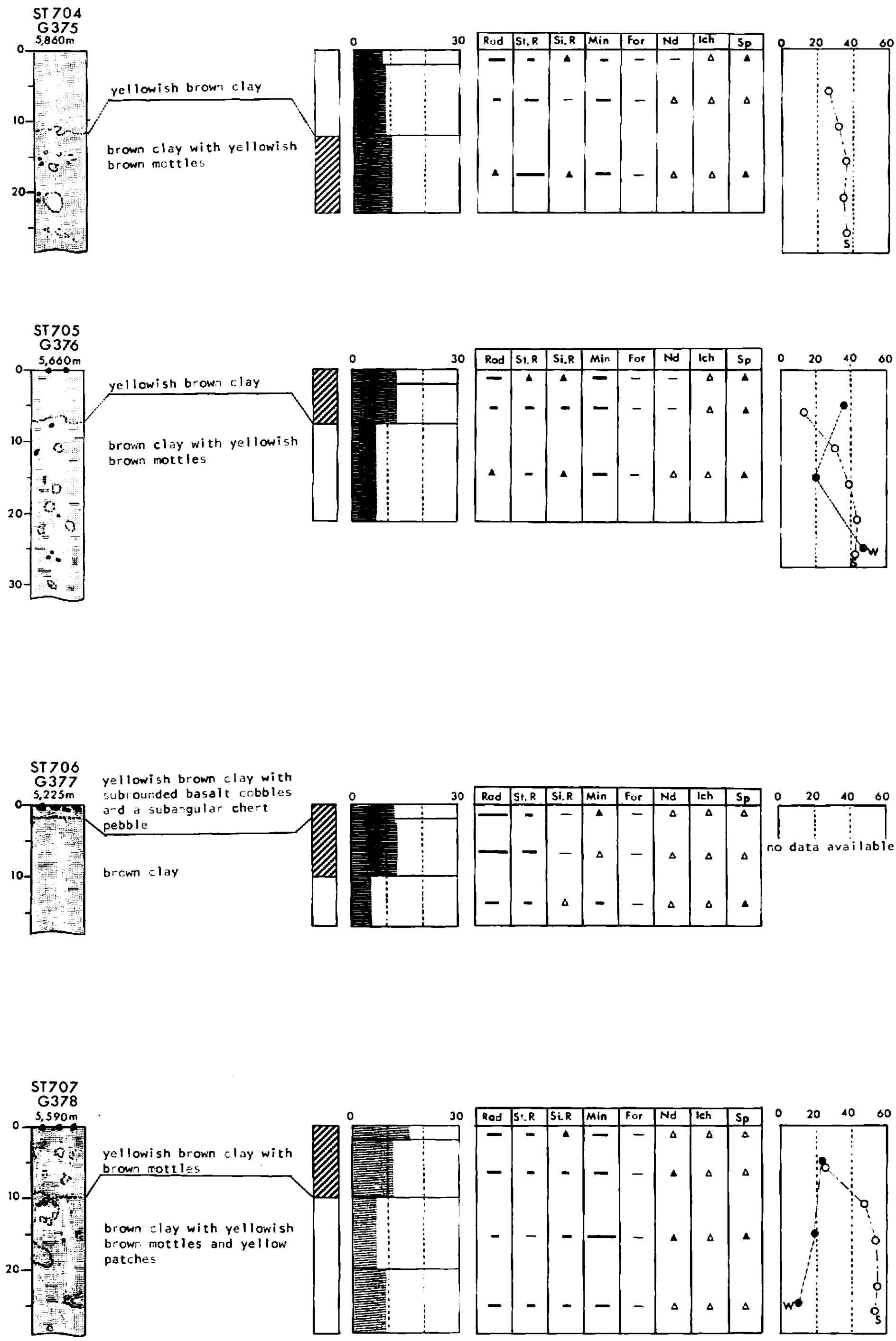
Photograph of G373 in Fig. IX–5 shows the phosphorite overlain by yellowish brown clay, that of G382 represents the profile of a special variety of deep sea clay colored with pale yellow or pale yellow dark grey, and that of G397 indicates an unconformable boundary.

Fig. IX–6 shows photographs of vertical sections of the samples from gravity corer. We can observe in them lamina structure of the lower part of the core, in cases of P97, P99 or P101, watery appearance of the uppermost part (siliceous ooze) of that, in cases of P100 or P101, besides the mottle structure and yellow or ivory patches resembling those in the samples from Okean-70.

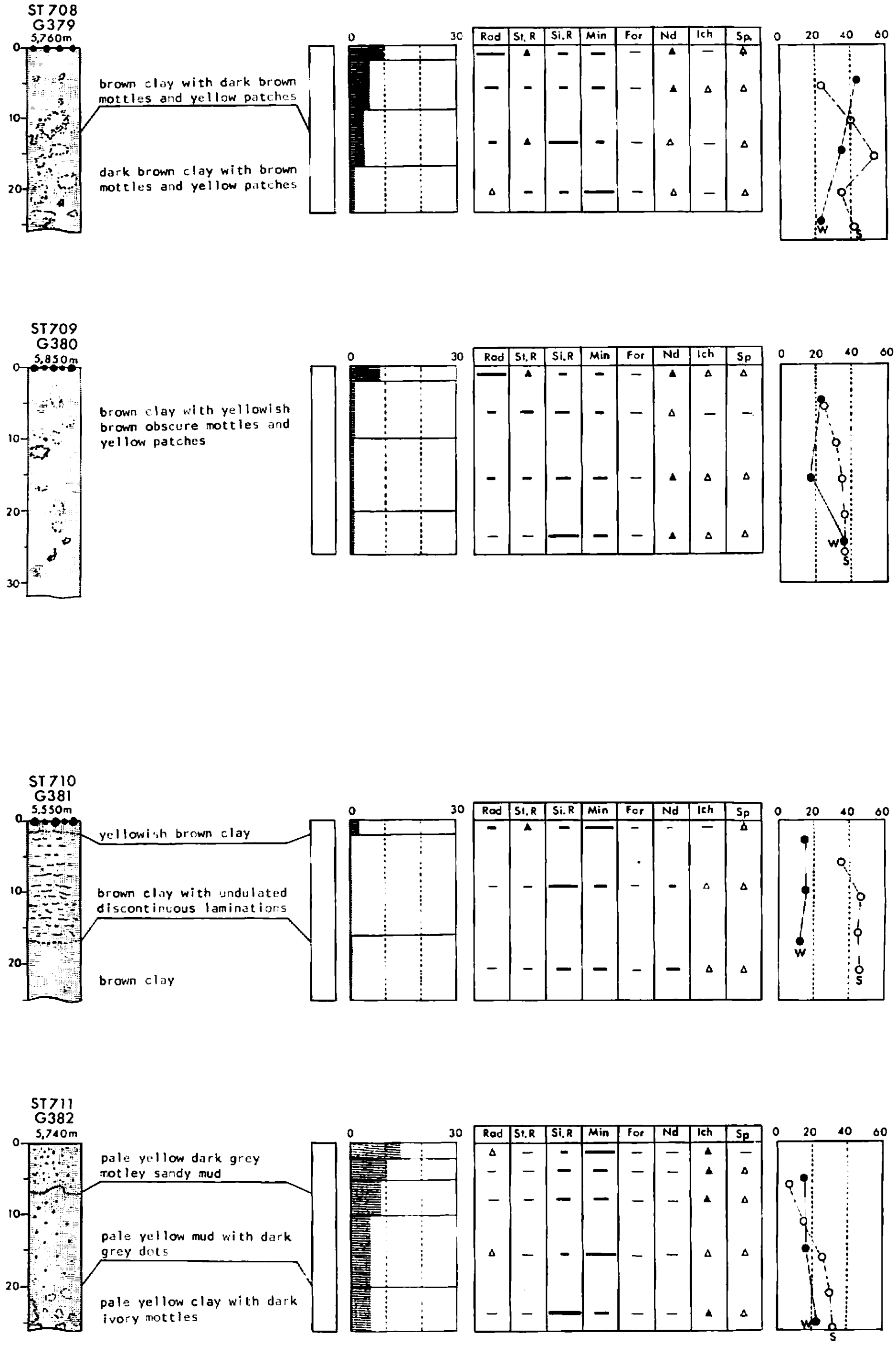
Fig. IX-3(a–g) Description of the samples from Okean-70.



