HIG-74-9

FERROMANGANESE DEPOSITS OF THE OCEAN FLOOR

Cruise Report Mn-74-01
R/V MOANA WAVE

Honolulu to San Diego
17 July to 10 August, 1974

PARTICIPATING SCIENTISTS

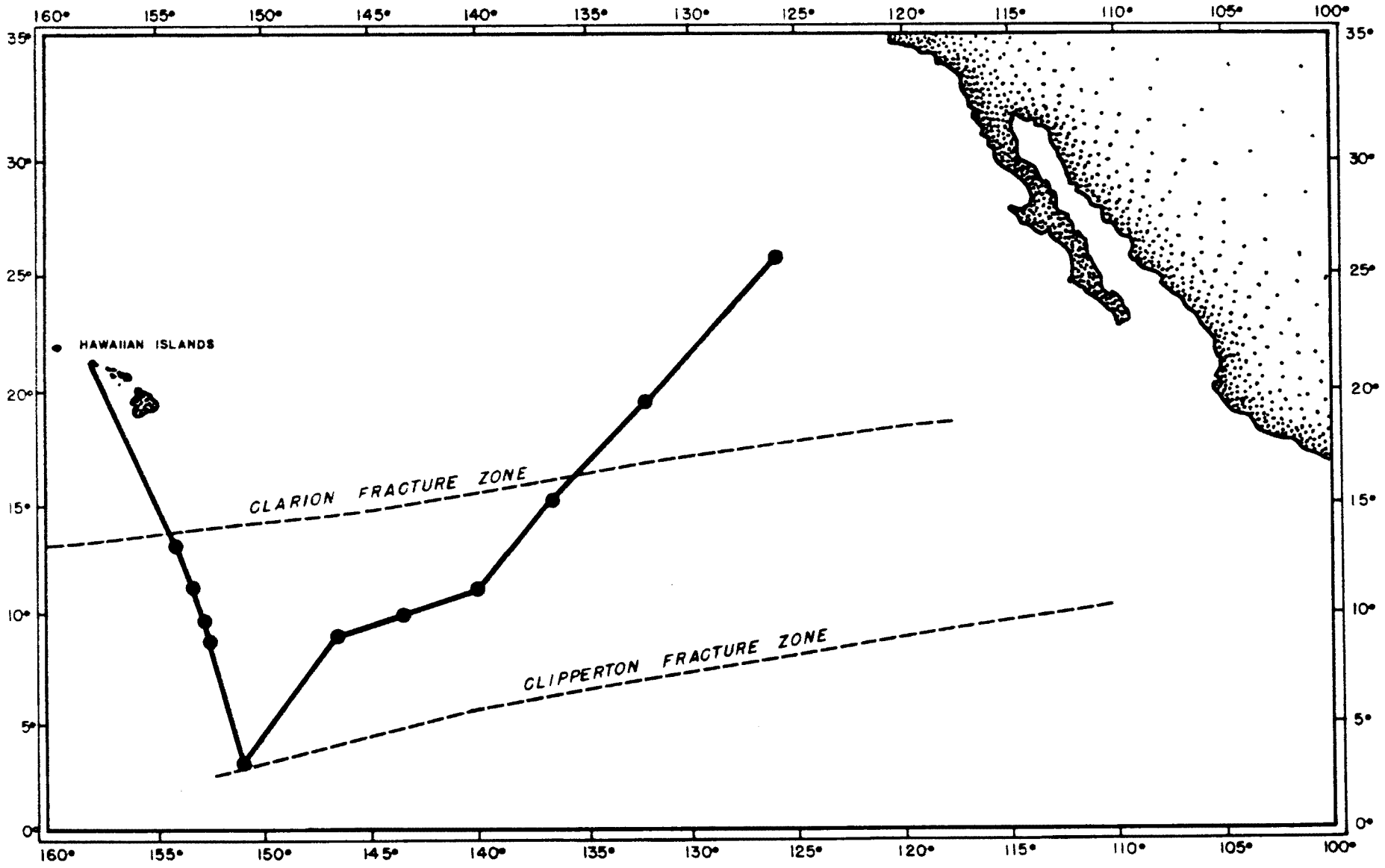
J. E. Andrews *(Chief Scientist)*, E. Callender,
C. J. Bowser, J. L. Mero, M. Gauthier, M. A. Meylan,
J. D. Craig, K. Binder, P. Volk, A. Chave, and W. Bachman

INTER-UNIVERSITY PROGRAM OF RESEARCH

Sponsored by
Seabed Assessment Program
International Decade of Ocean Exploration
National Science Foundation

SEPTEMBER 1974

HAWAII INSTITUTE OF GEOPHYSICS
UNIVERSITY OF HAWAII



Frontispiece. Mn-74-01 cruise track.

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Approved by Director

George P. Woollard

Date: 27 September 1974

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SECTION I

INTRODUCTION

Cruise Mn-74-01 of the R/V MOANA WAVE was the first part of the field work of the NSF-IDOE Inter-University Ferromanganese Research Program in 1974, and we gratefully acknowledge the support of the Office for the International Decade of Ocean Exploration and the Office of Oceanographic Facilities and Support. This program was designed to investigate the origin, growth, and distribution of copper/nickel-rich manganese nodules in the Pacific Ocean. The field effort was designed to satisfy sample requirements of the fifteen principal investigators, while increasing general knowledge of the copper/nickel-rich nodule deposits of the equatorial Pacific. This report is the first of a series of cruise reports designed to assist sample requests for documented nodules, sediment, and water samples so that laboratory results can be realistically compared and related to the environment of nodule growth.

Nodule samples, bathymetric and navigational data are archived at the University of Hawaii. Bulk analyses on nodules and reduction of survey data will be carried out at Hawaii. Sediment cores will be stored at the University of Hawaii and at Scripps Institution of Oceanography. The SIO analytical facility will provide stratigraphic data on sediment chemistry.

Samples may be requested from:

Dr. James E. Andrews
Department of Oceanography
University of Hawaii
2525 Correa Road
Honolulu, Hawaii 96822

PROGRAM AND CRUISE OBJECTIVES

The Ferromanganese Research Program of the United States National Science Foundation's International Decade of Ocean Exploration (NSF/IDOE) has one general goal: to elucidate and define the factors which initiate, influence, and alter the formation, growth, and distribution of manganese nodules. Why do nodules form, why are some nodules trace metal enriched, and what controls these occurrences in both local and regional patterns?

To examine these problems on the more specific level requires a variety of approaches. Several considerations must be established: a) the relationship of mineralogy to density and growth; b) the relationship of chemical variations (especially trace metal enrichment) to the environment, which in turn involves the immediately superjacent water mass and the underlying sediment and its pore water; c) the role of biological factors in, on, and around the nodules as influences; d) nodule structure--both internal and external and its relationship to mineralogy, chemical content, and locale; e) the geologic setting of nodule deposits--local and regional sea floor structure, sea floor history (e.g., sea floor spreading), and the effect of these on oceanographic conditions.

Investigators, representing several of the major U.S. oceanographic institutions, involved in the IDOE Ferromanganese Program are pursuing studies in each of these problem areas.

In viewing these objectives for cruise Mn-74-01 and subsequent field work in the NSF/IDOE Program, it is perhaps most direct to consider the various active hypotheses concerning the origin and growth with which the investigators have to deal in order to define the field goals and sample requirements.

1. Terrigenous Origin: Material provided for growth from the continents via the overlying water mass.

> Requirements: Well-documented nodule samples covering large areas of the sea floor, and corresponding water samples (particularly near bottom) for dissolved and particulate trace metals and water mass parameters.

2. Hydrothermal-Volcanogenic: Main contributions from hydrothermal sources related to submarine volcanism, both local (sea mountains and hills) and regional (sea floor spreading--mid-ocean ridges and fracture zones.)

> Requirements: Well-documented nodules sampled in detail especially towards regional and local sea floor structures--concentrating on samples patterned at various distances from major and minor potential volcanic sources. Well-documented bathymetry and profiles to establish small-scale volcanic sources, or absence thereof.

3. Halmyrolysis-Volcanogenic: Major elemental contribution derived from interaction of volcanogenic materials and sea water.

> Requirements: Well-documented nodule and sediment samples appropriately located with respect to seafloor structure (as for 2 above), sediment and pore water chemistry. Of prime importance is availability of box cores and free fall cores most appropriate for this work.

4. Diagenetic: Major contributions from the sediment column related to sedimentation rate, oxidation state, pore water migration during sedimentation, and diffusion.

> Requirements: Essentially, as for 3 above, box cores and free fall cores are most important. Preferred sample sites would contrast deposits adjacent to or overlying volcanic sources with deposits from "undisturbed" seafloor, and a variety of sediment types.

5. Biogenic: Major contributions via element-fixing microorganisms, tube-building foraminifera, and major environmental adjustments by local benthic populations.

> Requirements: Nodules should be collected with an absolute minimum of handling, special preservation (freezing, formalin), plus box cores and photos to document in situ relations.

The phrase "well-documented samples" is used here to indicate samples whose point of origin is well known, principally in terms of local and regional bathymetry, structure, sediment type and age, and for which reasonable documentation of in situ patterns is known (via TV or photographic examination), and for which bulk chemical data is known. Minimal handling and cold or freezing storage is desired to prevent mineralogical and chemical changes (see Table 12). These samples may be obtained by: a) free fall grab, b) box corer, c) or dredge--each having its own special advantages and disadvantages.

> a). Free fall grabs are precisely located and provide evidence of nodule density (kg/m^2), but yield only very small sediment samples and small quantities of nodules (seafloor area sampled by the grab is 0.08 m^2).
>
> b). Box cores give oriented and undisturbed samples of nodules and sediment in original relationships, and also permit density evaluation. Sample location is not easily controlled, and volume is low (except in dense deposits).

c). Dredging provides large volumes, but is also poorly controlled for precise sample location, and probably adversely affects samples desired for study of surface characteristics.

The 11 stations occupied during Mn-74-01 were designed to increase regional knowledge and to sample, in detail, the smaller areas while documenting the bathymetry of each site.

It is suggested that Mn-74-02 reoccupy two of these sites to complete work curtailed by equipment failures, and that it also conduct additional stations in the same manner to provide additional regional data.

CRUISE SCHEDULE - Mn-74-01

Depart Honolulu 0300Z 18 July 74
Pier 18
University of Hawaii

Station No.	Time on Station	Coordinates
1	1150Z 18 July-1139Z 21 July	13°00'N 154°00'W
2	2125Z 21 July-0310Z 22 July	11°21'N 153°37.5'W
3	1308Z-1800Z 22 July	9°59.2'N 152°56.7'W
4	0202Z-0751Z 23 July	8°40'N 152°37.8'W
5	0155Z 25 July 0630Z 26 July	3°00'N 151°00'W
6	0231Z 28 July-0044Z 30 July	9°00'N 146°30'W
7	2326Z 30 July-0336Z 31 July	10°00'N 143°20'W
8	0334Z-2230Z 1 August	11°00'N 140°00'W
9	1104Z-1625Z 3 August	15°08.5'N 136°20'W
10	0506Z 5 August-0821Z 6 August	19°40'N 132°00'W
11	0400Z-0800Z 8 August	25°36'N 126°06'W

Arrive San Diego 2200Z 10 August 74
Nimitz Marine Facilities
Scripps Institute of Oceanography

PERSONNEL - Mn-74-01

Name	Organization	Duties
Dr. James E. Andrews	University of Hawaii	Chief Scientist
Dr. Edward Callender	University of Michigan	Chemistry - Water Column Collection
Dr. Carl J. Bowser	University of Wisconsin	Chemistry - Pore Water
Dr. John L. Mero	Oceans Resources, Inc.	TV System
Dr. Michel Gauthier	Centre Oceanologique de Bretagne	Free Fall Grabs
Mr. Maurice A. Meylan	University of Hawaii	Samples/Photography
Mr. James D. Craig	University of Hawaii	Surveys
Mr. Kenneth Binder	University of Hawaii	Water Sampling
Mr. Patrick Volk	University of Hawaii	Navigation/Computer
Mr. Alan Chave	University of Hawaii	Computer
Mr. Walter Bachman	University of Hawaii	Organic Chemistry
Mr. Bruce Gottesburen	University of Hawaii	Electronics Technician
Mr. Clifford Buhl	University of Hawaii	Deck Technician

EQUIPMENT AND LABS - Mn-74-01

1 Box Core

10 Free Fall Grabs (CNEXO)

50 Free Fall Grab Weights

3 Free Fall Grab Floats (Benthos)

16 Free Fall Grab Bonnets

30 Free Fall Grab Collar Weights

30 Free Fall Grab Disc Weights

3 Cameras - EG & G

3 Strobes - EG & G

1 Pinger - Benthos

1 Pinger - EG & G

2 Dredges - Box Type

3 Dredges - Barrel Type

TV System - Hydroproducts (with Markey Winch)

Rosette (NOAA) with 12-liter Niskin Bottles

Magnetometer

Echo Sounding System 3.5 and 12 kHz

CESP - Correlation Processor

PTR - Transceiver

PDD - Digitizer

UGR - Recorder

Wang Computer/Disc Storage and Hewlett Packard Plotter

Double Chirp System (Experimental)

Satellite Navigation - Magnavox

EQUIPMENT AND LABS - Mn-74-01 (continued)

Liquid Nitrogen - 3 Dewars

Winches:

Markey - TV 3/4" Conductor Cable

Northernlines - Dredging
Coring
9/16" 3 X 19 Wire

Hydro-Remote Control - 3/16" Wire

Hydro-Markey - 1/4" Conductor Wire

Lab Vans:

General Lab Van - Core Extrusion
Pore Water Chemistry
Organic Separations

Chemistry Lab Van - Water Analysis
Alkalinity
Salinity
Dissolved O_2

Manganese Lab Van - Dark Room
TV & Camera Staging
Sample Description & Sorting

Cold Van - Core Squeezing
Sample Storage
Frozen Samples in Ship's Freezer, Temperature at 4°C

CRUISE NARRATIVE Mn-74-01

Cruise Mn-74-01 of the R/V MOANA WAVE for the Inter-University Ferromanganese Research Program (NSF/IDOE) departed Honolulu at 0300Z 18 July 1974 and arrived San Diego 2200Z 10 August 1974, after a voyage of 3677 nautical miles (nm) and 11 stations occupied. Five stations (1, 5, 6, 8, and 10) were of 20-45-hour duration and encompassed sediment and nodule sampling, as well as bathymetric surveys on 1-2 nm line spacing. The remaining six stations were of 4-5-hour duration for free fall grab collections and brief survey work.

Equipment problems severely hampered operations during the cruise. Control failure on a new Northernline winch resulted in the loss of the one box corer on board after only one successful core had been obtained. This same failure dictated the attempting of only one dredge due to very low winch speed. For this effort, recovery was minimal due to the small nodule size at station #8. An oil leak in the remotely controlled hydro winch curtailed its use after only one camera run; therefore a second run was made on the Markey hydro-winch. No pictures of the bottom were obtained on either attempt due to camera malfunctions, and a short in the battery curtailed further photo work.

Shorts in the camera harness for the underwater TV resulted in eventual failures in the camera circuits, and as a result no TV lowerings were made.

Drive problems in the Raytheon UGR recorder occasionally interrupted bathymetric work, however CESP records were obtained over most of the cruise track.

All of these problems appear susceptible to solution, and will be worked on in San Diego prior to Mn-74-02, scheduled for mid-September 1974.

The free fall cores and free fall grabs collected excellent samples, and many thanks are due to CNEXO for use of the free fall grab equipment. Well-located samples were collected at all stations, with station #6 being the best documented.

Water sampling also proceeded satisfactorily, and no major malfunctions affected the Rosette. The Benthos pinger worked well, but needs a near-vertical wire angle in order to provide good reception of the quite directional signal from the pinger. During most of the cruise, the 3.5 kHz CESP (correlation processed) records provided high resolution bathymetry and some sediment structure data.

Coordination of survey work was greatly enhanced by the use of the Magnavox satellite navigation system with the remote CRT on the bridge, and a program for great circle destinations. All operations were marked by PNDR on the satellite navigation tape to provide a dead-reckoned (DR) position for all events. Normal HIG laboratory and station logs were maintained for the cruise.

Navigation

The computer system dedicated to navigational control and data storage

consists of the following equipment:

1. Wang 702C computer, used for all calculations and system control;
2. Wang 702 printer/plotter used for final Mercator plots of the ship's track, and for on-line system messages;
3. Wang 710 magnetic disc used for storing DR positions, and other data from the ship's sensors;
4. Coupler-Controller (custom built) to permit interfacing of peripheral equipment to the Wang 702C, including the Raytheon digital depth recorder and the magnetometer;
5. Eico analogue to digital converter which accepts analogue signals fed from specially-built interfaces to the ship's gyro, E-M log, wind direction and wind speed sensors;
6. HP 7200A flatbed plotter used for uncorrected on-line plots of ship's track;
7. Model 33 teletype used for manual entry of satellite fixes.

The system was designed to sample the ship's sensors every ten seconds and to compute an integrated DR track, storing on magnetic disc, every two minutes, a DR position together with the course and speed, true wind, depth, and magnetometer data, if available. When a new satellite fix becomes available, the offset from the DR position is used to calculate the set and drift, and all DR positions stored since the last satellite fix are then corrected for the set and drift, yielding a final ship's track as accurate as the satellite fixes will allow. Various subfunctions were designed to predict ETA and course to steer to a destination (with a given set and drift), calculate true wind, facilitate changing of magnetic discs, etc.

Unfortunately, the system never operated as designed, due primarily to frequent failures of the coupler-controller buffer memory. Other problems were caused by cable connectors coming loose due to vibration, causing frequent temporary hang-ups. Finally, the Wang 702 printer/plotter became inoperative after one week at sea, and with no diagrams or schematics available it could not be repaired.

With these problems in mind, it was decided that the Magnavox satellite navigation computer, which was also interfaced with the ship's sensors, would be relied upon not only for fixes, but also for on-line DR navigation, with the Wang system being used to produce plots of the calculated DR positions. These near real-time plots, generated by manually keying the positions into the Wang keyboard, gave an immediate indication of the progress of a station survey, and were particularly useful in recovering free fall cores and free fall grabs, enabling the ship to accurately return to the site of a free fall drop at the time they were due to rise to the surface.

To produce the final track plot for a station, the Wang computer and disc were used with a previously written off-line DR program. This program used two satellite fixes as end points, and the DR track in between was calculated from course and speed changes requested as inputs. These DR positions were stored on the disc at specified increments of time. The program has a limit of eleven DR (course and speed) entries between any two fixes, but this did not prove to be a serious limitation. After writing a new program to plot the stored DR positions on the HP7200 flatbed

plotter (the program originally used for the Wang 702 plotter), all of the stations including bathymetric surveys were plotted to allow contouring the bottom and precise location of cores, water casts, free fall grabs, etc.

Double Chirp Profiling System

Double chirp is an experimental bottom and subbottom profiling system utilizing on-line computer signal generation and processing. The theory and programming for this system was developed by Dr. Wilton Hardy of the Hawaii Institute of Geophysics. The heart of double chirp is a Data General Supernova Computer which handles all timing, digital filtering, and input-output operations. This will result in higher quality records than are obtainable with a conventional short pulse or correlation bottom profiler. In addition, it is expected that subbottom structure will be more easily discernible.

Figure 1 is a block diagram of the electronics used in the double chirp system. Operation of the unit is based on a ten-second cycle as controlled by the Supernova. The transmit cycle occurs and lasts for two seconds. It starts when the computer closes a transmit/receive relay and begins generation of the modulating signal via the direct memory access (DMA) digital-to-analogue converter. The analogue interface filters this signal and generates a double sideband suppressed carrier output at 3.5 kHz. A power amplifier drives the ship's transducer at a power level of 1400 watts. During the entire transmit cycle, the Supernova retains a record of the output waveform.

The receive period lasts for most of the remaining eight seconds of the double chirp cycle. The transducer voltage is amplified, fed through a bandpass filter, and applied to a double sideband demodulator. The detected signal is filtered and goes to the analogue-to-digital converter. When the computer detects an echo by comparison to the transmitted signal further processing continues to remove random noise and produces a clean output. The return is displayed on a Universal Graphics Recorder (UGR) and stored on magnetic tape. In addition, a plot of bottom reflectivity and an hourly depth scale and time are printed on the UGR.

A number of difficulties prevented successful operation of the entire double chirp profiling system. Prior to cruise time, the system had not been integrated as one unit, leaving several interfacing difficulties to be solved. The poor AC power system on the R/V MOANA WAVE caused more than a hundred dollars damage to the digital-to-analogue converter. A failure in the analogue-to-digital converter required repair. The destruction of a major interface cable ended any chance of an operating system on this cruise.

Some testing with portions of the system was carried out. The transmit section of the profiler worked well at full power; the signal at the transducer appeared to be clean and free of distortion; the receive section was never fully tested; and several software bugs appeared as well.

In light of the experience gained on the first cruise, several hardware modifications are planned. This should result in a working double chirp profiler on the scheduled Mn-74-02 cruise in September.

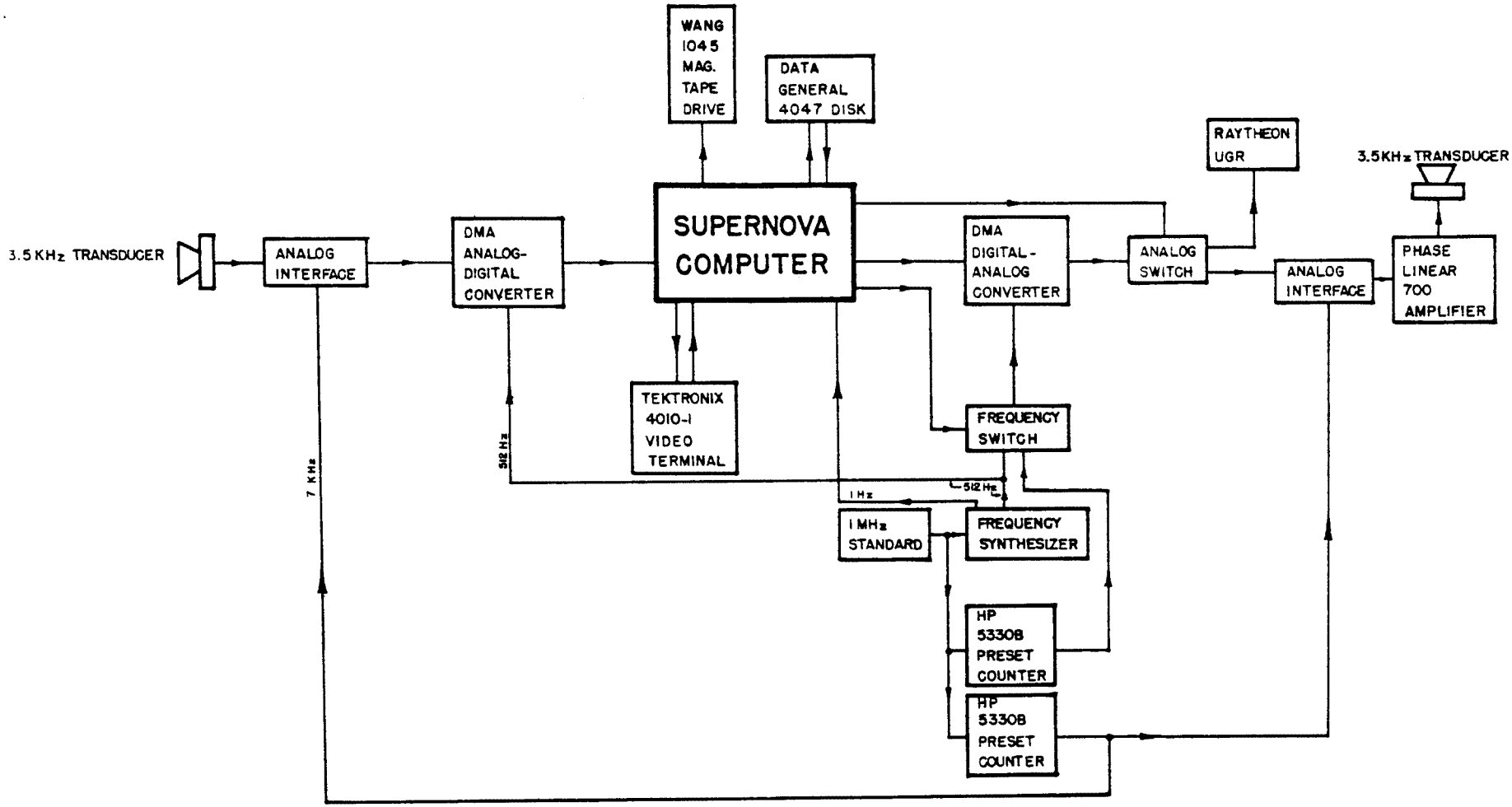


Figure 1. Double-chirp profiling system.

Nodule Documentation

With the exception of oriented nodules collected from the box corer at station #5 and two nodules found at the top of free fall cores, all other nodules were obtained with free fall grabs. Where possible, two to three nodules were collected from each grab for special handling and later mineralogical analysis. Special effort was made to collect nodules that demonstrated a "mud line" for special handling so that nodule orientation could be later assumed. The specially handled nodules were carefully placed in individual biologically sterile, poly bags. One sample was kept cool in a refrigerated van (6°C); one was frozen intact; and one was put into surface sea water and frozen as soon as possible. The variable handling techniques were used in an attempt to assess the effects of sample handling on possible mineralogical phase changes, and to attempt to get nodules whose outer surfaces are as little disturbed as possible. All samples, of course, were in contact with surface sea water for one-half to several hours before being brought aboard and therefore have a warming history prior to collection. Moreover, most of the cold-stored specimens were handled and brought to room temperature for one-half to one hour for describing. If possible, samples were hand-picked from the grabs before the grabs were set on the deck; however, this procedure was not always followed, and therefore contamination from deck oil and previous sediment cores is possible.

Although attempts were made to collect these special samples, the procedures were not rigidly adhered to during the whole cruise. Suggestions for special handling and collection came from only one project investigator; yet others are undoubtedly concerned with the collection of samples whose surface features and in situ mineralogy are as little disturbed as possible. Clearly agreed-upon procedures should be established and rigidly followed by all personnel on future cruises.

Several aspects of the cruise operations were documented on video tape for future reference and student training.

Free Fall Corers

Free fall corer disposable units consisting of a bonnet, disc weight (33 kg), barrel, and collar weight (10 kg) are assembled on deck prior to each station. Two 4.5" bolts with washers and nuts fasten the main assembly, and the collar weight is connected to the release arm by 1/16" stainless steel wire with nicropress fittings.

Recoverable portions consisting of 4' X 2-7/8" plastic liner, core catcher, valve release, and floats with strobe light, are assembled immediately prior to launch and installed in the corer. Strobe light batteries are good for 24-30 hours (8-12 launches). Corers are launched over the stern roller with vertical orientation. Round-trip time is approximately two hours at 5000 m depth. As the corers are located by the flashing strobe light, they are launched only during the night. In order to preserve core surfaces in very soft sediments, i.e. siliceous ooze, attempts will be made to slow the rate of descent and penetration by: (a) reducing the weight of the corer, or (b) by widening the I.D. of the core nose to equal, or greater than, the I.D. of the liner.

For free fall equipment, the sample recovered is assumed to come from directly below the drop point as marked on the echo sounder. In order to ease location problems, corers were normally launched near a free fall grab drop, and timed so that the grab and core would surface together.

Free Fall Grabs (CNEXO)

Grabs are prepared for launch by loading a weight (40 lbs. $\pm$ 4 lbs.) beneath the basket and locking a set of jaws back over the weight. The basket is then connected to the float unit by a shackle and line, and by the tripping mechanism. The latter is safe-armed by a piece of hard candy which dissolves prior to impact. Float units are equipped with a flag, a radio beacon, and a strobe light. New batteries should be used after each drop. The weights used on Mn-74-01 were cylinders consisting of concrete and lead measuring 13" long, 5" in diameter, and weighing 40 lbs. Round-trip time was 3 hours and 45 minutes in a water depth of 5,000 meters. Heavier weights ($\sim$45 lbs.) decreased round-trip time by 10-20 minutes.

Free fall grabs are launched on the port side aft of the deck house. Safety pins are removed from the basket jaws once the basket is over the side and there is tension on the lines of the release mechanism. The unit is released slowly via a tag line through the upper strut on the float unit.

Each free fall grab samples a sea floor area of 0.08 m^2. As in the case of the free fall corers, it is presumed that the site to be sampled is directly beneath the drop site within the limits of resolution of bathymetry. Displacement of units occurs after surfacing due to wind and currents. Grabs were normally launched successively along a survey track at 1-2 nm spacing.

Box Corers

The Reinicke-Bouma-type box corer is launched from the A-frame, which is mounted on the fantail. Load pins are removed from the weight stand before lowering the corer over the side so that the corer can move through its frame. The safety pin is pulled once the unit is in the water to avoid triggering on deck. Bungee cord is required to assist the removal of the release arm once tension is reduced on bottom contact. A pinger is flown on the wire 20 meters above the unit, and is used to guide the winch operator to the softest possible contact on the sea floor. A winch speed of 20 m/minute, or less, is required to minimize core surface disturbance.

EG & G Camera

Although the EG & G camera may be flown from any winch on board, the hydro winches are preferred so that the cable weight is low and kiting on descent is avoided. The remotely controlled winch is also preferred as it bypasses communication problems during the operation near the bottom.

SECTION II

Discussion of Station Data - Section II

This section presents station operations, sample descriptions, and summary tables. Bathymetric surveys, with sample locations noted, are included for the major stations (1, 5, 6, 7, and 10). Bathymetric contours are in meters. Track charts are included to show control on bathymetry. Dashed contours on bathymetry are extrapolated between widely spaced tracks. Photographs of free fall grab samples show nodule coverage as sampled by the grabs. The black outline enclosing the nodules represents the dimensions of the grabs (0.08 m^2), and nodule cover density (kg/m^2) are derived from weight of nodules recovered in the grabs. These are weights taken on board ship shortly after retrieving the grabs. Water chemistry (water column and pore water) results in the tables accompanying the station summaries were derived on board ship.

STATION SUMMARY

STATION: 01 TIME ON STATION: 20/7/74 1150Z

LATITUDE: 13°00'N TIME DEPART STATION: 21/7/74 1139Z

LONGITUDE: 154°00'W

SEDIMENT TYPE: Red clay

OPERATION: FFG #1, 2, 3 20/7/74 1150Z - 1700Z

Water Cast #1 21/7/74 0500Z - 1010Z (10, 20, 50, 100, 200, 500, 1000, 1500 m off bottom)

FFC #1, 2, 3 21/7/74 0850Z - 1120Z

DISCUSSION:

Bathymetry at station 1 (Figure 2, track control shown in Figure 3) is dominated by elongate troughs and hills and a general N-S pattern. Maximum relief is 300 m and maximum depth is 5600 m at the southern end of the narrow trough in the SW part of the area. A broad low hill or terrace and higher hill with an E-W separation occupy the western half of the area, but in broad outline preserve the N-S pattern. Small narrow valleys extend from the higher hill to the terrace with relief of 25-50 m. Steepest slopes of 5° (8%) occur between the terrace and the southern end of the trough. Average slopes are 3° (5%) to as low as 0.75° (1%).

The three FFG's were taken together near the center of the area between the hill and the trough at a depth equivalent to that of the low hill to the south (5413 m). Three free fall cores and a test of the Rosette system were made between hills.

The hills at this site appear to be of primary origin, i.e., formed at the mid-ocean ridge crest.

Nodule density for the three closely spaced grabs ranged from 1.75 to 4 kg/m^2 (average 2.8 kg/m^2). Nodules are all of the discoidal habit. See Figures 4-6.

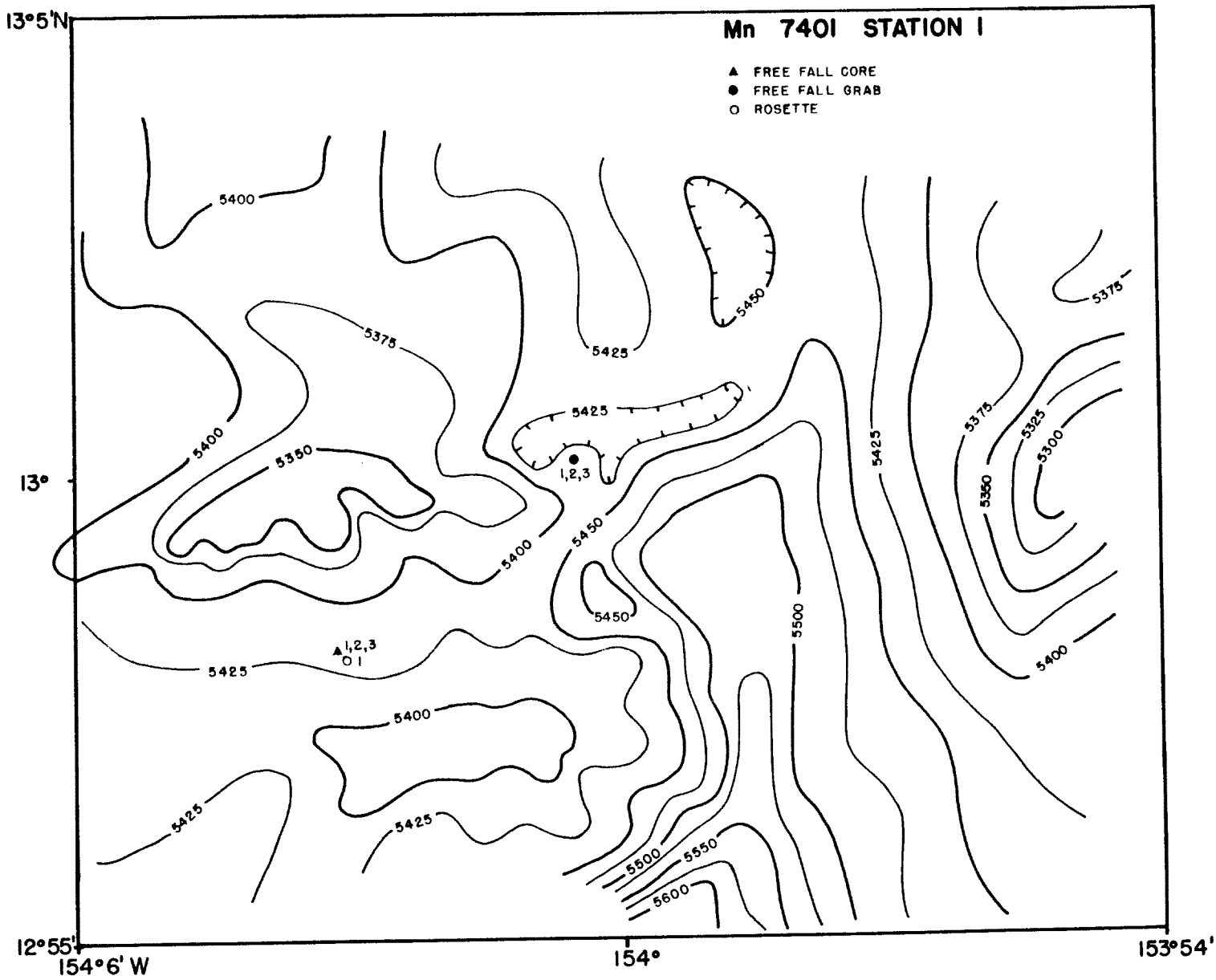


Figure 2.

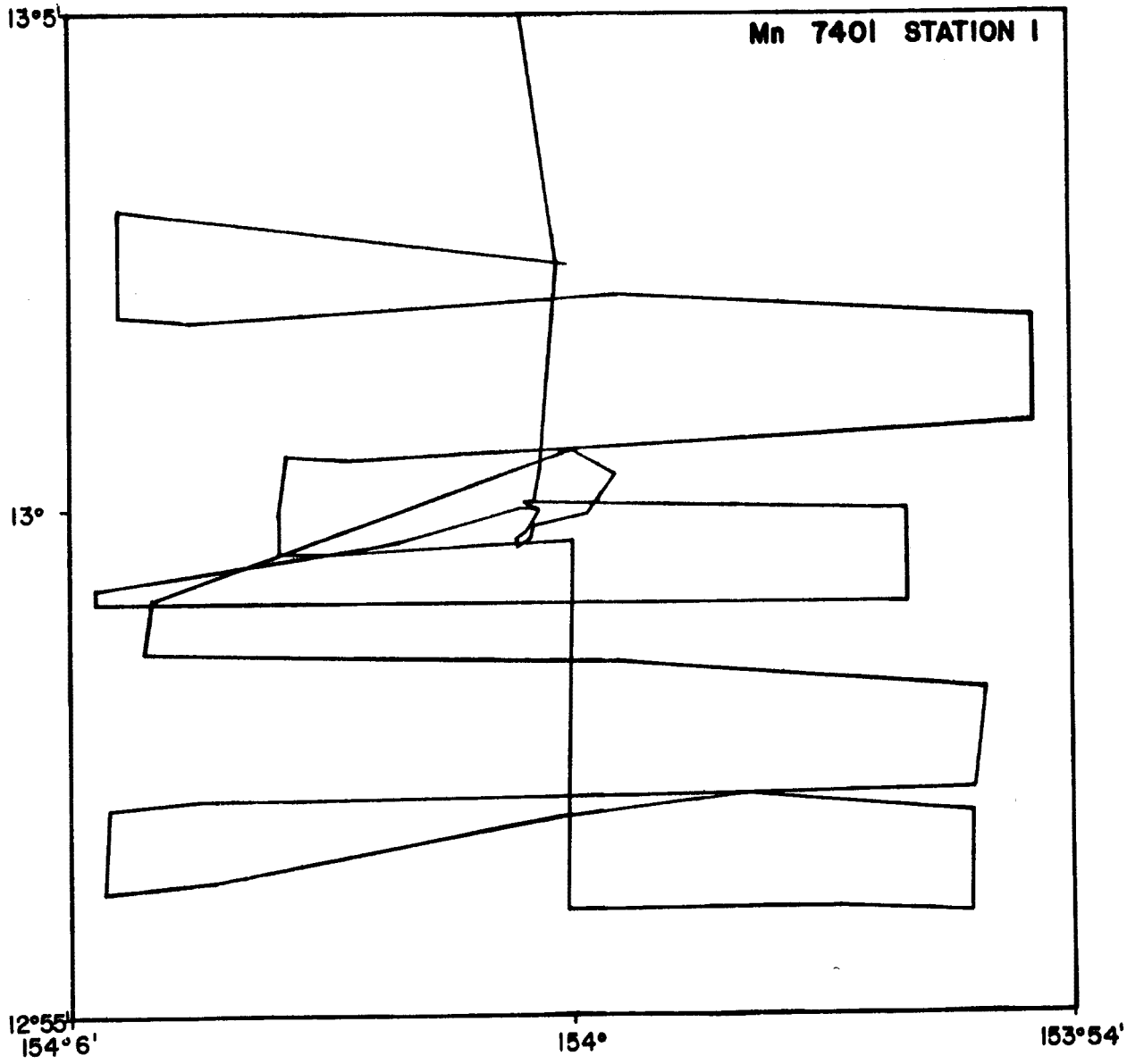


Figure 3.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO - FFG's

LAT. N.: 13°00.1'N

LONG. W.: 154°05.0'W

WATER DEPTH: 5413 m

STATION: 001

SAMPLE NO.: FFG-001, -002, -003

DATE: 20 July 74

TIME: LAUNCH 1242, 1248, 1252 Z

ON BOTTOM _____

RECOVER ~1700 Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

South of Clarion Fracture Zone, rolling abyssal hills, general relief 150 m.

SPECIFIC BATHYMETRIC LOCATION:

Valley between abyssal hills; all features covered by 25 - 35 m thick acoustically transparent sediment, with occasional strong surface reflections.

ASSOCIATED SEDIMENT--

Sample No.: FFC -001, -002, -003

Type: Brown silty/clay.

NODULE TYPES AT THIS STATION:

FFG -001: m[D]r (4) (see section on nodule classification) (number of nodules of this type)

FFG -002: m-1[D]r, 1[D]b (2) (1)

FFG -003: m[D]r (2)

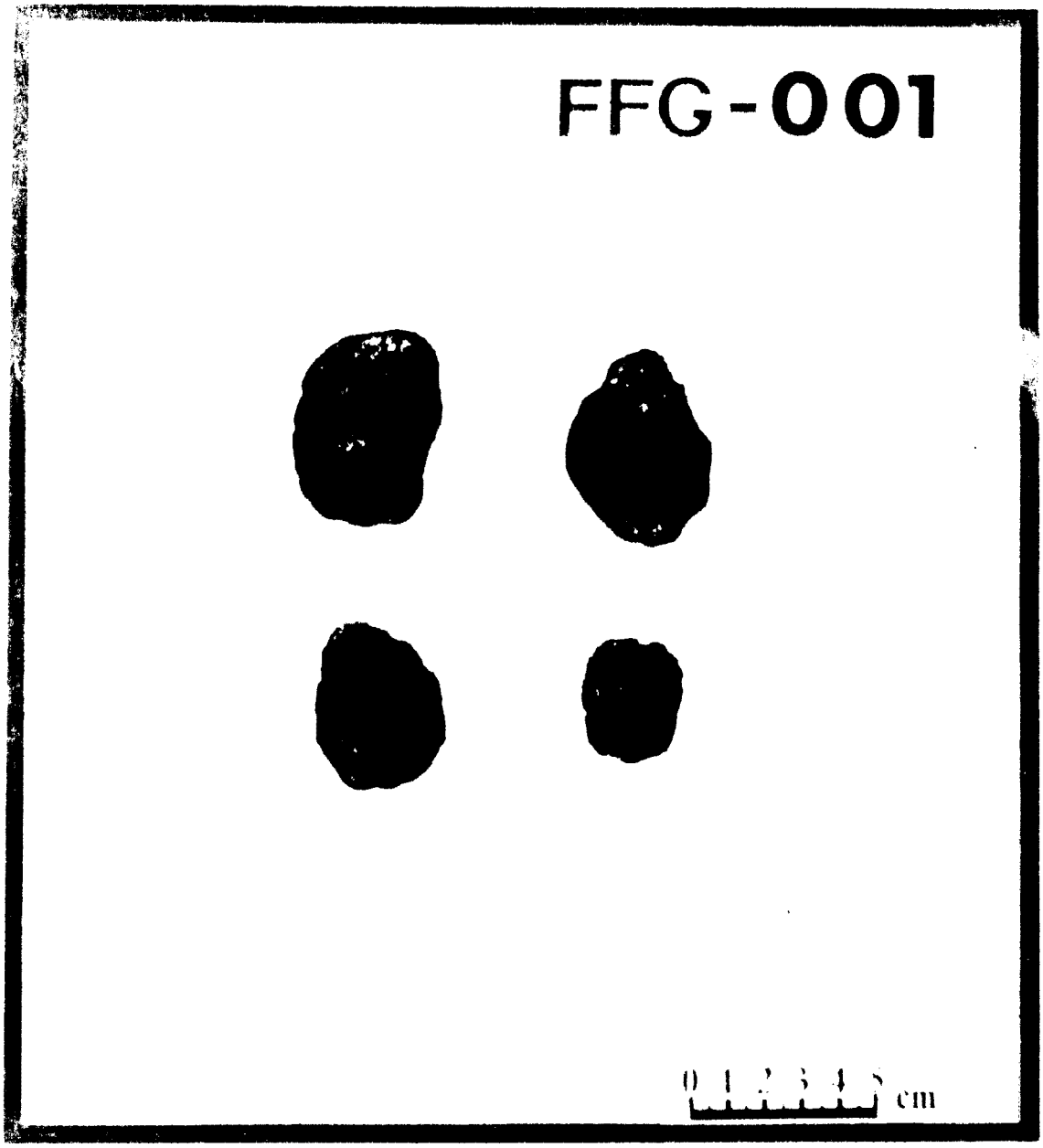


Figure 4.

STATION: 001 **SAMPLE NO.:** FFG -001

NODULE TYPES: 100% m[D]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	4	0	0	0	4	0
Weight (Kg)	0	0.22	0	0	0	0.22	0

SIZE RANGE OF MAX. DIAM.: 34, 45, 52, & 52 mm

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Smallest & largest are squared-off ellipsoidal discoids; other two approximate half-discoids.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

____ Surface:
____ Surface: } Granular { Equatorial belt slightly more coarsely granular. { Upper & lower surfaces indeterminant. Half-discoids may have been resting on "fracture" sides.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			←	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	↔				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Brown to dark brown

COMMENTS: Few worm tubes visible on surfaces.

STATION: 001 SAMPLE NO.: FFG -002

NODULE TYPES: 33% m[D]r, 33% l[D]r, 33% l[D]b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	1	2	0	0	3	0
Weight (Kg)	0	0.05	0.27	0	0	0.32	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 44, 62, 79

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Largest is ellipsoidal discoid; intermediate is reniform; smallest is half-discoid. All with incipient lobes. Bottoms somewhat flattened.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Granular
Lower Surface: Granular

} Equatorial belt slightly more coarsely granular

{ Granular texture of largest superimposed on knobby equatorial belt. Upper and lower surfaces are distinguishable.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			granular texture ← → knobby belt		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	gran. text. ← →		← knobby belt →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 to 20 mm (larger "knobs" can be considered as incipient lobes).

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Smallest has finely-dendritic adhering-sediment or worm tube pattern on apparent lower surface. Other two have worm tubes and organic fibers, esp. in lower equatorial region.

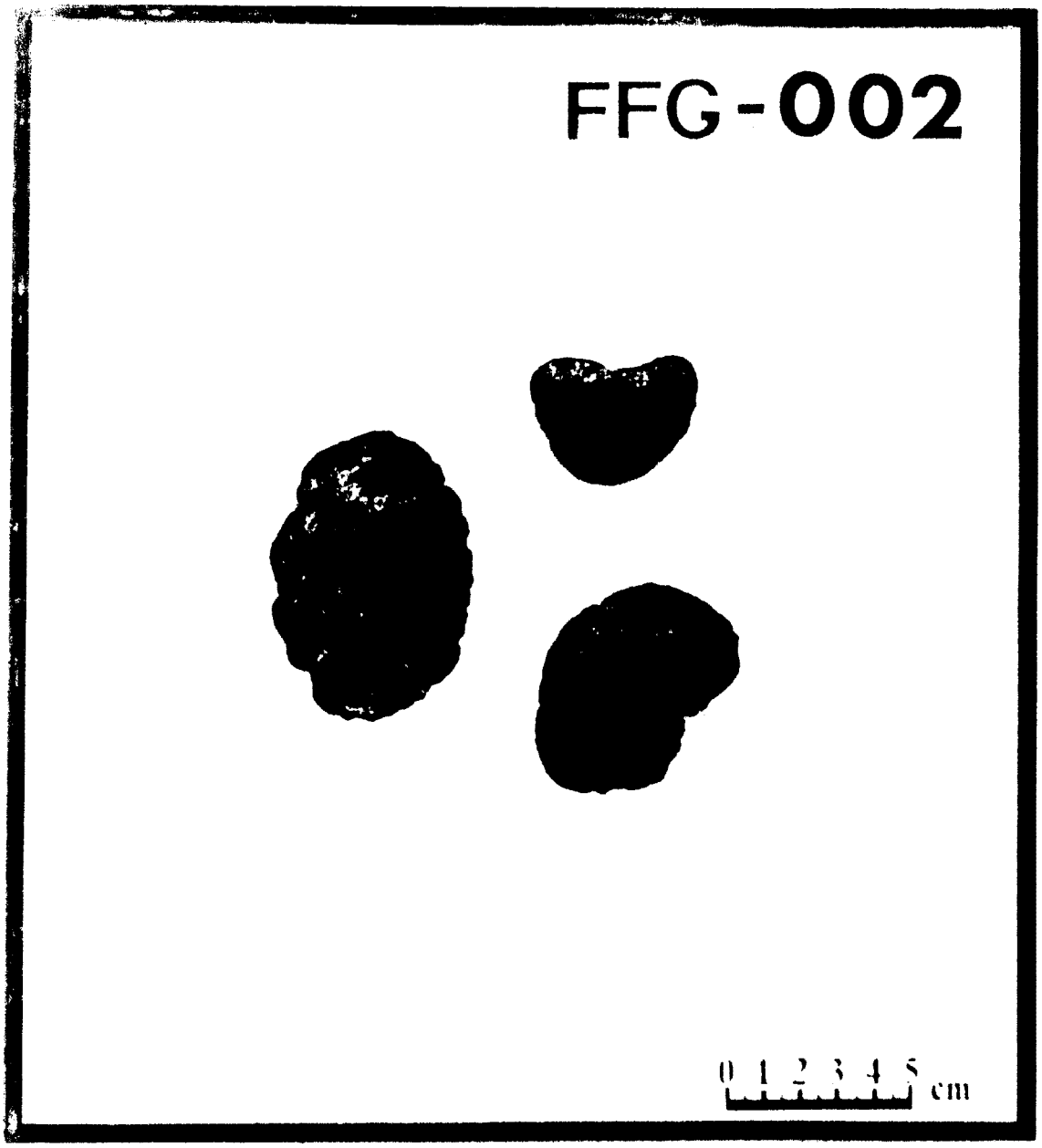


Figure 5.

STATION: 001 SAMPLE NO.: FFG -003

NODULE TYPES: 100% m[D]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	1	1	0	0	2	0
Weight (Kg)	0	0.05	0.09	0	0	0.14	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 45, 52 mm

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Both approximate half-discoidals. Both with incipient lobes. Bottoms somewhat flattened.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Granular
Lower Surface: Granular

} Equatorial belt slightly more coarsely granular

{ Upper and lower surfaces apparently can be distinguished: upper has gray-brown "blotches".

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			←	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm (some equatorial granule clusters assume an incipient botryoid form; up to 5 mm)

COLOR OF NODULE STREAK: Very dark brown

COMMENTS: Many worm tubes and organic fibers present on nodule surfaces, esp. in equatorial region.

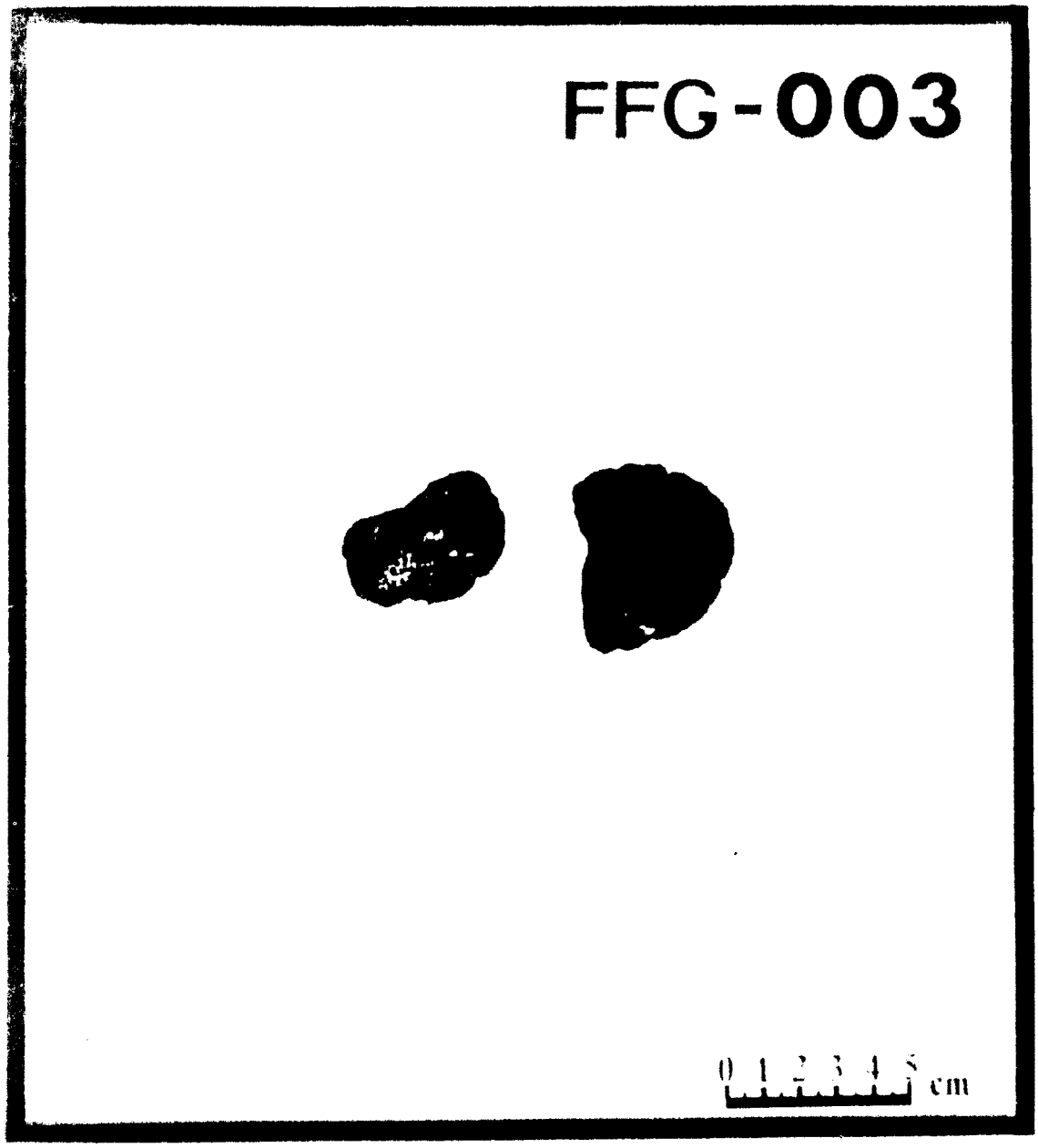


Figure 6.

STATION SUMMARY

STATION: 02

TIME ON STATION: 21/7/74 2125Z

LATITUDE: 11°21'N

TIME DEPART STATION: 22/7/74 0310Z

LONGITUDE: 153°37.5'W

SEDIMENT TYPE: Red clay/siliceous

OPERATIONS: FFG #4, 5, 6 21/7/74 2125Z - 22/7/74 0310Z
sediment samples (mini core) on #6

DISCUSSION:

Station for grabs only, was taken 20 N. M. south of a small seamount. (1050 m relief). A number of small nodules of various morphologies were recovered. Density of cover was 2.25 kg/m^2 for grab 4, and 0.25 kg/m^2 for #5 and 6. See Figures 7-9.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 002

COLLECTION DEVICE: CNEXO - FFG's

SAMPLE NO.: FFG -004, -005, -006

LAT. N.: 11°22'N

DATE: 21-22 July 74

LONG. W.: 153°37'W

TIME: **LAUNCH** 2132, 2134, 2135 Z

WATER DEPTH: 5190 m

ON BOTTOM _____

RECOVER 0316, 0307, 0311 Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

South of Clarion Fracture Zone; abyssal hills generally 100 m relief, between seapeaks up to 550 m.

SPECIFIC BATHYMETRIC LOCATION:

Very low (∿15 m) depositional mound, 2 miles south of 1050 m high seamount. About 50 m of transparent sediment, with strong bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -001A, -001B (recovered with FFG -006)

Type: Brown clayey silt.

