OCEAN DRILLING PROGRAM

LEG 110 PRELIMINARY REPORT

STRUCTURAL AND HYDROLOGIC FRAMEWORK OF THE NORTHERN BARBADOS RIDGE COMPLEX

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INTRODUCTION

During Leg 110 of the Ocean Drilling Program, the JOIDES Resolution achieved a first ever penetration of a detachment surface separating two plates converging in a subduction zone. This detachment, or decollement zone, lies between the underthrusting Atlantic ocean crust of the American Plate and the overthrusting Barbados Ridge at the eastern edge of the Caribbean Plate. At the deformation front, or contact of the Barbados Ridge and the Atlantic abyssal plain, the upper Neogene section of sediment riding passively on the Atlantic crust is offscraped to form part of the accretionary wedge. The decollement zone separates these deformed deposits from the lower Paleogene and Cretaceous sediments which continue to be underthrust with the oceanic crust. Pore water chemistry, temperature anomalies, and structural observations indicate that fluids are moving principally through zones controlled by fracture permeability associated with faults, and secondarily along stratigraphic levels controlled by intergranular permeability. The accretionary wedge and underthrust sediments comprise separate fluid reservoirs, separated by a permeability barrier paralleling the decollement zone. Methane-bearing fluids derived from a probable thermogenic source travel more than 20 km beneath the shallowly inclined decollement. Fluids sourced from beneath the decollement travel laterally at least six kilometers seaward of the deformation front.

Subduction zones are the most dynamic tectonic environment on Earth and provide insights on the very beginning of the mountain building process. Subduction zones consume water-rich sediments that evolve to highly deformed rocks of negligible porosity by the time of their exposure at the surface. This significant porosity reduction requires large-scale fluid expulsion which must occur during this uplift process. Located at the deformation front or structural boundary between the overthrusting Barbados Ridge complex and the Atlantic abyssal plain, Leg 110 was designed to investigate structural, hydrologic, and diagenetic effects of this transition from undeformed deep sea sediment to stratally disrupted melange on land.

The northern Barbados Ridge complex became the focus of subduction zone drilling because the sedimentary cover of the incoming oceanic crust is less than 800 m thick, consequently the decollement surface and related thrust faults occur at relatively shallow depths below the seafloor. Previous drilling during DSDP Leg 78A (Biju-Duval, Moore, et al., 1984) biostratigraphically documented thrust faulting in the accretionary wedge and discovered indications of high fluid pressures in the decollement, but failed to penetrate this major fault surface.

DRILLING RESULTS

SITE 671

The prime objective of ODP Leg 110, penetrating the decollement, was realized at our initial location, Site 671 (Figs. 1, 2); a surprising result in view of three former attempts to drill this mechanically unstable zone on Leg 78A. At Site 671 we cored 500 m of Pleistocene to lower Miocene, imbricately thrusted, offscraped calcareous mud and mudstone, a 40 m thick decollement zone of lower Miocene to upper Oligocene scaly (sheared and flattened) mudstone, and 150 m of little deformed underthrust Oligocene mudstone, marlstone, and siltstone (Fig. 3). Although we cored well into the underthrust sequence, the hole had to be terminated above the oceanic crust due to penetration of an unstable sand layer. Sites 671, 675, and 676, as well as Sites 541 and 542, all near the deformation front, provided excellent control on the geometry of the imbricate packages (Fig 2). Good biostratigraphic records permitted not only unequivocal recognition of thrust faults but provided a basis for correlation between all holes drilled during ODP Leg 110 and DSDP Leg 78A.

SITE 672

In order to understand the development of the structural fabrics, geotechnical properties, and water chemistry at the deformation front, we drilled a reference hole at Site 672, 6 km east of the deformation front along the Leg 110 transect. Here we were able to define the characteristics of all units penetrated in the accretionary prism in a relatively undisturbed state. A distinctive lithology and excellent fossil control at the top of the decollement zone at Sites 671 and 541 allowed identification of correlative strata at the reference site. Anomalously high porosity and probable correlative decrease in sediment strength characterize this "future decollement" and could explain why failure initiates at this stratigraphic level. Indeed, low angle shear zones, and normal and reverse faulting, suggest incipient failure, even at this substantial distance seaward of the deformation front. Because of enhanced cementation, the middle to upper Eocene sandy interval which stopped drilling at Site 671 was completely penetrated at the reference site. Low chloride and relatively high methane contents in pore water from sandy layers likewise suggest lateral fluid flow from beneath the accretionary prism. Thus, even at 6 km to the east of the deformation front, Site 672 appears to show some effects of the encroaching accretionary prism.

SITES 673 - 674

In addition to documenting initial accretionary history, Leg 110 drilled two sites, 12 and 17 km up slope and west of the deformation front, to measure the continuing evolution of the offscraped sediments. Here, at Sites 673 and 674, sedimentary rocks show complex deformation, far exceeding in intensity that in the sites near the deformation front. Structurally, these rocks include overturned sections, scaly fabrics, stratal disruption, veining and cataclastic shear zones similar to those that occur in subaerially exposed accretionary complexes. More remarkable, this intensity of deformation was achieved with only modest amounts of dewatering, resulting in sedimentary deposits retaining fifty percent porosity or higher. We were able to define thrust packages with relatively coherent internal stratigraphy near the deformation front; similar tectonic units at Sites 673 and 674 are cut by later thrusts that are discordant to their complexly evolving interiors. Moreover, the landward dipping seismic reflectors here appear to correlate with these later thrusts, not the internal stratigraphy of the tectonic units.

SITE 675

Site 675 penetrated to 388 m sub-bottom, taking a core at the mudline and coring the final 67 m in preparation for a packer test. The mudline core consists of lower Pleistocene foram-nannofossil ooze (Unit 1). From 321 to 363 m sub-bottom we encountered barren mudstone and claystone (Unit 2), below which we penetrated 25 m of locally siliceous lower Miocene mudstone (Unit 3). Orange-brown portions of Unit 3 with black manganese concentrations (especially Section 675A-8R-1) lithologically resemble the top of the decollement zone at Site 671. The lower Miocene radiolarian zones (R-10 through R-12) in Cores 675A-7R and -8R correlate well with the top of the decollement zone at Site 671.

Prominent zones of scaly fabric occurring at about 335 m and 360 to 378 m sub-bottom apparently correlate with the frontal thrust and the top of the decollement zone, respectively. Chloride lows and methane highs within or adjacent to both of these deformation zones suggest they are zones of active fluid transport. Rhodochrosite occurs in shear veins lying in, and dilatant veins cutting across, the scaly fabric of the lower deformation zone, indicating the presence of near lithostatic fluid pressures.

Similar to the patterns in stratigraphically equivalent rocks at Sites 671 and 672, porosity shows a localized high of 70% just above the inferred decollement. Sediments at Site 675 have a inferred in situ velocity of 1.61 km/sec which is consistent with their relatively high overall porosity. The low consolidation state and the active dewatering of the sediments at Site 675 produced hole-stability problems preventing any packer test.

SITE 676

Located only 250 m arcward of the deformation front, Site 676 was designed to explore the incipient stages of accretion. Here, lithologic Unit 1 (0-168 mbsf) consists of calcareous mudstone and claystone, marl, and ash layers of latest Miocene to Pleistocene age. At the probable level of the frontal thrust (25-55 mbsf) conspicuous folding occurs in the Pleistocene with bedding dips locally as steep as 75°. A second discrete thrust fault with folded scaly fabric occurs at 155 mbsf at the Miocene/Pliocene boundary. Unit 2 (168-263 mbsf) comprises middle and upper Miocene claystone and mudstone with ash beds. Calcareous nannofossils occur in the upper half of Unit 2. At 206 m a biostratigraphic defined thrust fault with 30 m of throw is associated with a scaly zone. The lower portion of Unit 2 includes traces of radiolarians that cannot be zoned. The seismic data suggests that this fault is very recent and probably propagating upward and forward from the decollement. Unit 3 (263-310 mbsf) is composed of lower Miocene claystone, siliceous mudstone and ash layers. At 270 to 280 mbsf this unit includes a zone of incipient horizontal shearing which may represent a seaward forerunner of the decollement.

Physical properties at Site 676 are very similar to those at the reference Site 672. The porosity profile is repeated at about 40 mbsf suggesting thrust faulting. The magnetic susceptibility profiles are also repeated below 40 m. Anomalously high temperatures in this interval suggest lateral flow of warm fluid into this fault zone.

High values of methane occur at four depths; three of these anomalies correlate well (within the limits of sampling) with the three main structural features of the hole. The methane anomaly at 33 mbsf is probably related to the fault near this level defined by physical property and magnetic susceptibility data. The high methane content at 190 mbsf is adjacent to the thrust repeating the late Miocene section. The high methane anomaly at 286 mbsf is adjacent to the incipient shear zone of the propagating decollement. Low chloride is observed only at 250 mbsf and does not correlate with any structural feature.

HYDROLOGIC FRAMEWORK

A combination of structural, biostratigraphic, seismic, and physical property data clearly define a structural setting within which the hydrologic evolution of the Leg 110 transect can be considered. Any model of the hydrogeology of the accretionary wedge must account for sources of fluids, mode of transport, and the geometry of the conduits.

Incoming sediment has a porosity of about 54%, estimated as an average value at reference Site 672. Decrease in average porosities of sites located at the deformation front and further up slope are not dramatic. Comparisons of particular stratigraphic intervals do, however, document localized dewatering. The modest dewatering of the offscraped sequence appears to occur principally in response to vertical, as opposed to lateral, tectonic loading. The underthrust portion of the incoming sediment, although undeformed, is progressively loaded by the westward thickening accretionary prism which would undoubtedly result in consolidation, overpressure, and water loss.

Sedimentary deposits in the Leg 110 area are dominantly fine grained and of low permeability (Marlow et al., 1984), with the exception of the locally sandy interval in the underthrust sequence. The geochemical evidence presented below argues for dewatering in the decollement zone; however, a simple calculation using Darcy's law shows that fluid movement through the intergranular permeability of the fine-grained sediments would be about one thousand times slower than the rate of underthrusting. Water cannot escape through the decollement zone unless the intergranular permeability is enhanced through a fracture permeability. Supporting this argument, the foliated decollement zone includes rhodochrosite-filled veins in the scaly fabric suggesting that fluid pressures were sufficiently high to open these surfaces for fluid flow. We surmise that flow through the fine-grained sediments of the accretionary wedge and decollement zone is dominated by fracture permeability, especially along faults. In contrast, the middle and upper Eocene sandy intervals in the underthrust section probably transport fluid by intergranular flow.

Chemistry of the pore water provides the most clear-cut evidence for fluid movement along faults and to a lesser degree stratigraphic conduits. Many faults penetrated during Leg 110 included waters with low chloride contents (Fig. 4). Apparently these low chloride values are caused by movement of fluid through a clay membrane which preferentially retains salts on the high pressure side. Accordingly, the faults are not only surfaces of fluid movement but must have a lower fluid potential (pressure) than the surrounding sediments which are their fluid sources. The low chloride contents noted just above the sandy interval at Site 671 (Fig. 4) and within the same sequence at Site 672 suggest lateral flow along this permeable horizon. Since the observed pore water anomalies would diffusively decay in 1 to 2 x 10^5 years (Gieskes, 1975) they must represent active fluid flow. Anomalously high concentrations of methane occur in pore waters within the decollement zone, in adjacent faults, and the sandy interval below the decollement. However, no methane anomalies are recognized in faults in the accretionary wedge above the decollement, even though these surfaces display low chloride values indicating flow (Fig. 4). The accretionary wedge and underthrust sediment appear to constitute discrete fluid reservoirs separated by the top of the decollement zone.

Rather than membrane filtration, the low chloride waters observed in the Leg 110 cores could be due to the decomposition of methane hydrate, as occurs in the slope sediments of the Middle America Trench (Hesse et al., 1984; Gieskes et al., 1984). Hydrate decomposition produces both methane and low chloride water. However, no hydrate reflectors appear in any of the seismic lines in the Leg 110 area. Moreover, low chloride values occur both with and without associated methane.

Temperature data provide additional evidence supporting the geochemical arguments for fluid flow. High temperature gradients (76 to 180°C/km) were measured at shallow levels at each site predicting unreasonably high temperatures at depth. These gradients are also higher that those measured at more southerly latitudes along the Barbados Ridge (Langseth et al., 1985). At Sites 674 and 676, where downhole temperature measurements were extended to several hundred meters sub-bottom, thermal gradients decreased to more normal values (28°C/km at Site 674; Fig. 4) suggesting that the high surface gradients are explained by lateral input along faults. In fact, at Site 674 a change in temperature gradient, a negative anomaly in chloride, and a probable fault all nearly coincide, providing strong evidence for lateral flow of warm, low chloride fluids along zones of higher fracture permeability.

Methane within and below the decollement zone is probably not biogenically produced <u>in situ</u> because of the locally high sulfate concentrations (Claypool and Kaplan, 1974), but is probably advected through the underthrust sediment from beneath the accretionary wedge. Enhanced sulfate concentrations and the absence of methane, present in the upper levels of the accretionary wedge, suggest methane is not being produced biogenically here. Because the background geothermal gradient is less than 30°C/km at Site 674 and the accretionary wedge there is less than 2 km thick, methane is probably not generated thermogenically in adjacent accreted materials. Conversely, sediment below the decollement eventually reaches a depth of thermogenic methane generation west of Site 674, suggesting that the methane observed at Sites 671, 672, and 675 has laterally advected more than 20 km.

From a simple geometric perspective, fluids exiting from below the decollement should flow vertically to the sea floor rather than laterally along the shallowly inclined decollement. Material just over the decollement zone must present a permeability barrier to vertical flow. The preference for lateral flow may reflect the higher fracture permeability of prominent scaly fabric along the decollement zone. Any permeability barrier over the decollement zone in part may be caused by the expected change in stress orientation across the top of the decollement zone (Fig. 2B). The approximately horizontal orientation of the maximum principal stress in the accretionary wedge would discourage opening of steeply dipping fractures by high fluid pressure while encouraging flow along shallowly dipping surfaces.

