DEEP SEA DRILLING PROJECT
TECHNICAL REPORT No. 1

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OPERATIONS RESUMÉS

CONTRACT NSF C-482

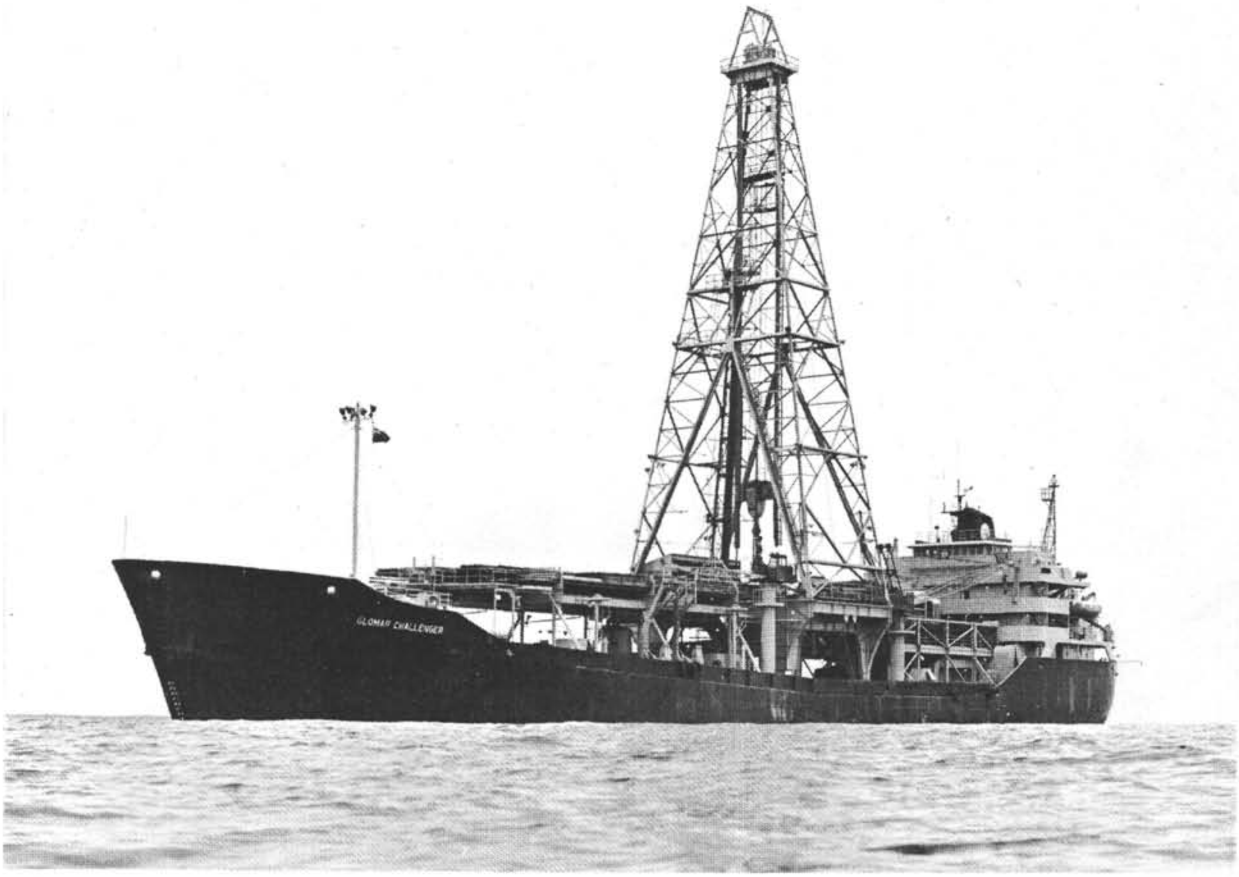
PRIME CONTRACTOR
THE REGENTS, UNIVERSITY OF CALIFORNIA

SCRIPPS INSTITUTION OF OCEANOGRAPHY
University of California at San Diego

OPERATIONS RESUMES

Leg 1 through Leg 18

August 11, 1968, through July 19, 1971



Prepared For

National Science Foundation
Under Provisions of Contract NSF C-482

By

Deep Sea Drilling Project
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INTRODUCTION

This report contains Operations Resumes for the first 18 legs - August 11, 1968, through July 19, 1971 - of the Deep Sea Drilling Project which is being conducted by Scripps Institution of Oceanography of the University of California at San Diego under contract to the National Science Foundation.

The resumes list technical achievements, drilling and coring results, drill bit performance and improvement, coring equipment modifications, test of new procedures and equipment, improvement of standard drilling and coring procedures, plus problems encountered and anticipated and what steps were taken or proposed to prevent recurrence.

A separate report will be made on re-entry.

Resumes were written at the conclusion of each expedition by Cruise Operations Managers who were - with one exception - drilling engineers loaned to the Deep Sea Drilling Project by major oil companies of the United States. The drill expertise of the engineers was invaluable to the Project in establishing and constantly refining operational procedures aboard D/V Glomar Challenger.

It is believed there is much valuable information in these resumes and that publication will be a solid contribution to others engaging in deep ocean drilling and coring in the future. The individual resumes are published largely in their original forms, because the development of techniques and lines of thought can best be followed from impressions at the time operations took place.

October, 1971

ACKNOWLEDGEMENTS

The direction of Mr. Valdemar F. Larson, Operations Manager, and the assistance of Mr. Darrell L. Sims, Project Engineer, and of the many cruise operations managers who have contributed to this volume and to the successful prosecution of the cruises of D/V Glomar Challenger, is gratefully acknowledged. We also thank Dr. W.W. Rand and Mr. K. E. Brunot, who served as prior project managers.

It is also recognized that D/V Glomar Challenger and her excellent support provided by Global Marine Inc., of Los Angeles, California, have contributed exceedingly to the overall technical and scientific success of the Deep Sea Drilling Project.

We further acknowledge the continuing help of Mr. A. R. McLerran, National Science Foundation Field Project Officer and the support of the National Science Foundation.

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OPERATIONS RESUMES

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OPERATIONS RESUME

LEG 1

SUMMARY

The drilling ship, Glomar Challenger, under contract to the University of California and the supervision of Scripps Institution of Oceanography of the University of California at San Diego, sailed from Orange, Texas, in the Gulf of Mexico enroute to New York on Leg 1 of the Deep Sea Drilling Project. It drilled ten holes at seven different sites taking 56 core samples. The average of the hole depths below the ocean floor was 356 meters the maximum depth reached being 771 meters. These holes were drilled in water depths varying from 2822 to 5360 meters with the average water depth being 4700 meters. This task was accomplished in 42 days with 30 days spent on location and 12 days in transit.

DRILLING

The formations encountered were generally of two types, either soft clays or chert. There were some sand stringers, but these were not hard nor consolidated. A very small amount of limestone was also penetrated. Primarily drilling was accomplished with maximum hydraulics. This kept the hole clean, clear of cuttings and in good condition.

The ability to pump down during all operations, i.e., pulling the core barrel with the sand line, logging etc., is believed to be the reason very little hole sticking was encountered. Only a small amount of continuous pumping seemed to be necessary to keep the hole clear and in good condition. During Leg 1 the pipe stuck only three times. On two of these occasions the pipe was worked free with a minimum of effort and within 15 to 30 minutes. On the other occasion the pipe was severely stuck. It was worked free after pulling 120,000 pounds over the pipe weight, working the pipe for approximately four hours, then spotting mud in the areas of the bit three times. It is doubtful and the mud slugs were of much value, but they kept the sea water from back flowing and the hole from caving in during the intervals when pumping could not be accomplished.

It is believed that the stuck pipe was caused by fairly large fractured pieces of chert falling in and packing around the bit. In every case it was possible to circulate although the pump pressures were comparatively high (2,100 psi versus 700 to 800 psi when coring).

The rotary power sub proved to be a very good tool for this operation. It was possible to drill the hole with doubles (18 meters at a time). Also the rotary sub makes it possible to actually drill up out of the hole when the pipe is stuck. To keep the hole clean and in good condition the drilling was controlled to 31 to 37 meters per hour. Except for the chert sections it was possible to drill as fast as the pipe could be dropped if desired.

At Site 7 a massive section of chert was encountered. With a diamond bit this chert section (40 meters) was penetrated. The drilling rate through the chert sections varied from .6 inches per hour to five to seven foot per hour. This chert was very hard and abrasive, but seemed to fracture easily. If it were possible to re-enter a hole and change bits these sections could probably be penetrated quicker and more easily with a "button" roller bit.

WIRELINE CORING

Overall core recovery for Leg 1 was 45 percent. In the soft clay formations recovery was excellent, but in the chert or sandy formations recovery was very poor. Each coring interval was vastly different and therefore had to be attacked in a different manner. As a general rule in the soft formations the procedure was as follows:

— As little pump as possible varing from zero to what was needed to penetrate. Sometimes the pump was kicked on for a very brief period of time during the coring interval.

— Slow rpm varing from 0 to 35 rpm's depending again on penetration and torque on the pipe.

— Constant bit weight.

In the chert formation recovery was poor but the best recovery was accomplished as follows:

— Sufficient hydraulics to lubricate and cool the diamond bit with the associated rotary speed and bit weight.

— A steady rotary speed of approximately 40 to 45 rpm's.

— A very light bit weight (5,000 to 10,000 lbs (until a pattern was cut then increasing the bit weight until a penetration of approximately 1 meter per hour was accomplished. There were times when this drilling rate could not be attained with a bit weight of 40,000 to 45,000 lbs which was the maximum weight that could be placed on the bit.

The technology of wireline coring needs to be studied for increased recovery. Although the recovery on Leg 1 is sufficient for a first operation, it is believed with further experience it can be increased considerably under the same circumstances.

DRILL PIPE

The drill pipe was 5 inch S135 19.5 lbs per foot. Rubber protectors were spaced every 5 feet along its entire length for longitudinal dampening. However, these rubbers also protected the pipe from abrasion against the guide shoe while drilling. The behavior of the drill pipe while hanging beneath the ship and while drilling was surprisingly good.

On one site the location was changed and the ship was moved two miles with 3353 meters of drill pipe hanging from the derrick. The movement of the ship did not exceed 1.5 knots, during this operation, and the slow movement did not cause any corresponding motion in the drill pipe.

The ship was moved one time inadvertently for a short time at a speed of 2.5 knots. At this speed the pipe began to vibrate with a very fast motion that appeared to be a combination of longitudinal and lateral movement. It is believed that this motion was caused by vortex shedding around the pipe. In both of these cases there were no directly opposing currents evident. Therefore, it seems practical to move the ship in a prudent direction at very slow speeds with extremely long lengths of pipe hanging beneath it.

In the 5334 meter water depth to increase penetration the rotary speed was increased to a maximum of approximately 65 rpm's. At this rotary speed the pipe motion (a visual longitudinal motion probably caused by the transverse whipping of the pipe) was of an amplitude that was dangerous and this rpm was never exceeded. Average rotary speed for a 5486 meter string was on the order of 45 rpm. At this speed there was no discernible motion caused by rotation.

BOTTOM HOLE ASSEMBLY

The bottom hole assembly used on Leg 1 was generally the same for all holes. Starting at the bit and going up to the drill pipe it consisted of:

— 9 1/4 inch x 2 1/2 inch core bit.

— Core barrel approximately 35 feet in length with 8 1/4 inch outside diameter.

— Two stands of 8 1/4 inch drill collars.

— Two bumper subs, 8 1/4 inch outside diameter x 4 1/8 inch inside diameter x 60 inch stroke.

— One 8 1/4 inch drill collar.

— A crossover sub from 6 5/8 inch API regular threads to 5 1/2 inch full hole threads.

— One 7 1/4 inch drill collar.

— One 40 foot joint of 5 1/2 inch 24.70 pounds per foot S135 drill pipe.

On one hole a stabilizer was placed between the core barrel and the first stand of drill collars. This was to strengthen a possible weak point in the core barrel connection. However, after one hole with no directly interpretable results it was taken out and never used again.

During most of Leg 1 the weather was excellent and very little vessel motion was experienced, therefore, one bumper sub was deemed sufficient. Also it was believed that the pipe stretch (approximately seven meters in a 5486 meter string) would aid in absorbing some of the vessel motion. This proved to be a false assumption because the pipe reaction time was longer than the vessel motion and did not act as a pulsed movement at the bit. When the vessel in increasing bad weather began to heave more than 5 feet, a core barrel was accidently jammed. After this incident occurred two bumper subs were run in tandem in the assembly and no further trouble of this type was experienced.

In drilling the bit weight was kept very light (less than 10,000 lbs) until the entire bottom assembly was in the hole. At this point when there was very little danger of laying the assembly on the bottom, the weight was increased as needed for a good penetration rate.

SHIP POSITIONING

The ship positioning system operated extremely well on Leg 1. At all times the ship held position within the limits of the drill string, and no drill string failure was experienced. In moderate weather the ship held position within a plus or minus 150 foot radius in the 5334 meter water depth with only very few greater excursions.

At the last site bad weather was experienced (25 knot winds with short 50 to 60 knot gusts and ten to 12 foot swells from the same direction). On this hole the ship was operated in a semi-automatic mode approximately 30 percent of the time. When the ship would move approximately 150 feet off location the mate at the controls would immediately switch from automatic to semi-automatic and initiate a recovery action. A man's reaction at this particular point proved to be better than the computer's reaction. Based on this experience it was believed the ship would be capable of holding position in weather when working on the drilling floor would not be safe.

Fuel consumption, both during cruising and while operating, was less than anticipated. A very conservative figure would be 120 barrels per day while operating, and 100 barrels per day while cruising. Actually on Leg 1 the fuel consumption was less than 95 barrels per day on the average. This was probably because very little bad weather was encountered.

Initial noise tests indicated that the acoustic signal power of the beacons for holding position would not be strong enough in the deeper waters. However in 5334 meters of water the signal proved to be strong and the pulse characteristics very good. Although a stronger beacon is needed to increase the signal to noise ratio for very good operation, the beacons aboard proved to be sufficient for this leg. There was only one beacon failure in eight free fall drops, and it occurred before the beacon reached bottom. The ship was moved out of the beacon's possible range and another was dropped. The technique for dropping the beacons improved with experience. The last two drops were accomplished in less than one and one-half hours in 5181 meters of water. Dropping time for the beacon in this water depth was approximately 55 minutes.

OPERATIONS RESUME

LEG 2

SCOPE

The Challenger departed New York on September 30, 1968, arriving in Dakar on November 25, 1968. In the interim, the ship steamed a total of 4,800 miles, and spent 32 days drilling on five sites. Of the 82 cores attempted, some recovery was obtained on 80 percent of them, with an overall footage recovery of 35 percent. The average water depth was 4602 meters, and average penetration, 425 meters. The maximum total depth was 5814 meters.

DYNAMIC POSITIONING SYSTEM

For the first time, the dynamic positioning system was tested under adverse weather conditions over sustained periods. During the leg no severe weather was encountered, but on several occasions drilling operations were conducted with winds in excess of 40 knots and seas ten to 12 feet. On one location, the current was two knots.

The most important factor delineating upper operational limits is the relative angle of wind and sea acting on the ship. If both were from the same direction, there was no problem. However, during periods of strong winds and seas approaching at an angle of more than a few degrees, serious problems developed. The normal operating practice was to head the ship into the sea, thus minimizing roll. A cross-wind, even as high as 20 knots, necessitated the use of high lateral thrust, accompanied by occasional loss of acoustic signal. During these periods, it was necessary to shift the operational mode from automatic to manual (or semi-automatic). This presents no major problem, but positioning is not quite as precise, and fatigue can become a factor. Under ideal conditions of automatic operation, position is held within a 40 foot circle. If control is manual, excursions up to 200 feet are not uncommon.

The signal strength of the beacon continued to be a problem. However, some promising developments were made toward improving the sonar system. As had been suspected, the zone of maximum signal strength is not necessarily on a vertical line with the beacon. It became a matter of practice to run a test pattern over the beacon with the ship, and select an optimum offset. Using this method, it was possible to increase signal input strength to the ship as much as 50 percent.

The Phase Comparison System (PCS) was restored to service, providing a valuable back-up to the Pulse Position Measurement System (PPM). The two systems are complimentary in behavior characteristics, so that when a loss of acoustics occurred in one mode, position could be maintained with the other.

DRILLING EQUIPMENT

Considering the sophistication and unique nature of the equipment, continuity of operations was very good. However, two isolated equipment failures marred total success of the leg.

The ship was drydocked in New York to modify and increase thruster capability. Unfortunately, it was necessary to return to Newport News to repair these units. Apparently, they were damaged during installation. The other problem was a series of failures in the power swivel motor. Some foreign matter, possibly welding slag, had contaminated the hydraulic fluid. On four occasions, these minute pieces of junk became dislodged, and were carried into the motor with disasterous results. The entire hydraulic system was dismantled, cleaned, and acidized at Dakar to prevent recurrence of this problem.

All other drilling equipment performed exceptionally well. Drill pipe inspections showed no indication of fatigue or corrosion. Equipment downtime was negligible. Two core barrels were lost, but these resulted from excursions of the ship during critical periods.

OPERATING PARAMETERS

Bit weights and rotary speeds generally conformed to those of Leg 1. Bit weights ranged from ten to 30,000 pounds. Rotary speeds were from 20 to 70 rpm's. Typical circulation rates were around 300 gpm. The rate of penetration varied from 91 meters per hour in the upper hole down to one meter per hour in chert.

HOLE STABILITY

As in all drilling operations, hole stability deteriorated as a function of time. Hole enlargement near the mud line must be one contributing factor. The plastic consistency of the formations was a problem on some holes. However, the chert sections caused the most serious difficulties. Even after they have been penetrated, pieces of broken cores and cuttings would wedge the bit and drill collars, making movement of the pipe difficult.

A breakdown of the formation seems to be a common occurrence. On one occasion, when hole trouble was being experienced, probably from a movement of the formation, the drill pipe had a back pressure of 600 psi. This could not be relieved until the drill collars were pulled above the tight hole, permitting communication.

Two problems complicate an analysis of drilling problems. The inability to visually inspect the fluid and cutting returns is the major problem. The other is that the heave of the ship causes wide fluctuations in the bit weight and pump pressure indicators.

BITS AND CORING

Two experimental bits were evaluated on Leg 2, showing promise of increased durability and rates of penetration. However, the massive set diamond bit remains the only solution to penetration in thick chert sections. Even with these bits, results have been marginal and costly.

Dependability of the wireline coring continues to improve. The number of dry runs to retrieve the core barrel was cut by 50 percent. In the final stages of the leg, there was a marked increase in core recovery in soft formations.

LOGGING

A concentrated effort was made to evaluate the wireline logging program with disappointing results. Mechanical failures marred almost every attempt to log. However, there is no basic reason why wireline logging cannot become a successful adjunct to the coring program on future legs.

SUMMARY

The most significant operational feature of Leg 2 was a sustained test of the dynamic positioning system under adverse weather conditions. Upper operating limits were delineated. Some shortcomings of the equipment were encountered, and remedial procedures applied. Isolated mechanical failures marred the total efficacy of the leg somewhat, but these were to be expected. Continued improvements in equipment and techniques assure increasing yields as the program continues.

OPERATIONS RESUME

LEG 3

SUMMARY

On December 1, 1968, the drilling ship, Glomar Challenger sailed from Dakar, Senegal, in West Africa enroute to Rio de Janeiro on Leg 3 of the Deep Sea Drilling Project. The ship and crew travelled 6,163 miles drilling 19 holes on ten sites thus accomplishing 25 percent more work than was originally programed for Leg 3 (see Table 1). This leg was completed in 55 days with 31 days spent in drilling and coring and 24 days in transit. The number of cores attempted was 105 and recovery was achieved in 103 of these cores. The total footage cored was 836 meters and the total footage recovered was 773 meters for a core recovery of 92 percent.

DRILLING

The formations encountered on Leg 3 were virtually the same type as experienced on the previous legs. Past experience with equipment and increased operational knowledge in very deep sea drilling instilled the personnel with much greater confidence, therefore, the drilling operations were accomplished with much more verve and speed.

Again, the holes were drilled using maximum hydraulics. A tight hole was experienced only on one site and this was alleviated after working free by reaming while pumping as much as possible. It was also found if enough hydraulics were used (both pumps) dropping the center bit was unnecessary until very hard formations were encountered. This speeded up operations considerably as wireline time is the second most time consuming operational function (see Figure 1).

On Site 13A with approximately 4877 meters of pipe in the hole, a chert section was encountered. Penetration of this formation required increased bit weight and increased rotary speed (35,000 lb bit weight and 80 to 85 rpm). During this operation the pipe was observed turning slightly in excess of 100 rpm for short periods. Close observation of the drill string revealed no excessive pipe motion or "whip" as reported on Leg 1 when with more than 5486 meters of pipe hanging beneath the ship excessive motion was observed at 65 rpm.

During the entire leg the rotary power sub was used for drilling. No failures were experienced and this tool appears to be a very successful advance in drilling. The power sub permits drilling in doubles (18 meters) instead of singles (9 meters) and on a standard rig where guide rails are not required for the traveling block, drilling could be accomplished in triples (27 meters). It is easily seen that this will permit increased bit time on bottom.

WIRELINE CORING

Overall recovery on Leg 3 was 92 percent. This is a substantial increase in core recovery over Leg 1 and Leg 2. Again this can be credited to the experienced personnel and confidence created in the equipment by use.

Some complete sediment sections were cored with virtually 100 percent recovery. This included the soft very slushy unconsolidated formations through dry consolidated formations to very hard basalt formations.

The procedures for coring these various types of formations is as outlined below:

1. Slushy unconsolidated formations -coring this type of formation required only a punch core procedure. The drill pipe was not rotated but was lowered evenly and steadily holding as close as possible a constant bit weight. No fluid was pumped during this operation.

   To prevent the core sample from falling out of the barrel during retrieval, a vinyl plastic sock was used. This sock was held in place by being inserted between the core catcher sub and the plastic core tube. Then a section of the sock about ten-inches long was stuffed inside the plastic tube. When the core sample would start to fall from the tube it forced the plastic sock onto the dog-type core catchers trapping the sample inside the plastic tube. Two dog-type core catchers were used when coring this type formation. This technique was used very successfully. Surface cores where the formation was very slushy and unconsolidated, were taken on every site with practically 100 percent recovery on each attempt.

2. Dry consolidated formations - at a point when the sediment changed from a wet consolidation to a dry consolidation, the plastic sock was removed and no longer used. The decision on when this point is reached is largely arbitrary and based on experience. The formation has to be dry enough and consolidated enough not to fall through the dog-type catchers.

   In coring this type formation the bit was turned slowly. The core was taken with no fluid being pumped until the bit weight and torque increased to a point where it was deemed necessary to pump fluid. Then the pumps were started and circulation was "broken". At the instance circulation was broken, the pumps were shut off. All this time the bit was being rotated slowly with the weight on the bit as constant as possible. When the circulation was "broken" the penetration would instantly increase and the above coring cycle would be repeated.

3. Hard basalt formations - the instant this type of formation was encountered the inner barrel was retrieved, the plastic tube was removed from the inner barrel, and one dog-type catcher and one standard type-catcher were inserted in the catcher sub. It was found that trying to core with the plastic tube in the inner barrel in this type of formation caused the plastic tube to collapse and breakup. If this happened the barrel would become jammed and no further core sample would be obtained.

   The bottom hole assembly was designed for coring in this type formation. When coring in a hard formation if the ship motion causes the bit to leave bottom, the bit is subject to extensive damage. Therefore, a bumper sub was inserted in the bottom hole assembly with only three drill collars and the core barrel between the bumper sub and the bit. This permitted the bit to start and cut a pattern with light bit weights and at the same time maintain contact between the bit and the bottom of the hole. The procedure was to maintain this light contact for a timed period (approximately three hours) while turning at about 40 to 50 rpm. Then the bit weight was increased to about 35,000 lbs moving the pumper sub action to the top bumper sub. During this interval the pump was running about 15 to 20 strokes per minute. This latter bit weight was carried until about three meters of formation was penetrated or until the penetration rate decreased substantially. It was found that after either of these two conditions existed core recovery decreased drastically.

Immediately before coming out of the hole after coring in a very hard formation a "rabbit" should be dropped into the top of the drill pipe. This is suggested because pieces of the hard core sample are susceptible to falling out of the core barrel and lodging in the drill pipe. These lodged pieces will block the drill pipe and on the next coring attempt the core barrel, when dropped, may not reach bottom and latch. If the "rabbit" is in the bit when the pipe is pulled then the pipe is obviously clear.

BOTTOM HOLE ASSEMBLY

The bottom hole assembly used on Leg 3 was different from Leg 1 in the spacing of the bumper subs and the use of one additional 8 1/4 inch drill collar above the bumper sub. The reasons for these changes will be discussed later. Starting at the bit and going up the string to the drill pipe the bottom hole assembly consisted of:

— 9 7/8 inch x 2 1/2 inch core bit.

- Hycalog Drill Collar Core Assembly*.
- Three 8 1/4 inch drill collars.
- One Type "E" Bumper Sub 8 1/4 inch outside diameter x 4 1/8 inch inside diameter x 60 inch stroke.
- Six 8 1/4 inch drill collars.
- One Type "E" Bumper Sub 8 1/4 inch outside diameter x 4 1/8 inch inside diameter x 60 inch stroke.
- Two 8 1/4 inch drill collars.
- A Crossover Sub from 6 5/8 inch API Regular Threads to 5 1/2 inch Full-Hold Threads.
- One 7 1/4 inch drill collar.
- One 40 foot Joint of 5 1/2 inch 24.70 lbs per foot S 135 Drill Pipe.

On Site 13 and 13A, the bottom hole assembly was the same as on Leg 1. This was with two bumper subs connected in tandem near the top of the assembly. An assembly of this type made it necessary to put 30,000 to 35,000 lbs on the bit before the bumper subs began to act. Therefore, any vessel motion is transmitted to the bit allowing it to "pound" the bottom of the hole.

Chert was encountered on these two holes. When the bit was pulled extensive damage was visible. The coring crown or inside diameter portion of the bit had been broken in several places. Pieces of steel with inset diamonds of notable size were recovered in some of the core samples.

An assumption was made that the bit should be first "drilled-in" with light bit weights when hard formations were encountered, but it was also reasoned that the bit must maintain contact with the bottom of the hole at all times to prevent "pounding" damage. Based on this, one bumper sub was moved nearer to the bit for light bit weights. Another bumper sub was placed further up the assembly when heavier bit weights were needed. Then the coring procedure as described under hard basalt formations was initiated.

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*This is the name given to the new Hycalog coring assembly unit used on this leg. This assembly used the standard 8 1/4 inch x 4 1/8 inch drill collar for the outer core barrel. The new assembly strengthens the outer barrel as a standard 6 5/8 inch American Petroleum Institute (API) Regular Tool Joint is used. No failures were experienced in the core barrel joints of this assembly. Also, this is a simpler assembly.

This bottom hole assembly was used on the remaining sites and holes of Leg 3 and no further bit damage as described above was noted. Also, basalt core samples were obtained with this assembly and procedure.

The placing of an additional 8 1/4 inch drill collar above the top bumper sub was for two reasons. First it was to "beef up" and to place more weight immediately about the top bumper sub before making the transition into the drill pipe. Second, it was to permit coming out of the hole on an even stand with the 7 1/4 inch drill collar. This lessened the stripping operation when removing the upper section of the guide shoe. It is necessary to remove this large section each time a trip is made into or out of the hole because the top section of the guide shoe will not clear the 8 1/4 inch drill collars. This is a time consuming and hazardous operation, therefore, any reduction in time and handling of this operation is extremely beneficial.

DRILLING TOOL FAILURES

Two drilling tool failures occurred on Leg 3. One failure resulted in the loss of a bit, core barrel, and three 8 1/4 inch drill collars. Both of these failures occurred in the sample place. The failure was at the joint between the top sub and upper barrel of the bumper sub.

On Site 17, when using a roller type coring bit, excessive torques occurred. While coming out of the hole the equipment was inspected very closely. This inspection revealed that both bumper subs were "belled out" at the box in the joint mentioned above. It was evident this failure was the result of the excessive torques and also contributed to the resulting loss of the cones on the roller bit.

The operational technique was reviewed and it was decided to limit the torque in the power sub to prevent a recurrence of this trouble. Also the torque records were being closely observed for any recurrence of excessive torques. High torques often occur when a very hard formation is first penetrated.

While drilling Site 20A three sharp and high torque peaks were observed. However, these torque peaks were so short in duration it was decided that possibly no damage was suffered to the tools. But on the next coring attempt a failure occurred. When the pipe was pulled out of the hole and inspected a bumper sub joint failure was found. The threads on this pin joint showed evidence of apparently failing in torque. The pin looked as if the box had become "belled out" from excessive torque then "wobbled" until failure occurred.

Both of these failures happened when the power sub was in second gear. The power sub second gear has a maximum torque of 17,000 ft/lbs and a maximum rotating speed of 90 rpm. It is believed that the torque limiting switch was not on its maximum setting during these operating periods, but the exact value of this setting is not known. Therefore, it is believed that a maximum torque operating value should be 12,500 ft/lbs until further experience is gained in this area. A maximum torque output in third gear is 12,500 ft/lbs so it would be unnecessary to limit torque in third or fourth gears but first and second gears should be red-lined at 12,500 ft/lbs.

BITS

Bits were selected at the beginning of the project based on available information for drilling ocean sediments with a minimum penetration into the basement. This knowledge was sketchy or non-existent and in anticipation of various possibilities three types of coring bits were placed aboard the Glomar Challenger. These types consisted of:

- Tungsten drag bits.
- Roller coring bits.
- Diamond bits.

All three of the above bits have been used with the following results:

- A tungsten drag bit does not penetrate and core satisfactorily in the harder formations.
- The roller bit is very susceptible to losing cones.
- The diamond bits have performed best in all types of formations.

Two types of diamond bits used were the massive set and the blade or drag type. There has not been enough difference in performance of these two to economically justify the continued use of the massive set diamond bit.

Two other options were used to gather more information for an effective bit design. These options were a face fluid discharge and a surface fluid discharge design. Each of these are necessary as different formations are encountered, therefore it was felt a combination of these two designs would be most beneficial.

A 9 1/4 inch x 2 1/2 inch and a 9 7/8 inch x 2 1/2 inch bit was also run and evaluated. There was no notable difference in the performance of the two sizes, but subjectively it was felt that the 9 7/8 inch bit was the better of the two.

Based on the above information and experience an all-purpose bit with the following design characteristics was ordered for use on Leg 5.

— The bit design would be 9 7/8 inch x 2 1/2 inch

— It would be a drag bit design but using diamonds on the drag blades.

— It would have face fluid discharge ports for drilling and coring in the soft sediments, but the coring crown or inside diameter portion would have surface fluid discharge to keep the diamonds cool when a very hard formation (chert or basalt) was encountered.

It is believed this general bit design will perform better in all types of formations. The drag design inherently uses less diamonds and is more economically attractive. The bit design for the program is still very flexible and design changes will be inaugurated as needed and as experience and knowledge of ocean floor formation increases.

SHIP POSITIONING

The ship positioning system operated better on Leg 3 than on the previous legs. This is another result of experienced personnel and their learning curve. At all times the ship held position within the limits of the drilling tools and no failures resulted from positioning. There was never any "shut down" of operations because of weather, but on several occasions operations were curtailed slightly when moderately bad weather was encountered (35 knot winds, ten to 12 foot seas, and sudden rain squalls). It was necessary in some instances to position the ship in an attitude that was not advantageous to vessel motion. This would occur when the wind and current would be from a different direction than the prevailing seas. In some of these instances the current and wind would be of sufficient strength to necessitate heading the vessel in a direction that the vessel motion made working on the drilling floor slow and awkward. A maximum roll of ten degrees to each side was observed and work continued on the floor.

Average fuel consumption both during cruising (6,163 miles) and while operating on location (31 days) was approximately 100 barrels per day. This is about the same as was consumed during Leg 1 (95 barrels per day average). The average weather during Leg 3 was more severe than was encountered on Leg 1. The thrusters were run at a higher thrust level than on Leg 1, therefore it is reasonable to anticipate the future fuel consumption of the Glomar Challenger on the basis of these figures.

SATELLITE NAVIGATION AND WEATHER EQUIPMENT PERFORMANCE

The satellite navigation is indespensible in locating the coring sites. When the ship is relatively stationary for days during a coring operation the satellite navigation equipment can take multiple fixes locating the site very accurately. It is estimated under these conditions the site may be located within plus or minus 160 feet relative to each other.

The Automatic Picture Taking (APT) Weather Satellite Equipment in conjunction with the ESSA weatherman also proved invaluable. With the cloud cover pictures (see Figure 2) the weatherman was able to anticipate fronts in areas where no other weather information was available. With this information the weatherman could forecast wind and sea conditions with relative accuracy as to magnitudes and times. This prevented the ship from being caught by surprise and endangering the operation by possible loss or damage to equipment and personnel.

TABLE 1

LEG 3 DEEP SEA DRILLING PROJECT

SUMMARY OF OPERATIONS

(Dakar to Rio de Janeiro)

Total days Leg 3 (December 1, 1968 to January 24, 1969)	55.00
Total days cruising	23.94
Average speed (knots)	10.70
Total miles travelled	6,163
Total time on sites	30.77

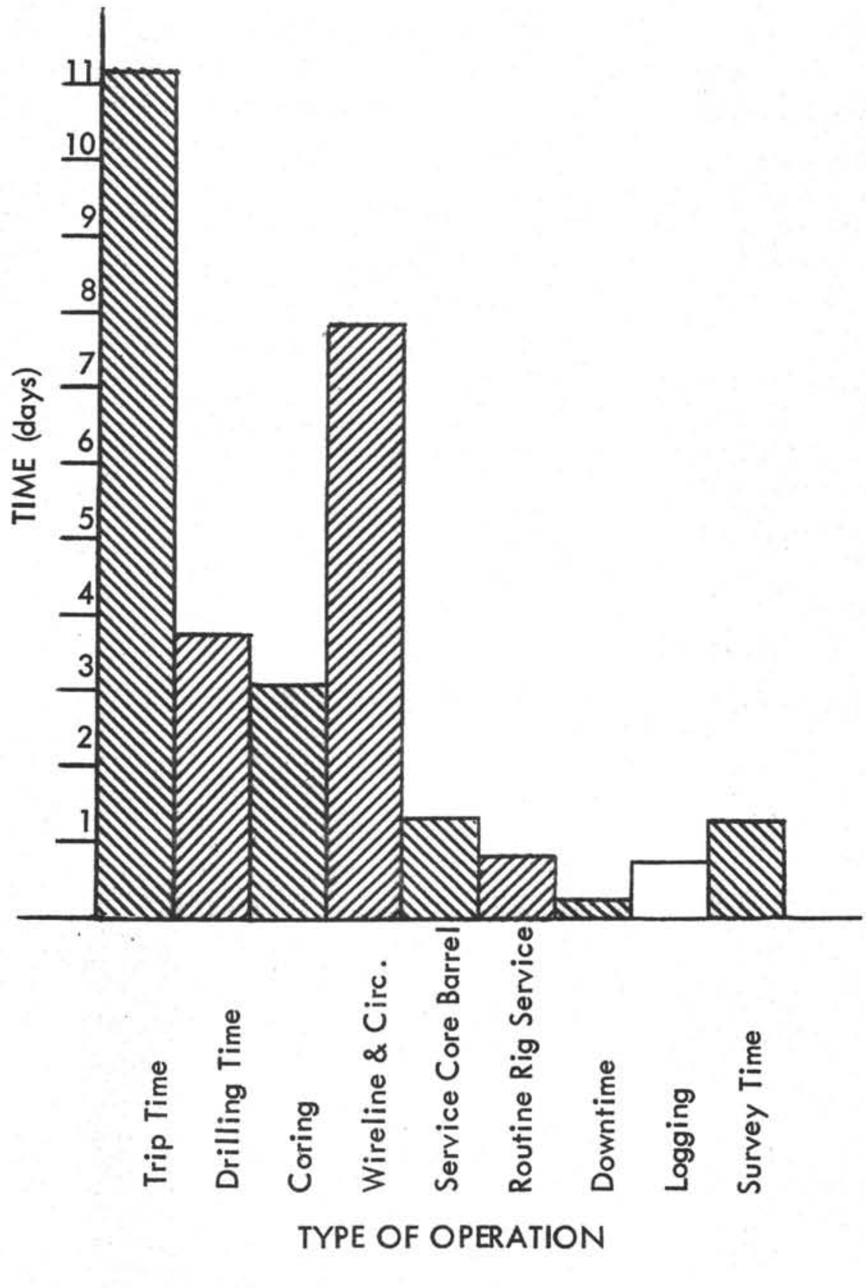
Trip time	268.75 hrs or	11.20 days
Drilling time	89.75 hrs or	3.75 days
Coring	74.00 hrs or	3.10 days
Wireline and circulation	188.25 hrs or	7.85 days
Service core barrel	31.25 hrs or	1.31 days
Routine rig service	19.75 hrs or	0.82 days
Downtime	6.00 hrs or	0.25 days
Logging	18.00 hrs or	0.75 days
Survey time	33.25 hrs or	1.30 days
Total		30.33 days

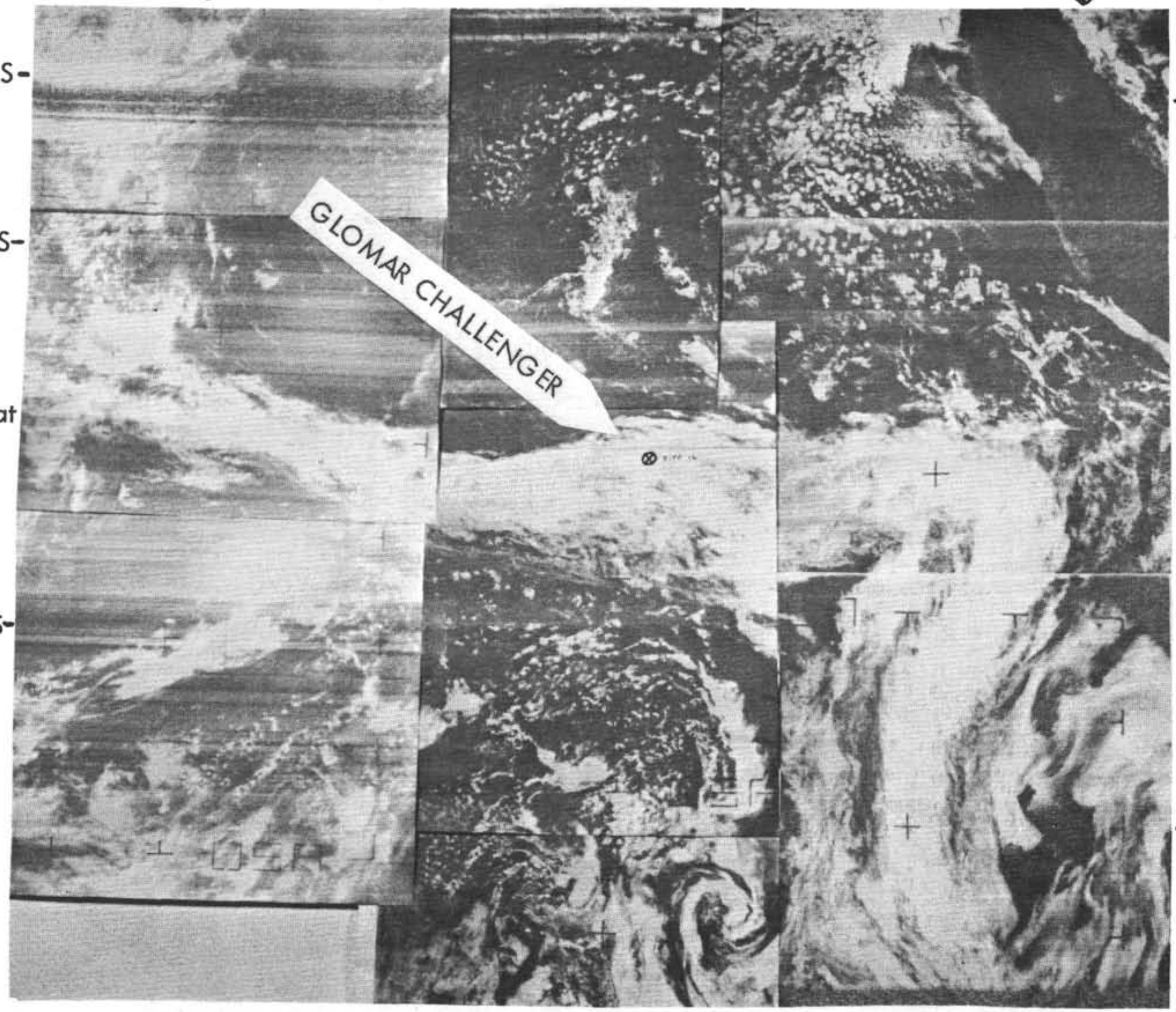
Sites drilled	10
Holes drilled	19
Number of cores attempted	105
Number of cores with recovery	103
Percent of cores with recovery	98.00
Total meters cored	836.00
Total meters recovered	773.00
Percent meters recovered	92.00

Figure 1

LEG 3 DEEP SEA DRILLING PROJECT

TIME RELATIONSHIP BETWEEN TYPES OF OPERATIONAL FUNCTIONS





LEG 3 DEEP SEA DRILLING PROJECT - CLOUD COVER PICTURE

Figure 2

OPERATIONS RESUME

LEG 4

Leg 4 was characterized by a continuing improvement in operating techniques and equipment. Each phase of the program marks an increase in knowledge assuring future legs success as more difficult objectives are achieved. Obtaining this knowledge can be painfully expensive, but this is not unexpected. Any project predicated on a combination of deep water and deep drilling is hazardous and costly per se. To the credit of each person involved in the project, four legs now have been successfully concluded. All of the major operational problems have been solved or minimized to a point where continuing success is assured.

All of the six sites originally scheduled for Leg 4 were investigated plus two new sites. The deepest penetration below sea level (5938 meters) of the entire project was made. Lost time was minimal. Weather presented no problem. The port call in San Juan was made in less than 36 hours.

DYNAMIC POSITIONING SYSTEM

The brightest aspect of this leg was the excellent performance of the positioning system using the new 111 db beacons. The high signal output permits using a very low gain on the computer, resulting in the exclusion of all ambient noise from the system. Even under conditions of maximum thrust noise, the beacons signal is dominant. The significance of this is that sea state is no longer a major factor in the positioning system. The controlling factor now becomes the drilling operation as far as upper limitations or weather are concerned.

A second but equally important benefit has accrued from use of the high power beacons. The computer does not "lock in" on transient noises and reliability is extremely high. It is not unusual to obtain periods of fully automatic operation for 24 hours or longer with maximum excursions of no more than 20 to 40 feet. Occasional adjustments of heading are advantageous but not necessary.

Despite a sustained effort to upgrade the reliability of the PCS as a backup , results have been disappointing. Serious doubts exist that this equipment in it's present form, will ever be of any value for redundancy.

RIG EQUIPMENT

The most serious failure of the leg was the loss of 15,000 feet of drill pipe during a trip out of the hole. One of the bales on the traveling block failed to fully engage in position in the elevator. As a result, the other bale took the full weight of the string, and the pipe broke and dropped.

This identical mishap had occurred before, but on those occasions the weight of the string was less, so that the pipe bent but did not break. There is no reason to believe that it will not recur unless positive steps are taken to modify or eliminate this system.

The intention of the dual elevator system is to prolong the life of the drill pipe by eliminating the use of slips and the resulting induced flaws. In practice it is hazardous and cumbersome. All that is needed for a repetition of this accident is for the ship to roll just as the driller picks up on the string.

Performance of the other rig equipment was excellent. The contractor's personnel and equipment made a very creditable showing.

BOTTOM HOLE ASSEMBLY

Another problem which came to light on Leg 4 is a weakness in the couplings in the collars and bumper subs. The bumper sub has a connection, used when servicing the sub, which has a maximum make-up torque of 18,000 foot pounds. This falls in the normal drilling range, so it will be necessary to reduce bit torque if this coupling is to be protected. Placing this limit on bit torque will reduce the rate of penetration, particularly in harder formations. Because this torque limitation had not been recognized previously, two sets of drill collars were lost on the leg due to failures in the bumper subs.

There is reason to believe that for the majority of holes drilled, no bumper subs are necessary. Since the "unbalanced" type sub currently being used remains either fully extended or fully retracted during drilling operations, it does not function as a sliding sleeve, the use for which it is intended. However, this does not pose the problem that it would in shallow water, since the elasticity of the string absorbs the heave of the ship to a great extent. The only advantage gained from the use of the bumper subs is to permit use of a constant bit weight while operating in shallow water or rough seas.

Another mechanical flaw which came to light for the first time, is the unstable dimensions of the drill collars. The collars now being used are 8 1/4 inch x 4 1/8 inch with a 6 5/8 inch regular thread. It had been the practice to make these collars up to 40,000 foot pounds. After a drill collar failure, an investigation showed that this torque should be reduced to 27,000 foot pounds to prevent damaging of the box and pin. However, it is the opinion of at least one drill collar expert, (Moak Rollins), this is less torque than is necessary to "hold the string together". Obviously the solution is to increase the outside diameter of the drill collars.

Another problem related to drill collar dimensions is encountered when a hole is spudded. Even in fairly calm seas the heave of the ship sets up harmonics in the drill string which make it impossible to read the weight indicator closer than plus or minus 5,000 pounds. Thus, when the bottom is very soft, it is impossible to detect the point that bottom is penetrated. When six to eight foot swells are encountered this problem is magnified so that the error increases to plus or minus 20,000 pounds. The effect of this is to raise the neutral point in the drill collar string up as high as the first or second tool joints when penetration of the mud line occurs. Since these connections have no lateral support at this point, there is a strong tendency toward column buckling failure. A similar situation prevails when hard formations are encountered near the mud line.

It is suggested that the drill collars size be increased to 9 inch (155 ft/lbs) or 10 inch (193 ft/lbs) instead of the 8 1/4 inch (119 ft/lbs) currently being used. This would serve the dual purpose of keeping the neutral point low in the string, and giving an increased cross-section area to improve the coupling. This would necessitate increasing the bit size to possibly 12 1/4 inches, but this too might be advantageous as will be outlined below. It would not be necessary to eliminate the existing eight inch drill collars. It is proposed that only the bottom three collars be large diameter, tapering the string back to eight inches at the third collar.

BITS

On the last half of the leg, two attempts were made to penetrate the Horizon A chert without success. On both occasions massive set diamond bits were completely demolished. Viewed in the light of other attempts to penetrate this chert section, it must be concluded that a diamond bit is incapable of penetrating this formation unless the section is very thin or is not completely developed into chert. Apparently Horizon A consists of chert sections possibly one or two feet thick laminated with other materials. In any event it is not a homogeneous chert section 15 to 31 meters thick as one might be led to believe. This probably accounts for earlier optimistic reports indicating penetration of 31 meters of chert, when actually it was more in the order of five to ten feet. In any event the statistical chances of success in penetrating this formation with existing equipment are so slight that further attempts should be discouraged.

One possible solution would be to seek aid from industry in constructing a 12 1/4 inch "insert" roller core bit. This is the type of bit normally used for drilling chert, and chances of penetrating chert sections would be greatly increased. This also points out the need for a re-entry system in expanding the scope of the project, since even with a chert bit, more than one run would probably be necessary.

Tungston carbide insert bits were used on the majority of holes with satisfactory results. Economic considerations suggest that this type bit, or the light set diamond bit, to be used on Leg 5, continue as the basic drilling bit.

Two other innovations in bit design were tried on the leg with inconclusive results. One was to reduce the throat diameter to facilitate entry of the core into the inner barrel. The other was use of a face discharge instead of a center discharge bit to prevent washing of the core. Both items have merit worthy of further experimentation.

CORING EQUIPMENT

Core recovery on Leg 4 was not as high as Leg 3 mainly due to the higher incidence of compacted, water sensitive clays, and harder formations generally. Mis-runs and core equipment failures were less of a problem than on previous legs. Coring techniques appear to have been optimized but improvement is still needed in equipment design and quality control.

It is suggested that as a matter of preventative maintenance, that the wireline on the auxiliary reel be replaced at the end of each leg. This line is subjected to extreme wear, and experience has indicated that the average life of these lines is only about two months. Replacing them as a matter of practice at the end of each leg would minimize the lost time incurred in a wireline failure.

DRILLING PARAMETERS

Drilling techniques have now become more or less standard, bit weights vary from ten to 30,000 pounds depending on the hardness of the formations. Weights above 30,000 pounds increase the drill pipe torque above an acceptable maximum. Rotary speeds have been increased to 75 to 80 rpm without deleterious side effects.

Selecting optimum hydraulics is difficult since hole erosion in incompetant formations must reach substantial proportions even after drilling only a few hours. It is the practice to drill with a minimum amount of fluid at the top of the hole (150 to 200 gpm), gradually increasing flow rate with depth. Despite these efforts to minimize hole enlargement, there is reason to believe that after the first few hours of drilling, nothing larger than colloidal size particles actually "escape" from the hole.

On one site, after reaching total depth on the first hole, it was decided to re-drill the upper part of the hole, a common practice. The bit was pulled up above the mud line, and the hole re-spudded. After about three hours it became apparent that we were back in the original hole. An "involuntary" re-entry had been effected.

One other drilling phenomenum was noted for the first time on this leg. If a very hard formation such as chert, is cored for several hours, the indications may be that ten to 15 feet have been penetrated. Upon retrieving the core barrel, recovery may be one or two feet. Upon attempting to core again, the 15 feet of "hole" supposedly drilled, had been lost.

Ship excursions or hole fill-up do not adequately explain all of the instances that this situation has occurred. It is hypothecated that rotating over a substantial period of time causes the string to bow in some manner, causing a shortening of the string. If the pipe is static or rotated slowly for a few minutes, the bow is eliminated, and net length returns to original.

LOGGING

Logging capability was available for the last four sites of Leg 4. Of the four holes, one was completely logged, one partially logged, one was not logged due to mechanical failure outside the logging program, and one was not logged at the Scientist's discretion.

From an operational standpoint, there is no reason that the logging program cannot be prosecuted successfully. The problem of rigging in the derrick appears to be solved by realignment of the sheaves. If the present method of rigging proves unsatisfactory on future legs, the problem is susceptible to alternate solutions. Unacceptable hole conditions and logging equipment failures have been common, but only slightly more so than with conventional oil well logging programs. Probably 25 to 30 percent of all comparable holes have had one or more mis-runs for these reasons.

In normal oil field drilling operations, where obtaining a log is a necessity, it is not unheard of to spend as long as four or five days attempting to log a hole. This is mentioned merely to stress the point that a certain minimum amount of time must be dedicated to logging on each site in order to make the program a success. A period of at least 24 hours should be spent attempting to log on each site if necessary to obtain the logs.

It is strongly recommended that all in-pipe logging be discontinued as being too hazardous operationally. To run these logs it is necessary to keep the drill pipe practically motionless for sustained periods of time, a practice which contravenes accepted drilling principles. If the drill pipe is rotated there is a strong likelihood of unraveling or otherwise damaging the line. The pipe may be reciprocated, but only for short distances due to the nature of the rigging. Finally, the logs now run inside the drill pipe can be run equally as well in open hole thus eliminating the necessity for taking the risks.

One item of interest should be noted. During this leg, a sleeve was developed which is dropped immediately before logging the hole. This sleeve seats in the outer barrel, and prevents the bit and protuberances in the barrel from cutting or chaffing the wireline. The only problem with its use is that once it is dropped, there is no way to retrieve it, thus there can be no subsequent coring. However, if the logging program is continued, a wireline fishing spear can be obtained which would permit retrieval of the sleeve.

OPERATIONS RESUME

LEG 5

SUMMARY

The Glomar Challenger departed San Diego, California on April 12 at 10:10 for the fifth leg of its contract to the University of California under the supervision of Scripps Institution of Oceanography. The ship arrived in Honolulu, Hawaii on June 5, 1969. During the interim the ship travelled 4,258 nautical miles. Drilled 14 holes on 12 sites. Attempted 1027 meters of cores and recovered 870 meters for a recovery of 84 percent. Total days at sea was 54 days, 3 hours. Steaming time was 17 days, 13 hours, 43 minutes or 32 percent. Survey time was 1 day, 12 hours, 42 minutes or 1.8 percent. Drilling time was 35 days, 42 minutes or 64.5 percent.

DRILLING AND CORING

Formations encountered included watery mud, loose sand, chert, basalt, and small amounts of calcareous material. Only small sections were drilled, with most holes being continuously cored. Almost all coring in soft formations was carried out with little or no circulation. Drill pipe was not stuck at any time. All coring was with diamond bits except for Site 43.

LOGGING

Although mechanical problems have continued, they do not appear to be related to equipment, but rather to operational technique. This is not to say that logging failures will not occur in the future but experience will develop successful logging procedures.

It appears that two semi-related mechanical problems continue to plague logging operations. These are (1) bridges at or near the bit and (2) kinked and mashed logging cable. The possible causes of these problems and suggested solutions follow.

It seems almost certain that bridges are being formed at or near the point where the bit is suspended while logging tools are being made up and run in the hole. This condition is aggravated by rough seas. The following procedure apparently corrected this problem on Site 35.

1. Make a wiper run before spotting mud, i.e. pull up to the point where the bit is to be suspended. Then run back to bottom. Circulate and ream any tight spots.

2. Spot mud. Viscosity 50 seconds or less.

3. Pull up one double above point where log is to start.

4. Make up logging tools.

5. Lower blocks one double and start in with logging tools.

6. Raise blocks one double while running in.

7. When logging tools are almost at the bit, lower drill pipe to knock out any bridges and pull up again as the logging tools leave the bit.

Although subject to personal opinion, it does not appear that the logging line is being kinked and mashed by any internal obstruction in the drill pipe, drill collars, core barrel, or bit. The most successful log run on Leg 5 was made without a dummy inner core barrel being run with no kinks or mashed line. On the other hand, severe kinking and mashing of the logging line occurred while running the heat probe on Site 35.1 where the probe was run on a 45 foot long inner core barrel and the cable was not run out of the bit.

It is suspected that either excess twist is being imparted to the logging line or that twist is not being worked out of the line using the usual procedures. It was noted that kinks or mashed line occurred in every case where slack was allowed to occur in the logging line. The probable cause of this is easily demonstrated by twisting a rubber band while in tension. As long as tension is maintained no kinks occur, but immediately after the tension is reduced the rubber band kinks. With the logging line these kinks will be flattened and mashed when the tools are retrieved.

The following is suggested:

1. Stop the logging sonde at least every 1,000 meters and before running out of the bit. Pull tools up five to ten meters at each stop to work out twist.

2. Do not slack off on logging line. Use measurements making no attempt to "feel" bottom.

3. Use weights on logging tools to increase tension in line.

4. Contact logging service companies for an anti-twist device.

CASING

One joint of 10 3/4 inch casing was run on Site 43. This run can only be considered partially successful. On the plus side, the joint was made up, run to bottom, drilled in, two cores taken and the casing left in the hole in 5405 meters of water. Negatively, the release mechanism failed to operate after numerous attempts, and the casing was actually left in the hole due to the failure of a coupling made up at the mill. The Global Marine Inc. landing base appears almost satisfactory as used.

Problems encountered were:

1. The Hycalog casing release tool was made up with shear pins welded in place. It was necessary to torch cut these pins out in order to make up the tools.

2. The old style Hycalog core barrel which was required for the running tool had been used on previous legs and had "galled threads" at three joints. It was necessary to weld and strap these joints.

3. For ease of making up the string under "at sea conditions" it was decided to run the release tool directly below the landing base, rather than at the bottom of the casing. This required welding and straping casing threads at the bottom of the running tool and landing base. The casing shoe provided with the Hycalog running tool was not used.

4. The shear pins holding the casing to the landing base were considered inadequate and were replaced with welded threads.

5. The shear pins in the Hycalog release tools are at the wrong end of the "J" slot. As used these pins must bear the entire weight of the casing to landing base during the entire running in time.

6. No rotary bushings of the correct size were available.

In summary, the landing base can be used with minor modifications. The running release tool is unsatisfactory. All eight round threads should be replaced by buttress or seal-lock threads. All casing is badly corroded and should be given a protective coating.

DYNAMIC POSITIONING

The introduction of the more powerful Burnett PPM beacon eliminated most dynamic positioning problems. On only one site (35.1) was it necessary to abort because of inability to maintain position. This occurred in very rough seas with wind gusts up to 50 knots. Even here beacon strength was such that position might have been maintained except for air bubbles around the hydrophones blocking the beacon signal. A total of 14 Burnett beacons were dropped. All except one operated within acceptable limits, but two had noticeably weaker signals than the remainder. One beacon failed completely at about the time it hit bottom.

Ocean Research Equipment Company (ORE) PCS beacons were dropped on Sites 32, 33 and 34. On the first two sites the beacon signal was lost. On Site 34 the signal could be detected after the beacon reached bottom but the PCS could not be made to work. Only the PPM System was used on subsequent sites.

The only other change made was to shorten the conductor and anchor cables from the battery pack to the signal transmitter to about five feet. About 140 pounds of additional weight was added to each battery pack. No additional floatation was used.

CREWS

Crew performance was excellent throughout the entire leg.

DRILLING EQUIPMENT

Problems continued with bumper sub operations. One complete failure occurred at the service joint, resulting in loss of a bottom hole coring assembly. In addition, three other subs were noted to be "belled" at the service joint and discarded. The following recommendations are made:

1. Extreme care should be used in making up joints to insure that proper torque is applied.

2. Bumper subs should be visually inspected each time out of the hole.

3. Torque applied at the surface through the power sub should be carefully observed and limited. In this regard torque applied at the surface appears to be almost instantly transmitted to the bit with no hole drag such as is encountered in oil well drilling. This could be resulting in shock loadings at the bottom of the string above those recorded at the surface when drilling in hard formations .

OPERATIONS RESUME

LEG 6

Leg 6 departed Honolulu on June 12, 1969 and arrived in Guam on August 5, 1969. In this period the ship sailed 5,509 miles, investigated 17 sites, and drilled a total of 36 holes. The amount of core recovered was 689 meters. The leg was characterized by some of the most difficult drilling conditions encountered since the inception of the project.

The lithological sequence on most sites consisted of a thin layer of soft sediment overlying a thick section of chert and cherty material. In most cases the upper transparent layer was neither thick enough nor solid enough to give adequate lateral support to the drill collars. As a consequence tool failure occurred from column buckling on the first four sites. After this unfortunate beginning, extreme care was exercised in site selection, and in the cases where hard formations were encountered before the drill collars were buried, the holes were abandoned. This served to conserve the drilling equipment but limited the scientific scope of the leg. On several occasions it was necessary to terminate drilling arbitrarily at a point of high scientific interest for fear of losing the drill collars.

It had been correctly anticipated that chert would be present on most sites, and several experimental bits were tried with disappointing results. In no case was penetration greater than a few feet, 15 to 20 where the chert was thinly laminated, and less than one foot in solid chert sections. Investigation of sections lying below the chert must await the development of a re-entry system or an alternate method.

Core recovery improved somewhat over the average of previous legs. This is attributed to the nature of the formation being cored rather than any improvement in equipment or techniques. Core recovery is consistently higher in the upper sediments than in the lower harder formations. This is compatible with the statistics of the other legs indicating that percentage of core recovery is inversely proportional to the average depth of holes drilled. There are exceptions to this. Water sensitive bentonitic materials are extremely difficult to core, irrespective of depth. Similarly, the dense formations have consistently yielded poor results. Nevertheless the trend is recognizable. It is unfortunate that some persons have measured the success of a leg by the amount and percentage of core recovered rather than the quality of information gained.

Weather did not pose the problem on the Shatsky Rise that had been anticipated. The decision to operate in this area during the summer months proved to be justified. However, one scare from the weather occurred while operating on Site 55, when Typhoon Viola developed in the immediate vicinity. This site was south of Guam in the intertropical convergence zone, and there was no advance warning. However, the storm at this point was not of sufficient intensity to pose a real threat. Needless to say, the ship departed the area immediately. Subsequently this typhoon struck the Philippines causing heavy damage.

Some of the highlights of Leg 6 were:

1. Operations in deepest water - 5990 meters.

2. Deepest core attempted - 6122 meters.

3. Oldest formation yet recovered in Pacific - Site 50.

4. Most sites investigated - 17.

5. Most holes drilled - 36.

SHIP AND DRILLING EQUIPMENT

The ship, drilling equipment, and positioning system performed extremely well. Lost time due to mechanical failure was at a minimum. The drill pipe inspection at Honolulu prior to departure indicated pitting and corrosion in four joints of drill pipe, which in itself is not significant, but could become increasingly so on future legs. Performance of the dynamic positioning system continues to be very good. No significant problems were encountered.

DRILLING AND CORING

For the first time since the inception of the project it became necessary to shoot the pipe off after it had become stuck. On Site 58.3 the pipe stuck while retrieving the core barrel, apparently in a section of lightly cemented material having a consistency similar to pea gravel. After working the pipe for three hours in an unsuccessful attempt to free it, the string was shot at the center bumper sub. The upper part of the bottom hole assembly and the drill pipe were retrieved.

As stated above core recovery continues to improve incrementally to a point where major increases appear improbable. One problem hindering full recovery is the tendency for the plastic inner liners to collapse when coring the more competent sediments. It is not known whether the core barrel jams collapsing the liner, or whether the liner collapses initially. In either event no further core is introduced into the inner barrel. Possible solutions may be to increase wall thickness or to change the type of plastic used in manufacture of the liners.

DRILL BITS

Experimentation continued on various types of diamond and carbide bits without conclusive results except to substantiate the fact that there is no core bit now being made that will penetrate thick chert sections. Two button insert core bits inherited from Project Mohole were taken aboard ship for trial on this leg, but none of the sites investigated provided sufficient cover of sediment above the chert to permit running the required 35 to 40,000 pounds of drill collars for this type bit.

One diamond-sintered bit containing many very small diamonds was tested without showing any marked advantage. Similar results obtained for a variety of light and massive set diamond and carbide bits of various configurations.

When chert sections are encountered two mechanisms contribute to the destruction of the bit. One is the compressive strength and abrasiveness of the chert acting upon the crown of the bit. The other is the action of broken pieces of chert core and bits of formation acting on the bit as a whole. It is this latter action which effects a complete and total destruction of the bit in a manner comparable to the mechanics of a ball mill. This chert gravel, once it has accumulated at the bottom of the hole, is impossible to either drill or wash out using present methods.

WIRELINE LOGGING

Of the 16 sites investigated, wireline logging was attempted on three holes, and was successful on two out of the three. The lack of success on the third (Site 54) was due to a piece of basalt core becoming lodged in a drill collar some 61 meters above the bit. The other 13 holes were not logged due to insufficient penetration (less than 153 meters). On Site 53 an E-log, gamma ray-neutron, and sonic caliper logs were run successfully. On Site 57 the same logs plus a gamma-gamma density log were run. No unusual incidents were encountered.

OPERATIONAL STATISTICS

Days in Port (Honolulu)	6.23	
Days Steaming	23.04	
Days on Location	30.75	
Total Days - Leg 6	60.02	
Total Distance Travelled	5,509	miles
Average Speed	10	knots

Sites Investigated	17
Holes Drilled	36
Number of Cores Taken	128
Number of Cores Recovered	124
Percent of Cores with Recovery	97.00
Number of Meters Cored	953.00
Number of Meters Recovered	689.00
Percent Recovery	72.20

TIME ON LOCATION

Drilling	77.5 hours	10.5 %
Coring	270.5 hours	36.6 %
Trips	274.0 hours	37.1 %
Condition Hole	3.0 hours	0.4 %
Rig Repair	3.5 hours	0.5 %
Wireline Logging	34.5 hours	4.7 %
Other	75.0 hours	10.2 %
	738.0 hours	100.0 %

Total Meters Drilled	3160.0 meters
Average Penetration Rate	41.0 meters per hour
Average Water Depth	4084.0 meters
Average Hole - Total Depth	115.0 meters

CRITIQUE OF MECHANICAL FAILURES

Site 44

This site was a guyot the top of which was in 1488 meters of water. The top formation was a soft calcareous ooze which was drilled and cored without incident. At 63 meters a layer of chert was encountered. Three hours were required to drill from 63 to 64 meters where the formation changed back to a soft ooze. While drilling the chert bit weight was 15,000 pounds, rotary 40 to 60 rpm, and torque 5,000 to 8,000 ft/lbs. After breaking through the chert the hole was cored and drilled to 76 meters where hard formation was again encountered. Two hours were spent attempting to core this section without any apparent penetration, and drilling was terminated. Upon pulling the string out of the hole it was found that a failure had occurred at the top of the sixth drill collar above the core barrel. Failure was at a point 71 meters above the bit.

The pin of the seventh drill collar was slightly bent but otherwise undamaged. It had not been rotated upon after failure. The Totco record indicated that the failure must have occurred while setting the power swivel back preparatory to coming out of the hole. Weather and sea conditions were practically ideal. The recorder on the dynamic positioning system indicated no excursions greater than 12 meters during period in question. Hole conditions were satisfactory. The collars had been made up to 27,000 ft/lbs. of torque. There were two bumper subs in the string, equidistant (28 meters) above and below the point of failure.

At the time it was felt that the failure occurred as a result of the box "belling-out". This was induced by a lack of lateral support which would have minimized wobbling. Additionally, the failure was attributed to the instability of the tool joint, and the resultant inability to apply sufficient make-up torque.

Site 45

This site was a deep basin south of the Hawaiian Ridge. Water depth 5518 meters. In an effort to eliminate possibility of failure similar to Site 44 the drill collar string was shortened to 64 meters. This was less than the 79 meters of sediment which was anticipated over the opaque layer. After running the pipe to bottom, an attempt was made to drill to 37 meters, the first core point. However, by the time the bit had reached 21 meters the formation had become so firm further washing-down seemed imprudent, and the core barrel was dropped.

A core was cut from 21 to 31 meters. Bit weight was 10,000 pounds, rotary 45 rpm, pump 200 psi at 10 spm, torque 3,000 to 5,000 ft/lbs. After coring for six meters the drill pipe torqued up, and a loss of hook load and pump pressure was observed. Maximum torque was 8,000 ft/lbs. Time to core, 30 minutes.

The drill pipe was retrieved. A failure had occurred in the service connection of the bumper sub. Threads on the pin appeared undamaged. Three drill collars and the inner and outer core barrel had been left in the hole. Point of failure was six meters above the mud line.

Site 45.1

At this point the feeling was that the failures resulted from:

1. Lateral buckling of the unsupported bottom hole assembly which was being rotated for sustained periods above the mud line.

