Cruise Report: J Anomaly and SE Newfoundland Sediment Drifts

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Summary:

A long-standing paradim in paleoceanography is the suggestion that vigorous deep ocean circulation did not begin until the onset of high latitude glaciation, first with growth of the Antarctic icesheet in the Oligocene (~33 Ma) and later the start of northern hemisphere glaciation in the middle Pliocene (~2.5 Ma). Indeed, nearly all sediment drifts in the North Atlantic began to grow in the later Oligocene or Neogene, indicating currents strong enough to transport sediment and erode it from the continental margin. Knorr 179, Leg 1 conclusively disproved the notion that pre-glacial, greenhouse oceans were relatively stagnant, with the discovery of abundant evidence of large scale sediment drift formation and abyssal bedforms indicative of strong bottom flows under the influence of the deep western boundary current. We collected high quality seismic reflection profiles on the J Anomaly Ridge and SE Newfoundland Ridge that show the presence of as much as 1.5 kilometers of sediment deposited between the late Cretaceous and early to middle Neogene, with about half that amount probably of Cretaceous and early Paleogene (pre-glacial) age. Our data reveal that many bedforms indicative of strong directional flows along the base of the slope are of Cretaceous and early Paleogene age while the Plio-Pleistocene brought mostly erosion and deposition of thin drapes of sediment over much of the survey area.

Despite breaks in operations due to weather (Hurricane Alex) and mechanical failures, the cruise achieved nearly all its scientific objectives, collected almost the entire planned cruise track of seismic reflection profiles, and demonstrated the ability to successfully core pre-Neogene sediments through the Pleistocene cover. High quality Seabeam bathymetry data present compelling images of the sediment ridges, current-generated moats, and progradation of drift deposits in the survey area. Coring demonstrated that at least part of the drift sediment is composed of volcaniclastics, including bentonite mud, zeolites and glass shards. We speculate that the sediment is sourced from the Greenland margin and is derived from the early Paleogene eruptions of the North Atlantic Magmatic Province.

The high quality seismic reflection profiles, 3.5 kHz profiles and Seabeam.bathymetry together

represent a key data set needed to advance a proposed Integrated Ocean Drilling Program leg to the J Anomaly and SE Newfoundland Ridges. The Extreme Climates Program Planning Group initiated under ODP recommended this area as an important drilling target to study Paleogene climate and biotic evolution during intervals of warmer-than-modern conditions. The Knorr 179-1 cruise has collected an abundance of high quality geophysical data with crossing points chosen to maximize our ability to drill relatively shallow holes (~500 m) into a diverse array of targets including Cretaceous reefs, Cretaceous abyssal sediments, possibly including black shales, Upper Cretaceous and Paleogene carbonate oozes and ?Neogene drift sediments. The available seismic reflection data also permit the construction of an extensive depth transect between the tops of seamounts at ~2200 m water depth to true deep ocean records at more than 5500 m depth, all within an array of Cretaceous and Paleogene strata.

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INTRODUCTION

The survey area (~39°N-42°N and 46°W to 52°W) started on J Anomaly Ridge and extended to the central and northern parts of SE Newfoundland Ridge. Four types of data were collected: Seabeam bathymetry, 3.5 kHz echo sounding, 48 channel seismic reflection profiles and sediment sampling. Routine shipboard data collection included water temperature, air temperature, wind speed and florescence among other weather parameters. The shipboard barometer did not work for about 2 weeks of the cruise. Two shipboard marine mammal observers collected data on marine mammal and sea turtle occurrences during day light periods of seismic operations.

Operations began with Seabeam and 3.5 kHz profiling at ~41°00N, 52°40'W. After an approach up Titanic Canyon, seismic profiling began with a survey of J Anomaly Ridge including shooting of both dip and strike lines and a pause to conduct coring operations in the vicinity of DSDP Site 384 (40°21.65"N, 51°39.80"W, 3909 m water depth). Initially, a leased Mitchum streamer was deployed with four birds supplied by the leasing agent. The streamer proved to be only a 24 channel model and two of the coils for electronic control of the depth-keeping birds did not work. The distal end of the streamer could not be reliably depth-controlled nor could depth be monitored. Accordingly, the Mitchum streamer was recovered and the Lamont 48 channel ITI streamer put in its place and floated at 2 m depth. The Lamont ITI streamer has at least 6 dead channels including several near the proximal position in the streamer. However, even 44 functioning channels provides better stacking capability than a fully functioning 24 channel streamer. Initially two 75 ci airguns were deployed, one on each side of the fantail, and were floated at 4 m depth with a firing rate of 10 seconds. Two guns were kept in the water initially so that a failure by one would not interrupt seismic operations and require a 30 minute delay while marine mammal observations were made. However, this strategy was ultimately abandoned. Instead, we operated under the principle that the guns could be turned off for as much as 1 hour without requiring a pre-start-up period of observation provided that at least one marine mammal observer had been on watch during the down time.