CONCLUSIONS

Seismic data and drilling results from near the deformation front in the Leg 110 area indicate that the Neogene oceanic sedimentary section is imbricately offscraped with the subjacent Paleogene and Cretaceous sedimentary deposits being underthrust with the oceanic crust beneath a well defined seismic decollement. Twelve to seventeen kilometers upslope of the deformation front the offscraped sediment packages continue to internally deform and are cut by prominent late thrusts that give rise to landward dipping reflections on the seismic data. The accretionary prism and much of the underthrust section is dominated by fine-grained, low permeability sedimentary deposits. Fluid escape must occur primarily through zones having a fracture permeability, commonly associated with faults, and secondarily along stratigraphically controlled intergranular permeability. Geochemical and temperature anomalies indicate fluid movement along faults. Fluid expulsion along faults requires these to be zones of lower fluid potential (pressure) than the adjacent source sediment. Pore water chemistry specifies two major fluid reservoirs: the accretionary wedge produces fluid with low chloride content and no methane, whereas fluids sampled adjacent to or below the decollement yield low chloride water with significant methane contents. Sediments overlying the decollement zone represent a permeability barrier constraining fluid to flow laterally below them.

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FIGURE CAPTIONS

Figure 1. Location map of ODP Leg 110 drillsites, 671 through 676. Also shown are the DSDP Leg 78A Sites 541 to 543. Bathymetric data printed by Seabeam survey (CEPM) with contours in meters. Contour interval 100 m.

Figure 2. Interpreted cross sections of seismic line CRV128 showing structural and hydrologic framework of Leg 110 area. A) Structural framework of Leg 110 area. B) Hydrologic framework of Leg 110 area. In the accretionary wedge, methane free, low chloride fluids are most conspicuous along faults at Sites 673 and 674, up slope, as opposed to sites near the deformation front. Although methane appears to only be sourced below the decollement along the Leg 110 site transect, methane-bearing fluids could also be expected in the accretionary wedge farther west as it thickens. Insets show state of stress in accretionary wedge and in oceanic sediment column well removed from disturbing effects of deformation front. Because of decoupling along below the decollement zone, the orientation of stress in the underthrust undeformed sediments should differ significantly from that in the overthrust accretionary wedge, and perhaps is more similar to their initial state on the oceanic crust.

Figure 3. Lithologic, biostratigraphic, and structural summary columns of ODP Leg 110 and DSDP Leg 78A sites.

Figure 4. Relationship of structural features, pore water chemistry, and temperature gradients at two Leg 110 sites. Low chloride and high methane pore water concentrations at Site 671 correlate with the decollement zone and characterize the methane-bearing fluid regime. At Site 674 many, but not all, faults correlate with lows in the chloride curve, suggesting some faults may be active conduits of fluid transport. The overall low chloride values probably reflect a diffusive lowering of this constituent due to long-term flow of fluids through the highly faulted section. The correlation of low chloride concentrations in pore water, with the change in temperature gradient at 30 to 40 m sub-bottom at Site 674, suggests currently active flow through this zone.

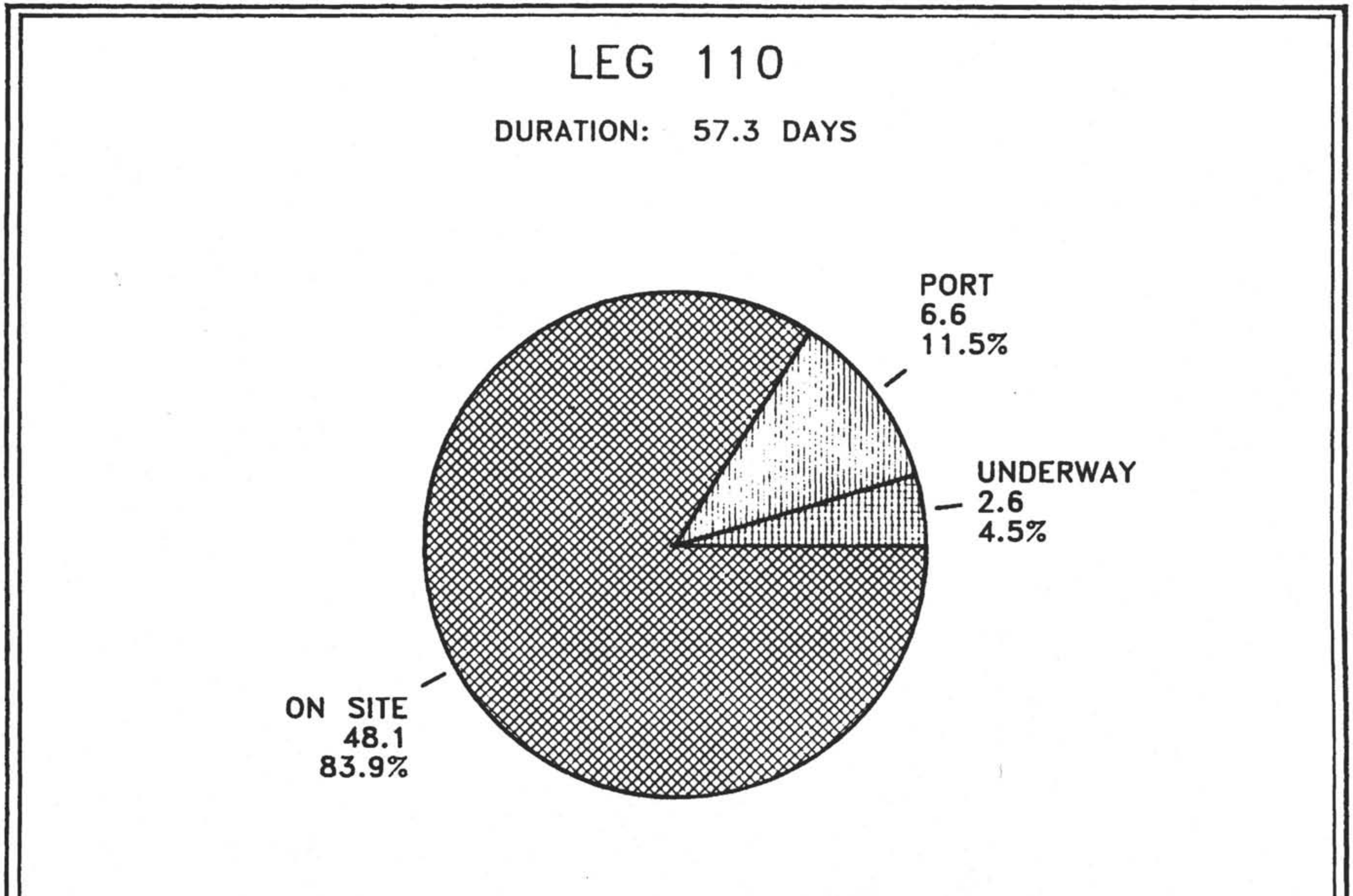

LEG 110
DURATION: 57.3 DAYS
PORT
6.6
11.5%
UNDERWAY
2.6
4.5%
ON SITE
48.1
83.9%

Figure 1.

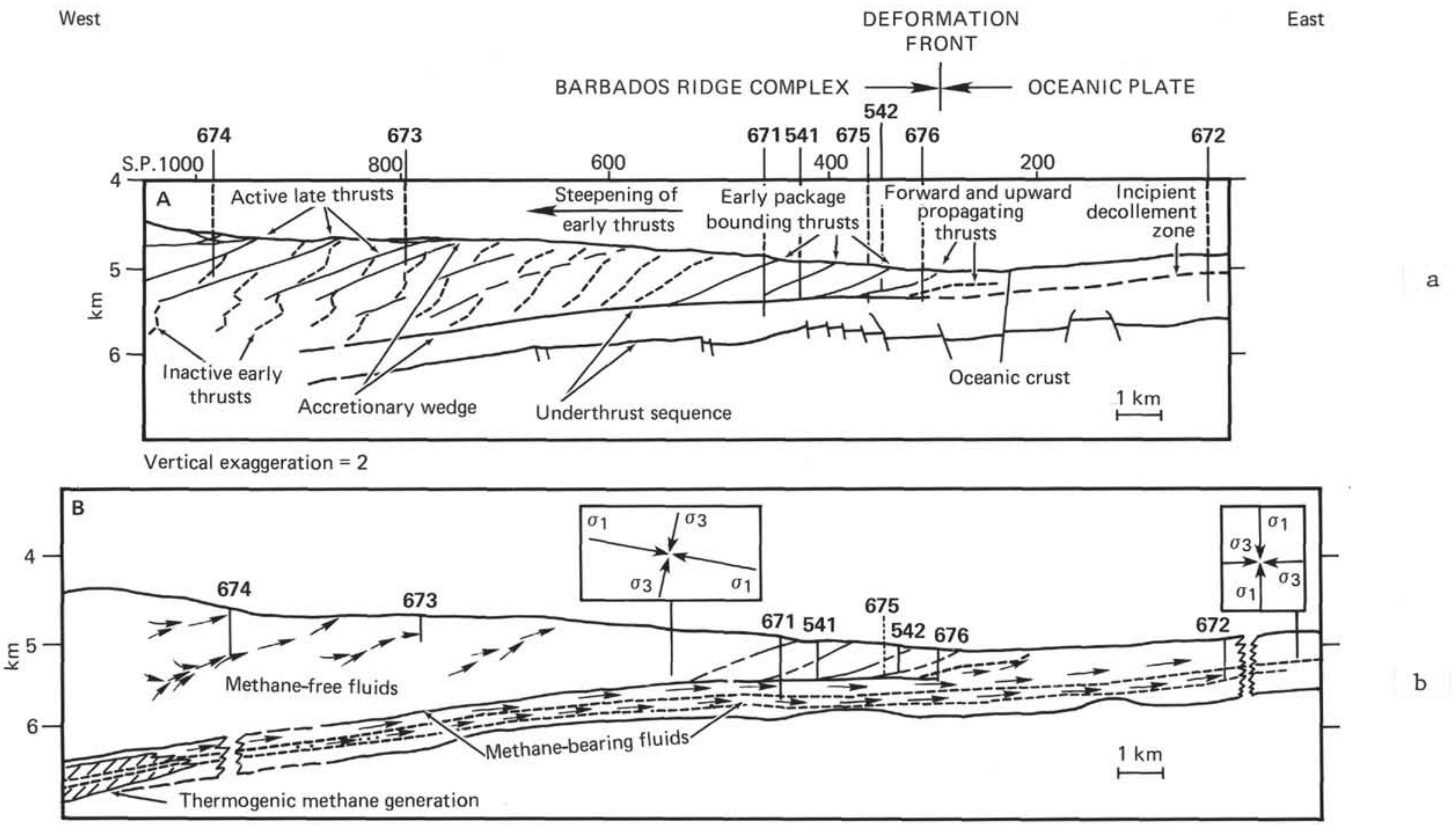
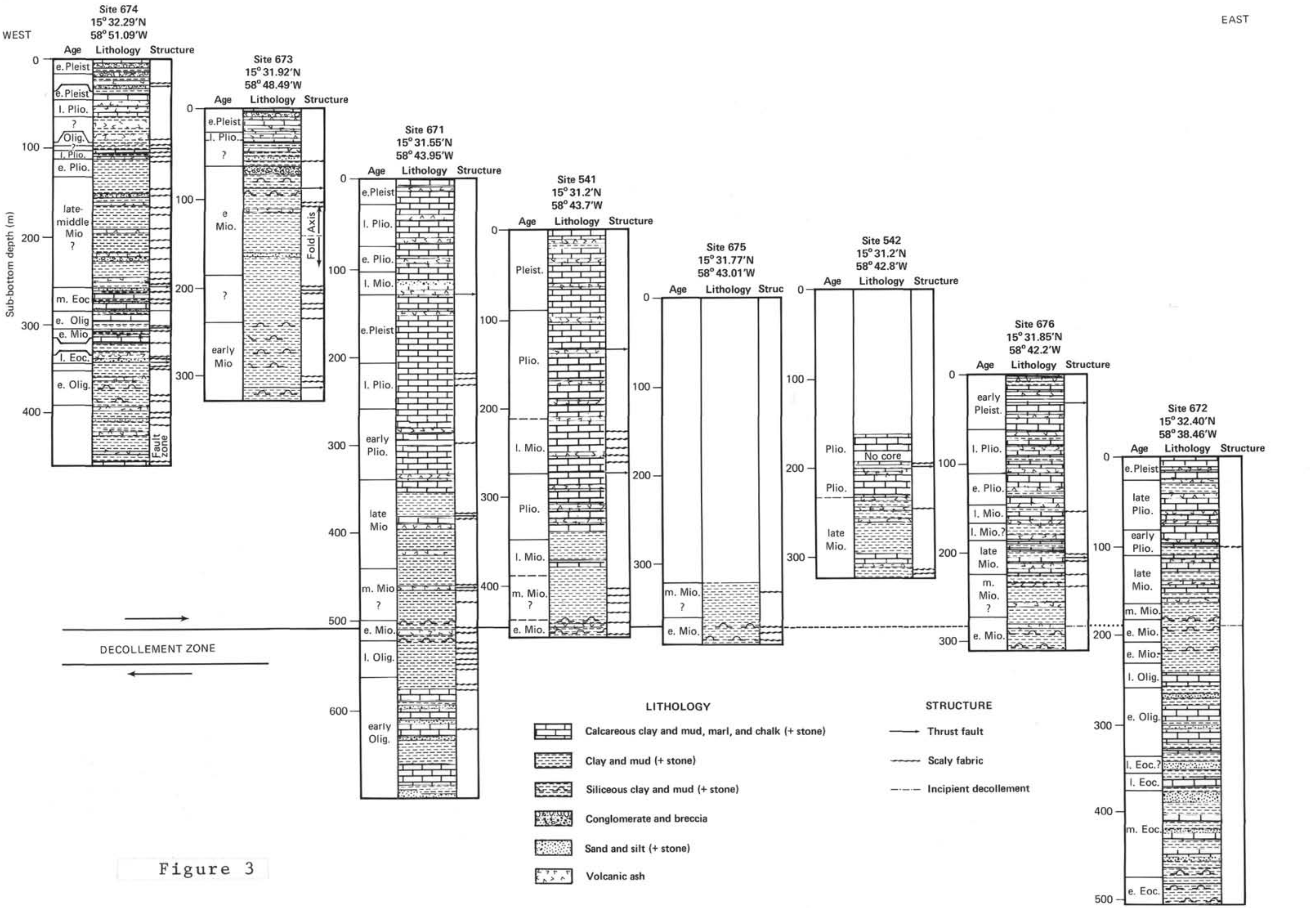
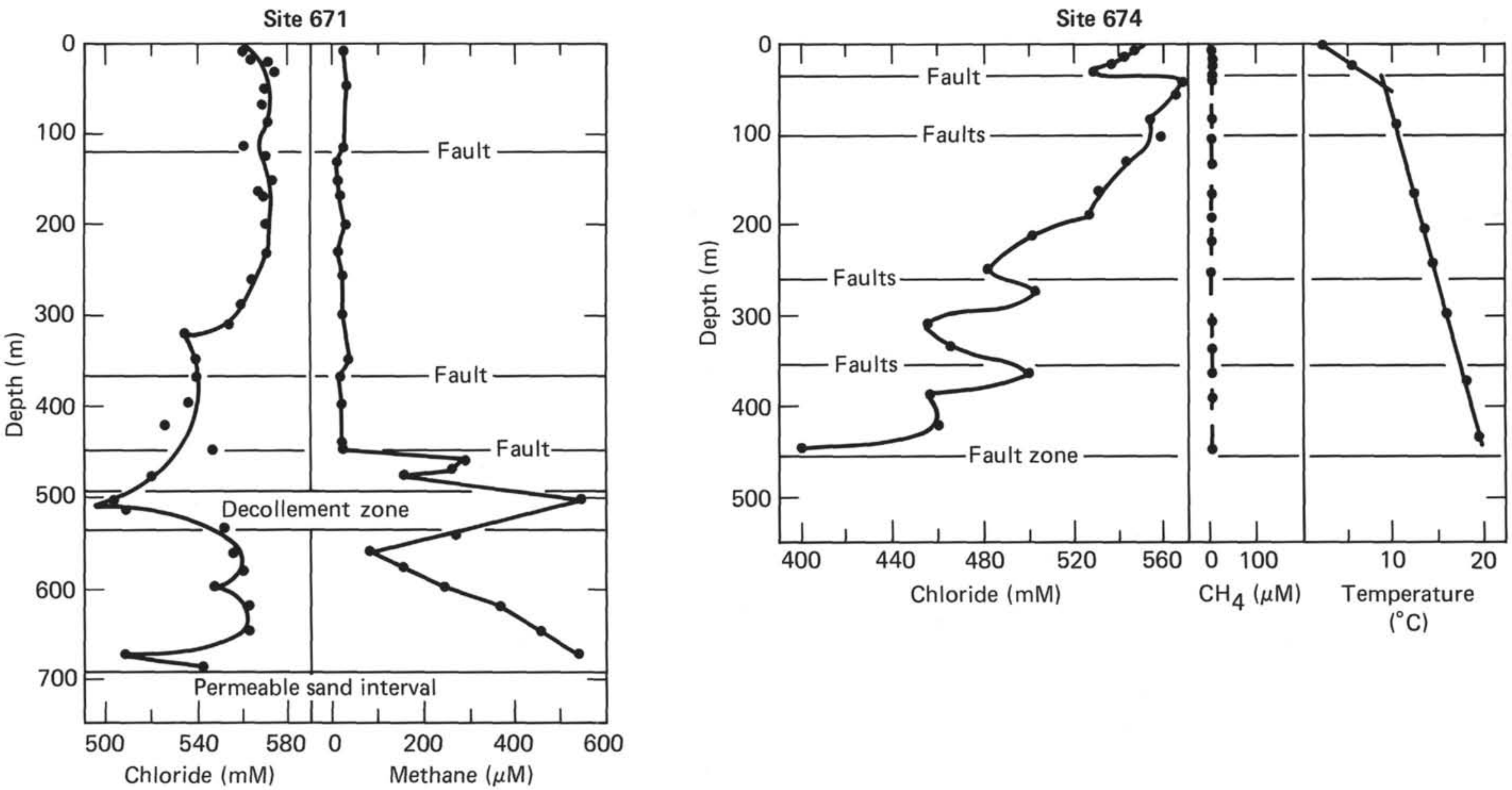

