Jan 23, 1985

Preliminary Cruise Report
R/V Robert D. Conrad Cruise 25, Leg 14
Amazon Deep-Sea Fan Seabeam/Watergun/Coring Study
November 26 - December 22, 1984 Belem to Belem

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I. Background and Cruise Objectives

In January, 1982, a long-range side-scan sonar (GLORIA) survey of the Amazon Deep-Sea Fan was undertaken from the vessel Farnella. This cruise was designed to map the large-scale pattern of submarine channels on the fan and to determine the overall structure of the fan (Damuth et al., 1983a; 1983b; Damuth and Flood, 1984). The sonar images collected during that cruise demonstrated that the channels which cross the surface of the fan are highly meandering with sinuosities similar to terrestrial rivers. Also, this data showed that only one of the channels is presently connected to the submarine canyon, and thus we infer that this is the most recently active channel. Although the GLORIA side-scan sonar data was essential to mapping the large-scale structure of the fan and the inter-relationships between the various channel/levee systems (Damuth et al., 1983a, 1983b; Damuth and Flood, 1984), a more detailed examination of the channel system was needed to understand the nature of these channels and the role they play in the construction of the fan and the formation of sedimentary units on the fan.

The present cruise on the R/V Conrad provided an opportunity to examine in detail the shape, structure and sediments of some of the active submarine channel on the Amazon Fan. By studying the channels in detail, we hope to learn what processes are important in forming and maintaining the channels, and also what role the channels play in transporting coarse-grained sediments to the sand-rich lower fan. Other morphological elements shown on the GLORIA side-scan sonar images were also studied to determine their importance to the overall fan structure.

There were four major objectives of the survey. These were (1) to understand the transition from the submarine canyon to the main leveed channel at the upper portion of the fan, (2) to determine what happens where one leveed channel changes into two leveed channels - an apparent branching, (3) to describe the channel and levee morphology along the entire length of the fan to see how these elements change down fan, and (4) to sample the sediments in and near the channel at several places down fan. Several other elements of fan morphology were also studied as time and opportunity permitted.

II. Methods

To study the fan at the level of detail required, we used several high-resolution geophysical tools. Our primary survey equipment was the Seabeam multi-narrow-beam bathymetric mapping system. Seabeam was operated during the entire cruise, and it operated well even at the highest ship speeds (11+ knots). Seabeam maps the bathymetry of a swath of sea floor with a width of about 2/3 the water depth (1 to 3 km wide in most of the survey area). This high-resolution bathymetric mapping system was complemented by precise GPS/Navstar navigation 10 hours/day. The GPS fixes were determined by a Magnavox T Set satellite navigation system. The GPS fixes were used to navigate the ship along pre-determined survey lines and to position the Seabeam bathymetric information precisely on the final maps. Navigation during the remaining 14 hours/day was by standard transit satellite fixes supplemented by one-minute speed/heading information. This allowed us to generate a fairly accurate dead-reckoning track. Additional fixes can be determined where these lines crossed GPS-navigated survey lines. Studies are presently underway by us to determine the overall accuracy of the GPS/Seabeam system based on this data set.

High-resolution 3.5 kHz subbottom profiles were collected along the entire ship track. These records are essential for mapping the near-surface (to ca. 100 m) structure, and they are also important to aid in interpreting the Seabeam bathymetric maps. High-resolution seismic data were also collected along portions of the cruise track using two 80 cubic inch watergun seismic sources fired simultaneously and a four-channel "single-channel" streamer. The waterguns have a sharp outgoing pulse and higher frequency content than conventional airgun systems, and they are thus ideal for studying near-surface sediments. The same subbottom reflector could be seen on both the 3.5 kHz and watergun records thus allowing important reflectors to be followed to shallow or deep depths. The seismic system recorded reflectors to depths of about 2 seconds. The towing configuration for the guns and flow noise in the streamer limited maximum ship speed while profiling to 7 to 7.5 kts. The seismic data was low-pass filtered at 250 Hz and digitally recorded on two channels with different streamer elements recorded on each channel. Six sonobuoys were launched to determine the velocity structure of the fan sediments and to aid in the identification of seismic units. These sonobuoys were also digitally recorded.

