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PHOTOGRAPHIC CONTROL OF DEEP-SEA DREDGING

(Report and 6 figures)

F. Aumento and D. E. Lawrence

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ABSTRACT

From an examination of the motions of a dredge on the sea floor, the authors propose improvements to existing deep-sea dredging techniques. A special dredge, fitted with photographic equipment, was built and this dredge and the observations it made possible are described in detail.

PHOTOGRAPHIC CONTROL OF DEEP-SEA DREDGING

INTRODUCTION

Collecting samples from rock outcrops on the sea floor often proves unrewarding; the technique most commonly employed, dredging from the end of a long cable, is, in effect, as unsatisfactory as attempting to sample the Rocky Mountains from above a 10,000-foot cloud shroud.

In recent years, difficulties in estimating the source of dredged samples have been partly solved by improved navigational aids at sea (e.g., positioning a ship using two or more fixed radar transponder buoys) which allow the ship to return to within at least one-quarter mile of a locality that may have appeared suitable for dredging during an earlier bottom photographic reconnaissance. However, the uncertain position of the dredge relative to the ship may still thwart the navigator's efforts to return to a predetermined position.

Knowledge of the length of cable paid out from the ship, the depth of water below and around the ship, and of the angle which the dredge cable makes to the vertical at the surface are all useful criteria for estimating the position of the dredge relative to the ship. However, as the configuration of the cable below sea level is unknown, the dredge may still be anywhere within the scope of the cable. Recently this 'probable area of sample recovery' has been considerably reduced by fitting the dredge with a bottom-hole pressure recorder (bathykymograph). This instrument inscribes a plot of the hydrostatic pressure against time onto a silvered glass, and severe scrapes (or bites) of the dredge on the sea floor cause the recording stylus to vibrate, producing jiggles on the time-pressure graph (Fig. 1). Knowledge of the exact depth of dredging therefore assists the geologists in narrowing down the possible areas of sample recovery.

Two serious problems must be overcome if the techniques of dredging are to remain useful at a time when deep-sea exploration is transcending preliminary exploration and entering an era of more detailed investigations. First, once the sample location has been established, there still remains the equivocal nature of the material brought to the surface – it may have been broken off a parent outcrop, or lying in situ on top of an outcrop, or it may merely be an erratic scooped off the sea floor. Second, basic dredge designs have remained unchanged during the last 100 years, mainly due to ignorance concerning the movements of the dredge as it is dragged over the sea floor at the end of many thousands of feet of cable, and as a result, lengthy hauls are needed to provide a satisfactory rock yield.

Manuscript received: January 10, 1968.