2. Failures were accelerated by inherently weak tool joints on the collars, and service connections on the bumper subs.

Based on this, the plan for re-drilling Site 45 called for further shortening of the bottom hole assembly length, and elimination of all bumper subs. The assembly run on Site 45.1 consisted of the core barrel, two eight inch collars, one seven inch collar, and one joint of 5 1/2 inch drill pipe. The length was 50 meters but the weight was only 15,000 pounds.

Bottom was again found at 5518 meters. Drilling and coring proceeded slowly because of light bit weight and slow rotary. However, the opaque layer was penetrated successfully. After drilling through this section the formation became softer. Drilling was terminated at 86 meters and a core was cut from 86 to 95 meters. The only recovery was a piece of lime, and a second core attempted. After the core barrel was dropped some hole trouble was encountered. It was necessary to ream back to bottom and at one point the bit became plugged. Apparently quite a bit of debris had accumulated at the bottom so 50 barrels of mud were pumped down to flush the hole. After this a core was cut from 95 to 105 meters. Bit weight was 10,000 pounds, rotary 50 to 60 rpm, torque 3,000 to 5,000 ft/lbs , coring time 10 minutes. As before, we could not retrieve the barrel, so the drill string was retrieved.

A failure had occurred in the sixth joint of drill pipe above the collars. The failure occurred 13 feet above the pin. It appeared to be a torsion failure. The point of failure was 333 feet above the bit, right at the mud line. Apparently the mud line is a dog leg configuration and failures occur there irrespective of the bottom hole assembly at the point of failure.

Site 46

This site was in a deep marine basin with lithology similar to the preceding holes. Water depth was 5779 meters. In selecting the bottom hole assembly the thinking was to keep the assembly short as possible but also to place sufficient bumper subs in the string to absorb any shock. Additionally a bumper sub would be placed just above the core barrel in an effort to spud in with the string as close to vertical as possible.

After spudding in, hard clay with pieces of ash and chert were encountered immediately. A core was cut from zero to nine meters in 30 minutes. After the core was retrieved, the center bit was dropped and the section from nine to 21 meters was drilled. Bit weight was 10,000 to 15,000 pounds, rotary speed 45 rpm, torque 5,000 to 6,000 ft/lbs, pump 8,000 psi at 40 spm. Drilling time for 12 meters was one hour. While drilling, a drop of 150 psi in the pump pressure was noted. After drilling the interval, attempts to retrieve the center bit were unsuccessful, and the drill string was pulled. A failure had occurred in the pin of the first drill collar above the lower bumper sub. The pin had broken off in a typical "last engaged thread" failure. The core barrel and one bumper sub were left in the hole.

Taking this series of failures as a whole, it must be concluded that we do not have the capability to penetrate a hard formation at any depth below the mud line shallower than the length of the bottom hole assembly, i.e. 92 to 122 meters. Proper placement of the bumper subs, correct make-up torque, optimizing drilling parameters are all significant, but do not solve the problem. This is best illustrated by the fact that we have had such a variety of failures, drill pipe, bumper subs, and various drill collar failures. The only recurring factor is that the failure is always close to the mud line. The probable reason for this is that the damage is being done at a point above the mud line, and the dog leg at the mud line, no matter how slight, is sufficient impetus to cause failure.

The failure on this site was a new drill collar so there is no question of prior defect. In addition to the drill collar failure, the service break on the bumper sub above this collar had "belled-out" and was close to failure.

It is suggested that a larger outside diameter collar is a necessity for the type of hole encountered in the Western Pacific. When attempting to drill with as little as 10,000 pounds bit weight, the actual weight at the bit is fluctuating from zero to 25,000 pounds with the heave of the ship. Proper placement of bumper subs may lessen but not eliminate this. Probably the reason that the bumper subs do not adequately perform their function is the lag in opening and closing with changes of weight. This lag results from friction in vertical movement of the sub while rotating, and from changes in dynamics of the string when pump pressure is applied.

At any rate, with this fluctuation in bit weight, the neutral point moves up and down the drill collar string with each heave of the ship so that the lower section of the bottom hole assembly is being run in compression at least half the time. Unsupported column buckling then results in premature failure.

OPERATIONS RESUME

LEG 7

SUMMARY

The seventh leg of the Deep Sea Drilling Project was completed October 2, 1969 when the Glomar Challenger arrived at Honolulu, Hawaii after 56 days at sea. The voyage began August 8, 1969, at Apra Harbor, Guam. During the voyage the ship travelled 5,934 nautical miles, drilled 15 holes at seven sites, and penetrated a total of 4436 meters of the ocean floor. Igneous rock (basement ?) was reached on four of the seven sites. Chert terminated operations on two sites and mechanical problems (plugged bit) on the other site. The deepest penetration below the ocean floor to date 985 meters, was made without any major problem and cores were taken in the deepest water depth to date, 6140 meters to a depth of 6327 meters. Several long highly fossiliferous sections were continuously cored. A total of 1174 meters were cored and 948 meters recovered. The overall core recovery was 80.7 percent. No wireline logging was attempted. Weather was good and no major equipment was lost.

The project is under the supervision of Scripps Institution of Oceanography (University of California at San Diego) under contract with the National Science Foundation. Operation of vessel and actual drilling and coring is performed by Global Marine Inc under a subcontract to Scripps Institution of Oceanography (SIO).

DRILLING AND CORING

A variety of ocean floor sediments were encountered. The two sites in the Caroline Basin (No. 62 and No. 63) and the one site on the Onton-Java Plateau (No. 64) were located near the equator in fertile water above compensation depth and consisted of long sections of calcareous oozes grading to chalk. Concern regarding the ability to penetrate the numerous reflectors at Site No. 64 proved to be unwarranted, although a lower major reflector did prove to be a flinty chert (Mid-Eocene) which rapidly destroyed the light set diamond core head after penetrating 985 meters and forced termination several hundred feet short of basement. No hole problems were experienced and no mud was required. Core recovery was good using proven techniques involving circulation only when the bit began to torque up.

Two sites (No. 65 and No. 66) were drilled in the Darwin Rise well below compensation depth. Sediments consisted almost entirely of acoustically transparent radiolarian oozes. Near basement at each of these sites a series of thin chert stringers was penetrated without major difficulty, however on Site 65 the core head became plugged with chert pebbles and the hole terminated 18 meters plus or minus short of basement. The chert pebbles were larger than the discharge ports in the core head and indicated that plugging occurred with the inner barrel removed. Cause can be contributed to either the commencement of coring prior to the inner barrel being latched into proper position or swabbing/back-flow during retrieval of core. A near bit float valve should eliminate this problem and development will be pursued as this has been a recurring problem. The radiolarian oozes proved to be extremely soft and cores were taken without circulation or rotation nearly to basement some 183 meters below the ocean floor. Core recovery of the radiolarian oozes was good. Poor recovery was experienced in the interbedded chert intervals and on Site No. 65 after the core bit initially plugged. Plugging occurred twice after becoming plugged the first time. Circulation was then required to prevent additional plugging and recovery of soft sediments (fossiliferous) was not possible. On Site 65 the water depth of 6140 meters slightly exceeded the design limitation (6096 meters) of the positioning equipment, however, no positioning problems were encountered. The second hole at this site resulted in the deepest hole to date, 6327 meters.

Site 61 near Guam was primarily drilled to sample sediments near basement. Core recovery was poor due to attempting cores among stratified layers of soft and hard sediments, the latter normally jamming the inner barrel.

At Site 67, near Hawaii, a firm clay (volcanic ash) bottom was encountered. Nearly an hour was required to drill the first six meters, after which penetration improved but remained firm, until chert was encountered at a penetration of 60 meters. Little coring was attempted as our plan was to attempt penetration to basement on the initial hole and then core interesting sections with a second hole. Concern regarding the mechanical strength of the bottom hole assembly after the severe service required to penetrate on the first hole required a trip to inspect the drill collar joints. Sufficient time was not then available and the port call at Honolulu was set-up a day and the site abandoned.

In general the voyage enjoyed good weather and calm seas. Site 67 near Hawaii was located in the trade winds and seven to 12 foot seas were experienced which the bumper subs in the bottom hole assembly would not fully compensate for. Firm sediments at this site along with the prevailing high seas made this quite pronounced and the hitting down of the bumper subs was more noticeable than in the soft sediments. However, the cores of the soft sediments indicate considerable movement during coring operations. More information on the actual downhole movement of the drill string would be helpful in developing better tools and techniques. Accelerometers are now run on many SIO piston coring operations and have been quite helpful. A similar device to be run as part of the inner barrel will be investigated.

SITE SELECTION

The project manager has established a minimum soft sediment cover of 100 meters for attempting penetration of hard formation with present drilling equipment. Implementation of this policy was effective in eliminating drill string failures. However, the only effective means of carrying out this policy is the air gun profiling system. Location of profiler tracks of other vessels by navigation alone was found to be unreliable. Indeed minor moves of the vessel during the dropping of the beacon, hauling hydrophones, etc. significantly changed the location of basement on Site 63. This was varified after abandonment by profiling of the site with the beacon as reference.

At the pre-leg conference in Hawaii, the Challenger reported the air gun profiling system to be inoperative. Arrangements were made to borrow SIO equipment, however, air shipment via TWA was delayed several days by the airline and return to Guam after drilling the first site was required to pick up the equipment. The resultant quality of the profile record was good, however, minor breakdowns at critical times demonstrated the need for a system with complete backup capabilities.

CORING BITS

Three types of core bits were utilized. Sites 61 and 63 were drilled and cored with a Hughes Tool Company tungsten carbide insert roller cutter core bit. This bit has three frusto-conical core forming cutters equally spaced around the core between three frusto-conical outside or gauge cutters. Water courses directly impinge on the top of each cone. On the two sites a total of 10 meters of basalt was cored with a recovery of seven meters. Torque was reduced, penetration of firm sediments was increased, overall core recovery was 66.7 percent (cored 270 meters and recovered 180 meters). At the end of 11 hours of basalt drilling the bearings on the core bit were nearly gone. This type of core bit holds promise of extending our capabilities of penetrating chert and enabling a longer section of basement rock to be obtained.

This core head had previously been built for Project Mohole. Hughes now indicated a reluctance to manufacture additional units and will require a minimum of four months delivery and a $60,000 order. We, therefore, are now working with a local bit manufacturer in an effort to build a suitable insert roller core bit from standard rock bit components for an earlier delivery. Discussions to date appear promising with a potential for improved bearings.

The remaining sites were drilled with light set diamond bits Hycalog DBFD-5R and Christensen No. 110927. The scientific party aboard indicated a less disturbed core was obtained with the Hycalog DBFD-5R which utilized a core forming extension on the face of the core bit. Further the smaller diamonds used on the bit appeared better suited in penetrating the harder formations. We plan to coordinate these thoughts into Request for Quotation's for core heads in the future.

CORING EQUIPMENT

Overall performance was good. Several weak points in our system were found and are discussed below.

Sand line on the coring winch parted while recovering an inner barrel. No attempt was made to fish for wireline. Shipboard review indicated that the line had failed due to fatigue caused by hard usage and had been accelerated by salt water corrosion. The line had been installed in San Diego and had been in use approximately four months. A periodic replacement schedule has been established with GMI, namely a new line each leg. Approximate cost of a new coring line is $4,000.00. The Challenger is poorly equipped at present to properly install sand lines under tension. We hope to negotiate terms with GMI to furnish this equipment in the near future.

Pull rod in inner barrel latch assembly failed and a round trip was required to recover core. Approximately 24 hours was lost. Review indicated a design weakness. Hycalog is now working on an improved design. Limiting overpull to 5,000 pounds when retrieving inner barrel was successful in preventing future problems.

POSITIONING EQUIPMENT

No major problems were encountered. Burnett beacons were used exclusively. One failed to operate after being dropped and the signal from another abruptly stopped after clearing the ocean floor with the drill string (approximately 48 hours).

DRILL PIPE

Inspection of five inch drill pipe at Guam turned up an additional three joints which appeared erratic on the internal sonde profile. These were marked for further inspection. The four joints found at the end of Leg 5 were borescoped and found to be pitted. Extensive rust prevented a full inspection, however, those pits near the ends appeared to be approximately 1/8 inch deep. These joints were put back in the string for further review and study and will be run near bottom where stresses are the least.

On Site 65 where our deepest work to date was done, all drill pipe on the automatic racker was used. Considerable rust and scale was then found in all cores during most of the hole. The scientific party expressed some concern as the rust will effectively mask the results of the X-ray. A better method of corrosion control and cleaning of the drill pipe is needed.

OPERATIONS RESUME

LEG 8

SUMMARY

Leg 8 of the Deep Sea Drilling Project commenced on October 8, 1969, in Honolulu, Hawaii and was completed on December 2, 1969, in Papeete, Tahiti.

During the intervening period, the ship cruised 4,616 nautical miles, drilled 17 holes on eight sites, attempted 183 cores with recovery on 178, cored a total of 1470 meters with 1225 meters of core recovery for a percentage recovery of 83.3, and had a total drilling and coring penetration of 3463 meters.

Two new techniques were employed. The first of these, the "Welex drill pipe logger" shows considerable promise for development into a speedy, inexpensive tool for obtaining electric and possibly radio active logs. The second, the turbocorer developed for the Mohole Project, was run on two occasions and will require on-shore machine shop adjustment prior to further testing.

Generally, weather was good with only thunder showers and heavy rain in the intertropical convergence zone both north and south of the equator. Easterly trade winds of 20 to 28 knots were common but did not build up swells to any significance.

DRILLING AND CORING

All sites with the exception of 68 and 69 were a continuation of the north - south profile down the 140 degree longitude line started on Leg 5. Sediments varied from relatively thin (less than 92 meters) sections of radiolarian ooze to calcareous sections of over 305 meters thickness. Igneous rock was encountered at Sites 74 and 75 only with drilling being terminated by chert at all other sites.

Perhaps the most significant feature of Leg 8 operations was the expenditure of considerable time in attempting to penetrate hard rock. A total of approximately 54 1/2 hours was spent coring on "hard rock" during Leg 8. These rocks consisted mainly of hard chalk, limestone, chert and combination of all three with some basalt at Sites 74 and 75.

Penetration rates varied from two hours to break through about four inches of chert to four to five feet per hour in the hard chalk. Penetration in limestone often approached that of chert. This is due probably to the cutting action of the diamond bits being less effective in the less friable rock.

Bits used varied from a "scatter set" tungsten carbide, massive set diamond (250 carats), circle set diamond (525 carats), to a light set diamond head of 225 carats. Center bits used were diamond or tungsten carbide.

Unquestionably, the circle set diamond gave the best overall performance. However, its excellent record cannot all be attributed to the bit design. These bits also had the most diamonds which must have contributed greatly to bit life. At the same time as the first circle set diamond bit was run, a change in bottom hole assembly was made. This assembly was (with a minor variation) continued throughout the remainder of the leg and appeared to give much better control of weight on bit.

Up until hole 70B the bottom hole assembly had been: bit, core barrel, three 8 1/4 inch drill collars, one 8 1/4 inch bumper sub, six 8 1/4 inch drill collars, two 8 1/4 inch bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar. On hole 70B this assembly was changed to include two bumper subs in both the lower and upper positions and on holes after 70B, two bumper subs were run in the lower with only one bumper sub in the upper position. In all cases where two bumper subs were run in the lower position better weight control and less torque variation resulted.

Leg 8 coring in hard rock has established that these formations can be cored and recovered in substantial quantities but at very low rate of penetration in most cases.

In order to speed up penetration rates the following recommendations are made:

1. Investigate the possibility of bit suppliers manufacturing a bit consisting of "scatter set" tungsten carbide with ridges, or blades set with 250 to 300 carats of diamonds. This type bit should give better results in the chalks and limestones with good penetration in chert or basalt.

2. Investigate the manufacturing of a combination milled tooth - tungsten carbide insert core head.

LOGGING

All logging attempts were with the "Welex drill pipe logger". This device is a completely self-contained tool recording on magnetic tape which is played back to produce an electric log after drill pipe has been pulled. A log was attempted on all sites except 68 where only 15 meters of sediment was penetrated.

After an initial failure on Site 69 slight modifications were made to the tool and all subsequent log runs were mechanically successful. Of particular interest is the very small amount of time required for logging. Even in the deepest water, only 50 minutes time was attributable to logging.

On the other hand, the data recorded (16 inches normal, amplified normal, 64 inches lateral and self-potential) is of doubtful value. The curves show little variation in resistivity and almost no self-potential response. This was not unexpected and Welex has been requested to investigate the possibility of developing a tool operating on the same mechanical principal but recording a natural gamma log. This log should provide some significant data in the type sediments encountered in the Deep Sea Drilling Project to date.

TURBOCORER

Encountering chert or other hard rock at shallow depths has imposed limitations on many sites in the Deep Sea Drilling Project. One possible solution to this problem is the use of a downhole motor to provide rotation of the core head, thus avoiding the severe stresses imposed on the bottom hole assembly by rotation of the entire drill string.

To test this solution, the turbocorer developed for Mohole and tested at the Uvalde test site was reassembled and tested on two sites on Leg 8. Neither of these tests proved conclusive.

It was established on Site 68, where a conventional assembly failed, that failure did not occur when the drill string was not rotated.

TOOL LOSSES

One bottom hole assembly failure occurred. This was on Site 68 where chert was encountered at 15 meters. Although, penetration rates did not fall below 18 m/hr a bit, core barrel and two 8 1/4 inch drill collars were lost due to pin failure (bending) of a drill collar. This incident clearly illustrates the necessity to avoid coring on any material that offers resistance until a substantial portion of the bottom hole assembly is buried below the mud line.

COMMUNICATIONS

Radio teletype was used exclusively both to and from La Jolla during the entire leg. Results were excellent with most daily "traffic" being cleared within 20 minutes.

POSITIONING SYSTEM

The new 13.5 kHz beacons were tested on five sites. Only one beacon gave an acceptable signal for any period of time. These failures are being investigated with the preliminary conclusion being that the transducers were incorrectly tuned to the electronic circuit.

Some concern has been expressed in the past about the ship drifting off site while geophones, air gun and magnetometer lines are retrieved and the beacon "soaked" and dropped. To avoid this problem the beacon was dropped "on the run" on the final four sites of Leg 8. The procedure used was to profile until a suitable site was selected, continue on course plus or minus three miles, make a gradual 180 degree turn with profiling continuing to confirm that excessive drift has not occurred until almost on site, slow abruptly to about three knots and drop the beacon without "soaking". The geophysical lines are then retrieved as the ship continues at plus or minus three knots. When retrieval is completed the ship again turns 180 degrees and returns to the site homing on the previously dropped beacon.

OPERATIONS RESUME

LEG 9

SUMMARY

The Glomar Challenger left Papeete, Tahiti, on December 6, 1969, and arrived in Balboa, Panama, on January 27, 1970. This 56-day cruise completed the final leg of the initial 18-month agreement between Global Marine Inc and Scripps Institution of Oceanography for the Deep Sea Drilling Project under a contract with the National Science Foundation as part of its National Research Program of Ocean Sediment Coring.

During this portion of the "Voyage of Discovery", nine sites were investigated within a narrow band along the equator from 146 degrees West Longitude to 83 degress West Longitude. The Challenger travelled 5,669 nautical miles, drilled 17 holes at nine sites, penetrated 3579 meters of ocean sediments, attempted 202 cores with recovery on 199, cored 1693 meters and recovered 1539 meters for a 90.9 percent core recovery rate.

Basement was reached on all locations except the first where penetration was halted by shallow chert deposits above the basement reflector.

Several long sections were continuously cored, and as a result of excellent crew performance and cooperation of all personnel concerned a number of new records were established to supplement the already highly successful accomplishments of the previous eight legs.

These achievements are as follows:

1. Most core recovered - 1539 meters.

2. Most core recovered on one hole - 438 meters (Site 77B).

3. Most cores attempted on one hole - 54 (Site 77B).

4. Most 9 meter-cores recovered on one hole - 41 (Site 77B).

5. Most consecutive 9 meter-cores recovered - 20 (Sites 83 and 84).

No wireline logging or heat probe measurements were attempted. The weather in general was good, but numerous showers and overcast skies were encountered on four of the nine locations.

A summary of operations is presented in Table 1, and a time distribution of the various operations is shown in Figure 1. Coring peformance of the first nine legs is presented in Figure 2, while Figure 3 shows the individual site performance of Leg 9.

DRILLING AND CORING

A variety of formations was encountered varying from soft oozes through volcanic ash and firm chalks to limestone, chert, and basalt. Core recoveries were equally good in all formations. Basement samples were usually broken into small pieces except for the first one obtained with the roller bit on the second site and the last one taken with the massive set diamond on the last site.

The configuration of the bottom hole assembly was not changed throughout the leg and was the same as was used successfully on the latter part of Leg 8. From the bit up it consisted of the outer core barrel, three 8 1/4 inch drill collars, two bumper subs, six 8 1/4 inch drill collars, one bumper sub, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar and one joint of heavy-weight drill pipe. The two bumper subs were run four collars above the bit with the thought that light bit weights could be controlled with more accuracy since the total weight of four collars amounted to 13,900 lbs in sea water. It was felt that weights in the order of 10,000 lbs should be run to establish a pattern in hard formations before full drill collar weight was applied. This procedure worked well in all cases except the one cited below.

Chert was encountered on the first hole after 28 meters of penetration and coring with light bit weight for 70 minutes resulted in no apparent penetration, although a small piece of chert was recovered. After coring the second hole and rotating for 30 minutes on a hard spot, encountered 16 feet higher than the first hole, a failure occurred in the drill collar tool joint which was at the mud line. The recording weight indicator showed a surge to 35,000 lbs at this point and probably caused the unsupported bottom hole assembly to fail from column buckling. It would appear that if the neutral point of the bottom hole assembly can be kept below the mud line, this type of failure can be eliminated.

BITS

Two types of bits were used on this leg and each performed satisfactorily. A new four cone tungsten carbide insert roller bit was used to core the second and third sites, and a total of 757 meters of core was recovered. Coring on basalt was attempted for three hours on the second site and for one and one-half hours on the third site before a cone partially locked and rapid oscillation of the drill string caused termination of the drilling operations. Drilling weights on basement ranged from 10,000 to 30,000 lbs with rpm from 35 to 52. All cones had peening marks due to ship heave, and the poor condition of the bearings was also attributed to this motion. Modifications for improvements of this design have been suggested to the manufacturer to be incorporated in future bits.

The other type bit used was a light set diamond with a crown at the center for coring hard formations. Two of these 250 carat bits were used and each recovered basalt on two separate sites. A massive set 500 carat diamond was used on two other sites and recovered basalt on both and still has approximately 90 percent salvage.

DYNAMIC POSITIONING

The ship positioning system operated very well holding the vessel within a 180 foot radius of the beacon. On the second site a burned-out relay in the computer allowed a 305-meter excursion before it was repaired. At the time of the computer failure a core had been retrieved from 4681 meters and the barrel dropped for the next core. The string was rotated slowly and circulation maintained off the bottom until repairs were affected and the ship repositioned. The time included was approximately 30 minutes and no unusual hole conditions were noted. Coring was resumed in a normal manner after repositioning. Burnett 16.0 kHz beacons were used exclusively and all but one of those operated satisfactorily. This beacon had a change in pulse repetition rate from 2.1 seconds at the surface to 2.3 seconds after landing on bottom. This exceeded the tolerance of the computer and required that a change in location be made to avoid interference before another beacon could be dropped. It was discovered on the fifth location that two more beacons were not performing to specifications at the surface, and these were set aside for return to the manufacturer. The balance of the beacons aboard was checked and found to be within operating tolerances.

A problem with the No. 1 bow thruster developed while on the third location when the d.c. motor bearings became overheated and smoke came boiling from the forward hatchway. The location was completed using only one forward thruster.

It was decided that shipboard repairs were impractical, and the leg was completed using the remaining bow thruster for positioning.

CORING EQUIPMENT

Overall performance was excellent and no major problems were encountered. Wireline speeds for retrieving cores increased from 90 m/min on the first hole to 134 m/min on the fourth hole with a subsequent decrease of trip time from 102 minutes per core to 68 minutes per core in the same depth of water. Part of the decrease in the time required to recover cores was due to cutting off 2438 meters of worn line allowing the balance of the line to spool more evenly. The balance of the decrease was due to increased efficiency of the crews as a routine was established. The balance of the holes maintained a 122 to 134 m/min wireline speed which allowed minimum wear on wireline packing and little loss of fluids to be blown over the ship. The core barrel was stuck one time and was released by setting the drill string on bottom and maintaining 5,000 lbs tension above weight of line until it came free. The barrel was apparently jammed at the lower end since working and pulling for 30 minutes prior to setting the string on bottom had not accomplished a release.

The practice of dropping the core barrel while drilling the last connection before coring was initiated about midway of the leg and reduced waiting time for the barrel to reach bottom by about 20 percent. This procedure can be used when the formations are soft but should not be attempted when the drilling time for a connection is nearly the same or exceeds the falling time of the core barrel.

CREW PERFORMANCE

Crew performance was excellent throughout the leg and is evident from the amount and percentage of core recovered.

TABLE 1

LEG 9 DEEP SEA DRILLING PROJECT

SUMMARY OF OPERATIONS

(Papeete to Balboa)

Total days Leg 9 (December 2, 1969 to January 27, 1970)	56.24
Total days cruising	24.55
Average speed (knots)	9.36
Total miles travelled	5,669.00
Total days on sites	25.90
Survey time	1.43
Port time	4.36

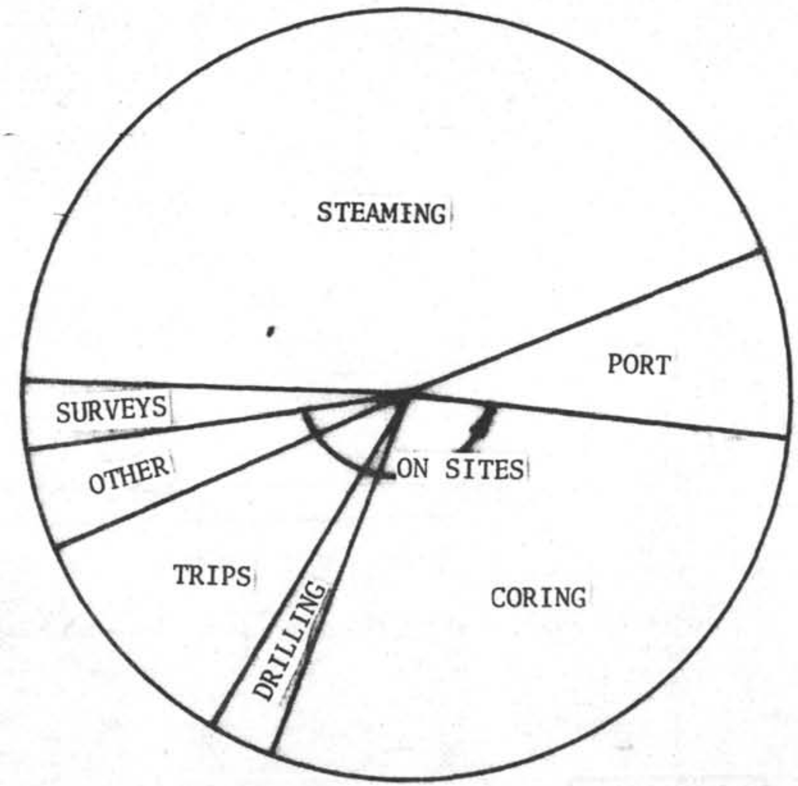
Trip time	147.50 hrs or	6.14 days
Drilling time	28.00 hrs or	1.18 days
Coring time	377.75 hrs or	15.62 days
Other		1.53 days
Survey time		1.43 days
Total		25.90 days

Sites drilled	9
Holes drilled	17

Number of cores attempted	202
Number of cores recovered	199
Percent of cores with recovery	98.60
Total meters cored	1693.00
Total meters recovered	1539.00
Percent meters recovered	90.90
Total penetration	3497.00
Percentage cored of total penetration	48.60
Number of sites on which basalt was recovered	8

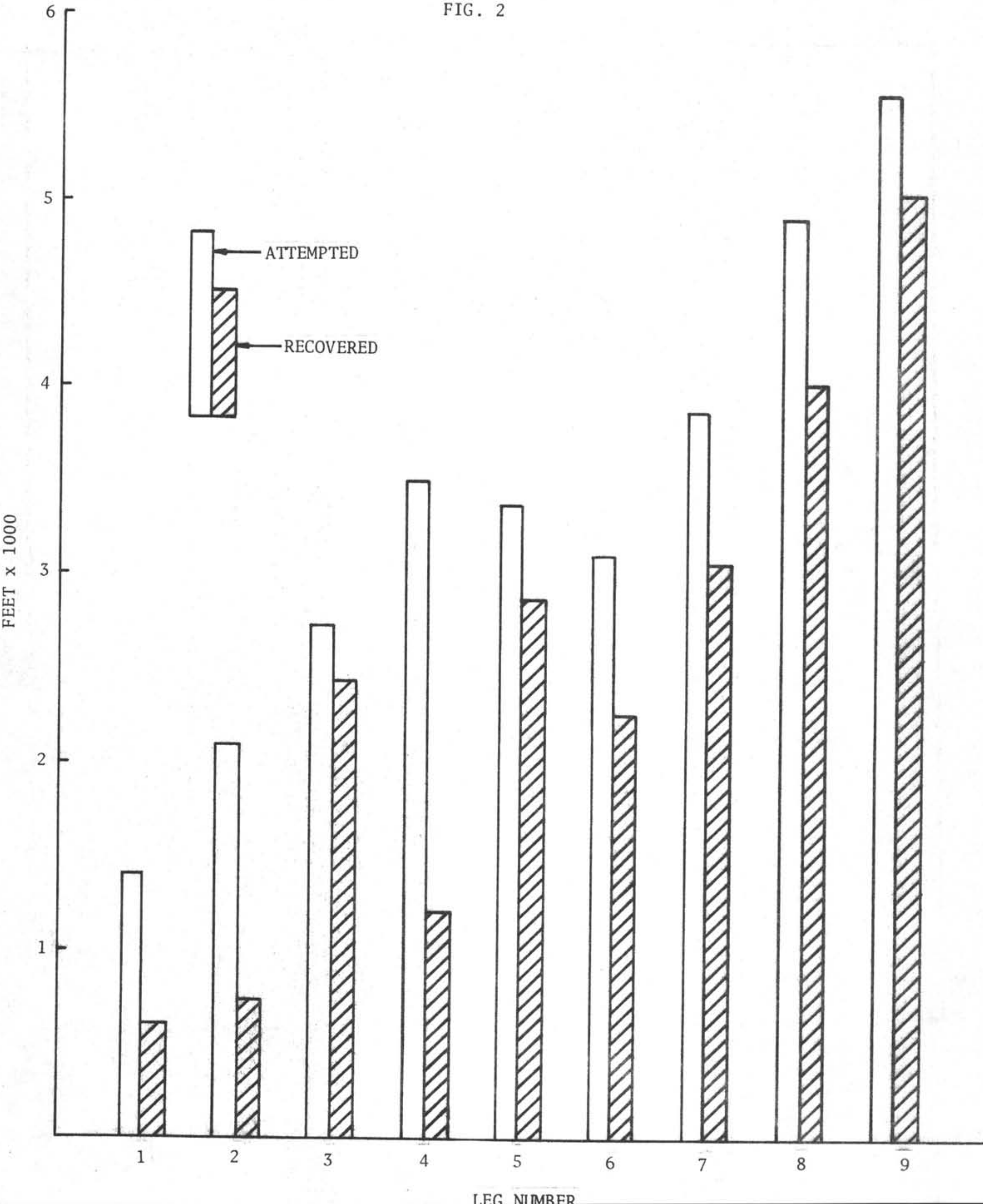
TIME DISTRIBUTION - LEG NINE

Figure 1



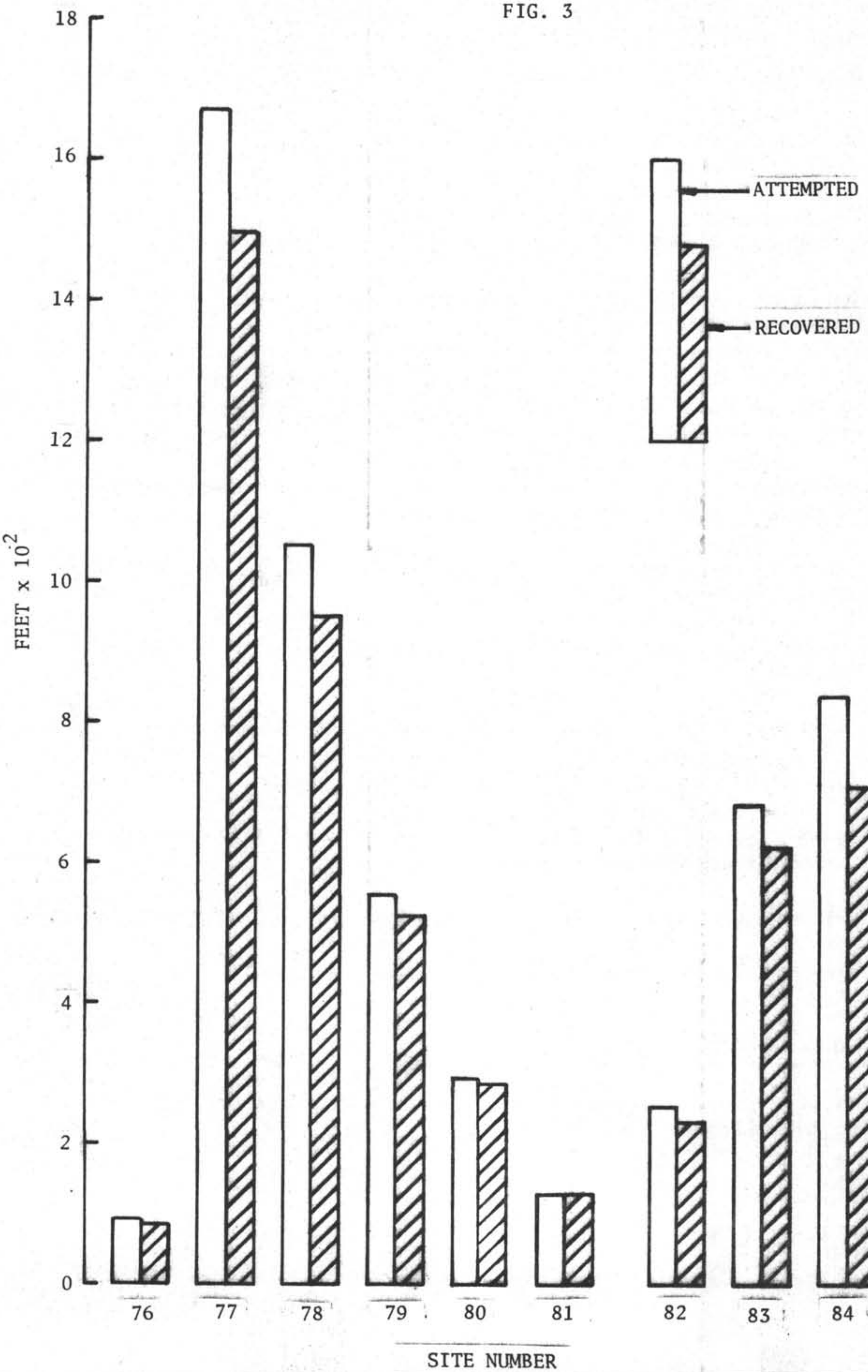
CORING PERFORMANCE BY LEGS

FIG. 2



CORING PERFORMANCE BY SITES LEG IX

FIG. 3



OPERATIONS RESUME

LEG 10

Leg 10 of the Deep Sea Drilling Project commenced on February 13, 1970 in Galveston, Texas and terminated in Miami, Florida on April 5, 1970.

During the intervening period, 14 holes were drilled and cored on 13 sites in the Gulf of Mexico. A total of 1154.25 meters was cored and 736.01 meters recovered.

The operational highlight of the leg was the large variety of formations encountered. Commonly little or none of the very soft sediment associated with the deep ocean basins was encountered. This caused great difficulty in spudding in and burying the bottom hole assembly. Sediments encountered were gumbo, limestone, chalk, cherty lime, shale, dolomite, chert, a variety of sands and a limestone rubble consisting of pebbles up to two inches in diameter.

Due to the known presence of hydrocarbons in the Gulf of Mexico, stringent precautions were taken to prevent pollution. These precautions were:

1. A careful review was made of each proposed site and certain sites modified to avoid potential hydrocarbon accumulations.

2. Each hole was completely filled with cement unless prevented by mechanical failure.

3. Each core was immediately examined for the presence of hydrocarbons visually, with ultraviolet light and gas analysis made with a chromatograph. Operations were terminated upon encountering hydrocarbons.

4. Continuous coring was performed either from a specified depth or from the point at which lithified sediments were encountered.

5. A continuous watch was maintained for gas bubbles around the ship.

6. Maximum penetration depth was specified on certain sites.

DRILLING AND CORING

The numerous sediment types encountered caused problems not previously associated with the Deep Sea Drilling Project.

SAND

The first major sands encountered were at Site 87. On this site, after penetrating 673 meters, loose unconsolidated sand caving around the bottom hole assembly stuck the core head while a center bit was being retrieved. Despite working pipe, spotting mud, etc. for several hours, the string could not be freed and after a shoot off shot failed, the drill pipe was backed off.

The second major encounter with sand occurred at Site 91. Here an unconsolidated coarse sand was recovered in cores and after penetrating plus or minus 30 meters, it became obvious that continued penetration posed extreme risk of drill string sticking. The hole was terminated at 899.6 meters.

Lesser sands were encountered at other sites but successfully penetrated by spotting mud.

This experience with sand sticking the drill string plus the previous string stuck in loose gravel on Leg 6, strongly indicates that clastic sediments cannot be penetrated without danger of stuck drill pipe. All indications are that the salt water used as a circulating medium on the Deep Sea Drilling Project is incapable of removing from the hole coarse sediments and when pumping stops this material immediately settles resulting in stuck pipe.

GUMBO

This stiff, sticky clay like sediment lived up to its reputation and was penetrated only after drilling and re-drilling intervals of some holes several times. Unfortunately on a number of sites, this material occurred only a few feet below the mud line and resulted in the loss of portions of two bottom hole assemblies on Site 93. (Failure at service joint of bumper subs). After Site 93, the policy of not rotating until 50 meters of sediment had been penetrated was insituted and no further losses were incurred.

SHALES AND CHALK

These sediments were penetrated without difficulty but at low rates. This problem has been identified on previous legs and is caused by using a bit designed for coring the hardest formation anticipated. These bits do not generally perform well in sediments of medium hardness.

LIMESTONE, DOLOMITE, CHERT

These hard to very hard formations were cored but at slow rates with diamond core heads. One run was made with a Smith tri-cone insert type core head. This bit had a much faster penetration rate but unfortunately core recovery was very poor due to the cone angle. This defect has been corrected.

In coring in hard formations, there is a strong tendency for the inner barrel to become stuck. It is believed that this is caused by the hard core shoving the inner barrel up until the latch is semi-frozen to the latch sleeve. This problem will be reviewed with the manufacturer.

POSITIONING SYSTEM

While in dry dock prior to the start of Leg 10, all four thrusters were removed and completely reconditioned. Thrusters performed well throughout the leg. The non-operative PCS was also removed while in dry dock.

Partially because of the modifications made to the system in removing the PCS console, Leg 10 was plagued with positioning difficulties. On the first site (85) the ship could not be positioned and it soon became apparent that the display presented was not real. After extensive attempts to correct the problem, the ship returned to Brownsville, Texas where computer specialists identified the problem as being due to the removal of certain interconnections between the PCS and PPM Systems.

After returning to Site 85, the oscilloscope display yawed badly in the Y axis. The vertical reference gyros were turned off and operations commenced in automatic with the gyros in the standby position.

Numerous beacon problems were encountered. Two 13.5 kHz Burnett and two 13.5 kHz ORE beacons were tested. None of the four were entirely satisfactory, apparently because the effective pulse length was not always acceptable to the computer. One 16 kHz Burnett beacon failed suddenly and completely. Shortly thereafter the floatation was sighted floating about 400 feet from the ship. Another 16 kHz Burnett would not respond when tested aboard ship. The electronics package was dismantled and and a burned out resistor replaced. These defects have been reported to the manufacturer.

Site 97 was located in the Gulf Stream. Currents appeared to be 3.5 to four knots. The beacon used was a 13.5 kHz ORE which was not good enough to allow automatic operation . Winds were up to 20 knots at right angles to the current. Despite these problems, position was held using the semi-automatic mode for a total of 75 hours. One excursion of over 1,000 feet was recorded without damage to the drill string.

CEMENTING

The requirement for filling all holes drilled in the Gulf of Mexico necessitated the installation of a cementing unit prior to departing Galveston. The unit selected was a Byron Jackson batch mixer with pacemaker pump. This unit proved simple to operate , reliable and quick. It should satisfy any foreseeable Deep Sea Drilling Project needs.

LOGGING

No logging was conducted on Leg 10.

CREWS

Crew performance was excellent throughout the leg. The seamanship displayed in holding position in the Gulf Stream on Site 97 using the semi-automatic mode of operation, was excellent and a tribute to Global Marine crews.

OPERATIONS RESUME

LEG 11 A and B

SUMMARY

The Glomar Challenger left Miami, Florida, on April 8, 1970 and arrived in Hoboken, New Jersey, on June 1, 1970. A stop over of 11 hours and 44 minutes for supplies and a crew change was made in Norfolk, Virginia, on May 11, 1970. This 57-day cruise was the second two-month voyage of the 30-month extension between Global Marine Inc. and Scripps Institution of Oceanography. Scripps manages the Deep Sea Drilling Project under a contract with the National Science Foundation as part of its National Research Program of Ocean Sediment Coring.

The track followed on Leg 11 was east from Miami to the Northeast Providence Channel and Northeast Bahama Slope, northwest to the South Blake-Bahama Ridge, then to Norfolk, Virginia, for a crew change. From Norfolk, the Challenger proceeded east-southeast to the Lower Continental Rise Hills, northwest to the Lower Continental Rise, northwest to the Upper Continental Rise and then to Hoboken, New Jersey, to load equipment for re-entry trials.

During this voyage 11 sites were investigated and 15 holes were drilled. The Challenger travelled 2,149 nautical miles, penetrated 6159 meters of ocean sediments, cored 1325 meters, and recovered 633 meters for a 47.8 percent recovery rate.

Basalt was reached and recovered on two sites (Site 100 and Site 105) and from these two locations and strong evidence from Site 99A, the age of the Atlantic Ocean has been determined to be approximately 160 million years. It is almost certain that Site 99A would have reached basalt within 46 meters deeper penetration if mechanical difficulties with the coring equipment had not forced abandonment of the hole.

Due to excellent crew performance and cooperation of all personnel concerned, six new records were established to add to the growing success of the Deep Sea Drilling Project.

The records established on Leg 11 are as follows:

1. Oldest sediment recovered to date - 160 million years.

2. Deepest penetration of ocean floor - 1016 meters (106B).

3. Most basalt recovered - 13 meters.

4. Most hard formation recovered - 155 meters.

5. Most core recovered with turbocorer - 8 meters.

6. Deepest penetration with turbocorer - 209 meters.

The weather was excellent on the portion of the leg from Miami to Norfolk but extremely bad weather was encountered on the second site out of Norfolk (Site 106) resulting in lost time waiting on weather and loss of the majority of a bottom hole assembly.

The use of tungsten carbide roller bits as recommended by the Drilling Technology Advisory Panel to DSDP and developed through DSDP guidance and manufacturer cooperation proved to be invaluable on Leg 11. All locations where hard limestone and cherty chalk rocks were encountered were successfully drilled and cored to obtain the information desired by the scientific group.

Some beacon problems were encountered but, in general, positioning control was good. The continued failure of bumper subs in the service joint was the greatest single problem encountered. Minor problems with some newly designed coring parts were eventually solved.

The use of the Mohole Turbocorer on Site 108 demonstrated the feasibility of this tool for drilling and coring shallow, hard formations. With some minor improvements in inner core barrel equipment, the turbocorer should prove to be a very valuable tool.

A summary of operations is presented in Table 1 and a time distribution of various operations is shown in Figure 1.

DRILLING AND CORING

The formations encountered varied from soft oozes through firm clays, hard clays, chalk and limestones to basalt. Good recoveries were obtained in those formations with uniform density but when the formations were alternately soft and hard, recoveries were usually poor. For the sake of obtaining more penetration the amount of core recovered was considered secondary to the additional information obtained with depth and frequently more than nine meters was attempted at one time. The basalt samples obtained were nearly true cylinders and this result was attributed to the stabilizer pads added to the box of the rock bit. In nearly all cases the cores were undergauge. This condition was probably due to bearing wear in the bit cones accumulated prior to reaching basement.

On Site 100, for example, 200 meters was drilled which was equivalent to the maximum penetration of Site 4, Leg 1, before a core was attempted and the first core was chalk containing chert pebbles. The remaining 117 meters prior to reaching basalt was firm to hard limestone with scattered chert pebbles and/or thin chert layers. Fourteen meters of basalt was cored and five meters was recovered. Penetration rate in the basalt averaged two meters per hour. This hole was drilled with a Smith four-cone tungsten carbide button bit in 37 and 3/4 rotating hours for an average penetration rate of nine meters per hour. The bit and bottom four drill collars were lost on the trip out of the hole and inspection of the bit was not possible.

On Site 105, the series and length of hard formations penetrated was almost identical to Site 100. A total of nine meters of basalt was cored and the Smith four-cone tungsten carbide button bit had all bearings worn out allowing the cones to touch the center post. The result was that an undergauge core was cut in the hard formations and it is felt that the condition of the bit on Site 100 should have been similar to this one. This hole was drilled and cored in 42 rotating hours.

The bottom hole assembly was changed twice during the leg to meet different requirements as drilling progressed. On Site 98 and 99 from the bit up it consisted of the outer core barrel, three 8 1/4 inch drill collars, two bumper subs, six 8 1/4 inch drill collars, one bumper sub, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar and one joint of 5-inch heavy wall drill pipe. This arrangement allowed up to 14,000 lbs of bit weight to be applied before closing the bottom bumper subs. The next weight increment was 21,000 additional pounds or a total of 35,000 pounds. It was determined, after two holes, that satisfactory penetration rates could be obtained with 20,000 to 25,000 pounds of bit weight. It was decided to reduce the number of collars above the bottom two bumper subs from six to three, thereby allowing the second increment of weight to be 11,000 pounds or a total of 25,000 pounds before the top bumper sub closed. After the top sub closed, a total of 35,000 pounds was available for bit weight. Shortening the bottom hole assembly allowed it to be buried and stabilized more rapidly in the medium firm to firm bottoms encountered on nearly all sites.

On the last site prior to arrival in Norfolk, the location of the bumper subs were exchanged by running one in the lower part of the assembly and two near the top to provide more compensation for the additional swell heights encountered as the leg progressed to the northern part of its track. This change in position of the bumper subs allowed better control in the rougher seas experienced after crossing 30 degrees north latitude.

BOTTOM HOLE ASSEMBLY FAILURES

Four separate failures in bottom hole assemblies occurred during the leg and in each case the break occurred in the service joint of the bumper sub. In three instances, a loss of bottom hole assembly occurred while in the fourth, the entire bottom hole assembly was recovered along with the parted bumper sub.

Site 99

This hole was spudded in medium hard formation and drilled to a total depth of 84 meters where tight hole conditions developed. A 100-barrel batch of mud was spotted in an attempt to free-up the hole and a loss of weight and pump pressure was noted while working the pipe. After pulling out of the hole it was found that a tension failure, with the possibility of a prior crack, had occurred in the box of the top service joint of the second bumper sub from bottom. The location of the joint at the time of the failure was 38 meters below the mud line. The top bumper sub was located 18 meters above the mud line and did not appear to be damaged from the rotation required while drilling.

Site 99A

The bottom hole assembly was shortened by replacing the six drill collars above the two bottom bumper subs with three drill collars in order to obtain better control over the loads applied to the bit.

This hole was spudded in soft bottom but required rotation to obtain a core from 12 to 21 meters where nannoplankton ooze containing chert fragments was recovered. Drilling and coring continued to 249 meters through hard chalk and limestone containing chert fragments. A long core was attempted in limestone from 249 to 265 meters because of low recoveries in the previous three cores. The wireline overshot assembly stuck at 762 meters from the surface while attempting to retrieve the core barrel. Subsequent pulling of the line with a T-bar retrieved the fishing tools and the pulling neck from the top of the core barrel. The drive pin holding the pulling neck worked out and had apparently lodged in a tool joint while the core barrel was falling. Further occurrence of this problem was eliminated by inserting a plug on top of the drive pin and tack welding the plug to the latch body. On the trip out of the hole it was found that the Shaffer bumper sub had parted at the lower service joint of the upper barrel. The upper pin had broken off the double pin drive sub and the knocker nut below the mandrel had prevented the sub from coming apart and dropping the drill collars below it. It is not known when the failure occurred, but considerable bouncing of the drill string was experienced while drilling and coring the hard formations containing chert fragments.

Site 100

This hole was spudded in soft formation and washed to 31 meters before rotation was required to obtain penetration. The hole was drilled through chalk containing chert fragments and through limestone to basalt. Two cores were taken in basalt before terminating the hole. The loss of the core barrel and three drill collars occurred as the stand of collars above the lower bumper subs was rotated out. The box on the upper barrel of the bottom Shaffer bumper sub failed at the end of the top sub pin. A visual inspection of the break indicated that more than 50 percent of the cross section was an older break which had accumulated silt in the cracked area. The final break exposed new metal. All bumper subs were magnafluxed during servicing after these two failures occurred and no further problems from prior cracks were experienced.

Site 106

This hole was spudded in sand silt and washed to 45 meters before rotation was required. The hole was then drilled and cored through firm clays to 363 meters when weather conditions made further operations impossible. While pulling out of the hole to clear the ocean floor, the Challenger was forced approximately 457 meters off location by the strong Gulf Stream current with six stands of pipe remaining below the mud line. Two bumper subs were being run in the upper part of the bottom hole assembly in an attempt to better compensate for the higher sea states encountered after crossing 30 degrees north latitude.

A failure occurred in the top service joint of the second bumper sub and was a typical bending failure. When the top bumper was serviced it was found to be bent to such an extent that the service joint could not be broken and the entire bumper sub had to be junked.

BITS

Five types of core bits were used on this leg and all performed satisfactorily. Two types of tungsten carbide button core bits were used to successfully penetrate the shallow hard, cherty chalks and the limestones overlying basalt. Average drilling and coring rates for the three-cone core bits ranged from six meters per hour to 26 meters per hour and for the four-cone core bits it varied from nine meters per hour to 15 meters per hour. Recoveries were equally good with both types and the low recovery rates are attributed to the alternating hard and soft layers encountered in most of the sections. Where the formation was of uniform density, either soft or hard, good recoveries were affected. This type bit has great potential for obtaining the necessary scientific data in hard formations if the sites are selected so that the final objective can be reached within the life of the bit bearings. Eight of the 15 holes on this leg were drilled with six tungsten carbide roller bits. One hole (Site 107) was terminated at 77 meters due to the slow progress (three meters per hour) of the button bit in hard clay and the amount of penetration required in a limited amount of time. The use of longer inserts in the cones should increase the penetration rates in clays to a point where this type bit may eventually become the standard for the Deep Sea Drilling Project.

The Williams controlled-bite diamond drag bit was used on three sites where thick clay deposits were expected. This bit performed very well and averaged better than 35 meters per hour. The record penetration of 1016 meters (Site 106B) was drilled and cored at an average rate of 39 meters per hour with this type of core bit.

A Varel light set diamond bit was tried on the thick clay accumulations of the Blake-Bahama Ridge (Site 102) and proved to be the least satisfactory of all the bits run due to its slow average penetration rate of 14 meters per hour. This rate was less than half the penetration rate achieved with a tri-cone button bit and about 40 percent of that obtained with the diamond drag bit on nearby locations in the same type sediments.

The last type of bit used was a Hycalog massive set diamond designed for and run on the turbocorer. An average drilling and coring penetration rate of 34 meters per hour was maintained for six hours and 13 minutes rotating time. At this time the hole was terminated due to loss of the core catcher sub from the inner core barrel. The bit was undamaged and is suitable for rerun.

DYNAMIC POSITIONING AND BEACONS

The ship positioning system worked very well on the portion of the leg from Miami to Norfolk except in one instance (Site 100) when the beacon signal amplitude began to vary approximately 20 percent after four days and 17 hours of automatic operation. The hole was terminated in basalt and the positioning system continued to operate in automatic by increasing the gains. On Site 102, a 13.5 kHz beacon failed on the drop to bottom. A 16.0 kHz beacon was utilized and the site completed in the automatic mode of operation.

On the first site (Site 105) out of Norfolk after 23 hours of automatic operation on a 16.0 kHz beacon with glass ball floatation, it was necessary to go to semi-automatic due to a fluctuation in signal amplitude received at the ship's hydrophones. There was no consistent change in this variation and rotating the ship 360 degrees in 90 degree increments after clearing the mud line had no effect on the ranging error displayed by the ship's positioning system. On the second site out of Norfolk, a similar situation developed after 19 hours of automatic operation. After the hole was terminated due to a storm, the ship was allowed to drift out of range of this beacon and a second 16.0 kHz beacon was dropped and two holes were drilled from it with no further problems.

WEATHER

The weather was good on all sites except 106 where a low pressure area developed near the location and resulted in the ship being unable to maintain position. As a result of the storm moving in an abnormal direction to most low pressure areas which develop in the Atlantic, sea conditions (ten to 12-foot swells) reached such a state that working conditions became impossible with the ship rolling 12 degrees and pitching five degrees. An attempt to clear the mud line with the drilling assembly resulted in the loss of a bottom hole assembly due to a bending failure in a bumper sub.

CEMENTING

Cementing was performed on Site 98 and was not done on any other holes. The last site prior to reaching Hoboken was to have been cemented but was not done due to the loss of part of the inner core barrel assembly in the turbocorer.

TURBOCORER

The Mohole Turbocorer was run on Site 108 without the use of the electronics package for measuring rpm after an attempt to make it operate failed. The turbine drilled and cored 209 meters in six hours and 13 minutes rotating time. Hard chalk was encountered 40 meters below the mud line and the turbine cored this material at an average rate of 37 meters per hour. Two cores were obtained totaling eight meters. The third coring attempt failed to recover any sample because the core catcher sub had twisted off inside the bottom hole assembly. This sub probably came into contact with the bit sub which was rotating at high rpm and weakened it through wear until it twisted off. A lower bearing assembly at the bit should improve the reliability of this tool.

TABLE 1

LEG 11 DEEP SEA DRILLING PROJECT

SUMMARY OF OPERATIONS

(Miami to Hoboken)

Total days (April 5, 1970 to June 1, 1970)	57.03
Total days cruising	9.54
Total nautical miles travelled	2,149
Average speed (knots)	9.40
Total days on sites	41.85
Survey time (days)	1.65
Port time (days)	3.49
Inside steaming (days)	0.29
Waiting on weather (days)	0.21

SITE TIME SUMMARY

Trip time (days)	9.71
Drilling time (days)	10.40
Coring time (days)	13.51
Other (days)	8.21
Total days	41.83
Sites drilled	11
Holes drilled	15
Number of cores attempted	153
Number of cores recovered	149
Percent of cores recovered	97.50
Total meters cored	1325.00
Total meters recovered	633.00
Percentage meters recovered	47.80
Total penetration	6159.00
Percentage cored to total penetration	21.50
Number of sites on which basalt was recovered	2
Basalt meters cored	23.00
Basalt meters recovered	13.00
Percentage basalt recovered	56.00

TIME DISTRIBUTION - LEG ELEVEN

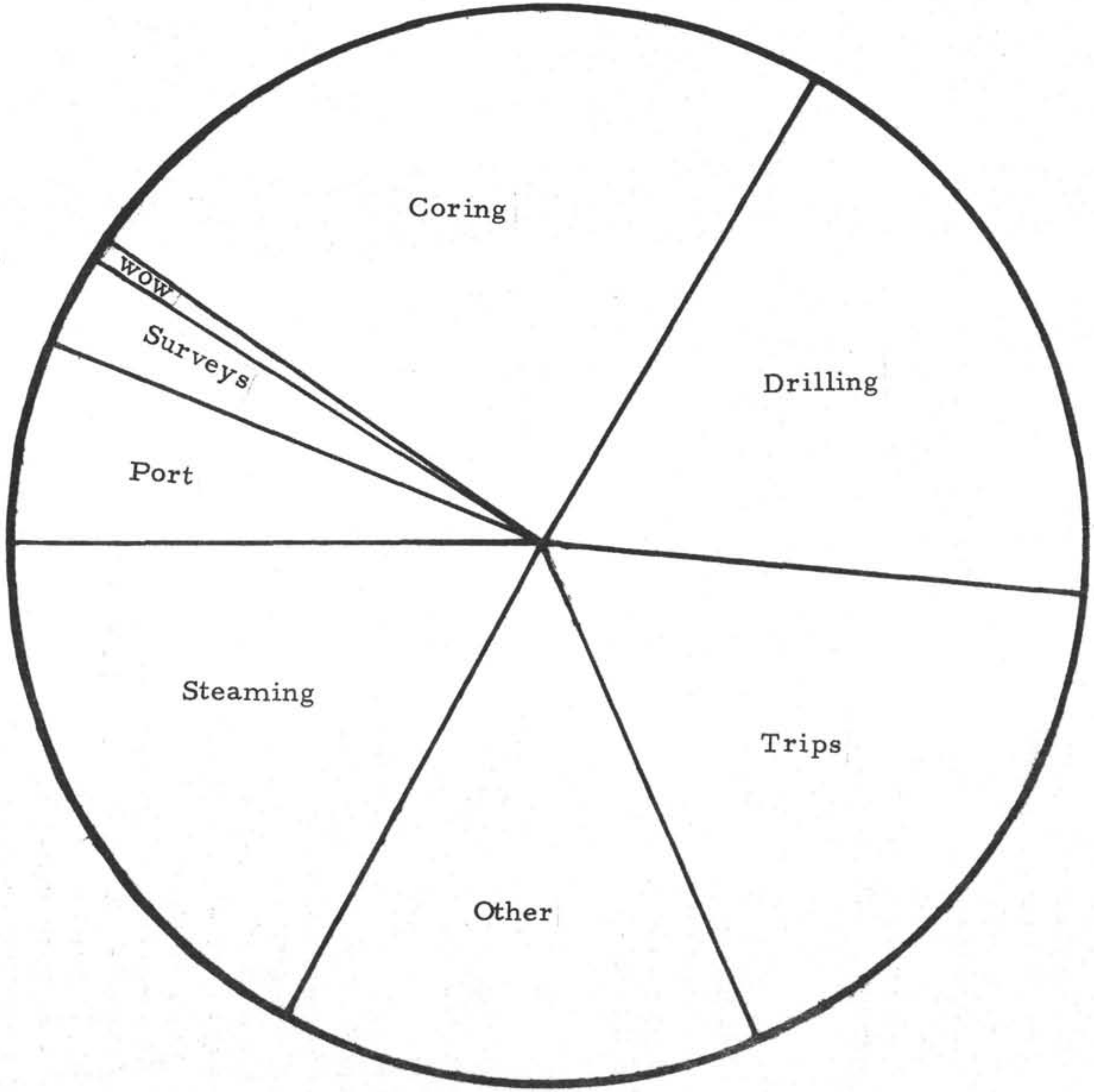


Figure 1

OPERATIONS RESUME

LEG 11 C

RE-ENTRY SEA TRIALS

ABSTRACT

This report covers the sea trials of the high resolution scanning sonar re-entry system designed and built for the Deep Sea Drilling Project. The system which was installed aboard the Glomar Challenger at Hoboken, New Jersey during the port call at the end of Leg 11 was tested at sea from June 10 through June 16, 1970. A complete description of the system and complete logs and comments of operations, scientific, electronics, Edo representative and observers from major oil companies, are included in the appendix.

INTRODUCTION

Cherty and other hard formations in the soft deep ocean sediments were encountered early in the Deep Sea Drilling Project. These formations prevented the drill ship from coring through all sediments to the basaltic basement with a single bit. An engineering study concluded the most positive way to penetrate these hard formations was to equip the Glomar Challenger with the capability of running two or more bits in the same core hole. This would also allow deeper penetration into the basalt. Evaluations of existing and proposed re-entry systems were conducted independently by DSDP and Global Marine Inc. (GMI).

The extension of the DSDP and the increasing requests of the scientific community made it possible for DSDP to actively engage in the procurement and test of a re-entry system.

As GMI would be the operator of this system, a change order to the subcontract was negotiated between DSDP and GMI for GMI to design and build a re-entry system to operate from the Glomar Challenger.

This system was to incorporate the Edo high resolution scanning sonar operating through the core bit on 24,000 feet of Schlumberger seven conductor logging cable in 6096 meters of water. The lower drill string was to have a jet sub with a sliding Otis sleeve to close or open the jet. The landing cone was hexagonal and attached to the drill string with two sets of shear pins. Just before delivery a method was added to attach the base to the drill string with acoustically actuated explosive bolts.

It was decided to perform the sea trials of the system aboard the Glomar Challenger. This decision was based on: (1) the high level of training of DSDP and GMI personnel from using specialized equipment from a dynamically positioned drill ship in open water, (2) the capability of the ship to handle the system without modifications, (3) repair and modification capabilities aboard ship which would allow completing the test on one trip, (4) training of the personnel that would later run the equipment.

As the last available ships' time before the Glomar Challenger left for the North Atlantic was June 1 through June 16, all deliveries of equipment were expedited to Hoboken, New Jersey, even though this meant bypassing a surface test of all equipment.

The Scientific Mission was requested to select a site for re-entry tests. Requirements for this site were: (1) minimum 3048 meters water depth, (2) not in the Gulf Stream, (3) bottom sediments similar to deep ocean basins and without hard layers near the ocean floor. In addition, the site should be as near Hoboken, New Jersey and Boston, Massachusetts, as possible to reduce steaming time. Such a site was picked at 37° 59.39' North Latitude and 71° 46.65' West Longitude. Bottom conditions proved to be excellent.

CONCLUSIONS

1. The presentation at the surface on the Positive Position Indicator (PPI) scope by the high resolution scanning sonar transducer has sufficient contrast between target "signature" and background to enable an observer to positively identify the target and follow relative movement between the core bit and the target (re-entry cone).

2. In deep ocean water a re-entry cone can be keel hauled, casing run and landed in the base, attached to the drill string, lowered to the ocean floor, the casing washed into the ocean floor, and the drill string released from the base.

3. If the drill string is removed from the re-entry cone, the cone can be located with the high resolution scanning head by moving the ship.

4. The ships' positioning system can be used to position the bit over the re-entry cone for successful re-entry.

5. A controllable force near the lower end of the drill string is needed to shorten the time required for re-entry using the positioning system only. (The testing of the jet sub was not possible because of mechanical problems).

6. The downhole instrument will operate on a 24,000 foot seven conductor logging cable.

7. Physical alignment of the bottom hole instrument to the drill string (jet) is desirable.

8. Orientation of the transducer head and the PPI screen (0°00') would advise the operator of slip in either and also give a zero reference to rotate either image or transducer.

9. A means of rotating either the image (electronically) or the scope (physically) to allow the operator to keep the zero degree of the PPI sweep aligned with the ship's centerline.

10. The downhole instrumentation and drill string components are sufficiently different from existing equipment to be classified as prototype equipment.

11. Spare and/or replacement parts were far below a safe minimum to conduct tests at a location where supplies or replacements were not immediately available.

12. The sea trials demonstrated re-entry with a core bit, high resolution scanning sonar and a re-entry cone of at least 16 feet diameter is possible. This means re-entry capability be incorporated in planning DSDP coring legs and selecting scientific objectives.

RECOMMENDATIONS

1. Assume all downhole instruments and drill string components are prototypes and are to be evaluated and modified.

2. Return all instrumentation and hardware to manufacturers for evaluation. DSDP, GMI and Edo Western to then jointly evaluate equipment as to original design concepts, performance, and to evolve revised design concepts.

3. Negotiate for:

   a. Modification of existing instruments and hardware if economically feasible, or

   b. Re-design and construction of a modified instrument with sufficient replacement and spare parts.

   c. Design and construction of one or more surface controlled release systems to latch the re-entry cone to the drill string.

      (1) Hydraulically actuated.

(2) Acoustically actuated explosive bolts.

4. With all components assembled at one place thoroughly test:

   a. All equipment on surface.

   b. Downhole instrumentation in deep water.

5. Train DSDP and GMI electronic technicians at Edo factory for operation and maintenance of downhole instrument and surface. Train DSDP Cruise Operations Managers and GMI Pushers in the assembly, operation and maintenance of downhole instrument, drill string components, and the landing base.

6. Establish the ship's drill floor as the control center for re-entry and design surface displays to give necessary information to this center.

7. Modify existing downhole instrument and manufacture new base cone, release, jet sub and jet sub pack off in order that re-entry will be operationally available for Leg 15.

DISCUSSION

This is a brief discussion of the sea trials. Complete logs and comments from operations, scientific, electronics, the Edo project engineer, and observers from major oil companies are included in the appendix.

The trip to the site was uneventful, weather, in general, for the entire test was excellent. The sea did pick up to Sea State 5 during the trials for and actual re-entry.

After reaching our approximate location, we tested the acoustical explosive bolts release system which was to fire the explosive shear bolts. The unit would not work in 3048 meters of water. We later turned the hydrophone and release unit 45 degrees to the sand line with the booster and an explosive bolt. This would not fire at 3048 meters. We fired the bolt at 61 meters. Additional tests indicated the unit would work at 610 meters but not at 914 meters.

We returned to location and after dropping a beacon, ran a coring assembly into bottom to establish the depth below the mud line that could be penetrated without rotation, bit weight not to exceed 10,000 lbs and pump pressure not over 500 psi. This proved to be 77 meters which indicated six joints or 73 meters of casing should be run. A core was taken at bottom.

Before this hole was drilled, an attempt was made to run the Edo to see if we could locate the beacon. The bore plugger (attached to the Edo instrument to seal off the bit so all drilling fluid would pass through the jet when jetting) stuck in a tool joint and the Schlumberger line pulled out of the rope socket, dropping the instrument, which wedges five joints down. The keys on the collet of the bore plugger were found to be 4 1/4 inch outside diameter and were removed. Two more attempts were made to run the bore plugger, one with the seal mandrel turned down. The tool stuck on both tries, so was laid aside. The core barrel was blanked off for jetting on runs No.2 and 3 by filling in the Hycalog landing seat (for the inner core barrel) and adding "O" rings.

In addition to pulling out of the cable head, the Edo instrument housing was damaged. The cover plates over the expansion tube were loose. The cable head was re-socketed and the cover plates replaced and additional screws added.

The Edo was run to bottom and the positioning acoustic beacon easily identified on the PPI scope. The ship was moved to observe action of the bit.

