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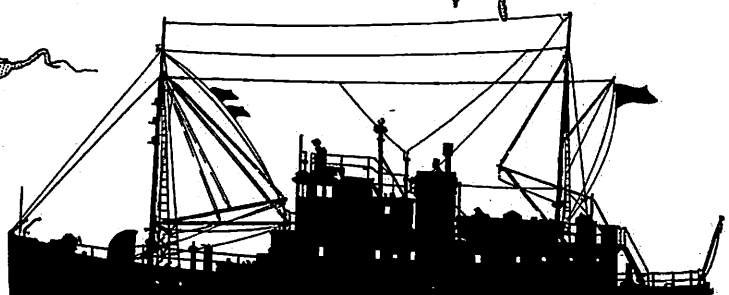

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FRANCIS A. RICHARDS
Principal Investigator

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Technical Report No. 276

LATE QUATERNARY TECTONICS, NORTHERN END OF JUAN DE FUCA RIDGE (NORTHEAST PACIFIC), by Dean A. McManus, Mark L. Holmes, Bobb Carson and Sandra M. Barr. Marine Geology, 12: 141-164. 1972

Technical Report No. 277

A GYROCOMPASS FOR MEASUREMENT OF CORE ORIENTATION AND CORE BEHAVIOR, by Douglas R. Morrison and Bobb Carson. Deep-Sea Research, 18: 935-939. 1971.

Technical Report No. 278

VOLTAMMETRIC MEASUREMENT OF ZINC IN THE NORTHEASTERN TROPICAL PACIFIC OCEAN, by Alberto Zirino and Michael L. Healy. Limnology and Oceanography, 16(5): 773-778. 1971.

Technical Report No. 279

PH-CONTROLLED DIFFERENTIAL VOLTAMMETRY OF CERTAIN TRACE TRANSITION ELEMENTS IN NATURAL WATERS, by Alberto Zirino and Michael L. Healy. Environmental Science & Technology, 6(3): 243-249. 1972.

Deep-Sea Research, 1971, Vol. 18, pp. 935 to 939. Pergamon Press. Printed in Great Britain.

INSTRUMENTS AND METHODS

A gyrocompass for measurement of core orientation and core behavior*

DOUGLAS R. MORRISON† and BOBB CARSON†

(*Received* 19 *March* 1971; *accepted* 6 *May* 1971)

Abstract—An instrument package has been designed to monitor continuously, the horizontal orientation and inclination of a standard piston corer. A gyrocompass is used as an azimuthal reference while two pendulum potentiometers sense deviations from the vertical. Azimuthal orientations obtained with this unit are thought to be accurate to within 5°. Preliminary results on 12 cores taken with this instrument indicate that a piston corer fluctuates less than 4° from the vertical throughout most of the coring operation. Rotational behavior, however, is significantly different during ascent and descent, and varies with water depth. Short period (<1 min) rotations are typical of the ascent, while longer periods (2–5 min) are characteristic during corer descent. The magnitude of rotation increases significantly in the upper 150 m of the water column, in response to wave action and ship motion. In the near-bottom phase of a coring operation, the corer undergoes rapid rotation (~30°/10 sec) during free-fall and, possibly, bottom penetration.

INTRODUCTION

IF PREFERRED grain orientation and anisotropy of magnetic susceptibility of marine sediment samples are to be related to their *in-situ* position, it is necessary that the orientation of the sampling device, while on the bottom, be known. At the same time, the behavior of a piston corer in deep water can be accurately evaluated only if horizontal and vertical deviations are monitored continuously. Uninterrupted recording is particularly important in assessing corer motions during the brief interval of free-fall and bottom penetration. To carry out core behavior and bottom orientation studies, an instrument has been developed which utilizes a directional gyrocompass and two pendulum potentiometers to give a continuous reading of horizontal and vertical motions of a piston corer during descent, bottom penetration and ascent.