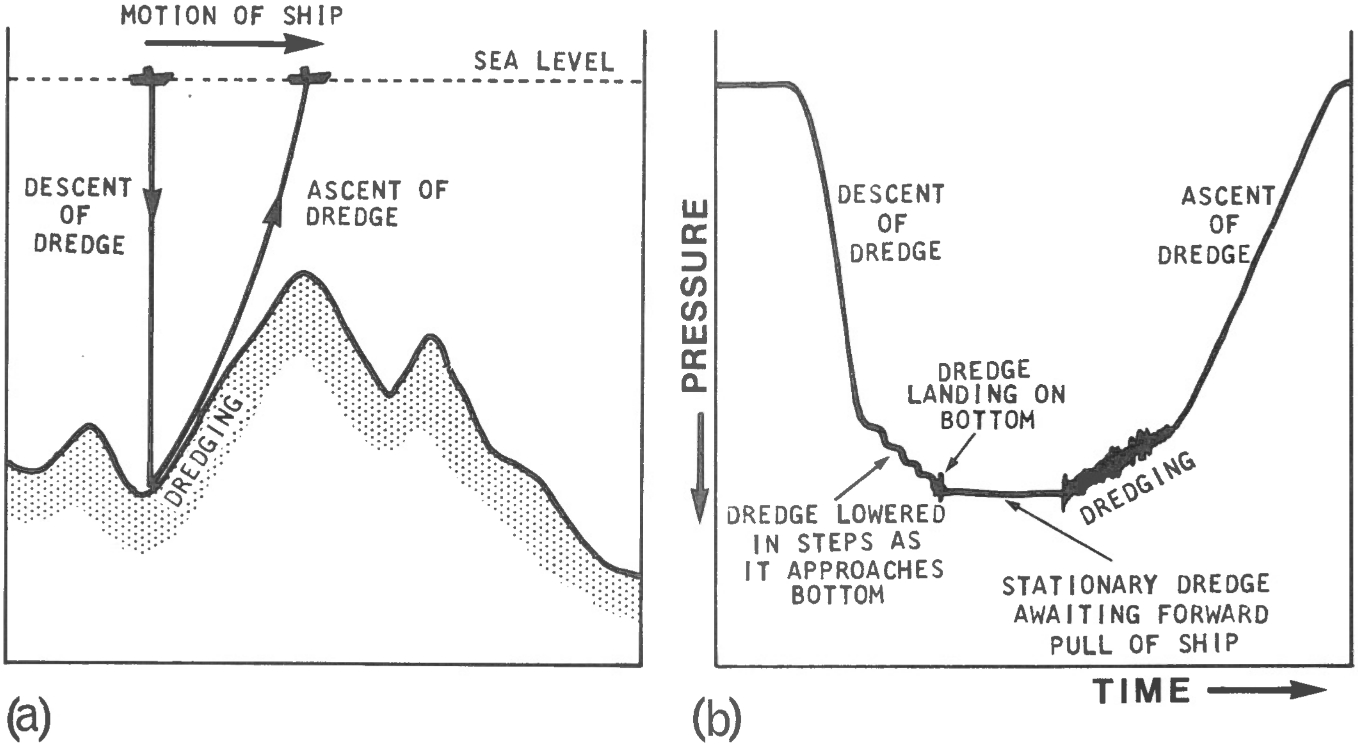

Figure 1. (a) Schematic of dredging operation. (b) Equivalent bathykymograph plot.

The senior author has attempted to clarify these problems and uncertainties by designing a dredge that would provide photographic coverage of events occurring at the dredge mouth. Its purpose is to study the motions of the dredge on the sea floor, to observe the mechanism of sample collection, and, at the same time, to record the origin of the samples.

THE CAMERA-DREDGE

As a first attempt, commercially available underwater camera/flash[1] equipment was installed on an existing dredge model[2] modified for the purpose. The dredge bore little resemblance to the original N.I.O. dredge when modifications were complete. Because commercial photographic equipment is generally bulky, a small instrument camera and flash had to be used in order to keep the total size of the dredge down to manageable proportions; this combination limits the number of exposures taken during a lowering to 36. The dredge nevertheless weighed over 600 kg and was 1.5 metres wide at its widest point.

The dredge may land and operate on the sea bottom on either of its two flat surfaces and thus the pressure cases containing the camera and flash must be mounted symmetrically (and as far apart as possible, to reduce backscatter of the flash) about the major axis of the dredge; this increases the potentiality of photographic success at each exposure.

The camera and flash units require considerable protection from damage during a rough landing and abrasive passage over the sea floor, and when crashed against the ship's deck on recovery. As there is a strong possibility that the dredge might not be retrievable, a mechanism was devised to release the considerably more expensive camera and flash units from the more expendable dredge, and to recover them safely.

The experimental dredge is shown schematically in Figure 2 and Figure 3 shows the actual dredge on the foredeck of the C.S.S. Hudson. The dredge casing was built from 1/2-inch mild steel plate. The camera and flash pressure cases were placed on either side of the dredge mouth, well inside the casing for maximum protection. The two pressure cases (which, although cylindrical, have a number of rough clamps and protrusions on their outer surfaces) were held tightly inside two smooth surfaced steel cylinders which could slide freely in and out of a second set of cylinders that formed an integral part of the dredge casing. These were positioned so that the camera and flash units focus approximately 10 feet in front of the dredge mouth. The camera, fitted with a wide-angle lens, records a clear view from the dredge mouth (slightly out of focus) to 15 feet or more beyond (the maximum distance being a factor of the power of the flash unit).

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[1] E.G.&G. International Cameras.

[2] National Institute of Oceanography Dredge, Wormley, Surrey, England.

The removable cylinders holding the photographic units were shock-mounted inside the fixed cylinders using thick rubber hose. The leading apertures were protected by 3/4-inch thick perspex discs (Fig. 2-8). These discs were of the smallest diameter possible so as to provide the lenses and flash bulb with maximum protection from oncoming rocks without obstructing the camera's field of view (see Fig. 4). The removable cylinders were held in place inside the fixed cylinders by a set of shear bolts. The latter were adequate to hold the system together during normal use, but could be sheared loose in an emergency by a backward pull of two tons, thereby releasing the photographic equipment from the dredge.

The leading edges of the dredge case were bevelled to provide a better 'bite' on outcrops encountered. Sharp corners, on the other hand, were removed to reduce the possibility of the dredge becoming stuck on the bottom.