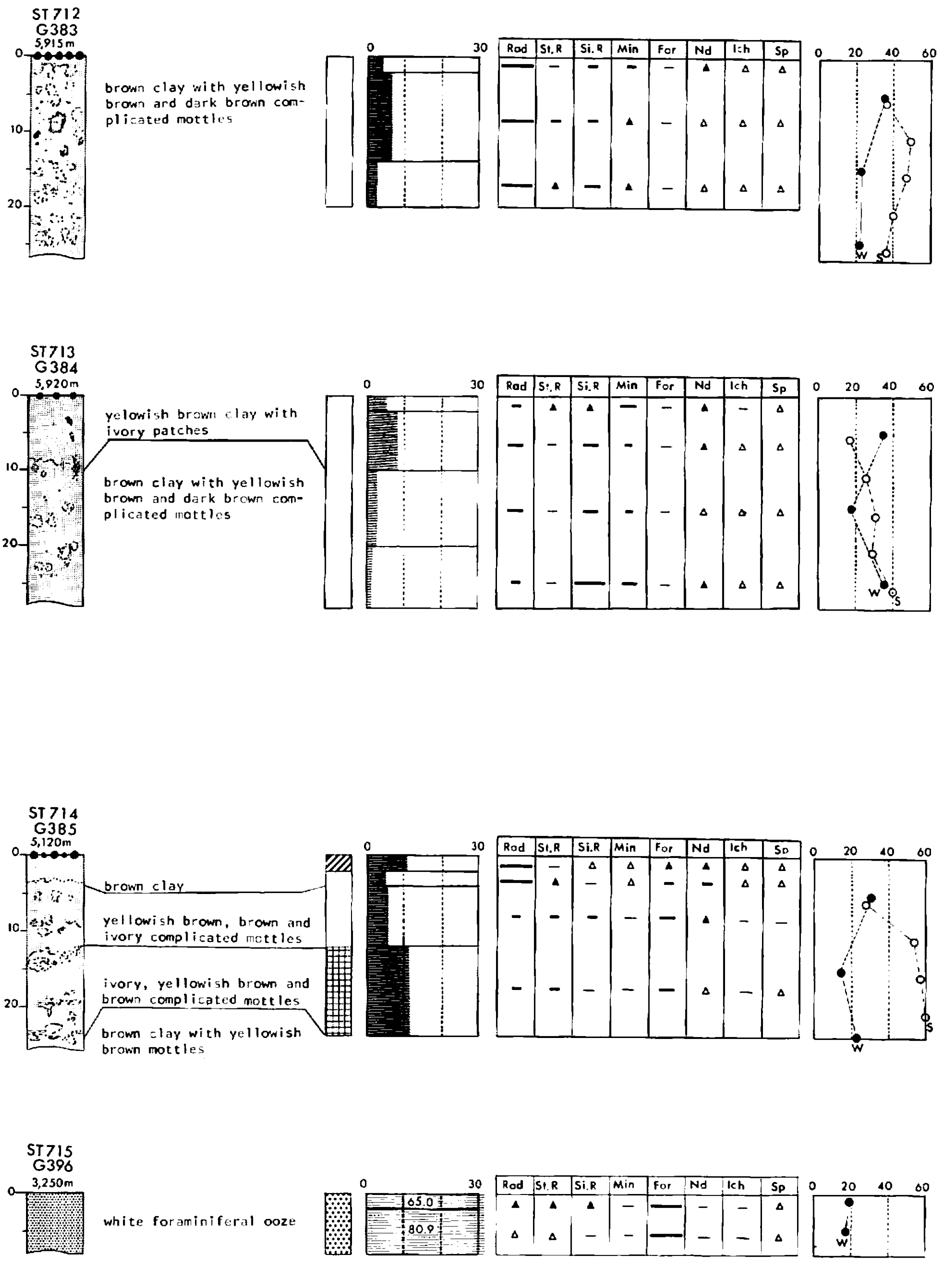
(a)


ST704
G375
5,860m
yellowish brown clay
brown clay with yellowish brown mottles
ST705
G376
5,660m
yellowish brown clay
brown clay with yellowish brown mottles
ST706
G377
5,225m
yellowish brown clay with subrounded basalt cobbles and a subangular chert pebble
brown clay
no data available
ST707
G378
5,590m
yellowish brown clay with brown mottles
brown clay with yellowish brown mottles and yellow patches
Rad
St.R
Si.R
Min
For
Nd
Ich
Sp

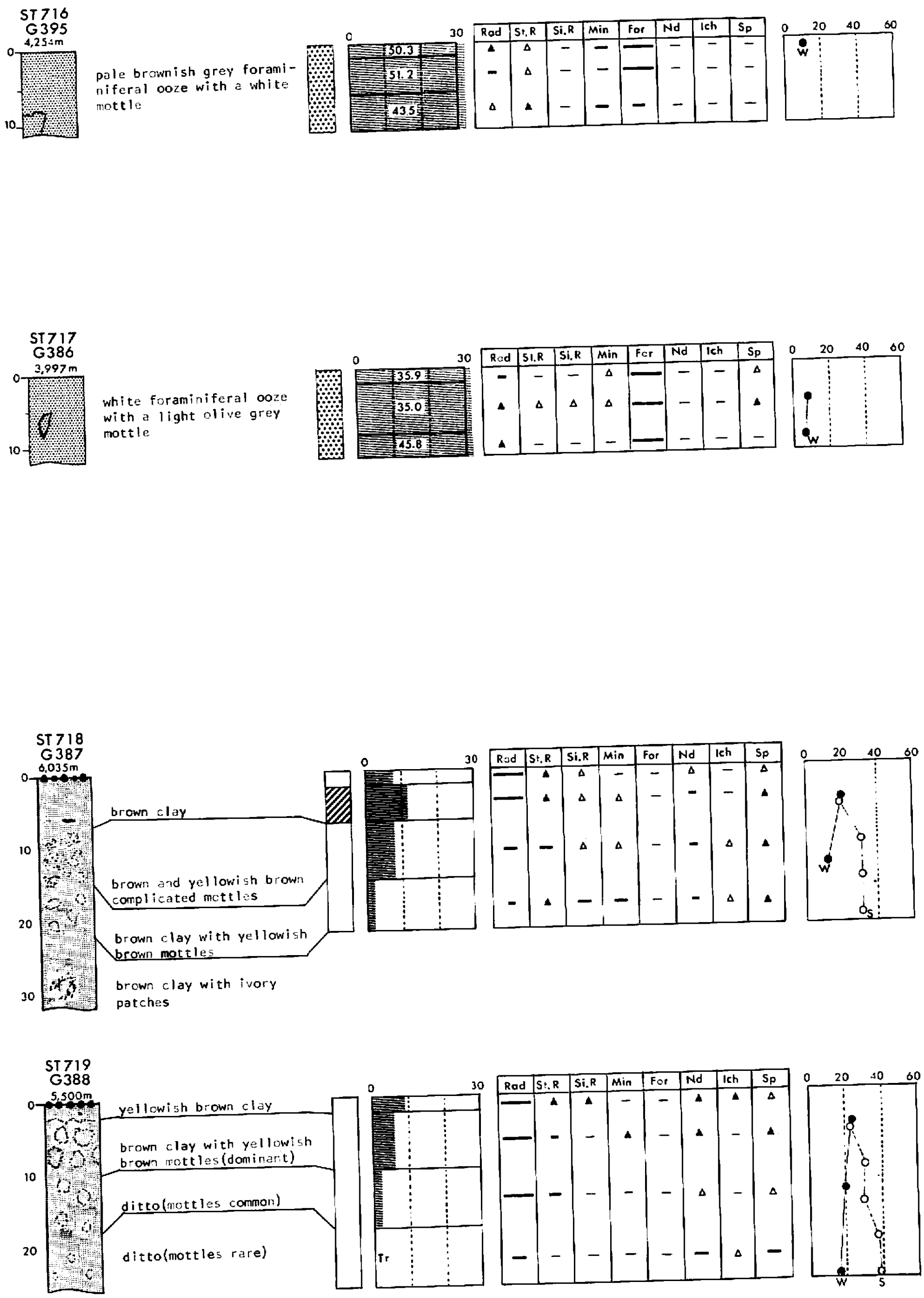
(b)