The next run for the Edo was after the landing base was dropped. If the casing was still attached to the drill collars, the scope would be blank.

On reaching bottom, the Edo presented an excellent picture of the landing base. Several hours were spent tracking the response of the drill string to the drill ship.

The Edo was again run when the second landing base was on bottom (new location). When on bottom (in the landing base) the Edo was pulled above cone, and ship and bit motion observed. An attempt was made to move the bit with the jet, resulting in a failure of the Edo.

The Edo was pulled and the motor-transducer section found to be flooded with sea water and the pressure equalizing bladder ruptured.

An attempt was made to clean, dry and refill the motor section. After a bench check, the Edo was started for bottom but would stop transmitting at approximately 30 meters below the surface. This failure would repeat indicating an air bubble in the housing.

The motor section was disassembled, vent holes added, and refilled with a low viscosity fluid. The Edo was then run to bottom and performed excellent for approximately 15 hours.

The surface units performed as anticipated with the exception of the remote PPI on the drill floor which apparently had electrical interference.

As mentioned earlier we dropped the first landing base. This base was hung over the port side and keel-hauled in good time. The base was pulled up under the ship and hung off. These slings did not line up going through the hull cover for the moon pool and tended to pinch in the landing cone.

The casing was run and attached to the shear sub. When the casing was landed in the landing base, the base collapsed and the landing cone leaned over to the pipe. (Confirmed by divers and pictures).

It was decided to run the base to bottom and shear. When about 300 meters of pipe had been run, the base and casing sheared off and fell to bottom (confirmed by the precision depth indicator). The pipe was run to bottom and the loss of the base and casing confirmed by running the Edo.

As the explosive shear bolts had proved to be inoperative, the "J" tool and "J" slot (used to land the casing on the expotential horn until the bottom hole assembly has been picked up) were modified to run the second landing base and re-entry cone.

The second base was reinforced by welding all bolted seams and adding the rods and gussets where needed. Collapsing pad eyes were added, so the support slings would be in line with the holes in the keel plate. The slings were also re-rigged so the base could be released without sending a diver into the moon pool.

This base was also hung over the side, keel-hauled and hung off in good time. Some trouble was experienced in adapting the modified hangers to the casing and base plate.

The landing base (with four joints of casing) was carefully run to bottom and washed in to within ten meters of the mud line. No problem was experienced in coming out of "J" slot.

While waiting for the Edo to be repaired, the pipe was pulled and the landing sleeve attached to the shear sub (placed two feet above the bit). This would (and did) give a surface indication when the sub sheared if the bit had actually re-entered the cone.

The modified bearing support (making a seal between the outer core tube and Edo instrument) was left in the bottom hole assembly so the jet could be used if re-entry could not be accomplished with the positioning system.

When the repaired Edo was back in place in the core bit, a search pattern was run and the base located. As a field modification on the Edo bypassed the capability of electronically orienting the transducer and the PPI scan with the ship, it was necessary to find this orientation by moving the vessel along preselected tracks. The trace of the bit was then established. The bit closely followed the ship's motion for normal positioning thrust corrections. As the positioning system does not signal thrust corrections until the ship has moved outside a 40-foot circle and as only 100-foot offset steps can be dialed into the computer, the ship had to be manuevered until its meander pattern would carry the bit across the cone.

The PPI display gave no doubt as to when the bit was passing over the cone, and after establishing the necessary lead, the bit was successfully dropped into the cone.

For additional proof a core was taken at the shoe of the casing string.

Before pulling the pipe, the jet sub sleeve shifting tool was run in an attempt to close the sleeve. The tool became stuck, the sand line was cut, and pulled out. The tool was retrieved with the drill string.

In addition to these tests, we rigged up an acoustic pulse generator to determine the limits for pulse shape, frequency, and length acceptable to the positioning system. Two 13.5 kHz beacons were lowered through the moon pool and their acoustic pulses checked.

As soon as the core from the bottom of the hole was on board, the drill string was pulled, all loose equipment secured, and the Glomar Challenger departed for Boston, Massachusetts, to load out for Leg 12.

REFERENCES

1. Study - Methods to Penetrate Hard Formations in Deep Ocean Basins
2. Re-entry Study - Deep Sea Drilling Project
3. Re-entry Study - Global Marine Inc.
4. Edo Western Manual
5. Blueprint Bore Plugger
6. Blueprint Shifting Tool
7. Blueprint Landing Base
8. Stage "A" Report Re-entry Sonar, Phase II, Project Mohole
9. AC-DRL Acoustic Guidance Sonar
10. Trade Literature
11. Concept for Coring in Deep Ocean Waters from Self-Positioned Vessels.

APPENDIX

1. Passenger List - Scripps Personnel, Guests, and GMI Personnel On Board for Re-entry

2. Weather Summary

3. Log

4. Observers Comments

    (a) Captain J. Clarke, GMI

    (b) M.N.A. Peterson - N.T. Edgar, SIO

    (c) G. J. Behunin, Edo

    (d) J. Maheur, GMI

    (e) K. Barrett - C. Wells, GMI

    (f) L. Blurton - T. Rayborn, GMI

    (g) D. N. Smith, GMI

    (h) Observer, Major Oil Company

    (i) Observer, Major Oil Company

    (j) Observer, Major Oil Company

    (k) Observer, Major Oil Company

APPENDIX NO. 1

Passenger List -- Scripps Personnel, Guests, and
GMI Personnel On Board for Re-entry

1. Mr. K. E. Brunot - Project Manager DSDP
2. Mr. V. F. Larson - DSDP Operations Manager
3. Mr. D. L. Sims - DSDP Project Engineer
4. Mr. W. Schneider - Re-entry Consultant *
5. Mr. A. R. McLerran - NSF Observer
6. Mr. Daniel Hunt - NSF Observer*
7. Mr. Morris Phillips - NSF Observer*
8. Dr. M.N.A. Peterson - Co-Chief Scientist
9. Dr. N. T. Edgar - Co-Chief Scientist
10. Miss F. L. Parker - Paleontologist
11. Mr. C. L. Collier - Electronics Technician
12. Mr. P. J. Garrow - Electronics Technician*
13. Mr. L. L. Lauve - Photographer
14. Mrs. S. Thompson - Yeoman
15. Mr. T. B. Gustafson - Laboratory Officer
16. Mr. D. Bos - Marine Technician - Chemist
17. Mr. B. Hamlin - Marine Technician
18. Mr. R. W. Gilkey - Marine Technician*
19. Mr. T. J. Wiley, Jr. - DSDP Public Information Officer
20. Mr. R. Bowman - Weatherman
21. Mr. James Maher - GMI Observer
22. Mr. L. Blurton - GMI Engineer
23. Mr. Ken Barrett - GMI Electronics Technician
24. Mr. Bruce Erickson - GMI Coring Technician
25. Mr. Don Smith - GMI First Mate
26. Mr. G. J. Behunin - Edo

*Off loaded June 9, 1970; replaced by:

<u>On loaded June 9, 1970</u>

Mr. R. R. Angel - Phillips Petroleum Company
Mr. Jim Caldwell - ESSO Production Research Company
Mr. Peter Briggs - Writer, self-employed
Mr. John L. Shaw - International Nickel Company
Mr. J. J. Weirda - Standard Oil Company of California

APPENDIX NO. 2

WEATHER OBSERVATIONS ON RE-ENTRY SITE
POSITION 38.0°N to 71.8°W

Local Date and Time	Wind	Wind Waves	Swell
6/06/70 - 20:00	SSW - 20 knots	5 feet	No Swell
6/07/70 - 08:00	NW - 12 knots	2 feet	S - 5 feet
6/07/70 - 14:00	WNW - 10 knots	2 feet	S - 5 feet
6/07/70 - 20:00	WNW - 20 knots	3 feet	SSW - 5 feet
6/08/70 - 08:00	WNW - 12 knots	2 feet	S - 3 feet
6/08/70 - 14:00	WNW - 4 knots	----	S - 3 feet
6/08/70 - 20:00	CALM	----	S - 3 feet
6/09/70 - 08:00	E - 17 knots	3 feet	----
6/09/70 - 14:00	ENE - 20 knots	3 feet	ESE - 5 feet
6/09/70 - 20:00	ENE - 15 knots	3 feet	ESE - 5 feet
6/10/70 - 08:00	SSW - 6 knots	2 feet	SE - 5 feet
6/10/70 - 14:00	SSW - 6 knots	2 feet	SE - 4 feet
6/10/70 - 20:00	CALM	----	SE - 5 feet
6/11/70 - 08:00	ENE - 5 knots	----	S - 3 feet
6/11/70 - 14:00	CALM	----	ESE - 3 feet
6/11/70 - 20:00	W - 7 knots	----	ESE - 3 feet
6/12/70 - 08:00	SSW - 10 knots	1 foot	ESE - 3 feet
6/12/70 - 14:00	SSW - 15 knots	2 feet	ESE - 3 feet
6/12/70 - 20:00	W - 9 knots	2 feet	SSE - 3 feet
6/13/70 - 08:00	WNW - 11 knots	2 feet	S - 3 feet
6/13/70 - 14:00	NE - 20 knots	4 feet	----
6/13/70 - 20:00	NE - 30 knots	5 feet	NE - 7 feet
6/14/70 - 08:00	ENE - 25 knots	5 feet	NE - 6 feet
6/14/70 - 14:00	E - 18 knots	4 feet	NE - 6 feet
6/14/70 - 20:00	E - 15 knots	3 feet	NE - 5 feet
6/15/70 - 08:00	ENE - 12 knots	2 feet	E - 4 feet
6/15/70 - 14:00	E - 15 knots	3 feet	E - 4 feet

OFF STATION - UNDERWAY FOR BOSTON

APPENDIX NO. 3

RE-ENTRY LOG

June 6, 1970

Arrived re-entry site 10:00. Ran profile line across site and beyond about 10 miles. With vessel drifting, rigged Edo Model 337 transducer six meters below hull line through the moon pool. Transducer was driven by a pulse carrier system such that pulse width, pulse repetition rate, and carrier frequency could be accurately varied. These signals were used to test the positioning system procession. (1) Pulse width tolerances were four plus .1, minus .8 milliseconds. (Note: these values were for the most critical channels.) (2) Pulse repetition rate was 2.28 sec to 1.57 sec. Repetition rate that T_o pulse generated within the system triggered the computer rather than the sonar signal. (3) Frequency changes of the carrier that could be tolerated were 15.45 kHz to 16.58 kHz. The basic conclusion, therefore, is that the pulse width is the most critical parameter and was not identical on all channels. Attempted tests of the 13.5 kHz but was unable to conduct tests because only two channels received signals of sufficient strength to validate data.

Cruised back to re-entry site at location 37°59.39' North Latitude and 71°46.65' West Longitude. Dropped Burnett 16 kHz beacon.

Placed re-entry target over the side in water six meters to nine meters below hull with Edo scanning tool in normal running position below the bit. Signature of target was obtained and target could be seen for all variations in the target azimuth. Maximum range tested was approximately 61 meters. Note: Physically unable to move target further.

Hook up acoustic recall to sand line with 100 lb weight hanging below release. Note: Operation checked okay before lowering.

19:05 - Lowered command ducer over side of vessel and send command. Pull sand line. Sand line had been overrun approximately 183 meters. Badly kinked. Weight had not released and would not release at surface.

Pick up second release. Note: Third release was inoperative as received from Inter Oceans. Run in to approximately 2743 meters. Attempt release, no good. Run to 61 meters plus or minus. Release was made - shackle fouled in pelican hook.

June 7, 1970

Subsequent work on first release indicated limit switch had not tripped to reverse release motor.

Decision made to run drilling assembly and continue work on release. Favorable results will attempt acoustic link after trip.

Water depth 3053 meters, Precision Depth Recorder (PDR) 3053 meters. Made up bottom hole assembly, core barrel, index sleeve, three 8 1/4 inch outside diameter drill collars, two bumper subs, three 8 1/4 inch outside diameter drill collars, one bumper sub, two 8 1/4 inch outside diameter drill collars, one 7 1/4 inch drill collar, one joint 5 1/2 inch outside diameter drill pipe.

Strip in horn.

Run drill pipe. Lay down bad order drill pipe in hole at 04:30. Pick up Edo tool. Attempt to work bore plugger in drill pipe. Tool bull dogged on collet. Pulled out of socket at 4,300 lbs versus 3,750 lbs design.

Pull out of hole. Locate tool five joints down. Broke case at equalizing section while breaking stand. Tool had stopped at tool joint upset. Collet had jammed.

June 8, 1970

09:00 - Ran inner barrel - punch cored ocean floor 3053 to 3062 meters and continued to punch core to 3065 meters. Took 10,000 lbs weight. Pulled inner barrel - no recovery (all washed out). Calipered Edo tool - found lower dog assembly to be 4 1/4 inch outside diameter - modified tool by removing same. Found split sleeves over diaphragm section loose. Increased number of screws to four each for each sleeve 1/4 inch set screws. Repaired Schlumberger cable head.

10:00 - With 500 lbs pump pressure, no rotation, total depth 3130 meters (77 meters penetration). Dropped inner barrel and cored 3130 to 3139 meters (nine meters penetration).

12:30 - Pulled and recovered ten meters grey-green clay. Looks good for setting casing shoe at about 73 meters plus or minus.

13:00 - Electrically tested Edo tool- okay, both in air and over the side.

17:00 - Make-up dummy on bore plugger. Tool hung up several joints down. Pull out. O-ring missing. Circulate hole approximately one and one-half hours. Remove sleeve from bore plugger completely. String Schlumberger line through blocks. Make-up torpedo.

19:30 - Pick up and run Edo scanning sonar head - approximately two hours to run in. Lower drill pipe and logging tool in three meter increments down. Locate acoustic positioning beacon on scope. Move vessel - pipe movement seems to lag five minutes, however, appears to come to rest at new location with a minimum of overshoot.

22:30 - Pull Edo tool - 1067 m/hr 200 to 300 lb overpull.

June 9, 1970

01:30 - Lay down Edo - break torpedo. Cannot pull through blocks due to lubricator.

02:00 to 08:00 - Pull out of hole.

08:00 to 09:30 - Keelhaul base plate - very smoothly done.

09:30 to 13:00 - Make-up and run six joints 10 3/4 inch casing and hang in moon pool.

13:00 to 15:00 - Make-up core barrel and six drill collars - lowering too. Engage casing bowl with bumper sub.

15:00 - Pick up drill collar and lower and engage base plate not over 5,000 lbs down.

17:00 to 19:00 - Divers report base plate torn up - pad eye one side torn off. Cone disengaged from base. Divers took movies and unshackled line.

19:00 - Run in - lost 15,000 lbs at 1600 meters. Run in - began to take weight 15 meters in on casing or six meters in on core bit - circulated hole. (Weight of base plate 11,000 lbs and casing 8,750 lbs = 19,750 lbs in water).

Decided to run Edo to verify whether 10 3/4 inch casing still on.

Rig up and run Edo.

Found good reflector.

Positioning vessel and building improved re-entry cone.

June 10, 1970

Recovered Edo.

Pull out of hole.

10:00 - Divers hooked up keel-haul lines. Hook up acoustic release, boom box, and explosive bolt to sand line. Acoustic release transducer held at 45 degree angle. Run in to 2743 meters plus or minus on sand line. Run command hydrophone over side of vessel and attempt to fire bolt. Pull out; bolt had failed to fire. Run bolt to 61 meters plus or minus and fired successfully.

12:30 - Position vessel to determine response at different offsets. Run pattern to determine strength level of beacon. Very good 16 kHz beacon. Move to new location.

Drop new 16 kHz beacon.

Run two new 13.5 kHz beacon on sand line. Take photos.

Continue welding.

June 11, 1970

Run release.

Released at 610 meters failed 914 meters.

07:00 - Rig up and keel-haul baseplate without divers. Make up 3 and 1/2 joint of casing. Mashed X-over with tongs (homemade) lay down joint and weld collar to bottom of casing bowl.

Make up four joints or 48.21 meters of 10 3/4 inch 40.5 lbs new singles K-55 buttress casing. All joints glued. Bottom fitted with Larkin open guide shoe. Top fitted with National latching head. Latching head fitted with modified "J" slot. Lower casing to elevators supported on homemade spider on guide horn. Make up bottom hole assembly with lugs on lowering tool four collars above bit (bit eight meters from shoe).

Latch into "J" slot and tack weld shear bar across "J" to prevent re-entry cone from floating out while running in. Sealing sleeve tack welded in place.

June 12, 1970

Run in to 3048 meters and pick up swivel. Wash in. Casing began to take weight at 932 meters. Circulated with both pumps at 65 spm each. Maximum pressure 500 psi. Wash in to 3078 meters. Would not go deeper. Top casing at 3030 meters with top of re-entry cone at 3026 meters. Took one quarter turn left hand torque with power sub and came out of "J" slot.

Pull to 3032 meters rig up Edo. Followed re-entry cone while running in an PDR. Lost reflection approximately halfway in.

Core barrel was fitted with tungsten carbide (crushed) core bit. Lower bearing support was packed off.

Run Edo and locate descriptive "cross" that was supposed to represent mud cross. Pull to 922 meters and re-enter, unable to see "cross". Pull up and make two unverified re-entries.

Use jet sub - saw considerable motion; used 250 to 450 lbs.

Increased pressure to 1,000 psi and tool failed. Pulled out and found equalizing bladder failed.

June 13, 1970

While working on Edo tool trip drill pipe and installed shear sleeve and jet sub at bit so that we could verify re-entry without trip with Edo tool.

Re-run Edo - tool would stop transmitting when in the water 17 meters.

Pull Edo tool and attempt repairs. Lower seal apparently damaged.

Drilled and tapped several vent holes. Refilled equalizing section with oil. Found several sections with galled joints during disassembly. Dressed joints in machine shop.

June 14, 1970

03:00 - Run Edo. Tool operating successfully.

06:00 - On bottom with tool. Unable to find re-entry cone. Approximately two hours searching. Locate re-entry cone. Attempt to position vessel for re-entry.

At 19:53 re-enter cone on second try and shear pins with 30,000 lbs plus or minus. Very easy.

Pull Edo tool and lay down tool.

Run to bottom at 3078 meters and circulate hole clean. Drop core barrel and take 14 meter core.

Core No. 1, Site 110, 3083 to 3092 meters (nine meters) recovered nine meters. Run Baker shifting tool. Attempt to shift sleeve on jet sub. Tool became stuck on sleeve. Moved up hole nine meters.

Attempt to part line with 22,000 lbs. Cut line and pull out. Found tool stuck in jet sub with sleeve closed.

Noon - Underway.

s/ Mr. K. E. Brunot
t/ Mr. K. E. Brunot
Project Manager
Deep Sea Drilling Project

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APPENDIX NO. 4(a)

RECOMMENDATIONS TO POSITIONING AND RE-ENTRY EQUIPMENT

1. It is my opinion, as I am sure that it was the original "intent" on planning re-entry, that the procedure would be as follows:

   a. The vessel would be positioned by the dynamic positioning within 50 feet of the sonar reflector target.

   b. We would then "jet" (first to see the direction of jet required).

   c. We would rotate pipe to orient the jet action in the direction desired to close the target.

   d. Using the remote display oscilloscope on the rig floor, the driller would jet to a position over re-entry cone.

   e. When the end of the string was in place we would lower away into the guide cone and accomplish re-entry.

2. Due to the fact that our "jet" capability was not functioning at the time of our re-entry trials, I endeavored to "spud in" using only the motion of the vessel 10,000 feet above the bottom hole assembly to accomplish re-entry. This method of operation proved extremely time consuming and with our present capabilities would only be recommended in emergencies.

3. The "fact" that this "can" be done has been proven.

4. In order to "minimize" the amount of jetting required, and for use in the event of a "jetting capability failure" I would recommend that the following modifications to our existing positioning and sonar scanning equipment be looked into bearing in mind engineering involved and financial feasibility.

   a. Modify the sonar scanning oscilloscope to present a "relative display" (i.e. relative to the ship's heading).

   b. Program, if possible, the bridge control console of the positioning system to include "smaller increments" of the offset capability as a "bias" control on the console. It might be suggested that the same "control" be accomplished using the "depth" control at present on the console. I do not concur, in

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that I can move only in two directions with this control (not then, necessarily the desired directions) whereby the "bias" control of smaller "increments" will allow me to move in any combination of eight cardinal and inter-cardinal points of the compass.

c. Install on the re-entry cone a magnetic or electronic "sensor" to assure that "positive" re-entry has been accomplished.

d. For items pertinent to modifications of re-entry cone, future use of same and procedures for keel-hauling, please refer to Mr. Blurton and Mr. Rayborn's report.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

RECOMMENDED PROCEDURE FOR MANEUVERING WITH PRESENT EQUIPMENT

1. In Automatic mode search out and approach target within nearest 100 feet by offsets.

2. Weather permitting, place vessel on a cardinal heading (since offsets are true). This lines up compass to points with X and Y axis of the vessel.

3. Endeavor to close the target to 20 feet by the below listed methods:

   a. Alter depth reading on control console

   b. Alter offsets by one-half (this can be done by demanding a 100 foot offset and altering this offset when the move is half accomplished.

4. Now lower sonar scanner and pipe to within one meter of the top of acoustic reflector on guide cone (depending upon weather conditions and vertical displacement).

5. Normal movement of the vessel will bring string over target, if not try small changes in heading.

6. With present 45 degree down scanner presentation on oscilloscope, the target makes a definite pattern, quite contrary to that expected, as explained below and shown in accompanying photograph.

7. Thought has been given by the writer to making the last 20 to 30 foot move by changing to a semi-automatic mode of operation. This was not done for the following reasons:

   a. With Sea State 5, 20 to 28 mile an hour winds, and on a heading one point from the wind, the vessel requires a very steady thrust to keep it within the 40-foot circle on the beacon display oscilloscope in an "automatic" mode of operation.

   b. By changing to semi-automatic, the computer immediately bases its memory for this required thrust and holds "heading" only.

   c. The display on the sonar scanning oscilloscope does not present true or relative azimuth and, therefore, the required thrust direction is not known.

   d. Thus the operator must concentrate on the sonar scanning oscilloscope to make a movement both fore and aft and athwartship by use of the speed adjust thumb wheels. If the move is in the wrong direction, the vessel will rapidly fall off position. The vessel must then be brought back to equilibrium (in a semi-automatic mode) and the procedure tried again.

e. If we are able to "stab" the cone in this mode, then the vessel must be held well within the 40-foot circle while the sonar probe is pulled (approximately one and one-half hours), the tool joint pulled to within one meter below the apex of the cone and a connection made before "lowering away" to a safe depth. (All the above in a semi-automatic mode.)

f. Only then will it be "safe" to change to an "automatic" mode and let the vessel "yaw" while the computer builds up its memory.

g. In the future the string will be "made up" to allow deeper penetration on the first stab. Then, wind and weather conditions permitting, I will attempt stabbing in semi-automatic.

h. In my opionion, the use of a "manual mode" is not feasible as we then would not even have the "heading" control afforded by semi-automatic; and since "heading" is the only hint of an "azimuth" the re-entry procedure would be made even more difficult.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

EXPLANATION OF PRESENTATION ON OSCILLOSCOPE OF RE-ENTRY CONE

1. Cone at 30 feet shows three distinct targets (however, not to scale).

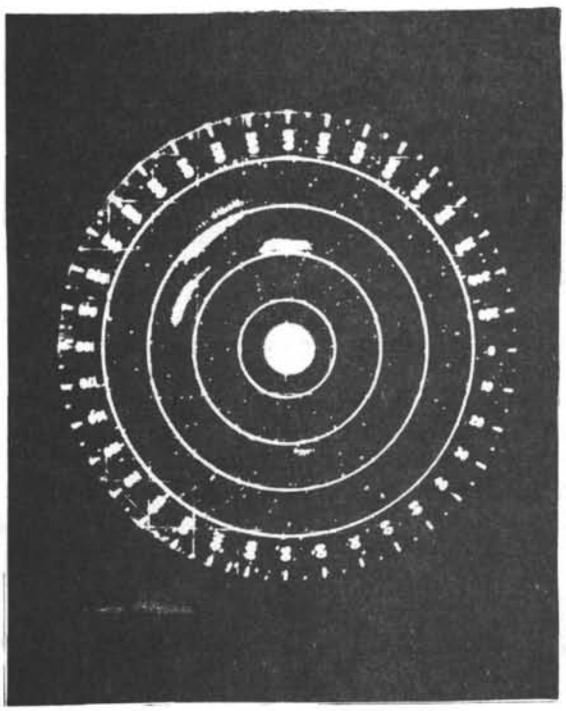
2. Upon closer approach to the target, the cone now begins to appear as a "triangle" (again not to scale).

3. As the string nears the center of the cone there appears a complete "circle" of targets on "all"sides. This is the point to drop the bottom hole assembly as rapidly as possible, leaving the sonar scanner on the Schlumberger line well up in the casing.

4. If attempted re-entry fails (and from time to time it will) pull up to one meter above sonar reflectors and re-seat sonar scanner to repeat procedure.

5. "Timing" is extremely important and I feel that with practice our percentage of "hits" will rapidly increase.

Direction of Ship's movement.



Approaching position to stab.

At position to stab.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

NOTES ON VESSEL'S SUCCESSFUL RE-ENTRY OF JUNE 14, 1970

1. The following conditions existed at the time of attempt at re-entry:

   a. The sonar reflector re-entry cone had been on the bottom since 00:30 June 12, 1970.

   b. During this time the sea state had increased from one to five, the winds from "airs" to 28 mph.

   c. The drill string had to be "round tripped."

   d. The heading had been changed 180 degrees.

2. Sonar scanning for the target commenced at 05:30 hours.

3. At 06:08, the Schlumberger line was raised to 3014 meters.

4. At 06:20, offsets of 100' North and 100' East were introduced.

5. At 06:25, additional offsets of 100' North and 100' East were introduced.

6. Target was detected at 06:27, bearing 270 degress relative, range 300 feet.

7. At 06:30, additional offsets of 100' North and 100' East were introduced.

8. Total offsets of 400' North and 300' East were introduced at time of sighting.

9. From 06:50 to 13:16 and with intermittent loss of acoustics due to weather conditions, we used various offsets to approach target.

10. It is interesting to note that we now require 400' North and 100' East offsets to reposition the ship over the sonar reflector cone which 48 hours previously required no offsets (this no doubt due to 180 degree heading change and increase in wind and sea state.

11. With offsets of 400' North and 100' East at 13:20, a re-entry attempt was made. Target missed by approximately ten feet.

12. At 13:55, vessel passed directly over target and observations for "presentation" were made. (No attempt at re-entry made at this time.)

13. At 14:10, we again passed over or very close to target.

14. During above observations of the sonar scanning oscilloscope from 06:50 to 14:00, several direct 180 degree changes in azimuth were apparent and many minor changes in azimuth (by maneuvering board plot).

15. From 14:10 to 18:06 many combinations of offsets and course changes (as much as weather conditions would permit) were made, all from apparent movement required by maneuvering board plot. (These moves were impaired by the apparent change of azimuth in the presentation on the sonar scanning oscilloscope.)

16. At 18:48, depth settings were altered in an attempt to close target.

17. At 19:10, a final depth setting of 11,000 feet was introduced.

18. At 19:26, it was decided by myself to return to original settings of 400' North and 100' East, which placed us so close to target at 14:00 , as time was running short.

19. At 19:30, it was decided by all concerned and concured in by myself to try positioning in automatic for four hours, then semi-auto for four hours, then attempt jetting if all else failed.

20. At 19:30, we passed directly over target and re-entry attempt was made. My timing was late in informing the drill floor to "slack away." (It is apparent that this takes practice.) We again missed target by approximately ten feet.

21. At 19:54, we re-entered and sheared shear pins (timing was perfect this time and a lot of "luck" was involved).

22. Vessel held well in automatic mode while sonar probe was pulled and connection was made to commence coring.

s/ Captain J. Clarke
t/ Captain J. Clarke
Master, Glomar Challenger

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APPENDIX NO. 4(b)

During the initial 18-month drilling program, coring in the young soft sediment has proven to be exceptionally rewarding, but within the older sediments penetration and recovery has been thwarted by the presence of widespread hard chert (flint) layers. Consequently, our knowledge of the early history of the ocean basin remains fragmentary. With a re-entry system, such as successfully tested by the Glomar Challenger, worn-out drill bits can be replaced and drilling continued until the layer is penetrated. Such a capability will enable the vessel to fully explore the older history of the entire Western Pacific, the eastern and western margins of the Atlantic and Indian Oceans as well as the smaller seas such as the Mediterranean, Caribbean and Coral Seas.

The re-entry system also provides the Glomar Challenger with the capability of placing long-term instrument packages at the bottom of the hole on completion of drilling. Downhole packages that have been considered in this context include seismographs, magnetometers and pressure sensors.

Recommendations for use and modification:

1. Some method to displace the ship's position, while retaining the essential elements of the fully automatic mode, from the 100 foot grid developed by the offset capability that now exists. Smaller increments, ideally of the order of one-tenth that which now exists in the offset capability, or a continually variable bias that could be optionally added to the computer commands for propulsion, would work very well.

2. Produce a relative azimuth presentation on the bridge, of the PPI display. This would ideally require known orientation of the transducer azimuth to the jet azimuth and also to the ship. Magnetic orientation from bottom sounds most simple way. Known azimuth is essential and can now be achieved experimentally, but requires time. It is absolutely essential that the azimuth not change, unpredictably; this requires firmly seating the transducer package at the bottom of the drill string.

3. Downward looking sonar. Would establish height of bit from bottom and locate edge of re-entry cone instantaneously.

4. Improve structural strength of re-entry funnel.

5. Design to allow jetting. It is anticipated that even movements of as little as ten feet would be an appreciable help.

6. Ability to mechanically turn drill string a small and controlled amount, for setting azimuth to produce relative azimuth presentation on bridge and for jetting. Perhaps a goniometer circle around the drill string and a brake in the power swivel would work.

7. Sensing system to establish carefully relative heights of top of re-entry cone and termination of drill string. Clearance at top of cone of two meters appears good for search and approach, clearing edge by one meter on final closure before stabbing seems desirable, if weather permits. This requires precise knowledge of relative heights at bottom. The same sensor could be used to verify re-entry. Proximity switch in Edo instrument package with magnetic activator in base of cone may be most simple way; signal to surface would be to switch off Edo signal briefly.

8. Some method to introduce re-entry cone and short casing after drilling without providing for re-entry initially would be good long range improvement. Possible slide assembly down drill string using funnel as parachute, having keel-hauled but not lowered unit initially, might work.

9. Recommended inventory of underwater transmitter-receiver units for standard operations would be two completely assembled units and one more not assembled, but available or to be cannibalized for module replacement, plus assorted spares.

10. Detailed reviews of documentation of ship's motion, ship's response to commands of varying relationship to cardinal points, drill string motion and response to ship's motion, lag times etc., appearance of target, weather conditions.

s/ Dr. M.N.A. Peterson
t/ Dr. M.N.A. Peterson
Chief Scientist
Deep Sea Drilling Project

s/ Dr. N. T. Edgar
t/ Dr. N. T. Edgar
Coordinating Staff Geologist
Deep Sea Drilling Project

APPENDIX NO. 4(c)

GENERAL

The Edo Western scanning sonar system in general met the anticipated requirements and performed within the design specification with the possible exception of the mechanical strength of the diaphram cover plates.

The diaphram cover plates support the total weight of the motor section of scanning sonar and these plates were mounted with only six stainless steel screws each. This configuration seems to be inadequate in light of the handling it will probably see. A possible solution is to make the cover plates into a tube assembly and fasten with some kind of ring clamp, such as a Marman clamp.

Several system deficiencies which were not within the original design goals were also noted. The most important of these being that the underwater scanning sonar has no reference to true bearing, which complicates the use of ship's positioning in the re-entry process. Also of major concern is the re-entry cone display signature which, while it is not fully understood, does not appear as three distinct targets centered on the display, but appears as multi-targets centered on the display at un-real distances. Also increase display persistance.

HARDWARE

Suggest hardware changes or rework:

1. General clean-up of electronics.
2. Tear-down of motor selection for inspection and repair of salt water damage.
3. Re-design diaphram covers for better mechanical strength.
4. Add true bearing reference.
5. Restore azimuth sync capability on control unit.
6. Install high persistence oscilloscope tubes in both displays. Black-out hoods should be provided at display installation locations.

OPERATING PROCEDURE

Use ship's position system to move within 100 feet, then use water jetting for final maneuvering and re-entry. Coarse maneuvering should be controlled by the bridge by persons familiar with the ship's positioning system. The fine maneuvering and re-entry should be controlled by the drill rig tool-pusher from the drill rig floor. If other displays are required to better define "over the cone position", thought should be given to putting it on the drill floor also.

HANDLING PROCEDURES

Electronic instruments, no matter how well packaged, should still be treated with care. Some type of fixture could be built to aid insertion of the underwater unit into the drill pipe on the drill floor, but supervision and some degree of caution should be exercised.

STAND BY EQUIPMENT

The test equipment now available on the Glomar Challenger is more than adequate.

PERSONNEL TRAINING

Personnel training should consist of a two-level approach, which are:

1. Maintenance and trouble-shooting aided by manuals, schematics and possibly special instructions.

2. Operational - enough training and experience to operate controls and identify target signatures. These people could be trained by the maintenance personnel.

SPARE PARTS

The spare parts already obtained should be supplemented with one or two spare underwater transmitter-receivers, since the underwater unit has to operate in an environment where retrieval is somewhat uncertain. Also some spare printed cards might be useful to minimize downtime of any of the underwater packages.

s/ G. J. Behunin
t/ G. J. Behunin
Edo Western

APPENDIX No. 4(d)

EFFECTS OF SHIP'S MOTION

Ship's motion resulting from automatic dynamic positioning appears to describe a figure-eight with the maximum motion occurring athwartships. This characteristic motion is determined by the thrust to resistance-to-motion ratio (control authority) in the ship's horizontal axes. The control authority is much greater in the fore-aft (X) axis than in the athwartships (Y) axis. Therefore, the fore-aft deviation from desired position is generally held to much smaller amplitudes than the athwartships position error.

Offsets were commanded into the dynamic positioning computer to perturb the bottom of the pipe string. It was hoped that the resulting motion could be used to establish an azimuth for the sonar unit. Generally, the motion of the drill string versus time was not in a straight line. The vessel tends to react to a command along its fore-aft axis first, and the drill string reacts to this motion. The athwartships motion follows somewhat later.

In a relatively calm sea, little or no offset was required to position the pipe string near the re-entry cone. Ship's position was generally held to within a forty-foot radius of the beacon. Relatively slow motions about the beacon occurred, and the pipe string excursions remained within about 30 feet for periods of an hour or more. Under these favorable conditions, the motion of the pipe string follows the motion of the vessel with approximately a two to three minute lag. The pipe string motion approximates the motion of a damped pendulum. Little overshoot was observed, and pipe string motion seemed to stabilize within 20 to 30 minutes after an offset command.

In the Sea State 5 seas encountered at Site 110, offsets of 400 feet North and 100 feet East were required to position the pipe string near the cone. Under these conditions, motion of the pipe was much less predictable. Much larger overshoot was observed, and settling time was considerably increased. At times a figure-eight pattern seemed to predominate, probably resulting from the controlled motion of the vessel coupled through the drill string.

Ship's roll angles of plus or minus three degrees and pitch angles of plus or minus two degrees were observed during the re-entry trials. These disturbances occur at a relatively high frequency when compared to the frequency-pass band of the drill string, and the effect of these disturbances should be greatly attenuated by 10,000 feet of pipe. Therefore, these disturbances will have little effect on pipe bottom motion.

Pipe velocities exceeding one ft/sec were observed during the trials. These velocities generally occurred near the crossover of the figure eight patterns. Attempts to re-enter the cone during such transients should be avoided, if possible, to minimize the risk of damage to the sonar unit, the pipe, and the re-entry cone.

Rotation of the drill string will be necessary in later re-entry tests to reorient the thrust vector of the jet sub in the desired direction. This was accomplished easily with no measurable time lag or observed oscillation of the bottom of the drill pipe.

RECOMMENDATIONS FOR FUTURE RE-ENTRY TRIALS

1. The sonar unit must be equipped with an azimuth reference relative to ship's head. This may take the form of a true azimuth reference with provisions to align this with cardinal points obtained from the ship's gyrocompass.

2. The pipe should be brought as close as possible to the cone using the ship's automatic dynamic positioning. The terminal phase of homing should be performed using jetting at the bottom of the drill string. Therefore, provisions must be made to seal the sonar unit from the water pressure used for jetting to avoid a large pressure differential across the sonar unit. A water jet with several thousand pounds thrust may be necessary for positioning in heavy currents. Experiments to determine the size of the jet sub required should be conducted as soon as possible.

3. The ship's dynamic positioning computer should be re-programmed to provide offset increments smaller than 100 feet. The offset increments should be reduced to ten feet, if possible. It is recognized that this may exceed the memory capabilities of the computer.

4. A bottom-scanning sonar unit should be considered as an addition to the downhole unit. Presently, the cone cannot be seen when the sonar unit is one or two meters directly above it. Addition of the bottom scanning unit would provide position information in the critical seconds just before re-entry.

s/ James I. Maher
t/ James I. Maher
Global Marine Inc.

APPENDIX No. 4(e)

EDO WESTERN SONAR SCANNING RE-ENTRY EQUIPMENT

Following is a list of recommendations on operating procedures and proposed modifications.

1. Operating Procedures:

   a. Initially, ship has been positioning over beacon, cone is then lowered to the ocean floor and spudded in. At this time pipe should be pulled clear of cone and Edo gear should be lowered and offsets should be computed before any drilling is accomplished. After offsets have been computed, the initial drilling and coring can be done. Afterwards, in event of bit replacement or other failures requiring pulling of drill string, a reference has already been established.

   b. Before any re-entry is attempted, offsets should be established. Ship's positioning should be settled out where ship is positioning within plus or minus 40 foot. (Desired heading etc. has been chosen.)

      At this point (if using only the ship to guide drill string for re-entry) it would seem more feasible to position ship in semi-auto to accomplish re-entry.

      However, if jet sub is being employed, ship should be settled out in auto to position with plus or minus 40 feet and then jet sub could be employed.

2. Modifications:

   a. Believe that downhole assembly should incorporate a unit to make it possible to read out actual bearings (preferably relative bearings) to the target.

   b. Believe a three-position transducer should be employed vice a two-position. (Present one has an eight degree down and 45 degree down.) Propose eight degree down, 45 degree down and 90 degree down.

   c. On the downhole assembly: eliminate expansion boot and a watertight assembly be made. Otherwise, without this modification use of jet sub for any effect is virtually impossible.

d. Believe that sector scan could be eliminated and rotation time on 500 foot scale should be increased to sweep around faster. (Sector scan is only useful at 500 foot and 250 foot scales, providing there is no azimuth drift, which is non-existant.)

e. Display transmission to rig floor remote display with our present wiring is inadequate (rig floor display is not receiving the display as being received on the bridge).

s/Ken Barrett
t/Ken Barrett
Global Marine Inc.

s/Carl Wells
t/Carl Wells
Global Marine Inc.

APPENDIX NO. 4(f)

EQUIPMENT ITEMS, RE-ENTRY SYSTEM

1. Guide Base Center Ring - (National)

   No modification needed, operation good.

2. Casing Hanger - (National)

   a. Outside latch ring design satisfactory for re-entry program.

   b. Inside shear pin design not operational. Loads applied to shear pins not connected with total weights of drilling assembly and casing. Design should be controlled lock to prevent movement up or down between handling sub and casing hanger during desent to ocean floor. Release could be rotation to the right with load applied up or down. Second method could be internal release with wireline. Third method, free drop down drill pipe to ocean floor.

3. Drilling Sleeve - (National)

   a. Could be removed with new design but would call for extra trip to remove larger handling sub out of drilling assembly.

4. Handling Sub - (National)

   a. Shear pins not operational.

   b. See Section B on Item 2, Casing Hanger.

5. Bore Plugger - (Baker)

   a. Not operational body outside diameter to large for inside diameter of scaled drill pipe. Do not need index sub or collet index on bore plugger tool.

   b. Re-design of this tool could be incorporated in top assembly of Edo tool.

6. Jet Sub with Index Sub - (Baker)

   a. Bottom index in jet sub should be re-cut to fit new index dogs in shifting tool.

b. Design should be gone through with Baker representative, Ray Dean, Houston Plant, to find out why tool hung up in index sub after closing of sleeve.

c. For operation on lowering of casing jet sub can go down with drilling assembly in the open position.

d. With bore plugger or pack off designed in top section of Edo unit, jet sub should decrease time for re-entry into cone base.

7. Hex Re-entry Base (Global Marine design)

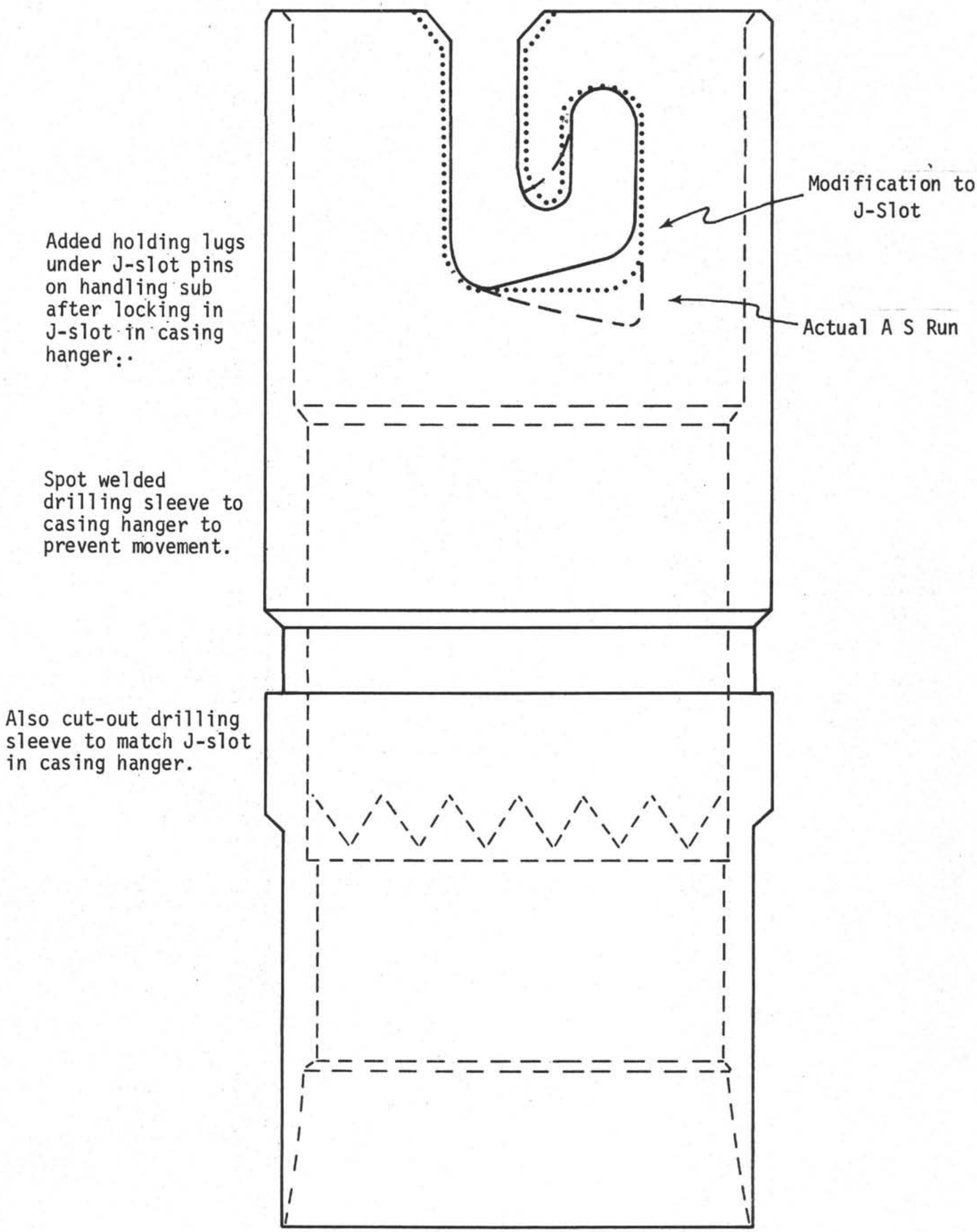
a. Construction design not heavy enough to carry loads applied by casing and drilling assembly in hanging position under ship. Pad eye loads applied on Unit No. 1 not a fair test due to location of pad eyes on base and location of holes in drill well in relation to location of pad eyes on box beams under rig floor.

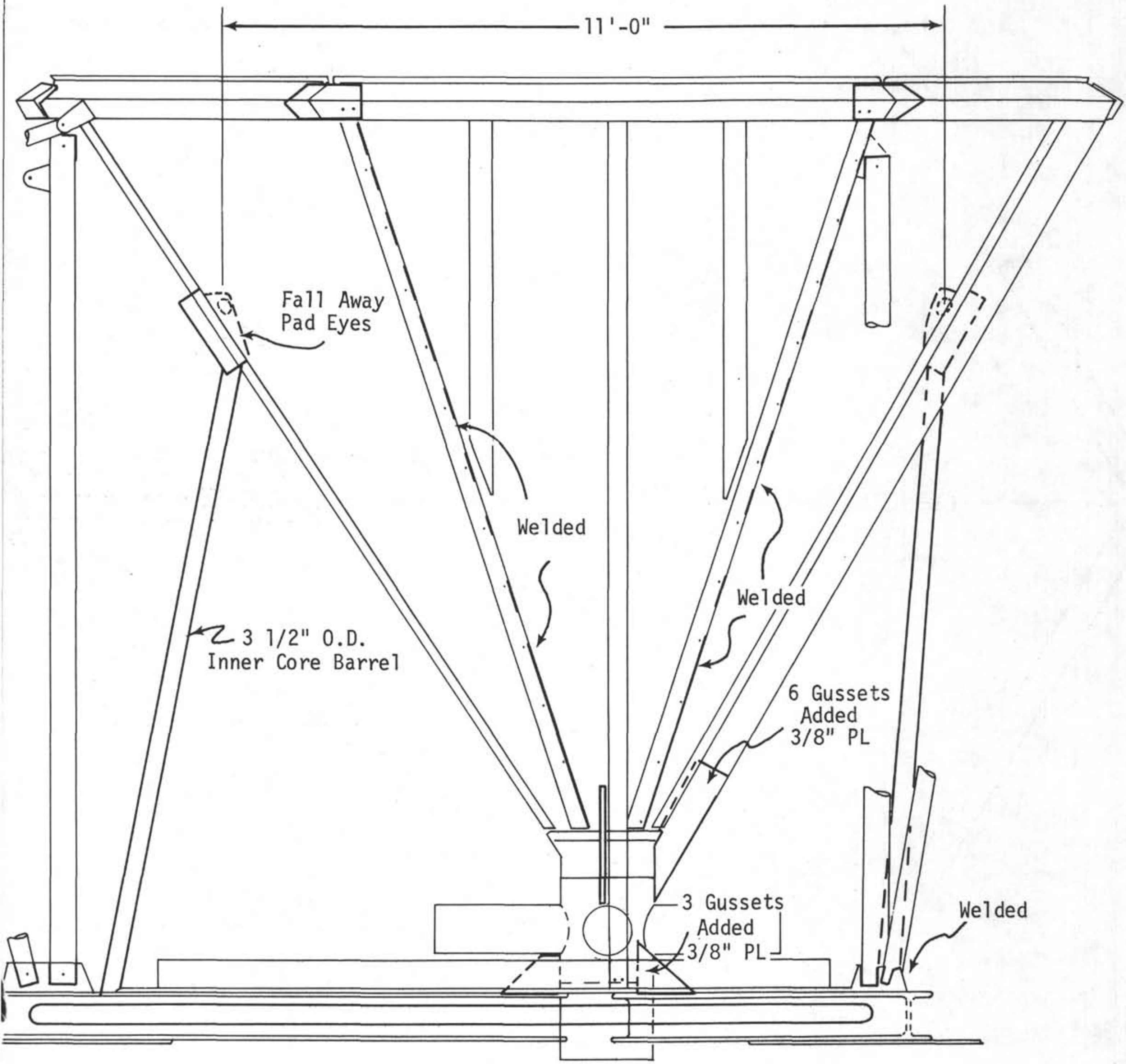
b. Second unit constructed the same as the first, but gussets and cross members were added to strengthen cross section of base. All bolted sections were chain welded or welded completely. Fall away pad eye were also added four feet down from top edge of cone on 11 foot centers. These pad eyes were tied into bottom base by a diagonal brace. See attached drawings for modifications.

s/ Leon Blurton
t/ Leon Blurton
Global Marine Inc.

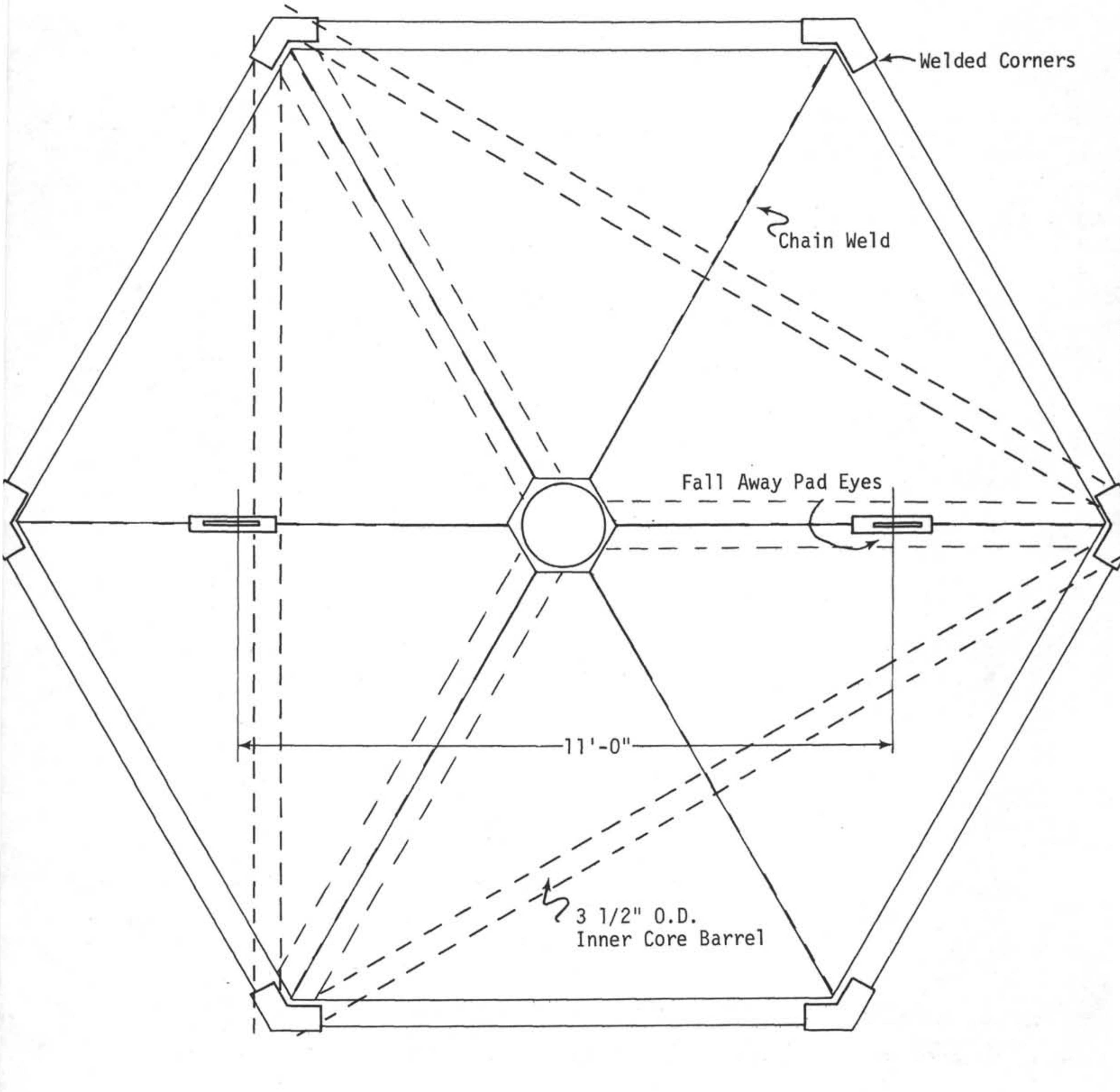
s/ Travis Rayborn
t/ Travis Rayborn
Global Marine Inc.

RE-ENTRY SYSTEM





MODIFICATIONS TO RE-ENTRY BASE



MODIFICATION TO EXISTING RE-ENTRY BASE

APPENDIX NO. 4(g)

COMMENTS ON RE-ENTRY 14 JUNE 1970

The Edo sonar tool was run at about 05:30 on the 14th with drill string still latched to re-entry cone. The first operation consisted of taking pictures of the obvious four-leg pattern on the scope believed to be caused by mud vents on the re-entry cone. Next the drill string was raised to obtain a scope signature of the top of re-entry cone which was shown very clearly. Then the pipe was pulled clear of the cone and re-entry was begun in earnest.

Approximately 14 hours later re-entry was accomplished. The interim period was consumed attempting to move the vessel using offsets (increments of 100 feet). By plotting the relative bearing and range to the cone, a picture of the movement at the drill bit was obtained. Also tried was varying the depth setting on the positioning console and heading changes.

Conclusions:

In the automatic mode of operation, a plot of the bits movements must be kept to determine the effect of the offsets. This will enable the operator to visualize the movement of the pipe in relation to the re-entry cone. The general mode of operation should be to locate the target, close it as closely as possible, establish the pattern of swing of the drill bit, adjust pattern to pass over the cone (offsets, heading change or depth variations) and when ready lower the drill string. However, since pipe movement is relatively rapid, the time to lower the pipe must be anticipated and this action initiated early.

Suggestions:

Modify re-entry tool so that jet on drill string may be used. Then when pipe and cone are close, the jet may be used to position bit over the cone. This should speed up the operation considerably. The balance is simply training operators, which will come with practice.

s/ D. N. Smith
t/ D. N. Smith
Global Marine Inc.

APPENDIX NO. 4(h)

OBSERVATIONS AND COMMENTS ON DSDP WORK CONDUCTED JUNE 8 to 15

By Subject Classification:

Ship - Glomar Challenger: Well suited and rigged for the work - plenty of adequate gear and well staffed. Food and accommodations were outstandingly excellent.

Personnel: All aboard appeared competent and well qualified for their respective assignments. Everyone seemed knowledgeable and enthused about the common purpose of the voyage. The amicability of this somewhat confined group is noteworthy. Decisions and instructions were handled tactfully, and personnel appeared very agreeable. The drilling crews are probably the best I've seen.

Planning: In view of the extremely high cost of operation at sea, I would visualize the following as being the minimum for this subject:

1. Responsbile personnel would hold meetings well in advance of the voyage to prepare detailed mechanical programs and equipment lists and consider various alternates to these programs depending upon possible unexpected operational results.

2. To the greatest extent possible, all equipment would be fabricated and checked out on the beach.

3. Strong consideration would be given to backup equipment.

4. Meetings of concerned personnel in authority would be held as necessary during operations whenever previously established plans are altered.

   Some examples of deviation from the above which I believe "hurt" us are:

   a. Shear pin failure during running of the first cone base.

   b. Jay-slot modification at sea.

   c. Pulling out of cone during second re-entry operation without first jaying in and taking a strain on the pipe to obtain proof positive that re-entry had been attained.

Responsibility and Authority: Did not appear to be clearly delegated and known - as in the case with most offshore operations I have observed.

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Ship's Positioning System: Did an excellent job, however, it should be convertable to semi-automatic or manual mode without loss of memory.

Re-entry Equipment: Performed very well for first trial (Edo). Mechanical equipment should be redesigned and thoroughly tested on the beach prior to the next attempt. Backup equipment should be preassembled. Some considerations for future operations are:

1. Use transmitters or transponders on the cone instead of reflectors to provide easier, more positive target identification.

2. Incorporate azimuth capabilities.

3. At a given location, three separate bottoms are observed as follows: Driller's , Edo's, PDR's. Care must be taken to insure the cone base reflectors are always set above Edo's bottom.

4. It may be found that manually controlling the ship's position is more reliable and expedient for re-entry. I would be interested in the results of any experimentation of this sort.

5. It would help if Edo could scan faster.

6. Edo should be made to disassemble faster for trouble shooting - possibly a spare tool could be kept on board.

7. Possibly, Edo output could be interfaced with "Elmer" to control ship's position automatically.

8. It will eventually be necessary to have a positive means of knowing re-entry has been accomplished without pulling out of the hole (other than drilled depth check). Under present system, if the hole sloughed in while making a bit change, we might not think we were back in the hole after a successful re-entry. Valuable time would be lost attempting to re-stab. Possibly the Edo tool could be adapted so that the reflectors could be observed above the tool after re-entry is accomplished.

9. I'm quite sure the scientists are interested in seeing the "surface" layers of the ocean floor. Therefore, it would be desirable to find a means of "coring in" the conductor rather than jetting it in.

Observer, Major Oil Company

APPENDIX NO. 4(i)

OBSERVATIONS AND COMMENTS ON DSDP WORK CONDUCTED JUNE 8 to 15

It has been an honor and a pleasure to witness the successful re-entry tests conducted on the Glomar Challenger. Certainly, a practical and economical re-entry concept has been demonstrated.

In addition to proving that the re-entry system is workable, the tests also point to a few minor improvements that promise to make future re-entry routine.

Equipment improvements that seem justified at this time are:

1. Modify the packoff around the Edo tool to permit jetting.

2. Provide for mechanical alignment of the Edo tool so that it can be set to sector scan a quadrant that is opposite the jet. Once the target is picked up on the Edo scope it can be placed in the reference sector by turning the drill pipe. With the tool scanning the reference sector, the bit can be jetted to the target. Steering of the bit can be accomplished by turning the drill pipe through small angles.

It may be advisable to provide a means of surveying the subsurface aligning device so that the scanning coordinates of the Edo scope can be referenced to the heading of the ship or to a compass heading. Available single shot surveying instruments can be adapted for this purpose. A non-magnetic collar can be employed or the survey instrument could be allowed to project through the bit.

Jetting and guidance can best be controlled from the rig floor since stabbing must be coordinated with these operations.

Observer, Major Oil Company

APPENDIX NO. 4(j)

Concerning the re-entry mission of this present leg of the Glomar Challenger, I would like to express my views of, first, the personnel relationships and, then, the technical aspect.

It appeared to me that there is a helpful working coordination among the ship's crew, rig's crew, and the scientific personnel. There seems to be an openness to exchange ideas among all the persons I came in contact with. I appreciated the briefing we "observers" had when we first got on board last Tuesday, June 9, via USS Fort Mandan. Your telling us of your technical progress along with the Challenger's accommodations was most helpful. However, I feel that not being told about the hard hat area or where your extra hard hats were stored was an oversight.

Also, since operations go on a 24-hour basis, it would have been more informative (not only to me but to all involved) to have a scheduled announced meeting from time to time in order to tell what has been done, what is being done, and what should be done. There was, of course, no problem in talking with any one person, if they weren't busy, but I think a "round table" discussion helps fill in the gaps.

As far as the technical aspect of re-entry is concerned, it was a great success. The important milestones were:

1. Getting the base funnel on the ocean floor.

2. Relocating the funnel's targets with Edo after re-running the pulled drill string.

3. The ship's motion is a figure eight.

4. The drill bit at 10,000 feet responds to the ship's motion some two to four minutes later in a highly over-dampened manner.

5. The drill bit responds immediately to rotation.

6. After 13 1/2 hours of learning 2 through 4, re-entry was accomplished by ship's displacement.

I am not in a position to know, but after re-entry it seemed to me that we should have tried the jet-sub in place of taking a core sample. As a result, we know very little about the jet-sub operation and have gained in its place even less additional information as far as core samples go.

Future designs needed for re-entry:

1. Edo direction relative to the ship must be know.

2. Mechanical redesign of Edo system to assure reliability when operating the jet-sub.

In conclusion, I consider this a most successful mission and I consider myself most fortunate to have been invited to be on this first re-entry leg.

Observer, Major Oil Company

APPENDIX NO. 4(k)

SUBJECT

Comments on Leg 11 C DSDP

Edo Unit

1. There should be added a crystal that looks straight down for positive location of the sea floor and relative position of the landing base.

2. Positive azimuth control is required. A magnet in the drill collar and a proximity switch in the unit would be a simple and reliable way. Position relative to North is probably too complicated and a simple movement of the ship can establish direction. If the magnet is in line with the jet hole that is also located.

3. A magnet in the landing base casing and a proximity switch would positively establish re-entry.

4. A longer persistance screen is needed.

5. If signals were brought up the line on a carrier (FM or AM), it would be more reliable and more channels would be available.

6. A proper hood for the scopes, a polaroid scope unit, and spare parts should be provided.

"Elmer"

1. The question of whether memory is the best way to control the ship should be addressed by control experts. The present system takes too long to settle down and overshoots its mark. A control system in which thrust is proportional to the distance off target might be a better method. Provision for manual correction for a fixed distance off target could be included.

2. If it is decided the present system should be retained then provision to retain the memory, if manual maneuvers are made, should be added.

3. I believe the use of a jet-sub is preferable to providing finer increments in Elmer's control system.

4. The beacon should be on the landing base.

5. The beacon might operate in two modes:

   a. Depth-responding to PDR signal

   b. Location-continuous

The present beacon and a sonar transponder would serve the same purpose.

Operations

Since I have not seen normal operations, these comments apply to a special test on new operations such as we observed on 11C. There should be one person clearly in charge of all operations during the testing phase. The nature of the test will determine the appropriate person, in this case, I would have had the project engineer in charge. Planning sessions should be held to get input from the captain, chief scientist, and operations manager, but final decision should rest with the project engineer. He should not make substantial changes in the program without consultation with the others.

An open intercom should connect the drawworks, the bridge and the logging winch for rapid communications during the critical re-entry.

Engine Room

Future designs of the engine room, I think could provide a great deal more flexibility and convenience. For example, all DC generators should be able to be connected to any load, i.e.: the drawworks, the side thrusters, or the main propulsion. This would give the captain more options on ship operations. Generators could be switched from the bridge. Also all meters and signal lights should be visible from the engineers room, if not placed inside it.

The epoxy I mentioned is made by:

Tra-con Inc.
55 North Street
Medford, Massachusetts 02155

They put up many grades with different setting times in plastic bags called Bi-Pax. When required you remove a clamp that keeps the two components apart and knead the bag. It can be squeezed out of the bag for use. This would seem to be an easier and more accurate way of preparing epoxy on the drilling deck when sealing threads.

The effect I mentioned is the "Magnus Effect," and concerns the force developed when rotating a cylinder in a moving fluid. It might have some application to control of the drill string when making re-entry, but the jet-sub is probably simpler and more straight forward.

Observer, Major Oil Company

OPERATIONS RESUME

LEG 12

The Glomar Challenger sailed on June 19, 1970, from Boston, Massachusetts, to begin Leg 12 of the Deep Sea Drilling Project and terminated on August 11, 1970, in Lisbon, Portugal. Figure 1 shows the track route.

During the intervening period, 13 holes were drilled and cored on nine sites in the North Atlantic Ocean. A total of 1449 meters was cored and 838.35 meters recovered for a recovery percentage of 57.2 percent. Total penetration of the ocean bottom was 5903 meters. While investigating these sites the Challenger travelled 4215 nautical miles.

The operational highlight of the leg was the extended operation in northern latitudes. For the first time during the Deep Sea Drilling Project extensive glacial type material was encountered. Mostly this consisted of very fine "glacial flour" clays but numerous ice rafted cobbles and stones were recovered in cores.

WEATHER

One of the major concerns was North Atlantic storms. However, weather was unusually calm with temperatures in the fortys. On Site 117 near Rockhall bank a swell with winds of 20 to 25 knots at right angles developed. In order to hold position the ship was headed into the wind. Severe rolling over ten degrees resulted and it was necessary to pull out of the hole when some rolls reached 17 degrees.

Thick pea soup fog was continuous throughout operations in the Labrador Sea and the Reykjanes Ridge. Several hours time was lost because of reduced speed in the fog to avoid other ships and icebergs.

BITS

Only one diamond bit was run on Leg 12. This was on Site 111. All subsequent runs were three-cone tungsten carbide insert, four-cone tungsten carbide insert or three-cone extended compact roller bits. Performance was excellent with high penetration rates and long life. Torque was noticeably reduced over diamond or drag type bits.

The reduced torque must be given much of the credit for the successful completion of Sites 115 and 116 where hard formation was encountered before the bottom hole assembly was buried. On Site 115, a hard black volcanic ash was encountered at 60 meters. Carefully controlled bit weight with the reduced torque allowed penetration to a depth of 227 meters without bottom hole assembly failure. On Site 116 firm chalk with thin chert layers was encountered at a depth of only 20 meters. Once again limited bit weight and low torque allowed penetration without bottom hole assembly failure. Since two holes were drilled on Site 116 this penetration was actually made twice.

No conclusions can be drawn between the various types of roller bits used.

WATER DEPTHS

Water depths ranged from 4911 meters to a low of 1048 meters. Some concern has been expressed as to operating in relatively shallow water with the dynamically positioned Challenger. No serious problems arose with the depths encountered on Leg 12 even under the fairly severe conditions of heavy swell and 20 to 25 knot winds causing rolling to 17 degrees. A small problem was caused by the limited cone area of the beacon at this depth. When the beacon is first released it has become standard procedure to use little thrust in staying near the beacon to avoid thruster noise blanking the hydrophones. In shallow water every effort must be used to stay near the falling beacon to avoid loosing it entirely.

NAVIGATION

Unfortunately, the satellite navigation system used so successfully on previous legs, failed early during Leg 12. The situation was further aggravated by almost continuous cloud cover and heavy fog making celestial navigation very intermittent. The Challenger's Loran also proved inadequate. This lack of navigational fixes caused much delay in site location and necessitated extensive air gun profiling in order to find suitable sites.

COMMUNICATIONS

As was anticipated, communications with the Scripp's Station WWD proved almost non-existent during the entire leg. Outgoing messages were limited to the essentials and transmitted commercially. During one period of 30 days, no incoming messages were received from Scripps. Thus, demonstrating once again the Challenger's ability to operate alone, unassisted and unadvised.

CORROSION

For the first time external corrosion pitting was noted on one joint of drill pipe (No. 1268). Figure 2 shows the pitting which is localized at a point which corresponds to the original location of a drill pipe rubber. It is recommended that the pitted section be cut out and sent to a metallurgical laboratory for examination. It seems possible that the drill pipe rubber or its adhesive might be establishing an electrolitic cell causing this pitting.

