Cruise Report: Project MAMBO

Cruise JVV009

23 April 1993 - 28 May 1993

by Jan Garmany

Introduction

This report concerns primarily scientific operations aboard the R/V John V. Vickers on cruise JVV009, 23 April to 28 May 1993. The ship operations are summarized in the Vickers cruise assessment report, which is attached. The scientific mission of this cruise was to test the hypothesis that there are melt accumulations at the base of the crust near mid-ocean ridges. The chief scientist designated the project as MAMBO, which is an acronym for Melt At the Moho BOundary. Except for a nearly disastrous first deployment that saw 50% instrument losses, the cruise was a great success. We had further instrument losses, but we were able to fulfill the mission of the cruise with the remaining instruments. We had excellent data from 43 ocean bottom seismograph (OBS) sites out of 46 recoveries. The data indicate the presence of melt at or near the Moho boundary more than thirty kilometers from the ridge axis. We also found a very high percentage (perhaps >50%) areal distribution of melt in regions within 10 to 15 km of the ridge. These findings are preliminary, but it is obvious that they are very significant The original hypothesis was strongly supported by the data, and the results place very strict constraints on methods of melt transport at mid ocean ridges.

MAMBO was perhaps the most logistically demanding cruise I have seen. The unstinting efforts of Yosio Nakamura, Yann Hello, and Perry Crampton were heroic, and their work was the foundation of the scientific success of the cruise. I salute their achievements and thank them most gratefully. I am hopeful that the exciting results of MAMBO will add to a growing prominence and reputation for the OBS effort at UTIG.

Chronology

We departed from Terminal Island, Port of Los Angeles late Friday 23 April 1993. We had a scientific crew of 11 on board:

Jan Garmany	UTIG
Yosio Nakamura	UTIG
Yann Hello	ORSTOM
Perry Crampton	SIO
Thomas Bodine	UTIG
Mark Stowers	UTIG
Vikramaditya Sen	UTIG
Matt Heavner	Southwestern Univ.
John Kerzaya	UT (Linguistics)
Inteshar Masud	UT (Physics)
Livia Squires	UTIG

On the beach, Archie Roberts waved good bye to us. Archie was indispensable in taking care of pre-cruise preparations, particularly assisting Perry Crampton with airgun source-related equipment and managing the fabrication of the OBS anchors. His management of our non-OBS crew, his productive interaction with the USC personnel, and his exemplary hard work were essential to getting us out of port on time. We deeply appreciate his help.

The first night out was as bad a ride as I have ever experienced. Things started getting rough early on, and I decided to retire to my stateroom while I still could, since there was only weatherdeck access to my room. As I was sorting out papers and belongings, the ride got worse and worse. I eventually could not hold myself in place sitting on the deck. I went to bed since I was safer there from the chairs that were beginning to roll around the room.

Conditions improved considerably after the first night, and indeed we were blessed with extremely calm seas during most of our operations. The transit took until 29 April. In the meantime, the OBS crew were busy setting up for the initial deployment of 20 OBSs on the first array. There were several hardware problems with sphere penetrators, chassis support blocks, and geophones. The schedule for OBS preparation and sealing was quite grueling, and the hardware difficulties prolonged the work. We continued assembly of the tripods, with generous help from the ship's crew. I prepared coordinates for shot lines and OBS deployments. We began the underway watch on the 25th.

Our first action in the work area was to survey the line to find the most level spots for deployment sites. We anticipated some difficulty with tilting that might disable the essential horizontal components, but we did not know how severe the tilting might become. We deployed OBSs until about 0200 30 April. The #1 airgun was deployed at about 0400. (The airgun operations are summarized in Perry Crampton's report, attached. Line 1 had very frequent problems with the compressors.) Shooting stopped at 1730 01 May. We then proceeded to OBS 1 for recovery.

The following night and day were very difficult. OBSs 1 and 2 did not show up, which was very worrisome. Then OBSs 3 through 10 returned, then two more losses, and 13 returned. OBS 18 was the next and last OBS to surface. Ten instruments had been recovered and ten lost. We searched until 1636 02 May for OBS 20. We began a search pattern for instruments that might have escaped in the meantime, abandoning the search after about 0400 03 May. It was a dismal time.