Seismic gear was deployed with the ship moving at about 3 knots through the water. Once deployed and operational, ship speed was held steady at about 4.5-4.9 knots over ground, a value that sometimes deviated significantly from speed through the water owing to surface currents. Ship-angle to the trackline sometimes also deviated significantly from a straight-line course since strong currents required the ship and streamer to "crab" at as much as a 45° angle to the trackline.

J Anomaly Ridge Operations

Profiling was interrupted once to avoid marine mammals (due to an approach within the safety radius [54 m of the gun] by Atlantic Spotted Dolphins) and four interruptions (once for ~14 hours) from problems with the air compressor. Issues with the compressor included replacement of valves in each of the compression phases, replacement of an impeller (and cleaning out the broken impeller blades from several previous generations of impellers in the same pump), and rigging a cooling unit consisting of a freshwater misting device to keep the compressor from overheating. Leaks in valves allowed hot gases to escape into earlier parts of the compression cycle and led to excessive heating. Evidence suggests that the radiators were not working to full efficiency and will require overhaul before the next seismic program.

The seismic profiling program was interrupted twice for extended periods: (1) While the compressor was seriously overheating, it was shut down for ~14 hours and a Seabeam-only phase of data collection was started to fill in holes in the bathymetric survey between existing and planned track lines; (2) while a coring program was initiated on the NW slope of J Anomaly Ridge along KNR179-1, Line 5. The coring program consisted of recovery of 5 GGCs all of which contained Pleistocene foraminifer ooze and lasted about 18 hours. Other interruptions lasted ~30-50 minutes each and consisted of looping back onto the original ship's track, restarting the guns and data collection and spending time lining the ship up on its previous track before the seismic data collection began again. Other minor interruptions included making loops on the end of the survey lines. These took from 15 minutes to 1 hour to complete in most cases because the ship was pulled out of autotrack mode and had to be steered in strong currents associated with the

Gulf Stream. After several less-than-perfect detours at the end of seismic lines, it was decided to turn inside the waypoints (rather than looping past them) and this approach resulted in far less time spent in turns (average of 15 minutes). The turns also provided convenient points to reset shot numbers (which have a maximum count of 10,000) on the seismic acquisition computer. We discovered that the computer needed to have the shot numbers reset after about every 20 hours of continuous data collection.

Operations near the "Titanic Site" on SE Newfoundland Ridge

Following coring on J Anomaly Ridge, a series of strike lines were shot across J Anomaly Ridge and then extended NE along the crest of the ridge to a series of seamounts on the spine of SE Newfoundland Ridge, near the Titanic site. A grid of tracklines was laid out and interrupted twice for coring and twice for dredging. One bowtie was shot to provide a crossing line off the regular track grid and two lines were extended to the NW to profile the edge of a sedimented ridge and the vicinity of the Titanic wreck. Aside from sediment sampling, operations were interrupted four times, once for marine mammals (another close approach by Atlantic Spotted dolphins) and three times for problems related to the compressor. These delays amounted to 1.5 to 3.5 hours of ship operations in each case. Deviations off the trackline were made to visit a coring site crossed early in the survey and this amounted to about two hours transit each way (including time to recover and redeploy the seismic gear).

Operations on Central SE Newfoundland Ridge

Eleven days of seismic survey were planned for Central SE Newfoundland ridge and seven of these were conducted without significant unanticipated interruptions. A coring program was initiated at the end of day 4 and was terminated due to weather and delays when the ship was prematurely moved off the coring site owing to miscommunication between the Chief Scientist and the bridge crew. The approach of Hurricane Alex created sea states increasingly unfavorable for coring, so we resumed seismic profiling for about 10 hours until sea state and US Navy weather forecasts indicated the need to leave the survey area at transit speeds. The ship was directed S-SW between planned and existing survey tracklines to provide Seabeam bathymetry until the survey area was cleared, whereupon course was set due south along a track line of ~48°40"W to a latitude of about 36°N. Plans were made to conduct a Seabeam survey of part of the Corner Seamount chain at ~35°N, but when weather reports indicated the early passage of Hurricane Alex, we returned to the survey area on a parallel trackline at ~49°50"W. In all, about two days were lost from normal survey operations owing to Hurricane Alex.

Upon return to the survey area, a reduced program of seismic data collection and coring was planned. Ten tracklines were run using the seismic system without problems. A tachometer on one of the aft thrusters failed during the third of these lines (line 48) and plans were made to change out the tachometer coupling during a stop to conduct coring operations. Repair of the thruster was done without issue in about 10 minutes as the ship was brought to the first coring station. Coring went well with a successful gravity core (GGC-14) and an apparently successful JPC. However, a catastrophic failure of the electronic control of the trawl winch occurred shortly after JPC pullout. Attempts to fix the problem or bypass damaged systems failed after more than 31 hours of effort and the core, coring equipment, and ~4400 m of wire were cut free on the evening of August 10, 2004. Seismic operations then resumed until the allotted time for science operations were reached on August 13 at 11:30 am. During that period operations were suspended once again because of a close approach to the airgun by dolphins.

