CORED SEDIMENTS OF THE MID-ATLANTIC RIDGE NEAR $45^{O}N$.

by
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ABSTRACT

Seven sediment cores, ranging in length from 90 to 1290 cm, were collected from sediment filled valleys of the Mid-Atlantic Ridge at 45^0N. The valleys are located from 55 to 110 km west of the Median Valley, in an area where ridge and basin topography of up to 1500 m relief exists. The cores were sampled at 10 cm intervals and the samples sieve-separated into +62 micron and -62 micron fractions. The carbonate content of the -62 micron fraction was determined. The percentage of Foraminifera and the distribution of temperature sensitive Foraminifera in the +62 micron fraction was determined. The cored strata which are widely correlative in the area of study, represent the glacial/interglacial climatic sequence of the Late Pleistocene. Glacial marine sediments in the cores are typified by a relatively low carbonate content (a high clay content), a cool water faunal assemblage and an abundance of ice-rafted sand and gravel. The interglacial sediments are typified by a high carbonate content (low clay content), warm water fauna and an absence of ice-rafted detritus. Isotopic dates at several points in the cores were obtained and indicate that the oldest penetrated strata are Sangamon in age. The succession was compared with the Late Pleistocene time scale of glacial and interglacial events and a significant correlation found between the established time/temperature scale for the Wisconsin and Late Sangamon periods, and the climatic sequence in the cores.

Correlation of the stratigraphic sequence encountered in the cores was substantiated within individual basins, where two or more cores were retrieved, and between separate basins. Since individual strata are correlative from basin to basin and are very similar in thickness regionally, and since strata possessing the sedimentary characteristics of turbidites are rare, it is concluded that particle-by-particle sedimentation is the dominant mode of sediment accumulation.

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LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

LIST OF APPENDICES

CHAPTER I

INTRODUCTION

This thesis describes an investigation of seven sediment cores obtained from the Mid-Atlantic Ridge in the vicinity of 45^0 N. (Figure 1). The cores were obtained with heavy piston coring apparatus aboard the C.S.S. HUDSON, during a geological and geophysical survey of the Mid-Atlantic Ridge in 1966. The survey over the Ridge extended from the Median Valley to about 138 km west of it and covered an area of approximately 6475 sq. km. Generally, the sea floor consists of elongated ridges with up to 1460 m of relief, separated by inter-montane valleys in which the degree of sediment filling increases westward.

Until recent years, our knowledge of the Mid-Atlantic Ridge has been gained from numerous, but widely spaced traverses of the Ridge by research ships. The traverse of the R/V Vema from Dakar to Halifax (Ewing,1964) is a relevant example, Based on comparisons of such traverses, certain generalities concerning the bathymetry, geology and geophysics of the Ridge have become apparent (Heezen and others, 1959, and Ewing and others, 1966, for example). A natural consequence of these observations is the desire to test the consistency of the observed phenomena in small areas of the Ridge as well as to examine the Ridge more closely in anticipation of discovering further evidence of its origin. The survey in the vicinity of 45^0 30' N. by the British ship DISCOVERY II in 1960, and subsequent surveys of contiguous areas by the C.S.S. HUDSON in 1965,1966 and 1968 have made a significant contribution to the detailed study of the Mid-Atlantic Ridge.

The cruise of the HUDSON in 1966 (designated cruise number: B10 19-66 by the Bedford Institute of Oceanography) had as its primary objective, the gathering of geophysical and geological data on the Mid-Atlantic Ridge. The bathymetric survey, covering approximately 6475 sq. km and partly overlapping the surveys of DISCOVERY II and HUDSON (B10 19-65), was conducted along parallel east-west lines of one mile separation. The ship's position while proceeding along the pre-selected survey lines was determined every two minutes by ship's radar, obtaining the range and bearing of the ship relative to two or three tautly moored, radar transponder buoys. The ship's course was subsequently altered to compensate for any deviation from the desired track. The position of the transponder buoys was fixed by means of celestial observations repeated over several days. In addition to geological station work (coring, dredging and sea floor photography), water depth, gravity, and total magnetic field were continuously recorded. Bathymetric measurements were made with a precision depth recorder in conjunction with either a hull mounted, or towed transducer. Upon obtaining a fix of the ship's position at the end of each two minute interval, notation was made of the water depth from the continuous records. By plotting these depths on a continuously maintained chart of the ship's track, a preliminary chart was developed as the survey progressed.

The sediment distribution study was initially intended to provide data on the three-dimensional distribution of sediments within the intermontane basins, by means of the long piston cores and indirectly, by means of a seismic sub-bottom profiling system. Design problems with the receiving array of the seismic system made it impossible to obtain the sub-bottom profiles originally hoped for. Such a study has since been completed by Keen and Manchester (1970).

Rather suprisingly, cores of the valley-filling sediments revealed on preliminary examination, an apparently time-continuous succession of lutites and calcilutites. One might have expected a succession of sediments deposited by turbidity currents considering the relatively steep slopes of the valley walls. To substantiate the lithologic succession, the relative carbonate and non-carbonate content of the sediments was determined at frequent intervals. The stratigraphic sequence in each core was thus established quantitatively and subsequently found to correlate closely from core to core within and between basins.

G.A. Bartlett (personal communication) examined Foraminifera of the +62 micron fraction of some core samples as part of his research on planktonic Foraminifera of the Mid-Atlantic Ridge. Using commonly accepted methods of determining the relative palaeotemperature of the seawater in which the microfauna dwelt, Bartlett was able to deduce generalized, relative temperature curves for the cores. Radiocarbon and Protactinium ages were determined at several intervals within the cores.

This core study has led the author to conclusions about the nature of sedimentary processes in the intermontane basins. The comparison of carbonate content of the sediments with the inferred palaeoclimatic succession strongly indicates a direct relationship between the carbonate content of sediments, in this geographic area, and the climatic conditions under which they were deposited. That is, sediments rich in calcium carbonate appear to have accumulated under relatively warm climatic conditions. A reasonably good correlation has been found in the present study between the Wisconsin time and temperature scale and the climatic sequence inferred from the carbonate analysis, the vertical distribution of ice-rafted mineral grains and rock fragments, the microfaunal study and Radiocarbon and Protactinium dating.

The sediment core station data are summarized in Table I following.

CORE NUMBER BIO 19-66:	LATITUDE	LONGITUDE	GENERAL LOCATION	DEPTH METRES CORRECTED	DEPTH FATHOMS	APPARENT PENETRATION CENTIMETRES	CORE LENGTH CENTI-METRES
12	45-15.6 N	29-11.4 W	intermontane valley 92 km west of Median Valley	3085	1646	?	513
15	45-22.2 N	28-52.5 W	intermontane valley 74 km west of Median Valley	2985	1592	1190	90
17	45-20.2 N	28-42.2 W	intermontane valley 55 km west of Median Valley	2880	1540	?	1030
18	45-23.6 N	29-00.2 W	intermontane valley 83 km west of Median Valley	2950	1575	1050	901
20	45-13.25 N	29-12.4 W	4.6 km SSE of core station: BIO 19-66-12	3100	1650	1650	1082
22A	45-12.6 N	28-55.8 W	atop Bald Mountain	1270	680	0	0
26	45-14.25 N	28-54.5 W	Bald Mountain apron	2810	1500	1220	1220
27	45-27.8 N	29-17.5 W	intermontane valley 111 km west of Median Valley	3130	1670	1220	1290
39	45-23.5 N	28-56.2 W	north end of Bald Mountain Ridge	2470	1320	488	?*
46	45-22.0 N	27-56.3 W	Median Valley	2970	1590	10	0
50	45-40.4 N	27-46.0 W	Median Valley	3560	1900	200	58

* Core number BIO 19-66-39 could not be extended from its core pipe.

TABLE I. SUMMARY OF CORE STATION DATA

CHAPTER 2

THE PHYSICAL SETTING

2.1 Bathymetry

Physiographically distinct zones are generally observed to occur with approximate bilateral symmetry about the Median Valley of the Mid-Atlantic Ridge (Heezen and others, 1959). The bathymetry map of the survey area (Figure 2), which represents a composite of several surveys, covers the Mid-Atlantic Ridge from the Median Valley westward for a distance of approximately 138 km and includes only a few kilometres of comparable physiography on the eastern side of the Median Valley.

The bottom topography displays a generally marked, north-south lineation. Three distinct physiographic provinces are apparent; the Median Valley, the flanking Crestal Mountains ("Rift Mountains" of Heezen) and the westernmost area of relatively subdued, sediment infilled topography; Heezen's "High Fractured Plateau".

The Median Valley is arbitrarily considered as being delineated by the 2560 m (1400 fm) contour. The Valley floor consists of an en echelon series of basins separated by low transverse ridges. The mean depth of the Valley floor which, from coring and photographic evidence, is held to be essentially devoid of sediments, increases northward where the maximum depth of approximately 3458 m (1900 fm) is attained.

The ridge and valley topography of the Crestal Mountains province, distinctly exhibits an approximately north-south lineation. Whereas the eastern boundary of this province (western boundary of Median Valley) is taken as the 2560 m (1400 fm) contour, the division between this Crestal Mountain province and the more subdued region to the west (High Fractures Plateau) is also arbitrarily taken to be the 2560 m (1400 fm) contour. The lateral extent of the Crestal Mountain province is approximately 37 km. The average water depth increases westward. Several peaks on the discontinuous ridges of this province approach to within 1820 m (1000 fm) of the surface and two, Bald Mountain and Confederation Peak to within 1092 m (600 fm) of the surface. Minor pockets of sediment occur in valleys of this region but the filling of the valleys increases in frequency and areal extent in a westerly direction as the next physiographic province is approached.

The topographically less severe province which occupies the western portion of the survey area owes its relatively subdued topography, in part, to the smoothing effect of sediment infilling. It is the sediment of the flat surfaced valley floors that was core sampled in the present study. As in the case of the Crestal Mountain province, the average depth of water increases westward.

2.2. Oceanography

Little detailed information is available concerning water-mass movements over the Mid-Atlantic Ridge in the survey area. In general terms however, the surface in the vicinity of of the Ridge at 45^0 N. belong to the easterly North Atlantic Current, which is a diffuse extension of the Gulf Stream. Sverdrup, Johnson and Fleming (1942), reporting on a series of stations along the Mid-Atlantic Ridge in Long. 30^0 W., were able to distinguish between two major branches of the North Atlantic Current. The northern branch flows in Lat.50^0 N. along the boundary between the Gulf Stream System and the Subarctic waters, and represents Gulf Stream Water mixed with waters of the Labrador Current. The southern branch flows in the vicinity of Lat. 45^0 N. and carries undiluted Gulf Stream water. Upon crossing the Mid-Atlantic Ridge, this branch turns southward and flows between the Azores and Portugal.

These same authors in illustrating the contrast between the Gulf Stream and the North Atlantic Current have shown the effect of the bottom topography, as encountered on the Mid-Atlantic Ridge, on oceanographic conditions.

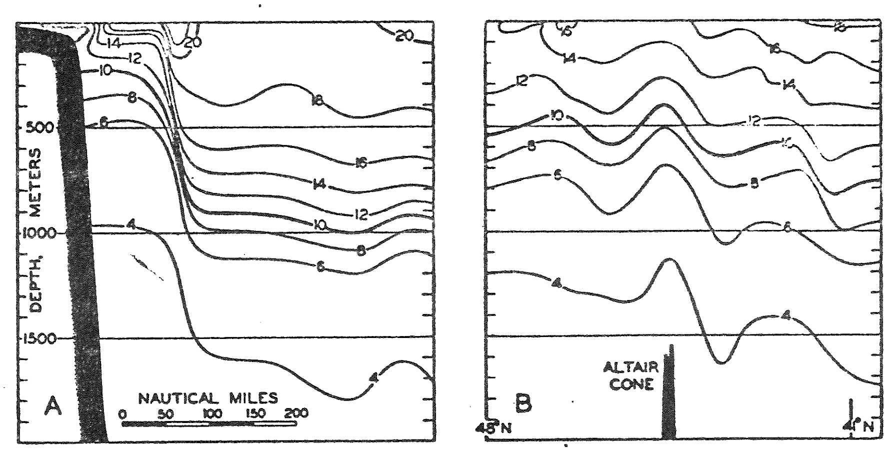

FIGURE 3. Temperature profiles across Gulf Stream off Chesapeake Bay (A) and across the North Atlantic Current north of the Azores (B). (after Sverdrup and others, 1942)

Their illustration is reproduced as Figure 3. The diagram on the left shows an isothermal section across the Gulf Stream from Chesapeake Bay toward Bermuda. The diagram on the right is an isothermal section from the Azores, north-northwest to 48^0 N. The generally south-dipping isotherms indicate flow toward the east whilst the departures from this trend indicate the presence of countercurrents or eddies between the east-flowing branches of the current. In this section also, is shown the effect of a submarine volcanic peak, "Altair Cone" which, as reported by Sverdrup and others (1942), rises from a depth of about 3,500 m to 980 m at its highest point. The density distribution resulting from the illustrated isothermal response to the submarine peak indicates that a counterclockwise eddy exists above the cone and extends to a depth of at least 1,500 m. This eddy is apparently observable even at the surface of the sea. The present author observed a possibly similar phenomenon while the HUDSON was occupying a station on Bald Mountain, the highest peak of a north-south elongated ridge, which rises to within 1274 (700 fm) of the sea surface. A large "slick" of relatively calm water with an apparently turbulent boundary was seen. The calm appearance of the body of water may have resulted from the attenuating effect of current, on small, wind-generated waves. Currents apparently caused a concentration of marine life as witness the fervent diving of sea birds at the periphery of the "slick". No attempts were made to substantiate the existence of this supposed eddy. Garner amd Ford (1969) found evidence of extensive vertical water mixing in their oceanographic study of the Mid-

Atlantic Ridge at 45° N.

The role of Mid-Atlantic Ridge bottom topography in controlling current flow, and thus influencing sedimentation, has been described by Klenova and others (1962). These investigators measured the abundance of suspended material in samples taken at the surface and at 10, 30, 100, 200, 800 and 2,000 m depth. They found that regionally, the abundance of suspended material diminished regularly from the highest reaches of the Ridge to the flanking abyssal basins. Locally, they found that near-bottom water at the base of slopes (about 3,000 m depth) on the Mid-Atlantic Ridge, contains a relatively great amount of suspended matter whereas intermediate depths contain little, and near-surface waters contain a relatively moderate amount. The authors attributed the high concentration at the base of the slopes to down-slope migration of fine suspended sediment in response to gravity. The concentration in the near-surface waters was attributed to the upward transport of very fine sediments by ascending currents. The carbonate analysis of Core 18 shows this core to have a significantly lower carbonate content than comparable zones of the other cores. The core nonetheless exibits a stratigraphic sequence that is correlative with the others. The core is therefore representative of an area of relatively higher non-carbonate lutite sedimentation (or an area with an abnormally low rate of calcilutite accumulation). Such oceanographic phenomena as described above may account for the apparently anomalous sedimentation in the vicinity of Core 18.

2.3 Geology

Ocean floor photography, dredge hauls and sediment cores reveal, to varying degrees, the surficial geological constitution of the Mid-Atlantic Ridge. Aumento and Loncarevic (1968) and Aumento, Loncarevic and Ross (1969) have studied the distribution of dredged rocks in the survey area. They found basalts and tuffs ubiquitous and ranging in composition from tholeiites to alkali-basalts. They have interpreted Bald Mountain (Figure 2) and other ridges as up-thrown, block-faulted features. Associated with the interpreted fault scarps are serpentized mafic and ultramafic rocks (dunites, harzburgites, gabbros, troctolitic gabbros and amphibolitic periodotites). This suite of rocks is absent from the Median Valley floor where fresh extrusions of pillow basalt have been photographed and sampled. Metabasalts and metadiabases of the greenschist metamorphic facies have been recovered from the lower reaches of the Median Valley walls. Interpreted fault scarps of elongate ridges, beyond the immediate walls of the Median Valley, have yielded matamorphic rocks which range in their metamorphic grade from the highest greenschist facies to the highest grades of the almandine-amphibolite facies. It appears that the Median Valley is the main centre of recent volcanic extrusion of basaltic lavas. The fault scarps of apparently uplifted ridges contain exposures of metamorphosed basalts, and of a variety of metamorphosed intrusive rocks representing a more deeply seated suite of dike and magmatic intrusives which reflect magma differentation with time.

Approximately one-quarter of the dredged specimens were abraded and sometimes striated, gneissic, granitic and sedimentary rocks of obviously ice-rafted origin. Significantly, rafted erratics are most common in the western portions of the survey area and their frequency of occurence diminishes toward the Median Valley in which none were found. The potassium-argon and fission track ages of extrusive rocks were observed by Aumento, Loncarevic and Ross (1969) to increase systematically with distance from the axis of the Mid-Atlantic Ridge. Similarly, the thickness of manganese coating on such specimens was seen to increase away from the Median Valley. The morphological boundary between the topographically severe Crestal Mountain Province and the more subdued and sediment-smoothed topography of the High Fractured Plateau was found coincident with a marked increase, west of the boundary, in the age of the country rock and in the thickness of the manganese veneer on the dredged specimens. The evidence points to the existence of ocean-floor spreading with a variable spreading rate. The absence of glacial debris in the Median Valley might suggest the post-Pleistocene origin of this valley or might simply mean that any such material has been covered or diluted by post-Pleistocene eruptive rock. Certainly the existence in bottom photographs of large lava pillows, essentially devoid of sediment cover, points to very recent volcanic activity in the Median Valley.

CHAPTER 3

OPERATIONAL METHODS

3.1 Coring

Kullenberg (1947) in quest of long, undisturbed cores of deep-sea sediment, introduced the piston corer as an improvement on the conventional gravity corer. Subsequently, coring devices were developed employing modifications to this original apparatus while retaining its principle. The device currently used is essentially that described in detail by Ericson and Wollin (1956), with a few improvements since added.

The simplest gravity coring device consists of a coring tube mounted below a streamlined and finned weight. Lowered rapidly from the ship at the end of a wire rope, the tube plunges into the sea-floor sediments, cutting a core. A core so obtained when compared with the in situ sediments will be compressed vertically because of the friction between the core barrel and the sediment. To overcome the retarding effect of friction, Kullenberg employed a piston in the core barrel and caused it to move relative to the walls of the barrel so as to produce a pressure differential across the piston, that is, a suction effect of a magnitude equalling, but not exceeding, the force of friction. Thus, an uncompressed core sample was obtained. Commonly, full penetration is not accomplished. Thus, to retrieve the apparatus, the piston must be pulled up to the constriction at the top of the core barrel, from its intermediate position between the constriction and the cutting end. The strong suction so produced lifts the sediment core and at the same time causes sediment surrounding the cutting end, to flow into the tube beneath the core. This "flow-in" is readily recognizable; as a monotonous, unlayered and relatively soft sediment, or as a soft sediment in which originally horizontal stratification is distended upwards. In practice, the finned coring head weighs 585 kg. Below the head are coupled 6.1 m lengths of 63.5 mm I.D. core pipe, with three lengths(18.3 m) the usual maximum. The cores which were taken in plastic tubes lining the core pipe, were removed in the liners. In the few cases where excessive suction had broken the core, allowing water to fill the voids, small holes were drilled in the plastic liner at the separation, to drain any free water. Such free water tends to erode the surrounding core due to agitation resulting from ship's motion. The cores remained in the Hudson's refrigerated core storage until the end of the cruise.

3.2 Core Logging

The core-liners were split while secured in a wooden trough or jig, along the top of which was drawn a woodworker's power router. A clean cut with little or no contamination or destruction of the core within, resulted from the use of this apparatus (Plate 1.). The sediment core was split with a knife blade. As the wet core was split longitudinally, it was immediately photographed, described and sampled. Photographs of the cores were taken with a 35 mm Nikon single-lens reflex camera attached to a heavy ringstand-like apparatus to which a flood lamp was fixed, providing constancy in lighting. The core was measured using a steel tape with centimeter divisions. Appropriately numbered thumb tacks were placed on the core at successive 10 cm intervals down its length to serve as

PLATE I CORE LINER SPLITTING APPARATUS

reference points for the photographs and for futue sampling. The camera apparatus was slid the length of the core at consistent vertical and horizontal distance, and a continuous series of photographs taken. Samples of the moist sediment, approximately 1.5cm^3 in volume, were generally taken from the cores at 10 cm intervals. Where sediments of unusual nature occured, additional samples were taken.

The cores were described when first opened and still wet. Noted were: sediment colour and lithology, sedimentary structures, and the nature of interstratal contacts. The terminology of the core descriptions is briefly defined below.

(a) Colour

Sediment colours were recorded by comparison with the Munsell Colour Chart and adoption of the name and number of the corresponding colour.

According to the Munsell system, a colour has a three component designation: Hue, Value and Chroma. Hue -- refers to one of the ten major hues. In sequence these are:

(1) Red (R)
(2) Red Purple (RP)
(3) Purple (P)
(4) Purple Blue (PB)
(5) Blue (B)
(6) Blue Green (BG)
(7) Green (G)
(8) Green Yellow (GY)
(9) Yellow (Y)
(10) Yellow Red (YR)

Each hue is subdivided into ten segments the number 5 marks the middle of the hue, and number 10, the boundary between one hue and the next in sequence. Value -- The Value of a colour refers to its degree of lightness and ranges from numbers 1-9 between end members black and white respectively. Chroma -- The Chroma of a colour represents its saturation or intensity. The Chroma ranges from a neutral gray to the most vivid (saturated) colour of any hue. Thus a Munsell colour designation takes the following form:

<u>Generalized</u> - Hue, Value/Chroma

<u>Example</u> - 10 YR 8/2

Through the Munsell name as well as symbolic designation has been generally adopted, modifiers, as for example: (dark) gray, have been added where it was felt the color name was too general. As shown above, these modifiers are enclosed in parentheses.

(b) <u>Lithology</u>

In general the various sediment types have been designated by one of the following descriptive terms, as appropriate:

lutite
foraminiferal lutite
calcilutite
foraminiferal calcilutite
forminiferal sand
mineral debris sand

The absence of detailed size analysis precludes the more precise subdivision of a nomenclature used primarily in megascopic examination.

Here, "lutite" is defined as consisting of particles, the mean diameter of which is less than 0.062 mm. "Sand" by definition, consists of particles, the mean diameter of which is greater than 0.062 mm but less than 2 mm. The adjective "foraminiferal" as in "foraminiferal lutite" refers to the presence of 10% or more Foraminifera (sand-sized) admixed with the lutite.

The carbonate content of lutite is reflected by its colour. The higher the colour value, the higher the carbonate content of the sediment. It was found by comparing the subsequent carbonate analysis and Munsell number for given sedimentary horizons, that a colour value of about 6.5 represents a carbonate content of about 60% by weight. Lutite with a colour value greater than 6.5 was termed "calcilutite", while that below 6.5 was referred to simply as "lutite". The nature of megascopic core description dictates that such an arbitrary and subjective division be made. In summary then, the terms "lutite" and "calcilutite" are here distinguished as follows:

	Mean Particle Diameter	$\%CaCO_3$	Colour Value
Lutite	$<$ 0.062 mm	$<$60	$<$6.5
Calcilutite	$>$ 0.062 mm	$>$60	$>$6.5

The sand-sized (coarser than 0.062 mm) sediments of the cores are designated as either "foraminiferal sand", consisting essentially of Foraminifera, or as "mineral debris sand". consisting of pyroclastics, and ice-rafted mineral grains and rock fragments, where these predominate over Foraminifera.

(c) Interstratal Contacts

Contacts between differing sedimentary horizons are in many places marked by either a change in sediment colour or average grain size, or by both. Thus two contact types are defined:

-- the colour contact (contrasting colours)

-- the textural contact (grain-size contrast)

In addition, a contact may be sharp, the change occuring over a distance of a centimeter or less; or gradational. Further, contact zones, because of the juxtaposition of sediments of contrasting colour, frequently display mottlings of one sediment type in another; the effect of burrowing by benthonic organisms. A contact obscured by this process is here referred to as a "burrow-mottled contact".

CHAPTER 4

SEDIMENT SAMPLE ANALYSIS

4.1 Discussion

The analysis of the core samples by sieving and calcium carbonate determination was made to substantiate the suspected stratigraphic correlation between cores and to aid in establishing the depositional environment of the sediments. The analytical approach to the study was chosen in the light of a preliminary examination which suggested that the cored sediments were essentially of two types: (a) light coloured, carbonate-rich sediments with a +62 micron fraction or Foraminifera tests and a -62 micron fraction of diminutive Foraminifera tests and extremely fine particulate carbonate, and (b) darker coloured sediments of correspondingly lower carbonate content and consisting of a varying admixture of carbonate components as above, volcanic ejectamenta and mineral and rock detritus. An investigation of the carbonate distribution in the cores was given first priority.

With respect to the carbonate analysis, it should be emphasized that one would like to determine the volume percentage carbonate in a given volume of sample. Since the volume of sediment in a sample is difficult to determine, one approximates the desired value by determining instead, the weight percentage of carbonate in a given weight of sediment, Consider a population of medium sand sized mineral grains which is composed equally of quartz grains (specific gravity (2.65) and solid calcium carbonate grains (specific gravity 2.72). Because of the similarity in the weight of grains of either composition but similar size, a weight percentage carbonate determination would closely approximate a volume percentage determination.

Consider now a population of medium sand, composed of an equal number of quartz grains and hollow spheres of calcium carbonate (Foraminifera). Because of the disimilarity in densities of the two grain types, the more dense grains (quartz) will contribute to the weight of a subsample used for carbonate analysis in a manner proportional to their density but disproportional to their frequency of occurence in the original population; fifty per cent. Thus a weight percentage carbonate determination is likely to be a poor approximation to the desired volume percentage. This effect applies to a lesser extent to the silt fraction and presumably still less to the clay fraction in which the component particles would be essentially solid. It was decided to minimize the bias by removing the +62 micron fraction from the bulk samples with wet sieving and comparing carbonate percentages of the -62 fractions only.

Ericson and Wollin (1956) have shown that in the equatorial Atlantic where the +62 micron fraction of deep-sea carbonate sediments consists solely of Foraminifera, the weight percentage of the +62 micron fraction of a bulk sample is a measure of Foraminifera productivity at the time of deposition and as such, is a significant parameter in correlating cores. This parameter could not, of course be derived by the separation of the +62 micron fraction from sediments of the temperate Atlantic with their heterogenous sands composed of ice-rafted debris and Foraminifera tests. It was supected however, that the percentage of +62 micron fraction, though representing the sedimentary products derived from two separate but super-imposed systems might nonetheless exibit overall trends of the composite system which would aid correlation. It was recognized that a possible cancellation of the effect of one system by the other system might exist. That is, if the rate of production (and preservation) of Foraminifera attained a maximum, coincident in time with a minimum of sand influx, the effects would cancel to some degree depending on the relative abundance of the two components present.

A further incentive for removing the +62 micron fraction derives from the fact that Foraminifera tests lie to a large extent in the sand size range. Removing these Foraminifera from the carbonate analysis would tend to minimize the effect of one variable (Foraminifera production) in the still multi-variant carbonate sedimentation system and increase the probability of detecting real trends in carbonate deposition. Concentrating the Foraminifera by wet sieving would also facilitate palaeontological analysis.

4.2 Sieve Separation

The still moist bulk samples, when taken from the cores, were stored in moisture-tight plastic vials. Several days before the sieve separation of the plus and minus 62 micron fractions was to be made, the vials were opened and filled with twenty to thirty ml of distilled water. Thereafter the vials and contents were shaken periodically using a Vortex Junior mechanical shaker to cause disaggregation of the sediment. When dispersed, the sediment-water mixture was poured onto a three inch diameter, 62 micron sieve which was nested in a funnel leading to a 250 ml beaker, the dry weight of which had been previously determined. Using an automatic wash bottle, the sample was thoroughly washed on the sieve and the -62 micron fraction collected in the beaker. The wash water was evaporated from the -62 micron fraction in about twenty-four hours, in an oven equipped with a forced air circulation system, at a temperature of approximately 120^{0}C. Similarly, the clean +62 micron fraction was washed into a weighed, 100 ml beaker and allowed to settle for thirty minutes. Two thirds of the supernatant water was siphoned off and the remaining water was evaporated in the oven. When dry, the samples were weighed and the weight percentage of the +62 micron and the -62 micron fractions computed.

Both suction filtering and centrifuging of the -62 micron fraction, as methods for rapidly removing wash water from the lutite were experimented with and discarded in favour of evaporation.

In the Wentworth-Udden grade scale classification of particle sizes, 62 microns is taken as the lower limit of the sand grade class. In separating the +62 micron fraction (sand and gravel) from the -62 micron fraction (silt and clay) several possible sources of significant error are apparent. These are discussed below.

Common practice in wet sieving sediments of the types studied is to oven dry the sample, weigh it, and then disaggregate the sample prior to wet sieving. By comparing the sum of the dry weights of the two fractions produced by sieving, with the dry weight of the original bulk sample, a check is made on possible loss of sediment in the sieving process. In the present study, loss of sediment in the single-stage separation was expected to be relatively small. Furthermore it was thought that the possible incomplete disaggregation of dried bulk sample might introduce significant error. For these reasons, the bulk sample was protected against loss of moisture during storage and not dried and weighed before sieving.

It has been remarked that some areas of the core contain rock fragments of gravel size (greater than 2mm). In order to obtain a representative sample of the gravel fraction, a sample larger than 1 cc would have to be taken. Therefore, where prominent gravel-sized fragments occurred in the dried, +62 micron fraction, they were removed with a pair of tweezers while the sample was weighed, and then returned to the sample for storage. Thus the sample weight excludes the weight of pebbles. The number of such fragments in individual samples never exceeded five. While the removal of these very large fragments would eliminate the gross exaggeration of the weight percentage of +62 micron fraction in the sample, there may be some exaggeration due to the presence of fine gravels which could not easily be removed.

In the plus and minus 62 micron fraction separation, no account of the salt content of the sediment samples has been taken. The salt of each sample was presumably washed from the +62 micron fraction by wet sieving, into the -62 micron fraction. The weight of salt in a sample would be a function of the water content of the sample which in turn, is related to carbonate content as well as depth below the sediment-water interface. Broecker and others (1966), determined the average salt content of water-free bulk samples for an Atlantic core (A 180-74; from the eastern flanks of the Mid-Atlantic Ridge at the equator) to be 0.04 gm/cc. Concentrating such an amount in the -62 micron fraction of the samples would increase the weight percentage of that fraction by approximately 1%. For the purposes of this study, the error is considered to be of no consequence.

4.3 Carbonate Analysis

The carbonate analytical procedure, a titration, is essentially that described by Herrin and others (1958) with minor modifications directed to speeding the analysis of a large number of samples. The chemical theory and procedures are discussed in some detail below. The equipment used for the carbonate analyses, as performed on a "mass production" basis, is listed below. Plate 2 shows the analytical equipment in use.

