OCEAN DRILLING PROGRAM

LEG 137 SCIENTIFIC PROSPECTUS

Return to Hole 504B

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This Scientific Prospectus is based on pre-cruise JOIDES panel discussions, and the operational plans within reflect JOIDES Planning Committee and thematic panel priorities. During the course of the cruise, actual site operations may indicate to the Co-Chief Scientists and the Operations Superintendent that it would be scientifically or operationally advantageous to amend the plan detailed in this prospectus. It should be understood that any proposed changes to the plan presented here are contingent upon approval of the Director of the Ocean Drilling Program in consultation with the Planning Committee and the Pollution Prevention and Safety Panel.

ABSTRACT

The primary purpose of Leg 137 is to clean out Hole 504B, the deepest hole ever drilled into oceanic crust, in preparation for subsequent deepening through the dike/gabbro and/or Layer 2/3 transition(s). Located in 5.9-m.y.-old crust, Hole 504B is perhaps the most important reference hole for the structure and composition of "normal" oceanic crust, and at present represents the best opportunity for sampling the transition between the sheeted dikes and underlying gabbros in the context of a complete crustal section.

The leg is scheduled for 21 March to 1 May 1991. The 22 days on site will be devoted to downhole measurements, clean-out operations, coring tests, and possible contingencies. Downhole measurements, including temperature logging and borehole-fluid sampling, will be made before clean-out operations begin. Clean-out operations involve removing pieces of core bit and other drilling debris from the bottom of the hole, inspecting and perhaps repairing the casing, and attempting to identify drilling parameters that will improve core recovery and penetration rates for subsequent coring efforts. Then, more downhole measurements may be made or, if the hole is ready, the remainder of the leg will be devoted to deepening Hole 504B by drilling and coring.

INTRODUCTION

The primary purpose of Leg 137 is to salvage Hole 504B -- the deepest hole ever drilled into oceanic crust -- in preparation for deepening through the dike/gabbro and/or Layer 2/3 transition(s) during a subsequent leg. Located in 5.9-m.y.-old crust formed at the Costa Rica Rift (Fig. 1), Hole 504B presently extends over twice as deep into oceanic crust as any other hole, and is the only DSDP/ODP hole that unequivocally penetrates through the extrusive lavas into the sheeted dikes of upper oceanic crust formed at a mid-ocean ridge (Fig. 2). It therefore is perhaps our most important reference hole for the structure and composition of "normal" oceanic crust, and at present represents our best opportunity for sampling the transition between the sheeted dikes and underlying gabbros in the context of a complete crustal section. Attaining this goal will be the objective of Leg 140, pending the success of Leg 137. The Leg 111 vertical seismic profile experiment indicated that Layer 3 may be in reach of the next full drilling leg to Hole 504B, so Leg 140 may be poised for a unique accomplishment if Leg 137 is successful.

A wealth of scientific results from Hole 504B has been published elsewhere (see Bibliography) and will not be summarized here, as Leg 137 will mainly involve downhole remedial operations. The leg is scheduled for 41 days, 21 March to 1 May 1991, beginning with a long transit from Honolulu estimated at about 17 days. About 22 days on site will be devoted to downhole measurements, clean-out operations, coring tests, and possible contingencies. The logical sequence and philosophy of these operations will be strongly influenced by past events and experiences in Hole 504B, so this prospectus begins with a brief summary of the drilling and operational problems faced in the hole.

DRILLING AND OPERATIONAL CHALLENGES IN HOLE 504B

Future drilling in Hole 504B poses major technological challenges that ODP must meet if the scientific successes already achieved at the site are to be continued. Except for the deepest 0.2 m, the basement section was cored with the standard DSDP/ODP rotary core bits (RCBs), but serious drilling problems were encountered deep in the hole during Legs 83 and 111 (Fig. 3). These problems included hardware losses as well as poor drilling performance even after junk had been cleaned from the hole. Also, fishing operations at the end of Leg 111 hinted at the possibility of problems with the 276 m of casing through the sediments. These three aspects of the drilling and engineering problems require distinctly focused efforts, and attacking these problems will dominate the operational plan and decision-making during Leg 137.

Hardware Losses

During Leg 83, the drill pipe broke twice, each time leaving the bottom-hole assembly (BHA) at the bottom of the hole. In each case, the lost BHA was successfully fished from the hole in about 3 days of operations, and Leg 83 was quite successful despite these interruptions. During Leg 111, the first two bits actually improved on the Leg 83 drilling performance, possibly because of the superior heave compensation on *JOIDES Resolution*. However, all eight roller cones were lost from the next two consecutive RCB bits, seriously disrupting operations and requiring extensive milling and fishing operations. After this junk was cleaned from the hole, an experimental diamond coring assembly was lost at the present total depth of the hole, 1562.3 mbsf, when the pin end of the bit sub above the bit broke due to a metallurgical failure (Fig. 4). Four fishing attempts at the end of Leg 111 succeeded in removing some of this junk, but the diamond bit, float valve, and parts of the support bearing remain at the bottom of the hole. Thus, one obvious challenge facing Leg 137 will be to clean this junk from the bottom of the hole, using standard milling and/or fishing operations. This approach is expected to provide a relatively straightforward solution to the junk problem, given sufficient time and a good stock of milling and fishing tools.

Possible Casing Problems

During the last two Leg 111 attempts to fish the lost diamond core assembly from the hole, an obstruction was encountered by the fishing overshot as it was lowered through the casing. It appears quite likely that the obstruction was caused by an expansion joint in the casing at this depth. An expansion joint presents a slight shoulder that could have caught the square profile of the fishing overshot, but it would not have impeded a normal BHA terminated with a drill bit. It is also possible that the obstruction was caused by some flaw that may have developed in the casing during Leg 111, and this possibility needs to be assessed early during Leg 137. Moreover, the reentry cone and casing were not particularly designed for such deep penetration, and have been subjected to many more reentries and hours of pipe rotation than was expected when the hole was originally spudded. Therefore, the casing will require thorough inspection during Leg 137 prior to deepening Hole 504B during Leg 140. It is possible that the casing may require minor repair during Leg 137 or the installation of a liner casing at the beginning of Leg 140.