NODULE TYPES AT THIS STATION:

FFG -004:	m[D]b,	s[E]r,	s[T]r,	s[P]r
	(1)	(3)	(1)	(1)
FFG -005:	s[E]r			
	(3)			
FFG -006:	s[S]r			
	(2)			

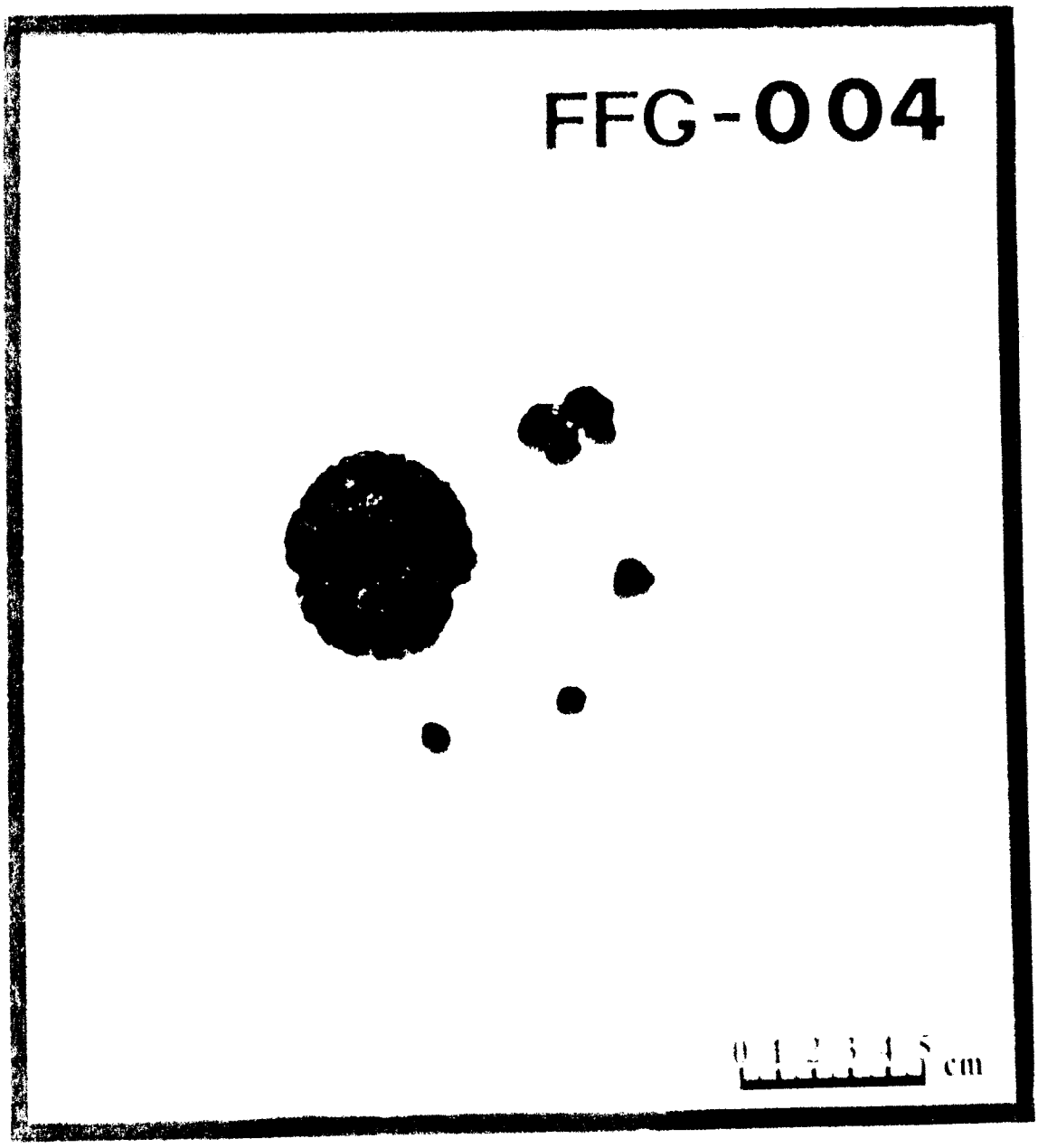


Figure 7.

STATION: 002 SAMPLE NO.: FFG -004
(see also next page)

NODULE TYPES: 100% m[D]b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	0	1	0	0	1	0
Weight (Kg)	0	0	0.15	0	0	0.15	0

SIZE RANGE OF MAX. DIAM.: 57 mm (x 50 mm x 25 mm)

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Approaches tabular-discoidal ("hamburger"); with incipient lobes; two small (~1/2 cm) satellite protrusions on upper (?) surface.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper (?) Surface: Granular
Lower (?) Surface: Granular

} Lower (?) surface has slightly higher relief than upper (?) surface

{ Equatorial belt has granular texture superimposed on botryoidal ("knobby") surface

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			←granular texture→		
		←knobby→			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	gran. text. ←→	knobby ←→			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm (granular), 2-5 mm (Knobby)

COLOR OF NODULE STREAK: Dark brown to black

COMMENTS: A few organic tubes present on nodule surface, esp. in equatorial region.

STATION: 002 SAMPLE NO.: FFG -004

NODULE TYPES: 60% s[E]r, 20% s[T]r, 20% s[P]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	5	0	0	0	0	5	0
Weight (Kg)	.03	0	0	0	0	.03	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 27, 26 (incl. shark's tooth nucleus), 13, 10, 10 mm

PRIMARY MORPHOLOGY: Ellipsoidal (except partially overgrown shark's tooth)

SECONDARY MORPHOLOGY: Vaguely to distinctly faceted. Largest nodule is a coalespheroid.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (with 2 major, 1 minor intergrown spheroids)

SURFACE TEXTURE:

_____ Surface: } Granular { Top and bottom not readily distinguishable, but part of surface seems to be free of worm tubes--which surface is this?

_____ Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			←	—	→
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	—	→		

ABSOLUTE DIAM. OF MAMMILLAE: $\leq$ 1 mm

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Worm tubes prominent on all nodules, esp. in "saddles" between lobes of coalespheroid. Only root of shark's tooth is Mn-encrusted; nuclei for other nodules probably not shark teeth.

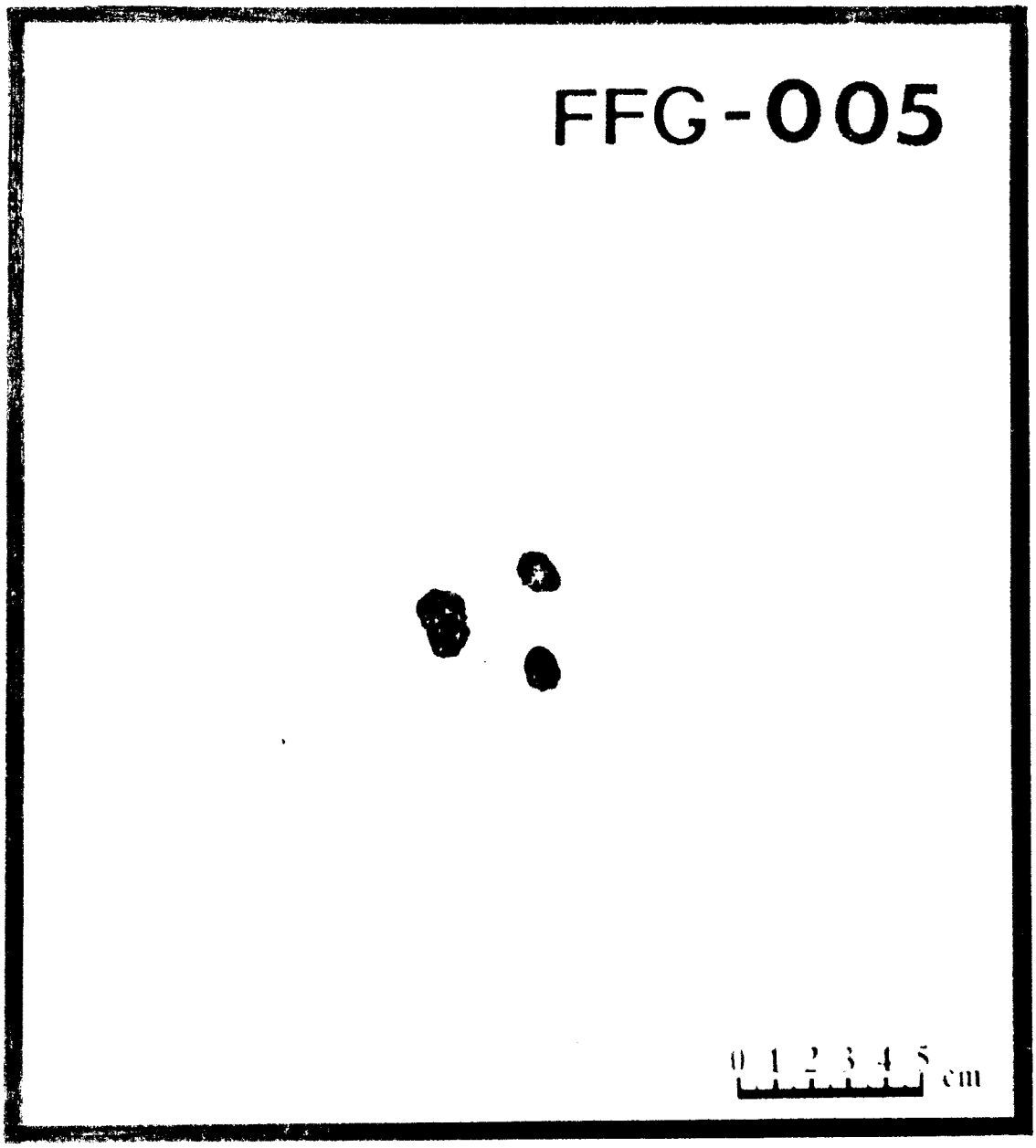


Figure 8.

STATION: 002 SAMPLE NO.: FFG -005

NODULE TYPES: 100% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	3	0	0	0	0	3	0
Weight (Kg)	.02	0	0	0	0	.02	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 20, 14, 13 mm

PRIMARY MORPHOLOGY: Ellipsoidal

SECONDARY MORPHOLOGY: Smallest is faceted ellipsoid; intermediate is discoidal ellipsoid; largest is flattened ellipsoid with one side "pinched".

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface:
_____ Surface: } Granular { Top and bottom indistinguishable but at least part of surface of each is free of worm tubes--which surface is this?

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			←	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←		→		

ABSOLUTE DIAM. OF MAMMILLAE: $\leq$ 1 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Worm tubes prominent on all 3 nodules.

STATION: 002 SAMPLE NO.: FFG -006

NODULE TYPES: 100% s[S]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	2	0	0	0	0	2	0
Weight (Kg)	.02	0	0	0	0	.02	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 17, 12 mm

PRIMARY MORPHOLOGY: Spheroidal

SECONDARY MORPHOLOGY: Largest is flattened; smallest is vaguely faceted.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface:
_____ Surface: } Granular { Upper & lower surfaces indistinguishable. Part of surface of both relatively free of worm tubes--which surface?

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			← →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	→			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Worm tubes prominent on both nodules.

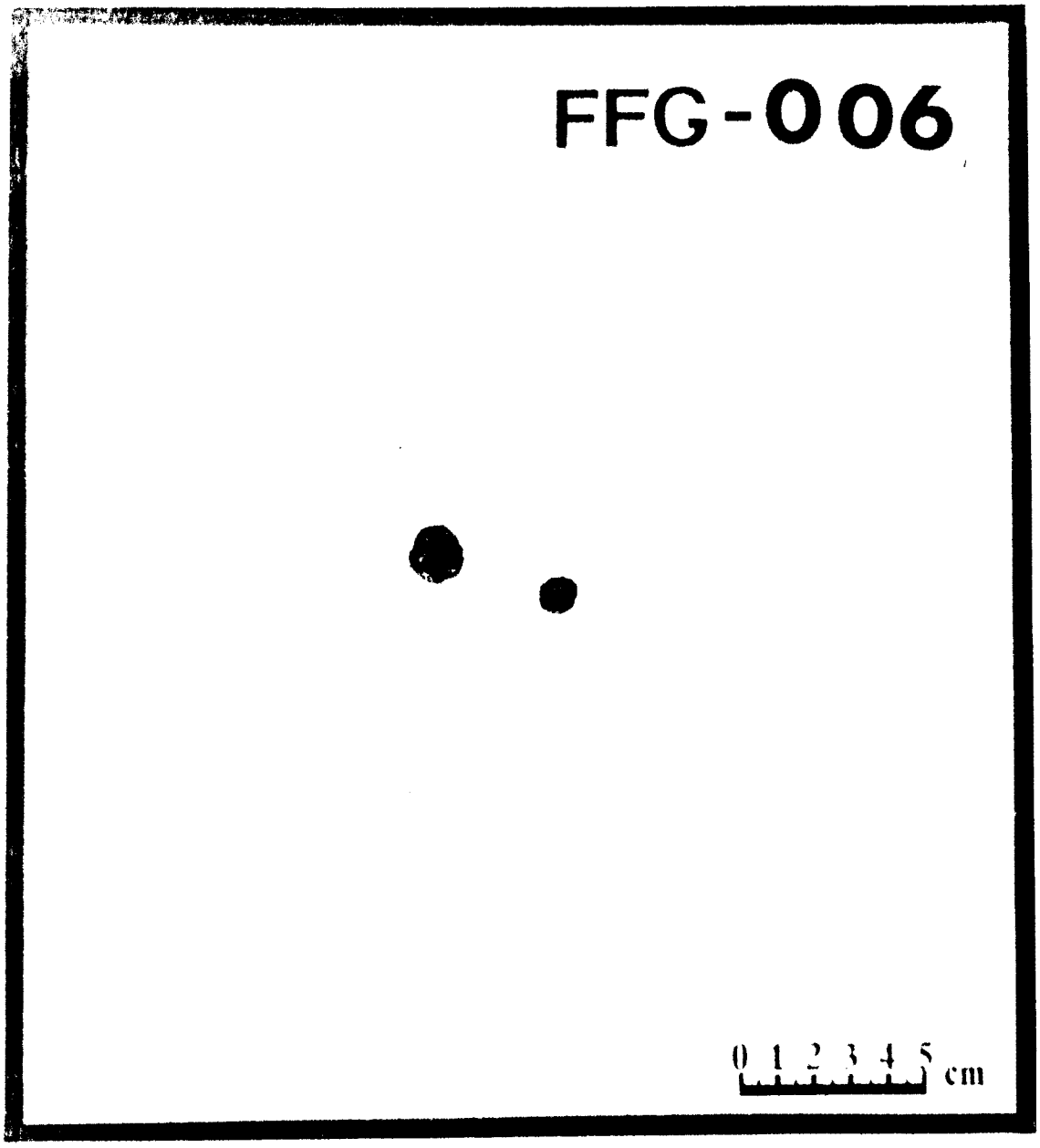


Figure 9.

STATION SUMMARY

STATION: 03

TIME ON STATION: 22/7/74 1308Z

LATITUDE: 9°59.3'N

TIME DEPART STATION: 22/7/74 1800Z

LONGITUDE: 152°56.7'W

SEDIMENT TYPE: Red clay/siliceous ooze

OPERATIONS: FFG #7, 8, 9 22/7/74 1308Z - 22/7/74 1800Z
sediment sample on #8

Box core #1 no sample, winch problems in tension and meter wheel

No bathymetry due to recorder clutch problem

DISCUSSION:

Nodule density of 5.63 and 6.25 kg/m^2 for grabs 9 and 7. No nodules in #8, but several clay balls and "organ pipe" structure - ?benthic foram? Dominant nodule shape is discoidal to ellipsoidal. See Figures 10-11.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG's

LAT. N.: 9°59'N

LONG. W.: 152°57'W

WATER DEPTH: ? (prob. ∿5000 m)

STATION: 003

SAMPLE NO.: FFG -007, -008, -009

DATE: 22 July 74

TIME: **LAUNCH** 1316, 1317, 1318 Z

ON BOTTOM _____

RECOVER ∿1758 Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:
Between Clarion & Clipperton Fracture Zones.

SPECIFIC BATHYMETRIC LOCATION:
PDR inoperative

ASSOCIATED SEDIMENT--

Sample No.: FFG -008

Type: Brown silty clay

NODULE TYPES AT THIS STATION:

FFG -007: s-l[E]r & s-m[D-E]r (25), s[S]r (10), s-m[P]r (4), s[B]r (2), and m[T]r (2)

FFG -008: No nodules

FFG -009: s-m[D]r & s-m[D-E]r (12), s-l[T]$^{s-b}_{s-r}$ (5), s[S]r (4), s-m[P]s-r (2)

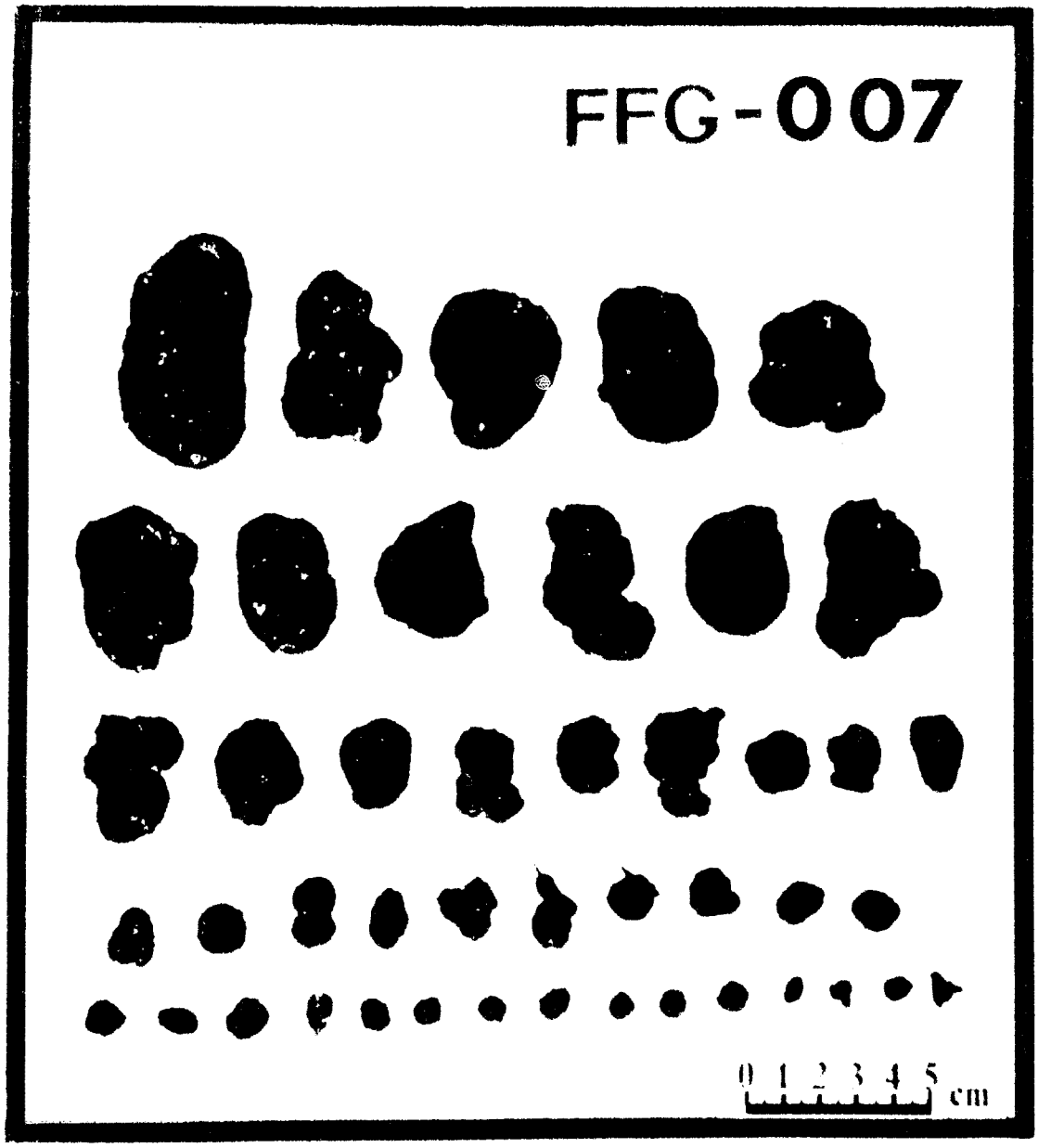


Figure 10.

STATION: 003 SAMPLE NO.: FFG -007

NODULE TYPES: 58% s-l[E]r and s-m[E-D]r, 23% s[S]r, 9% s-m[P]r, 5% s[B]r, and 5% m[T]r (differences between types gradational)

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	27	16	0	0	0	43	0
Weight (Kg)	0.05	0.45	0	0	0	0.50	0

SIZE RANGE OF MAX. DIAM.: 8 - 63 mm

PRIMARY MORPHOLOGY: Wide variety: Largest is prolate ellipsoid; most larger nodules are modified ellipsoids, some modified discoids, & two are platy. Most of smaller nodules are spheroidal.

SECONDARY MORPHOLOGY: Many of larger nodules have satellite protrusions. Many also have incipient to well-developed lobes with 2 resembling root tubers. Several larger ellipsoids flattened. Some of smaller shperoids flattened.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Four of smaller nodules appear to be coalespheroids rather than ellipsoids with well-developed lobes; they are 2-, 2-, 3-, and 4- poly, respectively.

SURFACE TEXTURE:

Upper Surface: Microgranular to granular.
Lower Surface: Granular to cavernous granular.

Some larger nodules have distinguishable upper & lower surfaces--these are the ones that typically display differences in surface granularity, lower equatorial belts having highest granularity.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	←				→
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←		→		

ABSOLUTE DIAM. OF MAMMILLAE: $\leq$1 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Sample includes one incipient nodule (a 12 mm max. diam. ellipsoidal volcanic frag. with one-half of surface Mn-encrusted). Shark teeth nuclei or satellites with 4 smaller nodules. Worm tubes prominent on most nodules.

STATION: 003 SAMPLE NO.: FFG -008

NODULE TYPES: No nodules recovered

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules						0	0
Weight (Kg)						0	0

SIZE RANGE OF MAX. DIAM.: _____

PRIMARY MORPHOLOGY: _____

SECONDARY MORPHOLOGY: _____

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: _____

SURFACE TEXTURE:

_____Surface: _____

_____Surface: _____

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF					
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE					

ABSOLUTE DIAM. OF MAMMILLAE: _____

COLOR OF NODULE STREAK: _____

COMMENTS: Sample consists of several lumps of brown silty clay, several clusters of "organ-pipes" (constructed by unknown organism), and a 11 mm maximum diameter angular fine-grained rock frag. (serpentinite?)

STATION: 003 SAMPLE NO.: FFG -009

NODULE TYPES: 55% s-m[D]r and s-m[D-E]r, 23% s-l[T]s-b, 17% s[S]r, 9% s-m[P]s-r (Differences between types gradational)

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	7	12	3	1	0	23	0? *
Weight (Kg)	0.02	0.20	0.13	0.10	0	0.45	0? *

(Sub-sample weights estimated)

SIZE RANGE OF MAX. DIAM.: 7-97 mm (largest is 13 x 62 x 97 mm)

PRIMARY MORPHOLOGY: Wide variety: Largest is platy tabular-discoid; most of larger ones are ellipsoidal or discoidal; smaller ones (<1/2 cm max. diam.) are spheroidal (but one is thin platy).

SECONDARY MORPHOLOGY: Several larger ones have satellite protrusions or agglutinated spheroids which are not large enough to make the nodule a coalespheroid. Few incipient lobes. Some botryoids may be considered well-developed lobes.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Two (one is 2-poly, one is multilobed).

SURFACE TEXTURE:

Upper Surface: Smooth to Granular.

Lower Surface: Microgranular to Granular.

Upper & lower surfaces distinguishable on some larger nodules. On some larger nodules, the smooth to granular textures are superimposed on a botryoidal surface which is best developed on the top side, esp. of the tubular and discoidal nodules.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			Granular ← Botryoidal →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ←		→ Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: ≤1 mm (granular), 4-12 mm (botryoidal)

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Worm tubes prominent on most nodules. *One small tabular nodule may be frag., but it has worm on apparent fracture surface.

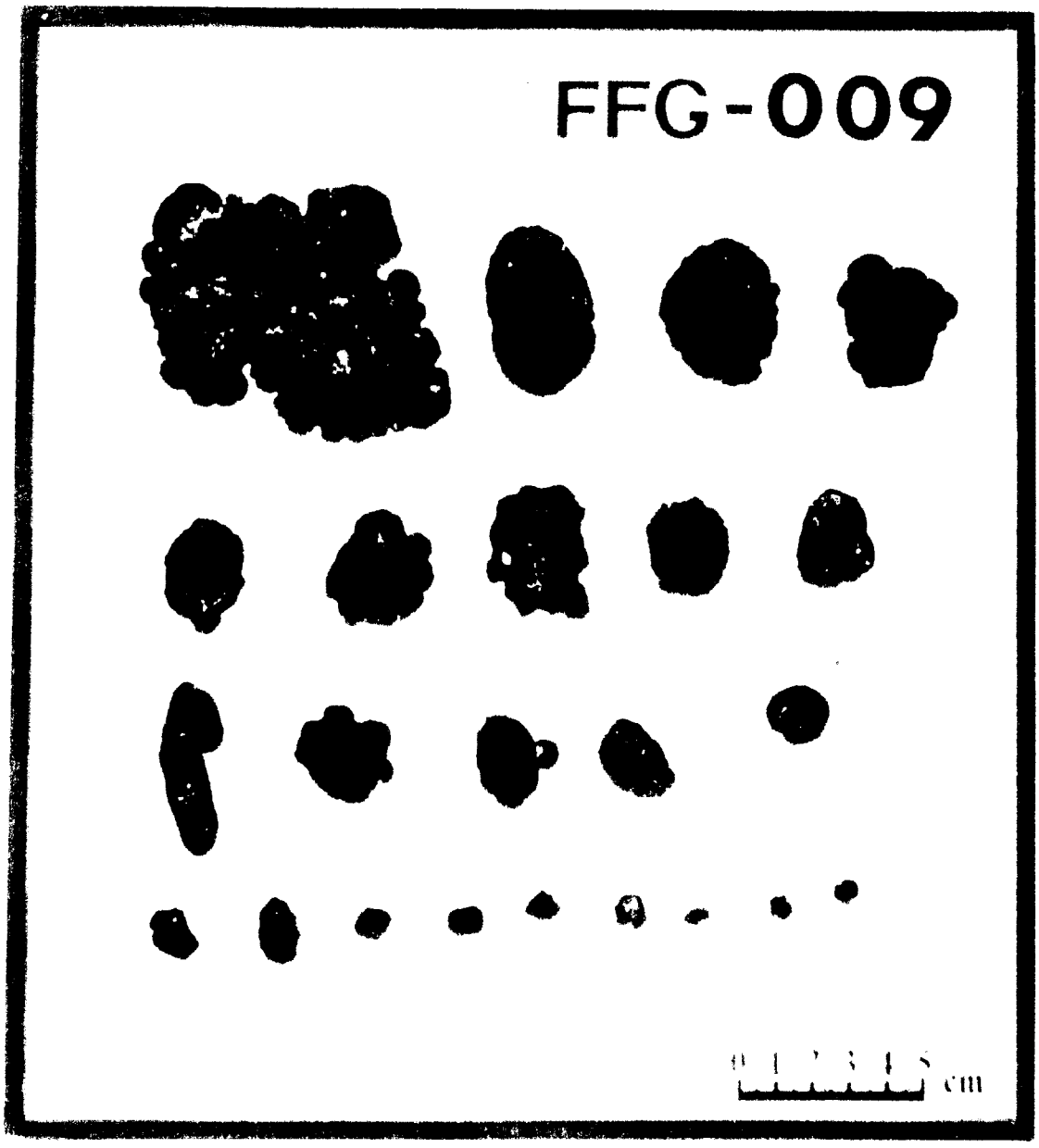


Figure 11.

STATION SUMMARY

STATION: 04

TIME ON STATION: 23/7/74 0202Z

LATITUDE: 8°40'N

TIME DEPART STATION: 23/7/74 0751Z

LONGITUDE: 152°37.8'W

SEDIMENT TYPE: Red clay/siliceous ooze

OPERATIONS: FFG #10, 11, 12 23/7/74 0246Z-0729Z

EG & G camera - poor pinger trace - not sure of bottom, only 1/4 of the film exposed, no bottom photos.

DISCUSSION:

Poor bathymetry - apparently primary type abyssal hills. Low nodule density 0.13 - 0.63 kg/m^2. Small to medium sized discoidal to ellipsoidal nodules. See Figures 12-14.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG's

LAT. N.: 8°39.8'N

LONG. W.: 152°37.8'W

WATER DEPTH: ∿5100 m

STATION: 004

SAMPLE NO.: FFG -010, -011, -012

DATE: 23 July 1974

TIME: **LAUNCH** 0246, 0247, 0248Z

ON BOTTOM _____

RECOVER 0738, 0751, 0729Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones.

SPECIFIC BATHYMETRIC LOCATION:

Apparently rolling abyssal hills (echo-sounder producing very poor record).

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -002 (recovered with FFG -011)

Type: Dark brown clayey silt.

NODULE TYPES AT THIS STATION:

FFG -010:	s[E]r			
	(1)			
FFG -011:	s[E]r,	s[S]r,	s[B]r,	s[T]r
	(2)	(2)	(1)	(1)
FFG -012:	m[D]r,	s[E]r,	s[P]r	
	(1)	(1)	(1)	

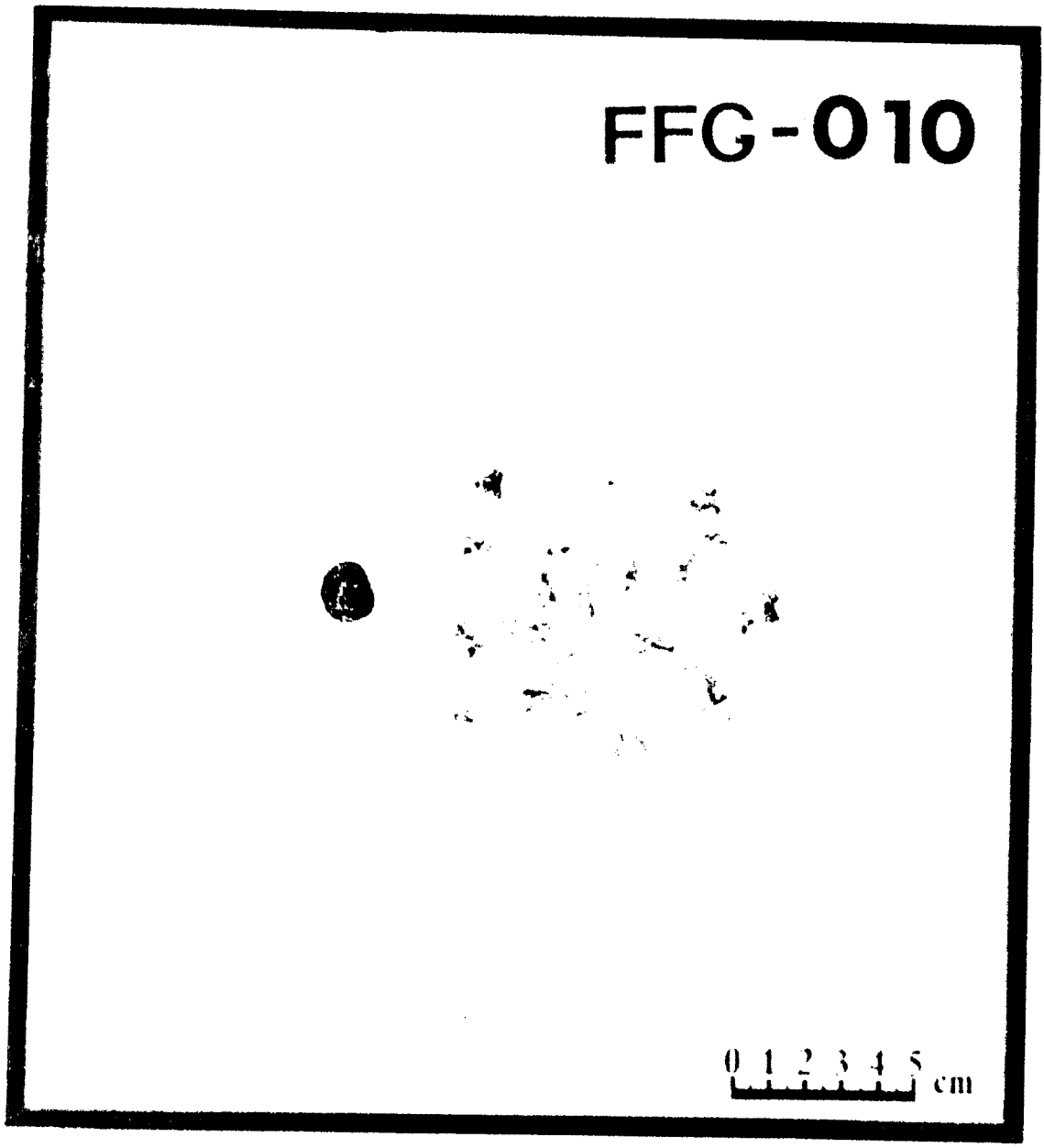


Figure 12.

STATION: 004 SAMPLE NO.: FFG -010

NODULE TYPES: 100% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	0	0	0	0	1	0
Weight (Kg)	0.01	0	0	0	0	0.01	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 18 mm

PRIMARY MORPHOLOGY: Ellipsoidal

SECONDARY MORPHOLOGY: Flattened

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper (?) Surface: Microgranular

Lower (?) Surface: Granular

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	←			→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	↔				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Brown to dark brown

COMMENTS: Abundant worm tubes on lower (?) surface. Sample includes many clusters of "organ pipes"-- white, twisted tubes, each tube about 1 mm in diameter and up to 1 1/2 cm long.

STATION: 004 SAMPLE NO.: FFG -011

NODULE TYPES: 33% s[E]r, 33% s[S]r, 17% s[B]r, 17% s[T]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	6	0	0	0	0	6	0
Weight (Kg)	0.02	0	0	0	0	0.02	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 18 mm (incl. shark's tooth nucleus), other 9-15 mm.

PRIMARY MORPHOLOGY: Two are spheroidal, two are ellipsoidal, one is tabular-discoidal, and one is partly encrusted shark's tooth.

SECONDARY MORPHOLOGY: Spheroidals are faceted and lobed, respectively. Ellipsoidals are flattened and prolate, respectively; tabular-discoidal is platy.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS:

SURFACE TEXTURE:

_____ Surface: } Microgranular to granular { Upper and lower surfaces not distinguishable.

_____ Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		←		→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	→			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Dark brown to very dark brown

COMMENTS: Sample includes a 12 mm max. diameter unencrusted subangular weathered pumice frag. and a 14 mm max. dia. partly encrusted subround weathered pumice frag. Shark-tooth nodule has only tooth root encrusted with manganese.

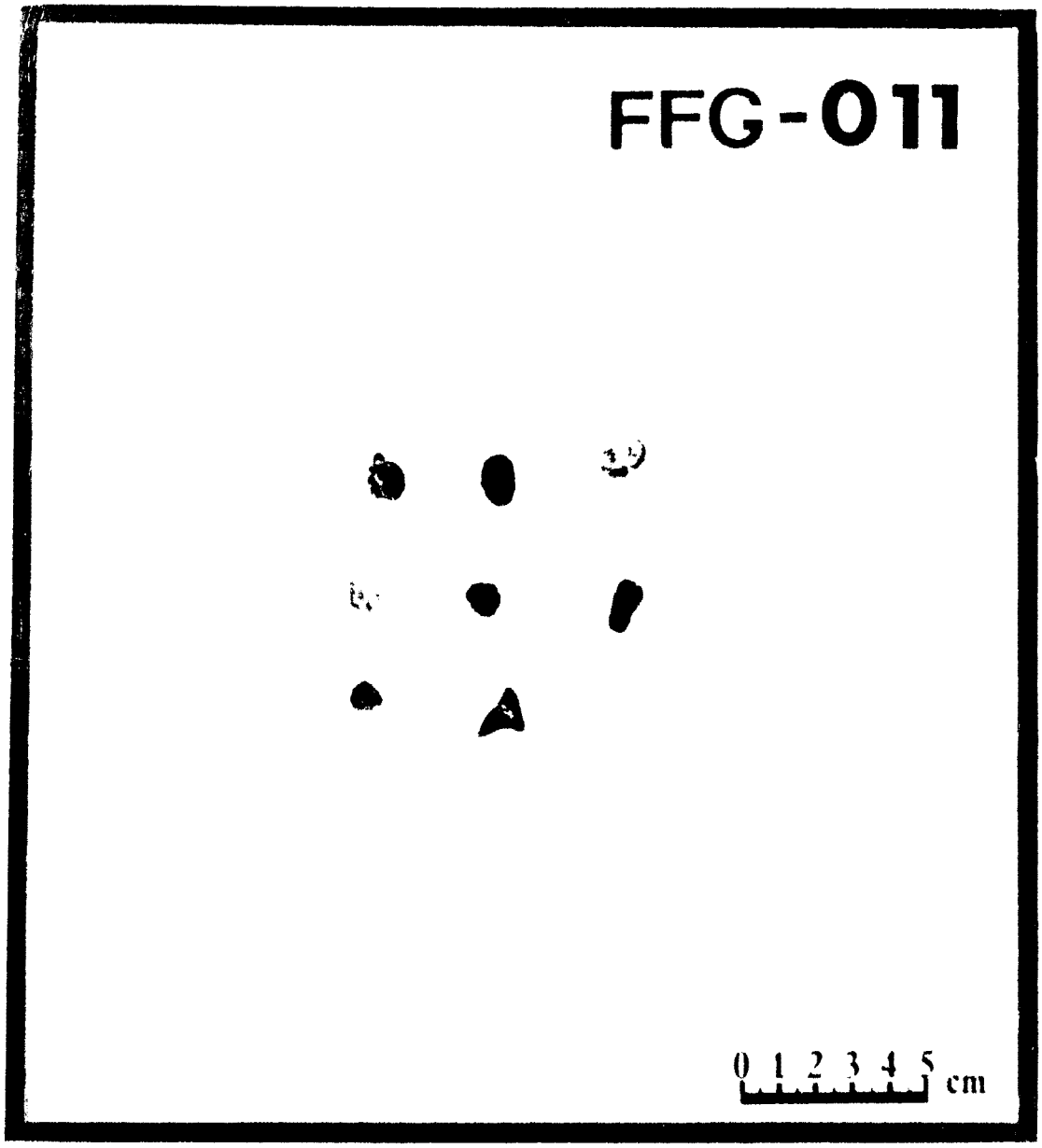


Figure 13.

STATION: 004 SAMPLE NO.: FFG -012

NODULE TYPES: 33% m[D]r, 33% s[P]r, 33% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	2	1	0	0	0	3	0
Weight (Kg)	0.01	0.04	0	0	0	0.05	0

(weights estimated)

SIZE RANGE OF MAX. DIAM.: 15, 18, 42 mm

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Largest is ellipsoidal discoid, intermediate consists of intergrown ellipsoid and spheroid, and smallest is tapered ellipsoid. Largest has partially developed lobes.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: 1 (2-poly)

SURFACE TEXTURE:

_____ Surface: } Micrognanular to Granular

_____ Surface: }

{ Upper and lower surfaces not distinguishable on smaller nodules, but on largest nodule, lower surface seems to be free of worm tubes. On equatorial belt of largest, granule clusters approach a botryoidal aspect.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	←				→
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	→			

ABSOLUTE DIAM. OF MAMMILLAE: ≤1 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Worm tubes prominent on all 3 nodules.

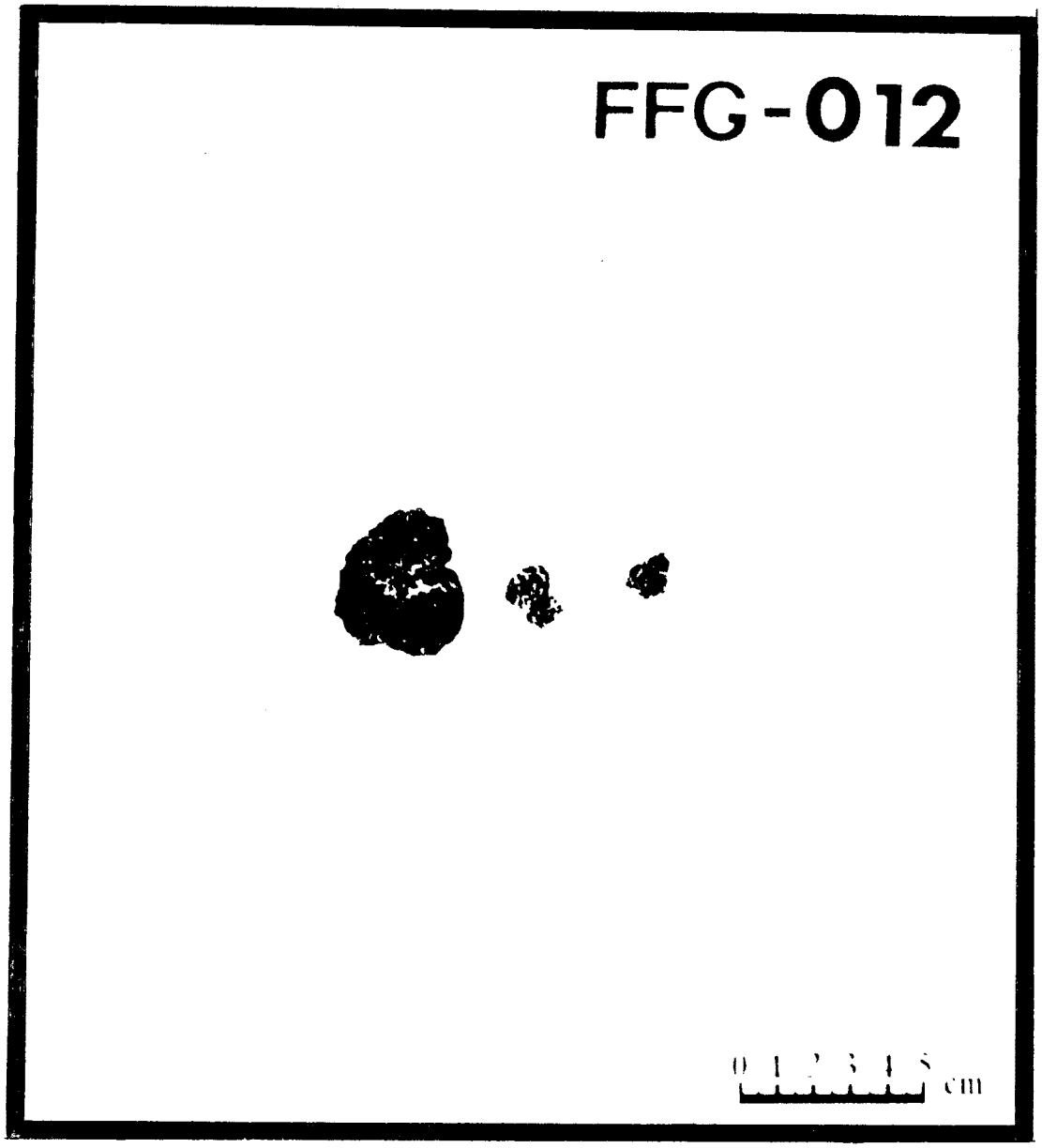


Figure 14.

STATION SUMMARY

STATION: 05

TIME ON STATION: 25/7/74 0155Z

LATITUDE: 3°00'N

TIME DEPART STATION: 26/7/74 0630Z

LONGITUDE: 151°00'W

SEDIMENT TYPE: Carbonate ooze/red clay

OPERATIONS: FFC #4 and 5 25/7/74 0439Z - 0745Z only #5 recovered, #4 lost CaCO3 and clay/siliceous ooze

Box core #2 25/7/74 1149Z - 1600Z good core Figure 18 (pore water Table 2)

Box core #3 25/7/74 1920Z - 2316Z no sample

FFG #13, 14, 15 Sediment sample #3 25/7/74 2000Z - 26/7/74 0139Z

Water cast #2 (Table 1) 26/7/74 0300Z - 0630Z

DISCUSSION:

Bathymetry (Figure 15, track control in Figures 16-17) shows an extremely flat area at 5075 m occupies the northern 1/2 of Station #5. Relief is less than 25 m over a distance of 10 N. M. The southern portion of the station is a large hill of 425 m relief with a narrow terrace at near 4800 m. Slopes are 5° (8.5%), and the bathymetric trend is E-W. Proximity to the Clipperton Fracture Zone suggests that the topography is controlled by that structure. One box core was obtained from the terrace at 4880 m, and one FFC about 1.5 mi. to the west. Three FFG's were taken between the top and base of the hill. Nodules are concentrated toward the base of the hill. Grab #13 at the crest had no recovery, number 14 on the flank 0.13 kg/m^2, and number 15 at the base 5.63 kg/m^2. The box core at the flank sampled 15 nodules on the sediment surface (all 2-6 cm dia.). These were removed in contact with sediment and preserved for study. Buried nodules in the box core totaled 7.5 kg/m^2. Figures 19-21 show grab samples and buried nodules from box core #2.

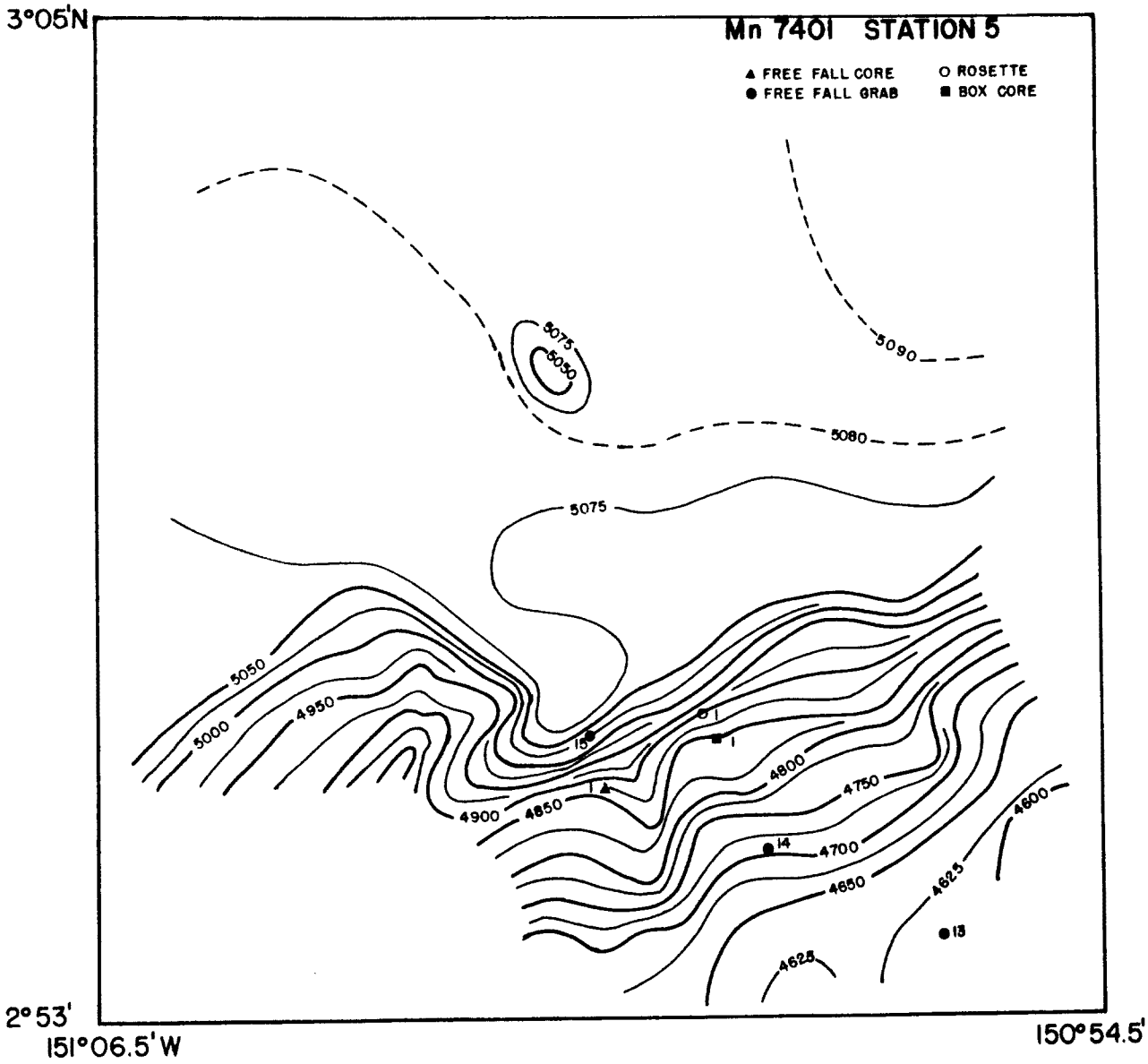


Figure 15.

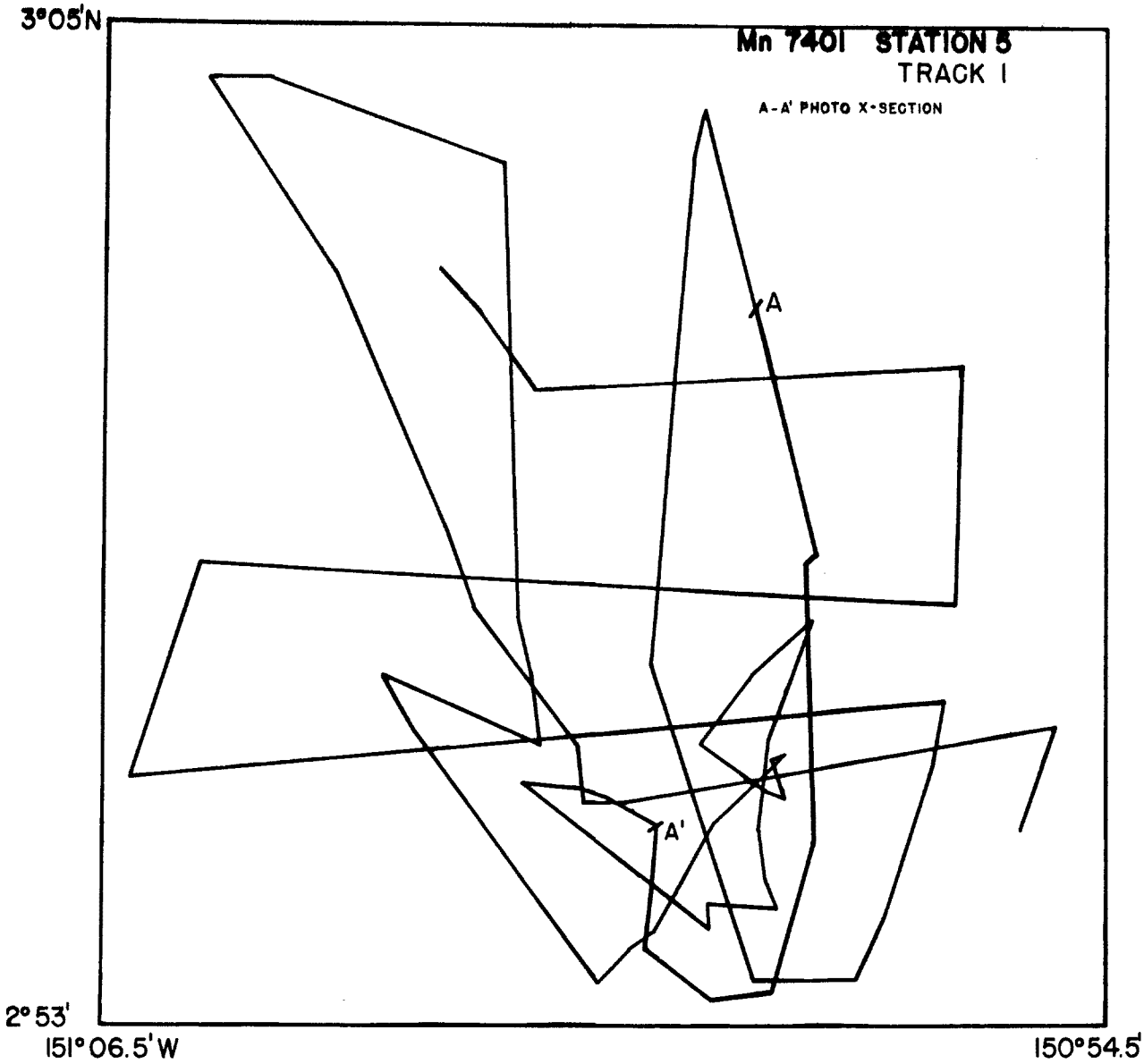


Figure 16.

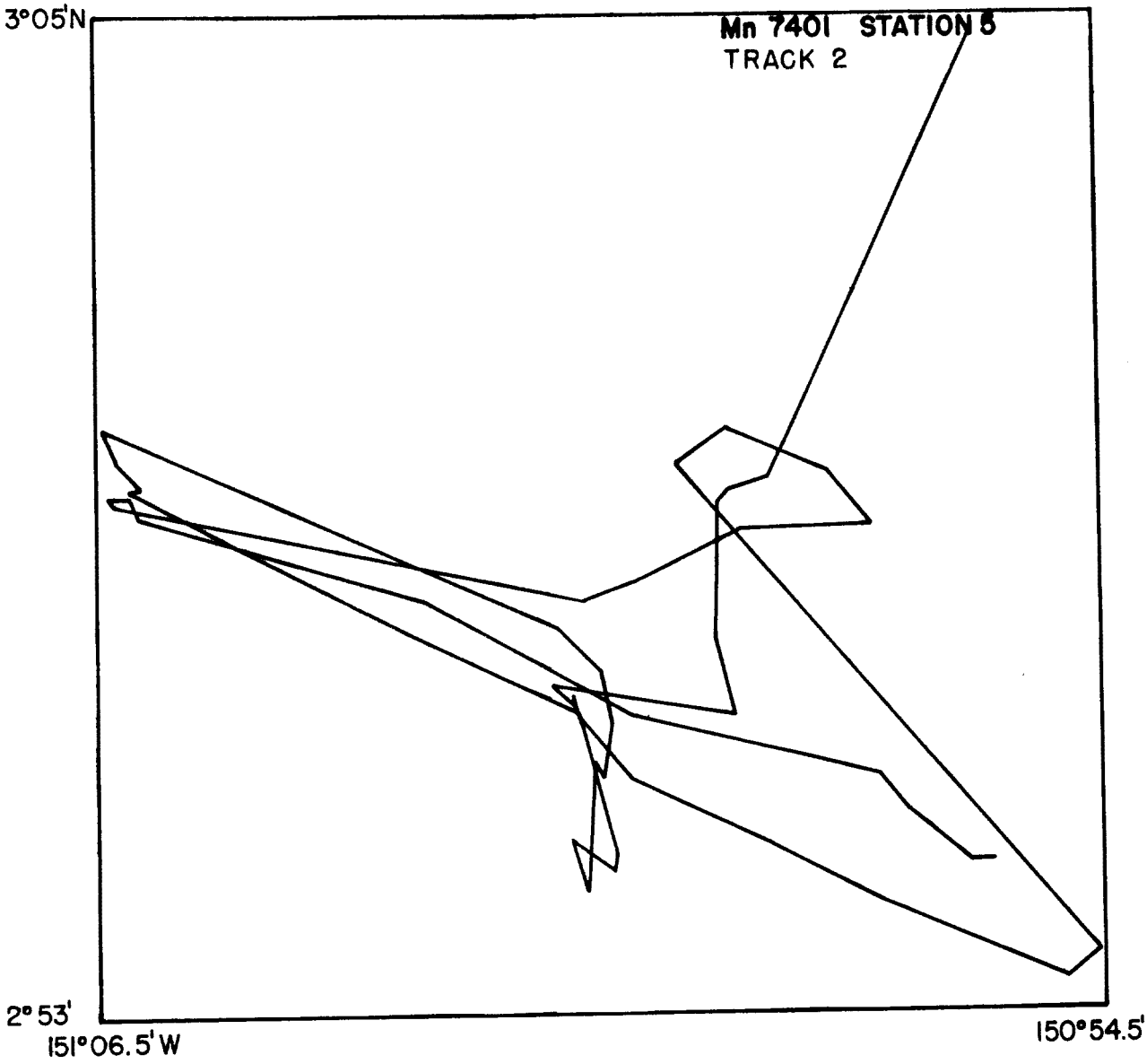


Figure 17.

TABLE 1: STATION NO. 5 - ROSETTE CAST #2

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Trace metals
1-1	4843	4.05	34.702	2.66	140	22		TM
1-2	4843	3.77	34.701	2.71	142	22		TM
1-3	4843	3.85	34.692	2.61	138	22		TM
1-4	4833	3.95	34.676	2.42	142	32		TM
1-5	4833	3.91	34.676	2.52	142	32		TM
1-6	4833	4.01	34.690	2.57	139	32		TM
1-7	4753	3.92	34.699	2.42	140	90		TM
1-8	4753	3.95	34.677	2.38	141	90		TM
1-9	4753	3.33	34.674	2.38	129	90		TM
1-10	3899	3.74	34.680	2.23	142	954		
1-11	3899	3.66	34.675	2.33	139	954		

TABLE 2: STATION NO. 5 - PORE WATER CHEMISTRY

Depth interval in core, cm	pH	Alkalinity, * meq/l
0-2	7.45	3.95
2-4	6.83	2.21
4-6	7.08	3.21
6-8	7.33	3.12
8-10	6.49	4.58
10-12	6.35	2.21
12-14	6.12	1.45
14-16	7.24	2.35
16-18	7.14	4.39
18-20	7.51	2.40
Near bottom water	8.0	2.59

* Titration alkalinity values need to be corrected for titer blank of 0.530 M NaCl solution and deviation of Standard Acid (HCl) from 0.010N.