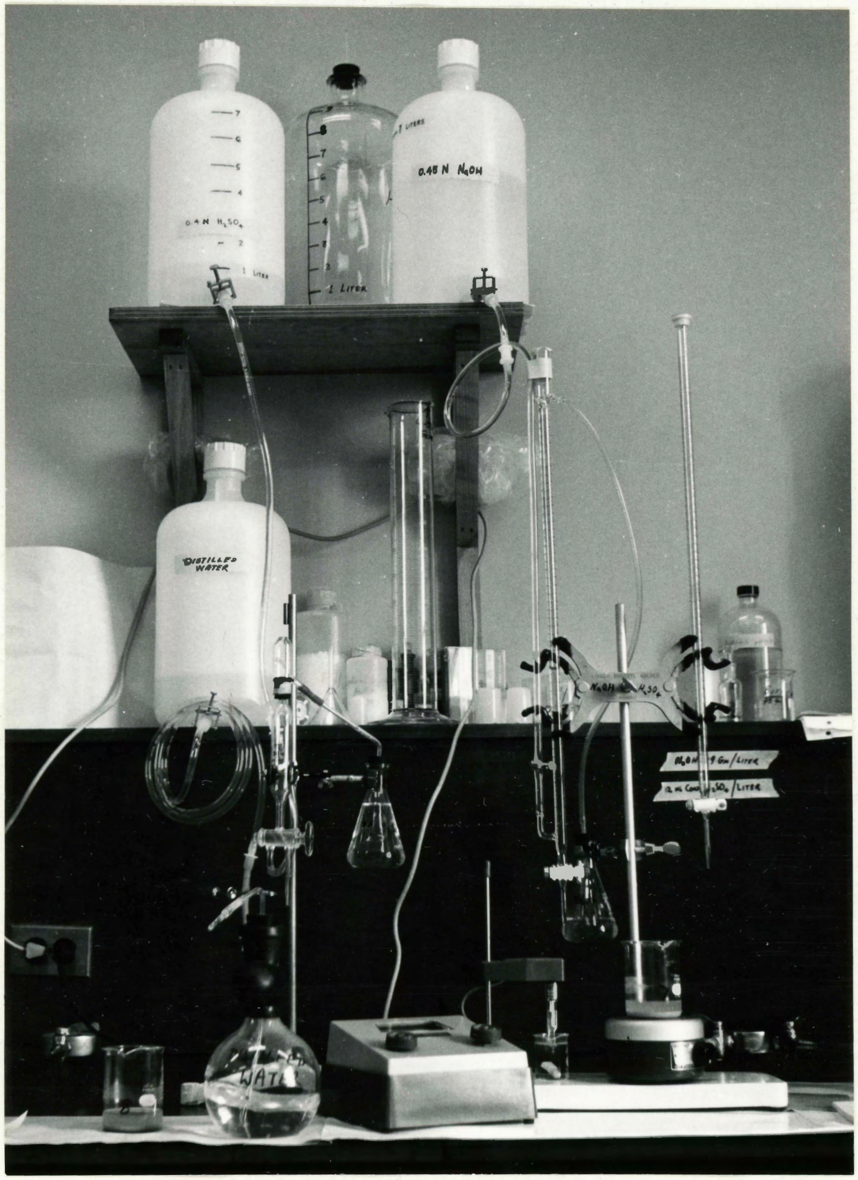

Plate 2. Carbonate Analysis Equipment

Apparatus

Quantity	Description
1	Coleman pH meter
1	Magnetic stirrer and magnets
1	Burette stand with burette clamp
1	50 ml automatic burette with two-hole, teflon stopcock
1	50 ml automatic pipette with teflon pipette
1	ring stand
3	ring stand clamps
3	8 liter polyethelene aspirator bottles
2	150 ml Erlenmeyer flasks
40	250 ml short beakers
1	1000 ml graduated cylinder
1	100 ml graduated cylinder
1	automatic wash bottle

Chemical Theory and Calculations

In the method described by Herrin and others (1958), and used in the present study, the calcium carbonate of a dried and weighed sediment sample is made to react with sulfuric acid, producing a precipitate of calcium sulfate as a chemically equivalent amount of CO_2 is evolved. The reaction is as follows:

$$CaCO_3 + H_2SO_4 = CaSO_4 + H_2O + CO_2$$

Consider a sample of carbonate-rich sediment weighing approximately 1 gram when dry. When the usual 50 ml aliquot of 0.45N H_2SO_4 is added and the reaction complete, a certain amount of H_2SO_4 (the amount being inversely proportional to the amount of $CaCO_3$ present) will remain unreacted because the amount of acid added is calculated to be more than equivalent to the amount of $CaCO_3$ with which it could react. The amount of H_2SO_4 remaining is determined by the subsequent back-titration with standardized NaOH. The amount of H_2SO_4 involved in the reaction is found by subtracting the volume of acid remaining after reaction, from the volume of acid initially introduced (50 ml). Examination of the chemical equation shows that one milli-equivalent (meq) of $CaCO_3$ reacts with one meq of H_2SO_4, producing one meq of each of the products. Thus the number of meq of H_2SO_4, involved in the reaction, as determined above, is equal to the number of meq of $CaCO_3$ in the sample. Summarizing:

(1) Initial meq H_2SO_4 added to sample = Vol H_2SO_4 x N H_2SO_4

(2) Reaction

(3) Back-titration of NaOH against H_2SO_4

(4) Neutralization point:
meq H_2SO_4 (reacted) = meq NaOH = Vol NaOH x N NaOH

(5) Meq $CaCO_3$ in sample = meq H_2SO_4 (reacted
= meq H_2SO_4 (initial -
meq H_2SO_4 (remaining)

(6) Weight of $CaCO_3$ reacting = meq $CaCO_3$ x meq
$CaCO_3$ reacted = 0.05mg x meq
$CaCO_3$ reacted

(7) Weight percentage $CaCO_3$ in the sample

$$= \frac{0.05 \text{ mg x meq } CaCO_3 \text{ reacted}}{\text{sample weight}} \times 100$$

Since, as shown by the reaction equation, the number of meq of $CaCO_3$ equals the number of meq of CO_2 evolved, the weight percentage CO_2 may be calculated if desired, simply by substituting the meq weight of CO_2 for that of $CaCO_3$ in the equation (7) above.

Procedure

Eight liter volumes of approximately 0.40 N NaOH and 0.45N H_2SO_4 were mixed and standardized by triplicate titrations as follows:

-- NaOH against Potassium Acid Phthalate solutions of known normality

-- H_2SO_4 against the standardized NaOH

Prior to analysis, the -62 micron fraction of a sample was powdered with a mortar and pestle, heated at 100° C to dry (generally for six hours), and a sub-sample weighed. Approximately 1 gm of sample was used in each analysis.

The weighed sample was placed in a 250 ml meaker and 50 ml of the standardized H_2SO_4 added from an automatic pipette. Though some loss of solution due to effervescence occurs when the acid is added, the loss is considered insignificant, Use of the wide-mouthed beaker as against the preferred Erlenmeyer flask was necessitated by the configuration and dimensions of the pH meter electrodes.

The acidified sample was heated at 90°C for twenty minutes to promote complete solution of the $CaCO_3$ in the sample. Herrin and others (1958) recommend that after heating, the pH of the solution be no greater than 2, i.e. indicate complete solution of the carbonate. Where the pH exceeds 2, 25 ml of H_2SO_4 should be added and the solution heated for ten minutes. After heating, approximately 125 ml of distilled water were added to the beaker and back-titration with standardized NaOH carried on to pH7. The pH was measured using a Coleman pH meter. A magnetic stirrer was employed to provide constant agitation. The volume of NaOH used in back-titration multiplied by its normality, yields the number of meq NaOH reacting. This equals the number of meq H_2SO_4 remaining after complete reaction with the $CaCO_3$. The weight percentage $CaCO_3$ in the sample is then calculable.

The use of the pH meter is preferred to the use of phenolphthalein indicator for the following reasons:

(1) Due to the presence of clay in the agitated solutions, the end point is difficult to detect when indicated by a color change.

(2) Comparisons of the pH curves for simple, strong acid-strong base titrations, with those for acid solutions containing a precipitate of $CaSO_4$ plus clay (the present situation), indicate for the latter, a significant difference between the volume of NaOH added to attain a pH value of 7 and the volume added to reach pH8.5 (the critical value for phenolphthalein). This is contrasted with the insignificantly small difference between these two volumes in the simple acid-base titration (Figure 4).

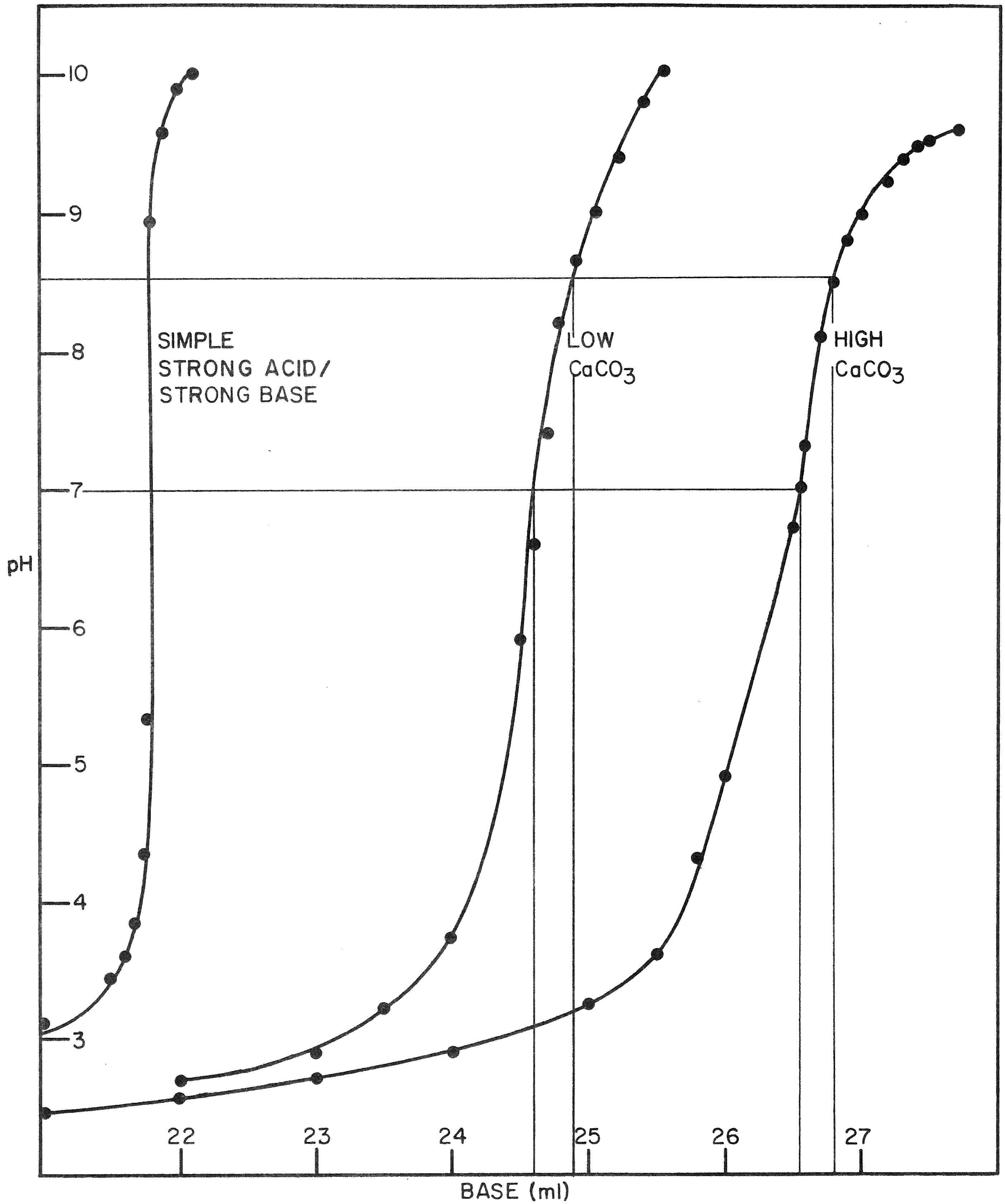

FIGURE 4 TITRATION CURVE COMPARISON

Carbonate Analysis Errors

Herrin and others (1958) analyzed samples of carbonate rock of known $CaCO_3$ content and compared their results with the known values. The tests of the analytical precision are summarized below as no such tests were made by the present author.

In eight tests (by the titration method) on a United States Bureau of Standards sample of argillaceous limestone, Herrin et al obtained a mean value of 32.19$\pm$ 0.2% CO_2. The mean value of eight analyses obtained by a second analyst using different standard solutions was 32.94$\pm$ 0.10 per cent CO_2. For both analyses, phenolphthalein (pk 8.8) indicator was used. The mean of three analyses in which the end point (pH 7.0) was indicated with a pH meter, amounted to 33.46$\pm$ 0.3%. According to the Bureau of Standards, the mean of five analyses using the (most accurate) gas-capture method was 33.53$\pm$ 0.05 per cent CO_2. The low value of CO_2 obtained using phenolphthalein to indicate the end point is due to the previously noted difficulty in detecting the end point by a color change in the mixture of clay, calcium sulfate and water.

Tests of reproduceability were made by the present author on a number of samples. Simultaneously, the necessity of heating the acidized samples to produce complete reaction was confirmed. Following are the results of these tests; all results representing potentiometric titrations. Groups One and Two represent respectively, unheated and heated, acidized sub-samples of one large sample.

Group One (Unheated)

Sample No.	Weight	$\%CaCO_3$	Deviation
1	1.0025 gm	76.11%	0.29
2	0.8837	76.44	0.04
3	0.9375	76.48	0.08
4	0.9991	76.92	0.52
5	0.8503	76.09	0.31
Average		76.40	0.25

Group Two (Heated)

Sample No.	Weight	$\%CaCO_3$	Deviation
1	0.6473 gm	78.02%	0.61
2	0.9177	78.40	0.23
3	0.9623	78.67	0.04
4	0.7528	78.84	0.21
5	0.9975	79.25	0.62
Average		78.63	0.34

These results indicate the degree of accuracy attained by the present author. Furthermore, there is a clear indication that heating the samples of Group Two, promoted more complete digestion of the $CaCO_3$ in the samples as compared with the unheated samples of Group One. It is possible that dissolution of iron oxide minerals by H_2SO_4 may have contributed to the increased take-up of H_2SO_4 after heating.

Sources of error in the determination of $CaCO_3$ are largely those attendant to the potentiometric titration and need not be discussed here. It is conceivable that soaking of the sediment samples in distilled water for several days during the disagregation process, may have dissolved some of the carbonate. However this carbonate is retrieved during the evaporation phase of the analytical procedure mentioned earlier.

It appears probable that the total error in a given carbonate determination is less than five per cent; a degree of accuracy quite adequate for the purposes of the present investigation. Further, it should be noted that the "carbonate" of the sediments is assumed here to be solely calcium carbonate. In view of the fact that the magnesium carbonate of pelagic sediments has been found to be very low, less than 3 per cent (Bramlette and Bradley, 1942), omission of this component in the calculation of "total carbonate" is of little significance.

CHAPTER 5

ESTABLISHMENT OF STRATIGRAPHIC CORRELATION

5.1 Lithology

In addition to visually logging the Munsell colour, grain size and textures of the fresh sediment cores, two aspects of sediment lithology were studied: the carbonate content of the -62 micron grain size fraction and in less detail, the composition of the +62 micron fraction. As noted in Section 3.2, the colour value of the lutites reflects their carbonate content; the higher the colour value, the higher the carbonate content. The plotted sediment colour values of Figure 5, suggest correlation from core to core of certain light and dark coloured (high and low colour value) sediment layers, as for example, that layer with a colour value of 5, lying between 46 cm and 72 cm in Core 17.

The quantitive determination of the carbonate content of the -62 micron grain size fraction, as plotted in Figure 5, fluctuates with a wide range of variation and exhibits a sequence of variation which can be recognized, at least in part, in all of the cores. Visual examination of the plotted carbonate content reveals that discrete zones of high and low carbonate content may be correlated with one another between cores. The author's proposed correlations are shown in Figure 5. The major zones of Core 17, as defined by carbonate content, are briefly described below:

The carbonate content diminishes from the top of the core , downward to approximately 45 cm depth. A zone of relatively low carbonate content and colour value (5-6), occurs between 45 cm and 331 cm. From 331 cm to 522 cm occurs a calcilutite with a colour value of 8, reflecting a consistently high carbonate content. A zone of moderate to low carbonate content lies between 522 cm and 780 cm. Between 780 cm and 860 cm, a white carbonate-rich calcilutite exists and is correlated with similar strata in cores 20 and 27.

Cores 18 and 26 contain extensive sections which cannot be correlated with other cores. The white, high-carbonate calcilutite below 515 cm in Core 18 is interpreted to be sediment which has been sucked into the core barrel during a period in the coring process when upward movement of the piston exceeded the rate of sediment penetration by the barrel. The sediment of this section exhibits the characteristics typical of sucked-in sediment:

- --It displays a vertically distended contact with the over lying, undisturbed sediments.
- -- Burrow mottlings are vertically distended.
- -- The sediment lacks horizontal layering and is extensively homogenized.

The horizontal attitude and undisturbed appearance of strata between 800 cm and the bottom of the core, suggest that following the period in which sediment was sucked in, equilibrium was again established in the relative movement of piston and core barrel, and normal core obtained. However, this normally cored section is now out of its proper stratigraphic position and its correlation is impossssible.

The correlation of Core 26 below 131 cm with other cores is not possible. The sediment between 131 cm and 710 cm is mainly a white calcilutite, largely devoid of stratification, but otherwise displaying no characteristics of sucked in sediment. This section may represent calcilutite which has slumped into its present location at the base of Bald Mountain. The section below 710 cm is obviously sucked in sediment.

The difficult correlation problem involving Cores 27 and 20 below approximately 790 cm is considered in Section 6.2.

5.2 Percentage Foraminifera in +62 Micron Grain Size Fraction

The +62 micron grain size fraction of the sediment is composed of Foraminifera tests, mineral grains and rock fragments. A visual estimate of the percentage of Foraminifera tests and of mineral grains and rock fragments combined was made under a binocular microscope. The estimated percentage composition of the +62 micron grain size fraction, between end members: (a) Foraminifera and (b) mineral grains and rock fragments, is presented in Figure 5 as percentage of Foraminifera in the +62 micron fraction. Reference to Figure 5 illustrates the general correspondance of high carbonate content of the -62 micron fraction with a high percentage of Foraminifera tests in the +62 micron fraction, and of low carbonate content in the -62 micron fraction with a high percentage of mineral grains and rock fragments in the +62 micron fraction. The compositional zonation of the +62 micron fraction suggests stratigraphic correlation from core to core which in general, corresponds with the correlation established from study of the -62 micron fraction alone. Thus correlation is established on the basis of the carbonate composition of the whole grain size spectrum represented in the cored sediments.

An interesting exception to the observed rule of variation occurs in Core 27 between 70 cm and 204 cm; a sequence of sediments, with a moderate carbonate content exibiting only minor variations, is observed to have major variations in the percentage of Foraminifera and mineral and rock fragments, which are in general, opposite in sign to the fluctuations of carbonate content of the -62 micron fraction. These variations are reflected in the sediment colour values. The sequence is recognized in the other cores as correlated in Figure 5, however the explanation of the observed relationship is unclear.

5.3 Radiocarbon Dating

Two Radiocarbon dates have contributed to the establishment of correlation between cores. An age of 27,600 $^{+1800}_{-1200}$ years B.P. was determined for the interval between 341 and 347 cm in Core 27. This interval lies 6 cm below the top of a carbonate-rich zone between 335 cm and 529 cm. The correlative zone in Core 17 (331 cm to 522 cm) was radiocarbon dated at its top (sample interval: 326-336 cm) as having an age of 24,350 $\pm$ 850 years B.P. Thus radiocarbon dating confirms the correlation of the top of this carbonate-rich horizon between Cores 27 and 17 and supports correlation with the corresponding layer in the other cores, as illustrated in Figure 5.

5.4 Micropalaeontologic Evidence of Correlation

A study of Foraminifera from the cored sediments by Bartlett (personal communication) which is cited in detail in Section 6.5, yields micropalaeontologic corroboration of the proposed stratigraphic correlations. Micropalaeontological evidence of stratigraphic correlation is relatively imprecise in sedimentary sequences not marked by sudden extinctions of one or more species. However, tentative correlations may be based on the relative abundance or scarcity of a species or suite of species, or upon other observations such as a dominance of right or left coiling directions of a Foraminifera species. At the same time, the frequency distribution of a species, or a dominance in coiling direction, may be indicative of marine palaeotemperatures (Ericson, 1963). Bartlett found a general coincidence of a dominance of right-coiling forms of all Foraminifera species, and the presence of *Globorotalia menardii*, with carbonate-rich layers. This association allows the micropalaeontologic differentation of these carbonate rich layers from adjacent, carbonate-poor layers and thus supports the proposed stratigraphic correlations.

It has been shown in this chapter, that the carbonate content of the -62 micron fraction, the Foraminifera to mineral grain and rock fragment ratio in the +62 micron fraction, the radiocarbon dating and the micropalaeontologic evidence, suggest stratigraphic correlations as illustrated in Figure 5.

CHAPTER 6

IMPLICATIONS OF CORE STRATIGRAPHY

6.1 Mode of Sedimentation

Having established correlation of the sedimentary sequence from core to core in the preceeding chapter, two points may now be emphasized:

(a) Cores 27, 20 and 12 were recovered from the same sedimentary basin (Figure 2). Thus the intrabasinal continuity of correlative strata is established for the basin.

(b) Cores 18, 15 and 26, and 17 were recovered from intermontane basins which are bathymetrically separate from one another and from the basin in which Cores 27, 20 and 12 were collected (Figure 2). Thus, interbasinal continuity of correlative strata is demonstrated.

In the intermontane valleys of the Mid-Atlantic Ridge, two modes of sedimentation might be expected to contribute to the accumulation of sediment:

(a) Particle by particle settling of sediment.

(b) Sporadic but rapid deposition of sediment from turbidity currents which would originate in sediment accumulations on valley walls.

The proportion of the sedimentary column contributed by each mode would presumably be a function of the rate of terrigenous and pelagic sediment influx, current activity, the inclination and surface roughness of the valley walls, and the frequency and severity of seismicity in the area.

Particle by particle deposition on valley floors would occur as a result of direct settling from seawater, or after a number of depositional cycles consisting of: deposition on a valley wall, resuspension as a result of current activity, and downward gravity transport. It has been suggested (M.J. Keen, personal communication) that a similar mode of sedimentation would occur if continuous seismicity promoted clearance of sediment from the valley walls, as described above, allowing no sediment accumulations of sufficient size to form turbidity currents. Particle by particle sedimentation with only infrequent and thin incursions of turbidity current deposits, would yield widely correlative sedimentary strata, with individual strata, areally similar in thickness.

Were the sedimentary section composed largely of turbidites graded foraminiferal or mineral sand layers, exhibiting additional characteristics of turbidity current regimes would be common. Such strata are rare in the cores under study, though one is described below. Because the areal extent and thickness of a turbidite are dependent on the volume of a sediment pile and the geometry of the basin, and because the time of flow initiation is dependent on the degree of instability of the sediment mass, a highly variable depositional regime would exist in each intermontane basin. These variables would be expected to produce a less ordered vertical sequence than observed in the cores of this study. That is, variations in the volume of sediment involved in each flow, in the depth of erosional scouring at the base of a turbidity current, and in the time and frequency of flow initiation in separate basins, would combine, making it unlikely that turbidity current activity would produce the widely and precisely correlative stratigraphic sequence observed.

The foraminiferal sands which occur infrequently in the cores and which in general cannot be traced from core to core, may well represent local turbidity current deposits. Alternatively, they may represent lag deposits which remain after sediment has been winnowed away by bottom currents. One foraminiferal sand unit which occurs in cores 20, 12, 18 and 17 (see description below and refer to Figure 5) may be an example of a thin turbidity deposit which resulted from the synchronous triggering of flow in several bathymetrically separate basins by a seismic shock. A description of this sand layer as it occurs in each core follows:

Core 20: 325-329 cm; foraminiferal sand, possibly graded, upper and lower contacts appear gradational.

Core 12: 280-286 cm; foraminiferal sand. Between 283.5 and 285cm, numerous gray laminae, 1 mm in thickness occur. The laminae appear to pinch out and bifurcate and are curved with their concave side up (ripple-drift lamination). This laminated sand is in contrast with structureless sediment above and below. The whole sequence is suggestive of a turbidity current hydraulic regime.

Core 18: 295-308 cm; foraminiferal sand with up to 30% lutite admixed. The upper contact appears texturally gradational while the lower contact is marked by a sharp textural contrast.

Core 17: 393-396 cm (approx.); foraminiferal sand with gradational upper and lower contacts.

Van Andel and Komar (1969) studying similarly ponded sediments of the Mid-Atlantic Ridge between 22° N and 23° N, discovered stratigraphic correlation between cores of individual basins but no correlation from basin to basin. Nowhere could the vertical extent and amplitude of the calcium carbonate fluctuations of the cored sediments be related to the Pleistocene climatic sequence. A detailed examination of the sediments led the authors to conclude that the intermontane valleys in the area received their sediment primarily by means of slumping and turbidity current transport from the valley walls.

Referring to Core 18, note that the colour values through the upper 500 cm show it to be visibly darker than comparable levels in the other cores and yet the carbonate analysis suggests ready correlation with the other cores, while confirming the apparently lower carbonate content. As suggested in a previous section (2.2) in which the oceanographic setting was examined, an anomalous current pattern, induced by topography, may be responsible for the apparently higher rate of terrigenous lutite accumulation of Core 18. The core was taken immediately west of the northern extension of Bald

Mountain, a topographic feature which undoubtedly must impose local deviation and eddying on regional patterns of water movement.

6.2 Rate of Sedimentation

The established stratigraphic correlations (Figure 5) serve as a reference in critically evaluating the rates of sedimentation derived from four isotopic datings within the cores. These dates and the sedimentation rates derived from them are summarized below:

Carbon - 14

	Sample depth	Age	Sedimentation Rate
(1) Core 27:	341-347 cm	$27{,}600^{+1800}_{-1200}$ yrs. B.P.	12.4 cm/1000 yrs.
(2) Core 17:	326-336 cm	24,350 ± 850 yrs. B.P.	13.5
Protactinium - 231			
(3) Core 27:	1000 cm	75,000 ± 8000 yrs. B.P.	13.3
(4) Core 20:	1000 cm	125,000 ± 12,000 yrs. B.P.	8.0

The first three dates yield an average sedimentation rate for the past 75,000 years of the order of 13 cm/1000 yrs. The similar rates derived for the upper 300 cm or so of Cores 27 and 17 are consistent with the fact that the dated samples are from stratigraphically correlative levels in the cores (Figure 5). The rate derived from the Protactinium -231 date at 1000 cm depth in Core 27 is consistent with the radio-carbon-derived rates.

The rate of 8 cm/1000 years calculated for the 1000 cm depth in Core 20 is at variance with the other sedimentation rates. Reference to Figure 5 reveals that correlation between Cores 27 and 20 below approximately 790 cm, (assuming near-parallelism with the correlation lines above) is impossible. An examination of the core descriptions, core photographs and core logs suggests that the dark gray lutite beds, between 1196 and 1209 cm in Core 27 and between 845 and 862 cm in Core 20, are correlative. Similarly, adjacent strata may be correlated as illustrated in Figure 5. On the basis of this correlation, an unconformity is inferred to exist at a depth of approximately 805 cm in Core 20. Thus a section corresponding to the interval between approximately 790 cm and 1158 cm (368 cm thick) in Core 27, is absent in Core 20. If we assume that this section was indeed deposited but has been removed by slumping, we may restore the Protactinium -231 dated sample from 1000 cm depth in Core 20 to its original depth which would be about 150 cm beneath the top of the dark gray lutite reference bed (845 to 862 cm in Core 20) or to a depth of approximately 1350 cm in Core 27. An age of 125,000 years B.P. at a depth of 1350 cm yields a sedimentation rate of the order of 11 cm/1000 years.

It may be concluded that the high sedimentation rates result from the fact that the valley floors receive sediment from the valley wall which constitute a catchment area much greater than that of the valley floor alone. Sediment initially settling on the flanks of a valley, moves down slope under the influence of gravity, continuously agitated, and perhaps resuspended, by water currents or seismic activity. This mechanism of clearing the valley walls appears to be so rapid that large volumes of sediment are not permitted to accumulate on the walls. Thus, sudden slides of sediment such as produce turbidity currents rarely occur. Only in the zone of transition from valley wall to valley floor does sediment accumulate in sufficiently large masses to initiate solifluction.

6.3 Significance of the +62 Micron Grain Size Fraction

The cored sediments may be thought of as varying in composition between two "end members"; biogenic carbonate and non-biogenic clastics:

	Carbonate	Non-Carbonate
-62 Microns	100% biogenic carbonate (diminuitive and comminuted Foraminifera tests & fine, particulate carbonate	100% non-biogenic clastics (presumably clay and silt sized mineral and rock fragments
+62 Microns:	100% Foraminifera tests	100% mineral grains and rock fragments

Examination of the mineral grains and rock fragments of the +62 micron grain size fraction yields indications of the climatic significance of this suite and by inference, of the associated finer-grained sediments.

The non-biogenic clastics of the +62 micron grain size fraction may be divided into two categories:

(a) mineral grains and rock fragments,

(b) volcanic ejectamenta.

For both categories, the grain size distribution varies between coarse and very fine sand sizes. A few rock fragments of fine gravel size were also observed.

Within category (a), quartz is highly predominant among the mineral grains. Limestone, dolomite, siltstone, granite and metamorphic rock fragments were identified. The quartz varies between being frosted and well rounded with a high degree of sphericity, and being unfrosted and angular. Similar stages of abrasion are evident in the case of rock fragments. The great variety of rock types represented, the common evidence of fragment abrasion, the wide grain size range and the presence of coarse sands and fine gravels suggests ice-rafting as the transport mechanism for this suite. This suggestion is consistent with the previous observation (Section 2.3) that, of the rock specimens dredged from the Mid-Atlantic Ridge in the study area, approximately 25 per cent were abraded and sometimes striated, granitic, metamorphic and sedimentary rocks of ice-rafted origin.

Within category (b), volcanic ejectamenta dark brown or black, commonly vesicular, volcanic glass is common. Common also is a light coloured and extremely vesicular pumice. Nowhere do concentration of volcanic glass alone, occur. That is, the volcanics, when present in significant quantities, invariably occur in the presence of ice-rafted mineral grains and rock fragments. Significantly, no concentrations of volcanic debris were observed in strata having high carbonate content.

In view of the association of volcanic debris with apparently ice-rafted sediments, and of its non-association with high carbonate content sediments, one is tempted to suggest that the volcanics were transported to the area of deposition by ice-rafting. Thus volcanism on Iceland, during the cool periods of ice-advance and prolific iceberg production in the Pleistocene, would shower with volcanic ejectamenta, the same ice flows which were already carrying terrigenous sediments to their southern destination. Two alternatives to this theory may be considered:

(1) That volcanism in the study area coincided in time with the influx of ice-rafted clastics. Such coincidence could no doubt occur; however, local volcanism would also be expected to produce concentrations of volcanic sand during periods of exclusively carbonate accumulation. No such concentrations were observed. Thus this alternative is untenable.

(2) That locally produced volcanic debris as well as ice-rafted clastics were concentrated into correlative horizons in all cores by the winnowing action of currents in removing fine sediments and Foraminifera tests, or by widespread carbonate solution; the volcanic and ice-rafted clastics representing an insoluble residue.

Both suggestions seem untenable. These sands constitute no more than 50 to 60% (and generally much less) of the sediment in a given sample, the remainder being in the silt and clay size ranges. This association indicates that concentration by winnowing does not occur. Similarly, the sands are always combined with a -62 micron fraction which contains a significant carbonate content (15 - 50% with an average of about 40%). A much lower carbonate content would be expected if significant volumes of sediment were subjected to carbonate solution by bottom waters. Pyro-clastic concentrations would again be expected in carbonate rich sediments not subjected to solution if the volcanism were local.

It is suggested that the pyroclastic and terrigenous sands were deposited concomitantly and were therefore ice-rafted to the study area. The sediment characterized by the relative abundance of these sands and by a relatively high clay content in the -62 micron fraction is believed to represent periods of climatic cooling. This suggestion is supported below (Section 6.4) where the lithologic and faunal stratigraphy is correlated with the Pleistocene climatic sequence. It is recognized that some of the minor strata which reflect water palaeotemperature variations in their characteristics, may represent short term changes in the near-surface current pattern of the area.

6.4 Climatic Significance of Calcium Carbonate Content

The significance of the calcium carbonate content of deep-sea sediments has been investigated by many authors. Most pertinent to the present study is the work of Correns (1939) and of Bramlette and Bradley (1942). Correns in his examination of cores from the North Atlantic, reported a distinct correlation between sediment layers of high pelagic carbonate content and the presence of the warm water Foraminifera, Globorotalia menardii . Similarly, he reported that low-carbonate sediments were marked by the absence of Globorotalia menardii. Bramlette and Bradley described sedimentary zones which they attributed to glacial periods and which alternated with carbonate-rich interglacial sediments, in a series of cores which form an east-west cross section of the near surface sediments of the North Atlantic. They found these glacial marine sediments typified by a diminished calcium carbonate content, a decrease in the number of Foraminifera and coccoliths, and an increased clastic sediment content in the form of sand and gravel. These clastics ranged up to more than a centimeter in diameter, were sub-rounded to sub-angular and represented a variety of continental rock types: limestone, shale, mudstone, sandstone, gneisses, schists, dolerite, granodiorite and others, all presumably ice-rafted. The similarity between these glacial marine sediments and the low carbonate sediments of the present study is marked and indicates that the cored sedimentary sequence of the Mid-Atlantic Ridge represents a portion of the alternating, glacial-interglacial succession of the Pleistocene epoch.

6.5 Climatic Significance of the Microfaunal Sequence

G.A. Bartlett, (personal communication), studied the micro-fauna of selected samples among the +62 micron fractions separated by the author. In summary, he found that the Foraminifera, Globorotalia menardii, which is generally assumed to be the most sensitive climatic indicator in deep-sea sediments, occurs only in small numbers and exhibits aberrant characteristics where present. Whereas an abundance of Globorotalia menardii typifies tropical waters, its presence in the cores under study suggests that the area of deposition was approaching or was beyond, the limit of cool water tolerance for the species throughout the depositional period sampled by the core. In the absence of Globorotalia menardii, Bartlett was able to define zones of relatively warm water deposition by tracing the distribution of right-coiled Globorotalia truncatulinoides which, when common, indicates warm conditions. Where Globorotalia truncatulinoides was sparse, Bartlett found the fauna dominated by Globigerina bulloides, Globigerina pachyderma and Globigerina inflata, a faunal suite representative of transitional or sub-arctic water temperatures. Further, he found a general agreement in the dominance of right-coiling forms of all species at stratigraphically comparable levels in the cores. Since right coiling forms are characteristic of relatively warm and left coiling forms of relatively cold water masses (Ericson, 1963) we have an additional indication of paleotemperatures. From the microfaunal evidence, a generalized climatic sequence is established which, when compared with the carbonate distribution of the cores (discussed below), strongly suggests a direct relationship between the carbonate content of the sediments and paleoclimate; highest carbonate contents indicating warmest conditions.

The qualitative distribution of Globorotalia menardii, perhaps the best indicator of warm waters, has been plotted in Figure 5. Generally the presence of Globorotalia menardii coincides with zones of high carbonate content, suggesting that these are the product of interglacial periods and that the low carbonate zones in which Globorotalia menardii is absent, represent glacial periods. The other faunal evidence described above supports this inference.

6.6 Stratigraphic Sequence and Pleistocene Time Scale

Many have contributed to the evolution of the Pleistocene time scale from dated events on the continents and in deep-sea sediments. In the marine environment, the sequence of glacial and interglacial climatic variations that mark the Pleistocene has been established and confirmed by several methods including:

(1) absolute dating of events by means of radiocarbon and isotopes of other elements,

(2) oxygen isotope determination of water palaeotemperatures,

(3) determination of relative water palaeotemperatures using coiling directions of temperature-sensitive Foraminifera (Ericson, 1963).

(4) measurement of Foraminifera productivity (Ericson, 1956).