Linered piston cores were taken to sample specific environments and thus to further aid our interpretation of the morphological information from Seabeam and 3.5 kHz records (Table I). These cores were collected using the standard LDGO piston coring system. The cores were generally "two-pipers", or about 40′ (12.2m) long, although some "one-pipers" (20′, 6.1m, long) were taken in areas where our experience showed that cores were being bent. However, these shorter cores were also often bent. The GPS/Seabeam/coring combination proved to be a powerful tool for the precise coring of small targets. We used the GPS/Seabeam/3.5 kHz combination to identify the precise target for coring, and then with GPS the ship was able to maintain position directly over the core location - even with the strong surface currents in the area (up to 2 kts.). Seabeam showed the location of the morphologic feature with respect to the ship, and we could hold position until the core wire was vertical and the ship was directly over the coring target. A 12 kHz pinger on the core helped to verify that the core was over the correct target on the sea bed. With this system we were able to core small channels (to about 500 m wide) in water depths up to 4000 m. The addition of a system for determining the position of the core with respect to the ship with more accuracy than presently possible would allow one to precisely core almost any target which could be identified from the surface.

III. Participants and Sources of Support

Several different groups were represented on the cruise both as scientific participants and for technical support. A list of personnel, affiliations*, and participation follows.

1.	Roger D. Flood	Chief Scientist	L-DGO
2.	Alexander N. Shor	Scientist	L-DGO
3.	Renato O. Kowsmann	Scientist	Petrobras
4.	Lt. Hans Fensterseifer	Observer	Brazilian Navy (DHN)
5.	Isa Brehme	Scientist	UFRJ
6.	Cleverson Silva	Scientist	UFRJ
7.	Carlos Pirmez	Scientist	UFRJ
8.	Gilberto Mello	Scientist	UFRJ
9.	Gilberto Griep	Scientist	URG
10.	Paul Manning	Res. Assistant	L-DGO
11.	John Freitag	Seabeam Tech.	URI
12.	John Blue	Seabeam Tech.	URI
13.	Joe Stennett	Electronics Tech.	L-DGO
14.	Kevin Little	Electronics Tech.	L-DGO
15.	Martin Iltzsche	Watergun Tech.	L-DGO
16.	Ropate Maiwiriwiri	Coring Tech.	L-DGO

* L-DGO = Lamont-Doherty Geological Observatory
UFRJ = Federal University at Rio de Janeiro, Brazil. (all soon to change to UFF, the State University at Niteroi)
URG = the University of Rio Grande, Brazil
URI = the University of Rhode Island

The primary funding for the cruise came from the U.S. National Science Foundation via a grant from the Submarine Geology and Geophysics Program. The title of the grant is "Quantitative bathymetric studies of distributary channels and associated morphologic features on the Amazon Cone (deep-sea fan) using Seabeam", grant number OCE 82-14819. Additional support, primarily in terms of supporting Brazilian participation in the cruise, came from Petrobras, the Brazilian national oil company,

and from CNPq, the Brazilian national science foundation.

Since the Amazon Deep-Sea Fan is in large part located within 200 miles of the Brazilian coastline, permission was sought from the Brazilian government to carry out much of this study. This permission was granted in Presidential Decree No. 90,499 dated November 12, 1984. We carried an observer from the Brazilian Navy as part of our compliance with the terms of that decree, and his assistance on the cruise is also acknowledged.