PREVIOUS WORK

For some time, corers which incorporate a magnetic compass as a directional reference have been used to gather submarine orientation data. Typically, the compass heading at the bottom is recorded either mechanically or photographically.

Purely mechanical instruments (BOUMA, 1964; FELSHER, 1964; ROSFELDER and MARSHALL, 1966, 1967) are commonly either free-flooding or are pressure compensated for deep water operation. In either type, a single measurement of azimuthal direction and/or inclination from vertical is obtained by locking a compass disk, hemisphere, or sphere in position upon contact with the bottom.

Photographic techniques have been applied by some workers (LEUTERT, 1954, 1964; PLANKEEL and VAN DER SLUIS, 1960; EWING, HAYES and THORNDIKE, 1967; HARRISON, BELSHÉ, DUNLAP, MUDIE and REES, 1967; MCCOY and VON HERZEN, 1971) to record inclination and azimuthal orientation. This is usually done by placing a compass-inclinometer within the field of view of an underwater camera that is mounted on the sampling apparatus. HARRISON, BELSHÉ, DUNLAP, MUDIE and REES (1967) used a single-shot deep-sea camera that triggered shortly after the corer penetrated the bottom. EWING, HAYES and THORNDIKE (1967) and MCCOY and VON HERZEN, (1971) employed multiple exposure camera assemblies to monitor core behavior and orientation in the near-bottom phases of piston coring. These units were set to take photographs at predetermined time intervals.

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A photographic technique to continuously record piston corer orientation has been developed by PLANKEEL and VAN DER SLUIS (1960) but its application is limited to water depths of less than 100 m.

Although methods of recording vary among these instruments, they all share a common factor in the use of a magnetic compass. Because most coring devices are constructed all or in part of magnetic or slightly magnetic material, the accuracy of a compass placed on or near these devices can be impaired. Precautions have been taken by previous workers to minimize the influence of the sampler on the magnetic compass. EWING, HAYES and THORNDIKE (1967), HARRISON, BELSHÉ, DUNLAP, MUDIE and REES (1967), and BOUMA (1964) positioned their compasses on short arms protruding from the sampler to reduce the magnetic interference. BOUMA (1964) states that such positioning reduces the compass error to less than 5°. In addition, McCOY and VON HERZEN (1971) used a corer composed largely of aluminum, stainless steel, and lead.

The difficulties in isolating a magnetic compass from the corer without impairing penetration, and the inherent advantage of continuous recording has led to the development of an instrument which employs a gyrocompass as the directional reference. This unit continuously monitors azimuthal direction and inclination of a standard piston corer during an entire surface to surface coring operation.

DESCRIPTION

The instrument package contains the following components (Fig. 1): a surplus missile gyrocompass to monitor horizontal rotations of the corer, two oil-damped pendulum potentiometers (mounted at right-angles) for measuring deviations from the vertical, two Rustrak strip chart recorders, an Accutron time base, an electronics board which controls the setting, caging, and uncaging of the gyrocompass, and Ni–Cd battery packages. All parts are mounted in an aluminum pressure case which clamps to the piston corer weightstand.

The gyrocompass is a directional type which reads out a variable resistance to a single-channel, strip chart recorder operating on one of two scales: 0°–180°, and 180°–360°. An event-marker shift indicates on which scale the gyrocompass is operating at a given time. The event marker also responds to a signal from the Accutron time base at one minute intervals. The instrument is equipped with cage, uncage, and rotate controls, and a fail-safe circuit which automatically cages the gyrocompass in the event of a power loss or accidental shut down. An external meter (I, Fig. 1) can be plugged into the unit to monitor the gyrocompass read-out.

The pendulum potentiometers also indicate change by variable resistance. Pitch and yaw components of deviation from the vertical (0°–45°) are fed to a dual-channel strip chart recorder. By calculation, a true deviation from vertical and its direction can be ascertained.