West
DEFORMATION FRONT
East
BARBADOS RIDGE COMPLEX
OCEANIC PLATE
674
673
671
541
675
542
676
672
S.P.1000
800
600
400
200
A
Active late thrusts
Steepening of early thrusts
Early package bounding thrusts
Forward and upward propagating thrusts
Incipient decollement zone
Inactive early thrusts
Accretionary wedge
Underthrust sequence
Oceanic crust
1 km
km
4
5
6
Vertical exaggeration = 2
B
Methane-free fluids
Methane-bearing fluids
Thermogenic methane generation
σ1
σ3
a
b

Figure 2



WEST
EAST
Sub-bottom depth (m)
Site 674
15° 32.29'N
58° 51.09'W
Site 673
15° 31.92'N
58° 48.49'W
Site 671
15° 31.55'N
58° 43.95'W
Site 541
15° 31.2'N
58° 43.7'W
Site 675
15° 31.77'N
58° 43.01'W
Site 542
15° 31.2'N
58° 42.8'W
Site 676
15° 31.85'N
58° 42.2'W
Site 672
15° 32.40'N
58° 38.46'W
Age
Lithology
Structure
Fold Axis
Fault zone
No core
DECOLLEMENT ZONE
LITHOLOGY
Calcareous clay and mud, marl, and chalk (+ stone)
Clay and mud (+ stone)
Siliceous clay and mud (+ stone)
Conglomerate and breccia
Sand and silt (+ stone)
Volcanic ash
STRUCTURE
Thrust fault
Scaly fabric
Incipient decollement

Figure 3



Site 671
Depth (m)
Fault
Fault
Fault
Decollement zone
Permeable sand interval
Chloride (mM)
Methane (μM)
Site 674
Fault
Faults
Faults
Faults
Fault zone
Chloride (mM)
CH4 (μM)
Temperature (°C)

Figure 4

OPERATIONS REPORT

The ODP Operations personnel aboard JOIDES Resolution for Leg 110 of the Ocean Drilling Program were:

Operations Superintendent:	Lamar Hayes
Packer Operations:	Patrick Thompson

Also aboard JOIDES Resolution was:

Steve Rector, Schlumberger Logger (Schulmberger, Houston, TX)

INTRODUCTION

The Leg began June 19, 1986 in Barbados, West Indies and ended August 16, in Barbados. Total length of the leg was 57.3 days, of which 48.1 days were spent on site, 6.6 days in port, and 2.6 days under way. There was no mechanical breakdown time.

BARBADOS PORT CALL

Leg 110 had its official beginning when the first mooring line was put ashore in Bridgetown Harbor of Barbados, West Indies at 2200 hours, June 19, 1986. Five and one half work days were spent transferring and inspecting drill pipe, repairing drilling equipment and carrying out logistical tasks. Major ship work items for the port call included:

1. Installation of a 3 x 18 by 26,500 foot long sand line on number one sand line winch.
2. Replacement of the middle section of the guide rails in the derrick.
3. Replacement of the drilling line deadline anchor.
4. Replacement of the armature of number eleven thruster.
5. Replacement of the Fawick brake on the Varco top drive.
6. Loading 405,100 U.S. gallons of fuel.

Drill Pipe Transfer

The following drill pipe was transferred to and from the vessel:

SIZE	GRADE	ONLOAD	OFF-LOAD
5"	S-135 used	-	391
5"	S-140 new	301	0
5-1/2"	S-140 new	2	0

Drill Pipe Inspection

Baker Tubular Services provided the drill pipe inspection for the 5" and 5-1/2" drill pipe. Inspection procedures consisted of a check of the pipe tube with a flux leakage tool and end area inspection using wet magnetic particle techniques. Inspection was performed on the skate section of the pipe racker, one stand at a time. The special drill pipe lifting ram extensions fabricated by Leg 109 worked well. Fifteen stands of 5-1/2" drill pipe and 303 joints of 5" drill pipe were inspected. Inspection rate was 5 to 6 stands per hour. Work was halted for two days while a new inspection coil was flown from Houston. Forty-three joints of 5" drill pipe were downgraded. Concern was expressed about damage to the 5-1/2" drill pipe tool joint shoulders. Drill pipe stabbing aids will be used on a trial basis on future legs.

UNDERWAY OPERATIONS

BARBADOS TO SITE 671

The last line was cast off from Barbados at 1230 hours on June 26, 1986. After clearing the harbor, the vessel proceeded to Site LAF-1. Seismic gear was streamed to aid in site selection and a beacon was dropped at 0445 hours on June 27, 1986. GPS satellite navigation did not coincide with site arrival time and the last two hours of the pre-site survey were conducted using dead reckoning. Preparations for drilling were slowed because sea conditions prevented the use of the cranes until arrival at the site.

SITE 671

Site 671 was chosen from seismic records as a good place to penetrate the decollement and reach the underlying basement. The site location was moved landward about one kilometer to avoid an active fault zone overlying LAF-1. The seismic record indicated two inactive fault zones overlying the decollement. The decollement was estimated to be 400 meters below the seafloor and basement 400 meters below the decollement.

Hole 671A

Hole 671A was used both to establish the mud line depth and to perform a jet-in test for 20-inch casing. An 11-7/16" APC-XCB bit and bottom-hole assembly were assembled and lowered to the seafloor. During the trip into the hole, 43 joints of the 5" drillpipe that were downgraded at the Barbados pipe inspection were removed from the drill string. Eighty four joints of new 5-1/2" pipe that had never been used were added while tripping to 100 meters above the seafloor. Each stand was broken in per A.P.I. recommended practice. One stand of 5-1/2" drill pipe was positioned in the guide horn and the ship was then offset 800 meters to the east, based on the GPS satellite data received after dropping the beacon. The bit was positioned two meters above PDR seafloor depth of 4925 meters and three "water cores" were taken before a seafloor depth was established at 4942 meters. The mud line was penetrated at 1000 hours on June 28, 1986. Site location was 15° 31.55'N, 58° 43.95'W.

An XCB barrel (without the spring in the spring housing) was dropped and the following jet-in test was performed to estimate sediment resistance to setting the 20" casing string:

1. The rig pump was set to 20 strokes per minute and 5000 lbs. of weight placed on the bit.

2. Three drill collars were washed-in at a penetration rate of 3 minutes per collar before resistance was indicated and the penetration rate slowed.

3. The pump rate was increased to 30 strokes per minute and 10,000 lbs. of weight was applied to the bit.

At 45 meters below the sea floor, penetration slowed and it was apparent that 20" casing could not be washed below that point. The pipe was pulled clear of the mud line and the test was terminated. A total of 5.0 meters of cored material was recovered from Hole 671A. The total depth of this hole was 46.4m BSF and the time on the hole was 29 hours, 45 minutes.

Hole 671B

Hole 671B was drilled to complete the objectives of 671A. The location is $15^{\circ}31.55'$N, $58^{\circ}43.95'$W.

APC Hole 671B was spudded at 1430 hours on June 29, 1986. The hole was offset 20 meters to the south of the soil test hole (671A). The bit was positioned at 4940 meters and Core 671B-1H established the mud line at 4942 meters. APC cores were taken to a total depth of 5033.8 meters where overpull of 40,000 lbs. on the last three cores indicated that the sediment was becoming too sticky for safe operation of the APC. The absence of collapsed core liner problems reported on earlier legs was attributed to sealing the inner barrel joints with plastic thread sealing compound and the success of the new molded liner seal sub.

The Barnes-Uyeda Heat Flow Tool was attached to the end of a modified XCB coring assembly and deployed after Cores 671B-5H and -18X. In both tests 10,000 lbs. of weight was applied to the bit. Dwell times on bottom were 20 and 15 minutes respectively. It required 40,000 lbs. of drill string overpull to free the bit at the conclusion of each test. A short probe, spaced to stop 10" outside the bit, was used on the second test to minimize the danger of bending the probe in the firming sediment.

HPC shoes modified to carry the Von Herzen temperature recorder were deployed on alternating APC cores until core barrel pullout force raised concerns for their safety. The core orientation multishot equipment was deployed on each APC coring run in the upper sediments.

Two hole deviation surveys were taken, one above and one below the decollement. Both surveys indicated 3-1/4° deviation.

Since pullout forces on the APC had increased to 40,000 lbs. on the preceding three cores, the coring system was switched to XCB at 5033 meters. The drilling strategy to maintain good hole conditions consisted of:

a) Establishing pumping rates sufficient to maintain annular velocities above 50 ft/min between hole and drill pipe while cutting cores in the soft clays. In Hole 671B this proved to be 50 strokes, which gave a 1000 lb. standpipe pressure. The pump pressure was raised to 1350 psi as the sediments firmed. In the harder formations, the pump rate was increased to 70 strokes per minute with a 1700 psi standpipe pressure.

b) Conducting short wiper trips three times while coring the hole to remove bridges forming above the BHA.

c) Three KCl-inhibited mud slugs were used to sweep the hole of cuttings. ODP standard fresh water hydrated mud was not used in this hole. Lab tests on clays from the top of the hole indicated significant swelling and sloughing of the formation when subjected to fresh water or fresh water bentonite gel.

d) If fill was detected at the bottom of the hole after retrieving a core, the driller cleaned the hole back to bottom. After cutting the next core, the driller circulated one annular volume of the hole (bottoms-up) to remove the cuttings before the XCB barrel was retrieved.