While isotopic dating of biogenic carbonate yields the most precise age of the material, oxygen isotope determination of palaeotemperatures permits the most precise determination of palaeotemperatures. Using the oxygen isotope method, Emiliani (1955,1957,1966, 1970) has established palaeotemperature curves for the Pleistocene. The isotopic determination of palaeotemperature depends on the fact that the abundance of the O^{18} isotope in biogenic carbonate relative to O^{16} is a function of the seawater temperature from which the carbonate was precipitated. Since planktonic Foraminifera precipitate their test in the euphotic zone of the oceans (where climatic temperature changes are most readily expressed), determination of the oxygen isotope ratio of planktonic Foraminifera tests along a sediment core, will be indicative of the palaeotemperature changes along the core. Underlying assumptions of the technique are: that the O^{18} of the calcium carbonate is precipitated in concentration equilibrium with the seawater, that there have been no diagenic changes in the O^{18} content of the calcium carbonate, and that the O^{18} content of seawater has remained constant with time. This last assumption has been challenged by Shackleton (1967) who has noted that the O^{18} content of modern ice caps is less than that of modern seawater (presumably because of the resistance to evaporation resulting from the greater mass of O^{18} atom). It is reasonable to assume that similar discrepancies existed during the Pleistocene. Thus with fluctuation in the volume of the continental ice caps during the Pleistocene, the O^{18}/O^{16} ratio in seawater must have changed. Instead of yielding absolute palaeotemperatures, the O^{18}/O^{16} ratio may be reflecting variations in the amount of water held as ice in Pleistocene continental ice caps. Emiliani (1966), stressed that he recognized this differential and that his palaeotemperature curves derived from such isotopic data are corrected for it. Whether properly corrected or not, the variation of this ratio is presumably a valid indicator of relative temperature changes during the Pleistocene.

Frerichs (1968), basing his definition of the Wisconsin climatic sequence in sediments of the Andaman Sea and Bay of Bengal, upon faunal criteria and one Carbon-14 date, has arrived at a sequence which in general correlates with those derived for the equatorial Atlantic and Caribbean by Emiliani (1955) and Erickson and others (1964). Frerich's proposed Wisconsin sequences are compared with those of Emiliani and Erickson in Figure 6. Dansgaard and others (1969) have measured the climatic oscillations through the past 100,000 years in an oxygen isotope analysis of a long core from the Greenland ice cap. When these climatic oscillations were related to time, the resulting time-temperature curve was found to correlate well with a time/temperature curve derived by Van Der Hammen and others (1967) for the Netherlands which was based on various field data, pollen analyses and 30 radiocarbon dates. The palaeoclimatic curves of Dansgaard and of Van Der Hammen are also contained in Figure 6.

Correlation of the Mid-Atlantic Ridge core sequence with these time/temperature curves is difficult in the absence of more absolute dates. A correlation with the Pleistocene sequence is suggested below using the nomenclature of Frerichs (1968) when possible. The chronostratigraphy of the cores is illustrated in Figure 5 and summarized in Figure 6.

Holocene

The Holocene is well established as having extended between 10,000 years BP and the present. The Holocene represents a period of progressive climatic warming following the close of the last glacial period. The carbonate content of the cores which, as illustrated in Figure 5, decreases from the top of the cores downward, reflects this gradual climatic amelioration during the Holocene. Without absolute dates, the base of the Holocene in the cores cannot be established with certainty. The author suggests that its base be taken at about 50 cm depth (56 cm in Core 27). An accumulation of 50 cm of sediment in 10,000 years yields a sedimentation rate of only 5 cm/1,000 years. This is markedly below the average of about 13 cm/1,000 years established for the past 24,000 years by radiocarbon dating (Section 6.1b). Broecker and others (1958) reported that in an equatorial core, both carbonate and clay fractions show an abrupt decrease in rate of accumulation at the end of the Late Wisconsin Stadial. The glacial to postglacial ratio of sedimentation rates was determined to be 3.7 for clay and 2.1 for carbonate. These observations lend credibility to the author's correlation of the Holocene.

Late Wisconsin Stadial

Below the Holocene sequence occurs a zone, approximately 250 cm thick, which is characterized by a generally low carbonate content, a cool-water faunal assemblage and widely correlative variations in carbonate content and grain size distribution. The lower limit of this zone, that is, the top of the subadjacent zone, has been dated at slightly less than 24,000 years BP and represents a glacial marine zone which corresponds with Frerichs' Late Wisconsin Stadial. This zone constitutes a time span of about 13,000 years (10,000 years BP to about 23,000 years BP) which is represented by about 250 cm of sediment (assuming the lower limit of the Holocene to be correctly drawn). These figures yield a rate of sediment accumulation of the order of 19 cm/1,000 years. This determination reflects the increased sedimentation rates during the Late Wisconsin Stadial as reported by Broecker and others (1958).

Late Wisconsin Interstadial

Below the Late Wisconsin Stadial occurs a sedimentary sequence, 150 to 200 cm thick, which is characterized by a high carbonate content, a warm water fauna, a complete lack of mineral debris in the +62 micron fraction and relatively little lithologic variation throughout the zone. The top of this zone may be extrapolated from two nearby radiocarbon dates as having an age of about 23,000 years BP. This interstadial would therefore be the Late Wisconsin Interstadial. By analogy with Frerichs' chronology, the base of this interstadial occurs at approximately 42,000 years BP (529 cm in Core 27).

Middle Wisconsin Stadial

The Middle Wisconsin Stadial of Frerichs' (1968) extends from 42,000 to 54,000 years BP. This period corresponds approximately with the Port Talbot Interstadial of Dansgaard and others (1969). However, reference to the temperature curve for the Late Pleistocene in Van Der Hammen and others (1967) shows that the mean July temperature in the Netherlands during this "interstadial" was in fact only about 6^{o} C as compared with a mean of 15^{o} C to 20^{o} C during the Holocene, a maximum of 10^{o} C during the Late Wisconsin Interstadial and a mean of about 3^{o} C during the true glacial periods. Thus for about 12,000 years preceding the onset of the Late Wisconsin Interstadial, a relatively cool climate existed. If we assume the top of this Middle Wisconsin Stadial (42,000 years BP, 529 cm in Core 27), to occur as correlated in Figure 5, and if we assume a sedimentation rate of 12 to 15 cm/1,000 years, we determine that between 150 and 200 cm of sediment may have accumulated during this interglacial period. Thus the base of the stadial may be drawn as in Figure 5 (675 cm in Core 27) and inferred to have an age of about 54,000 years BP.

Early Wisconsin Interstadial

The Early Wisconsin Interstadial of Frerich (op.cit.) extends between 54,000 years BP and 108,000 years BP. The Protactinium date, at 1,000 cm in Core 27, places this point near the middle of the interstadial. Assuming an average sedimentation rate of 10cm/1,000 years for the interstadial, (approximately 54,000 years in duration) we would expect about 540 cm of sediment to accumulate in this time interval. In fact, the depth to the base of this Early Wisconsin Interstadial calculated from the estimated sedimentation rate (1215 cm) is only 32 cm below the base of this interstadial as chosen on the basis of lithology (1,183 cm in Core 27). This lithologic boundary is therefore tentatively assigned as marking the base of the Early Wisconsin Interstadial and top of the Early Wisconsin Stadial.

Early Wisconsin Stadial

The dark coloured, low carbonate sediments (1,183 cm to 1,270 cm in Core 27) beneath the Early Wisconsin Interstadial, may represent the glacial marine sediments of the Early Wisconsin Stadial assuming the correlations of Cores 27 and 20 to be correct as drawn in Figure 5. The Protactinium dates of 75,000 years BP (at 1,000 cm in Core 27) and 125,000 years BP (at 1,000 cm in Core 20) which bracket this glacial marine zone, lend credence to its correlation with the Early Wisconsin Stadial.

Sangamon

The date of 125,000 years BP at 1,000 cm in Core 20 suggests that the carbonate-rich sediment section with its top at 930 cm represents Late Sangamon Interglacial sedimentation.

CHAPTER 7

SUMMARY OF CONCLUSIONS

(1) The bathymetry of the survey area indicates that the degree of topographic smoothing due to sediment infill of intermontane valleys, increases westward. The degree of topographic smoothing is dependent upon the original relief of the intermontane depression, on the rate of sediment accumulation in the depression, and upon the time span during which sediment has accumulated. Keen and Manchester (1970) have shown by means of continuous seismic profiling that the crystalline basement topography of the partially-filled valleys west of the Median Valley, is similar in its relief to that of the ridge and valley province flanking the Median Valley, where significant sedimentary deposits have yet to accumulate. The excellent correlation of strata from basin to basin, at similar depths below the water-sediment interface, indicates that average sedimentation rates, to the depths cored, do not vary markedly from basin to basin. Thus the observed westerly trend of increasing degree of topographic smoothing indicates an increasing period of sedimentation from east to west and suggests that the age of the Mid-Atlantic Ridge increases westward from the Median Valley.

(2) The Protactinium-231 date of approximately 75,000 years BP at 1,000 cm in Core 27 yields an average sedimentation rate in the order of 13 cm/1,000 years for the last 75,000 years. Carbon 14 dates at 340 cm in Core 27 and at 330 cm in

Core 17 were determined as being approximately 27,000 years BP and 24,000 years BP respectively. These dates yield sedimentation rates of the order of 12 to 14 cm/1,000 years. There is evidence that this average may represent the widely varying sedimentation rates of glacial and interglacial periods.

(3) The high degree of stratigraphic correlation within and between topographically separate basins has been established by comparison of sediment lithology and carbonate content, microfaunal zonation and radiocarbon dates. Correlative strata vary little in thickness from basin to basin. Strata possessing sedimentary features attributable to deposition from turbidity currents are rare. The high degree of interbasinal correlation of strata, the consistent thickness of correlative strata from basin to basin, and the paucity of turbidites suggests that during the geologic time represented by the cores, sedimentation has been by particle-by-particle accumulation rather than by sporadic and massive sedimentation from turbidity currents.

(4) Two sediment suites are recognized as typifying the Wisconsin stadials and interstadials.

(a) The stadial sediments are characterized by:

- -- an abundance of ice-rafted rock fragments and minerals, varying in grain size from fine sand to fine gravel,
- -- a relatively low carbonate content in the +62 and -62 micron grain size fractions,
- -- a relatively high non-biogenic silt and clay content in the -62 micron fraction,
- -- a lack of warm water-indicating Foraminifera.

(b) The interstadial suite is characterized by:

- -- the absence of ice-rafted detritus,
- -- a +62 micron fraction consisting mainly of Foraminifera tests,
- -- a high carbonate content in the -62 micron fraction,
- -- warm water-indicating Foraminifera.

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APPENDIX 1

CORE LOGS AND PHOTOGRAPHS

BIO 19-66-12

DEPTH, CM	DESCRIPTION
Top-32	Pale brown, 10YR6/3, foraminiferal calcilutite. A disc-shaped fragment of manganese (?) crust, 1cm maximum diameter and 0.1cm thick, occurs at 22.5 cm. Little mottling can be observed. The lower contact is a gradational color contact and is burrow mottled.
32-45	Between these limits, a gradational downward color darkening occurs, accompanied by a marked increase in the frequency of burrow mottling (lighter colored mottlings in darker host sediment). A buff-colored carbonate pebble occurs at 40 cm and is approximately 0.5 cm maximum diameter.
45-69	Grayish-brown, 10YR5/2, foraminiferal lutite, containing faintly darker laminae to 56 cm depth. Semi-consolidated pellets are scattered throughout the horizon. The lower two centimeters are extensively mottled with slightly lighter colored sediment. The lower contact is marked by a distinct textural change.
69-71	Foraminiferal sand, 10YR6/2. Size gradation from coarsest at the bottom to finest at the top is apparent. Both upper and lower contacts are irregular surfaces, giving the sand layer a boudinage-like structure. Both contacts are distinct textural contacts. Several granitic pebbles (.2 cm diameter) occur at the base of the layer.

Nov/69 30-40cm Platypods. (2 picked slides 30 + 40cm) E.J.

BIO 19-66-12

DEPTH, CM	DESCRIPTION
71-101	Light brownish gray, 10YR6/2, lutite. The layer may be subdivided on the basis of estimated Foraminifera content: 71-81 Foraminifera: 30 % 81-96 Foraminifera: less than 10 % 96-101 Foraminifera: 30 % A 1 cm diameter carbonate (?) pebble occurs in the 81-96 cm horizon. The lower contact is a burrow-mottled gradational, color contact and is indistinct.
101-108	Light brownish gray, 10YR6/2, foraminiferal calcilutite. The lower contact is again burrow mottled and indistinct.
108-120	Grayish brown, 10YR5/2, foraminiferal lutite. The lutite is burrow mottled. The lower contact is burrowed, indistinct and arbitrarily located.
120-136	Grayish brown foraminiferal lutite. The upper and lower contacts are burrow-mottled color contacts and are indefinite.
136-162	Gray, 5Y5/1, lutite. The upper 6 cm have an indistinct brownish tinge. A layer of lighter colored sediment occurs as a contorted bed, 1 cm think at approx. 152 cm. A few black particles, 0.5 mm diameter, are scattered throughout the 136 cm - 162 cm horizon and may be glass shards. A carbonate (?) pebble

BIO 19-66-12

DEPTH, CM	DESCRIPTION
	0.5 cm diameter, occurs at 140 cm. The lower contact is marked by a distinct color contrast and is only slightly burrowed.
162-181	Grayish brown foraminiferal calcilutite, extensively burrow mottled with darker gray sediment. A small (1 mm), quartz fragment was observed at 177 cm. The lower contact is a distinct but burrowed contact.
181-190	(greenish) Gray, 5Y5/1, lutite. Between 181 cm and 183 cm, is a darker greenish gray lutite horizon which grades into the lighter greenish gray mentioned above. The lower contact is marked by a distinct color change but is extensively burrow mottled.
190-217	(light brownish) Gray, 5Y5/1, foraminiferal calcilutite, extensively burrow mottled with slightly lighter-colored sediment. Numerous manganese (?) micronodules occur. The faint but definite lower contact is marked by a color contrast.
217-238	Light brownish gray, 10YR6/2, lutite.
238-248	Light gray, 2.5Y7/2, foraminiferal calcilutite, burrow mottled with darker lutite. The lower is a distinct color contact.
248-269	White, 2.5Y8/0, foraminiferal calcilutite. The top 10 cm are extensively burrow mottled

Nov/09 200-210cm Platey Ash picked slide at 210cm. K.G.

DEPTH, CM	DESCRIPTION
	with light brown calcilutite. The calcilutite is more compact, relatively speaking, than the other lutites of the core. (This condition is typical of calcilutite sediments of such purity). The lower contact is marked by a faint color contrast.
269-280	Light gray, 2.5Y7/2, calcilutite. Compared to the layer above, a relative paucity of Foraminifera is noted. Some burrow mottling is apparent, with mottlings of lighter colored sediment (from above) predominating, though a lens of darker brown sediment is present at 276.5 cm. The lower contact is marked by a distinct textural change to foraminiferal sand below.
280-286	Very find, foraminiferal sand, light gray, 2.5Y7/2, in color. Between 283.5 cm and 285 cm, occur numerous gray laminae, 1 mm thick. The laminae appear to pinch out and bifurcate, and are curved with their concave side up. The lower contact is distinguished by a marked textural contrast as above.
286-294	Light grayish brown, 10YR7/1, foraminiferal calcilutite. Foraminifera constitute perhaps 40 % of the sediment. A few sand-sized (1 mm maximum diameter), rock fragments were observed. The lower contact is an indistinct yet sharp textural contact with an accompanying color change. This contact would not have been precisely photographed because of smear. A gneissic pebble, 3 mm in diameter, occurs at 286.5 cm.

BIO 19-66-12

DEPTH, CM	DESCRIPTION
294-302 (approx.)	An extensively burrow mottled zone of light brown calcilutite, exhibiting darker grayish brown mottlings. One prominent burrow, extends vertically from 298 cm to a depth of 306 cm. The lower contact is arbitrarily assigned to the depth where the "host" calcilutite predominates over the mottling; downward, mottling rapidly becomes scarce.
302-319	White, 10YR8/1, foraminiferal (20 %), calcilutite. The calcilutite is apparently structureless except for a few mottlings of grayish brown. The lower contact is distinctly marked by a color change. The contact has a dip of about 5 degrees.
319-319.5	Light brownish gray, 10YR6/1, foraminiferal (20 %), calcilutite. The lower contact is a distinct color contact.
319.5-353	A layer of foraminiferal (10 %), calcilutite which darkens in color downward from white at the top to a light brownish gray, (10YR6/2), at the bottom. A granitic (?) pebble occurs at 346 cm and is 5 mm maximum diameter. The lower contact is marked by a distinct color contrast.
353-410	White, 10YR8/1, calcilutite, which darkens toward the bottom (in the last 10 cm) to light brownish gray, 10YR6/2. The upper 10 cm of

DEPTH, CM	DESCRIPTION
	the layer contain several prominent mottlings. The lower contact is indefinite due to the extent of burrow mottling in the contact zone.
410-482	Light brownish gray, 10YR6/2, to (darker) grayish-brown, 10YR5/2, lutite (foraminifera less than 10 %). Burrow mottling is ubiquitous. Indurated, dark brown pellets (up to .5 cm diameter) are common. The lower contact is indefinite due to extensive burrow mottling.
482-493.5	White, 10YR8/1, calcilutite. The calcilutite is prominently burrow mottled with (dark) grayish-brown 10YR5/2, lutite. The lower contact is a sharp textural and color contact.
493.5-496	Light brown, 10YR7/2, foraminiferal sand with apparent mottlings of grayish brown foraminiferal (40 %) lutite. The lower contact is again marked by a distinct color and textural change.
496-501	White, 10YR8/1, calcilutite. Some mottling is present. The lower contact is a distinct color contact.
501-506	Grayish-brown lutite. Some mottling is present. There is an apparent increase in Foraminifera near the bottom contact which is marked by a sharp color change.

430-480 cm
amber ash
Black "
Pumice "

BIO 19-66-12

DEPTH, CM	DESCRIPTION
506-513, approx. (bottom)	White, 10YR8/1, calcilutite. This layer passes into a disturbed zone; "flow-in," which extends from 513 cm. to 567 cm. At 555 cm, a mafic rock fragment, 1.5 cm maximum diameter, occurs.

* * *

BIO 19-66-15

DEPTH, CM	DESCRIPTION
Top - 35 approx.	Light yellowish-brown, 10YR6/4, foraminiferal calcilutite. Foraminifera constitute 10 - 15 % of the sediment. Pteropod shells occur down to approximately the lower contact. The lower contact is a gradational, textural contact of arbitrary location.
35-46	Light yellowish-brown, 10YR6/4, lutitic, fine foraminiferal sand. The lower contact is marked by a distinct color and textural contact.
46-72	Grayish-brown lutite, containing numerous indistinct laminations and burrow mottlings. The lower contact is a distinct color contact.
72-84	Grayish-brown, 2.5Y5/2, lutite, intensely burrow mottled. The lower contact is a mottled color contact.
84-90 (bottom)	Light grayish-brown, 2.5Y7/2, calcilutite, markedly burrow mottled with dark sediment from the super-adjacent layer.

Below 90 cm is light grayish-brown calcilutite which has been sucked in by the corer piston. This sucked-in sediment is uniform in texture and color except where foraminiferal sand layers occur between 575 and 580 cm and, 625 to 650 cm. The upper and lower contacts of these layers are distended vertically.

* * *

DEPTH, CM	DESCRIPTION
Top-45	Pale brown, 10YR6/3, foraminiferal calcilutite. Throughout the top 30 cm, the Foraminifera content is about 10 % (by volume). A gradual increase in abundance occurs below 30 cm, reaching a maximum at 42 cm, of perhaps 90 % of the sediment, which is here a foraminiferal sand. Downward the sediment displays a rapidly gradational increase in the calcilutite fraction to the lower contact at 44 cm which is marked by a color and textural change. A thinly manganese (?) - coated carbonate pebble, grayish brown in color, occurs at 29 cm and has a max. dia. of 1 cm. Two gravel-sized fragments, 2 mm dia., occur at 33 cm. One is of crystalline igneous rock. A grayish-brown, carbonate rock fragment, 0.5 cm max. dia., occurs at 40 cm.
45-76	(dark) Grayish brown, 10YR5/2, lutite. The top and bottom 5 cm of the layer are burrow mottled. Between 52 cm and 71 cm, numerous laminae of darker brown sediment occur. At approximately 70 cm, a layer containing an abundance of Foraminifera, sand-sized mineral fragments and volcanic glass (?) occurs. Sand and find gravel-sized detritus is scattered throughout the whole horizon. The lower contact is an indistinct color contact.
76-104	Light brownish gray, 10YR6/2, lutite. A few mottlings are present, as are scattered fine gravel fragments. The lower contact is marked

DEPTH, CM	DESCRIPTION
	by an indistinct color change.
104-117	Slightly darker lutite than the super-adjacent layer. A gneissic rock fragment, 1 cm dia. occurs between 111 cm and 112 cm. The lower contact is marked by an indistinct color change.
117-155	Light brownish gray, 10YR5.5/2, lutite. Foraminifera constitute approximately 10 % of the sediment by volume. The lutite is extensively burrow mottled. At about 138 cm, a darkening occurs; above this, the mottling is darker than the host, while below, the mottling is lighter than the host color. The lower contact is burrowed and arbitrarily located.
155-176	Light brownish gray, 10YR6/2, lutite. The top 2 cm are rich in Foraminifera (30 - 40 %), and include a granitic fragment at 156 cm. Burrow mottling is apparent. The lower contact is defined by a distinctive color change (darkening).
176-202	(greenish) Gray, 5Y5/1, lutite. The top 5 cm are burrow mottled with sediment of the color of the super-adjacent layer. NB: Generally, burrow mottling results in the downward transport of sediment and is most apparent therefore, where two layers of different color contact one another.

DEPTH, CM	DESCRIPTION
	Below this, the lutite is essentially structureless. A large quartz biotite gneiss pebble (well rounded) occurs at 198 cm. The lower contact is a distinct color and textural contact.
202-229	(light brownish) Gray, 10YR6/1, foraminiferal lutite. The top of the layer is lutitic foraminiferal sand and is distinctly mottled with lutite from above. The lutite becomes predominant by 215 cm depth. Between 223 cm and 227 cm occur fifteen or more, gray, 7.5 YR5/0, lutite laminae, each less than 0.5 mm thick. These are apparently composed of gray-stained foraminiferal tests and volcanic (?) debris. The lower contact is a burrow-mottled color contact.
229-242	The sequence of the previously described layer between 176 cm and 202 cm is repeated; (greenish) gray lutite, mottled with lighter-colored lutite from above but otherwise, structureless. The lower contact is a burrowed, color and textural contact.
242-254	Light brownish gray foraminiferal lutite. The upper two to three centimeters are foraminiferal sand which grades into foraminiferal lutite (Foraminifera 10 %) by 248 cm depth. The lower contact is an arbitrary, mottled color contact.

BIO 19-66-17

DEPTH, CM	DESCRIPTION
254-331	Grayish brown, 10YR5/2, to light brownish gray, 10YR6/2, lutite. The sediment is extensively mottled throughout the top 20 cm with lighter colored lutite. The lower contact is marked by a distinct color contrast.
331-364	White, 10YR8/1, calcilutite. The top 5 cm are burrow mottled with brown lutite from above. The lower is a faint color contact.
364-376	Light brownish gray lutite, extensively burrow mottled with calcilutite from above. Some mottlings consist of foraminiferal tests, as if concentrated by the burrowing animal. The upper and lower contacts are extensively mottled and arbitrarily drawn.
376-522	White, 10YR8/1, calcilutite. The upper 10 cm are extensively mottled with lutite from above. Mottling is most intensive at the contact and diminishes in frequency downward. Between 390 cm and 429 cm, the sediment appears structureless. Below 429 cm the host sediment darkens slightly and lighter mottling (white) occurs throughout. A concentration of Foraminifera occurs between 329 cm and 396 cm. The boundaries of this horizon are gradational. Between 445 cm and 460 cm, a predominantly darker, (light brownish gray, 215Y5/2) horizon occurs; its contacts with the host layer are indefinite. Below 460 cm, the sediment is

DEPTH, CM	DESCRIPTION
	again white and structureless to a depth of approximately 505 cm where a gradual darkening begins. The lower contact is a distinct textural contact. The lower 8 cm of sediment contain an increased population of Foraminifera, reaching an estimated 50 % at the lower contact.
522-526	Foraminiferal, and rock and mineral-fragment sand. The sand is apparently graded, with Foraminifera predominating at the top and accompanied by fine to medium-sand sized mineral particles. Toward the bottom, mineral and rock fragments (medium coarse sand) predominate. The lower contact is distinctively marked by a color and textural contrast. (This sand, possibly represents the sediment deposited by an eroding current as witness the diametrically opposite sediment types on either side of the sand layer).
526-536	(dark)Grayish brown, 2.5Y5/2, lutite. Some burrow mottling is present. The lower contact is a sharp color contact.
536-650	This unit consists of light to dark grayish brown lutites which occur in indistinct horizons, each being color gradational, one into the other: - a distinctly gray colored layer occurs between 544.8 cm and 545 cm. - a quartzone pebble, 1.5 cm maximum diameter occurs at 555 cm.

DEPTH, CM	DESCRIPTION
	- a dark grayish-green siliceous pebble, 1 cm maximum diameter, occurs at 619.5 cm. - an horizon containing frequent, medium sand-sized particles of undetermined nature (volcanic ?) occurs between approximately 610 cm and 630 cm. This is accompanied by a marked color darkening. Burrow mottling is ubiquitous. The lower contact is a burrow mottled, color contact.
650-662	Light brownish-gray, 2.5Y6/2, calcilutite. The lower contact is burrow mottled and arbitrary.
662-692	Extensively burrow mottled light gray-brown and darker gray-brown calcilutite. A grayish-brown, limestone fragment, 1 cm maximum dimension, occurs at 682 cm. The lower contact is marked by a distinct color contrast.
692-753	Light gray, 10YR7/1, calcilutite distinctively mottled with darker sediment from the super-adjacent layer. Several faint laminae (manganese ?) laminae occur at 718 cm. Concretion-like phenomena occur at 734 cm and 741 cm. The uppermost; 3 cm maximum diameter, is elliptical in cross-section and consists of several concentric layers of dark gray sediment (manganese ?). The lowermost; more closely approaches a

DEPTH, CM	DESCRIPTION
	circular cross-section. This body again consists of concentric laminae. Its diameter is approximately 4 cms. Below 735cm the sediment darkens and mottling is common. The lower contact is defined by an abrupt textural change.
753-764	Brownish-gray foraminiferal find sand. Between 753 cm and 757 cm Foraminifera are abundant (90 %), and generally large. Between 757 cm and 764 cm the content is about 70 % and the Foraminifera are relatively diminutive. The lower contact is a gradational textural contact and is arbitrarily located.
764-780	Light brownish gray, 10YR7/2 (top 6 cm) grading to grayish brown, 10YR5/2 (lower 10 cm) lutite. Mottling is very prominent in the lower 10 cm. Two blebs of Mn (?) encrusted Foraminifera occur between 764.5 cm and 765.5 cm. The blebs are about 1 cm in diameter. The lower contact is a burrow-mottled color contact and is arbitrarily located.
780-860 (approx.)	White, 10YR8/1, calcilutite. The top 15 cm are slightly darker in color and distinctively mottled with grayish brown lutite from above. Between 818 cm and 828 cm, a slight darkening occurs and is accompanied by faint but abundant mottling. The upper and lower contacts are indefinite.

DEPTH, CM	DESCRIPTION
	The lower contact displays a gradational color change.
860-885 (approx.)	Greenish gray, 5Y5/1, lutite intensively mottled with sediment from above. The intensively mottled lower contact is marked by a sharp color contrast.
885-905	Light grayish brown calcilutite. The lower contact dips very steeply at about 80° and may represent a disturbance during coring, though the surrounding sediments give no confirming evidence. The lower contact is marked by a sudden appearance of mottling.
905-957	Brownish gray, 10YR8/1, calcilutite, distinctly burrow mottled throughout the top 7 cm with small diameter, elongate burrow, 1 mm diameter. Between 929 cm and 937 cm, the calcilutite takes on a greenish tinge. The upper contact of this sub-layer is a rapidly gradational color contact while the lower contact is a burrow mottled contact. Between 937 cm and 950 cm, large mottlings of the greenish gray sediment occur. The lower contact is a mottled yet distinct color contact.
957-982	Light gray foraminiferal calcilutite. The upper 6 cm are grayish brown foraminiferal sand and contain perhaps 75 % Foraminifera.

DEPTH, CM	DESCRIPTION
	Several rock fragments, 0.5 cm maximum diameter, accompany this zone at 960 cm. Downward, the Foraminifera content slowly diminishes to the lower burrow-mottled color contact.
982-1002	The top 8 cm are greenish gray, 5Y5/1, lutite, burrowed with the lighter colored calcilutite from above. Beneath this, burrow mottling ceases and the color darkens to dark greenish gray, 5Y4/1, lutite. The lower contact is a distinct color contact.
1002-1030 (bottom)	Light to dark brownish gray, mottled lutite. Some disturbance caused by the coring process is apparent below 1010 cm. A reddish-brown, siliceous pebble occurs between 1002 cm and 1003 cm.

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depth, cm	Description
Top - 38	Pale brown, 10YR6/3, calcilutite. Approximately the top 10 cm have been disturbed in the coring process and the location of the 10 cm depth position is uncertain. The lower contact is a burrowed, color contact.
38 - 52	Grayish brown, 10YR5/2 to dark grayish brown, 4/2, lutite containing faint, dark brown laminae. The lower contact is a gradual color change.
52 - 70	Light brownish gray, 10YR5.5/1, lutite containing faintly darker laminae to 57 cm. The lower contact is a gradational color contact.
70 - 92	Light brownish gray, 10YR6/1, lutite. Between 72 cm and 73 cm occurs a layer of foraminiferal sand. The lower contact of the sand layer is a sharp textural contact and appears to dip at 5 to 10 degrees though the apparent dip may be due to the coring process. The lower contact is a rapidly gradational color change.
92 - approx. 190	(greenish) gray, 5Y5/1, lutite. A slight color lightening occurs between 142 cm and 150 cm.

BIO 19-66-18

depth, cm	Description
	This zone contains a concentration of Foraminifera between 146 cm and 147 cm. The whole zone appears to have a relatively high Foraminifera content. The lower contact is an extensively burrowed color contact and is arbitrarily located.
190-208	White calcilutite, thoroughly mottled with dark lutite from the adjacent layer. The lower contact is again thoroughly burrowed and arbitrarily located.
208-240	Gray, 5Y6/1, lutite. The lower, arbitrarily located contact is color gradational.
240-402	(light) Gray, 5Y6.5/1, calcilutite. A high foraminiferal content, about 70% by volume, occurs between approximately 295 cm and 308 cm. The upper contact appears texturally gradational while the lower contact is a sharp textural contact. At 335 cm occurs a notable concentration of Foraminifera in a zone, 2-3 cm thick. Throughout the layer, areas of black-colored sediment are present. One was sampled at 347 cm.

depth, cm	Description
	The lower contact is marked by a distinct and sudden color darkening.
402-515	(greenish) Gray, 5Y6/1, lutite. Some manganese (?) mottlings occur throughout the layer. The lower contact is a steeply arcuate (convex up), sharp color contact, distorted by insipient "flow in". While distortion has occurred, it seems that the essential sequence of layers has not been destroyed. The layered appearance of a horizontal section through the core at this contact zone, shows that calcilutite from below has been drawn upward into the lutite above. Thus the lower contact might be located at about 530 cm.
515-825	White, 10YR8/1, calcilutite. The color darkens to 10YR6/1 between about 560 cm and 578 cm. Considerable distortion is evidenced by the distended mottlings between approximately 530 cm and 590 cm. Below 590 cm, this distortion appears absent. A few prominent black (manganese?) mottlings occur below 600 cm. Between 800 cm and the lower contact, a

depth, cm	Description
	gradational darkening occurs. The lower contact is marked by a burrowed color contact.
825-850	(brownish) Gray, 5Y5/1, lutite. The lower contact is a slightly distorted color contact.
850-901 (bottom)	White calcilutite.

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BIO 19-66-20

DEPTH, CM	DESCRIPTION
Top-40	Light yellowish brown, 10YR6/4, foraminiferal calcilutite. The lower contact is marked by a gradational color darkening and is arbitrarily located.
40-70	(dark) Grayish brown, 10YR5/2, lutite. Between 50 cm and 60 cm a series of darker laminae occur. The lower contact is marked by a color lightening and is burrow mottled.
70-147	(lighter) Grayish brown lutite, apparently structureless. The lower contact is marked by a sharp color contrast.
147-175	(greenish) Gray, 5Y4/1, lutite. A large brown pebble occurs at 160 cm. The lower contact is a mottled color contact.
175-195	(light) Gray, 5Y6/1, lutite. The lower contact is a sharp, mottled color contact.
195-209	Grayish brown lutite. A dark gray lamination, 0.5 cm thick occurs at 197 cm. The lower contact is marked by a distinct color contrast.
209-229	Light gray, 5Y7/1, calcilutite. The lower contact coincides with the severed end of one core section and is obscured. An ochre-colored, limonite (?) pebble occurs at 229 cm.