MODIFICATIONS TO THE CORER

In order to use a conventional piston corer for the collection of oriented samples with this instrument, it was necessary to make some minor modifications. Alignment holes were drilled in the weightstand to receive pins on the pressure case mounting clamps (H, Fig. 1). The position of the instrument within the pressure case is fixed by an internal pin. An additional hole, for an alignment and locking screw, was drilled and tapped at the coupling between the weightstand and the core barrel. When a pointed screw is installed in this hole it immobilizes the plastic core liner and the core barrel relative to the weightstand and provides a reference mark on the core liner which can be correlated with the gyrocompass read-out. If more than one section of core barrel is used, liner sections are faced, fitted, and welded securely together so that the lower portions cannot rotate with respect to the marked section.

SHIPBOARD PROCEDURE

Once the vessel is positioned on a coring site and its heading stabilized, the instrument package, with the pressure case end-cap removed for access to the controls, is aligned with a deck seam, parallel to the ship's center line. The gyrocompass is started and allowed to come to full rotational speed. The external meter (I, Fig. 1) is connected to the package to monitor azimuthal direction and the gyrocompass is rotated until it coincides with the ship's heading. The gyrocompass is then uncaged and the pressure case is sealed and made ready for installation on the corer.

During the time required to start, synchronize, and seal the instrument package, the corer has been launched and is being held vertically at the ship's rail. The pressure case is clamped in place just prior to lowering.