IV. Cruise Narrative

Pre-Cruise Activities

The R/V Conrad left the dock in Belem at 0108L, 27 November, 2 3/4 days after the planned start time of the morning of 24 November. The delay was due to a problem with the visas of the six U.S. scientists joining the ship in Belem. These scientists had obtained tourist visas for Brazil in New York since our scientific studies were confined to offshore regions. However, the local Federal Police officials ruled that our tourist visas were appropriate and wanted us to have different visas. The reason for this was apparently because we were working within 200 miles of Brazil, we had a Presidential Decree authorizing this work, and we were returning to Belem. Although several different approaches were tried to get us out on time, it became clear on Friday night that this visa problem would hold up the scheduled Saturday sailing. In an effort to get the ship out as quickly as possible, Saturday was spent contacting various people and agencies in Brazil. We sought and obtained the assistance of the Consular Officer (Mr. Purdy) at the U.S. Embassy in Brasilia. Mr. Purdy talked with the Brazilian Foreign Office and with the Federal Police, but we could only confirm that nothing could happen until Monday when the visa problem could be addressed. With the Consular Officer's help, the passports were retrieved from the Federal Police, and on Sunday afternoon I went to Brasilia accompanied by Renato Kowsmann. The passports were delivered to the U.S. Embassy on Monday morning, and by 5 pm we had obtained an additional visa to allow us to do our work. We returned to Belem Monday evening where the local officials signed the required papers, and we left shortly after 0100 on Tuesday morning.

The visas which were obtained in Brasilia were granted under Article 13, Item I. These visas are granted for "educational or cultural visits." The local Federal Police officials apparently had thought we needed a visa granted under Article 13, Item V, visas for scientists working under contract to the Brazilian government. In any case, the new visas proved sufficient and we were allowed to leave on the ship. Scientists joining research cruises have always been unsure of their legal position since they are not joining the ship as passengers or as crew members. Some of our problems may have been due to the local Belem officials interpreting the regulations without the benefit of a uniform interpretation or other guidance. The visa which was issued was different from the one which the local police officials expected suggesting that the local police was not really familiar with our situation or with the visa laws, although they are the agency which has to interpret and apply the laws. We could have avoided this problem by obtaining the correct visas beforehand, however non-tourist visas take several weeks to months to get and it is still not clear what kind of visa we should have or if the kind of visa we obtained this time will be needed next time. The only advice that the U.S. Embassy could provide was to (1) explain the program to the N.Y. Brazilian Consulate to obtain the correct visas, (2) plan for passports to go to Brasilia should this problem arise again, but do it as soon as feasible so that the ship schedule will not be held up. This could be done through the U.S. Consulate in Rio.

Ship-Board Studies

A summary cruise track is shown in Figure 1. The study concentrated on one channel/levee system on the fan, with two excursions to study other features.

The study of the Amazon Deep-Sea Fan was undertaken in three parts. First we did a series of transects working downfan going across the submarine canyon and the most recently active channel/levee system using the watergun seismic system, Seabeam, and 3.5 kHz. These lines were spaced about 5 to 10 km apart and served to show the structure of the levee and its relationship to other elements of the fan and to show where additional Seabeam data should be collected. Second, we worked upfan with Seabeam and 3.5 kHz to map the channel morphology in detail. During this phase we collected cores of the channel, levee, and far-levee sediment sequences at several depths. Several other important sedimentary sequences were also cored (older levee complexes, debris flows).

The third phase of the study consisted of several smaller surveys using the watergun seismic system and/or Seabeam to study specific areas of fan morphology and additional coring. A set of supplementary seismic lines was run in the upper fan/canyon area to determine the nature of the transition and to map the seismic reflectors. Five sonobuoys were deployed during this study. We then surveyed and sampled a 500 m high diapir in a water depth of 1700 m which Petrobras had discovered. Two cores were taken from this diapir. Following the diapir survey, the ship worked downfan with the seismic gear completing some detailed surveys where GLORIA sonographs suggested that channels bifurcated. When we reached the limit of our previous survey, we continued to follow the channel until the levee complex abruptly ended. We collected some cores at this site, and filled in between the seismic lines with Seabeam. The channel was then followed further northward until it became too small to follow with Seabeam. A sonobuoy was launched to determine velocity structure in this area. By this time there was only a short time left in the cruise. We crossed over to an older, now disconnected channel/levee system where a small survey was followed by a core in the channel. We left the fan by following this channel upslope, finally breaking off and heading to the pilot station. The pilot came on board at 0235L on 22 December, and we were at the dock in Belem at 1118L, 22 December; 25 days, 10 hours and 10 minutes after leaving Belem.