DEPTH, CM	DESCRIPTION
229-241	A zone of extensively burrow-mottled lutite. The lower contact is burrowed and arbitrarily located.
241-284	Grayish brown, 2.5Y5/2, lutite, lightening at about 267 cm to light brownish gray, 2.5Y6/2, lutite. The lower contact is a burrowed, color contact. A dark gray metasedimentary (?) pebble, 5 cm maximum diameter, occurs at approximately 245 cm. The pebble exhibits prominent striae.
284-315	White to light gray calcilutite. The lower contact is a color-gradational, arbitrary boundary.
315-341	Light gray, 2.5Y7/2, calcilutite. A zone containing lutitic, fine foraminiferal sand (Foraminifera 75-85 %), occurs between 325 cm and 329 cm (several samples were taken). The layer may be graded. The layer's contacts appear gradational. The lower contact of the 315 cm to 341 cm layer, is a mottled color contact.
341-437-476	White to very light gray foraminiferal calcilutite. A darkened zone with gradational contacts occurs between 406 cm and 415 cm. A dark gray (Mn ?) lamination occurs in the vicinity of 384 cm and has a dip of 45°. The lower contact is thoroughly burrow mottled.

DEPTH, CM	DESCRIPTION
476-492	(greenish) Gray, 5Y5/1, lutite. At 482 cm, occurs an angular, reddish brown quartzite pebble, approximately 3 cm in diameter. The lower contact is a gradational color contact.
492-525	(light greenish) Gray, 5Y6/1, lutite. The lower contact is a sharp color contact.
525-550	Dark greenish brown lutite. The lower contact is marked by a gradational color lightening.
550-584	Light brownish gray, 2.5Y6/2, lutite which is thoroughly burrow mottled. The lower contact coincides with the cutting of the core but is apparently a color contact.
584-587	Light gray, 2.5Y7/2, calcilutite. The lower contact is marked by a gradational color change.
587-609	Light gray, 2.5Y7/1, calcilutite. Two darker gray, 2.5Y6/1, laminae; 2 cm to 3 cm thick occur between 602 cm and 603 cm. The lower contact is drawn in a burrow mottled zone beneath which the sediment color darkens.
609-637	Gray, 5YR6/1 to (darker) gray, 5Y5/1, lutite. Mottling is common throughout. The lower contact is marked by a sharp color change and possibly a gradational textural change; an

DEPTH, CM	DESCRIPTION
	increase in per cent Foraminifera toward the lower contact.
637-647	Light (brownish) gray, 2.5Y7/2, Foraminiferal sand. The top 3 cm are finely mottled with lutite. The lower contact is marked by a faint color darkening but appears texturally gradational.
647-656	Gray, 5Y6/1, foraminiferal lutite. The Foraminifera content diminishes downward from about 50 % at the upper color contact. The lower contact is a burrow mottled color contact.
656-664	Grayish brown, 2.5Y5/2, lutite, containing lighter colored mottlings from the layer above. The lower contact is a thoroughly burrow-mottled color contact.
664-731	White, 10YR8/1, calcilutite. The upper six centimeters contain numerous dark mottlings from the super-adjacent layer. Curious linear burrow mottlings occur at 657 cm and 680 cm curving back at 682.5 cm and 689 cm. Each is 0.2 to 0.3 centimeters thick.
	Slight darkening occurs between 689 cm and 700 cm. The lower contact is marked by a gradational color darkening.

BIO 19-66-20

DEPTH, CM	DESCRIPTION
731-744	(dark) Gray, 5Y5/1, lutite containing numerous mottlings. The lower contact is burrowed and arbitrary.
744-780	(brownish) Gray, 5Y6/1, lutite. A darker brownish gray lutite layer occurs between 749 cm and 751 cm. Below 760 cm burrow mottling is intensive. The lower contact is burrowed and arbitrary.
780-805	White to light gray, 215Y7/1, calcilutite. At 782 cm a distinct color change to gray from white occurs with the gray color diminishing in intensity downward to zero at about 795 cm. The lower contact is color gradational.
805-818	(dark brownish) Gray, 5Y5/1, lutite. The lower contact is marked by a sharp color contrast.
818-845	Gray, 5Y6/1, lutite which encompasses a Foraminifera-rich layer between approximately 830 cm and 840 cm. Foraminifera per cent ranges between 50 % and 80 %, with the maximum at about 837 cm. The lower contact is a gradational color contact.
845-862	(dark) Gray, 5Y4.5/1, lutite. The lower contact is a mottled, distinct color contact.

DEPTH, CM	DESCRIPTION
862-876	Gray, 5Y6/1, lutite. The lower contact is a gradational color contact.
876-912	Grayish brown, 2.5Y5/2, lutite. The lower contact is a sharp, burrowed color contact.
912-918	Light brownish gray, 2.5Y6/2, lutite. The lower contact is a sharp color contact.
918-930	(lighter) Light brownish gray, 2.5Y6.5/2, calcilutite. The lower contact is a sharp color contact.
930-949	White, 10YR8/1, calcilutite. The lower, mottled contact apparently coincides with the end of a core section and could not be observed.
949-957	Light brownish gray, 2.5Y6.5/2, calcilutite. The lower contact is marked by a distinct color lightening.
957-975	White, 5Y8/1, calcilutite, grading downward to gray, 5Y6/1, calcilutite. The lower contact is a slightly mottled color contact.
975-1047	White calcilutite, including: between 982 cm and 991 cm; about six laminae (2 mm thick). Of slightly darker sediment, the lowermost lamination is distinct from the others in that it has a gray color between

DEPTH, CM	DESCRIPTION
	1010 cm and 1015 cm; the sediment has a darker (brown) color with mottlings appearing beneath this zone in the white, host calcilutite. The lower contact is marked by a laminated zone in which the sediment color darkens notably.
1047-1062	Olive gray, 5Y4.5/2, lutite. The lower contact is marked by a rapidly gradational color contact.
1062-1077	Gray, 5Y6/1, calcilutite. The lower contact is marked by a rapidly gradational color darkening.
1077-1082 (bottom)	(dark)Gray, 5Y5/1, lutite containing abundant indurated black pellets; 0.2 cm to 0.3 cm diameter. Below 1082 cm occurs "flow in", similar to the dark gray lutite just described.
	"flow-in"
1082-1156	(dark) Gray lutite.
1156-1193	Foraminiferal sand with calcilutite inclusions.
1193-	Light brownish gray calcilutite.

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DEPTH, CM	DESCRIPTION
	Penetration of the corer exceeded 1200 cm (the combined length of the two pipes attached below the head), this a section of undetermined length was lost from the top of the core. Comparing the stratigraphy of this core with that of the other cores, a minimum loss of 30 cm is suggested. The depths following have not been corrected accordingly, however the diagrammatic representation of core lithology is so adjusted.
"Top"-02	Light yellowish-brown, 10YR6/4, foraminiferal calcilutite. The lower contact is an irregular but sharp color contact. N.B. The upper 10 cm have been somewhat distributed in the coring process.
02-50	Brownish-gray lutites: 09-16 cm (light) gray, 5Y6/1 16-32 cm (brownish) gray, 10YR5/1 Between 19 and 23 cm numerous dark laminae occur. 32-50 cm (light) gray, 5Y6/1 becoming (dark) gray 5Y5/1 toward the bottom. The darker section is finely burrow mottled.
50-63	(light) Gray, 5Y6/1, lutite. The lower contact is burrow mottled.

BIO 19-66-26

DEPTH, CM	DESCRIPTION
63-80	Light gray, 5Y7/1, calcilutite. Between 75 cm and 80 cm several faint gray laminae occur. The lower contact is a gradational color contact.
80-90	(light) Gray, 5Y5.5/1, lutite, thoroughly burrow mottled with lighter colored sediment from above. The lower color contact is burrowed.
90-131	Light gray, 5Y7/2, calcilutite. The lower contact is burrowed. The top 20 cm are finely burrow mottled. Between 107.5 cm and 108 cm, a layer containing an abundance of fine burrow mottling, occurs. The lower contact is a burrowed, color contact.
131-190	White, 10YR8/1, calcilutite.
190-218	A disturbed zone caused by a water pocket. Foraminiferal sand and white calcilutite apparently occupied most of this area.
218-250	White, 5Y8/1, calcilutite. The lower contact is a gradational color contact and is arbitrarily located.
250-272	(light) Gray, 5Y6/1, lutite. The lower contact is a burrow mottled, color contact.

BIO 19-66-26

DEPTH, CM	DESCRIPTION
272-300	White, 10YR8/1, calcilutite. The lower contact is indistinctly marked by a gradational color change.
300-380	(greenish) White, 5Y8/2, calcilutite. The lower contact is an indefinite (arbitrary) color contact.
380-546-696	White, 10 YR8/1, calcilutite, frequently exhibiting (greenish) white, 5Y8/2, mottlings. A graded (?) foraminiferal sand layer occurs between 420 cm and 423 cm. (Samples at 420 cm and 422 cm). The lower contact of the foraminiferal sand layer is a sharp textural contact while the upper contact appears gradational. A layer of yellow sediment (origin unknown) occurs between 554.5 cm and 555 cm. Zones of light gray, 5Y7/1, calcilutite occur between 609 cm and 622 cm, and 670 cm and 684 cm. The lower contact is a sharp color contact.
696-710 (bottom)	Greenish-gray lutite.

Below 710 cm depth, occurs "flow-in".

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BIO 19-66-27

DEPTH, CM	DESCRIPTION
Top-56	Pale brown, 10YR6/3, foraminiferal calcilutite. The top few centimeters contain an abundance of pteropods. To 40 cm depth, the sediment is essentially structureless, while between 50 and 56 cm, burrow mottling is apparent. The lower contact is a faint but distinct contact.
56-70	Darker brown lutite containing numerous laminae. The lower contact is an indistinct color contact.
70-103	Light brownish-gray, 10YR6/2, foraminiferal calcilutite. An area of contorted darker sediment occurs between 74-84 cm. The lower contact is a faint yet distinct color contact.
103-124	Slightly darker brownish-gray, calcilutite. The lower contact is a burrowed, color contact.
124-204	Light brownish-gray foraminiferal lutite which darkens below 172 cm, to gray, 5Y5/1. Burrow mottling is infrequently evident. The lower contact is a burrow-mottled color contact.
204-230	(lighter) Gray, 5Y6/1, foraminiferal calcilutite. The lower contact is a distinct color contact.
230-248	Gray, 5Y5/1, lutite. Several thin (less than

DEPTH, CM	DESCRIPTION
	.5 mm) laminae of blue-gray lutite occur between 232 and 233 cm. The lower contact is marked by a distinct color contrast.
248-290	Light gray _foraminiferal calcilutite_. Burrow mottling by darker colored sediment is common and causes a general darkening of the sediment to 290 cm. Between 260 and 261 cm, the sediment has an indistinct yellow tinge. The lower contact is a distinct color contact.
290-335	Grayish brown, 2.5Y5/2, changing downward to light brownish-gray, 2.5Y6/2, lutite. Burrow mottling is common. The lower contact is a sharp color contact though burrow mottled.
335-387	White _foraminiferal calcilutite_. Burrow mottling is faintly evident. The lower contact is a gradational color contact.
387-398	Light brownish gray, 2.5Y6/2, _calcilutite_. Extensively burrow mottled with white calcilutite. The lower contact is an abrupt and distinct color contact.
398-440-489	White _foraminiferal calcilutite_. Mottlings of dark sediment from the super-adjacent layer are present in the top 10 cm of this horizon. Between approximately 465 cm and the lower contact, the sediment darkens to a greenish-

DEPTH, CM	DESCRIPTION
	gray color. The lower contact is a burrowed color contact.
489-529	White foraminiferal calcilutite which darkens slightly toward the lower color contact at 529 cm.
529-608	Grayish-brown, 2.5Y5/2, lightening below 590 cm to light brownish-gray, 2.5Y6/2, lutite. A considerable dark mineral content is present. The lower contact is burrow mottled and marked by a color contrast.
608-630	Light gray, 10YR7/1, calcilutite. The lower contact is an indefinite color contact.
630-645	(dark) Light gray, 10YR6/1, foraminiferal calcilutite. Foraminifera constitute perhaps 30 % of the sediment. The lower contact is marked by a distinct color and textural change.
645-657	(yellowish) Light gray, 10YR7/2, foraminiferal sand. Foraminifera constitute about 90 % of the sediment; calcilutite, about 10 %. The lower contact is gradational.
657-667	Light gray, 10YR7/2, calcilutite. The lower contact is marked by a color change.
667-675	Light brownish-gray, 10YR6/2, lutite which is thoroughly burrow mottled.

DEPTH, CM	DESCRIPTION
675-726	White foraminiferal calcilutite. The lower contact is a burrow-mottled color contact.
726-738	Dark brownish-gray lutite. The lower is an indefinite burrow-mottled contact.
738-765-775	Light brownish-gray, 10YR6/2, lutite. The sediment is thoroughly burrow mottled.
775-790	White, 10YR8/1, calcilutite. A probable gneissic pebble containing garnet, occurs at 789 cm. Its maximum diameter is 2 cm and it is subrounded. The top 5 cm of this layer exhibit an abundance of fine mottlings of brown lutite from the super-adjacent layer. The lower contact is a sharp color contact.
790-792.5	Gray, 5Y5/1, lutite. The lower contact is a sharp color contact.
792.5-797	Light gray, 10YR6/1, lutite. The lower contact is marked by a color change.
797-803	Gray, 5Y5/1, lutite. The color of the sediment lightens downward to the lower contact where it is light gray, 10YR6/1. The lower burrowed contact is marked by a color contrast.
803-860	(light) Gray, 5Y6/1, lutite. Between 834 cm and 837 cm a layer of (darker) gray, 2.5Y5/0, lutite occurs; its upper contact distinct and unburrowed, its lower contact burrowed.

BIO 19-66-27

DEPTH, CM	DESCRIPTION
	Between 822 and 828 cm, several laminae of faintly darker sediment occur. Each is approximately 1 mm thick.
	Between 830 and 830.5 cm, a layer of (dark) gray lutite similar to that just mentioned, occurs. The lower contact is marked by a sharp color change.
860-894	Gray, 5Y5/1, lutite. Between 890 cm and 894 cm, a sequence of 5 or more thin layers of lighter colored sediment occurs. The lower contact is a remarkably sharp color contact and is undisturbed.
894-907	Dark gray, 5Y4/1, lutite. The lower contact is marked by a color lightening.
907-930	Gray, 5Y6/1, foraminiferal lutite. The Foraminifera content increases suddenly at about 914 cm from approximately 25 % to about 90 %. A considerable gravel-sized fraction is present. A quartz grain, 3 mm in diameter, occurs at 918 cm. A shale fragment 2 mm in diameter occurs at 914 cm. The lower contact is marked by a color change.
930-976	(dark) Gray, 5Y5/1, lutite; becoming gray, 5Y6/1 beneath 950 cm. Burrow mottling is very common. The mineral and rock-fragment sand and gravel fraction appears considerable in this horizon. A sub-angular, dark gray shale pebble, 0.9 cm maximum diameter, occurs at 943 cm.

BIO 19-66-27

DEPTH, CM	DESCRIPTION
976-988	Calcilutite.
988-998	Gray, 2.5Y6.5/2, foraminiferal lutite (Foraminifera 30 %). The lower contact is a burrowed color contact.
998-1011	Gray, 5Y6/1, foraminiferal lutite. Between 1007 cm and 1011 cm, the Foraminifera content is approximately 75 %. Above 1007 cm Foraminifera constitute about 50 % by volume of the sediment. A sharp boundary exists between these two horizons. The lower contact is marked by a sharp color change.
1011-1024	Gray, 10YR6/1, foraminiferal calcilutite; Foraminifera constituting 60 - 80 % of the sediment. Foraminifera abundance diminishes downward. An area blackened by manganese (?) occurs at 1023 cm. The lower contact is a faint, yet sharp color contact.
1024-1036	Light brownish-gray, 10YR6/2, foraminiferal lutite, extensively burrow mottled with white calcilutite from above.
1036-1073-1087	(light) Gray, 5Y6/1, calcilutite. The lower contact is marked by a color darkening.
1087-1101	(darker) Gray, 5Y5/1, lutite. The lower contact is a burrowed, color contact.

BIO 19-66-27

DEPTH, CM	DESCRIPTION
1101-1119	Light brownish-gray, 2.5Y6/2, lutite. The layer is mottled. The lower contact is a distinct color contact.
1119-1138	Light gray, 10YR7/1, calcilutite. The lower contact is marked by a sudden color darkening.
1138-1150	(dark) Gray, 5Y5/1, lutite. The lower contact is a burrow-mottled color contact.
1150-1158	(light) Gray, 5Y6/1, calcilutite. The lower contact is marked by a gradational color darkening.
1158-1165	Gray, 5Y5.5/1, lutite.
1165-1177	(light) Gray, 5Y6/1, calcilutite. The Foraminifera content increases downward between 1173 cm and 1177 cm from less than 10 % by volume to approx. 70 % at the lower textural contact.
1177-1183	(light) Gray lutitic foraminiferal sand. Foraminifera constitute approximately 80 % of the sediment. The lower and upper contacts are textural contacts.
1183-1196	(dark) Gray, 5Y5/1, lutite. The lower contact is marked by a sharp (unburrowed) color darkening.

BIO 19-66-27

DEPTH, CM	DESCRIPTION
1196-1209	Dark Gray, 5Y4.5/1, lutite. The lower contact is marked again by a distinctly sharp and unmottled color contact.
1209-1213	(dark) Gray, 2.5Y5/1, lutite. The lower contact is a mottled, color contact.
1213-1231	Light gray, 10YR6/1, lutite. The lower contact is marked by a faint color contrast.
1231-1270	Gray, 5Y5/1, lutite. The lower contact is burrowed.
1270-1279	Very light brown calcilutite. The lower contact is distinguished by a faint color contrast.
1279-1290 (bottom)	White calcilutite.

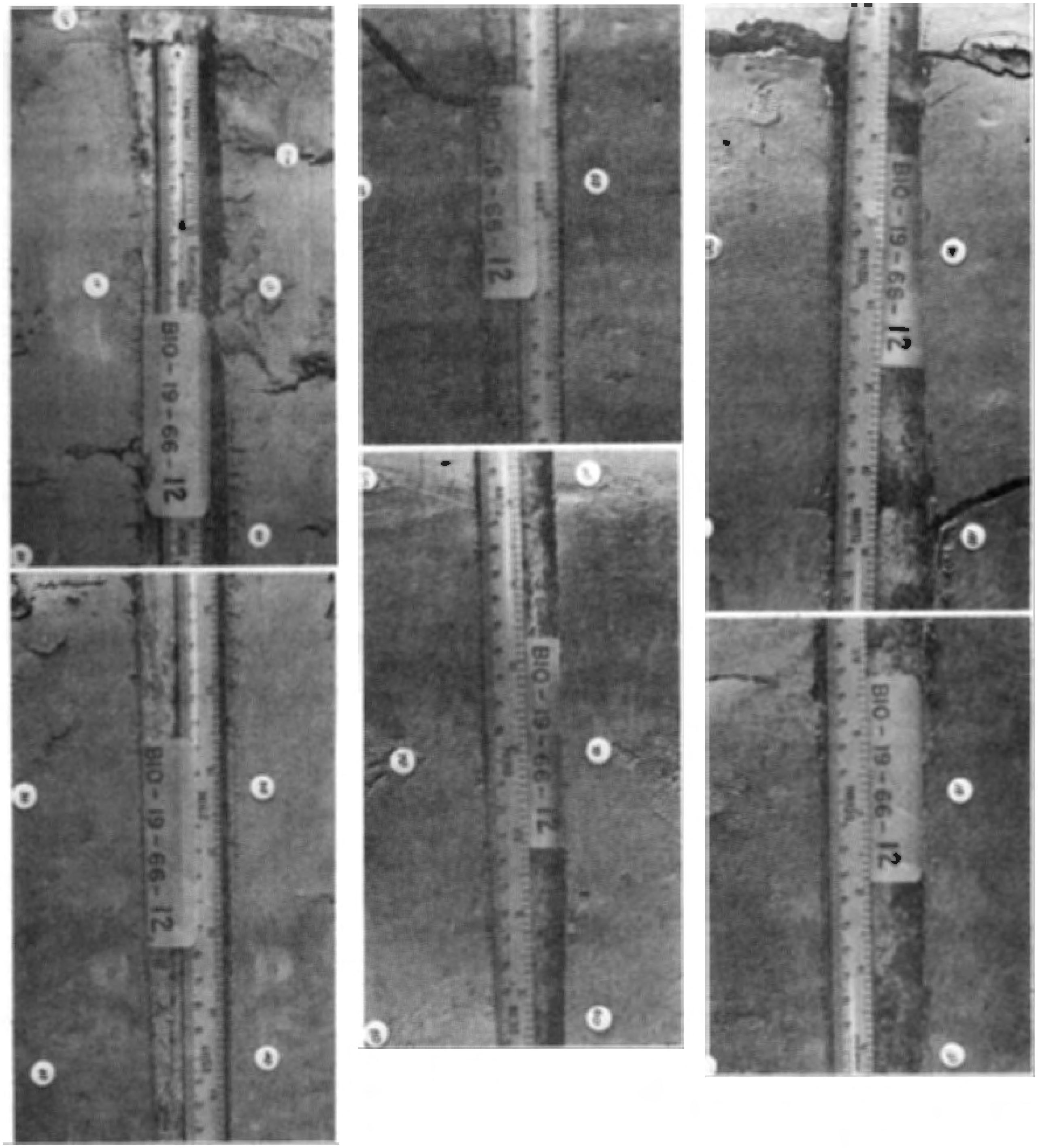
* * *

BIO 19-66-50

DEPTH, CM	DESCRIPTION
Top-58 (bottom)	Yellowish-brown, 10YR5/4, calcilutite. The core became mobile when subjected to the ship's vibrations, destroying any structures present.

* * *

STN 12



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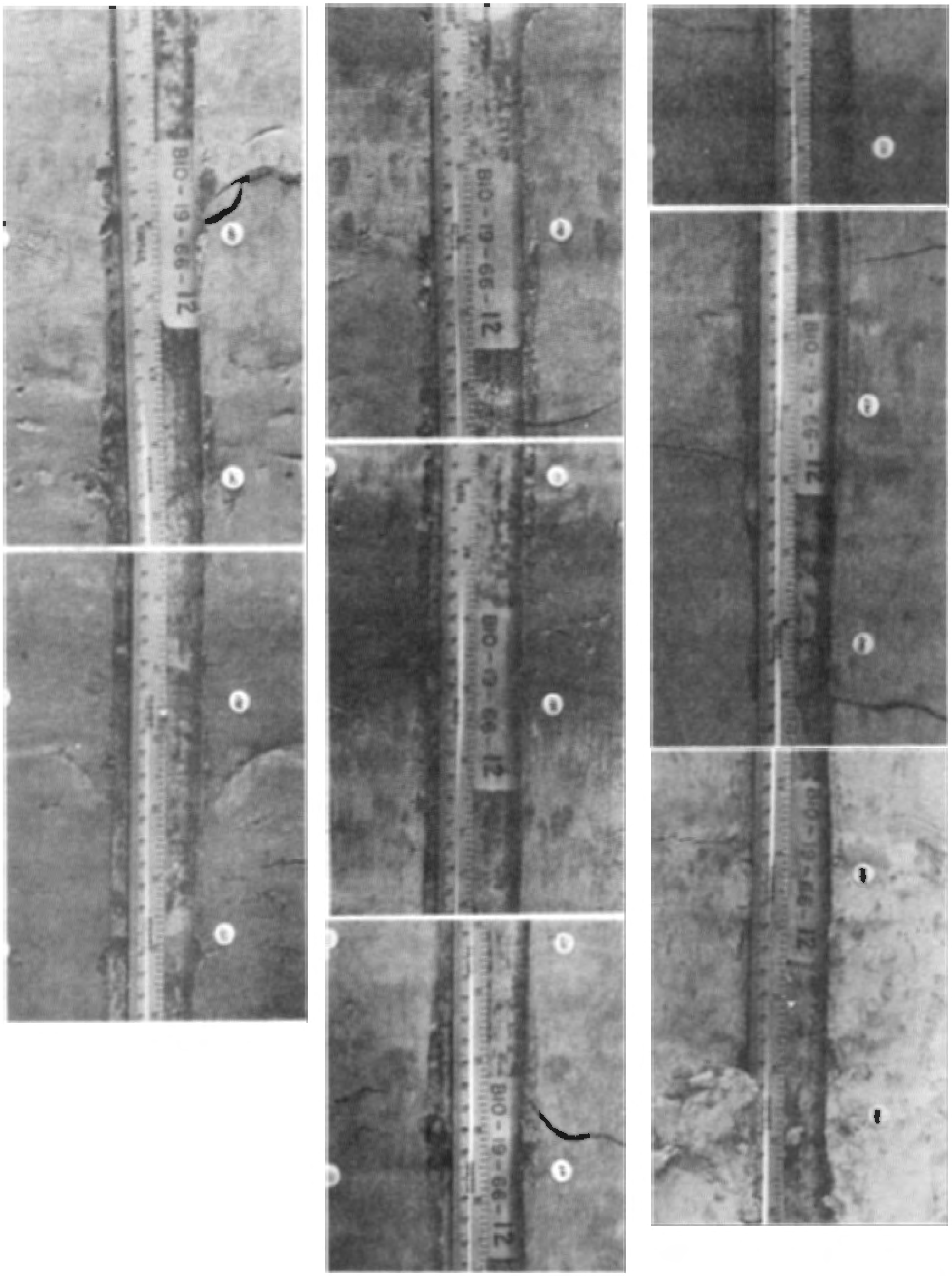
BIO-19-66-12
BIO-19-66-12
BIO-19-66-12
BIO-19-66-12

STN 12



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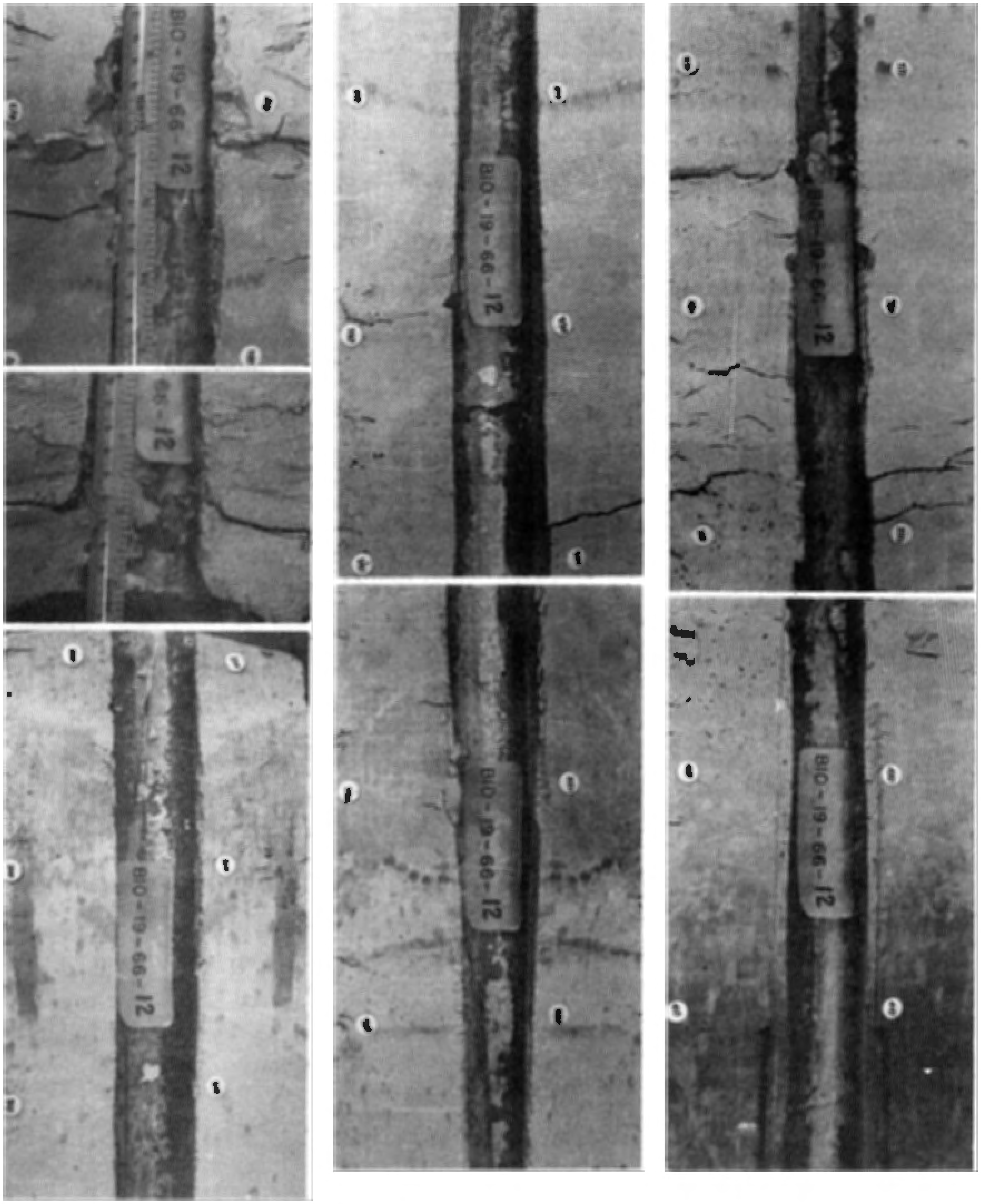

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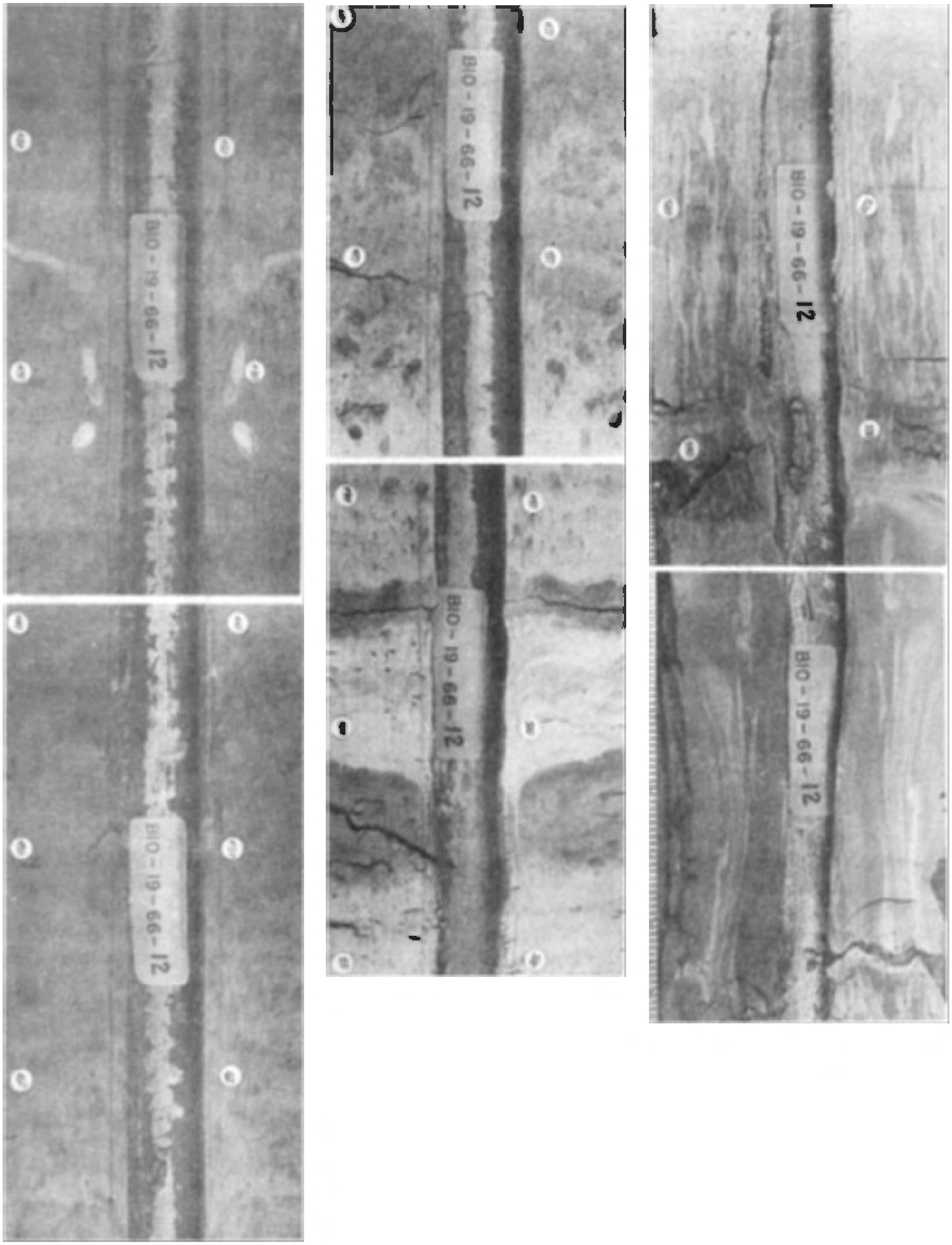

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BIO-19-66-12
BIO-19-66-12
BIO-19-66-12