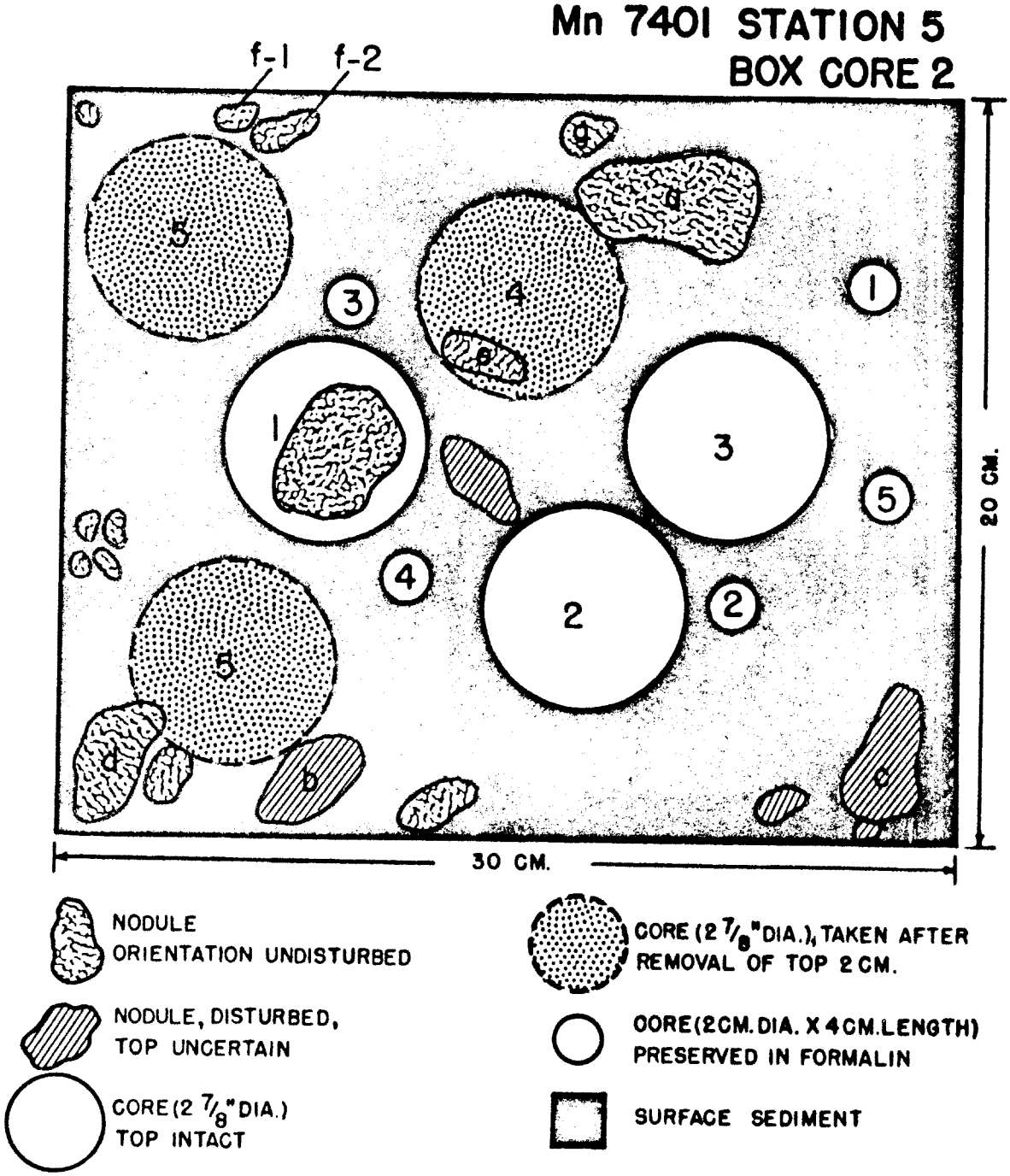

Mn 7401 STATION 5
BOX CORE 2
f-1
f-2
20 CM.
30 CM.
NODULE
ORIENTATION UNDISTURBED
NODULE, DISTURBED,
TOP UNCERTAIN
CORE (2 7/8" DIA.)
TOP INTACT
CORE (2 7/8" DIA.), TAKEN AFTER
REMOVAL OF TOP 2 CM.
CORE (2 CM. DIA. X 4 CM. LENGTH)
PRESERVED IN FORMALIN
SURFACE SEDIMENT

Figure 18.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 005

COLLECTION DEVICE: Kennecott Box Corer

SAMPLE NO.: B-2 [Nodules at Core Top]

LAT. N.: 2°56.3'N

DATE: 25 July 1974

LONG. W.: 150°59.1'W

TIME: LAUNCH _____

WATER DEPTH: 4850 m

ON BOTTOM 1405Z

RECOVER _____

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just north of Clipperton Fracture Zone. Abyssal plain with relief mostly <10 m.

SPECIFIC BATHYMETRIC LOCATION:

Lower flank of 450 m abyssal hill surrounded by flat abyssal plain.

ASSOCIATED SEDIMENT--

Sample No.: B-2

Type: Red-brown carbonate clay

NODULE TYPES IN THIS SAMPLE:

Note: Nodules removed from core top immediately after collection and frozen. Detailed description of nodules not made at that time. See report by Carl Bowser for description of box core surface. At surface were found about 15 nodules, about 2-6 1/2 cm max. diam., the larger ones mostly discoidal or tabular-discoidal, and the smaller ones apparently ellipsoidal or botryoidal. Granular and botryoidal surfaces seem to predominate. See Description of buried nodules from the box core on the following page.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: Kennecott Box Corer

LAT. N.: 2°56.3'N

LONG. W.: 150°59.1'W

WATER DEPTH: 4850 m

STATION: 005

SAMPLE NO.: B- 2 [Buried Nodules]

DATE: 25 July 1974

TIME: LAUNCH _____

ON BOTTOM 1405Z

RECOVER _____

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just north of Clipperton Fracture Zone. Abyssal plain with relief mostly <10 m.

SPECIFIC BATHYMETRIC LOCATION:

Lower flank of 450 m abyssal hill surrounded by flat abyssal plain.

ASSOCIATED SEDIMENT--

Sample No.: B-2 depth in core about 10-15 cm and deeper.

Type: Burrow-mottled cream-colored carbonate ooze and brown clay.

NODULE TYPES IN THIS SAMPLE:

l[E]r	l[F]r	s[D]b-r	s[P]b	s[F]r
(1)	(1)	(3)	(1)	(1)

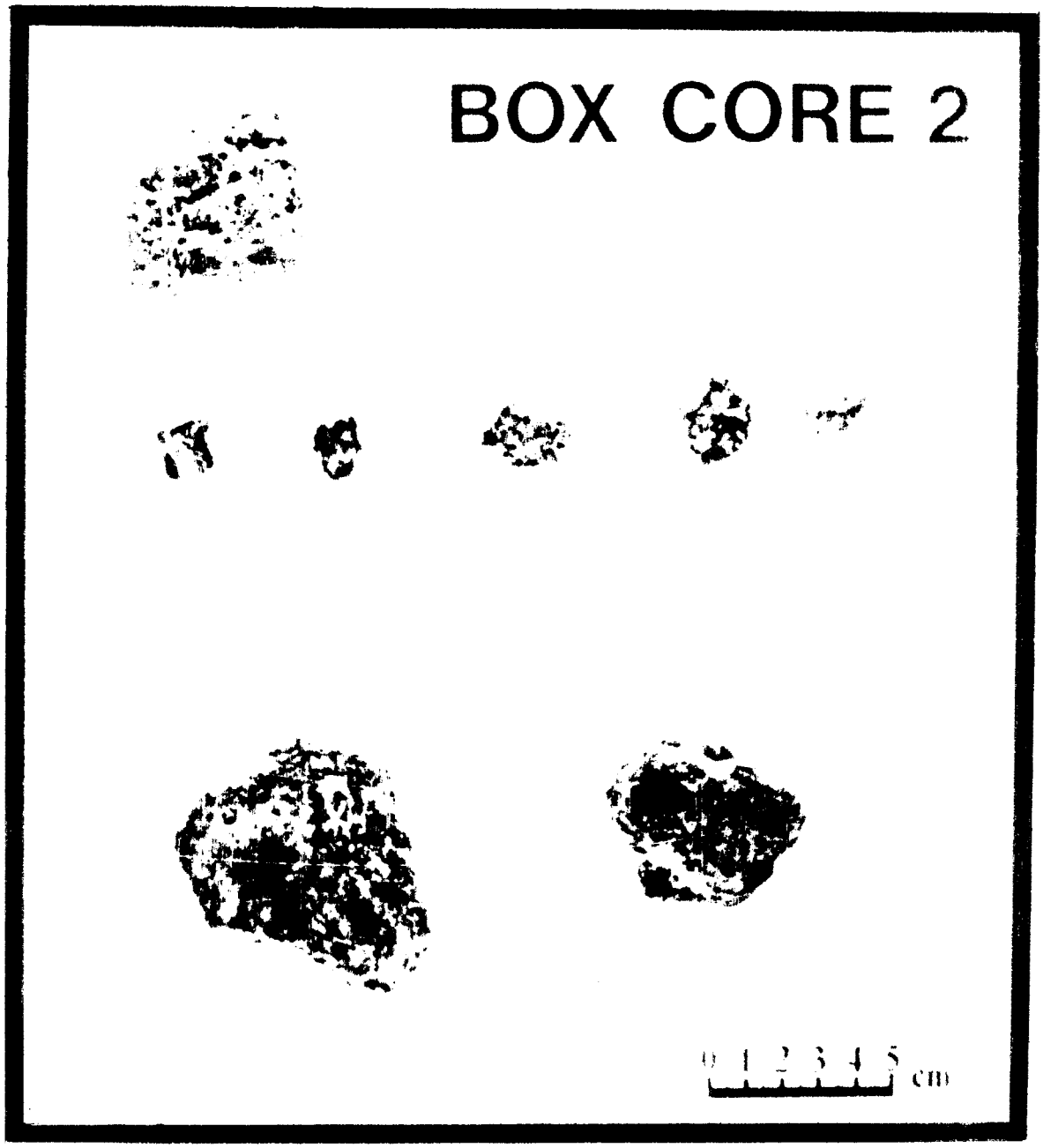


Figure 19.

STATION: 005 SAMPLE NO.: B-2 [Buried Nodules]

NODULE TYPES: 14% l[E]r, 14% l[F]r, 43% s[D]b-r, 14% s[P]b, 14% s[F]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	3	2	1	1	0	7	4*
Weight (Kg)	0.01	0.02	0.12	0.28	0	0.43	0.02

(weights of fragments and three smallest size classes estimated)

SIZE RANGE OF MAX. DIAM.: 10-88 mm (largest are 88 x 55 x 48 mm and 61 x 55 x 50 mm)

PRIMARY MORPHOLOGY:
Largest is ellipsoidal, next largest is polygonal, as is one of the smaller nodules. Three nodules, including the smallest, are discoidal. One is botryoidal.

SECONDARY MORPHOLOGY: Largest ellipsoidal is faceted, but not to the extent of the polygonal nodule, which is almost a square. Discoidals range from thick and lobed to elongate tabular-discoidal.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (a botryoidal nodule 20 mm max. dia.)

SURFACE TEXTURE:

_____ Surface: } Microgranular to granular to friable granular superimposed (on all but the largest nodule) on poorly-developed botryoids. Smallest nodule has smooth botryoidal surface.

_____ Surface: }

{ Nodule tops and bottoms not identifiable. On largest nodule, part of surface is mostly covered with cream carbonate ooze, remainder by brown clay--as if nodule was sitting at boundary of sediment types.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	- - - -	Botryoidal →	— Granular →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ↔		Botryoidal ← →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 1 cm

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Largest nodule fractured during removal from sediment; light yellow-brown clay on fracture surface. *Frags. 7.5 to 30 mm max. dimension from unknown number of nodules; location in core relative to whole nodule not known. Nodules probably mostly from 30-35 cm depth in core.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 2°53.9'N

LONG. W.: 150°56.4'W

WATER DEPTH: ∿4600 m

STATION: 005

SAMPLE NO.: FFG-013

DATE: 25-26 July 1974

TIME: LAUNCH 1923Z

ON BOTTOM _____

RECOVER 0039Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just north of Clipperton Fracture Zone abyssal plain with relief mostly <10 m.

SPECIFIC BATHYMETRIC LOCATION:

Near crest (?) of 450 m abyssal hill surrounded by nearly flat abyssal plain.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC-003 (recovered with FFG-013)

Type: Light brown foram ooze

NODULE TYPES IN THIS SAMPLE:

No nodules recovered; grab recovered only a mini-core.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 2°55.0'N

LONG. W.: 150°58.5'W

WATER DEPTH: 4710 m

STATION: 005

SAMPLE NO.: FFG -014

DATE: 25-26 July 1974

TIME: **LAUNCH** 2000Z

ON BOTTOM _____

RECOVER 0032Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just north of Clipperton Fracture Zone; abyssal plain relief mostly <10 m.

SPECIFIC BATHYMETRIC LOCATION:

Upper flank of 450 m abyssal hill surrounded by nearly flat abyssal plain.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFGMC -003 (collected with FFG -013), Box Core # 2, or FFC -005.

Type: Probably foram ooze/clay.

NODULE TYPES IN THIS SAMPLE:

s[D]r,	s[T]s-r,	s[B]s
(1)	(1)	(1)

72

STATION: 005 SAMPLE NO.: FFG -014

NODULE TYPES: 33% s[D]r, 33% s[T]s-r, 33% s[B]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	3	0	0	0	0	3	0
Weight (Kg)	0.01	0	0	0	0	0.01	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 12, 12, 12 mm

PRIMARY MORPHOLOGY: Discoidal; tabular; and Mn-encrusted vertebra (?), respectively.

SECONDARY MORPHOLOGY: Discoidal nodule is 3-cornered; tabular nodule is curled.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface: } Microgranular to granular
_____ Surface: }

{ Upper & lower surfaces cannot be distinguished. On discoidal nodule, granule clusters approximate a botryoidal form.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		←	—	—	→
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	—	→		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Prominent worm tubes on discoidal and tabular nodules.

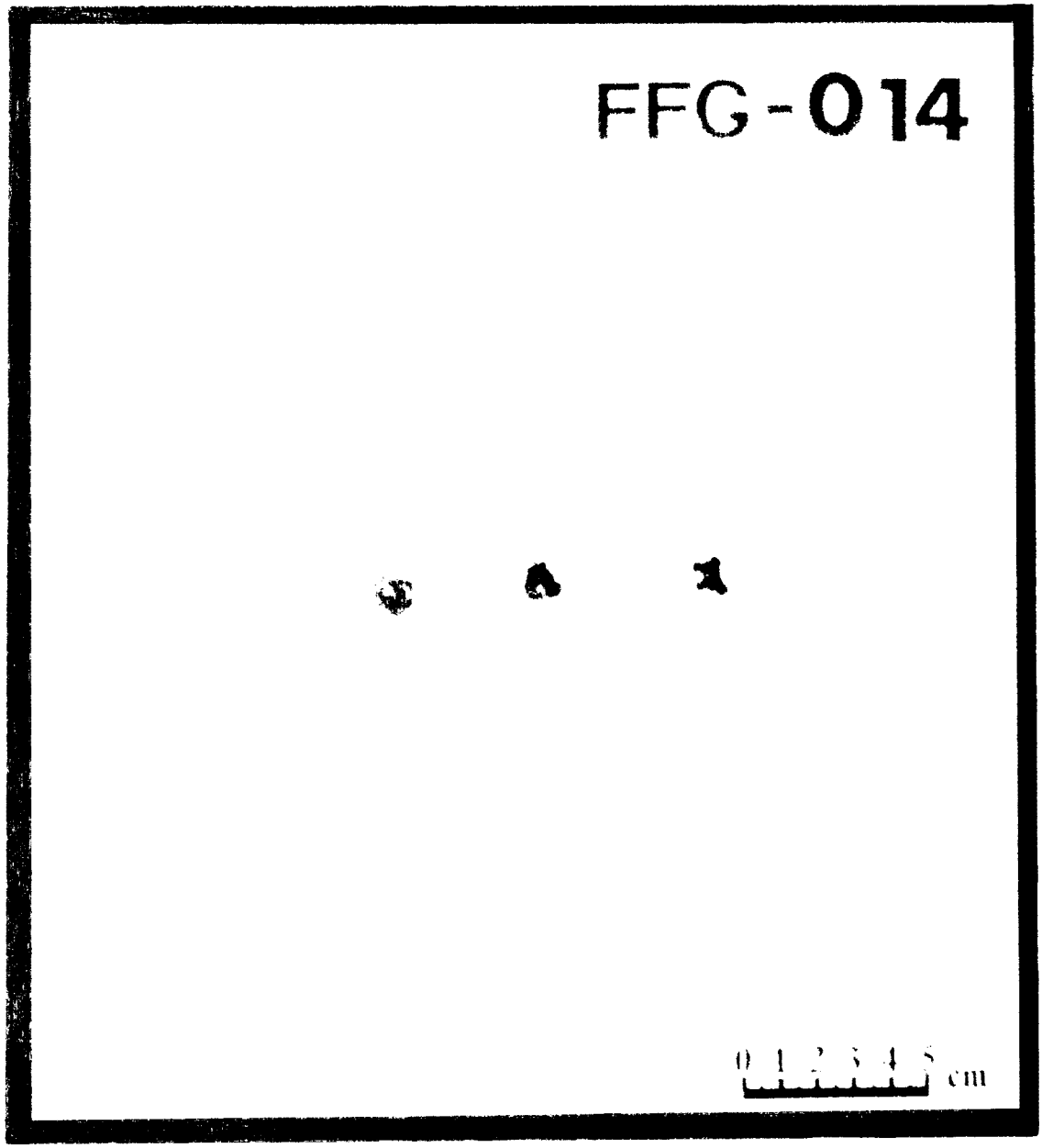


Figure 20.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 005

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -015

LAT. N.: 2°56.3'N

DATE: 25-26 July 1974

LONG. W.: 151°00.6'W

TIME: LAUNCH 2124Z

WATER DEPTH: 5025 m

ON BOTTOM _____

RECOVER 0139Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just north of Clipperton Fracture Zone; abyssal hill surrounded by nearly flat abyssal plain.

SPECIFIC BATHYMETRIC LOCATION:

Near base of 450 m abyssal hill surrounded by nearly flat abyssal plain.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to Box core #2 or FFC -005.

Type: Probably foram ooze/clay

NODULE TYPES IN THIS SAMPLE:

m[D]s-r,	s-m[P]s-r,	m[E]s-r
(11)	(7)	(5)

STATION: 005 SAMPLE NO.: FFG -015

NODULE TYPES: 48% m[D]s-4, 30% s-m[P]s-r, 22% m[E]s-4

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	23	0	0	0	23	33*
Weight (Kg)	0	0.45	0	0	0	0.45	0.35

SIZE RANGE OF MAX. DIAM.: 28-58 mm (frags. up to 43 mm max. diameter)

PRIMARY MORPHOLOGY: Discoidal and ellipsoidal

SECONDARY MORPHOLOGY: Discoids range from thick (approx. flattened spheroids) to thin (approx. tabular-discoidal). Some ellipsoids reniform. All shapes, esp. ellipsoidals, have incipient to well-developed lobes. Few bottoms flattened.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: 7 (6 are 2-poly and 1 is 3-poly, although the 3-poly looks like nodule that was fractured and the segments regrown together).

SURFACE TEXTURE:

Upper Surface: } Microgranular to granular
Lower Surface: }

{ Upper and lower surfaces distinguishable only on a few larger nodules. Lower surfaces & equatorial belts have roughest surface textures.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		←	— — —	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm

COLOR OF NODULE STREAK: Dark brown to black

COMMENTS: * Number of frags. includes all frags. >1 cm max. diam. Frags. probably represent about 8-12 whole nodules. Several frags. obviously the result of sea-floor processes, as fracture surfaces are partly Mn-encrusted.

- cont. -

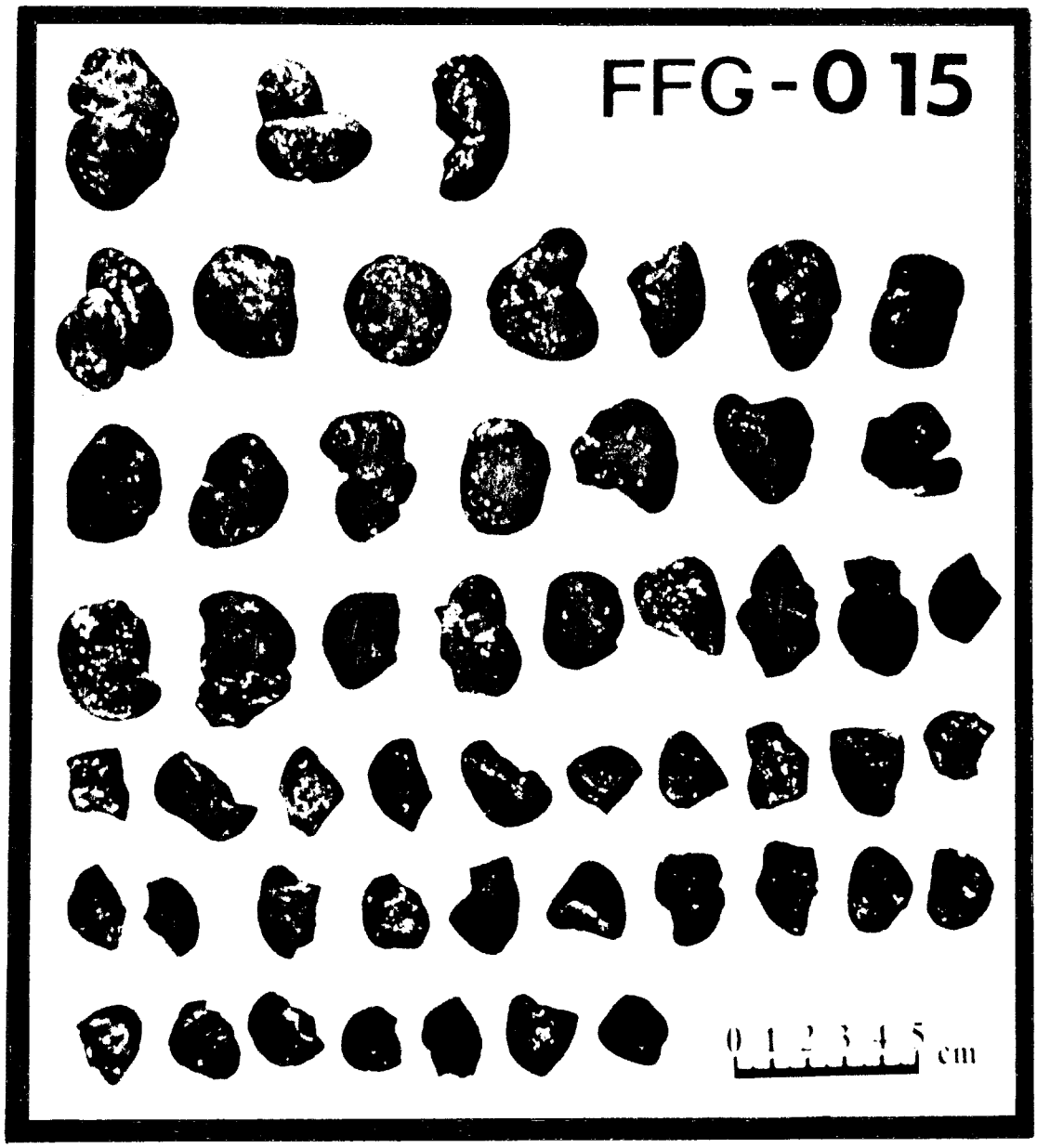


Figure 21.

COMMENTS: - cont. -

At least two of the "whole" nodules have had fracture surfaces completely re-encrusted with Mn.

Only a few worm tubes are present, and these are mostly restricted to equatorial belts and crevasses between lobes.

STATION SUMMARY

STATION: 06

TIME ON STATION: 28/7/74 0231Z

LATITUDE: 9°00'N

TIME DEPART STATION: 30/7/74 0044Z

LONGITUDE: 146°30'W

SEDIMENT TYPE: Siliceous ooze/red clay

OPERATIONS: FFG #16, 17, 18, 19 28/7/74 0352Z - 0904Z

Water cast #3 (Table 3) 28/7/74 0920Z - 1400Z

Box core #4 winch ran away, two-blocked corer - lost box corer

FFG #20, 21, 22, 23 28/7/74 1836Z - 29/7/74 0004Z

Camera #2 29/7/74 0100Z - 0544Z camera malfunction, no photos

FFG #24, 25, 26, 27 29/7/74 0613Z - 1202Z

FFC #5, 6, 7, 8 - core tube lost on #6 (spheres recovered)

Water cast #4 (Table 4) 29/7/74 1227Z - 1630Z

Water cast #5 (Table 5) 29/7/74 2100Z 30/7/74 0044Z

DISCUSSION:

This is the best-documented station of the cruise. The area has low relief of 100 m with average depth near 5200 m (Figure 22, track control-Figure 23). The general topographic trend is NW-SE with greatest depths to south, and the most clearly defined hill to NE. Essentially, one hill (5150 - 5100 m) and a series of en echelon basins (5200 -5250 m) occur within the station area. Three sets of grabs (12 total were dropped) at a 2-mile spacing sampled the area. Densest nodule cover is near the center of the area - FFG 23 - but there it consists of smooth-faceted-type nodules at >50% cover; by contrast, all other grabs recovered small to large discoidal/ellipsoidal nodules with finely botryoidal surfaces (Figure 24-25). Nodule densities ranged from 3.75 - 9 kg/m^2 along the northern transect. Along the two N-S transects values ranged from 3.1 - 18.1 kg/m^2.

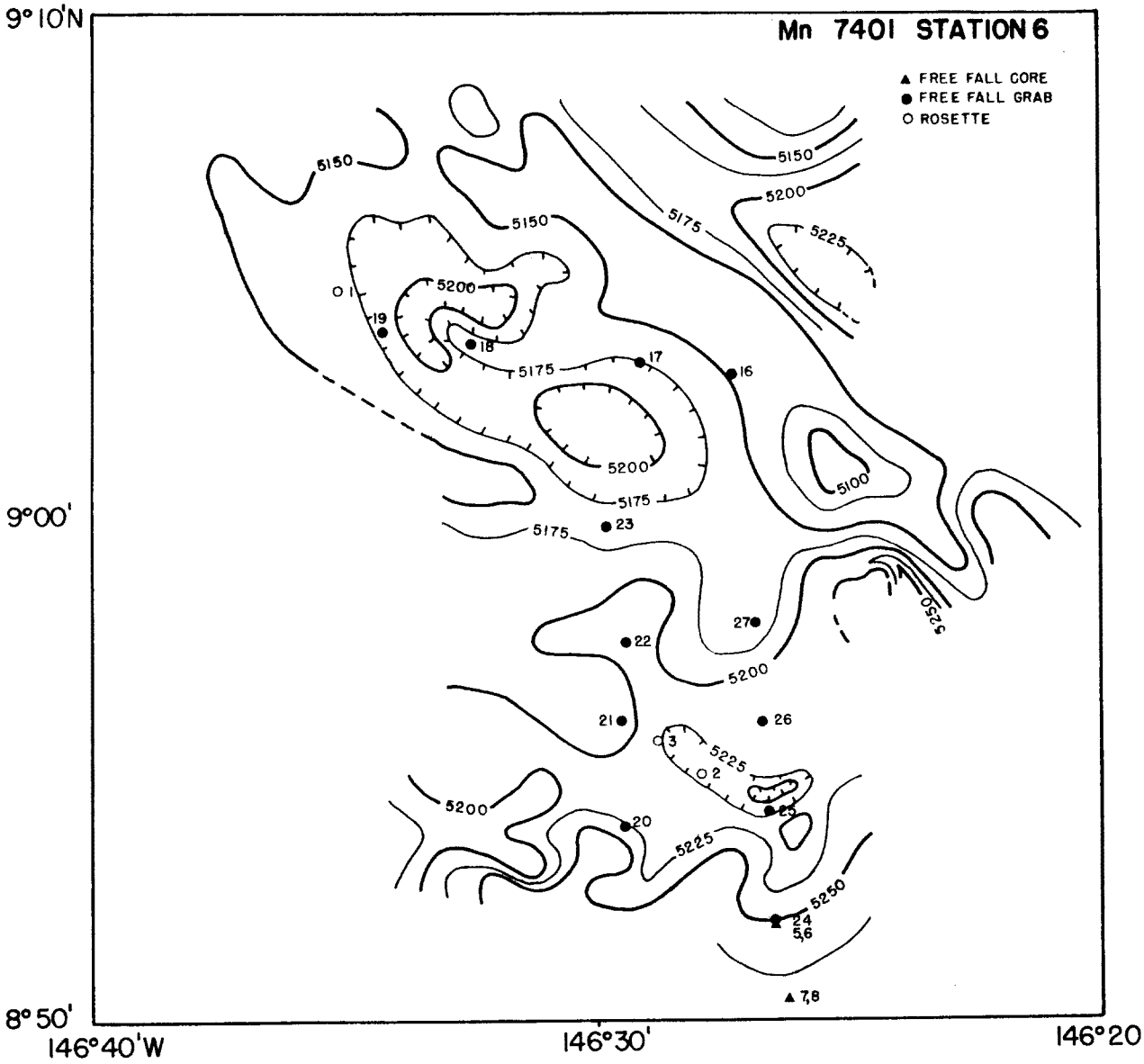


Figure 22.

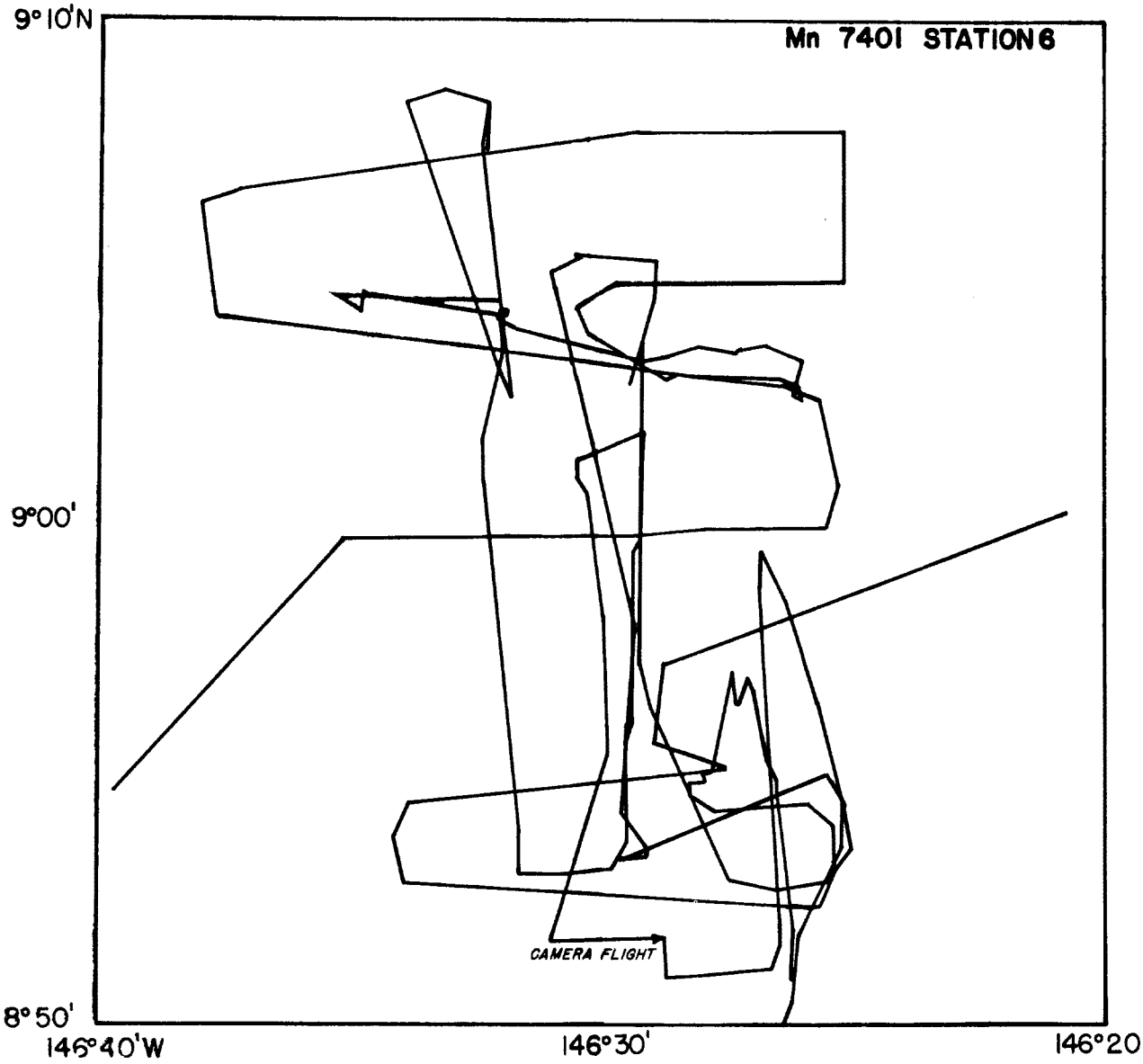

9°10'N
Mn 7401 STATION 6
9°00'
8°50'
146°40'W
146°30'
146°20
CAMERA FLIGHT

Figure 23.

TABLE 3: STATION NO. 6 - ROSETTE CAST #3

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
1-1	5184					10		
1-2	5084	4.02	34.674		136	100		
1-3						300		
1-4	4584	4.11	34.668		154	560		
1-5	4284	3.89	34.685		138	935		
1-6	4004	3.79	34.670		131	1280		
1-7	1225	1.61	34.557		121			
1-8	1022	1.41	34.536		105			
1-9	719				82			
1-10	415	1.35	34.615		51			
1-11	1022	.50			103			

TABLE 4: STATION NO. 6 - ROSETTE CAST #4

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
2-1	5215	3.95	34.689			4		Ex
2-2	5215					4		Ex
2-3	5215	4.02	34.683			4		Ex
2-4	5215					4		Ex
2-5	2568							Ex
2-6	2568	2.67	34.673					Ex
2-7	2568							Ex
2-8	2568	2.65	34.622					Ex
2-9	15							Ex
2-10	15	5.38	34.288					Ex
2-11	15	5.27	34.291					Ex

TABLE 5: STATION NO. 6 - ROSETTE CAST #5

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica. µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
3-1	5234	3.96	34.681			10		TM
3-2	5234					10		TM
3-3	5234	3.92	34.679			10		TM
3-4	5134					105		TM
3-5	5134	4.01	34.707			105		TM
3-6	5134	4.02	34.685			105		TM
3-7	4743							TM
3-8	4743	3.95	34.677					TM
3-9	4743							TM
3-10	4241							TM
3-11	4241	3.89	34.688					

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 9°02.8'N

LONG. W.: 146°27.4'W

WATER DEPTH: 5150 m

STATION: 006, FFG run #1

SAMPLE NO.: FFG -016

DATE: 28 July 1974

TIME: **LAUNCH** 0355Z

ON BOTTOM _____

RECOVER 0803Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly low, rolling abyssal hills with relief <50 m; occasional abyssal hill of a few hundred meters relief.

SPECIFIC BATHYMETRIC LOCATION:

Flank 100-150 m abyssal hill. Good bottom reflection; 5 m sub-bottom penetration.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFGMC-004A,B (recovered with FFG -017).

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

$s\text{-}1[D]_{r}^{r-b}$, $s[S]r$, $s\text{-}m[E]r$
(4) (4) (3)

STATION: 006 SAMPLE NO.: FFG -016

NODULE TYPES: 36% s-l[D]$_r^{r-b}$, 36% s[S]r, 27% s-m[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	7	1	2	1	0	11	0
Weight (Kg)	0.04	0.05	0.14	0.12	0	0.35	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 9-65 mm

PRIMARY MORPHOLOGY: Three largest (65, 57, 45 mm max. diam.) are discoidal; next two largest (38, 23 mm max. diam.) are ellipsoidal; next (20 mm) is discoidal; next (18 mm) is ellipsoidal; all smaller spheroidal.

SECONDARY MORPHOLOGY: Rough botryoidal surface constitutes principal deviation from ideal shapes. Largest ellipsoidal approximates a discoid.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: } Microgranular to granular on suppressed to well-developed botryoids. Granular to coarsely granular superimposed on poorly developed botryoids. } High relief botryoids on equatorial belt, esp. on larger nodules. Upper & lower surfaces can be distinguished on most nodules

Lower Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Upper & Lower Surfaces →		← Equatorial Belt →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ← →		Botryoids ← →		

ABSOLUTE DIAM. OF MAMMILLAE: << 1 mm to 1 cm (largest being on largest nodule)

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Fairly abundant worm tubes and other organic remains, esp. in equatorial regions. Sample includes several pieces of poorly consolidated sediment, probably a clayey siliceous ooze, mottled beige and dark gray brown.

- cont. -

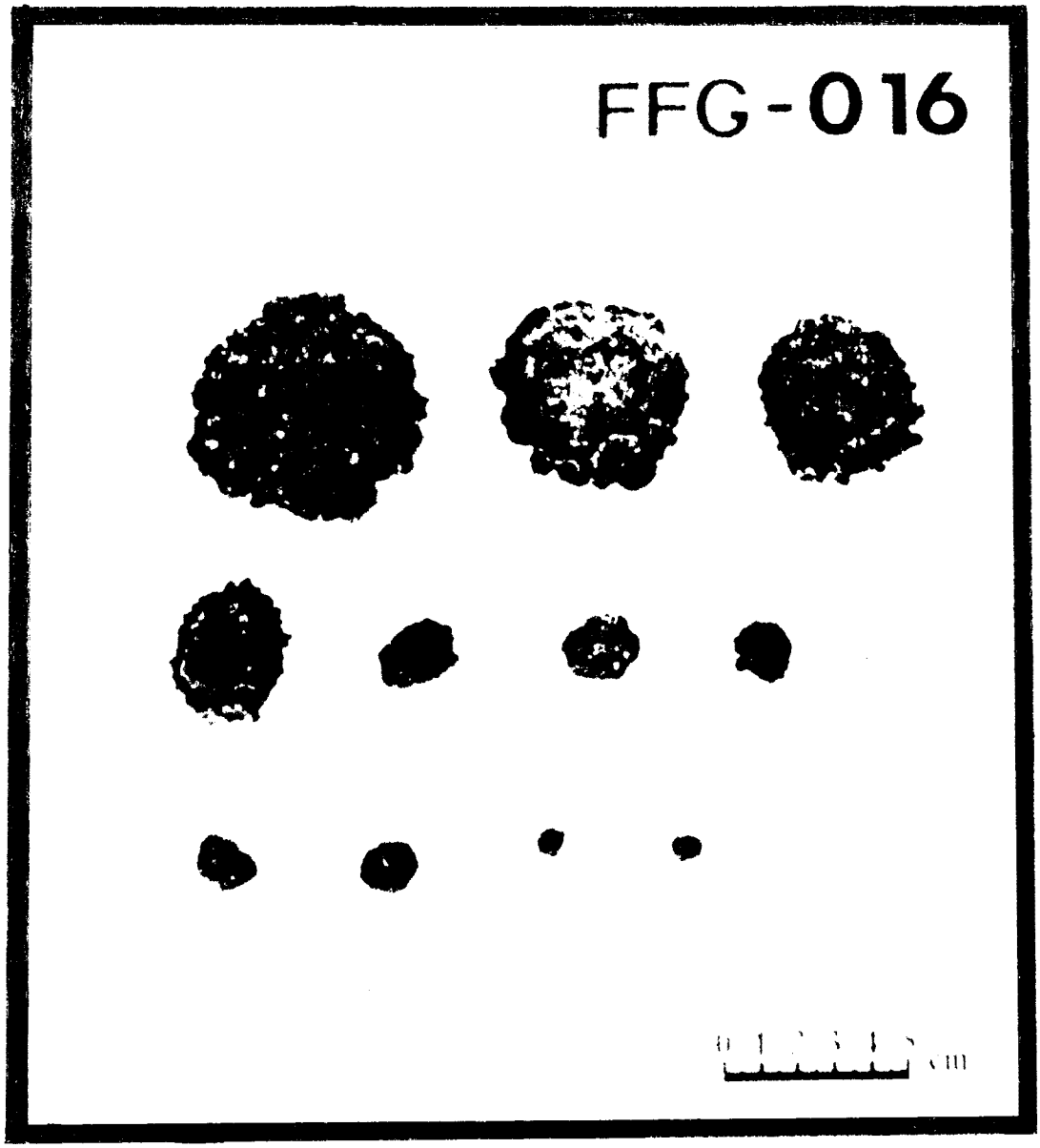


Figure 24.

COMMENTS: - cont. -

One small beige fragment better consolidated than others. Possible nodule nucleation sites.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 9°03.0'N

LONG. W.: 146°29.2'W

WATER DEPTH: 5180 m

STATION: 006, FFG run #1

SAMPLE NO.: FFG -017

DATE: 28 July 1974

TIME: LAUNCH 0405Z

ON BOTTOM _____

RECOVER 0818Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly low rolling abyssal hills with relief <50 m; occasional abyssal hill of a few hundred meters relief.

SPECIFIC BATHYMETRIC LOCATION: Flank of 100-150 m abyssal hill/ridge. Good bottom reflection; sediment minimum thickness probably about 10 m.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -004A, -004B (recovered with FFG -017)

Type: Clayey siliceous ooze, mottled light brown and gray brown.

NODULE TYPES IN THIS SAMPLE:

s-m[P]s-r, s-m[D]$^{s}_{b}$-r, s-m[E]s-r, s[S]s-r
(25) (24) (23) (16)

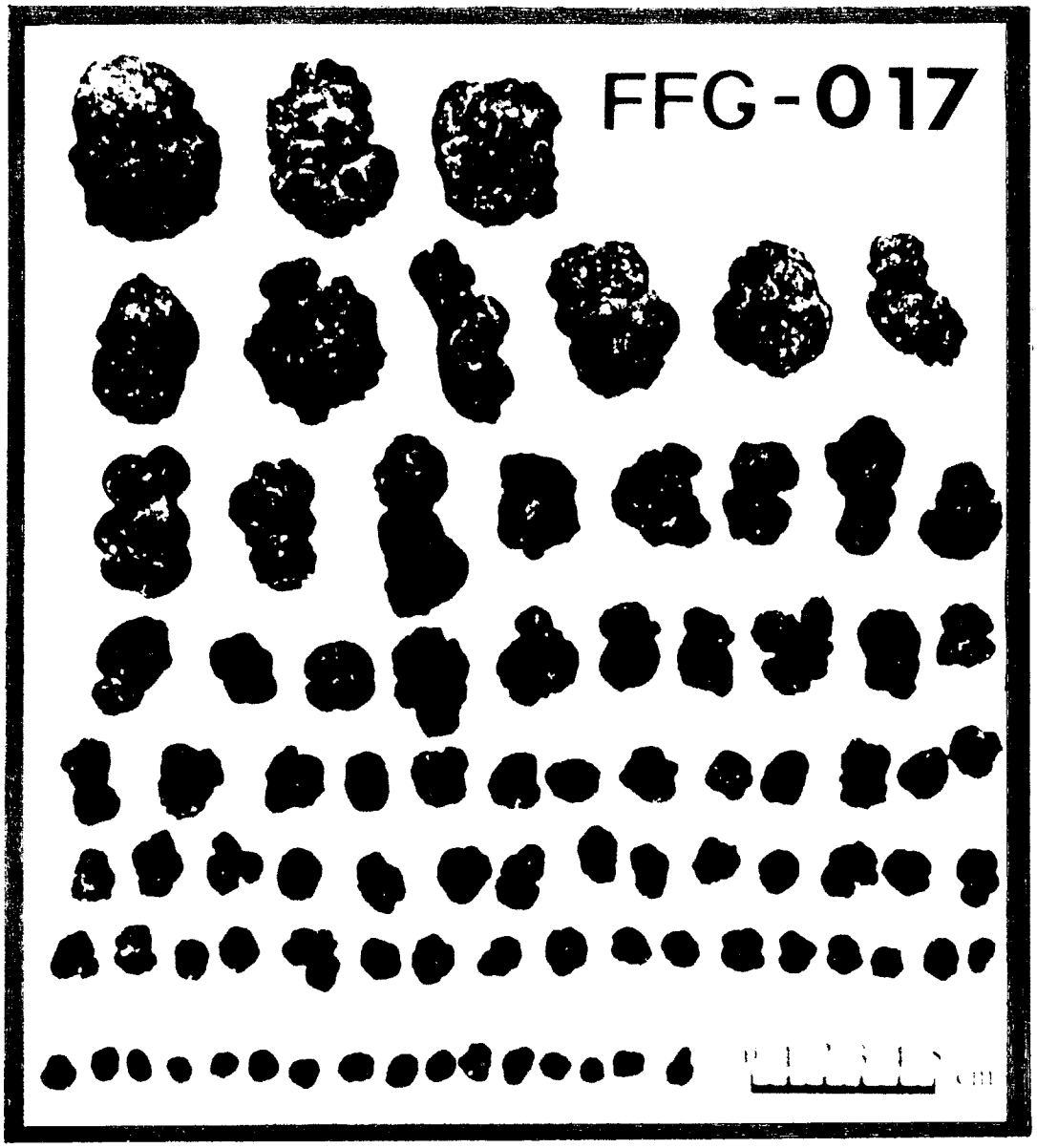


Figure 25.

STATION: 006 SAMPLE NO.: FFG -017

NODULE TYPES: 28% s-m[P]s-r, 27% s-m[D]$^{s}_{b-r}$, 26% s-m[E]s-r, 18% s[S]s-r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	64	22	2	0	0	88	0
Weight (Kg)	0.10	0.45	0.15	0	0	0.70	0

SIZE RANGE OF MAX. DIAM.: 7-53 mm

PRIMARY MORPHOLOGY: Largest are discoidal or coalespheroidal, with some ellipsoidal. Intermediate sizes almost all coalespheroidal or botryoidal; smallest mostly spheroidal, with a few ellipsoidal.

SECONDARY MORPHOLOGY: Most nodules have incipient to well-developed lobes, development grading to point where nodules are considered as coalespheroidal. Additionally, many nodules with satellite protrusions or agglutinated spheres.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: 25 nodules of intermediate size (14-49 mm max. diam.), mostly 2-poly, but botryoidal forms multi-sphered.

SURFACE TEXTURE:

Upper Surface: Micrognanular
Lower Surface: Granular

Upper & lower surfaces distinguishable on many larger nodules. Smaller nodules have more uniform texture. Granular textures superimposed on botryoidal surfaces of some larger nodules. Some equatorial belts coarsely granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Granular →		← Botryoidal →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	← Granular →		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm - 18 mm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Sample includes one rounded gray-brown pumice frag., 11 mm max. diam. Prominent worm tubes on many nodules. Shark tooth frag. embedded in shell-like structure adhering to one small nodule.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 9°03.4'N

LONG. W.: 146°32.5'W

WATER DEPTH: 5155 m

STATION: 006, FFG run #1

SAMPLE NO.: FFG -018

DATE: 28 July 1974

TIME: **LAUNCH** 0424Z

ON BOTTOM _____

RECOVER 0904Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly low, rolling abyssal hills with relief 50 m; occasional abyssal hill of a few hundred meters relief.

SPECIFIC BATHYMETRIC LOCATION:

Near crest of 50 m abyssal hill. Good bottom reflection; no apparent sediment penetration.

ASSOCIATED SEDIMENT--

Sample No.: None at this site. Refer to FFGMC -004 A,B (from FFG -017) or FFGMC -007 (from FFG -023)

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

s-m[E]r-b,	s-m[D]r-b,	s[S]r-b,	s[P]r-b
(6)	(6)	(6)	(1)

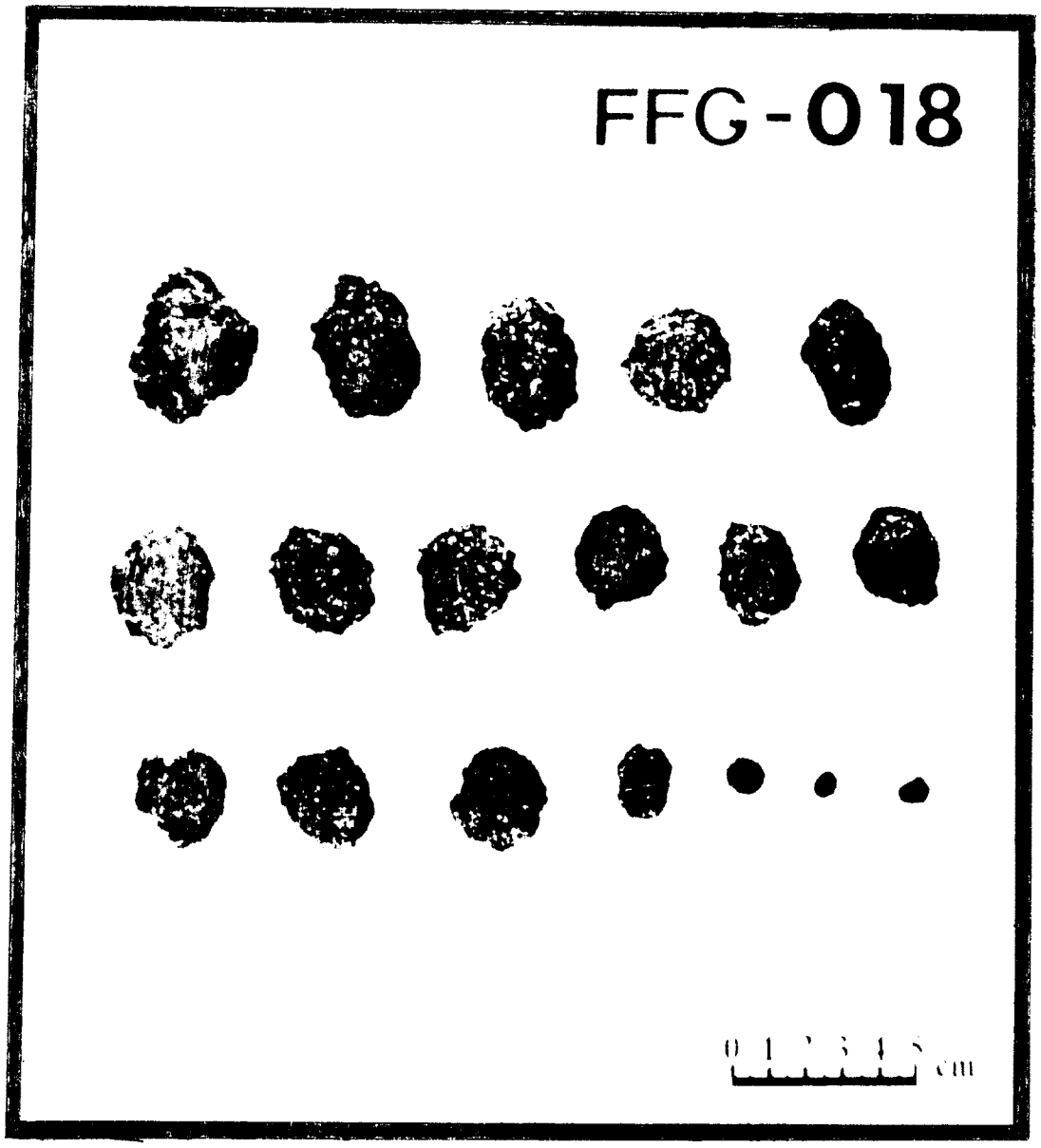


Figure 26.

STATION: 006 SAMPLE NO.: FFG -018

NODULE TYPES: 32% s-m[E]r-b, 32% s-m[D]r-b, 32% s[S]r-b, 5% s[P]r-b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	4	15	0	0	0	19	0
Weight (Kg)	0.02	0.28	0	0	0	0.30	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 8-44 mm

PRIMARY MORPHOLOGY: Spheroidal (incl. the 3 nodules <1 cm max. diameter), discoidal, and ellipsoidal, with forms of some transitional between the 3 types.

SECONDARY MORPHOLOGY: Some ellipsoidals approximate discoids or flattened spheroids.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (is essentially an ellipsoidal nodule with smaller aggutinated bi-lobed ellipsoid).

SURFACE TEXTURE:

Upper Surface: Granular to friable coarsely granular.
Lower Surface: Granular.

Upper & lower surfaces distinguishable on most nodules. Granular texture superimposed on poorly-developed to well-developed botryoids on some nodules; highest relief in equatorial belts.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Granular		← Botryoids →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ← →	← →	← Botryoids →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to 8 mm.

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Sample includes a few small frags of partly consolidated beige siliceous ooze, as well as one 9 mm max. diam. subround gray-brown pumice frag. partly Mn-stained. Prominent worm tubes on most nodules, particularly in crevasses.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 9°03.7'N

LONG. W.: 146°34.3'W

WATER DEPTH: 5175 m

STATION: 006, FFG run #1

SAMPLE NO.: FFG -019

DATE: 28 July 1974

TIME: **LAUNCH** 0434Z

ON BOTTOM _____

RECOVER 0904Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly low rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Mound in depression between small abyssal hills. Good bottom reflection; no apparent sediment penetration.

ASSOCIATED SEDIMENT--

Sample No.: None at this site. Refer to FFGMC -004A, B (from FFG -017) or FFGMC -007 (from FFG -023).

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]b,	s[S]r,	s[P]r,	s[E]r,	s[B]r
(2)	(4)	(1)	(1)	(1)

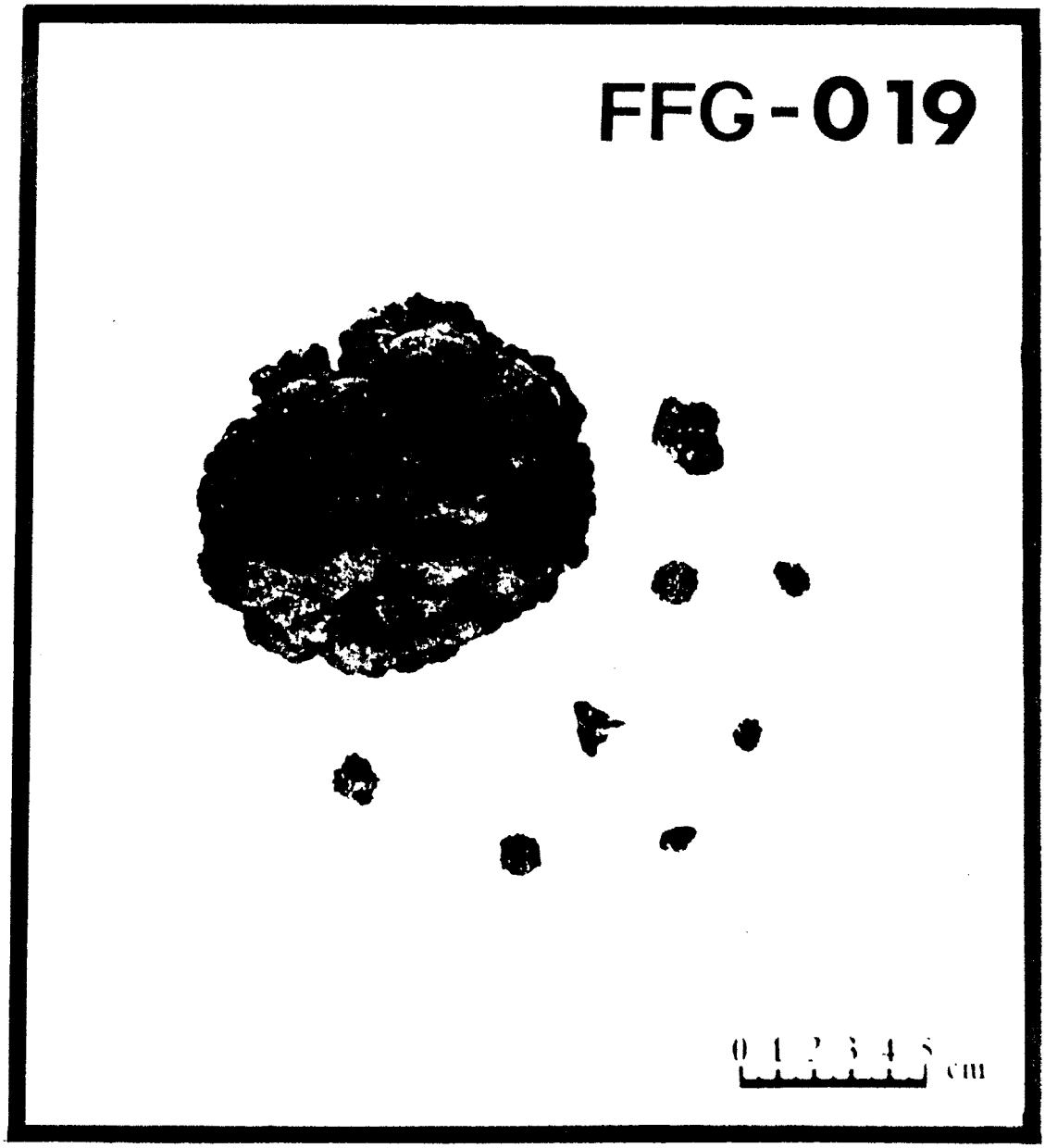


Figure 27.