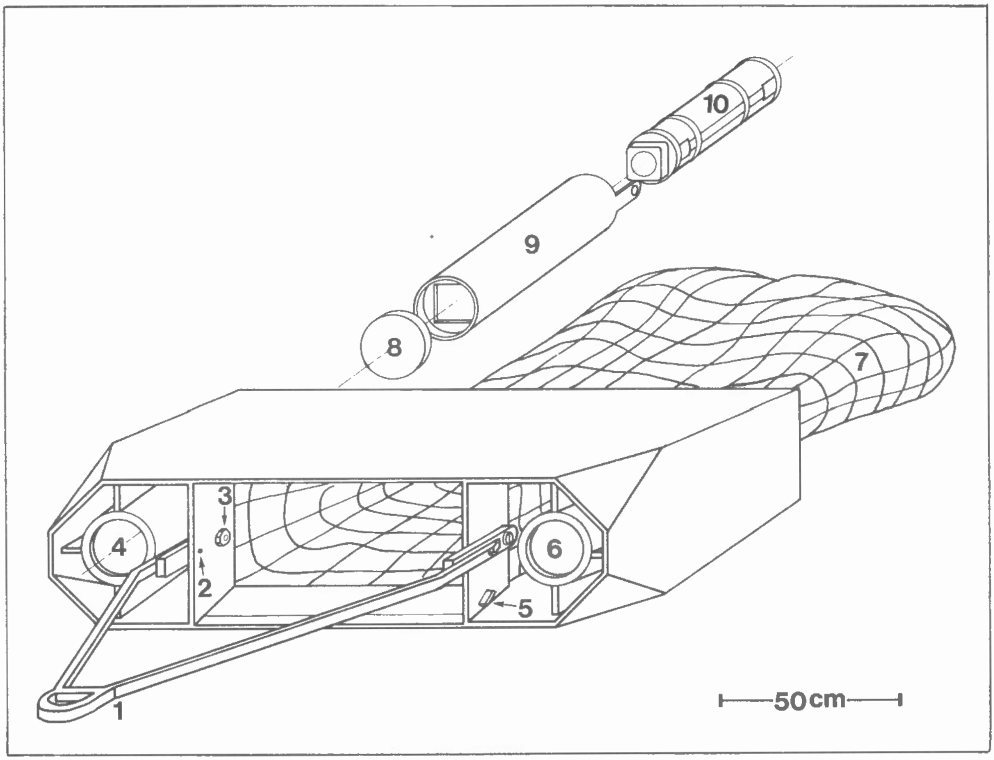


Figure 2. Experimental dredge with exploded view of instrument mountings: (1) Towing bridle. (2) Shear pin. (3) Pivot pin. (4) Camera mount. (5) Stop block. (6) Flash unit mount. (7) Wire mesh dredge bag. (8) Perspex instrument window. (9) Removable mounting cylinder. (10) Instrument camera.