POSITIONING SYSTEM

The Challenger's dynamic positioning system operated without fault throughout the leg. 16 kHz and 13.5 kHz beacons were in general alternated between sites. For the first time the 13.5 kHz beacons gave an acceptable dependable signal for extended periods of time. Although two of the 13.5 kHz beacons failed, the failure was sudden and complete after several hours of successful operation, and in no way connected with the pulse shape or ringing.

On one site, sea conditions caused "air around the hydrophones" with attendant loss of acoustics.

BOTTOM HOLE ASSEMBLIES

No bottom hole assembly failures occurred during the entire leg.

MISCELLANEOUS

A number of minor modifications have been made to equipment as a result of past legs. Two are of particular note.

The steel sleeve for retaining the bottom end of the plastic core liner continued to work without failure. Not a single collapsed liner occurred during Leg 12.

The modified inner core barrel latch was completely successful. Not a single stuck inner barrel occurred despite much hard formation coring which has caused stuck inner barrels on past legs.

GLOBAL MARINE CREWS

Global Marine crews performed with the usual high efficiency which has become expected of them.

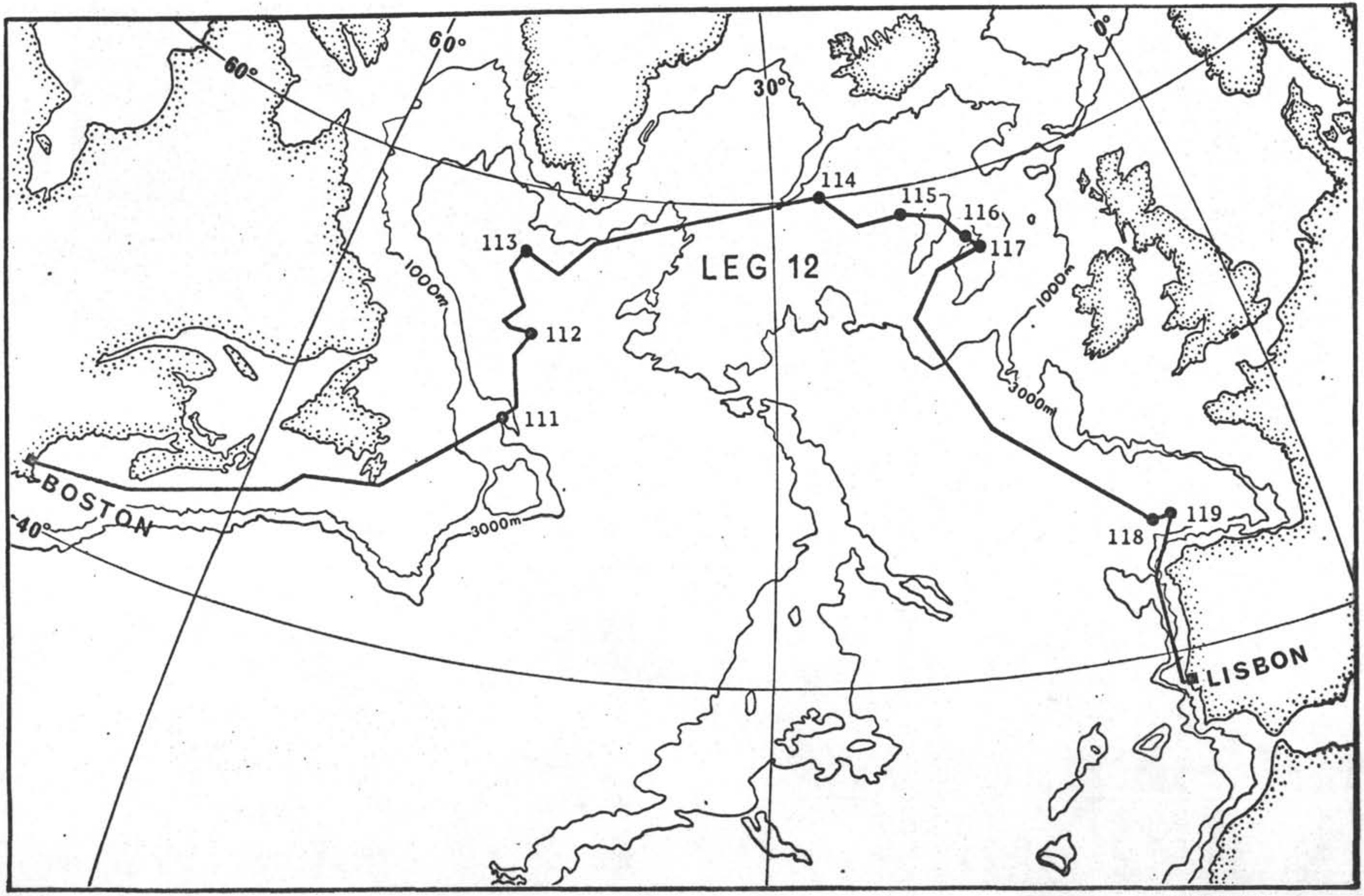

60°
60°
30°
0°
114
115
116
117
113
LEG 12
1000m
1000m
112
111
3000m
BOSTON
40°
3000m
119
118
LISBON

FIGURE 1

FIGURE 2

OPERATIONS RESUME

LEG 13

SUMMARY

Leg 13 of the Deep Sea Drilling Project commenced on August 11, 1970, in Lisbon, Portugal, proceeded through the Mediterranean Sea and terminated in Lisbon, Portugal, on October 6, 1970.

During the interim period, the Glomar Challenger cruised 4,480 nautical miles, drilled 28 holes at 15 sites, cored 1423.5 meters in 201 coring attempts with recovery on 183 (91%) of the cores for a total of 640.3 meters (44.3%), and drilled 4853.5 meters for a sub-bottom penetration totaling 6277 meters. Water depth ranged from 1163 meters to 4654 meters, averaging 3045 meters. Penetration below the sea floor ranged from 11 meters to 867 meters with the average being 224.1 meters per hole.

Time distribution for the 56.01 days on Leg 13 consisted of 2.70 days in port, 20.48 days cruising, and 32.83 days on site. The on-site time consisted of 7.25 days trip time, 14.87 days coring, 7.50 days drilling, 0.77 days abandonment, and 2.44 days other time, which included conditioning hole, working stuck pipe, testing new equipment, mechanical downtime, and routine maintenance. There was no time lost due to weather.

Significant accomplishments of Leg 13 included:

1. The most penetration, 6277 meters, for any leg of the project to date.

2. The 183 cores with recovery equaled the project record, first established on Leg 9.

3. The recovery of reference beacons from the ocean floor on two sites, using an acoustic release mechanism, established a project first and should result in significant monetary savings in the future.

4. The recovery of side wall cores, using a mechanical side wall sampler established a project first and provides another valuable tool.

5. The first halite (NaCl) core of the project was recovered on Site 134.

6. There were no losses of drilling or coring equipment.

7. Leg 13 also established records ranking second in the project to date for sites investigated (15), holes drilled (28), shallowest water depth (1163 meters) and cores attempted (201).

DRILLING AND CORING

The bottom hole assembly used throughout Leg 13 consisted of the core bit, one 8 1/4 inch core barrel, three 8 1/4 inch drill collars, one bumper sub, three 8 1/4 inch drill collars, two bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar and one joint of heavy wall drill pipe. This assembly was approximately 125 meters in length and provided approximately 30,000 pounds weight in sea water. Drill pipe rotation varied from 35 to 75 rpm. Bit weights varied from 2,000 to 25,000 pounds. Circulation was minimal while coring and maximum while drilling.

Departure from the previously established policy of having at least 100 meters of penetration prior to coring was successfully carried out on several sites due to the nature of the sites selected and due to the desire of the scientific staff for cores at shallow penetrations. Many of the sites were located on the walls of subsea canyons and the holes of the site were moved up or down the wall to investigate the outcropping strata at various levels. This technique provided maximum information with minimum drilling and coring time but it necessitated coring with shallow penetration. The successful use of this technique, without loss of equipment, was due primarily to the excellent weather and absence of vessel motion.

Although all of the coring techniques used on previous legs were applied on Leg 13, the 44.3 percent core recovery on a footage basis was relatively low, ranking tenth in comparison to the previous legs. This low recovery was due, to a large extent, to the wide spectrum of formations encountered. These included the pelagic oozes, sapropels, silt, unconsolidated sand, tephra, sandstone, limestone, dolomite, nodular anhydrite, detrital gypsum, salt, ophiolites, basalt, obsidian, andesite, gabbro, metasandstone, semi-schists, marls, and conglomerates.

Two failures of drilling equipment occurred on Leg 13. A crack was detected in the outer mandrel of a Shaffer bumper sub. This crack was in the tong area of the service connection for the top sub. The other equipment failure was the loss of the flapper valve from a drill collar float valve. The float valve was experimental equipment used for the first time on Leg 13. Although used successfully on Sites 123 and 124, the hinge of the flapper valve failed on Site 125. This resulted in the loss of 16 hours rig time in analyzing the problem and making a round trip to correct the problem. Operational personnel were of the opinion that the flapper valve hinge design was inadequate. The float valve was removed from the string until a design modification can be completed.

Bits plugged on Site 112 with unconsolidated sand and gravel and on Site 125A with anhydrite requiring round trips to remove the plug. On Site 131 the bit also plugged with coarse unconsolidated sand, but unplugged after pulling approximately halfway out of the hole.

Hole stability was relatively good. The drill pipe stuck in tephra on Site 123 and preparations were made to shoot the string off after two hours of working the pipe and circulating mud had proved ineffective. However, just as the explosive charge was lowered into position, the drill pipe came free. Drilling was continued to basement. Minor sticking was also encountered on Site 125A in evaporites, on Site 131 in sand, on Site 133 in detrital gypsum, and Site 134 in sandstone breccia and conglomerate.

A mechanical side wall sample device was used on Hole 134E as an experimental tool and successfully recovered two 1 1/8 inch diameter side wall cores 20 and 40 centimeters in length. This tool has merit for future use in obtaining samples from a drilled hole where additional information is desired. Time required for running is the same as that required for a round trip with the wireline inner core barrel.

CORE BITS

Ten new bits and two rerun bits were used on Leg 13. These included four tungsten carbide insert ("button") bits, four milled cutter bits, two light set diamond bits and two "Klusterite" bits. The cone type bits generally experienced poorer core recovery than the drag type bits. It appears that core recovery with core bits could be improved by using throat diameters of with a maximum of 2 7/16 inch inside diameter and dressing the throats with a fine grained sintered tungsten carbide, similar to the surfacing on a hard formation core catcher. This would result in a continuously gauged core which would reduce core barrel jamming in the plastic formations. It would also reduce throat enlargement in the harder, more abrasive formations.

The milled cutter bits were superior for penetration in the lithified formations encountered in the Mediterranean and core recovery was adequate for the scientific objectives. The "Klusterite" bits also maintained a fair penetration rate and provided 75 and 58 percent core recovery.

ABANDONMENT

Where mechanically possible, all holes in excess of 200 meters deep were plugged with cement, or with a combination of cement and mud plugs, unless seismic profiles indicated outcropping on the immediate vicinity. This resulted in eleven holes being plugged. Two holes could not be plugged due to plugged bits. There was no evidence of hydrocarbons encountered throughout Leg 13.

POSITIONING EQUIPMENT

The dynamic positioning system performed satisfactorily throughout the leg. Minor difficulties were encountered with faulty relays in the dynamic positioning console on the bridge. This resulted in the vessel thrusting opposite to the direction signaled by the computer. At such times, vessel position was maintained in semi-automatic operation. Faulty relays in the engine room also caused minor difficulty resulting in power failures to the thrusters. The bridge console was repaired. Due to the infrequent occurrence of the relay failures in the engine room, the faulty relays hadn't been detected at the end of the leg. The maximum excursion experienced on Leg 13 was 1,500 feet. This occurred while going in the hole and no damage resulted.

All beacons used on Leg 13 functioned satisfactorily. This included four Burnett 13.5 kHz, seven Burnett 16.0 kHz, and two ORE 16.0 kHz beacons. The two ORE beacons were experimental equipment. Both beacons had excellent pulse strength, pulse period and repeatability. One Burnett beacon and two Burnett batteries failed on pretesting. One experimental Inter Ocean 16.0 kHz beacon failed to function on pretesting due to an electrical short in the battery cable.

Two Inter Ocean acoustic release mechanisms were tested on Leg 13. A total of 15.5 hours rig time was consumed in running the release mechanisms on sand line and testing at various water depths. Problems encountered were as follows:

1. The external electrical connections were exposed and required fabrication of a protective guard.

2. The external electrical connections through the body were of cast plastic bushings which failed. These should be brass or stainless.

3. The mail-female terminal sockets lack integrity for making good electrical contacts and should be replaced with more positive connectors.

4. The acoustic transmitter signal appeared to have inadequate strength, especially for water depths in excess of 3,000 meters.

Following several tests, the release mechanism was attached to the beacon on Sites 130,131 and 132. The release mechanism functioned satisfactorily on Sites 130 and 131, and the beacons were recovered, resulting in another project first. However, the release failed to function on Site 132 and the beacon was not recovered. With further modifications to improve reliability and increase signal strength, the beacon release mechanism should prove an asset to the project and result in significant savings for beacon expenditures. Recovery of the beacons proved very easy with the maneuverability of the Glomar Challenger. The beacons were released one or two hours prior to location departure . They were tracked to within approximately 1,500 feet of the surface by the computer prior to losing the beacon signal on the computer. The drilling vessel was offset 600 to 800 feet aft of the location so the beacon could surface forward and be in the best position for recovery. Ascent time from 3,000 meters water depth was 1.5 hours with 15 pounds positive buoyancy and 50 minutes with 45 pounds positive buoyancy. The buoyancy was provided with three floatation rings, each consisting of five Corning glass spheres which were ten inches in diameter. Although no difficulty was encountered with surface location and recovery, a radar reflector and/or a radio signal could be advantageous in addition to the flashing light mounted on the beacon.

COMMUNICATIONS

Communications with La Jolla were extremely difficult during Leg 13. Although preliminary contacts had been made for using NAVCOM, the details had not been completely developed causing complications at the outset. All messages were by CW throughout the leg. Several inquiries regarding the use of the teletype failed to produce intelligent and logical answers.

In addition, ship-to-shore radio telephone communications were very limited due to the lack of proper crystals for the set. In an area such as the Mediterranean, the ship-to-shore radio telephone should have the proper crystals installed, or the set should be tunable.

A marine VHF radio set should also be aboard for use with pilot stations and ship to ship communications.

NAVIGATION EQUIPMENT

The Loran "C" receiver failed to function on Leg 13. However satellite navigation, celestial navigation and land fixes proved adequate.

The ship's radar functioned perfectly throughout the cruise until a couple of days out of Lisbon, on the return to port, at which point some difficulty was encountered with tuning.

The TMC radio also ceased functioning approximately two days prior to the return to Lisbon.

Weather data was received throughout the trip and the maps were generally of excellent quality. Good weather was experienced throughout the cruise except for a twenty-four hour period after conclusion of the last site when drill collar inspection was suspended due to weather. A strong gale, with 15 to 20 foot seas and 50 to 60 mph winds, resulted in the ship rolling in excess of 30 degrees for several hours. Drill collar inspection was completed later while underway at a speed of four knots.

CHALLENGER CREW

The Challenger crews are well trained and performed superbly throughout the cruise. The drill crews are outstanding in their ability, knowledge, experience, and desire to do an outstanding job.

TABLE 1

LEG 13 DEEP SEA DRILLING PROJECT

SUMMARY OF OPERATIONS

(Mediterranean Sea)

Total Days Leg 13 (August 11, 1970 to October 6, 1970)		56.01
Total Days in Port		2.70
Total Days Cruising		20.48
Total Days on Site		32.83
Trip Time	(174.00 hrs)	7.25 days
Coring Time	(357.00 hrs)	14.87 days
Drilling Time	(180.00 hrs)	7.50 days
Abandonment Time	(18.50 hrs)	0.77 days
Other Time	(58.50 hrs)	2.44 days
Total Distance Travelled (Nautical Miles)		4,480
Average Speed		8.40 kt/hr
Sites Investigated		15
Holes Drilled		28
Number of Cores Attempted		201
Number of Cores with Recovery		183
Percent of Cores with Recovery		91.00
Total Meters Cored	(4,669 ft)	1423.50
Total Meters Recovered	(2,090 ft)	640.30
Percent of Meters Recovered		44.30
Total Meters Drilled	(15,920 ft)	4853.50
Total Penetration	(20,589 ft)	6277.00
Percent Cored of Total Penetration		22.80

TABLE 2

LEG 13 - SITE SUMMARY

Site	Hole	Latitude	Longitude	Water Depth (m)	No. Of Cores	Cores With Rec.	Meters Cored	Meters Rec.	Meters Drilled	Total Meters Pene.	Avg. Rate Pene. (m/hr)	Time On Hole (hrs)	Time On Site (hrs)
Gorringe Bank - Atlantic													
120	0	36°41.39'N	11°29.94'W	1711	8	8	25.5	6.2	227.5	253.0	6.5	56.5	56.5
West Alboran Basin													
121	0	36°09.60'N	04°23.00'W	1163	24	23	161.0	46.5	706.0	867.0	13.0	66.5	66.5
Valencia Trough													
122	0	40°26.87'N	02°37.46'E	2146	4	3	30.0	5.6	132.0	162.0	23.2	25.0	25.0
Valencia Trough Wall													
123	0	43°37.83'W	02°50.27'E	2290	8	7	71.0	19.7	327.0	398.0	26.4	38.0	38.0
Balearic Abyssal Plain													
124	0	38°52.40'N	04°59.70'E	2726	15	14	71.0	41.0	351.0	422.0	7.1	74.5	74.5
Mediterranean Ridge - Ionian Basin													
125	0	34°37.31'N	20°25.68'E	2782	11	8	97.0	47.5		97.0	5.7	27.5	
125	A	34°37.31'N	20°25.68'E	2782	11	10	91.0	17.7	30.0	121.0	7.4	28.0	55.5
Cleft in Mediterranean Ridge - Ionian Basin													
126	0	35°09.53'N	21°23.42'E	3730	6	5	30.0	18.6	99.0	129.0	6.5	26.5	
126	A	Offset 1,500 ft SW of 126		3733	1	1	1.0	0.9	65.0	66.0	8.8	15.0	41.5

Table 2 - Leg 13 - Site Summary continued

Site	Hole	Latitude	Longitude	Water Depth (m)	No. Of Cores	Cores With Rec.	Meters Cored	Meters Rec.	Meters Drilled	Total Meters Pene.	Avg. Rate Pene. (m/hr)	Time On Hole (hrs)	Time On Site (hrs)
Hellenic Trough													
127	0	35°43.95'N	22°29.67'E	4654	19	19	136.0	92.5	301.0	437.0	8.2	65.5	
127	A	Offset 2,000 ft NE of 127		4636	5	5	31.0	23.2	49.0	80.0	7.6	14.0	
127	B	Offset 1,400 ft NE of 127		4640	1	1	1.0	0.5	165.0	166.0	21.4	9.5	89.0
Hellenic Trough Axis													
128	0	35°42.58'N	22°28.09'E	4640	11	11	91.0	73.7	390.0	481.0	13.4	52.5	52.5
Strabo Mountains - Levantine Basin													
129	0	34°20.30'N	27°05.00'E	3048	4	3	13.0	2.8	99.0	112.0	5.6	28.0	
129	A	Offset 2,200 ft NW of 129		2832	3	3	13.0	1.7	68.0	81.0	8.1	11.5	
129	B	Offset 2,280 ft SW of 129		3052	2	2	15.0	1.4	27.0	42.0	8.2	18.5	58.0
Folded Bed on Mediterranean Ridge - Levantine Basin													
130	0	33°36.30'N	27°52.00'E	2979	7	7	67.0	23.2	496.0	563.0	21.7	36.5	
130	A	Offset 100 ft S of 130		2982	1	1	11.0	1.0	0.0	11.0	7.4	7.5	44.0
Nile Cone - Levantine Basin													
131	0	33°06.33'N	28°52.69'E	3035	1	1	9.0	8.0	40.0	49.0	14.0	13.5	
131	A	Offset 2,000 ft W of 131		3037	5	5	45.0	7.5	227.0	272.0	22.6	21.0	34.5
Tyrrhenian Basin													
132	0	40°15.67'N	11°26.46'E	2835	27	26	223.0	168.3	0.0	223.0	6.0	49.5	49.5

Table 2 - Leg 13 - Site Summary concluded

Site	Hole	Latitude	Longitude	Water Depth (m)	No. Of Cores	Cores With Rec.	Meters Cored	Meters Rec.	Meters Drilled	Total Meters Pene.	Avg. Rate Pene. (m/hr)	Time On Hole (hrs)	Time On Site (hrs)
Eastern Flank of Buried Basement Ridge in Balearic Basin													
133	0	39°11.79'N	07°20.13'E	2563	8	6	68.0	6.0	124.0	192.0	9.2	31.0	31.0
Balearic Abyssal Plain													
134	0	39°11.84'N	07°17.96'E	2864	10	7	73.0	22.9	291.0	364.0	14.3	30.5	
134	A	Offset 2,900 ft E of 134		2864	2	1	14.0	1.8	36.0	50.0	8.3	7.0	
134	B	Offset 2,600 ft E of 134		2869	1	1	5.0	0.2	67.0	72.0	43.0	3.0	
134	C	Offset 2,000 ft E of 134		2869	0	0	0.0	0.0	131.0	131.0	37.4	4.5	
134	D	Offset 1,400 ft E of 134		2871	3	3	15.0	1.3	199.0	214.0	25.2	9.5	
134	E	Offset 1,100 ft E of 134		2869	3	2	16.0	0.6	206.0	222.0	27.7	17.5	72.0

SUMMARY

Totals:													
15	28				201.00	183.00	1423.50	640.30	4853.50	6277.00		788.00	788.00
%						91.00	22.80	44.30	77.20				
Avg.	1.87			3045	7.18	6.54	50.80	22.90	173.30	244.10	11.70	28.14	52.53
Max.	6.00			4654	27.00	26.00	223.00	168.30	706.00	867.00	43.00	74.50	90.00
Min.	1.00			1163	0.00	0.00	0.00	0.00	0.00	11.00	5.60	3.00	25.00

TABLE 3

LEG 13 - BIT SUMMARY

SITE	BIT DESCRIPTION				CORES TAKEN			FOOTAGE CORED			TOTAL PENET.	ROT. TIME	PENT. RATE	CONDITION	REMARKS
	Make	Size	Type	Ser. No.	Core Numbers	Recovery Numbers	%	Core Meters	Recovery Meters	%	Meters	Hrs.	M/RH		
120	Smith	10 1/8 x 2 15/32	9-C	EV643	8	8	100.0	25.5	6.2	22.6	253.0	26.5	9.55	T-1,B-8,IG	Clay, Shale Gabbro
					(rerun from Leg 12 Site)										
121	Reed	9 7/8 x 2 31/64	PD-2	9117	24	23	95.5	161	46.6	28.8	867.0	22.5	38.50	T-7,B-8,IG	Clay, Sd., Sh. Marl, Basalt
											(Inner cone teeth broken) (Outer cone locked)(Large throat w/ circ. ports)				
122	Reed	9 7/8 x 2 31/64	PD-2	8098	4	3	75.0	30.0	5.6	18.7	162.0	2.1	77.1	T-1,B-1,IG	Ooze, Sand Clay, Turb.
											(Bit plugged w/sand & gravel) (Large throat w/circ. ports)				
123	Reed	9 7/8 x 2 31/64	PD-2	8098	8	7	87.5	71.0	19.7	27.7	398.0	5.86	68.1	T-3,B-3,IG	Clay, Sand Tephra & Andesite
	Cumulative Performance		(rerun)		12	10	83.3	101.0	25.3	25.0	560.0	7.96	70.4	(see above)	
124	Hycalog	9 7/8 x 2 15/32	SSFD 3WC	10865	15	14	93.5	71.0	41.0	57.8	422.0	33.9	12.5	70% Salv.	Ooze, Marl, Gypsom Anhydrite
125	Varel	9 7/8 x 2 7/16	250 Kt. Dia.	7903 (see 127 & 128)	11	8	72.7	97.0	47.5	49.0	97.0	5.33	17.1	90% Salv.	Ooze, Marl, Anhydrite
								(BP.V. Failure)							
125A	Smith	10 1/8 x 2 15/32	9-C	EV644	11	10	91.0	91.0	17.7	19.5	121.0	4.77	25.4	T-1,B-5,IG	Ooze, Marl Anhydrite, Dolomite, Gypsum
					(rerun from Leg 12)						(Plugged bit with Anhydrite)				

Table 3 - Leg 13 - Bit Summary continued

SITE	BIT DESCRIPTION Make	Size	Type	Ser. No.	CORES TAKEN Core Numbers	Recovery	%	FOOTAGE CORED Core Meters	Recovery Meters	%	TOTAL PENT. Meters	ROT. TIME Hrs.	PENT. RATE M/RH	CONDITION	REMARKS
126	Smith	10 1/8 x 2 15/32	9-C	FB-195	6	5	83.3	30.0	18.6	62.0	129.0	11.5	11.2	(left in hole)	Ooze, Hard Marl
126A	Smith	10 1/8 x 2 15/32	9-C	FB-195	1	1	100.0	1.0	0.9	90.0	66.0	4.0	16.5	T-1,B-6,IG	
	Cumulative Performance				7	6	85.7	31.0	19.5	62.8	195.0	15.5	12.5		
127	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	(see 125) 7903	19	19	100.0	136	92.5	68.0	437.0	22.67	19.2	Move to 127A	Clay, Sand Shale, Dolomite
127A	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	(see 125) 7903	5	5	100.0	31	23.2	75.0	80.0	3.73	21.4	Move to 127B	Ooze, Clay, Sand, Limestone
127B	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	(see 125) 7903	1	1	100.0	1	0.5	50.0	166.0	4.83	34.4	Move to 128	Clay, Sand, L.S., Dolomite
128	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	(see 125) 7903	11	11	100.0	91	73.7	81.0	481.0	14.35	33.5	See Cum. Data Below	Ooze, Marl
	Transfer 125 Data	=			11	8	72.7	97	47.5	49.0	97.0	5.33	17.1	" "	(See 125)
	Cumulative Performance				47	44	93.5	356	237.4	66.9	1261.0	50.91	24.4	Est. 35% Salv.	
129	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	7921	4	3	75.0	13	2.8	21.6	112.0	13.08	8.6	See 129A	Dolomite, L.S., S.S., Dolomatic Marl

Table 3 - Leg 13 - Bit Summary continued

SITE	BIT DESCRIPTION				CORES TAKEN			FOOTAGE CORED			TOTAL PENET.	ROT. TIME	PENT. RATE	CONDITION	REMARKS
	Make	Size	Type	Ser. No.	Core Numbers	Recovery Numbers	%	Core Meters	Recovery Meters	%	Meters	Hrs.	M/RH		
129A	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	7921	3	3	100.0	13	1.7	13.0	81.0	5.23	15.4	See 129B	Sand, Marl, Dolomite, Dolomatic Marl
129B	Varel	9 7/8 x 2 7/16	Diamond 250 Kt.	7921	2	2	100.0	15	1.4	9.4	42.0	6.92	6.1	See Below	Marl, Sand, Sandstone
	Cumulative Performance				9	8	88.9	41	5.9	14.4	235.0	25.33	9.3	Est. 85% Salv.	
130	Reed[1]	9 7/8 x 2 31/64	PD-2	8074	7	7	100.0	67	23.2	34.7	563.0	14.33	39.4	See 130A	Ooze, Marl Sand, Clay, Sandstone
130A	Reed	9 7/8 x 2 31/64	PD-2	8074	1	1	100.0	11	1.0	9.1	11.0	0.33	33.0	T-2, B-2, IG	Mud, Ooze
	Cumulative Performance				8	8	100.0	78	24.2	31.0	574.0	14.66	39.1	Teeth broken on inside of large cone & outside on gauge cone	
131	Reed[1]	9 7/8 x 2 31/64	PD-2	8157	1	1	100.0	9	8.0	88.9	49.0	0.55	89.0	See 131A	Coarse, Uncon-solidated sand
131A	Reed	9 7/8 x 2 31/64	PD-2	8157	5	5	100.0	45	7.5	16.7	272.0	5.82	46.6	Teeth Broke T-2, B-2, IG	Mud, Sand, Silt, Gravel Marl
	Cumulative Performance				6	6	100.0	54	15.5	28.7	321.0	6.37	50.5	Large cone inside Gauge outside	

Table 3 - Leg 13 - Bit Summary continued

SITE	BIT DESCRIPTION				CORES TAKEN			FOOTAGE CORED			TOTAL PENET.	ROT. TIME	PENET. RATE	CONDITION	REMARKS
	Make	Size	Type	Ser. No.	Core Numbers	Recovery Numbers	%	Core Meters	Recovery Meters	%	Meters	Hrs.	M/RH		
132	Hycalog	9 7/8 x 2 15/32	SSFD-3WC	10866	27	26	96.5	223	168.3	75.5	223.0	12.8	17.4	90% Salv.	Ooze, Tephra, Red Clay, Gyp., Anhydrite
133	Varel	9 7/8 x 2 7/16	4C-TCI	6	8	6	75.0	68	6.8	8.8	192.0	11.93	16.1	See 134	Ooze, Sand Detrital Gyp, Sand-stone
134	Varel	9 7/8 x 2 7/16	4C-TCI	6	10	7	70.0	73	22.9	31.4	364.0	11.60	31.3	See 134A	Ooze, Sand S.S., Salt, Anhydrite
134A	Varel	9 7/8 x 2 7/16	4C-TCI	6	2	1	50.0	14	1.8	12.9	50.0	3.98	12.5	See 134B	Ooze, Sand, Hard Silt-stone
134B	Varel	9 7/8 x 2 7/16	4C-TCI	6	1	1	100.0	5	0.2	4.0	72.0	1.67	43.0	See 134C	Ooze, Sand, Hard Silt-stone
134C	Varel	9 7/8 x 2 7/16	4C-TCI	6							131.0	3.50	37.4	See 134D	?
134D	Varel	9 7/8 x 2 7/16	4C-TCI	6	3	3	100.0	15	1.3	8.7	214.0	4.47	47.9	See 134E	Gypsum Anhydrite, S.S., Phillite

Table 3 - Leg 13 - Bit Summary concluded

SITE	BIT DESCRIPTION				CORES TAKEN			FOOTAGE CORED			TOTAL PENET.	ROT. TIME	PENET. RATE	CONDITION	REMARKS
	Make	Size	Type	Ser. No.	Core Numbers	Recovery Numbers	%	Core Meters	Recovery Meters	%	Meters	Hrs.	M/RH		
134E	Varel	9 7/8 x 2 7/16	4C-TCI	6	3	2	66.7	16	0.6	3.7	222.0	4.68	45.5	T-8, B-8, OG (2) 1/4"	Ooze, Sand, S.S. Phillite
	Cumulative Performance				27	20	74.2	191	33.6	17.7	1245.0	40.83	30.6		

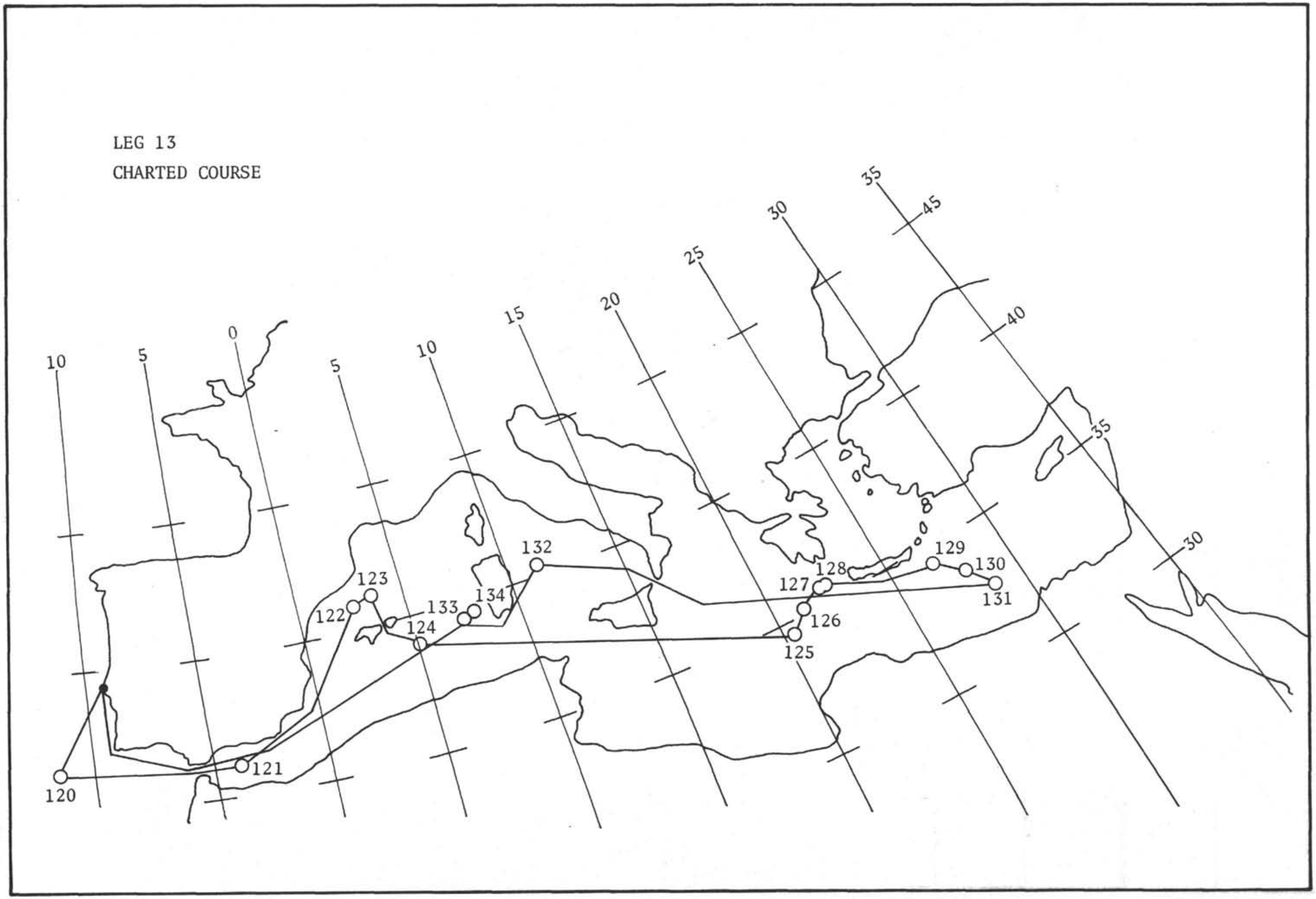
(1) Reduced Bit Throat With 6 Vertical Weld Beads to ± 2.5" I.D. Welded Circ. Ports in Throat.

(2) All 4 Cones Broken and Locked. Shirttail Gauge Cones Pinched, Throat Enlarged and Tapered.

SUMMARY OF BITS USED

2 Rerun Button Bits
2 New Button Bits
4 New Tooth Bits
2 Diamond Bits
2 Klusterite Bits

Total - 10 New
2 Rerun


LEG 13
CHARTED COURSE
10
5
0
5
10
15
20
25
30
35
45
40
35
30
120
121
122
123
124
125
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129
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131
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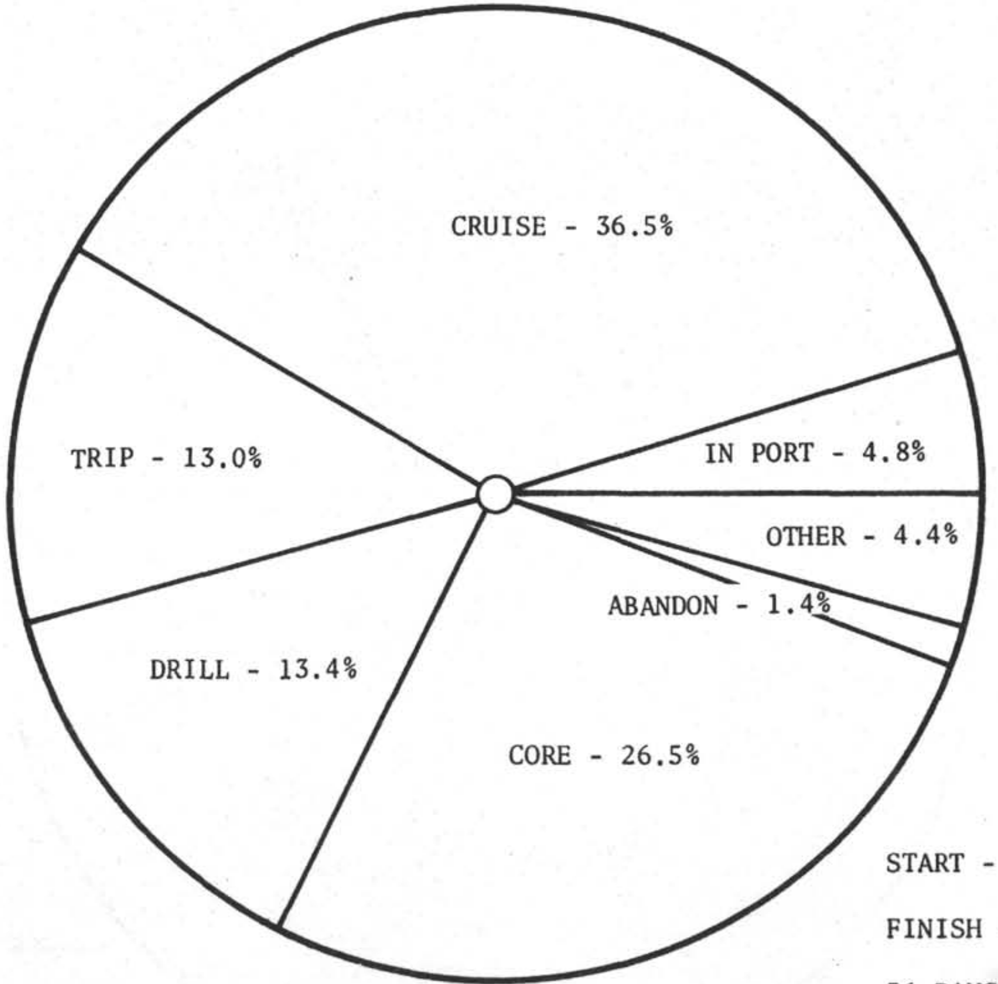
133
134

Figure 1

DEEP SEA DRILLING PROJECT LEG 13



START - 0715 HRS. AUG. 11, 1970

FINISH - 0730 HRS. OCT. 6, 1970

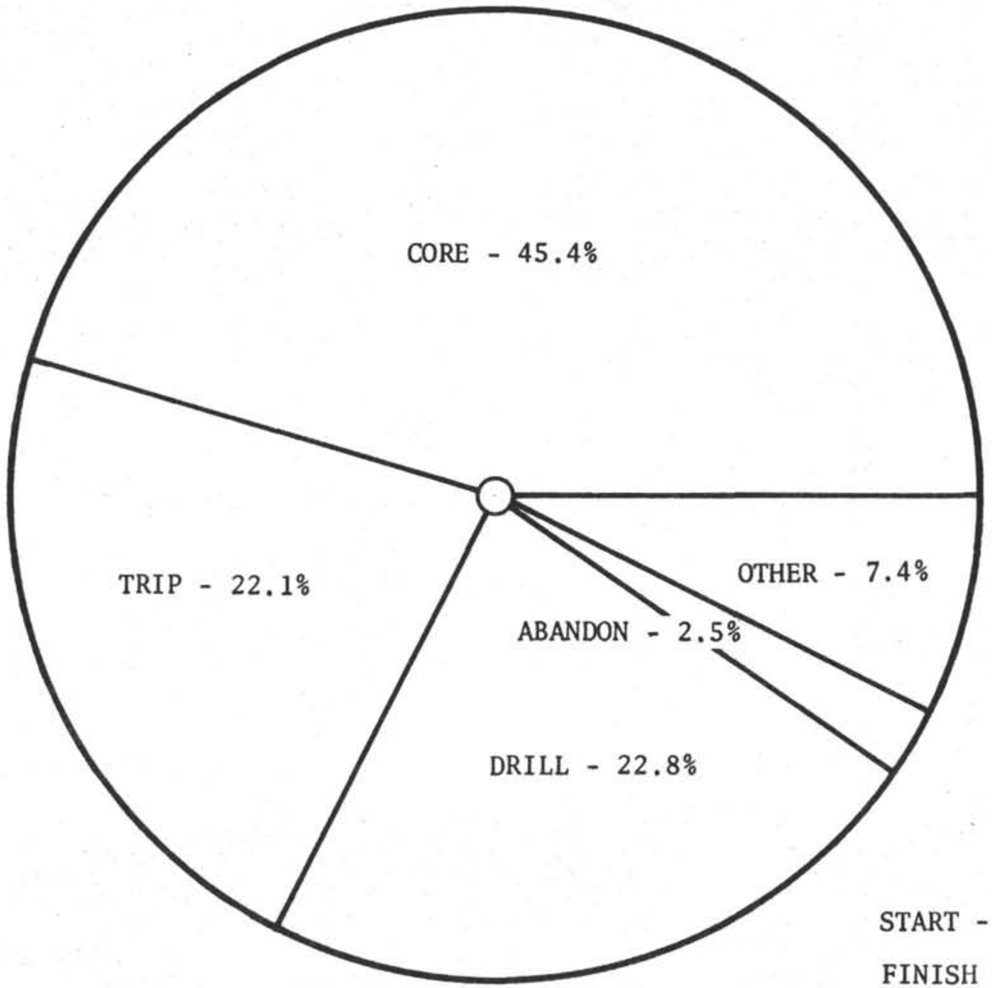
56 DAYS 0 HRS. 15 MIN

15 SITES - 28 HOLES

TOTAL TIME DISTRIBUTION

Figure 2

DEEP SEA DRILLING PROJECT LEG 13



START - 0715 HRS. AUG. 11, 1970

FINISH - 0730 HRS. OCT. 6, 1970

ON SITE 32 DAYS 20 HRS.

15 SITES - 28 HOLES

ON-SITE TIME DISTRIBUTION

Figure 3

OPERATIONS RESUME

LEG 14

SUMMARY

Leg 14 of the Deep Sea Drilling Project departed Lisbon, Portugal, October 9, 1970 and arrived at San Juan, Puerto Rico, on December 1, 1970.

During the 56-day voyage, the vessel steamed 5,420 nautical miles and drilled 18 holes at ten sites. While on these 18 holes, 751 meters were cored and 406.78 meters were recovered for a 54 percent recovery. Out of 98 attempts to core, 93 were successful and recovered usable samples. In addition, 4,242 meters were drilled making a total penetration of 4,993 meters.

Generally, the weather was very good. The only exception was delay in spudding a hole for 6 1/4 hours because of a ten degree plus roll which caused frequent acoustic signal loss and as a result, the automatic positioning equipment did not function properly.

Rendezvous was completed off the Cape Verde Islands at approximately 03:00 hours, November 8, 1970. Three additional technicians, various equipment and mail was transferred from the chartered tug Damao.

On Site 144, the Challenger received a call for medical assistance from a Greek tanker. When the tanker arrived at the site, the Challenger's doctor was transported to the tanker by motor life boat to treat an injured seaman. Because of the seriousness of the injury and the length of time before the tanker would reach port, the seaman was brought back to the Challenger and subsequently taken to the hospital in San Juan.

DRILLING AND CORING

Generally, the geologic section in all the holes was quite similar. The section consisted of chalk ooze, clay without lime, limey clays and limey mudstones, limestone and basalt.

The soft chalk ooze drilled and cored easily without circulation and had good core recovery. As the depth increased, the ooze became drier and harder which necessitated "breaking circulation". With occasional circulation, it drilled and cored very easily resulting in good core recovery.

The clays without lime were easy to drill with continuous circulation but in order to obtain decent core recovery it had to be cored without the pump or with occasional "breaking of circulation". When this was done, coring went rather slowly.

Limey clays and limey mudstones were the most frustrating materials to drill or core. They were not hard enough to require a button bit to drill them; however, when drilled with a button bit, penetration was very slow. Core recovery in this material was medium to low.

The limestone was hard but drillable with a button bit. Core recovery was medium. Basalt was hard and abrasive but could be drilled successfully with a button bit. Core recovery was medium to good.

Button bits were used on all holes except one. Although the button bit has a low penetration rate in the limey clays and mudstones, its ability to drill limestone, chert and basalt and remain on bottom for long periods of time, make it almost a necessity.

A Reed four-cone, mill-tooth bit was run on Site 139 in an attempt to increase the penetration rate. It was run on this hole because chert or basalt was not expected. The penetration rate did increase as expected but the core recovery dropped far below an acceptable figure.

The core recovery in the soft clays was about 60 percent but in the harder clay and sand the recovery dropped to two percent.

The conclusion drawn from this low core recovery is that probably in the hard formations this bit tends to "walk" (i.e., does not rotate about the axis of the bit) and drills up the core before it can get in the barrel. This is probably caused by lack of stabilization. This bit does not have the built-in stabilizer pads as does the Smith button bit. I suggest that if we use this type bit again, we use a full gauge stabilizer immediately above it.

SIDEWALL CORING

The sidewall core barrel was used much more on this leg than any other. It was run six times and recovered usable sample five times.

The first two times that it was run, the sample barrel did not fall over and engage the side of the hole. However, in each instance, a sample was recovered from the hinge that was sufficient to give the age of the formation.

To eliminate this problem, the sidewall core barrel was modified by addition of a coil spring that ensured that the sample barrel would kick out and engage the wall of the hole when the assembly passed through the bit.

The next attempt was a failure because pieces of basalt in the drill pipe and drill collars prevented the core barrel from getting down to the bit.

The next attempt was an unqualified success. The barrel was filled completely with hard clay.

On the fifth run, the barrel was dropped, the drill pipe picked up but the core barrel could not be retrieved with the wireline. After pulling the pipe out of the hole, we found that the sidewall barrel below the bit had been badly bent after the barrel had been completely filled with hard clay. We felt that this was caused by lowering the drill pipe after cutting the core.

The final run was another unqualified success. We recovered a full core of hard clay.

In order to successfully run the sidewall core barrel, a coil spring should be incorporated to ensure that the sample barrel engages the side of the hole. To ensure cutting the core, the drill pipe has to be picked up only one time and need not go back down until the core barrel is retrieved.

From the results on this leg, we feel that the sidewall core barrel has been proved as another useful tool and can be counted upon to work reliably when needed.

POSITIONING EQUIPMENT

The dynamic positioning equipment on board the Challenger performed without problems throughout the entire leg. We did, however, have problems with malfunctioning beacons.

On Site 137, the first beacon dropped was a Burnett 13.5 kHz. After operating three hours and 45 minutes, it lost signal strength and a 16 kHz beacon was dropped to replace it. Before we left the location, the vessel was moved on a square pattern around the beacon in an attempt to determine if the beacon was tipped, causing the low signal strength. As far as could be determined, the beacon was not tipped but evidently had malfunctioned.

On Site 142, a Burnett 13.5 kHz beacon was dropped. On initial drop, the signal strength was slightly lower than normal but the frequency, pulse rate and repetition rate were all within specifications. After approximately 24 hours, the pulse width increased from 4.1 millisecond to 4.4 millisecond making the signal unacceptable to the signal processor, which in turn made positioning very erratic and nearly impossible.

Shortly after the 13.5 kHz beacon became unacceptable, a 16 kHz Burnett beacon was dropped. The signal strength, frequency, pulse width and repetition rate were all within specifications. After 23 hours, the signal strength of this beacon dropped an estimated six to eight decibels and the pulse width increased from 4.0 millisecond to 4.3 millisecond. This caused the same problem that was experienced with the other beacon on the site.

With both beacons unacceptable but still operating, we had no choice except to abandon the site.

During the entire leg, 12 beacons were dropped, eight of which were Burnett 16 kHz and four were Burnett 13.5 kHz. Of the 16 kHz beacons used, one malfunctioned. Of the 13.5 kHz beacons used two malfunctioned.

POSITIONING EQUIPMENT TESTED

Two tether tests were made to test various new and experimental equipment.

Number one test in 4877 meters of water:

1 - 16 kHz Inter Ocean beacon - signal strength, frequency, pulse width and rep rate all within specifications.

1 - American Machine and Foundery (AMF) beacon release mechanism - released as designed.

1 - ORE beacon release mechanism - failed to release.

Number two test in 3353 meters of water:

1 - Inter Ocean beacon release mechanism - released at surface, failed to release at depth.

1 - InterOcean explosive bolt detonator device - functioned as designed.

BOTTOM HOLE ASSEMBLIES

Damage or loss of the bottom hole assembly occurred on only one site, of the ten sites drilled.

Site 143 was on the flank of the Demerara Rise. The bottom sloped down at an angle of ten degrees and was hard limey mudstone overlaid by ten meters of softer material.

Five different attempts to drill at this site resulted in one badly bent bumper sub, one jumped drill collar pin and one broken bumper sub outer barrel. The two failures resulted in loss of about half the bottom hole assemblies.

These damages and failures serve again to illustrate the problems encountered when the bottom hole assembly cannot be buried quickly in soft formation before attempting to drill hard formations.

HEAT PROBE PROGRAM

A prototype downhole temperature probe was tested on Sites 142 and 144.

Initially, the probe and the empty electronics case were placed in position in a core catcher and the inner core barrel dropped various distances in air, into place inside the core barrel. The maximum distance dropped was 29 inches. This distance tested the probe's ability to withstand the maximum shock to which it would be subjected in being pumped down the drill pipe and into position in the core barrel. The probe and case suffered no damage in the test.

Following the dropping test at the surface, the probe was tested four times downhole.

The first two tests were made in soft ooze. When retrieved, the probe and the empty case were at the top of the core, inside the plastic tube, completely surrounded with soft sediment. The soft sediment had successfully worked the release mechanism and let the probe move up into the core barrel as planned.

The third test was in harder ooze. Again, the probe and empty case were found on top of the core inside the plastic tube. However, one latch spring was badly bent. Indications were that the probe had only penetrated a few inches into the harder sediment and the increased pressure on the latch caused the spring to fail and let the probe enter the core barrel. Again, this was in accord with the way it was designed; the spring failing before the probe itself bent. It was felt that the spring should be made stronger to allow the probe to penetrate farther into the hard sediment.

The last test was run with heavier latch springs installed and the electronic data recording system installed inside the case. Again, the inner barrel was retrieved with the probe and case inside the plastic tube on top of the core. The latch itself had completely sheared off, indicating that it was not heavy enough to withstand the force imposed on it by the heavier spring.

The electronic data system survived the shock but erratic operation of the temperature recording system destroyed any usable information.

The tests indicate the feasibility of the use of the probe in soft formation but point up the need for a reliable latch and the necessity for additional work on the electronic data system. It also demonstrated the difficulty that can be experienced when the probe is used in harder formations.

HYDRAULIC POSITION INDICATOR

Acting on Captain Dill's suggestion, an experimental system was installed that could determine the vessel's position in relation to the hole and be used in an emergency if the dynamic positioning system became inoperative.

It consisted of four Martin Decker Sensator load cells, one end of each was attached to and spaced equally around the top of the guide shoe. The other end was fastened to the derrick substructure. Turnbuckles are included with each load cell to adjust the tension. Attached to each load cell is a pressure gauge. All four gauges are mounted on a board near the piccolo and are easily seen from the main deck, aft of the moon pool. Each load cell was adjusted to 2,000 pounds with the drill pipe in the center of the hole.

A test was conducted on Site 136 in 3962 meters of water by moving the vessel off location 1,000 feet and changing the heading through a 360 degree arc. The system worked very well. Indications were very erratic until the vessel was 150 feet off location. Thereafter we were able to tell very easily which direction the vessel was off location and obtain some measure of the distance.

The system was put into operation at the end of Site 142 when the dynamic positioning system became almost inoperative because of two bad beacons. We were able to hold position long enough to pull the bit out of the hole by using a combination of the very erratic dynamic positioning system and the hydraulic positioning indicator.

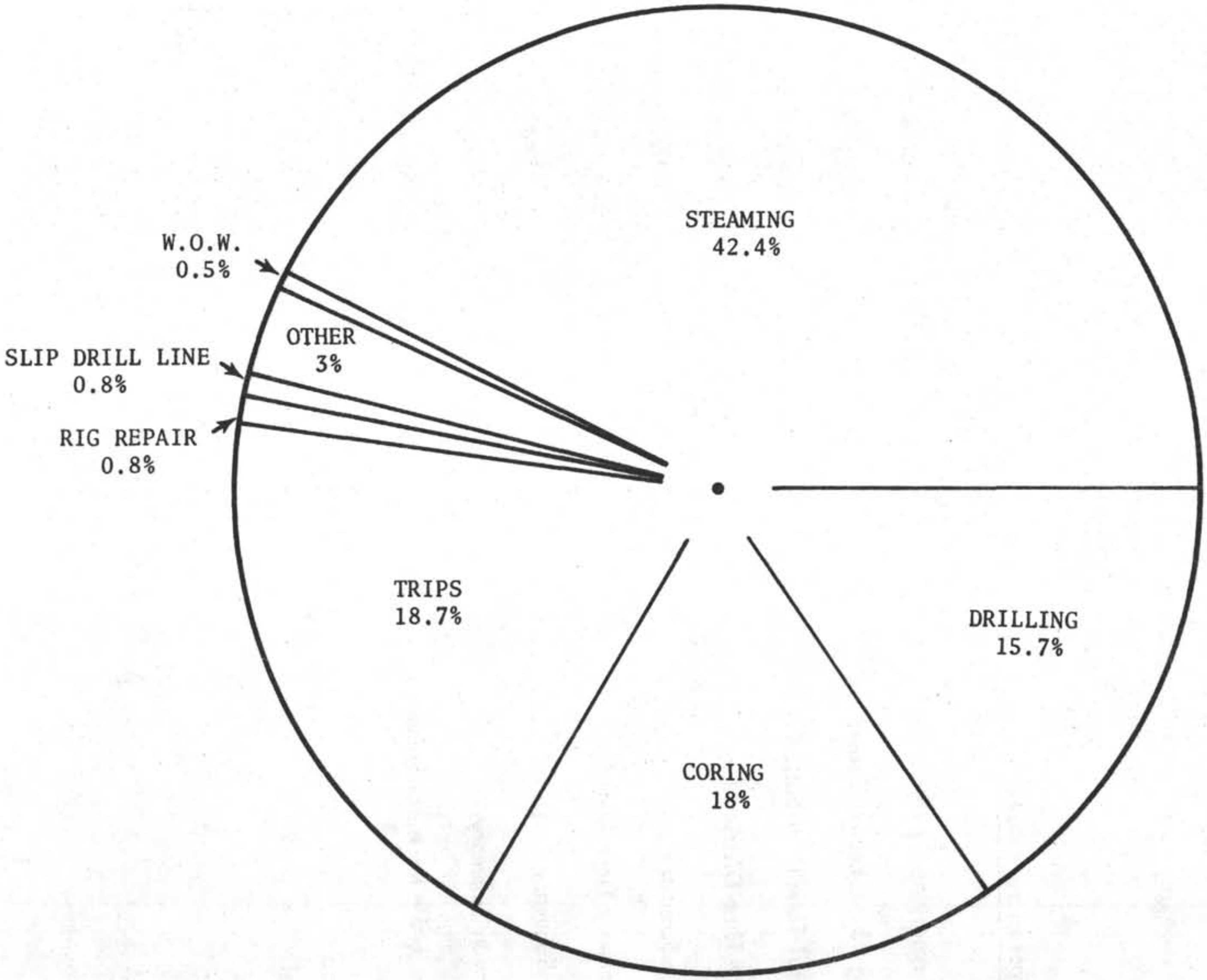
A further refinement of the system will probably be made in the future by placing four recorders in the wheel house with the pressure signals supplied by transducers attached to the load cells.

TIME ANALYSIS

The Global Marine Crews displayed a high degree of professional excellence throughout the entire leg.

There were very few breakdowns or problems with the equipment. It is felt that this is due in a large part to good maintenance on Global's part. When problems with equipment did develop, they were quickly and efficiently overcome.

LEG 14 TIME ANALYSIS



OPERATIONS RESUME

LEG 15

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OPERATIONS RESUME

LEG 15

SUMMARY

Leg 15 of the Deep Sea Drilling Project commenced on December 1, 1970, in San Juan, Puerto Rico, proceeded through the Caribbean Sea and terminated in Cristobal, Panama on February 2, 1971.

During the interim period, the Glomar Challenger cruised 4,083 nautical miles, drilled 15 holes at ten sites, cored 2331.0 meters in 264 coring attempts with recovery on 254 (96.2%) of the cores for a total of 1233.4 meters (52.9%) and drilled 2079.0 meters for a sub-bottom penetration totaling 4410.0 meters. Penetration below the sea floor ranged from 13 to 776 meters, with the average being 294.0 meters per hole.

Time distribution for the 62.90 days on Leg 15 consisted of 9.33 days in port, 18.38 days cruising, and 35.19 days on site. The on site time consisted of 5.98 days trip time, 2.50 days drilling, 18.56 days coring, 0.58 days abandonment, 6.15 days for re-entry, 0.40 days downtime, and 1.02 days of other miscellaneous time, which included conditioning hole, testing new equipment, routine maintenance, and eight hours waiting on weather. In addition to the 0.40 days downtime noted above, in-port time includes 5.58 days and cruising includes 2.15 days of 7.73 days mechanical downtime due to bow thruster failures which necessitated drydock repairs at Willemstad, Curacao.

Significant accomplishments of Leg 15 included:

1. The first operational re-entry, accomplished at Site 146.
2. The most cores (264) attempted for any leg of the project.
3. The most cores with recovery (254) for any leg of the project.
4. The 1233.4 meters of core recovery ranks second for any leg of the project.
5. There were no losses of drilling or coring equipment, marking the fourth leg in which no losses have occurred.

DRILLING AND CORING

The bottom hole assembly used throughout Leg 15, exclusive of re-entry at Site 146, consisted of core bit, one 8 1/4 inch core barrel, three 8 1/4 inch drill collars, one bumper sub, three 8 1/4 inch drill collars, two bumper subs, two 8 1/4 inch drill collars, one 7 1/2 inch drill collar, and one joint of heavy wall five-inch drill pipe. This assembly was approximately 125 meters in length and provided 30,000 pounds in sea water. Drill pipe rotation ranged from 25 to 60 rpm. Bit weight varied from 2,000 to 25,000 pounds. Circulation was minimal for coring and maximum for drilling.

The above bottom hole assembly was altered for Site 146 (re-entry) by the addition of one 8 1/4 inch drill collar below the lower bumper sub and by the addition of various special subs required for re-entry procedures.

Departure from the previously established practice of having at least 100 meters penetration prior to coring was successfully carried out on nine of the 15 holes drilled due to specific scientific objectives requiring cores at shallow depths. Five holes with geochemical objectives required continuous coring from the mud line. The ability to take shallow penetration cores, without loss of equipment, was due primarily to the soft sediment encountered within the first 100 meters penetration.

Coring techniques were the same as used on prior legs. The 52.9 percent core recovery ranks as average with other legs. The extensive amount of coring done on Leg 15 is primarily due to the geochemical objectives of three sites. The formations encountered were silt, clay, ooze, marl, chalk, chert, volcanic ash, volcanic sands, limestone, basalt , and diabase.

There were no failures of drilling equipment on Leg 15.

Hole stability was excellent throughout Leg 15. No difficulties were experienced from plugged bits or stuck drill pipe.

CORE BITS

There were seven new and two rerun bits used on Leg 15 of which five were four-cone and two were three-cone tungsten carbide insert ("button") bits, and two were 250 carat diamond bits. Diamond bit use was confined to those sites with geochemical objectives. Button bits were used at all other sites in anticipation of chert layers. Extensive, interbedded, chert sections were encountered and were successfully penetrated with the button bits. In no case was drilling terminated due to the inability to penetrate chert beds. Basement, diabase or basalt, was cored at five sites.

A core bit failure occurred on Site 147-C when the complete crown of a Varel 250 carat diamond bit separated from the bit shank. Failure was apparently a matrix bond failure due to defect in manufacturing.

Cores recovered from several sites exhibited a high degree of formation damage due to water sensitive clays. Several cores completely disintegrated with time and exposure to water trapped in the plastic liners. The susceptability to damage appeared greater in fresh water, which was used for some geochemical cores.

ABANDONMENT

Eight holes were abandoned with cement, or combination cement and 10.0 lbs.per gal. mud, plugs. Five holes were abandoned by filling with 10.0 lbs. per gal. mud and two holes (96 meters and 13 meters penetration) were abandoned with sea water. There was evidence of "sour-march gas" (methane and hydrogen sulfide) in the cores of Site 147. The interval penetrated was soft clay, rich in organic material, it was continuously cored, and no formation of a reservoir nature was encountered. The holes of Site 147 were abandoned with cement and mud plugs. There was also evidence of "marsh gas" (methane and carbon dioxide) recovered with the cores of Site 154. As with Site 147, no formation of a reservoir nature was encountered and the holes were abandoned with cement and mud plugs. In both cases the amount of gas was considered insignificant.

RE-ENTRY ON SITE 146

The first operational re-entry was accomplished at Site 146 of Leg 15. Site 146 was chosen for re-entry since it was in the vicinity of Site 29 - Leg 4 , where investigation had been terminated due to the inability to penetrate chert layers with diamond core bits.

The re-entry site, in 3939 meters of water, was initiated by jetting 50 meters of casing, with a guide cone attached, into the sea floor to place the base of the four meter high by five meter diameter guide cone at the mud line. After mechanically releasing the casing and cone assembly, routine drilling and coring proceeded to 4650 meters, for 701 meters penetration. At this depth, the four-cone "button" bit had 29.8 hours rotating time. The dull bit was pulled from the hole, a new bit was installed, and a jet sub was installed in the drill string. The drill string was run back to within ten meters of where the top of the re-entry cone had been released. A sonar scanning transceiver was then lowered through the drill pipe on conductor cable to place the transceiver scanning head through and approximately eight inches below the core bit. The re-entry cone was located at 300 foot range from the bit. The Glomar Challenger was maneuvered to place the bit above the re-entry cone and the bit was lowered for an apparent re-entry. However, it was soon apparent, from bit weight while attempting to lower the drill string in the hole, that a false re-entry had occurred. An attempt to pull above the mud line and re-stab was aborted when the transceiver scanning head was broken off while spudding on a soft sediment plug at the bit. A round trip was made with the drill pipe to remove the jet sub which proved ineffective on the first attempt and to check for further obstructions at the bit. The drill string was rerun to place the bit at a level coinciding with the top of the re-entry cone at release, assuming that some settling of the casing and cone assembly had occurred. The sonar transceiver was lowered into position, the re-entry cone was located at 95 foot range from the bit, the ship was maneuvered to place the bit above the cone, the drill string was lowered and a valid re-entry was made at 05:30 hours on December 25, 1970. Following retrieval of the sonar transceiver, the drill string was lowered to 4650 meters without obstruction. Continuous coring operations were resumed at 4650 meters and proceeded to 4711 meters total depth, terminating in diabase after 762 meters total penetration. The hole was abandoned after filling with mud. Total time required for Site 146 was 295.5 hours of which 147.5 hours were required for re-entry procedures.

Site 146 confirmed that re-entry is a working operational technique which provides Deep Sea Drilling Project with a means of accomplishing scientific objectives in deeper and harder formations previously inaccessible due to core bit limitations. However, it was generally concluded that the scientific objectives of Site 146 could have been accomplished without re-entry, since the first bit had an estimated 25 to 30 percent remaining life and probably was capable of drilling the additional 61 meters of penetration accomplished with the second bit.

The basic re-entry equipment and procedures used on Site 146 are technically sound and, with minor modifications, the incremental time required for re-entry can conceivably be reduced to 18 or 20 hours plus round trip time.

A detailed discussion of re-entry on Site 146 is included in Attachment E.

POSITIONING EQUIPMENT

The dynamic positioning system developed bow thruster trouble immediately after arrival on Site 145, the first site for Leg 15. No. 1 bow thruster developed a gear train problem and serious oil leakage was discovered in the gear train housing of the No. 2 bow thruster. After eight hours attempting to diagnose and remedy the difficulty, it was concluded that neither bow thruster was operable. The drill string, which had been run to 3000 meters, was pulled and the Glomar Challenger departed Site 145 at 20:30 hours, December 6, 1970, to profile in the area of Sites 145 and 146 while drydocking arrangements were made. The Challenger received word to proceed to drydock facilities at Willemstad, Curacao at 17:00 hours on December 7. Arrival at the Curacao Shipyard dock was at 24:00 hours on December 8. The Challenger went into a graving dock at 15:00 hours on December 9. Inspection of the bow thrusters revealed damage to both propellers from contact with foreign objects, gear damage to the No. 1 thruster and a loose gear train housing on the No. 2 thruster. Both propellers were replaced, the No. 1 thruster gear train was replaced and the No. 2 thruster was repaired. The Challenger departed the graving dock at 11:15 hours on December 14, completed sea trials and departed for Site 146 at 14:00 hours on December 14. A total of 185.5 hours were lost due to the thruster failures.

There were no additional major problems with the dynamic positioning system during the remainder of Leg 15. The positioning system functioned quite satisfactorily holding location in view of the relatively rough weather throughout most of Leg 15. For most of the leg the seas averaged eight to ten feet, frequently ranging up to 12 to 14 feet and the wind averaged 20 to 25 mph with frequent velocity to 35 to 38 mph. The maximum excursion experienced was between 200 to 300 feet.

The computer dumped the program on two occasions, once due to low voltage and once due to conflicting commands. On both occasions the ship was underway or preparing to get underway.

Thirteen beacons were used on Leg 15. This included eight Burnett 16.0 kHz, four Burnett 13.5 kHz and one Inter Ocean 16.0 kHz beacon. Fourteen batteries and 14 floatation rings were also utilized. Three beacon failures occurred. A 16.0 kHz Burnett beacon failed on Site 146 after less than one hour, a 16.0 kHz Burnett beacon also failed on Site 152 after 99.5 hours and an Inter Ocean 16.0 kHz beacon failed at Site 145 on pre-test.

An attempt at beacon recovery on Site 145 was unsuccessful using the Inter Ocean acoustic release mechanism when the release mechanism failed to function.

Two half-power 13.5 kHz Burnett beacons functioned satisfactorily in shallow water at Sites 147 and 148 where water depths were 892 and 1232 meters, respectively.

COMMUNICATIONS

Communications between the Challenger and La Jolla, although greatly improved over Leg 13, were still difficult on Leg 15. Throughout Leg 15 all communications were by CW, except for the Cruise Press Release. Fortunately, due to the length of this message, WWD was able to read the teletype and the press release was transmitted by teletype.

NAVIGATION EQUIPMENT

The Loran "A" receiver functioned satisfactorily and the satellite navigation system functioned satisfactorily except for a brief period due to computer malfunction which was corrected by electronic adjustments.