SHIP AND SEISMIC OPERATIONS

Data quality was generally excellent and ship's staff worked and communicated efficiently with the science party. The science party was kept abreast of weather, course changes, and mechanical difficulties in an expeditious and professional manner. We found the ship's crew to be of uniformly high caliber and have been impressed by their ability to not only maintain full functioning of the ship under sometimes trying conditions, but also to maintain good humor and communication with the science party. We also extend our gratitude to the galley staff for a succession of excellent meals, friendly and personal manner, and their skill in somehow never repeating a recipe for dinner. Likewise we found the SSSG's always helpful, knowledgeable and pleasant to work with both on and off duty. We also appreciate the willingness of the SSSGs to provide advice and expertise in assistance with non-ship's equipment such as the core logger, plotters, and personal computers. We greatly appreciate the willingness of every member of the ship's staff to welcome the science party into their home.

About 5 days of science time were lost to various causes, the major issues being (1) Hurricane Alex, (2) the failure of the trawl winch, and (3) repeated, mostly minor, shutdowns of the air compressor. Marine mammal avoidance constituted a minor cause of lost operational time (~2 hours, 20 minutes) and was entirely due to close approaches by dolphins on three separate occasions. Compressor problems were fixed promptly once problems were diagnosed. Most compressor problems appeared early in the cruise, and by the second week, nearly all the major compressor issues had been solved. Thereafter, the compressor was shut down only for operational reasons (coring, weather delays, marine mammals) or for routine maintenance (oil changes and changes in line numbers on the seismic acquisition computer). The non-functioning channels on the ITI Streamer did not seem to pose major problems for data quality. Indeed, the seismic operations went remarkably smoothly, particularly in the second half of the cruise and the Lamont staff did an excellent job keeping the High Resolution Seismic System functioning effectively.

Minor issues that resulted in delays or missed data included:

(1) Early problems completing loops at the end of seismic lines in an expeditious fashion. Irregular turns were caused mainly by strong currents and the need to take the ship out of autotrack mode during turns; this problem was solved by either turning inside waypoints or, where the angles between lines were unusually tight, establishing waypoints past the cross-over point on lines (making bowties). Both suggested changes in handling turns were made by the Bridge staff and were instituted for the remainder of the cruise.

(2) Possible interference between seismic operations and the use of an arc welder on the ship during the shooting on Line 43 on August 4, 2004. We suspect some aspect of ship's operation such as a welder or out-of-phase motor produced millisecond pulses that created mostly episodic bursts in returns to the streamer. The problem was not isolated to any single cause, although Erich Scholtz noted the use of an arc welder during daytime ship operations and speculated about a linkage with seismic noise. Welders produce a millisecond pulse to start the arc and have sufficient power to be detected in the frequency range of the streamer. The problem has not occurred at any other time during the cruise.

(3) Minor miscommunication between the Chief Scientist and Bridge crew about the exact placement of waypoints. This problem resulted from attempts by the Chief scientist to pick waypoints off the rough bathymetric maps available before the cruise, errors by the Chief Scientist in typing waypoints into waypoint files, and lack of follow-up with the bridge crew once the waypoints were entered into the autotrack system. A result of these problems was one missed waypoint and an offset between parts of the same seismic line at the completion of a bowtie turn. Both problems were rectified by having the Chief Scientist check all future tracklines on the bridge computer after new waypoints had been entered. It was also useful, but not absolutely necessary, for the Chief Scientist to be present when waypoints were entered into the Bridge computer so that any corrections

could be made immediately. We did not find it adequate to merely phone the Bridge with waypoint corrections since this often lead to confusion. It is suggested that the bridge crew retain a complete file of all waypoints used during a cruise so that the positions of future track lines can be compared against existing tracklines. Archiving waypoints would have been useful since the process of discovery required regular changes in the operational plan which, in turn, required the regular comparison of old track data with proposed new track lines.

(4) Miscommunication between the Chief Scientist and bridge crew about the sequence of site changes during coring operations. This issue resulted in the ship being moved off a coring station between the deployment of a GGC and follow-up JPC and resulted in about 2 hours transit time between sites. This issue was solved by improving communication of expected future changes in ship location between the Coring staff and Bridge crew.

(5) Failure of the Lamont Line Scan Plotter recording data from the streamer. This plotter replaced a WHOI plotter (which itself had failed before the start of our cruise), but never produced clear near trace profiles and eventually broke down altogether. The lack of realtime plots of the seismic data required that we had to wait until data tapes were loaded onto the ship's computer system and processed (a delay of at least several hours, and an extra long shift for S. Swift) before being able to view seismic data and make decisions on coring targets, line crossings, and other operational details. As a result, we had to make longer-than-necessary transits to coring sites and risk choosing non-optimal coring sites in a bid to minimize transit times. Line scanners are an important part of ship operations and should be provided in functioning status for seismic cruises.