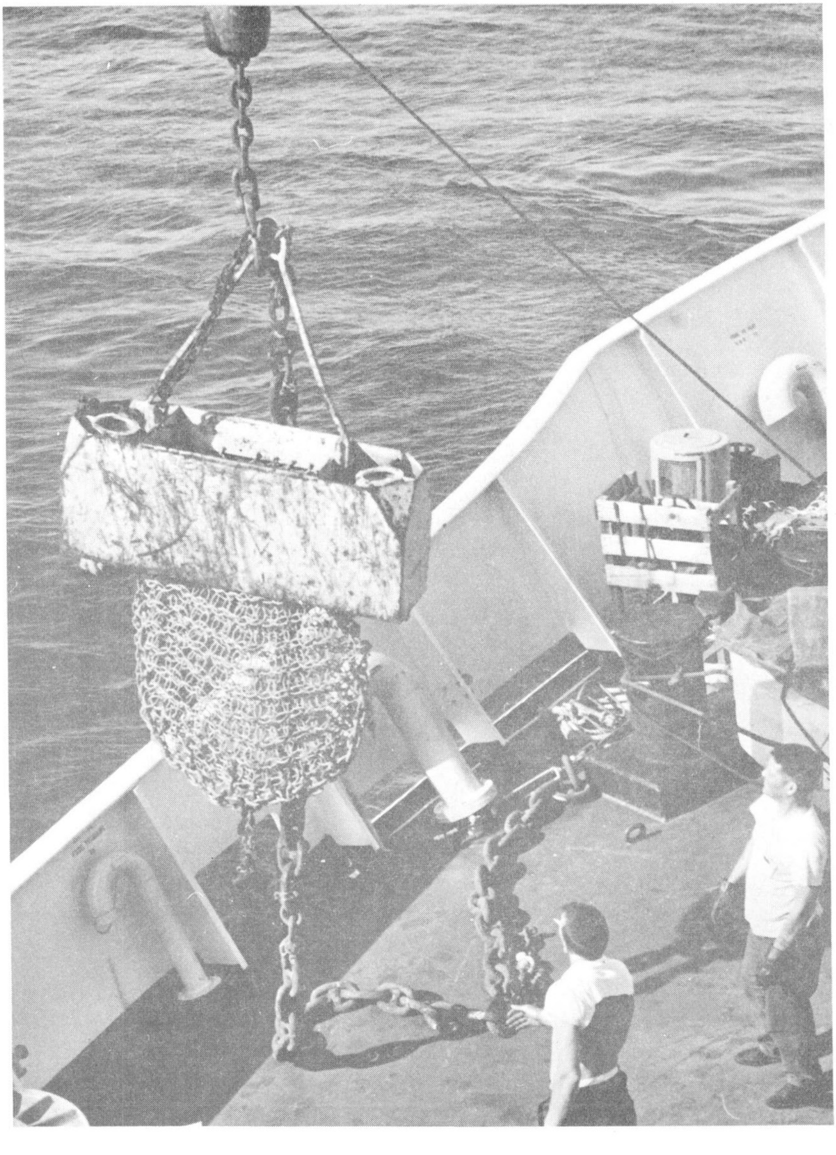
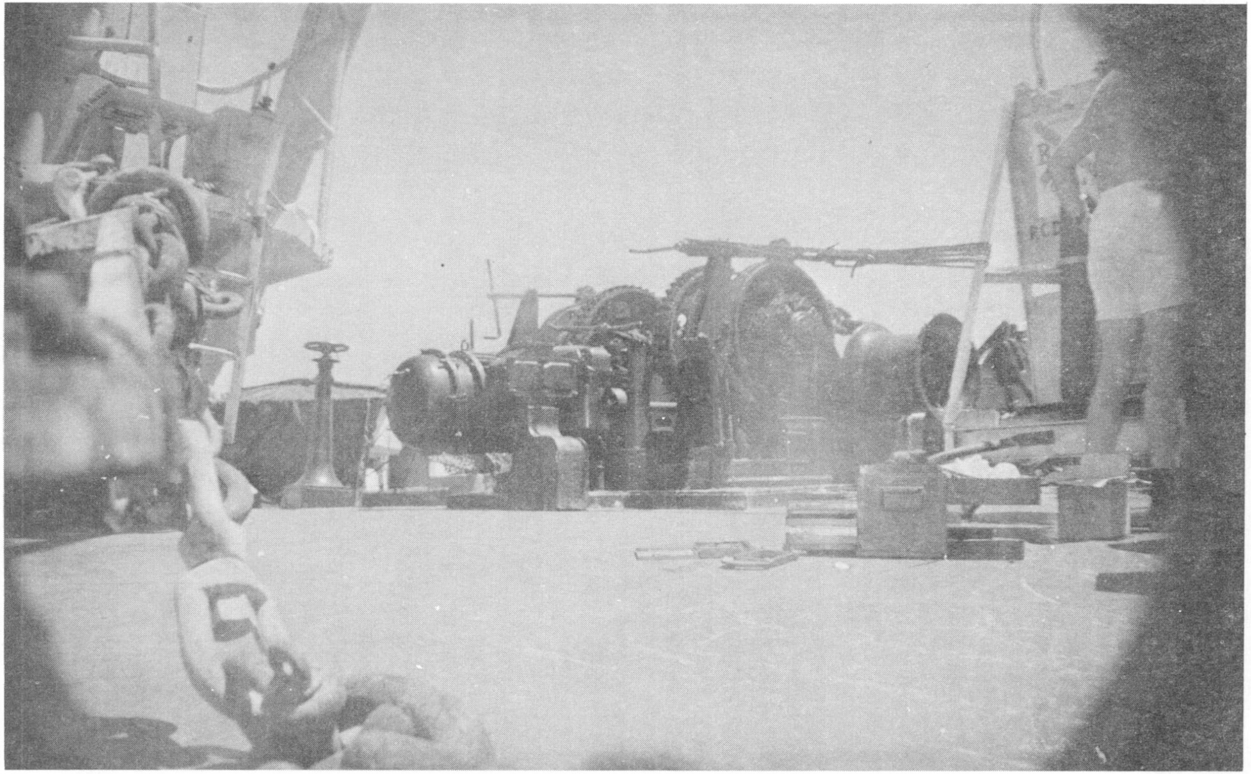
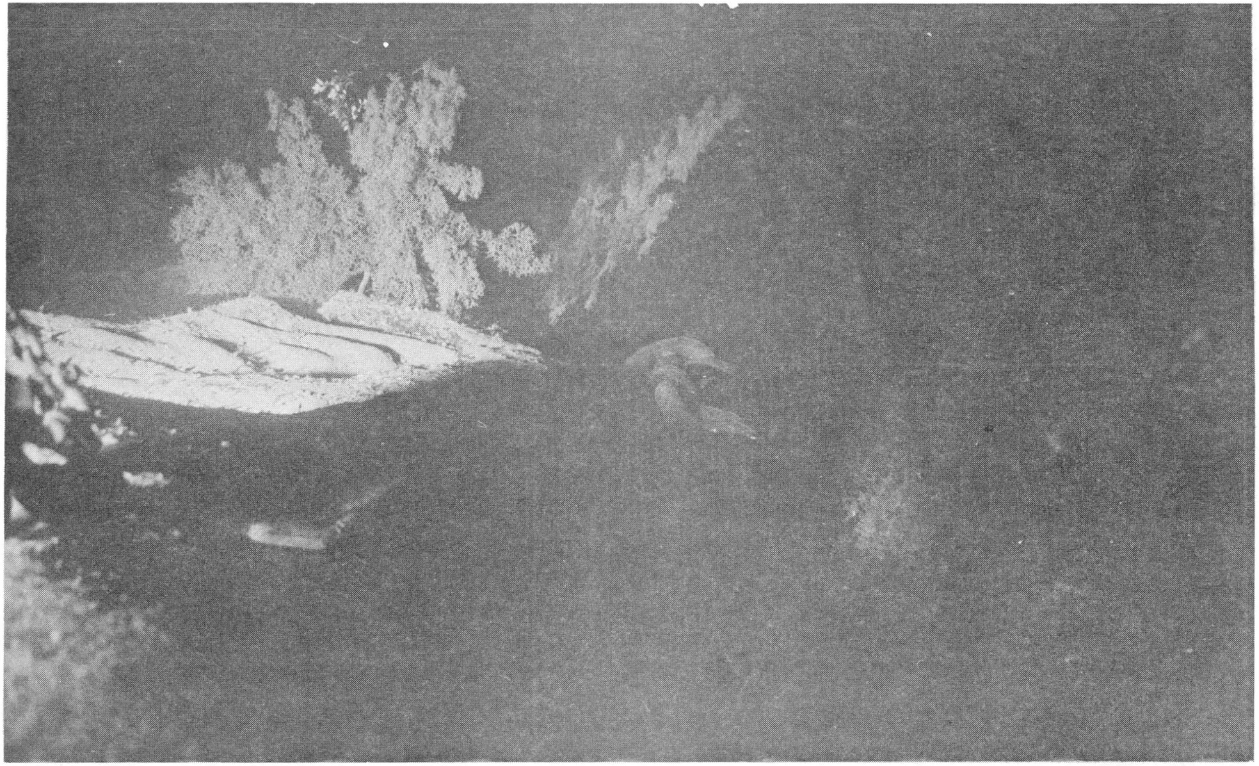