STATION: 006 **SAMPLE NO.:** FFG -019

NODULE TYPES: 22% 1[D]b, 44% s[S]r, 11% s[P]r, 11% s[E]r, 11% s[B]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	7	0	0	1	1	9	1
Weight (Kg)	0.02	0	0	0.15	0.55	0.72	0.001

(weights of frag. and <20 mm fraction estimated)

SIZE RANGE OF MAX. DIAM.: 10-107 mm (largest if 107 x 90 x 63 mm)

PRIMARY MORPHOLOGY: Two largest (107 & 74 mm max. diams.) are discoidal. Next largest (23 mm) is botryoidal; 4 of smallest are spheroidal, one is ellipsoidal, and one is encrusted shark's tooth.

SECONDARY MORPHOLOGY: Bottoms of large discoids more convex than tops, i.e., they approximate "mushroom" discoids.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (botryoidal - poly-poly)

SURFACE TEXTURE:

Upper Surface: 107 mm nodule-Microgranular on botryoidal; 74 mm nodule-Granular to coarsely granular on poorly developed botryoidal.

Lower Surface: 107 mm nodule-Granular on botryoidal; 74 mm nodule-Granular on botryoidal.

Upper & lower surfaces of smaller nodules indistinguishable. They have a more uniform granular surface texture, with some granular clusters resembling botryoids.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		← Botryoids →			
		← Granular & Granule Clusters →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE			← Botryoids →		
		← Granular & Clusters →			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to 3 cm.

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Worm tubes prominent on all nodules, but mostly restricted to equatorial belts of two largest nodules. Sample includes one 11 mm max. diam. rounded yellow-brown volcanic frag., partly Mn-stained.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 8°53.8'N

LONG. W.: 146°29.5'W

WATER DEPTH: 5225 m

STATION: 006, FF run #2

SAMPLE NO.: FFG -020

DATE: 28 July 1974

TIME: LAUNCH 1836Z

ON BOTTOM ____

RECOVER 2253Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Middle slope of 50 m abyssal hill group. Good bottom reflection; sediment penetration not obvious.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -005 (from FFG -020)

Type: Beige clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

s-1[D]b-r,	s[E]b,	s[D]s,	s[P]r
(13)	(1)	(1)	(1)

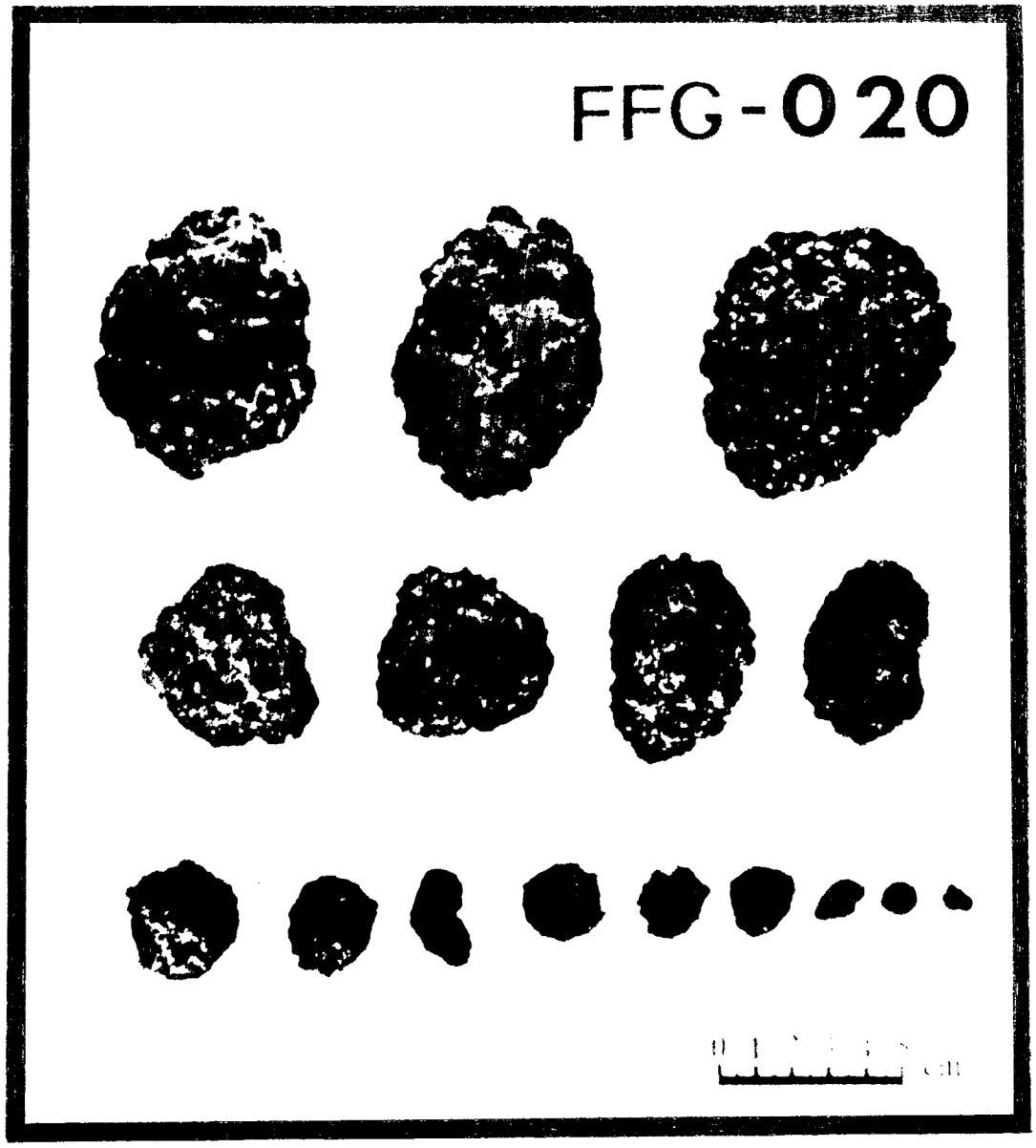


Figure 28.

STATION: 006 SAMPLE NO.: FFG -020

NODULE TYPES: 81% s-1[D]b-r, 6% s[E]b, 6% s[D]s, 6% s[P]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	4	4	7	1	0	16	1
Weight (Kg)	0.05	0.15	0.75	0.20	0	1.15	0.01

(sub-sample wts. for <40 mm sizes estimated)

SIZE RANGE OF MAX. DIAM.: 10-77 mm

PRIMARY MORPHOLOGY: Most nodules in all size ranges are discoidal, with the remainder being ellipsoidal.

SECONDARY MORPHOLOGY: Many discoids approximate flattened ellipsoidals. Several nodules have incipient to fairly well-developed lobes. Bottoms of most discoidals more convex than tops.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (2-poly)

SURFACE TEXTURE:

Upper Surface: Microgranular to granular on supressed to well-developed botryoids.

Lower Surface: Granular, on some superimposed on poorly developed to well-developed botryoids.

Upper and lower surface easily distinguished on most larger nodules. Equatorial belts have highest relief, often with coarsely granular texture superimposed on well-developed botryoids. Smaller nodules more uniformly granular; smallest have microgranular surfaces.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Botryoids →				
	← Granular & Granule Clusters →				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE		← Botryoids →			
	← Granular & Clusters →				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to 2 1/2 cm.

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Sample includes one 16 mm max. diam. subround red-brown volcanic frag., almost completely stained or thinly encrusted with manganese. Prominent worm-tubes & organic structures on most nodules, especially on equatorial belts.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 8°55.9'N

LONG. W.: 146°29.6'W

WATER DEPTH: 5190 m

STATION: 006, FF run #2

SAMPLE NO.: FFG -021

DATE: 28 July 1974

TIME: LAUNCH 1851Z

ON BOTTOM _____

RECOVER 2311Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

On flat terrace between FFG -020 & -023. Fairly good bottom reflection, with possibly 25 m of acoustically transparent sediment.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -006 (from FFG -021)

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

s-m[D]r-b,	s-m[E]r-b,	s-m[P]r-b,	s[S]r-b
(9)	(9)	(6)	(5)

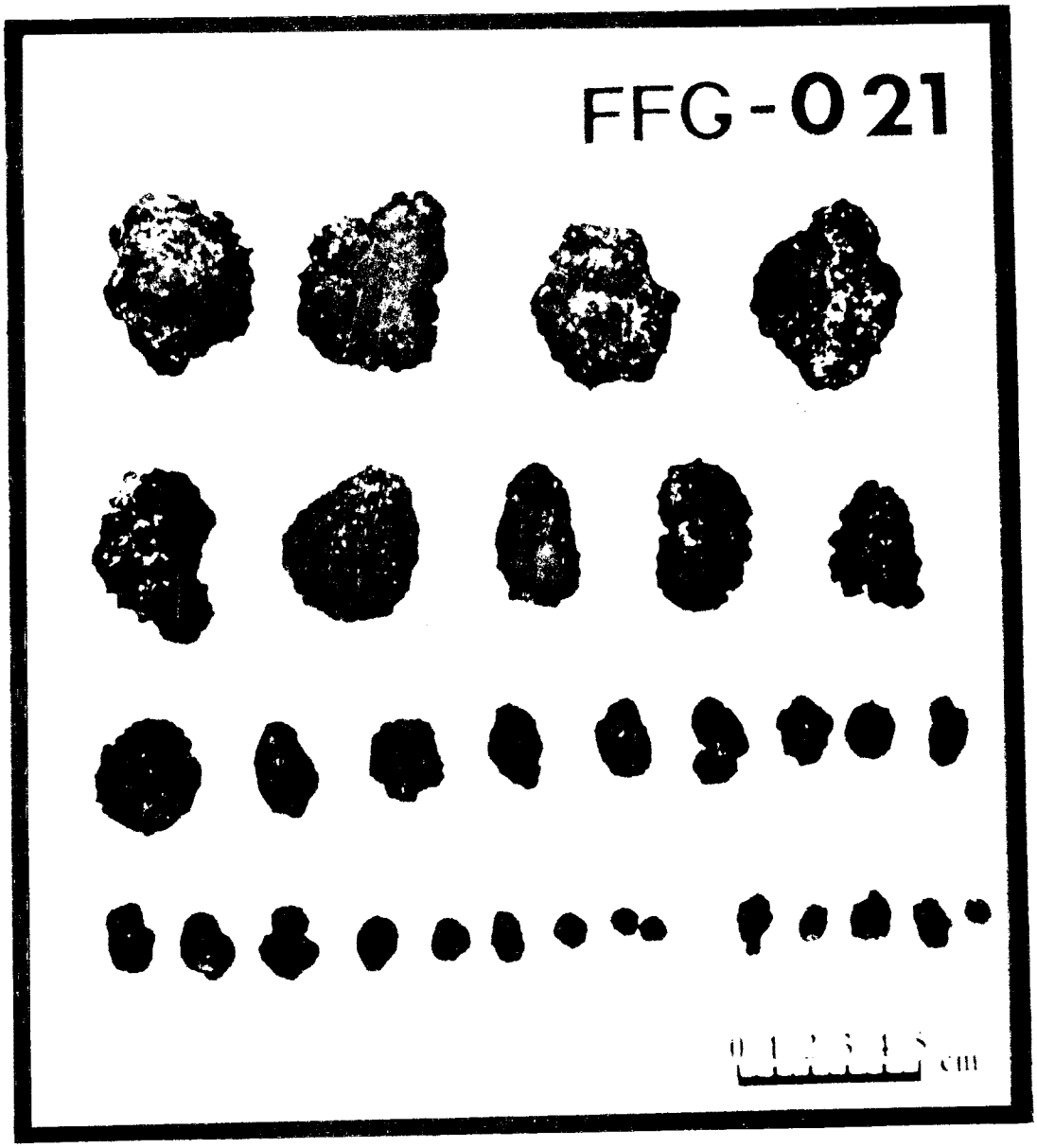


Figure 29.

STATION: 006 SAMPLE NO.: FFG -021

NODULE TYPES: 31% s-m[D]r-b, 31% s-m[E]r-b, 21% s-m[P]r-b, 17% s[S]r-b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	15	7	7	0	0	29	0
Weight (Kg)	0.05	0.10	0.35	0	0	0.50	0

(sub-sample wts. <40 mm estimated.)

SIZE RANGE OF MAX. DIAM.: 8-55 mm

PRIMARY MORPHOLOGY: Most of larger nodules are discoidal, a few are ellipsoidal Intermediate size (2-4 cm) mostly ellipsoidal. Smaller nodules primarily spheroidal.

SECONDARY MORPHOLOGY: Most discoidals and ellipsoidals have incipient lobes.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS:

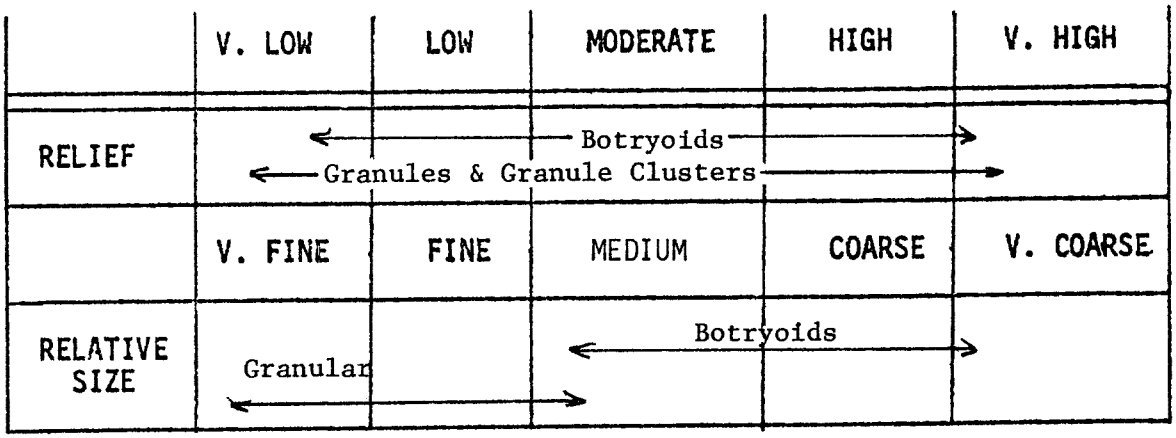
SURFACE TEXTURE:

Upper Surface: Micrograular to granular.

Lower Surface: Granular, sometimes on poorly developed botryoids.

Top and bottom distinguishable on most intermediate to large nodules. Roughest surface typically in equatorial belt, where a granular texture is superimposed on mostly well-developed botryoids. Surface roughness decreases with decreasing size--smallest nodules have micrograular surfaces.

CHARACTER OF SURFACE MAMMILLAE:



ABSOLUTE DIAM. OF MAMMILLAE: Mostly <1 mm to 1/2 cm.

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Sample includes 5 subangular to round volcanic frags., 9-19 mm max. diam., which are gray pumice and yellow-brown weathered pumice or basalt, unstained to nearly completely Mn-stained. Sample also includes one frag. of "organ pipe"

- cont. -

COMMENTS: -cont.-

growth. Worm tubes visible on most nodules (and on 3 volcanic rock frags.) esp. in equatorial belts and crevasses.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 006, FF run #2

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -022

LAT. N.: 8° 57.5'N

DATE: 28 July 74

LONG. W.: 146°29.5'W

TIME: LAUNCH 1907Z

WATER DEPTH: 5205m

ON BOTTOM _____

RECOVER 2330Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

On flat terrace between FFG -020 & -023. Fairly good bottom reflection; amount of transparent sediment not obvious.

ASSOCIATED SEDIMENT--

Sample No.: FFG -022

Type: Lumps of poorly consolidated beige siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

m[D]b, s-m[P]r-b, s[E]r
(1) (4) (4)

STATION: 006 SAMPLE NO.: FFG -022

NODULE TYPES: 11% m[D]b, 44% s-m[P]r-b, 44% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	5	4	0	0	0	9	0
Weight (Kg)	0.03	0.12	0	0	0	0.15	0

(sub-sample and total wts. estimated)

SIZE RANGE OF MAX. DIAM.: 11-46 mm

PRIMARY MORPHOLOGY: Largest nodule is discoidal; next 4 largest are coalespheroidal or botryoidal; smallest 4 nodules are ellipsoidal.

SECONDARY MORPHOLOGY: Segments of coalespheroidal or botryoidal nodules are discoidal, ellipsoidal, or spheroidal. Several nodules or nodule segments have incipient to well-developed lobes. Largest nodule discoidal.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Two (one 2-poly, one 3-poly) with additional prolate ellipsoidal, 14 mm max. diam., gray-brown pumice frag. agglutinated to upper surface.

SURFACE TEXTURE:

Upper Surface: Microgranular to granular.

Lower Surface: Granular (on largest nodule superimposed on botryoids)

} Tops and bottoms distinguishable on most of the larger nodules. Smaller nodules more uniformly granular. Roughest texture in equatorial belts, where granules are superimposed on a botryoidal ("knobby") surface.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Granular →	← Botryoids →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	← Granular →	← Botryoids →			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 1 cm.

COLOR OF NODULE STREAK: Vary dark brown to black.

COMMENTS: Worm tubes on all nodules, most prominent on smaller ones. Sample includes many small (≤2 cm) frags. of poorly consolidated sediment, speckled and impregnated with manganese; the sediment is beige siliceous ooze. May

-cont.-

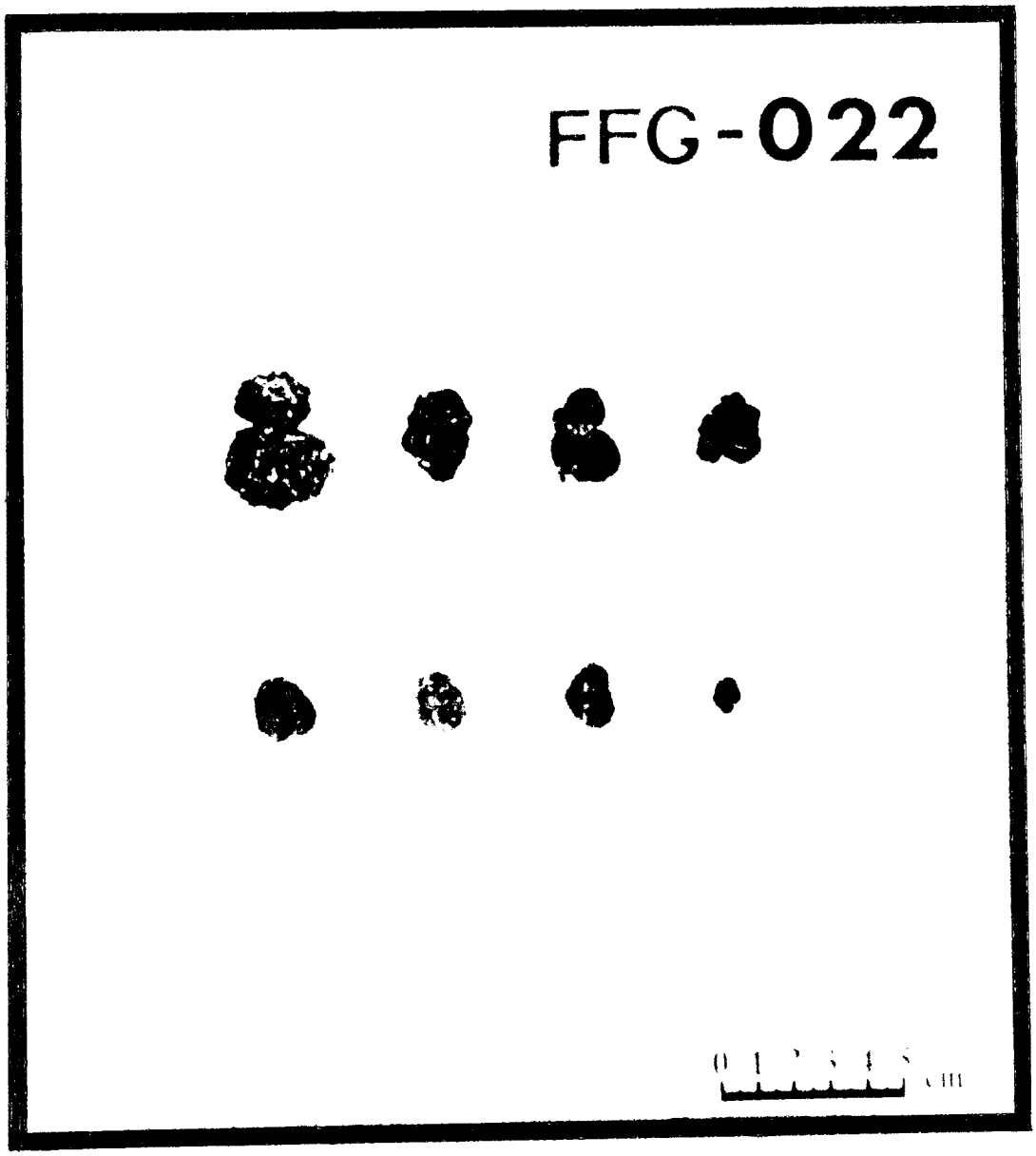


Figure 30.

COMMENTS: -cont.-

represent proto-nodules. Sample also includes many "organ pipe" clusters.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 8°59.8'N

LONG. W.: 146°29.8'W

WATER DEPTH: 5170 m

STATION: 006, FF run #2

SAMPLE NO.: FFG -023

DATE: 28-29 July 1974

TIME: **LAUNCH** 1923Z

ON BOTTOM _____

RECOVER 0004Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Crest of 25-40 m abyssal hill/ridge. Good bottom reflection; amount of transparent sediment not obvious.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -007 (from FFG -023)

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

$s\text{-}m[P]^{s}_{s-r}$ (19), $s\text{-}m[D]^{s}_{s-r}$ (19), $m\text{-}l[D]^{s}_{r-b}$ (9), $m[E]^{s}_{s-r}$ (6), $m\text{-}l[F]^{s}_{r}$ (4)

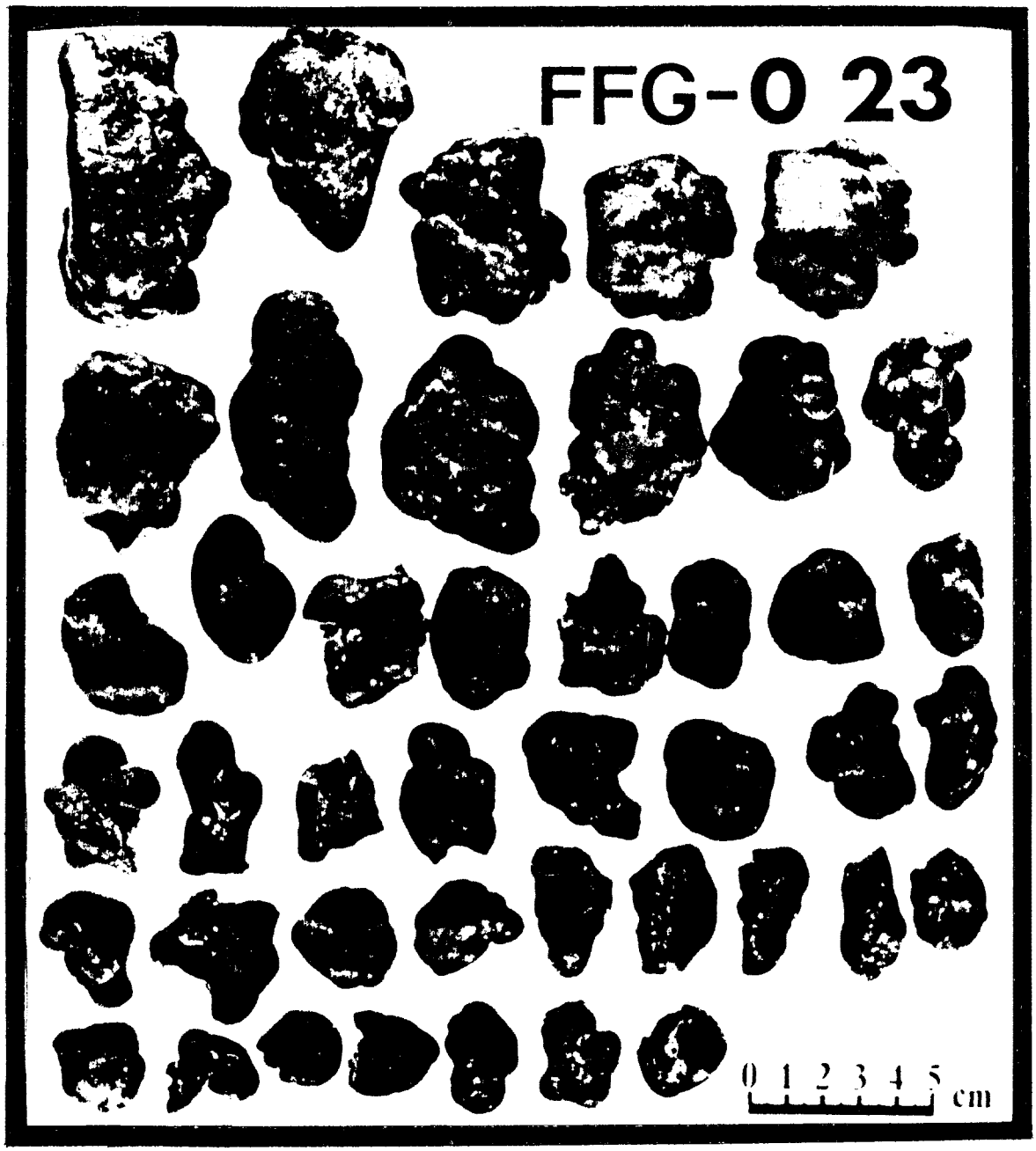


Figure 31.

STATION: 006 SAMPLE NO.: FFG -023

NODULE TYPES: 33% s-m[P]$^{s}_{s-r}$, 33% s-m[D]$^{s}_{s-r}$, 16% m-l[D]$^{s}_{r-b}$, 11%m[E]$^{s}_{s-r}$, 7% m-l[F]$^{s}_{r}$

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	14	33	10	0	0	57	33*
Weight (Kg)	0.15	0.60	0.70	0	0	1.45	0.25

(wt. of smallest size class estimated)

SIZE RANGE OF MAX. DIAM.: 12-82 mm

PRIMARY MORPHOLOGY: Largest nodules have most irregular shapes, being polygonal or distorted ellipsoids or discoids; one of largest size class is prolate ellipsoid. Most of intermediate size (20-40 mm) are ellipsoidal or coalespheroidal, some are discoidal. Smallest nodules are discoidal or ellipsoidal.

SECONDARY MORPHOLOGY: Most nodules and coalespheroidal segments have incipient to well-developed lobes, some quite irregular, and/or satellite protrusions or agglutinated spherules.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Nineteen (10 of intermediate size, and 8 of smaller size nodules), 13 being 2-poly, and the others 3- or 4-poly.

SURFACE TEXTURE:

Upper Surface: Smooth to microgranular, sometimes superimposed on suppressed botryoids.

Lower Surface: Granular, on some superimposed on suppressed to well-developed botryoids

Tops and bottoms of most large and intermediate size nodules readily distinguishable. Smaller nodules uniformly microgranular. Nodules in this FFG sample do not have roughest surfaces in equatorial belt. Septarian fractures sometime outline botryoids on upper surface.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Granular	Botryoidal →		→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ↔		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to about 1 cm.

COLOR OF NODULE STREAK: Very dark brown

COMMENTS: * Number of nodule frags. includes all frags. >1/2 cm; weight is total of all frags. This group includes nodules that have recently been fractured on the seafloor, and the fracture surfaces thinly re-encrusted. Several nodules

-cont.-

COMMENTS: -cont.-

fractured aboard ship. Septarian fracture pattern evident on surface of many nodules. Irregular shape of the majority of nodules probably due to multiple generations of fracturing and growth on seafloor. Nodule frags. probably represent 5-10 whole nodules. Largest frag. 46 mm max. diam. Very few worm tubes evident, and these are mostly in equatorial belts. Relative surface smoothness vs. lack of tubes: which is cause, which is effect?

Sample includes 6 discrete frags. of scoriaceous or angular yellow-brown to red-brown basalt, 10-23 mm max. diam., partly to nearly completely Mn-stained plus many more fragments of similar material adhering to nodule surfaces (upper and lower).

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 006

COLLECTION DEVICE: Free Fall Corer

SAMPLE NO.: FFC -005 (Core Top)

LAT. N.: 8°52.0'N

DATE: 28 July 1974

LONG. W.: 146°26.4'W

TIME: LAUNCH 0620Z

WATER DEPTH: 5250 m

ON BOTTOM _____

RECOVER 0813Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Lower slope of 75 m abyssal hill. (Note: Location and depth based on bathymetric map, but PDR record).

ASSOCIATED SEDIMENT--

Sample No.: FFC -005

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

s[E]r
(1)

STATION: 006 SAMPLE NO.: FFC -005

NODULE TYPES: 100% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	0	0	0	0	1	0
Weight (Kg)	0.015	0	0	0	0	0.015	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: ∿2 1/2 cm.

PRIMARY MORPHOLOGY: Ellipsoidal

SECONDARY MORPHOLOGY: Faceted--appears to be lengthwise quadrant of ellipsoid.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface:
} Appears granular { Top and bottom not identifiable.
_____ Surface:

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		←	—	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←	→			

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm?

COLOR OF NODULE STREAK: ————

COMMENTS: Nodule examined after it was frozen, hence detailed description not possible.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 006, FF run #3

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -024

LAT. N.: 8°52.0'N

DATE: 29 July 1974

LONG. W.: 146°26.4'W

TIME: **LAUNCH** 0620Z

WATER DEPTH: 5250 m

ON BOTTOM _____

RECOVER 1035Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Lower slope of 75 m abyssal hill. (Note: Location and depth based on bathymetric map, not PDR record.)

ASSOCIATED SEDIMENT--

Sample No.: FFC -005 and FFGMC -008 (from FFG -024)

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

$s\text{-}1[D]^{s}_{b\text{-}r}$ (19), $m\text{-}1[P]^{s}_{b\text{-}r}$ (3), $s\text{-}m[E]^{s}_{b\text{-}r}$ (2), $s[S]r$ (2)

STATION: 006 SAMPLE NO.: FFG -024

NODULE TYPES: 73% s-1$[D]^{s}_{b-r}$, 12% m-1$[P]^{s}_{b-r}$, 8% s-m$[E]^{s}_{b-r}$, 8% s[S]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	4	14	8	0	0	26	0*
Weight (Kg)	0.03	0.53	0.55	0	0	1.11	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 7-75 mm (largest nodule 75 x 60 x 34 mm discoid)

PRIMARY MORPHOLOGY: Large and intermediate size nodules mostly discoids, with a few coalespheroidal or ellipsoidal; smallest nodules ellipsoidal or spheroidal.

SECONDARY MORPHOLOGY: Most nodules have incipient, and a few have well-developed lobes. Some discoidals approximate flattened ellipsoidals. One large ellipsoidal is prolate. Some discoidal bottoms slightly more convex than tops. One 53 x 48 x 31 mm discoid squared off on one end, as if fractured and healed on seafloor.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS:
Three (two 2-poly, one 3-poly).

SURFACE TEXTURE:

Upper Surface: Micro-granular to granular.

Lower Surface: Friable granular, sometimes superimposed of poorly developed botryoids.

Upper and lower surfaces of most nodules readily distinguishable. Coarsest texture - granular on well-developed botryoids--found in equatorial belt. Smallest nodules more uniformly granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	← Botryoids →				
	← Granules and Granular Clusters →				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ← →		Botryoids ← →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 1 cm (those in equatorial belt mostly ≤1/2 cm).

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: *Largest nodule fractured during collection process, pieces placed in separate bag so reconstruction possible. Worm tubes present, but not prominent, on most nodules.

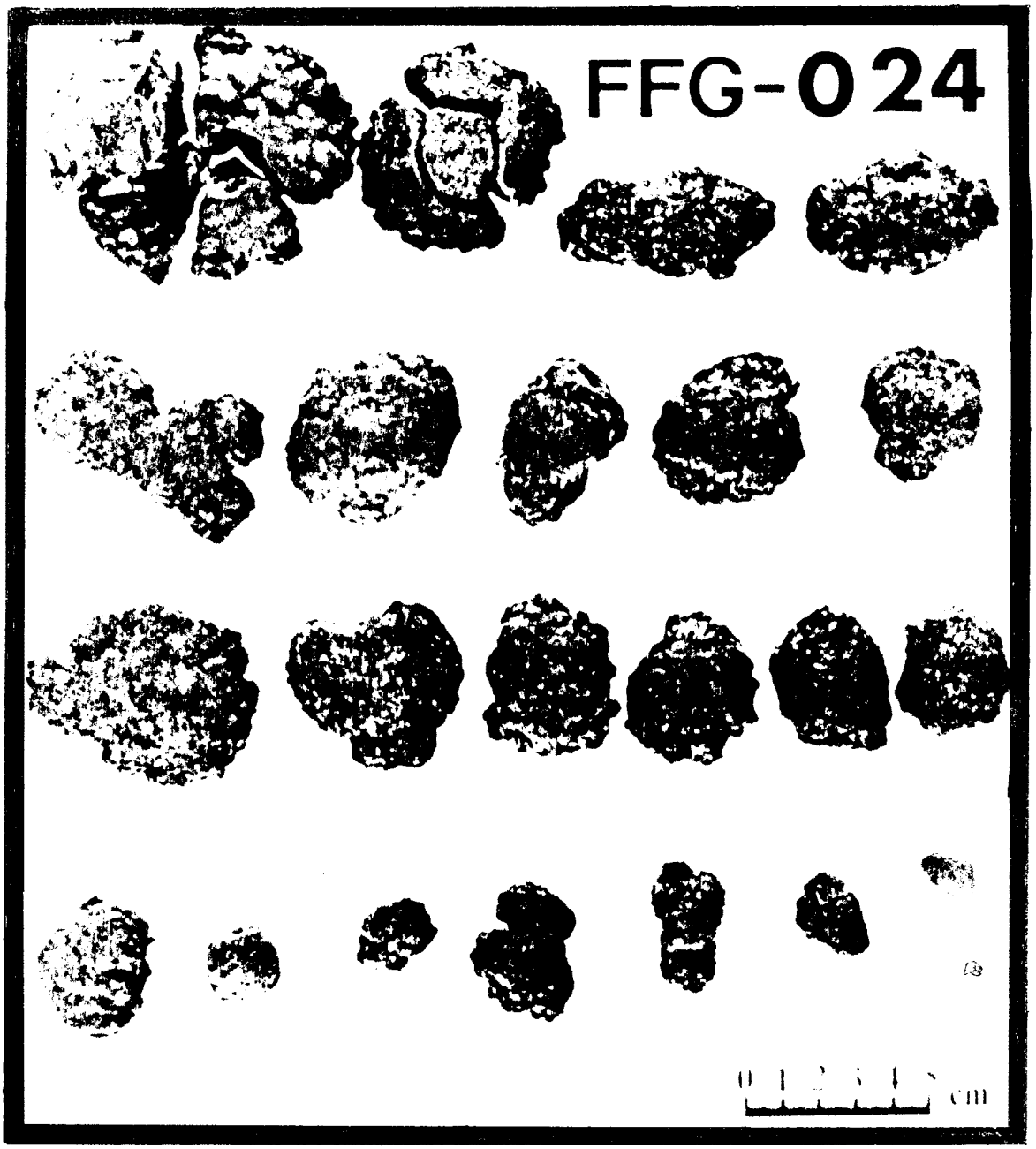


Figure 32.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 006, FF run #3

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -025

LAT. N.: 8°54.1'N

DATE: 29 July 1974

LONG. W.: 146°26.6'N

TIME: LAUNCH 0642Z

WATER DEPTH: 5240 m

ON BOTTOM _____

RECOVER 1125Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Depression surrounded by small abyssal hills (up to 75 m relief). (Note: Location & depth based on bathymetric map, not PDR record).

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -009 (from FFG -025)

Type: Mottled beige and light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

m-l[D]b,	m[P]r,	s[D]s-r,	s[E]s-r
(16)	(6)	(3)	(1)

STATION: 006 SAMPLE NO.: FFG -025

NODULE TYPES: 62% m-1[D]b, 23% m[P]r, 12% s[D]s-r, 4% s[E]s-r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	3	12	10	0	0	26	0
Weight (Kg)	0.03	0.27	0.60	0	0	0.90	0

(wts. of two smallest size classes estimated)

SIZE RANGE OF MAX. DIAM.: 13-71 mm (largest is 71 x 50 x 26 mm discoid)

PRIMARY MORPHOLOGY: Most discoidal; some are coalespheroidal; and the smallest nodule is ellipsoidal.

SECONDARY MORPHOLOGY: A few discoidals approximate flattened ellipsoids. Some discoidal outlines triangular. Top of largest nodule more convex than bottom.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Six (31-46 mm max. diam.); 3 are 2-poly, others are 3- or 4-poly. Coalesced discoids, ellipsoids.

SURFACE TEXTURE:

Upper Surface: Microgranular to granular, on a few superimposed on suppressed to well-developed botryoids.

Lower Surface: Friable granular, on a few superimposed on poorly-developed botryoids.

Tops and bottoms of most discoidals readily distinguishable. Medium to large discoidals have highest relief in equatorial belt--granule clusters and well-developed botryoids. Smallest nodules more uniformly microgranular or granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		Botryoidal →			
		Granules & Granule Clusters →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular →	←	Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to 1 cm

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Only a few worm tubes are present.

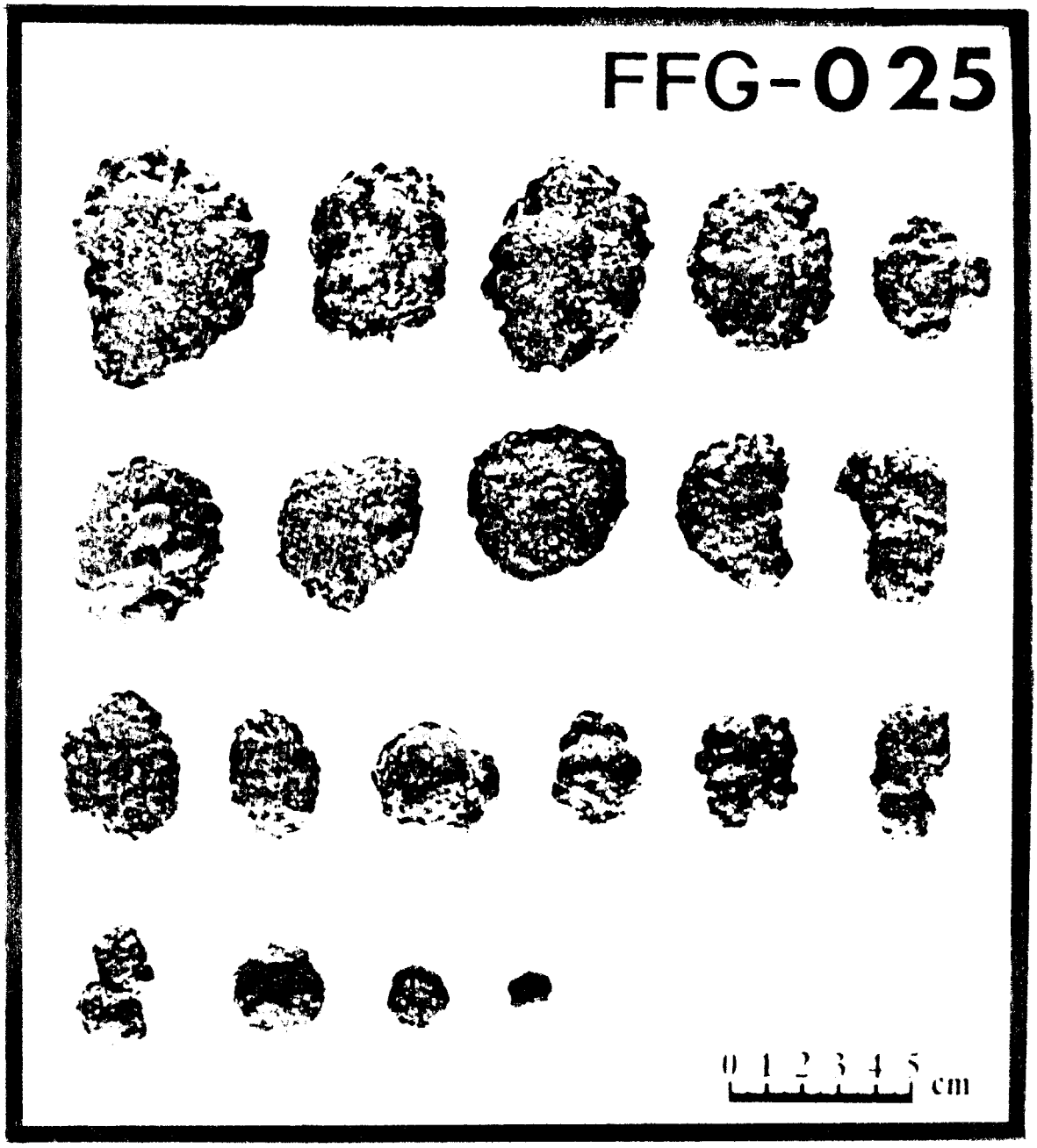


Figure 33.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 8°55.9'N

LONG. W.: 146°26.7'W

WATER DEPTH: 5220 m

STATION: 006, FF run #3

SAMPLE NO.: FFG -026

DATE: 29 July 1974

TIME: **LAUNCH** 0657Z

ON BOTTOM _____

RECOVER 1140Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Terrace on flank of 100-150 m abyssal hill. (Note: Location & depth based on bathymetric map, not PDR record.)

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFGMC -009 (from FFG -025) or FFGMC -010 (from FFG -027).

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

m-l[D]b-r,	s-m[P]r,	s[E]s-r,	s[S]s-r,	s[D]s-r
(13)	(15)	(12)	(8)	(5)

STATION: 006 SAMPLE NO.: FFG -026

NODULE TYPES: 25% m-1[D]b-r, 28% s-m[P]r, 23% s[E]s-r, 15% s[S]s-r, 9% s[D]s-r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	29	18	6	0	0	53	0
Weight (Kg)	0.10	0.35	0.40	0	0	0.85	0

SIZE RANGE OF MAX. DIAM.: 9-65 mm

PRIMARY MORPHOLOGY: Most of larger nodules, including the largest, are discoidal or coalespheroidal. Smaller nodules generally ellipsoidal or spheroidal.

SECONDARY MORPHOLOGY: Few discoidals approximate flattened ellipsoids. Several nodules of different types have agglutinated spherules. A few discoids have triangular or squared-off outlines.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Fifteen (10-53 mm max. diam.). Six are 2-poly, rest are mostly 3- or 4-poly. Smallest have botryoidal aspect. Coalesced discoids and ellipsoids.

SURFACE TEXTURE:

Upper Surface: Microgranular to Granular.

Lower Surface: Granular, on a few superimposed on poorly developed botryoids.

Tops and bottoms of larger nodules readily distinguishable. Highest relief generally in equatorial belt--granule clusters to botryoid. Smaller nodules more uniformly microgranular to granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	Granules & Granular		Botryoidal	Clusters	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular		Botryoidal		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 1 cm

COLOR OF NODULE STREAK: Very dark brown to black

COMMENTS: Sample includes a couple of small frags. of "organ-pipe" to "spaghetti" growth. Very few worm tubes present. Two small coalespheroids have a shark-tooth nucleus. One has a small angular volcanic rock frag., unstained by Mn, adhering to surface.

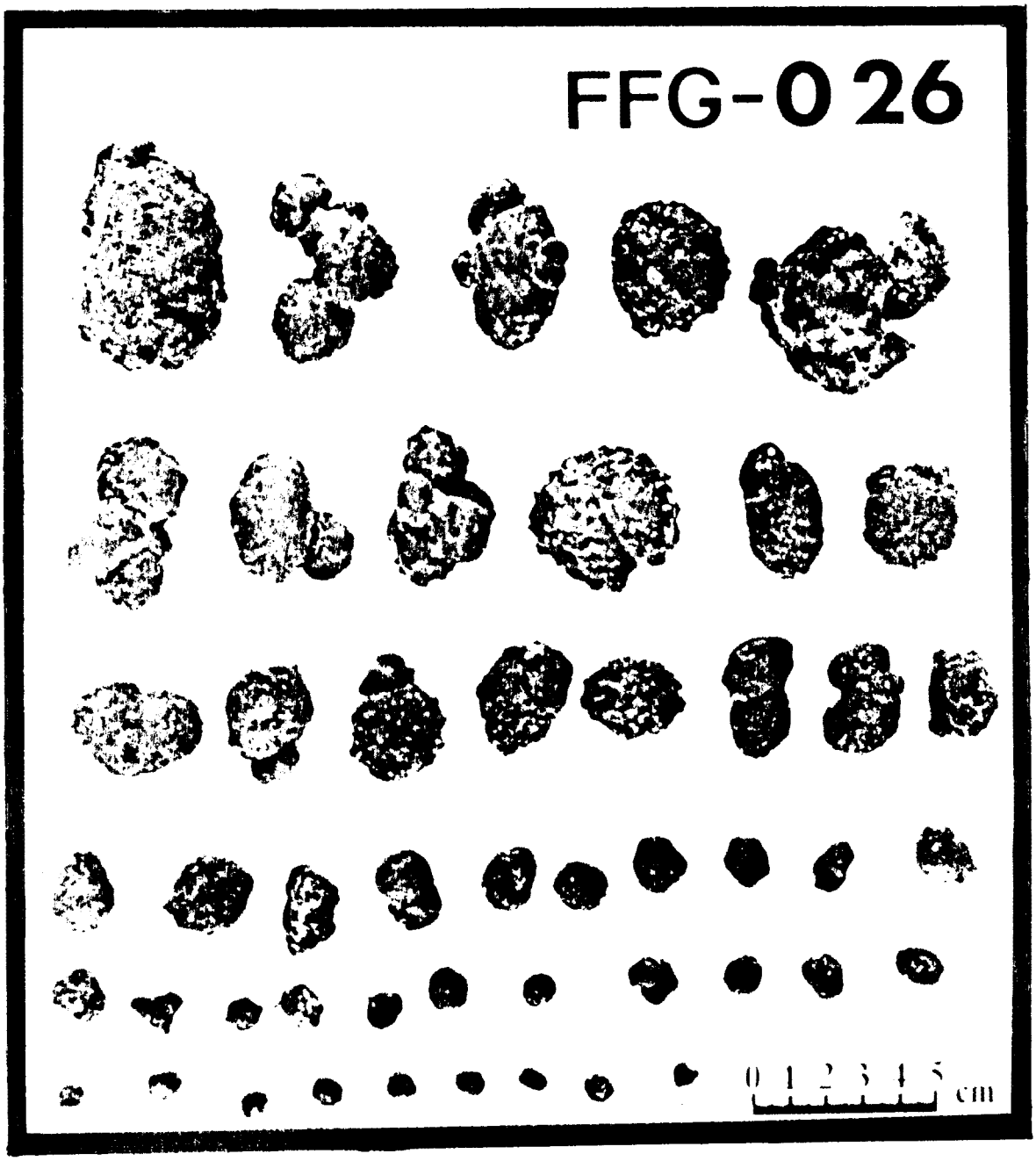


Figure 34.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 8°57.9'N

LONG. W.: 146°26.75'W

WATER DEPTH: 5170 m

STATION: 006, FF run #3

SAMPLE NO.: FFG -027

DATE: 29 July 1974

TIME: LAUNCH 0713Z

ON BOTTOM _____

RECOVER 1202Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with a few hundred meters relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper terrace of 100-150 abyssal hill. (Note: Location and depth based on bathymetric map, not PDR record.)

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -010 (from FFG -027) (see also sediment lumps collected with FFG -027)
Type: Mottled beige, light brown & gray brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]b, s[E]r
(1) (1)

STATION: 006 SAMPLE NO.: FFG -027

NODULE TYPES: 50% 1[D]b, 50% s[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	0	1	1	0	2	0
Weight (Kg)	0	0	0.05	0.20	0	0.25	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 82 & 21 mm (largest is 82 x 62 x 42 mm)

PRIMARY MORPHOLOGY: Larger one discoidal, smaller one ellipsoidal.

SECONDARY MORPHOLOGY: Large discoidal flattened on one side, as if part had been fractured off, and fracture surface overgrown; bottom slightly more convex than top.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE: (of large discoidal)

Upper Surface: Granular

Lower Surface: Coarsely friable granular

} Surface textures of readily distinguishable tops and bottoms superimposed on poorly developed botryoids. Relief highest in equatorial belt--coarsely friable granular texture superimposed on well-developed botryoids.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	Granular ←	←	Botryoidal	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ↔	←	Botryoidal	→	

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 1 cm.

COLOR OF NODULE STREAK: Dark brown to black

COMMENTS: A few worm tubes are present, mostly in equatorial belt. Sample also includes several lumps (total weight about 0.025 kg) of poorly consolidated sediment, mottled beige, light brown and gray brown clayey siliceous ooze.

-cont.-

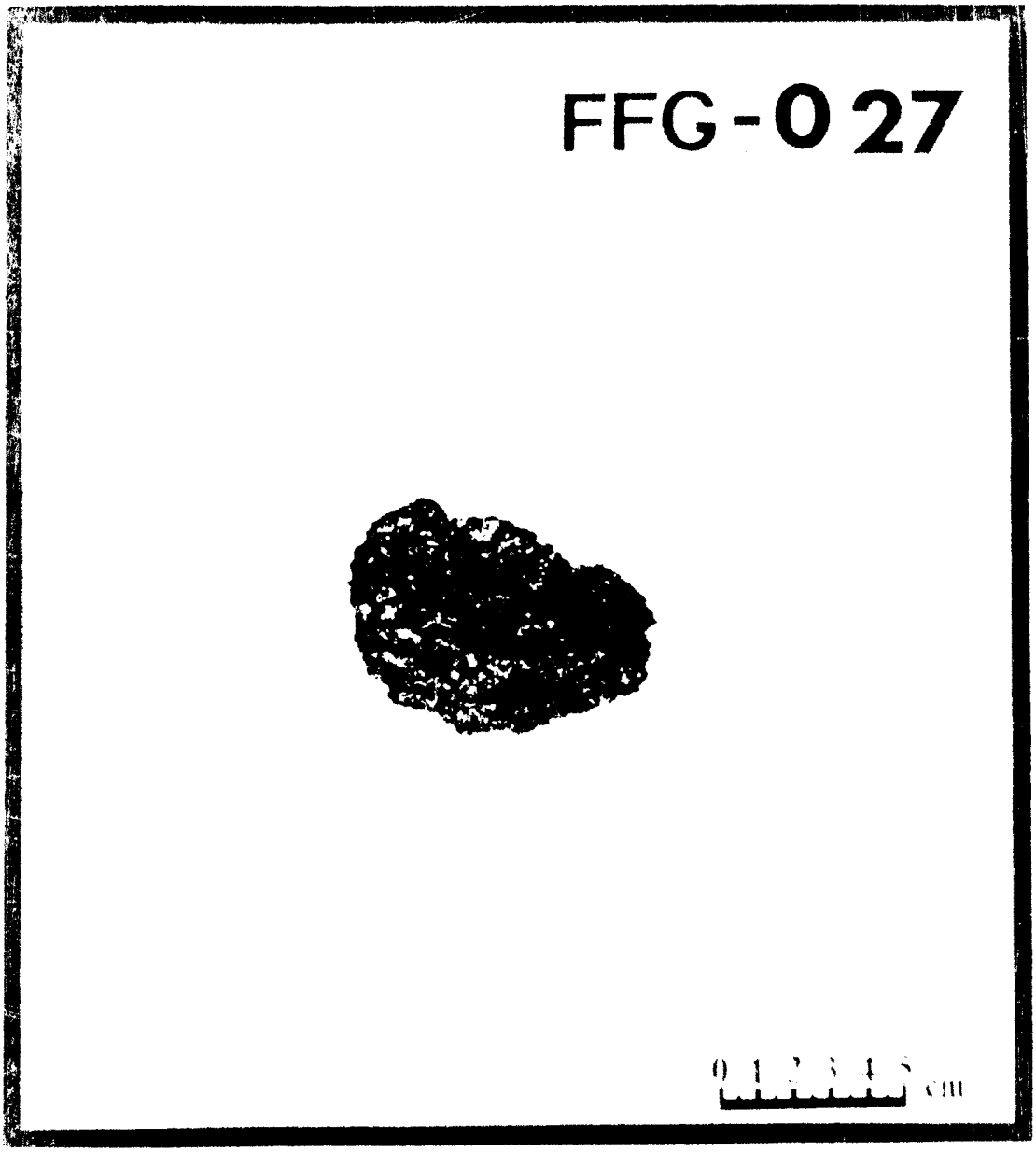


Figure 35.

COMMENTS: -cont.-

Gray-brown coloration mostly restricted to one surface of lump--a possible indication of Mn-staining (first stage in nodule development.)

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 006

COLLECTION DEVICE: Free fall corer

SAMPLE NO.: FFC -007 (at coretop)

LAT. N.: 8°50.4'N

DATE: 29 July 1974

LONG. W.: 146°26.2'W

TIME: LAUNCH 0901Z

WATER DEPTH: 5175 m

ON BOTTOM _____

RECOVER 1053Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones. Mostly rolling abyssal hills with relief <50 m; occasional abyssal hill with relief of a few hundred meters.

SPECIFIC BATHYMETRIC LOCATION:

Crest of 60-80 m abyssal hill. (Note: Depth & location based on recovery site, not launch site).

ASSOCIATED SEDIMENT--

Sample No.: FFC -007

Type: Mottled beige/light brown/gray brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

m[P]r
(1)

STATION: 006 SAMPLE NO.: FFC -007

NODULE TYPES: 100% m[P]r (at core top)

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	1	0	0	0	1	0
Weight (Kg)	0	0.04	0	0	0	0.04	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 41 mm

PRIMARY MORPHOLOGY: Coalespheroidal

SECONDARY MORPHOLOGY: Ellipsoidal segment is lobed.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (2-poly), coalesced spheroid and ellipsoid.

SURFACE TEXTURE:

Upper Surface: Microgranular to granular

Lower Surface: Granular

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	- - →			→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: ———

COMMENTS: ———

STATION SUMMARY

STATION: 07

TIME ON STATION: 30/7/74 2326Z

LATITUDE: 10°00'N

TIME DEPART STATION: 31/7/74 0336Z

LONGITUDE: 143°20'W

SEDIMENT TYPE: Siliceous ooze/red clay

OPERATIONS: FFG #28, 29, 30 30/7/74 2326Z - 31/7 0336Z

Bathymetric survey - (Figure 36); track control (Figure 37)

DISCUSSION:

Three grabs were taken at approximately 2-mile spacing. Nodules of varying morphologies recovered at densities of 1.25 - 21.25 kg/m^2. Grabs 29 and 30 are 18.125 and 21.25 kg/m^2 respectively and are almost entirely large discoidal nodules (Figures 38-40). All samples from upper slopes of adjacent hills.

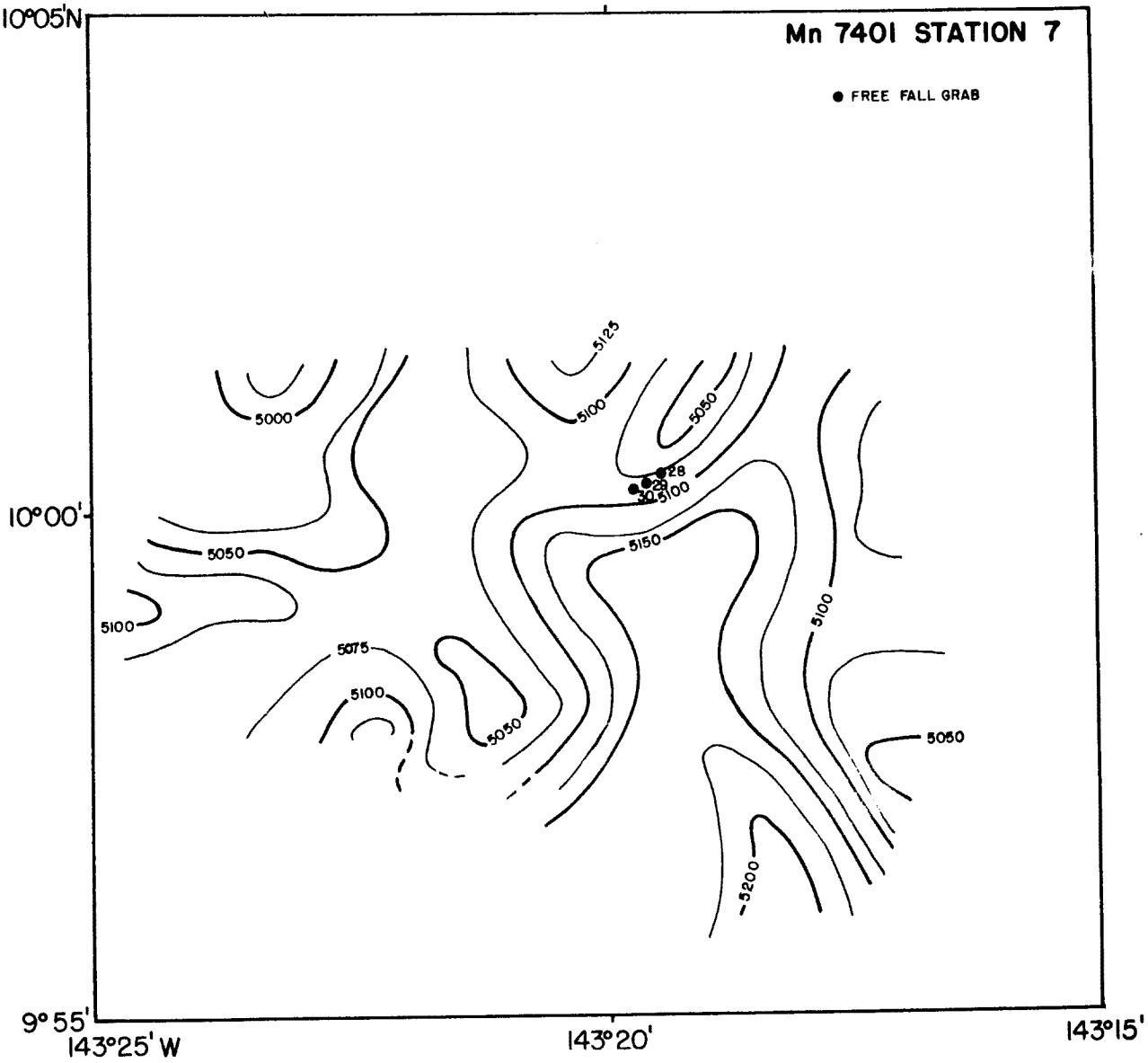

Mn 7401 STATION 7
● FREE FALL GRAB
10°05'N
10°00'
9°55'
143°25' W
143°20'
143°15'
5000
5125
5100
5050
5100
5150
5100
5050
5100
5075
5100
5050
5050
5200

Figure 36.