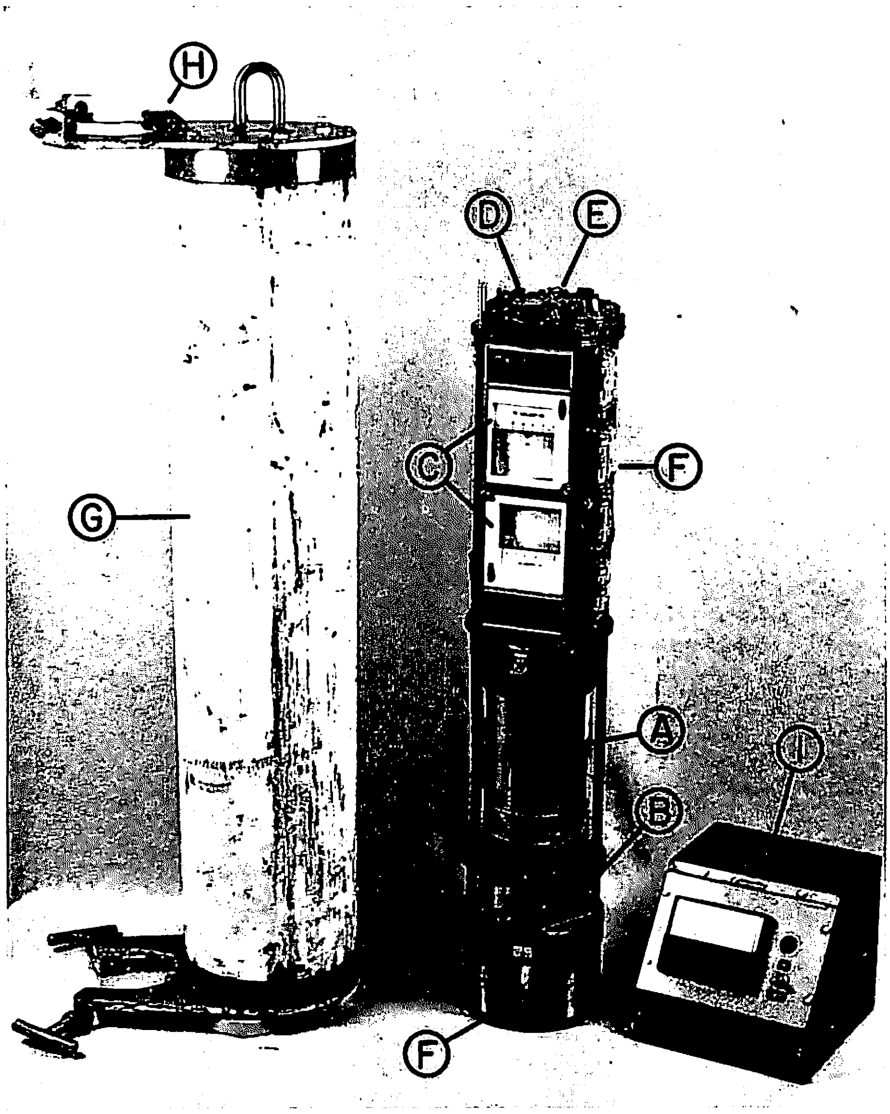

Fig. 1. Instrument package and external meter. The total assembly includes: (A) gyrocompass, (B) oil-damped pendulum potentiometers, (C) Rustrak strip chart recorders, (D) Accutron time base, (E) electronics board, (F) Ni–Cd batteries, (G) pressure case, (H) pin for alignment on weightstand, and (I) meter for monitoring gyrocompass heading.

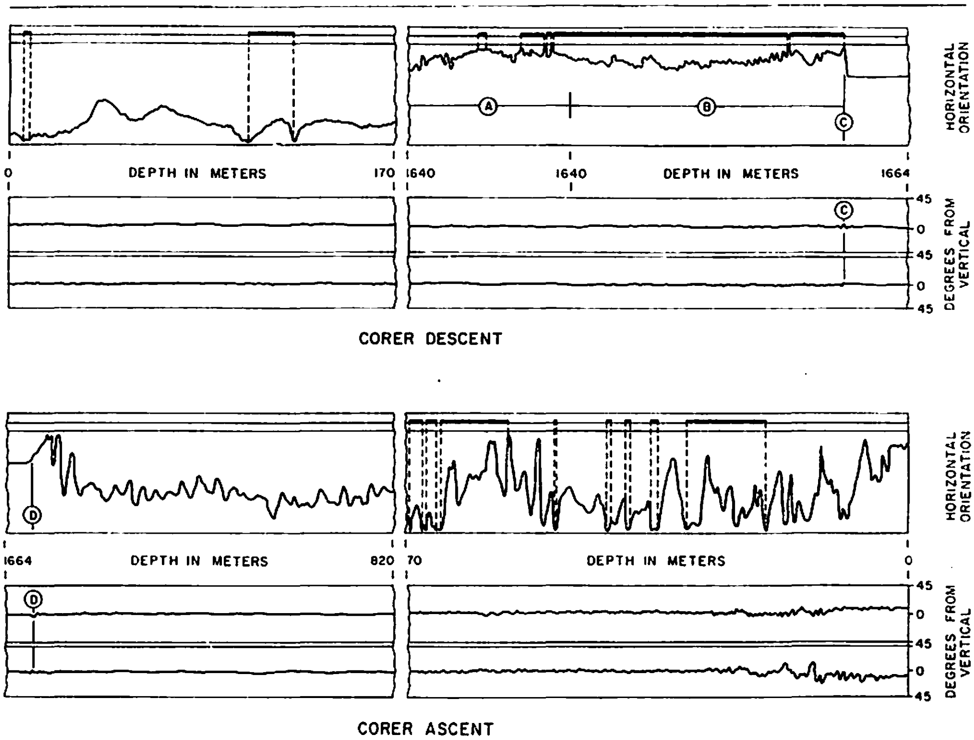

Fig. 2. Line reproduction of vertical and horizontal orientation records, Core 53-16. Heavy line at top of horizontal orientation records indicates 0°–180° scale and light line indicates 180°–360° scale (180° always lies at the top of the record). (A) Corer rotation at a stationary depth, (B) corer rotation descending at approximately 10 m/min, (C) bottom contact and/or penetration, (D) pullout or removal from bottom.