The hole problems associated with drilling the sites on Leg 78A did not appear on Site 671B. This is probably a result of the differences in drilling hydraulics between the rotary core barrel used in 1979 and the APC/XCB coring system in use today (1986). The extended cutting shoe of the XCB allows the use of higher pumping rates while coring, without sacrificing core recovery. The increased pumping rate generates a larger volume of flushing fluid for better removal of cuttings from the well bore. A second factor is the larger (11-7/16") well bore annulus drilled by the XCB bit. The larger hole reduces the annular velocity around the 8-1/4" drill collars, significantly reducing the hole erosion that led to sticking problems associated with work in the 9-7/8" diameter hole drilled at Hole 541A.

Three XCB cores had zero recovery which is attributed to sticky clay formations. The problem clays were encountered above the decollement and continued into the harder underlying formations. The dogs in the core catchers of the empty barrels were locked in the open position by packed clay and required hand tools and water jets to free. The coring technician tried many types of core catcher combinations. Details of those tests are described in the Special Tools Section of this report.

Several XCB cores were retrieved with partially crushed liners. Crushing was attributed to suction forces incurred while pulling the cutting shoe out of the sticky clays after the core was cut. In most cases the liner deformation started at the point where the liner support sleeve terminates. The absence of core disturbance above the collapse point indicated crushing took place after the core was in the liner. Collapsed liners were useful in some core recoveries as the core catcher was empty below the crushed point and the collapsed liner retained the core.

Hole 671B coring terminated with a stuck core barrel at 691.2 meters below the seafloor. Attempts to fish the barrel were unsuccessful because free running quartz sand had invaded the well bore and flowed up around the XCB inner barrel. Two drill collars above the outer core barrel were packed with sand and required several hours to clean. Recovery of the last core was accomplished only after laying down the outer core barrel and using 3000 lbs. of hydraulic force to jack the XCB barrel out of the outer core barrel.

The drill string was pulled until only the BHA was below the mud line. An eight-foot diameter free-fall re-entry cone with six feet of 13-3/8" casing was assembled around the drill pipe. Two hours were required to assemble the cone and weld up the split 13-3/8" casing stinger. One hour was allowed for the cone to fall to the sea floor and then the drill string pulled back on the ship.

The TV was lowered to the seafloor to detorque the cable and to observe the free-fall re-entry cone location. The TV survey revealed that the cone had sunk below the cuttings and that only the two black floats were visible above a crater washed in a featureless sea floor. The crater was judged to be about sixteen feet long, twelve feet wide, and two feet deep. The TV was then recovered to the ship.

A logging BHA was assembled and run to the sea floor. The TV was lowered down the drill pipe and a box search pattern was used to relocate the crater. After 5 hours of maneuvering the ship, the pipe was stabbed between the floats. No movement of the balls was visible during or after the stab. The drill string was run to 5221 m below rig floor and the pore-water-temperature-pressure sampling tool was lowered to the bit. The bit was lowered to 5231 m and 5241 m below rig floor to give a total of three sampling stations, and then the sampler was retrieved. The bit was run to 60 meters above the original TD to avoid the sand zone. The hole was conditioned by displacing 2-1/2 volumes of seawater, a 50 bbl flush of seawater polymer mud, and the displacement of 214 bbl's of KCl inhibited seawater polymer mud.

With the bit positioned above the decollement, the first set of logging tools was run to bottom. The logging tools stopped ten meters below the bit. The tools were recovered and the pipe was lowered to clean out the bridge. Numerous firm bridges were encountered below the bit and it was judged that further logging efforts in Hole 671B without the side door logging sub would not be productive. The hole was filled with weighted mud and operations at Hole 671B were terminated.

<u>Hole 671C</u>

Hole 671C was offset 200 meters to the north of 671B. The purpose of the hole was to penetrate the decollement and obtain a packer test of the shear zone. If successful, the hole would be deepened and the zone below the decollement would be tested. A 10-1/2" core bit was installed on a long bit sub. The flapper valve and lower support bearing inner race were not used. The TAM drilling packer was positioned above the outer core barrel. The rest of the BHA consisted of five 8-1/4" drill collars, a McCullough drilling jar, two more 8-1/4" collars, a 7-1/4" drill collar, and two stands of 5-1/2" drill pipe.

XCB - The bit was positioned above PDR depth and an XCB core barrel was dropped. The landing shoulder of the XCB barrel was turned down to pass through the packer sleeve. The mud line was established at 4947 meters on July 11, 1986 at 1300 hours by loss of weight on the weight indicator. The hole was drilled to about 360 meters BSF. High torque and slow penetration rate led to a decision to pull the "wash barrel" and drop a modified center bit at about 360 meters BSF. The penetration rate improved, but moderate torque remained. Hole sloughing and fill between connections was a problem through the lower section. Short wiper trips and mud slugs were necessary to maintain hole stability. The hole was cored from 495 meters to 514 meters BSF to confirm the stratigraphic location for the selected packer test interval. Hole conditions at the bottom of the hole continued to deteriorate and the packer was positioned at 466 meters BSF in a zone that had drilled tight.

PACKER - The inflate go-devil was dropped and multiple attempts were made with the rig cementing pumps to set the packer. Several pump cycles of pressuring-up the drill pipe to 1500 psi resulted in rapid pressure bleed off. The setting plug of the go-devil was sheared out at 2200 psi, but the packer did not set. The bit was pulled up the hole to 103 meters BSF and the inflate go-devil retrieved with the overshot. It was judged the packer element had failed in some manner and additional attempts to set the packer would not be productive.

The logging tools were run to bottom, but only the nose would go out the bit. Twenty-three meters were logged by raising the drill string above the logging tools. The logging tools were recovered, the pipe was run back to 250 meters BSF and the hole was filled with weighted mud. The drill string was recovered and the work in the area of Site 671 was terminated.

SITE 672

Site 672 was located seaward of Site 671 by about five nautical miles. The site was chosen to be across the fault from the accretion and subduction zone of the prism. The drilling objectives were to investigate the stratigraphy of the oceanic sediments before they become involved in the wedge. The location of Hole 672A is 15°32.40'N., 58°36.46'W.

The GPS navigation system was not functioning and the site was located from seismic lines and dead reckoning navigation. The beacon was dropped at 1110 hours on July 15, 1986 and the site was spudded at 1830 hours. The BHA consisted of a long-toothed APC/XCB 11-7/16" diameter core bit with a six drill collar bottom-hole assembly. The flapper was removed from the float valve in the bit sub to allow logging through the bit.

APC - The hole was cored with the APC to 123.3 meters BSF where sediment stiffness increased and pullout forces on the inner barrel reached 55,000 lbs. APC recovery was excellent (100%). In-situ temperature measurements were taken on Cores 672A-2H, -4H and -6H. The new porewater-pressure-temperature (PWPT) was deployed after Cores 672A-5H and -10H.

XCB - The XCB coring system was deployed after Core 672A-14H and used until hole termination at 493.8 meters below the sea floor. XCB recovery was 69.3%. The PWPT probe was deployed after Cores 672A-15X and -20X. The second sampler run was aborted when the sampler barrel stuck in the drill pipe 500 meters below the rotary table.

Particular attention was given to the drilling parameters of Site 672 in order to keep the cuttings from overwhelming the circulation system. The amount of fill found in the bottom of the hole after each core was monitored by the driller. If the fill exceeded two meters, two annular volumes of seawater were circulated after cutting the next core but before retrieving the core barrel. Pump pressure was increased as the hole deepened and the sediment firmed. In cases where the fill was increasing between cores, the rig weight indicator would indicate increased hole drag at the bottom of the hole. The safety procedure for the last few cores was to pull the bit off bottom before retrieving the core and allow the pipe to stand five minutes without circulation. If a significant overpull above the string weight was required to move the pipe after sitting five minutes the pipe was moved to a spot higher up the hole. More water was then circulated and the test was repeated.

The described test approximated the conditions encountered while running into the well to retrieve the core barrel with the sand line. A twenty-barrel mud flush was pumped at 5420 meters to aid in removing the cuttings. The target depth was obtained at 493.8 meters below the seafloor.

LOGGING - The hole was conditioned for logging by pumping a twenty-barrel mud flush and making a short wiper trip back up to 5116 meters below the rig floor. The hole was reamed down to bottom to clean out fill from 5460 meters to 5477 meters. The bit was positioned at 5101 meters and the DIL-GR-SONIC-CAL logging tool was run into the hole. The logging tools stopped working shortly after leaving the bit at 5131 meters below the rig floor. The logging tools were retrieved and inspected. The short bridle between the top of the logging tools and the torpedo connection at the end of the logging line was found to be at fault. A second short bridle was installed and the same tools were run back into the hole. The tools quit working at 500 meters below the rig floor. They were retrieved and the short bridle was again found to be at fault.

The Lamont multichannel sonic was attached to the logging cable and deployed. The tool functioned well outside the drill pipe but stopped on a bridge at 5249 meters. The tool was initially stuck, but became free after one-half hour of repeated line pulls at 1800 lbs. over cable weight. The sonic tool was retrieved and the cable was found to be kinked over the bottom forty meters. Caving conditions in the hole were such that further logging could not be carried on successfully. The pipe was run back to 300 meters below the rig floor and the well was abandoned with heavy mud.

Total operating time at Site 672 was 7.1 days, during which 493.8 meters were cored, 381 meters recovered (77.3%) and approximately 30-50 meters logged.

SITE 673

<u>Hole 673A</u>

Hole 673A is located higher on the accretionary wedge, west of Site 671. The purpose of the site was to sample sediments exhibiting tilting structure in geophysical records. It was hoped these cores would give insight into the mechanism of rock building that outcrops on the island of Barbados. The site was approached from the seaward side and chosen by the scientists based on dead reckoning navigation from Site 672 and the seismic records from underway geophysics. The GPS navigation was not operative at the time. The beacon and a spar buoy were dropped at 1800 hours on July 22, 1986. As the ship retrieved the geophysical gear and turned around to return to the spar buoy, it was decided to occupy a new site 1-1/2 kilometers east of the original beacon drop. While the vessel was steaming to the new site, the spar buoy was sited and the original beacon was seen floating beside it. The ship proceeded to the new requested location and dropped a second beacon. The onset of darkness precluded launching the Zodiac boat to search for the first beacon until the following morning. The derelict beacon was never located. Location of Hole 673A is 15°31.9'N, 58°48.6'W.

The BHA consisted of a long-toothed APC/XCB 11-7/16" diameter core bit with a six-drill collar bottom-hole assembly. The flapper was removed from the float valve to allow logging without dropping the bit.

APC - The mud line was established at 4677.9 meters. The hole was cored using the APC to 4714 meters below rig floor where two cores with 65,000 lb. pullout precluded further APC work. Recovery was excellent. Cores 673A-3H and -4H were oriented using the Eastman equipment.

XCB - The XCB core barrel was dropped on Core 673A-5X and a normal XCB core was recovered. The geological age of the samples was increasing rapidly and the core catcher contained chunks of limestone. The next core barrel (core six) would not pressure up when it landed. When the overshot was dropped to recover the core barrel, a 15000 lb overpull was required to free the sand line. When the sand line was recovered, the link jar had parted at the lower end of the sinker bar and the jars and overshot had been lost. Brown clay was found on the end of the sinker bar, which would indicate a failure of the BHA.

The pipe was tripped out of the hole back to the ship. The bottom drill collar, core bit, head sub, top sub, landing/saver sub and jar-overshot were left in the hole. Careful examination of the positioning and drilling recorder records do not indicate excessive weight, torque or vessel moving off location. It is surmised from examination of the broken thread on the end of the Gammaloy collar that improper makeup between the head sub and the drill collar may have occurred and the bottom collar subsequently wobbled off while drilling.

Hole 673B

Hole 673B is offset 600 meters east of 673A. The objectives were the same as 673A, namely to drill to a maximum of 600 meters and log if the formation allowed. A six-drill collar bottom-hole assembly was used. The bit was a 11-7/16" diameter APC deep throat, long tooth with sealed journal bearings. The flapper was not installed in the float valve. If the hole proved to be stable, the formation could be logged without dropping the bit.

APC - The first APC core established the mud line at 4689.2 meters. Five cores were taken to 55.1 meters BSF where pullout forces of 55,000 lbs. required the XCB system be deployed. On Cores 673B-3H and -8H, temperature measurements were taken using the APC pocket shoe with the Von Herzen temperature recorder. Recovery was excellent throughout the sequence.

XCB - The hole was cored by XCB to a sub bottom depth of 330 meters. The formation was composed of sticky clay which softened with depth. The geological age of the sediments decreased as the well was deepened. Many of the beds were tilted at 45 degrees. Below 200 meters, 1700 lbs. to 2500 lbs. were required to break circulation. After circulation was obtained, the pressure dropped back to a pressure consistent with the strokes on the pump. Numerous flushes of salt-water based polymer mud were used in an attempt to improve hole conditions but did little good. Torque and drag on the drill string increased with depth. The well exhibited backflow when connections were made or cores were retrieved.

After Core 673B-35X was cut, the fishing neck on the XCB latch was engaged with the sand line overshot and the core barrel was pulled up through the bottom hole assembly into the 5-1/2" drill pipe. The winch operator stopped the winch to check the hanging weight of the sand line. The sand line weight indicator suggested that the core barrel was not attached. The operator returned the overshot to bottom in an attempt to re-engage the core barrel fishing neck and to regain the correct weight. When the winch was reversed, the line pulled tight and the cable depthometer indicated that the inner barrel was hung up 52 meters above the bit.

The sand line could not be freed by pulling or jarring action, so a sand line cable cutter was fabricated and go-deviled down the pipe. The cutter did not work and the pulling cycles on the sand line were continued until the line parted 2200 meters below the ship.

The hole was displaced with heavy mud and the drill string was recovered. The junk sand line in the pipe was cut into 30-meter pieces for disposal. The BHA was completely balled up with sticky mud. It appeared that the soft formation had packed off around the drill string below 200 meters BSF and circulation had been lost into the formation. We suspect that when the core barrel latch was released after Core 673B-35X, the core barrel was pushed up the BHA by formation pressure created from pumping while cutting the core. Thus, when the operator stopped to check the tool weight after clearing the drill collars, the inner barrel attempted to by pass the sand line, and the sand line snagged in the gap between the sand line swivel shaft and body. A spacer later was installed to narrow the gap in the swivel to prevent the line from becoming so entangled in the future.