INTERRUPTIONS IN SEISMIC OPERATIONS AND THEIR CAUSES

(Total down times including time to return to last shotpoint)

1. 20 July, 21:55:35 GMT, to 23:25:59 GMT	1 hr 30 min (90 min)	Compressor work
2. 21 July, 01:37:29 GMT to 02:22:05 GMT,	45 min	end of line
3. 21 July, 10:16:06 GMT to 11:04:58 GMT	49 minutes	Marine mammals
4. 22 July, 02:57:55 GMT to 04:47:57 GMT,	1 hr, 50 min (110 min)	Compressor failure
5. 22 July, 12:30:10 GMT to 14:40:18 GMT,	2 hr, 10 min (130 min)	Compressor hose blown

6. 22 July, 16:50:33 GMT to 23 July, 19:13:40 GMT 14 hr, 3 min (843 min) Compressor down

7. 26 July, 11:11:04 GMT to 27 July, 00:33:40 GMT 13 hr, 22 min (802 min) Coring Operations

8. 27 July, 01:55:35 GMT to 05:35:02 GMT 3 hr; 30 min (210 min) Compressor overheating

9. 27 July, 15:01:11 GMT to 16:46:22 GMT 1 hr, 45 min (165 min) Compressor repairs

10. 28 July, 15:16:24 GMT to 15:48:15 GMT 32 min Compressor work

11. 30 July, 12:59:05 GMT to 31 July, 06:07:58 GMT 17 hr, 6 min (1026 min) Core and Dredge operations

12. 31 July, 7:37:09 GMT to 9:19:39 GMT 1 hr, 42 min (102 min) Air leak

13. 1 Aug., 01:53:49 GMT to 02:13:47 GMT 20 min Marine mammal shutdown

14. 2 Aug, 23:21:24 GMT to 3 Aug, 00:49:44 GMT 1 hr 28 min (88 min) Controller breakdown

15. 3 Aug, 11:47:56 GMT to 12:33:59 GMT 46 min Marine mammals

16 4 Aug, 13:15:00 GMT to 13:49:37 GMT 34 min Guns off

17. 4 Aug, 15:19:24 GMT to 5 Aug 3:14:23 GMT 12 hrs, 5 min (725 min) Coring (guns resumed 01:21:02 GMT)—time to back on line after coring: 2 hrs, 7 min (127 min)

18. 5 Aug, 11:07:00 GMT to 7 Aug, 12:56:54 GMT 48 hrs, 59 min (2939 min)Fan belt broke on compressor; end line due to Hurricane Alex (resumed firing on Line 46, Aug 7)

19. 7 Aug, 16:13:19 GMT to 16:30:00 GMT 17 min File numbers repeating

20. 9 Aug, 11:15:47 GMT to 11 Aug, 00:53:11 GMT 37 hr, 38 min (2258 min)Coring break; Trawl Winch down

21. 12 Aug, 8:43:17 GMT to 9:29:28 GMT 46 min Marine mammals

Totals:

Compressor issues: 30 hours, 35 min

Trawl Winch: 37 hr, 38 min total, (31 hr, 25 min spent effecting repairs; remainder in coring operations that ultimately proved useless owing to inability to recover the JPC)
Weather: 48 hr, 59 min
Marine mammals: 2hr, 23 min
Coring/dredging operations: 79 hr, 2 min (including time to resume shooting but not including mechanical problems)
Inside Turns averaged: 15-20 min each

Total non-operational time: 118 hrs and 48 min (4 days, 22 hrs, 24 min)

RESULTS OF THE CORING PROGRAM

Operations:

The coring program was intended to sample outcrops of sediment representing the major acoustic packages of sediment in the area and was partly successful. Sampling methods included the use of (1) Giant Gravity Cores (GGC) composed of 12-15 ft lengths of white Schedule 40, 4" PVC pipe rigged with a cutter head and core catcher, and a finned, 700 pound lead weight; (2) Jumbo Piston cores built from sections of threaded white Schedule 40, 4" PVC pipe in a metal tube and driven by a 5000 pound core head (with attached trigger arm and weight); and (3) a steel dredge with chain basket [the dredge has an aperture 95 X45 cm with a chain bag composed of 6 cm diameter links. A canvas bag was sewn into the lower half of the chain bag with cable ties to catch small objects and was held in place with a 2.5 inch diameter steel pipe roped in place along the length of the chain bag].

To avoid completely wearing out our small coring staff (two expert members, the bo'sun, winch crew and frequent assistance from two science party members and one SSSG), we limited coring to 12-15 hour blocks separated by seismic operations. During an average block of time for coring we could deploy and recover about four or five GGCs or one or two GGCs and one piston core. Dredge hauls were made twice and each lasted about five to six hours. Given the time required to take in and redeploy seismic gear (~1.5 hours) and get on site and back on our seismic track lines (as much as 2 hours) we tried to space coring operations throughout the cruise between two to three day intervals of seismic data collection.