The descent, bottom contact, and ascent of the corer follow a standard procedure except that more care is taken to log any events that might affect corer behavior, for later correlation with the strip chart records. After penetration, the corer is allowed to remain in the bottom for approximately 60 sec, to give the strip chart records time to establish clearly corer orientation and inclination (Fig. 2). The records indicate that this prolonged in-bottom phase has no effect on the attitude of the corer.

When the corer is brought to the surface, the instrument package is removed, again aligned with the fore-aft deck seam, and its heading compared with the ship's gyrocompass. The sediment core in its plastic liner is removed from the core barrel, and is placed in a rack which doubles as a guide for a scribing tool. The mark left on the upper portion of the core liner by the pointed, weightstand alignment screw is scratched in the plastic for the entire length of the core liner. The core sample is then ready to be cut into sections and capped for cold storage and subsequent laboratory study.

GYROCOMPASS ACCURACY

Prior to shipboard operation, the gyrocompass was tested in the laboratory to determine instrument errors and idiosyncrasies. A static test, over a four-hour period, showed no discernible drift from the initial setting. Upon rotation, however, deviations from correct values were observed. The magnitude of drift was related to the rate of rotation: rapid rotation (360°/30–60 sec) produced little apparent drift, while slower rotations (360°/5–10 min) showed losses of up to 4°/360°, i.e. a rotation of 360° was recorded as 356°. Since this apparent hysteretic effect is not constant, it is nearly impossible to correct for, and limits the precision of the instrument. In addition to this effect, it was found that after 15–20 revolutions in one direction, the gyrocompass tended to 'hang-up', almost as though it had caged itself, and showed no change in the heading as the unit continued to turn in the same direction. Upon reversing the direction of rotation, the unit responded properly. This behavior may be attributed to the use of a surplus gyrocompass, but does not pose a major problem as it is readily recognized on the record and occurs infrequently.

Table 1. A comparison between initial gyrocompass heading and final ship and gyrocompass headings upon completion of core stations. Gyrocompass drift is the final difference between ship heading and gyrocompass heading.

Core no.	*Initial ship and gyrocompass heading* (°T)	*Final ship heading* (°T)	*Final gyrocompass heading* (°T)	*Gyrocompass drift* (°)	*Bottom orientation* (°T)
48–1	270	242	222	−20	246
48–2	310	309	151	−158	63
48–4	311	316	315	−1	94
48–5	308	301	302	+1	148
48–7	311	310	332	+22	87
48–8	294	304	293	−11	64
48–9	300	299	293	−6	110
48–10	180	211	205	−6	255
53–4	355	302	146	−156	189
53–14	193	169	171	+2	317
53–16	184	176	184	+8	213
53–17	176	174	162	−12	303

The fact that the gyrocompass is set to the ship's heading at the beginning of a coring operation, and is compared to the heading upon return to the deck, allows some estimate to be made of the accuracy and precision of the unit. Table 1 lists the results of 12 cores taken during the summer of 1970. Excluding cores 48–2 and 53–4 (on which the gyrocompass 'hung-up' as described above), 10 cores showed drift ranging from −20° (counterclockwise) to +22° (clockwise) over the entire coring operation. Using the normal approximation to the circular normal distribution (KRUMBEIN and GRAYBILL, 1965; AGTERBERG and BRIGGS, 1963), the mean drift for the 10 cores is −2·3°, and the standard deviation is 11·7°. The mean drift is a measure of the instrument's accuracy, while the standard deviation reflects the precision of the device.

A t-test on the mean drift reveals that the value of −2·3° does not differ significantly (with 95 per cent confidence) from a drift of 0°, i.e. no drift. Hence, the instrument appears to be accurate, if somewhat imprecise. It should be remembered, however, that the precision of ±11·7 applies to the entire coring operation and not simply to the descent phase. Examination of all gyrocompass records indicates that the corer rotates at least twice as many times on ascent as on descent. This fact, coupled with the laboratory observation that drift is a function of rotation, suggests that the imprecision of the bottom reading is less than one half the total imprecision. It is our belief that the bottom orientations obtained with this instrument are good to ±5°.