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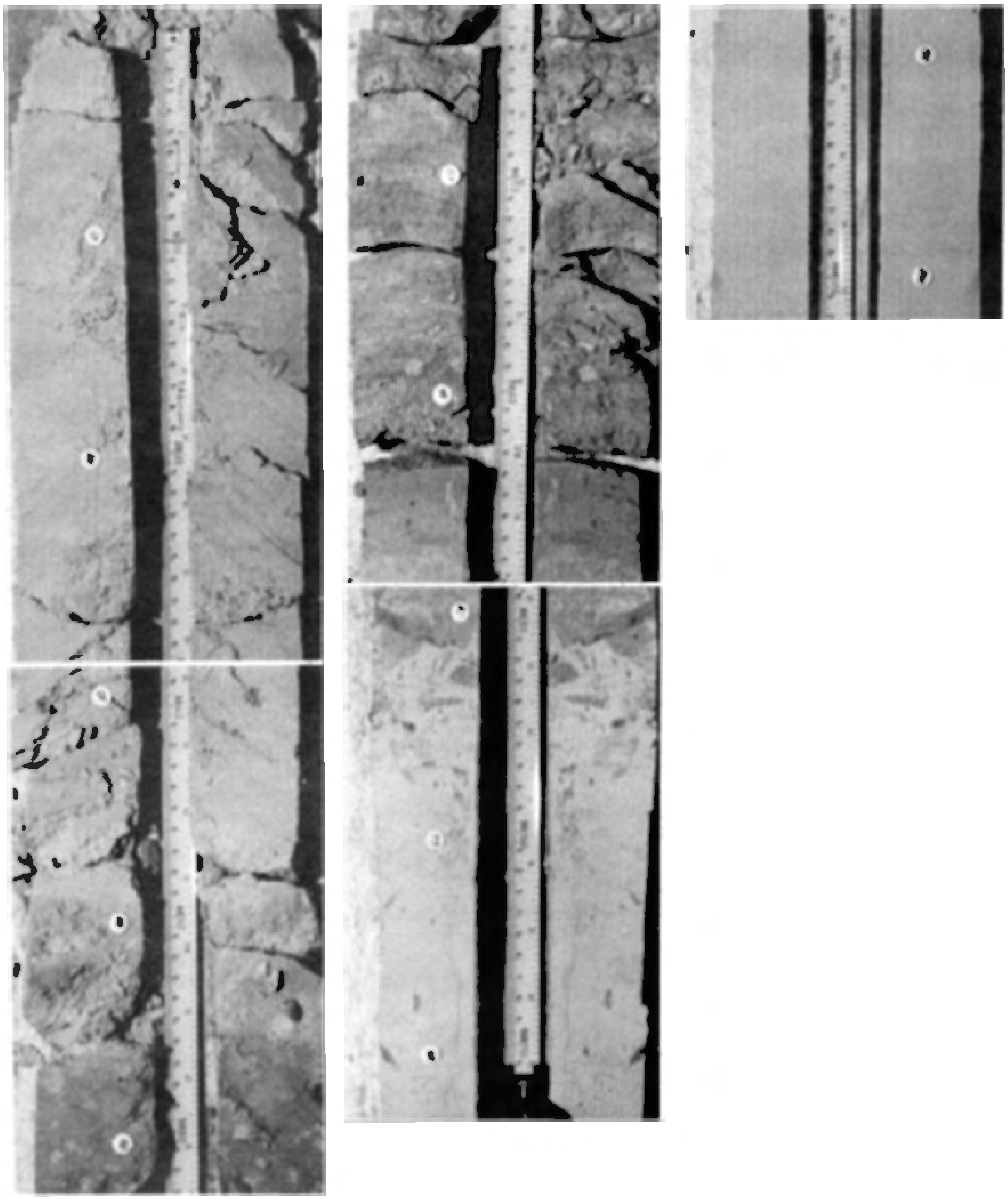

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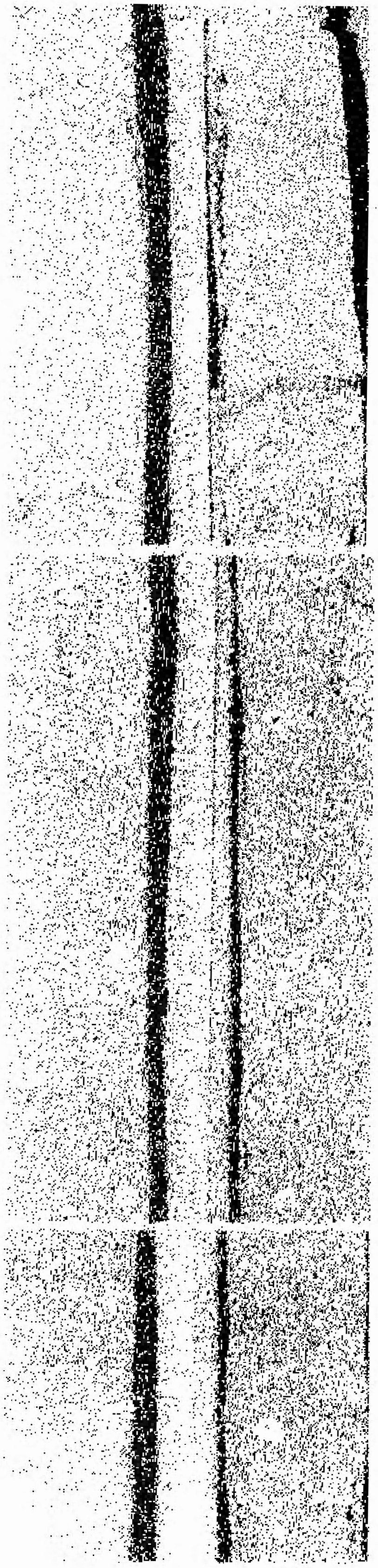

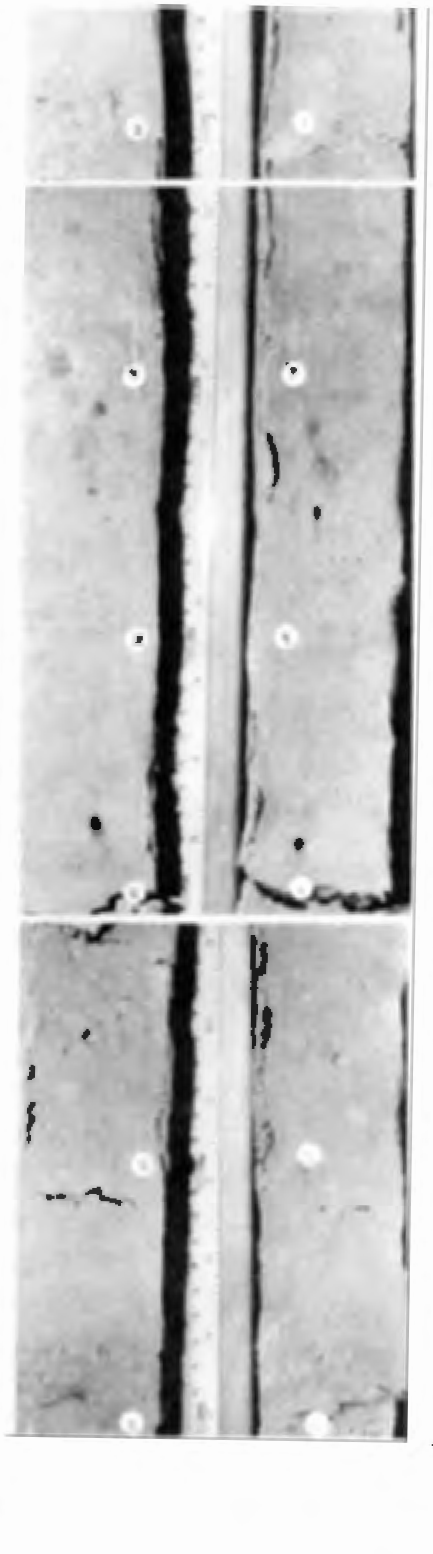

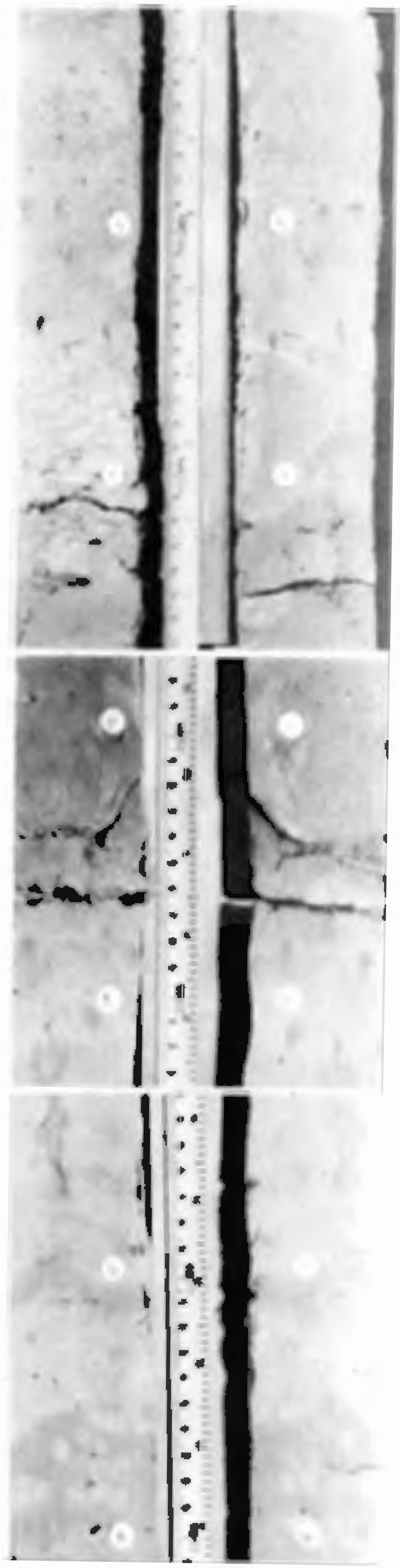

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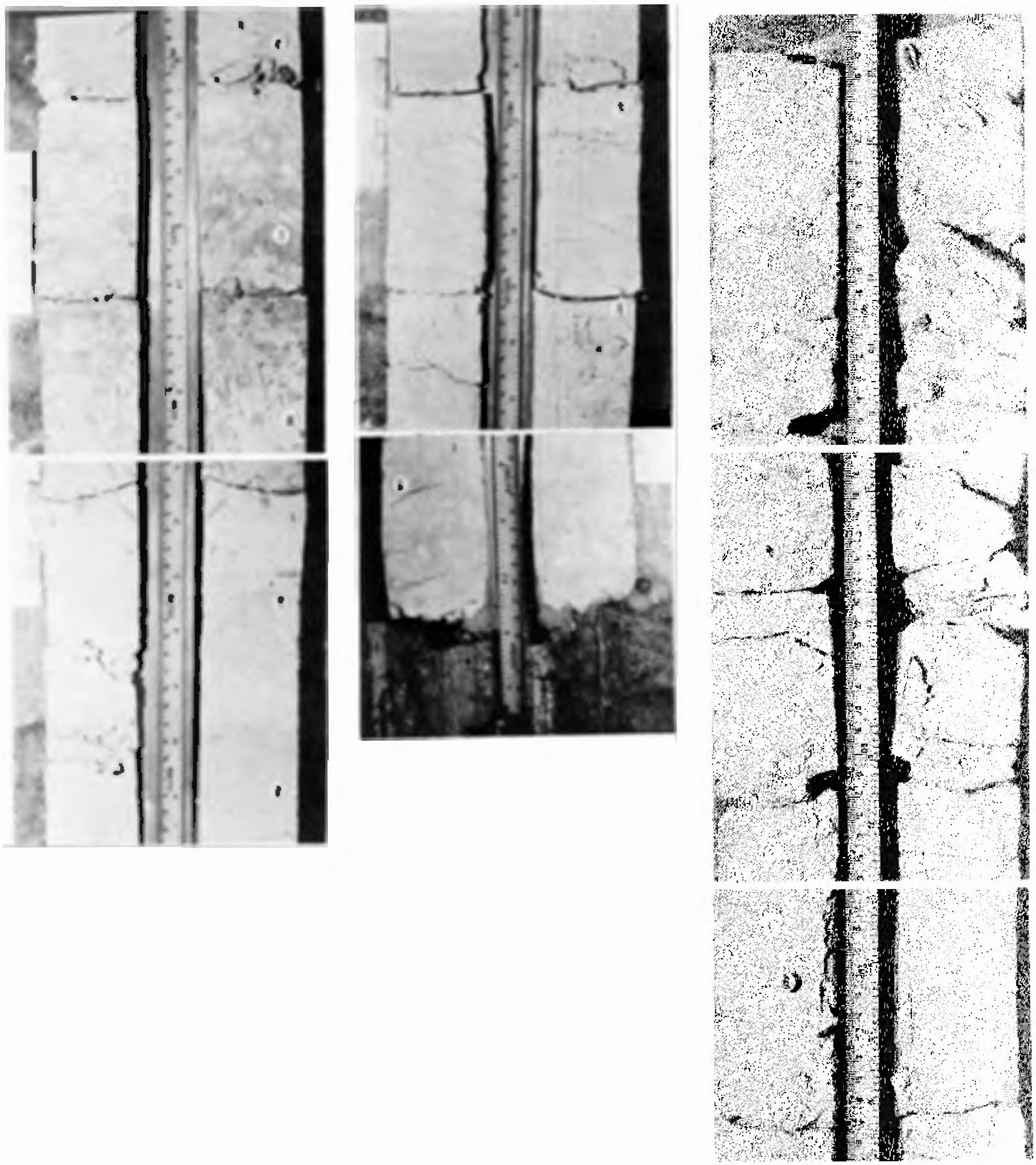
STN 17



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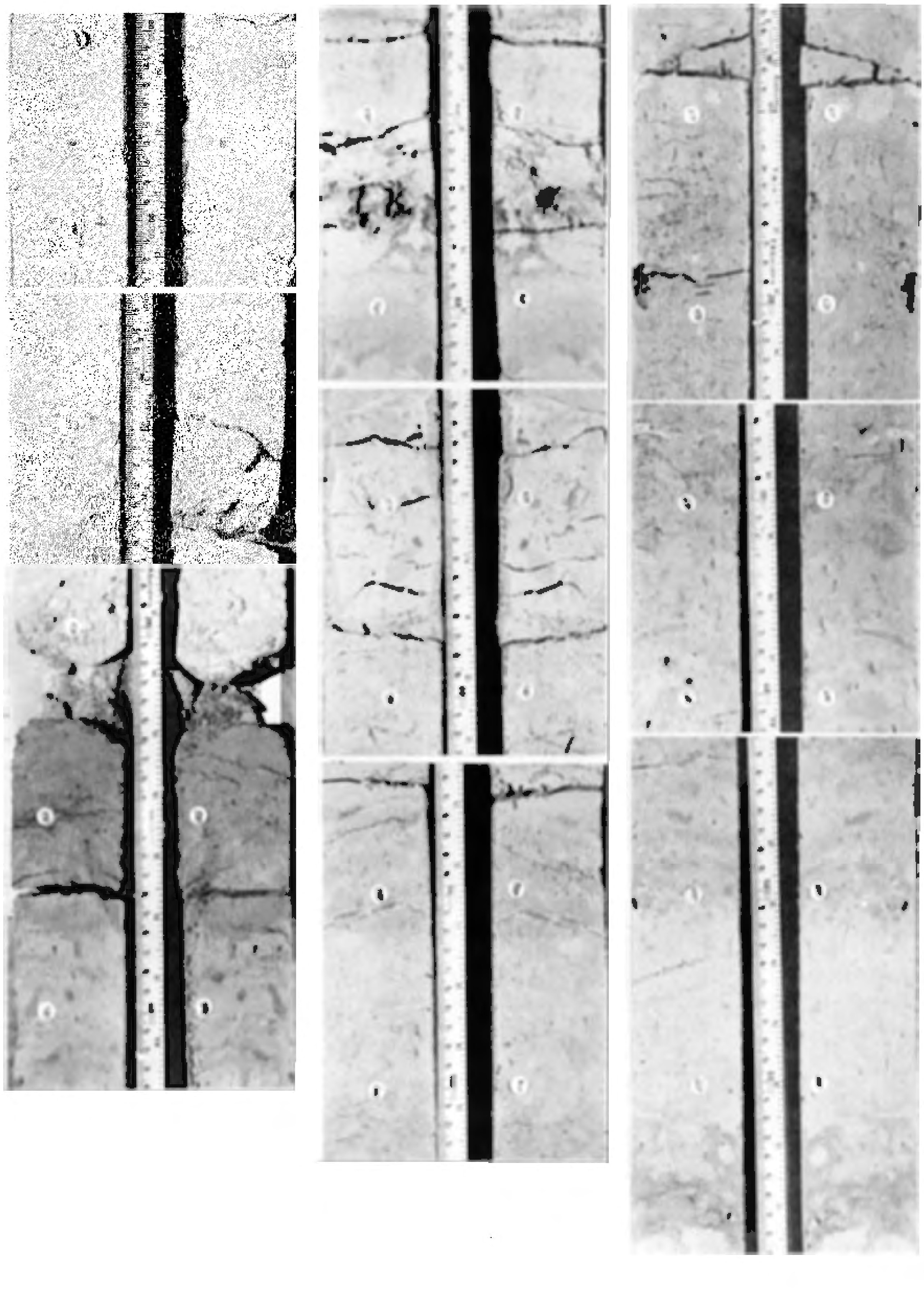

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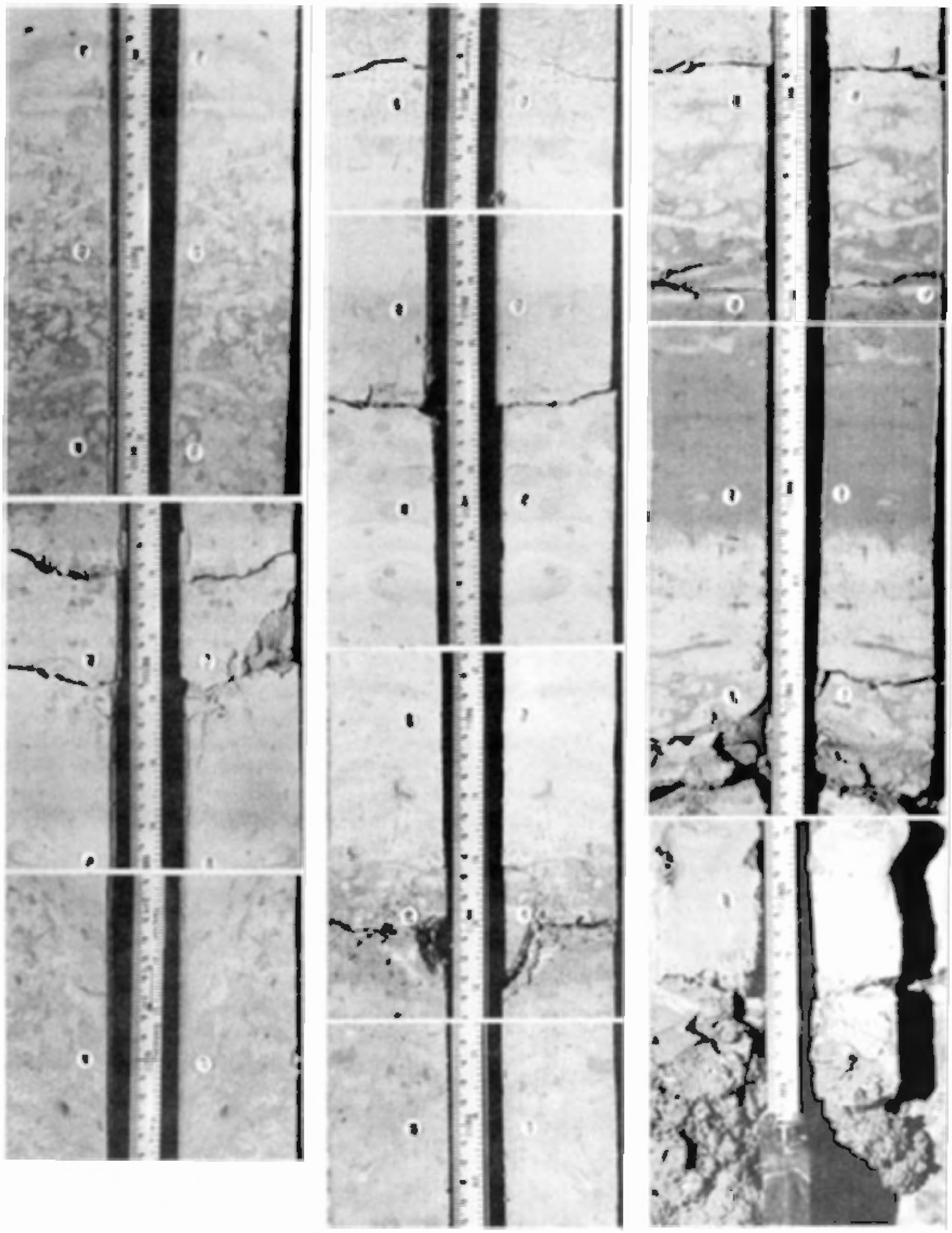

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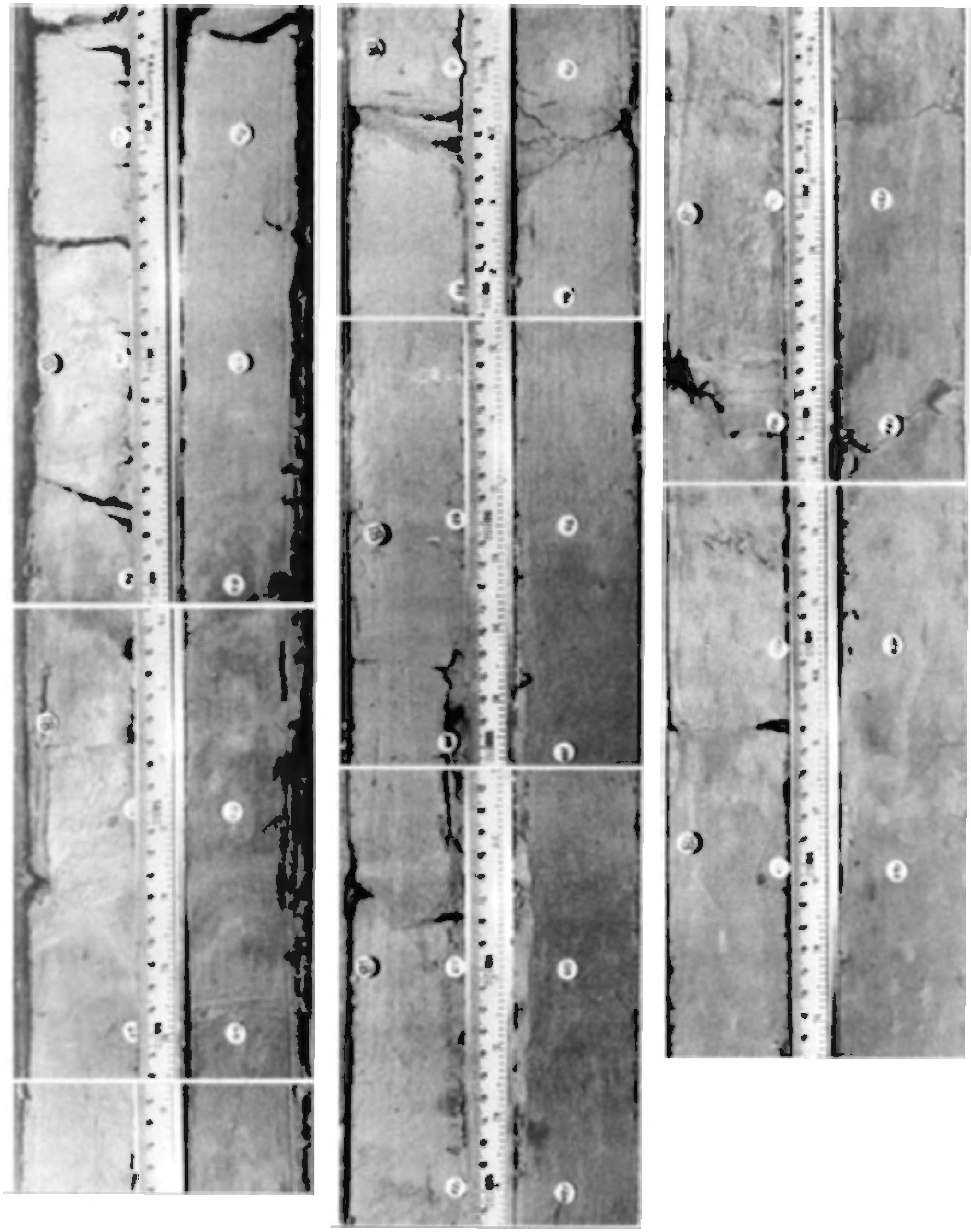

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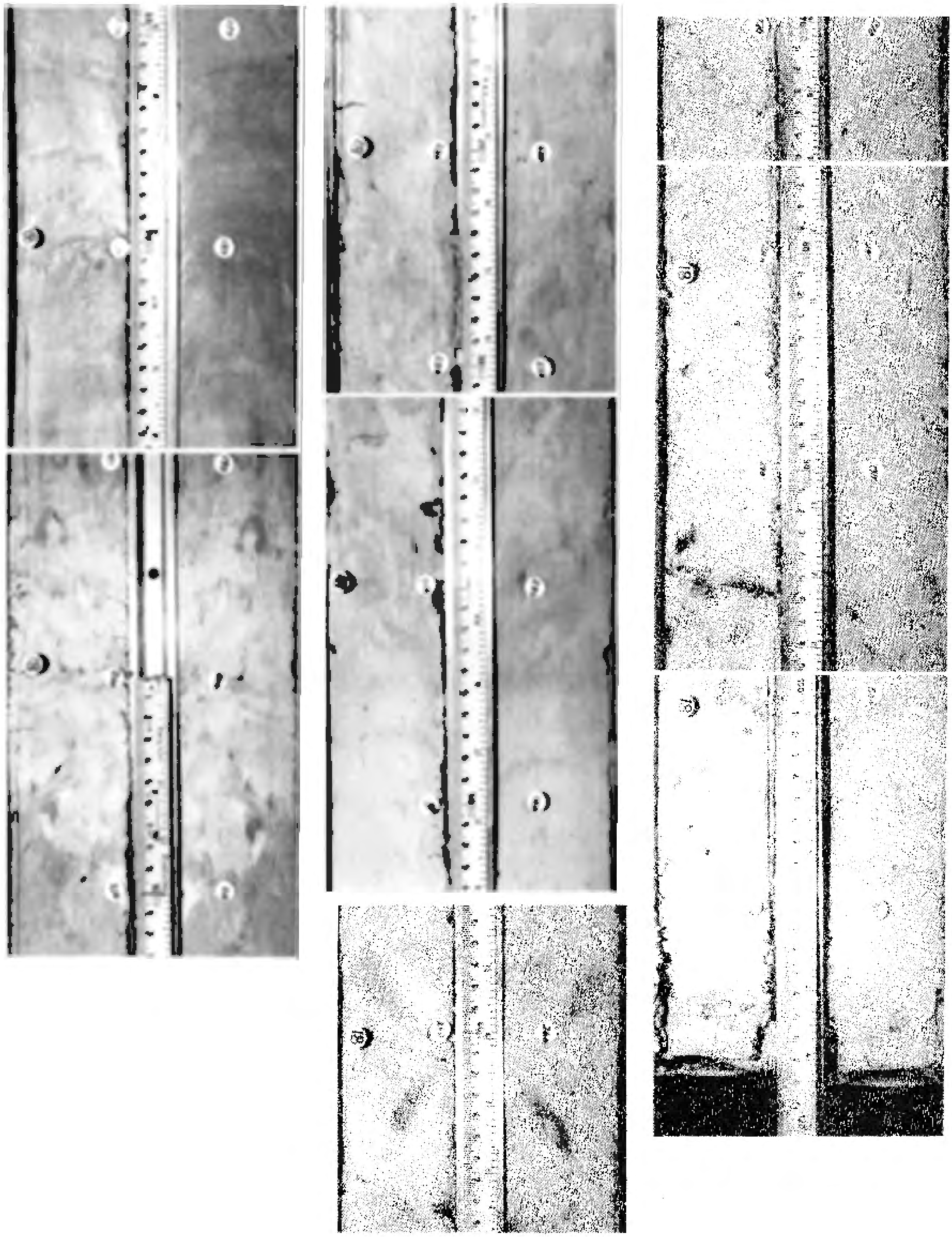

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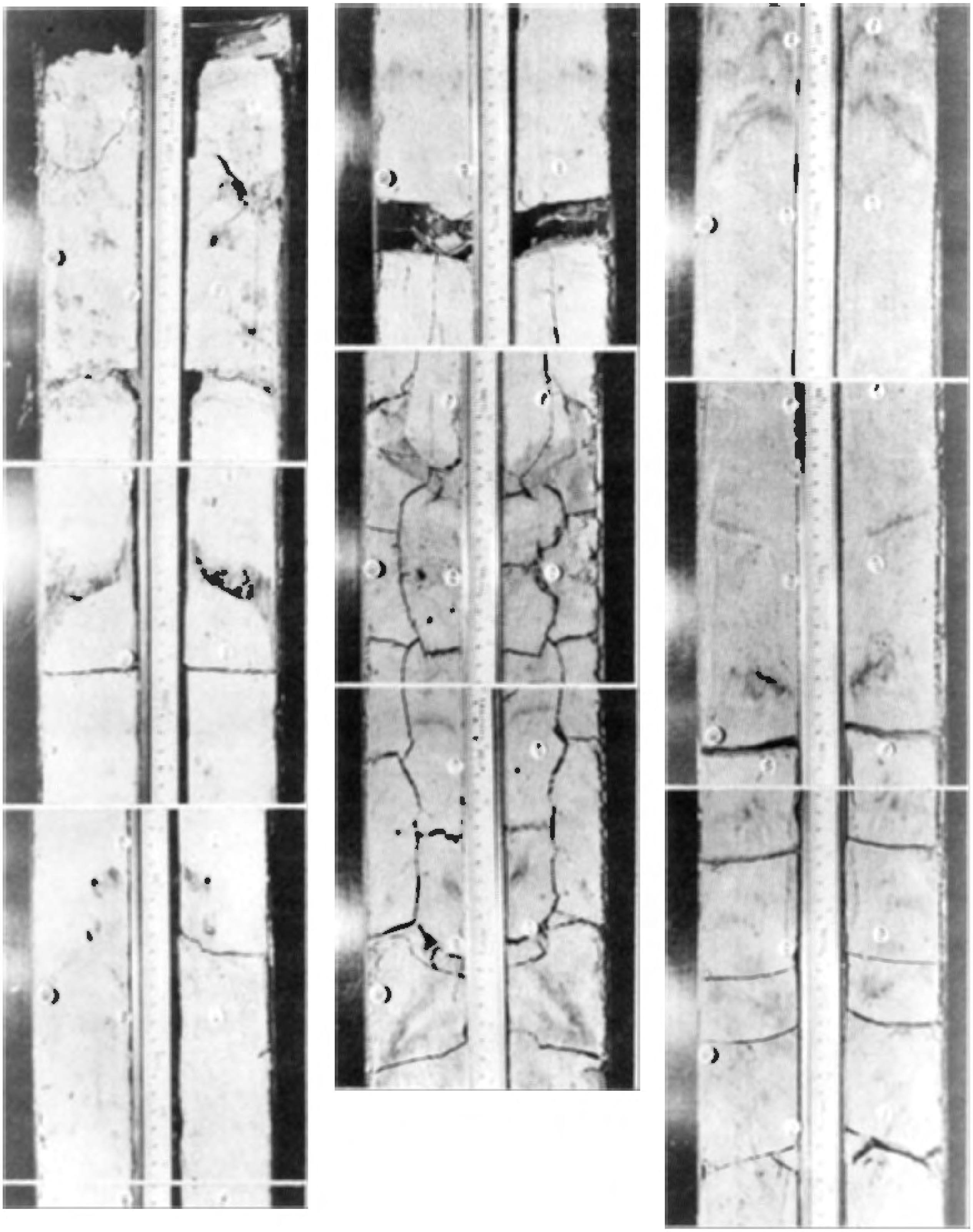

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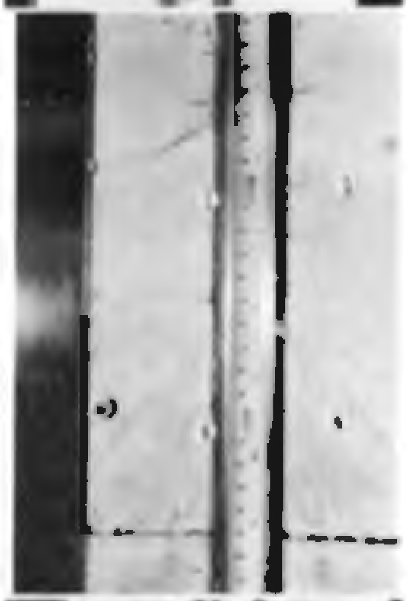