ST708
G379
5,760m
brown clay with dark brown mottles and yellow patches
dark brown clay with brown mottles and yellow patches
ST709
G380
5,850m
brown clay with yellowish brown obscure mottles and yellow patches
ST710
G381
5,550m
yellowish brown clay
brown clay with undulated discontinuous laminations
brown clay
ST711
G382
5,740m
pale yellow dark grey motley sandy mud
pale yellow mud with dark grey dots
pale yellow clay with dark ivory mottles
Rad
St. R
Si. R
Min
For
Nd
Ich
Sp
W
S

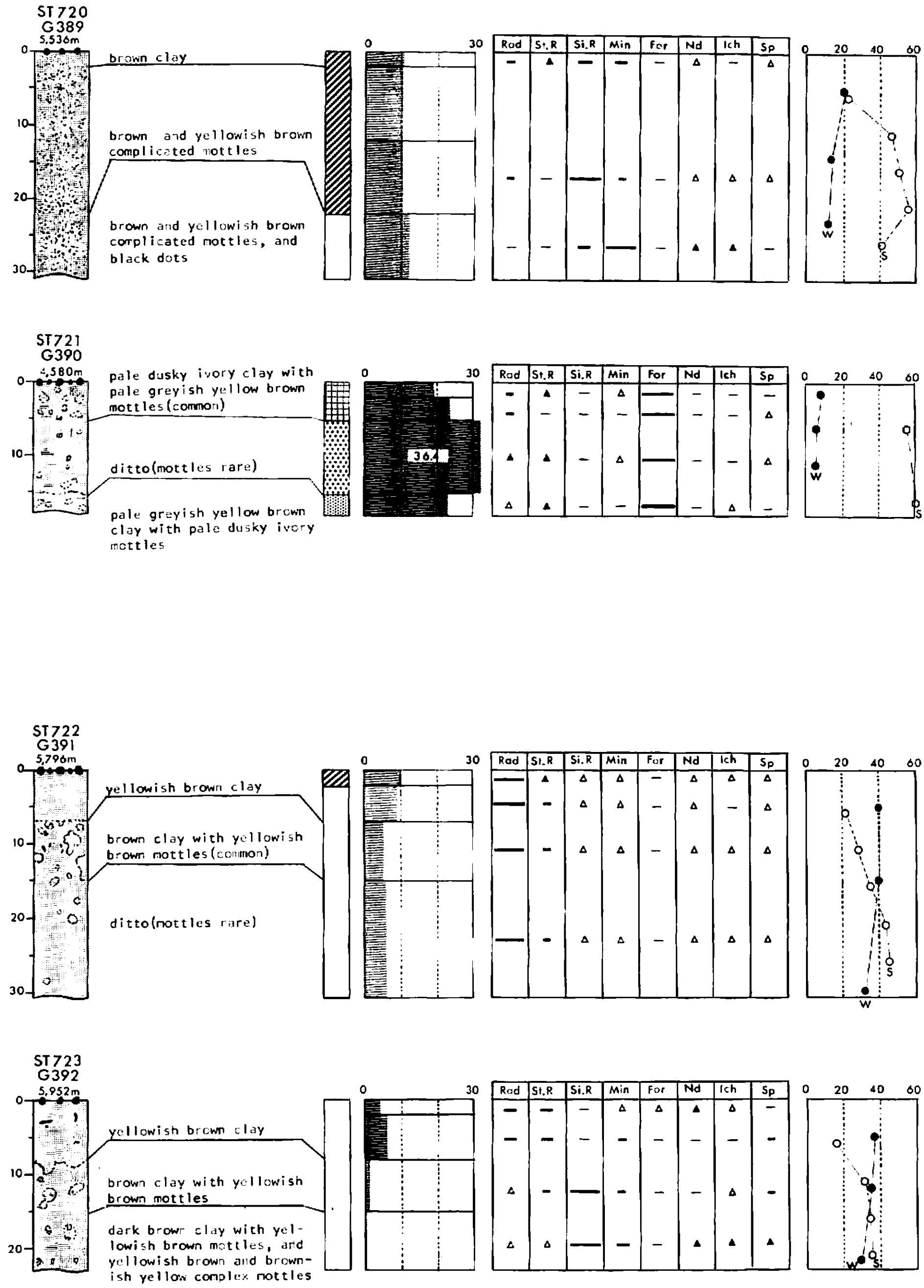
(c)


ST712
G383
5,915m
brown clay with yellowish brown and dark brown complicated mottles
ST713
G384
5,920m
yelowish brown clay with ivory patches
brown clay with yellowish brown and dark brown complicated mottles
ST714
G385
5,120m
brown clay
yellowish brown, brown and ivory complicated mottles
ivory, yellowish brown and brown complicated mottles
brown clay with yellowish brown mottles
ST715
G396
3,250m
white foraminiferal ooze
65.0
80.9
Rad
St.R
Si.R
Min
For
Nd
Ich
Sp
W
S