We discussed causes of the failures and possible courses of action. We realized that the tripods were faulty: apparently the tripods were tipping upon impact with the rough seafloor, and the OBSs were being trapped under the inverted anchors. We considered modifying the frame so that the OBS sphere would not sit so low in the frame, which might enable the sphere to escape from a severely tipped instrument. We also considered increasing the mass of the anchor to increase the separation of centers of buoyancy and gravity (CB and CG). Finally, we settled on the solution of shortening the legs and reattaching the cut-off pipe to the base to preserve the weight. This made the CB and CG closer, but reduced the torque due to impact or contact on a single tripod leg. It also permitted a larger angle of tilting before toppling on two points of contact.

We established a routine of 4-day cycles for subsequent arrays, which was a pretty relaxed pace. In a perverse way, the loss of ten instruments was providential in that it made it impossible to field enormous 20-drop arrays. As it turned out, the more modest-sized arrays were generally satisfactory for the science objectives. The ambitious plan of 100 (or even 120) drops was thankfully shelved. We were very cautious on the second array. With the newly modified frame, we risked only 5 OBSs, and all of them returned. The third array had ten instruments, of which the last two at the west end were lost. We became slightly more cautious in deploying only eight on the fourth array. Again, there was a loss, this time the westmost OPS. Evidently, the terrain became rougher away from the ridge, presumably due to weathering and the collapse of volcanic edifices. The most distant OBSs were only about 30 km from the ridge (-600 kyr), but apparently this was sufficiently distant to encounter

highly fractured seafloor. The last two arrays were deployed on the flanks of the ridge, presumably on fresh and relatively smoother terrain. These were 8-OBS arrays, and all 16 drops were recovered.

In all, thirteen instruments were lost, ten in the disastrous first array. We need to decide how to make anchors for future mid-ocean ridge deployments. The special problems of this rough terrain may be important, since I hopefully expect that much of our future OBS work will be on determination of melt distributions near ridges. Clearly, physical and numerical modelling will be a central theme in any future design efforts. I regret the losses we have incurred through the unanticipated anchor design problems, but I also take much consolation in the spectacular scientific success of this program.

We went to Acapulco to enjoy some R&R and to discharge most of the scientific crew. We arrived the afternoon of Friday 21 May, cleared customs, and proceeded to reinforce the ugly American stereotype. I had a good time in port, but I was happy to wave to the shore, saying *"Vaya con huevos"* to our now landlubbing crew members as we got underway. Our scientific crew now consisted of Garmany, Kerzaya, and Masud. There was no watch on the transit. Despite a mild but annoying intestinal disorder, I managed to get a lot of work done in playing back the data and inspecting it for the P-to-S conversions. They were abundantly present: everywhere was the glint of melt, to paraphrase Carter. I was greatly elated. I am only starting to work out the consequences of this finding, but it is already clear that they are important.

The five-day transit was otherwise uneventful. In fact, the docking was so boring that I slept through it. We cleared US customs on the morning of the 28th of May, a Friday.

After the cruise Hello, Bodine and I unloaded the ship the following Tuesday, 01 June (after Memorial Day). I add this item in order to include a thank you for a USC hand named Tom who did much more than he had to to help us to unload. He was the crane-and-forklift operator for us, and his efforts are greatly appreciated.

Personnel

All personnel contributed to the success of this cruise. It was an honor for me to have such a committed group working in concert to achieve the scientific objectives of this program. I would like to remark on some of the individual contributions.

Garmany

I learned a great deal in conducting this cruise, the first on which I was chief scientist, and I am grateful for the experience. Many of the lessons were hard, especially in recovering from severe losses of equipment and in the management of personnel. I was fortunate to have the experienced help of Yosio, Yann, and Perry. I think I could anticipate certain difficulties better in a future cruise. In particular, I would probably be more ruthless toward watch-standers, especially those who have no vested interest in the conduct of the science. My scientific planning and conduct were very good: this was a well-conceived piece of work and, thanks to the technical people, well-executed. OBSs are uncannily well suited to the problem of determining melt abundance near mid-ocean ridges, and in the arena of ridge-concerned scientists, the results of this work will loom very large.

Nakamura

Yosio was, of course, essential. He is supremely dedicated to the instruments, and I know that the instrumental losses of this cruise are most difficult for him to bear. He helped greatly to lift my spirits by pointing out that, despite the losses, we could still accomplish the science. I appreciated the selflessness of the remarks.

Hello

Yann was superhuman in his efforts to demonstrate the flexibility and power of the fleet of OBSs. On cycles of recovery/deployment, he would stay up for more than 48 hours at a time. He could not be replaced by a single person in this role. He brought the idea of using an inflatable boat for instrument recovery to our attention and helped to make it work. He has sacrificed a great deal to help us make MAMBO a success, and we owe Yann a great debt of gratitude for his work before, during, and after this cruise.