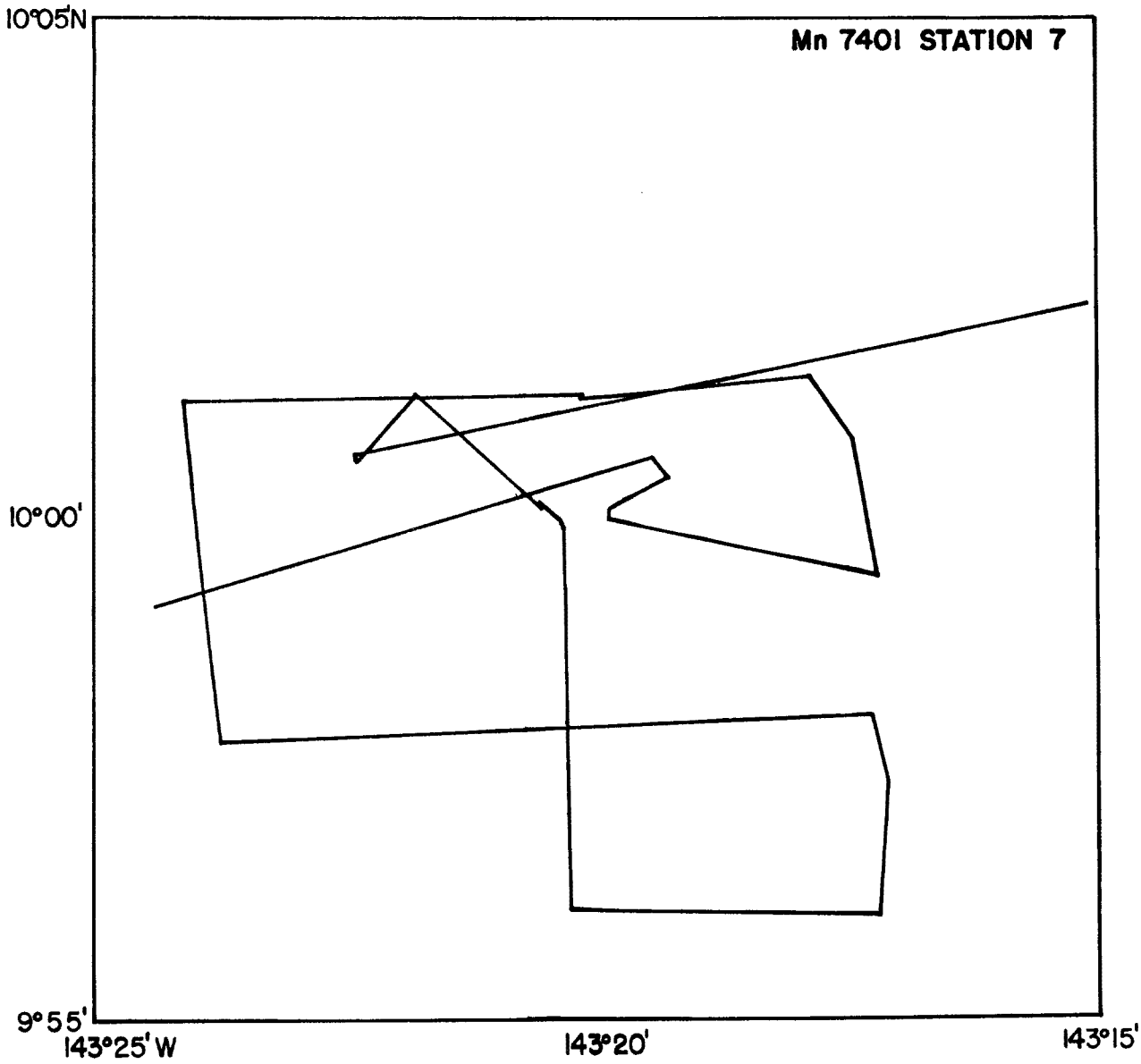


Figure 37.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 10°00.75'N

LONG. W.: 143°18.7' W

WATER DEPTH: 5090 m

STATION: 007

SAMPLE NO.: FFG -028

DATE: 30-31 July 1974

TIME: **LAUNCH** 2326Z

ON BOTTOM _____

RECOVER 0254Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones. Rolling abyssal hills, mostly 100-300 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper slopes of 100 m abyssal hill. Strong bottom reflection, possibly 10-20 m penetration.

ASSOCIATED SEDIMENT--

Sample No.: None (but see sediment clinging to bottom of 2-poly coalespheroidal).

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

s[E]r,	m[P]r,	m[D]b-r,	s[S]r,	s[T]r,	s[B]r
(7)	(2)	(2)	(4)	(3)	(1)

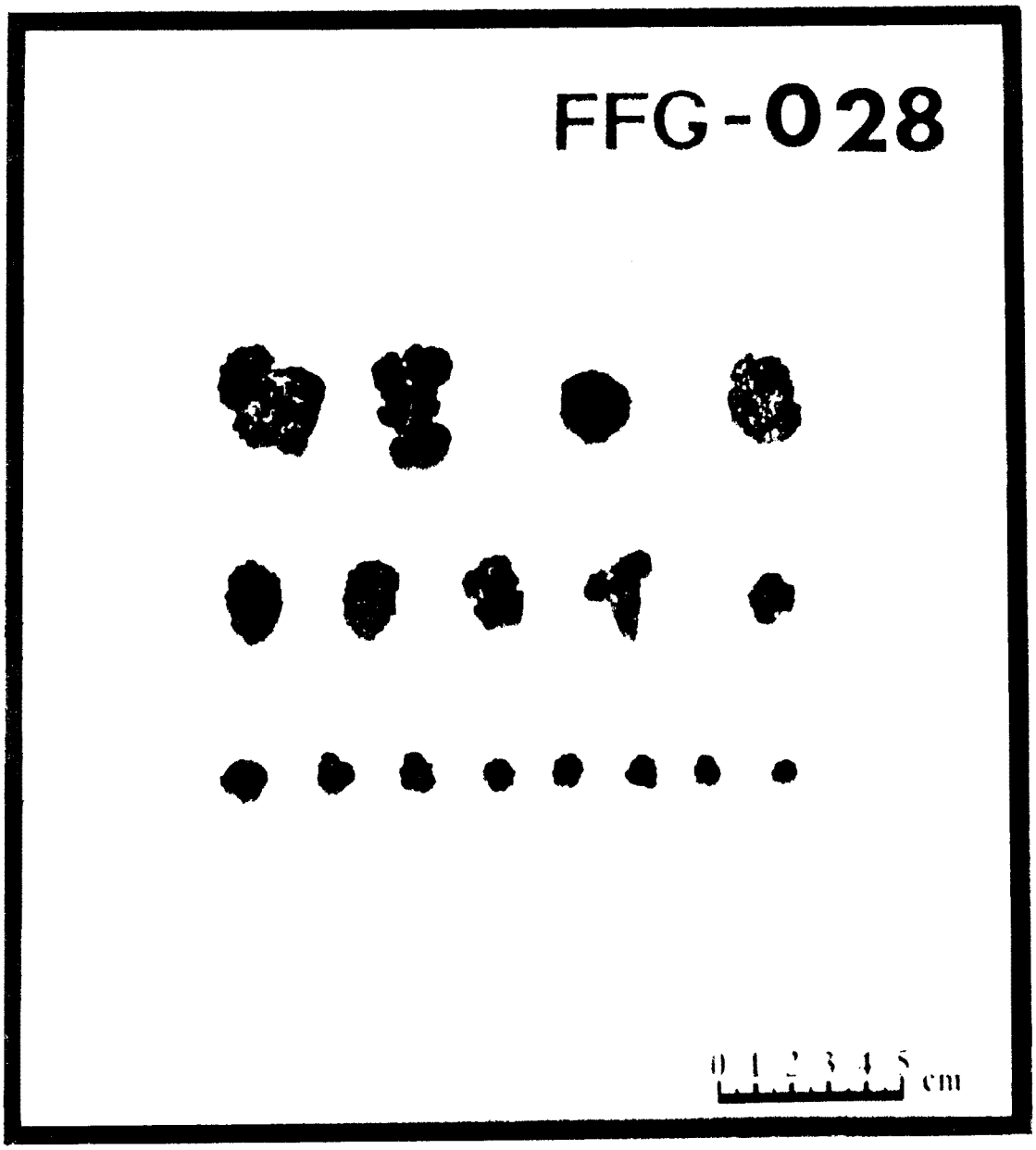


Figure 38.

STATION: 007 SAMPLE NO.: FFG -028

NODULE TYPES: 37% s[E]r, 11% m[P]r, 11% m[D]b-r, 21% s[S]r, 16% s[T]r, 5% s[B]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	12	7	0	0	0	19	0
Weight (Kg)	0.03	0.07	0	0	0	0.10	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 8-35 mm

PRIMARY MORPHOLOGY: A wide variety: medium-size discoids, more abundant but smaller ellipsoids & spheroids, two medium-size coalespheroids, small tabular nodules & a partially encrusted shark tooth.

SECONDARY MORPHOLOGY: Some of smallest ellipsoids irregularly faceted. Small tabular nodules have squared-off outline. Larger ellipsoidals flattened.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Two (34 & 35 mm max. diam.), one 2-poly & the other a poly-poly with over-all tabular aspect.

SURFACE TEXTURE:

Upper Surface: { Granular to coarsely granular or botryoidal }

Lower Surface: { Granular to coarsely granular. }

Tops and bottoms distinguishable only on a few larger nodules. Highest relief in probable equatorial belts--where granule clusters assume a botryoidal aspect. Smaller nodules more uniformly granular or microgranular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		Botryoidal ← →			
		← Granules & Granular Clusters →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE		← Botryoidal →			
		Granular ← →			

ABSOLUTE DIAM. OF MAMMILLAE: < 1 mm to about 3 mm.

COLOR OF NODULE STREAK: Dark brown to black

COMMENTS: Small subangular volcanic frag., vaguely Mn-stained, adhering to underside of 2-poly coalespheroidal. Worm tubes apparent on many nodules.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 007

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -029

LAT. N.: 10°00.6'N

DATE: 30-31 July 1974

LONG. W.: 143°19.0'W

TIME: LAUNCH 2336Z

WATER DEPTH: 5075 m

ON BOTTOM _____

RECOVER 0337Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion & Clipperton Fracture Zones. Rolling abyssal hills, mostly 100-300 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper slopes of 100 m abyssal hill. Strong bottom reflection; possibly 10-20 m penetration.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -011 (from FFG -029)

Type: Mottled beige & light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

m-1[D]b
(6)

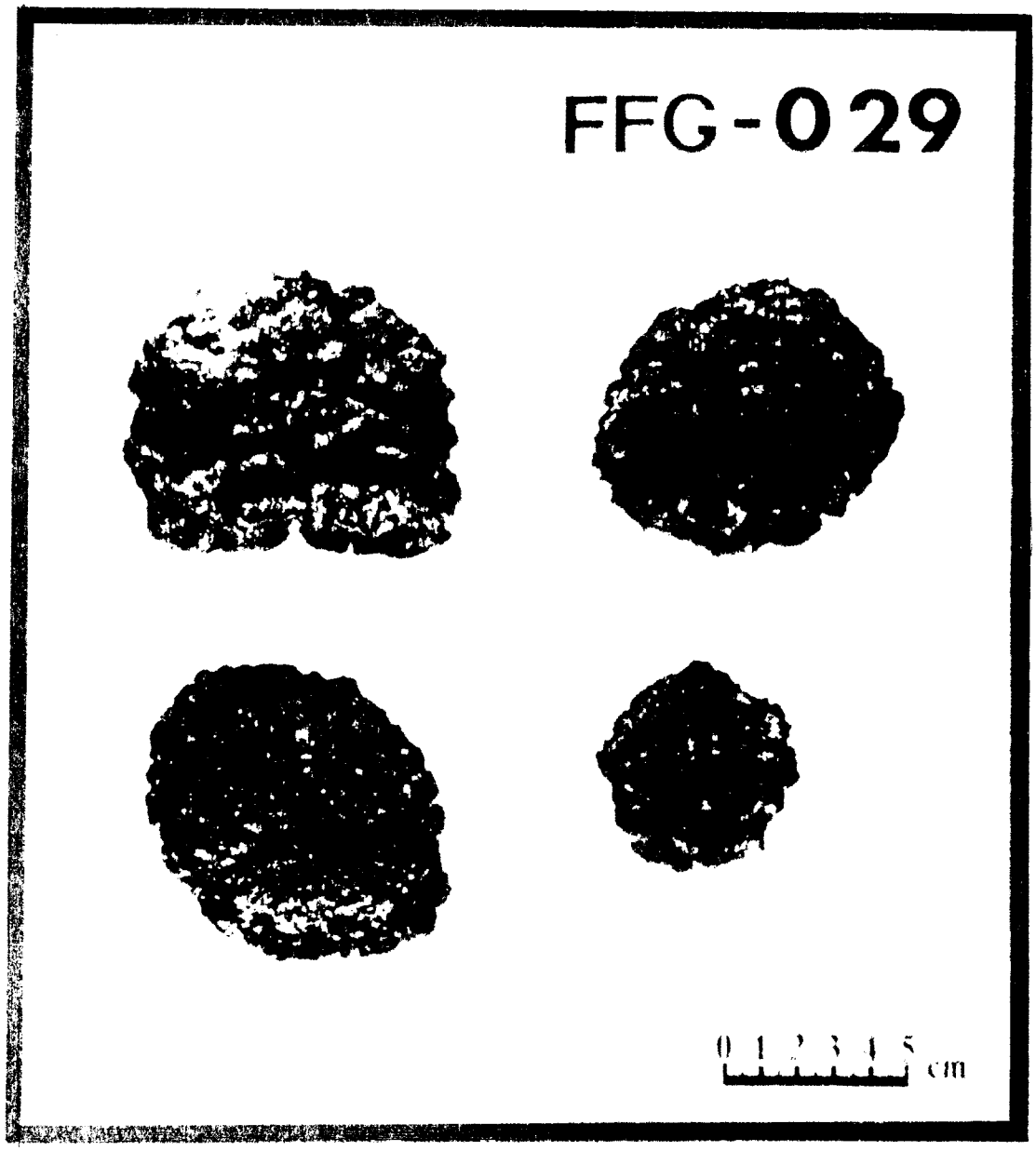


Figure 39.

STATION: 007 SAMPLE NO.: FFG -029

NODULE TYPES: 100% m-1[D]b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	0	1	5	0	6	0
Weight (Kg)	0	0	0.15	1.30	0	1.45	0

SIZE RANGE OF MAX. DIAM.: 55-92 mm (largest are 92 x 69 x 55 mm, 92 x 72 x 46 mm, and 80 x 75 x 52 mm).

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Bottoms slightly more convex than tops. Smallest approximates a flattened spheroid. One of largest has irregular satellite growth on upper surface.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None.

SURFACE TEXTURE:

Upper Surface: Microgranular to granular superimposed on poorly to well-developed botryoids.

Lower Surface: Granular superimposed on mostly poorly developed botryoids.

Tops and bottoms readily distinguishable on all nodules. Except on smallest, equatorial belts have highest relief--friable coarsely granular texture superimposed on well-developed botryoids.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	Granular ←	← Botryoidal →		→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ← →		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to about 2 1/2 cm.

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Very few worm tubes present.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 10°00.5'N

LONG. W.: 143°19.2'W

WATER DEPTH: 5075 m

STATION: 007

SAMPLE NO.: FFG -030

DATE: 30-31 July 1974

TIME: **LAUNCH** 2341Z

ON BOTTOM _____

RECOVER 0336Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Rolling abyssal hills, mostly 100-300 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper slopes of 100 m abyssal hill. Strong bottom reflections; probably at least 20 m penetration.

ASSOCIATED SEDIMENT--

Sample No.: None (but see sediment clinging to bottoms of larger nodules).

Type: Light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]b,	1[E]b,	s[P]r
(5)	(1)	(1)

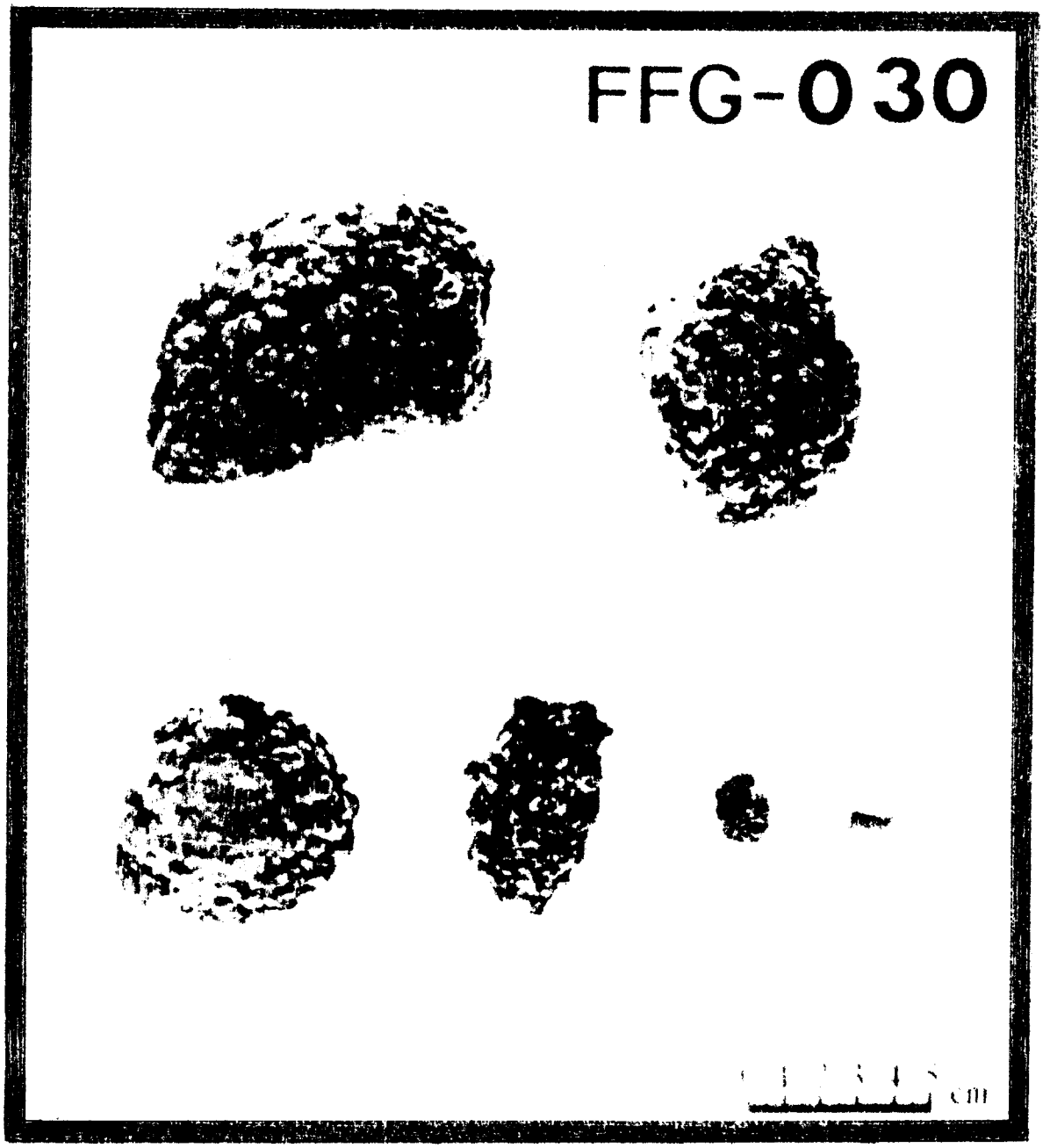


Figure 40.

STATION: 007 SAMPLE NO.: FFG -030

NODULE TYPES: 71% 1[D]b, 14% 1[E]b, 14% s[P]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	0	1	4	1	7	0
Weight (Kg)	0.01	0	0.06	1.18	0.45	1.70	0

(wts. of two smallest size classes estimated)

SIZE RANGE OF MAX. DIAM.: 21-104 mm (largest are 104 x 81 x 67 mm and 90 x 85 x 60 mm)

PRIMARY MORPHOLOGY: Five largest are discoidal; next largest (62 mm max. diam.) is ellipsoidal; smallest is coalespheroidal.

SECONDARY MORPHOLOGY: Largest nodule is half-discoidal, as if broken and the fracture surface re-encrusted. Two of large discoidals are of "mushroom" variety. The ellipsoidal nodule is prolate.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (2-poly)--coalesced ellipsoid and tabular-discoid.

SURFACE TEXTURE:

Upper Surface: Granular (two are microgranular) superimposed on some poorly developed, but mostly well-developed, botryoids.

Lower Surface: Granular superimposed on fairly well-developed botryoids.

Tops and bottoms distinguishable on all nodules. Highest relief in equatorial belt--granule clusters and high relief botryoids. Texture of two smallest nodules has rough aspect due to predominance of coarse granules and granule clusters.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	--- Granules & Granule Clusters →	← Botryoids →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ← →		← Botryoids →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to >2 cm.

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Sample includes one 25 mm long bone segment, altered to a gray pumice-like texture. Worm tubes present but not abundant.

STATION SUMMARY

STATION: 08

TIME ON STATION: 01/8/74 0334Z

LATITUDE: 11°00'N

TIME DEPART STATION: 01/8/74 2230Z

LONGITUDE: 140°00'W

SEDIMENT TYPE: Siliceous ooze/red clay

OPERATIONS: FFG #31, 32, 33 1/8/74 0334Z - 0740Z

Dredge #1 1/8/74 0930Z - 1718Z Poor recovery due to winch malfunction

Water cast #6 (Table 6) 1/8/74 1800 - 2230Z

FFC #9, 10, 11 #11 lost due to bad weather and poor visibility. Pore Water Chemistry - Table 7.

Track control shown in Figure 41.

DISCUSSION:

Two grabs were recovered - #32 from mid slopes of a 150 m hill had 15 kg/m^2, and #33 from lower slopes 5.63 kg/m^2. Discoidal, botryoidal surfaced nodules, generally medium size (Figures 42-43). Dredge #1 recovered only a few small nodules of the same description. (See Figure 44.)

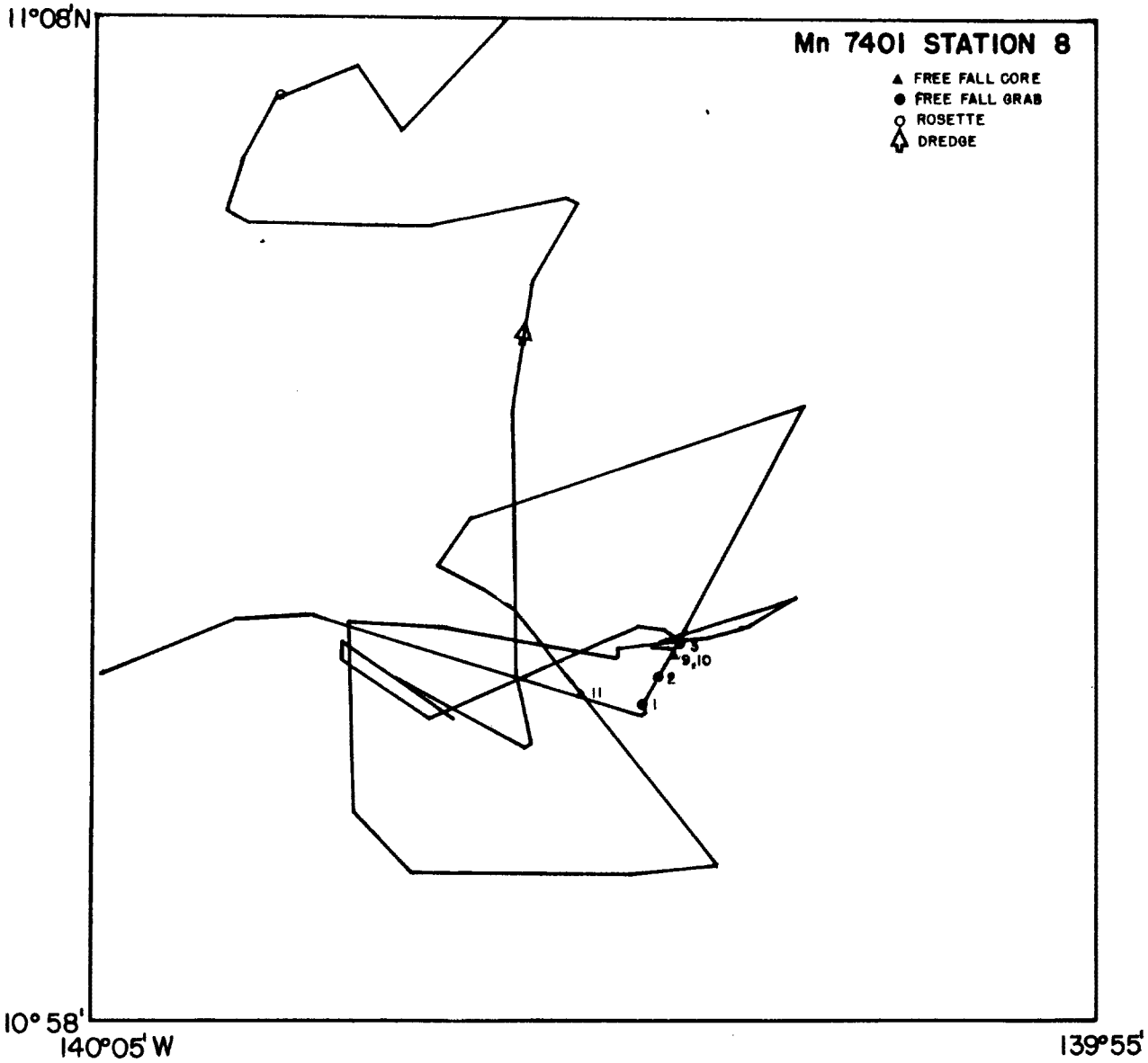


Figure 41.

TABLE 6: STATION NO. 8 - ROSETTE CAST #6

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
1-1	4750	3.93	34.680	2.38	144.9	8		
1-2	4648	4.02	34.681	2.47	147.7	102		
1-3	4453	3.90	34.680	2.34	144.2	296		
1-4	4160	3.85	34.683	2.34	144.2	575		
1-5	3858	3.70	34.691	2.43	144.7	850		
1-6	3571	3.40	34.669	2.43	153.2	1150		
1-7	1249	1.08	34.555	2.96	120.2			
1-8	952	0.82	34.547	3.01	107.0			
1-9	952	0.85	34.539	3.14	100.6			
1-10	395		34.507	3.23	80.5			
1-11	395		34.567	2.61	47.6			

TABLE 7: STATION NO. 8 - PORE WATER CHEMISTRY

Depth interval in core, cm	pH	Alkalinity, * meq/l
0-2	7.80	2.60
2-4	7.77	2.72
4-6	7.75	2.67
6-8	7.70	2.81
8-10	7.78	2.86
10-12	7.75	2.76
12-14	7.76	2.80
14-16	7.75	2.81
16-18	7.75	
18-20	7.75	2.83
25-30	7.45	2.78
35-40	7.62	2.89
45-49	7.63	2.81
55-60	7.66	2.82
65-70	7.66	2.90
75-80	7.65	2.83
Near bottom water	7.93, 8.05	2.87, 2.89
∿100 meters off bottom	7.97, 7.93	3.00, 2.88

* Titration alkalinity values need to be corrected for titer blank of 0.530 M NaCl solution and deviation of Standard Acid (HCl) from 0.010N.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 008

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -031

LAT. N.: 11°00.4'N

DATE: 1 August 1974

LONG. W.: 139°59.4'W

TIME: LAUNCH 0334Z

WATER DEPTH: 4825 m

ON BOTTOM _____

RECOVER _____

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper slope of 150 m abyssal hill. Poor 3.5 kHz record.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -009, -010 at Station 008.

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE: None

(Grab not recovered)

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 11°00.5'N

LONG. W.: 139°59.3'W

WATER DEPTH: 4850 m

STATION: 008

SAMPLE NO.: FFG -032

DATE: 1 August 1974

TIME: LAUNCH 0347Z

ON BOTTOM ____

RECOVER 0740Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Middle slope of 150 m abyssal hill. Poor 3.5 kHz record.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -009, -010 at Station 008.

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]b, s[S]r
(4) (1)

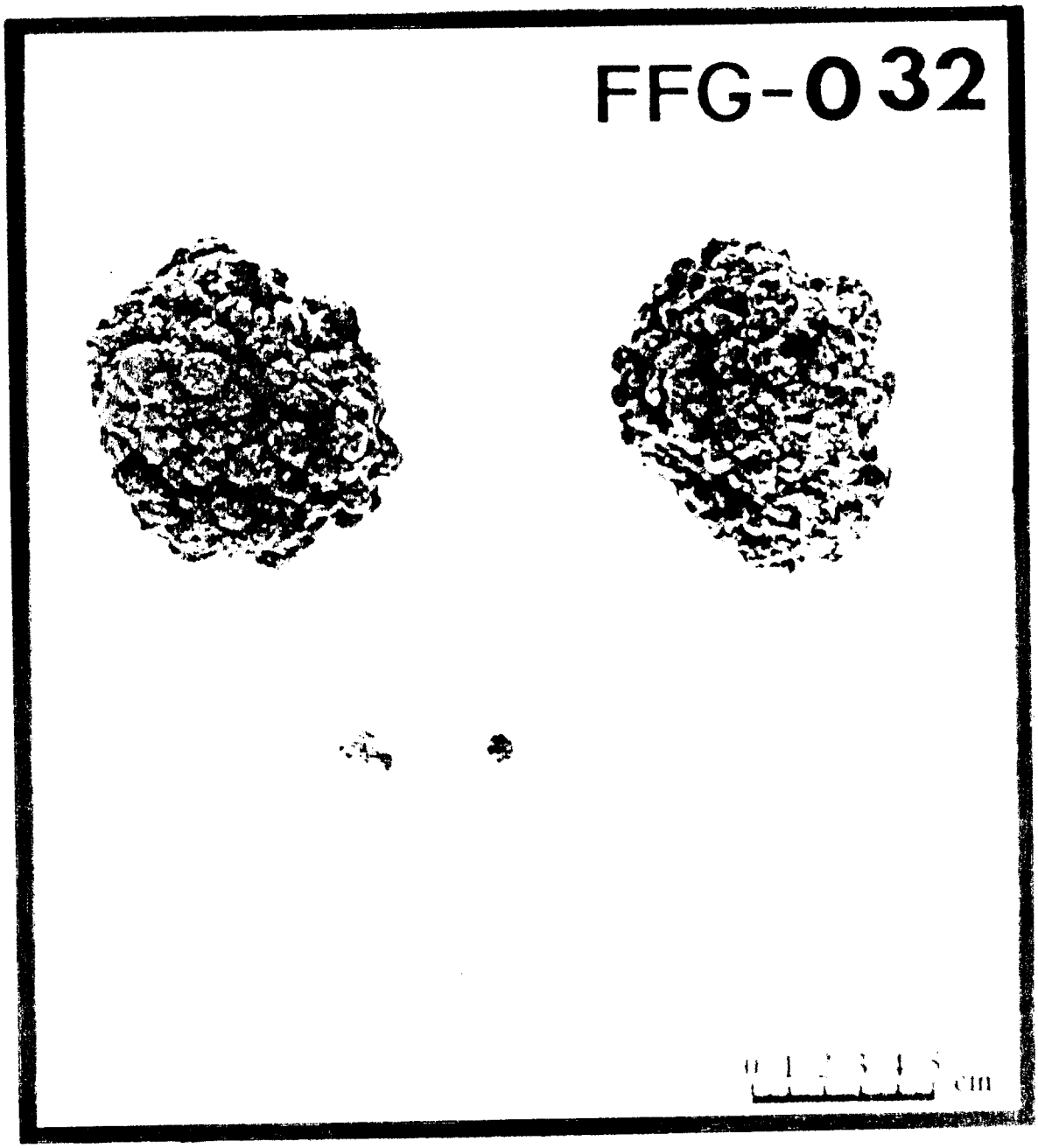


Figure 42.

STATION: 008 SAMPLE NO.: FFG -032

NODULE TYPES: 80% t[D]b, 20% s[S]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	0	0	3	1	5	0
Weight (Kg)	0.005	0	0	0.80	0.40	1.20	0

(wt. of smallest size class estimated)

SIZE RANGE OF MAX. DIAM.: 10 and 79-90 mm (largest are 88 x 80 x 60 mm & 90 x 67 x 68 mm; smallest discoidal 79 x 73 x 38 mm)

PRIMARY MORPHOLOGY: Four largest discoidal; smallest is spheroidal.

SECONDARY MORPHOLOGY: Three largest discoids are thick, approximating flattened spheroids or ellipsoids; all three also have a "mushroom" aspect. Third largest discoidal has coalespheroidal-like satellite growth on upper surface.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Granular superimposed on well-developed botryoids.

Lower Surface: Granular to coarsely granular superimposed on well-developed botryoids.

Tops and bottoms readily apparent on all but smallest nodule. Relief of equatorial belt somewhat but not markedly, higher than remainder of surface. Granular clusters concentrated in the belt. Smallest nodule has coarsely granular surface.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		← Botryoidal →			
		Granules and Granular Clusters - - - →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE		← Botryoidal →			
	← Granular →				

ABSOLUTE DIAM. OF MAMMILLAE: < 1 mm to 1 1/2 or 2 cm.

COLOR OF NODULE STREAK: Dark brown to black.

COMMENTS: Sample includes one 17 mm max. diam. subround dark-gray pumice frag. Worm tubes and other evidence of organic activity (including "organ-pipe frags.) present but not prominent.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 11°00.8'N

LONG. W.: 139°59.1'W

WATER DEPTH: ~4900 m

STATION: 008

SAMPLE NO.: FFG -033

DATE: 1 August 1974

TIME: **LAUNCH** 0400Z

ON BOTTOM _____

RECOVER 0818Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Lower slopes of 150 m abyssal hill. Poor 3.5 kHz record.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -009, -010 at Station 008

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]b
(1)

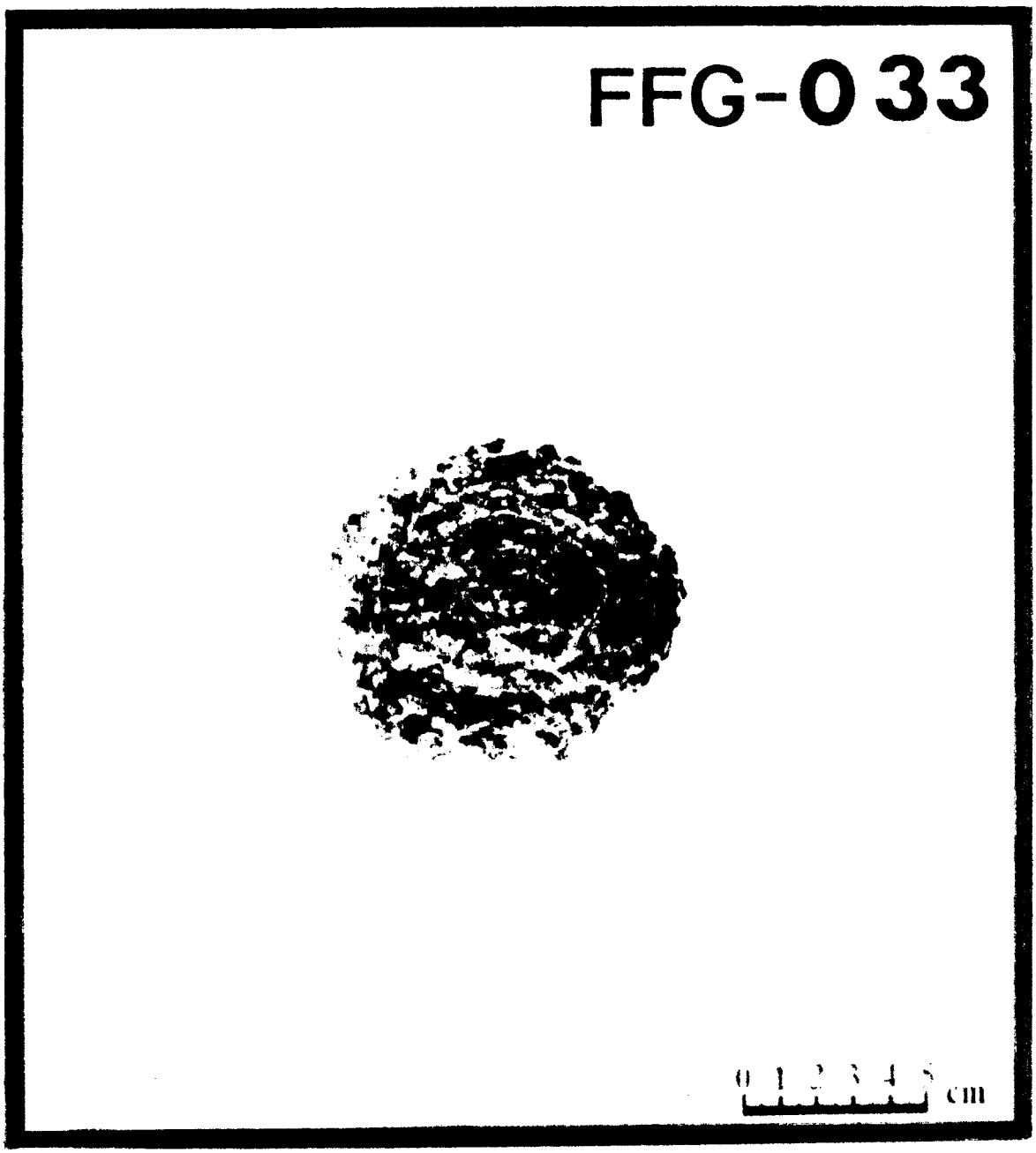


Figure 43.

STATION: 008 SAMPLE NO.: FFG -033

NODULE TYPES: 100% 1[D]b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	0	0	0	1	1	1?*
Weight (Kg)	0	0	0	0	0.45	0.45	0.005

SIZE RANGE OF MAX. DIAM.: 90 (x 85 x 75 mm)

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Unusual--is "mushroom" variety, but top surface, rather than bottom, is "stem".

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Microgranular to granular on suppressed to well-developed to irregularly-developed botryoids.

Lower Surface: Granular on well-developed botryoids.

Top and bottom apparent; nodule may have been more than one-half buried in sediment. Equatorial belt has highest relief--granule clusters & well-developed botryoids.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		← Botryoidal → Granules and Granular Clusters →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	← Granular →		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: 1 mm to 2 1/2 cm. (botryoids mostly 1/2-1 cm.)

COLOR OF NODULE STREAK: Dark brown to black.

COMMENTS: *Frag. may be spherule formerly agglutinated to under surface of nodule. Worm tubes present but not abundant.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: Dredge

LAT. N.: 11°07'N

LONG. W.: 140°00'W

WATER DEPTH: 4810 m

STATION: 008

SAMPLE NO.: Dredge #1

DATE: 1 August 1974

TIME: LAUNCH _____

ON BOTTOM 1335Z

RECOVER _____

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Between Clarion and Clipperton Fracture Zones. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Slopes of 50 m abyssal hill (?)

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -009, -010 at Station 008.

Type: Probably clayey siliceous ooze

NODULE TYPES IN THIS SAMPLE:

m[P]r,	m[S]r-b,	m[D]r-b
(2)	(1)	(1)

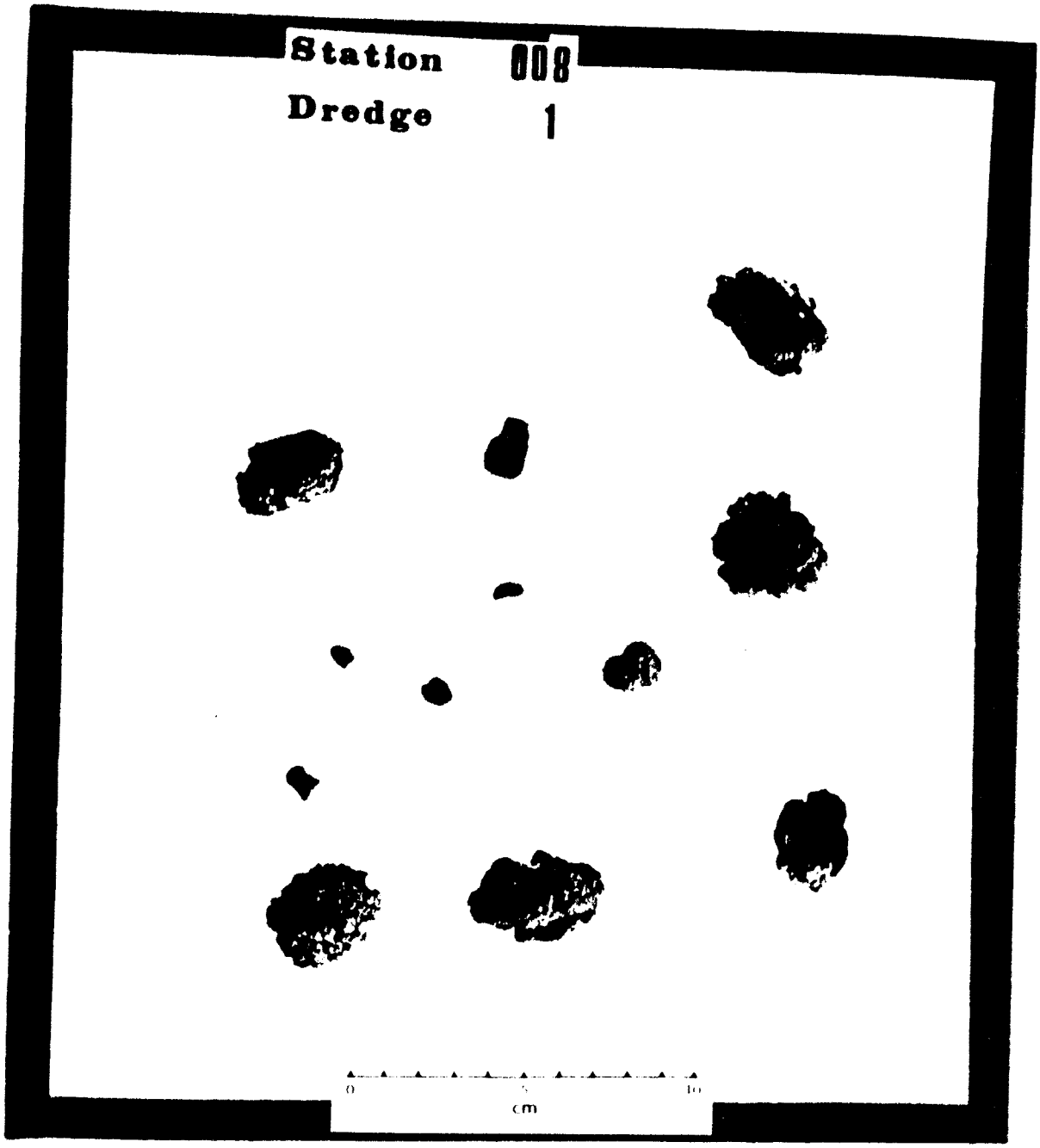


Figure 44.

STATION: 008 SAMPLE NO.: Dredge #1

NODULE TYPES: 50% m[P]r, 25% m[S]r-b, 25% m [D]r-b

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	0	4	0	0	0	4	3*
Weight (Kg)	0	0.10	0	0	0	0.10	0.02

(weights estimated)

SIZE RANGE OF MAX. DIAM.: 32, 33, 33, 40 mm

PRIMARY MORPHOLOGY: Largest is apparently coalespheroidal, as is one other; one is spheroidal; and one is discoidal.

SECONDARY MORPHOLOGY: Discoidal nodule has agglutinated spherule. Largest coalespheroid consists of two agglutinated irregular ellipsoids with a sediment cavity at the area of joining.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Two (both 2-poly).

SURFACE TEXTURE:

_____ Surface: } Tops & bottoms not readily apparent. Discoidal nodule has granules on botryoids on one surface, coarse granules & granule clusters on the other side, and granule clusters & botryoids in the equatorial belt. Spheroidal has granule clusters & botryoids scattered over most of surface, with superimposed granular texture. Coalespheroidals mostly coarsely granular, with patches of granule clusters or small botryoids.

_____ Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		← Botryoids →			
		← Granules and Granular Clusters →			
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE			← Botryoids →		
	← Granular →				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to almost 1 cm.

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Spheroidal nodule has partly lithified sediment on one surface (white when dry) and fresher sediment (light brown) on parts of other surface. Worm tubes present on most nodules & fragments. *The 3 frags., up to 31 mm max. dimension,

-cont.-

COMMENTS: -cont.-

are probably from 2 whole nodules. There are also 4 frags. <1 cm max. dimension. Red dredge paint on several nodule surfaces.

STATION SUMMARY

STATION: 09

TIME ON STATION: 3/8/74 1104Z

LATITUDE: 15°08.5'N

TIME DEPART STATION: 3/8/74 1625Z

LONGITUDE: 136°20'W

SEDIMENT TYPE: Red clay

OPERATIONS: FFG #34, 35, 36 3/8/74 1104Z - 1625Z

DISCUSSION:

Nodule density 0.4 - 1.9 kg/m^2 sampled near crest of small (125 m) abyssal hill. Nodules shown in Figures 45-47.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 15°07.9'W

LONG. W.: 136°21.7'W

WATER DEPTH: 4890 m

STATION: 009

SAMPLE NO.: FFG -034

DATE: 3 August 1974

TIME: LAUNCH 1139Z

ON BOTTOM ____

RECOVER 1603Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just south of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Near crest of 125 m abyssal hill. Strong bottom reflection over 20 m of acoustically transparent sediment.

ASSOCIATED SEDIMENT--

Sample No.: None

Type: Probably clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

1[D]s-r,	s[T]r
(1)	(1)

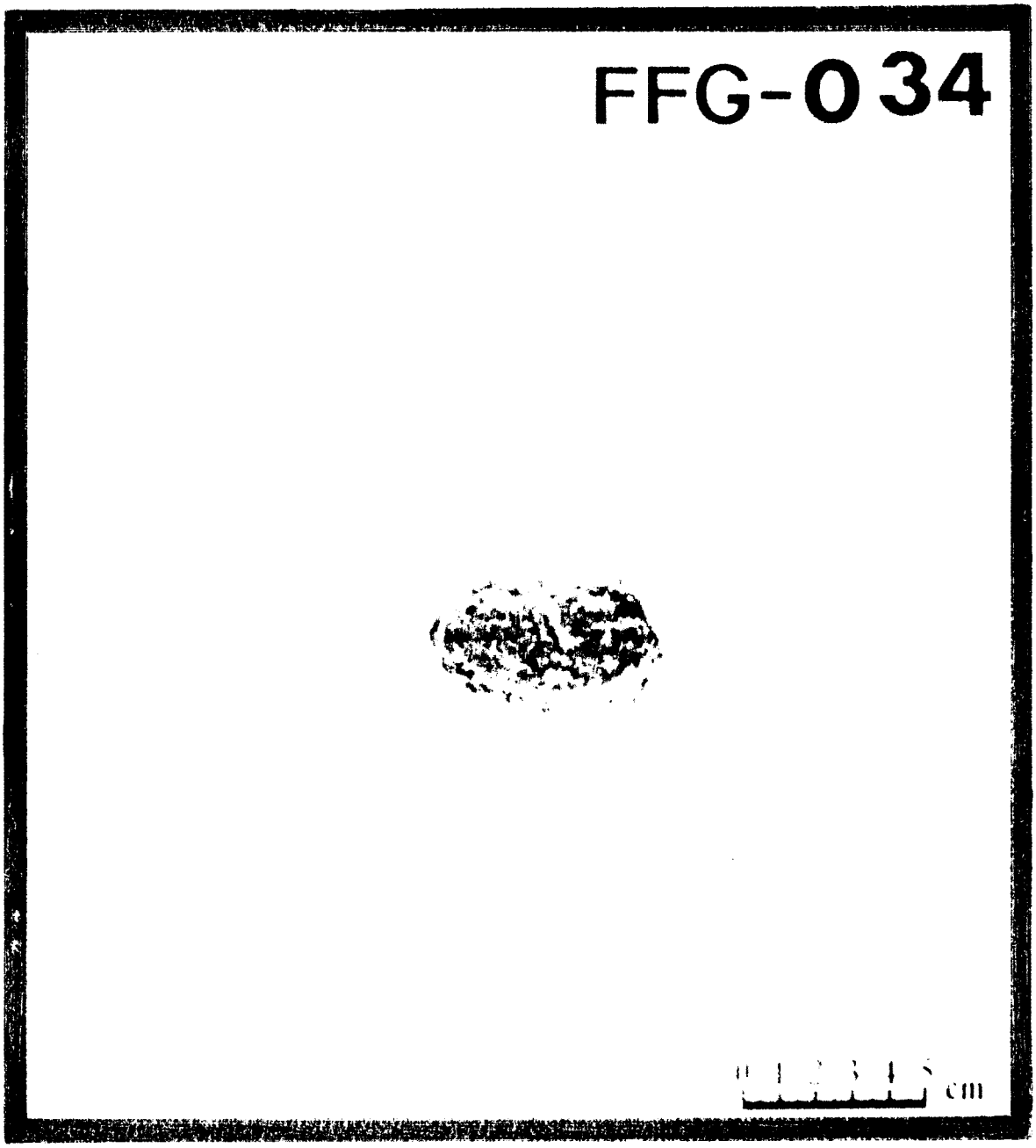


Figure 45.

STATION: 009 SAMPLE NO.: FFG -034

NODULE TYPES: 50% 1[D]s-r, 50% s[T]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	1	0	1	0	0	2	0
Weight (Kg)	0.002	0	0.15	0	0	0.15	0

(wt. of smallest size class estimated)

SIZE RANGE OF MAX. DIAM.: 12 & 62 mm

PRIMARY MORPHOLOGY: Larger is discoidal; smaller is tabular.

SECONDARY MORPHOLOGY: Discoidal approximates a flattened ellipsoid with a "mushroom" aspect. Tabular nodule is squared-off in outline and very thin (being only 1 mm thick). Discoidal has incipient lobe development.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Granular on suppressed botryoids.

Lower Surface: Microgranular to granular

Tops & bottoms in doubt--discoid may have been mostly buried. Discoid has highest relief in equatorial belt--granules on fairly well-developed botryoids. Small tabular nodule uniformly granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	Granular ←		Botryoidal →	Granular →	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ↔		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to 1 cm

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Small tabular nodule may represent fragment of upper (?) surface of larger nodule that was fractured on the seafloor. Worm tubes present, but rare.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 15°07.9'N

LONG. W.: 136°21.7'W

WATER DEPTH: 4885 m

STATION: 009

SAMPLE NO.: FFG -035, -036

DATE: 3 August 1974

TIME: LAUNCH 1150Z, 1200Z

ON BOTTOM _____

RECOVER 1616Z, 1610Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just south of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-200 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Near crest of 125 m abyssal hill. Strong bottom reflection over 10 m transparent sediment; apparent additional sub-bottoms.

ASSOCIATED SEDIMENT--

Sample No.: None (but see sediment adhering to FFG -035 nodule)

Type: Mottled beige & light brown clayey siliceous ooze.

NODULE TYPES IN THIS SAMPLE:

FFG -035:	s[D-E]r, (1)	s[S]r (1)
FFG -036:	m-l[D]r, (2)	m[E]r (1)

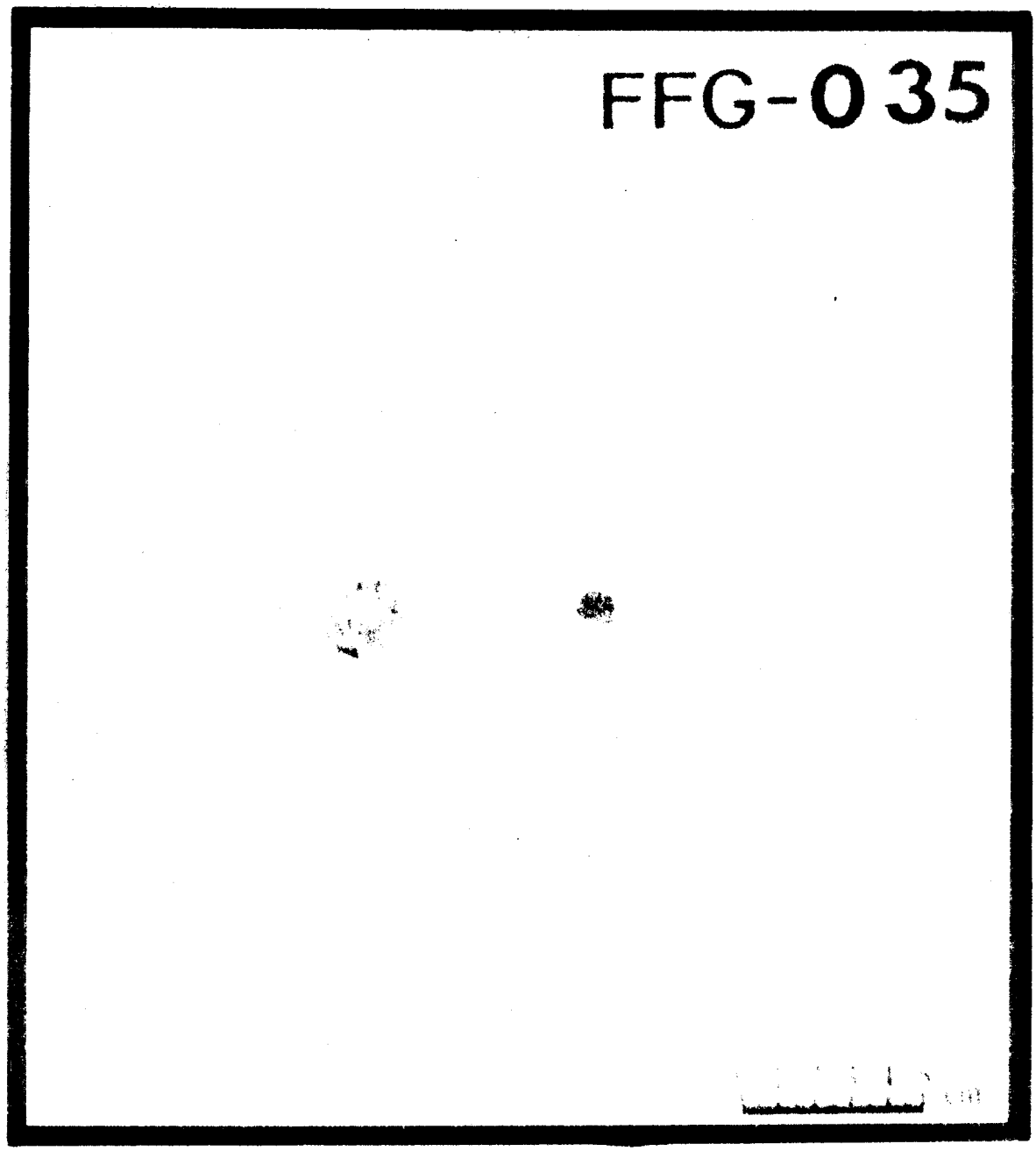


Figure 46.