The ship's radar functioned satisfactorily until the last week of the cruise. Efforts to repair the set aboard ship were unsuccessful since the necessary spare parts were not available in the ship's inventory of spares.

PERSONNEL

Since the objectives of Leg 15 were threefold, re-entry, geochemical investigations, and stratagraphic and geological, two rendezvous off Curacao were made to change out scientific and technical personnel. One rendezvous was made on December 28, 1970, to disembark engineering personnel involved with re-entry and to embark geochemists for the three geochemical sites. The second rendezvous occurred after Site 150 on January 13, 1971, when the geochemists were disembarked and stratigraphers and geologists were embarked for the last portion of the leg.

Two compassionate emergencies developed during Leg 15. The weatherman was disembarked at Kingston, Jamaica, on January 16 and the Global Marine Inc. drilling superintendent was disembarked at Kingston, Jamaica, on January 18, 1970.

There were no serious accidents on Leg 15 and the Challenger crew performed in their usual, outstanding manner doing a superb job throughout the cruise.

TABLE 1

LEG 15 - DEEP SEA DRILLING PROJECT

SUMMARY OF OPERATIONS

(Caribbean Sea)

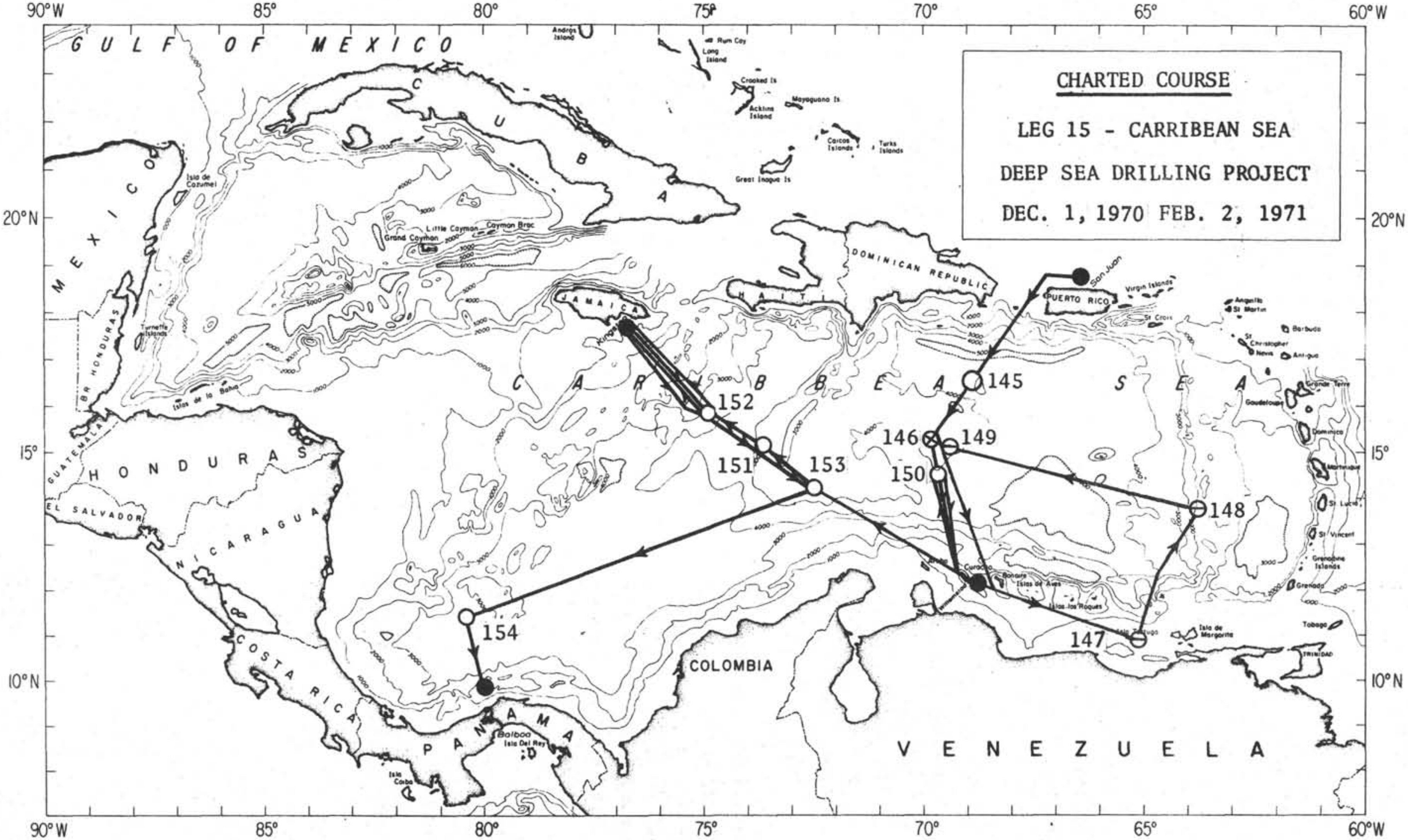
Total Days Leg 15 (December 1, 1970 to February 2, 1971)			62.90
Total Days in Port			(a) 9.33
Total Days Cruising			(b) 18.38
Total Days on Site			(c) 35.19
Trip Time	(143.5 hrs)	5.98 days	
Drilling Time	(60.0 hrs)	2.50 days	
Coring Time	(445.5 hrs)	18.56 days	
Abandonment Time	(14.0 hrs)	0.58 days	
Re-Entry Time	(147.5 hrs)	6.15 days	
Mechanical Downtime	(9.5 hrs)	0.40 days	
Other Miscellaneous Time	(24.5 hrs)	1.02 days	
Total Distance Travelled (Nautical Miles)			4,083.00
Average Speed (knots)			9.26
Sites Investigated			10
Holes Drilled			15
Number of Cores Attempted			264
Number of Cores With Recovery			254
Percent of Cores With Recovery			96.20
Total Meters Cored		(7,645.7 ft)	2331.00
Total Meters Recovered		(4,045.5 ft)	1233.40
Percent of Meters Recovered			52.90
Meters Drilled		(6,819.1 ft)	2079.00
Total Penetration		(14,464.8 ft)	4410.00
Percent of Total Penetration Cored			52.90
Maximum Penetration Per Hole		(2,545 ft)	776.00
Minimum Penetration Per Hole		(43 ft)	13.00
Average Penetration Per Hole		(964 ft)	294.00

Footnotes:

(a) Includes 134.0 hrs. of Mechanical Downtime in Drydock for Bow Thruster Repair.

(b) Includes 51.5 hrs. of Mechanical Downtime Steaming to Drydock for Bow Thruster Repair.

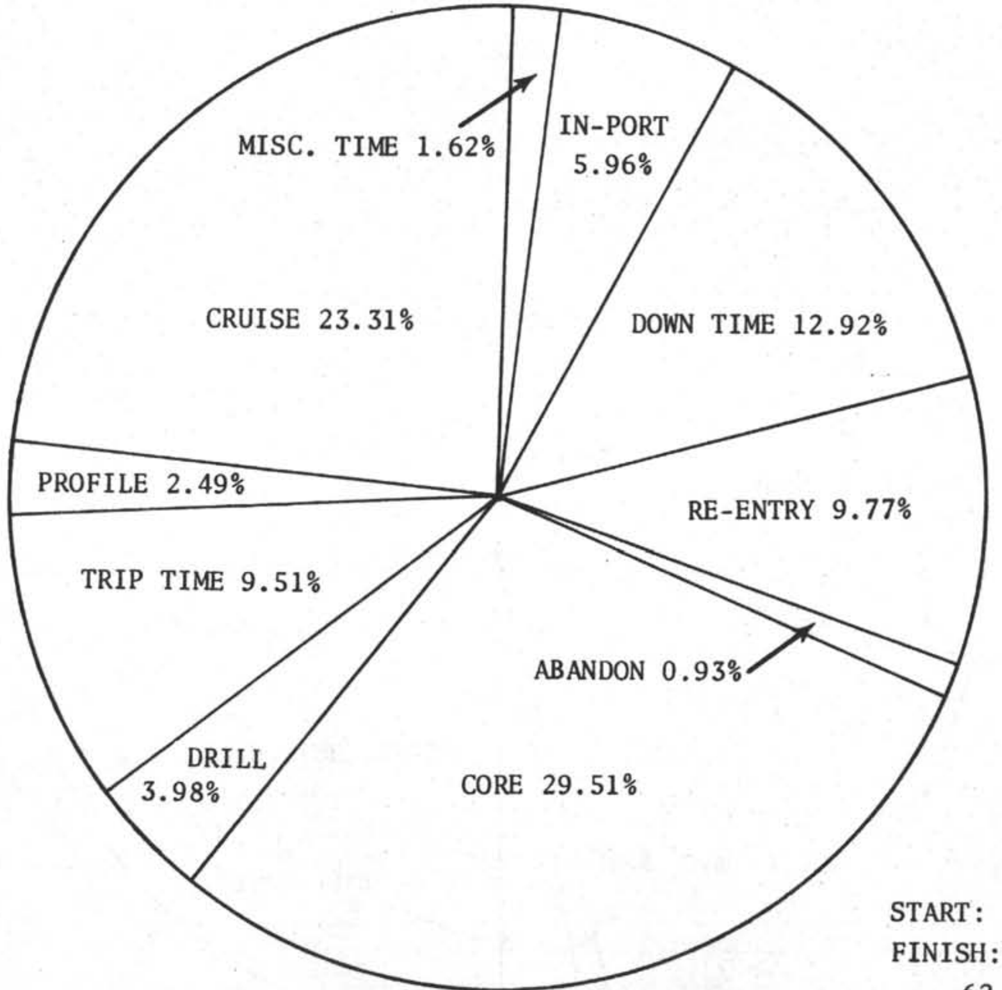
(c) Excludes 185.5 hrs. of Mechanical Downtime for Bow Thruster failure.



- ● PORTS OF CALL
- ⊗ RE-ENTRY SITE
- ⊖ GEOCHEMISTRY SITE
- O STRATAGRAPHIC SITE

Figure 1

LEG 15 D.S.D.P.

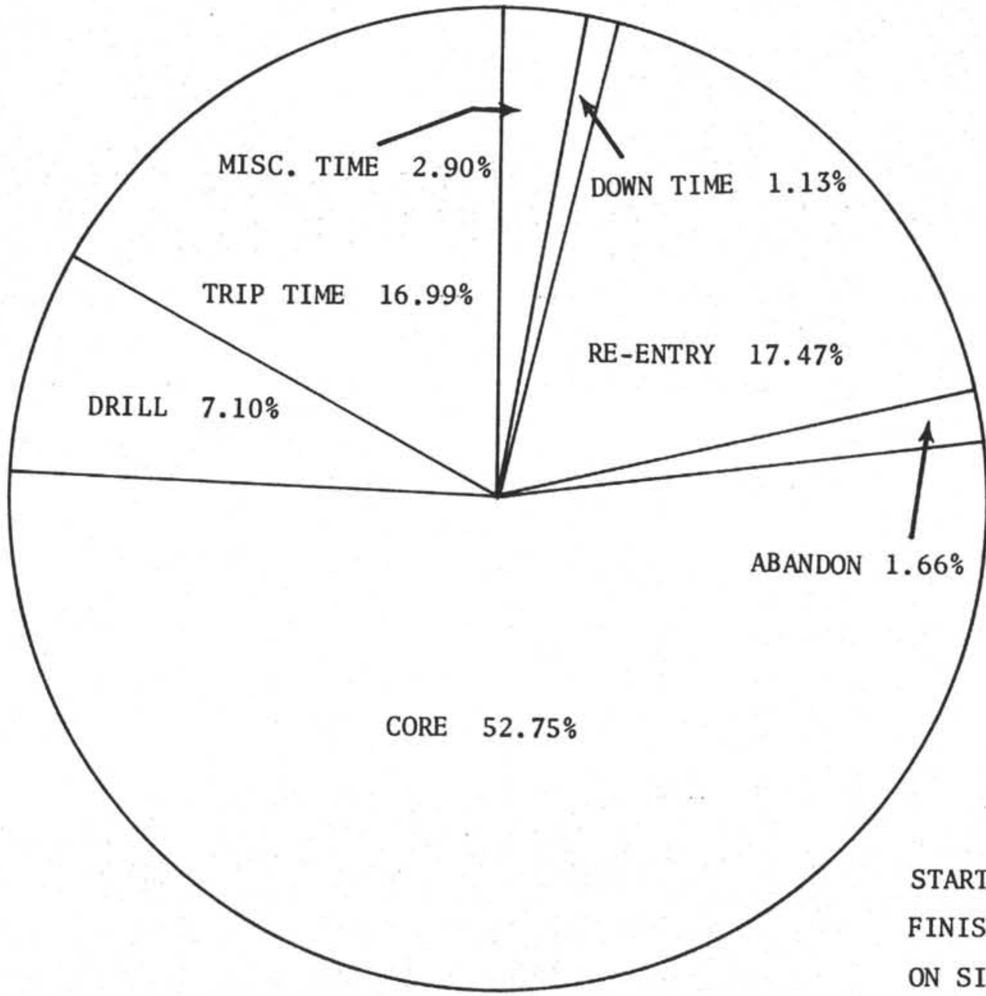


START: 1123 GMT - DEC. 1, 1970
FINISH: 0849 GMT - FEB. 2, 1971
62 DAYS 21 HRS. 26 MIN.
10 SITES - 16 HOLES

TOTAL TIME DISTRIBUTION FIGURE

Figure 1B

LEG 15 - D.S.D.P.



START: 1123 GMT - DEC. 1, 1970
FINISH: 0849 GMT - FEB. 2, 1971
ON SITE: 35 DAYS 4 HRS. 30 MIN.
10 SITES - 16 HOLES

SITE TIME DISTRIBUTION

Figure 2B

SITE SUMMARY

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 1, 1970 - FEBRUARY 2, 1971

ATTACHMENT - A

LEG 15 - DSDP

SITE SUMMARY

Site	Hole	Latitude	Longitude	Water Depth (Meters)	No. Of Cores	Cores With Rec.	Meters Cored	Meters Recovery	Meters Drilled	Total Meters Pene.	Avg. Rate of Pene. (M/Hr)	Time On Hole (Hours)	Time On Site (Hours)
Venezuelan Basin Basement High													
145	0	16° 34.74'N	68° 03.37'W	4358	Abandoned prior to spud due to bow thrusters failure.								15.0
Venezuelan Basin - Re-entry Site													
146	0	15° 06.99'N	69° 22.67'W	3939	44	40	374.0	145.6	388.0	762.0	6.34	295.5	
146	A	Same	Same	3947	1	1	9.0	4.6	87.0	96.0	(a)	(a)	295.5
Cariaco Trench - Geochemistry Site													
147	0	10° 42.48'N	65° 10.48'W	892	18	17	162.0	119.2		162.0	10.40	24.5	
147	A	Offset 200 ft. East of 147-0		892	2	2	13.0	6.5		13.0	6.50	2.0	
147	B	Offset 200 ft. East of 147-0		892	12	12	115.0	81.0	10.0	125.0	10.90	15.0	
147	C	Offset 200 ft. East of 147-0		892	8	6	73.0	32.1	125.0	198.0	17.20	18.5	60.0
Aves Ridge - Geochemistry Site													
148	0	13° 25.12'N	63° 43.25'W	1232	31	30	272.0	181.8		272.0	7.70	44.5	44.5
Venezuelan Basin - Geochemistry Site													
149	0	15° 06.25'N	69° 21.85'W	3972	43	42	390.0	239.9		390.0	5.70	99.5	99.5
Venezuelan Basin													
150	0	14° 30.69'N	69° 21.35'W	4545	12	12	99.0	39.3	81.0	180.0	7.20	35.5	49.5
150	A	Same	Same	4545	2	2	18.0	1.0	110.0	128.0	25.50	14.0	

Leg 15 - DSDP - Site Summary concluded

Site	Hole	Latitude	Longitude	Water Depth (Meters)	No. Of Cores	Cores With Rec.	Meters Cores	Meters Recovery	Meters Drilled	Total Meters Pene.	Avg. Rate of Pene. (M/Hr)	Time On Hole (Hours)	Time On Site (Hours)
Beata Ridge													
151	0	15° 01.02'N	73° 24.58'W	2029	15	15	115.0	56.7	266.0	381.0	16.20	34.0	34.0
Nicaraguan Rise													
152	0	15° 52.72'N	74° 36.47'W	3899	24	23	211.0	59.0	266.0	477.0	9.20	72.0	72.0
Aruba Gap													
153	0	13° 58.33'N	72° 26.08'W	3932	20	20	177.0	70.1	599.0	776.0	9.00	105.5	105.5
Colombian Basin													
154	0	11° 05.11'N	80° 22.75'W	3338	14	14	132.0	66.0	146.0	278.0	12.10	34.0	
154	A	Offset 100 N & 100	W	3338	18	18	171.0	130.6	1.0	172.0	6.25	35.0	69.0
Summary													
Tot. 10	15				264	254	2331.0	1233.4	2079.0	4410.0		844.5	844.5
%						96.2	52.9	52.9	47.1				
Avg/Site	1.6			3214	26.4	25.4	233.1	123.3	207.9	441.0		52.8	84.4
Max/Site	4.0			4545	45.0	42.0	390.0	239.9	599.0	858.0		295.5	295.5
Min/Site	1.0			892	14.0	14.0	115.0	40.3	0.0	272.0		15.0	15.0

Footnotes:

(a) Included as re-entry time for Site 146-0

SUMMARY TIME ANALYSES

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 1, 1970 - FEBRUARY 2, 1971

ATTACHMENT - B

Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-Entry Time	Mechanical Downtime	In-Port Time	Other Misc. Time	Remarks
12-1	Port	-	-	-	-	-	-	-	-	-	16½	-	Dock at San Juan at 0730 Hr Dec. 1, 1970
12-2	"	-	-	-	-	-	-	-	-	-	24	-	Insp. D.P., Offload Cores & Equip., Load Equip. & Supplies
12-3	"	-	-	-	-	-	-	-	-	-	24	-	" " " " " " " "
12-4	"	-	-	-	-	-	-	-	-	-	24	-	" " " " " " " "
Tot.	Port	-	-	-	-	-	-	-	-	-	88½	-	Total Port Time = 88½ Hr
Leg	Cum.	-	-	-	-	-	-	-	-	-	88½	-	Cum Tot = 88½ Hr
12-5	145	21½	2½	-	-	-	-	-	-	-	-	-	Dep't. San Juan 0008 Hr 12/5/70. Arr At Site 2130 Hr
12-6	"	-	5½	8	-	-	-	-	-	4½	-	2½	On Site at 0530 Hr. Slip D.L. - ½ Hr., Attempt Recall Beacon - 2 Hr.
Tot	145	21½	8	8	-	-	-	-	-	4½	-	2½	Dept. Site at 2030 Hr 12/6/70, On Site 15 Hr., Site Tot = 44½ Hr
Leg	Cum.	21½	8	8	-	-	-	-	-	4½	88½	2½	Cum. Tot = 133 Hr.
12-6	Dry Dock	-	-	-	-	-	-	-	-	3½	-	-	Profile Site 145 & Site 146 Awaiting Dry Dock Order
12-7	"	-	-	-	-	-	-	-	-	24	-	-	Profile; Orders To San Juan - 0845 Hr; Orders To Curacao - 1700 Hr
12-8	"	-	-	-	-	-	-	-	-	24	-	-	First Line to Dock at Curacao Dry Dock Yard at 2400.
12-9	"	-	-	-	-	-	-	-	-	24	-	-	Move into Grave Dock 1500-1700 Hr. Pumped Out at 2000.
12-10	"	-	-	-	-	-	-	-	-	24	-	-	Dry Dock - Repair Bow Thrusters
12-11	"	-	-	-	-	-	-	-	-	24	-	-	" " " " "
12-12	"	-	-	-	-	-	-	-	-	24	-	-	" " " " "
12-13	"	-	-	-	-	-	-	-	-	24	-	-	" " " " " Dry Dock Flooded at 0930. Out of Dry Dock at 1115 Hr.
12-14	"	-	-	-	-	-	-	-	-	14	-	-	Depart Curacao after Sea Trial at 1400 Hr.
Tot.	Dry Dock	-	-	-	-	-	-	-	-	185½	-	-	Total Repair Time - 185½ Hr
Leg	Cum	21½	8	8	-	-	-	-	-	190	88½	2½	Cum Tot = 318½ Hr
12-14	146	10	-	-	-	-	-	-	-	-	-	-	Underway to Site 146
12-15	"	9½	-	-	-	-	-	-	14½	-	-	-	Arr. on Site 0930 Hr. Launch 1st Cone - 1 Hr.; Welding - 13.5 Hr.
12-16	"	-	-	-	-	-	-	-	24	-	-	-	W.O.W. - 8 Hrs.; Reentry - 16 Hrs.
12-17	"	-	-	9	4½	1	-	-	5½	4	-	-	Bowen Sub Failure - 4 Hr.
12-18	"	-	-	-	4½	19½	-	-	-	-	-	-	
12-19	"	-	-	-	-	24	-	-	-	-	-	-	
12-20	"	-	-	-	-	24	-	-	-	-	-	-	
12-21	"	-	-	-	-	9½	-	-	14½	-	-	-	Reentry: 5 Hr Wireline, ½ Hr Cut D.L., 7 Hr Trip, 2 Hr Cond. Hole

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Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-Entry Time	Mechanical Downtime	In Port Time	Other Misc. Time	Remarks
12-22	146	-	-	-	-	-	-	-	24	-	-	-	TRIP-12HR; WIRELINE 11½HR., SLIP D.L. - ½HR
12-23	"	-	-	-	-	-	-	-	24	-	-	-	WIRELINE -20HR., LOWER DP & CORE TO CHECK STAB -2HR.
12-24	"	-	-	-	-	-	-	-	24	-	-	-	WIRELINE 10HR; ROUND TRIP 14HR.
12-25	"	-	-	-	-	8½	-	-	15½	-	-	-	WIRELINE 8½HR, MANEUVER SHIP & SCAN 2½HR; RIH & WASH 4½
12-26	"	-	-	-	-	24	-	-	-	-	-	-	
12-27	"	-	1	5½	-	½	-	3	1½	-	-	6½	CUT DL-3HR. ATTEMPT SWC-3½HR. DEPT. LOC 1700. DEPT. SITE 1300
TOT.	146	19½	1	14½	9	111	-	3	147½	4	-	6½	ON SITE 295½HR.; SITE TOTAL-316HR.
LEG	CUM.	41	9	22½	9	111	-	3	147½	194	88½	9	CUM. TOT. 634½HR.
12-27	147	6	-	-	-	-	-	-	-	-	-	-	START 1800HR.
12-28	"	24	-	-	-	-	-	-	-	-	-	-	ARR. CURACAO 1430HR.; DEPT. 1500HR.
12-29	"	19½	4½	-	-	-	-	-	-	-	-	-	ARR. AT SITE 1930HR.
12-30	"	-	½	4½	-	15½	-	-	-	-	-	3½	ARR. ON SITE 0030HR.; TEST PISTON CORE 3½HR.
12-31	"	-	-	½	-	-	-	½	-	-	-	-	DEPT. HOLE 147 AT 0100HR., HOLE TOTAL = 24½HRS.
12-31	147-A	-	-	-	-	2	-	-	-	-	-	-	DEPT. HOLE 147A AT 0300HR., HOLE TOTAL = 2HR.
12-31	147B	-	-	3	-	11	-	1	-	-	-	-	ARR. 0300, DEPT. AT 1800HR., HOLE TOTAL = 15HR
12-31	147C	-	-	3	1	2	-	-	-	-	-	-	ARR. 1800HR.
1-1	"	-	-	3½	½	8	-	½	-	-	-	-	DEPT. 1230HR. HOLE 147C TOTAL = 18½HR.
TOT.	147	49½	5	14½	1½	38½	-	2	-	-	-	3½	ON SITE 68HRS; SITE TOTAL 114½HR
LEG	CUM.	90½	14	37	10½	149½	-	5	147½	194	88½	12½	CUM. TOT. 749HR.
1-1	148	11½	-	-	-	-	-	-	-	-	-	-	START 1230HR.
1-2	"	8	7½	3½	-	3½	-	-	-	-	-	1½	AT SITE 0800HR.; ON SITE 1530HR.; CHECK PISTON CORE 1½HR.
1-3	"	-	-	-	-	24	-	-	-	-	-	-	
1-4	"	½	3½	-	-	8	-	½	-	-	-	-	DEPT. HOLE 1200HR. DEPT. SITE 1230HR.
TOT.	148	19½	8	7	-	35½	-	½	-	-	-	1½	ON SITE 44½HR.; SITE TOTAL 72HR.
LEG	CUM.	110	22	44	10½	185	-	5½	147½	194	88½	14	CUM. TOT. 821HR.
1-4	149	11½	-	-	-	-	-	-	-	-	-	-	START 1230HR.
1-5	"	21½	-	2½	-	-	-	-	-	-	-	-	ARR. ON SITE AT 2130HR.
1-6	"	-	-	19	-	5	-	-	-	-	-	-	ROUND TRIP FOR PISTON CORE FAILURE
1-7	"	-	-	-	-	24	-	-	-	-	-	-	

DATE	SITE NUMBER	CRUISE TIME	PROFILE TIME	TRIP TIME	DRILLING TIME	CORING TIME	CONDITION HOLE	ABANDON TIME	RE-ENTRY TIME	MECHANICAL DOWNTIME	IN PORT TIME	OTHER MISC. TIME	REMARKS
1-8	149	–	–	–	–	24	–	–	–	–	–	–	
1-9	"	–	–	6½	–	15	–	2	–	–	–	½	SLIP D.L. ½ HR.
1-10	"	–	–	½	–	–	–	–	–	–	–	½	CUT OFF 4000 FT. OF SAND LINE ½ HR.; DEPT. SITE 0100 HR
TOT.	149	33	–	28½	–	68	–	2	–	–	–	1	ON SITE 99½ HR.; SITE TOTAL 132½ HR.
LEG.	CUM.	143	22	72½	10½	253	–	7½	147½	194	88½	15	CUM. TOT. 953½ HR.
1-10	150	5½	–	8½	1	7½	–	–	–	–	–	½	ARR. ON SITE 0630 HR. SLIP & CUT D.L. ½ HR
1-11	"	–	–	1	½	16	–	½	–	–	–	–	DEPT. HOLE 150 AT 1800 HR.; HOLE TOTAL 35½ HR
1-11	150A	–	–	–	1	4	–	1	–	–	–	–	SPUD 150A AT 1800 HR
1-12	"	–	–	8	–	–	–	–	–	–	–	–	DEPT. HOLE 150A AND SITE AT 0800 HR.; HOLE TOT. 14 HRS.
TOT.	150	5½	–	17½	2½	27½	–	1½	–	–	–	½	ON SITE 49½ HR.; SITE TOTAL 55 HRS.
LEG	CUM	148½	22	90	13	280½	–	9	147½	194	88½	15½	CUM. TOT. 1008½ HR.
1-12	151	16	–	–	–	–	–	–	–	–	–	–	START 0800 HR.
1-13	"	24	–	–	–	–	–	–	–	–	–	–	OFF CURACAO AT 0100 HR; DEPT. AT 0200 HR. (25 HR DAY)
1-14	"	4	4½	5	3	8	–	–	–	–	–	½	SLIP D.L. ½ HR. ARR. AT SITE 0300 HR. ARR. ON SITE 0730 HR
1-15	"	–	–	4	–	12½	–	1	–	–	–	–	DEPT. SITE 1730 HR.
TOT.	151	44	4½	9	3	20½	–	1	–	–	–	½	ON SITE 34 HR.; SITE TOTAL 82½ HR.
LEG	CUM	192½	26½	99	16	301	–	10	147½	194	88½	16	CUM TOT. 1091 HR
1-15	152	6½	–	–	–	–	–	–	–	–	–	–	START 1730 HR.
1-16	"	22½	–	–	–	–	–	–	–	–	1½	–	ARR KINGSTON 1800 HR; ANCHOR DROP 1846 HR.; LIFT ANCHOR 2018. SEA. DEPT. 2100 HR.
1-17	"	17	5½	–	–	–	–	–	–	–	–	1½	ARR AT SITE 1500 HR. ARR ON SITE 2030 HR. WAIT 1½ HR. DEPT. 2200
1-18	"	24	–	–	–	–	–	–	–	–	–	–	LAUNCH B.F. II AT 1150 HR. ARR. OFF KINGSTON 1345 HR., DEPT. 1445 HR
1-19	"	9	–	6½	1½	7	–	–	–	–	–	–	RETURN ON SITE 152 AT 0900 HR.
1-20	"	–	–	–	1½	22½	–	–	–	–	–	–	
1-21	"	–	–	3	2	17	–	1	–	–	–	1	WOW ½ HR, SLIP D.L. ½ HR., ATTEMPT TO SPUD 152A - 3 HR
1-22	"	–	–	7½	–	–	–	–	–	–	–	–	DEPT. SITE AT 0730 DUE BEACON FAILURE
TOT.	152	79	5½	17	5	46½	–	1	–	–	1½	2½	ON SITE 72.0 HR.; SITE TOTAL 158 HR.
LEG	CUM	271½	32	116	21	347½	–	11	147½	194	90	18½	CUM. TOT. 1249 HR.
1-22	153	16½	–	–	–	–	–	–	–	–	–	–	START 0730 HR.
1-23	"	8½	3½	7	3	1½	–	–	–	–	–	½	CUT D.L. ½ HR. AT SITE 0830; ON SITE 1200 HR

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Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-Entry Time	Mechanical Down Time	In Port Time	Other Misc. Time	Remarks
1-24	153	–	–	–	9½	14½	–	–	–	–	–	–	
1-25	"	–	–	–	9	15	–	–	–	–	–	–	
1-26	"	–	–	–	14½	9½	–	–	–	–	–	–	
1-27	"	–	–	6½	–	10	–	1½	–	–	–	3½	CUT. D.L. ½ HR.; INSPECT DRILL COLLARS 3 HR. DEPT. 2130 HR.
TOT.	153	25	3½	13½	36	50½	–	1½	–	–	–	4	ON SITE 105½ HR.; SITE TOTAL 134 HR.
LEG	CUM.	296½	35½	129½	57	398	–	12½	147½	194	90	22½	CUM TOTAL 1383 HR.
1-27	154	2½	–	–	–	–	–	–	–	–	–	–	START 2130 HR.
1-28	"	24	–	–	–	–	–	–	–	–	–	–	
1-29	"	16	2	6	–	–	–	–	–	–	–	–	ARR. AT SITE AT 1600 HR. ARR. ON SITE AT 1300 HR
1-30	"	–	–	1	3	18	1	–	–	1	–	–	SPUD AT 0100 HR.; WAIT FOR POWER TO DRAW WKS. 1 HR.
1-31	"	–	–	1	–	2	–	1	–	–	–	–	DEPT. LOC. AT 0400 HR.; HOLE TOTAL 34 HRS.
1-31	154A	–	–	1	–	19	–	–	–	–	–	·	START AT 0400 HR
2-1	"	–	–	5	–	8½	–	½	–	–	–	1	CUT DL ½ HR. DISCARD SANDLINE ½ HR. DEPT. 1500 HR. HOLE TOT. 35 HR.
TOT	154	42½	2	14	3	47½	1	1½	–	1	–	1	ON SITE 69. HR.; SITE TOTAL 113½ HR.
LEG	CUM	339	37½	143½	60	445½	1	14	147½	195	90	23½	1496½ HR
2-1	TO PANAMA	9	–	–	–	–	–	–	–	–	–	–	START 1500 HR.
2-2	"	4	–	–	–	–	–	–	–	–	–	–	ANCHOR DROPPED AT 0349 HRS.
TOT	TO PANAMA	13	–	–	–	–	–	–	–	–	–	–	
LEG	CUM	352	37½	143½	60	445½	1	14	147½	195	90	23½	CUM. TOTAL = 1509½ HR.
	%	23.31	2.49	9.51	3.98	29.51	(a)	0.93	9.77	12.92	5.96	1.62	TOTAL TIME DISTRIBUTION IN PERCENT
	%	—	—	16.99	7.10	52.75	(a)	1.66	17.47	1.13 (b)	—	2.98	ON-SITE TIME DISTRIBUTION IN PERCENT

FOOTNOTE:

(a) 1 HR. CUM. INCLUDED IN "OTHER MISC. TIME"

(b) EXCLUDES 185.5 HRS MECHANICAL DOWN TIME FOR BOW THRUSTERS OF WHICH 51.5 HRS WAS CRUISING FOR DRYDOCK PORT AND 134.0 HRS WAS DRYDOCK TIME IN PORT.

REA/ 2/1/71

BIT SUMMARY

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 1, 1970 - FEBRUARY 2, 1971

ATTACHMENT - C

LEG 15 - DSDP

BIT SUMMARY

Site	Make	BIT DESCRIPTION Size	Type	Ser. No.	CORES TAKEN	Core Recovery Number	%	FOOTAGE CORED Meters	Core Recovery Meters	%	TOTAL PENET. Meters	ROT. TIME Hrs.	PENET. RATE M/RH	CONDITION	REMARKS
145	Smith	10 1/8 x 2 7/16	9-C	Hole abandoned prior to spud due to bow thruster failure.											
146 (Bit #1)	Smith	10 1/8 x 2 7/16	9-C	FF-718	35	33	94.3	313.0	128.6	41.1	701.0	29.80	23.6	T-1, B-5, IG	Ooze, Marl, L.S. Chalk, Chert
146 (Bit #2)	Smith	10 1/8 x 2 7/16	9-C	FK-666	9	7	77.9	61.0	17.0	27.9	61.0	17.10	3.6	T-8, B-8 1 cone gone 2 cones locked	Chert, Limestone, Diabase
	NOTE: Bit may have been damaged in cone at re-entry resulting in pinched cone which could account for severe condition of bit for relatively few hours service.														
146-A	Smith	10 1/8 x 2 7/16	9-C	FK-666	1	1	100.3	9.0	4.6	51.1	96.0	0.30	320.0	T-1, B-1, IG	Ooze
	NOTE: Missed stab on re-entry attempt. Resulted in Hole 146-A														
	Cumulative Performance			FK-666	10	8	80.0	70.0	21.6	30.9	157.0	17.40	9.45		
147	Varel (Rerun from Site 129 with est. 85% salvage)	9 7/8 x 2 7/16	250 kt.	7921	18	17	94.4	162.0	119.2	73.5	162.0	3.40	47.8	Used in 147-A	Clay
147-A	Varel	9 7/8 x 2 7/16	250 kt.	7921	2	2	100.0	13.0	6.5	50.0	13.0	0.11	118.0	Used in 147-B	Clay
147-B	Varel	9 7/8 x 2 7/16	250 kt.	7921	12	12	100.0	115.0	81.0	70.3	125.0	2.48	50.5	Used in 147-C	Clay
147-C	Varel	9 7/8 x 2 7/16	250 kt.	7921	8	6	87.5	73.0	32.1	44.0	198.0	2.13	93.1	Crown Gone	Clay
	Prior Performance (Site 129)				9	8	88.9	41.0	5.9	14.4	235.0	25.33	9.3	Est. 85% Salv.	Various
	Cumulative Performance			7921	49	45	91.8	404.0	244.7	60.7	733.0	33.45	21.9	No Salvage	

NOTE: Crown of bit completely separated from shank of bit indicating of Matrix bond failure.

Leg 15 - DSDP - Bit Summary concluded

Site	Make	BIT DESCRIPTION Size	Type	Ser. No	CORES TAKEN	Core Recovery Number	%	FOOTAGE CORED	Core Recovery Meters	%	TOTAL PENET. Meters	ROT. TIME Hrs.	CONDITION		REMARKS
148	Hycalog	9 7/8 x 2 15/32	250 kt.	10458	31	30	96.8	272.0	181.8	66.7	272.0	12.33	22.1	90% Salv.	Clay & Tephra
149	Hycalog	9 7/8 x 2 15/32	250 kt.	10458	43	42	97.7	390.0	239.9	61.8	390.0	8.83	46.8	60% Salv.	Chalk & Clay
	Cumulative Performance			10458	74	72	97.3	662.0	421.7	63.7	662.0	21.16	26.5	60% Salv.	
150	Smith	10 1/8 x 2 7/16	9-C	FK-665	12	12	100.0	99.0	39.3	39.7	180.0	7.15	25.1	Run in 150-A	Clay, Chert, Diabase
	(Rerun from Site 144 - no data on prior performance)														
150-A	Smith	10 1/8 x 2 7/16	9-C	FK-665	2	2	100.0	18.0	1.0	5.9	128.0	0.93	13.8	T-4, B-6, IG	Clay & Chert
	Leg 15 Cumulative Performance			FK-665	14	14	100.0	117.0	40.3	29.0	308.0	8.08	38.3		
151	Smith	10 1/8 x 2 7/16	3 TCR	FK-936	15	15	100.0	115.0	56.7	48.3	381.0	9.62	39.6	T-1, B-5, IG	Chalk, Marl, Diabase
152	Smith	10 1/8 x 2 7/16	9-C	FF-707	24	23	95.8	211.0	59.0	28.0	477.0	17.18	27.7	T-1, B-4, IG	Chalk, Chert, L.S Diabase
153	Smith	10 1/8 x 2 7/16	9-C	FF-704	20	20	100.0	177.0	70.1	39.8	776.0	46.13	16.8	T-8, B-8, IG	Chalk, Limestone, Chert, Diabase, Ash
							(Bearings gone out of 1 cone-inserts broken on all cones)								
154	Smith	10 1/8 x 2 7/16	3 TCR	FF-946	14	14	100.0	132.0	66.0	50.0	278.0	5.10	53.2	Run in 154-A	Clay, Marl, Ash
154-A	Smith	10 1/8 x 2 7/16	3 TCR	FF-946	18	18	100.0	170.1	130.6	76.5	172.0	5.68	30.4	T-1, B-8, IG	Silty Sand
	Cumulative Performance			FF-946	32	32	100.0	302.1	196.6	65.0	450.0	10.78	41.9	(cones locked)	

SUMMARY OF BITS USED

4 - New Smith 9-C 4 Cone Button Bits
1 - Rerun Smith 9-C 4 Cone Button Bit
1 - Rerun Varel 250 kt. Diamond Bit
1 - New Hycalog 250 kt. Diamond Bit
2 - New Smith 3 TCR 3 Cone Button Bits

BEACON SUMMARY

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 1, 1970 - FEBRUARY 2, 1971

ATTACHMENT - D

LEG 15 - DSDP

BEACON SUMMARY

Site No.	Beacon Description Make	Freq. kHz	Ser. No.	Batt. Ser. No.	Site Time Hrs.	Remarks
145	Inter Ocean	16.0	?	?		Failed on pretest after prior satisfactory test terminated with cable damage.
145	Burnett	16.0	128	120	15	OK - Used three floatation rings & Inter Ocean acoustic release. Failed to release
146	Burnett	16.0	144	125/126	1	Two batteries used in parallel circuit. Failed in first hour due weak signal.
146	Burnett	13.5	154	143	151	OK - Weak signal after 151 hrs. No failure since service exceeded six days.
146	Burnett	16.0	141	128	144	OK - Total of 295.5 hrs. on Site 146.
147	Burnett	13.5	158	129	60	OK - Half power beacon due to shallow water depth of 892 meters.
148	Burnett	13.5	157	85	45	OK - Half power beacon due to shallow water depth of 1232 meters.
149	Burnett	16.0	138	132	100	OK
150	Burnett	13.5	152	136	50	OK
151	Burnett	16.0	139	137	34	OK
152	Burnett	16.0	133	145	99	Failed after 99.5 hrs. of service due to erratic signal strength. Site completed.
153	Burnett	16.0	132	146	106	OK
154	Burnett	16.0	129	153	69	OK - Functioned satisfactorily although pulse period was only 3.6 ml. sec.

Used nine 16.0 kHz beacons (1 Inter Ocean & 8 Burnett). One Inter Ocean and 2 Burnett beacons failed.
Used four 13.5 kHz beacons. All were Burnett beacons and all functioned satisfactorily.
Used fourteen batteries.
Used fourteen floatation rings.
End of leg shipboard inventory includes the following:

(a) Six 16.0 kHz Burnett beacons
(b) Twelve 13.5 kHz Burnett beacons
(c) Twenty Burnett batteries.
(d) Thirteen floatation rings.

SITE 146 - RE-ENTRY SUMMARY

LEG 15 - CARIBBEAN SEA

DEEP SEA DRILLING PROJECT

DECEMBER 15 - 27, 1970

March 11, 1971

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ATTACHMENT E

SITE 146 - RE-ENTRY SUMMARY

Table of Contents

SITE 146 - RE-ENTRY SUMMARY

SUMMARY

The first operational re-entry of the Deep Sea Drilling Project was accomplished at 05:30 hours on December 25, 1970, at Site 146 of Leg 15 in the Caribbean Sea. An experimental re-entry had been accomplished in June 1970 in the Eastern Atlantic.

The Glomar Challenger arrived at Site 146 at 09:30 hours on December 15, 1970. A five meter diameter by four meter high re-entry cone was attached to 50 meters of 13 3/8 inch casing which was lowered to the sea floor at 3949 meters with the drill string. The casing was jetted into the sea floor to place the base of the re-entry cone at the mud line. After mechanically releasing the casing and cone assembly, routine coring and drilling operations were carried out to a depth of 4650 meters for 701 meters penetration through ooze, marl, chert, chalk, and limestone. The dull bit was then pulled, replaced with a new bit, and the drill string was rerun to 3937 meters. An Edo sonar scanning transceiver was then lowered through the five-inch drill pipe on a conductor cable to place the scanning head approximately eight inches below the core bit. Scanning with the transceiver located the acoustic reflectors of the re-entry cone approximately 300 feet from the bit. The ship was then maneuvered to position, the bit immediately above the cone and the drill pipe was lowered for an apparent re-entry. However, resistance to lowering the bit and a core, recovering undisturbed sediment, later indicated that a false re-entry had been made. An attempt to pull back above the mud line, rerun the sonar transceiver and make a second re-entry attempt, was terminated after attempts to run the transceiver were stymied by a plugged core bit. A round trip was made to check the drill string for obstructions and to remove a jet sub. The drill string was rerun to 3947 meters, the sonar transceiver was lowered into position, and the re-entry cone was located at 95 foot range from the bit. The ship was again maneuvered to place the bit above the cone and the drill string was lowered for a valid re-entry. The drill string was lowered to 4635 meters without resistance, 15 meters of fill were washed from 4635 to 4650 meters and routine coring operations were resumed at 4650 meters. The hole was continuously cored to total depth of 4711 meters, terminating in basement (diabas), after 762 meters total penetration. The hole was then filled with 10 pounds per gallon mud and the drill string was recovered for departure from the site.

Total time required for the site was 295.5 hours. The total time requirement for re-entry was 147.5 hours. The time required for the first re-entry attempt, from sighting of cone to lowering of drill string, was 13 hours, while the same operation was accomplished in 2.5 hours on the valid re-entry.

Ironically, the objective of Site 146 could probably have been accomplished without re-entry. The first bit, upon inspection after recovery, had an estimated 25 to 30

percent additional life and probably could have made the 61 meters of additional penetration accomplished with the second bit. Although the second bit was virtually destroyed after only 17.1 rotating hours compared to 29.8 rotating hours on the first bit, it is believed that cone damage occurred to the second bit as it was obstructed in the base of the re-entry cone on stab-in.

Regardless of whether re-entry was or was not required to accomplish the scientific objectives of Site 146, the re-entry technique was established as a working operational technique which provides the project with the capability of exploring the deeper horizons of harder formations, which heretofore have been inaccessible.

CONCLUSIONS AND RECOMMENDATIONS

The re-entry procedure, as utilized on Site 146, is a workable system which is technically sound and the basic equipment is adequate. However, minor modifications of equipment and procedures should drastically reduce the time required for future re-entry.

Recommendations for modifications are as follows:

1. The re-entry cone settled an estimated 11 meters on Site 146 which was the primary factor for the false re-entry. Additional bearing area of 200 to 300 square feet needs to be fabricated into the base of the cone. Round cutting discharge parts of at least four inches diameter should be fabricated into the cast housing at the base of the cone above the casing hanger and the bearing plate. The acoustic reflectors should be braced at the top of the cone with steel plate which is streamlined around the reflector to reduce the hazard of fouled keelhaul lines.

2. The keelhauling procedure, using the side launch technique, is satisfactory for keelhauling in ten to 12-foot seas. However, keelhauling, using an inverted launch technique, appears to offer all the advantages of the side launch plus reduced tendency for fouling of keelhaul lines, reduced handling, additional safety for personnel, and a reduction in time.

3. The casing hanger, after modification at Site 146 to reduce thebevel in the leading edges of the "gates", appears adequate. There are no recommendations for further modification.

4. The latch sub, although providing a mechanical release at Site 146, should be modified to hold the sleeve in the "up" position, once shifted, so that torque can be applied to assist in the mechanical release of the latch sub from the casing hanger.

The explosive bolt release for the latch sub appears to offer a potential means of positive release if a reliable acoustic system can be developed to detonate the explosive bolt. It is recommended that the acoustic release system be developed since the same system could be utilized for release of the acoustic reference beacons used for ship positioning.

5. The casing program and jetting procedure appear to be adequate. It does not appear that the casing frictional forces developed in soft sediments contribute substantially to the vertical support of the re-entry cone. Hence, the casing provides hole stability through the soft sediments at the mudline and keeps the re-entry cone oriented in the upright position. Based on project experience to date, it appears that 30 to 40 meters of casing would be adequate in most areas. There is generally sufficient thickness of transparent sediment to permit jetting to 30 to 40 meters without undue resistance. The bit of the jet string should be positioned within four or five meters of the casing shoe. The packoff used on Site 146 was satisfactory. A segmented, wrap-around packoff with seal rubber and tapered base should be provided for future re-entry work.

6. The Baker shifting tool, although sufficient to accomplish re-entry on Site 146, is not satisfactory. It should be replaced with a shifting tool which will permit more positive control from the surface and which will provide more positive surface indications. The proposed shifting tool should be designed to shift a sleeve and hold it in the "up" position without automatic release of the "shifting-dogs". The "shifting-dogs" should release only with the application of force in excess of that required to shift the sleeve.

7. The jet sub was ineffective in providing significant lateral displacement of the drill string. Qualitative evaluation indicated that maximum displacement was approximately 20 feet. Since the jet sub necessitates the use of a bore plugger and shifting of the jet sub sleeve, the negligible benefit gained doesn't justify the added rig time. Re-entry, both false and valid, was accomplished without the jet sub. It is recommended that the jet sub be eliminated for future re-entry work.

8. The bore plugger, both cup and seal nipple, were satisfactory with minor modifications to the check valve assembly. However, the bore plugger is not required if the jet sub is eliminated from the string.

9. The indexing sub, designed to index the Edo sonar transceiver, was unsatisfactory and was not required. Re-entry was accomplished without evidence of Edo sonar transceiver rotation and it is recommended that further efforts for indexing be suspended.

10. The Edo sonar scanning transceiver was satisfactory. The only difficulty encountered was the breaking of a scanning head when it was attempted to spud the Edo transceiver through a soft sediment plug in the drill collar assembly. Although re-entry was accomplished with the 45 degree scanning head on both attempts, the 45 degree head leaves a 15 degree from vertical "blind spot" in its vertical scan sector. The 60 degree scanning head covers a 30 to 90 degree from horizontal scan sector, thus eliminating the "blind spot". This should provide better resolution for the actual stab-in, although a slight reduction in scan range will be sacrificed.

11. The Glomar Challenger was successfully maneuvered in the automatic mode to successfully place the bit over the re-entry cone. The false re-entry required 13 hours of maneuvering to position the bit, of which two hours were utilized in jetting efforts. The valid re-entry required only 2.5 hours to position the bit. The significant reduction of time is attributable to development of a systematic method of ship maneuvering in the automatic mode using offsets, water depth adjustments and plotting of average range and bearing to the cone for each step of the maneuver. The ability to adequately maneuver the ship eliminates the need for jet sub and bore plugger.

12. Depth Correlation of drill pipe measurements with the top of the cone, just prior to pulling out of the hole, is a necessity. Inadequate depth correlation, due to cone settling, is the primary factor for the misstab on the first re-entry attempt. It is recommended that a magnetic collar survey be run prior to pulling the bit above the cone to correlate the base of the drilling assembly with a 13 3/8-inch casing coupling. This correlation can then be referred back to the top of the cone.

13. There is presently no means for positive identification of a valid or false re-entry. A means of positive surface indication at re-entry could have saved several hours rig time on Site 146 when the false re-entry occurred. Positive indentification may be ascertainable from different scan patterns of the sonar transceiver as additional experience is gained. However, it is recommended that a shear pin centralizer or shear pin stablizer be utilized in the near future to provide positive surface indication for a valid re-entry.

The elimination of the jet sub and bore plugger, the procedure developed for maneuvering the ship, a means of depth correlation between drill pipe and re-entry cone at time of stab and a means for positive surface indication for a valid re-entry could conceivably reduce the actual re-entry time (time off bottom to time back on bottom), to about eight hours plus trip time. The time required for keelhauling the re-entry cone, running casing, and for running the jetting ssembly was 11.5 hours, exclusive of the time lost for the first keelhaul attempt and the assembly time for the second re-entry cone. With practice this may reduce 25 to 30 percent. The jetting procedure and release of the cone and casing required four hours. This could be reduced 25 percent with modification of the latch sub sleeve and shifting tool. Thus, the incremental total time required to accomplish re-entry can conceivably be reduced to 18 or 20 hours plus the round trip time.

The decision for a pre-committed re-entry needs to be continually evaluated in view of the improved core bits which exist today. As mentioned in the summary, hindsight indicates that the scientific objectives of Site 146 could probably have been accomplished without re-entry. To substantiate this thinking, a very similar objective was accomplished in similar formations at Site 153 where 776 meters were penetrated in 46.13 rotating hours with one bit and in 105.5 hours on site. This compares with 762 meters penetration, a total of 46.9 hours rotation on two bits and 295.5 hours on site for Site 146. The most recent improvement in bit bearing designs should provide even greater bit life and should be evaluated at the earliest possible date.

If re-entry proves to be a frequent requirement for the project's future program, consideration should be given to modification of the drilling vessel which would make the hyperbolic guide and moon pool plug removable. This would permit launching of the re-entry cone through the moon pool and it would expedite casing handling and jet string assembly. It should also make possible the development of a technique which would permit re-entry to be instigated after a valid need for re-entry had been established in the course of normal drilling and coring without sacrificing the hole already drilled.

DISCUSSION OF RE-ENTRY OPERATIONS

At 09:30 hours on December 15, 1970, the Glomar Challenger arrived on Site 146 in the Caribbean Sea at Latitude 15° 07' North and Longitude 69° 23' West, which is approximately midway between the northern coast of Venezuela and Puerto Rico. Water depth was measured at 3939 meters by precision depth recorder. A 16.0 kHz acoustic beacon with two batteries wired in a parallel circuit to provide a minimum of 12 days signal emission was dropped to the sea floor as a geographical reference for the ship's position which is automatically controlled by the computerized dynamic positioning system. Signal strength of the first beacon proved inadequate and a 13.5 kHz beacon with a single battery was dropped within the first hour.

Efforts were then concentrated on final stages of assembly of the re-entry cone, a five meter diameter by four meter high inverted cone with three acoustic reflectors spaced equidistantly around the circumference. All joints of the cone assembly were welded, wire cables were attached between the drop away pad-eyes and the cone base for additional strength and doubled lifting slings were attached to each of the drop away pad-eyes. A 50-foot sling was also attached to the top of each doubled lifting sling to allow the keelhaul lines, secured to the port rail, to be shackled into the loose ends of the 50-foot slings as the cone was lowered over and swung to the port rail at midship. The whip line of the 50-ton crane was attached to the doubled slings and the cone was lowered over the port side. The upright cone was momentarily buoyant until filled with sea water through the 16-inch opening in the base and the cuttings discharge slots in the lower apex of the cone. During the short period of buoyance, the cone surged heavily in the eight to ten foot swells. The surging fouled one of the 50-foot slings, to be attached to a keelhaul line, around one of the cones acoustic reflectors. The cone was raised back to the surface to facilitate unfouling of the 50-foot sling. A large swell surged the water filled cone making it extremely dangerous for equipment and personnel. Instead of lowering the cone below the wave action for reassessment of the situation, the cone was swung away from the ship at surf level and the next swell broke the whip line dropping the cone.

The Glomar Challenger was then positioned to the east with a 1,000 foot offset.

Twelve hours were required to assemble and weld the standby cone, which was completed at 01:00 hours. However, the sea state had further deteriorated and swells were then ten to 12 feet with an occassional 14-foot swell. It was then decided to rig the cone for keelhauling in a horizontal position. This necessitated new rigging of some of the keelhaul lines and structural reinforcement of the cone. Six hours were required to weld three-inch x 1/4-inch angle iron braces around the mid-section of the cone and to reinforce and add pad-eyes to one of the vertical (base and rim) members. All joints of the cone assembly were welded. By 14:00 hours on December 16, the sea had abated slightly with swells estimated at ten to 12 feet and the decision was made to keelhaul the cone. The cone was rigged, picked up by attaching the block of the 50-ton crane to short slings fastened to the vertical member of the cone by attaching the whip line to doubled keelhaul slings on the fall away pad-eyes. The cone was raised vertically with the ship line and then the load was transferred to the block to turn the cone in a horizontal position and swing it to the port side. The cone was then brought to rest against the casing rack main deck and port rail where the whip line was disconnected from the keelhaul slings and attached to the vertical member. The keelhaul lines were shackled to the keelhaul slings and the block was disconnected from the vertical member. The cone was then picked up with the whip line, swung over the port side at midship and lowered into the water while slack was kept out of the keelhaul lines with the travelling block. The cone was lowered smoothly without buoyant effect or surging until the whip line hook was level with the main deck rail. After determining that the keelhaul lines were taut, an eye of the doubled line from the whip line hook to the horizontal slings was cut and the cone swung to the vertical position under the moon pool and the doubled lines attached to the fall away pad-eyes of the cone could be shackled into hangoff lines attached to the rotary beams. The weight of the cone was then transferred from the keelhaul lines to the hangoff lines and the keelhaul lines were disconnected. Good visibility existed below the moon pool and the cone appeared to be in perfect position with no handling damage and with no fouling of lines. One and one half hours had elapsed from cone pick up until it was secured on the hangoff lines at the moon pool. Another one and one half hours were required to rig down the keelhaul equipment and rig up to run the 13 3/8 inch casing.

The casing string consisted of a Baker guide shoe, muleshoed at a 30 degree angle to facilitate stabbing the casing through the base of the cone, four joints of 13 3/8 inch outside diameter, J-55, 54.5 ft/lb buttress casing, and a casing hanger to latch into the base of the cone by means of spring loaded snap ring segment. All joints were thread locked and the casing was run and hung off on a spider and elevators setting on top of the hyperbolic guide cone at main deck level. Overall measurement of the casing assembly was 49.36 meters.

The bottom hole assembly was then run as follows. A (10 1/8 inch x 2 7/16 inch Smith four-cone tungsten carbide insert) core bit, one 8 1/2 inch outer core barrel, four 8 1/2 inch drill collars, and latch sub with profile locator sub on top were made up and run inside the 15 3/8 inch casing. Overall measurement of the jetting assembly was 46 meters. A lucite packoff was placed around the drill collars immediately below the latch sub and the latch sub was landed inside the casing hanger. The "dogs" or "gates" of the casing hanger were engaged with the latch sub. The Baker shifting tool was then made up and run on sandline for a satisfactory trial disengagement of the latch sub from the casing hanger. The latch sub was again engaged with the casing hanger and the casing and jetting assembly were lowered until the casing hanger latched into the base of the re-entry cone by means of snap ring segments engaging in a snap ring groove machined in the bottom of the casing hanger. The weight of the re-entry cone and casing string was 15,000 pounds.

After engagement of the casing hanger in the face of the re-entry cone, the weight of the re-entry cone was transferred to the bottom hole assembly and the doubled keel-haul slings, attached to the fall away pad-eyes of the cone, were cut and stripped through the fall away pad-eyes.

The remainder of the bottom hole assembly was run above the latch sub and consisted of one Baash-Ross bumper sub, three 8 1/4 inch drill collars, two Baash-Ross bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar, and one joint of heavy wall five-inch drill pipe. The entire assembly, casing, re-entry cone, and bottom hole assembly, was lowered on drill pipe until sea floor was tagged at 3957 meters by drill pipe measurements which corresponded to 3949 meters measured by the precision depth recorder from the rotary table.

The casing was then jetted into the sea floor to place the shoe at 3998 meters, with the base of the cone at 3950 meters and the top rim and reflectors of the cone at 3946 meters by drill pipe measurements. Jetting required 90 pump strokes per minute (720 gpm) and 15,000 to 20,000 pounds weight for the final ten meters penetration, indicating a fairly firm bottom for the casing seat.

The latch sub was then disengaged from the casing hanger by running the Baker shifting tool on the sandline and engaging the sliding sleeve of the latch sub. The sliding sleeve in the latch sub had six lug nuts that held the three, spring-loaded, hinged gates of the casing hanger in recesses of the latch sub when the sliding sleeve was in the "down" position. When the sleeve was shifted to the "up" position, the lug nuts on the sleeve matched with notches in the hinged gates, allowing the spring-loaded gates to swing on their hinge pins into recesses in the casing hanger. This released the latch sub from the casing hanger, which released the bottom hole assembly from the cone and casing. Two hours were required to run the shifting tool and release the latch sub, of which one half hours was spend in reciprocating and torquing the drill pipe after the sleeve was apparently shifted to the "up" position. Up to 25,000 pounds of pull and weight were alternately put on the latch sub along with alternate applications of right hand and left hand torque. Ultimately, the latch sub was released and the shifting tool was retrieved. Difficulty was encountered with the shifting tool hanging up during retrieval. Examination of the shifting tool, after retrieval, indicated that one of the three profile keys had broken and was apparently hanging in the tool joint recesses.

After release of the casing and cone, drilling with minimal circulation proceeded from 3998 to 4045 meters without difficulty. From 4045 meters a routine drilling and coring procedure was carried out to a depth of 4650 meters for 701 meters of penetration. The formation consisted of ooze,chalk,chert, marl, and limestone. Elapsed time, after release of the latch sub, was 86.5 hours and the bit had accumulated 29.8 rotating hours. This was estimated to be 70 to 75 percent of the maximum bit life and it was decided to pull out of the hole and replace the bit as a precautionary measure, even though no evidence of bearing failure had been indicated by the torque level.

The hole was filled with 10.0 pounds per gallon mud and over-displaced by approximately 50 barrels to clean the hole of cuttings. The bit was pulled up to 3960 meters and it was decided to run the Edo sonar scanning transceiver to scan for the re-entry cone as the bit was pulled above the cone. However, two attempts to run the Edo transceiver were aborted at approximately 800 meters depth due to an electrical short in the Schlumberger cable head. Since several hours were required to rehead the Schlumberger cable, the idea of scanning for the re-entry cone, as the bit was pulled above it, was abandoned.

At this point, the 16.0 kHz acoustic reference beacon signal strength became erratic and a 13.5 kHz beacon and battery were dropped.

The trip out of the hole was made and the latch sub, with profile locator sub, was removed from the string. Examination of the latch sub indicated no damage. The bit was dull graded as T-1, B-5, IG.

A new (Smith 10 1/8 inch x 2 7/16 inch four-cone tungsten carbide insert) core bit was made up on the bottom hole assembly consisting of the following. Outer core barrel, core barrel latch sub with special bore (3.87 inch inside diameter latch sub sleeve for 3 1/2 inch Baker seal nipple, jet sub with sleeve in "down" (open) position profile locator sub, four 8 1/2 inch drill collars, one 8 1/2 inch bumper sub, three 8 1/2 inch drill collars, two 8 1/2 inch bumper subs, two 8 1/2 inch drill collars, one 7 1/2 inch drill collar, and one joint of heavy wall five-inch drill pipe. The bit was run to 3937 meters and spaced out to permit lowering to 3957 meters on re-entry.

The Edo sonar scanning transceiver with a 45-degree scanning head and bore plugger, were run on the Schlumberger cable and the re-entry cone was located 300 feet from the bit. The ship was maneuvered in the automatic mode by manually dialing 100-foot offset commands into the computer of the dynamic positioning system to place the bit at approximately 70-foot range to the cone. Attempts to move the bit nearer to the cone with the jet sub were unsuccessful. Displacement of the bottom hole assembly with the jet sub was, at most, 15 to 20 feet using 600 gpm and 1,000 psi maximum pump pressure with the 0.75 inch diameter jet. Rotation of the drill pipe to various quadrants with jetting resulted in average range variations of 50 to 90 feet. After approximately two hours, jetting was discontinued and the semi-automatic and manual modes of operation were attempted to maneuver the ship over the cone. After approximately two hours of semi-automatic and manual modes of operation without success, the mode of operation was returned to automatic and various combinations of offsets and water depth adjustments were utilized to maneuver the ship over the cone. Apparent re-entry was accomplished after 13 hours, at 06:58 hours on December 23, 1970, as the drill pipe was lowered to 3957 meters.

The sonar transceiver and bore plugger were retrieved. The drill pipe was lowered 41 meters to 3997 meters with negligible weight on the bit. Vessel heave, estimated at five to six feet, made it difficult to monitor any significant weight and the re-entry was thought valid. The Baker shifting tool was run to close the sleeve of the jet sub. The bore plugger, with Baker seal nipple, was run to pressure test the drill string to insure closure of the jet sub. A pressure test could not be obtained and the bore plugger was pulled. The check valve of the bore plugger was modified and the bore plugger was rerun. Again, a pressure test was not obtained. The bore plugger was pulled and the shifting tool rerun. The shifting tool momentarily hung in the jet sub sleeve but was worked loose with reciprocation. On retrieval, another profile key of the shifting tool was found broken. The bore plugger, with Baker seal nipple, was rerun, a satisfactory pressure test of 2,000 psi was obtained, and the bore plugger was retrieved.

The inner core barrel was dropped and the drill pipe was lowered from 3997 to 4044 meters with 2,000 to 5,000 pounds weight on the bit. A core was cut at 4044 to 4053 meters and relatively undisturbed sediment was recovered, confirming that a misstab had occurred.

The drill pipe was pulled above the mud line and spaced out to put the bit at 3937 meters. It was decided to attempt the re-entry without jetting. This eliminated the need for the power sub and swivel and it would permit a 29 meter stroke for re-entry. The Edo sonar transceiver, with the 60-degree scanning head, was run. It apparently encountered a soft sediment plug at the bit since the only scan pattern monitored was similar to that monitored inside the drill collars. Since the swivel and power sub were not on the drill pipe there was no means of circulation without pulling the wireline. Shaking the drill pipe and spudding the Edo transceiver proved unsuccessful. Eventually, all scan was lost indicating the scanning head had probably broken off. The Edo transceiver was recovered and the loss of the scanning head was confirmed.

At this point, it was decided to pull the drill pipe since it was impossible to determine if the transducer head was lodged at the bit. It was also decided to remove the jet sub from the drill string since the negligible benefit gained by jetting did not justify the difficulty caused by having the jet sub in the string.

A round trip was made with the drill pipe. No evidence of plugged bit or scanning head was found. The jet sub and profile locator sub were removed from the bottom hole assembly. The bit was spaced at 3947 meters and the swivel and power sub were installed. The Edo sonar transceiver, with the 45-degree scanning head, was run without the bore plugger. The re-entry cone was located at an average range of 95 feet from the bit. A systematic procedure, using automatic mode of operation, various combinations of offsets, water depth adjustments, and plotting average ranges and average bearings, proved highly successful in maneuvering the bit to within 40 feet average range. At this point, no combination of offset or water depth adjustment was effective in closing the range. It was concluded that the bit was at an excessive height above the re-entry cone. The bit was lowered in two meter increments to 3955 meters, as offset and water depth adjustments were made to close the range to within 18 or 20 feet. At this point, the bit was making a slow oscillation across the cone and the drill string was lowered to coincide with the bit being centered over the cone. As the bit was lowered from 3955 to 3964 meters, it suddenly took weight at 3961 meters and had 12,000 pounds weight at 3964 meters. Torque prevented rotation of the drill string. It was theorized that the bit had entered the cone at an angle and slid down the cone wall, lodging against the opposite side at the base of the cone. Based on this assumption, the drill pipe was picked up to 3961 meters at which point all the weight was off the bit, the drill string was rotated without torque, and the bit was lowered without weight to 3968 meters at 05:30 hours on December 25, 1970. Elapsed time from initial scan to re-entry was 2.5 hours. After recovery of the Edo transceiver, the bit was raised to 3964 meters to make a connection. Three doubles of drill pipe (56 meters) was run in the hole to lower the bit to 4021 meters without evidence of weight. The power sub and swivel were set back and the drill pipe was run into the hole, without obstruction, to 4635 meters where bottom fill was encountered. The fill was washed out to 4650 meters where hard bottom was encountered.

Continuous coring was resumed at 4650 meters and continued to 4711 meters total depth for 61 meters of additional penetration and a total penetration of 762 meters. The hole was terminated in diabase with 0.7 meter per hour penetration rate.

After two unsuccessful attempts to take sidewall samples due to an apparent obstruction at the bit preventing the sidewall samples from extending through the core bit, the hole was filled with 10.0 pounds per gallon mud and the drill string was pulled. Inspection of the second core bit revealed that it was virtually destroyed after 61 meters penetration in 17.1 rotating hours. One cone was gone, two of the remaining three cones were locked, all three cones had skidded, and inserts were broken on the remaining three cones. The cones were also pinched, which had prevented the sidewall sampler from extending through the core bit. It should also be noted that excessive torque, although unexplainable at the time, had been experienced throughout the second bit run.

A total of 295.5 hours had elapsed from launch of the first beacon to departure from the site.

From the above observations, of the second bit, and from the firm obstruction encountered at the base of the re-entry cone on re-entry, it must be concluded that the second bit was damaged at re-entry and the damage was most probably a pinched cone, or cones, resulting in cone mis-alignment and roller cone interference.

If the above conclusion is valid, it must also be concluded that the re-entry cone and casing settled at least 11 meters. This observation and conclusion is substantiated by the fact that the top of the re-entry cone was released at 3946 meters, with the base at 3950 meters. However, on the valid re-entry, the bit was lowered from 3947 to 3955 meters while scanning continued, which placed the cone rim at some depth below 3955 meters. Also, if the obstruction encountered at 3961 meters were the base of the cone the top of the cone would have been at 3957 meters which coincides with the mud line by drill pipe measurements. And, if the rim of the cone were at the mud line partially or wholly obscured with sediment, it could account for the sonar transceiver never picking up the cone rim as was done on the experimental re-entry. Only the three acoustic reflectors, which are approximately one foot higher than the cone rim, were picked up by the sonar transceiver on re-entry of Site 146.