Crampton

Along with Yosio and Yann, Perry was one of the essential people. Perry worked tremendously hard and under very difficult conditions to keep our airgun sources working. He spent a lot of time baking in the tropical sun on an unshaded back deck maintaining the heavy and unwieldy airguns. He devised a new towing arrangement that seems to have been very successful despite the excessive towing speeds. He contrived a relatively safe deployment scheme using the ship's winch, although it always worried me to watch the towing chain get snatched off the deck by the lowering of the airgun. In my opinion. Perry was hampered from the start by Bolt's unwillingness to do any serious refurbishment on the gun we sent them. He notes to us that the guns are merely getting older, not better. The very warm surface water in the work area and the limited water flow available made for spotty compressor performance. Perry's work with Roger Harrington (chief engineer) made the last array feasible.

Bodine

Tom did a good job setting up the computer systems and their networks in the lower dry lab. This was the heart of the OBS data processing and assessment. The system permitted immediate back-up of the still-cold tape cassettes, display and print-out of the data, preparation and distribution of schedules for general operations and for OBS programming, and easy access to email service. (The mail service was a great boon to the crew's morale. Cruises seem not to be as isolated as they used to be.) Tom also worked hard to provide data management on the Sun system for the OBS data. This effort was essential to the quick display of the data provided by the Transform software on the Macintosh Quadra 700. I hope this useful and effective programming effort will continue so that the data from future OBS programs will become more straightforward to manage.

Sen

Vik Sen came along to help with the data management, drawing on his experience from the Barbados cruise. He was very helpful in doing the data back-up and collaborating with Tom Bodine and Yosio on the data management. He also helped greatly with OBS preparation and sealing with Yann and Matt Heavner. I think he will continue to make a fine contribution to the OBS program at UTIG.

Students

The remaining crew were intended to be watchstanders. Generally, all were good humored, tolerant of the living conditions, adaptable, and good sailors. All pitched in on OBS deployment, recovery, and search duties, and two of the watchstanders provided some video documentation of the cruise. This trip was a long time at sea even for some veterans, so the first-timers may be excused if their performance was not 100% of what we had hoped for.

Because of the paucity of interest among the students at UTIG in OBS-related matters, I was obliged to hire people from outside to fill out the watch-schedule. This is an acceptance of reality, not a criticism. People disinterested in the data undervalue the essential drudgery of the watch, unless the correct expectations are inculcated by the institution or the chief scientist. There were some lapses in the watchstanding that could have been avoided with some better management from me, although I would say that a reasonable but inexperienced person on the watch would normally err on the side of caution in executing the job. I think most of the problems we encountered could be avoided in the future. As to the present cruise, the watch was conducted adequately for our needs, though not entirely smoothly.

System performance and future work

There were three systems, apart from the ship's operations, used in this cruise: OBSs; compressors and airguns; and computer systems. We note here some observations about their performance and expectations for the future.

The performance of the OBSs was nearly perfect, apart from the problems with the anchors discussed above. Certainly the current OBSs, with their expected evolutionary development, are superb for the kind of work done on this cruise. There are no instruments on Earth to match their ease of use and their effectiveness for similar programs, and this is likely to remain the case for years to come. We have requested NSF assistance in replacing the lost instruments, and I am reasonably confident that the NSF will manage to provide us with some of their year-end money.

The specific causes of OBS hardware failures were as follows:

Station 30: Horizontals failed due to excessive tilt
Station 32: failure due to salt-water contamination of pre-amp board
Station 40: tape drive failure (bad cassette?)

Although this hypothesis is not universally held, there is one OBS problem that appears to stem from the current tie-down arrangement. This is the occurrence of high amplitude monochromatic wavetrains in the data. There is no propagation effect or anchor-to-ground coupling effect that could plausibly account for such high Q oscillations. I suspect that the sphere is lifting just free of the anchor and forming a mechanical oscillator with the bungee cords as springs and the sphere as the mass. (Yann Hello tells me he has pictures of a deployed OBS showing the sphere hovering above the supporting ring.) The predominant mode of oscillation of the sphere appears to be rotational or a combination of rotation and displacement.

The computer system that was set up was adequate to the task, although we were hardware-limited from time to time. The Suns are appropriate platforms for OBS data management, even for such a logistically demanding cruise, but I think that next time I would take one more Sun and another good-sized disk. I would also make sure that Telnet was working correctly on all the Macintoshes. We found a way around this problem, but a more conven-

ient system could have been configured with a Sun UNIX window and a Mac graphic display running on the same Mac. Transfer of data from the Suns to the Mac is currently limited to AppleTalk speeds, but the future may hold a technical fix for this problem.