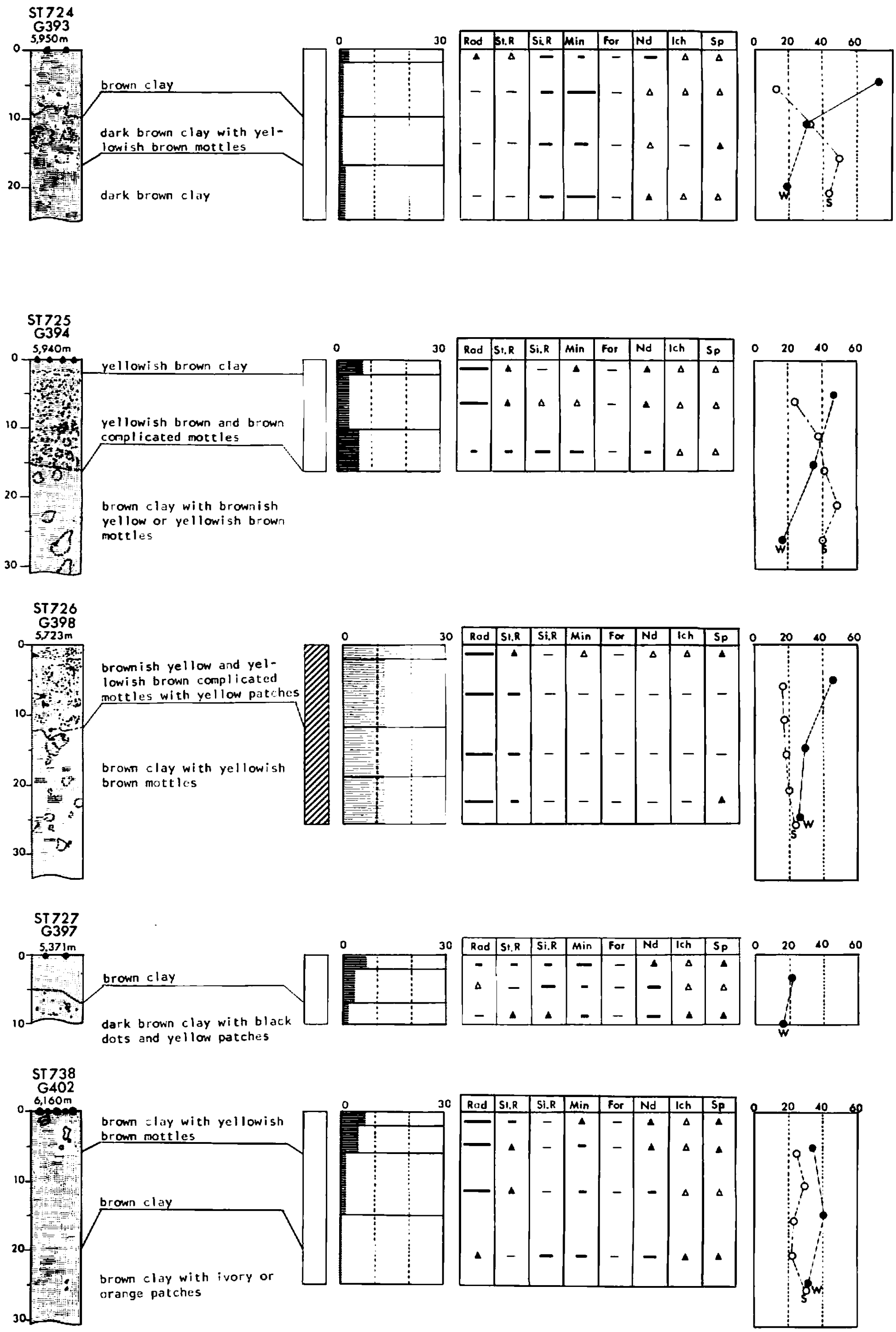
(d)


ST716
G395
4,254m
pale brownish grey foraminiferal ooze with a white mottle
50.3
51.2
43.5
Rad
St.R
Si.R
Min
For
Nd
Ich
Sp
ST717
G386
3,997m
white foraminiferal ooze with a light olive grey mottle
35.9
35.0
45.8
ST718
G387
6,035m
brown clay
brown and yellowish brown complicated mottles
brown clay with yellowish brown mottles
brown clay with ivory patches
ST719
G388
5,500m
yellowish brown clay
brown clay with yellowish brown mottles(dominant)
ditto(mottles common)
ditto(mottles rare)
Tr

(e)

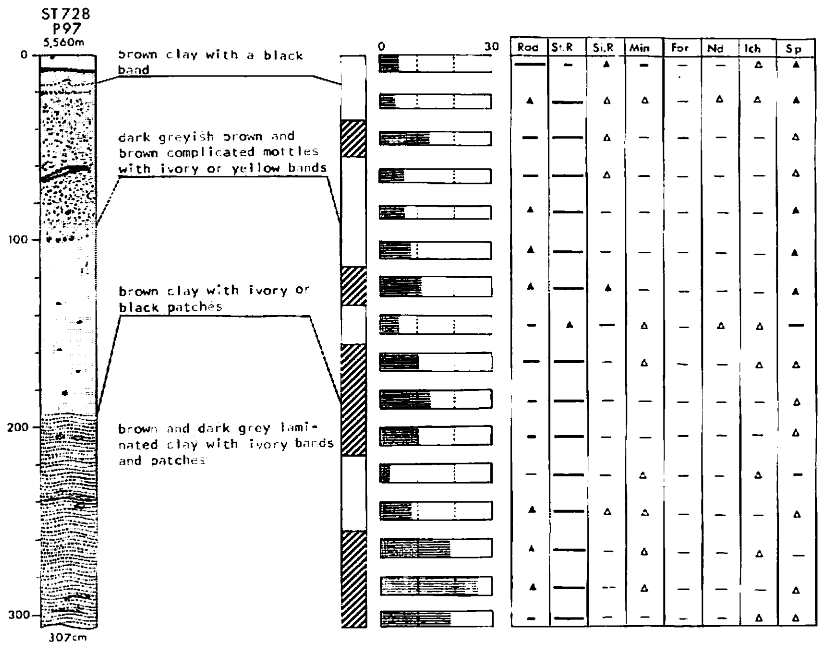

ST720
G389
5,536m
brown clay
brown and yellowish brown complicated mottles
brown and yellowish brown complicated mottles, and black dots
ST721
G390
4,580m
pale dusky ivory clay with pale greyish yellow brown mottles (common)
ditto (mottles rare)
pale greyish yellow brown clay with pale dusky ivory mottles
364
ST722
G391
5,796m
yellowish brown clay
brown clay with yellowish brown mottles (common)
ditto (mottles rare)
ST723
G392
5,952m
yellowish brown clay
brown clay with yellowish brown mottles
dark brown clay with yellowish brown mottles, and yellowish brown and brownish yellow complex mottles
Rad
St.R
Si.R
Min
For
Nd
Ich
Sp
0
10
20
30
40
60
W
S

(f)