Summary of Data Collected

Seabeam and 3.5 kHz bathymetric records were collected continuously throughout the cruise, although Seabeam was secured on the shelf because it is not effective in shallow water. A total of about 4800 n.mi. of 3.5 kHz records and 4300 n.mi. of Seabeam records were collected at ship speeds up to 11 knots. The actual Seabeam coverage totalled about 12,100 square kilometers of bathymetric data, or about one square degree. Primary navigation and Seabeam data reduction occurred on shipboard each day for the data collected on the previous day. Seabeam bathymetric plots were made at a scale of 40"/degree longitude. Final navigation and Seabeam data reduction will need to use additional navigation fixes determined where Seabeam tracks cross.

The watergun seismic profiler was deployed six times during the cruise resulting in 12 days, 13 hours of seismic profiling (about 2160 n.mi., 96,425 shots). Ship speeds were kept below 8 knots when profiling. Six sonobuoys were done during the cruise. Most were in the canyon region, and one was on the lower fan. All the seismic data was collected digitally and logged on the L-DGO data logger, as was navigation data throughout the cruise.

The upper layers of the sediment column were sampled by piston core 17 times (core numbers RC25-19 to RC25-35). A summary of the cores is given in Table I. Many of the cores were stopped by coarser layers in the sediment, and several of the core barrels came up bent. However, all of the cores were successful and contained sediments. Several of the cores showed evidence of degassing: either small cracks in the sediments or large gas pockets and material extruding from core liners. In some cores hydrogen sulphide was detected by smell, but in others the gas was odorless. This gas was generally restricted to the deeper sediment layers.

IV. Preliminary Results

Several major results of this survey are listed below. These results are preliminary in nature, but summarize several of the important outcomes of the cruise.

During this survey we mapped the most recently active channel and its associated levee nearly continuously with Seabeam from a channel depth of 921 m to 4273 m. This complete bathymetric map, and the associated high-resolution 3.5 kHz and watergun seismic subbottom profiles, provide an excellent picture of the down-fan evolution in channel morphology and of the details of the meandering channel pattern. This data base will provide an excellent base for studying channel patterns (channel depth, width and sinuosity), the character of the levee, and the relationships between the channels and levees. Also, new information is now available on the character and structure of other elements of fan morphology such as small debris flows and abandoned channels. These studies generally supported the previous interpretations made from the GLORIA long-range side-scan sonar profiles while providing additional data on the fan at a smaller scale than possible with GLORIA.

We studied the transition from the canyon to the upper fan to determine how this transition occurs. A preliminary evaluation of this data set indicates that the canyon cuts down into Pliocene-Pleistocene shelf deposits. On our seismic profiles there is a diffuse but strong reflector at 0.25 - 0.4 seconds below the sediment surface in shallow water which limits penetration. Further seaward (at a water depth of 1400 m), this reflector either ends or becomes too deep to observe with this seismic system. Seismic lines perpendicular to the shelf show that this diffuse reflector cuts across bedding horizons in the profile, and generally follows the shape of the seafloor. Such bottom simulating reflectors (BSR) are generally thought to be caused by natural gas clathrates forming in the sediments at those subbottom depths (Tucholke et al., 1977; Shipley et al., 1979). Such clathrate horizons have not been previously reported from the Brazilian margin, and they could indicate that significant amounts of gas are present in the sediments.