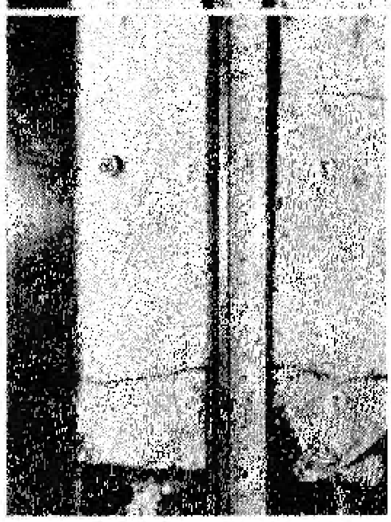


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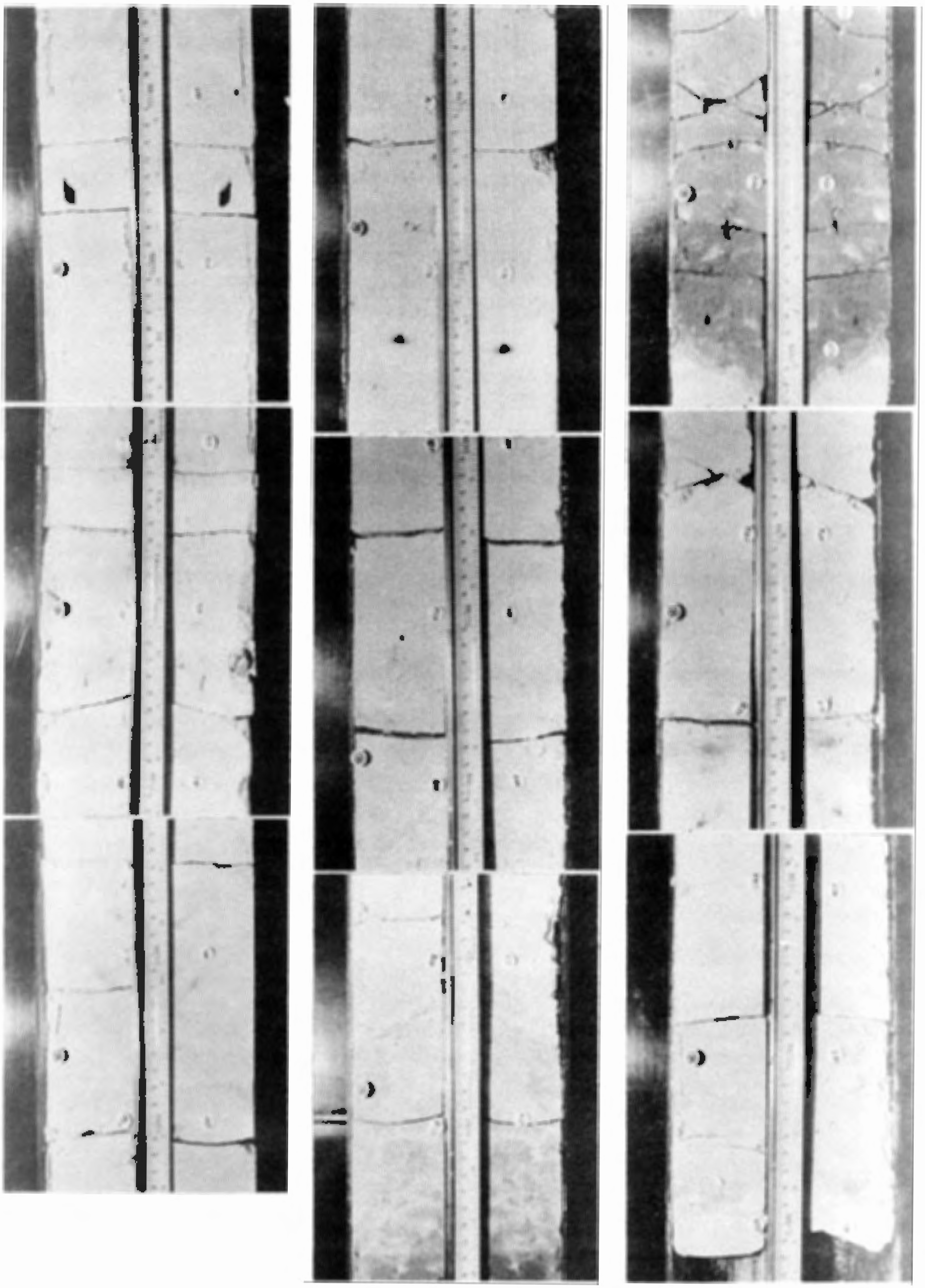

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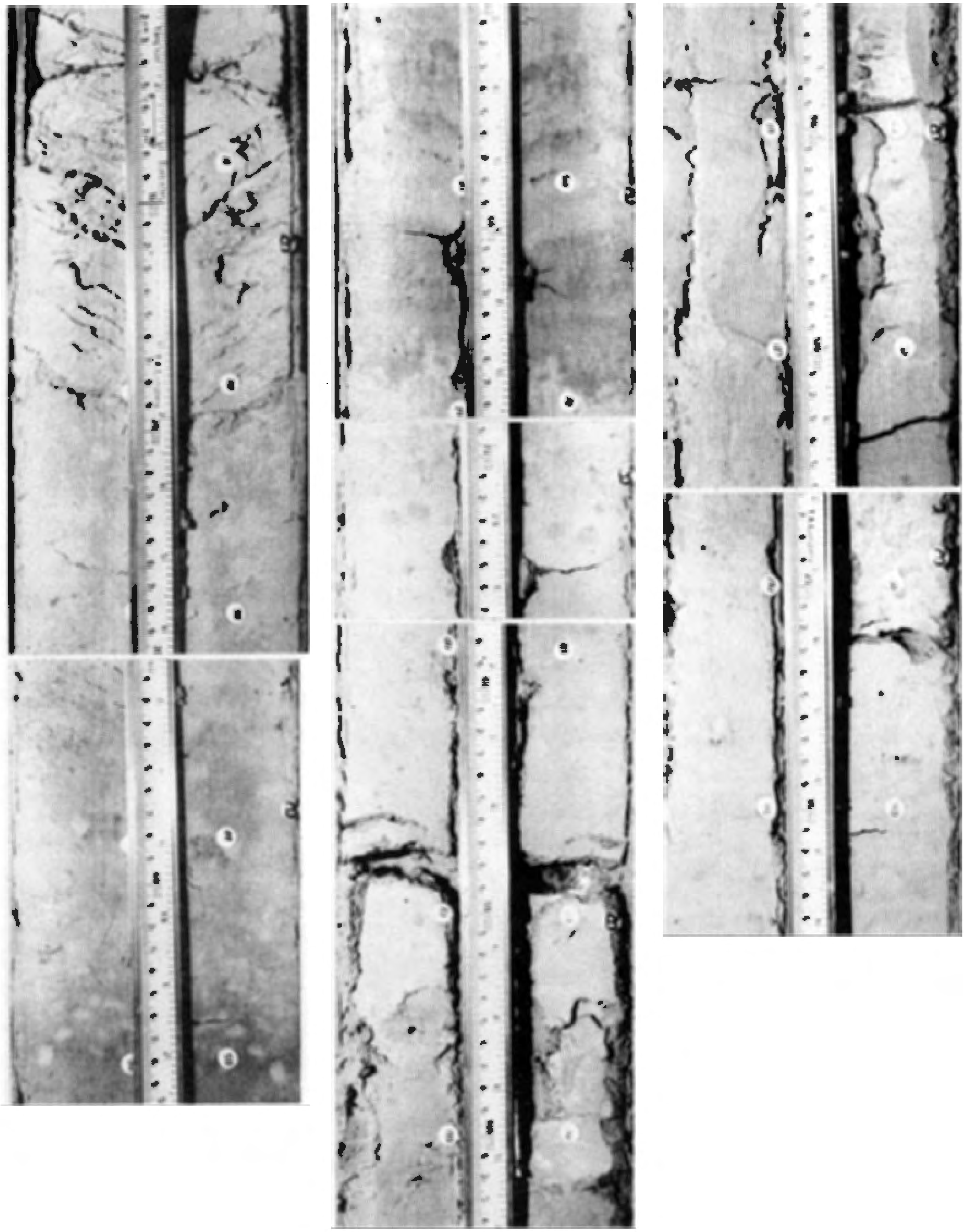

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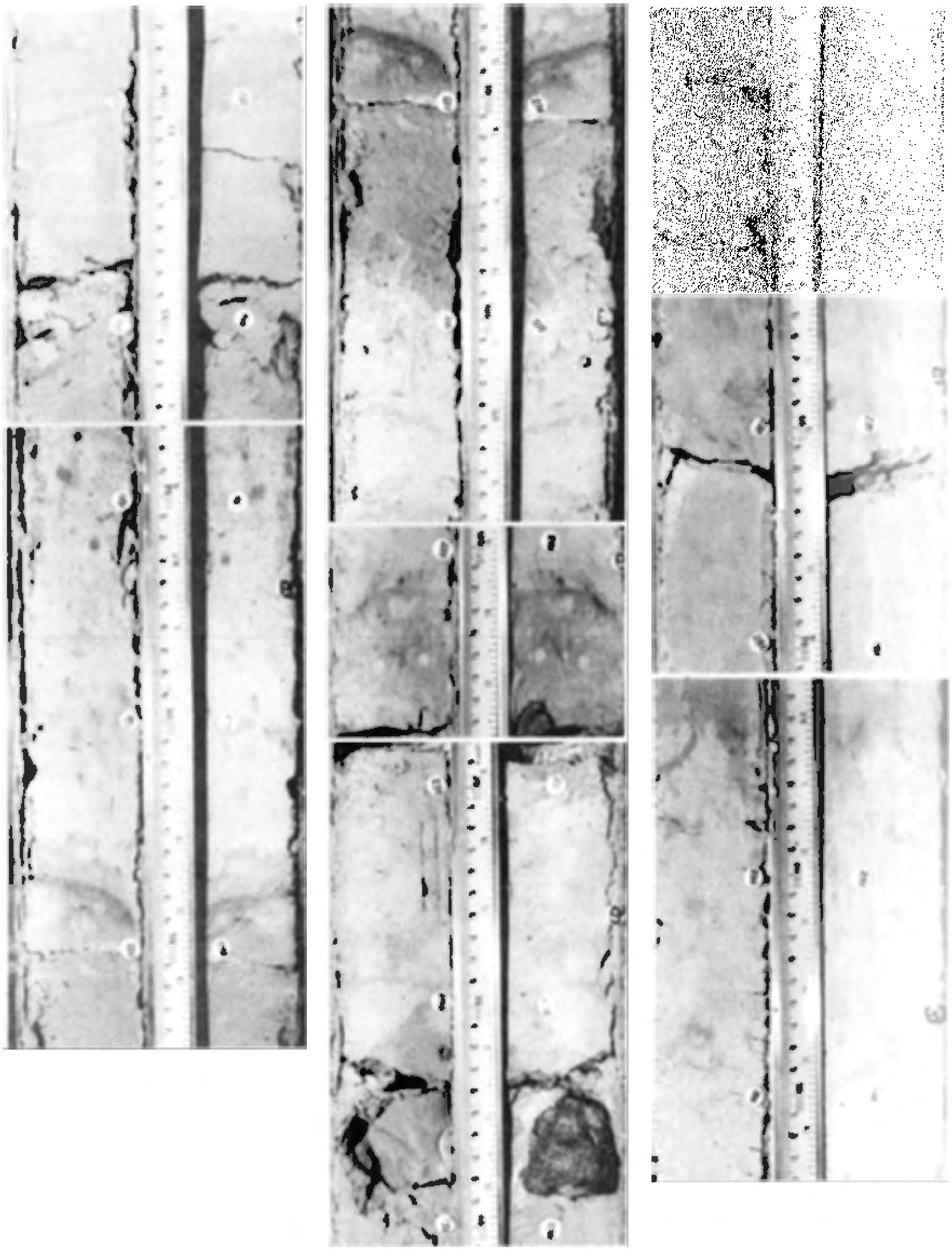

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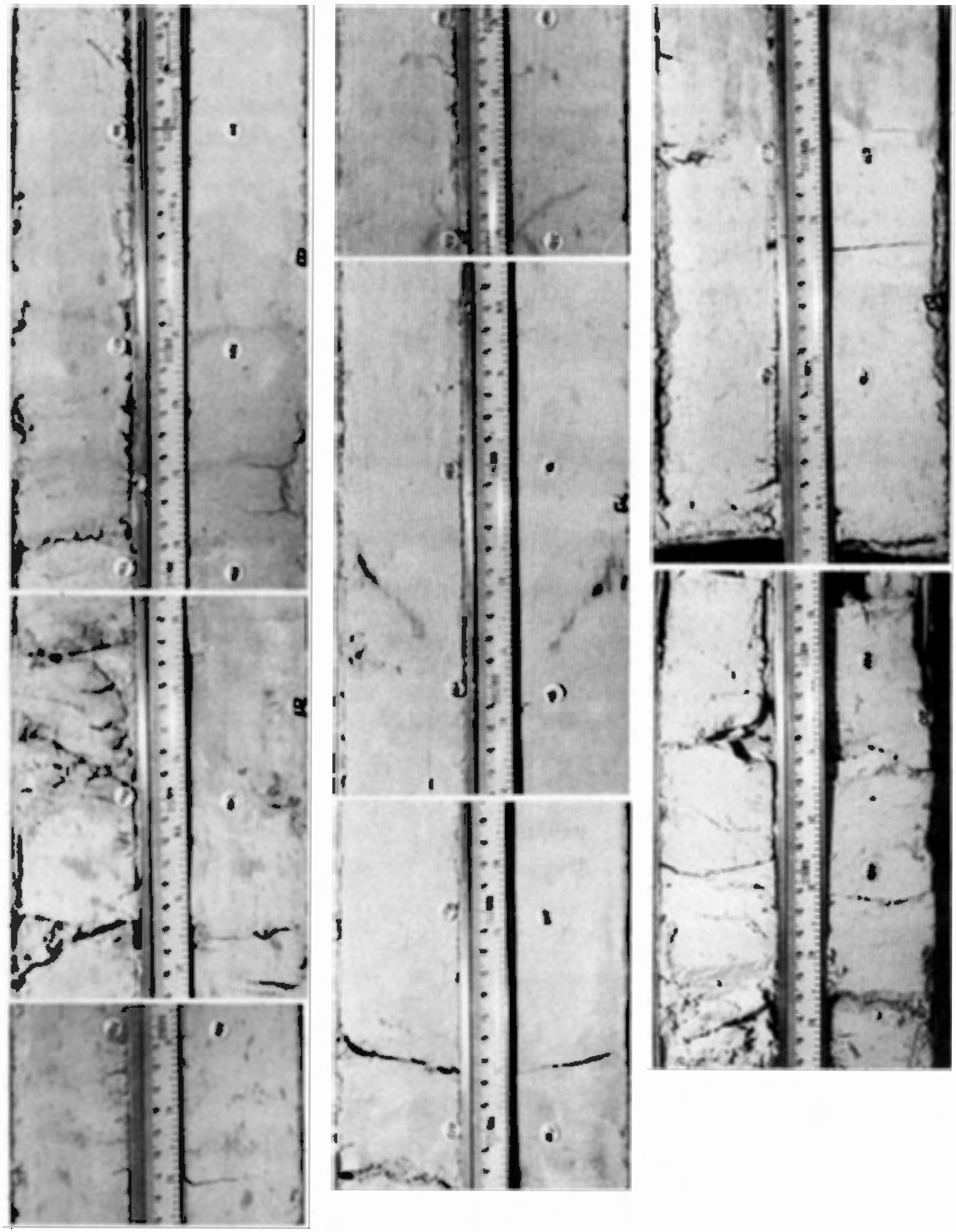

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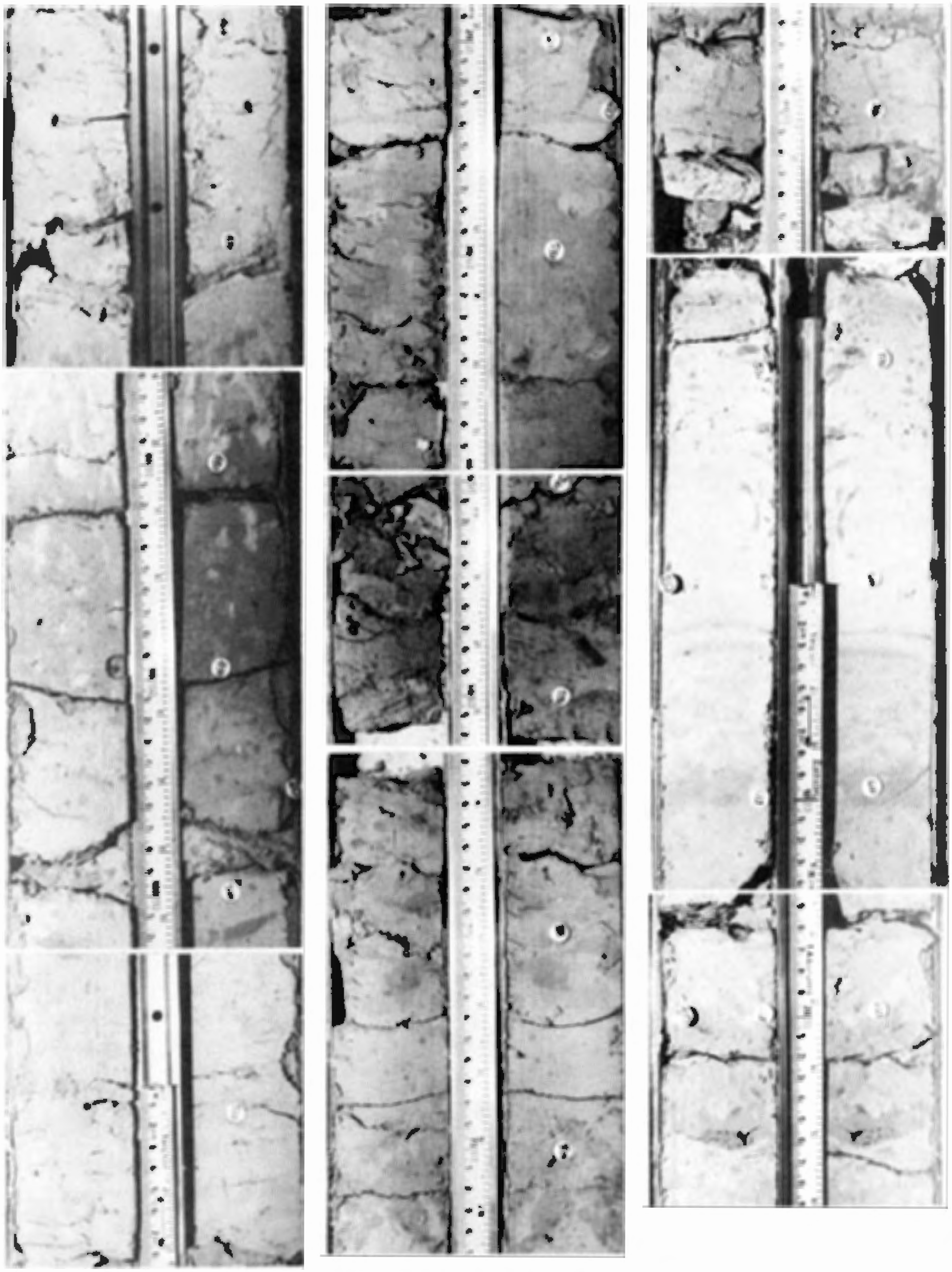

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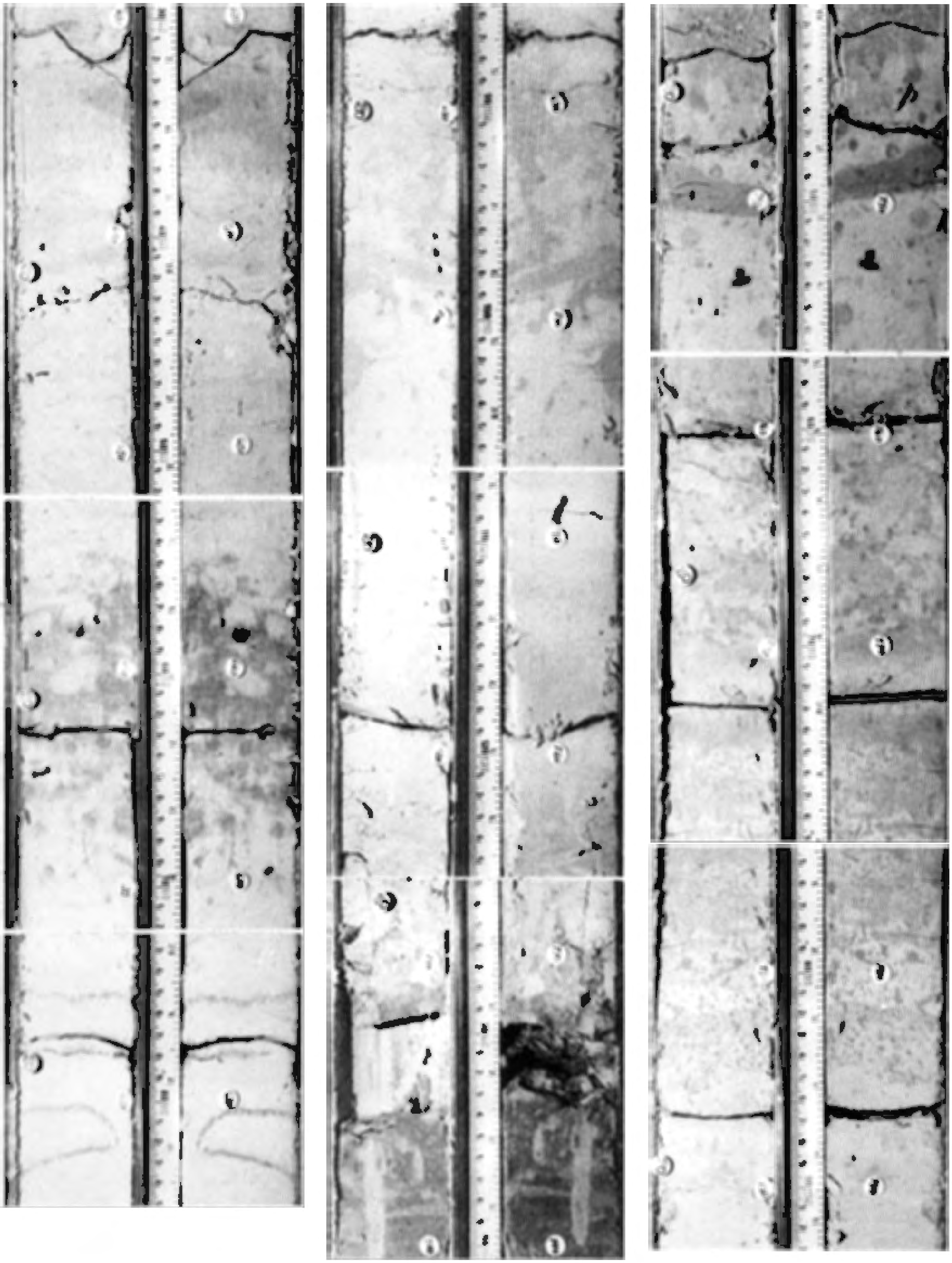

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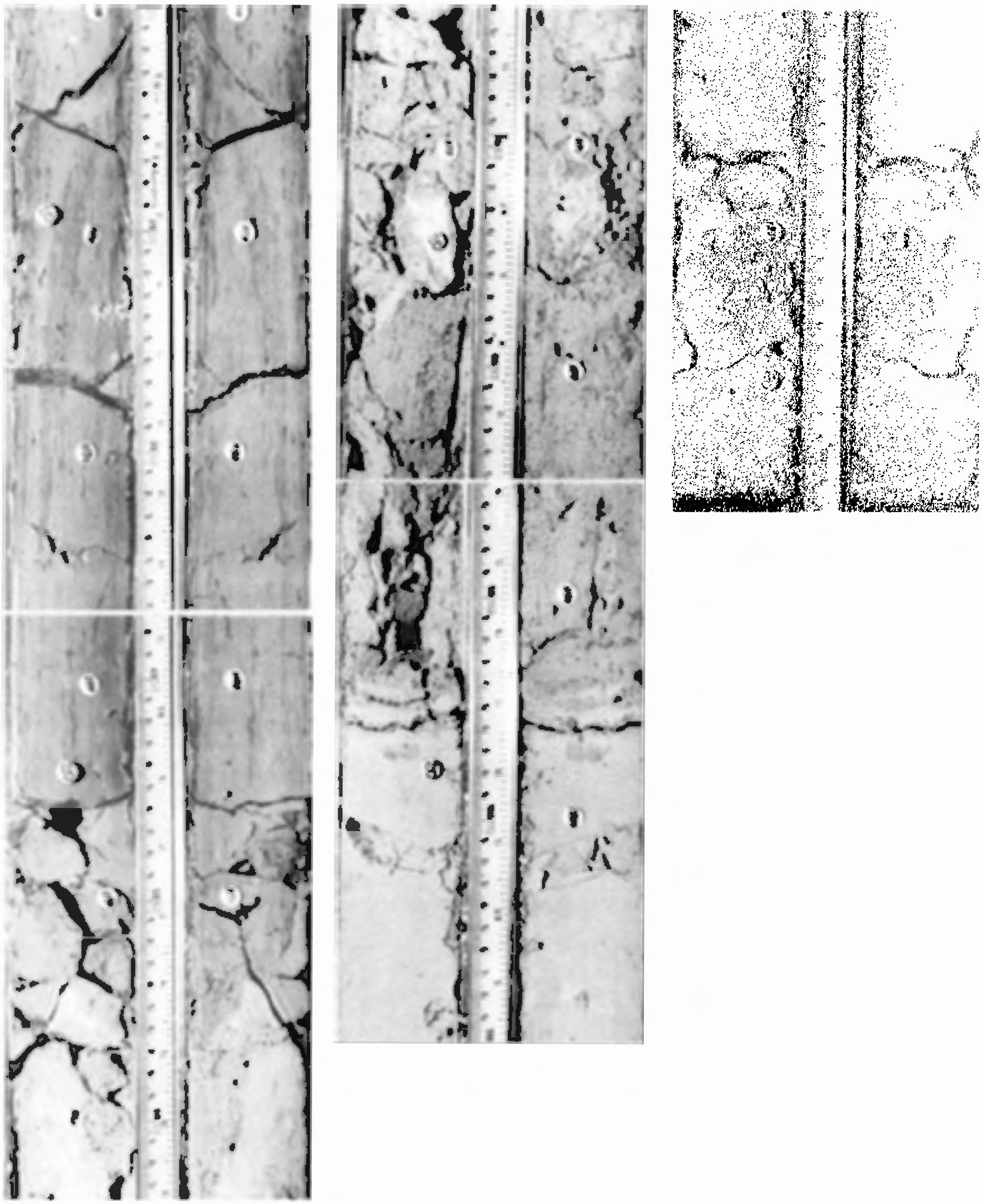
STN 20

STN 20



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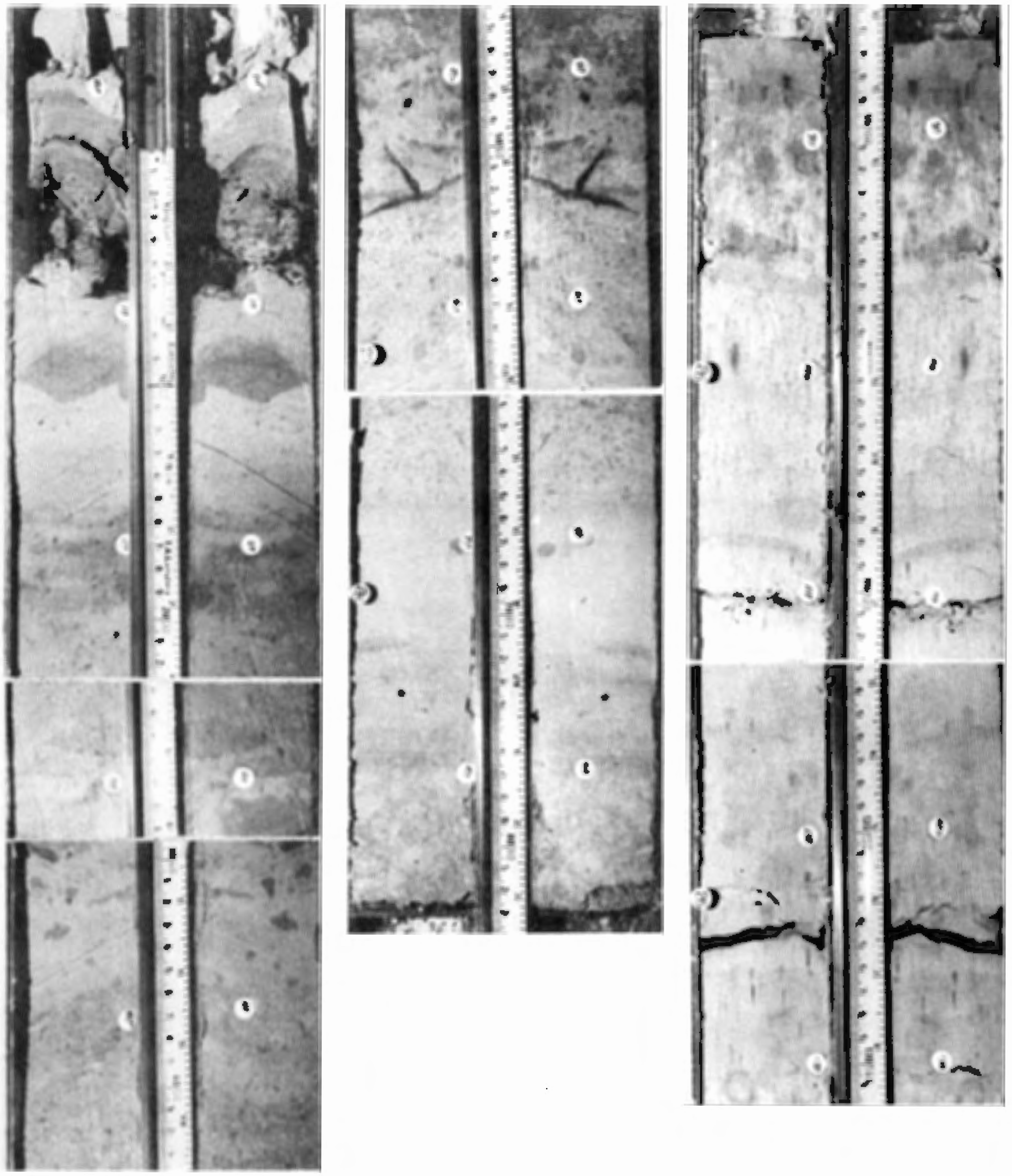

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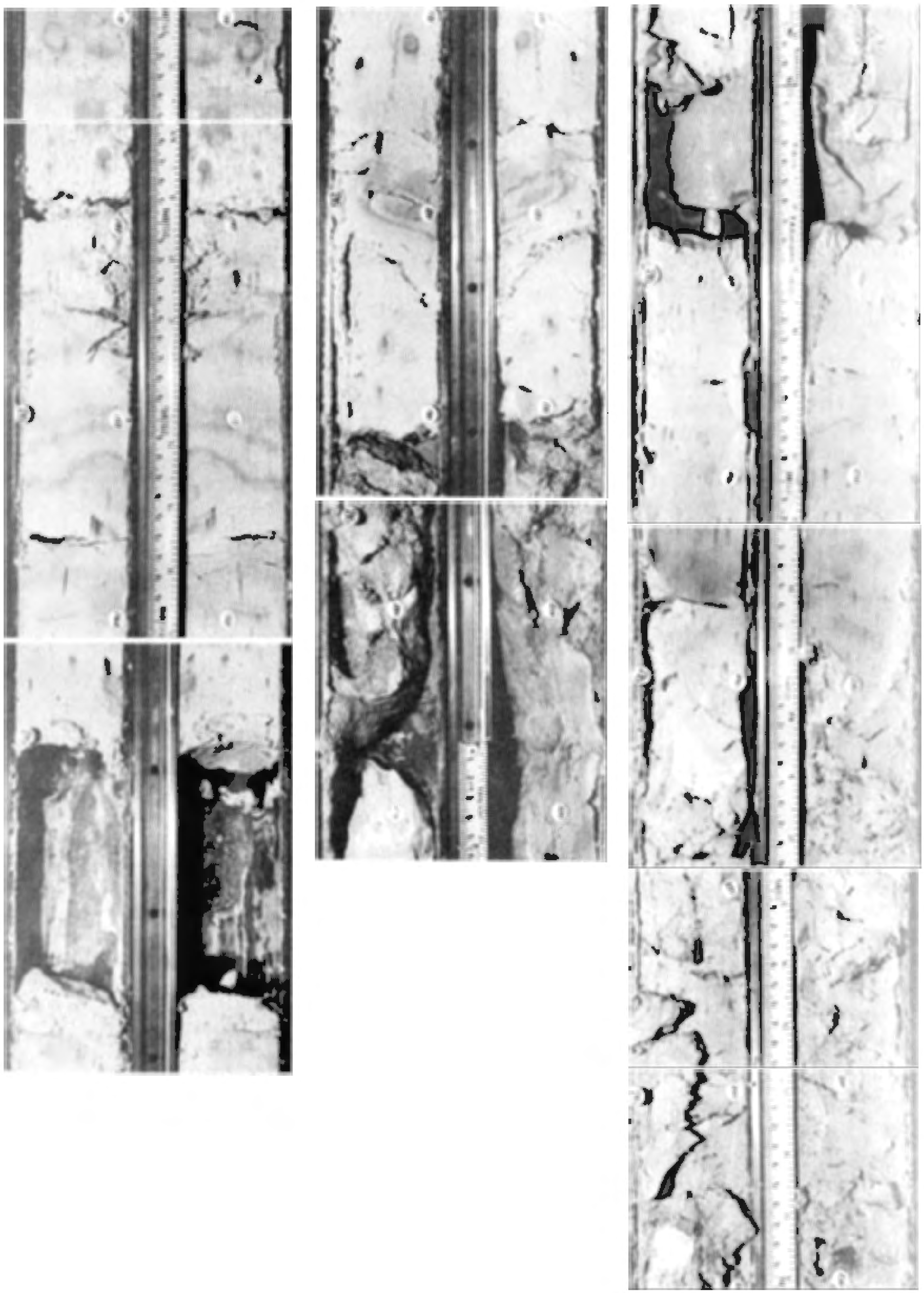