Poor Drilling Performance

Perhaps the most worrisome and enigmatic problem will be improving the relatively poor drilling performance experienced deep in Hole 504B to demonstrate the feasibility of coring success during Leg 140. Past drilling problems in Hole 504B involved several unacceptable symptoms, including poor recovery and penetration rate deep in the hole as well as several sudden failures of the drilling equipment (Fig. 3). This poor performance may have resulted from a combination of several factors, including:

1. The recurrence of steel junk in the hole during Legs 83 and 111, including parts of logging tools and coring assemblies;
2. Hole instabilities, probably caused by stress release in the formation, resulting in spalling of wall rocks into the hole and undue wear on the coring assemblies;
3. A decreasing ability to flush cuttings completely from the very deep hole, compounded by the junk in the hole and the apparent disintegration of the formation during drilling.

It is possible that junk in the hole contributed to the catastrophic bit failures during Leg 111. It may be reasonable to expect that a successful solution to the junk problem would result in future drilling performance using standard RCBs like that achieved by the first two bits used during Leg 111 (15%-20% recovery, 3 m/hr penetration; Fig. 3). As is described below, Leg 137 will be equipped to test another coring system that holds promise for improved performance.

The effect of formation stress release and hole instabilities on past drilling experience is difficult to quantify. Ultrasonic borehole televiewer logs indicate numerous breakouts throughout the dike section, consistently oriented such that plate stresses were being relieved as or shortly after the hole was drilled (Newmark et al., 1985; Morin et al., 1990; Moos and Zoback, 1990). The stress relief evidenced by these breakouts was probably accelerated by the thermal contrast between the cool circulating fluids and the hot formation. The present bottom-hole temperature is about 160°C, and the thermal contrast between formation and circulating fluids can only become worse as the hole is drilled deeper. Morin et al. (1990) present evidence that the discontinuous nature of circulation and resultant cycling in borehole fluid temperatures may have been a key factor in inducing stress release and the attendant drilling difficulties. Leg 137 operations will therefore avoid vigorous and discontinuous circulation whenever possible, particularly when the drill string is not rotating; for example, vigorous circulation will not be used to cool the hole just to run a particular temperature-sensitive logging tool.

DOWNHOLE MEASUREMENTS PRIOR TO DRILLING OPERATIONS

In accordance with recommendations from the JOIDES Lithosphere (LITHP) and Downhole Measurements (DMP) panels, there will be a short phase of downhole measurements when Hole 504B is first reentered. There may also be a later phase toward the end of Leg 137 as a contingency that may arise if drilling operations in the hole are either very successful or very unsuccessful. The latter possibilities are discussed in more detail in the Contingencies section below.

When Hole 504B is first reentered, 2 days will be devoted to temperature logging and fluid sampling before any clean-out operations invalidate conditions for these measurements. The hole will have been undisturbed for nearly 4-1/2 years since Leg 111, which will provide excellent conditions for conducting an equilibrium temperature log and for sampling borehole fluids with the aim of deducing the composition of formation fluids. First, the temperature log will be conducted with the French high-temperature tool that was used successfully during Leg 111 (Gable et al., 1989), requiring about 1/2 day. Next, no more than 1-1/2 days will be devoted to sampling borehole fluids, using a Los Alamos high-temperature sampler. This will provide a moderately high-temperature test of the Los Alamos sampler, which may also be used at even higher temperatures during Leg 139 (Sedimented Ridges I).

LEG 137 DRILLING OPERATIONS

A number of scenarios are possible when Leg 137 attempts to salvage Hole 504B, given the three main uncertainties described above regarding conditions in the hole. Figure 5 illustrates the logical order in which operations will proceed to assess and, it is hoped, redress these uncertainties. Figures 6 and 7 illustrate how events might proceed on Leg 140, should Leg 137 be successful. Whether or not Leg 137 clean-out operations are successful, every effort will be made to leave a hole suitable for future reentry, either from a drillship or by wireline from a conventional oceanographic vessel.

Casing Assessment

By far the least likely and potentially most disappointing of the possible scenarios for Leg 137 would involve the slight chance that serious casing failure or hole collapse may have occurred and that Hole 504B may not be reenterable to total depth. If that is the case, it will probably become apparent during the downhole measurements scheduled before the clean-out operations. If the drillship cannot resolve the problem, it may be necessary to terminate operations in Hole 504B without attempting to clean the junk from the bottom of the hole, and to proceed with contingency plans. Such a decision would not be made lightly, as it would then be difficult to justify a future leg to the hole when it had not been salvaged during Leg 137.

Given the more likely scenario that no fatal problems are encountered during the downhole measurements, a careful inspection of the 11-3/4-in. surface casing in Hole 504B will follow. The purpose is to determine whether excessive wear or corrosion has taken place since the casing was set in 1979. The casing inspection may be accomplished by means of either conventional oilfield casing-inspection logging tools and/or a digital borehole televiewer (BHTV). If the BHTV is used, it is anticipated that the log will be extended to the uppermost 300-400 m of open hole without circulation to cool the hole. This section has not been satisfactorily logged with a BHTV and is suspected to be the least stable and least in-gauge. If conditions in the casing or upper crust warrant, it may become necessary to install a protective liner when the hole is reoccupied for deepening on Leg 140. Minor repairs to the casing could probably be accomplished during Leg 137, but the possible installation of a liner casing would be deferred to the subsequent science leg.