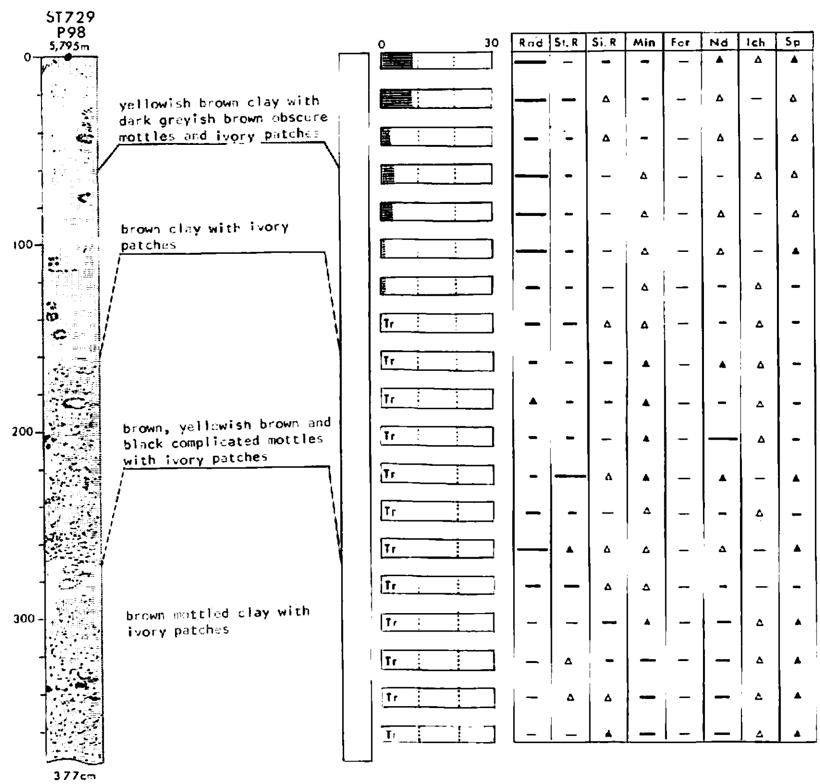

ST724
G393
5,950m
brown clay
dark brown clay with yellowish brown mottles
dark brown clay
ST725
G394
5,940m
yellowish brown clay
yellowish brown and brown complicated mottles
brown clay with brownish yellow or yellowish brown mottles
ST726
G398
5,723m
brownish yellow and yellowish brown complicated mottles with yellow patches
brown clay with yellowish brown mottles
ST727
G397
5,371m
brown clay
dark brown clay with black dots and yellow patches
ST738
G402
6,160m
brown clay with yellowish brown mottles
brown clay
brown clay with ivory or orange patches
Rad
St.R
Si.R
Min
For
Nd
Ich
Sp
0
10
20
30
40
60
W
S

(g)

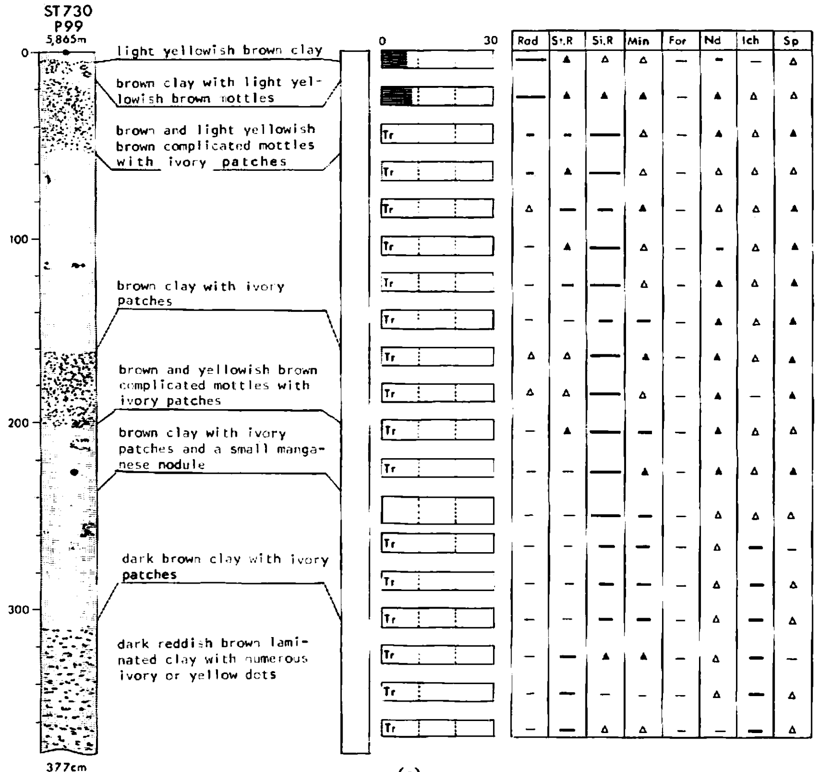
Fig. IX-4(a-e) Description of the samples from the Gravity corer.



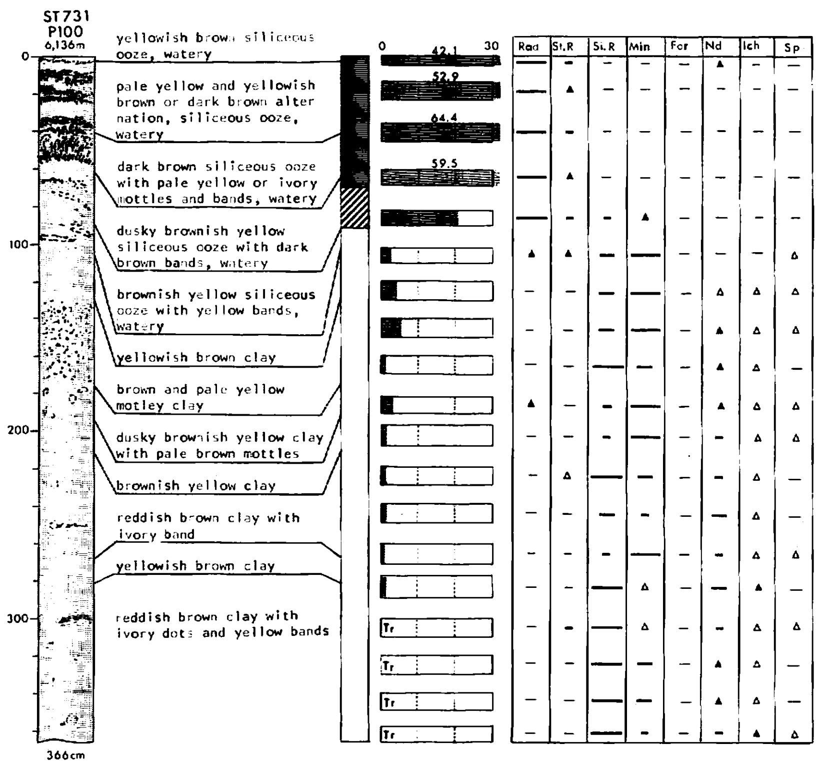
(a)



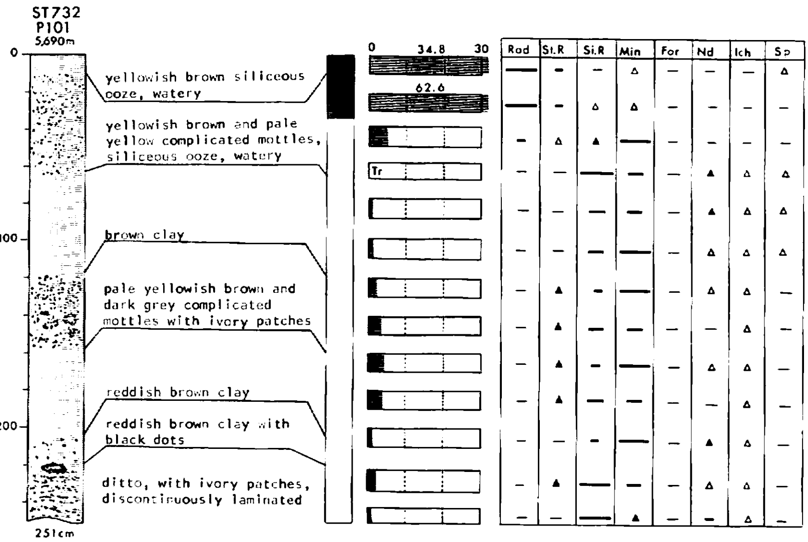
(b)