We recovered two dredge hauls, two Jumbo Piston Cores (JPC's), and 11 Giant Gravity Cores (GGCs). A 12th GGC hit at too high an angle (probably because of strong currents judging from the wire angle) and slid off without recovery. We also got a positive hit on a third JPC, and wire tension indicating a barrel full of sediment, but this core was lost shortly after pullout when the electronic controller for the trawl winch burned out. The profiler record suggested that the lost JPC should have easily penetrated to the target depth and given us a sample of the drift sediment. Gravity cores were rigged for a mixture of 12 ft (3.7 m) and 15 ft (4.6 m) lengths and JPCs for 50 foot (15.3 m) lengths.

Early on in the cruise, we tried to do all our sampling with gravity cores to save time since we could deploy and recover two to three GGCs in the time it would take to rig, deploy, recover, and re-rig one JPC. However, after the 9th GGC full of Pleistocene mud, that strategy was abandoned since it was obvious that we were not able to penetrate the foraminifer sands with gravity cores. Indeed, none of our gravity cores ever recovered anything other than Pleistocene sediments. However the JPCs recovered older sediments which proved to be soft, unconsolidated mud in both cases. Both JPCs also showed that the Pleistocene cover is about four to five meter thick even where the 3.5 kHz profiles showed no overlying sediment cover, so our three to four meter-long GGCs were just too short penetrate the surface sediment and collect a sample of the underlying mud. Our approach in later cases was to use the gravity cores to determine the stiffness of the bottom sediment. Cores with full recovery and moderate pullout tensions (under 2500 pounds) indicated the presence of bottom sediments suitable for piston coring. Bent gravity core barrels with high pullout tensions were used as indications not to deploy piston cores.

Dredging was conducted by lowering the dredge at ~10 m/minute to a depth of ~250 m. At that point an active pinger was placed on the trawl wire at 250 m above the dredge so that once the pinger reached a height of 200 m above bottom we could be assured that the dredge had touched down. The ship was held in dynamic positioning mode over the deep end of the dredge transect. Wire was spooled out at ~45 m/minute until the pinger was about 300 m above the bottom at which point wire out-rates were reduced to about 10 m/minute. Once the dredge was down, wire was spooled out at about 5-7 m/minute and the ship was moved slowly (~0.25 to 0.5 knots/hour) toward the uphill part of the dredge transect. In retrospect, this ship speed could have been somewhat higher since we never seemed to pull the dredge off the bottom during these transits. When the ship was positioned near the end of the transect, wire was brought in at ~7-10 m/minute while recording 'hits' of increased tension followed by decreased tension. Tension naturally varied by several hundred pounds during both dredge runs, while "hits" generally involved increases of tension of more than 1000 pounds. In the first dredge run, the dredge got hung up and the ship had to be backed toward the beginning of the dredge transect while spooling out wire. This strategy freed the dredge and still resulted in recovered samples. Both dredge hauls evidently picked up considerable sediment that, judging by the falloff in tension, was probably winnowed out of the bag within a few hundred meters of the sea floor during recovery. Recovery rates were about 65 m/minute for the first run and 45 m/minute for the second. The difference in dredge recovery rate did not seem to make a difference in volume of recovered sediment. However the presence of the pipe in the bottom of the dredge bag did help to retain a sample of some sandy bottom sediment.

CORE LENGTHS, LITHOLOGIES, AND CONTRA-INDICATIONS FOR PISTON CORING ARE AS FOLLOWS:
GGC-1; 2.8 m, foram ooze, 2523 pounds tension on pullout, bent pipe (moderate recovery and bent pipe indicate target unsuitable for piston coring).
GGC-2; 3.6 m, foram ooze; 2372 pounds tension on pullout, (nearly full barrel and modest pullout tension--we could have piston-cored this site in retrospect).
GGC-3: 3.8 m, foram ooze; 2535 pounds tension on pullout (also full barrel; in retrospect this was suitable for piston coring but we played it safe early in the cruise).
GGC-4: 3.7 m, foram ooze, 2607 pounds tension on pullout; over penetrated; at the time the tension was deemed too high for piston coring but we could have piston cored this site in retrospect.
GGC-5: 1.8 m; foram ooze, 2486 pounds tension on pullout, bent pipe; poor recovery and bent pipe indicates not suitable piston core target.
GGC-6; 1.8 m: foram ooze, 2024 pounds tension on pullout and bent pipe; not suitable for piston coring.
GGC-7: no recovery other than a smear of Pleistocene foram ooze; core appears to have hit at too high an angle in strong current.
GGC-8: 3.5 m; foram ooze; 2404 pounds tension on pullout; later experience suggest this could have been piston cored too since tension was moderate and barrel was full.
GGC-9, 2.07m, foram ooze, 2108 pounds tension on pullout but bent pipe and low recovery suggest not suitable for piston coring.
GGC-10; 3.8 m; foram ooze, pullout at 2223 pounds tension, full recovery and moderate pullout tension indicate piston coring possible. This core was used to verify suitable coring conditions for JPC-11which was deployed on the same target.
JPC-11: 11.5 m, Pullout 21,927 pounds tension; half Pleistocene foram ooze, half creamy yellow Eocene unconsolidated nanno-foram ooze; upper part of mud horizon with a dissolved