The compressor and airgun systems may be the most difficult to improve or to sustain in the long run. The compressors had an excessive rate of failure because of overheating problems. It may be that the redesign of the compressors for an increase of rate to 180+ scfm was an ill-advised change. It may be worthwhile to ask for reports on performance from other users of this water-cooled system. The surface water temperatures were about 85° F in the work area, but one would think that a modest increment in water flow would make up for the higher ambient water temperature. We may need to supply additional saltwater pumping on future cruises.

The future is less clear for our big guns. Bolt's disappointing technical support is hard to interpret; perhaps we should think more in terms of better-supported sources. Clusters of sleeve guns may be an eventual solution, or closely spaced Bolt 1500C guns may get our low frequency limits below 10 Hz. The single gun shots used in this cruise were fairly effective: the trade-offs between energy, shot interval, and reverberation worked adequately for the needs of this program. Single-trace data showed rather poor S/N, but I think this is not so much the fault of the source. We had anticipated some problems of this sort due to reverberation on the hard rock bottom, and it may be a difficulty we have to accept. Record sections show the phases we seek with adequate clarity to confirm the presence of melt. We are just beginning to work on more traditional data analysis to determine if these data are more generally usable.

Research Vessel Cruise Assessment

R/V John V. Vickers
Project MAMBO
23 April - 28 May 1993
Jan Garmany, Chief Scientist

This report concerns ship operations aboard the R/V John V. Vickers on cruise JVV009, 23 April to 28 May 1993. The scientific mission of this cruise was to test the hypothesis that there are melt accumulations at the base of the crust near mid-ocean ridges. The chief scientist designated the project as MAMBO, which is an acronym for Melt At the Moho BOundary. Except for a nearly disastrous first deployment that saw 50% instrument losses, the cruise was a great success. We had further instrument losses, but we were able to fulfill the mission of the cruise with the remaining instruments. We had excellent data from 43 ocean bottom seismograph (OBS) sites out of 46 recoveries. The data indicate the presence of melt at or near the Moho boundary more than thirty kilometers from the ridge axis. We also found a very high percentage (perhaps 50%) areal distribution of melt in regions within 10 to 15 km of the ridge. These findings are preliminary, but it is obvious that they are very significant

The Vickers turned out to be an excellent platform for this project. Our scientific crew was small, so the ship was uncrowded. The food was excellent (thanks to Deb Cillo and Charlene D'Amore) and the staterooms were comfortable. The Vickers is prone to rolling, but she seems no worse than the AGOR 3 class ships I have been on before (the Washington and the Thompson). With the high freeboard, the backdeck was typically dry, which is unusual in my recent experience. The inside scientific space available to us was of high quality and readily adaptable to our needs. The conditioned electrical power in the labs worked very well with a lot of transient-sensitive electronics, even while switching the ship's generators. My only real complaint about the physical amenities is that the potable water is only just barely so. If disguised in coffee or bug juice, the water is acceptable. Fortunately, the needs of chemical oceanographers provided us with a source of high quality filtered and deionized water.

The underway data acquisition was very limited on this cruise. We took bathymetry to survey OBS deployment sites, but with the extensive prior swath-mapping in this area, it was like bringing coals to Newcastle. There are some problems with ship-generated noise on the 12 kHz bathymetry, but we were not much impaired.

The methods worked out for deployment and recovery of our instruments were effective and safe. Yann Hello suggested the use of an inflatable boat to recover the OBS's. We are indebted to Jeff McDonald, the Vickers's bosun, for his expert help all around, but especially in piloting the launch on recovery. He and Yann Hello endured some marathon recovery sequences. Jeffs seamanship is of the very highest level, and his helpful can-do attitude is an inspiration to all.

The deployment and recovery of the airguns always made me nervous, but this was not the fault of SIO airgun tech Perry Crampton or the ship's crew. There seems to be no graceful way to hurriedly lower a 1200-lb airgun and its heavy rigging. Also, the deep sea winch used in suspending the airgun seems to have no speed between dead stop and 1 meter per second. Perry did most of the work on the airguns. However, when the early difficulties with the rented compressors became too great to ignore, the help provided by Roger Harrington, the Vickers's chief engineer, was absolutely indispensable.