ST730
P99
5,865m
0
100
200
300
377cm
light yellowish brown clay
brown clay with light yellowish brown mottles
brown and light yellowish brown complicated mottles with ivory patches
brown clay with ivory patches
brown and yellowish brown complicated mottles with ivory patches
brown clay with ivory patches and a small manganese nodule
dark brown clay with ivory patches
dark reddish brown laminated clay with numerous ivory or yellow dots
0
30
Tr
Rad
Si.R
Si.R
Min
For
Nd
Ich
Sp

(c)


ST731
P100
6,136m
0
100
200
300
366cm
yellowish brown siliceous ooze, watery
pale yellow and yellowish brown or dark brown alternation, siliceous ooze, watery
dark brown siliceous ooze with pale yellow or ivory mottles and bands, watery
dusky brownish yellow siliceous ooze with dark brown bands, watery
brownish yellow siliceous ooze with yellow bands, watery
yellowish brown clay
brown and pale yellow motley clay
dusky brownish yellow clay with pale brown mottles
brownish yellow clay
reddish brown clay with ivory band
yellowish brown clay
reddish brown clay with ivory dots and yellow bands
0
30
42.1
52.9
64.4
59.5
Tr
Rad
Si.R
Si.R
Min
For
Nd
Ich
Sp

(d)



(e)

Type of sequence

The types of sediments are the same throughout each one core sample, both upper and lower parts, except the case of the sample G390 in which calcareous clay is confined only at the bottom.

ARITA (1977) classified the vertical sequence of the sediment core from Okean-70 into the following five types; type I: only deep sea clay, type II: siliceous clay–deep sea clay (in the order from top to bottom of core sample), type III: siliceous clay–calcareous-siliceous clay–deep sea clay, type IV: siliceous clay, and type V: calcareous ooze.

In this cruise (GH77-1), the author distinguished four more types, i.e. type VI: calcareous-siliceous clay–calcareous ooze–calcareous clay (G390), type VII: deep sea clay–siliceous clay (G375), type VIII: deep sea clay–siliceous clay–deep sea clay (G387), and type IX: siliceous clay–deep sea clay–calcareous-siliceous clay (G385). Among these new types, only the type VI is essentially new in terms of the sequence type in which calcareous sediment is overlain by calcareous-siliceous sediment, while the others may be considered the variation of some previously defined ones because of their similarities in the compositions of the coarse fractions.

Petrographic sequence of each core obtained with gravity corer is outlined as follows.

P97: This consists of alternation of deep sea clay or siliceous clay. The lowermost part of about 1.2 m thick has lamina structure. Stained radiolarian remains are dominant in the coarse fraction of most parts.

P98: This is made up wholly of deep sea clay. Volumetric ratio of the coarse fraction to bulk sample is less than one percent below the depth of about 140 cm. In some cases, minute fragments and/or micro-spheres of manganese nodules (Nd), or siliceous sponge spicules and/or radiolarian spines (Sp) are common (10–30%) composition of the coarse fraction. Furthermore, Nd is abundant (30–50%) below the depth of 300 cm, where few radiolarian remains including the stained ones, occur in the coarse fraction.

P99: This is made up wholly of deep sea clay. The coarse fraction less than one percent is included below the depth of 40 cm. Dominant composition is radiolarian remains

(0–30 cm) or silicified radiolarian remains (40–250 cm). Ichthyoliths are abundant in the coarse fraction below the depth of 250 cm.

P100: The uppermost part (0–70 cm) consists of siliceous ooze, in the coarse fraction of which radiolarian remains are exclusively dominant. The type of sediment changes gradually into deep sea clay through the part of siliceous clay (80–100 cm). Silicified radiolarian remains or "mineral" becomes dominant alternatively below the depth of 100 cm. Nd is abundant or common between the depths of 200 cm and 320 cm.

P101: The uppermost part (0–40 cm) consists of siliceous ooze with the composition of the coarse fraction similar to that of P100. The rest consists of deep sea clay, in the coarse fraction of which silicified radiolarian remains or "mineral" is alternatively dominant.