SITE 674

Site 674 is located at 15°32.29'N, 58°51.09'W. The location is the westernmost site drilled on the accretionary wedge. The coring goals here were to sample the older rocks and to find better drilling conditions. The site was spudded in a sediment pond to provide lateral support for the BHA. It was located by offsetting 4 km west of Hole 673C. The hole was drilled with a six-drill collar BHA and an 11-7/16" APC deep throat core bit. The hole was continuously cored to a sub bottom depth of 452.6 meters.

APC - Cores 674A-1H through -4H were taken with the APC. Recovery was 97.3% but high pullout forces required the switch to the XCB system on Core 674A-5X. A heat flow shoe with the Von Herzen temperature recorder was deployed on Core 674A-3H.

XCB - The XCB was used on Cores 674A-5X through -48X. Recovery was 76.7%. Hole problems were encountered twice but mud sweeps and short trips reduced the fill between cores. The bulk of the coring was accomplished with 65 pump strokes and 75 RPM on the bit. Recovery was good in the sediments that varied from chalky green clay to waxey clay. The coring was characterized by repeating age stratigraphy and near-vertical beds with dip angles at 60 degrees. On the last three cores the new XCB venturi sub was used. Results are given in the special tools section. Coring was suspended at the request of the Co-chief Scientists. The hole was abandoned with heavy mud and the ship departed for Site 675.

SITE 675

Site 675 is located on the accretionary wedge approximately 400 meters west of DSDP Hole 542. Site 675 was approached by dead reckoning navigation as the GPS navigation system was not working. The beacon was dropped and drill pipe had been started into the hole when the transit satellite system indicated that the ship was two miles north of the intended location. The ship was offset two miles south utilizing the Site 671 beacon that was still working after forty days. After the ship's position was verified, a new beacon was dropped and the vessel was offset fifty meters. Location of the site is 15°31.77'N, 58°43.01'W.

The objective of Site 675 was to drill to the decollement and test the formation with a Retrievable Formation Tester (RFT - sometimes called an open hole packer). The drilling strategy was:

1. Drill to the decollement with an XCB bit and six drill-collar BHA without coring. Use a 10-1/2" bit and sufficient pump to clean the hole without eroding the well bore. Spot core above the decollement to find a packer seat.

2. Drop the free-fall re-entry cone and come out of the hole.

3. Buildup a nine-collar BHA with the retrievable formation tester located directly above the core barrel. The BHA would have a mechanical bit release, float valve and 10-1/2" XCB bit.

4. Re-enter the bore hole and trip down to a stable formation above the decollement. Set the RFT in the stable formation and test the well.

5. Deflate the packer and drill/core through the decollement until a second packer seat is located.

6. Set the packer and test below the decollement to determine the permeability of the section.

The drill string was tripped to the seafloor and the PDR indicated depth of 5004.3 meters. After one "water core", the mud line was established at 5018 meters. PDR depth was suspect because three distinct bottoms were visible on the records. The site was drilled as planned, but hole conditions deteriorated as the hole was deepened. Three to five meters of fill were common on each connection. Torque increased in the bottom of the hole and the cores indicated that the decollement had been crossed without finding a suitable packer seat. The last three cores were drilled down in three minutes rotating time each. The hole conditions on the last cores were as follows:

1. A dramatic increase in rate of penetration.

2. Porosity in the last core that was approximately the same as the upper 50 meters of the hole.

3. Drill string torque was increasing and overpulls of twenty to thirty thousand pounds were required to move the drill pipe under the sticky hole conditions.

Those conditions are not unlike the drilling conditions reported at DSDP Site 542.

The softness of the formation at or above the zone of interest precluded the use of open-hole packers. The scientific party agreed with Operations to abandon the hole and move back up slope to Site 671 where the formation might provide a better packer seat. The hole was displaced with heavy mud and the drill string was retrieved.

HOLE 671D

Hole 671D is located 200 meters south of the first packer hole, Hole 671C. The site was chosen because drilling experience in the area indicated the stratigraphy offered the best chance for stable hole conditions and firm packer seats. The site approach was made by positioning off the Site 675 and 671 beacons. The beacon at Site 671 was still operating after 41 days but had weakened to the point that a new beacon was dropped after the location was established. Location of Hole 671D is 15°31.48'N, 58°43.88'W.

The drilling packer was assembled above the core barrel of a nine-drill collar bottom-hole assembly. A 10-1/2" diameter XCB bit and mechanical bit release (with a flapper valve) was used to drill the hole. The pipe was tripped to three meters above the PDR depth. A center bit was attached to the bottom of an XCB inner barrel and dropped. The landing shoulder on the XCB latch was turned down to 3.837" to pass through the 3-7/8" diameter packer inflation sleeve. The mud line was established by weight indicator reading at 4953 meters and the hole was drilled to 450 meters BSF. Drilling conditions were excellent with little fill or torque. At 450 meters BSF the decision was made to begin coring to find a packer seat above the decollement. Initially the center bit was stuck and two wireline trips were required to free it. A core barrel was dropped and the first core was cut. The core barrel was stuck and could not be retrieved. It was decided to conduct a packer test with the inner barrel in place. The hole was deepened to 519 meters BSF to provide communication with the decollement. Sticking and torquing of the BHA began after the core barrel was dropped at 452 meters BSF and reached the point where the BHA would be endangered by further drilling. The packer element was pulled back to 439 meters BSF and the well was circulated with seawater. The first packer inflation cycle was normal up to 1500 psi. After 2-1/2 barrels of fluid were pumped, the pump gauge gave a sharp kick and the standpipe pressure dropped back to 1300 psi. After that an increase in flow rate was necessary to maintain the pressure at 1600 psi. (This can be interpreted as the point where the system developed a leak.) The drill pipe pressure slowly bled off after the test. The second cycle required 3-1/2 barrels of fluid to achieve a pressure of 1600 psi, which returned to zero in two minutes. The packer was moved to a new location up the hole and the inflate cycle was repeated with the same results. On the fourth cycle, the drill pipe pressure was taken up to 2200 psi where the shear pin failed and the drill pipe pressure was released. The pipe was moved up and down with no indication of drag and it was concluded that the packer had failed to set. The drill string was tripped out of the hole.

The packer was disassembled from the drill string and inspected for damage. The element jacket was ripped opened and the wires were exposed. A two-inch slit was found in the bladder. The failure analysis is given in the special tools section of this report.

The XCB landing collar was found wedged in the landing saver sub. The wedge was a result of compression of the XCB landing shoulder that had been reduced to pass through the packer inflation sleeve. A hydraulic wireline jar would have been useful for freeing the wedged landing collar.

SITE 676

Site 676 was drilled on the toe of the accretionary wedge to sample a forward and upward propagating thrust zone. The goal was to drill through the decollement at 300 meters BSF, looking for evidence of fluid flow in the cores. The site was located by offsetting from beacons at Holes 671D and 675A. The location of Site 676 is 15°31.49'N, 58°42.20'W.

The BHA consisted of six drill collars with a nonmagnetic collar above the core barrel. An 11-7/16", C-3 XCB bit and mechanical bit release with a float valve were used to drill the hole.

APC - The bit was positioned three meters above PDR depth and the mud line was established after one water core at 5070 meters. Eleven APC cores were taken with excellent recovery. There were no crushed liners. APC coring was terminated when pullout forces reached 65,000 lbs. All APC cores were oriented except Core 676A-9H. The pore water and temperature tool was run after Cores 676A-4H, -8H and -11H. The HPC temperature tool was run on Cores 676A-5H, -7H and -9H.

XCB - The XCB was used to core from 5171.3 meters to TD of 5380.3 meters below rig floor. The objective of coring through the decollement was achieved. Core recovery was 75% with one lost core due to the flapper and core catcher dogs sticking open. Coring was stopped at the request of the Co-chief scientists who wished to use the remaining time for logging. The hole was conditioned for logging by tripping the bit up to 5220 meters below rig floor and back to bottom. Bridging was encountered at 5326 meters below rig floor. The rotary shifting tool was attached to the bottom of the XCB barrel and the bit dropped off on the first shifting attempt. The pipe was rotated at high speed to ensure that the bit was off the end of the pipe and the hole was displaced with 9.5 lb/gal seawater polymer gel mud. Backflow was observed out the top of the drill pipe after the mud was displaced.

LOGGING - The DIL-GR-SONIC-CAL Schlumberger logging tool was attached to the logging cable and run out the end of the drill pipe. The tools stopped 36 meters below the end of the pipe on a bridge and could not be lowered further. Logging was terminated and the drill pipe was retrieved. The vessel was made ready for steaming and departed for Barbados.

SITE 676 TO BRIDGETOWN

The transit from our last operations area to Bridgetown was carried out at variable speeds. Recently completed work on a main shaft bearing seal required the shaft to be rotated at different RPM's to test the seals. Leg 110 officially ended when the first mooring line was cast ashore at 0500, 16 August, 1986 in the deepwater harbor of Bridgetown, Barbados.

SPECIAL REPORTS

SUPPORT VESSELS

There were two charter vessel trips to the JOIDES Resolution during Leg 110. The first was sponsored by Lamont. It arrived at 1600 hours on July 16, 1986 and departed at 1700 hours the same day with a defective side door logging sub and one subcontractor employee.

The second charter was by JOI and its arrival was at 1200 hours on August 7, 1986. It brought one NSF person, one JOI person, one sub-contractor consultant and one ODP photographer. The vessel departed at 1300 hours with one ODP crew member.

Both charters utilized the motor vessel Brownskin Gal, headquarted in St. Lucia.

DOWNHOLE SONAR-TELEVISION

The Colmek downhole televison and Mesotech sonar were deployed twice on Hole 671B. The sonar picture was unintelligible on both lowerings. The TV was intermittent on the first run but gave acceptable picture resolution to judge the state of the free fall re-entry cone. The downhole package failed on deck before the second run and was replaced with a spare unit. The second run was trouble free and re-entry was accomplished without problem.

WEATHER

The weather for Leg 110 was as expected for the area and season. No tropical storms nor hurricanes were reported within the area. Fair skies and fresh tradewinds prevailed for most of the leg with only a few days of unsettled weather with resultant showers and squalls. The heavier squalls usually produced wind gusts of 35-40 knots and brief, heavy rainshowers. The only abnormal weather was on the positive side. A weak high pressure center moved over the site on July 23, 1986 causing nearly calm winds and slight seas for about 48 hours.

The wind averaged 15-20 knots from the east-northeast. The seas were 3-5 feet with a very persistent east-northeast swell of 6-8 feet; a few building to a maximum of 10 feet. The air temperature ranged from 26.0°C (79.0°F) to 29.0°C (84.0°F). The seawater temperature only varied from 27.0°C (80.7°F) to 27.8°C (82.0°F).

CORING EQUIPMENT

APC - The APC performed very well with almost 100% recovery on every core. The only problem was the new 4130 shear pins. Two pins would shear at random pressures between 2200 and 3000 psi. Additional stocks of the older 17-4 PH stainless steel pins were located and used through the leg. The soft 4130 shear pins pins brought to the rig as backup were not used.

XCB - The XCB was used throughout the leg as the main coring system. Collapsed liners were the major problem encountered. Numerous times the liner was crushed above the liner support sleeve and in three case the sleeve was crushed. The problem appears to be related to drilling in soft sticky clays. The failure mode usually followed this pattern:

1. There is core in the core liner; in most cases the core liner is full and mud is up to the check valve.

2. The pressure builds up in the bit throat, bit jets and cutting shoe jet inlet port.

3. Pressure is applied to the liner directly at and above the liner support sleeve. The core in the liner above the cutting shoe inlet ports is compressed and the liner collapses.

4. The "O" ring designed to stop fluid flow up the core liner is not used because the clearance does not allow installation.

In most cases of liner failure the jets in the cutting shoe are completely clean. Usually the core catcher sub is without core. In the firmest materials the core was still in the throat of the core catcher but the jets in the core catcher sub were clean. On a normal XCB core, one to two jets in the cutting shoe are open and the rest plugged with mud. Many times the liner was completely full and the collapsed core liner helped to hold the core in the barrel. In these cases the core catcher dogs were locked back by the clay.

The path of the fluid flow to the collapse point is fairly well defined. It almost certainly comes through the cutting shoe inlet ports and up the barrel to the liner support sleeve. The pressure on the outside of the barrel is the same as the pressure in the port. Therefore, the core material can be compressed or displaced out the check valve and space created to push the liner into. Two possible causes for the collapse have been advanced by Leg 110 personnel:

1. Since the barrel was filled with core before the failure occurs, the compression is due to a suction occurring when the cutting shoe is pulled out of the mud.

2. The material becomes firm while coring and the pressure builds up in the seal bore drill collar annulus. The pressure is sufficient to force the core in the cutting shoe back out the core catcher. In most cases the

> sticky clays had disabled the core catcher dogs by freezing them in the retracted position. The reverse flow of core catcher material creates space for the liner support sleeve to collapse into the cored material.

The XCB system was designed to have an "O" ring seal at the point between the isolation sleeve and the cutting shoe. These seals are not installable because the threads of the cutting shoe will not allow assembly. One solution would be to use a molded seal in place of the "O" rings in the isolation sleeve.

Hex Landing Sub - The hex landing sub exhibited axially oriented cracks running down the inside of the hex and into the flow holes of the landing flange. Two landing subs were replaced during the voyage.

XCB Venturi Subs - The XCB venturi sub with the one-inch diameter venturi was used on the last two cores of Hole 674A. One core was highly disturbed and one core was excellent. No decision was possible as to the effectiveness of the new system. The assembly is most unpopular with the coring technicians because of the time and maintenance necessary to clean the unit. Future use will require direction by the Special Tools Engineer.