The submarine canyon cuts down near or into these presumed clathrate horizons in shallow water, and into layered deposits at depths up to about 1400 m. In deeper water the seismic profiles show that the channel has associated with it a levee deposit with the laminated deposits present under the levee deposit. This transition between non-leveed and leveed channel appears to occur over a distance of about 15 km. The transition from canyon to leveed channel occurs so as to maintain the desired grade level down fan. Associated with this change in character from a canyon to a leveed channel is a change in the character of the channel itself. Where the levee is absent or poorly developed, the channel appears to follow a slightly sinuous course with no large meander bends. Deeper than 1450 m, where the levee deposits are well developed, the channel becomes highly sinuous with large channel meanders present.

The sinuous channel itself has a character quite similar to that shown on the GLORIA records. However, shallower than 2000 m where the channel character was only poorly resolved on GLORIA, Seabeam was better able to resolve the sinuous nature of the channel. Seabeam provides a quantitative detailed bathymetric map of the channel downfan, and suggests that its character changes somewhat downfan. The channel sinuosity generally increases downfan, although there is a region in the upper fan where the sinuosity is decreased. In the upper fan the channel walls sometimes show areas where slumps or other processes have removed sections of the walls, whereas in the middle and lower fan the channel walls are rarely irregular. Several meanders were surveyed which were totally, or almost nearly, cut off. Also, one cut-off meander was surveyed which turned out to be a hanging meander loop thus suggesting that the channel had cut down after the meander was cut off. Further study will be needed to fully understand the significance of these studies to the channels themselves and to the fan as a whole.

The channel and the associated levee decreased in size down fan. The prominent levee structure ended abruptly at a depth of 4100 m and the channel continued downfan now accompanied by much smaller levees. We continued to follow the meandering channel down fan until it became too small to adequately resolve with Seabeam. Several cores were taken near the end of the leveed deposit.

The GLORIA records had shown that the channel had apparently branched at several locations downfan, but the nature of that branching was only poorly known. We surveyed four branchings in detail using Seabeam, 3.5 kHz, and watergun. These surveys showed that the branchings actually occurred deep in the sediments with two channels clearly present under the present levee deposits of the most recent channel. While at present we cannot say what caused the initial branching, it is clear that the branching predates the formation of the more recent levee deposit, and that those deposits have filled in the older channel. Some of the finer material may continue down the older channel for a while, but at present the levee deposits of the younger channel are burying the older channel.

Sediment cores were collected of the channel, levee crest (near levee), and far levee at several points along the channel. While only the most rudimentary core descriptions have been made, some observations are now possible. Cores from the channels on the middle fan generally were stopped by coarse material. Samples from the bottom of the core showed quartz grains up to 1 mm, but the structure of the deposit is not known. Cores from the levees are generally finer. The coarse, gray sediments from the channel and levee were overlain by a brown foram ooze of Holocene age suggesting that the channel is less active at the present time than it has been in the past. As mentioned above, many of the cores contained gas which is probably biogenic in origin. We also collected a core in a channel, or channel wall, from an older part of the fan. This core, from a depth of 3620 m, contains abundant pteropods in the upper layers perhaps suggesting that mass sediment movement was responsible for depositing this sediment.

In addition to studying the channel complex, we also did a survey of, and sampled, a diapir which protrudes 500 m above the sediment surface in a water depth of 1700 m. Multi-channel-seismic lines collected by Petrobras had shown the existence of this diapir, and we wished to learn its age and nature since diapirs may play an important role in initiating large sediment slumps and debris flows on the cone. After surveying the diapir, which turned out to be elongated along contours, we sampled it in two locations. One place was on a ledge at the side of the diapir where the seismic profiles suggested the deepest material might be exposed, the other was on the crest of the diapir. The core from the ledge was mostly sand with mud at the base. The core from the crest was a partially lithified, fossiliferous mud. The crest core also was gassy.