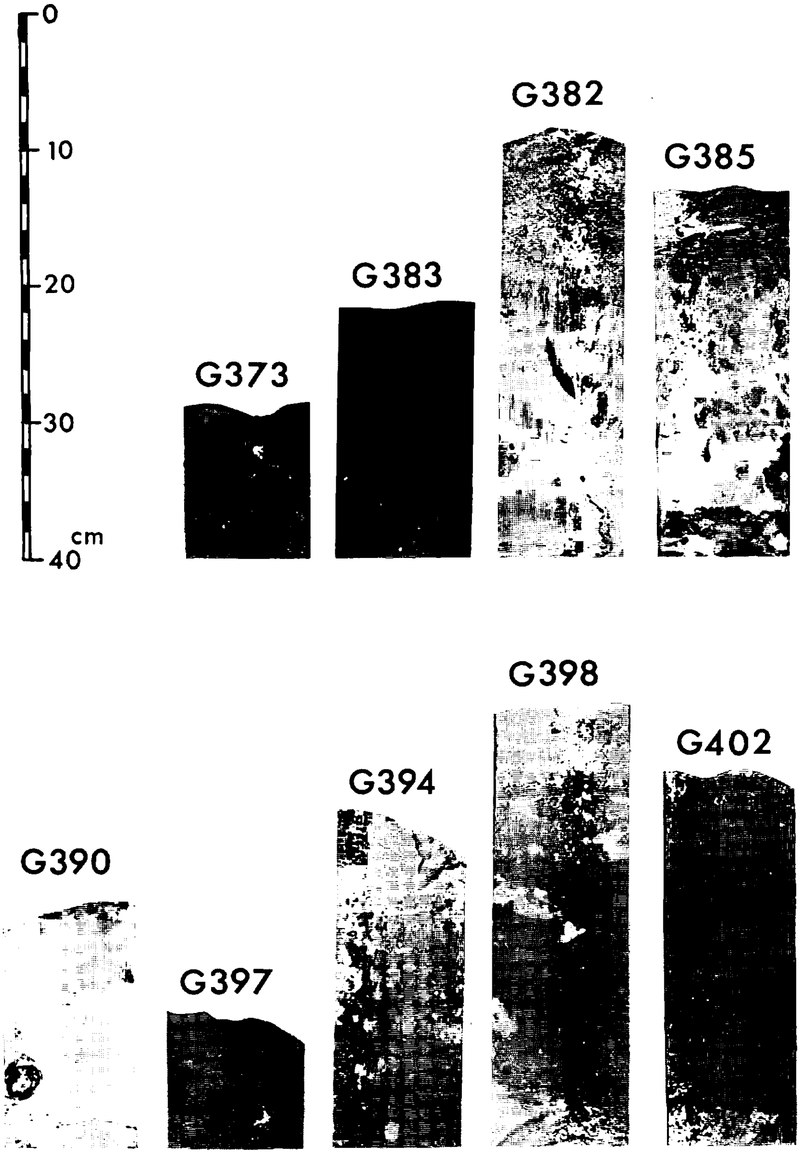
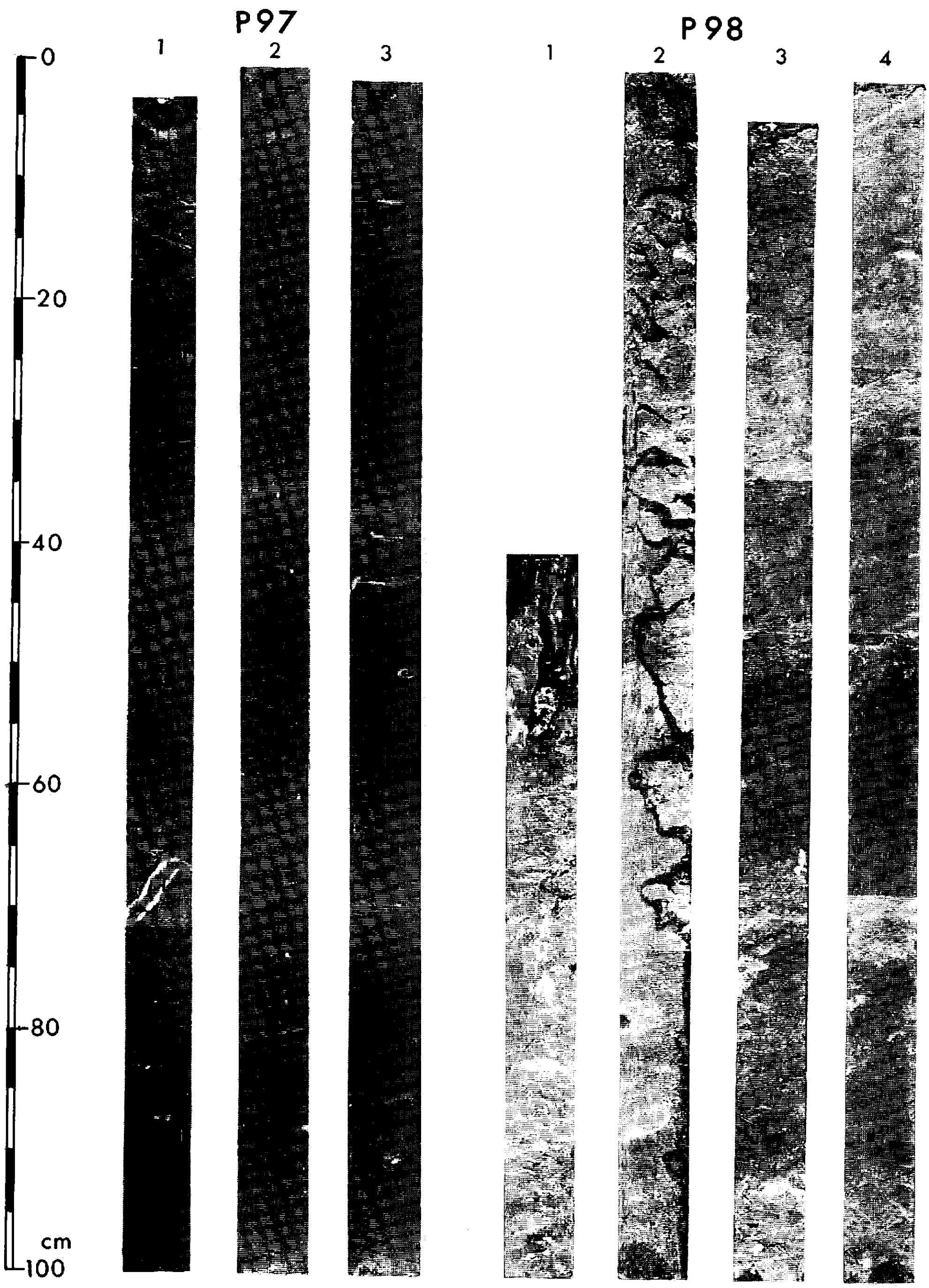
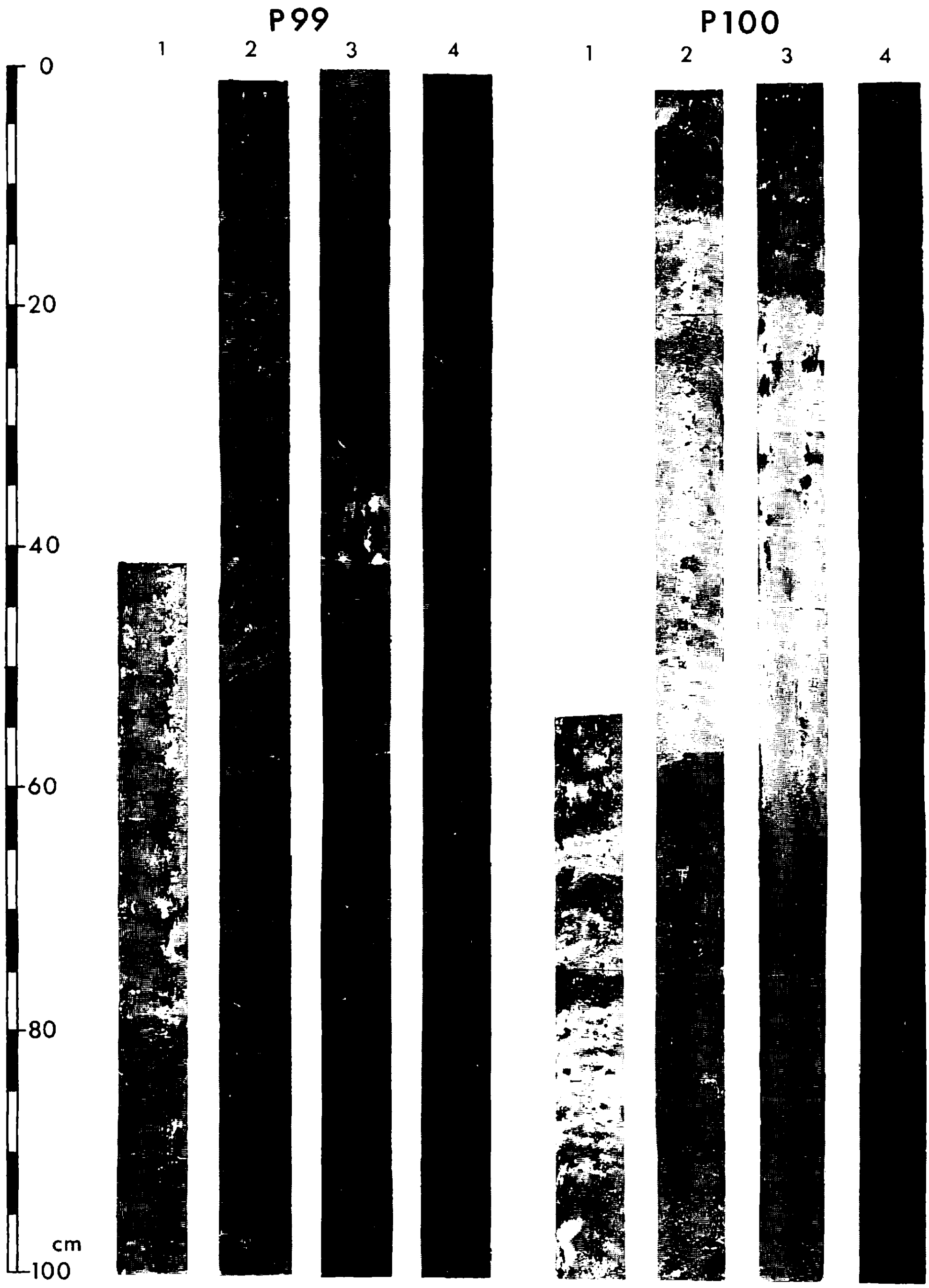


Fig. IX–5 Photographs of vertical section of the samples from Okean-70.