Assuming the above conclusions are valid, the first re-entry attempt could have been a technically valid re-entry. But, due to cone settling and drill pipe spacing, which allowed a net stroke from 3937 to 3957 meters, the bit could not be lowered enough to keep it inside the cone.

DISCUSSION OF EQUIPMENT AND PROCEDURES

RE-ENTRY CONE (Photos No. 1 and No. 2)

The re-entry cone is basically adequate and requires no major revisions. Minor modifications are suggested as follows:

1. Bearing area needs to be incorporated into the base of the cone. The three main members on the base of the cone should be extended to provide an eight to ten foot radius circle and the area between the main members should be covered with light gauge steel plate. This would require only angle iron bracing between the main members to which 1/8 inch to 1/4 inch steel plate is welded. The fabrication can be done aboard ship. This would place the bearing area of the cone below any cuttings discharge ports. With the present cone, the cuttings discharge slots in the apex of the cone tend to erode any bearing area as the cone settles into the sea floor. It is doubtful that the frictional forces on the casing are adequate to support the combined weight of casing and cone in the soft sediments. On Site 146, it was definitely established that the cone and casing assembly settled approximately 11 meters. The settling of the cone and a lack of correlation between cone depth and drill pipe measurements were the primary factors contributing to the misstab in the first re-entry attempt. The drill pipe was simply spaced too high to permit it to stab into the cone as it was lowered from 3937 to 3957 meters, since the top of the cone had settled from 3946 to 3957 meters by drill pipe measurements. The final depth for the top of the cone also coincided with the drill pipe measurements for the mud line. Aside from the depth correlations that were established on the second re-entry attempt, the cone settlement was further substantiated by the fact that the sonar transceiver never provided a reflection of the cone rim as was done on the experimental re-entry in June 1970. Only the three acoustic reflectors, which are approximately one foot higher than the cone rim, were detected by the sonic transducer on Site 146. This fact substantiates that the cone rim was at the mud line and covered with sediment and cuttings. It is conceivable that, without adequate bearing at the cone base, settling of the cone and casing could be severe enough to bury the acoustic reflectors which would preclude re-entry.

2. The cuttings discharge slots at the apex of the cone used for Site 146 are probably ineffective due to the relatively large cuttings that are developed from fast penetration and the use of salt water as the circulating fluid. However, if the present cuttings discharge slots were significantly widened they would provide a potential snag for the bit cones at stab-in. It is

recommended that the cost and machined base of the cone be lengthened to provide room for approximately four four-inch diameter discharge ports at the base of the cone above the casing hanger and above the recommended bearing plate. These could be added for negligible cost and without significant reduction in structural strength of the cone base. The existing cone slots can be retained in the lower part of the cone apex and may be beneficial in discharging the smaller cuttings.

3. The acoustic reflectors, with their present angle iron bracing and lack of streamlining, present a potential source for snagging of keelhaul lines. It is also conceivable that the bit could be lowered between the reflector and the outside rim of the cone on a misstab. It is recommended that plate material be used to brace the reflectors to the top of the cone and that it be streamlined around the reflector to eliminate potential snags for keelhaul lines. The plate will also eliminate the possibility of a misstabbed bottom hole assembly going between the cone on the reflector which could seriously damage the reflector, the guide cone, or the bit.

4. After loss of the first cone launched in the normal upright position, the side or horizontal launch of the second cone proved very effective in eliminating the buoyant effect and in getting the cone below wave action in minimum time. The cardinal rule for keelhauling any object in significant seas is to get it through the surf as quickly as possible and keep it there. However, the side launch does require structural reinforcement on the vertical member used for lifting and at the midsection to prevent possible collapse. The side launch also required that the cone be picked up then turned to the horizontal position and set down while the block is removed and the whip line is attached to the horizontal left slings and the keelhaul slings are shackled to the keelhaul lines. The required turning and handling presents a serious hazard to personnel, expecially if vessel motion is of significant magnitude. The side launch keeps the top of the cone leading in the proper direction at all times, which reduced potential line fouling as compared to the upright launch. However, an inverted launch would provide all the advantages of the side launch. There would be no buoyant effect, the possibility of line fouling is even further reduced, the cone doesn't require turning, assuming the cone was assembled in the inverted position and bearing plate is fabricated aboard ship, which reduces the handling hazard to personnel, the necessity for changing from block to whip line is eliminated which reduces personnel exposure, the requirement for additional structural reinforcement is eliminated and a time saving would be realized. In summary, the side launch is preferable to the up right launch, however, the inverted launch appears to offer some advantages over the side launch and should be considered in the future.

CASING HANGER (Photos No. 3 and No. 5)

The casing hanger required modification of the hinged gates. The gates were initially fabricated with a significant bevel on the leading edge to assist with release from the latch sub. However, on assembly and testing the bevel proved to be too great and allowed the gates to turn out of the latch sub with right hand rotation similar to gear tooth action. Consequently, the gates were built up and squared off on the leading edge. Otherwise, no difficulties were encountered. The snap ring groove for latching the hanger into the base of the re-entry cone was effective and satisfactory.

LATCH SUB (Photos No. 4 and No. 5)

Although the latch sub did provide a mechanical release between the casing and cone assembly and the jetting string, the releasing action is not positive enough, as was noted in the operational discussion. Approximately 30 minutes of torquing and reciprocation of the drill pipe along with several passes of the shifting tool to shift the latch sub sleeve, was required to release the latch sub. The difficulty apparently is due to the following causes:

1. The present (Baker) shifting tool automatically releases the shifting dogs from the sleeve when the sleeve reaches the limits of its' "up" travel.

2. The latch sub had no means of holding the sleeve in the "up" position once shifted and upon release of the sleeve by the shifting tool gravity causes the sleeve to instantaneously drop to the "down" position.

3. In assembly and pretesting of the latch sub, it was noted that the gates of the casing hanger would disengage instantaneously if the alignment between the latch sub and casing hanger was perfect and if they were in a neutral weight position. If there was mis-alignment or differential weight between the latch sub and casing hanger, the frictional force on the tops or bottoms of the gates was sufficient to prevent one or more of the gates from swinging out of the latch sub into their respective hanger recesses. The latch sub sleeve would then fall back to the "down" position and the lug nuts locked the remaining gate or gates in the engaged position.

4. If the latch sub sleeve was momentarily held in the "up" position by the shifting tool, the application of right hand torque pivoted the gates out of the latch sub recessed into their casing hanger recesses to release the latch sub.

Since it is virtually impossible to obtain perfect alignment and zero differential weight at depth, the frictional forces on the gates held them in place and the latch sub sleeve fell back into "down" position before torque could be applied. Only through repetitive shifting of the sleeve and repetitive applications of torque and reciprocation was it possible to pivot all of the gates into their hanger recesses and release the latch sub from the casing hanger and cone assemble.

In view of the above, the following recommendations are made:

1. Modify the latch sub sleeve with a collet, or snap ring latch which will hold it in the "up" position, once shifted, until torque can be applied to pivot the gates back into their casing hanger recesses.

2. An alternate would be to provide a shifting tool which would not release automatically at the upper limit of travel until additional force was applied to release the shifting dogs. This would also permit the latch sub sleeve to be held in the "up" position until torque could be applied to pivot the gates.

The latch sub was also designed with two alternate means of release, namely, a "J" slot arrangement and an explosive bolt arrangement. The "J" slot arrangement requires a round trip and re-entry after release of the casing and cone assembly. Thus, it is the least desirable method due to the additional rig time required. The explosive bolt arrangement was not tested due to the unreliability of the present acoustic equipment required to detonate the explosive bolts. If a reliable acoustic system is developed the explosive bolt should provide the most positive release mechanism.

ANNULAR PACKOFF FOR JET STRING

The lucite packoff was too fragile and it was fabricated with a square, full diameter base which made it extremely difficult to stab into the casing hanger with the relative motion existing between the jetting string and the casing string. A segmented, wrap around packoff with tapered base similar to a wrap around casing or tubing hanger is preferable. It could be made of cast aluminum hard moulded rubber or bakelite and a rubber insert. A packoff is desirable to eliminate annular flow between the jet string and casing. Even minor annular flow can carry drill solids that could settle around the latch sub difficult or impossible. If fabrication of a packoff developes to be difficult and/or expensive, a satisfactory packoff can probably be accomplished with "soft-line" and "rags" in view of the restricted flow area around the latch sub and the low differential pressure involved.

BAKER SHIFTING TOOL (Photo No. 6)

Although the Baker shifting tool accomplished the assigned tasks, it is considered unsatisfactory and should be modified or replaced with a more reliable and more "positive" tool. Difficulty experienced with the shifting tool is as follows:

1. The tool is designed to automatically release the shifting dogs once the sleeve travels its' limit. This type of tool doesn't provide a positive surface indication that the sleeve has been shifted.

2. The profile locator keys were inadequately secured in the body of the tool, which would let the keys turn along their longitudinal axis. The protrusion of the turned key caused the tool to hang in tool joint recesses. The profile locator keys were extremely brittle, which caused several keys to break at their minimum cross sectional area.

Another shifting tool needs to be provided for shifting the latch sub and jet sub sleeves. The design of the tool should incorporate a means of providing a more positive indication at the surface when the sleeve has shifted. Namely, a tool which will engage the sleeve, shift the sleeve, and then release only with the application of additional force which will "cam" or shear a pin to let the shifting keys recess into the mandrel.

JET SUB

The jet sub consisted of a drill collar sub with a 0.75 inch diameter jet port and sliding sleeve. A profile locator sub was run on top of the jet sub for locating the Baker shifting tool. The jet sub was designed to provide lateral displacement of the drill string with jump pressure and to control the direction of the lateral displacement by rotation of the drill string. As mentioned in the operational discussion, the jet sub was ineffective in providing significant lateral displacement of the drill string. In view of its' ineffectiveness and in view of the ability to maneuver the ship to place the bit over the guide cone, the jet sub is not considered necessary for re-entry. The elimination of the jet sub from the re-entry system eliminates the necessity for a bore plugger on top of the Edo transceiver which reduces wireline time for running the Edo transceiver by an estimated 50 percent. It also eliminates the necessity for a wireline trip with the shifting tool to close the jet sub sleeve following stab-in and it eliminates a wireline trip with the bore plugger to pressure test the drill string to assure that the jet sub was ineffective, it complicates the re-entry procedure and it consumes a significant amount of time.

INDEXING SUB

An indexing sub was designed to orient the Edo transceiver and bore plugger so as to align and hold the Edo transceiver in a fixed and relative position with the port of the jet sub. On the experimental re-entry, the Edo sonde reportedly turned inside the drill collars which prevented the establishment of a reliable relative bearing reference. On pretest of the indexing sub, it was ineffective in orienting the sonde. The indexing lug on the bore plugger mandrel was spring loaded and the spring did not have sufficient compressional force to keep the lug protruded when it contacted the indexing incline in the sub. The indexing incline also appeared to be of inadequate length. Consequently, there was no attempt to index the transciever on the re-entry work of Site 146. Also, there was no evidence of the transceiver rotation inside the drill collars. If the transceiver is allowed to rest on the face of the core bit, it is inconceivable that the transceiver could rotate considering its' weight and assuming there is ample slack in the conductor cable. Therefore, it doesn't appear that indexing of the Edo transceiver is necessary and it is recommended that further efforts toward development of an indexing sub be discontinued.

BORE PLUGGER (Photos No. 7 and No. 8)

Two types of bore pluggers were provided. One was fabricated from a conventional Baker seal nipple assembly and packed off in a special bore (3.87 inch inside diameter) latch sub sleeve for the inner core barrel. The other consisted of a packer cup and tapered mandrel which packed off against the drill collar wall as the mandrel weight and fluid pressure forced the tapered mandrel inside the cup. With minor modification of the check valves for fluid by-pass while running, both tools performed satisfactorily holding 2,000 psi maximum pressure. The bore plugger is run on top of the Edo transceiver to packoff below the jet sub and permit jetting. It was also used, without the Edo transceiver and spaced out with inner core barrel sections, to obtain a pressure test of the drill string to assure that the jet sub sleeve was in the closed position.

EDO SONAR SCANNER (Photos Nos. 9, 10, 11, 12)

The sonar scanner worked satisfactorily. The only failure experienced on Site 146 was the breaking of a scanning head when it was attempted to spud the tool through a soft sediment plug in the bottom of the drilling assembly. Both the apparent and the valid re-entries were made using the 45-degree scanning head. However, it appears that the 60-degree scanning head would be more appropriate for most re-entry attempts. Although the horizontal range is slightly reduced, the 60-degree head provides a vertical plane scan-sector of 15 to 75 degrees from horizontal. Therefore, using the 45-degree scan head can result in a 15-degree "blind spot" when the scan head is directly above the re-entry cone. A 60-degree scan head should be procured to replace the one lost and it should be the primary tool with the 45-degree head serving as the stand-by head.

MANEUVERING OF SHIP

The re-entry, both valid and apparent, made at Site 146 was accomplished by maneuvering the ship to place the bit over the cone. This was also the case with the experimental re-entry. A giant step was made in the progress of maneuvering the ship on Site 146 with the development of a systematic procedure where the automatic mode of operation, offsets, and water depth adjustments were used with plotting of all ship movements and average range and bearings of the target for each movement. This method permits an expedient and systematic method of maneuvering the bit over the target. This technique is described indetail in Attachment III. Although the semi-automatic and manual modes of maneuvering were traced briefly in the false re-entry attempt, these attempts were too hurried and weren't systematically plotted. Although the automatic mode described above would appear to cover all conceivable circumstances, there just isn't enough experience, to date, to make this a valid conclusion. However, from using this technique with automatic mode of operation, it would appear that re-entry could be accomplished in approximately three hours after the target has been located by the sonic transducer, therefore, with elimination of the jet sub and bore plugger, future re-entry could conceivably be accomplished in six to eight hours plus trip time, allowing two hours for rig up and running of the streamlined sonic transducer, three hours for maneuvering and two hours to retrieve and rig down the sonic transducer.

DEPTH CORRELATION REQUIRED BETWEEN CONE AND DRILL PIPE MEASUREMENTS

As mentioned earlier, settling of the cone and the casing assembly between time of release and re-entry attempt probably caused the false re-entry on Site 146 and it is anticipated that this will be the usual phenomenon although the recommended addition of a bearing plate on the cone base should reduce the amount of settling. Thus, a real need exists for adequate correlation of drill pipe measurements with the casing and cone assembly. It appears that such a correlation could be obtained economically and expediently with a conventional 2 1/8 inch outside diameter or 1 11/16 inch outside diameter magnetic collar locator survey on the Schlumberger line just prior to the drill bit being pulled from the hole. If the bit were pulled to within approximately 20 meters of the top of the hole, the collar locator survey should identify the bottom of the drill collar assembly and identify one or more collars of the 13 3/8 inch casing. If the collar locator survey proved inadequate in the large diameter casing, the use of a radioactive marker in both casing string and drill collar string along with a small diameter gamma sonde should definitely accomplish the task. Once this correlation is established, the round trip for a new bit is completed and the bit can then be accurately placed eight to nine meters above the top of the cone for re-entry.

It would also be of assistance to accurately correlate sea floor depth with drill pipe measurement. Generally there is five to 15 meters discrepancy between drill pipe measurements and precision depth recorder measurements. This always poses the questions of how far has the drilling or jetting assembly penetrated the soft sediments prior to measurable indication on the weight indicator and at what depth should the casing and cone assembly be released to put it at mud line. It was probably coincidence, but on Site 146 the drill pipe measurement with the casing and jetting string tagged bottom at 3957 meters, which was generally accepted as the mud line after the valid re-entry. Also, experience may prove that release of the cone at the precision depth recorder measurement, which is generally a few meters less than drill pipe measurements, is adequate. If the cone is released a few meters high and allowed to settle to the ocean floor, it only affects the reference for re-entry measurements, which can be checked with the collar locator survey as described above. However, it may be desirable to acquire a narrow-focus, vertical-beam transceiver head which could be run to the bottom of the jet string and casing assembly. This survey would provide a return from the sea floor as the jet string and casing assembly are lowered to within 30 meters of bottom to provide an accurate depth correlation between mud line and drill pipe measurements. This would assure that the cone is released at the mud line.

POSITIVE DETERMINATION OF VALID RE-ENTRY

A positive indication of re-entry is required. This may be done by a simple mechanical means such as a shear pin centralizer or a shear pin stablizer, which will give a surface indication on the weight indicator when the bit passes through the casing hanger. Also, with experience, a difference of scan pattern between drill collar and 13 3/8 inch casing may be detectable. If the re-entry is valid lowering the transducer to read the casing scan would identify a valid re-entry. If the re-entry is a misstab it would appear that the soft sediment in the drill collars would hold the transducer up in the drill collars providing only the drill collar scan. This technique was not evaluated on Site 146.

CASING PROGRAM

The 50 meters of casing used on Site 146 was adequate. Hole stability in most areas is surprisingly good and it is doubtful if additional casing will prevent settlement in the soft sediments generally encountered without cementing. Since the purpose of the casing is to provide a stable conduct through the very soft sediments at the mud line and to keep the cone properly oriented, it would appear that 30 meters would be adequate in most cases. As mentioned previously, it is doubtful if the frictional forces developed around the casing in soft sediment provide appreciable vertical support to the casing and cone assembly. If the recommended addition of bearing area to the base of the cone is effective in preventing settling of the cone assembly, 30 to 40 meters of casing should adequately stablize the top of the hole and keep the cone properly oriented. Also, most areas will permit jetting of 30 to 40 meters of casing based on project experience to date and on the profile data taken at each site.

ATTACHMENT I

SITE 146 - RE-ENTRY SITE

DRILLERS LOG

December 15, 1970

00:00 to 09:30	Enroute from Curacao to Site 146. Beacon away at Site 146 at 09:30.
09:30 to 12:00	Assemble and weld re-entry cone reflectors.
12:00 to 13:00	Attempted to keelhaul cone. Keelhaul line fouled on reflector. Raised cone to surf to unfoul keelhaul line. Swell (eight to ten feet) surged cone and broke crane whip line. Dropped cone.
13:00 to 24:00	Assemble, reinforce, and weld stand by cone for keelhauling. Rig up to launch cone on its side to reduce surge effect.

December 16, 1970

00:00 to 08:00	Finish assembly of cone and welding of connections while waiting on weather. Swell of ten to 14 feet.
08:00 to 14:00	Rig up to keelhaul cone on its side.
14:00 to 15:30	Keelhauled cone in ten to 12 foot seas.
15:30 to 17:00	Rig down keelhaul equipment and rig up to run casing.
18:00 to 20:30	Run four joints 13 3/8 inch casing with muleshoe and casing hanger (49.36 meters) and land on elevators at moon pool.
20:30 to 24:00	Space drill collars inside casing (46 meters), make up casing hanger latch sub and test operate same. Assemble latch sub to casing and lower casing and hanger to latch up into re-entry cone.

December 17, 1970

00:00 to 01:30	Cut keelhaul lines to re-entry cone and run remaining drill collar of bottom hole assembly.

01:30 to 10:00	Run in hole with drill pipe, bottom hole assembly, casing and re-entry cone.
10:00 to 10:30	Rig up Bowen power sub.
10:30 to 14:30	Work on power unit of Bowen sub. Found safety switch on rig floor in "off" position. Circulate through drill pipe and bottom hole assembly.
14:30 to 15:00	Tag bottom at 3957 meters. Drill pipe measurement. (3949 meters PDR.)
15:00 to 15:30	Jet casing setting shoe at 3988 meters, base of re-entry cone at 3950 meters and top of cone at 3946 meters.
15:30 to 17:30	Run in hole with shifting tool. Shifted sleeve in latch sub and released latch sub from casing hanger.
17:30 to 19:00	Pull out of hole with shifting tool. Had to pull sandline slow due to shifting tool hanging up in drill pipe while pulling out of hole.
19:00 to 20:00	Wash and rotate from 3988 to 4045 meters.
20:00 to 21:00	Core No. 1 cut from 4045 to 4054 meters with eight meter recovery.
21:00 to 23:00	Drill with center bit from 4054 to 4203 meters.
23:00 to 24:00	Retrieve center bit.

December 18, 1970

00:00 to 02:00	Cut core No. 2 from 4203 to 4212 meters. Recovered nine meters.
02:00 to 06:30	Drill with core bit from 4212 to 4355 meters.
06:30 to 09:00	Cut core No. 3 from 4355 to 4362 meters with zero recovery.
09:00 to 24:00	Cut core No. 4 from 4362 to 4416 meters.

December 19, 1970

00:00 to 24:00	Cut cores No. 10 through No. 22 from 4416 to 4533 meters.

December 20, 1970

00:00 to 24:00 Cut cores No. 23 through No. 32 from 4533 to 4623 meters.

December 21, 1970

00:00 to 09:30 Cut cores No. 33 to No. 35 from 4623 to 4650 meters.

09:30 to 11:00 Circulate and fill hole with 250 barrels of 9.8 pounds per gallon mud, with bit at 4650 meters.

11:00 to 12:30 Rig down power sub and pulled out of hole to 4050 meters.

12:30 to 13:00 Spot 100 barrels of 9.8 pounds per gallon mud.

13:00 to 13:30 Pull out of hole to 3960 meters.

13:30 to 15:00 Rig up Schlumberger unit and Edo sonic tools.

15:00 to 17:00 Run Edo to 800 meters. Edo quit functioning.

17:00 to 18:30 Rig down Edo. Drop 16.0 kHz beacon to replace 13.5 kHz beacon.

18:30 to 24:00 Pull out of hole for new bit.

December 22, 1970

00:00 to 02:00 Finish pulling out of hole.

02:00 to 04:00 Lay latch sub out of bottom hole assembly. Pick up jet sub and make up in bottom hole assembly. Operate jet sub sleeve with shifting tool - okay. Change bit.

04:00 to 11:00 Run in hole.

11:00 to 11:30 Slip drill line.

11:30 to 12:00 Rig up Bowen power sub.

12:00 to 12:30 Go in hole with power sub.

12:30 to 14:30 Rig up Schlumberger unit and Edo tool.

14:30 to 18:00 Run Edo to bottom of drill pipe.

18:00 to 24:00 Scanning with Edo and attempting to position ship over cone.

December 23, 1970

00:00 to 07:00 Maneuvering ship in various modes and jetting to position bottom hole assembly over re-entry cone. Made apparent re-entry at 06:58.

07:00 to 09:00 Recover Edo tool and rig down Edo tool.

09:00 to 09:30 Lower drill pipe 40 meters without taking weight.

09:30 to 12:30 Run in hole with sandline and shifting tool to close sleeve of jet. Shifting tool dragging coming out of hole.

12:30 to 14:00 Run bore plugger with Baker seal sub on sandline and pressure tested jet sub. Failed to hole pressure. Jet sub open.

14:00 to 18:00 Retrieve, modify and rerun bore plugger and test jet sub. Failed to get satisfactory pressure test.

18:00 to 19:30 Rerun shifting tool and attempted to close jet sub sleeve. Shifting tool momentarily hung in jet sub retrieved same. Profile key missing from shifting tool.

19:30 to 21:30 Run bore plugger (Baker Seal) and pressure tested drill pipe with 2,000 psi. Jet sub sleeve closed.

21:30 to 22:00 Drop core barrel and wash 3995 to 4044 meters with 2,000/5,000 pounds weight on bit.

22:00 to 24:00 Core from 4044 to 4053 meters and recover undisturbed sediment indicating not stabbed in old hole.

December 24, 1970

02:00 to 08:00 Run in hole with Edo. Unable to get Edo out bottom of drill pipe trhough bit. Worked pipe and spud Edo without success indicating bit plugged. Pull out of hole with Edo and found 60 degree transducer broken off and left in hole.

08:00 to 09:00 Rig down Edo and Schlumberger.

09:00 to 14:00 Pull out of hole with drill pipe. Slip drill line.

14:00 to 15:00 Set back bottom hole assembly and removed jet sub from string.

15:00 to 15:30 Rig up floatation ball on bit and outer core barrel.

15:30 to 22:00 Run in hole to 3947 meters.

22:00 to 24:00 Rig up Schlumberger and Edo.

December 25, 1970

00:00 to 01:00 Run in hole with Edo to 800 meters. Developed short in Schlumberger cable. Pull out of hole.

01:00 to 01:30 Repair short in Schlumberger torpedo.

01:30 to 03:00 Run in hole with Edo.

03:00 to 05:30 Maneuver ship over cone (95 foot range) using offsets and water depth changes in automatic mode of operation. Made re-entry at 05:30 lowering bit from 3955 to 3964 meters. Bit took 12,000 pounds weight from 3961 to 3964 meters. (Indication of bit hung in base of cone.) Picked up four meters to take weight off bit and rotated pipe. Lowered drill pipe to 3964 meters without taking weight.

05:30 to 08:30 Pull out of hole with Edo and rig down Schlumberger.

08:30 to 09:00 Run in hole with three doubles (50 meters) without taking weight.

09:00 to 12:00 Rig up power sub and running in hole.

12:00 to 13:00 Replace hydraulic hose on bumper sub.

13:00 to 14:00 Finish in hole to 4635 meters. Hit obstruction.

14:00 to 14:30 Wash out fill from 4635 to 4650 meters.

14:30 to 15:30 Pull inner core barrel and drop new barrel.

15:30 to 24:00 Cut cores No. 36 through No. 38 from 4650 to 4668 meters.

December 26, 1970

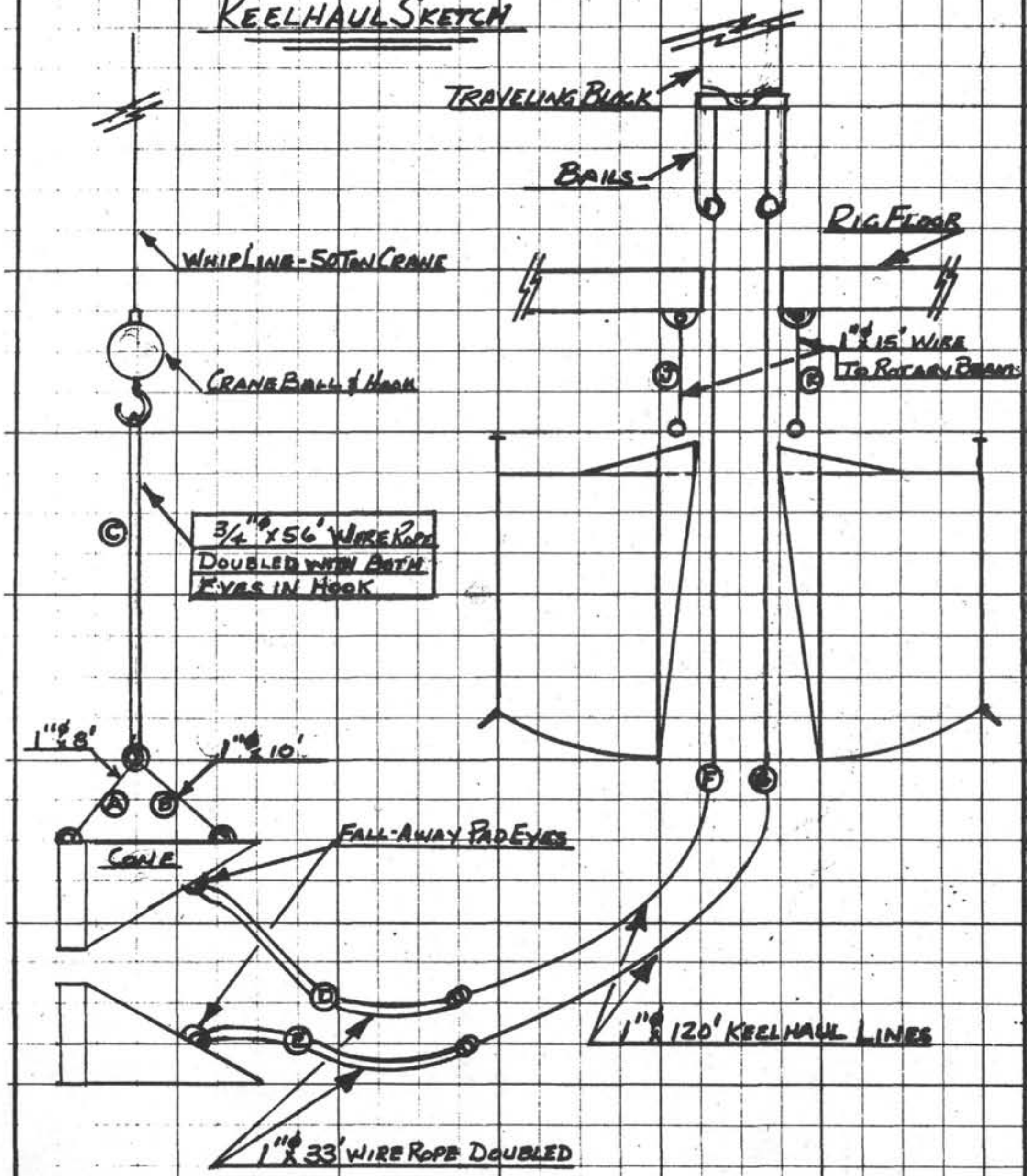
00:00 to 24:00	Cut cores No. 39 through No. 44 from 4668 to 4711 meters in basement.

December 27, 1970

00:00 to 03:00	Spot 130 barrels mud in hole and pull up to 4307 meters.
03:00 to 05:00	Attempt sidewall core. Barrel stuck momentarily. Pull out of hole with no recovery.
05:00 to 06:30	Pull up to 4297 meters with drill pipe. Make second attempt for sidewall core. No recovery.
06:30 to 07:30	Spot 73 barrel mud in hole.
07:30 to 09:00	Pull up to 4050 meters and spot 17 barrel mud in hole.
09:00 to 12:00	Cut drill ine.
12:00 to 13:30	Pull up to plus or minus 1500 meters.
13:30 to 15:00	Test cup type bore plugger with 2,000 psi.
15:00 to 17:00	Finish pulling out of hole.
17:00 to 24:00	Depart site at 17:00 for rendezvous at Curacao.

ATTACHMENT-II

KEELHAUL SKETCH



"TRAVIS"
12/16/70

KEELHAUL PROCEDURE

1. MODIFY CONE TO BE KEELHAULED IN A HORIZONTAL POSITION.
2. WITH LINES Ⓓ & Ⓔ IN PLACE, HOOK CRANE BLOCK TO LINES Ⓐ & Ⓑ. MOVE CONE TO PORT SIDE & LAND ON PIPE RACK, DECK, & PORT RAIL
3. PICK UP LINE Ⓒ WITH "WHIP LINE" & REMOVE CRANE BLOCK FROM LINES Ⓐ & Ⓑ
4. SHACKLE LINES Ⓕ & Ⓖ, CONNECTED TO BAILS OF TRAVELING BLOCK, TO LINES Ⓓ & Ⓔ.
5. PICK UP WITH "WHIP LINE", SWING CONE TO MID-SHIP AND LOWER INTO WATER TO WHERE "WHIP LINE" HOOK IS AT RAIL ON MAIN DECK. KEEP CONE BELOW WAVE ACTION.
6. PICK-UP ON LINES Ⓕ & Ⓖ WITH TRAVELING BLOCK UNTIL ALL SLACK IS OUT OF LINES.
7. WITH CUTTING TORCH, CUT ONE EYE OFF LINE Ⓒ AT "WHIP LINE" HOOK TO LET LINE Ⓒ STRIP THRU RING ON LINES Ⓐ & Ⓑ
8. PICK-UP ON LINES Ⓕ & Ⓖ UNTIL LINES Ⓓ & Ⓔ MAKE UP WITH LINES Ⓙ & Ⓚ.
9. REMOVE LINES Ⓕ & Ⓖ.

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ATTACHMENT III

Proposed Method for Re-entry Using Vessel's Positioning Equipment Only

1. Leave vessel in automatic mode of operation during all operations and leave vessel on same heading.

2. During all observations, make frequent notation of blip heading on sonar oscilloscope to assure that Edo tool has not slipped in azimuth. Also, be certain that all observations of range and bearings are taken with the vessel centered over beacon display of computer oscilloscope.

3. All movements of vessel, range and bearing of target should be plotted on U.S. Navy Manuevering Board HO 2665-20 with original positioning beacon plotted as center and the vessel's position in relation to this beacon plotted using any offsets previously put into computer. This must be done so that the final movements of the vessel by use of depth changes will be along a path angle in direct relation to the true position of the positioning beacon.

4. Using 500 foot scan on sonar oscilloscope and with vessel directly centered over positioning beacon display on computer, take initial range and bearing of re-entry cone target. Plot the circle of observed range from the vessel's plotted position.

5. Make an arbitrary move of vessel by using offsets in one direction only, preferably as near as possible to the vessel's heading. (Vessel's heading will of necessity be determined by existing elements and has no significant effect upon the operation).

6. Observe whether offset move has increased or decreased the range of re-entry cone target. If vessel's move has increased range it immediately becomes obvious that the arbitrary move was in the wrong direction and in this case the offsets should be removed and opposite direction offsets should be put into computer. Offsets of 200 to 400 feet should be used depending upon the distance of the original range of target. If there has been a substantial decrease in range of target, allow sufficient time for vessel and drill pipe to settle and then by an average of new ranges on target draw another circle of range from the vessel's newly plotted position. This circle will intersect the original plotted range circle at two locations either of which could be the potentially true position of re-entry cone.

7. The approximate true position of the re-entry cone target may now be ascertained by having observed the apparent relative motion of the re-entry target either to the right or left, the correct position may be selected.

8. Having ascertained the true position of the re-entry cone, now draw a line from the center of the plotting sheet (i.e. true position of the beacon) through the true position of the re-entry cone.

9. Now! Before any further movement of the vessel, plot three or more alternate coordinates of 100 foot offsets adjacent to the position of the re-entry cone. Now draw a dotted line from the center of the plotting sheet disecting these coordinates to the outer edge of the plotting sheet. (It is along these lines that the vessel may be moved by altering depth settings).

10. If desired, at this point the drill pipe may be rotated to display true azimuth as follows:

    a. Plot the true position of the re-entry cone target.

    b. Calculate the relative bearing.

    c. Rotate the drill pipe with chain tongs until the relative azimuth of the re-entry cone is displayed in its proper position on the sonar oscilloscope.

    (Please note that the above procedure may be desirable to the Master, however in our present stage of evaluation of re-entry capabilities it is not a requisit.)

11. Now! By visual inspection of the plotted alternate coordinates, select that set of coordinates whose azimuth will most closely approach the target by adjustment of depth selections.

12. Now move the vessel in 100 foot increments by "offsets" to your selected co-ordinates.

13. At this point a brief explanation of the movements of the vessel by depth adjust-ments is appropriate.

    a. To decrease range along plotted azimuth to beacon "increase" water depth.

    b. To increase range from beacon "decrease" water depth.

    c. The following formula may be used to pre-compute "closest point of approach" of re-entry cone target.

$$\text{Depth Setting Required} = \text{True Depth} \times \frac{\text{Range From Beacon}}{\text{New Range Desired}}$$

$$\text{or} \quad X = \text{True Water Depth} \times \frac{\text{Coordinate Selected Range From Beacon}}{\text{Desired Range Over Cone From Beacon}}$$

EXAMPLE

In attached "example plot" the water depth is 13,000 feet. The coordinate selected range from beacon is 590 feet, the position of re-entry cone target from beacon is 450 feet. $X = 13{,}000 \text{ feet} \times \frac{590}{450} = 16{,}900 \text{ feet}$

(16,900 feet = required depth setting to place vessel over sonar re-entry cone within ten feet in example.)

14. Now after the vessel and bottom hole assembly has settled over new offset coordinates, increase or decrease depth settings as required to approach "CPA" of re-entry cone target.

15. A third alternate should always be borne in mind and that is our capability of moving "forward" or "aft" along a line of azimuth with our heading a distance of approximately 54 feet by selecting alternate hydrophone selections.

16. The above explained method of re-entry using vessel positioning only, does not preclude the future possibilities of movement in semi-automatic or manual modes of operation as our evaluation of ideas and techniques develope. However, at our present stage of development of techniques it is the firm belief of the writer that an automatic mode of operation is by far the most expeditious and desirable.

17. Please refer to attached plotting sheets for a graphic display of vessel and target movements. Also an approximate evaluation of the time required to re-enter using this system.

18. The writer would like to acknowledge the fact that the "maneuvering board" techniques, the "line of azimuth" by depth settings, the "change of hydrophones" technique were in no way solely the "concept" of the writer and each of the following persons spent many long hours and much research to make this concept of re-entry by "vessel positioning only" a reality. Mr. V. F. Larson, Mr. Roy Anderson, Mr. Bruce Leavitt, Mr. Carl Wells, and Dr. Terry Edgar.

This method also does not preclude the future possibility of "jetting" using a "jet sub" on which Mr. Darrell Sims and Mr. Larson spent many long hours of hard work. And last, but certainly not least, it is needless to say that without the advice, help, close cooperation and just plain "hard work" on the part of Mr. Travis Rayborn and his superb crews, not only re-entry but our entire program could not exist. The techniques in assembly and keelhauling of the re-entry cone was by far one of the finest pieces of "rigging know-how" I have ever seen.

Respectfully submitted,

s/ Captain Joseph Clarke
t/ Captain Joseph Clarke
Master, Glomar Challenger

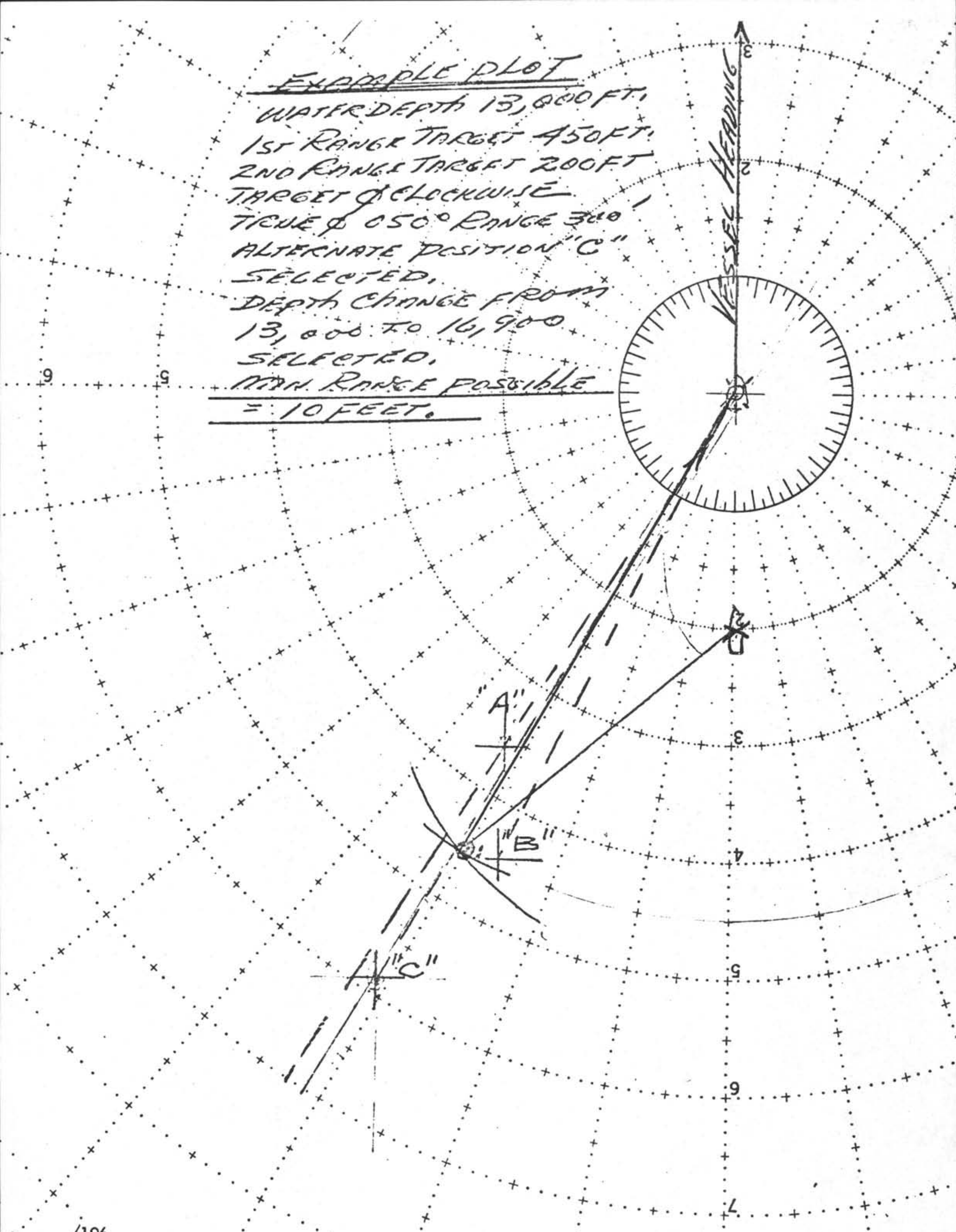
TIME ESTIMATE

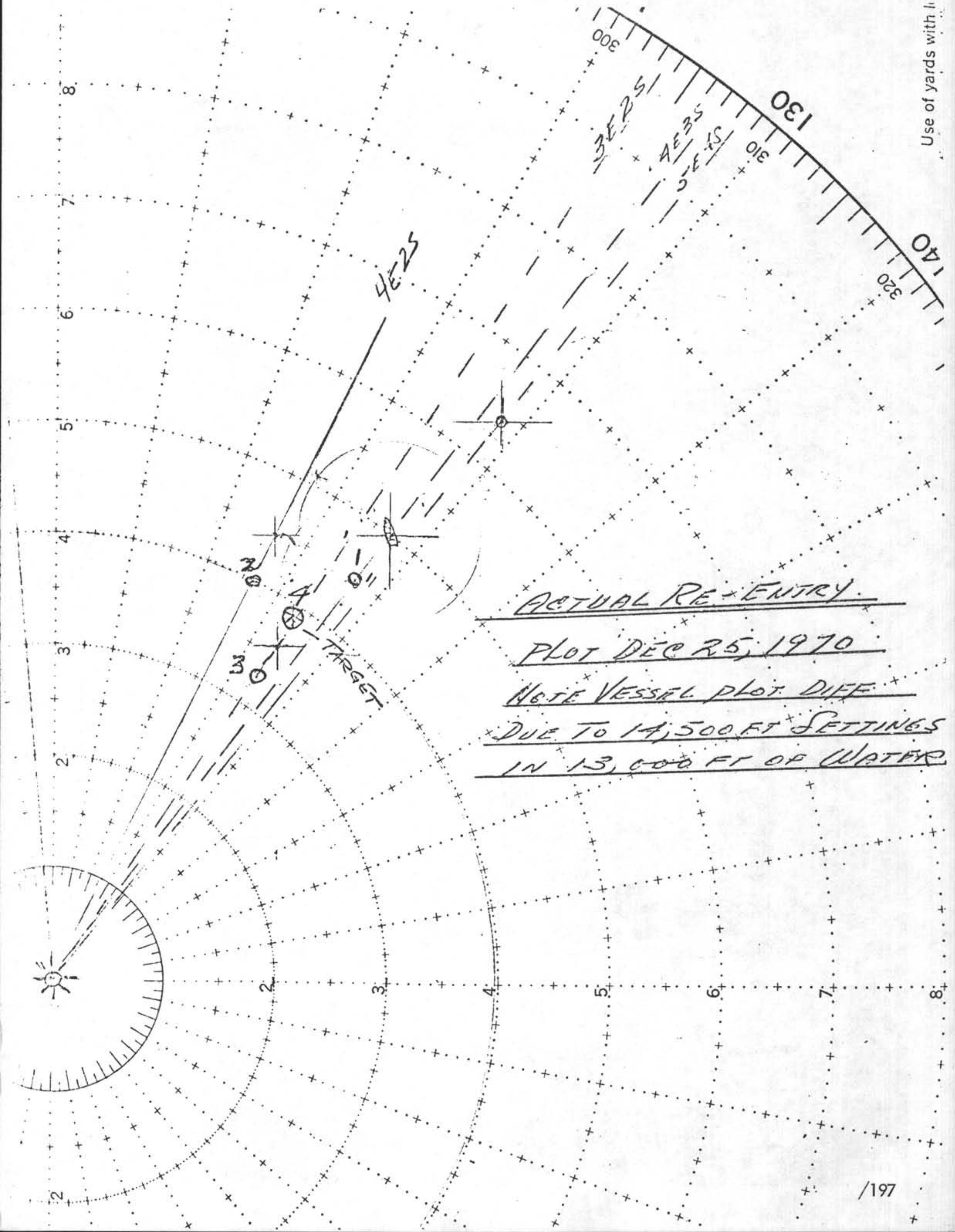
1.	Sight Sonar Target	20 minutes
2.	Initial Move	10 minutes
3.	Second Move and Plotting	20 minutes
4.	Third Move and Plotting..............	30 minutes
5.	Fourth Move and Settling	30 minutes
6.	Close by Depth	10 minutes
	Total Time........................	2 hours

With an estimated time of first pass over target of two hours, it is reasonable to assume that three hours is a fairly accurate estimate of time required to stab re-entry cone with present techniques. This of course will vary with wind and weather conditions, currents, heading changes that may be required during pulling and running string, etc.

Respectfully submitted,

s/ Captain Joseph Clarke
t/ Captain Joseph Clarke
Master, Glomar Challenger


EXAMPLE PLOT
WATER DEPTH 13,000 FT.
1ST RANGE TARGET 450 FT.
2ND RANGE TARGET 200 FT
TARGET ∅ CLOCKWISE
TRUE ∅ 050° RANGE 300
ALTERNATE POSITION "C"
SELECTED.
DEPTH CHANGE FROM
13,000 TO 16,900
SELECTED.
MAX. RANGE POSSIBLE
= 10 FEET.
VESSEL HEADING
"A"
"B"
"C"


ACTUAL RE-ENTRY
PLOT DEC 25, 1970
NOTE VESSEL PLOT DIFF
DUE TO 14,500 FT SETTINGS
IN 13,000 FT OF WATER
TARGET
4E2S
3E2S
4E3S
5E4S
130
140
300
310
320
Use of yards with