Hole 504B Clean-out

Upon completion of the casing assessment using wireline tools, the drill string will be tripped to recover the packer/logging BHA and to begin cleaning the junk from Hole 504B. As is noted above, a complete diamond core bit, flapper-type float valve, and part of a support bearing must be removed from the bottom of hole (Fig. 4). Fishing tools will be available, but the odds of removing all the junk by fishing are low, considering the nearly equidimensional profiles of the individual items and the possibility that they may be covered with even a little rubble from higher in the formation. The primary approach used to clean out the hole will be reducing the junk by means of concave junk mills. The small bits of metal produced by the milling operations will be flushed from the hole by fluid circulation, and some will be trapped in the pockets of "junk baskets" located in the BHA immediately above the mill.

As the logging and casing assessment described above will be conducted with the BHA in the upper part of the hole, the first "junk run" will entail the initial circulation in the hot, deeper section. To minimize the risk of additional damage to the hole through thermal shock, pump circulation will be applied very gradually to the levels required for the initial milling operations. If no serious obstructions are met by the drill string, and normal circulation is established at total depth, the chances of casing or hole problems adversely affecting the remainder of the work are considered to be minimal.

Several round trips and reentries are anticipated for the cleaning-out operation, taking several days. Worn mills will need replacement and rebuilding, junk baskets will need emptying, and experimentation may be required with alternative techniques of breaking up the junk, fishing, spotting cement to immobilize loose junk, and so on. Because of uncertainties with regard to hole conditions, the ease with which junk can be removed, and the number of round trips that will be required to change mills, it is unrealistic to estimate the time required for this phase of the operations more closely than "several days." It should become apparent within a few days of commencing milling operations whether these operations are likely to succeed. Even if progress is relatively slow, the necessary time will be devoted to cleaning out the hole, as this is obviously the top priority of Leg 137.

Drilling and Coring Tests and Permeability Measurements

After clean-out operations in Hole 504B have been completed, the remaining portion of the leg will be devoted to deepening the hole by coring and drilling, and to making permeability measurements. When milling parameters and recovered junk fragments indicate that the hole is clean, several meters of new hole will be made with a rugged hard-formation drill bit (without coring). If drilling parameters with this bit verify that the hole has been successfully cleaned, rotary coring will be attempted,with several different types of hard-formation RCBs if time permits.

Because of declining recovery with depth using the standard four-cone insert RCB during earlier coring operations in Hole 504B, alternative rotary coring bits and coring systems will be evaluated during the leg. One alternative system to be tested will be conventional oilfield diamond coring (as opposed to the small-diameter diamond coring system now under development at ODP). The conventional diamond coring system is known for excellent core recovery and quality, but it will require a round trip of the drill string to recover each core. This disadvantage may be offset by cores up to 100 mm in diameter and 18 m long, providing jamming does not occur.

This approach is considered a viable alternative because the last three RCBs run during Leg 111 averaged only 25 m penetration before bit distress dictated tripping the drill string and conducting subsequent fishing and milling operations. In addition, this system will require lower circulation rates for effective coring and hole-cleaning than the rotary coring system. This should diminish any fracturing and spalling problems in the borehole wall and core that may be initiated by thermal shock.

In accordance with JOIDES LITHP recommendations, most of the time available after cleaning the hole will be devoted to coring ahead with these systems. In addition, a drill-string packer will be inflated in the upper part of the hole to better document the rapid decrease of permeability with depth in that section, using conventional formation tests as well as a new flowmeter injection experiment (Morin et al., 1988). If all coring and packer objectives are met, or if further coring operations are not deemed worthwhile, some time may be devoted to logging the hole with the formation microscanner (FMS) and other tools, as has been recommended by the JOIDES DMP and is described more fully in the Contingencies section below.

LEG 137 CONTINGENCIES

As is described above, Leg 137 clean-out operations will involve multiple possibilities depending on various decisions, and may require the entire leg. However, there are several scenarios in which time might become available for scientific contingencies. In the best-case scenario, Hole 504B might be cleaned out quickly, in which case the intent is to drill ahead to demonstrate the feasibility of devoting a full science leg to deepening the hole, possibly leaving some contingency time available. In the worst-case scenario, a decision might be made to abandon the hole relatively early in the leg, possibly leaving significant time for scientific contingencies. Thus, the amount of time available during Leg 137 for contingencies could range from none to slightly more than two weeks.

If sufficient time arises during Leg 137, three contingencies will be attempted in the order of priorities assigned by JOIDES PCOM at the November 1990 Annual Meeting. Leg 137 will be staffed with a small scientific and technical party that is fully capable of handling the first contingency, but not the sedimentological aspects of the second and third contingencies. In priority order, the three Leg 137 contingencies approved by PCOM are these:

1. Running additional logs and downhole measurements in the basement section before abandoning Hole 504B. A number of new and improved tools that were unavailable during Leg 111 would complete the extensive suite that has already been run in Hole 504B. Leg 137 will be staffed with experienced logging scientists, and any increment of contingency time greater than 12 hours could be effectively utilized for additional downhole measurements. DMP has already recommended that five such tools -- FMS, wireline packer, flowmeter/packer, enhanced geochemical resolution tool, and sidewall coring -- should be run in Hole 504B before any possible recasing program, which would be scheduled during Leg 140 if Hole 504B is cleaned out. Of these five tools, the FMS, flowmeter/packer, and possibly the wireline packer will be available for Leg 137. Implicit in the DMP recommendation is that these logs should be run during Leg 137 contingency time if it is decided that the hole is to be abandoned. Note that the flowmeter/packer experiment will probably have been run during the phase of measurements before clean-out operations begin, and another new tool, the digital borehole televiewer (BHTV), may have been run as part of the program to assess the condition of the casing and hole stability.