nannofossil flora; all Middle Eocene; NP-14 nanno zone.
GGC-12: 3.5 m; foram ooze, pullout at 2409 pounds tension, core site deemed suitable for piston coring and followed by JPC-13 on same target.
JPC-13: 13.01 m; 17,864 pounds tension on pullout; upper half Pleistocene foram ooze; lower half creamy yellow unconsolidated carbonate ooze (unfortunately without fossils in shipboard spot samples, but with similar lithology to Eocene sediments in JPC-11).
GGC-14: 4.24 m; 2575 pounds tension on pullout; foram ooze; full recovery suggested positive indications for piston coring; JPC-15 deployed on same target;
JPC-15: 16,610 pounds tension on pullout, winch failed during core recovery about 120 m above bottom. No indications of unusual winch tension at the time of electronic failure. Core was lost with ~4400 m of wire when the wire was cut with a torch at the starboard railing.

GGC-1 to GGC-5 were all on J Anomaly Ridge near DSDP Site 384; GGC-6 to 9 were in a small canyon on the east-facing crest of SE Newfoundland Ridge, GGC-10 and JPC-11 were on a ridge near the "Titanic Site" on the west-facing crest of SE Newfoundland Ridge, GGC-12 and JPC-13 were on an outcrop area on the north slope of central SE Newfoundland Ridge, and GGC-14 and JPC-15 were on the south east flank of SE Newfoundland Ridge.

Of the GGCs, five cores had bent pipes, low recovery, or some other indication against piston coring while seven GGCs showed suitable indications for follow-up piston cores. In retrospect, all areas targeted for coring had sites with indications for successful piston coring. We had no indications that penetration was limited by hard subsurface layers. However, in some cases in which GGC's arrived on deck with bent pipes or partial recovery, damage to the cutter heads suggested the presence of drop stones or crusts that prevented full penetration.

Dredge #1 from the crest of a seamount on SE Newfoundland Ridge recovered pieces of Cretaceous shallow water dolomite, manganese crust and deep sea corals; the other (Dredge #2)on a slump scar near GGC-10 and JPC-11 recovered only manganese crusts and corals; (I suspect the sediment itself was too soft to dredge).

PRINCIPAL CRUISE RESULTS--DRIFT MORPHOLOGY AND HISTORY

The Newfoundland ridges are covered by up to 1.5 km of sediments that ranges in age from early Middle Cretaceous to Pleistocene. Seismic data provided generally excellent resolution of the internal structure of the sedimentary record with useful penetration to about 1.5 seconds two way travel time. The Lamont system fail to resolve volcanic basement on only a small portion of the SE end of the SE Newfoundland Ridge where MCS profiling suggests sediment thicknesses of more than 2 seconds TWT.

As anticipated from pre-existing geophysical data, seismic features fell into five categories: (1) volcanic basement (Unit 1) with fuzzy, dense reflections, (2) an interval of several discrete packets of well defined parallel to subparallel reflections (Unit 2) sometimes displaying "white out" features, (3) an interval of generally no internal reflections (the transparent zone; Unit 3), (4) an interval of parabolic, poorly defined reflections (Unit 4) that sometimes shows the character of long wavelength mud waves and other times shows features suggesting rotated growth faults or compression-folding, and (5) an interval of generally strong parallel reflections (Unit 5), often in erosional contact with underlying units. All these seismic intervals were found throughout the survey area and all show considerable regional variation in thickness.

Some units, most notably Unit 2, could be subdivided into at least four distinct packets including a basal subunit with strong, but laterally discontinuous reflections, and intervals of diapirism or reef development. Unit 2 is best developed on and around the seamounts in the "Titanic area" but is also found as possible paired drifts on the western toe of J Anomaly Ridge and the central SE Newfoundland Ridge. Areas where the profiles show abundant vertical streaks and pull-ups are concentrated around the base of the seamounts and have not been noted anywhere else in the survey area. One area near the Titanic site shows acoustically-transparent diapirs or reefs more than 4 seconds TWT thick with multiple zones of semiparallel reflections in an onlapping or overlapping relationship. Unit 2 is believed to be of Cretaceous age based upon (1) seismic ties to DSDP Site 384 and (2) a dredge haul (Dredge 1) on the crest of one of the seamounts that recovered yellow dolomite similar to that recovered in the Coniacian-Santonian from DSDP Site 384. Unit 2 was not otherwise sampled during the cruise. It is possible that the upper part of Unit 2 is of Early Paleogene or late Cretaceous age since a Piston Core (JPC-11) recovered yellowish nannofossil-foraminfier ooze of early middle Eocene (NP 14, P10) from an outcrop near the contact of Unit 2 and overlying Unit 3. Seismic ties to DSDP Site 384 argue against an age this young and the issue is unresolved pending further coring studies.