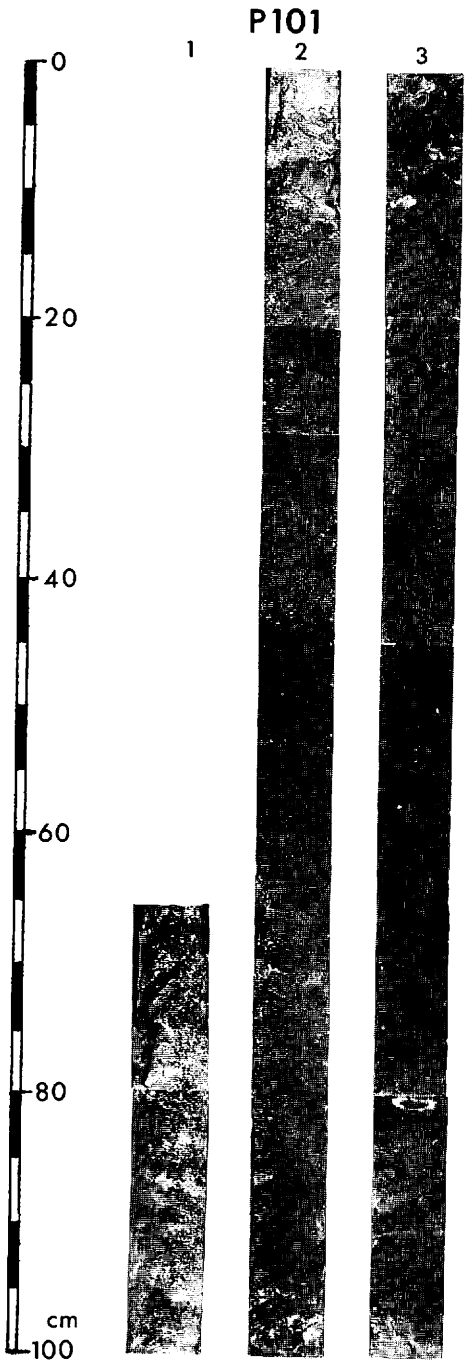
Fig. IX–6(a–c) Photographs of vertical section of the samples from the gravity corer.



(a)



(b)



(c)

Stratigraphy

In general, siliceous sediments (siliceous ooze, siliceous clay and some deep sea clay, in the coarse fraction of which radiolarian remains including the stained ones are dominant) overlie deep sea clay, the coarse fraction of which consists mainly of silicified radiolarian remains or "mineral". Calcareous sediments are distributed at four stations, i.e. Sts. 715, 716, 717 and 721, where the underlying sediment has not been obtained.

Early Miocene radiolaria *Dorcadospyris dentata* and early-middle Miocene radiolaria *Calocycletta costata* occur between the depths of 260 cm and 307 cm of the core P97.

According to NATORI (personal communication), fossil foraminifera from most of the calcareous sediments and calcareous-siliceous sediments are of Pleistocene-Holocene (*Pulleniatina obliquiloculata finalis* and *Sphaeroidinella dehiscens excavata*) (Table IX–1). As the sediment including *Globorotalia tumida tumida* (G385 surface) which indicates latest Miocene-earliest Pliocene age overlies that including *P. obliquiloculata finalis*, *G. tumida tumida* may be a reworked fossil.

WINTERER, EWING *et al.* (1973) reported that the sedimentary section resting on basalt is 1,172 meters thick and comprises five stratigraphic units, the uppermost one (Unit 1) of which is early Miocene to Quaternary calcareous ooze (200 m), at the Site 167, Leg 17, Deep Sea Drilling Project (DSDP) situated on the Magellan Rise near the station St. 715 in this cruise area.

It is obvious that there is an interrelation of contemporaneous heterotopic facies between the siliceous sediment in the lowermost part of the core P97 and the calcareous sediment in the lowermost part of the Unit 1, Site 167, Leg 17, DSDP.

Near the distribution area of calcareous sediment, the sediment lithology becomes more siliceous upward along the cores as shown at St. 714 (G385) and St. 721 (G390). Though the change in composition of the coarse fraction is rather gradual. It may have been resulted from the method itself of analysis in which the mixture of ivory colored

Table IX–1 Characteristic fossil foraminifera from some samples (Identified by H. NATORI).

G385 (ST714)	
Surface (Siliceous clay)	*Globorotalia tumida tumida*
12–24 cm (Calcareous-siliceous clay)	*Pulleniatina obliquiloculata finalis*
G386 (ST717)	
Surface (Calcareous ooze)	*P. obliquiloculata finalis*, *Sphaeroidinella dehiscens excavata*
2–9 cm (Calcareous ooze)	ditto
G390 (ST721)	
Surface (Calcareous-siliceous clay)	*P. obliquiloculata finalis*, *S. dehiscens excavata*
2–5 cm (Calcareous-siliceous clay)	ditto
5–15 cm (Calcareous ooze)	ditto
15–18 cm (Calcareous clay)	ditto
G395 (ST716)	
Surface (Calcareous ooze)	ditto
2–7 cm (Calcareous ooze)	*P. obliquiloculata finalis*
G396 (ST715)	
Surface (Calcareous ooze)	*P. obliquiloculata finalis*

clay (calcareous) and brown colored mottles (siliceous) is sieved together under pouring water and those mottles colored in brown are evidently derived from the overlying brown clay, which is not observed, however, in the case of the core G390. Therefore it can be pointed out that there is an abrupt or unconformable change (provisionally named as "St. 714 event") in sedimentary condition. The changes in facies from deep sea clay to siliceous clay or siliceous ooze at Sts. 731 (P100) and 732 (P101), and some other similar changes probably show also "St. 714 event".

The stratigraphical interrelation between deep sea clay which includes few radiolarian remains and siliceous sediments is very important and interesting. We have no evidence which leads to concrete conclusions for this problem, though ARITA (1977) suggests the boundary between siliceous clay and deep sea clay in the sequence of type II shows the unconformity between Quaternary and Tertiary deposits in the area of GH76–1, east of this area.

The author presumes that there is a burried geomorphic surface older than early Miocene age somewhere beneath the bottom of the core P97 because there is not any clear boundary within it, and that the boundary between deep sea clay and siliceous clay does not necessarily mean the boundary between Tertiary and Quaternary ages in this area because similar boundaries, which may indicate "St. 714 event", are observed within the continuous sequences solely of siliceous clay (Fig. IX–5, G398) or deep sea clay (Fig. IX–5, G394) as mentioned above.

Interrelation between distribution of manganese nodules and type of sediments

We can point out firstly that the highest abundance of manganese nodules (20.0 kg/m^2 or more) are restricted between the two parallels of latitude, 9°N and 10°N, except St. 729.

The interrelation between the distribution of nodules and the type of sediments is summarised as follows;

(1) The nodules do not occur with calcareous ooze or siliceous ooze.

(2) The surface sediment which is distributed with the most abundant manganese nodules is deep sea clay, the coarse fraction of which consists dominantly of radiolarian remains, except St. 722 (siliceous clay).

(3) In addition to the deep sea clay mentioned above, at the stations in which are found 10 kg/m^2 or more nodule abundances, various types of sediments, i.e. siliceous clay, calcareous-siliceous clay, and deep sea clay which includes the coarse fraction composed mainly of silicified radiolarian remains or "mineral" are distributed.

Overall consideration of the results both of the present cruise and of the past two cruises (GH74–5 and GH76–1, (ARITA and KINOSHITA, 1976; ARITA, 1977)) suggests that the interrelation between the distribution of manganese nodules and the sediments should be discussed based upon the historical geology of the area.

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