2. Fulfilling the operational plan for proposed site EEQ-2, which is otherwise scheduled to be cored and logged as part of the eastern equatorial Pacific Neogene Transect of Leg 138. This site is slightly more than 2 days' steam northwest of Site 504, and would require about 4-5 days of operations on site for double-APC holes followed by XCB

coring and logging. Therefore, this will be a feasible contingency only if about a week of time is available after the first-priority contingency is completed. If insufficient time is available, the third-priority contingency will be started. As Leg 137 will not be staffed with sedimentologists, any cores collected at EEQ-2 would be left unsplit for the Leg 138 scientific party.

3. Investigating the hydrogeochemistry of the sediments and upper basement near Site 504, as originally proposed by Mottl et al. in 1984 (JOIDES proposal 123/E). During Leg 111, nearly a day was devoted to such work at Site 678 in a local heat-flow high. The Leg 137 contingency would involve APC and XCB coring at the greatest local heat-flow high, about 5 km southwest of Hole 504B, and would also include downhole temperature measurements and logging the sediment section.

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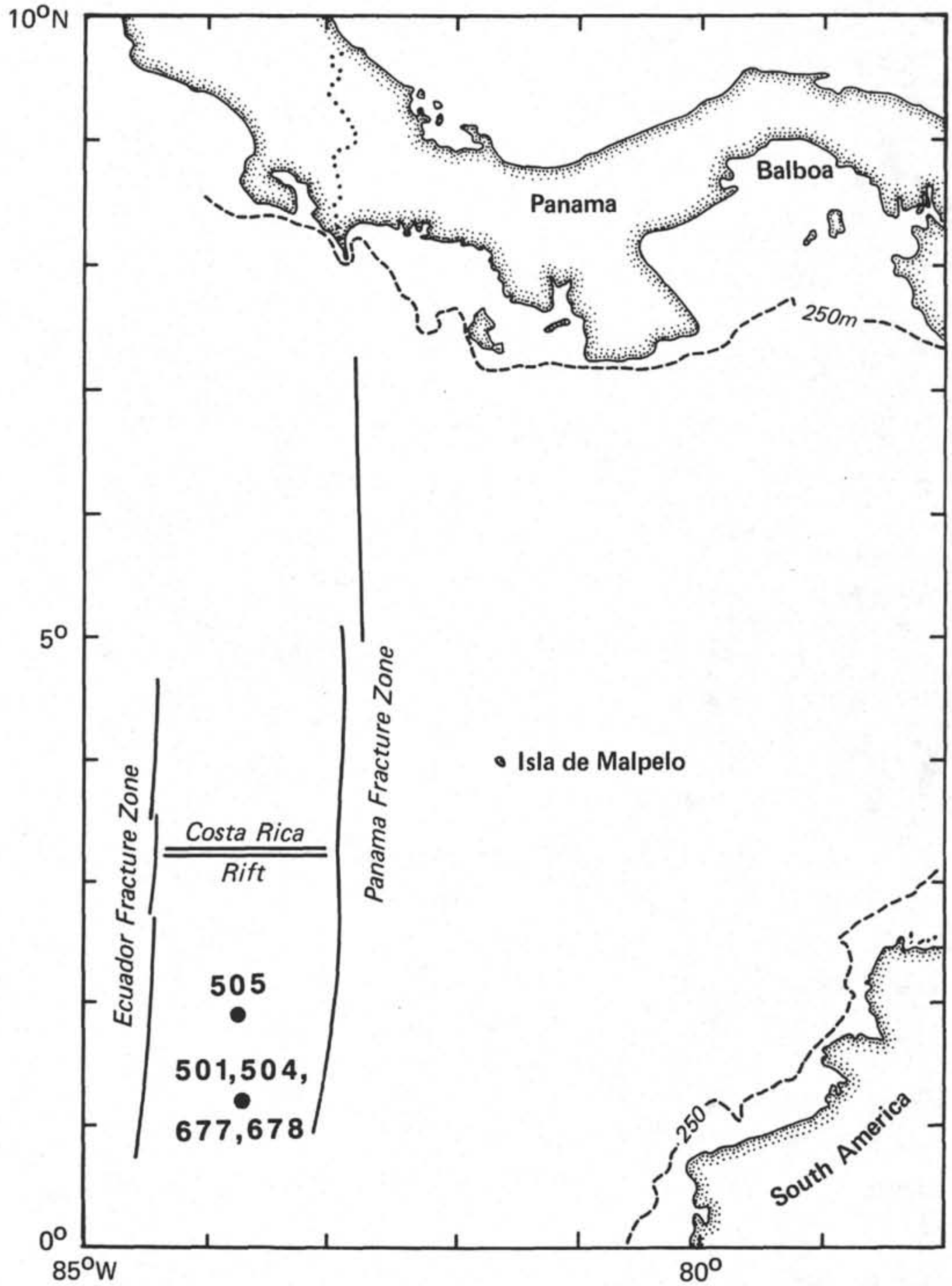

Figure 1. Location of DSDP/ODP Sites 501, 504, 505, 677, and 678 south of the Costa Rica Rift in the eastern equatorial Pacific Ocean.