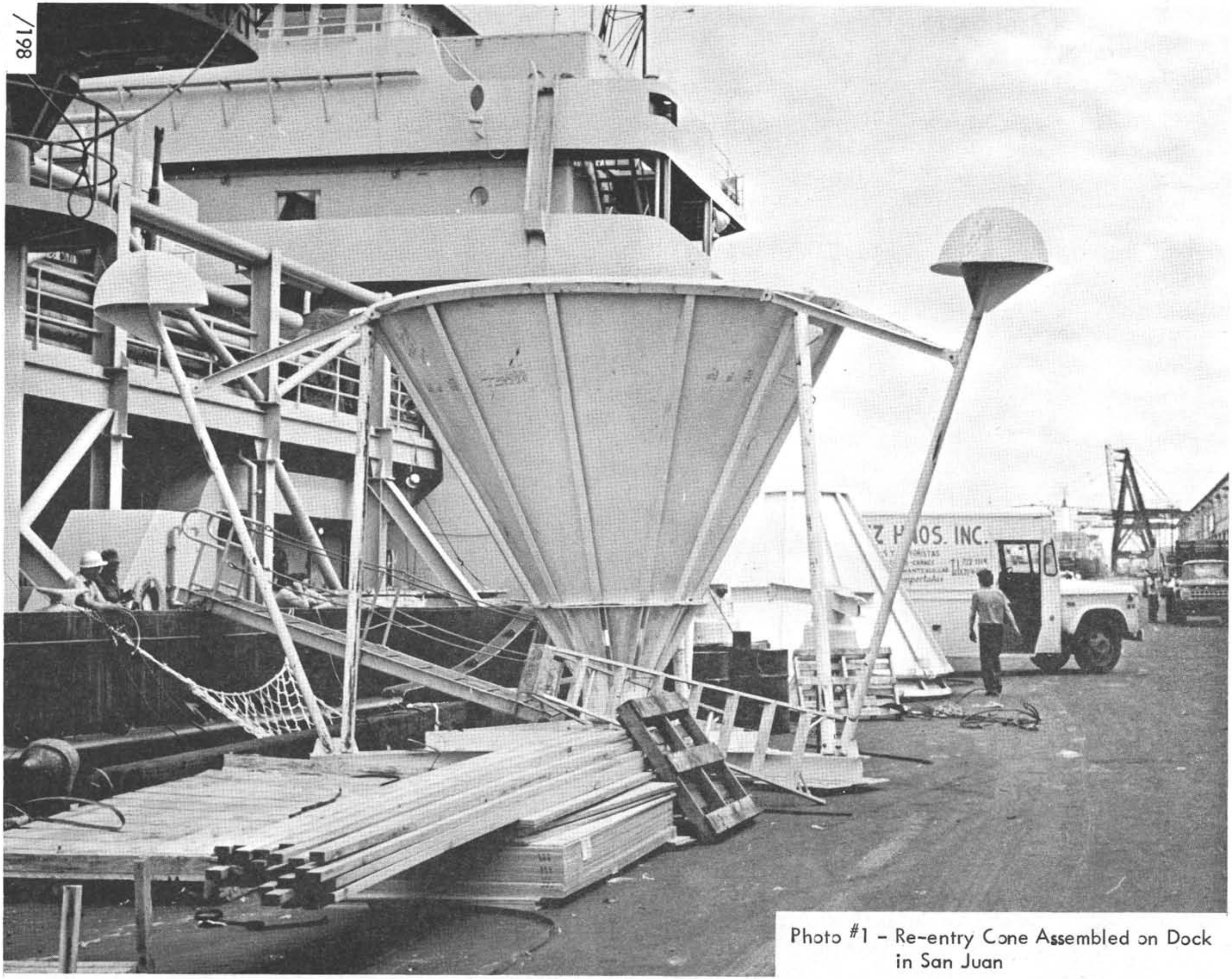


Photo #1 - Re-entry Cone Assembled on Dock in San Juan

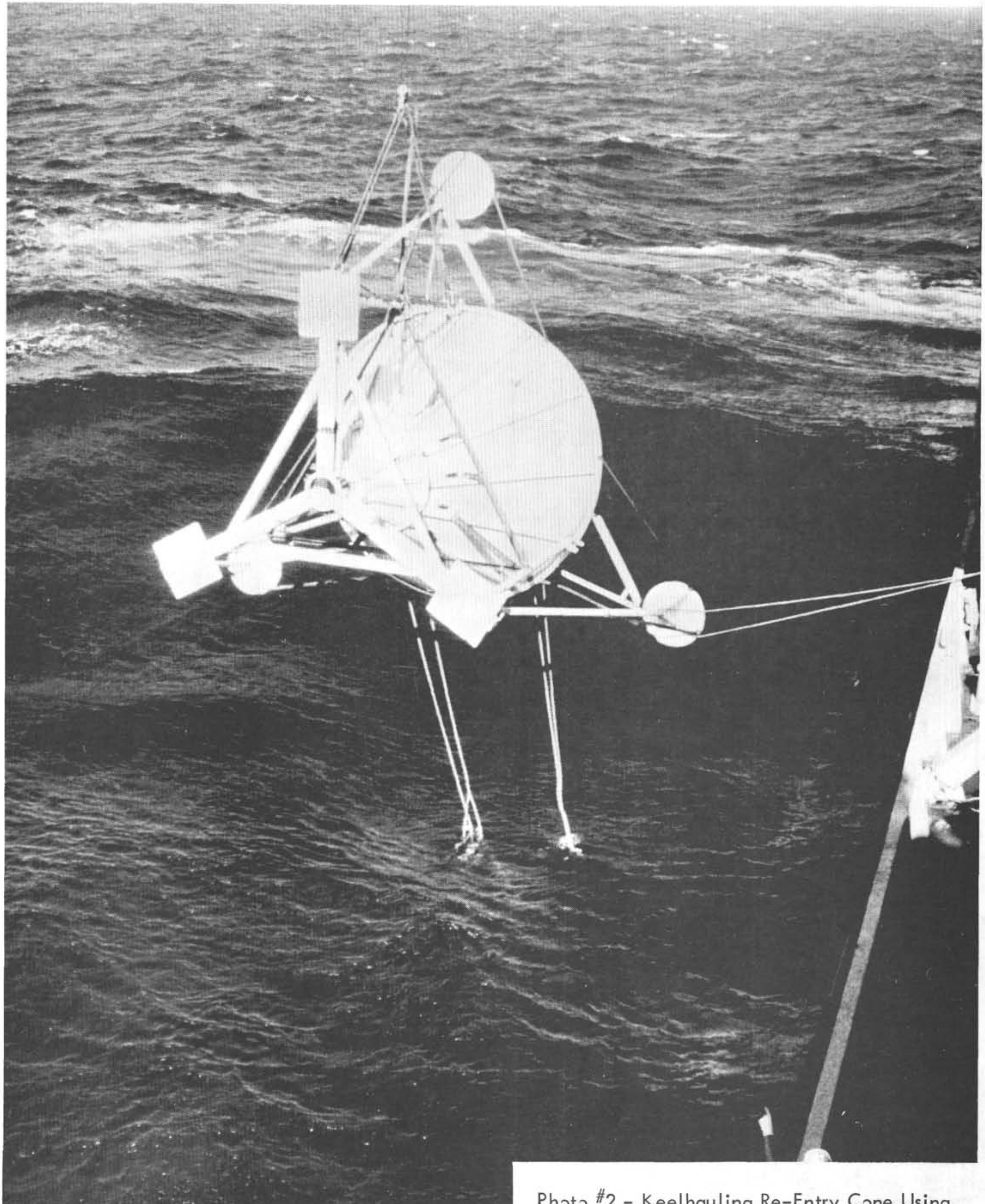


Photo #2 - Keelhauling Re-Entry Cone Using Side Launch

Photo #3 - Casing Hanger

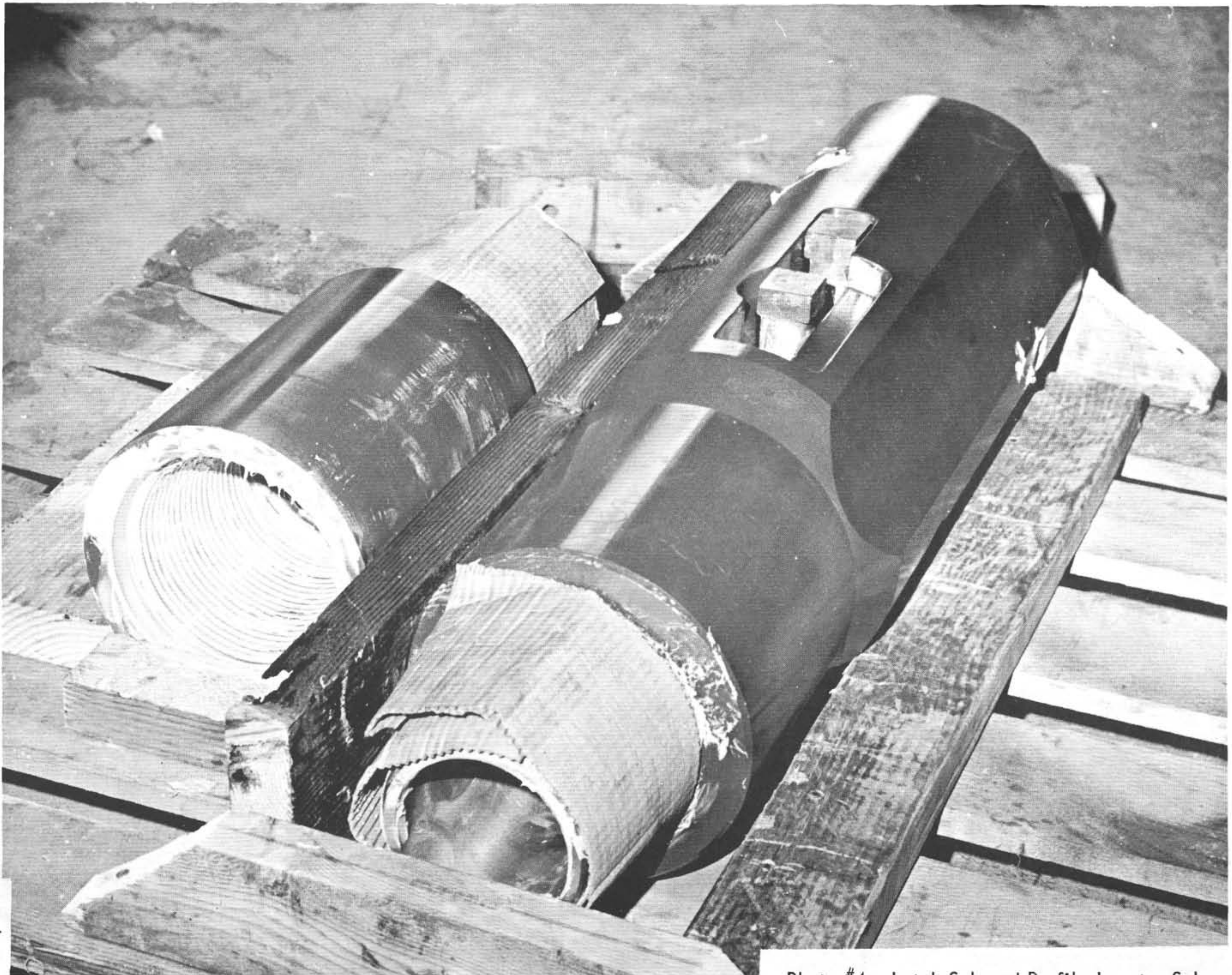


Photo #4 - Latch Sub and Profile Locator Sub

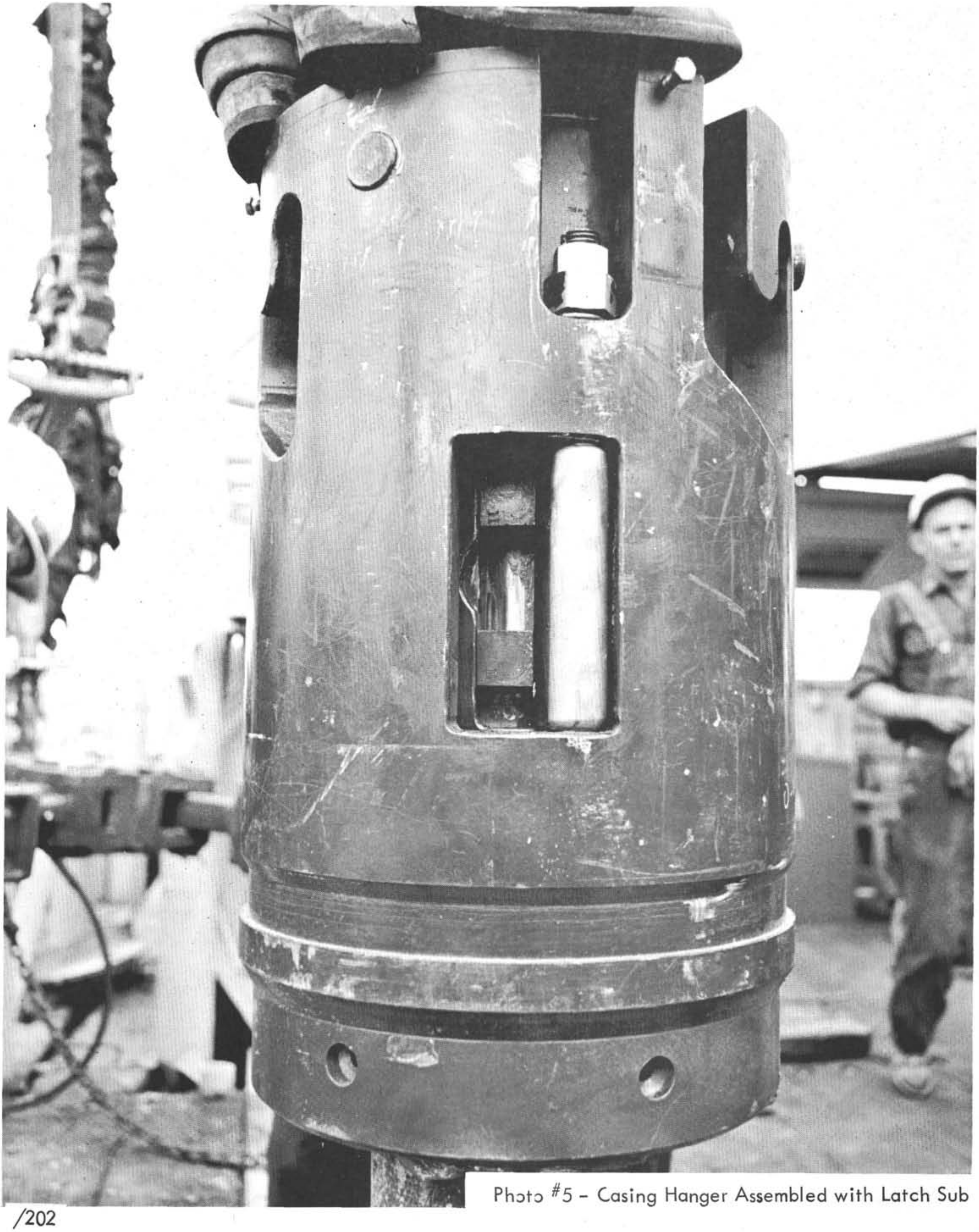


Photo #5 - Casing Hanger Assembled with Latch Sub

Figure #6 - Baker Shifting Tool

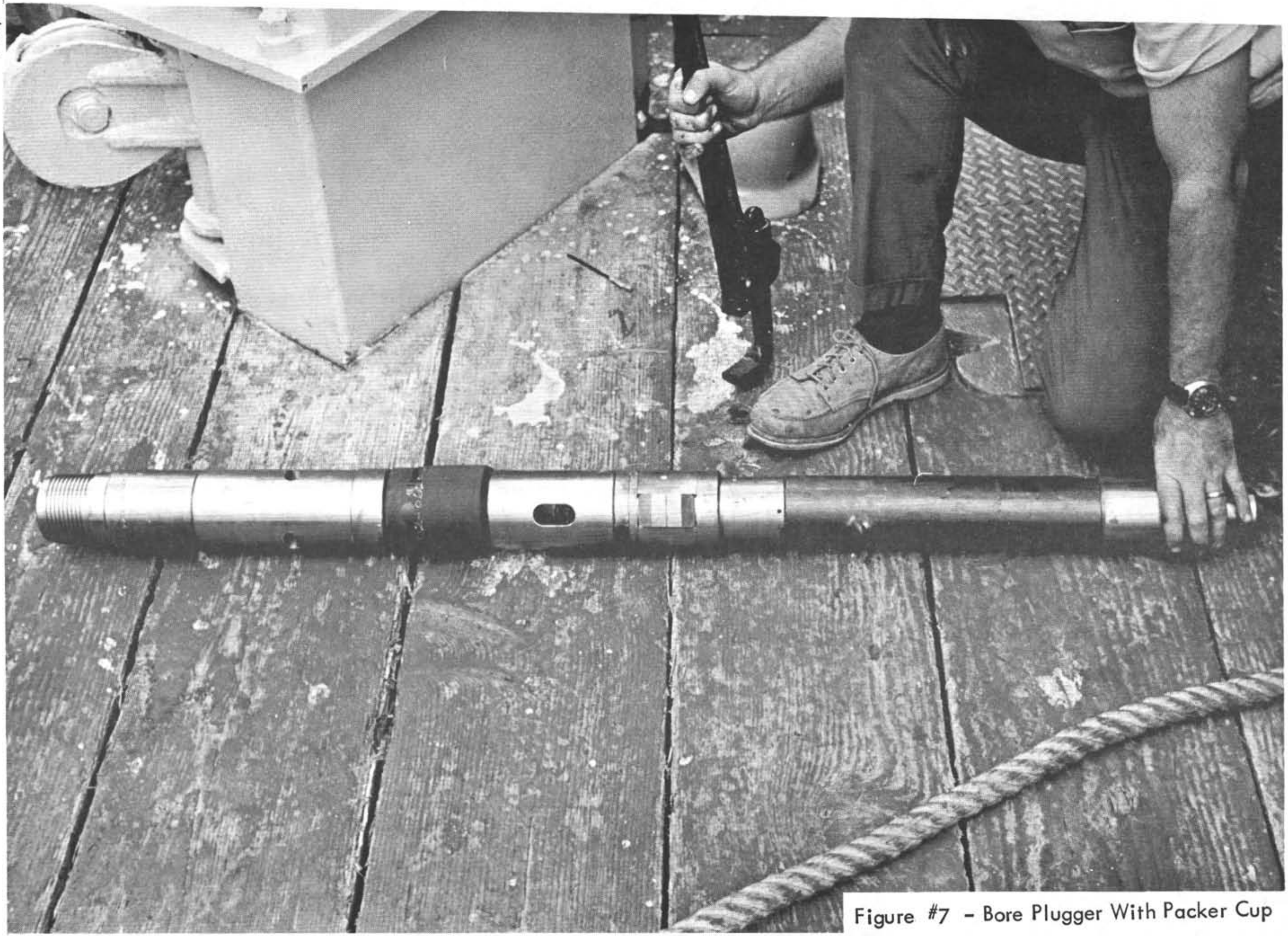


Figure #7 - Bore Plugger With Packer Cup

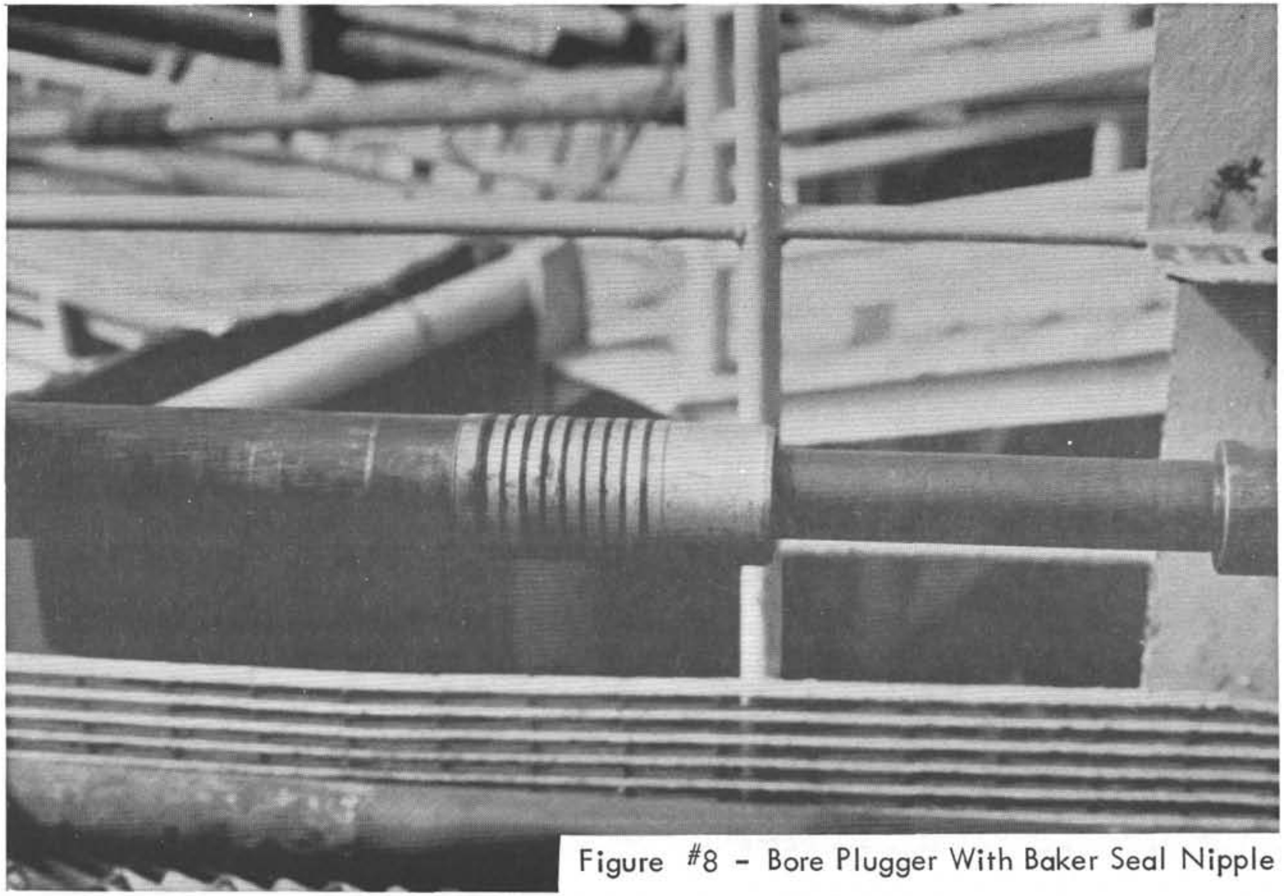


Figure #8 - Bore Plugger With Baker Seal Nipple

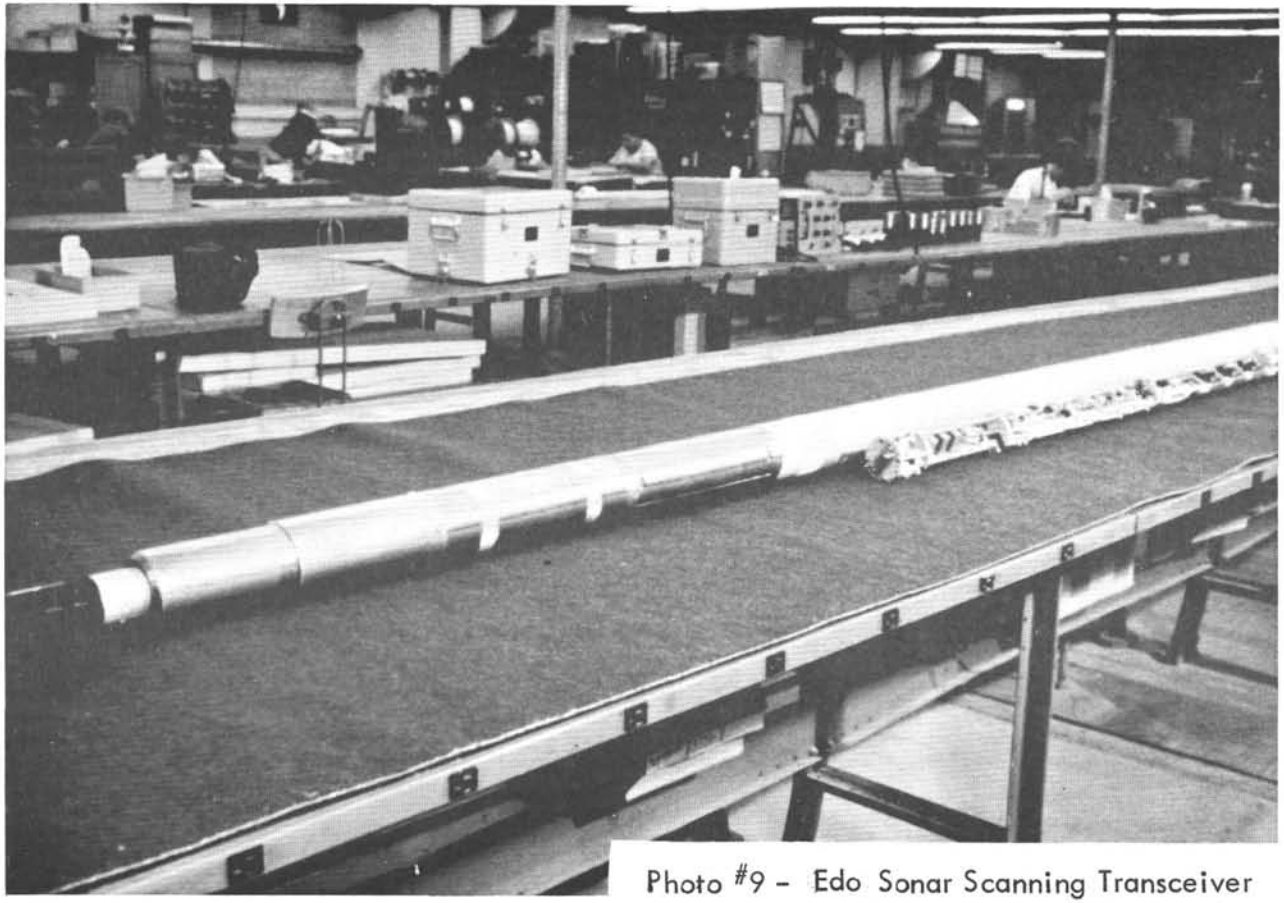


Photo #9 - Edo Sonar Scanning Transceiver

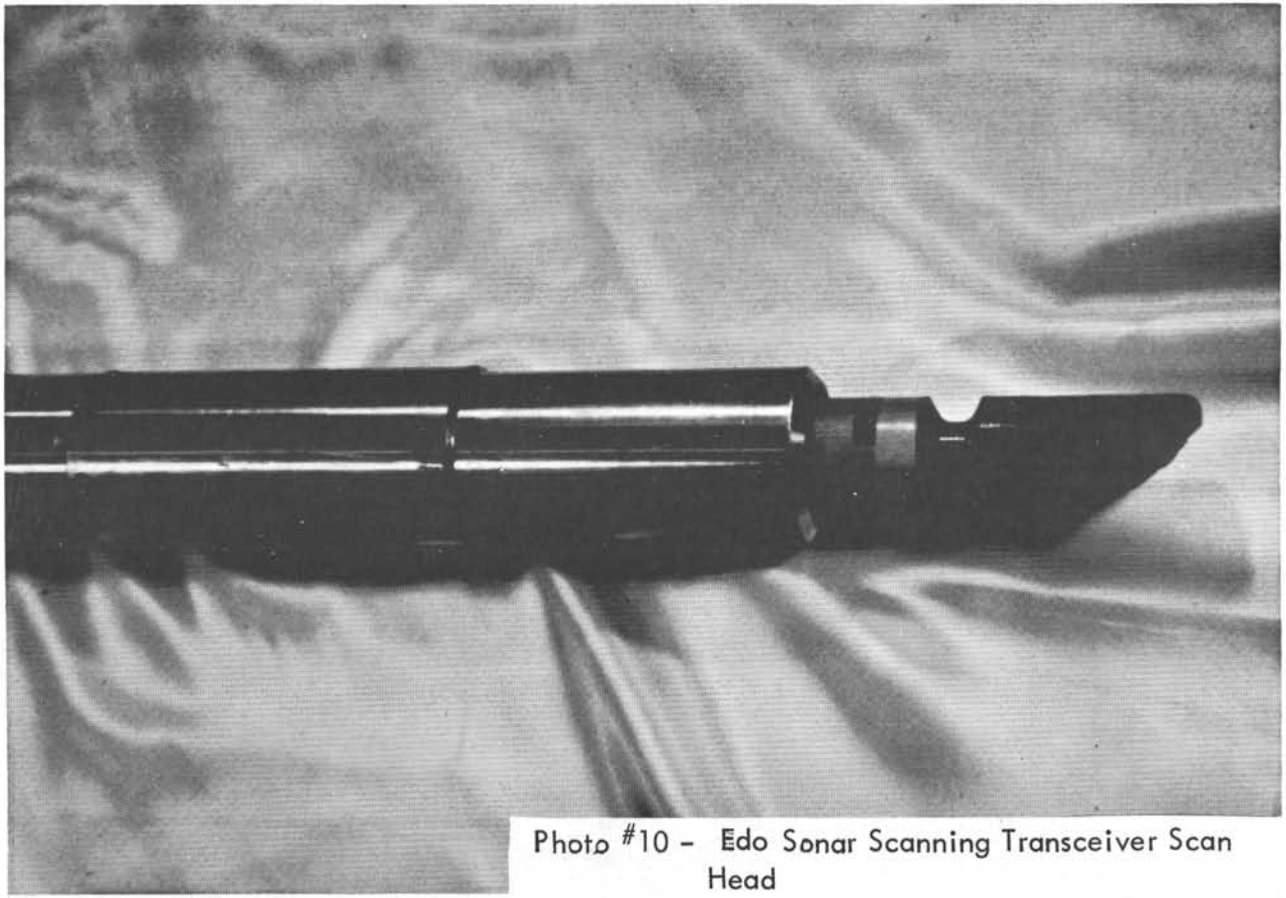


Photo #10 - Edo Sonar Scanning Transceiver Scan Head

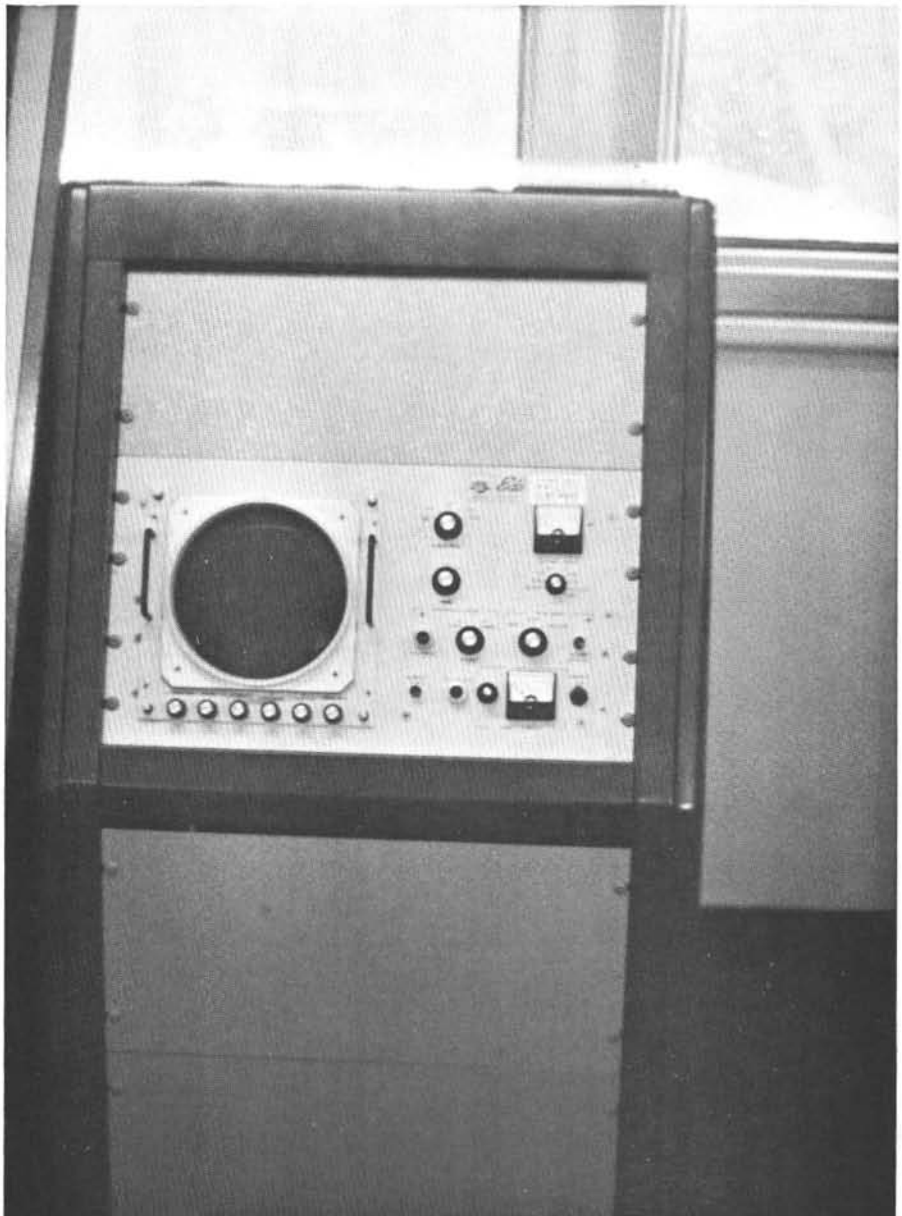


Photo #11 - Edo Sonar Scope Bridge Console

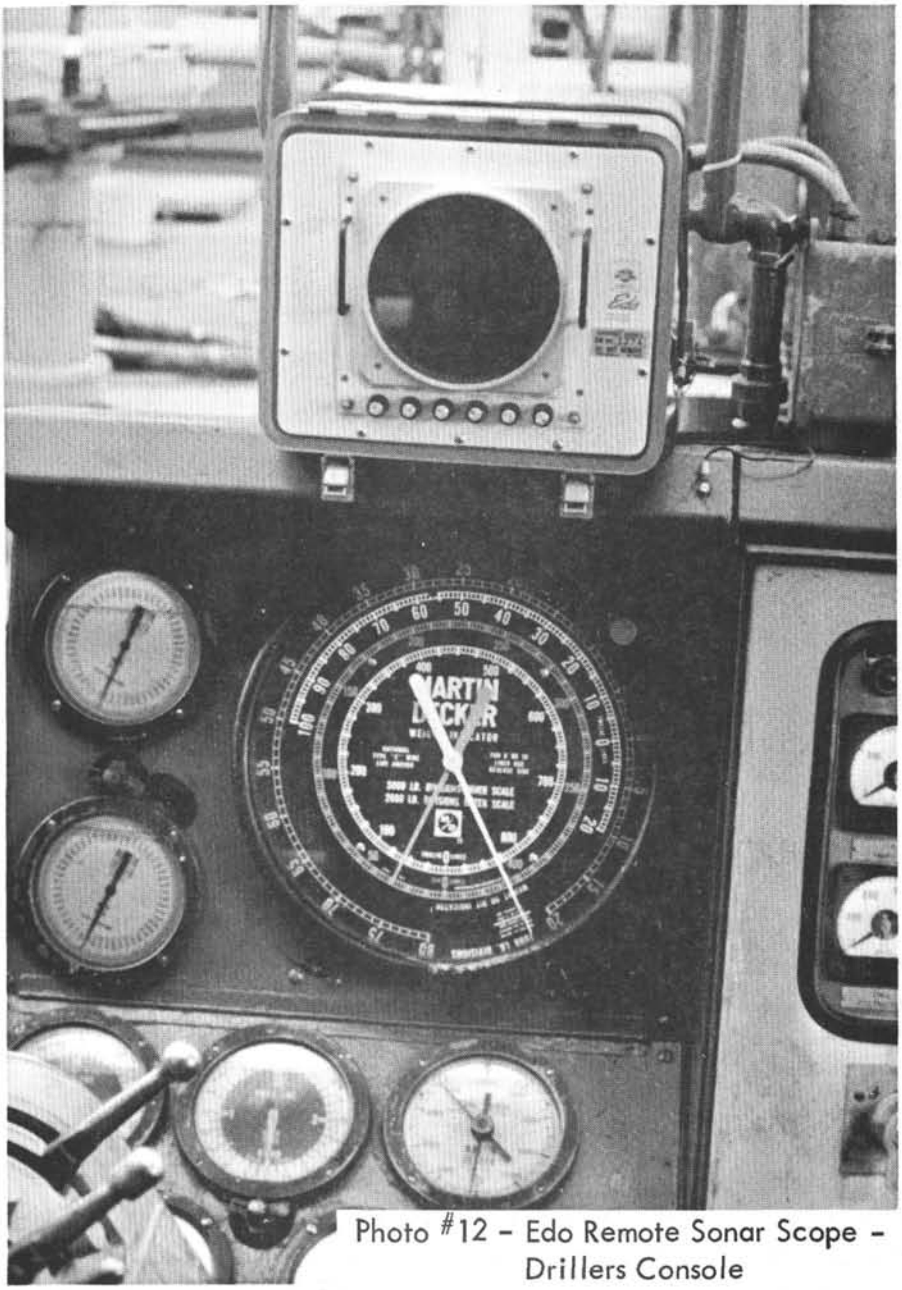


Photo #12 - Edo Remote Sonar Scope - Drillers Console

OPERATIONS RESUME

LEG 16

SUMMARY

Leg 16 of the Deep Sea Drilling Project departed Cristobal, Canal Zone, February 2, 1971 and arrived in Honolulu, Hawaii, on March 30, 1971.

During the 56-day voyage, the vessel steamed 6,411 nautical miles and drilled 12 holes on nine sites. While on these 12 holes, 1761 meters were cored and 1259.80 meters were recovered for a 71.5 percent recovery. Out of 207 attempts to core, 201 were successful and recovered usable samples. In addition, 752 meters were drilled, making a total penetration of 2513 meters. Of the 12 holes drilled, eight were continuously cored.

The weather and sea conditions were mostly a result of the trade winds. On the first four sites, which were close to Panama and South America, winds were light, seas calm and the skies relatively clear. However, as the ship moved westward and the trade winds again picked up, the seas became rougher and the skies more overcast. There was no lost time due to weather, but on two of the last five sites, rough seas did make positioning difficult.

Rendezvous was completed at the last site at approximately 12:30 hours, March 20, 1971. Two Scripps Institution of Oceanography personnel,one Edo Western technician, various equipment and mail were transferred from the chartered vessel, Holokai.

On Site 157, which was approximately 215 nautical miles west of Ecuador, the Challenger was visited by two gun boats of the Ecuadorian Navy. There was no attempt at communication between the gun boats and the Challenger. The two gun boats, with the crews at battle stations, came within 500 yards of the Challenger. One of the gun boats remained at this distance for approximately ten to 15 minutes and then slowly steamed away.

DRILLING AND CORING

Generally, the geologic section in all the holes was quite similar. Soft unconsolidated ooze or clay was encountered at the surface. As the depth increased, the ooze became firmer because of loss of water, but very seldom became very hard. Near the basalt basement, chert layers, a maximum of two inches thick, were found interbedded with the clay and ooze. On one site, the chert was found interbedded with a firm limestone.

The main question on this leg as far as drilling and coring was concerned, was whether or not the button bits that had been developed since the Challenger had left the Pacific, would successfully drill the chert and still be in good enough condition to cut a core in the basalt.

It was this same chert that started the development of the re-entry technique when the Challenger, drilling with diamond bits, was unable to penetrate the chert in the Western Pacific.

The performance of the button bit was outstanding. It proved that it was capable of drilling any chert that was encountered and still be in condition to cut a core in the basalt.

During this leg, two new type button bits were tested to determine their capability. The first, a shaped insert button bit, was outstanding. Three bits of this type were run. Each one was not only able to cut the chert and basalt successfully, but cut the whole section faster than the regular button bits. In addition, the only good recoveries in the basalt were made with this type bit. There is no doubt in my mind that this type bit will drill the hard clays and shales encountered in the Atlantic Ocean much faster than the regular button bits. This will be an outstanding advance because there are quite a few instances that holes were abandoned before reaching the basalt because of slow penetration rates in the hard clay and shale.

The second new type bit tested was the sealed bearing bit. This bit also appears to be a big improvement. The one bit that was used was run on four holes and drilled 677 meters. The bearings were still in fair condition.

I believe that a sealed bearing, shaped insert button bit is the answer to the bit problems on the Challenger. There are various sizes and lengths of shaped inserts being developed by the oil well bit industry. These need to be used and tested to further improve bit performance.

It is my opinion that the performance of button bits as demonstrated on this leg, will probably make re-entry unnecessary, as long as the only requirement is to reach the basalt and get a reasonable amount of core. However, it is premature to write off re-entry on the basis of one leg. Leg 17 should give much more information on the problem.

Core recovery on the leg was 71.5 percent. This represents very high recovery in the soft formations and low in the chert and basalt. Most of the soft formation was drilled without circulation which usually results in high recovery. However, when chert layers were encountered, the pump had to be used. This dropped core recovery almost to zero because the circulation seems to wash away all the soft material before it gets up into the barrel.

DRILLING AND CORING - EXTENDED CORE HEAD

In an attempt to obtain undisturbed cores, an extended core head was tried briefly on Leg 15 and again tested on Leg 16.

The regular inner core barrel and core head is 3 1/2 inch outside diameter and does not extend through the cones of the bit but stops up in the bit, approximately six inches off bottom. The inside diameter of the hole through the bit is 2 1/2 inches and the cones are set to cut a core of 2 7/16 inch diameter. It was thought that if the core head could be extended to protrude through the hole in the bit and the end be flush with the bottom of the bit, a better, more undisturbed core could be obtained.

An extended core head was built that was 2 3/8 inch outside diameter and thus small enough to go through the hole in the bit and extend to the bottom of the bit, or further if desired. In doing this, the core size was reduced to two inches in diameter.

The first time that the extended core head was tried on Leg 16 was on Site 156. It was in place when the hole was spudded, however, this was the one hole that was spudded in very hard formation. We cored only a few meters before we realized we had missed the site, so we came out of the hole and moved to a different site. As a result of coring the hard formation, the extended core head had broken off approximately one to two inches from the lower end.

On Site 157, the hole was spudded with the regular core head to avoid any chance of breaking the extended core head again. Cores one through seven were taken with the regular core head. Cores eight through 12 were taken with the extended head cut off even with the bottom of the bit. The geologists thought that the cores eight through 12 were less disturbed than cores one through seven, so it was decided to re-core the first seven cores and use the extended core head. This time the core head was extended approximately four inches below the bit. This re-coring was referred to as Hole 157A. Three cores were cut. The first core was a good, undisturbed core while cores two and three were not any better and possibly worse than the same depth core taken with the regular core head. With these results, Hole 157A was abandoned and the extended core head was not used again on the leg.

It was concluded from these runs, that the extended core head did not extend far enough ahead of the bit to get undisturbed sediments. Also, the reduction in core diameter from 2 7/16 inch to two inches probably contributed to, rather than helped avoid, formation disturbance. It was evident that the only undisturbed core that could be taken with the present core barrel was the first core. The reason being that it acted almost like the standard punch core that has been used by oceanographic vessels for years.

It is my opinion that if undisturbed cores are really required, they might be obtained by extending the regular core barrel out through the bit much farther than the four inches that was tried on this test. In addition, it may be wise to hold the bottom hole assembly still and allow the weight of the core barrel to push itself through the sediment free from the up and down motion of the vessel.

SIDEWALL CORING

The sidewall core barrel was run seven times. Three runs resulted in 100 percent recovery. Two times the sidewall core barrel was broken and two times the bit was so damaged that the sidewall barrel could not get through the hole in the bit.

One of the broken barrels occurred when a new type, three barrel sidewall assembly was tried. This assembly was designed to take three separate samples, simultaneously, at about three foot intervals. It is unknown if the principle is practical or not because the assembly broke in the weld at the top connection and was lost in the hole.

In defense of the broken standard sidewall barrel, it was run in the chert section in an attempt to sample the soft sediment between the layers of chert. Evidently the barrel hit a chert layer which caused the damage.

It is my opinion that the sidewall core barrel is still a useful tool when used under proper conditions.

DYNAMIC POSITIONING

Dynamic positioning on Leg 16 was adequate enough to avoid any lost time but displayed erratic tendencies throughout the entire leg that caused much speculation and experimentation.

The main problem with the system was that it never would quite settle down. It would either continually hunt 50 feet either side of the beacon or settle down for a few hours and then without any apparent reason, drift off over 100 feet, usually along the long axis of the vessel.

The positioning problem was further complicated by delivery to the vessel of a considerable number of new style ORE beacons that were to be run in place of the well liked and dependable Burnett beacons.

The new ORE beacon is unique in that the transducer/floatation assembly consists of a framework supporting four glass floatation spheres and the transducer is mounted in a gimbal. The bridle assembly which secures the transducer/floatation assembly to the electronics pressure case is so designed that the manufacturer claims the floatation will always align itself with any bottom currents and any tilt imparted to the floatation by the action of the current will not disturb the vertical orientation of the transducer, since it is free to swing in the gimbal. The floatation is designed to maintain the transducer in a near vertical orientation in currents of up to two knots.

Examination of this beacon gives cause for speculation into the credibility of the manufacturer's claim. The way the bridle assembly is designed is that the battery pack and weight hangs directly below one end of the floatation unit and when in the water, the floatation unit supposedly floats level. Thus, when a current is encountered, the unit is supposed to rotate around the end under which the weight is suspended and the long axis of the unit lines up in the direction of the current. Any up and down movement of the unit and the transducer caused by the current is eliminated by the gimbal mount on the transducer.

However, the floatation unit does not float level. The weight, no matter how it is bridled to the unit, hangs directly under the center of floatation. Since the bridle is uneven, the floatation unit tips. The beacon was tried out in the moon pool of the Challenger and the floatation unit was found to tip about 20 degrees off horizontal. Thus, with the floatation unit tipped and the axis of rotation through the center of buoyancy, it is hard to see how the long axis of the floatation unit could consistantly line up with the current.

On the first three locations, the new type ORE beacons were dropped. No unusual problems were encountered except the vessel constantly hunted in the range of 40 to 50 feet from the beacon. In an attempt to determine if the beacons were at fault, a Burnett beacon was dropped on the fourth site. The Burnett beacon seemed to work better than the ORE beacon. It held the vessel within 30 feet of the beacon. From this, it was concluded that the ORE beacon must be at fault.

On the fifth site, an ORE beacon was dropped that had been modified by re-stringing the bridle so that the floatation unit would float horizontally, directly over the weight. Also, the gimbal was secured so that the transponder was fixed and level with the floatation unit.

The results of this site were uncertain. The seas and the wind were coming from different directions, 40 degrees apart, and a current came 90 degrees to the seas. This made positioning difficult. The acoustic signal was lost for two to three hours and the ship had to be positioned in semi-automatic mode. Under these conditions, it was difficult to determine if the beacon had any influence on the positioning problems.

On the sixth site, an unmodified ORE beacon was dropped and positioning acted in a similar manner as it had on the fifth site. In an effort to determine if the beacon was at fault, a Burnett beacon was dropped so that the ship could be positioned on each beacon alternately, under the same conditions and thus be compared. The results of this test showed that there was very little, if any, difference in the way the ship positioned on either beacon. From this it was concluded that the positioning trouble was probably caused by the wind and sea conditions.

Two more sites were drilled using ORE beacons. Generally, the ship positioned well except every few hours the ship would slowly move over 100 feet off, along the long axis of the vessel and would be slow about returning to its original position.

On the last location, a Burnett beacon was dropped. The ship positioned very well with no problem of getting off in the long axis.

Of the eleven beacons that were dropped throughout the site, there was only one failure. On the last site, a Burnett beacon with a dual battery pack lasted only 45 minutes.

DYNAMIC POSITIONING - CONCLUSIONS

Although most of our positioning problems on Leg 16 occurred with an ORE beacon on bottom, a fair test was conducted using both competive beacons under the same conditions and no difference could be found.

Even though the claims of transducer stability in a bottom current made by ORE are doubtful, the beacon seems to operate satisfactorily.

It is my opinion that the ORE and the Burnett beacons operate equally well and most of the positioning problems on Leg 16 were caused by sea and wind conditions. The other problem of occasional deviation in the x-axis that seemed to be worse with the ORE beacon, in my opinion, is some problem in the programing in the computer. It is hard for me to believe that the beacon would move in such a way as to always effect the positioning in only the one axis.

It is my recommendation that further work be done on the design of the ORE beacon. I suggest that the uneven bridle be eliminated and replaced with an even bridle. Perhaps a rudder or some such device could be fashioned from a piece of plywood and placed in a vertical position along the long axis of the floatation. This would align the floatation with the current and the gimbal could erase any movement vertically due to the action of the current.

RE-ENTRY

Site 163 was scheduled to be a re-entry site. It was originally thought that in order to drill through the chert and into the basalt, it would require more than one bit. However, the button bits proved so effective in drilling the chert, that it was evident that probably re-entry would not be needed unless a sizable number of cores in the basalt were required.

It was decided therefore to go ahead on Site 163 and land the re-entry cone on bottom with five joints of casing below it, attempt to reach basalt and cut the necessary cores, all with one bit. If we were successful, we would pull the bit up above the mud line and then make a practice re-entry for the benefit of the crews on this leg who had never made a re-entry. If we were not successful in reaching basalt with one bit, we would pull out of the hole, put on a new bit and re-enter and complete the hole in basalt.

As it turned out, the one bit drilled the chert and took two very fine cores in the basalt, fulfilling all the requirements of the chief scientists.

RE-ENTRY - NARRATIVE

The cone was picked up, laid on its side, keelhauled and suspended under the vessel with no problem. Five joints of 13 3/8 inch casing (61.41 meters) were picked up, the hanger made up on the top joint and set on a set of elevators on the platform under the floor at the top of the permanent section of the horn. The bottom hole assembly was run in and the latch sub positioned so that the bit would be approximately one foot above the shoe on the 13 3/8 inch casing.

When an attempt was made to attach the latch sub to the casing hanger, it was found that the paddles on the hanger slightly interferred with the "lug nuts" attached to the sliding sleeve on the latch sub and would not allow the sleeve to drop down into the lock position. In order to alleviate this problem, the sides of all three paddles were ground off enough to allow the "lug nuts" to move down.

With the latch sub in the locked position, the whole assembly was lowered and latched into the cone. After latching, the entire assembly; cone, casing and bottom hole assembly, were picked up two feet and "shaken" to insure that the latch in the cone was secure.

The latch was pronounced secure, the assembly was picked up approximately two feet and the crew prepared to unhook the slings supporting the cone. Just at this time, the latch sub and the hanger suddenly unlatched from each other and the cone and the casing dropped. One sling was all that ended up supporting the cone and the casing. Evidently when the cone dropped, all the weight was momentarily supported by one sling, causing the fall away eye on the cone to break and release the sling.

The bottom hole assembly was pulled up and the latch sub removed. Examination of the latch sub showed that the "lug nuts" and the sleeve were still in the locked position.

What had happened was that evidently grinding off of the paddles had changed the angle relationship between the paddles and the "lug nut" and had introduced too much slack into the latch. These two conditions made it possible for the latch sub on the inside, to rotate in a right hand direction and release the paddles, dropping the cone and casing.

It was then decided to continue in the hole and drill as far as possible before the sling broke. When it broke, the cone and casing would fall to bottom and hopefully come to rest at the mud line in the required position.

This was done and four and one half days later the sling had not parted. Finally, while trying to ream back to bottom after cutting the second good core in the basalt, the drill pipe started rattling against the casing to such an extent that the noise was blocking out the beacon signal and was making positioning difficult. It was decided that in order to continue to drill, we would have to release the cone and casing. This was done.

It was determined by following the cone down with the Precision Depth Recorder (PDR) that the cone and casing fell at a speed of ten feet per second and took about 30 minutes to get to bottom. During the time that the cone and casing were falling, no undue noise was heard on the hydrophones nor was there any fluctuation in drill pipe weight.

Six hours later the bit was pulled out of the hole. There was no indication of any drag while coming through where the casing was thought to be, so it is safe to assume that the casing survived the fall without significant damage.

There was still time enough left on the site so it was decided to go back to bottom and attempt a re-entry. Since we had no idea of the exact depth of the cone, it was decided to attempt the re-entry without the Bowen sub in the string. This would allow a full 90 to 100 feet that the pipe could be raised or lowered while re-entering. It was thought that this would be more useful than the ability to pump through the drill pipe while the Edo tool was being lowered into the hole.

The re-entry attempt had to be scrubbed because of the malfunction of the Edo sonar scanning transceiver. It failed at 200 meters while being lowered into the hole. The tool was pulled from the hole, a broken wire on the torpedo repaired and re-run into the hole. Again, it malfunctioned at about the same depth. Emergency repairs were attempted but the tool could not be made to operate in the short time left for this re-entry attempt.

It is interesting to note that had the hanger and latch sub not become disengaged, we no doubt would have had trouble getting the cone seated successfully on bottom. We ran 62 meters of casing below the cone. When we spudded the hole and started taking cores, we found that the PDR showed bottom to be approximately 26 meters too shallow. In addition, an unexpected chert layer was found at 28 meters. It is entirely possible that we might have assumed bottom was at the PDR measurement, then when the chert was encountered 54 meters below, we would have thought we were off six meters in depth and assumed the cone was resting on bottom. In truth, the cone would have been 34 meters above the ocean floor.

This points up the problem of running the casing and cone without drilling a hole first to determine if re-entry is necessary, to find bottom, and to find a good seat for the casing.

I feel that we have proved the feasibility of the idea of hanging the cone and casing below the vessel, drilling the hole and if a re-entry is necessary, drop the cone and casing before coming out of the hole. We cannot be entirely sure that the cone and casing were completely undamaged and in the correct position after it was dropped, but all indications are it was undamaged. It will have to be left to a later test to completely prove out the idea.

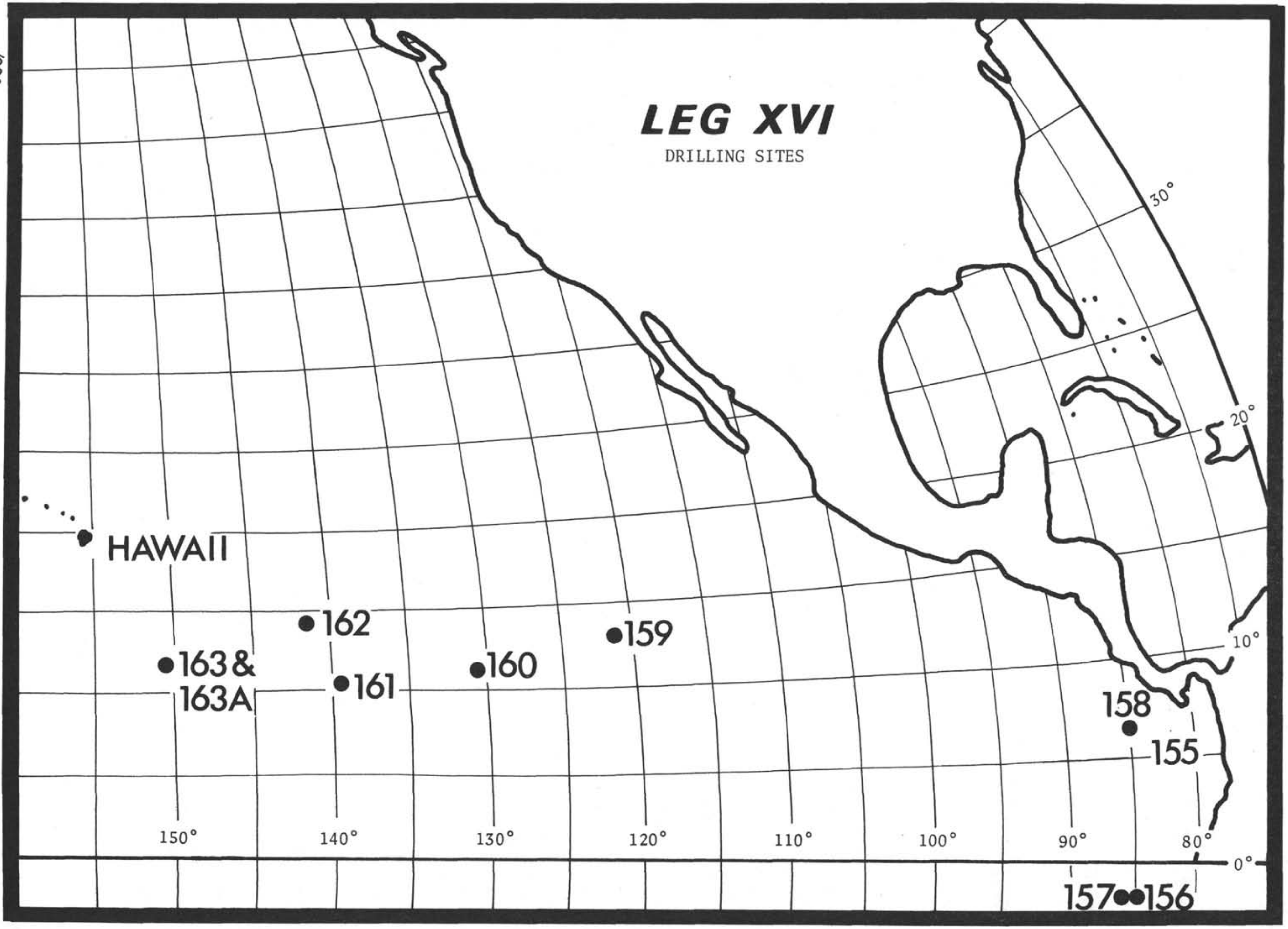
PERSONNEL

The Global Marine personnel performed in an outstanding manner. Again, their maintenance and repair kept any downtime to an absolute minimum.

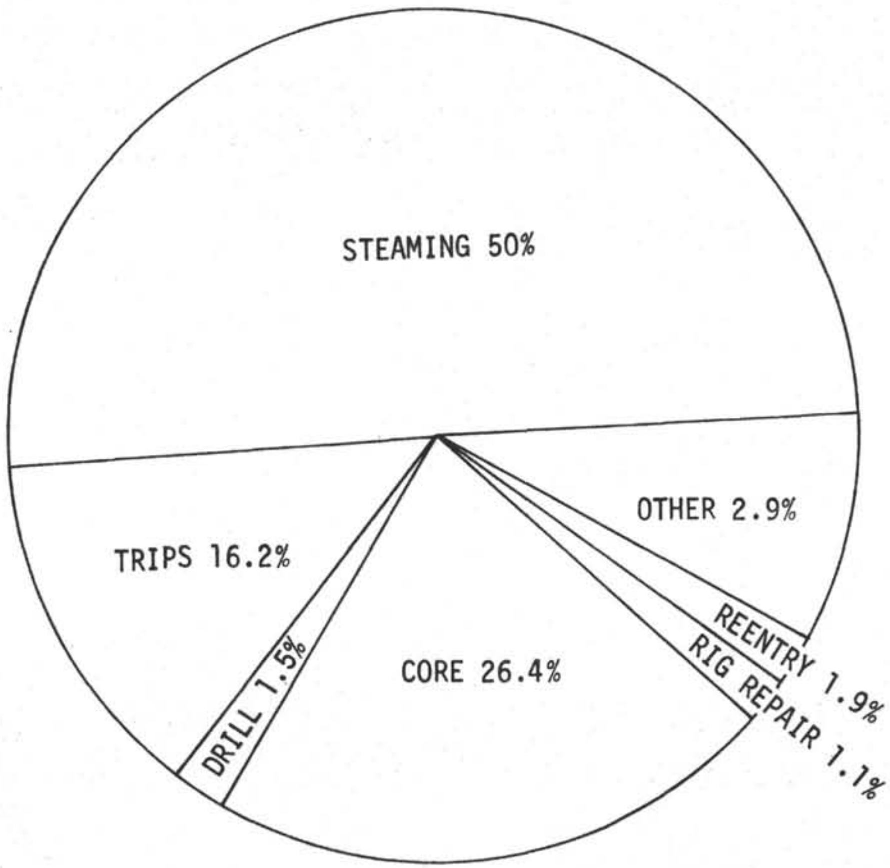
TABLE 1

LEG 16 - SUMMARY OF OPERATIONS

Total Days Leg 16 (February 2, 1971 to March 30, 1971)		56.16
Total Days in Port		3.18
Total Days Cruising		26.46
Total Days on Site		26.52
Trip Time	(205.25 hrs)	8.55 days
Drilling Time	(19.75 hrs)	.82 days
Coring Time	(336.25 hrs)	14.10 days
Re-entry Time	(23.50 hrs)	.98 days
Mechanical Downtime	(14.25 hrs)	.59 days
Other Miscellaneous Time	(37.50 hrs)	1.56 days
Total Distance Travelled (Nautical Miles)		6,411
Average Speed (knots)		10.63
Sites Drilled		9
Holes Drilled		12
Number of Cores Attempted		207
Number of Cores with Recovery		201
Percent of Cores with Recovery		97.60
Total Meters Cored		1761.00
Total Meters Recovered		1259.80
Percent Recovery		71.50
Meters Drilled		752.00
Total Penetration		2513.00
Percent of Penetration Cored		70.30
Maximum Penetration		538.00
Minimum Penetration		4.00
Average Penetration per Hole		209.00

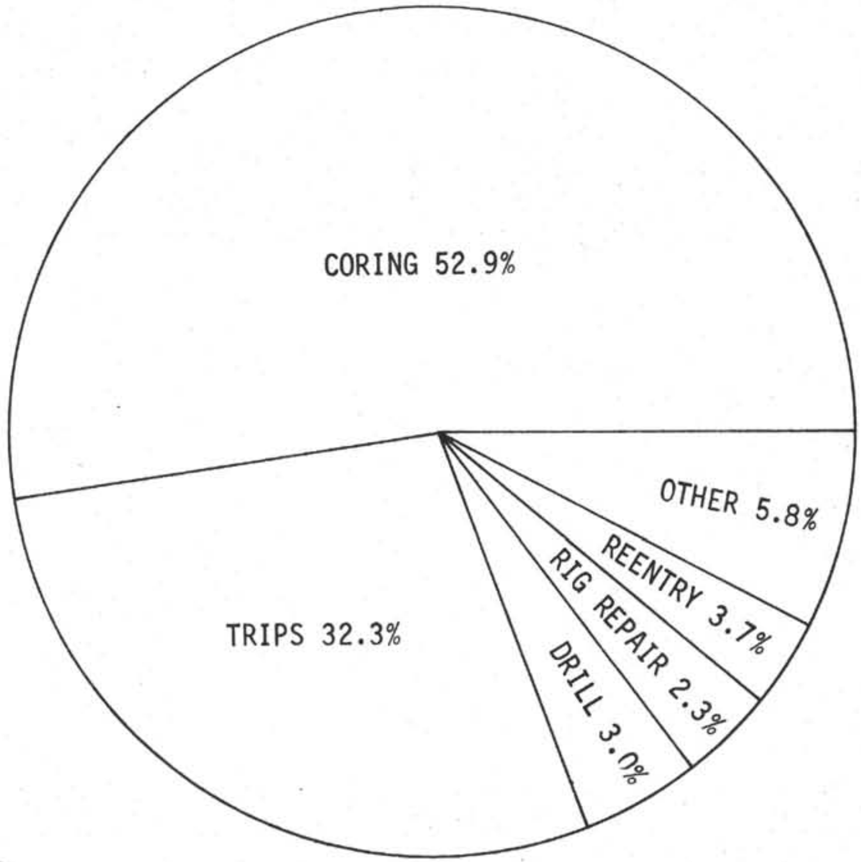

LEG XVI
DRILLING SITES
HAWAII
162
159
163 &
163A
161
160
158
155
157
156
150°
140°
130°
120°
110°
100°
90°
80°
0°
10°
20°
30°

LEG 16
TIME ANALYSIS



OVERALL TIME DISTRIBUTION

LEG 16
TIME ANALYSIS



ON SITE TIME DISTRIBUTION

LEG XVI - DEEP SEA DRILLING PROJECT

SITE SUMMARY

Site	Hole	Latitude	Longitude	Water Depth Meters	No. Of Cores	No. Of Cores With Recovery	Meters Cored	Meters Recovered	Meters Drilled	Total Meters Penetrated	Ave Rate Of Penetration Coring (M/hr)	Ave Rate Of Penetration Drilling (M/hr)	Time On Hole	Time On Site
155	0	06' 7.38'N	81° 02.62'W	2762	12	12	102	56.85	436	538	13.8	85.6	57.75 hrs.	57.75 hrs.
156	0	01° 40.8' S	85° 24.06'W	2394	1	0	4	0	0	4	2.7	--	20.00 hrs.	20.00 hrs.
157	0	01° 45.71'S	85° 54.17'W	2611	49	49	427	272.55	-	427	31.0	--	83.0 hrs.	
157	A	01° 45.71'S	85° 54.17'W	2611	3	3	27	19.3	-	27	147	--	10.75 hrs.	93.75 hrs.
158	0	06° 37.35'N	85° 14.6' W	1963	36	35	323	246.82	-	323	34.2	--	54.5 hrs.	54.5 hrs.
159	0	12° 19.92'N	122° 17.27'W	4494	14	13	109	96.72	-	109	38.0	--	49.0 hrs.	49.0 hrs.
160	0	11° 42.27'N	130° 52.81'W	4950	14	14	114	95.77	-	114	59.8	--	42.5 hrs.	42.5 hrs.
161	0	10° 40.25'N	139° 57.21'W	4949	14	12	126	94.53	-	126	66.3	--	49.75 hrs.	--
161	A	10° 40.25'N	139° 57.21'W	4949	15	15	126	87.82	119	245	47.3	145	53.75 hrs.	103.5 hrs.
162	0	14° 52.19'N	140° 02.61'W	4864	18	16	155	128.5	-	155	38.0	--	51.0	51.0 hrs.
163	0	11° 14.66'N	150° 17.52'W	5330	29	29	243	155.99	51	294	31.4	61.5	123.25hrs.	--
163	A	11° 14.66'N	150° 17.52'W	5330	2	2	5	4.95	146	151	5.0	102.0	41.25 hrs.	164.50 hrs.

TIME BREAKDOWN
PERCENTAGES ARE OF TIME ON LOCATION

Site No.	Steam	Going in Hole	Pulling out of Hole	Drill	Core	Rig Repair	Cut Drilling Line	Waiting on Weather	Other	Total
155	19:15 hrs	11 1/4 hrs 19%	6 1/2 hrs 11%	10 1/2 hrs 18%	26 1/4 hrs 45%		1 1/4 hrs 3%		2 hrs 4%	57 3/4 hrs
156	60:30 hrs	8 1/4 hrs 41%	3 3/4 hrs 18.75%		6 1/2 hrs 32.5%	1 hr 5%	1/4 hr 1.25%		1/4 hr 1.25%	20 hrs
157	5:45 hrs	16 hrs 19.2%	1 1/2 hrs 1.8%		65 hrs 78.3%				1/2 hr .7%	83 hrs
157A			5 1/4 hrs 49%		3 1/2 hrs 32.6%				2 hrs 18.4%	10 3/4 hrs
158	51:15 hrs	5 1/2 hrs 10.1%	5 3/4 hrs 10.6%		37 hrs 67.9%		1/2 hr .9%		5 3/4 hrs 10.6%	54 1/2 hrs
159	8 days 22 hrs	13 3/4 hrs 28.0%	9 1/4 hrs 18.9%		23 1/4 hrs 47.5%			2 3/4 hrs 5.6%		49 hrs
160	2 days 00:45 hrs	11 hrs 25.9%	8 1/2 hrs 20%		22 hrs 51.7%		1/2 hr 1.2%		1/2 hr 1.2%	42 1/2 hrs
161	52:30 hrs	11 hrs 22.2%	6 hrs 12.1%		23 hrs 46.2%		1/2 hr 1%		9 1/4 hrs 18.5%	49 3/4 hrs
161A		6 3/4 hrs 12.5%	10 1/2 hrs 19.6%	1 3/4 hrs 3.3%	26 1/2 hrs 49.3%	5 1/2 hrs 10.2%	1 hr 1.8%		1 3/4 hrs 3.3%	53 3/4 hrs

Time Breakdown concluded

Site No.	Steam	Going in Hole	Pulling out of Hole	Drill	Core	Rig Repair	Cut Drilling Line	Waiting on Weather	Other	Total
162	35 3/4 hrs	10 3/4 hrs 21.1%	10 1/4 hrs 20.1%		28 3/4 hrs 56.3%	1 hr 2%			1/4 hr .5%	51 hrs
163	71 1/2 hrs	9 1/2 hrs 7.8%	13 1/2 hrs 10.9%	4 1/4 hrs 3.5%	67 3/4 hrs 54.9%	5 3/4 hrs 4.7%	1 1/2 hrs 1.2%	re-entry 17 3/4 hrs 14.4%	3 1/4 hrs 2.6%	123 1/4 hrs
163A		11 3/4 hrs 28.4%	9 hrs 21.8%	3 1/4 hrs 7.9%	6 3/4 hrs 16.4%	1 hr 2.4%	3/4 hrs 1.6%	5 3/4 hrs 14.1%	3 hrs 7.4%	41 1/4 hrs
To Port 75 3/4 hrs								WOW-R/E		
On Location Total		115 1/2 hrs 18.2%	89 3/4 hrs 14.1%	19 3/4 hrs 3.0%	336 1/4 hrs 52.9%	14 1/4 hrs 2.3%	6 1/4 hrs 1%	2 3/4-23 1/2 .4%-3.7%	28 1/2 hrs 4.4%	636 1/2 hrs
Overall Total	635 hrs 50%	115 1/2 hrs 9.1%	89 3/4 hrs 7.1%	19 3/4 hrs 1.5%	336 1/4 hrs 26.4%	14 1/4 hrs 1.1%	6 1/4 hrs .5%	2 3/4-23 1/2 .2%-1.9%	28 1/2 hrs 2.2%	1,271 1/2 hrs

LEG XVI - DEEP SEA DRILLING PROJECT

BIT RECORD

BIT DESCRIPTION						CORING			DRILLING			TOTAL	TOTAL	COND.	REMARKS
Make	Size	Type	S/N	Site	Hole	Meters Cored	Rotating Time Hrs.	Penet Rate	Meters Drilled	Rotating Time Hrs	Penet Rate	Meters Penetrated	Hours on Bit		
Smith	10 1/8	9–4	GC-282	155	0	102	7.37	13.8	436	5.1	85.6	532	13.95	T-1 B4	Shaped insert button bit. Drilled hard clay and basalt faster than regular button bit. Bit lost when BHA dropped on 157.
		4 cone		156	0	4	1.48	2.7	---	---	---				
						106	8.85		426	5.1					
Smith	10 1/8	9–4	GC-299	157		427	13.72	31.0	---	---	---	454	13.90	T-2 B5	Shaped insert button bit drilled over 90 meters broken chert and lime and 3 meters of basalt. One insert broken, one gone.
		3 cone		157	A	27	.18	147.0	---	---	---				
						454	13.90								
Smith	10 1/8	3 cone	FR-922	158	0	323	9.43	34.2				432	12.29	T-2 B6	Regular button.
				159		109	2.86	38.0							
						432	12.29								
Smith	10 1/8	4 cone	GB-783	160	0	114	1.92	59.8				114	1.92		Regular button.
Smith	10 1/8	3 cone	GF-606	161	0	126	1.90	66.3						T-1 B3	Sealed bearing regular button bit.
		sealed		161	A	126	2.68	47.3	119	.82	145.0	677	12.67	cones	
		bearing		162		155	4.84	38.0						pinched	
				163	A	5	1.00	5.0	146	1.43	102.0				
						412			265	2.25					
Smith	10 1/8	9–4	GC-298	163	0	243	7.72	31.4	51	.83	61.5	294	8.55	T-8 B8 all 3 cones gone	Shaped insert bit, drilled entire chert section and drilled 18 meters of basalt. Ran cones off of bit in attempt to ream back to bottom after second basalt core.
		3 cone													

LEG 16 - BEACON SUMMARY

Site No.	Make	Freq. kHz	Ser. No.	Battery Ser. No.	Site Time Hrs.	Remarks
155	ORE	16	124	---	57:45	Vessel seemed to hunt within 50 feet of beacon.
156	ORE	13.5	105	---	20:00	Vessel seemed to hunt within 50 feet of beacon.
157	ORE	13.5	106	---	93:45	Vessel seemed to hunt within 50 feet of beacon.
158	Burnett	13.5	138	155	54:30	Dropped to compare with ORE beacon. On Site 157 vessel did not hold position very close. Suspected ORE beacon was moving. Burnett held vessel within 30 feet.
159	ORE	16	117	---	49:00	Beacon bridle restrung to make floatation unit float level. Secured transducer gimbal. Swell and wind from different directions, 40 degrees apart with a current 90 degrees to swell. Positioning difficult. Lost acoustic for a period of two to three hours and had to position vessel in semi-automatic. Uncertain if beacon had any influence on positioning problems.
160	ORE Burnett	16 13.5	119 162	--- 144	42:30 37:15	Dropped ORE 5-1445 March 71. Positioning erratic so dropped Burnett beacon to compare ORE and Burnett beacons under same conditions. Burnett dropped 5-200 March 71. Both beacons acted the same. Erratic positioning evidently due to sea and wind conditions.
161	ORE	16	107	---	49:45	Positioned better except vessel periodically drifted 100 plus feet along x-axis. Slow to return to position.
161A	ORE	16	107	---	53:45	Same as 161.
162	ORE	16	112	---	51:00	Positioned same as Site 161.

Leg 16 - Beacon Summary concluded

Site No.	Make	Freq. kHz	Ser. No.	Battery Ser. No.	Site Time Hrs.	Remarks
163	Burnett	16	136	471	00:45	Dropped Burnett 16 kHz beacon with dual battery pack for use on re-entry site. Beacon failed in 45 minutes.
	Burnett	13.5	163	163	163:45	Dropped Burnett 13.5 kHz beacon after re-surveying site. Vessel positioned very well with no problem of drifting off along x-axis as experienced with ORE beacon.

OPERATIONS RESUME

LEG 17

SUMMARY

Leg 17 of the Deep Sea Drilling Project, commenced on March 30, 1971, in Honolulu, proceeded on a large loop through the Line Islands, east of the Marshall Islands, across the Mid-Pacific Mountains and returned to Honolulu on May 25, 1971.

During the 55.88 day voyage, the Glomar Challenger cruised 4,783 nautical miles, drilled ten holes at eight sites, cored 2371 meters in 248 coring attempts with recovery on 196 or 79 percent. A total of 904.6 meters of core was recovered for an average of 38.2 percent. In addition to the coring, 879 meters were drilled for a total penetration of 3250 meters.

Major time distribution for the 55.88 days consisted of 4.68 days in port, 19.18 days cruising and 30.70 days on site. Major time distribution of the 30.70 site days, 7.01 days were used for trip time and 20.49 days for coring.

The dynamic positioning system operated very erratic during the leg primarily due to the loss of a bow thruster on Site 166. Due to weather and sea conditions, mostly a result of the trade winds and the loss of the thruster, vessel positioning was accomplished by using the semi-automatic mode a large percentage of the time.

The most significant accomplishment on Leg 17 was the maximum penetration depth record of 1185 meters which was established on Site 167. Even after penetrating numerous chert layers and hard limestone formations, the bit successfully cored 18 meters of basalt basement and the dull condition indicated that more basalt could have been cored if so desired.

DRILLING AND CORING

The geologic sections on all eight sites were very similar with the main difference being the depths at which the chert layers and basalt were encountered. The sediments near the sea floor were soft, unconsolidated oozes and became firmer as the depth increased. Numerous relative thin layers of chert were found interbedded in clays and limestones and occurred from 18 meters below the ocean floor to as deep as 1167 meters or just above the basalt basement.

To drill and core the above type sediments on Leg 17, five different bottom hole assembly configurations were used, however the modification from the basic assembly was minimal. The basic assembly used on six sites consisted of the core bit, one 8 1/4 inch core barrel, three 8 1/4 inch drill collars, two bumper subs, three 8 1/4 inch drill collars, two bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar and one joint of heavy wall drill pipe. This assembly was approximately 127 meters long and provided approximately 30,000 pounds of weight in sea water. On Site 164 the change in the assembly was the use of only one lower bumper sub and the addition of a stabilizer above the first drill collar. On Site 165, the modification was only the addition of the stabilizer above the first drill collar. No firm evidence of improved bit performance resulted from the addition of the stabilizer to the string and it was subsequently removed. The second lower bumper sub was added to the string to help compensate for the heave of the vessel in the relative rough seas.

A total of seven bits were used on the eight sites with one bit being used on two sites.

Five - 4 cutter, sealed bearing, shaped inserts
One - 4 cutter, non-sealed bearing, shaped inserts
One - 3 cutter, non-sealed bearing, compact type inserts

All of the bits performed very well in that each successfully penetrated the hard chert stringers and was still in satisfactory condition to penetrate the basalt basement. Penetration rates indicate, however, that the shaped inserts are better for coring the basalt and in most instances also penetrate the chert better than the compact inserts. The limiting factor on the bits seems to be the bearing life, even though total rotating time is very low as is bit weight. Average rotating time per bit was 11 hours 35 minutes, with bit weights varying from 2,000 to 30,000 pounds or 250 to 3,800 pounds per inch of effective bit diameter. Drill pipe rotation varied from 25 to 80 rpm. Circulating rates were minimal while coring and maximum while washing or drilling. It is suspected that the dull bearing grades ranging from five to eight was caused primarily by the continual pounding on the bottom of the hole as a result of the heave of the drilling vessel. The seals on several of the bearings had failed, however some of the failures appeared to have been caused by chert chips cutting away a portion of the shirt tail of the legs and exposing the seal itself to the chips.

Two sites were successfully drilled in areas where the first reflector or chert layer was less than 100 meters below the sea floor. On Sites 169 and 170, the first chert was encountered at 37 and 18 meters respectively. Departure from the established policy of having a minimum of 100 meters of sediment cover was due to the intense desire of the scientific staff for core data at these two sites. The successful technique used was to run very low bit weight, less than 10,000 pounds, which prevented the lower bumper subs from closing and low rpm, 25 to 35. These conditions were maintained until the bottom hole assembly was buried deep enough so as to have lateral support. Again, high pump volumes were used except when coring. Even though the above techniques were used, the lower bumper subs and drill collars were lost on Site 168. The data is not conclusive as to what caused the failure but it appeared to simply be a "back-off" in the upper portion of one of the bumper subs. When the above drilling techniques were used, however, the dull bits normally indicated numerous broken or missing shaped inserts. This was probably the result of the bouncing action on the extremely hard chert.

The problem of getting through the hard chert layers and to the basalt with a bit capable of additional drilling appears to have been solved, however, core recovery with the insert bits and present core barrel arrangement has been very low. For the entire Leg 17 the recovery was 38.2 percent with the lowest recoveries being in the multiple chert stringers with soft chalks, clays, or limestone between the layers. Recovery in the massive basalt formations was generally very good. Any time that the pumps and circulation was required, except in the very hard formations, the recovery was very low. Hole stability throughout the leg was good with the drill string sticking only occasionally. On these occasions, it was possible to work the pipe free with the aid of high circulation rates. On two occasions the bit plugged but, again, by working the pipe and use of the pumps the bits were cleared and operations continued.

Data is not conclusive but both the drill pipe sticking and the bit plugging appear to be related to the chert stringers and very fine chert chips. Raw sea water would be used as a circulating medium to drill several stringers, normally using light weight in the shallow stringers, and then following the cutting of a core, the pipe would tend to stick and the bit would plug. Large volumes of fine chert chips would then be recovered on the next core barrel. The practice of pumping 50 to 100 barrels of mud following the cutting of a core after penetrating several chert stringers, but prior to pulling the core barrel was an effective solution to the problem. The magnitude of the problem was greater when drilling the shallow stringers with light weight then when drilling the deep stringers with maximum weight.

In an effort to facilitate the unplugging of bits and thus preventing a round trip and the loss of a hole, it is recommended that a drill pipe swab be purchased and placed on the vessel. With such a tool, several hundred feet of water could be removed from the drill pipe when the bit is plugged and thus create a differential across the bit from the outside to the inside. With subsequent working of the pipe, it is believed that most bits could then be unplugged.

In addition to the bumper sub failure previously mentioned, the only other failure in the drilling equipment on Leg 17 occurred in a saver pup joint on the Bowen power swivel. The leak occurred in what appeared to be a fatigue crack about 1 1/2 feet above the tool joint in an area that is subject to considerable wear in the rotary bushing. This sub had been inspected and approved for use just prior to sailing from Honolulu. Similar failures have occurred on other subs in the past and thought is now being given to the possible use of heavier and possibly longer subs in an effort to compensate for the wear. Because several failures have occurred following established inspection practices, the entire inspection program should be thoroughly evaluated.

To complement such a study and to evaluate and if necessary, modify the corrosion protection program for the five-inch drill pipe, twelve corrosion rings were exposed in the drill pipe on Sites 168 and 169. The rings were exposed in such a manner so as to determine if most corrosion is taking place downhole during operations or while the pipe is on the rack on deck. Metal loss and the inhibitor program will be evaluated by Baroid.

At the beginning of Leg 16 a new 1/2 inch 6 x 9 Seale AMGAL Super Tensil Monitor AA Preformed Right Regular Lay F.C. sand line was installed but use was very limited. The line was used extensively on Leg 17 with a total of 263 trips at an average depth of 16,100 feet. The galvanized line was clean and free of rust at the end of the leg and showed very little wear. Rather than replace the line every two legs as has been the recent practice, wear on the galvanized line should be monitored and the line replaced only as required. A secondary benefit from the use of the clean galvanized line was the reduction in the number of stripper rubbers used. About one-half were used on Leg 17 as would have normally been used.

POSITIONING EQUIPMENT

The dynamic positioning system operated very erratic on this leg and on only three holes was the vessel held on station in the automatic mode for the majority of the time. On the other sites the ship's crew did an excellent job of holding station in the semi-automatic mode.

The exact problem with the automatic system was never clearly defined, but several conditions probably contributed.

1. The loss of bow thruster No. 1 due to mechanical failure on Site 166. This thruster was not used the remainder of the leg but was held in reserve and available for emergency use. The heavy load on bow thruster No. 2 then caused heating problems and limits (reduced rpm) had to be imposed.

2. Excessive thruster rpm was being received for the magnitude of signal being sent by the positioning computer when operating in the automatic mode. The thrusters rpm was later calibrated to the received signal and considerable improvement was noted in the operating system. On the last site, 171, the system operated continuously in the automatic mode following calibration.

3. On several occasions there was a complete loss of power to the bow thrusters. The problem could never be completely isolated because after five to 15 minutes the power would restore itself automatically. A faulty relay was suspected as the same problem had occurred on previous legs.

A total of ten beacons were used with seven performing satisfactorily and three failing. The satisfactory beacons included four Burnett 16.0 kHz, one Burnett 13.5 kHz and two ORE 16.0 kHz. One Burnett 13.5 failed along with two ORE 16.0 kHz. All of the failures were due to amplitude fluctuation and occurred after being in the water an average of 50 hours. The average operating time of the satisfactory beacons was 106 hours. A Burnett 16.0 kHz with two battery packs was used on Site 167 and operated satisfactorily for 328 hours or 9 1/2 days.

Due to rough seas and fairly strong winds, trouble was experineced marking and holding a selected site with a spar buoy until the beacon could be dropped. To alleviate this problem all beacons with the exception of the one on Site 164 were dropped while underway at speeds of six to eight knots. The scientists were pleased with the site marking and from close observation, it appeared the beacons received no rougher treatment than if placed in the water after being on station. The only draw back is that the beacon cannot be immersed and checked prior to dropping underway. The number of failures due to flooding has been extremely low, however, and is negligible when compared to the possibility of drilling on a station other than the pre-selected site caused by a drifting spar buoy.

COMMUNICATIONS AND WEATHER

During the 55.88 day cruise, 515 messages were transmitted from the Glomar Challenger, 106 of which were to Global Marine, 121 were to Scripps (DSDP), 251 were meteorological reports and 37 were personal messages for the crew over commercial channels. Received messages totaled 143. All messages were transmitted by radio telegraph, via Scripps Radio Station WWD, except for the commercial messages and some of the meteorological messages. No delays longer than a few hours were encountered with any traffic. Radio teletype communication was impractical due to low signal strength and interference for most of the leg.

The Technical Material Company (TMC) transmitter failed during the fifth week of the cruise due to a casualty in the radio frequency exciter unit. All other equipment performed satisfactorily. A VHF radio transceiver was installed at the May 25th Honolulu port call and should facilitate ship to shore communications while entering or leaving port. It will also increase emergency ship to ship communications capabilities.

In general, the weather during the cruise was excellent and nothing out of the ordinary experienced. Several of the sites were located in the edge of the convergence zone and some inclimate weather experienced but none so severe that operations had to be suspended.

Extremely sharp and clear satellite mosaic weather data was received during the entire leg. It was found impractical, however to receive Coast Guard Radio Honolulu (NMO) consistently from the operating area, hence incoming meteorological and satellite prediction information was routed through station WWD with good results. The facsimiles received were of very good quality and proved especially useful for individuals lacking formal weather training.

Several facsimile schedules were held with the R/V Thomas Washington (KGWU) for receipt of scientific information concerning site locations. At ranges of 500 to 1,500 miles, the results were satisfactory.

NAVIGATION EQUIPMENT

The Loran "A" and "C" receiver functioned very well and was used effectively on the five sites which were within the area of Loran transmission. Celestial and satellite navigation were also used with the satellite and Loran checking very close.

The Marconni radar was repaired prior to sailing from Honolulu and functioned very well until May 18. Repairs were deferred until the next port call due to lack of parts on board. A new Decca Model 914 radar set is scheduled to be installed at the Honolulu port call and should provide redundancy for future cruises, especially applicable in the Bering Sea on Leg 19.