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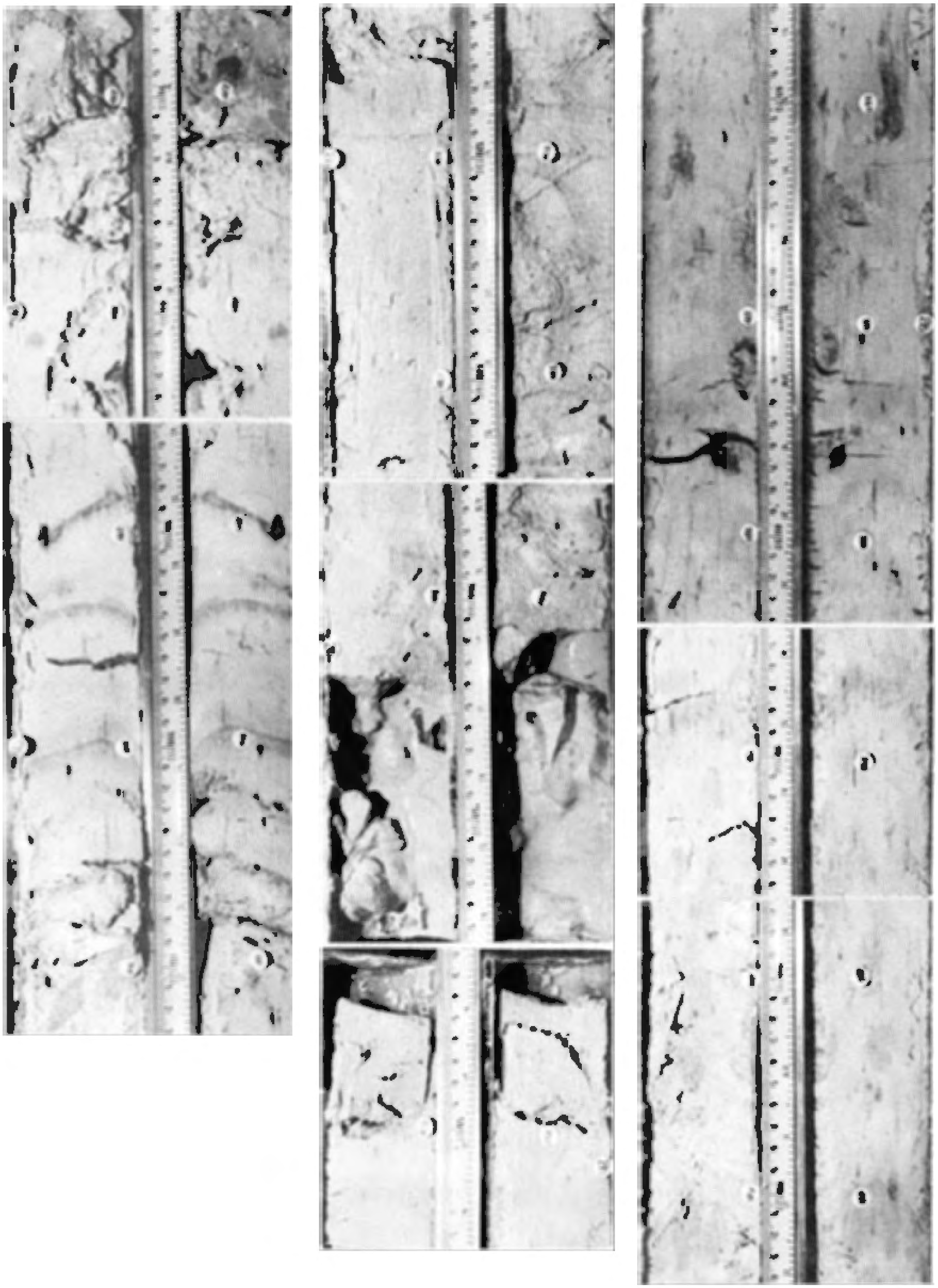

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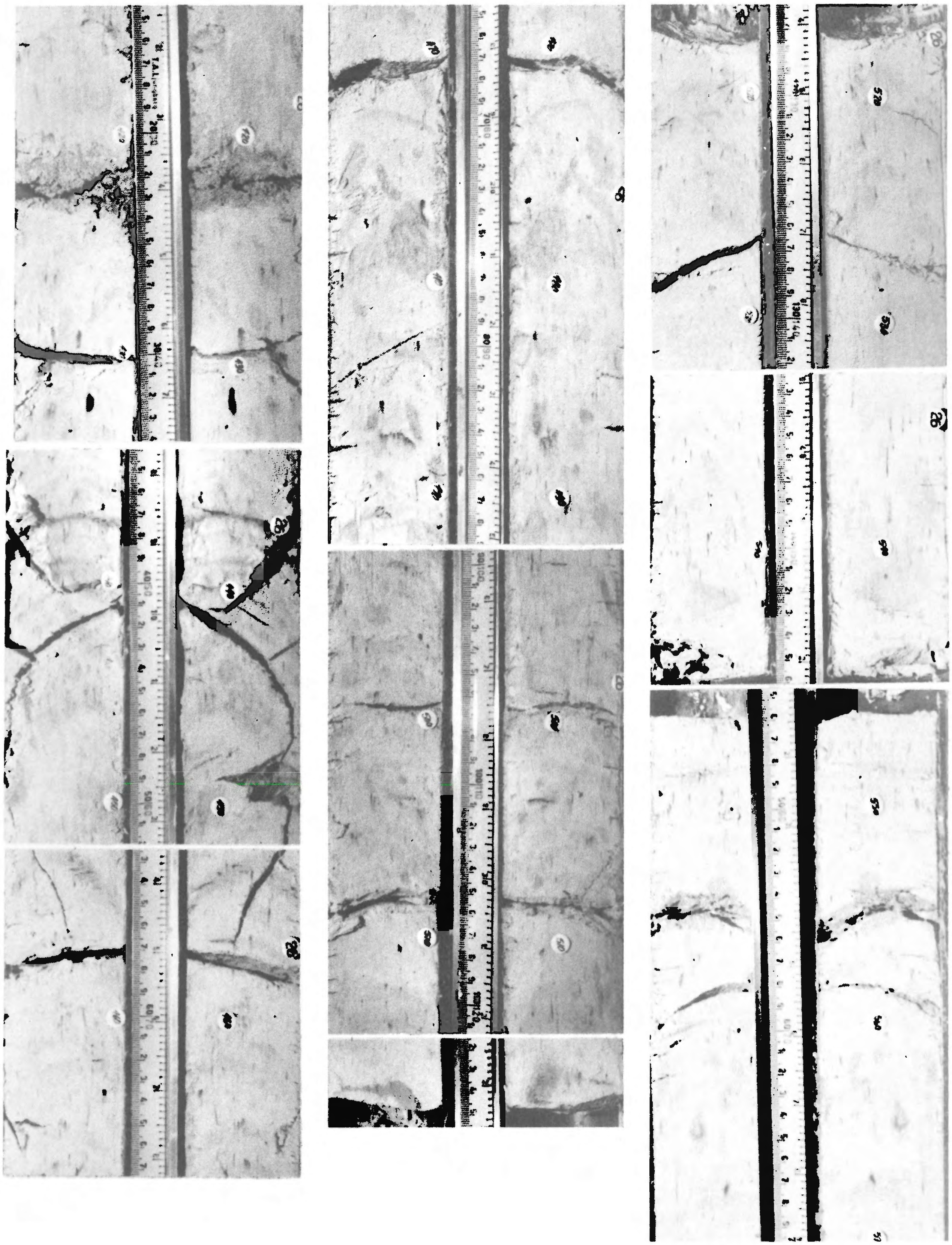

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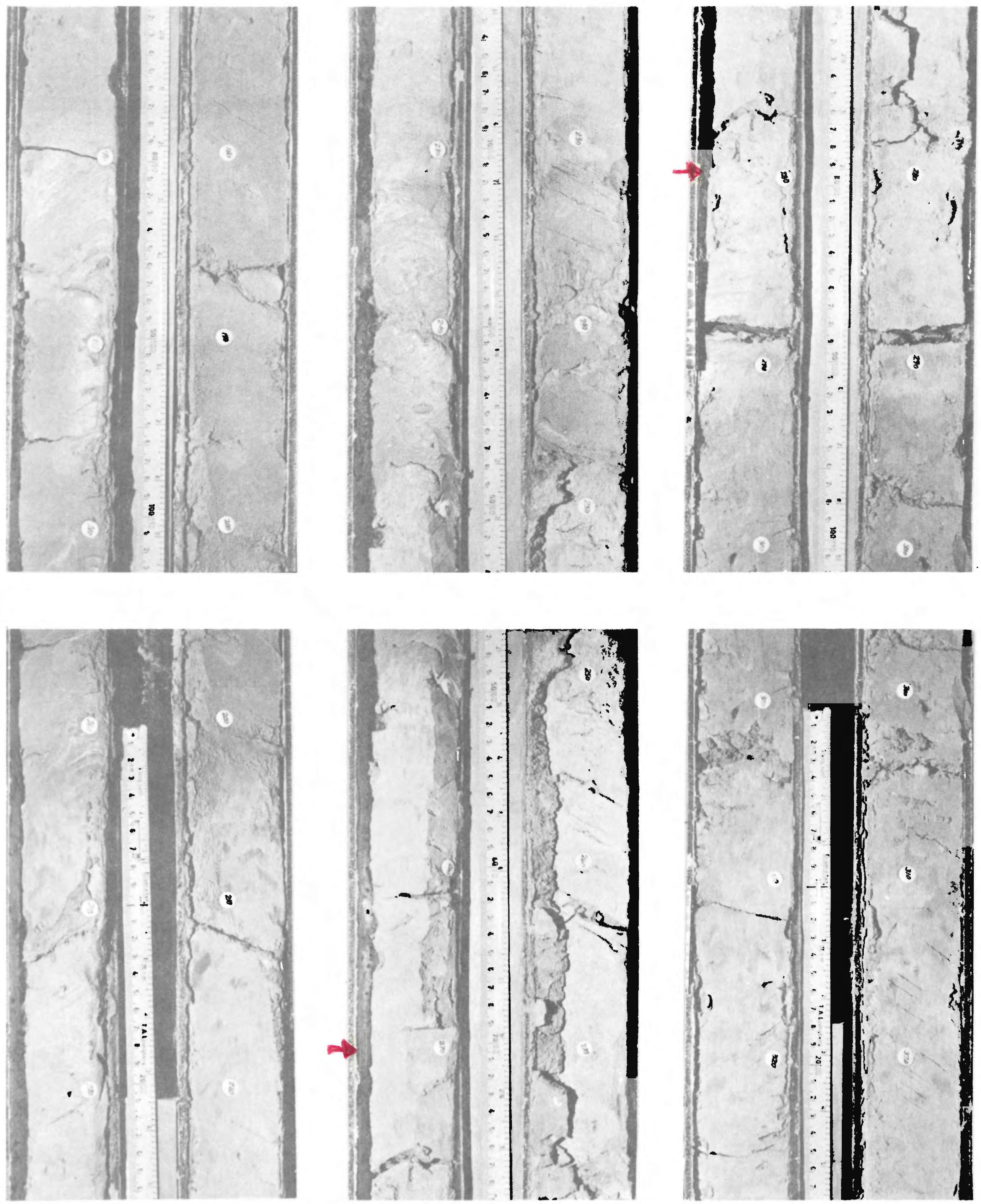
STN 27

STN 27



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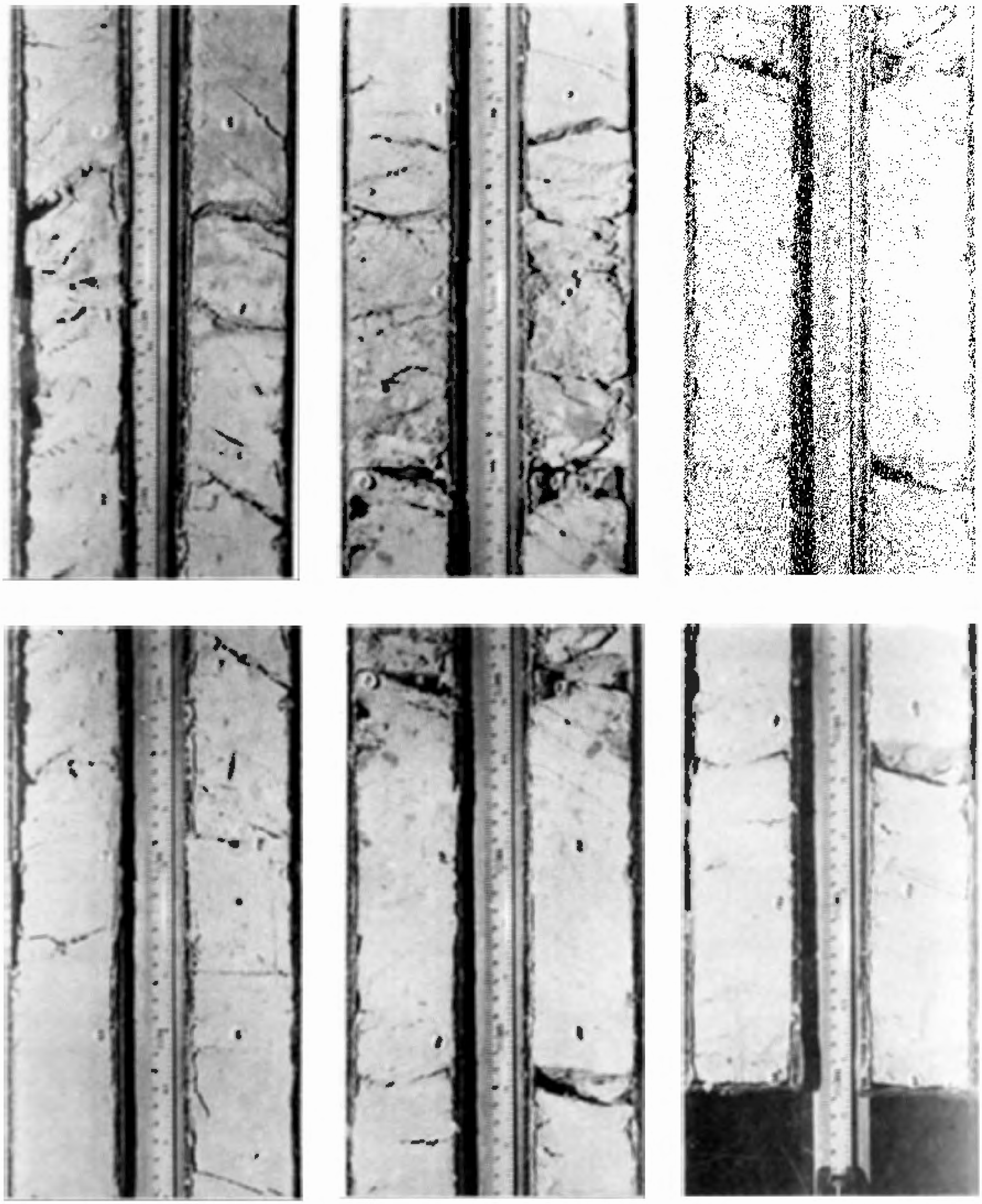

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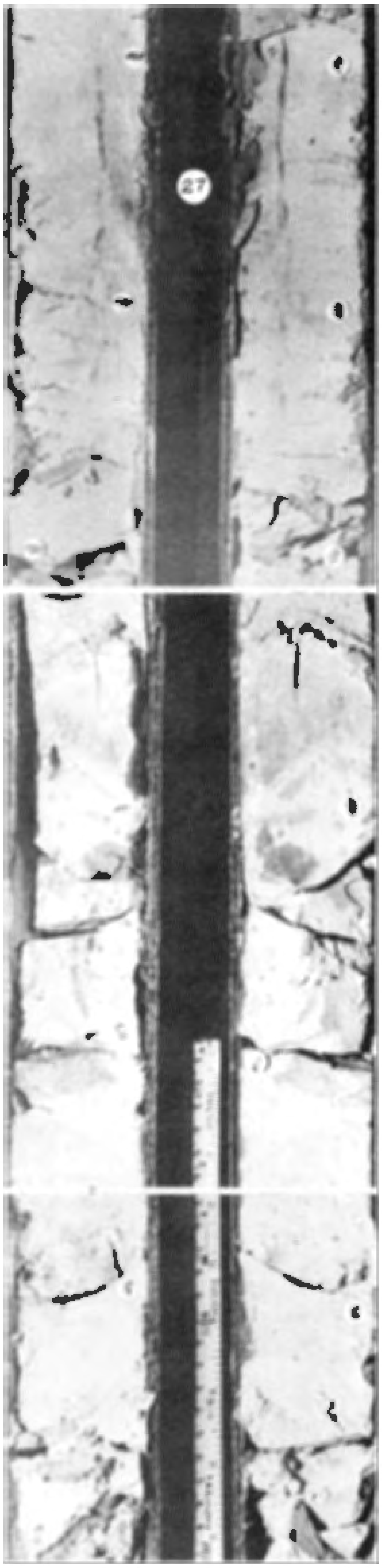

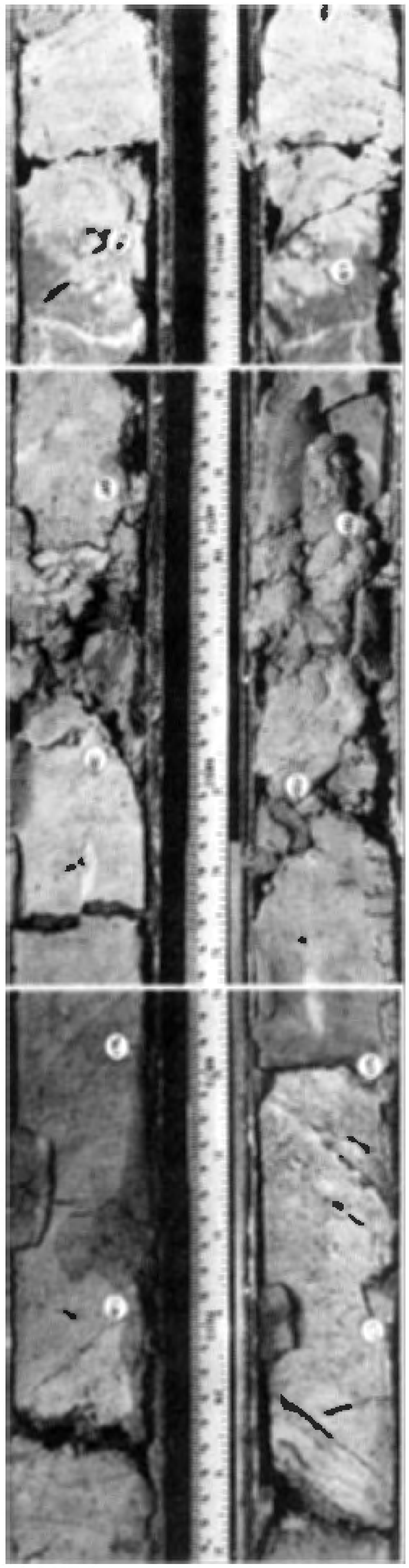

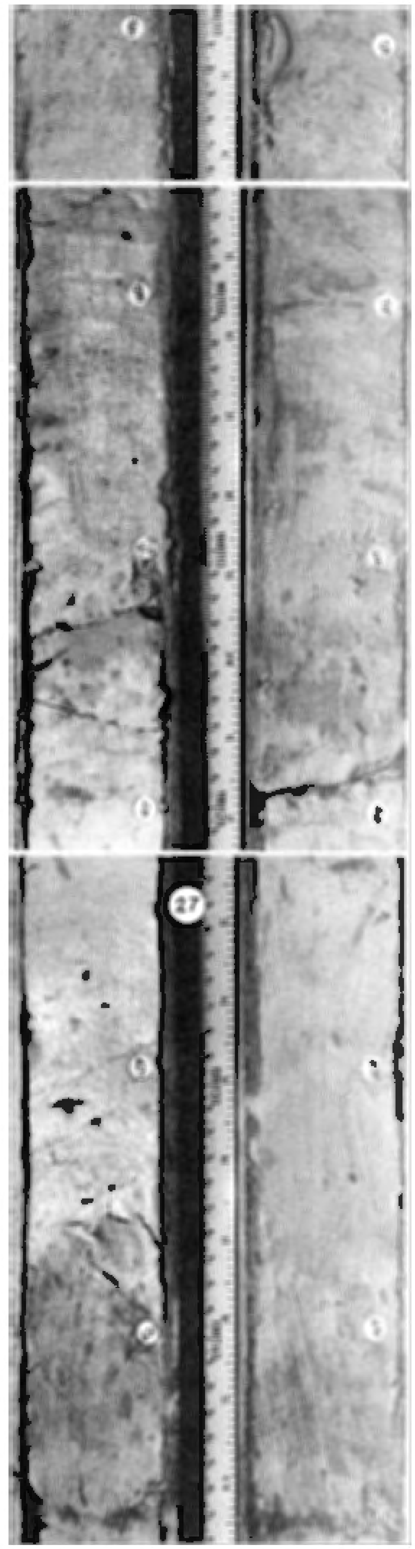

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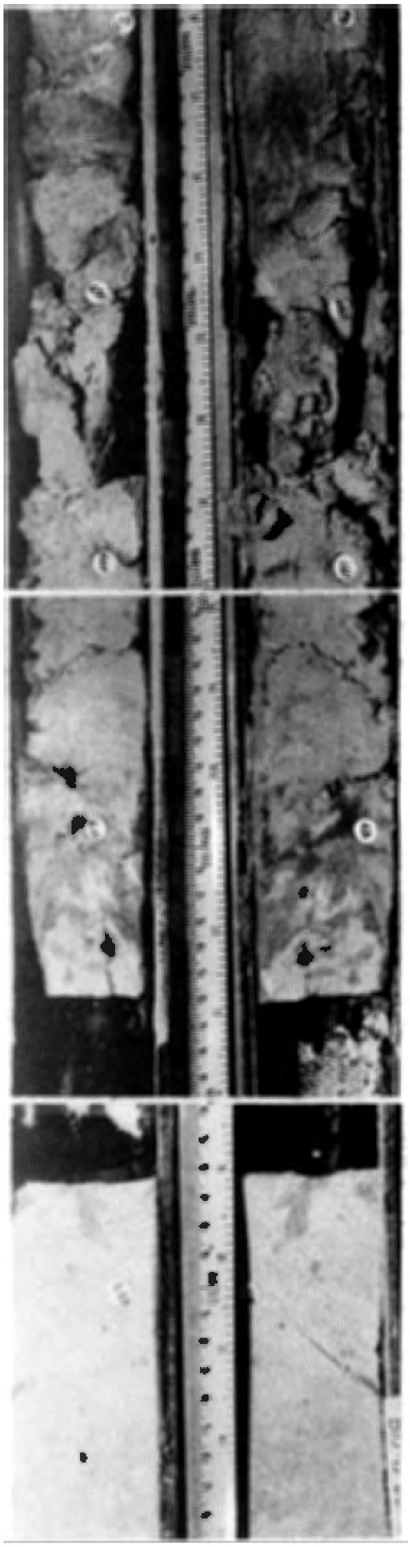

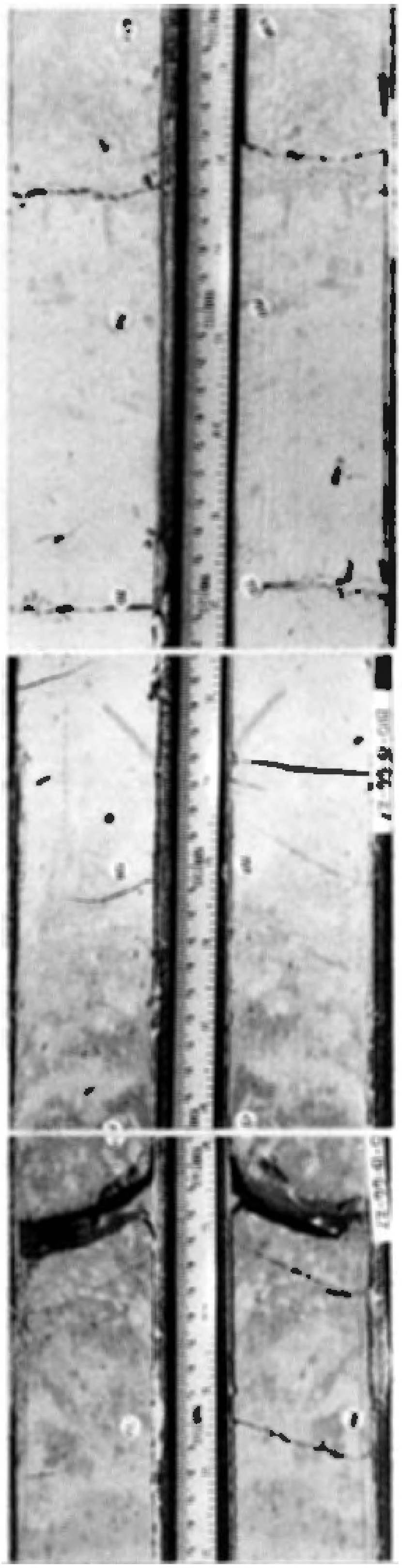

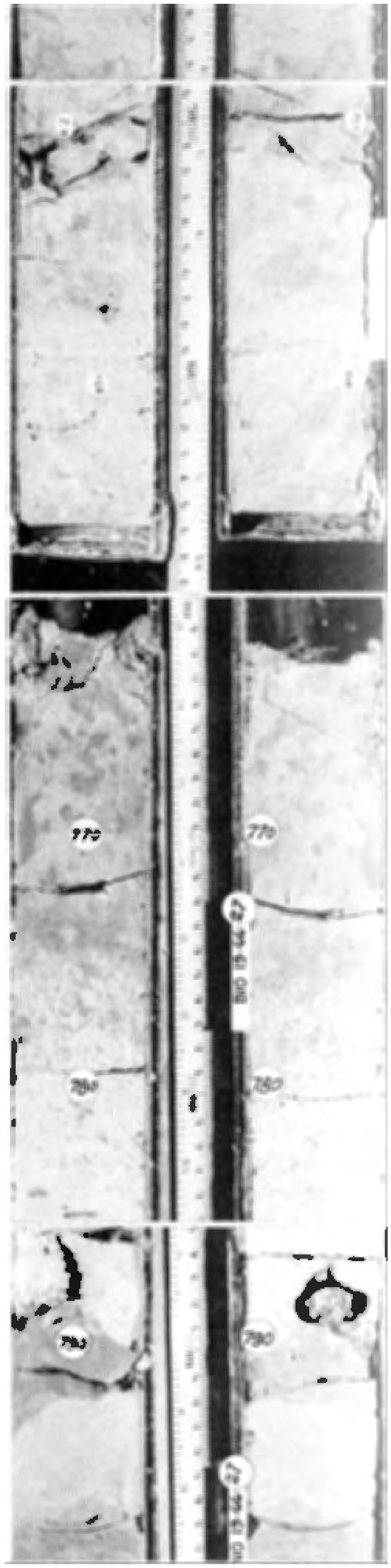

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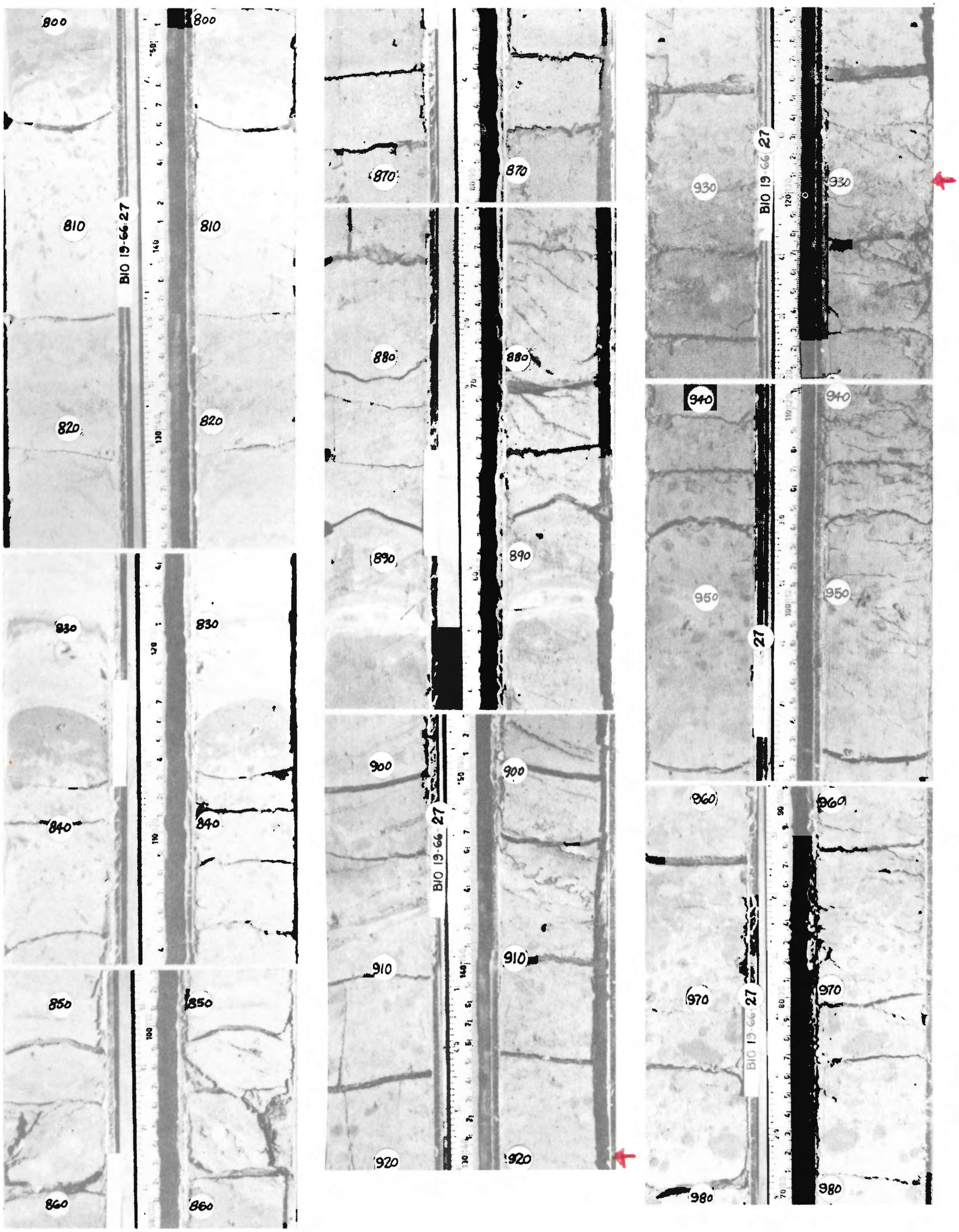


STN 27

STN 27

APPENDIX 2

SIEVE SEPARATION DATA

SIEVE ANALYSIS DATA

Note: The number of asterisks following sample depths indicate the number of gravel-sized pebbles removed from the +62 micron fraction while weighing.