CORER BEHAVIOR

In order to completely describe the hydrodynamic behavior of a piston corer in deep water, variations in acceleration would have to be monitored as well as rotation and deviation from vertical. Nevertheless, some insight can be gained from analysis of the records acquired with this unit. Portions of a typical record (core 53–16) are presented in Fig. 2.

During descent the corer's magnitude of rotation decreases with distance from the surface until the corer reaches a depth of over 150 m. Except for the very near-surface phase affected by ship propeller wash and surface wave action, the average rotation is approximately 150° with a period of 2–2·5 min. Below 150 m, fluctuations are less pronounced. Commonly, small-scale rotations (~12°/5 sec) are superimposed on less rapid motions of about 25°/4–4·5 min. The smaller and shorter fluctuations may be related to the pitching and rolling of the ship. Significant variations in the rate of descent, as seen in sections A (corer stationary) and B (descending at ~10 m/min) of Fig. 2, do not have a pronounced effect on the rotational pattern at depth. Deviations from the vertical follow a similar pattern during lowering with some near-surface fluctuations of 9° and reduced deviations (<1°) at depth.

Bottom contact and/or penetration can be clearly seen (C, Fig. 2) on both horizontal and vertical read-outs. Unfortunately, lack of resolution on the recorder read-outs prohibits separation of free-fall from actual bottom penetration. Nevertheless, some general observations can be made. The corer apparently rotates rapidly during free-fall. The average change in orientation for a 10-sec period prior to the corer becoming stable in the bottom (a period which should include free-fall and penetration) is 30°; the range is 11°–33°. Vertical deviation increases slightly (~4°) at the start of free-fall, perhaps due to the release characteristics of the tripping mechanism, but returns to a nearly vertical attitude by the time complete penetration is achieved.

Removal of the corer from the bottom, or pullout, is evidenced by small deviations from the vertical and by significant horizontal rotation (D, Fig. 2). For a period of 20 sec, beginning with the first motion of pullout and ending after the corer is clear of the bottom, the records show rotations of 5°–200°, with a mean rotation of 62°. In all but two instances the direction of rotation on pullout opposed the direction during free-fall. The vertical deviation records show a slight inclination (~4°) of the corer during pullout. This is apparently caused by ship drift relative to the position of the implanted corer. Once the corer is clear of the bottom, a vertical position is maintained.

During ascent the corer rotates with a shorter period and greater magnitude than it does during descent. At depth the average rotation is about 40° with a period of approximately 15 sec. It appears that the absence of a tripping arm attached to the weightstand during ascent allows the corer to rotate with increased freedom. Vertical deviation remains very stable after pullout and holds a nearly vertical attitude (<1°) until the corer is near the surface. The added weight of the core sample within the barrel may have a stabilizing effect on the corer. When the corer is less than 150 m from the surface, azimuthal rotations become more pronounced, increasing to 150°–300°. The periods of these fluctuations are short (<1 min), but very irregular. Vertical deviation maxima occur just below the surface, with values of ~18°.

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13. ABSTRACT

An instrument package has been designed to monitor continuously the horizontal orientation and inclination of a standard piston corer. A gyrocompass is used as an azimuthal reference while two pendulum potentiometers sense deviations from the vertical. Azimuthal orientations obtained with this unit are thought to be accurate to within 5^{o}. Preliminary results on 12 cores taken with this instrument indicate that a piston corer fluctuates less than 4^{o} from the vertical throughout most of the coring operation. Rotational behavior, however, is significantly different during ascent and descent, and varies with water depth. Short period ($<$1 min) rotations are typical of the ascent, while longer periods (2-5 min) are characteristic during corer descent. The magnitude of rotation increases significantly in the upper 150 m of the water column, in response to wave action and ship motion. In the near-bottom phase of a coring operation, the corer undergoes rapid rotation ($\sim 30^{o}$/10 sec) during free-fall, and possibly, bottom penetration.

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