Figure 3. Experimental dredge being hoisted on board the C.S.S. Hudson.



(a)

Figure 4. (a) Field of view of camera in position in the tube mount on the dredge. Note bridle and chain on left hand side; also field of view being restricted by the protective ring.



(b)

Figure 4. (b) Field of view on ocean floor under the same conditions as for above. Note that the refractive index of water has magnified the picture such that the bridle is only barely visible in the left hand side of the field of view, and the protective ring no longer restricts the field of view. The photograph shows the manganese pavement on San Pablo Seamount.

Electrical connections from the camera case to the flash case were made by way of a 'ground' consisting of the dredge case, and also through an insulated cable inside a steel tube welded flush within the dredge case. The leading edge of the steel tube was protected from damage from passing rocks by a steel flange which covered the tube and was welded at a low angle to the case.

Various methods of activating the camera were proposed. Tilt and contact switches were eliminated, as they are unreliable under the rough conditions the dredge would provide. Eventually a clockwork timing mechanism was incorporated inside a separate pressure case. This timer activated a second timing mechanism within the camera; the first provided a delay to allow the dredge to be handled over the side, to reach the bottom and to commence dredging; the second, once activated, synchronized the camera/flash combination to take photographs at pre-determined time intervals. These could be varied from two to thirty seconds.