Core: BIO 19-66-12

sample depth, centimeters	+62 micron percentage
0	17
10	20
20	20
30	31
40	20
50	24
60***	26
70**	58
80	35
90	26
100	42
110	21
120	36
130	29
140***	19
150	28
160***	25
170	29
180	19
190	39
200	21
210	25
220	24
230	19
240	25
250	24
260	20
270	11

Core: BIO 19-66-12

sample depth, centimeters	+62 micron percentage
280	9
282	58
286	83
290	38
300	10
310	36
320	32
330	21
340	22
350	46
360	25
370	21
380	26
390	19
400	26
410	17
420	36
430	32
440	22
450	28
460	22
470	17
480	18
490	32
495	55
500	15
510	19

Core: BIO 19-66-15

sample depth, centimeters	+62 micron percentage
10	
20	18
30	24
40	38
50	25

Core: BIO 19-66-15

sample depth, centimeters	+62 micron percentage
60	29
70	26
80	17
90	1

Core: BIO 19-66-17

sample depth, centimeters	+62 micron percentage
0	18
10	17
20	--
30	22
40	44
50	22
60	24
70	34
80	27
90	25
100	23
110	22
120	28
130	24
140	17
150	24
160	31
170	31
180	9
190	24
200	21
203	63
210	43
220	--
226	16
230	18
240	24
250	42
260	24
270	28
280	17
290	11
300	11

Core: BIO 19-66-17

sample depth, centimeters	+62 micron percentage
310	13
320	19
330	24
340	28
350	28
360	37
370	20
380	24
390	44
400	34
410	25
420	20
430	22
440	23
450	43
460	40
470	17
480	18
490	17
500	18
510	27
520	70
522	90
526	94
530	29
540	26
550	26
560	30
570	19
580	16
590	17
600	20
610	21

Core: BIO 19-66-17

sample depth, centimeters	+62 micron percentage
620	23
630	21
640	12
650	11
660	12
670	14
680	15
690	18
700	17
710	24
720	23
730	25
740	23
750	29
755	65
760	74
770	17
780	15
790	16
800	14
810	21

Core: BIO 19-66-17

sample depth, centimeters	+62 micron percentage
820	31
830	26
840	31
850	15
860	17
870	22
880	18
890	22
900	17
910	18
920	24
930	29
940	17
950	21
960	40
970	42
980	24
990	20
1000	17
1010	27

Core: BIO 19-66-18

sample depth, centimeters	+62 micron percentage
10	23
20	26
30	41
40	38
50	20
60**	27
70	9
73	84
80	34
90	32
100	22
110	33
120	32
130	29
140	32
146	29

Core: BIO 19-66-18

sample depth, centimeters	+62 micron percentage
150	21
160*	19
170	23
180**	25
190	34
200	28
210	31
220	32
230	37
240*	28
250	17
260	16
270*	24
280	23
290	12
300	48

Core: BIO 19-66-18

sample depth, centimeters	+62 micron percentage
310	17
320	25
330	46
340	30
347	49
350	16
360	14
370	21
380	19
390	11
400	14
410	41
420	21
430	32
440	23
450	23
460	32
470	28
480	36
490	19
500	34
510	33
520	23
530	28
540	20
550	29
560	30
570	30
580	19
590	23
600	22

Core: BIO 19-66-18

sample depth, centimeters	+62 micron percentage
610	16
620	42
630	34
640	17
650	20
660	20
670	18
680	27
690	31
700	25
710	19
720	13
730	15
740	25
750	21
760	22
770	20
780	26
790	22
800	18
810	22
820	28
830	21
840	19
850	25
860	14
870	23
880	19
890	30
900	1

Core: BIO 19-66-20

sample depth, centimeters	+62 micron percentage
10	14
20	18
30	29
40	23
50	20
60	22
70	12
80	34
90	24
100	22
110	89
120	14
130	31
140	26
150	19
160	20
170	25
180	35
190	25
200	21
210	41
220	22
230	31
240	23
250	21
260	13
270	15
280	20
290	29
300	22
310	17
320	4
326	15
329	39
330	29
340	10
350	33
360	39
370	31
380	30
390	22
400	22
410	25
420*	14
430	29
440	3

Core: BIO 19-66-20

sample depth, centimeters	+62 micron percentage
450	18
460	14
470	21
480	19
490	26
500	30
510	21
520	15
530	19
540	20
550	19
560	15
570	17
580	8
590	21
600	19
610	31
620	28
630	23
640	62
645	57
650	29
660	16
670	29
680	26
690	24
700	21
710	16
720	12
730	24
740	16
745	17
750	25
760	18
770	14
780	25
783	29
790	38
800	23
810	31
820	17
830	41
835	52
840	32
850	21
860	26

Core: BIO 19-66-20

sample depth, centimeters	+62 micron percentage
870	24
880	20
890	19
900	11
910	10
920*	15
930	22
940	16
950	10
960	7
970	7
980	17

Core: BIO 19-66-20

sample depth, centimeters	+62 micron percentage
990	22
1000	4
1010	19
1020	23
1030	15
1040	14
1050	18
1055	37
1060	18
1070	24
1080	21

Core: BIO 19-66-26

sample depth, centimeters	+62 micron percentage
0	--
10	--
20	--
30	18
40	5
50	17
60	14
70	17
80	16
90	15
100	11
110	9
120	7
130	12
140	12
150	11
160	12
170	11
180	11

Core: BIO 19-66-26

sample depth, centimeters	+62 micron percentage
190	16
200	13
210	17
220	26
230	36
240	12
250	8
260	8
270	11
280	12
290	13
300	14
310	10
320	11
330	11
340	5
350	7
360	6
370	6

Core: BIO 19-66-27

sample depth, centimeters	+62 micron percentage
10	17
20	16
30	25
40	35
50	26
60	27
70	31
80	27
90	28
100	22
110	21
120**	34
130	27
140	28
150	29
160	24
170	24
180	21
190	30
200	24
210	25
220	24
230	20
240	23
250	36
260	32
270	16
280	37
290**	21
300	22
310	20
320	18
330	16
340	17
350	28
360	15
370	21
380	21
390	18
400	9
410	22
420	29
430	29
440	3
450	23

Core: BIO 19-66-27

sample depth, centimeters	+62 micron percentage
460	23
470	24
480	30
490	25
500	28
510	22
520	21
530	24
540	42
550	34
560	29
570	25
580	24
590	20
600	32
610	27
620	30
630	38
640	40
650	63
660	35
670	24
680	36
690	29
700	24
710	21
720	19
730	22
740	27
750	24
760	25
770	23
780	27
790	26
800	17
810	26
820	38
830	17
835	20
840	26
850	19
860	26
870	23
880	16
890	14

Core: BIO 19-66-27

sample depth, centimeters	+62 micron percentage
900	20
910	32
920	35
930	33
940	33
950	23
960	22
970	39
980	40
990	28
1000	39
1010	47
1020	39
1030	26
1040	30
1050	32
1060	15
1070	28
1080	14
1090	19

Core: BIO 19-66-27

sample depth, centimeters	+62 micron percentage
1100	26
1110	30
1120	31
1130	27
1140	25
1150	21
1160	22
1170	26
1180	51
1190	17
1200	20
1210	16
1220	24
1230	15
1240	26
1250	19
1260	14
1270	19
1280	19

Core: BIO 19-66-50

sample depth, centimeters	+62 micron percentage
20	15
30	22
40	18
50	33
60	42
70	36
73	47
80	15

Core: BIO 19-66-50

sample depth, centimeters	+62 micron percentage
90	10
100	13
110	15
120	20
130	17
140	45
150	38
160	10

APPENDIX 3

FORTRAN PROGRAM FOR CALCULATION OF CARBONATE PERCENTAGE

```
**GEORGES DRAPEAU    CARBONATE CONTENT OF SEDIMENTS
C     TAIL DATA CARD MUST HAVE SAMPLE NUMBER  000.000
C     PAN = PAN WEIGHT
C     SUL = QUANTITY OF H2SO4 USED TO DISSOLVE THE SAMPLE
C     RW = SAMPLE WEIGHT PLUS PAN WEIGHT
C     SULN = NORMALITY OF H2SO4
C     SOD = QUANTITY OF NAOH
C     SODN = NORMALITY OF NAOH
C     SUFR = QUANTITY OF SOLUTE USED FOR TITRATION
C     CARB = CACO3 PER CENT CONTENT
C     CO2 = CO2 PER CENT CONTENT
C     IC = 1   SUL = 50.0
C     IC = 2   SUL = 75.0
C     IC = 3   SUL =100.0
C     IC = 4   SUL =125.0
C     IC = 5   SUL =150.0
C     IC = 6   SUL =175.0
C     IC = 7   SUL =200.0
C     IC = 8   SUL =225.0
C     IC = 9   SUL =250.0
C     AND SO ON BY INCREMENT OF 25.0
C     SENSE SWITCH 1 ON FOR SUFR = SUL
C     PUNCH A DUMMY VALUE FOR SUFR IF NO REAL VALUES ARE USED
      READ 1,PAN,SULN,SODN,SUFR,CAREQ,CO2EQ
    1 FORMAT(6F10.4)
      PUNCH 20
   20 FORMAT(32H  CARBONATE CONTENT OF SEDIMENTS)
      PUNCH 49
      PUNCH 49
   49 FORMAT(49X)
      PUNCH 21
   21 FORMAT(44H  SAMPLE NUMBER  CACO3 PERCENT  CO2 PERCENT )
      PUNCH 49
  100 READ 2,SAMP,RW,SOD,IC
    2 FORMAT(3F10.4,3X,I2)
      IF (SAMP)30,30,3
    3 QUA=IC
      SUL = 25.0+25.0*QUA
      W=RW-PAN
      IF(SENSE SWITCH 1)5,15
    5 SUFR =SUL
   15 CARB=100.*(SUL/SUFR)*((SUL*SULN)-(SOD*SODN))*CAREQ/W
      CO2 =100.*(SUL/SUFR)*((SUL*SULN)-(SOD*SODN))*CO2EQ/W
      PUNCH 22,SAMP,CARB,CO2
   22 FORMAT(2X,F10.4,5X,F10.2,5X,F10.2)
      GO TO 100
   30 STOP
      END
```

APPENDIX 4

PERCENTAGE CARBONATE IN -62 MICRON FRACTION

CARBONATE ANALYSES

CORE BIO 19.66.12

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
12.0000	82.61	36.35
12.0010	82.89	36.47
12.0020	77.44	34.07
12.0030	68.36	30.08
12.0040	55.33	24.34
12.0050	48.46	21.32
12.0060	39.44	17.35
12.0070	47.46	20.88
12.0080	46.00	20.24
12.0090	49.40	21.73
12.0100	23.09	10.16
12.0110	14.99	6.59
12.0120	29.05	12.78
12.0130	39.87	17.54
12.0140	39.26	17.27
12.0150	38.84	17.09
12.0160	34.10	15.00
12.0170	44.43	19.55
12.0180	41.74	18.36
12.0190	47.30	20.81
12.0200	56.19	24.72
12.0210	55.54	24.43
12.0220	30.67	13.49
12.0230	27.17	11.95
12.0240	59.91	26.36
12.0250	74.05	32.58
12.0260	84.67	37.25
12.0270	78.46	34.52
12.0280	73.14	32.18
12.0290	75.05	33.02
12.0300	74.01	32.56
12.0310	87.24	38.38
12.0320	86.47	38.05
12.0330	84.24	37.06
12.0340	77.61	34.14
12.0350	74.72	32.87
12.0360	85.52	37.63
12.0370	85.35	37.55
12.0380	86.08	37.87
12.0390	87.32	38.42
12.0400	80.68	35.50
12.0410	34.68	15.26
12.0420	47.03	20.69
12.0430	46.09	20.27
12.0440	30.58	13.45
12.0450	17.97	7.90
12.0460	37.22	16.37

CARBONATE ANALYSES

CORE BIO 19.66.12

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
12.0470	42.68	18.78
12.0480	46.74	20.56
12.0490	72.54	31.92
12.0500	85.31	37.53
12.0510	87.30	38.41

CARBONATE ANALYSES

CORE BIO 19.66.15

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
15.0010	86.20	37.93
15.0030	77.98	34.31
15.0040	46.12	20.29
15.0050	46.56	20.48
15.0060	46.74	20.56
15.0070	53.99	23.75
15.0080	36.93	16.25
15.0090	66.59	29.30

CARBONATE ANALYSES

CORE BIO 19.66.17

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
17.0000	86.76	38.17
17.0010	85.94	37.81
17.0030	76.88	33.82
17.0040	67.80	29.83
17.0050	49.36	21.71
17.0060	50.33	22.14
17.0070	31.65	13.92
17.0080	40.13	17.65
17.0090	47.80	21.03
17.0100	46.89	20.63
17.0110	49.02	21.57
17.0120	28.51	12.54
17.0130	35.68	15.70
17.0140	22.86	10.06
17.0150	16.69	7.34
17.0160	39.76	17.49
17.0170	44.96	19.78
17.0180	44.42	19.54
17.0190	40.48	17.81
17.0200	34.05	14.98
17.0203	29.28	12.88
17.0210	50.88	22.38
17.0220	52.38	23.04
17.0226	48.09	21.16
17.0230	38.34	16.87
17.0240	32.89	14.47
17.0250	71.36	31.39
17.0260	39.60	17.42
17.0270	45.13	19.86
17.0280	27.21	11.97
17.0290	34.71	15.27
17.0300	41.42	18.22
17.0310	58.02	25.53
17.0320	65.54	28.83
17.0330	63.13	27.78
17.0340	85.93	37.81
17.0350	87.30	38.41
17.0360	86.34	37.99
17.0370	70.46	31.00
17.0380	84.24	37.06
17.0390	90.12	39.65
17.0400	87.39	38.45
17.0410	87.28	38.40
17.0420	86.93	38.25
17.0430	83.03	36.53
17.0440	81.05	35.66
17.0450	78.39	34.49

CARBONATE ANALYSES

CORE BIO 19.66.17

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
17.0460	84.33	37.10
17.0470	86.72	38.15
17.0480	88.10	38.76
17.0490	87.54	38.52
17.0500	88.81	39.07
17.0510	82.86	36.46
17.0520	69.84	30.73
17.0530	32.10	14.12
17.0540	42.17	18.55
17.0550	56.64	24.92
17.0560	55.23	24.30
17.0570	50.36	22.15
17.0580	51.43	22.62
17.0590	44.48	19.57
17.0600	37.78	16.62
17.0610	30.10	13.24
17.0620	17.49	7.69
17.0630	28.34	12.47
17.0640	38.04	16.74
17.0650	55.25	24.31
17.0660	54.40	23.93
17.0670	42.68	18.78
17.0680	52.63	23.16
17.0690	46.62	20.51
17.0700	69.89	30.75
17.0710	74.62	32.83
17.0720	75.34	33.15
17.0730	66.65	29.32
17.0740	65.72	28.91
17.0750	56.49	24.85
17.0755	52.77	23.21
17.0760	65.77	28.94
17.0770	58.82	25.88
17.0780	60.44	26.59
17.0790	76.55	33.68
17.0800	86.14	37.90
17.0810	87.25	38.39
17.0820	82.44	36.27
17.0830	87.81	38.64
17.0840	85.36	37.56
17.0850	83.72	36.84
17.0860	78.71	34.63
17.0870	60.16	24.06
17.0880	49.07	19.62
17.0890	63.64	25.45
17.0900	62.71	25.08
17.0910	54.48	21.79

CARBONATE ANALYSES

CORE BIO 19.66.17

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
17.0920	76.22	30.48
17.0930	83.19	33.27
17.0940	86.74	34.69
17.0950	82.44	32.97
17.0960	52.59	21.03
17.0970	58.50	23.40
17.0980	53.05	21.22
17.0990	41.96	16.78
17.1000	43.76	17.50
17.1010	43.09	17.23

CARBONATE ANALYSES

CORE BIO 19.66.18

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
18.0010	81.43	35.82
18.0020	79.67	35.05
18.0030	73.16	32.19
18.0040	54.09	23.80
18.0050	49.49	21.77
18.0060	45.37	19.96
18.0070	44.20	19.44
18.0080	42.27	18.60
18.0090	43.79	19.27
18.0100	50.55	22.24
18.0110	27.61	12.15
18.0120	28.97	12.74
18.0130	18.83	8.28
18.0140	29.91	13.16
18.0146	38.57	16.97
18.0150	41.89	18.43
18.0160	39.50	17.38
18.0170	40.99	18.03
18.0180	38.28	16.84
18.0190	39.63	17.44
18.0200	72.08	31.71
18.0210	46.44	20.43
18.0220	49.13	21.61
18.0230	45.87	20.18
18.0240	71.44	31.43
18.0250	50.61	22.27
18.0260	73.31	32.25
18.0270	69.83	30.72
18.0280	67.34	29.63
18.0290	73.19	32.20
18.0300	70.98	31.23
18.0310	72.69	31.98
18.0320	73.16	32.19
18.0330	72.19	31.76
18.0340	72.30	31.81
18.0347	71.20	31.32
18.0350	73.39	32.29
18.0360	73.44	32.31
18.0370	70.95	31.22
18.0380	63.91	28.12
18.0390	66.91	29.44
18.0400	68.28	30.04
18.0410	44.73	19.68
18.0420	50.70	22.30
18.0430	46.63	20.51
18.0440	46.14	20.30
18.0450	46.17	20.31

CARBONATE ANALYSES

CORE BIO 19.66.18

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
18.0460	51.90	22.83
18.0470	46.83	20.60
18.0480	47.68	20.98
18.0490	50.11	22.04
18.0500	48.73	21.44
18.0510	52.92	23.28
18.0520	86.07	37.87
18.0530	83.59	36.78
18.0540	81.27	35.76
18.0550	75.97	33.42
18.0560	73.58	32.37
18.0570	68.00	29.92
18.0580	79.90	35.15
18.0590	81.62	35.91
18.0600	86.23	37.94
18.0630	83.88	36.90
18.0640	84.08	36.99
18.0650	86.48	38.05
18.0660	86.17	37.91
18.0670	87.64	38.56
18.0680	86.23	37.94
18.0690	90.22	39.69
18.0700	87.86	38.66
18.0710	87.55	38.52
18.0720	87.94	38.69
18.0730	87.96	38.70
18.0740	86.29	37.97
18.0750	85.70	37.71
18.0760	86.23	37.94
18.0770	85.40	37.57
18.0780	86.07	37.87
18.0790	84.89	37.35
18.0800	82.04	36.09
18.0810	80.71	35.51
18.0820	61.04	26.86
18.0830	32.88	14.47
18.0840	33.86	14.90
18.0850	26.06	11.46
18.0860	85.82	37.76
18.0870	84.36	37.11
18.0880	86.26	37.95
18.0890	80.64	35.48
18.0900	88.70	39.03

CARBONATE ANALYSES

CORE BIO 19.66.20

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
20.0010	84.94	33.97
20.0020	80.42	32.16
20.0030	68.86	27.54
20.0040	57.17	22.87
20.0050	48.31	19.32
20.0060	55.39	22.15
20.0070	46.38	18.55
20.0080	43.37	17.35
20.0090	47.97	19.18
20.0100	50.49	20.19
20.0110	26.68	10.67
20.0120	11.93	5.25
20.0130	30.12	12.04
20.0140	39.35	15.74
20.0150	39.65	15.86
20.0160	40.17	16.07
20.0170	40.22	16.08
20.0180	45.00	18.00
20.0190	48.36	19.34
20.0200	37.95	15.18
20.0210	55.11	22.04
20.0220	54.22	21.68
20.0230	45.86	18.34
20.0240	46.17	18.47
20.0250	30.94	12.37
20.0260	34.78	13.91
20.0270	57.50	23.00
20.0280	63.47	25.38
20.0290	79.62	31.85
20.0300	86.60	34.64
20.0310	86.61	34.64
20.0320	74.33	29.73
20.0326	70.19	28.07
20.0329	67.56	27.02
20.0330	76.17	30.47
20.0340	64.11	25.64
20.0350	83.78	33.51
20.0360	84.68	33.87
20.0370	84.36	33.74
20.0380	84.73	33.89
20.0390	83.21	33.28
20.0400	80.71	32.28
20.0410	70.38	28.15
20.0420	85.07	34.03
20.0430	83.44	33.37
20.0440	88.48	35.39
20.0450	88.72	35.49

CARBONATE ANALYSES

CORE BIO 19.66.20

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
20.0460	87.63	35.05
20.0470	76.06	30.42
20.0480	38.50	15.40
20.0490	30.80	12.32
20.0500	54.12	21.64
20.0510	45.73	18.29
20.0520	35.85	14.34
20.0530	20.45	8.18
20.0540	17.72	7.09
20.0550	24.89	9.95
20.0560	42.44	16.97
20.0570	35.48	14.19
20.0580	45.95	18.38
20.0590	65.84	26.33
20.0600	77.79	31.11
20.0610	59.19	23.67
20.0620	55.34	22.13
20.0630	43.09	17.23
20.0640	62.41	24.96
20.0645	62.91	25.16
20.0650	60.65	24.26
20.0660	45.46	18.18
20.0670	73.67	29.46
20.0680	84.47	33.78
20.0690	79.18	31.67
20.0700	82.11	32.84
20.0710	82.69	33.07
20.0720	72.95	29.18
20.0730	71.59	28.63
20.0740	35.23	14.09
20.0745	44.03	17.61
20.0750	35.26	14.10
20.0760	53.56	21.42
20.0770	50.43	20.17
20.0780	69.77	27.91
20.0783	73.94	29.57
20.0790	81.20	32.48
20.0800	77.23	30.89
20.0810	45.75	18.30
20.0820	57.42	22.97
20.0830	48.36	19.34
20.0835	51.90	20.76
20.0840	49.91	19.96
20.0850	39.39	15.75
20.0860	40.91	16.36
20.0870	56.34	22.53
20.0880	38.89	15.55

CARBONATE ANALYSES

CORE BIO 19.66.20

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
20.0890	19.68	7.87
20.0900	18.30	7.32
20.0910	33.78	13.51
20.0920	62.57	27.53
20.0930	75.06	30.02
20.0940	90.22	36.08
20.0950	67.12	26.84
20.0960	81.69	32.67
20.0970	72.80	29.12
20.0980	87.37	34.95
20.0990	77.73	31.09
20.1000	89.54	35.81
20.1010	80.72	32.29
20.1020	87.57	35.03
20.1030	83.85	33.54
20.1040	89.57	35.82
20.1050	16.09	6.43
20.1055	12.69	5.07
20.1060	10.78	4.31
20.1070	64.12	25.65
20.1080	27.50	11.00

CARBONATE ANALYSES

CORE BIO 19.66.26

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
26.0000	88.59	38.98
26.0010	55.67	24.49
26.0020	24.50	10.78
26.0030	33.43	14.70
26.0040	32.99	14.51
26.0050	40.79	17.94
26.0060	56.45	24.83
26.0070	74.68	32.85
26.0080	57.84	25.45
26.0090	52.09	22.92
26.0100	80.09	35.24
26.0110	82.11	36.13
26.0120	71.77	31.58
26.0130	62.53	27.51
26.0140	82.43	36.27
26.0150	82.64	36.36
26.0160	88.25	38.83
26.0170	89.84	39.53
26.0180	89.74	39.48
26.0190	88.54	38.96
26.0200	84.94	37.37
26.0210	85.97	37.82
26.0220	85.15	37.46
26.0230	85.43	37.59
26.0240	83.43	36.71
26.0250	76.68	33.74
26.0260	66.77	29.38
26.0270	64.52	28.39
26.0280	86.42	38.02
26.0290	86.06	37.86
26.0300	85.63	37.67
26.0310	84.23	37.06
26.0320	85.27	37.52
26.0330	84.75	37.29
26.0340	85.33	37.54

CARBONATE ANALYSES

CORE BIO 19.66.27

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
27.0010	82.16	36.15
27.0020	77.87	34.26
27.0030	72.88	32.06
27.0040	55.30	24.33
27.0050	52.15	22.94
27.0060	46.64	20.52
27.0070	49.89	21.95
27.0080	30.30	13.33
27.0090	43.34	19.07
27.0100	46.47	20.44
27.0110	49.03	21.57
27.0120	32.63	14.35
27.0130	26.13	11.49
27.0140	18.14	7.98
27.0150	30.31	13.33
27.0160	39.65	17.44
27.0170	46.06	20.26
27.0180	39.58	17.41
27.0190	41.49	18.25
27.0200	40.32	17.74
27.0210	48.90	21.51
27.0220	51.44	22.63
27.0230	36.85	16.21
27.0240	38.96	17.14
27.0250	55.96	24.62
27.0260	68.78	30.26
27.0270	55.04	24.22
27.0280	53.62	23.59
27.0290	48.31	21.25
27.0300	22.08	9.71
27.0310	34.24	15.06
27.0320	52.75	23.21
27.0330	58.06	25.54
27.0340	77.31	34.01
27.0350	82.96	36.50
27.0360	88.34	38.87
27.0370	84.74	37.28
27.0380	81.44	35.83
27.0390	69.16	30.43
27.0400	82.47	36.28
27.0410	87.04	38.29
27.0420	85.17	37.47
27.0430	84.39	37.13
27.0440	86.66	38.13
27.0450	86.36	37.99
27.0460	82.94	36.49
27.0470	81.41	35.82

CARBONATE ANALYSES

CORE BIO 19.66.27

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
27.0480	78.57	34.57
27.0490	82.78	36.42
27.0500	84.34	37.11
27.0510	83.69	36.82
27.0520	84.13	37.01
27.0530	45.13	19.85
27.0540	46.74	20.56
27.0550	34.73	15.28
27.0560	13.32	5.86
27.0570	22.33	9.82
27.0580	32.66	14.37
27.0590	41.64	18.32
27.0600	44.73	19.68
27.0610	73.22	32.21
27.0620	61.76	27.17
27.0630	39.72	17.48
27.0640	48.43	21.31
27.0650	54.12	23.81
27.0660	60.04	26.41
27.0670	43.94	19.33
27.0680	80.54	35.43
27.0690	79.53	34.99
27.0700	83.27	36.64
27.0710	80.50	35.42
27.0720	78.20	34.41
27.0730	39.97	17.59
27.0740	46.67	20.53
27.0750	46.14	20.30
27.0760	56.29	24.76
27.0770	48.34	21.27
27.0780	70.86	31.18
27.0790	77.84	34.25
27.0800	41.87	18.42
27.0810	60.65	26.68
27.0820	59.13	26.01
27.0830	45.03	19.81
27.0835	24.23	10.66
27.0840	56.87	25.02
27.0850	63.23	27.82
27.0860	25.60	11.26
27.0870	19.01	8.36
27.0880	24.22	10.66
27.0890	29.21	12.85
27.0900	21.15	9.30
27.0910	35.88	15.79
27.0920	44.25	19.47
27.0930	29.28	12.88

CARBONATE ANALYSES

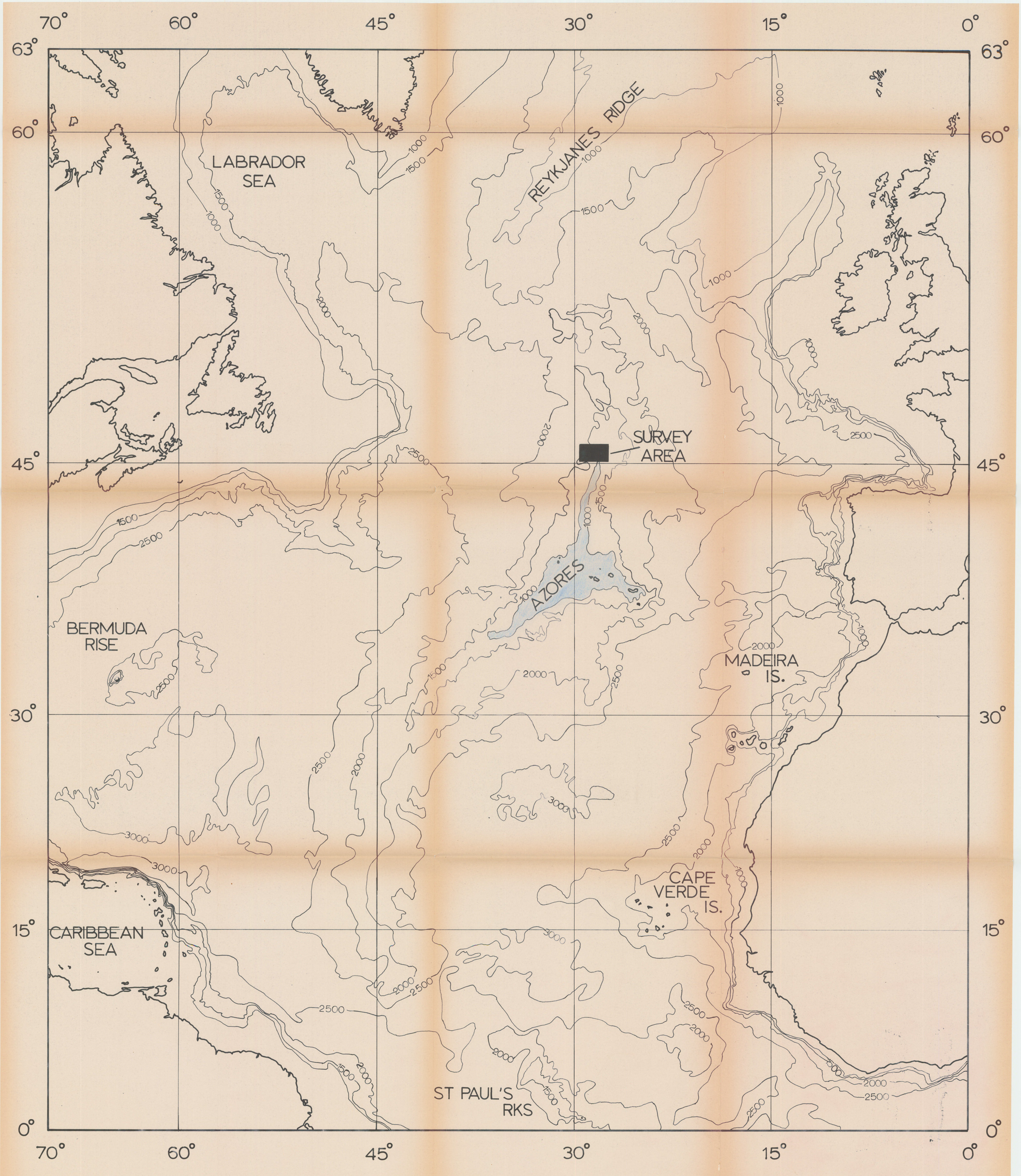
CORE BIO 19.66.27

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
27.0940	14.23	6.26
27.0950	31.75	13.97
27.0960	45.71	20.11
27.0970	46.51	20.46
27.0980	67.74	29.80
27.0990	69.10	30.40
27.1000	39.09	17.20
27.1010	43.21	19.01
27.1020	60.82	26.76
27.1030	51.64	22.72
27.1040	83.17	36.59
27.1050	75.73	33.32
27.1060	85.40	37.57
27.1070	83.00	36.52
27.1080	71.94	31.65
27.1090	41.24	18.14
27.1100	34.67	15.25
27.1110	44.87	19.74
27.1120	69.15	30.42
27.1130	80.22	35.29
27.1140	59.50	26.18
27.1150	47.69	20.98
27.1160	46.91	20.64
27.1170	61.15	26.90
27.1180	56.03	24.65
27.1190	43.79	19.26
27.1200	40.17	17.67
27.1210	25.80	11.35
27.1220	55.63	24.47
27.1230	56.85	25.01
27.1240	20.15	8.86
27.1250	20.00	8.80
27.1260	25.42	11.18
27.1270	55.48	24.41
27.1280	81.26	35.75

CARBONATE ANALYSES

CORE BIO 19.66.50

SAMPLE NUMBER	CACO3 PERCENTAGE	CO2 PERCENTAGE
50.0030	78.96	34.74
50.0120	71.60	31.50
50.0160	78.19	34.40



BATHYMETRY OF NORTH ATLANTIC

FIGURE I

CONTOUR INTERVAL: 500 FATHOMS

BATHYMETRY

HUDSON GEOTRAVERSE

SCALE 1 300,000
AT LATITUDE 48°

COMPILED BY

DATE

ATLANTIC OCEANOGRAPHIC LABORATORY
BEDFORD INSTITUTE
SEPTEMBER 1968

FIGURE 2
BATHYMETRY OF SURVEY AREA WITH CORE LOCATIONS
CONTOUR INTERVAL: 100 FATHOMS
DISTRIBUTION OF VALLEY FLOOR SEDIMENT

A COMPOSITE PLOT OF LITHOLOGY, PERCENTAGE CARBONATE IN -62 MICRON FRACTION AND PERCENTAGE FORAMINIFERA IN +62 MICRON FRACTION

FIGURE 5

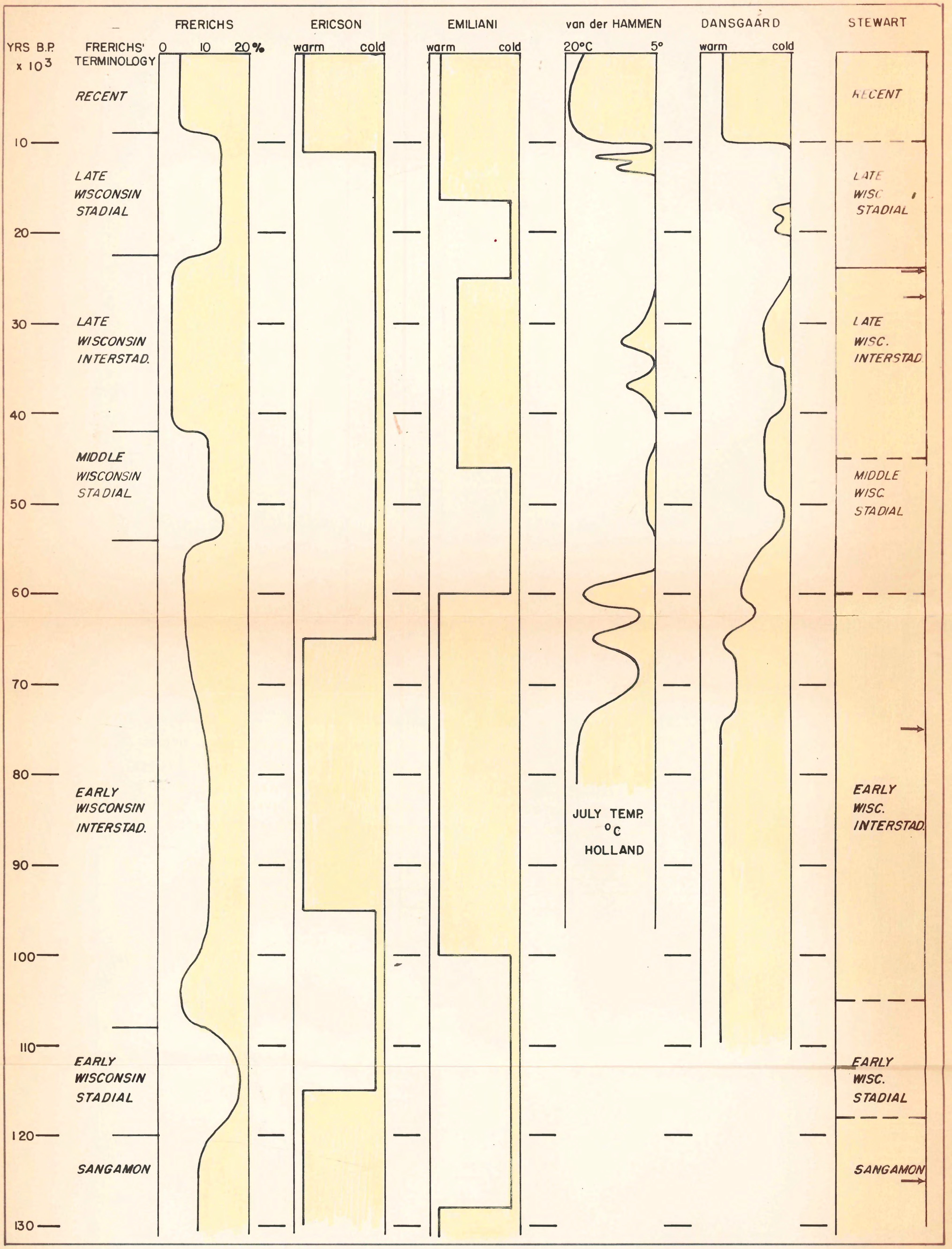


FIGURE 6 COMPARISON OF LATE PLEISTOCENE CLIMATIC CURVES

Frerichs (1968) abundance curve for Globigerina rubescens in Andaman Sea and Bay of Bengal

Dansgaard et al (1969) O^{18} concentrations in ice core from Greenland ice cap

van der Hammen et al (1967) temperature curve from field data, pollen analysis, & radiocarbon dates

Ericson et al (1964) climatic curve for tropical Atlantic from abundance of Globorotalia menardii

Emiliani (1955) isotopic determinations of temperatures from Caribbean

Stewart extrapolated zonation. isotopic dates indicated by arrows