STATION: 009 SAMPLE NO.: FFG -035

NODULE TYPES: 50% s[D-E]r, 50% s[S]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	1	0	0	0	2	0
Weight (Kg)	0.005	0.025	0	0	0	0.03	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 11 & 30 mm (27 mm plus agglutinated spherule)

PRIMARY MORPHOLOGY: Largest is discoidal; smallest is spheroidal.

SECONDARY MORPHOLOGY: Discoidal nodule approximates a flattened ellipsoid. It has a small agglutinated spherule in equatorial belt.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper ? Surface:
Lower ? Surface:
} Uniformly granular { Probable lower surface of discoidal has adherent gray-brown sediment. Equatorial belt of discoidal does not have higher relief than rest of surface.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF		←	—	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	← →				

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm

COLOR OF NODULE STREAK: Dark brown to black.

COMMENTS: Sediment lump adhering to small spheroidal nodule. Worm tubes present, but prominent only on smaller nodule.

STATION: 009 SAMPLE NO.: FFG -036

NODULE TYPES: 67% m-1[D]r, 33% m[E]r

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	0	1	2	0	0	3	0
Weight (Kg)	0	0.05	0.20	0	0	0.25	0

(sub-sample weights estimated)

SIZE RANGE OF MAX. DIAM.: 39, 57, 69 mm

PRIMARY MORPHOLOGY: Two largest are discoidal; smallest is ellipsoidal.

SECONDARY MORPHOLOGY: Both discoids are half-discoids, as if fractured on seafloor, with fracture surface overgrown with Mn. One discoidal has small agglutinated spherule on upper surface. All have incipient lobe development.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Uniformly granular (lower surface may be slightly more coarsely granular)

Lower Surface:

Tops & bottoms of discoidals distinguishable. Highest relief in equatorial belt--granules on fairly well-developed botryoids. Ellipsoidal has no apparent equatorial belt.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF			Botryoidal →		
			Granular →		
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	Granular ↔		← Botryoidal →		

ABSOLUTE DIAM. OF MAMMILLAE: <1 mm to almost 1 cm.

COLOR OF NODULE STREAK: Dark brown to black.

COMMENTS: Worm tubes present, but prominent only in patches on surfaces of largest & smallest nodules. Sample includes frags. of "organ-pipe" growth.

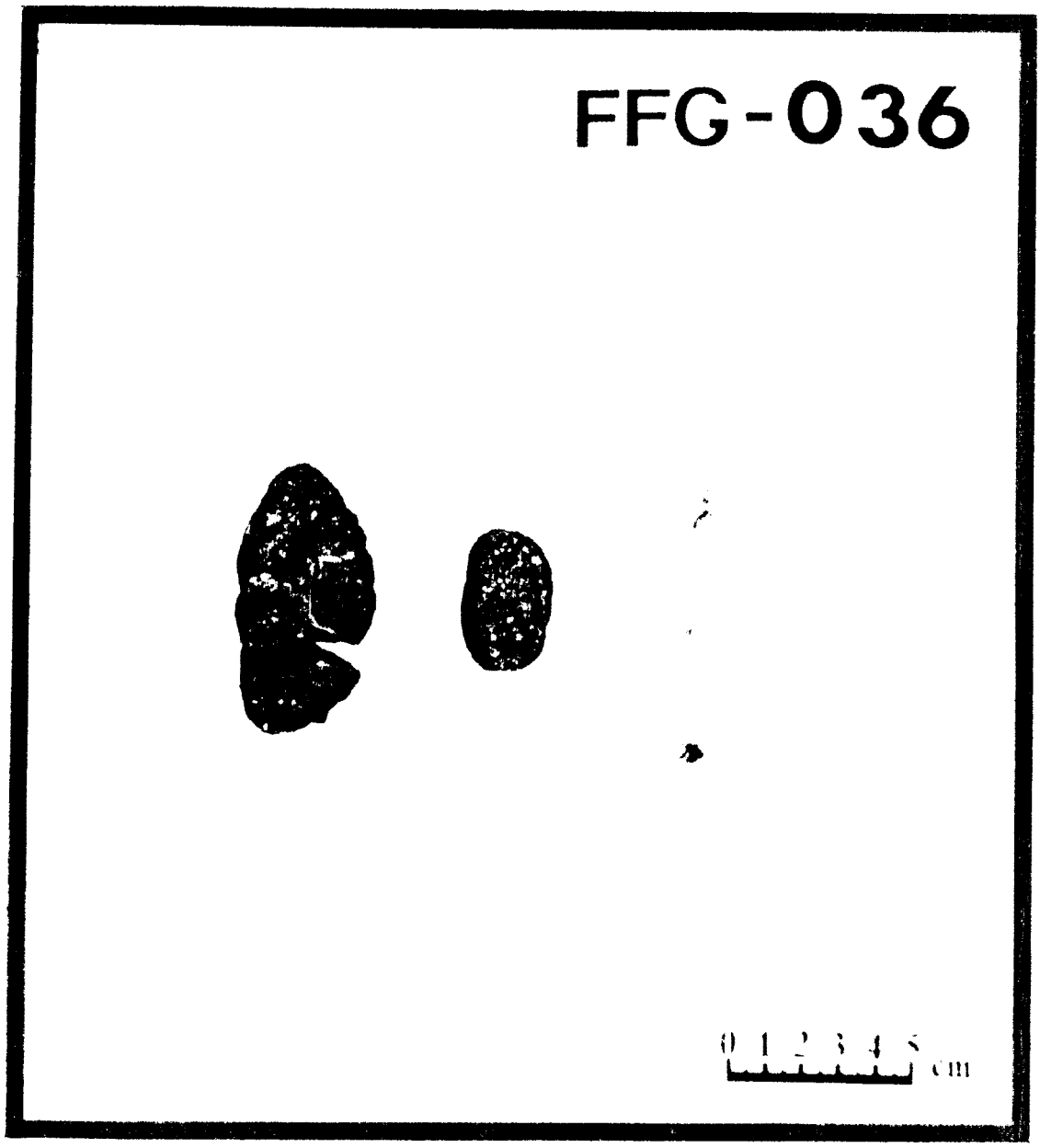


Figure 47.

STATION SUMMARY

STATION: 10

LATITUDE: 19°40'N

LONGITUDE: 132°00'W

TIME ON STATION: 5/8/74 0506Z

TIME DEPART STATION: 6/8/74 0821Z

SEDIMENT TYPE: Red clay

OPERATIONS: FFG #37, 38, 39, 40 5/8/74 0506Z - 1052Z

Water cast #7 5/8/74 1200Z (Table 8)

FFC #12 6/8/74 0732Z - 0950Z pore water chemistry - Table 10

FFG #41, 42, 43, 44 1739Z - 2236Z #41 basket lost, #44 unit lost

Water cast #8 (Table 9)

FFC #13, 14 0347Z - 0821Z 6/8/74

Bathymetry shown in Figure 48 (track control in Figure 49) Dashed contours are poorly controlled.

DISCUSSION:

Low nodule densities common, 0.6 - 2.75 kg/m^2 of small nodules of varying morphologies. Samples obtained from base, flanks, and crest of several hills, and are probably quite representative of the area. Nodules shown in Figures 50-58.

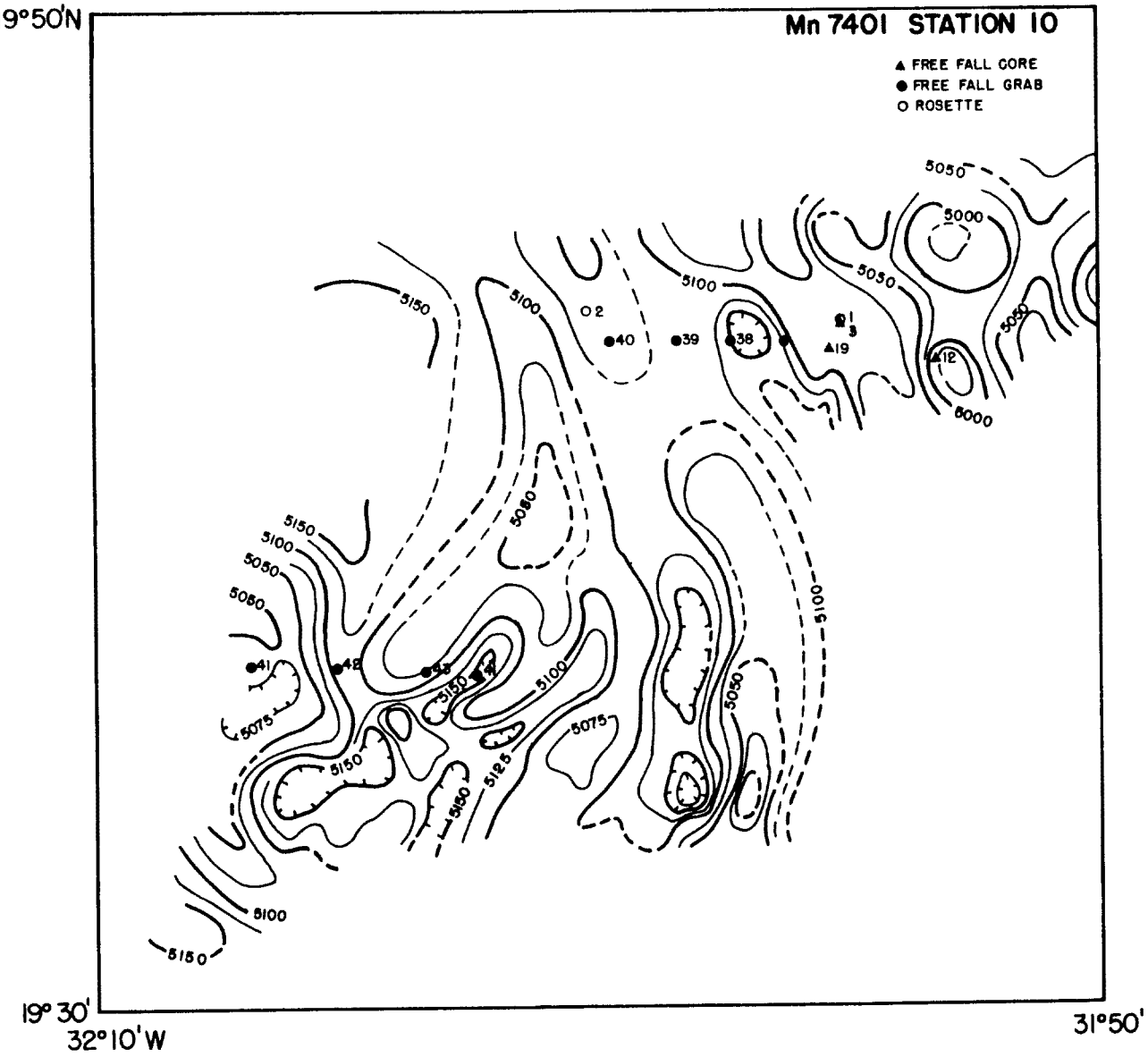

19°50'N
Mn 7401 STATION 10
▲ FREE FALL CORE
● FREE FALL GRAB
O ROSETTE
5050
5000
5100
5150
5080
5075
5125
6000
19° 30'
32°10'W
31°50'

Figure 48.

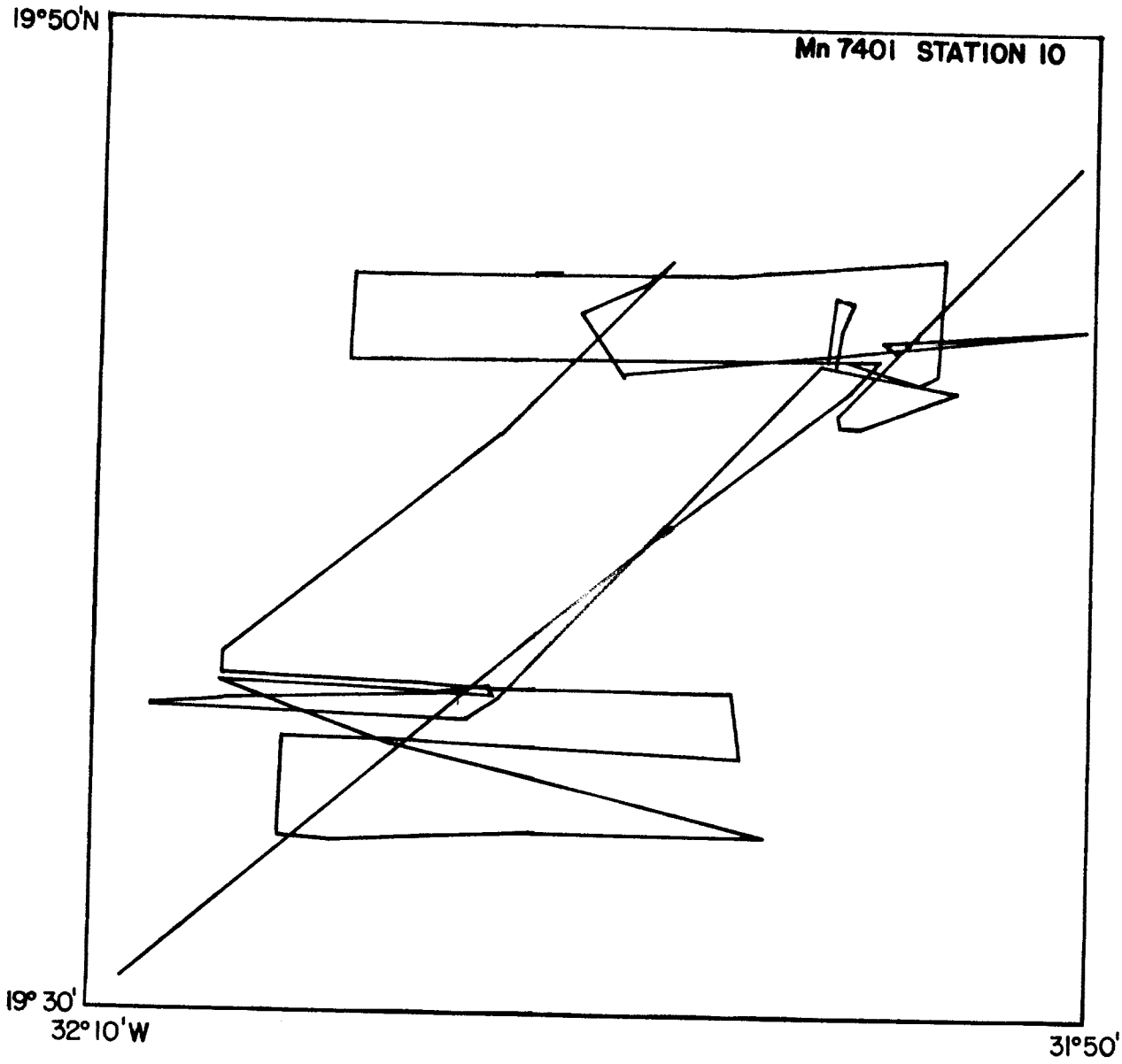


Figure 49.

TABLE 8: STATION NO. 10 - ROSETTE CAST #7

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
1-1	5110	3.92				17		TM
1-2	5110					17		TM
1-3	5110	3.97				17		TM
1-4	5110					17		TM
1-5	5010					140		TM
1-6	5010	3.91				140		TM
1-7	5010					140		TM
1-8	5010					140		TM
1-9	4165	3.58						TM
1-10	4165	3.60						TM
1-11	4165	3.60						TM

TABLE 9: STATION NO. 10 - ROSETTE CAST #8

Bottle #	Depth, m	Oxygen, ml/liter	Salinity, °/₀₀	Phosphate, µg-at P/liter	Silica, µg-at/ liter	'PDR' Distance off bottom	Alkalinity	Extraction and trace metals
2-1	5150	3.91		2.42	141.0	3		Ex
2-2	5150					3		Ex
2-3	5053	3.90		2.37	141.2	98		Ex
2-4	5053					98		Ex
2-5	4600	3.83		2.46	141.8	400		
2-6	4104	3.53		2.51	150.6			Ex
2-7	4104							
2-8	1150	0.84		3.08	110.6			
2-9	812	0.55		3.21	92.3			
2-10	575	0.34		3.03	74.9			
2-11	307	3.08		1.92	35.5			

TABLE 10: STATION NO. 10 - PORE WATER CHEMISTRY

Depth interval in core, cm	pH	Alkalinity, * meq/l
0-2	7.68	2.52
2-4	7.78	2.41
4-6	7.78	2.34
6-11	7.81	2.45
11-13	7.78	2.36
13-15	7.78	2.37
15-19	7.77	2.47
20-22	----	2.37
22-24	7.82	2.43
24-29	7.76	2.36
Near bottom water		2.71, 2.8, 2.89
100 m off bottom		2.69
1000 m off bottom		2.68

* Titration alkalinity values need to be corrected for titer blank of 0.530 M NaCl solution and deviation of Standard Acid (HCl) from 0.010N.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 19°41.9'N

LONG. W.: 131°59.04'W

WATER DEPTH: 5037 m

STATION: 010

SAMPLE NO.: FFG -037

DATE: 5 August 1974

TIME: **LAUNCH** 0506Z

ON BOTTOM _____

RECOVER 0845Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Near crest of 150 m abyssal hill. Strong bottom reflection over 10 m of transparent sediment.

ASSOCIATED SEDIMENT--

Sample No.: FFG -037 (sediment lumps brought up with grab)

Type: Brown silty clay

NODULE TYPES IN THIS SAMPLE:

s-m[P]s,	s[D]s,	m[D-E]s,	m[T]s
(8)	(8)	(1)	(1)

STATION: 010 SAMPLE NO.: FFG -037

NODULE TYPES: 44% s-m[P]s, 44% s[D]s, 5% m[D-E]s, 5% m[T]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	8	10	0	0	0	18	0
Weight (Kg)	0.03	0.12	0	0	0	0.15	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 12-44 mm

PRIMARY MORPHOLOGY: Coalespheroidal (mostly the larger nodules) or discoidal (mostly the smaller nodules).

SECONDARY MORPHOLOGY: One discoidal approximates a flattened prolate ellipsoid. The tabular nodule is elongate, with curled-up long edges. Several nodules & coalespheroid segments lobed (fracturing without separation followed by healing?) One discoid has end fractured off.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Eight (23-44 mm max. diam., six being 2-poly and two being 3-poly). Mostly coalesced discoids, a few ellipsoids.

SURFACE TEXTURE:

Upper Surface: Smooth to microgranular

Lower Surface: Microgranular

Tops & bottoms apparent on many of the larger nodules. Equatorial belt, with granular texture, has highest relief. Even smallest nodules seem to display textural pattern of larger nodules.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	------	------	----------	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←——→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 m to <1 mm.

COLOR OF NODULE STREAK: Dark brown.

COMMENTS: Septarian fracture pattern evident on many nodules. Worm tubes apparently not present. Sample includes soft lumps of brown silty clay; as well as many frags. of "organ-pipe" growth.

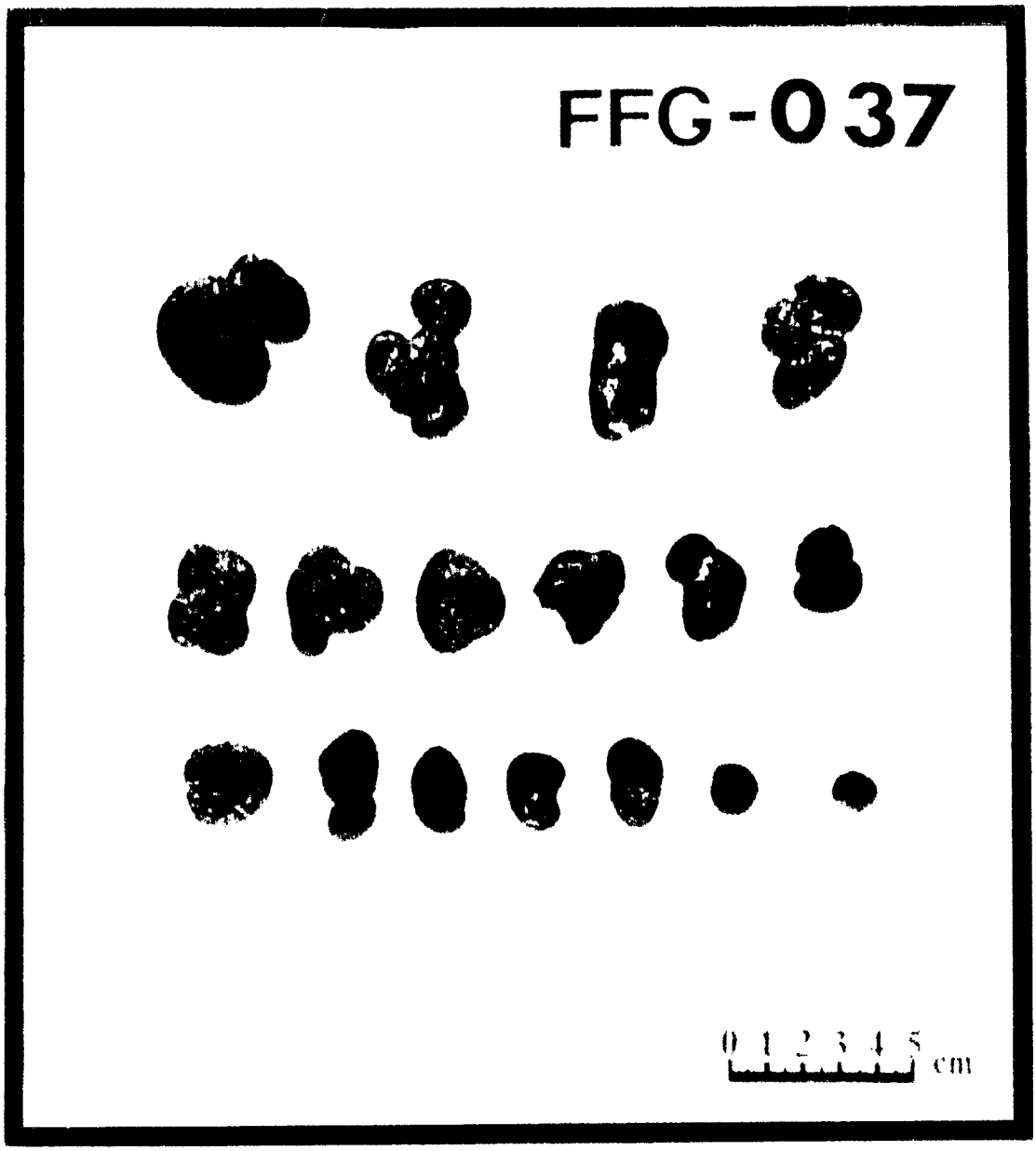


Figure 50.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 19°41.87'N

LONG. W.: 132°00.56'W

WATER DEPTH: 5155 m

STATION: 010

SAMPLE NO.: FFG -038

DATE: 5 August 1974

TIME: **LAUNCH** 0515Z

ON BOTTOM _____

RECOVER 0914Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Valley between abyssal hills. Good bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -012 (from FFG -038)

Type: Brown silty clay.

NODULE TYPES IN THIS SAMPLE:

m[D]s,	m[D-E]s
(5)	(2)

STATION: 010 SAMPLE NO.: FFG -038

NODULE TYPES: 71% m[D]s, 29% m[D-E]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	1	6	0	0	0	7	0
Weight (Kg)	0.01	0.09	0	0	0	0.10	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 32-44 mm

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Two nodules approximate flattened prolate ellipsoids. Discoidals have incipient lobes associated with septarian fracture patterns.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper Surface: Smooth to microgranular
Lower Surface: Microgranular

} Tops & bottoms apparently distinguishable on several nodules. Highest relief in equatorial belt, where texture is granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	- - - -	- - - - -	- - - - - - - -	→	
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	⟷				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to <1 mm.

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Worm tubes apparently not present. Sample includes one frag. of "organ-pipe" growth, as well as one barnacle (?) shell, the latter probably scraped off side of the ship during recovery.

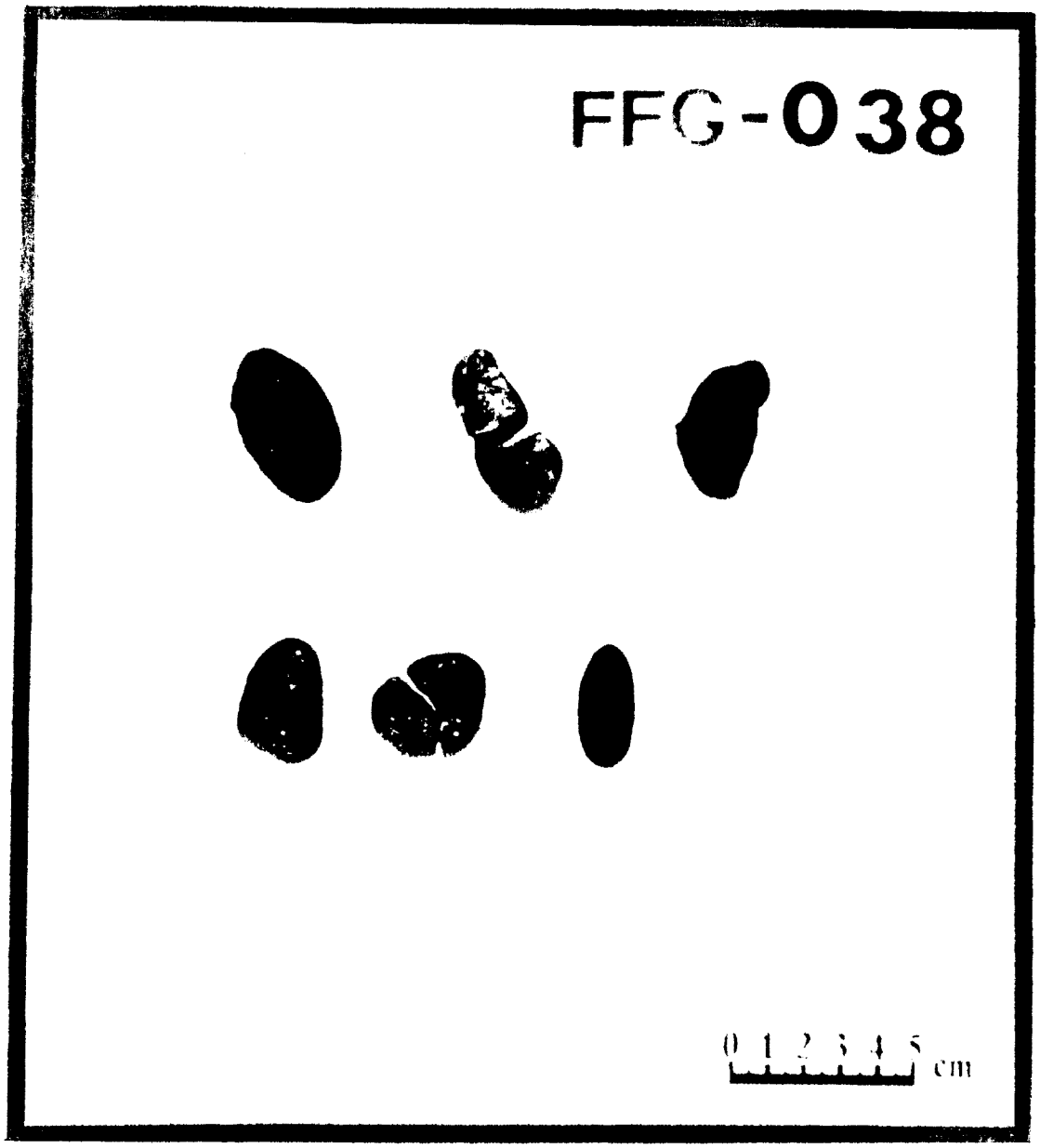


Figure 51.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 010

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -039

LAT. N.: 19°41.95'N

DATE: 5 August 1974

LONG. W.: 132°02.73'W

TIME: LAUNCH 0525Z

WATER DEPTH: 5120 m

ON BOTTOM _____

RECOVER 1027Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Middle slope of 75 m abyssal hill. Strong bottom reflection over 15 m transparent sediment.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -012, -013, -014 at Station 010.

Type: Probably brown silty clay.

NODULE TYPES IN THIS SAMPLE:

s[D]s or s[D-E]s,	s-m[P]s,	s[B]s
(3)	(2)	(1)

STATION: 010 SAMPLE NO.: FFG -039

NODULE TYPES: 33% s-m[P]s, 50% s[D]s or s[D-E]s, 17% s[B]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	3	3	0	0	0	6	0
Weight (Kg)	0.01	0.05	0	0	0	0.06	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 22-38 mm

PRIMARY MORPHOLOGY: Two are coalespheroid; three are discoidal; one is a partially encrusted shark tooth fragment.

SECONDARY MORPHOLOGY: Two discoidals elongate; one discoidal approximates a flattened ellipsoidal.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Two (one 2-poly, one 3-poly)

SURFACE TEXTURE:

Upper Surface: Smooth to microgranular

Lower Surface: Microgranular

Tops and bottoms of some nodules apparently distinguishable. Highest relief in equatorial belt, where texture is granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	---------->				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	<---------->				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to 1 mm

COLOR OF NODULE STREAK: Dark brown to black.

COMMENTS: Nodule growth on shark's tooth is near tip of tooth, rather than near base which is more normal. Worm tubes apparently absent.

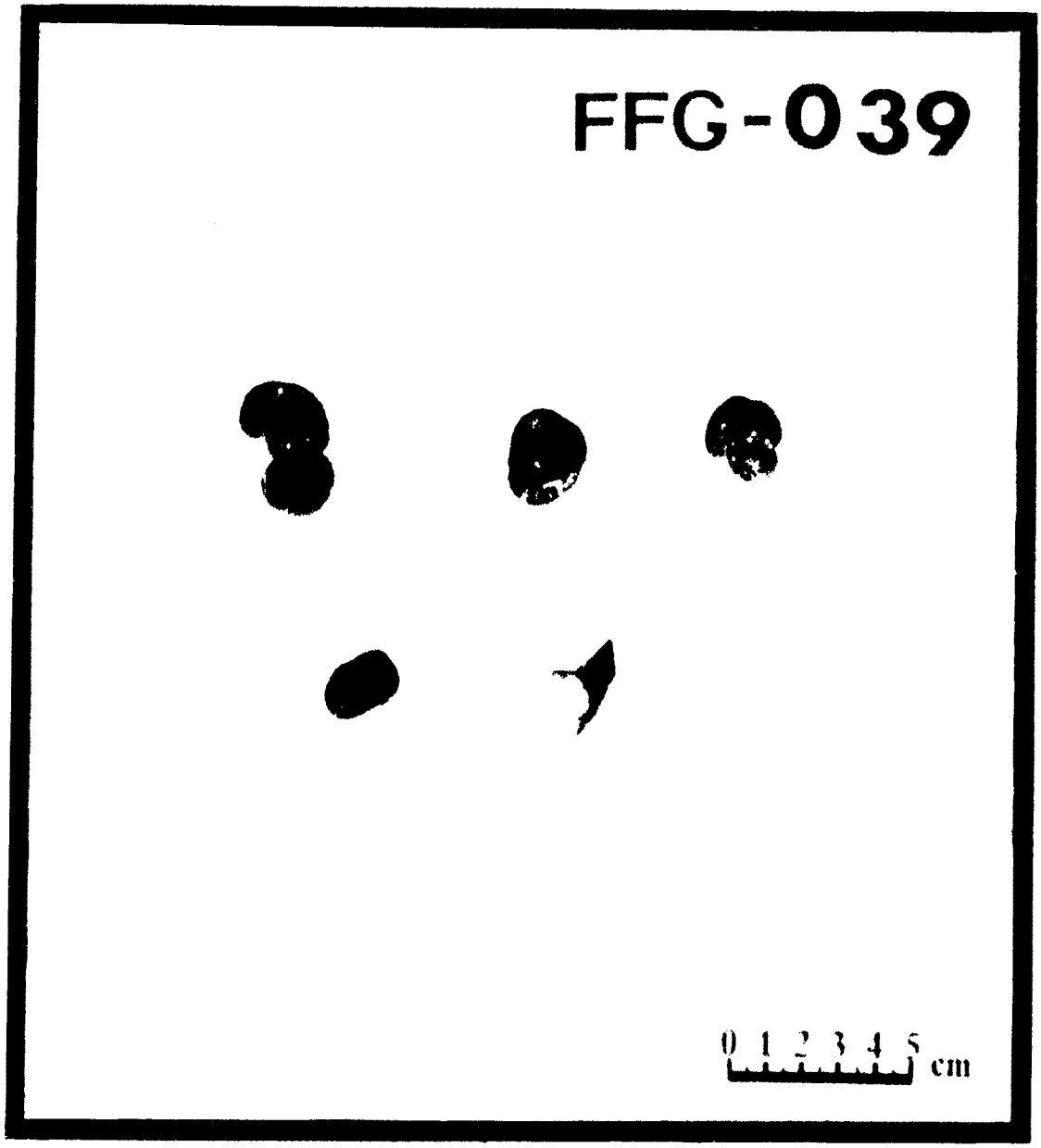


Figure 52.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 010

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -040

LAT. N.: 19°42.01'N

DATE: 5 August 1974

LONG. W.: 132°04.81'W

TIME: LAUNCH 0535Z

WATER DEPTH: 5145 m

ON BOTTOM _____

RECOVER 1052Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Lower slopes of 50 m abyssal hill. Strong bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -013 (from FFG 040)

Type: Brown silty clay.

NODULE TYPES IN THIS SAMPLE:

s-m[D]s,	s[E]s
(3)	(1)

MGG 0 8 0 2 5 0 0 1

STATION: 016 SAMPLE NO.: FFG -040

NODULE TYPES: 75% s-m[D]s, 25% s[E]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	3	1	0	0	0	4	0
Weight (Kg)	0.01	0.04	0	0	0	0.05	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 13, 14, 16, 35 mm

PRIMARY MORPHOLOGY: Three discoidal, one ellipsoidal

SECONDARY MORPHOLOGY: Largest discoidal is missing a septrian-fracture segment. Ellipsoidal nodule is prolate.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

Upper ? Surface: Smooth to microgranular

Lower ? Surface: Microgranular

} Tops & bottoms distinguishable with difficulty. Equatorial belts have slightly higher relief, but texture of surface still microgranular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	----------→				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to <1 mm

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Worm tubes apparently not present.

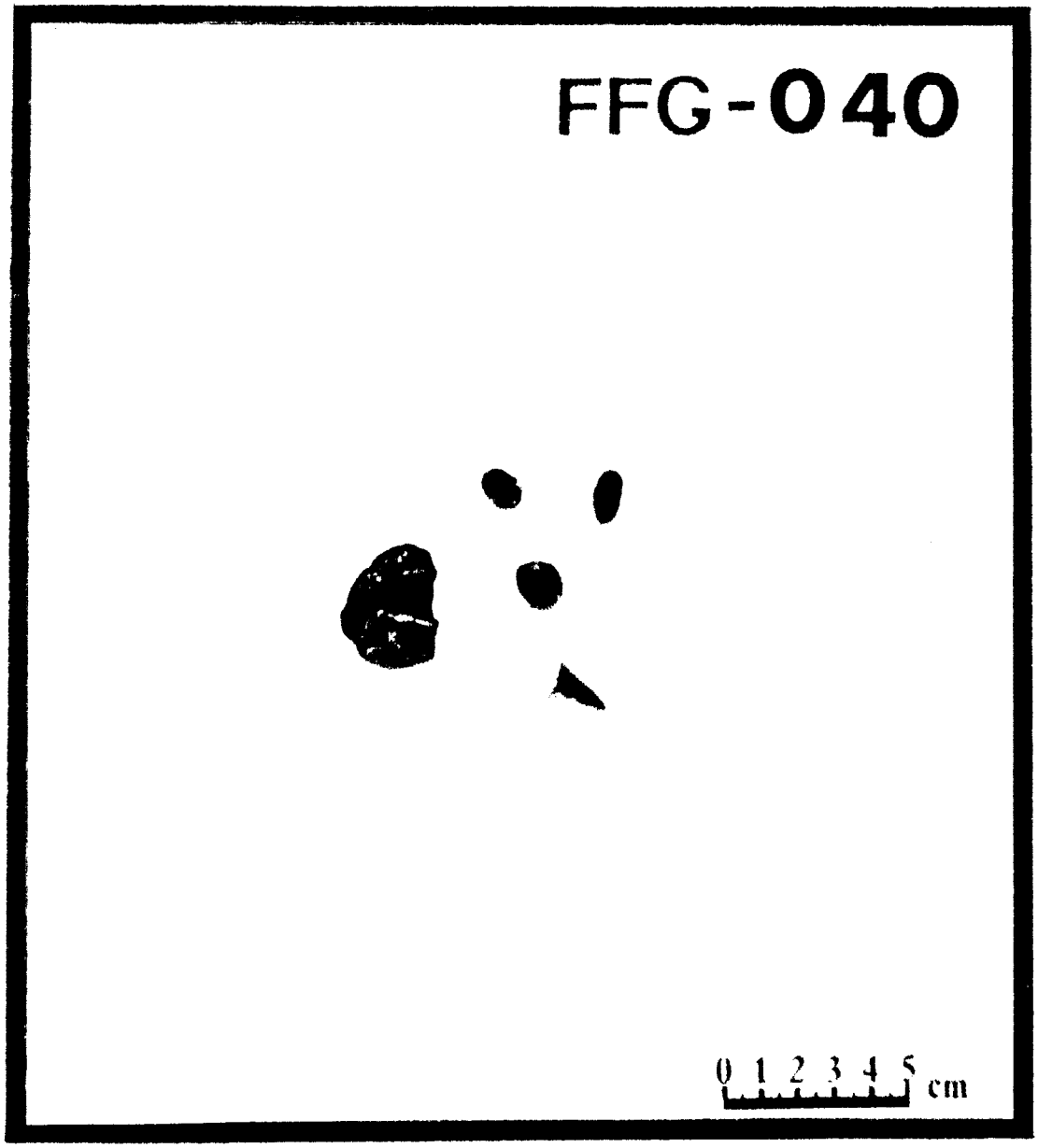


Figure 53.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 010

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG-041

LAT. N.: 19°36'N

DATE: 5 August 1974

LONG. W.: 132°08'W

TIME: LAUNCH 1739Z

WATER DEPTH: 5072 m

ON BOTTOM _____

RECOVER 2345Z*

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Upper slope of 125 m abyssal hill. Strong bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -012, -013, -014 at Station 010.

Type: Probably brown silty clay.

NODULE TYPES IN THIS SAMPLE:

*No nodules recovered (grab basket did not return with floatation spheres), line attaching grab basket to the spheres evidently severed after grab returned to surface (radio signal picked up, then lost).

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1
STATION: 010
COLLECTION DEVICE: CNEXO-FFG
SAMPLE NO.: FFG -042
LAT. N.: 19°36'N
DATE: 5 August 1974
LONG. W.: 132°08'W
TIME: LAUNCH 1752Z
WATER DEPTH: 5125 m
ON BOTTOM _____
RECOVER 2327Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 relief.

SPECIFIC BATHYMETRIC LOCATION:

Lower slopes of 125 m abyssal hill. Fair bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -012, -013, -014 at Station 010.

Type: Probably brown silty clay.

NODULE TYPES IN THIS SAMPLE:

s-m[D]s,	s-m[E]s,	m[P]s
(7)	(2)	(1)

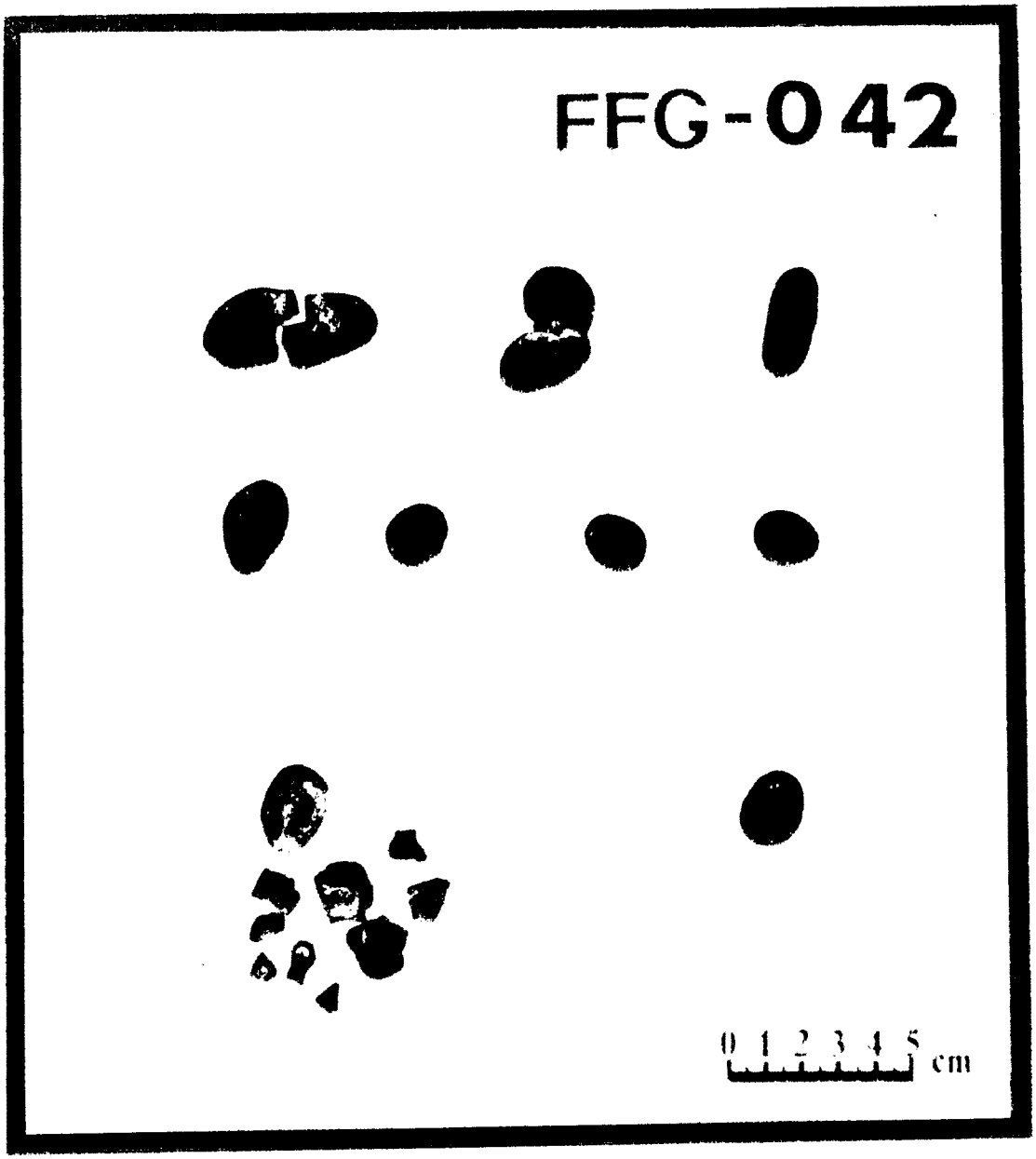


Figure 54.

STATION: 010 **SAMPLE NO.:** FFG -042

NODULE TYPES: 70% s-m[D]s, 20% s-m[E]s, 10% m[P]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	6	4	0	0	0	10	0*
Weight (Kg)	0.05	0.10	0	0	0	0.15	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 18-45 mm

PRIMARY MORPHOLOGY: Seven essentially discoidal; two ellipsoidal; and one is coalespheroidal.

SECONDARY MORPHOLOGY: One discoidal and one ellipsoidal have satellite protrusions. Three discoids elongate to prolate. One ellipsoidal is flattened and prolate. Differences between discoidal and ellipsoidal shapes transitional.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: One (2-poly), coalesced discoids.

SURFACE TEXTURE:

Upper? Surface: } Smooth to microgranular
Lower? Surface: }

Tops & bottoms distinguishable, with difficulty, on only a few nodules. Equatorial belt slightly higher relief microgranular. Surface texture apparently more uniform than on previously collected nodules at this station.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	----------→				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to ~ 1 mm

COLOR OF NODULE STREAK: Very dark brown to black.

COMMENTS: Two nodules broken during collection process. Septarian fracture pattern evident on several nodules. Worm tubes apparently not present.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

COLLECTION DEVICE: CNEXO-FFG

LAT. N.: 19°36'N

LONG. W.: 132°08'W

WATER DEPTH: 5080 m

STATION: 010

SAMPLE NO.: FFG -043

DATE: 5 August 1974

TIME: LAUNCH 1804Z

ON BOTTOM _____

RECOVER 2236Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Near crest of 75-100 m abyssal hill. Strong bottom reflection.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -012, -013, -014 at Station 010.

Type: Probably brown silty clay.

NODULE TYPES IN THIS SAMPLE:

s-m[D]s,	s-m[P]s
(12)	(4)

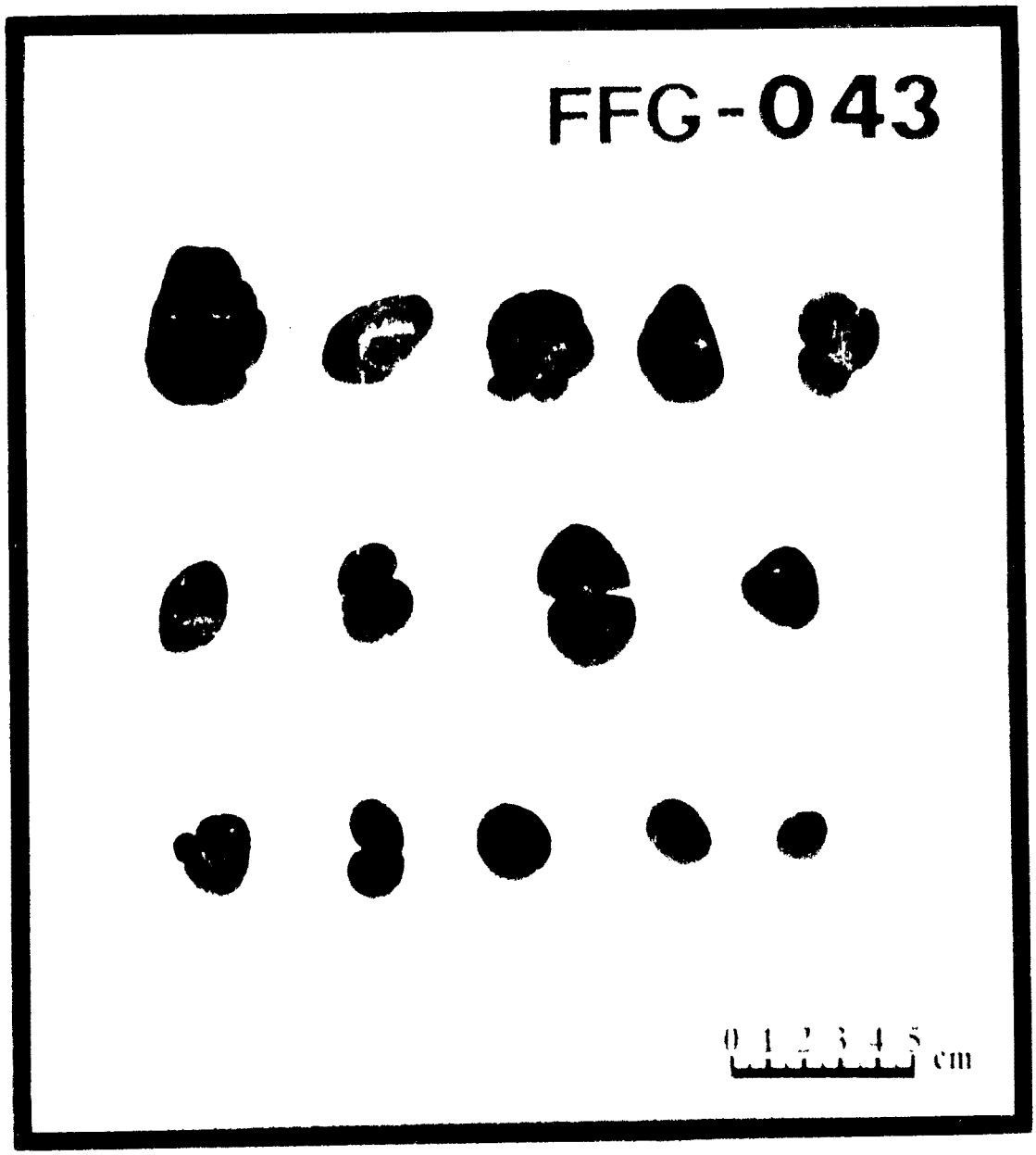


Figure 55.

STATION: 010 SAMPLE NO.: FFG -043

NODULE TYPES: 75% s-m[D]s, 25% s-m[P]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	4	12	0	0	0	16	0
Weight (Kg)	0.02	0.20	0	0	0	0.22	0

(sub-sample wts. estimated)

SIZE RANGE OF MAX. DIAM.: 15-44 mm

PRIMARY MORPHOLOGY: Mostly discoidal; four are coalespheroidal.

SECONDARY MORPHOLOGY: Several discoids elongate; two discoids have satellite protrusions, and several are lobed in conjunction with a faint septarian fracture pattern. Two coalespheroids might be considered discoids with agglutinated spherules.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: Four (three 2-poly, one 3-poly)

SURFACE TEXTURE:

Upper Surface: Smooth to microgranular
Lower Surface: Microgranular

} Tops & bottoms apparent on many larger nodules. Equatorial belt has highest relief--approaching granular.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	---------->				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	<---------->				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm to <1 mm.

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Worm tubes apparently not present.

Note: One 30 mm max. diam. coalespheroid found in sphere #4 grab basket several days after Station 10, and assumed to be from FFG -043 on basis of similar appearance; bagged separately.

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 010

COLLECTION DEVICE: CNEXO-FFG

SAMPLE NO.: FFG -044

LAT. N.: 19°36'N

DATE: 5 August 1974

LONG. W.: 132°08'W

TIME: LAUNCH 1814Z

WATER DEPTH: 5204 m

ON BOTTOM _____

RECOVER ---

BATHYMETRIC PROVINCE, GENERAL RELIEF:

North of Clarion Fracture Zone. Rolling abyssal hills, mostly 50-150 m relief.

SPECIFIC BATHYMETRIC LOCATION:

Valley between 75-100 m abyssal hills. Poor record at launch site.

ASSOCIATED SEDIMENT--

Sample No.: None at this site; refer to FFC -012, -013, -014 at Station 010.

Type: Probably brown silty clay.

NODULE TYPES IN THIS SAMPLE:

No nodules recovered---------grab lost.

STATION SUMMARY

STATION: 11

TIME ON STATION: 8/8/74 0440Z

LATITUDE: 25°36'N

TIME DEPART STATION: 8/8/74 0800Z

LONGITUDE: 126°00'W

SEDIMENT TYPE: Red clay

OPERATIONS: FFG #45, 46, 47

DISCUSSION:

Very few nodules in grabs from flank of a small (40 m) abyssal hill. Densities of 0.05 - 0.3 kg/m^2 are estimated from recovery.

10-

Mn-NODULE SAMPLE LOG

CRUISE: Mn '74, Leg 1

STATION: 011

COLLECTION DEVICE: CNEXO-FFGs

SAMPLE NO.: FFG -045, -046, -047

LAT. N.: 25°16.54',25°16.77', 25°16.82'N

DATE: 8 August 1974

LONG. W.: 126°21.33', 126°21.09', 126°21.04'W

TIME: LAUNCH 0425, 0432, 0438Z

WATER DEPTH: 4415, 4410, 4415 m

ON BOTTOM _____

RECOVER 0801, 0809, 0812Z

BATHYMETRIC PROVINCE, GENERAL RELIEF:

Just south of Molokai Fracture Zone.

SPECIFIC BATHYMETRIC LOCATION:

Flank of 40 m abyssal hill.

ASSOCIATED SEDIMENT--

Sample No.: FFGMC -014 (from FFG -046)

Type: Brown silty clay.

NODULE TYPES AT THIS STATION:

FFG -045: s-m[D]s (2)

FFG -046: s[E]s (1)

FFG -047: s[D]s (1)

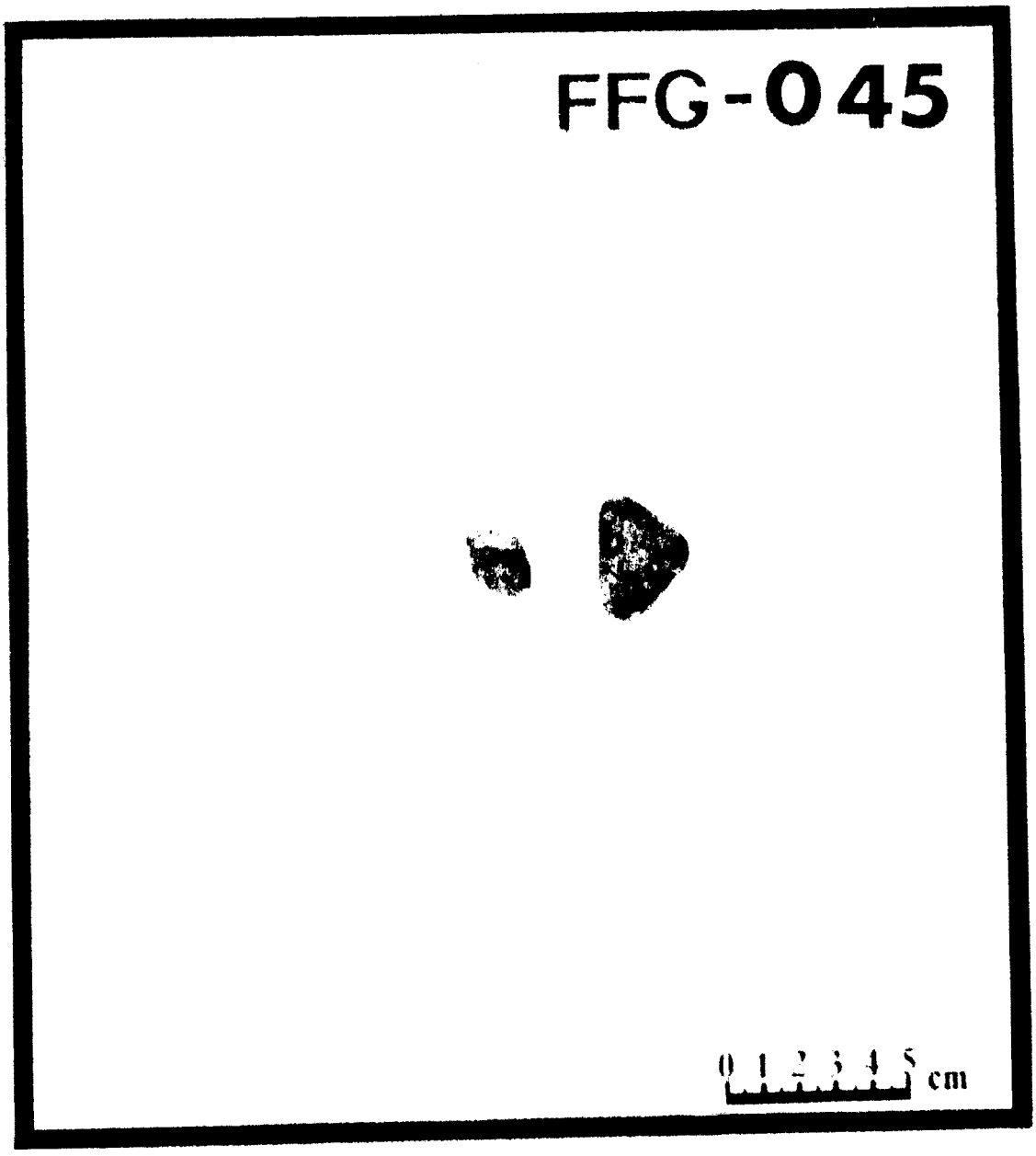


Figure 56.

STATION: 011 SAMPLE NO.: FFG -045

NODULE TYPES: 100% s-m[D]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	1	0	0	0	2	0
Weight (Kg)	0.008	0.017	0	0	0	0.025	0

(all weights estimated)

SIZE RANGE OF MAX. DIAM.: 22.35 mm (largest is 35 x 25 x 12 mm)

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: Largest has triangular outline, smallest is faceted.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

------ Surface:
------ Surface: } Smooth to microgranular { Tops and bottoms not readily identifiable. Relief in equatorial belt not higher than rest of surface.

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	----------→				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm

COLOR OF NODULE STREAK: Brown

COMMENTS: Worm tubes not present. Sample also includes soft lumps of brown silty clay and attached "organ-pipe" structures.

STATION: 011 SAMPLE NO.: FFG -046

NODULE TYPES: 100% s[E]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	<20	20-40	40-60	60-80	>80	TOTAL	FRAGS.
Number of nodules	1	0	0	0	0	1	0
Weight (Kg)	0.002	0	0	0	0	0.002	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 9 mm

PRIMARY MORPHOLOGY: Ellipsoidal

SECONDARY MORPHOLOGY: Vaguely faceted.