V. Schedule for Data Reduction and Transmittal to Brazil

In receiving permission to work in Brazilian waters, we have contracted several obligations to the Brazilian Government. These obligations include the reservation of place on the ship for Brazilian scientists and observers, and the transmittal to Brazil copies of all data obtained. We also have a good working relationship with scientists at several organizations in Brazil, and we plan to keep working with them on this data set. Several of the obligations have been met, and a time table is presented for meeting the remaining obligations.

(1) We carried seven Brazilian scientists and observers on this cruise. One of these individuals was an official observer from the Brazilian Navy. The scientists were cooperating in this study of the Amazon Fan. The names and affiliations of the individuals on board are given in the cruise personnel list.

(2) Navigation and preliminary data was provided to Brazilian scientists and to the Naval Observer at the end of the cruise leg. This data included:

Listing of ship navigation at 1 minute intervals.
Track plot of the survey at 8 inches/degree longitude.
Track plot of the survey at 4 inches/degree longitude.
Seabeam bathymetric chart of part of the Middle Fan.
Seabeam bathymetric chart of the diapir survey area.
Samples from several of the piston cores.
Copy of all seismic profiling data.

(3) Final processed data will be provided to the Brazilian scientists involved with the project as follows.

Microfilm copy of 3.5 kHz records.	April, 1985
Computer tape listing of navigation.	Feb., 1985
Copies of digitally replayed seismic data.	Sept., 1985
Final bathymetric maps of all areas studied.	Sept., 1985
Descriptions of all cores taken.	Sept., 1985

VI. References Cited

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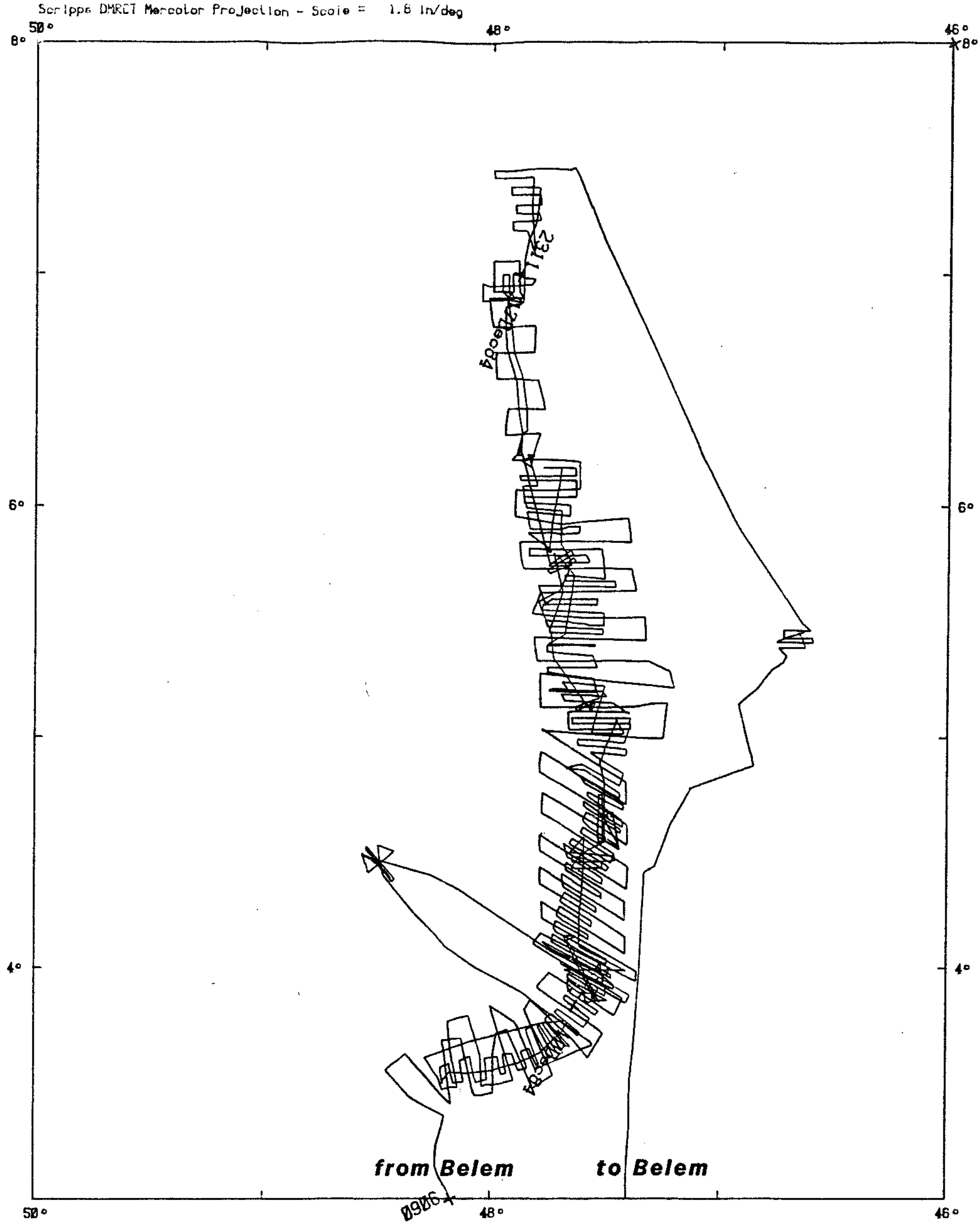
VII. Figure Caption