THE SAFETY RELEASE MECHANISMS

The cable and winch available for dredging have relatively low safe working loads and therefore precautions were taken to protect these expensive items from damage.

A number of release mechanisms, designed to activate at progressively higher loads, were incorporated into the camera-dredge system. They are described in order of increasing breaking strength (Fig. 5).

The bridle is pivoted at the dredge case, allowing the two units to swing independently. At the start of the dredging operation the bridle is held rigidly against the frame, by means of two shear pins, at an angle best suited to maximum sample recovery (Fig. 5-1). However, should the leading edge of the case become stuck on an obstacle on the sea floor, the shear pins will break when the load exceeds 3 tons shearing stress. Once this happens, the bridle is free to swing relative to the frame, allowing it to tip and release itself from the obstacle (Fig. 5-2). The pins were found to shear so often that they were replaced by 4-ton shear breaking strength pins; these improved dredging without additional hazard to the equipment.

The leading eye of the bridle was attached to the towing cable by means of a 4-ton weak link and a swivel. Should parting of the shear pins on the bridle prove insufficient to free the dredge (Fig. 5-3), the weak link mentioned would be next to part with a straight pull of 4 tons. In order not to lose the dredge should this occur, the weak link was bypassed by a thin, extremely strong DCCOLOY alloy chain (8-ton breaking strength). A break of the 4-ton weak link would result in the load being suddenly transferred to the rear of the dredge bag, thus tipping up the dredge and sliding over the obstacle backwards (Fig. 5-4).