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface: } Microgranular { Top & bottom not identifiable, but half of surface is covered with brown "bubble" (organic?) structures.

_____ Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	----------→				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm

COLOR OF NODULE STREAK: Dark brown

COMMENTS: Sample also includes small soft lumps of brown silty clay.

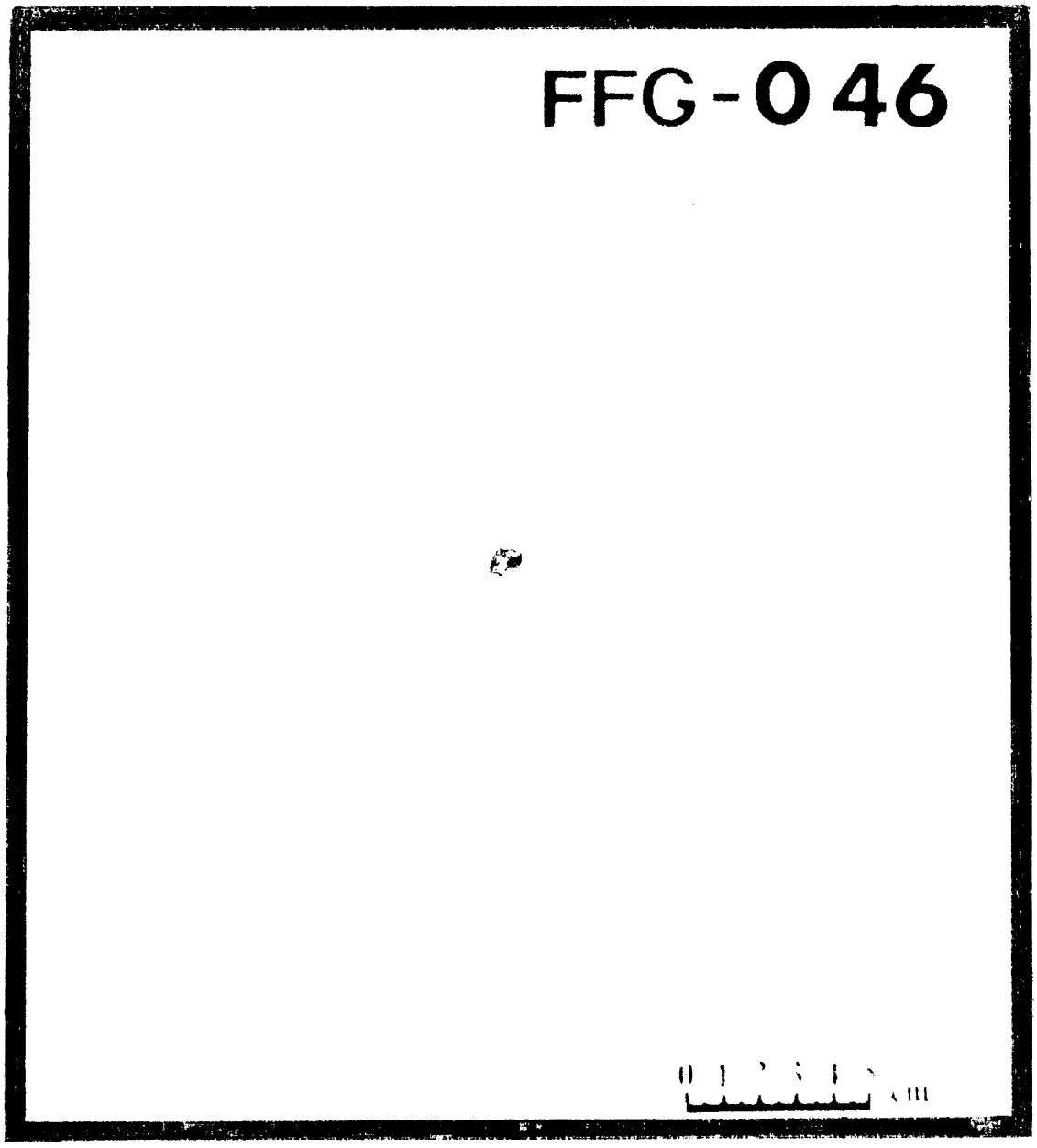


Figure 57.

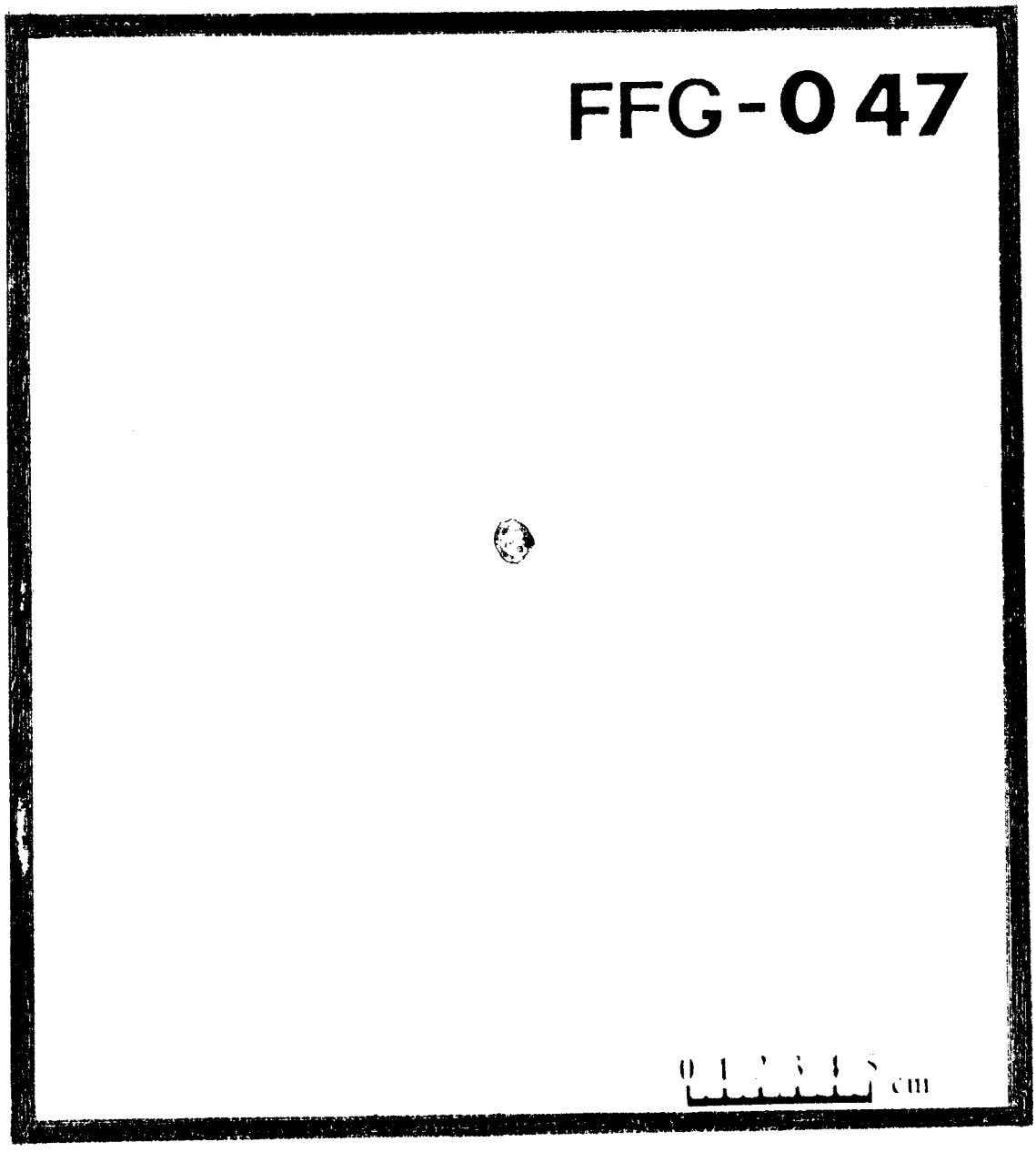


Figure 58.

STATION: 011 SAMPLE NO.: FFG -047

NODULE TYPES: 100% s[D]s

NUMBER AND WEIGHT OF NODULES:

Template Size (mm)	< 20	20-40	40-60	60-80	> 80	TOTAL	FRAGS.
Number of nodules	1	0	0	0	0	1	0
Weight (Kg)	0.004	0	0	0	0	0.004	0

(weight estimated)

SIZE RANGE OF MAX. DIAM.: 13 mm

PRIMARY MORPHOLOGY: Discoidal

SECONDARY MORPHOLOGY: ----

NUMBER AND MULTIPLICITY OF COALESPHEROIDS: None

SURFACE TEXTURE:

_____ Surface: } Micrognanular { Top & bottom not indentifiable, but part of surface is covered with brown "bubble" (organic?) structures.

_____ Surface: }

CHARACTER OF SURFACE MAMMILLAE:

	V. LOW	LOW	MODERATE	HIGH	V. HIGH
RELIEF	----------→				
	V. FINE	FINE	MEDIUM	COARSE	V. COARSE
RELATIVE SIZE	←→				

ABSOLUTE DIAM. OF MAMMILLAE: <<1 mm

COLOR OF NODULE STREAK: Very dark brown.

COMMENTS: Sample also includes several soft lumps of brown silty clay.

TABLE 11: SUMMARY OF Mn-NODULE SAMPLES

STATION	SAMPLE NO.	LAT. N.	LONG. W.	DEPTH (m)	BATHYMETRIC LOCATION	ASSOCIATED SEDIMENT	NUMBER OF NODULES	SIZE RANGE (mm)	TOTAL WEIGHT (kg)	EXTRAPOLATED DENSITY (kg/m^2)	NODULE TYPES
001	FFG-001	13°00.1'	154°05.0'	5413	Valley between abyssal hills	Brown silt/clay	4	34-52	0.22	2.8	m[D]r
001	FFG-002	13°00.1'	154°05.0'	5413	Valley between abyssal hills	Brown silt/clay	3	44-79	0.32	4.0	m-l[D]r, l[D]b
001	FFG-003	13°00.1'	154°05.0'	5413	Valley between abyssal hills	Brown silt/clay	2	45-52	0.14	1.8	m[D]r
002	FFG-004	11°21.4'	153°37.5'	5190	Low depositional mound near seamount	Brown clayey silt	6	10-57	0.18	2.2	m[D]b, s[E]r, s[T]r, s[P]r
002	FFG-005	11°21.4'	153°37.5'	5190	Low depositional mound near seamount	Brown clayey silt	3	13-20	0.02	0.2	s[E]r
002	FFG-006	11°21.4'	153°37.5'	5190	Low depositional mound near seamount	Brown clayey silt	2	12-17	0.02	0.2	s[S]r
003	FFG-007	9°59.3'	152°56.7'	∿5000	PDR inoperative	Brown silty clay	43	8-63	0.50	6.2	s-l[E]r, s-m[E-D]r, s[S]r, s-m[P]r, s[B]r, m[T]r
003	FFG-008	9°59.3'	152°56.7'	∿5000	PDR inoperative	Brown silty clay	0	0	0.00	0.0	No nodules in grab
003	FFG-009	9°59.3'	152°56.7'	∿5000	PDR inoperative	Brown silty clay	23	7-97	0.45	5.6	s-m[D]r, s-m[D-E]r, s[S]r, s-l[T]$^{s-b}$r, s-m[P]s-r
004	FFG-010	8°39.8'	152°37.9'	∿5100	Rolling abyssal hills (?)	Dk. brn. clayey silt	1	18	0.01	0.1	s[E]r
004	FFG-011	8°39.8'	152°37.9'	∿5100	Rolling abyssal hills (?)	Dk. brn. clayey silt	6	9-18	0.02	0.2	s[E]r, s[S]r, s[B]r s[T]r
004	FFG-012	8°39.8'	152°37.9'	∿5100	Rolling abyssal hills (?)	Dk. brn. clayey silt	3	15-42	0.05	0.6	m[D]r, s[P]r, s[E]r
005	B-2 (Top)	2°56.3'	150°59.1'	4850	Lower flank of 450 m seapeak on abyssal plain	Red-brown carbonate clay	∿15	∿20-65	——	——	Probably m-l[D]b-r, s-m[E]r
005	B-2 (Buried)	2°56.3'	150°59.1'	4850	Lower flank of 450 m seapeak on abyssal plain	Burrow-mottled cream carbon. ooze, brn. clay	7	10-88	0.45	——	l[E]r, l[T]r, s[D]b-r, s[P]b, s[F]r, Frags.
005	FFG-013	2°53.9'	150°56.4'	∿4600	Near crest (?) of 450 m seapeak on abyssal plain	Light brn. foram ooze	0	0	0.00	0.0	No nodules in grab
005	FFG-014	2°55.0'	150°58.5'	4710	Upper flank of 450 m seapeak on abyssal plain	Foram ooze/clay	3	12-12	0.01	0.1	s[D]r, s[T]s-r, s[B]s
005	FFG-015	2°56.3'	151°00.6'	5025	Near base of 450 m seapeak on abyssal plain	Foram ooze/clay	23	28-58	0.80	10.0	m[D]s-r, s-m[P]s-r, m[E]s-r, Frags.
006	FFG-016	9°02.8'	146°27.4'	5150	Flank of 100-150 m abyssal hill	Clayey siliceous ooze	11	9-65	0.35	4.4	s-l[D]$^{r-b}$r, s[S]r, s-m[E]r
006	FFG-017	9°03.0'	146°29.2'	5180	Flank of 100-150 abyssal hill/ridge	Mottled lt. brn. & gray brn. clayey sil. ooze	88	7-53	0.70	8.8	s-m[P]s-r, s-m[D]$^{s}_{b}$-r, s-m[E]s-r, s[S]s-r
006	FFG-018	9°03.4'	146°32.5'	5155	Crest of 50 m abyssal hill	Clayey siliceous ooze	19	8-44	0.30	3.8	s-m[E]r-b, s-m[D]r-b, s[S]r-b, s[P]r-b
006	FFG-019	9°03.7'	146°34.3'	5175	Mound in depression between small abyssal hills	Clayey siliceous ooze	9	10-107	0.72	9.0	l[D]b, s[S]r, s[F]r, s[E]r, s[B]r

TABLE 11: (continued)

STATION	SAMPLE NO.	LAT. N.	LONG. W.	DEPTH (m)	BATHYMETRIC LOCATION	ASSOCIATED SEDIMENT	NUMBER OF NODULES	SIZE RANGE (mm)	TOTAL WEIGHT (kg)	EXTRAPOLATED DENSITY (kg/m^2)	NODULE TYPES
006	FFG-020	8°53.8'	146°29.5'	5225	Middle slope of 50 m abyssal hill group	Beige clayey siliceous ooze	16	10-77	1.16	14.5	s-l[D]b-r, s[E]b, s[D]s, s[P]r
006	FFG-021	8°55.9'	146°29.6'	5190	Terrace on middle slope of abyssal hill group	Lt. brn. clayey siliceous ooze	29,	8-55	0.50	6.2	s-m[D]r-b, s-m[E]r-b, s-m[P]r-b, s[S]r-b
006	FFG-022	8°57.5'	146°29.5'	5205	Terrace on middle slope of abyssal hill group	Beige siliceous ooze	9	11-46	0.15	1.9	m[D]b, s-m[P]r-b, s[E]r
006	FFG-023	8°59.8'	146°29.8'	5170	Crest of 25-40 m abyssal hill/ ridge	Lt. brn. clayey siliceous ooze	57	12-82	1.70	21.2	s-m[P]$^{s}_{s}$-r, s-m[D]$^{s}_{s}$-r, m-l[D]$^{s}_{r}$-b, m[E]$^{s}_{s}$-r, m-l[F]$^{s}_{s}$, Frags.
006	FFC-005 (core top)	8°52.0'	146°26.4'	5250	Lower slope of 75 m abyssal hill	Lt. brn. clayey siliceous ooze	1	∿25	0.015	——	s[E]r
006	FFG-024	8°52.0'	146°26.4'	5250	Lower slope of 75 m abyssal hill	Lt. brn. clayey siliceous ooze	26	7-75	1.11	13.9	s-l[D]$^{s}_{b}$-r, m-l[P]$^{s}_{b}$-r, s-m[E]$^{s}_{b}$-r, s[S]r
006	FFG-025	8°54.1'	146°26.6'	5240	Depression surrounded by small abyssal hills	Mottled beige & lt. brn. clayey sil. ooze	26	13-71	0.90	11.2	m-l[D]b, m[P]r, s[D]s-r, s[E]s-r
006	FFG-026	8°55.9'	146°26.7'	5220	Terrace on flank of 100-150 m abyssal hill	Clayey siliceous ooze	53	9-65	0.85	10.6	m-l[D]b-r, s-m[P]r, s[S]s-r, s[E]s-r, s[D]s-r
006	FFG-027	8°57.9'	146°26.75'	5170	Upper terrace of 100-150 m abyssal hill	Mottled beige, lt. brn. & gr.-brn. clayey sil. ooze	2	21-82	0.25	3.1	l[D]b, s[E]r
006	FFC-007 (core top)	8°50.4'	146°26.2'	5175	Crest of 60-80 m abyssal hill	Mottled beige, lt. brn. & gr.-brn. clayey sil. ooze	1	41	0.04	——	m[P]r
007	FFG-028	10°00.75'	143°18.7'	5090	Upper slopes of 100 m abyssal hill	Lt. brn. clayey siliceous ooze	19	8-35	0.10	1.2	s[E]r, m[P]r, m[D]b-r, s[S]r, s[T]r, s[B]r
007	FFG-029	10°00.6'	143°19.0'	5075	Upper slopes of 100 m abyssal hill	Mottled beige & lt. brn. clayey sil. ooze	6	55-92	1.45	18.1	m-l[D]b
007	FFG-030	10°00.5'	143°19.2'	5075	Upper slopes of 100 m abyssal hill	Lt. brn. clayey siliceous ooze	7	21-104	1.70	21.2	l[D]b, l[E]b, s[P]r
008	FFG-031	11°00.4'	139°59.4'	4825	Upper slopes of 150 m abyssal hill	Clayey siliceous ooze	—	———	——	——	Grab not recovered
008	FFG-032	11°00.5'	139°59.3'	4850	Middle slope of 150 m abyssal hill	Clayey siliceous ooze	5	10-90	1.20	15.0	l[D]b, s[S]r
008	FFG-033	11°00.8'	139°59.1'	∿4900	Lower slope of 150 m abyssal hill	Clayey siliceous ooze	1	90	0.45	5.6	l[D]b
008	Dredge #1	11°07'	140°00'	4810	Slopes of 50 m abyssal hill (?)	Clayey siliceous ooze	4	32-40	0.12	——	m[P]r, m[S]r-b, m[D]r-b, Frags.
009	FFG-034	15°07.9'	136°21.7'	4890	Crest of 125 m abyssal hill	Clayey siliceous ooze	2	12-62	0.15	1.9	l[D]s-r, s[T]r
009	FFG-035	15°07.9'	136°21.7'	4885	Crest of 125 m abyssal hill	Clayey siliceous ooze	2	11-30	0.03	0.4	s[D-E]r, s[S]r

TABLE 11: (continued)

STATION	SAMPLE NO.	LAT. N.	LONG. W.	DEPTH (m)	BATHYMETRIC LOCATION	ASSOCIATED SEDIMENT	NUMBER OF NODULES	SIZE RANGE (mm)	TOTAL WEIGHT (kg)	EXTRAPOLATED DENSITY (kg/m^2)	NODULE TYPES
009	FFG-036	15°07.9'	136°21.7'	4885	Crest of 125 m abyssal hill	Clayey siliceous ooze	3	39-69	0.25	3.1	m-l[D]r, m[E]r
010	FFG-037	19°41.9'	131°59.04'	5037	Crest of 150 m abyssal hill	Brown silty clay	18	12-44	0.15	1.9	s-m[P]s, s[D]s, m[D-E]s, m[T]s
010	FFG-038	19°41.87'	132°00.56'	5155	Valley between abyssal hills	Brown silty clay	7	32-44	0.10	1.2	m[D]s, m[D-E]s
010	FFG-039	19°41.95'	132°02.73'	5120	Middle slope of 75 m abyssal hill	Brown silty clay	6	22-38	0.06	0.8	s[D]s or s[D-E]s, s-m[P]s, s[B]s
010	FFG-040	19°42.01'	132°04.81'	5145	Lower slope of 50 m abyssal hill	Brown silty clay	4	13-35	0.05	0.6	s-m[D]s, s[E]s
010	FFG-041	19°36'	132°08'	5072	Upper slope of 125 m abyssal hill	Brown silty clay	—	———	———	——	Grab basket not recovered
010	FFG-042	19°36'	132°08'	5125	Lower slope of 125 m abyssal hill	Brown silty clay	10	18-45	0.15	1.9	s-m[D]s, s-m[E]s, m[P]s
010	FFG-043	19°36'	132°08'	5080	Crest of 75-100 m abyssal hill	Brown silty clay	16	15-44	0.22	2.8	s-m[D]s, s-m[P]s
010	FFG-044	19°36'	132°08'	5204	Valley between 75-100 m abyssal hills	Brown silty clay	--	———	———	——	Grab not recovered
011	FFG-045	25°16.54'	126°21.33'	4415	Flank of 40 m abyssal hill	Brown silty clay	2	22-35	0.025	0.3	s-m[D]s
011	FFG-046	25°16.77'	126°21.09'	4410	Flank of 40 m abyssal hill	Brown silty clay	1	9	0.002	0.02	s[E]s
011	FFG-047	25°16.82'	126°21.04'	4415	Flank of 40 m abyssal hill	Brown silty clay	1	13	0.004	0.05	s[D]s

Explanation: Summary Table

(1) Positions (Lat. N., Long. W.) are based on satellite navigation: continually updated or positions corrected with periodic satellite fixes; most positions accurate to ± 0.5 km.

(2) Depths are uncorrected meters; depth and bathymetric location were determined from the 3.5 kHz echo-sounder profiles and/or bathymetric maps constructed by James D. Craig.

(3) Most of the descriptions of sediment associated with the Mn-nodule samples are based on rapid field examination; in some cases (Stations C01 and 008) the sediment type is inferred from the published sediment maps.

(4) The number of nodules does not include appreciable-size nodule fragments, but the weight of the fragments is included in total weight. Samples that contain many nodule fragments are identified by "Frags." in the column for nodule types. The total weight is accurate to ± 0.5 kg for samples with a total weight ≥ 1.0 kg. Smaller total weights are based, to some degree, on estimation, and are probably accurate to ± 0.2 kg for samples with a total weight ≥ 0.5 kg, and to ± 0.1 kg for still smaller samples.

(5) Nodule size range is the spread of lengths of maximum diameters in meters.

(6) Extrapolated density is based on a grab area of 0.8 m^2 for the CNEXO free fall grabs.

(7) The meaning of symbols for nodule types is discussed in the text.

TABLE 12: INVENTORY OF SPECIALLY HANDLED NODULES FOR MINERALOGICAL AND CHEMICAL ANALYSIS

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1) Collected in separate bag and kept refrigerated at 6° C. (no. of samples in parenthesis) samples from:

   FFG 009, 017 (2), 018, 019, 020 (2), 021 (2), 023, (2), 025, 026

   Stations 3, 6, 7, 8, 9, 10

2) Frozen in separate bags, samples from:

   FFG 25, 26

   Station 6

3) Frozen in contact with surface seawater, samples from:

   FFG 22-30

   Stations 6, 7

SECTION III

Section III

This section presents discussions of shipboard sampling and analytical procedures and problems. The nodule classification system used for sample summary and description logs is presented with a glossary of terms. Pore water and water column analytical procedures are reviewed.

FIELD DESCRIPTION AND CLASSIFICATION OF MANGANESE NODULES

Maurice A. Meylan

DESCRIPTION

No generally accepted procedure for the description of manganese nodules exists. Various research organizations and companies routinely collect data on the size, shape, and surface features of nodules, but no standard format or discussion of descriptive terminology has been published. Except for the lucid and comprehensive observations of Murray and Renard (1891), the available literature dealing with Mn-nodules is devoid of attempts to systematically describe the diverse features that visually characterize Mn-nodules. Thus, preparation for this cruise included the construction of forms for recording observations of nodule size, shape, and surface features.

The description procedure followed on this cruise has evolved from observational experience with nodules from the extensive deposits of the Pacific-Antarctic Ocean, the Southwestern Pacific Basin, and the North Equatorial Pacific, coupled with a knowledge of the types of observations considered important by certain research groups, e.g., the VALDIVIA group.

The recognition of the need for a means of classifying nodules led to the development of such a classification during the cruise. Following is a discussion of the types of observations made (see the detailed sample logs for examples of each type):

Nodule Types

See section on Classification.

Weight and Number of Nodules

Using an aluminum template with four circular holes (2, 4, 6, and 8 cm diameters), the nodules were placed in one of five size categories (<20, 20-40, 40-60, 60-80, and >80 mm) by trying to fit the nodules through the holes. (The template holes essentially measure the intermediate diameters of the nodules). The number of whole nodules of each size was counted, and each size group weighed. The number of fragments of broken nodules was also counted and weighed as a separate category. This latter group includes nodules that apparently were fractured at some time in the past on the sea floor, but not long enough ago so that the fractured surfaces have "healed", i.e., been substantially re-encrusted with manganese.

Size Range of Maximum Diameter

The maximum dimension of the smallest and the largest nodule in each sample was measured. In samples with only a few nodules, all the maximum

diameters were measured. The maximum, intermediate, and minimum diameters of particularly large or unusual nodules were also measured and recorded.

Primary Morphology

Primary morphology is the over-all geometric form of the nodule, disregarding deviations from the ideal shape. There were only seven primary morphologies recognized during this cruise: (1) spheroidal; (2) ellipsoidal; (3) discoidal; (4) tabular; (5) faceted or polygonal; (6) coalespheroidal (variously called "poly", intergrown, tubercular, botryoidal, or grape-shaped); and (7) biological (where the shape is determined by growth around an organic nucleus, e.g., a shark's tooth, a bone, or a vertebra). These seven morphologies are the basis of the classification scheme devised during the cruise.

Secondary Morphology

Secondary morphology describes the deviations from the ideal form, or the primary morphology. Spheroids are commonly partially faceted with one or more flat surfaces, or slightly flattened at the poles. Ellipsoids show many deviations from the ideal, at times being prolate, cigar-shaped, slightly flattened, reniform, or lobed. Discoids often have different degrees of convexity to upper and lower surfaces, sometimes even assuming a "mushroom" form when a central protrusion or mound develops, usually occurring on the lower surface. Discoids occasionally display an almost triangular surface. Tabular nodules usually have a more irregular outline than discoidals. Transitional tendencies between primary morphologies are also considered as part of the secondary morphology of a nodule.

Number and Multiplicity of Coalespheroids

A new term, "coalespheroid", was coined to include those nodules that in the past have been called "poly", intergrown, polylobate tubercular, agglomerate, botryoidal, or grape-shaped, **i.e., those** nodules that appear to consist of more-or-less regular geometric forms joined together, or coalesced, to some degree or other. The multiplicity of a coalespheroid is the number of apparent segments that make up the nodule as a whole. For instance, where two spheres have been joined together, the multiplicity is 2-poly. A botryoidal nodule which consists of many intergrown spheres could be called a "poly-poly".

Surface Texture

The distinguishing feature of many nodules is a mammillated surface, the nodule being covered by closely-spaced hemispherical protrusions of various sizes. Depending upon the mammillae size, the surface texture of nodules collected on this cruise was visually categorized as either: (1) smooth; (2) microgranular; (3) granular; (4) coarsely granular; (5) micro-botryoidal; or (6) botryoidal. The categorization, of course, is subjective, and determinations of average mammilla size for the different categories have not been made. Since the upper and the lower

surfaces of nodules often display different textures, an attempt was made to identify nodule tops and bottoms. Bottom surfaces generally were observed to be rougher. The equatorial belt of nodules, i.e., the circumferential zone which probably was closest to the sediment-water interface, often displays a surface texture differing from either the top or bottom surface, usually having mammillae of larger size and higher relief. Also noted in the detailed descriptions are samples where nodules of different size possess different surface textures. For example, smaller nodules often were seen to be smoother.

Character of Surface Mammillae

The granules and botryoids on a nodule surface are not uniform in size or prominence above the general nodule surface, i.e., they display a range of relative sizes and relief, and these ranges can be used to characterize the surface texture. On the detailed description logs, the approximate ranges are designated by arrows. Relief is here defined as the ratio of mammilla height to the mammilla basal diameter:

Ratio Value	Type of Relief
1	Very high
1:2 - 1	High
1:4 - 1:2	Moderate
1:8 - 1:4	Low
1:8	Very low

See Figure 59 for a graphic display of a range of reliefs.

Relative size is here defined as the ratio of mammilla basal diameter to nodule intermediate diameter:

Ratio Value	Relative Size
1:4	Very coarse
1:4 - 1:8	Coarse
1:8 - 1:16	Medium
1:6 - 1:32	Fine
1:32	Very fine

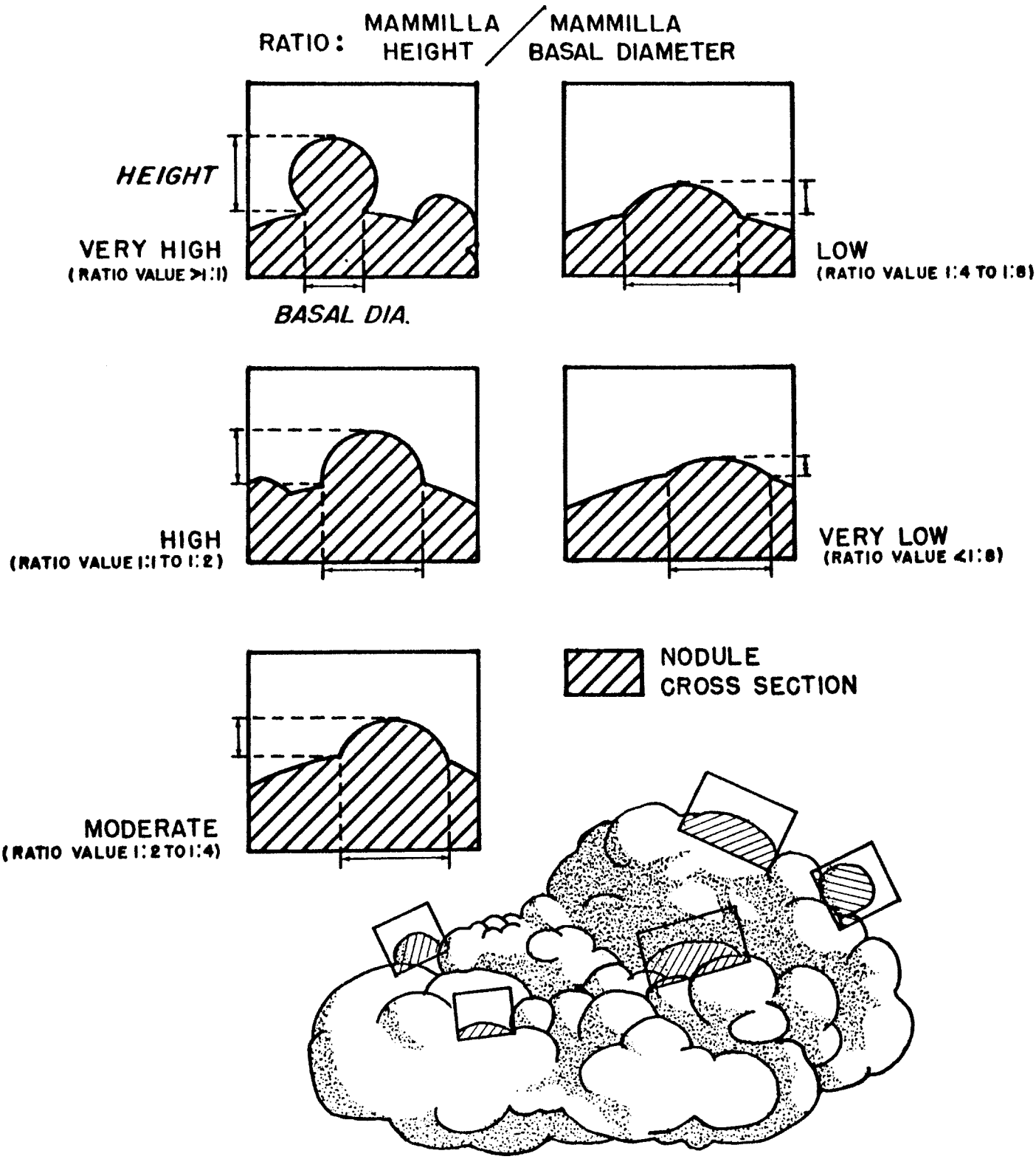


Figure 59. Mammillae relief.

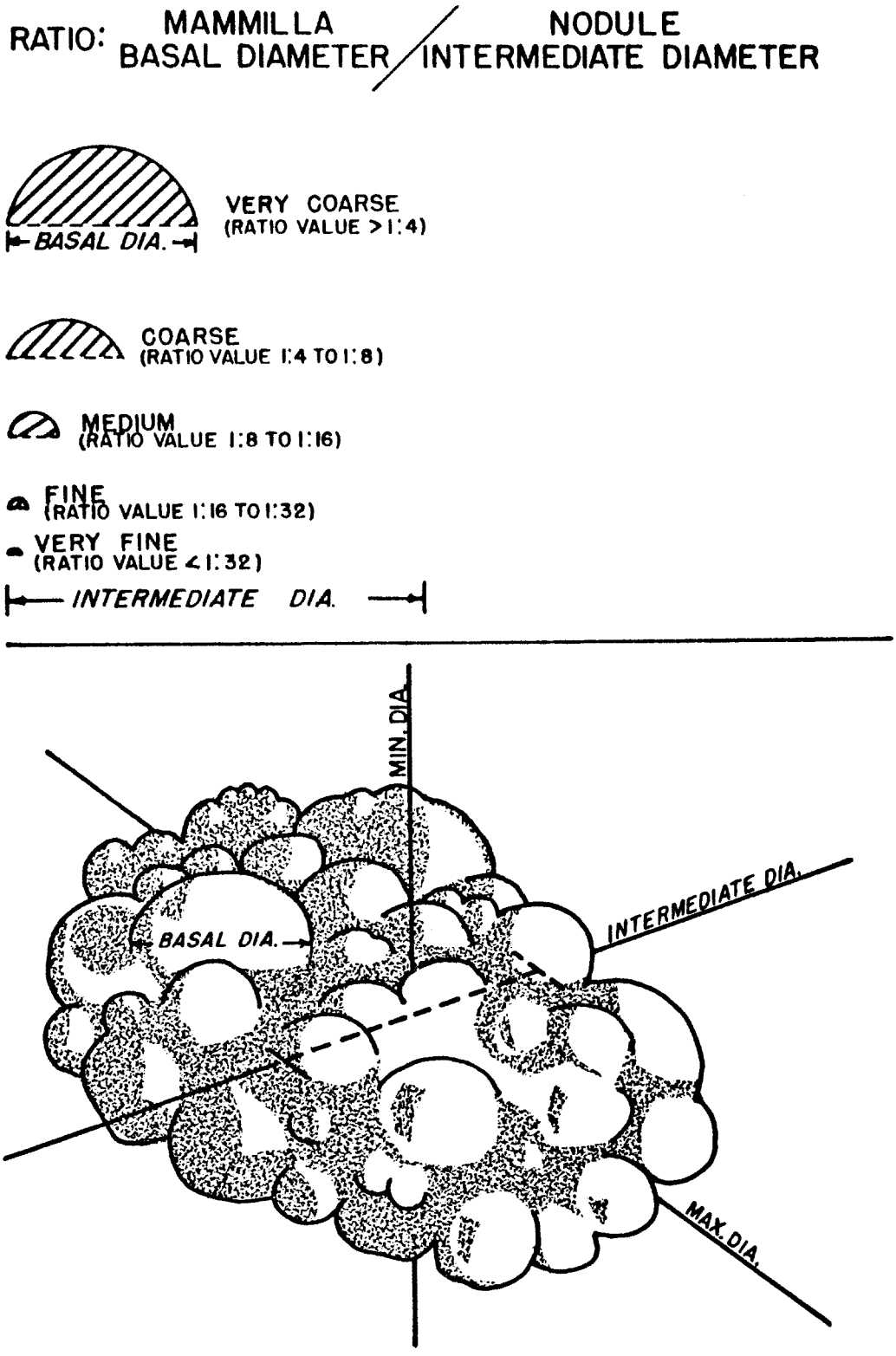


Figure 60. Mammillae relative size.

See Figure 60 for a graphic display of a range of relative sizes. The definition of relative size could make use of the mammilla maximum diameter, but this is very seldom greater than the mammilla basal diameter. On some nodules distinctions have been made between the relief and size of the surface botryoids, and the relief and size of smaller granules which may be superimposed on the larger botryoids.

Absolute Diameter of Mammillae

This is the size range between the basal diameters of the smallest and the largest mammillae.

Color of Nodule Streak

An edge or corner of a nodule from each sample was rubbed on paper cloth to examine the color of the powdered nodule material. Streaks of nodules generally show a range in color from brown to black, but most nodules collected on this cruise showed very dark brown to black streaks. The subtle color differences reported in the descriptions are not considered significant.

Comments

The following types of information are listed in the "Comments" section of the Description Sheet: evidence of organisms attached to the nodules and a description of non-nodule material (rock fragments, sediment lumps, and biologic debris) collected by the free fall grabs.

CLASSIFICATION

During the cruise, a field classification of manganese nodules was devised by Maurice A. Meylan and James D. Craig. The classification is essentially a nodule description in abbreviated format, and does not a attempt to convey genetic interpretations. The nodules have been classified on the basis of size, primary morphology, and surface texture. This information appears in a three-membered symbol: prefix indicates size; central member indicates primary morphology; and suffix indicates surface texture. See Table 13 for a more complete explanation of the classification. Terms are further defined in the Glossary that follows this section.

A comparable classification has been devised by Meyer (1974), based on his examination of nodules from over 300 samples taken in the siliceous ooze belt of the North Equatorial Pacific. The seven categories of Meyer are based on size, over-all shape, surface texture, frequency of intergrowths, and internal structure, but the class designation only conveys a part of this information. The classification of Meylan and Craig considers only size, shape and surface textures, but expresses this information more precisely. The latter classification includes all intergrowths in the coalespheroidal primary morphology, and does not attempt to convey information on internal structures. A comparison of the two schemes is made in Table 14.

The Meylan/Craig nodule classes for each sample collected during this cruise are listed in the summary table (see Table 11) under the heading of "nodule types".

TABLE 13: FIELD CLASSIFICATION OF Mn-NODULES

Prefix: s = small = < 3 cm } nodule
m = medium = 3-6 cm } size
l = large = > 6 cm } (maximum diameter)

Primary Morphology:

[S] = Spheroidal

[E] = Ellipsoidal

[D] = Discoidal (or tabular-discoidal form)

[P] = "Poly" (coalespheroidal or botryoidal form)

[B] = Biological (shape determined by tooth, vertebra, or bone nucleus)

[T] = Tabular

[F] = Faceted (polygonal form due to angular nucleus or fracturing)

Suffix: s = smooth (smooth or microgranular)
r = rough (granular or microbotryoidal) } surface texture
b = botryoidal

Examples: l[D]b = large discoidal nodule with botryoidal surface

m-l[E]$^{s}_{r}$-b = medium to large ellipsoidal nodules with smooth tops, rough to botryoidal bottoms

TABLE 14: CLASSIFICATION COMPARISON

MEYER CLASS =	MEYLAN/CRAIG CLASS
B	m-l [D, D-E, or E-D] b or $\overset{s}{r}$
E/S	s-m [E, E-D, or S] s
Kr	s-m [P, S, or E] r
Kg	s-m [P, S, or E] s
SG	m-l [S] s
G	m-l [S] s
KRU	Variable depending on size, shape, surface texture; no specific symbology to denote nodules with non-ferromanganese nuclei, except for obvious biologic nuclei.

Glossary of Nodule Description Terms

Agglutinated Spherule - a spheroidal object, usually a nodule, attached to a larger nodule by a film or thin encrustation of manganese. If the object's size equals or is slightly smaller than that of the object to which it is attached, the two together make up a coalespheroid. Compare to satellite protrusion.

"Blotches" - circular discolorations on the surfaces of some nodules. May be an organic growth.

Botryoid - a mammilla large enough to have a distinctive hemispherical form visible. Smaller mammillae are termed granules. Botryoids with moderate to very high relief are considered to be "well-developed". Botryoids with low relief are called "poorly developed" and those with very low relief are "suppressed".

Botryoidal - (1) a type of coalespheroidal primary morphology which describes nodules shaped like a bunch of grapes, i.e., multiple coalesced spheres; (2) a type of surface texture characterized by closely spaced botryoids.

"Bubble" structures - groups of small hemispherical domes on a nodule surface, apparently constructed of sediment (by an organism?).

Cavernous - describes a type of microbotryoidal or botryoidal surface texture where the bases of the botryoids are deeply recessed below the general nodule surface.

Coalespheroid - a type of nodule consisting of intergrown spheroids (or ellipsoids, discoids, etc.).

Coalespheroidal - a type of primary nodule morphology wherein the shape is characterized by intergrown spheroids, ellipsoids, discoids, etc.

Crevasse - an indentation in a nodule surface, usually between two adjoining lobes.

Discoidal - a type of primary nodule morphology wherein the shape is characterized by one short and two sub-equal long axes.

Ellipsoidal - a type of primary nodule morphology wherein the shape is characterized by one long and two sub-equal short axes.

Equatorial belt - a circumferential zone on a nodule that is usually identified by a more pronounced development of surface relief; probably that part of a nodule surface that was in close proximity to the sediment-water interface.

Faceted - (1) a secondary morphologic feature, the primary shape being modified by one or more flat surfaces, applied to spheroidal, ellipsoidal, or discoidal nodules that show such a modification; and (2) a type of primary nodule morphology synonymous with polygonal, where essentially the entire nodule surface is characterized by adjoining flat surfaces.

Granular - a type of surface texture that could also be called gritty or rough. Made up of closely spaced tiny mammillae of such a size that a hemispherical growth form is not readily visible. "Coarsely granular" texture is essentially equivalent to microbotryoidal. "Friable granular" indicates a type of surface texture where individual granules are easily rubbed off.

Granule - a very small mammilla of such a size that a hemispherical growth form is not readily visible. Larger mammillae are called microbotryoids or botryoids.

Granule Cluster - a group of closely-spaced granules where some of the group are in superjacent growth positions relative to other members of the group. At a distance the group as a whole resembles a botryoid form.

"Healed" - describes a nodule fracture surface that, subsequent to fracturing, has been re-encrusted with manganese.

Intergrown - coalesced spheroids, ellipsoids, discoids, etc.

Irregular - a type of secondary morphology characterized by complex deviations from, or distortions of, the primary morphology.

"Knobby" - surface texture characterized by relatively large botryoids, usually with moderate to high relief.

Lobe - a discrete segment of a nodule visibly separable from the remainder of the nodule by a partial or complete circumferential constriction of, or crevasse in, the nodule body. The constriction or crevasse is only vaguely developed for an "incipent" lobe. If the constriction is essentially complete and highly developed, the nodule may be considered coalespheroidal rather than lobed.

Mammilla - a hemispherical protrusion on a nodule surface, the form being the result of the growth habit of precipitating ferromanganese oxides. Small mammillae, where the hemispherical form is not readily visible, are called microgranules or granules. Larger mammillae are called microbotryoids or botryoids.

Microbotryoids - a type of mammilla intermediate in size between a granule and botryoid. A "microbotryoidal" surface texture is essentially the same as "coarsely granular".

Microgranules - very small, low-relief mammillae that characterize "microgranular" surface texture, which is less rough than a granular texture.

Multiplicity - the number of discrete segments of more or less regular geometric forms that have been joined together to form a coalespheroidal nodule. In nodule descriptions made during the cruise, the multiplicity is the "x" number in the "x-poly" term.

"Mushroom" - a secondary morphologic feature, usually a modification of the discoidal form, where one surface of the nodule has developed a pronounced central convexity or "stem".

"Organ pipes" - a type of organic growth structure recovered with many nodule samples. These are white tubes, approximately 1 mm in diameter and up to a centimeter or more in length, grown together to resemble a set of organ pipes. The tubes are often somewhat curved, and if significantly curved and entangled, were called "spaghetti" growths. These were presumably constructed by benthic forams.

Outline - the two-dimensional form of a nodule, usually applied to the planar view of a flattened nodule.

Platy - a thin tabular nodule.

Polygonal - a type of primary nodule morphology, synonymous with faceted, where essentially the entire nodule surface is characterized by adjoining flat surfaces. Such a nodule form is usually the result of manganese encrustation of angular volcanic rock fragments, or, less frequently, of fragments of nodules broken on the sea floor.

"Poly-poly" - the multiplicity of botryoidal types of coalespheroidal nodules.

Prolate - a secondary morphologic description of a nodule, usually an ellipsoid, with an exaggerated long axis, i.e., the form is like that of a cigar.

Relative size - a comparison of the size of a mammilla to the size of the nodule on which it has grown. The value of the ratio: mammilla basal diameter/nodule intermediate diameter.

Relief - the prominence of a mammilla above the general nodule surface. The value of the ratio: mammilla height/mammilla basal diameter.

Reniform - a secondary morphologic description of a kidney-shaped ellipsoidal nodule.

Rough - a granular or "coarsely granular" surface texture, characterized by a gritty feel.

Satellite Protrusion - a small knob, bump, or irregularly shaped growth on a nodule surface that does not have a well-developed constriction at the juncture between itself and the main nodule body. When the constriction is well-developed, the attached object may be called an agglutinated spherule.

Septarian Fractures - a pattern of connected fractures or incipient fractures that are expressed on a nodule surface as a set of raised or indented lines. These fractures develop internally during the growth of certain nodule types.

Smooth - a type of nodule surface texture characterized by the absence of visible mammillae, and a smooth feel.

Spheroidal - a type of primary nodule morphology characterized by three mutually perpendicular sub-equal axes.

Tabular - a type of primary nodule morphology characterized by two perpendicular non-equal horizontal axes and a much shorter vertical axis; and usually a non-spherical outline.

Tabular-Discoidal - a type of primary nodule morphology characterized by two sub-equal horizontal axes, a shorter vertical axis, and usually a spherical outline. Tabular-discoidal differs from the discoidal by a lack of pronounced tapering from the central area of the nodule to the edges. Nodules of this type have been called "Hamburger" nodules.

"Worm-tubes" - organic growth structures, presumably constructed by benthic forams, appearing as a set of anastomosing tubes on a nodule surface, the individual tubes being a few tenths of a millimeter in diameter.

REFERENCES CITED

Meyer, K., 1974, Surface sediment and manganese nodule facies, encountered on R/V VALDIVIA cruises 1972-73, p. 125-130 in Morgenstein, Maury, Ed., The Origin and Distribution of Manganese Nodules in the Pacific and Prospects for Exploration; VALDIVIA/HIG (Honolulu) Symposium, 23-25 July, 1973: NSF-IDOE, 175 pp.

Murray, John and A. Renard, 1891, Manganese Nodules, p. 341-378 in Thomson, C. W., Ed., Report of the Scientific Results of the Voyage of HMS CHALLENGER, v. 5, Deep-sea Deposits: Eyre and Spottiswoode, London, 525 pp.

WATER COLLECTION AND GENERAL ANALYSIS

Kenneth Binder

All water sampling was done using a General Oceanics Rosette Multi-Sampler which actuated 12-liter Niskin Bottles. The Rosette unit is an electronic tripping device which causes the Niskin bottles to close sequentially on command from a shipboard deck unit. There are 12 bottle positions on the Rosette unit, but a Benthos pinger was secured in the position of bottle number 12. Consequently, all water casts consisted of 11 samples (trace metal analysis), Niskin bottles were tripped in sets of 3; thus giving 36 liters from each depth.

In order to render the Rosette unit operational, the initial problem of mounting 12-liter bottles on a rack designed for 30-liter bottles had to be overcome. This problem was solved by using 7" all-stainless hose clamps which seemed to be strong enough, except in one instance when the Rosette hit the ship during surfacing. Even then, with both clamps broken, the bottle was held on by the screw mechanism being jammed in between the tripping rod and the bottle body. These hose clamps were also used to hold the pinger in bottle position number 12.

The Rosette was attached to the sea-cable with a specially designed brass clamp which spreads the weight of the Rosette over a large section of the cable. This prevented crimping of the wire and loss of conductance.

The main problem with putting the Rosette over the side concerns the hard chine vertical hull design of the R/V MOANA WAVE. This makes it quite difficult to launch the Rosette; even with the A-frame fully extended, the Rosette still smashed against the side of the ship in all but the calmest seas. This contact, in some cases, caused bottles to pre-trip and thermometer lanyards to become "hung up". Fortunately, due to relatively calm seas, most of the casts were completed without mishap. However, if operations are to continue, especially in heavy seas, an extension to the A-frame will be required.

Thermal depths of samples were calculated with the use of deep-sea reversing thermometers attached to bottles 1, 3, 6, 9, and 11. Upon receiving a "fire" signal from the surface, these thermometers reverse, along with their respective bottle closing. However, it is possible for a thermometer rack to reverse without the sample bottle closing; this can cause some problem when assigning depths to sample bottles.

The final action before putting the Rosette "over the side" was to try to keep the bottles as clean as possible. This is especially important with a trace metal cast. Since there was some difficulty keeping "dirt" away from the bottles (i.e., the ship and sea-cable were full of dirt, grease, and gunk), perhaps a plastic cover can be made to cover the Rosette when it is not in use.

On station one, the Rosette was tested and performed satisfactorily; however, the bottles did not close because the bottom lanyards were too short. This problem was corrected by making new lanyards of the proper length. The thermometers tripped properly, and a thermal depth of 5436

meters was calculated for bottle 1; this confirmed that the bottles actually fired on command.

The general condition of the Niskin bottles could have been better, i.e., leaky valves, weak rubbers, broken vents, etc. To improve the water retaining capability, all new latex rubbers were installed and broken valves, vents, and "O" rings were replaced. Some bottles continued to leak slightly, but this presented no problem as long as the leaks could be kept to a minimum.

The results of the 8 Rosette cases on stations 5, 6, 8, and 11 are shown on the processed data sheets which are included in this report. In total, 1056 liters of sea water were collected for analysis.

Oxygen samples were drawn from all depths and concentrations were determined by the Winkler titration method. Each bottle was carefully rinsed twice and then filled, allowing the volume of the bottle to be displaced at least once with overflow. Besides the lack of a sufficient number of the calibrated sample bottles, there was little problem with the oxygen determinations. These bottles were ordered several months in advance, but did not arrive in time for cruise departure. Thus, when more than one cast was done per station, oxygen samples had to be run in between casts. Oxygen concentrations were fairly stable in the deep bottom water, running from 3.95 - 4.05 ml dissolved oxygen per liter of sea water. When compared with the oxygen content of the core water, bottom water ran about one-third higher in dissolved oxygen.

Nutrient, phosphate, and silica analyses were carried out as soon as possible after each sample was drawn. Samples were drawn into 250-ml Nalgene bottles from which 50 cc and 25 cc samples were taken. The methods used were those found in Strickland and Parson, Practical Handbook for Sea Water Analysis (Bull. 167, Fish. Res. Bd. Canada, Ottawa, 311 pp.).

Silica determinations went quite smoothly using a Beckman model DU-2 spectrometer, the only problem being that the concentration of the bottom water was so high that samples had to be diluted by a factor of 2 before even a 1-cm cell could be used in the DU.

Phosphate analysis presented just the opposite problem; because the concentration of the samples was so slight, a 1-cm cell was too small. If phosphate analysis is to be run again, it is suggested that the program acquire a set of 5-cm and 10-cm cells for the next cruise.

Concentrations for bottom water ran about 140 µg-at S/liter and about 2.4 - 2.6 µg-at P/liter, and there was little change between stations.

Salinity was run using a Bissett-Berman inductive salinometer. This instrument was standardized with Copenhagen sea water having a salinity of 35·071°/$_{oo}$. The salinometer was a constant problem because it was very unstable, and at times drift was excessive. Therefore, salinity data should be looked at most carefully before being accepted. Even though the salinometer was cleaned with isopropyl alcohol twice, it was of little help. Also, the vacuum pump filler was by-passed in order to reduce bubbles in the inductive cell. At the time of arrival in San Diego, the salinometer still could not be standardized, and salts for station 10 could not be run. Salinity for bottom water was approximately 34·675°/$_{oo}$.

WATER SAMPLING FOR SOLUBLE AND PARTICULATE TRACE METALS

Edward Callender

Samples were collected using 12-liter Niskin Bottles mounted on a Rosette stand. The stand consisted of 11 bottles and a pinger to locate bottom. The exposed metal screws were coated with "Filled Epoxy Cement" (Sears, Craftsman #80605). Two days prior to station 5 (23 July 1974), the Niskin bottles were filled with surface sea water, and 50 ml of concentrated nitric acid were added to make the pH of water ~ 2. The bottles had previously been restrung with pure latex rubber tubing (1/4"). The acidified sea water remained in the Niskin bottles for about 30 hours, after which the latex rubber tubing was stretched about 40 times at either end of the Niskin bottle.

At station 5, no other preparation on the Niskin bottles was accomplished. It was discovered at station 6 that there was grease and oil from the hydrowire on the Niskin bottles, on the inside of the end caps and in contact with the "O"-ring. On both stations 6 and 10, isopropyl alcohol and large wipettes were used to clean the tops and bottoms of the Niskin bottles mounted on the Rosette. The exposed surfaces were cleaned twice with the solvent.

The Ocean Sonics depth recorder was used to monitor the descent of the Rosette with the pinger attached; this method enabled getting within 10 meters of the bottom.

Once the Rosette had been fired at all sample depths and brought to the surface, water samples were withdrawn for oxygen, salinity, and nutrient analyses. After these samples were withdrawn, the sampling nipples were cleaned, and sampling procedures were initiated for soluble and particulate trace metals. Pre-cleaned (acid/distilled water) Tygon tubing was used to withdraw trace metal samples. (See Table 15 for intercalibration samples.)

The 2-1/2 liter polyethylene Jerry Cans (from Mike Bender, University of Rhode Island) were rinsed twice with the sample water. Disposable poly gloves were used when sampling for trace metals. After rinsing the Jerry Cans, a sampling tube was placed in the Jerry Cans and the sample withdrawn. The opening of the Jerry Can was exposed, but the inside cap was wrapped in one poly glove. Once the sample had been withdrawn, the cap was sealed. Trace metal sampling of the Rosette was done on the starboard side of the ship, which was generally well-ventilated by a brisk crosswind. Sampling of 11 Niskin bottles took about one hour.

Within 12 to 15 hours after sample withdrawal, 6M HCl (G. Frederick Smith, Certified, Assayed) was added to preserve water samples for future trace metal analysis. Two ml of 6M HCl per 1 liter of sea water gave a final pH of about 2.1.

The filters (Nucleopore 0.22 μm or Millipore HA) used for obtaining particulate material were held in Millipore Swinnex filter holders. The water samples for particulate filtering were placed in 5-gallon or 2-gallon carboys with tribulation ports, and the Swinnex filters (47 mm diameter)

TABLE 15: WATER SAMPLES COLLECTED FOR TRACE METAL INTERCALIBRATION STUDIES AND PARTICULATE CHEMISTRY

Station	Niskin Bottle #	Jerry Can #	Approximate Depth, m	6M HCl Preserved	Filtered Particulates
05	1	1	4843	11 ml/5.5 L	
05	4	2	4833	12 ml/6 L	
05	2	3	4843	12 ml/6 L	
05	5	4	4833	14 ml/7 L	
05	7	5	4753	16 ml/8 L	
05	8	6	4753	17 ml/8.5 L	
05	3		4843		7.5 L
05	6		4833		5 L
05	9		4753		8 L
06	1	1	5234	21/10.5 L	
06	4	4	5134	21/10.5 L	
06	7	7	4743	20/10 L	
06	10	10	4241	21/10.5 L	
06	11	11	4241	21/10.5 L	
06	2	2	5234		10 L
06	3	3	5234		9 L
06	5	5	5134		7.5 L
06	6	6	5134		8.5 L
06	8	8	4743		9 L
06	9	9	4743		10 L
10	1	1	5110	18 ml/8 L	
10	3	3	5110	20 ml/10 L	
10	7	7	5010	17 ml/8.5 L	
10	8	8	5010	21 ml/10.5 L	
10	9	9	4165	20 ml/10 L	
10	10	10	4165	20 ml/10 L	
10	2	2	5110		10 L
10	4	4	5110		10 L

hooked in-line between the reservoir and a 5-gallon glass carboy which was connected in-line to another glass carboy and a vacuum pump with a moisture trap.