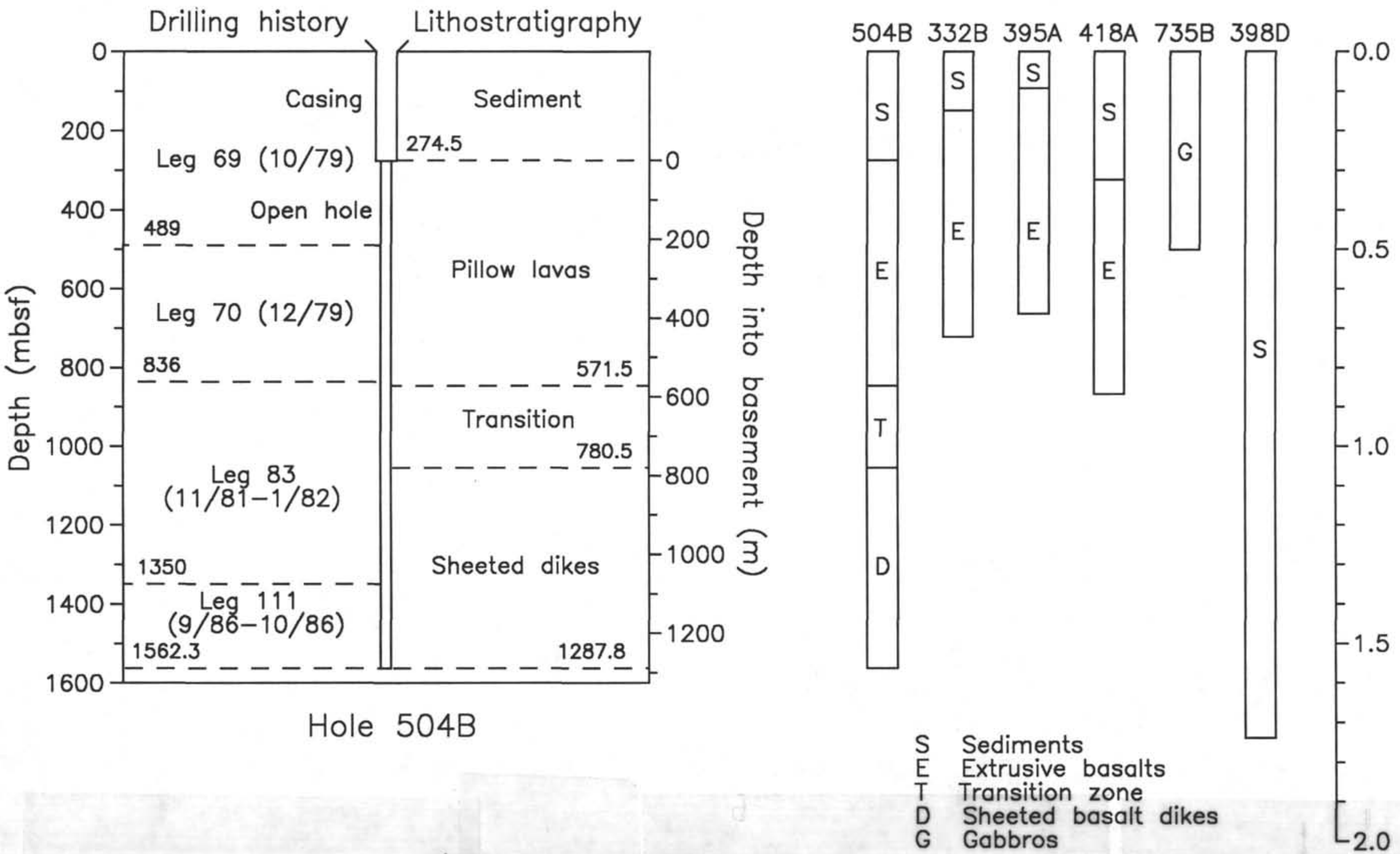

Figure 2. On the left, generalized drilling history and lithostratigraphy of Hole 504B. On the right, a comparison of this lithostratigraphy with (a) that encountered in the four other DSDP/ODP holes that penetrate at least 500 m into "normal" oceanic crust formed at a mid-ocean ridge and (b) the deepest DSDP/ODP hole into any lithology, Hole 398D near the Galicia Bank.