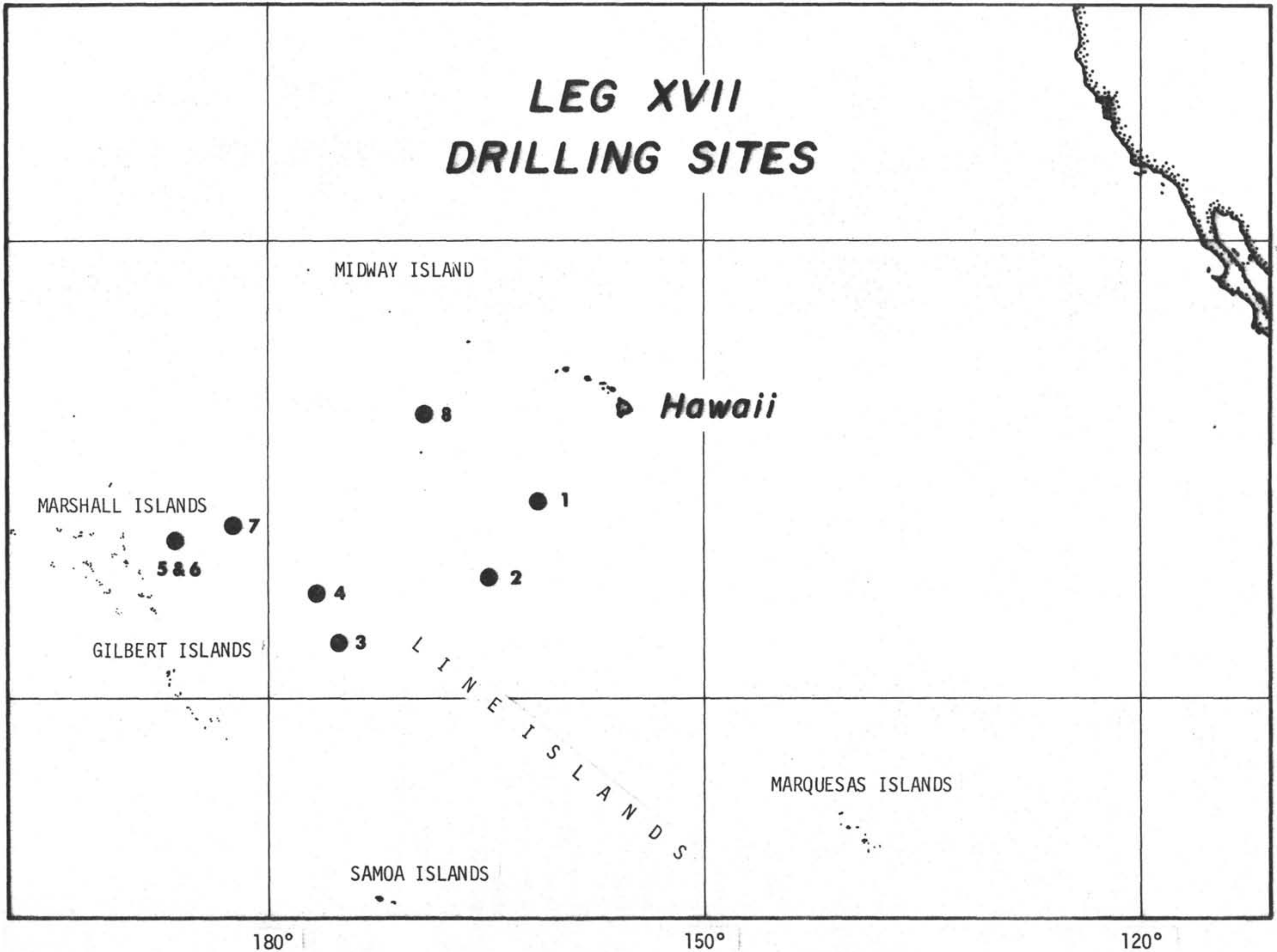
All other navigation equipment, gyro, radio direction finder, and fathometer, operated satisfactory with the exception of the pit log which read consistently low.

PERSONNEL

All Global personnel performed in an outstanding manner and contributed greatly to a successful cruise. Only one lost time and two minor accidents occurred. The crews conscientious attitude toward maintenance and preventative maintenance programs certainly maximized the time available for coring operations.

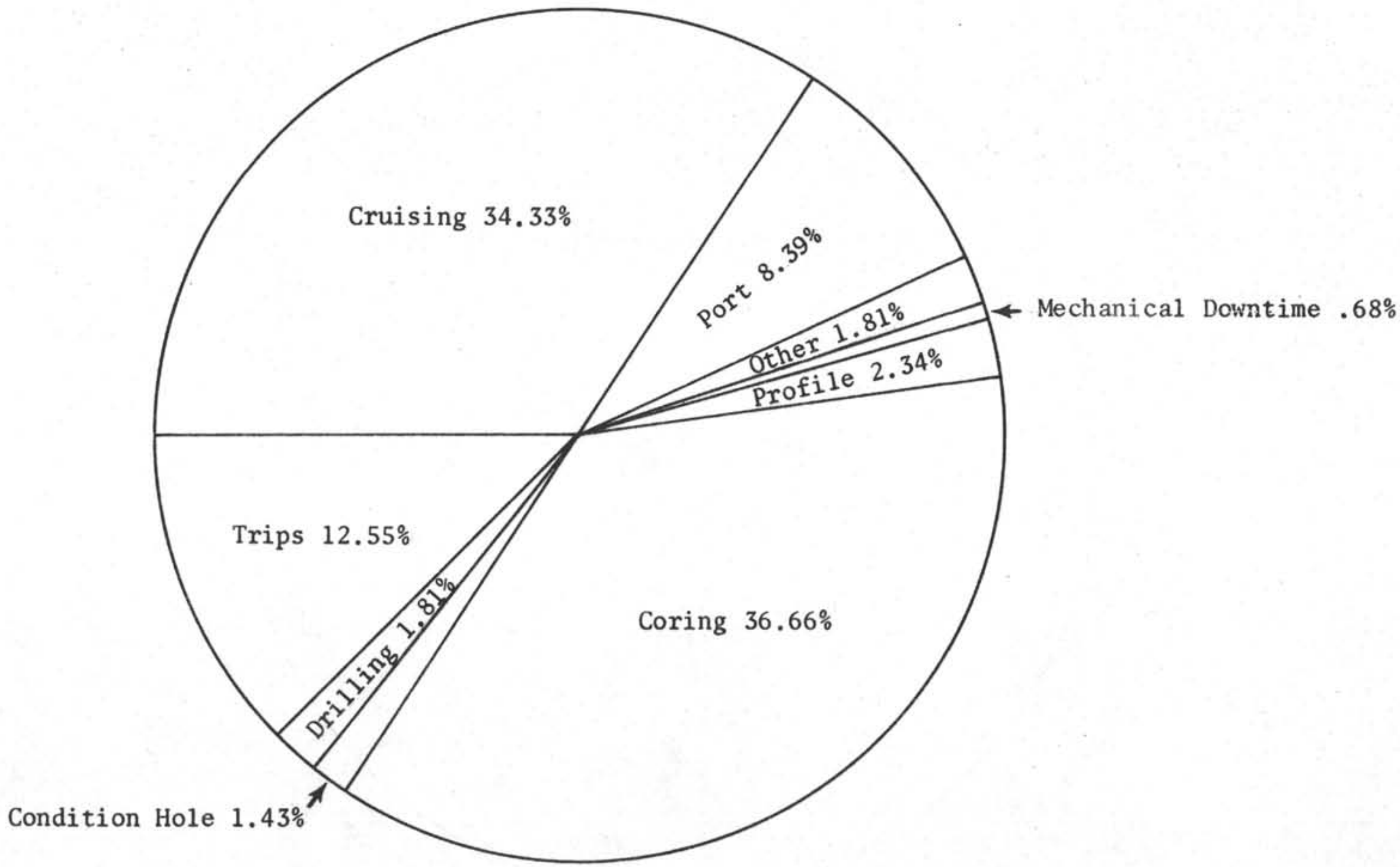
LEG 17 - SUMMARY OF OPERATIONS

Total Days Leg 17 (March 30, 1971 to May 25, 1971)		55.88
Total Days in Port		4.68
Total Days Cruising		19.18
Total Days Profiling		1.31
Total Days on Site		30.70
Trip Time	(168.3 hrs)	7.01
Drilling Time	(24.5 hrs)	1.01
Coring Time	(491.6 hrs)	20.49
Mechanical Downtime	(9.0 hrs)	.38
Condition Hole	(19.0 hrs)	.80
Miscellaneous	(24.5 hrs)	1.01
Abandonment	(0.0 hrs)	0.00
Re-entry	(0.0 hrs)	0.00
Total Distance Travelled (Nautical Miles)		4,783
Average Speed		9.16
Sites Investigated		8
Holes Drilled		10
Number of Cores Attempted		248
Number of Cores With Recovery		196
Percent of Cores With Recovery		79.00
Total Footage Cored	(7,778.7 ft)	2371.00
Total Footage Recovered	(2,967.8 ft)	904.60
Percent of Footage Recovered		38.20
Footage Drilled	(2,883.8 ft)	879.00
Total Penetration	(10,662.6 ft)	3250.00
Percent of Total Penetration Cored		73.00
Maximum Penetration per Hole	(3,887.7 ft)	1185.00
Minimum Penetration per Hole	(29.5 ft)	9.00
Average Penetration per Hole	(1,328.7 ft)	405.00


LEG XVII
DRILLING SITES
MIDWAY ISLAND
Hawaii
MARSHALL ISLANDS
GILBERT ISLANDS
LINE ISLANDS
MARQUESAS ISLANDS
SAMOA ISLANDS
1
2
3
4
5&6
7
8
30°
0°
180°
150°
120°

LEG XVII - DSDP

TOTAL TIME DISTRIBUTION

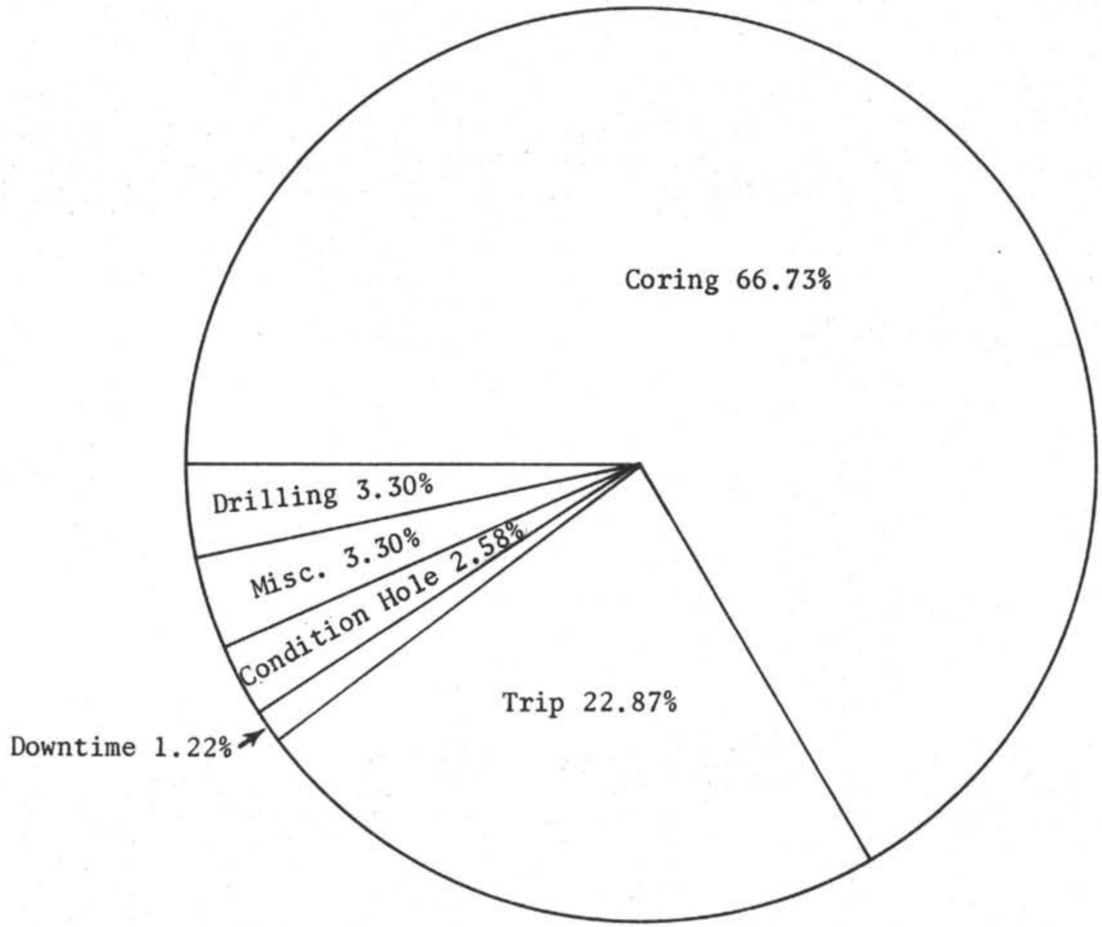


Start: 2200 GMT March 30, 1971
Finish: 1800 GMT May 25, 1971

55 Days 21 Hours 30 Minutes
8 Sites 10 Holes

ATTACHMENT IV
LEG XVII - DSDP

SITE TIME DISTRIBUTION



Start: 2200 GMT March 30, 1971
Finish: 1800 GMT May 25, 1971

On Site 30 Days 17 Hours
8 Sites - 10 Holes

LEG 17 - SITE SUMMARY

Site	Hole	Latitude	Longitude	Water Depth Meters	No. of Cores	Cores with Rec.	Meters Cored	Meters Rec.	Meters Drilled	Total Meters Penet.	Avg. Rate Penet. (m/hr)	Time on Hole (hours)	Time on Site (hours)
East of Line Islands													
164	0	13°12.14' N	161°30.98' W	5513	28	25	259	81.1	0	259	20	104.5	104.5
West of Line Islands													
165	0	08°10.73' N	164°51.64' W	5053	2	2	14	8.0	0	14	84	17.3	
165	A	08°10.73' N	164°51.64' W	5053	27	25	371	131.4	119	490	31.5	89.2	86.5
South of Magellan Rise													
166	0	03°45.7' N	175°04.9' W	4962	29	29	237	155.3	73	310	36	77.0	
166	A	03°45.7' N	175°04.9' W	4962	1	1	9	6.0	0	9	180	4.0	81.0
Magellan Rise													
167	0	07°04.12' N	176°49.52' W	3176	95	72	867	298.6	318	1185	19	228.0	228.0
NW of Marshall Islands													
168	0	10°42.21' N	173°35.92' E	5430	5	2	28	7.8	47	75	67	42.0	42.0
169	0	10°40.16' N	173°32.98' E	5415	12	6	96	12.4	142	238	20	65.0	65.0
170	0	11°47.97' N	177°37.02' E	5792	16	7	134	30.7	62	196	19	64.0	64.0
Horizon Guyot													
171	0	19°07.85' N	169°27.59' W	2295	33	27	356	173.3	118	474	42	66	66
Summary													
Total 8 Sites - 10 Holes					248	196	2371	904.6	879	3250		737.0	737.0
Percent						79.0	73.0	38.2	27.0				
Avg/Site 1.2 Holes				4765	31	24.5	296	112	110	405	51.8	73.7	92.0
Max/Site 2 Holes				5792	95	72	867	298.6	318	1185	180	228	228
Min/Site 1 Hole				2295	1	1	2	2	47	9	19	4.0	4.2

SUMMARY TIME ANALYSIS - LEG XVII - DEEP SEA DRILLING PROJECT

Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-Entry Time	Mechanical Downtime	In Port Time	Misc.	Total	Remarks
3-30	-	-	-	-	-	-	-	-	-	-	1200	-	1200	Dock Honolulu - 1200 hrs - 3-30-71
3-31	-	-	-	-	-	-	-	-	-	-	2400	-	2400	Insp. DP - Repair BT #1 Load Equip & Supplies
4-1	-	-	-	-	-	-	-	-	-	-	2400	-	2400	" " " " "
4-2	-	-	-	-	-	-	-	-	-	-	2400	-	2400	" " " " "
4-3	-	-	-	-	-	-	-	-	-	-	2400	-	2400	" " " " "
4-4	-	-	-	-	-	-	-	-	-	-	0440	-	0440	Sailed @ 0440 - Ck BT #1 OK
Total Port			-	-	-	-	-	-	-	-	11240	-	11240	Total Port Time = 112 40
Leg. Cumm.			-	-	-	-	-	-	-	-	11240	-	11240	Cumm Total = 112 40 hrs
4-4	164	1920	-	-	-	-	-	-	-	-	-	-	1920	Enroute to Site 164
4-5	164	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
4-6	164	1430	200	730	-	-	-	-	-	-	-	-	2400	Beacon in H_2O @ 1620
4-7	164	-	-	1000	-	1400	-	-	-	-	-	-	2400	Inspect DC's · Coring
4-8	164	-	-	-	-	2200	200	-	-	-	-	-	2400	Coring
4-9	164	-	-	-	-	2230	130	-	-	-	-	-	2400	"
4-10	164	-	-	930	-	1330	-	-	-	100	-	-	2400	" Hit Basalt @ 0600
4-11	164	-	300	100	-	-	-	-	-	-	-	-	400	Profile 3 hrs · Underway to 165 @ 0400 ·
Total	164	5750	500	2800	-	7200	330	-	-	100	-	-	16720	Site Total = 167 hr 20 min.
Leg Cumm.		5750	500	2800	-	7200	330	-	-	100	11240	-	28000	Cumm Total = 280 hr
4-11	165	2000	-	-	-	-	-	-	-	-	-	-	2000	Enroute to Site 165
4-12	165	1500	30	730	-	-	-	-	-	100	-	-	2400	Beacon in H_2O @ 1500
4-13	165	-	-	520	-	1840	-	-	-	-	-	-	2400	Cut 2 cores on 165 · Repeated #2 & called 165A
4-14	165A	-	-	-	-	2200	100	-	-	100	-	-	2400	Replace 20' pup on Bowen
4-15	165A	-	-	430	-	1930	-	-	-	-	-	-	2400	Coring
4-16	165A	-	400	600	-	-	-	-	-	-	-	-	1000	Underway @ 0600 - Profile 0600 to 1000
Total	165 165A	3500	430	2320	-	6010	100	-	-	200	-	-	12600	Site Total = 126 hr.
Leg Cumm.		9250	930	5120	-	13210	430	-	-	300	11240	-	40600	Cumm Total = 406 hr.

Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-Entry Time	Mechanical Downtime	In Port Time	Misc.	Total	Remarks
4-16	166	1400	-	-	-	-	-	-	-	-	-	-	1400	Enroute to Site 166
4-17	166	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
4-18	166	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
4-19	166	600	300	1000	-	500	-	-	-	-	-	-	2400	Beacon in H_2O @ 0800
4-20	166	-	-	-	200	2130	-	-	-	30	-	-	2400	Power Loss to BT #1
4-21	166	-	-	-	-	2300	-	-	-	100	-	-	2400	ORE Beacon Failure - Wait for Burnett 13.5 to fall
4-22	166	-	230	1230	-	530	-	-	-	-	-	-	2030	Depart 166 @ 2030 hr.
Total	166	6800	530	2230	200	5500	-	-	-	130	-	-	15430	Site Total = 154 hr 30 min.
Leg Cumm		16050	1500	7350	200	18710	430	-	-	430	11240	-	56030	Cumm Total = 560 hr 30 min.
4-22	167	330	-	-	-	-	-	-	-	-	-	-	330	Enroute to Site 167
4-23	167	2130	130	100	-	-	-	-	-	-	-	-	2400	Beacon in H_2O @ 2300
4-24	167	-	-	630	400	1330	-	-	-	-	-	-	2400	Coring
4-25	167	-	-	-	230	2100	30	-	-	-	-	-	2400	" Lost time accident
4-26	167	-	-	-	-	2200	200	-	-	-	-	-	2400	"
4-27	167	-	-	-	-	2400	-	-	-	-	-	-	2400	"
4-28	167	-	-	-	-	2400	-	-	-	-	-	-	2400	"
4-29	167	-	-	-	-	2400	-	-	-	-	-	-	2400	"
4-30	167	-	-	-	-	2100	100	-	-	-	-	200	2400	Core BBL stuck - Worked loose
5-1	167	-	-	-	-	2000	100	-	-	300	-	-	2400	Repair Bowen Unit
5-2	167	-	-	-	-	2030	300	-	-	30	-	-	2400	" " "
5-3	167	-	130	1100	-	-	-	-	-	-	-	-	1230	Depart Site 167 @ 1230 hrs
Total	167	2500	300	1830	630	19000	730	-	-	330	-	200	25600	Site Total = 256 hr
Leg Cumm		18550	1800	9220	830	37710	1200	-	-	800	11240	200	81630	Cumm Total = 816 hr 30 min.

Date	Site Number	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Reentry Time	Re [illegible] Time	Mechanical Downtime	Downtime [illegible] Time	Misc.	Total	Remarks
5-3	168	1130	-	-	-	-	-	-	-	-	-	-	1130	Enroute to Site 168
5-4	168	2400	-	-	-	-	-	-	-	-	-	-	2400	" " "
5-5	168	2400	-	-	-	-	-	-	-	-	-	-	2400	" " "
5-6	168	400	30	1300	30	600	-	-	-	-	-	-	2400	Beacon in H_2O @ 0430HR
5-7	168	-	-	900	30	530	-	-	-	100	-	630	2230	BHA parted: Beacon failed - Departed 168@2300
Total	168	6330	30	2200	100	1130	-	-	-	100	-	630	10600	Site Total = 106 HR.
Leg Cumm		24920	1830	11420	930	38840	1200	-	-	900	11240	830	92230	Cumm Total = 922 HR 30 min.
5-7	169	-	130	-	-	-	-	-	-	-	-	-	130	Beacon in H_2O @ 0200
5-8	169	-	230	1030	330	200	200	-	-	-	-	500	2530	Time change - PU DC & BS - Unplug bit
5-9	169	-	-	-	200	2200	-	-	-	-	-	-	2400	Coring
5-10	169	-	130	1000	-	800	-	-	-	-	-	-	1930	Depart 169 @ 1930HR
Total	169	-	530	2030	530	3200	200	-	-	-	-	500	7030	Site Total = 70HR 30min.
Leg Cumm		24920	2400	13450	1500	42040	1400	-	-	900	11240	1330	99300	Cumm Total = 993 HR
5-10	170	430	-	-	-	-	-	-	-	-	-	-	430	Enroute to Site 170
5-11	170	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
5-12	170	-	130	1030	600	430	30	-	-	-	-	100	2400	Beacon in H_2O @ 0130 HR
5-13	170	-	-	-	100	2200	100	-	-	-	-	-	2400	Coring
5-14	170	-	100	930	-	800	-	-	-	-	-	-	1830	Depart Site 170 @ 1730HR.
Total	170	2830	230	2000	700	3430	130	-	-	-	-	100	9500	Site Total = 95 HR.
Leg Cumm		27750	2630	15450	2200	45510	1530	-	-	900	11240	1430	108800	Cumm Total = 1088 HR
5-14	171	530	-	-	-	-	-	-	-	-	-	-	530	Enroute to Site 171
5-15	171	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
5-16	171	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
5-17	171	2400	-	-	-	-	-	-	-	-	-	-	2400	" " " "
5-18	171	2300	-	-	-	-	-	-	-	-	-	100	2400	Change course to Johnson Isl - Ill seaman - 2300HR
5-19	171	-	430	530	100	400	-	-	-	-	-	900	2400	Alter course Site 171 - Arrived 0900 - Beacon in H_2O 1230

Date	Site	Cruise Time	Profile Time	Trip Time	Drilling Time	Coring Time	Condition Hole	Abandon Time	Re-entry Time	Mechanical	Downtime In Port Time	Misc.	Total	Remarks
5-20	171	-	-	-	100	2200	100	-	-	-	-	-	2400	Coring
5-21	171	-	30	800	30	1030	230	-	-	-	-	-	2200	Depart Site 171 @ 2200 HR
Total	170	10030	500	1330	230	3630	330	-	-	-	-	1000	17130	Site Total
Leg Cumm		37820	3130	16820	2430	49140	1900	-	-	900	11240	2430	125930	Cumm. Total
5-21	Honolulu	200	-	-	-	-	-	-	-	-	-	-	200	Enroute to Honolulu
5-22	"	2400	-	-	-	-	-	-	-	-	-	-	2400	" "
5-23	"	2400	-	-	-	-	-	-	-	-	-	-	2400	" "
5-24	"	2400	-	-	-	-	-	-	-	-	-	-	2400	" "
5-25	"	800	-	-	-	-	-	-	-	-	-	-	800	" "
Total	"	8200	-	-	-	-	-	-	-	-	-	-	8200	Site Total = 82 HR
Leg Cumm		46020	3130	16820	2430	49140	1900	-	-	900	11240	2430	134130	Cumm Total = 1341 HR 30 MIN.
	%	34.33	2.34	12.55	1.81	36.66	1.43	-	-	.68	8.39	1.81		Total Time Distribution - %
	%			22.87	3.30	66.73	2.58			1.22		3.30		On Site Time Distribution %

LEG 17 - BIT SUMMARY

Site	Make	Bit Description Size	Type	Ser. No.	Cores Taken Core No.	Cores Taken Recovery No.	Cores Taken Recovery %	Footage Cored Core M	Footage Cored Recovery M	Footage Cored Recovery %	Total Penet. M	Rot. Time Hr.	Penet. Rate M/Hr.	Bit Condition	Remarks
164	Smith	10 1/8	94	GT 331 1 4	28	25	90	259	81.1	31.5	259	13.5	20	T-1, B-6 2 cone locked 4 inserts gone 0 - 1/4 - cone ID-2 1/2	1/8 UG on cone - new 1/4 UG on pads - new Clay, Chert 10M - Basalt
165	Smith	10 1/8	94	GT 332	2	2	100	14	8	57.0	14	10 min	84	Not Pulled	
165A	Smith	10 1/8	94	GT 332 1 4	27	25	93	371	131.4	35.0	490	11 hr 48 min	31 1/2	B-1, T-1 IG Excellent Condition	Cut min of 20M Basalt.
166	Smith	10 1/8	94	GT 332 Rerun	29	29	100	237	155.3	65.3	310	8 hr 37 min	36	T-3, B-7 IG	Good Penetration Cut 7M Basalt
166A	Smith	10 1/8	94	GT 332 Rerun 1 4	1	1	100	9	6	66	9	3	180	T-3, B-7 IG ID - 2 7/16	Piston Core
	Cumulative Performance			GT 332	59	57	96	631	300.7	47.6	823	20 hr 38 min	39		
167	Smith	10 1/8 x 2 7/16	94	GT 101 1 4	95	72	76	867	298.6	34.5	1185	60 hr 44 min	19	T-5, B-8 IG Throat 2 1/2	Good Penetration. Poor recovery in chert. Cut 18M basalt.
168	Smith	10 1/8 x 2 7/16	94	GS 956 1 4	5	2	40	28	7.5	26.7	75	1 hr 7 min	67	Lost in hole. No dull grade.	

Leg 17 - Bit Summary concluded

Site	Make	Bit Description Size	Type	Ser. No.	Cores Taken Core No.	Recovery No.	%	Footage Cored Core M	Recovery M	%	Total Penet. M	Rot. Time Hr.	Penet. Rate M/Hr.	Bit Condition	Remarks
169	Smith	10 1/8 x 2 7/16	94	GS 957 (1) (4)	12	6	50	96	12.4	12.9	238	12 hr 5 min	20	T-8, B-5, 1/4 OG ID - 2 7/16	Cut numberous chert layers - 31M Basalt
170	Smith	10 1/8 x 2 7/16	9	GR 567 (2) (3)	16	7	43	134	30.7	22.8	196	10 hr 38 min	19	T-1, B-5, IG ID - 2 7/16	Chert, LS and 4M Basalt
171	Smith	10 1/8 x 2 7/16	94	GC 281 (2) (4)	33	27	82	356	173.3	48.7	474	11 hr 23 min	42	T-1, B-5, IG ID - 2 7/16	Chert, LS, and 9M Basalt

Summary of Bits Used

5 - New Smith 10 1/8 x 2 7/16, Type 94, 4 Cone Sealed Bearing
1 - New Smith 10 1/8 x 2 7/16, Type 94, 4 Cone Non-Sealed Bearing
1 - New Smith 10 1/8 x 2 7/16, Type 9, 3 Cone Non-Sealed Bearing

(1) Sealed Bearing
(2) Non-Sealed Bearing
(3) 3 - Cutter
(4) 4 - Cutter

LEG 17 - BEACON SUMMARY

Site No.	Make	Freq. kHz	Ser. No.	Battery Ser. No.	Site Time Hrs.	
164	Burnett	16.0	143	162	107 1/2	Gave unstable timing pulse - operated vessel in semi-automatic mode.
164	Burnett	13.5	151	165	0	Failed immediately.
165	Burnett	16.0	135	164	90	Okay - Unstable timing pulse for 1/2 hour but cleared up okay. Beacon dropped underway at 8 knots.
166	ORE	16.0	121	0	50 1/2	Beacon dropped underway at 8 knots. Failed after 50 1/2 hours.
166	Burnett	13.5	153	169	33	Okay.
167	Burnett	16.0	137	158 & 160	328	Okay - Dropped underway at 6 knots. Two battery packs. Operated near perfect for 9.5 days.
168	ORE	16.0	122	0	42	Dropped underway at 8 knots. Failed after 42 hours. Unstable timing pulse.
169	Burnett	16.0	131	159	65 1/2	Okay - Dropped underway at 8 knots.
170	ORE	16.0	118	0	64	Okay - Dropped underway at 8 knots.
171	ORE	16.0	120	0	56	Okay - Dropped underway at 8 knots.

Summary

4 - Burnett 16.0 kHz - 4 satisfactory, 0 failed
2 - Burnett 13.5 kHz - 1 satisfactory, 1 failed
4 - ORE 16.0 kHz - 2 satisfactory, 2 failed

OPERATIONS RESUME

LEG 18

SUMMARY

The Glomar Challenger departed Honolulu May 25, 1971, proceeded through the Gulf of Alaska and terminated Leg 18 in Kodiak, July 19, 1971.

During this period, the Challenger cruised 4,026 nautical miles and explored 15 holes on 11 sites. While on these 15 holes, 1683 meters were drilled and 2483 meters were cored and 1215 meters of core was recovered for a 49.0 percent recovery. Total sub bottom penetration was 4166 meters.

Generally, the weather was good, however, some bad weather was encountered in the Northern Gulf of Alaska. Site 177 was abandoned because of high seas with winds gusting up to 50 knots. The spudding of Site 182A was dealyed because of sea, wind, and erratic current conditions.

On Site 174A, the Challenger was visited by the Oregon State University's research vessel, Yaquina. The press party was transferred to the Challenger at 06:00 hours and remained on board until 20:00 hours. While the press party was on board the Challenger, Professor Bill Schneider was transferred to the Yaquina. With the cooperation of the crew of the Yaquina, he was successful in measuring thruster noise of the Glomar Challenger while at sea under drilling conditions. This information was very helpful in determining the noise envelope of the Glomar Challenger.

Through careful site selection, the expected problems with turbidites encountered during most of the leg were minimal. As a result of this and excellent crew performance and cooperation of all personnel aboard, a number of new records were establsihed to supplement the highly successful previous 17 legs.

Some of the highlights of Leg 18 were:

1. Most cores attempted - 280.

2. Most cores recovered - 273.

3. Released beacon in deepest water - 3798 meters.

4. Positioned in 197 meters of water - Site 176.

DRILLING AND CORING

The bottom hole assembly used throughout Leg 18 consisted of a core bit, one 8 1/4 inch drill collar (core barrel), three 8 1/4 inch drill collars, one bumper sub, three 8 1/4 inch drill collars, two bumper subs, two 8 1/4 inch drill collars, one 7 1/4 inch drill collar and one joint of heavy wall drill pipe. On Site 176, the assembly was shortened by leaving out three 8 1/4 inch drill collars.

One Site 173, an extended inner core barrel was used and was very successful in recovering less disturbed cores. On this assembly a 11 1/4 inch four-cone button bit was used. The inner barrel is extended down through the three and one-half inch opening in the bit. With the core barrel extending four inches below the bit and directly on the formation, the core is cut and is not exposed to as much disturbance from the core bit. In firm or hard formations, the spring tensioned barrel would be compressed upward until the bottom of the barrel was flush with the core bit. Site 173 was 95 percent sand with some clay and thin chert streaks, 333 meters were cored for 59.5 percent recovery, ten to 15 strokes per minute of pump was used continuously (80 to 120 gpm). The extended barrel was used again on Site 180 in the Eastern Aleutian Trench, but recovery was only 34.3 percent. The fine silty sand would jam in the barrel and only a core catcher of core would be recovered if no pump was used. These silts were very water sensitive, the only successful technique in core recovery was to dry drill approximately a meter then break circulation with the least pump pressure, however, this method of coring did cause excessive torque on the extended inner barrel which caused the latch fingers on the upper end of the core barrel to fail, permitting the core barrel to release and move up the drill pipe and resulted in no core recovery. Operational people were of the opinion that this tool will be effective in the coarse sands and some clays, but should not be run in the sticky clay (gumbo) type formations.

A drill collar float valve that was first used on Leg 10 was successfully used on Site 173, the hinge pin failed on Site 174. Since Leg 10, the hinge on the flapper had been strengthened and seems to be capable of receiving in excess of a 100 core barrel drops, however, the hinge pin will have to be strengthened. The hinge pin broke after the core barrel had been dropped 79 times. To be a dependable tool, the float valve should be of sufficient strength to permit 100 cores to be recovered on any hole.

Three failures of drilling equipment occurred on Leg 18. A crack was detected on a joint of drill pipe three feet above the pin. The crack was 7/8 inch long and apparently was caused by fatigue. The other two equipment failures were in bumper subs, both resulting in partial loss of the bottom hole assembly. A Baash Ross bumper sub failed on Site 176, but this was not due to a faulty bumper sub. While attempting to position in only 197 meters of water, the bumper sub parted at the service break when the ship had moved 46 feet off location. The other equipment failure was a new style Shaffer bumper sub on Site 177A. This failure occurred after five meters of basalt had been cored. While coring this basalt, some chatter of the drill string was observed. It was felt that this chatter was the cause of the lock nut backing off the bumper sub mandrel. This resulted in the loss of a part of the bottom hole assembly.

BITS

Four types of bits were used on this leg. Of these bits, it was felt that the Smith 10 1/8 inch three-cone sealed bearing bit with extended shaped inserts (type 94) gave the best performance. On Site 174A this bit drilled 875 meters of sand with very little pump pressure. The shaped inserts were like new but the bearings were loose. A four-cone Smith bit with the same characteristics as the three-cone was used on Site 178, but it was felt that the three-cone provided the faster penetration. On Site 182, a Reed PD2 four-cone milled tooth bit was used and the results were disappointing. After drilling only 38 meters of sand and gumbo, the cones were sanded up and locked, the recovery was only 21.2 percent. The other type that was used on Site 173 and 180, was the 11 1/4 inch Reed four-cone sealed bearing bit. This bit was designed to be run in conjunction with the extended core barrel. Penetration was some slower than the 10 1/8 inch three-cone bits, but this was to be expected because of drilling a larger hole.

It is evident that much progress has been made in bit development for the Challenger. Penetration rates and bit life has been greatly improved without sacrificing core recovery percentages or quality and in most cases, both have been improved. The sealed bearing shaped insert bits have proven that they are durable enough to penetrate the hard formations such as chert, limestone, and basalt, as well as the softer sediments.

DYNAMIC POSITIONING

With Professor William Schneider on the Challenger to assist the Global Electronics Technician, a thorough study was made on beacons and the ship's positioning system.

On Site 172, an Inter Ocean's 16 kHz beacon was tested on board and then dropped in 4778 meters of water. After 1 1/2 hours on bottom the signal strength dropped 20 decibels. The signal to noise ratio was too marginal for reliable positioning. A Burnett 13.5 kHz was tested and dropped.

A continuation of the same problems with the positioning system that occurred on the end of Leg 17 were still present on the first site on Leg 18. It was apparent that roll was not being compensated for and the thrusters and main screws were not perfectly balanced and were not operating at speeds actually commanded by the computer.

On Site 173 an Inter Ocean's 16 kHz beacon was pretested and dropped in 2984 meters of water. At the request of the chief scientist, the vessel was offset 1,300 feet south and 700 feet east to provide better sedimentation for spudding in. The beacon signal was lower than normal, but was acceptable because of the shallow water.

Repair to the vertical gyro, thruster and main screw adjustments with a set of new gains programed into the computer had greatly improved the positioning performance of the Challenger. On Site 173, the maximum excursion was 80 feet during winds gusting up to 35 mph. In general, excursions did not exceed 40 feet.

Positioning was generally good on Site 174, 174A and 175, with one exception. On Site 175, the ship had one excursion of 220 feet in the Y axis. The ship was repositioned in semi-automatic. It was thought that the excursion was caused by changing tides.

On Site 176, located on the outer edge of the Northern Oregon Continental Shelf, a Burnett 13.5 kHz beacon was tested and dropped in 197 meters of water. The weather conditions were excellent with swell and sea conditions being less than two feet and the winds slight. It was felt if maximum excursions did not exceed five percent of water depth (30 feet) that by shorting the bottom hole assembly, 100 meters could be successfully cored. The ship stayed within 24 feet of target for one hour and 45 minutes. On excursions of more than 30 feet, the pipe would not be rotated until positioning was corrected. The pipe parted on a third excursion of 46 feet. Positioning response particularly in the Y axis was too slow to keep the ship within the five percent of water depth of the hole.

On Site 177 and 177A the positioning system was well tested under storm conditions. Drilling operations were terminated on Site 177 because of rough seas and increasing wind. With winds gusting up to 50 knots and seas 15 feet to 18 feet, tripping operations were suspended with the bottom hole assembly left hanging in the elevators. By this time, the Challenger had lost the beacon off its display oscilloscope. After 15 hours of riding out the storm the beacon was relocated and Site 177A was drilled. Positioning was excellent.

Site 182 was in 1421 meters of water and was drilled to 60 meters. The bit locked at this time and a trip to change bits was required. Prior to clearing the mud line with the drilling assembly, an excursion of 200 feet was experienced that was caused by a stern thruster dropping off the line. Before tripping out was completed, both stern thrusters were lost which resulted in a 1,000 foot excursion. While waiting on weather, the problem was corrected by replacing a faulty relay.

Hole 182A presented the same problems that had occurred on Site 182. Tidal changes seemed to cause very erratic currents. Ship's heading could not be corrected fast enough to counter these currents requiring the ship to thrust broadside into the currents. The ship moved off hole 190 feet. Because of erratic positioning and hazardous hole conditions caused by turbidites and glacial erratics, drilling operations were terminated.

It would appear that drilling in areas with such a strong current as was encountered in the Northern Gulf of Alaska, a current meter would be extremely helpful in selecting and maintaining an optimum ship's heading.

It is generally felt that the Challenger can presently work in no less than 610 meters of water. Apparently the hardware is adequate but the computer should be reprogramed before suitable positioning can be achieved to maintain the ship within the three to five percent excursions of water depth. It was noticed that changing the bit weight while drilling or picking the drill string up off bottom that the ship would move 60 to 70 feet in the Y axis, this being more noticeable when other forces were not present for the ship to position against.

It was discovered that a loss of acoustics to the hydrophones was experienced when air bubbles were trapped in the hydrophones. It is felt that a solution to this would be to cover the hydrophones with a bubble type dome or some other type cover such as rubber or teflon with a hole in the hydrophone cover to free flooding the inside.

BEACONS

Three makes of beacons were used on Leg 18. Two Inter Oceans were used, the first beacon lost its signal strength in five hours. The other beacon provided a signal sufficient to finish the site, however, if the beacon had been used in deep water, the signal would have been too weak.

Eight Burnett beacons were used with good strong signal from all. Most of these beacons were dropped on the run. The design of the Burnett floatation seems to maintain a more vertical position while falling to bottom.

Two ORE beacons were used and signals on both beacons were excellent. Because of the design of the ORE floatation both beacons were dropped with ship not moving. On one occasion the beacon appeared to stop sending its signal as soon as it was in the water. A lapse of nine minutes were required from the time it was in the water before it was picked up by the hydrophones. The signal was very weak at times. Apparently the beacon was wobbling on its decent. The ORE beacon seems to be dependable and has a good pulse. The floatation is not designed to be dropped in areas of strong currents due to planning effects.

ACOUSTICAL RELEASING

On Site 179, a Burnett 16 kHz beacon with two floatation rings with an Inter Oceans acoustical release mechanism was dropped in 3798 meters of water. After being on site for approximately 24 hours, the beacon and release mechanism was released from the anchor. The ship was positioned approximately 400 feet from where the beacon would surface. The beacon was followed by the oscilloscope to within 1,500 feet of the surface. The ship was unable to locate the beacon because of choppy seas and poor visibility.

Apparently the release mechanism worked perfectly but our inability to locate the floatation balls at surface points to how this can be avoided in the future. Since half of all recoveries will be at night, in rough seas and fog, it is apparent that a radar transmitter and a strobe light extending above the floatation would solve this problem. The black floatation ball should be painted yellow.

The beacon was released while the crews were handling the drill collars. Ascent time was 90 minutes.

AT ANCHOR

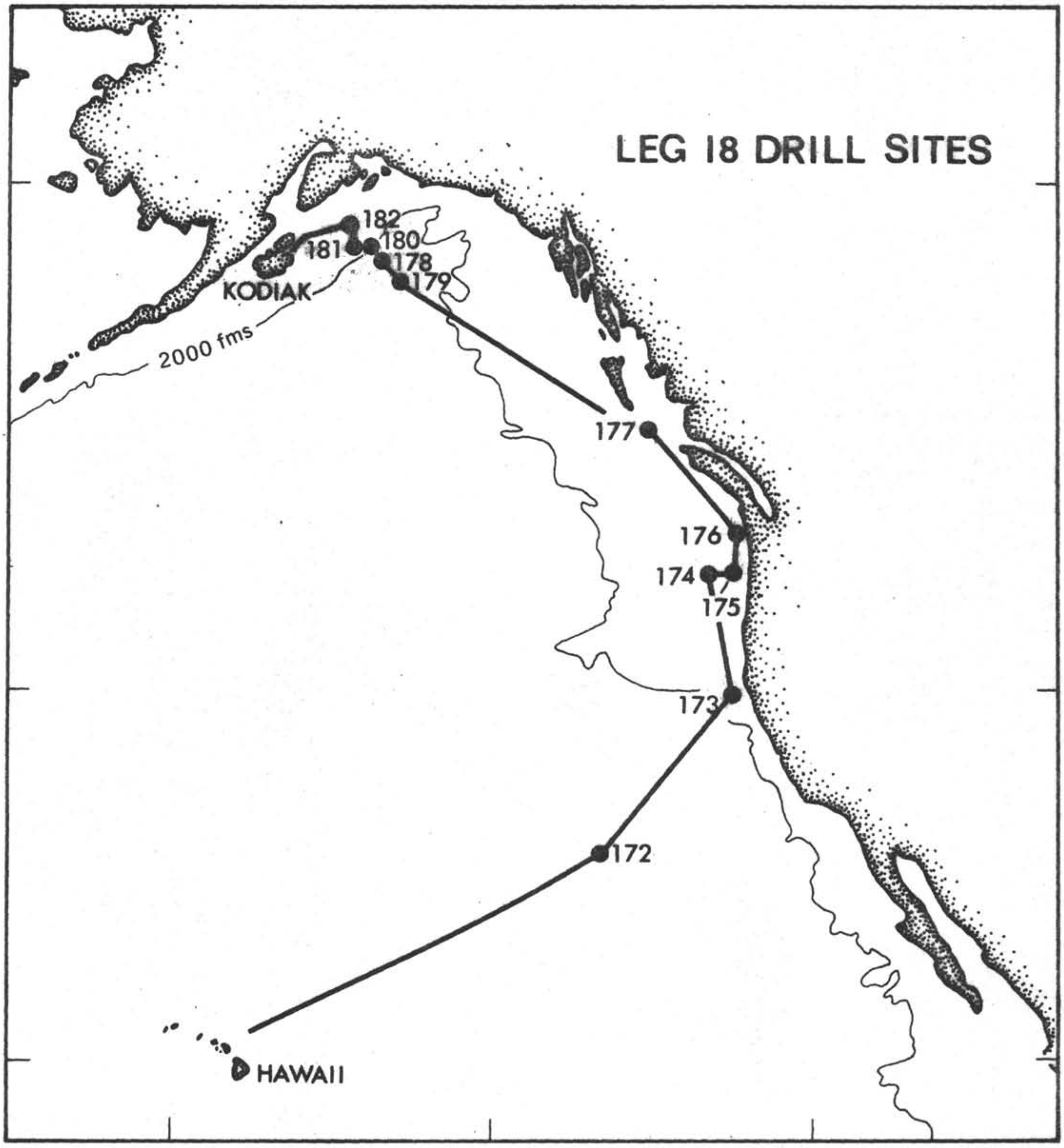
After terminating drilling operations on Site 182A because of drilling problems and the Challenger's inability to maintain position because of wind and strong currents, no other drill site in the immediate area would provide any better conditions for positioning and it was concluded that it would be best to vacate the area and go to the Port of Kodiak. Berthing facilities were not available at the Navy docks until 06:00 hours, July 19. The Challenger anchored in Chiniak Bay at 23:00 hours. While anchoring, the starboard anchor chain jumped the wildcat resulting in loss of the starboard anchor and chain. The anchor was located while in port and recovered when the Glomar Challenger left port.

CREWS

The Global Marine crews, both drilling and marine crews, displayed a high degree of professional excellence throughout Leg 18.

LEG 18 - SUMMARY OF OPERATIONS

Total Days Leg 18 (May 25, 1971 to July 19, 1971)	55.02
Total Days in Port	3.93
Total Days Cruising	19.52
Total Days at Anchor	.31
Total Days on Site	31.26
Trip Time	7.84
Coring Time	18.01
Drilling Time	2.75
Weather	1.17
Downtime	.20
Other	1.29
Total Distance Travelled (Nautical Miles)	4,026.50
Average Speed (knots)	8.90
Sites Investigated	11
Holes Drilled	15
Number of Cores Attempted	280
Number of Cores with Recovery	273
Percent of Cores with Recovery	97.60
Total Meters Cored	2483.00
Total Meters Recovered	1215.00
Percent of Meters Recovered	48.90
Total Meters Drilled	1683.00
Total Penetration	4166.00
Percent of Total Penetration Cored	59.60


LEG 18 DRILL SITES
60°
40°
20°
160°
140°
120°
182
181
180
178
179
KODIAK
2000 fms
177
176
174
175
173
172
HAWAII

/254

LEG 18 - DEEP SEA DRILLING PROJECT

SITE SUMMARY

Site	Hole	Latitude	Longitude	Water Depth Meters	No. Of Cores	Cores With Rec.	Meters Cored	Meters Rec.	%	Meters Drilled	Total Meters Penet.	Avg. Rate Penet. (M/Hr)	Time On Hole (Hours)	Time On Site (Hours)
172	172	31° 33' N	133° 22' W	4778	4	4	23.0	27.0	100		23	16	26	
172A	172A	Offset 1500 S	E 100'	4778	1	1	1.0	0	0	22	23	29	14.50	40.50
173	173	39° 57.71' N	125° 26.43' W	2984	38	37	333.5	196.0	58.7	0	333.5	42	76.75	76.75
174	174	44° 53.38' N	126° 21.44' W	2837	3	3	19.0	3.0	15.8	0	19.0	61	13.00	
174	174A	45° 53.38' N	126° 21.44' W	2818	43	36	404.0	200.0	49.4	475	879.0	34	91.75	104.75
175	175	44° 50.2' N	125° 14.5' W	2011	25	22	233.0	121.0	52.1	38	271	26	42.75	42.75
176	176	45° 56.0' N	124° 37.0' W	197	5	5	41.0	41.0	100	0	41.0	29	12.00	12.00
177	177	50° 28.24' N	130° 12.14' W	2013	1	1	9.0	9.0	100	0	9.0	60	19.50	88.25
177	177A	50° 28.24' N	130° 12.14' W	2013	26	26	233.0	136.5	58.5	274	507	32	68.75	
178	178	56° 57.44' N	147° 07.81' W	4229	59	53	519.5	212.5	40.9	275	794.5	37	124.50	124.50
179	179	56° 25' N	145° 58.5' W	3798	13	13	109.0	69.5	63.8	0	109	31	39.00	39.00
180	180	57° 21.8' N	147° 51.0' W	4933	25	25	237.5	81.5	34.3	233	470.5	48	70.25	70.25
181	181	57° 26.8' N	148° 27.5' W	3114	30	30	259.5	106.5	41	109.5	369	25	88.75	88.75
182	182	57° 54.1' N	148° 48.8' W	1421	6	6	54.0	11.5	21.2	69	123	15	26.75	
182	182A	Offset 1660 W	148° 48.8' W	1444	1	1	7.5	0	0	187.5	195	19	35.75	62.50
15					280	263	2483	1215	49.0	1683	4166	34	750	750

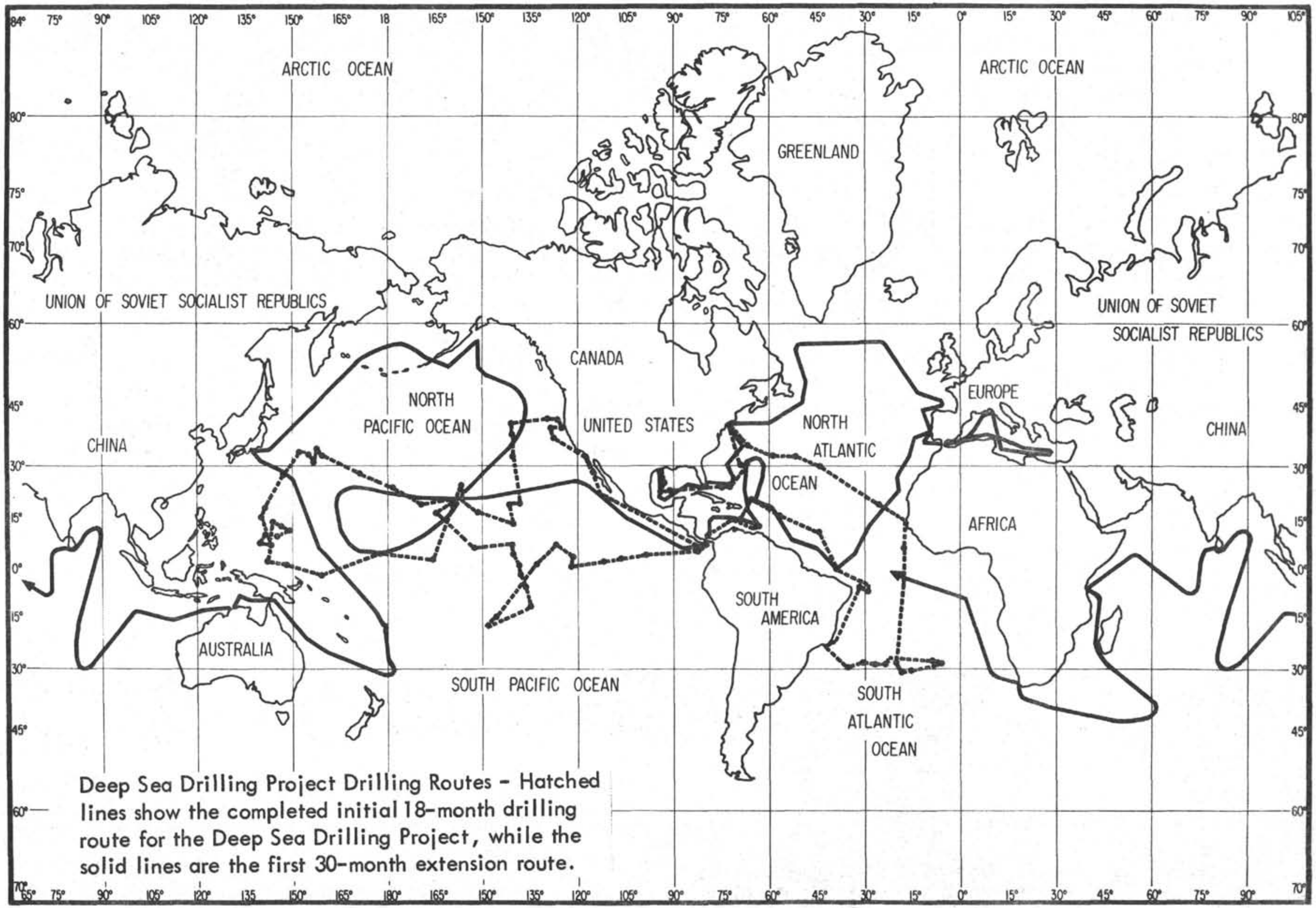
LEG 18- DEEP SEA DRILLING PROJECT

BIT SUMMARY

Bit Description				Coring				Drilling		Total			
Make	Size	Type	Ser. No.	Site	Hole	Meters Cored	Rot. Time	Meters Drilled	Rot. Time	Total Penet.	Hours On Bit	Condition	Remarks
Smith	10-1/8	4-101	GB 784	172	0	23	1.50	0	0	23	1.50	--	Basement
				172	A	1	1.00	22	.75	23	1.75	--	Basement
				176	0	41	1.50	0	0	41	1.50	--	Lost in hole
						65	4.00	22	.75	87	4.75		
R.S.S.	11-1/4	4 Cone	58728	173	0	333.5	9.50	0	0	333.5	9.50	T3-B8-6	
Smith	10-1/8	3 Cone		174	0	19	.50	0	0	19	.50		Turbidites
				174	A	404	14.25	475	11.25	879	25.50	T3-B7-6	Sand & Basalt
						423	14.75	475	11.25	898	26.00		Chert.
Smith	10-1/8	3 Cone	HG645	175	0	233	8.50	38	1.50	271	10.00		Sand
				179		109	3.50	0	0	109	3.50		Clay
				181		259.5	14.00	109	12.00	369	26.00	T2-B7-06	
						601.5	26.00	147	13.50	749	39.50		
Smith	10-1/8	3 Cone	HG646	177	0	9	0	0	0	9	0		Storm
				177	A	233	10.25	274	5.50	507	15.75		Lost in hole
						242	10.25	274	5.50	516	15.75		
Smith	10-1/8	4 Cone	HG647	178	0	519.5	17.50	275	3.50	794.5	21.00	T2-B2-06	Clay & Sand
R.S.S.	11-1/4	4 Cone	--	180	0	237.5	8.75	233	2.50	407.5	11.25	T1-B2-6	
Reed	9-7/8	Mill tooth	8163	182	0	54	3.50	69	5.25	123	8.75	T3-B2-6	Sand Locked w/sand
Smith	10-1/8	3 Cone	HG649	182	A	7.5	.25	187.5	9.75	195	10.00	T1-B1-6	Sand & Turbidites

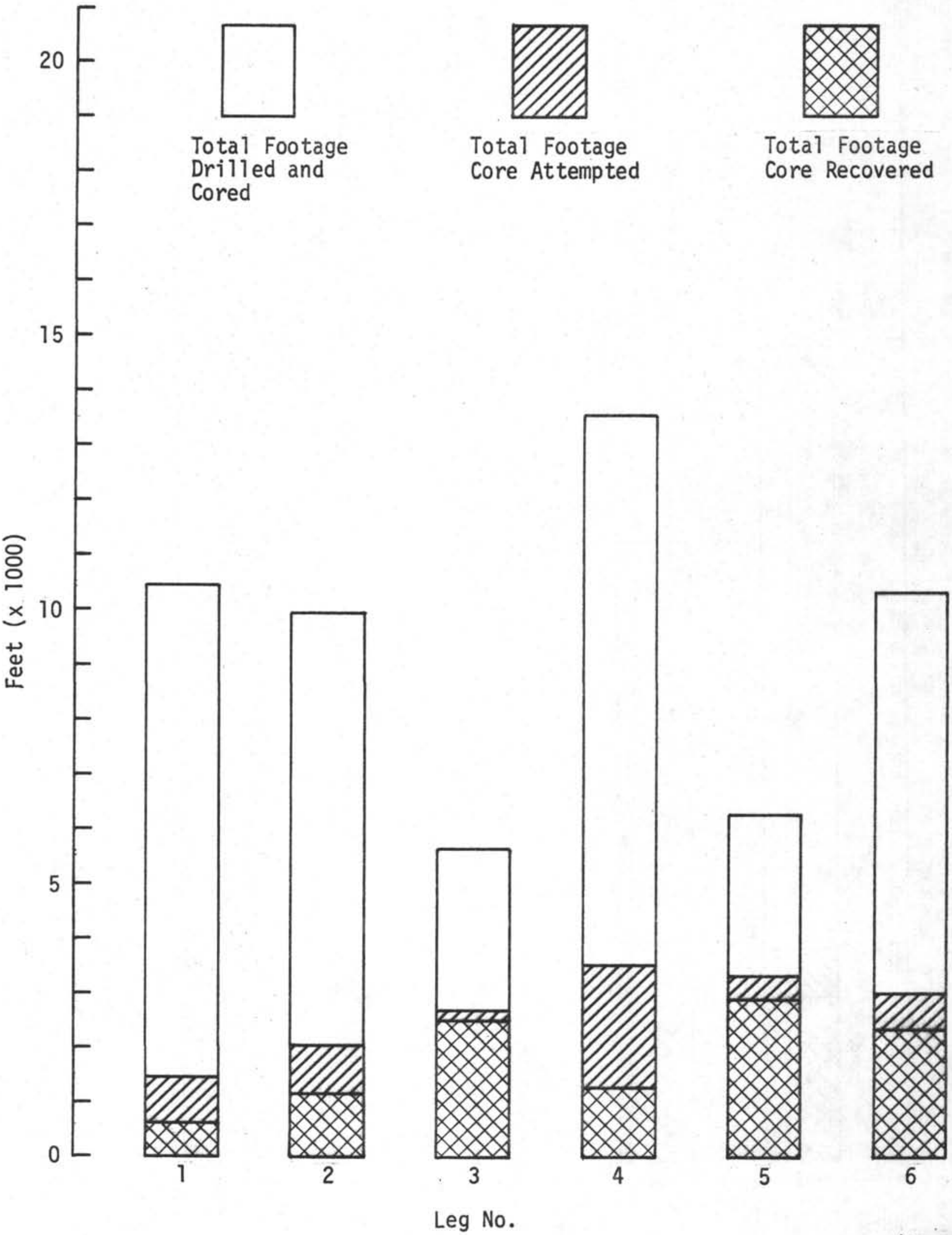
LEG 18 - BEACON SUMMARY

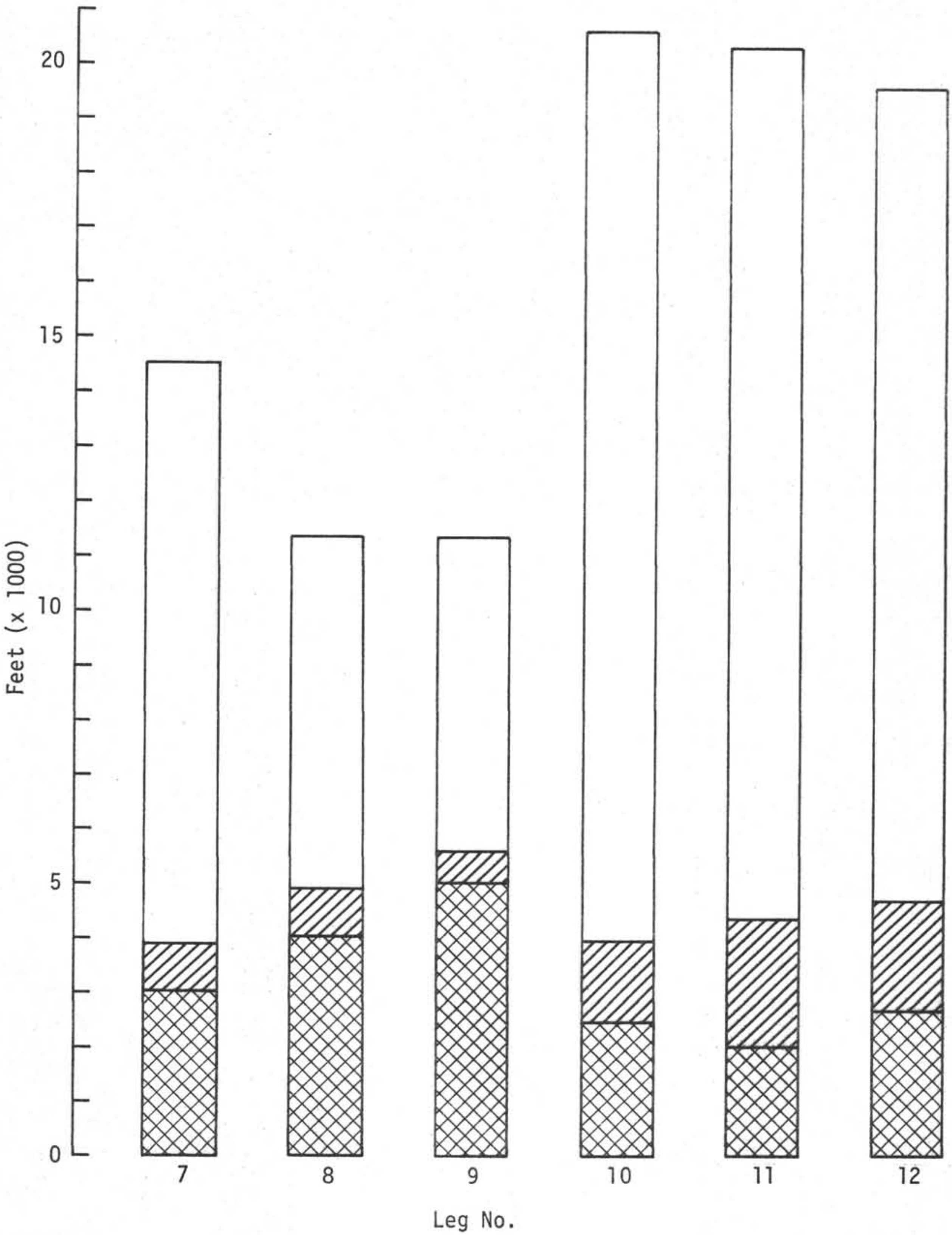
Site No.	Make	Freq. kHz	Ser. No.	Battery Ser. No.	Site Time Hrs.	
172	Inter Ocean	16	0	0	5.00	After 5 hours beacon signal was too weak for positioning.
172	Burnett	13.5	170	157	35.00	Beacon signal was good.
173	Inter Ocean	16	0	0	76.75	Used Burnett Floatation, beacon was weak, but sufficient for positioning.
174	Burnett	13.5	167	126	91.75	Signal good, positioning was excellent.
175	Burnett	13.5	156	86	42.75	Signal good, positioning was excellent.
176	Burnett	13.5	165	165	12.00	In 201 meters of water signal was very strong.
177	Burnett	16	145	161	91.25	Beacon was lost in storm, but was able to relocate and drill hole 177A.
178	ORE	16	109	0	35.00	Signal good, but floatation permits beacon to drift on the way to bottom.
179	Burnett	16	130	158	44.75	Was run with releasing mechanism. Signal was excellent.
180	ORE	16	115	0	72.25	Good signal, maximum excursion was 200 feet; mostly plus or minus 40 feet.
181	Burnett	13.5	171	148	90.50	Strong signal, some excursions caused by tidal currents.
182	Burnett	13.5	164	149	55.25	Strong signal, erratic positioning because of strong winds and changing tides.



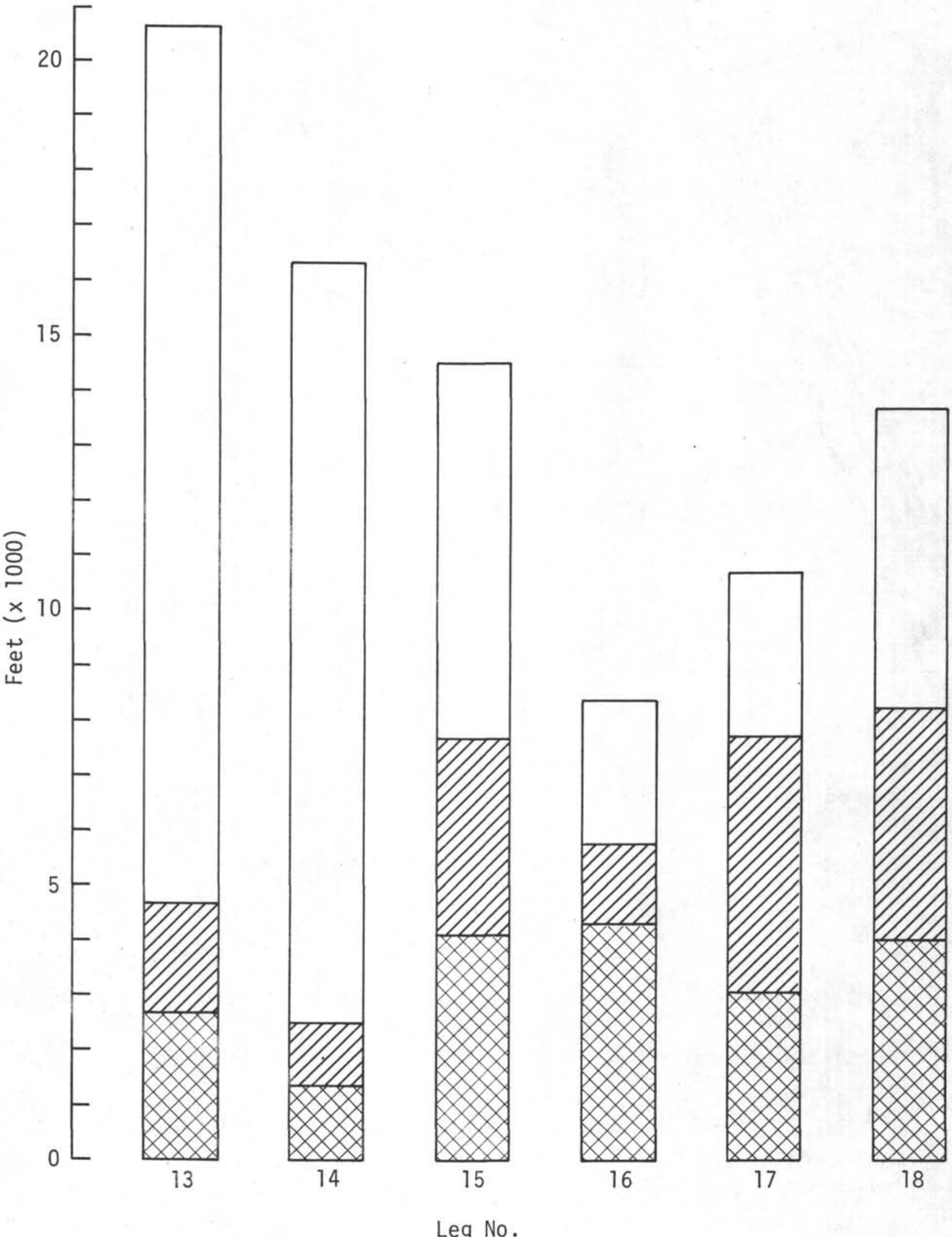
Deep Sea Drilling Project Drilling Routes - Hatched lines show the completed initial 18-month drilling route for the Deep Sea Drilling Project, while the solid lines are the first 30-month extension route.

DRILLING RECORD





20
15
10
5
0
Feet (x 1000)
7
8
9
10
11
12
Leg No.



Feet (x 1000)
0
5
10
15
20
13
14
15
16
17
18
Leg No.

Glomar Challenger drilling crew rigs hydraulically operated power sub, center, preparatory to commencing drilling operations at a deep water drilling site. At right is the drawworks and, on opposite side of derrick floor is the specially designed core line reel used in the retrieving of the core barrel. Beyond derrick floor is automatic drill pipe racker which holds 24,000 feet of five-inch drill pipe.