Unit 3, the "Transparent zone", is widespread in the survey area and shows an erosive upper contact in some places (where it is overlain by Unit 5 or is exposed on the seabed) or a possibly conformable relationship with Unit 4. Unit 3 is a laterally continuous drape between 500-700 milliseconds thick on J Anomaly Ridge and the central part of SE Newfoundland Ridge, but is much more lenticular in character in the vicinity of the “Titanic Site” seamount area where it occurs on the NE flanks of several seamounts. The unit is believed to be of partly Eocene age based upon seismic ties to DSDP Site 384. A piston core (JPC-13) on the NE flank of central SE Newfoundland Ridge recovered an apparently non-fossiliferous carbonate ooze in a site correlative with the upper part of the “Transparent zone”; This ooze has a similar lithology to middle Eocene ooze in JPC-11 and provides suggestive, but not conclusive, evidence that the “Transparent zone” is at least partly of Eocene age.

Unit 4 reaches its maximum thickness of ~1 second over the central SE Newfoundland Ridge and NE end of J Anomaly Ridge. Internal reflectors are typically difficult to trace over long distances. A strike line (line 47) on the eastern end of the seismic survey area shows a reflection character suggestive of eastward-prograding, long-wavelength mud waves, but elsewhere only parts of concave down folds or wave forms are resolved. The southern flank of SE Newfoundland Ridge displays possible slump scars and rotated fault blocks that extend into the overlying Unit 5 reflector series. We currently have no dates on Unit 4, but it is similar to the seismic character of drift deposits of Oligocene to Neogene age elsewhere in the North Atlantic. Unit 4 forms a clear onlapping relationship with Unit 2 and volcanic basement, but appears to have a gradational contact with Unit 3. The absence of a strong reflector at the contact between Units 3 and 4 suggests a conformable relationship and raises the possibility of a complete boundary sequence between the Eocene and ?Oligocene-Miocene section.

Unit 5 is represented mostly by rather thin drapes over subcrops of Units 3 and 4. In many cases the contact between Unit 5 and underlying units is clearly erosional with significant relief, onlapping relationships, and distinctly stronger, and more parallel, reflectors in the overlying unit. This unit has a distinctive set of parallel strong reflections in 3.5 kHz echo sounding records in contrast with mostly transparent, or unresolved reflections, from other acoustic units. Unit 5 is typically less than 2 milliseconds thick and is best developed on the saddle between J Anomaly ridge and the central ridge of eastern SE Newfoundland Ridge. There are patches of Unit 5 in the vicinity of the seamounts in the “Titanic area”. An extensive interval of Unit 5 is present lapping up against the NE flank of the seamounts and underlying the Titanic wreck site as well as lapping onto the northern and northeastern flank of SE Newfoundland Ridge. The strong, parallel reflectors in Unit 5 and the erosive basal surface suggest that Unit 5 postdates the onset of Northern Hemisphere glaciation and has either a Plio-Pleistocene or Pleistocene age. All cores taken during Knorr 179-1 obtained samples of foraminifer ooze that probably represent the main lithology in Unit 5. However, no cores were taken where Unit 5 is clearly resolved on either 3.5 kHz or airgun profiles so the dating of the sedimentary sequence is provisional. The foraminifer fauna in the gravity cores has a distinctly cool-water aspect in cores from the NE side of SE Newfoundland Ridge whereas cores from elsewhere in the survey area contain a foraminifer fauna typical of the warm Gulf Stream and Sargasso Sea. Surface water temperature data collected during ship operations confirm that there is distinctly cooler surface water along the NE boundary flank of SE Newfoundland Ridge than is present elsewhere. The temperature data also reveal a distinct thermal divide along the southern flank of SE Newfoundland Ridge (at approximately the top of the steep slope) between waters of ~24-15°C and waters warmer than this to the south.

MAJOR CONCLUSIONS ABOUT THE HISTORY OF THE DEEP WESTERN BOUNDARY CURRENT

The survey of J Anomaly and SE Newfoundland ridges was conducted to test the hypothesis that the Deep Western Boundary Current flowing out of the Labrador Sea was an important player in global heat transport and ocean circulation before the onset of large-scale polar ice growth. Our results provide strong support for this hypothesis, both from Seabeam bathymetry and seismic reflection profiles. The combination of both types of data suggests that the sedimentary cover in the survey area has not formed a simple mound or drape at any time in the history of these sediment drifts. Indeed, there is extensive evidence that strong bottom flows have sculpted the drifts on J Anomaly and SE Newfoundland Ridges for a considerable period of time. Most notably, J Anomaly Ridge displays a large, elongate sediment ridge nearly 1000 m high, that is built obliquely across the ridge, and connected to the main mass the J Anomaly drift by a series of four ridges. In aggregate the large ridge and secondary ridges appear to have prograded to the SE. Their orientation and depth suggests the current that formed them flowed from the east along the middle of the slope at ~4400 m depth. The ridges are accompanied by several large sediment lobes on the SE flank of J Anomaly Ridge and several prominent moats formed around the western flanks of two large seamounts. Similar moats and localized sediment lobes are found around the seamounts on the central and northern SE Newfoundland Ridge. Sediment is piled mostly on the NE side of the seamounts suggesting deposition under a directional flow.