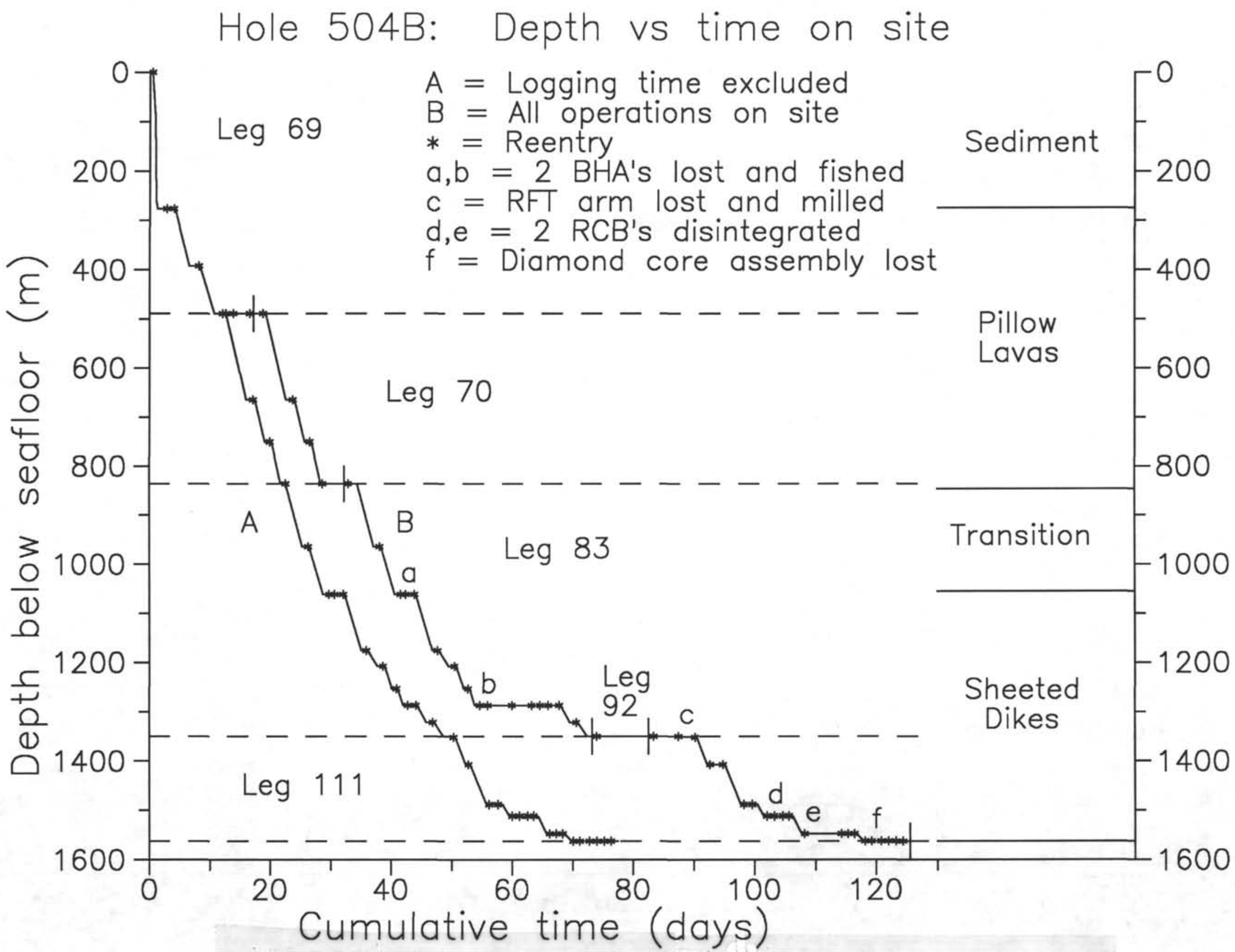

Figure 3. Detailed drilling history in Hole 504B.

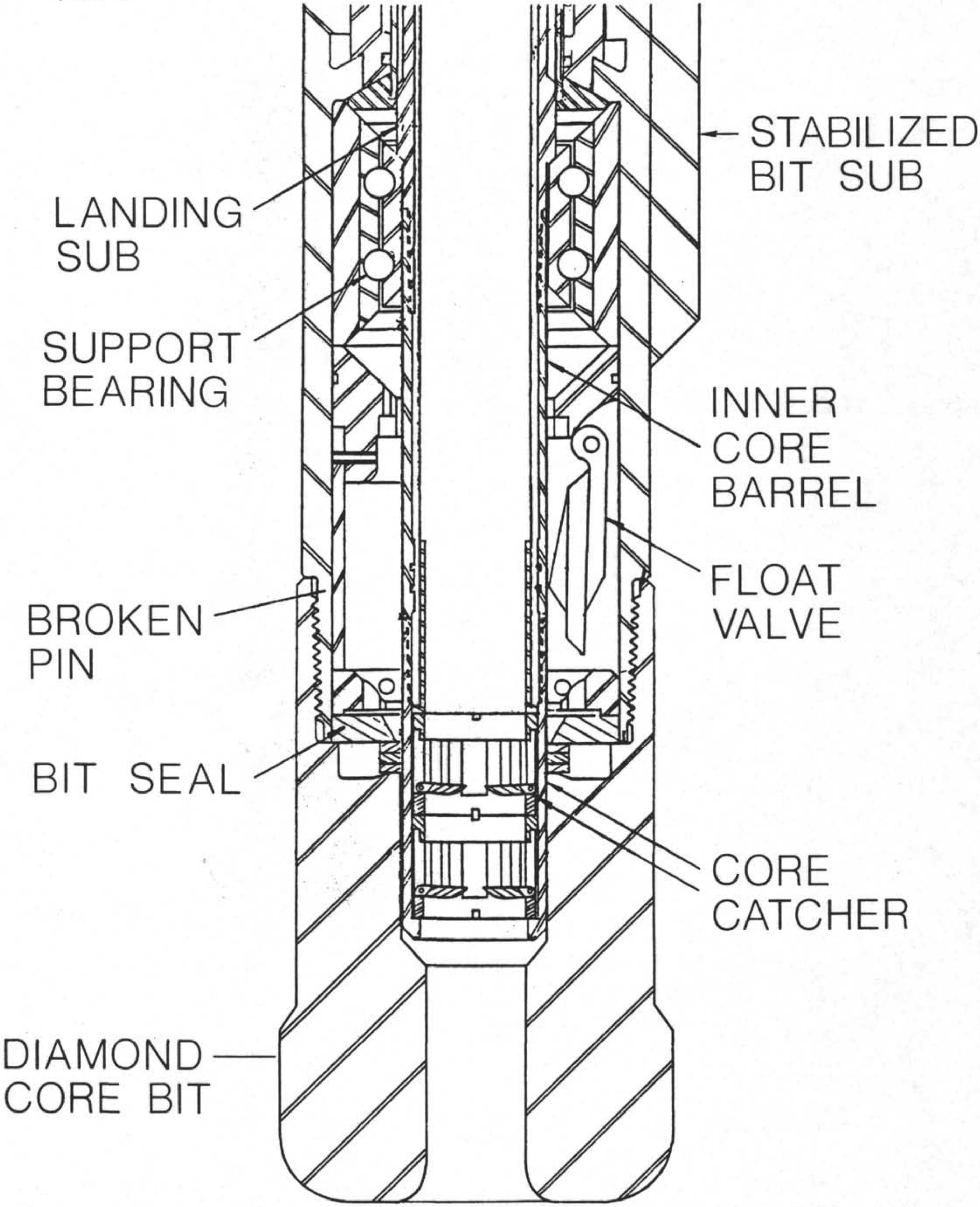

Figure 4. Schematic of the diamond coring assembly lost in Hole 504B at the end of Leg 111. The pin thread of the bit sub-assembly broke, leaving the core barrel, support bearing, float valve, and diamond core head in the hole. The core barrel and outer race of the support bearing were recovered before Leg 111 ended.