Water Sampling

With reference to trace metal samples, the grease-dirt-paint contamination problem is critical. Apparently, the hydro-wire has grease embedded in the wire strands that is squeezed to the surface as the wire passes through the block. The grease collects on the block and finally falls on the deck and on the Niskin bottles that are mounted on the Rosette rack. Although nothing may be able to remove the grease from the cable, measures can be taken to insure that this contamination does not get on the Niskin bottles and in contact with water samples. The Niskin bottles should be covered with canvas or cotton cloth at all times when not in use; Niskin bottles should be thoroughly cleaned before each station where a cast is to be made; the deck should be thoroughly scrubbed with grease solvent and washed down immediately prior to the Rosette Cast coming up; the starboard side of the ship should be to windward when sampling Niskin bottles for trace metals; handling of water for trace metals should always be done with poly gloves; and finally, no painting, chipping of paint, or other ship's work should be done in the vicinity of Rosette stand when on station for a hydro (Rosette) cast.

With reference to filtering for particulate material, the Swinnex-type of filter holders greatly disturb the membrane filters, especially the Nucleopore type. In addition, air locks develop in the Swinnex holder and can only be broken by partly unscrewing the holder. Also, 40 liters rather than 20 liters should be collected, as 20 liters does not appear to be a large enough sample of water to collect adequate quantities of particulate material.

Pore Water Chemistry

Extrusion of box cores, sub-cores, and free fall cores was accomplished jointly by C. J. Bowser and E. Callender; this procedure is fully explained in the "Core and Pore Fluid Studies" section of this report.

Most of the sediment subsections were squeezed and recovery included up to 20 ml of pore fluid in red-brown clay, to 30 ml in 2-cm sections of siliceous ooze. The squeezing and pore water recovery processes are discussed in the "Core and Pore Fluid Studies" section of this report.

From 15 to 30 ml of squeezed pore water was obtained to be used for: 1) on-board analysis of titration alkalinity (1 ml), ferrous iron by a chemiluminescence technique (2-3 ml), ammonia (3 ml), and phosphate (3 ml); and 2) laboratory analysis of silicate (1 ml), major ions (3 ml), and trace transition metals.

On-Board Analyses:

Titration alkalinity - 1 ml of each sample was transferred to a 1 ml disposable syringe and stored in the refrigerator for analysis. The sample was dispensed into a polystyrene vial along with 2 ml of 0.530M NaCl

to minimize changes in the liquid junction potential during titration A miniature stirring bar was placed in the vial and the combination semi-micro pH electrode was placed in the solution after calibration with pH 7.02 and 4.00 buffers. Stirring commenced and an initial pH was measured. Hydrochloric acid (approx. 0.01N HCl) was dispensed with a 2.0 ml micrometer screw burette. Acid was dispensed quickly until the bicarbonate end point was approached (+157 mv) after which it was dispensed in 0.02 ml increments with attendant measurement of electrode potentials. At least 10 points were measured beyond the equivalence point and the last recorded potential was about +220 mv. The titration vessel was not temperature-regulated and thus was at ambient laboratory temperature. In essence, the above potentiometric titration is the Gran titration and the bicarbonate endpoint was determined using a Gran function. A complete description of the method as applied to sea water is given by Edmond (Deep-sea Research, 1970, vol. 17, p. 737-750). Results of alkalinity titrations for pore water from stations 5, 8, and 10 are given in the tables accompanying the stations where samples were obtained. These values must be corrected for a titer blank of the 0.530M NaCl and the restandardization of the HCl. It is interesting to note that bottom sea water appears to have a slightly higher (up to 20%) titration alkalinity than underlying pore water extracted from siliceous ooze and red clay. This is especially true for the red clay samples (station 10).

Chemiluminescence Fe++ analysis - This is a relatively new technique and has not been previously applied to sea water. Trace amounts of iron (Fe++) are determined by measuring Fe (++) - catalyzed light emission from luminol reaction in the presence of oxygen alone. The detection limits for ferrous iron (Fe++) in freshwater is 0.005 µg/L or (10^{-9}M Fe++). A complete description of the method is given by Seitz and Hercules (Anal. Chemistry, v. 44, no. 13, Nov. 1972, p. 2143-2149; and Seitz, Suydarn, and Hercules, Anal. Chemistry, v. 44, 1972). The chemiluminescence apparatus consists of a flow system which, in this case, is driven by N_2 pressure, a flow cell, a photomultiplier tube operated at 1kV by a Heath Power Supply, and a Kiethley Pico-Ammeter connected to a multi-range strip-chart recorder. Luminol is dissolved in 0.1M KOH - H_3BO_3 buffer controlling the pH of light-emitting reaction. In the cell, luminol is mixed with distilled water; slugs of the sample and standards are inserted into the water line using a chromatronix sample injection valve. For standards mixed in distilled water, the system gave a strong, relatively linear response in the range of $1X10^{-7}$ to $1X10^{-5}$ M Fe++. However, in sea water matrix standards, the signal dropped drastically and was barely detectable for $1X10^{-5}$ M Fe++ @ 1 µ Amp full scale. Diluting sea water with distilled water improved the signal a little; acidifying the sea water standards to pH 2 increased the signal strongly which undoubtedly reflects placing iron as Fe++ in solution. Pore water samples from stations 8 and 10 gave no signal, suggesting that there was undetectable ferrous iron (Fe++) or that it was complexed or rapidly oxidized in sea water. Station 5 (alternating carbonate ooze and brown clay) from a box core showed a discernable Fe++ peak that reached a maximum of 14 cm and then dropped to zero below this depth. Pore water from the free fall core at station 6 showed these samples also had a low pH ($\sim$2-4) due to acid contamination in the pressed teflon filter disc. It is obvious that

much chemistry needs to be done in order to clarify under what conditions the chemiluminescence method gives a valid Fe++ signal for ionic solutions such as sea water.

Ammonia Analysis - The method of Solorzano (1969) was used in an attempt to measure ammonia in extracted pore water. Ammonia analysis was attempted on pore water samples from stations 5 and 6. Only 1 ml of sample was used from station 5 and gave no measurable NH_3 absorbance above background. In analysis of samples from station 6, a 2-ml sample was pipetted into a plastic reaction bottle along with 0.5 ml phenol solution, 0.5 ml nitroprusside solution, and 10 ml oxidizing solution. Reagents were mixed and absorbance was measured at 640 μm after one hour. Several intervals in the core yielded samples that were just above the limit of detection of this method using a 1-cm path length, 0.08 ppm as N. Most of the samples were frozen to be transported to the shore laboratory for analysis.

Phosphate Analysis - The standard method of Strickland and Parsons (1968) was used. Phosphate analysis was attempted on pore water samples from station 8 only. Two ml of sample was placed on acid-cleaned pyrex culture tubes and 2 ml of mixed reagent added to this. Color was allowed to develop in one-half hour and absorbance measured at 885 μm. The limit of detection for P with this technique using a 1-cm cell is 0.25 ppm and only the lower intervals in the free fall core from station 8 gave absorbances that were barely above this detection limit. Most samples were frozen for future analysis of phosphorus at the shore-based laboratory.

Disposition of Pore Water and Samples

The 1 ml used for titration alkalinity was spiked with $Pb(NO_3)_2$ solution in order to determine the SO_4 concentration (gravimetric/precipitation) at the shore-based laboratory.

A 3 ml aliquot of pore water was placed in a polyethylene vial for future analysis of major ions - namely, Ca++, Mg++, Cl^-. Both the SO_4 samples and the major ion samples were stored in a water-saturated plastic refrigerator box.

Up to 5 ml of pore water was placed in a clean, soft polyethylene bottle and frozen for future nutrient analysis (NH_3, PO_4, SiO_2). Only two stations (stations 6 and 8) had nutrient samples preserved in this way.

Up to 10 or even 15 ml of pore water was placed in an acid clean linear polyethylene bottle. Fifty or 100 μl of concentrated AP grade HNO_3 was added to each sample with an Eppendorf pipette. The resulting pH is between 1 and 2. These bottles were stored in water-saturated refrigerator boxes.

REFERENCES

Solorzano, L. (1969), Determination of ammonia in natural waters by the phenolhypochlorite method: Limnol. Oceanogr. 14, p. 799-801.

Strickland, J. D. H. and T. R. Parsons (1968), A Practical Handbook of Seawater Analysis: Bulletin 167, Fisheries Research Board of Canada, Ottawa, 311 pp.

CORE AND PORE FLUID STUDIES

Carl J. Bowser

Coring

Sediment cores were collected from 5 of the 11 stations occupied on the cruise. Free fall cores were originally intended for preliminary site evaluation and for later sediment dating and stratigraphic analysis. Replicate box cores were planned for detailed nodule documentation and subcoring for mineralogical and chemical analysis, including pore fluids. One box core was obtained from station 5 and a second attempt was unsuccessful. A winch malfunction at station 6 sheared the cable and the box corer was lost overboard. Consequently, free fall cores were depended on exclusively for the pore fluid studies.

A total of 14 free fall cores were attempted of which 11 were recovered. Where possible, three free falls were collected; one for pore fluid studies; one for liquid nitrogen freezing; and one to be kept at 6°C for archive storage at Hawaii. Detailed studies of the top few centimeters of the cores was made impossible by the fact that the shock of the initial coring and bobbing of the core at the surface prior to recovery caused mixing of the overlying sea water and the top sediment. Further, the core catcher and core cutting assembly scored the sediment core wall and allowed sea water to drain along the sides, thus making extraction of uncontaminated pore waters difficult. The sediment/water interface was collected within the core tube for the red clay and carbonate ooze stations (1, 5, and 10); however, in the lower strength siliceous ooze, the top several centimeters of core were lost through the valve at the top of the core tube assembly. All interval measurements from these cores are arbitrarily listed as relative to the top of the first interval sampled with some unknown amount of core missing (probably less than 5 cm). Clearly, future studies of the interrelationships between nodules and associated sediments, particularly those near the interface, require carefully documented box cores and not free fall cores. Table 16 shows the disposition of cores collected.

Pore Fluid Collection

Pore fluid sampling was performed with a system specially designed to eliminate atmospheric contact from sediment, allow handling of sediment at near in situ temperatures, and to have a minimum of handling prior to analysis. The system was designed and contructed at the University of Wisconsin by C. Bowser and consists of a core extruder-thermostatting device, separate squeezer bodies for each interval squeezed, and an air-ram actuated squeezer press.

A core which had been kept cold in a refrigerated van (6°C) was mounted vertically in a hydraulic extruder, (Figure 61) consisting of a core tube piston, an "O"-ring sealed core tube base through which pressured sea water from the ship's sea water line could be used to drive the

TABLE 16. SUMMARY OF FREE FALL CORES COLLECTED

Station	Library Core	Pure fluid Core	Liquid Nitrogen Frozen
1	FF 003	FF 001	-------
5	FF 004	FF 004 Box 003	Box 001
6	FF 005	FF 007	FF 008
8	FF 011	FF 009	FF 010
10	FF 013	FF 014	FF 012

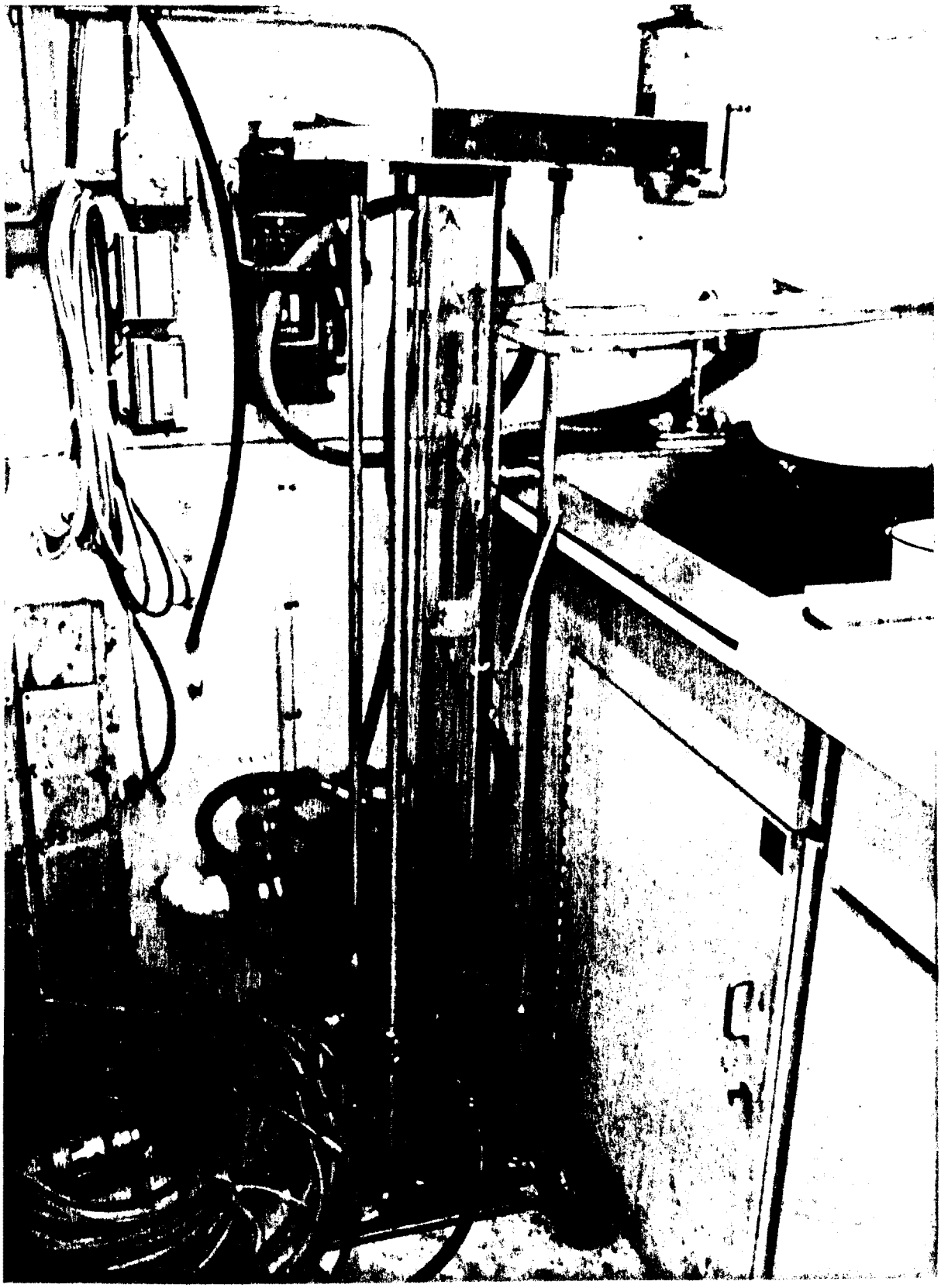


Figure 61. Core extruding and thermostatting system used in collection of pore waters.

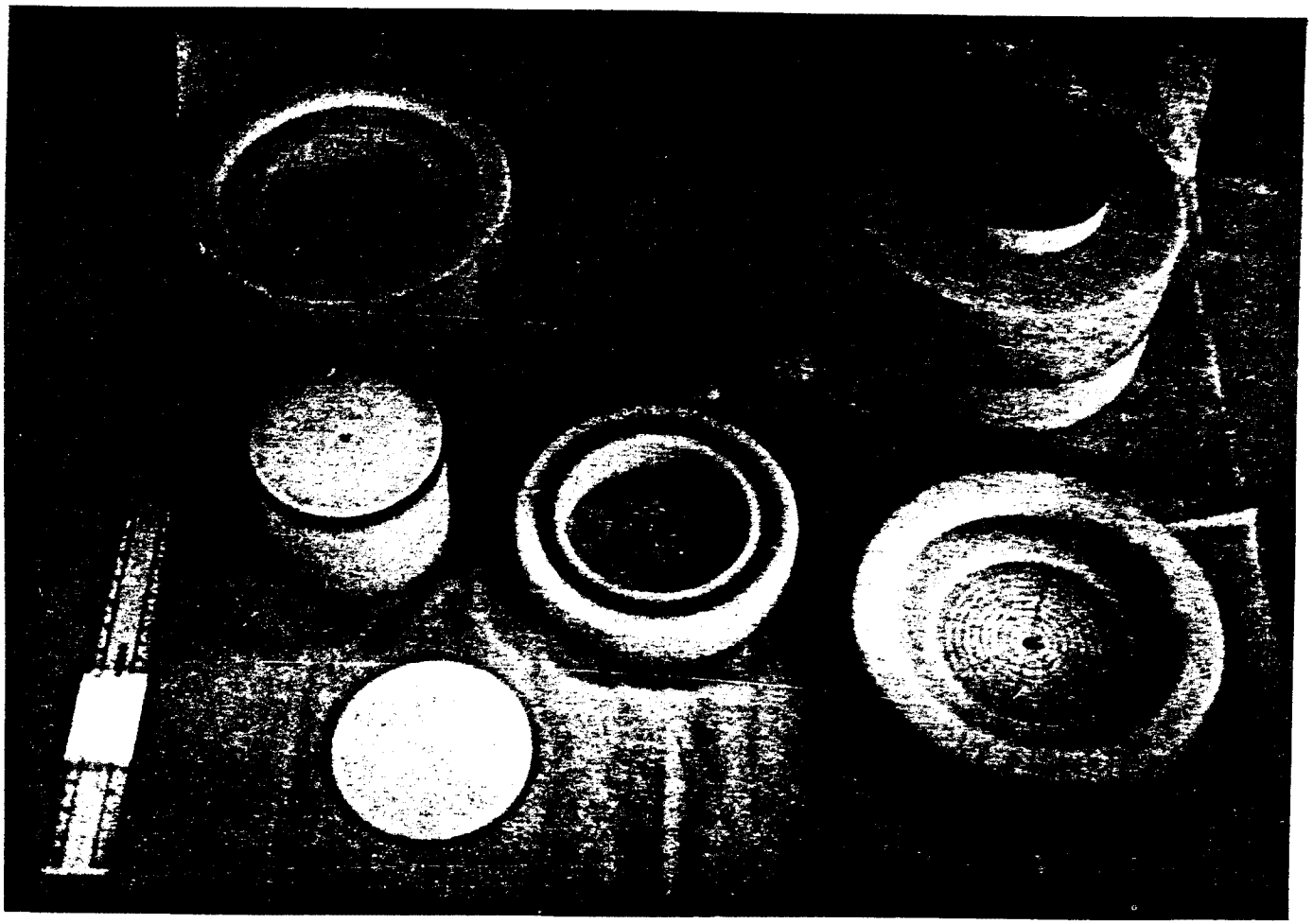


Figure 62. Squeezer used for extraction of pore fluids from sediments. Clockwise from upper left are shown: completely assembled squeezer assembly; filter base plate with porous Teflon disk removed to show grooved fluid channels; 2-cm-thick squeezer body with base plate O-ring seal; porous Teflon disk from filter base plate; piston showing hole for collection of solid phase; piston guide to keep piston axial to squeezer during beginning of squeezing process; and aluminum top plate with O-ring seal for hole in piston. Rule is 30-cm scale.

extruding piston, a thermostatted core jacket utilizing the core tube as the inner wall of the fluid chamber, and a lucite slide and core cutoff assembly at the top of the core tube which holds the squeezer assembly for sample collection. The core is thermostatted to 5°C with a refrigerated circulator (Lauda K4/RD) using an antifreeze-distilled water mixture to prevent thermostat cooling-coil freeze-up at operating temperatures (5°C). The lucite slide and cutoff assembly consists of a base plate rigidly attached to the core tube and an overlying slide assembly. An offset hole containing a piston from the squeezer assembly is built into the plate. A grooved lucite slide is mounted on the plate and holds an inverted squeezer assembly (less piston) whose inside diameter is the same as the core tube (6.7 cm). The squeezer thus can be slid from a position directly over the core to directly over the piston in the base assembly. A 2-mm thick cutoff slide is mounted into the base plate to slide at right angles to the direction of the main slide assembly.

In operation, a pre-cooled squeezer assembly is inverted directly over the core tube, nitrogen purged for five minutes, and then the core is hydraulically extruded directly into the squeezer. The cutoff slide is moved into place to isolate the core and the now-loaded squeezer from one another. The main slide is then pulled over so that the squeezer assembly is now directly over the awaiting piston and the completed squeezer is removed and stored in the refrigerated van preparatory to squeezing.

The squeezer, (Figure 62), is constructed of delrin plastic and consists of a filter base with porous teflon for filter support, a body whose inside diameter is the same as the core tube and piston. The height of the squeezer body determines the thickness of core collected. Squeezer bodies of 1.5, 2, and 5 cm were available. The squeezer piston has a 1/8" diameter axial hole which allows pre-squeezed, sub-samples of the solid phases to be extruded from the filled squeezer without oxygen contamination. The hole is capped with an aluminum end plate to seal during the squeezing operation.

Ten separate squeezers were constructed, each having its own set of 1.5, 2, and 5 cm height bodies. Thus, various combinations of core thicknesses could be taken from each core. Generally, 2 cm intervals were collected from the first 22 cm of core with 5 cm intervals used thereafter. Two millimeters of core were pushed out the side of the core extruder by the cutoff slide and were rejected. Pore fluids were passed through 0.2 μm "Nucleopore" 90 mm filters with "Watman" 40 pre-filters.

The pressurizing system for the squeezers, (Figure 63), consisted of 10.2 cm (4") diameter air rams driven by compressed air with a maximum rated pressure of 14 kg/cm^2, (200 psi). The 10.2 cm diameter air rams acting on the 6.67 cm (2-5/8") diameter piston of the squeezer gives a pressure magnification of 2.32 times, thus allowing a maximum pressure of 32.5 kg/cm^2 to be exerted on the sediment. In practice, however, the maximum pressures used on each core section ranges from 16.3 to 22.9 kg/cm^2. The air ram system has the advantage that pressure during pore-fluid squeezing is constant and does not require attention after the squeezing pressure is set. Hydraulic rams, on the other hand, require frequent "pumping" of the system to keep the pressure up on the pistons.

Three complete air ram systems were used during the cruise. All actual squeezing was done in the refrigerated van where temperatures were

held to 6°C. Sample squeezing was performed within 36 hours of sample collection.

Expressed fluids were collected into 20-and 5-cc disposable syringes through small volume liquid chromatographic tubing and minimum volume valves. Sample recoveries ranged from a low of 6 ml to a maximum of 26 ml for 2-cm core sections and from 14 to 60 ml in the 5-cm core sections. Approximately one-half hour was required to squeeze each section. Maximum possible volumes are 70 ml and 174 ml for the 2-and 5-cm sections, respectively. Volumes recovered were generally highest in siliceous oozes, somewhat less in carbonate sediments, and lowest in the more plastic red clay samples at station 1 and 10. Interestingly, the sample recoveries from 5-cm sections of the red clay were not substantially greater than the 2 cm intervals in the same sediment. During the squeezing process de-watered sediment would build up next to the filter and the substantially lowered permeability of this "cake" would prevent further egress of pore fluids from the squeezer. Such problems were not apparent in siliceous ooze and carbonate sediments.

Summary results for squeezer operations are found in Table 17.

Analysis

Pore fluids from sediments were collected for a variety of analyses both on ship and for later laboratory analysis. A summary of these analyses are found on page 181 in this report under the heading "Type of Analysis" and are merely listed for sake of completeness here. On-board analyses for pH, dissolved oxygen, and Eh were performed by the author of this section and are further elaborated on the following pages.

Both dissolved oxygen and pH measurements were made on a commercial blood gas/pH system (Instrument Laboratories Model 229) which was thermostatted to 5°C, (Figure 64). The device requires little sample volume for actual measurements, 0.2 ml for O_2 and 0.1 for pH, but to completely flush the sample chambers and insure reproducibility of measurements, 1 to 2 ml were used for both measurements.

Special low-volume fluid lines and valves were used to insure no oxygen contamination and small "dead volume" losses. Polarographic oxygen readings were taken as percent saturation value to 5°C by comparison with nitrogen gas and compressed air readings. Concentrations were then calculated from sea water saturation values from 5°C using an approximated pore water chlorinity of $20°/_{oo}$. Calibrating gasses were water saturated with porous disc bubblers. (Shown in left center of Figure 64.)

Standard buffers covering the pH range of 9.2 to 6.95 were used for calibration of the capillary electrode of the IL 229 system. High humidity and condensation on cooling lines for the system made pH measurements somewhat difficult, however, the pH's are accurate to within 2 millivolts or 0.03 pH units.

Potentials for pH and currents for dissolved oxygen were measured with a digital electrometer (Kiethley Model 615) noted for its excellent stability and ruggedness under field conditions. Measurements were continuously monitored on a 10-inch, strip-chart recorder to establish equilibrium readings.

Eh measurements were attempted on an internal electrode cell of small

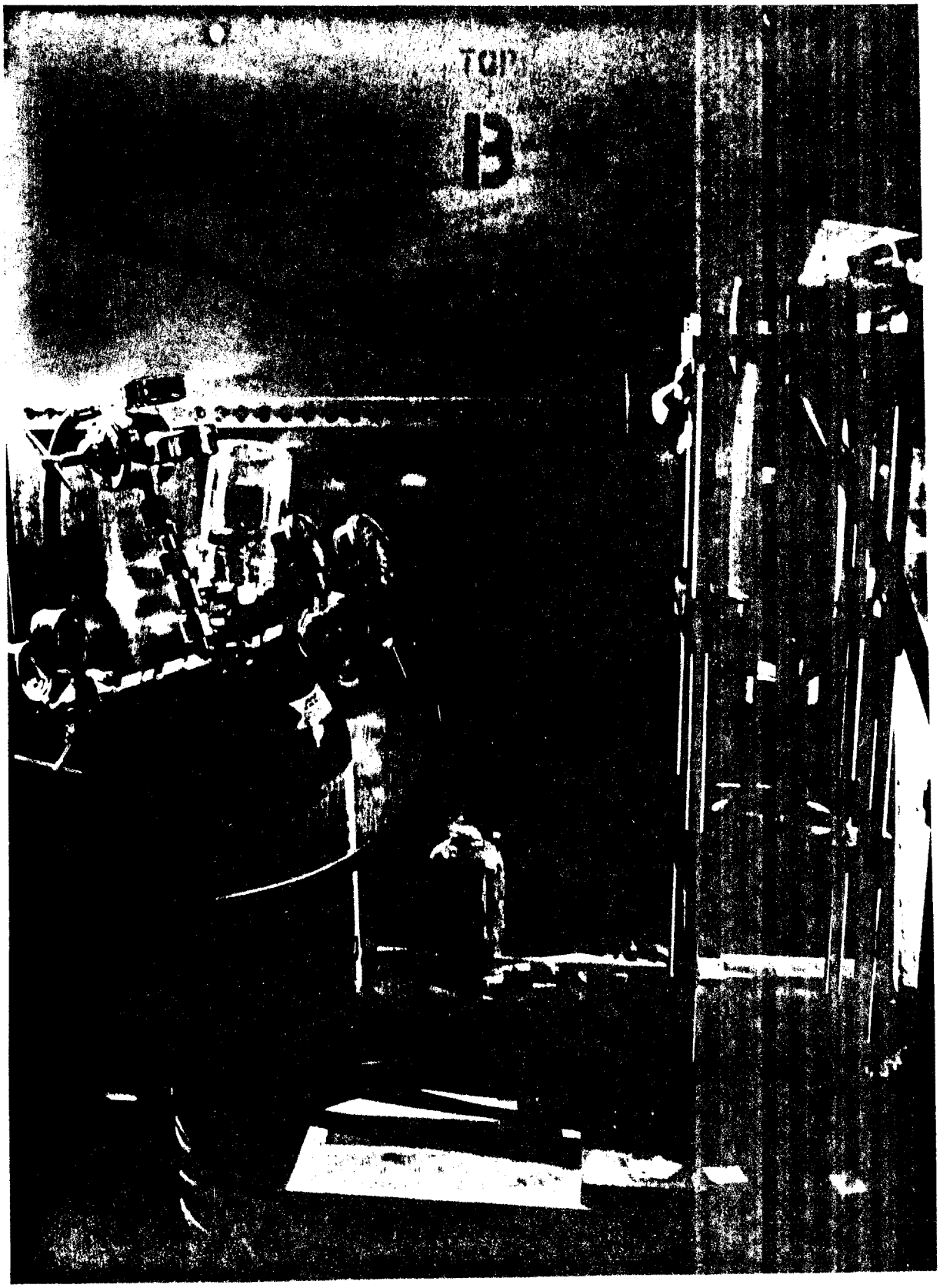


Figure 63. Air-ram for sediment squeezers. Samples collected through access hole in lower plate once squeezer is in place. Control valve for air-ram actuation is seen at lower left of squeezing rig.

TABLE 17 : SUMMARY OF CORES FROM WHICH PORE WATERS WERE COLLECTED

Station	Total Interval Sampled	Sampling Interval	Average Sampling Recovery	Sediment
1	0-23 cm	2 cm	10 ml	Red clay
5	0-20 cm	2 cm	13 ml	Carbonate ooze
	0-25 cm	5 cm	38 ml	Siliceous ooze
6	0-22 cm	2 cm	24 ml	Siliceous ooze
8	0-22.2 cm	2 cm	25 ml	Siliceous ooze
	22.4-84.2 cm	alternate 5 cm	50 ml	
10	0-95.5 cm	2 & 5 cm	15 (2 cm)	
			21 (5 cm)	Red clay

TABLE 18: PORE FLUID ANALYSES PROTOCOL

Type of Analysis	Volume required	Technique	How Handled
pH	0.2 ml	potentiometric	analyzed on ship
Dissolved oxygen	1-2 ml	polarigraphic	analyzed on ship
Eh	1 ml	potentiometric	analyzed on ship
Alkalinity	1 ml	potentiometric titration	analyzed on ship
Fe^{2+}	2-3 ml	chemiluminescence	analyzed on ship
Sulfate	1 ml	indirect Atomic Abs.	to be analyzed
Nutrients (Ammonia, phosphorus, silica)	3-5 ml	colorimetric colorimetric colorimetric	some on ship, some to be analyzed later
Trace metals	8-12 ml	Atomic Abs. Neutron Activation	to be analyzed

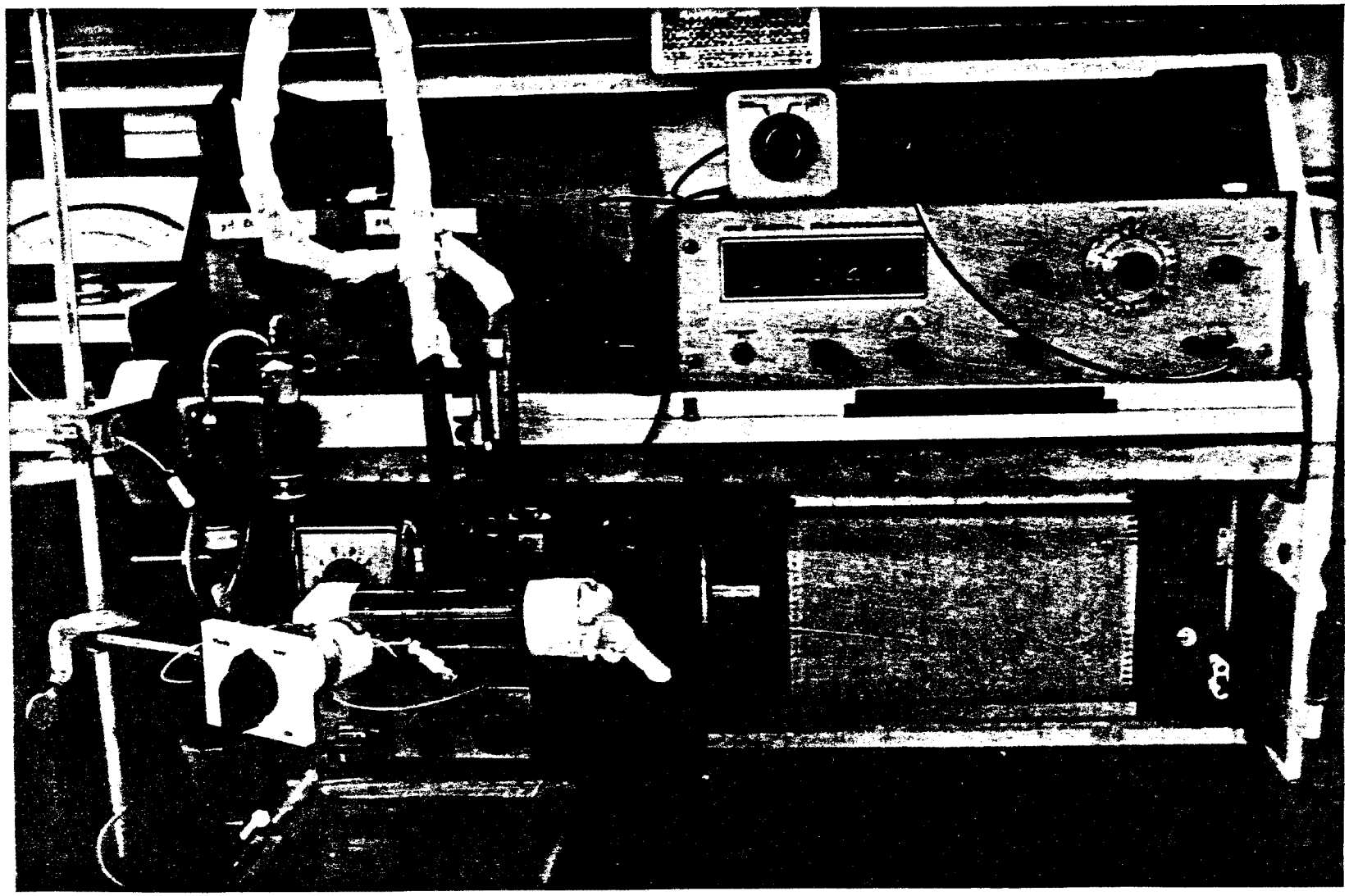


Figure 64. Instrumentation for oxygen and pH measurements. Clockwise from upper right are: electrometer for current and potential measurements; recorder for monitoring steady state of electrodes; blood gas/pH system (oxygen sensor in right-hand side of horizontal cylinder and pH electrode in vertical cylindrical assembly connected in flexible loop to instrument electronics); and switch boxes for connecting electrodes to electrometer.

volume (0.1 ml) similar in nature to the capillary pH electrode used. Measurements were made on raw and oxygen-sparged samples and compared against freshly prepared Zoebell's solution. Long-term electrode potential drifts observed from sample to sample indicate a relatively long time for equilibrium (generally greater than one to two hours) and hence, reliable measurements were impractical within the time constraints of the cruise. Measurements were therefore attempted on only a few samples. Table 18 summarizes pore fluid analyses.

Preliminary Results

Lacking other control experiments with varying kinds of sediments and known oxygen content fluids, the oxygen data can only be considered preliminary at this time. The system for collecting, squeezing, and analyzing the pore fluids was designed specifically to make atmospheric oxygen contamination virtually impossible. However, some of the problems encountered with some cores (previously discussed) makes some contamination with overlying sea water unavoidable in all but the box core sub-sample. In spite of these potential problems, the oxygen measurements show somewhat consistent values ranging between 2.5 and 3.5 ml/liter throughout all cores measured, as compared to typical values of around 4 ml/liter observed in bottom water, Rosette samples. Few, if any, measurements exceeded the bottom water values even though complete atmospheric equilibration at 5°C would give values as high as 7 ml/liter. Those values in excess of 4 ml/l were rationalizable in terms of some obvious procedural mistake, such as incomplete flushing of the oxygen cell, bubble hang-up on the elctrode membrane surface, or accidental entrapment of air into the sample syringe. On the other hand, no values below 2 ml/liter were observed in any samples down to the greatest depth sample (>85 cm). Even in the box core sample where sub-core contamination with overlying sea water was impossible, the oxygen values were observed to fall between approximately 2 to 4 ml/l and are believed to be realistic minimum values for the sediments.

The measurements seem consistent with the concept of quite low concentrations of organically oxidizable material in the sediments. The preliminary alkalinity and nutrient data collected by Callender (see section on water samples) in the same pore fluids seems to confirm the oxygen observations.

Measurements of pH values showed remarkable consistency throughout the whole core sample range investigated, having values that lie between 7.4 to 7.8. Gradients, if they exist at all, are on the order of a few millivolts or at most 0.2 pH units. Further comment on these data would be appropriate when all alkalinity data is available. Measurements of pH on samples taken early in the cruise were abnormally low; however, this problem was traced to incomplete rinse-out of acid-wash from the teflon filters and was rectified in later measurements.

Eh measurements were commented on in the previous discussion and little needs to be said of their meaning here. Those samples that were given sufficient time to approach steady state (equilibrium) had positive potential ranging from +200 to +400 millivolts, again seemingly consistent with the oxygen contents of the pore fluids. No obvious evidence for sulfide deposition was seen in any of the core intervals examined.

TRACE METAL SAMPLES AND ORGANIC EXTRACTIONS

Walter Bachman

Samples were collected from two locations: the first at 08°55'N, 146°28'W and the second from the last Rosette cast at 19°47'N, 132°05'W.

The first cast was taken at 12:27Z, 29 July, 1974. As the cable to the Rosette had been spliced prior to the cast with considerable spraying of petroleum products, and although the Niskin bottles remained sealed during this period, there was the probability of contamination with petroleum-based compounds.

The Rosette neared the bottom at 1431 hours; after five minutes, for equilibration purposes, the first four Niskin bottles were triggered and sealed at a depth of 4 meters above the ocean floor. The Rosette was raised to a level of 2,600 meters off the bottom, half the distance to the surface (the depth of the ocean being 5,205 meters at this position) and four more bottles were sealed. The last three were sealed at 17 meters from the surface.

The samples were filtered through 0.45 meter Millipore filters in a closed filtration system. The filters stained light yellow.

Trace Metals

Ten liters of the filtrate was acidified to pH 2 with 20 ml of 6 N hydrochloric acid. There were three 10-liter samples, one from each depth, acidified in this manner. After acidification, the samples were placed directly into the ship's walk-in freezer for storage.

Additional Samples

In order to obtain some samples for analysis, which would probably have less contamination than the ones collected at station 6, three additional 10-liter samples were collected from the last Rosette cast at station 10. The depths of the three samples were 1000 meters off the bottom, 100 meters off the bottom, and within a few meters of the ocean floor. The depth of the ocean at this position is 5,130 meters. The samples were filtered, acidified, and stored frozen.

Organic Extractions

The remainder of the filtrate (25-27 l at each depth) was then extracted with Dichloro Methane and Methyl Isobutyl Detone in the following manner:

(1) 150 ml of Dichloro Methane was poured into each of the two large glass "cooler" bottles used in the extraction process. Then, half of the filtrate was siphoned into each bottle. The bottles were swirled for five minutes and then allowed to settle for another five minutes.

(2) The lower organic phase was pipetted out and into a separatory funnel. The samples were then extracted twice again with CH_2Cl_2; however,

only 100 ml were added at each subsequent extraction since the solution was already saturated with the solvent. The lower organic phase was transferred from the separatory funnel to a glass-stoppered bottle for storage.

(3) 150 ml of Methyl Isobutyl Ketone (MIBK) was poured into each bottle, and again the bottles swirled for five minutes and settled for five more. The lower aqueous phase was then siphoned off into a carboy container except for the last liter or so which was decanted into the separatory funnel, which had been rinsed with MIBK. 100 ml of MIBK was then added to each bottle and the aqueous phase siphoned back over and through it. The bottles were swirled again and the process repeated for a total of three extractions with each solvent. With the MIBK extractions, the upper organic phase was transferred into brown nalgene bottles for storage in the ship's walk-in freezer.

The same extraction process was repeated with the filtered water samples from the other two depths.

Sampling Difficulties and Recommendations

The filtering process was rather slow. The filters were only changed after the maximum amount of samples had been drawn through them. This was done in order to maximize the amount of material collected for particulate analysis. There was also an initial problem with the first few filters which became impervious to the sea water after only about one liter had been drawn through. It may be that they had become clogged with air which was leaking into the system through faulty connections. The fitting, and even the special plastic adapters sent by Mike Bender bled slightly. This problem was solved by using filter holders that had been trimmed with a mechanical cork-borer at the Hawaii Institute of Geophysics. This enabled a short piece of Tygon tubing to be placed directly between this aspirator carboy, which stored the sample, and the filter holder. This connection did not leak or bleed air into the system.

In order to cut down on the filtering time, and thus speed up the processing of the sample, the filters should be changed after 5 liters have passed through, instead of waiting for 10 to 20 liters to be squeezed through.

A further delay in the processing of the sample was incurred due to fatigue and rough seas. The first third of the sample, the bottle sample, was processed the same day the sample was drawn; however, the balance of the samples were not completely processed until they had been left standing at room temperature for at least 48 hours. Refrigeration of samples during this period was overlooked.

For the organic extractions, initially the bottles were shaken in a horizontal position; however, the plastic cap fitted with a Teflon plate did not fit well and therefore leaked. Black electrical tape was used to hold the cap down more securely and, thus, improved the seal. As the bottle was being shaken, the vapor pressure of the solvent built up, pushing against the cap. Eventually, the pressure forced gas and some solvent past the seal and the tape, thus probably contaminating this initial extraction with some adhesives from the electrical tape. On

subsequent extractions, electrical tape was not used, and the bottles swirled in a vertical position. In this manner, the solution was kept away from the neck and the danger of a loss of solvent and solution through leakage eliminated.

Many of the samples that were originally sought were not obtained. Those that were collected are of dubious quality since the probability of contamination was high. Determinations of the extent of contamination will be attempted through laboratory analysis of the samples. A measurement of any trace metal contamination incurred in the extraction process itself will be made by comparing the atomic-absorption spectroscopic analysis of the trace metal samples (unextracted), and those that were extracted on board. Secondly, any gross discrepancies between the values obtained for the trace metal concentrations in the samples, especially those drawn from the first cast, and published reports of previous trace metal content determinations in sea water, will give an indication of the level of contamination. Thirdly, the atomic-absorption analysis of the samples will be supplemented with further analyses employing gas chromatography infra-red and ultra-violet spectroscopy in an attempt to qualitatively and quantitatively determine the levels of contamination from adhesives and cable grease, although the precision of this work will be hampered by the lack of a pure sample of these contaminatory agents. If contamination of samples is suspected, in future operations, portions of the contaminants should be taken for comparison studies.

A FORTRAN PROGRAM TO EVALUATE DEEP-SEA REVERSING THERMOMETER DATA AND CALCULATE THE THERMOMETRIC DEPTH*†

Peter Kroopnick

Introduction

This program and the required subroutines are used to process the readings from deep-sea reversing thermometers. The wire length to each thermometer and the calculated thermometric depth are compared and a smooth curve is fit to the data. The output is a table giving the accepted depth for each sampling bottle and the corrected in situ temperature.

For sampling bottles without a thermometer attached, the depth is interpolated from a plot of wire length (L) - versus the difference between the wire length and the thermometric depth (L-Z). Finally, a plot of L vs. L-Z is given to facilitate the diagnosis of pre- or post-tripped bottles.

Deep-Sea Reversing Thermometers

Protected - A DSRT is composed of two thermometers, a main and an auxiliary. The main is a double-ended thermometer having a large reservoir at one end and a small bulb (smaller reservoir) at the other, joined by a capillary (see Figures 66 and 67). In the "set position", mercury fills the large reservoir, the capillary, and part of the small bulb. When reversed, a constriction (appendix) at the top of the capillary breaks the thread of mercury. The mercury runs into the small bulb, filling it and part of the capillary. This fixes the in situ temperature. Readings are made with a magnifying lens system mounted on a flashlight.

Mounted beside the main thermometer is a conventional thermometer called the auxiliary. It is read in conjunction with the main thermometer and indicates the ambient temperature at the time of reading. Usually the temperature in the lab differs from the temperature at which the main thermometer was reversed. This information is needed to correct for the expansion (or contraction) that has taken place in the main thermometer since reversal.

The protected thermometer system is completely enclosed in a sealed glass shell, protecting it from the effects of pressure.

Reading Thermometers

Procedure - When the cast is aboard, a waiting period of 15 minutes is necessary for the thermometers to stabilize to lab temperature. They are then read by two readers, the results being recorded. The senior observer reads first. After reading thermometers on about five bottles, the readers rotate, the second reader reading the same thermometers.

Accepted reading tolerances - The first reader is responsible for verifying that the readings are within acceptable limits. Re-read any that are not. The limits are as follows:

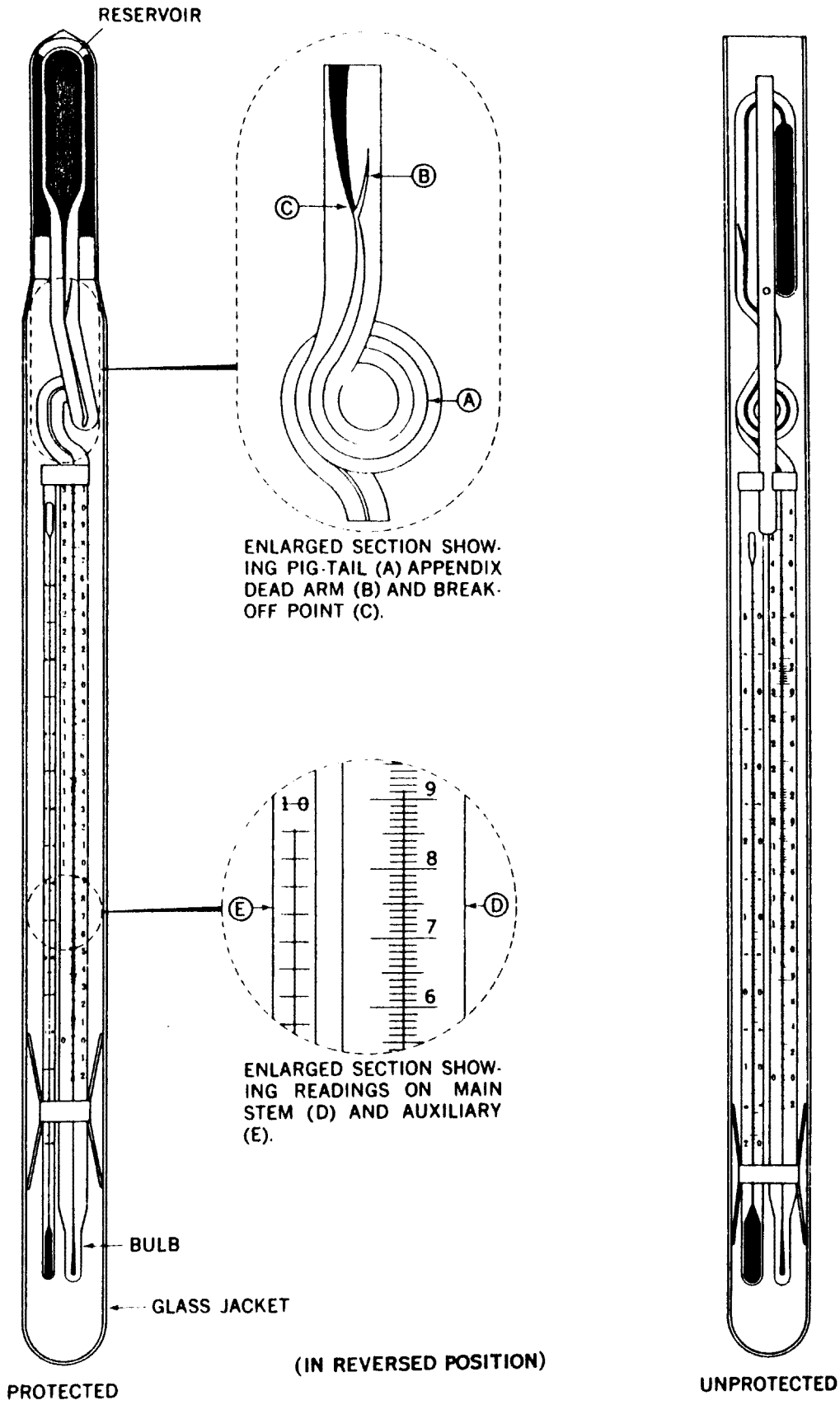
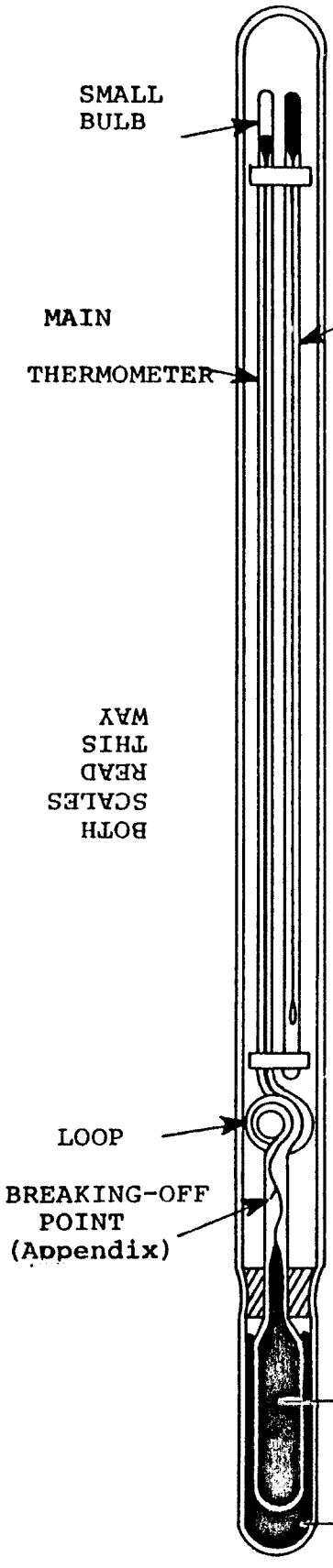


Figure 65. Protected and unprotected deep-sea reversing thermometers. (From U. S. Hydrographic Manual, H.O. 607, Reprint 1959.)



1. IN SET POSITION (GOING DOWN)

2. IN REVERSED POSITION (COMING UP TO BE READ)

The Loop traps the Mercury Expanding Past Appendix After Tripping

COMMON MALFUNCTIONS

1. FT (FELL THROUGH): When the instrument is reversed, mercury from LARGE RESERVOIR flows down through the constriction at the BREAKING-OFF POINT and completely fills the SMALL BULB and capillary of the MAIN THERMOMETER.

2. WB (WRONG BREAK): When the instrument is reversed, the mercury column of the MAIN THERMOMETER breaks off at some point other than the designated BREAKING-OFF POINT.

3. ST (STUCK): When (the instrument being in set position in preparation for descent) the mercury in the SMALL BULB and upper part of capillary cannot be forced down to connect with the remainder of the mercury system in the LARGE RESERVOIR and lower part of the capillary, there is a "Stuck" malfunction.

Figure 66. Protected reversing thermometer. (From U. S. Hydrographic Manual, H. O. 607, Reprint 1959.)

Shallow casts (1500 meters or less)

±0.03°C on unprotected thermometers etched in 0.2°C

±0.02°C on all others

An additional 0.01°C is allowed for each 0.5°C change in the auxiliary, provided both main and auxiliary are higher, or both are lower than the values of the first reader. The main thermometers should be read to the nearest 0.01°C, and the auxiliaries to 0.1°C, unless otherwise instructed.

Deep casts

Etching Interval	Read to	Tolerance between readers	Read Auxiliary to
0.2° C	0.01° C	±0.03° C	0.1° C
0.1	0.01	0.02	0.1
0.05	0.005	0.01	0.05
0.02	0.001	0.005	0.01
0.01	0.001	0.005	0.01

As with the shallow casts, an additional 0.01°C is allowed for each 0.5°C change in the auxiliary.

On deep casts, no more than three bottles should be read before rotating readers. This will insure against excessive temperature drift between readings.

Processing Deep-Sea Reversing Thermometer Data

The in situ temperature for any Nansen bottle is determined by averaging the corrected readings of the two protected thermometers. Using this in situ temperature and the "temperature" from the unprotected, one can calculate a value which is directly related to the pressure on the thermometer and thus the depth. Multiplication of this value by the "Q factor" (a pre-determined factor specific for any unprotected thermometer) gives the depth in meters. This is referred to as the thermometric depth.

Formulas Used

Accepted, protected temperature: (left and middle thermometers are calculated separately and the average is used if the two values are within 0.5°C of each other.)

T=TW = accepted temperature

T'=TW or TL = reading of reversing thermometer plus index calibration correction

K=6100 = coefficient of expansion of glass and mercury system

t=LAUXT to MAUXT = reading of auxiliary thermometer plus index calibration correction

Vo = volume of mercury from the 0°C mark to the small-bulb end of the reversing thermometer

$$TW=T'' + \frac{(T' - t)\ (T' + Vo)}{K - 1/2\ (T-t) - (T' + Vo)}$$

TU = accepted unprotected temperature

TU'=LGM = reading of unprotected thermometer corrected for index calibration

t'= UAUXT = reading of auxiliary thermometer plus index calibration correction

$$TU=TU' + \frac{(TW - t')\ (TU' + Vo)}{K\ 1/2\ (TW - t')}$$

Thermometric depth:

$$TD = \frac{TU - TW}{Q\rho_m}$$

Q = depth factor in °C/meter

ρ_m = the average density of the water column, approximately 1.0275 for the Pacific Ocean

Procedures

The index calibration corrections for the main thermometer (MI) and for the auxiliary thermometer (AI) are entered as DATA statements. Each thermometer has one set of DATA statements catalogued by the thermometer number (ITH) assigned at the factory. The VZERO and Q factors, where appropriate, are also included. The DATA statements are entered through BLOCK DATA.

The program performs a linear interpolation for the appropriate index correction at the measured temperature. The following interpolation scheme is used:

$$B \begin{Bmatrix} MT(JB) \\ T \\ MT(JB-1) \end{Bmatrix} A \qquad H \begin{Bmatrix} MI\ (JB) \\ LI \\ MI\ (JB-1) \end{Bmatrix} C$$

$$H=A/B \times C$$

$$LI=MI(JB) - H$$

where MT and AT are the main and auxiliary thermometer calibration bath temperatures.

Subroutines

RHOM - This program calculates the density corrections to the thermometric depth (TD), assuming a p_m of 1.0275 was used in calculating the unprotected pressure factor. The gravitational constant is evaluated at the given latitude and a separate expression correcting the thermometric depth for the increasing density with depth is used for each major ocean.

The user must set

OCN = 1 Pacific and Indian

= 2 Atlantic

= 3 Mediterranean

= 4 Arctic and Antarctic

in line 13 of the main program.

DEPFIT - This program sets up arrays of wire length (L) and wire length minus depth (L-Z) for plotting. Dummy arrays are set up containing the depths 0 to 60 in steps of 5 plus 60, and 80 in order to force the best fit polynomial through zero. Third and fourth order polynomials are fit to L vs. (L-Z).

As many as two bad results are removed and the standard deviation recalculated. The result with the lowest standard deviation is adopted as the best fit polynomial. This polynomial is then used to calculate the accepted depth for each wire length entered.

LSOPL - Modified least squares polynomial fitting program, calls POLYE1.

PKPLOT - Line printer plotting routine.

Variables to be set by the user in program THERM (MAIN)

NPLOT: 1 for printer plot of L versus 1-Z (line 10)

IUNIT: input device = 5 for IBM card reader. (line 11)

ZUNIT: output device = 6 for IBM line printer. (line 12)

ICN: see subroutine RHOM (line 13)

NT: maximum number of thermometers = 50

References

Keyte, F. K., 1965, On the Formulas for Correcting Reversing Thermometer, Deep-Sea Res. 12, 163-172.

Pollak, M. J., 1950, Notes on Determining the Depths of Sampling in Serial Oceanographic Observations. Journ. Mar. Res. 9 No. 1.

Sturges, W., 1968, Thermometric Depth and Gravity Variations, Deep-Sea Res. 15, 645-646.

Sverdrup, H. U., 1947, Notes on the Correction of Reversing Thermometers. Journ. Mar. Res. 6, 136-138.

Sample of Input and Results

See data sheet for input formats of all required variables not discussed in section G (do not keypunch decimals).

Wire Angle and Title Card

NO. BOT. = number of sampling devices attached to the wire. (set equal to zero to terminate the program).

Wire = deviation of wire from the vertical

Term. Read. = terminal reading of winch

Bottom Depth = depth to bottom

Latitude and Longitude in degrees, minutes and tenths of a minute

MWCF = meter wheel correction factor

Wire Length and Thermometer Data Cards

BOT. NO. = Identification number for device on the wire.

UP Read. = Winch depth reading as each device is removed from the wire (set equal to 9999 to indicate the end of a cast).

Left Protected Thermometer: Thermometers are usually installed with the protected ones on the left and the unprotected on the right, as the observer reads the result.

Ther. No. = Factory identification number for each thermometer. Used to find index correction.

T_1 = Temperature reading of main thermometer as read by the first observer.

t_1 = Temperature reading of auxiliary thermometer as read by the first observer.

T_2 and t_2 = as above, read by the second observer.

T_{u1} = as above but referring to the unprotected thermometer.

Listing of Programs and Subroutines
Available from Dr. Kroopnick

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† An abbreviated version of this program for use on the shipboard computer system is currently under development.