Heat Flow-Pore Water-Pressure - The new downhole recorder and deck readout box fabricated by Randy Current worked well and is a real improvement over equipment used in the past. It has the possibility of becoming a good downhole data logger for many of the measurements that scientists would like to accomplish.

Pore Water Collection and Poor Hole Conditions - A persistent problem with downhole sampling probes is the requirement to set the bit on bottom for extended periods without drill pipe circulation. Overpulls of 20,000 to more than 40,000 lbs. are required to free the pipe at the end of the measurement cycle. Superintendents are very reluctant to expose the drill string to such overpull conditions. One solution would be to lock the probe into the outer barrel and push it into the mud. The drill string would then be pressured up and a hydro-mechanical shear tool similar to the APC would release a scoping member inside the drill collar. The bit could then be pulled off bottom and circulation could be resumed while the measurement was in progress. The taking of downhole measurements is dependent on sea state and hole conditions. That trend will continue until such time as circulation can be continuous and drill string motion can be decoupled from the probe.

Hard Formation Core Catchers - The stiff, sticky clays encountered throughout the area often locked the core catcher fingers into the catcher body and resulted in loss of the core catcher material and sometimes the whole core. Increased tension was applied to the fingers by using two springs. The spring slot in the dog was widened to accept two springs. There is room for a much stiffer spring if the dog slot is widened, and that should be considered for the future. Another option is to drill a hole through the dog and insert a rubber button to kick the dog back into the the sticky core material.

Soft Formation Core Catchers - Soft formation core catchers are presently assembled with the dogs reversed. That practice aids in core recovery under certain circumstances. If the mud is sliding out of the catcher, the points of the dogs can dig into the core. When the dog is assembled in the reverse position, the spring yields when the dog is flexed into the full closed position. The slot in the dog needs to be re-designed to work with the spring when the dog is used in the reverse position.

Torsion Spring, Float Valve - The torsion spring in the float valve usually comes out of the hole in a yielded condition. Commonly, the flapper is hanging at a 45 degree angle. Two failed springs have been returned for analysis.

Wireline Jars - Sinker Bar String - The 2-3/4" spang jars were lost on Hole 673A when the overshot and jars passed outside the pipe when attempting to recover the inner barrel on core six. The jars hung up under the pin of the drill collar and parted in the base of the top pin. The surface of the break exhibits a faceted-crystalline structure. The metal structure may be weak from the heating necessary to remove the Bakerlok connections in the field.

The continued use of 1-1/4", 8 thread connections is a candidate for review. With the advent of the larger 2-3/4" Spang jars presently in use, there seems little reason not to use a larger diameter, shorter sinker bar and stronger threaded connections. That modification would allow the sinker bar string to be shortened for easier rig floor handling.

Drill String Pressure Loss - The pressure loss through the drill string and surface equipment was measured before spudding Site 671. The test was conducted with 4925 meters of 5" drill pipe and a six-collar BHA. The readings were taken from the driller's console gauges. The pumps were dressed with 6-1/2" liners.

PUMP STROKES	STANDPIPE PRESSURE
100	750
120	120
140	140

The test results indicate less parasitic pressure loss in drill pipe than indicated from typical nomograms for 5" drill pipe. The results should be useful when designing hydraulic programs for wells in the future.

CONTRACTOR EQUIPMENT

The contractor equipment was free from breakdown except as noted below. No lost time was recorded except for the requirement to depart the last site early in order to reach port if shaft repairs were not successful.

Port Shaft - The port pinion shaft bearings of the port shaft gear reduction box were replaced at the Dakar port call. The shaft developed a growl on Leg 110 and was secured after the first site. The gear box was unhooked from the couplings and 60 tons of pressure were applied to the bearings. The bearings were compressed 0.018" of the 0.020" recommended by the manufacturer and the unit was reassembled. The noise was unchanged and a maintenance person from Philadelphia Gear Corporation arrived on the JOI charter to aid in replacing the bearings. The gear box was repaired and speed tested after departure from the last site. The noise was no longer present.

APPENDIX I: SPECIAL TOOLS REPORT

TAM RETRIEVABLE FORMATION TESTER

The TAM retrievable formation tester was assembled in port and inflated with the setting go-devil. Inflation was normal without leaks, but when the go-devil pins sheared at 2200 psi the packer deflated. Inspection through the safety plug port revealed the inflation sleeve stuck in the inflate position. The go-devil was removed and the sleeve was removed by expanding the jaws of an internal slide hammer behind the sleeve and pulling 2000 lbs. with an air tugger. Both the sleeve and internal bore of the packer sub were miked and found to be per print. The test was repeated twice for verification. The sleeve slides free in the sub with the seals and spring removed.

The failure of the inflation sleeve to return was attributed to seal drag and 0.010" was removed from the sleeve to produce an OD diameter of 6.103". Because of the increased clearance the polypack seals were installed with all lips facing the fill port to aid in sealing the pressure spikes expected from a set packer element. The packer was re-assembled with the reduced-diameter sleeve and retested. The sleeve retracted after shear-out of the go-devil plug and the element held 2000 psi for six hours.

Packer Test at Hole 671C

The bottom-hole assembly consisted of a 10-1/2" by 3.8" APC bit, seal bore drill collar, landing saver sub, top sub, head sub, packer, 5 collars, McCullough jar, 3 drill collars and tapered BHA section. The drill string was run to the seafloor and a standard APC barrel was dropped. The APC did not seal when it landed and would not shear the pins. It is believed that the APC landed in the packer shifting sleeve and partially inflated the packer above the mud line. The 12-1/4" maximum inflation bypass slots on the packer mandrel probably saved the element from rupture. The landing sleeve on the XCB was turned down to 4.835" to pass through the 3-7/8" packer inflation sleeve and the barrel was dropped as a "wash barrel". The hole was drilled through the zone of interest with a great deal of sticking and torquing. The bit was pulled back to 466 meters BSF to find a firm packer seat.

The rig cementing pumps were connected to the drill string and a pressure recording instrument was attached to the stand pipe. Seven attempts were made to inflate the packer and hold 1500 psi inflate pressure at three different setting depths. The pumping rates varied from 0.5 to 1.5 barrels per minute. Stand pipe pressure would be obtained after one to two minutes pumping, but dropped as soon as the pumps were stopped. The go-devil plug was sheared out on the eighth attempt at 2200 psi, but no indication of packer set or hole drag could be seen at the rig floor. The drill string was pulled to logging depth and the logging tools were deployed through the packer.

The drill string was retrieved and the packer was removed from the drill string for inspection. Inspection revealed:

1. Ninety percent of the packer jacket rubber was missing and appeared to be ripped off by torsion. One rubber attachment ring had slid two thirds of the way up the basket weave.

2. The aircraft cable basket weave material was intact but several wires were ripped loose from their attaching points. The weave material was bunched up at the top of the packer tube. The braid indicated wear and chafing as if it had been exposed to rotation.

3. The internal bladder of the packer element was ripped and twisted in two places.

4. The spring housing was displaced about six inches up the mandrel and the stop pins were inside the spring housing.

5. The inner seal surface of the shifting sleeve was gouged and scarred.

6. The packer tube and control valve sub were galled in the area of the "O" ring groove.

7. Rig tong space below the packer sub is insufficient and the packer tube could not be disassembled from the bottom sub. The packer was disassembled from the top end.

8. The spring appears to be weak (250 lbs. to compress to solid height).

The packer was rebuilt and static pressure-tested at 1500 psi without a go-devil. No leakage was observed into the element. The inflate go-devil was inserted and the inflation started. The control sleeve shifted at 70 psi and the packer inflated to 400 psi where the fluid was observed passing out of the end of the packer tube. The inflation pressure was released, but the packer stayed inflated. Element pressure did not drop and the leak was judged to be in the go-devil.

An "O" ring gland was machined in the inside seal surface of the 3-7/8" wedge seal and the packer was re-tested. Packer inflation was normal up to 1100 psi with the modified seal, but the go-devil resumed leakage at that point. Several tests established that the stop ring on the go-devil mandrel was extruding through the packer inflate sleeve. A new inflation sleeve was turned down on the OD to 6.103" and installed in the control sub. A new go-devil stop ring with an OD of 3.937" was fabricated and installed on the go-devil. The packer cycled normally through all inflation tests.

<u>Packer Test at Hole 671D</u>

The drilling packer was assembled thirteen meters above the XCB bit of a nine-drill collar bottom-hole assembly. A 10-1/2" core bit and a bit release with flapper were used to drill the hole. Hole conditions were projected to be good and neither a mechanical jar nor a bumper sub was deemed necessary. The pipe was tripped to three meters above the PDR depth. A center bit was attached to the bottom of an XCB inner barrel and dropped. The landing shoulder on the XCB latch was turned down to 3.837" to pass through the 3-7/8" diameter packer inflation sleeve. The hole was drilled to 450 meters BSF. Drilling conditions were excellent with little fill or torque. At 450 meters BSF the decision was made to begin coring to find a packer seat above the decollement.

Initially the center bit was stuck and two wireline trips were required to free it. Drill pipe pump pressure was increased to 4000 psi in an attempt to wash away formation that might be sticking the inner barrel. The barrel was jarred free on the second wireline run.

A core barrel was dropped and the first core was cut. The XCB core barrel stuck and could not be retrieved. The decision was made to conduct a packer test with the inner barrel in place. The hole was deepened to 519 meters BSF to provide communication to the zone of interest. Sticking and torquing of the BHA began at 450 meters and reached the point at 519 meters BSF where the BHA would be endangered by further drilling. The packer element was pulled back to 439 meters BSF and the hole was circulated with seawater. The inflation go-devil was dropped with one Kuster pressure recorder because the XCB barrel was stuck and sufficient clearance did not exist between the go-devil and the top of the stuck XCB barrel for two Kuster units.

The first packer inflation cycle flow rate was normal up to 1500 psi. After pumping 2-1/2 barrels of fluid the pump gauge gave a sharp kick and the stand pipe pressure dropped back to 1300 psi. After that an increase in flow rate was necessary to maintain the pressure at 1600 psi. (That can be interpreted as the point where the system developed a leak.) The drill pipe pressure slowly dropped to zero when the pump was stopped, indicating that a leak existed in the system. The second cycle up to 1600 psi required 3-1/2 barrels of fluid to achieve 1600 psi, which dropped to zero in two minutes. The packer was moved to a new location up the hole and the inflate cycle was repeated with the same results. On the fourth cycle the standpipe pressure was taken up to 2200 psi using 4-1/2 barrels of fluid where the shear pin failed and the drill pipe pressure was released. The pipe was moved up and down with no indication of drag and it was concluded that the packer had failed to set. The drill string was tripped out of the hole.

The packer was disassembled from the drill string and inspected for damage. The observations are:

1. The element cover was ripped in a circular pattern completely down one side. All the rubber was attached with with one long flap hanging.

2. All the wire braid of the element was intact and unbroken.

3. The area between the outer jacket an the element braid was free of mud.

4. The inner bladder was pierced with a two inch slit one foot down from the top.

5. Very little mud was inside the bladder.

6. The second polypak under the inflation sleeve was cut through the inner lip.

7. The inflation sleeve holes were packed with mud.

8. Chalky mud was dried between the polypak seals and in the inflate port annulus.

9. Mud and grit were packed into the area under the inflate sleeve spring where the inflate sleeve shifts at inflation.

Failure Analysis

The drilling record for Hole 671D indicates little or no hole trouble until the center bit was removed at 450 meters BSF. After retrieving the stuck center bit and dropping a core barrel, the drilling recorder indicates that hole conditions deteriorated to a point that drilling had to be terminated within eighty meters. There is some reason to believe that the drilling torque is related to partial packer inflation caused by running the drill pipe pressure up to 4000 psi in an attempt to clear a stuck center bit. One reason to suspect a leak was the necessity to machine down the OD of the inflate sleeve to stop the sleeve from jamming in the control sub at inflation. The increased clearances may have allowed the polypaks to leak under the 4000 psi drill pipe pressure.

The other suspect point of failure is at the first inflation cycle. The packer element does not indicate the damage one would expect from drilling eighty meters with a torn element.

1. All the rubber of the ripped jacket is still attached to the element body. One would expect the failed jacket material to be lost in the hole if it had ripped while drilling.

2. A complete lack of broken or abraded wires points to jacket failure at inflation. Drilling with the braid exposed on the first packer test caused extensive ripping and tearing of the wires.

3. On the first test, only 2-1/2 barrels of fluid were required to bring the packer up to 1500 psi. At that point the gauge dropped to 1300 psi and an increased flow rate was necessary to reach 1600 psi. That fill pattern indicates a rupture of the element jacket or inner bladder at that point.

Proposed Modifications

The following suggestions are put forth for consideration to improve future packer operations:

1. Go-Devil Seals: The go-devil seal exhibited leaks on two different occasions. The first time occurred in deck test when a water leak occurred under the Lynes seal at 400 psi. That problem was arrested by machining a radial "O" ring gland in the ID of the Lynes seal. The second leak occurred when the stop ring on the go-devil extruded through the stop shoulder on the inflation sleeve. That problem was overcome by machining a larger diameter stop ring.

2. Go-Devil Stop Rings: In the future stop rings should be designed with not less than 1/16" diametrical interference. One stop ring lost 0.008" on one run in and out of the drill pipe. Eleven hundred psi was sufficient to force a stop ring through the inflate sleeve with 0.015 interference.

3. Packer Element: The second packer element exhibited a lumpy shape after the first inflation test and was still 9.3 inches in diameter after three days of standing in a shuck. Any increased diameter above the bit will cause an increase in annular velocity and increased hole erosion. The increased diameter also forms a place for cuttings to lodge and stick the pipe. A stronger spring can be used to pull the element back into shape after inflation. An element construction that returns to its original shape after inflation is desirable.

4. Control Valve Inflation Sleeve: The control valve inflation sleeve is exposed to damage and inadvertent shifting whenever a tool is run through the packer. Since most tools are pumped down with drill pipe pressure, there is a good chance of element inflation if tools hangup. A change of design to put the the control sleeve behind ports such as the hydraulic bit release or Lynes packer would be desirable.