Notably, the sediment ridges are composed mostly of Units 3 and 4, suggesting the ridges formed in the Paleogene or early Neogene and may be inactive now. Our tentative dating of Unit 3 suggests that the drifts began to form in the upper Cretaceous or early Paleogene and are therefore considerably older than any other large drift complex known in the North Atlantic, most of which were initiated in the Oligocene or Miocene. The J Amonaly sediment ridges are mostly free of overlapping sediments, except as basin-fills, which suggests that the ridges are at least partly fossil features of strong directional flows in the Paleogene. Similar fossil drifts are seen on the NE flank of the seamount area on SE Newfoundland Ridge where they are partly overlapped by probable Pleistocene sedimentary cover of seismic Unit 5. The erosion of the upper surfaces of some of these partly buried drifts suggests that they are likely to be pre-Pleistocene in age.

Older sediments represented by Unit 2 are also deposited in lobes and drifts that suggest the presence of strong bottom currents. On the southern toe of J Anomaly Ridge, Unit 2 occurs in two distinct areas, a shallow pile on the upper crest of the ridge (centered at ~4400 m) and a lower pile mostly below about 4900 m. This depth range and the distribution of the seismic unit as elongate masses parallel to depth contours suggests deposition as paired sediment drifts adjacent to a current centered about 4600 m present water depth. Sediment drifts in Unit 2 also seem to be present around the seamounts on the northern end of SE Newfoundland Ridge where they have a broadly similar distribution to the Cenozoic drifts.

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In sum, the Seabeam and seismic operations show that there has been an extensive history of current-controlled deposition on J Anomaly and SE Newfoundland Ridges, beginning in the Cretaceous and continuing into the ?Oligocene/Neogene. Drift morphology suggests progradation of the J Anomaly drifts to the west-southwest under a current flowing from the east along the slope. The regional dip of reflectors in Unit 4 on the eastern end of SE Newfoundland Ridge suggests the progradation of sediment waves to the east, probably under a current system flowing from the north and following bathymetric contours around the east end of the ridge. Extensive erosion (down to Unit 3) along the NE crest of SE Newfoundland Ridge shows that there has been a shift from deposition and ridge growth during formation of Unit 4 to erosion and reduced sediment supply during formation of Unit 5. It appears that Unit 5 sediments have been blown over the crest of SE Newfoundland Ridge and deposited in a small drift complex along the central spine of the ridge system. However, the volume of sediment deposited on the ridge during Unit 5 time is vastly smaller than that deposited during the time represented by Units 3 and 4, probably contributing to widespread erosion and non-deposition over large areas of the SE Newfoundland Ridge.

An unresolved question concerns the origins of the sediments making up the ridge complex.

Pleistocene sediments previously cored just north of SE Newfoundland Ridge contain dropstones, red-coated grains and ice rafted debris suggesting an origin from the eastern Canada, Greenland and the Laurentide ice sheet. We also found glacial debris in all of our piston and gravity cores including drop stones, red-coated grains, frosted and rounded quartz grains, and metamorphic rock debris. However, while these sediments are up to several seconds thick on the North side of SE Newfoundland Ridge, they constitute a small minority of sediments in the survey area.

The majority of drift sediments are found in Units 3 and 4, and their thickness, lack of obvious internal erosion surfaces, and relative transparency in seismic reflection profiles suggests that they were deposited rapidly. Seismic evidence for large scale, and continuing slumping and growth faulting in both units on the southern flank of SE Newfoundland Ridge is also in accord with rapid deposition in fluid-rich sediment drifts. It is not obvious where more than a kilometer of sediment was derived from, particularly in the Paleogene or upper Cretaceous. However, the presence of abundant zeolites, glass shards, and bentonitic clays in Unit 3 sedimentary equivalents suggests an origin from Greenland plume volcanism or from rifting of Baffin Bay in the late Cretaceous to Eocene. The early Paleogene age of the North Atlantic magmatic province eruptions (with dates clustering in the latest Paleocene and early Eocene (~58-52 Ma) is consistent with lithological evidence from Unit 3 for abundant volcanic components and suggests that much of the sediment on SE Newfoundland Ridge and J Anomaly Ridge may be derived from the Greenland and Labrador seas.