Figure 1. Summary navigation track for Robert D. Conrad Cruise 25-14. The cruise started and ended in Belem, and the pilot was dropped off/picked up at the pilot station in Salinopolis.

TABLE I

Summary of Preliminary Core Data from Robert D. Conrad 25-14

Core Number	Date (mm/dd/yr)	Time Hit (GMT)	Lat. (N)	Long. (W)	Depth (m)	Length (cm)	Comments
RC2519	12/05/84	0200	5 48'	47 44'	3623	825	levee (near)
RC2520	12/05/84	1800	6 10'	47 43'	3830	890	levee (old)
RC2521	12/05/84	2237	5 48.9'	47 46.3'	3626	1026	channel axis
RC2522	12/06/84	1938	5 47.8'	47 43.9'	3650	784	levee (far)
RC2523	12/07/84	2009	5 02.2'	47 24.2'	3202	873	levee (d.f.)
RC2524	12/08/84	1723	4 39.8'	47 31.3'	2827	593	channel axis
RC2525	12/08/84	2051	4 39.7'	47 30.2'	2737	894	levee (near)
RC2526	12/09/84	0044	4 39.7'	47 28.4'	2777	809	levee (far)
RC2527	12/10/84	1649	4 07.1'	47 40.5'	2288	571	channel axis
RC2528	12/13/84	1850	4 27.7'	48 30.0'	1545	341	diapir
RC2529	12/13/84	2230	4 26.8'	48 30.3'	1324	100	diapir
RC2530	12/16/84	2021	6 12.0'	47 52.2'	3794	819	channel axis
RC2531	12/17/84	2244	6 59.6'	47 52.7'	4149	215	channel axis
RC2532	12/18/84	1806	6 54.1'	47 56.3'	4117	257	channel axis
RC2533	12/18/84	2227	6 54.1'	47 55.6'	4078	244	levee (near)
RC2534	12/19/84	0142	6 54.0'	47 54.5'	4090	672	levee (far)
RC2535	12/20/84	1551	5 27.2'	46 39.3'	3620	740	ch axis (old)



R/V ROBERT D. CONRAD CRUISE 25-14
AMAZON FAN SEABEAM/SEISMIC SURVEY
NOVEMBER 27 - DECEMBER 22, 1984

FIGURE 1