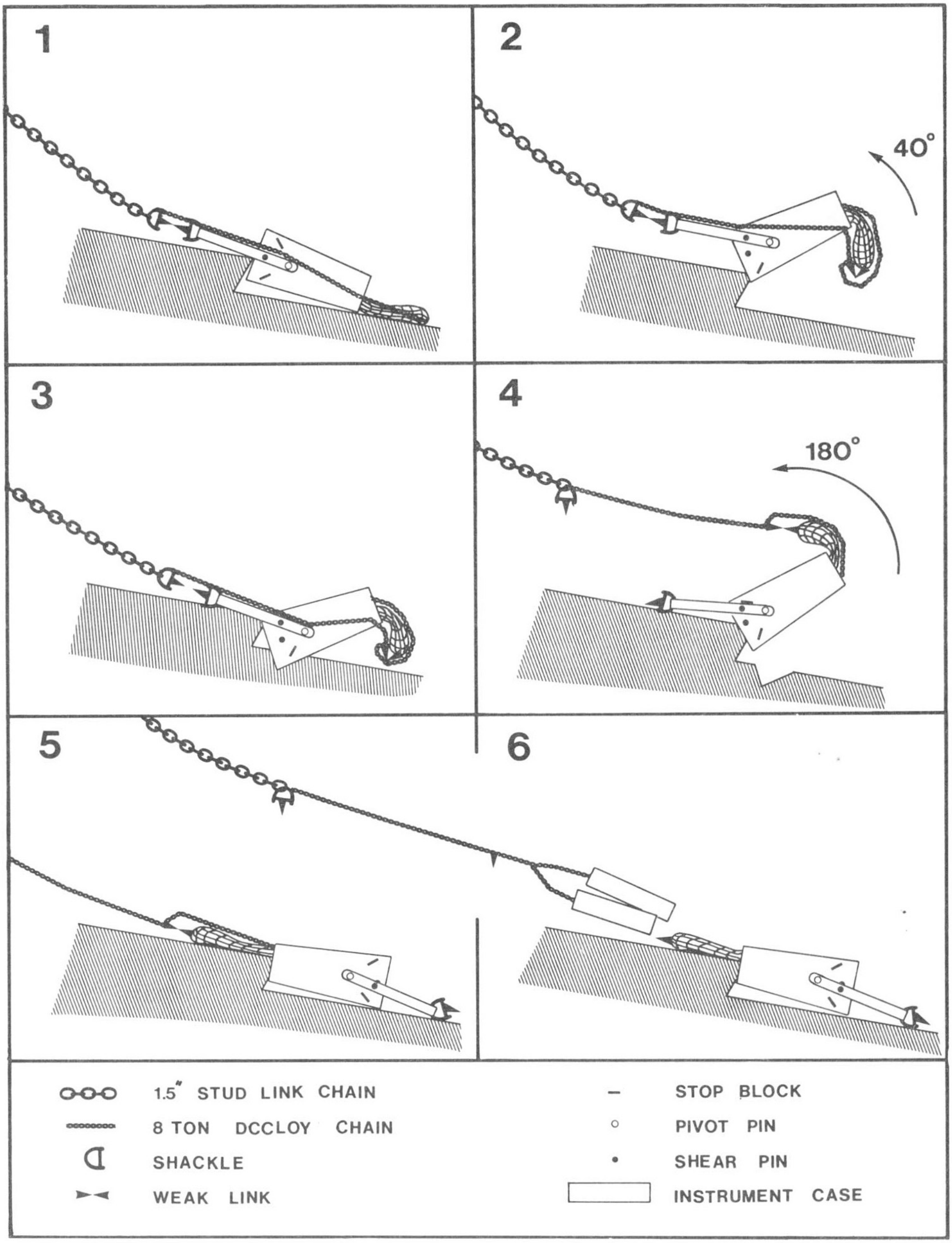


Figure 5. Schematic sequence of dredging with the activation of the safety release mechanisms; *see* text for detailed explanation.

Should the above mentioned safety mechanisms fail (Fig. 5-5), a final weak link between the cable and the heavy chain in front of the bridle breaks away at 6 tons, thereby saving the cable by abandoning the dredge. In this case a further effort is made to save the photographic equipment. Just before final parting of the 6-ton weak link on the cable occurs, a weak link detaches the DCCOLOY chain from the rear of the dredge and transfers the pull to the two removable cylinders containing the camera and flash units. If the dredge has been overturned by the previous operations, then the two cylinders will shear their 2-ton retaining bolts and slide free of the lost dredge (Fig. 5-6). However, this can only occur if the dredge has tipped over previously, otherwise the result will be a loss of all the equipment. In practice, it was found that with careful handling of the operation, the safety mechanisms only once exceeded the shearing of the bridle locking pins, and in this case the dredge was successfully overturned and recovered when the 4-ton weak link ahead of the bridle broke.

DREDGING OPERATIONS

The dredge, fully equipped but without the camera and flash units, was tested a number of times on San Pablo Seamount (Kelvin Seamounts) and on Flemish Cap (North Atlantic).

It became apparent that the angle of attack of the dredge's leading edge was too low for it to be used with maximum success on rocky outcrops; the dredge tended to slide over an obstacle rather than to dig into it. However, this minor drawback became an asset when the dredge was used to collect samples of the manganese pavements on San Pablo Seamount. The low angle of attack permitted the dredge to pry off a large slab of manganese pavement from the seamount floor, facilitating its entrance into the dredge mouth. The angle of attack should therefore be adjustable according to the terrain to be sampled. This can be accomplished by having removable bolt-on teeth on the leading edges, similar to those on power shovels used in open pit mining.

The protections incorporated for the safety of the photographic equipment proved to be completely adequate. No damage whatsoever was reported even to the perspex hatches ahead of the camera tubes. The safety release mechanisms also operated successfully.

The camera-flash units were therefore installed, and a trial photographic run was made on deck to adjust the timing mechanisms, electrical contact, and fields of focus (Fig. 4a). The camera-dredge combination was then lowered for a trial run on the sea bottom. At this lowering a poor electrical connection to the flash unit resulted in a blank film, although all the other triggering processes worked satisfactorily. No damage was reported to the instrumentation.

On three subsequent lowerings usable photographs (Fig. 4b) and two good hauls of rock were obtained from the sea floor on San Pablo Seamount.

RESULTS

The photographs obtained did not reach the standard expected from routine bottom photographic techniques. This was entirely due to the use of a small 'instrument camera' flash unit which did not have sufficient power to illuminate fully the lens' field of view. Improved photographs were obtained, however, by using photographic film with a faster emulsion (Tri-X) and a wider lens opening (F. 5.6). Both these factors will be improved further before changing over to a more powerful flash unit. The limitations of a maximum of 36 exposures can be partly overcome by using a thin-base photographic film; modification of the camera film-spools would improve matters further. An altogether more efficient camera design is also under consideration.

The most striking discovery was that of the unexpected motion of the dredge on the sea floor. Although 36 exposures (approximately 5 minutes of photography) are insufficient for a complete analysis of dredge motions, some deductions can be made. Of the three sets of films taken, two were exposed immediately following the start of the dredging operations and the remainder was exposed towards the middle. All have one common factor: the dredge was completely stationary during each five minute interval, even though the ship was moving at about one knot. This contradicts the common conception of a dredge sliding continuously over the ocean bottom collecting material. It now appears likely that the dredge jerks forward, each leap being separated by long stationary periods when the cable from the ship slowly takes up the slack, tenses, and jerks the dredge forward. With a depth below the ship of 1,000 fm (6,000 feet) and approximately 8,000 feet of cable out, 2,000 feet of slack is available. At one knot, the ship travels approximately 500 feet in five minutes: these 500 feet could be taken up in slack without excessive increase of the cable load.