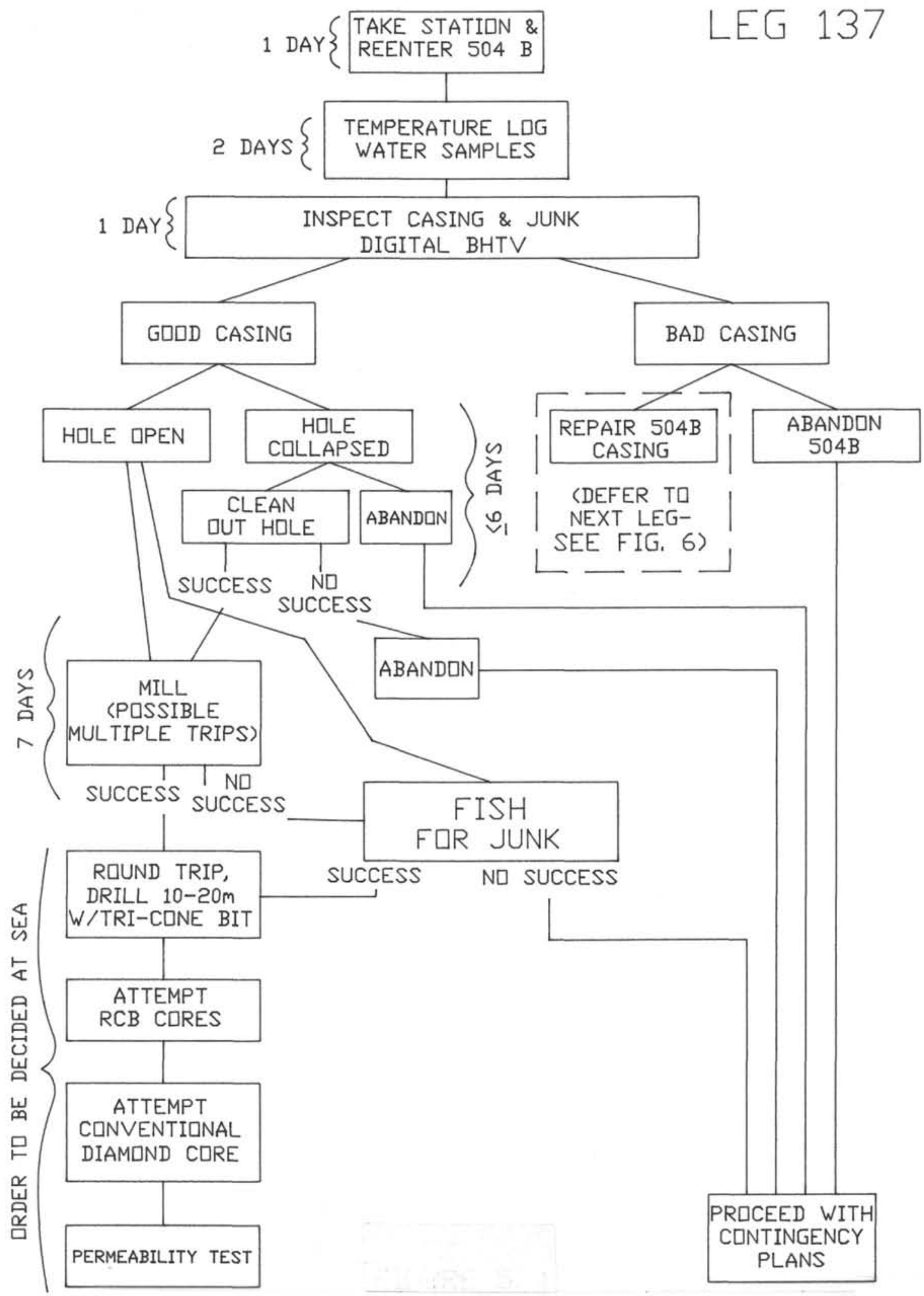

Figure 5. Operational flow chart for Leg 137.