   The other problem with the sleeve exposed to the annulus is sand packing in the shifting sleeve area which would cause the sleeve to lock in the up or down position. In Hole 671D drilling conditions were ideal with only soft clay, but the spring area was packed with chalk and grit. Had the packer been run directly above the bit the contamination problem would have been much worse. A third problem with an exposed landing shoulder design is damage to the seal surface from coring and logging tools as they pass through.

5. Polypack Seal Area: The polypack seal area repeatedly jammed on efforts to shift the sleeve. The field fix

of turning down the inflation sleeve until it operated freely may have caused the leakage that inflated the packer on the second run. Larger polypacks may help this problem and provide a bearing surface. A complete inspection of the control valve bore should be made when the equipment is returned to ODP.

6. Landing Shoulder Wear: The landing shoulder area in the inflation sleeve wore oversize 0.009" with one run in the hole. Hardfacing on this critical area should be considered for future work.

7. Tong Area: The eight inches of tong space provided for removing the bottom sub from the packer mandrel is insufficient for the rig tongs and must be lengthened to ten inches on future fabrications.

8. The maximum inflation bypass slots on the junk mandrel were removed by welding up the slots and machining round. That mandrel would have been used if the packer could have been deployed on a logging run. That capability is desirable for future use in larger bore holes that have already been drilled.

Design Modifications For Future Work

Future work for a drilling packer in the sediment sections of the accretionary margins will require a tool capable of working with the XCB and hopefully with the APC. The principal requirement is to measure in-situ pore pressure to better understand fluid transport through the sediments. Those are low pressure tests with almost zero gradient across the elements. The present packer was designed to operate with a 9-7/8" core bit and a rotary core barrel. The sediments at the Barbados active margin site do not lend themselves to coring with small bits. Sufficient annulus is required between the drill collars and the hole to generate an annular velocity sufficient for good hole cleaning without eroding the hole. The bigger hole sizes will require packer elements that can span larger clearances than the present 12-1/4" limitations on our element design. In work in the sediment column of the active margin, large pressure differentials are not required. The fracture pressure for the Barbados work was 600 psi and the investigators wanted to stay below that number to keep from damaging the hole. Modifications necessary to work in that type of pressure regime are:

1. Variable over expansion slots in the mandrel so that the elements can work in different size bore holes.

2. Inflation sleeves that are protected from core and logging tools that will be run through the packer tube.

3. The use of logging tools before setting the packer to pick the best packer seat. This requirement assumes the use of lockable flappers and probability of side entry subs.

4. The ability to control the packer experiment from the rig floor would be very helpful. The inability to see the drill pipe and the weight indicator while pumping from the Halliburton room is a real problem. Rig floor controls for the Halliburton pumps, such as those installed on the SEDCO 472, would be a real help.

In summary, the major accomplishments of the packer work on Leg 110 were a better understanding of downhole requirements for testing soft sediments and an indication that packer elements can successfully drill soft sediments. Many of the expected problems with drill string heave and downhole chafing of the elements did not materialize. The element demonstrated its ability to drill through 450 meters of soft sediment without wearing through or failing. Future field work will require a better inflation valve section and better understanding between science and engineering on the work to be accomplished and the equipment furnished for that particular leg.

TABLE AND FIGURE CAPTIONS

OCEAN DRILLING PROGRAM
SITE SUMMARY
LEG 110

HOLE	LATITUDE	LONGITUDE	DEPTH METERS	NUMBER OF CORES	METERS CORED	METERS RECOVERED	PERCENT RECOVERED	METERS DRILLED	TOTAL PENET.	TIME ON HOLE	TIME ON SITE
671A	15° 31.55N	58° 43.95W	4941	1	5.0	5	100		5.0	34.00	
671B	15° 31.55N	58° 43.95W	4942	74	691.0	553.1	80		691.0	296.75	
671C	15° 31.55N	58° 43.95W	4947	2	19.0	16.6		495.7	514.0	104.25	435.0
672A	15° 32.40N	58° 38.46W	4983	53	493.8	381.0	77	--	493.8	171.25	171.3
673A	15° 31.90N	58° 48.60W	4677.9	4	36.4	33.3	91.4		36.4	30.00	
673B	15° 31.92N	58° 48.49W	4689.2	35	330.0	247.5	74		330.0	108.50	138.5
674A	15° 32.29N	58° 51.09W	4650.3	48	452.6	354.5	78.3		452.6	138.50	138.5
675A	15° 31.77N	58° 43.01W	5018.6	8	66.5	44.7	67	321.	388.2	81.00	81.0
671D	15° 31.48N	58° 43.882W	4953	0				510	510.0	79.25	79.3
676A	15° 31.85N	58° 42.2W	5070	33	310.2	262.1	84.5		310.2	109.25	109.2
TOTALS			4887	258	2404.5	1897.8	78.9	1326.7	3731.2	1152.75	1152.8

TABLE 1.

TABLE 2.

OCEAN DRILLING PROGRAM
TIME AND RECOVERY SUMMARY
LEG 110

DURATION (JUNE 19, 1986 - AUGUST 16, 1986)	57.3
TOTAL DAYS IN PORT	6.6
TOTAL DAYS UNDERWAY INCLUDING SITE SURVEY	2.6
TOTAL DAYS ON SITE	48.1
TRIP TIME	9.1
CORING TIME	24.7
DRILLING TIME	5.8
DOWNHOLE MEASUREMENT	4.3
RE-ENTRY	0.9
OTHER	3.3
TOTAL DISTANCE TRAVELED (NAUTICAL MILES)	401
AVERAGE SPEED (KNOTS)	5.6
NUMBER OF SITES	6
NUMBER OF HOLES DRILLED	10
NUMBER OF CORES ATTEMPTED	258
TOTAL METERS CORED	2404.5
TOTAL METERS RECOVERED	1897.8
PERCENT RECOVERY	78.9%
TOTAL METERS DRILLED	1326.7
TOTAL METERS OF PENETRATION	3731.2
PERCENT OF PENETRATION CORED	64.5
MAXIMUM PENETRATION (METERS)	691.0
MINIMUM PENETRATION (METERS)	36.0
MAXIMUM WATER DEPTH (METERS)	5018.0
MINIMUM WATER DEPTH (METERS)	4650.0

TABLE 3.

OCEAN DRILLING PROGRAM
BEACON SUMMARY
LEG 110

SITE	S/N	MODEL	FREQ.	DAYS	WATER DEPTH	REMARKS
671	288	351	15.5	42	4941	Dropped 6/27, good signal
672	289	351	15.5	7.1	4983	Dropped 7/15, good signal
673	292	352	16.5	?	4689	Dropped 7/22, tether parted
673	298	352	14.5	5.7	4689	Dropped 7/22, good signal
674	294	352	15.5	5.7	4650	Dropped 7/28, good signal
675	296	352	16.5	3.3	5018	Dropped 8/3, good signal
671D	297	352	14.5	3.3	4953	Dropped 8/6, good signal
676	295	352	15.5	4.5	5070	Dropped 8/10, good signal

OCEAN DRILLING PROGRAM
BIT SUMMARY
LEG 110

HOLE	MFG	SIZE	TYPE	SERIAL NUMBER	METERS CORED	METERS DRILLED	TOTAL PENET	CUMULATIVE METERS	HOURS THIS HOLE	TOTAL HOURS	CONDITION	REMARKS
671A	MSDS	11-7/16	C-4	511	5	47	47					Jet in test.
671B	MSDS	11-7/16	C-4	511	691.2	—	691.2		34.5	65.75	T2,B2 1/16	
671C	RBI	10-1/2	C-36	AV717	19.	495	514	514	25.7	25.7	New	Packer hole.
672A	RBI	11-7/16	C-3	AV645	493.8	--	493.8	493.8	8.7	8.7	New	
673A	RBI	11-7/16	C-3	AV645	36.	--	36	529	--	8.7	--	Lost in hole.
673B	RBI	11-7/16	C-3	AV673	330.6	--	330.6	330.6	10.7	10.7	New	
674A	RBI	11-7/16	C-3	AV673	452.6		452.6	783.2	11.7	22.5	B2, T1 G	
675A	RBI	10-1/2	C-36	AV717	66.7	321	387.7	901.7	13.3	39	B2, T1 G	5 Cone.
671D	RBI	10-1/2	C-36	AV717		510	510	1411.7	13.	52	B2, T1 G	Packer hole.
676A	RBI	11-7/16	C-3	AV673	310.2		310.2	1093.4	4.5	27		Released in hole.

TABLE 4.

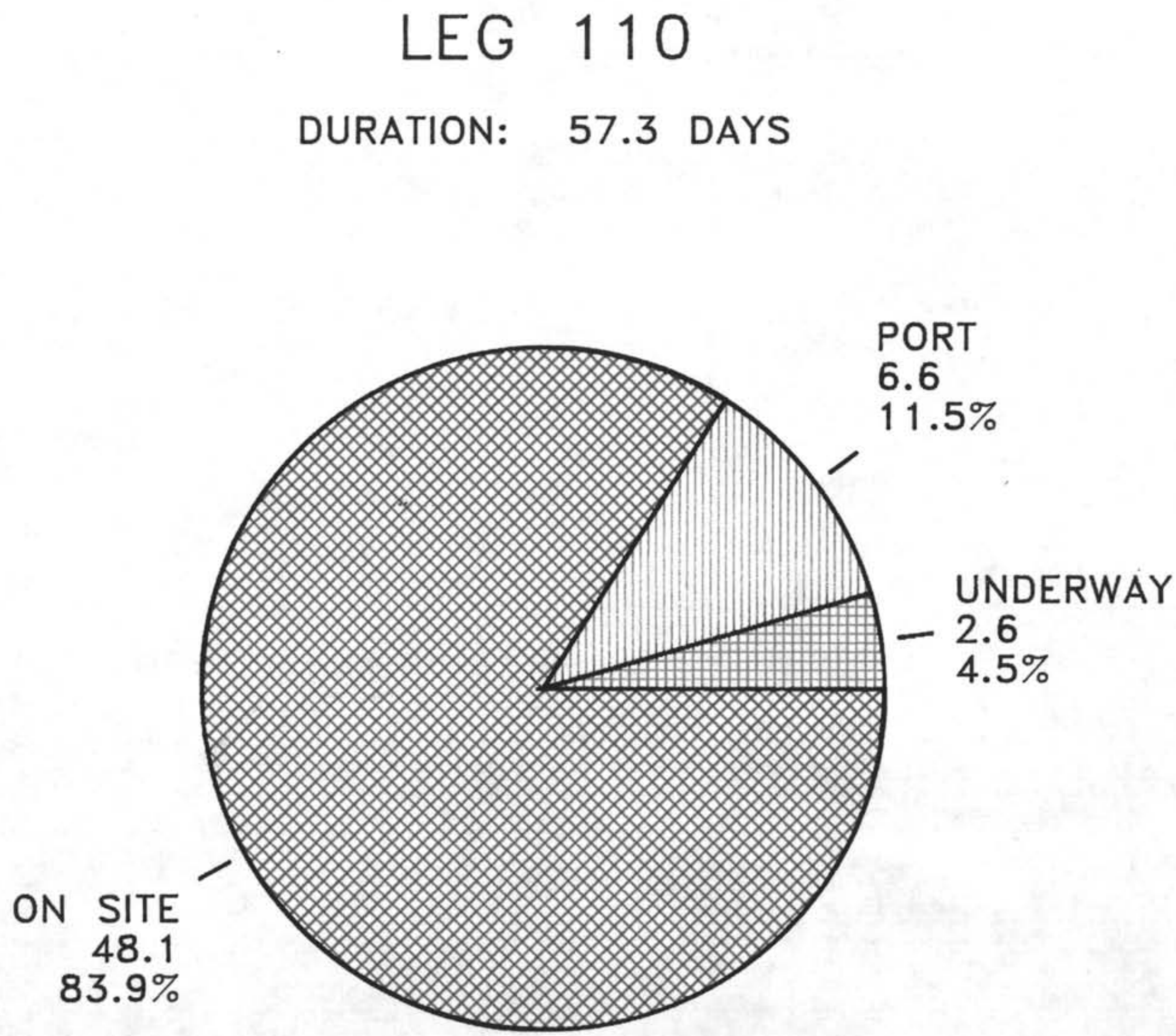

LEG 110
DURATION: 57.3 DAYS
PORT
6.6
11.5%
UNDERWAY
2.6
4.5%
ON SITE
48.1
83.9%

Figure 1.