The larger load fluctuations are of three types:

1. Rapid load variations at short intervals. These variations may be due to the irregular scraping of the dredge on the sea floor.

2. Much larger load increases which are preceded by a 'quiet' period, followed, in turn, by a gradual load build-up which is suddenly released. In such instances, the dredge may have been snarled on an outcrop, until a build-up in the cable tension was able to release it. The dredge may then have leaped forward several hundred feet to a new, temporarily tension-free resting place on the bottom.

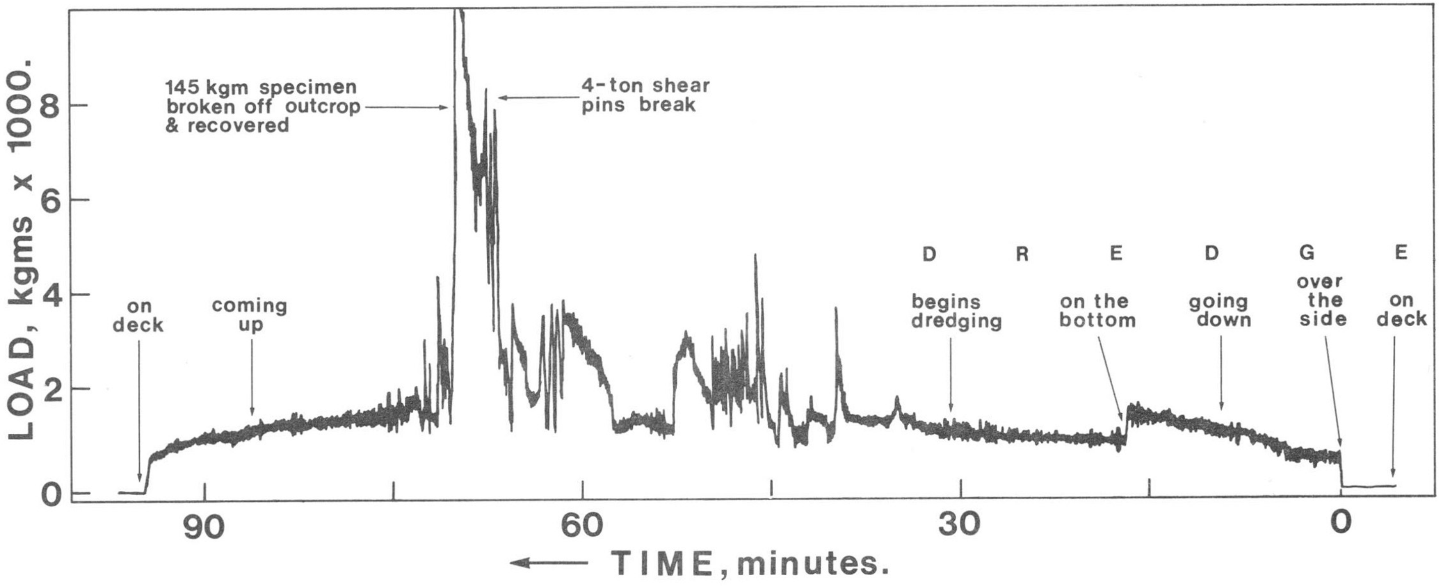


Figure 6. Load cell record of a typical dredging operation; see text for explanation.

3. Those which exceed the breaking strengths of the weak links (the first one breaking at 4 tons). With the yielding of the first weak link the dredge may move ahead, or may snarl again; in the latter case it would await the breakage of the second weak link, or the rupture, from its parent outcrop, of the rock holding the dredge (see Fig. 6).

CONCLUSIONS

It has been demonstrated that photography from a working underwater dredge is both feasible and desirable. A great deal of information has been, and will be obtained concerning the motion of dredges on the sea floor and on the origin of the samples collected.

The data will help the designing of more efficient dredging systems, readily adaptable to different types of terrain and modes of operation. This may lead eventually to a dredging technique sufficiently efficient and accurate to allow detailed sampling programs to be undertaken with confidence.

The inadequacy of the deep-sea winches and cables available for dredging on board the Canadian Survey Ships is a problem that remains to be solved. Cables with a breaking strength of 12 tons and winches with a maximum safe working load of 5 tons are not designed to prise rocks from solid outcrops. An upgrading of the winch-cable combinations to safe working loads of 20 tons or more would allow geologists to make better use of the equipment under development, and to undertake more serious sampling programs.

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