504B REPAIR SCENARIOS

LEG 140

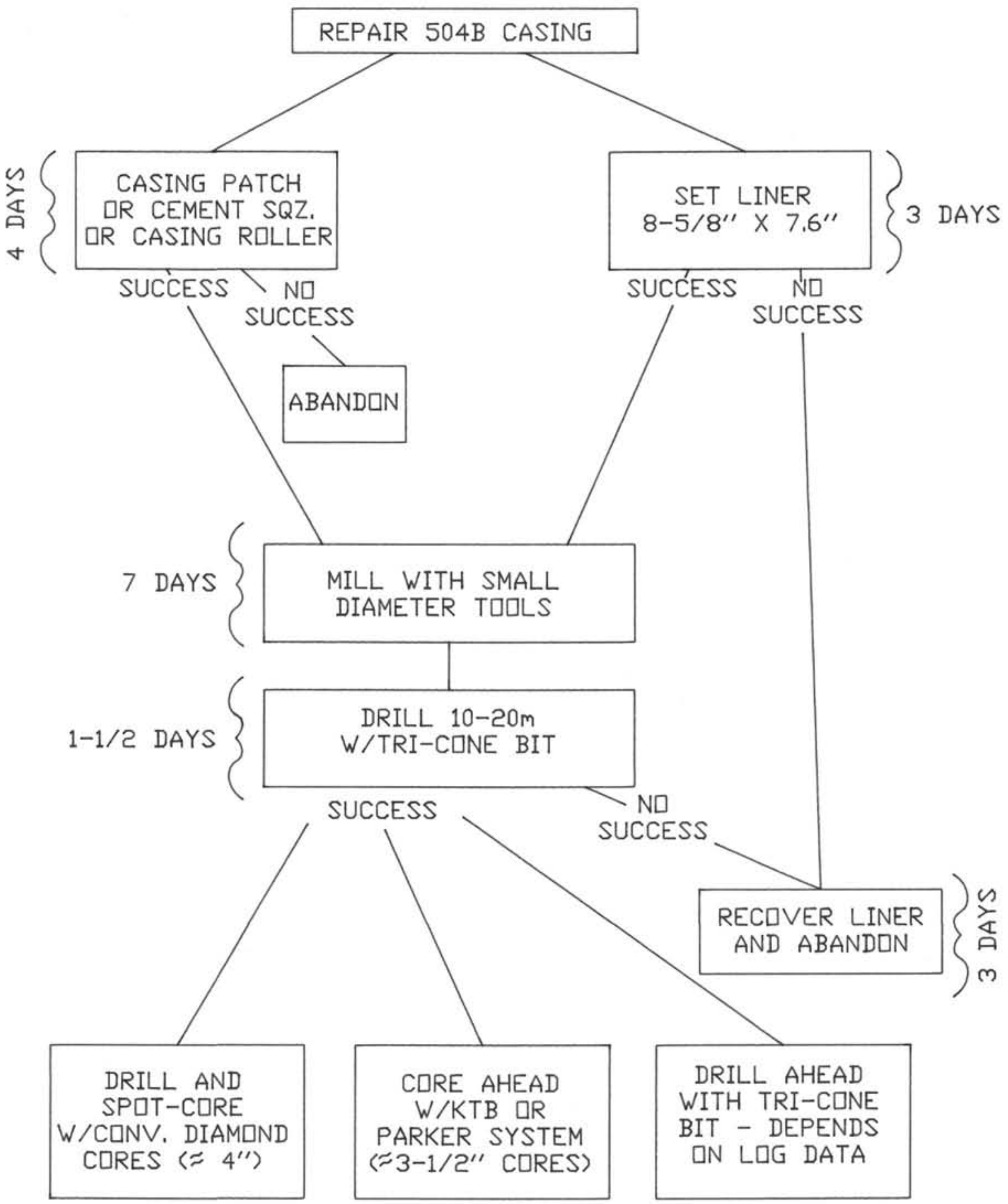

Figure 6. Tentative operational flow chart for a future leg to Hole 504B, should the casing be determined to require major repairs.

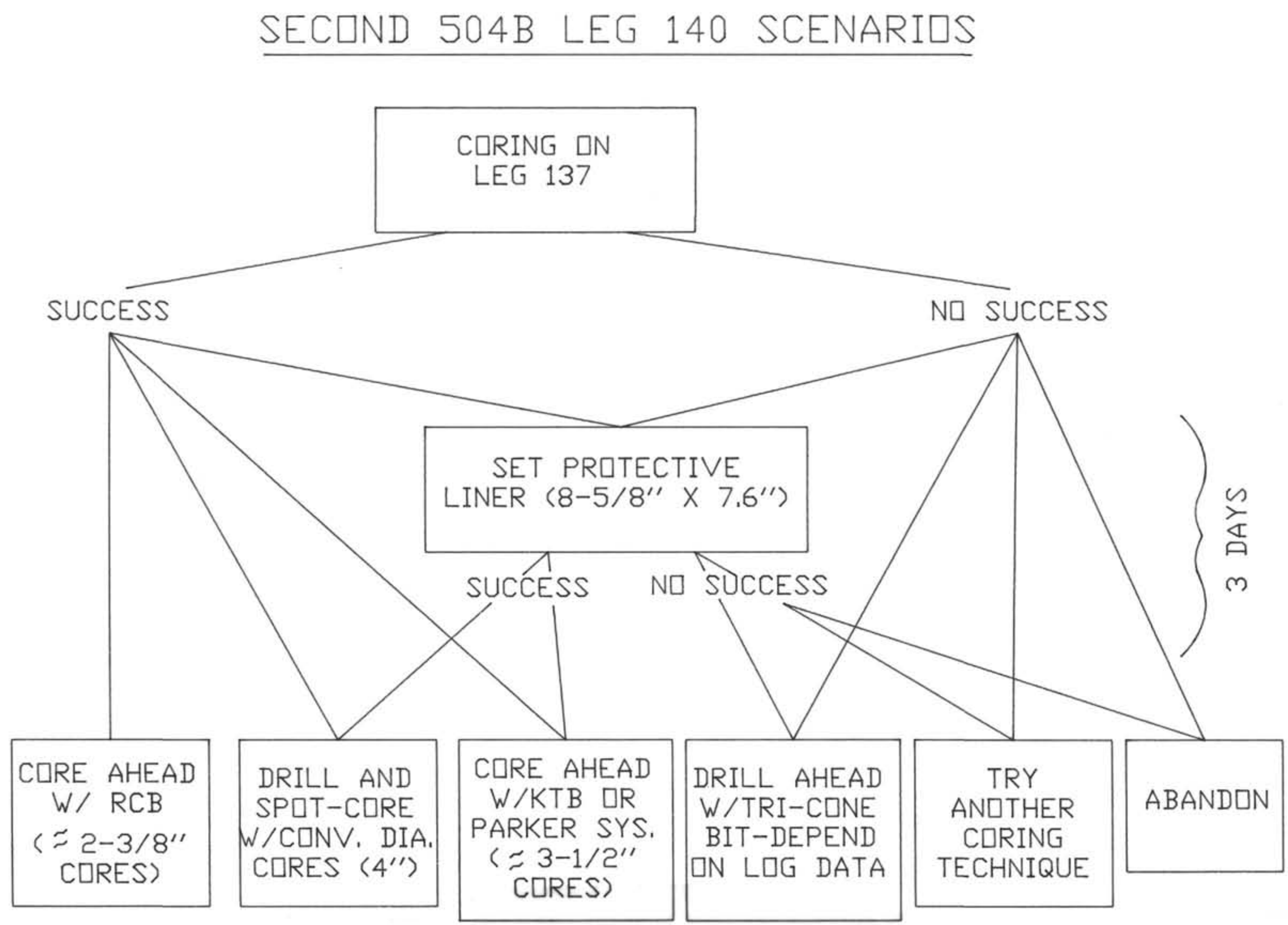

Figure 7. Coring options for a future leg to Hole 504B, should Leg 137 succeed in cleaning the junk from the bottom of the hole.

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