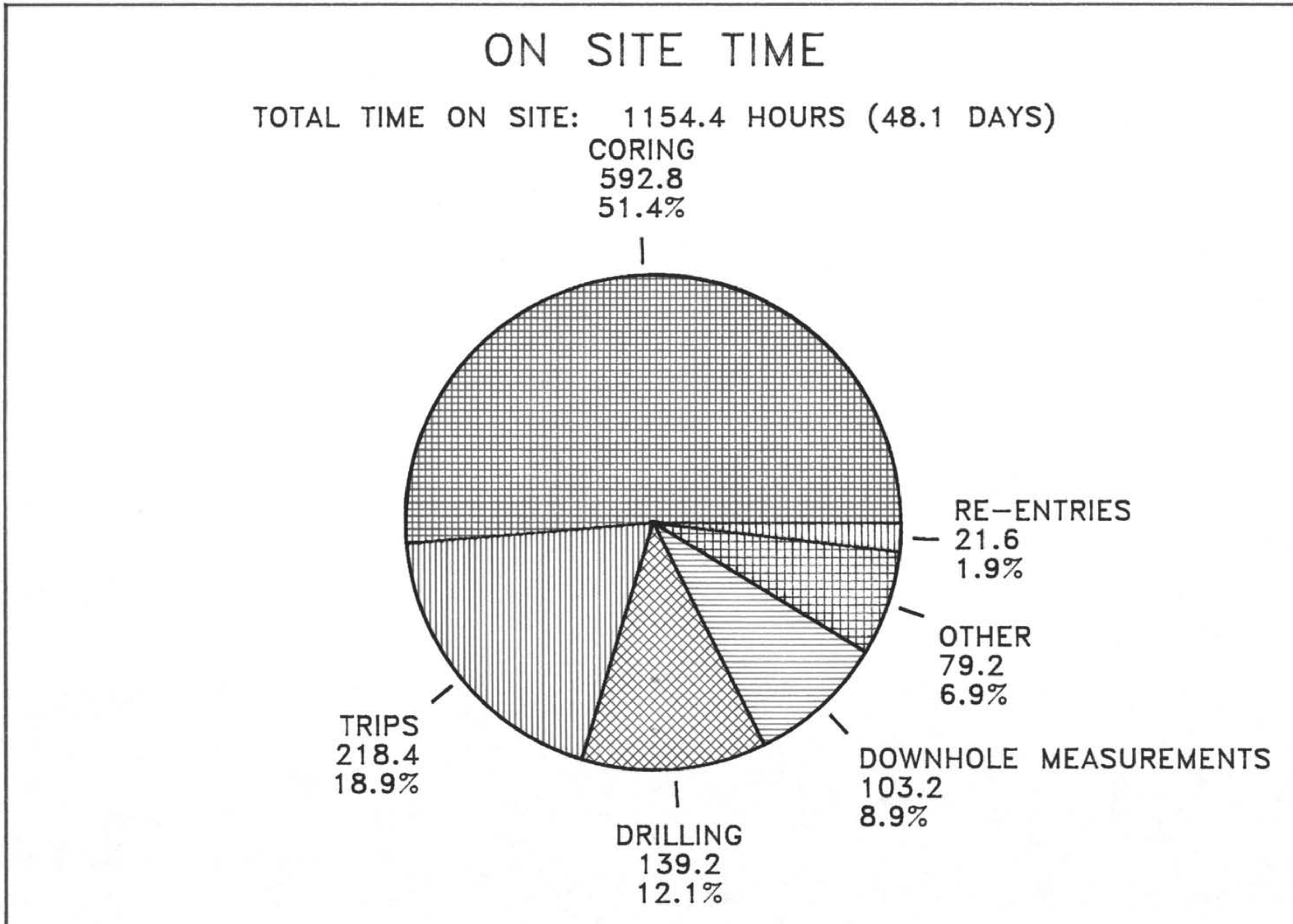

ON SITE TIME
TOTAL TIME ON SITE: 1154.4 HOURS (48.1 DAYS)
CORING
592.8
51.4%
RE-ENTRIES
21.6
1.9%
OTHER
79.2
6.9%
DOWNHOLE MEASUREMENTS
103.2
8.9%
DRILLING
139.2
12.1%
TRIPS
218.4
18.9%

Figure 2.

TECHNICAL REPORT

The ODP Technical and Logistics personnel aboard JOIDES Resolution for Leg 110 of the Ocean Drilling Program were:

Laboratory Officer:	Burney Hamlin
Computer System Manager:	Daniel Bontempo
Curatorial Representative:	Steve Prinz
Senior Marine Technician:	Brad Julson
Yeoperson:	Michiko Hitchcox
Photographer:	Roy Davis/John Beck
Electronics Technician:	Daniel Larson
Electronics Technician:	Mike Reitmeyer
Chemistry Technician:	Matt Mefferd
Chemistry Technician:	Katie Sigler
X-Ray Technician:	Mark Dobday
Marine Technician:	Jenny Glasser
Marine Technician:	Joe Powers
Marine Technician:	Kevin Rogers
Marine Technician:	Christian Segade
Marine Technician:	Don Sims
Marine Technician:	John Tauxe
Marine Technician:	Jeri Wackler
Weather Observer:	Farrell Johnson

INTRODUCTION

The technical staff for Leg 110 arrived in Bridgetown, Barbados 19 June 1986 to meet the JOIDES Resolution. Most flew direct from College Station though some arrived in port early to enjoy a few days of holiday. The ship arrived the evening of the 19th and was dockside for prompt clearing of the vessel by quarantine and customs officials.

PORT CALL

One refrigerated container was spotted adjacent to a ship crane so cores could be immediately off loaded after port formalities. The anticipated second core container, needed to accommodate the complete shipment, was not available until Monday, 23 June 1986. Service representatives from 2G for the cryogenic magnetometer and Alden for the weather system began work immediately. Technician crossover continued Saturday as did the loading of a container of D-tubes and general supplies. The staff worked late into the evening to accomplish this assignment while crane service was available. The shipment was opened and the contents dispersed the following day. Xerox made a service call Monday, 23 June 1986.

The pacing service for the port call was a pipe inspection conducted by Baker Tubular Service. Preparation for this inspection entailed breaking down all of the ship's 90-foot stands of drillpipe and offloading a large amount of the pipe. Baker's equipment failed, delaying the inspection and prolonging the port call until Thursday, 26 June 1986.

A diver was obtained to inspect the ship's forward 12-kHz transducer mount to see what condition the cover plate studs were in. The inspection was necessary for possible future transducer exchanges. Diving technicians assisted the engineers by attaching tethered cables to the ship's rudders for tests of the steering hydraulics; future refurbishing is planned.

The Baker inspection tools were packaged Thursday morning, the shipping papers were prepared, and the tools joined shipments by Lamont, Schlumberger, and 2G leaving the ship.

The JOIDES Resolution departed Barbados at noon Thursday, 26 June, 1986.

LABORATORY OPERATIONS

Underway Geophysics

Shortly after leaving port a magnetometer sensor was deployed giving measurements to augment the navigation data. A two-hour seismic survey with two S-80 water guns and the port Teledyne streamer was conducted as we approached the first site area. The records were obtained to complement and tie together the multi-channel records available.

The 400-cubic inch SSI water gun was deployed for a couple hours prior to

Site 673 and recorded basement below the selected site. The port eel failed during this survey and was quickly replaced by the starboard array. The eel problem was due to corrosion deposits in a streamer connector.

The last two sites selected for the leg were in close proximity and were located solely through beacon offsets. The 12-kHz and 3.5-kHz depth recorders were used to select these and other sites when the seismic gear was not deployed.

Core Lab

The pace of activities in the lab was moderate as the sediment firmed rapidly at each site and XCB coring began. This drilling mode limits several physical property measurements such as G.R.A.P.E., P-wave logger, and magnetic susceptibility as there is too much disturbance. The sediment, being just too firm to cut with a wire, was mostly cut with the diamond saw.

P-wave logger data is now transferable to the VAX for processing. G.R.A.P.E section data were collated into cores to allow conventional data presentation. In conjunction with the downhole temperature measurements, core thermal conductivity measurements were made, although the unit suffered a few broken thermistor probes. Erratic results initially obtained from the pycnometer were accepted as normal error for the machine on small samples of clay-sized minerals.

The cryogenic magnetometer, with leaks fixed at the port service call, continued cooling this leg with the rates monitored far longer than most installations allow. Liquid helium was not available to fill the unit after the repairs and the unit was not used this leg. The Minispin unit was used for the routine paleomagnetics measurements. Software development continued for the Minispin and susceptibility meter so data from the section measurements are now linked into cores, are assigned depths, and can be uploaded to the VAX.

In general all the lab equipment used worked well. Almost 1900 meters of cored sediment were recovered, processed and an estimated 7600 samples taken.

Downhole Tools

The WHOI heat flow device for the APC shoe was deployed 20 times, a couple of times with the Barnes tool. Twelve of the runs were successful with the majority of the failures associated with worn electrical connectors. An attempt will be made to upgrade the connectors between the battery and the sensor and plans are to modify the software to give assurance that the unit has been programmed.

Dr. Ross Barnes of Rosario Geoscience Associates introduced us to his second generation pore water sampling tool. It can collect a larger sample, 1200 cc, than the previous tool and incorporates two pressure transducers and the heat flow thermistor tip made for Dr. Von Herzen of Woods Hole Oceanographic Institution. The electronics package was modified from a Deep Sea Drilling Project prototype and can transfer its files to PRO floppy disks and then to the VAX computer system for processing and plotting. Several tool modifications were made on the ship, drawings revised, and a handbook generated to aid future users.

The pressure and heat flow measurements were made at most sites as often as statistical requirements and sediment firmness allowed. This resulted in 19 successful runs and 6 failures, 3 of which were battery or electronics related. Most runs were made with the new tool which worked well, collecting 15 water samples although the volume of water recovered was often extremely small (less than 20 cc). Programming progress was also made in making the graphing of heatflow temperature curves less time consuming. The tools were serviced in the downhole instruments lab.

Chemistry Lab

Numerous squeeze and in-situ pore water samples were taken for lab analysis. Sulfate determinations were very successful on the ion chromatograph. Some time was also spent trying to optimize a potassium determination and promising results were achieved.

The CHN, Rock-Eval, and Total Carbon Analyzer all worked fine. A Natural Gas Analyzer was modified to improve its ability to detect and separate methane/ethane ratios quickly and, with the head space analyzer, was able to detect methane in the 1 to 10 ppm range.

The lab PC computers were upgraded with memory, firmware, and software. The ability to upload data from the HP1000 to the VAX via an HP150 terminal is now within reach. Files from the HP1000 direct to the VAX should soon be achieved using BLAST hardware when difficulties with cable lengths are worked out. Total communication between the various instruments and computers seems imminent.

XRD/XRF Lab

An X-ray diffraction training session was conducted in port to acquaint an off going tech with the use of some of the available software and with some routine maintenance. One Leg 110 tech was also trained to use the unit during the cruise. Quantitative analysis for several minerals and clays was done on one scientist's samples and all physical property samples.

The unit operated near its maximum capacity, making over 1500 scans of some 800 samples. Technicians kept the unit operating 20 to 22 hours each day.

The XRF unit was not used this leg other than to help identify a metal alloy.

Thin Section Lab

A few thin sections of recovered bits of mudstone and limestone were made but the majority of the 37 time consuming slides were made from vacuum impregnated clays exhibiting micro-structure and texture. The thick and thin polished slides were made from a selection of 60 impregnated samples. Equipment worked well and was maintained as necessary.

Computer System

Classes were conducted in port for the scientists unfamiliar with CT*OS word processing and PicSure. Tutorials on VMS MAIL were offered to the staff to facilitate message and requisitions and to keep a machine-readable, easily searchable copy of outgoing traffic from the LO office. There is much to be gained by continuing the computer education of the staff.

Data handling procedures and naming conventions were arrived at for the temperature and pressure data from the electronics package now used with the pore water tools.

Heat flow programs were improved. Andy Fisher (Univ. of Miami) is documenting the selection of programs he used and they will be set aside as a separate usable software package.

BLAST usage is increasing and with it the hope of transferring the message formatting and handling of the Systems Managers desk, especially for ordinary traffic, onto the SEDCO Radio Officer's desk.

Photo Lab

Few problems were encountered this leg as equipment performed well and print volume was moderate. Color chemistry sent to Barbados was heat damaged, requiring the color core photos to be carried to shore for processing. Routine PM on the processing equipment was done as needed.

Electronics Lab

One re-entry was done this leg and re-entry systems were inventoried as preparations took place to turn the re-entry operation over to SEDCO, who will have the responsibility in the future.

Various pieces of lab equipment, computers and components, downhole tools, and Xerox machines were repaired as necessary.

Storekeeping

Few problems were noted with shipments as most arrived in order. One pallet of paper missed the shipment but was included in the paper work and this caused some undue searching. Also, accounting for all pieces in the hazardous shipment was complicated when it was noted that our forwarder had repackaged some of it, altering the number of pieces accountable.

Inventory verification was done after Barbados and an updated MATMAN was transmitted to the beach at the request of the computer services group. This effort revealed that a number of transactions entered by the Leg 109 storekeeper last leg were unknowingly lost during a computer crash that occurred. This problem was corrected.

Weather

A weather observer joined the staff for Leg 110. This was for the ship's protection as the drilling area was located, this time of year, in the path of tropical storms and hurricanes. Routine weather observations and a few XBT's were made; several hundred satellite and facsimile maps were recorded. Fair weather and fresh tradewinds were typical with no tropical storms reported in the area.

Special Projects

Physical properties augmented their equipment by sending out a device known as a GDS (Geotechnical Digital Systems) consolidometer which measures permeability and compaction. A computer controls the measurements, which can take several days. It is set up in the second look lab and will be used routinely next leg.

The decision was made mid-cruise to re-configure the Scanning Electron Microscope room by rotating the unit 90^{o} and preparing the area to accept a long bench which will accommodate the petrology microscopes. This was started near the end of the cruise to keep the unit available as long as possible for one of the scientists. Welding priorities and the fact that only one welder was on the ship delayed the reconstruction of the area until late in the cruise.

Lessons were conducted to instruct all technicians in the use of the VAX mail utility. This allowed a communications link for TELEX routing and requisitions with the Lab Officer, and was useful in disseminating or requesting information from the group or individuals. The knowledge will also be useful ashore.

Safety

The elevator certification from the ABS inspection done in Pascagoula arrived in the Barbados mail. It was surprising to find that there was no mention of personnel usage as written in the original specifications. The elevator was restricted to freight for a week while that point was clarified; it is indeed certified for personnel. A new certificate for the elevator reflecting this may be made available in Panama.

The gas alarm in the chemistry lab was calibrated with standard calibration gases giving two ranges: a yellow light showing a low range of 20% Lower Explosive Limit (L.E.L.) and a red light and an alarm for 40% L.E.L. The unit can sense the acetone on a tissue dropped on the floor near the sensor. The unit in the acetone locker on the lower 'tween deck was also calibrated.

The METS team worked with the SEDCO fire team in the weekly drills, taking a more active role. A night drill in the accommodations worked far smoother than a similar drill a year ago, in that communications were clear, we knew where the various meeting points were located, and personnel were more familiar with breathing apparatuses.

Spot type fire detectors were wired under the mezzanine deck and over our cardboard stock.

The safety showers and eye wash stations were tested. The acetone locker was checked and rusty containers moved forward for immediate use.