There was some confusion about the available range of ship's speed early in the cruise. When the schedule of operations I prepared called for towing the airgun at less than 6 knots, the captain informed me that the direct diesel drive could not turn slowly enough. Some quick consultation with USC and the engine manufacturers gave us a fix that permitted us to cruise at 6-7 knots, which was acceptable. In the end, the airguns seemed not to be too adversely affected, and the extra time allowed by the higher cruising speed permitted more contingency time for gun maintenance. To be frank, the misunderstanding about ship speed arose because it did not occur to me to ask if the ship could go as slowly as I wanted.

We appreciate the work done by the USC office on the beach. Don Newman and Rick Pieper were most helpful in our preliminary and operating arrangements. We especially appreciate the email service. Thanks to Bob and Dave on the beach for their fine welding. Scott (Tonn), Bruce, and Al also helped us with cutting and welding at sea: thank you, too.

The crew of the Vickers are a fine team, and it seems a pity to break them up. Captain Steve Manzo and executive officer Mike Mallette run a good operation, and we appreciate all of the hard work they have done leading a crew to perform most professionally under the cloud of the Vickers's uncertain future. On the basis of the ship's technical capability and the proficiency of her crew, I would not hesitate to choose the Vickers again for this project.

From perry@sdsioa.UCSD.EDU Fri Jun 4 11:29:25 1993
Return-Path: <perry@sdsioa.UCSD.EDU>
Received: from ucsd.edu by utig.ig.utexas.edu.ig.utexas.edu (4.1/SMI-4.1)
id AA08865; Fri, 4 Jun 93 11:29:22 CDT
Received: from sdsioa.ucsd.edu by ucsd.edu; id AA21542
sendmail 5.67/UCSD-2.2-sun via SMTP
Fri, 4 Jun 93 09:33:11 -0700 for jan@utig.ig.utexas.edu
Received: by sdsioa.UCSD.EDU (5.61/UCSDGENERIC.4)
id AA11506 to jan@utig.ig.utexas.edu; Fri, 4 Jun 93 09:31:40 -0700
Date: Fri, 4 Jun 93 09:31:40 -0700
From: perry@sdsioa.UCSD.EDU (Perry Crampton)
Message-Id: <9306041631.AA11506@sdsioa.UCSD.EDU>
To: jan@utig.ig.utexas.edu
Subject: Mambo Gun/Compressor Ops
Cc: perry@sdsioa.UCSD.EDU
Status: R

24 May 1993

To: Jan Garmany University of Texas Institute for Geophysics
From: Perry Crampton SIO/SGG

Subject: MAMBO EXPEDITION R/V John V. Vickers

AIR GUN AND COMPRESSOR OPERATIONS SUMMARY
2 each PAR 800CT Air Guns S/N 22 & 29
2 each Price Diesel driven Air Compressors
S/N 080292 Located on PORT side main deck
S/N 080892 Located on STARBOARD side main deck

23 April to 21 May 1993

Line #1 30 April to 1 May

Air Gun operation time:	36 hours 07 minutes	
Shots :	1700	
Comments :	No gun down time	
Compressor comments :	Had seven shut downs between the two compressors due to overheating.	
Starboard Compressor:	1st after	21 hours 12 minutes ops
	2nd "	0 " 45 " "
	3rd "	0 " 10 " "
Port Compressor :	4th "	0 " 20 " "
	5th "	0 " 15 " "
Starboard Compressor:	6th "	11 " 05 " "
	7th "	0 " 23 " "

Between Lines 1 and 2 removed the Port Compressor heat exchanger and plumbed it into the Starboard Diesel Engine, now Starboard Diesel and Starboard Compressor are each served by a dedicated heat exchanger.

Line #2 4/5 May

Air Gun operating time:		25 hours 03 minutes
Shots	:	1178 + 1 test shot
Comments	:	No gun down time, however gun was leaking but firing at 2000 psig at end of line.
Compressor comments	:	No overheating problems, no compressor problems.

Between Lines 2 and 3 had to swap air guns.

Line #3 7/8 May

Air Gun operating time:		28 hours 55 minutes
Shots	:	approx. 1360 (watch unaware gun failed)
Comments	:	Gun quit firing when Firing Source failed.
Compressor comments	:	Diesel engine shut down due to low fuel. No other problems with compressor.

Line #4 11/12 May

Air Gun operating time:		36 hours 07 minutes
Shots	:	1698
Comments	:	No problems, no shots lost.
Compressor comments	:	Began oil blowby out of crankcase vent of compressor.

Between Lines 4 and 5 move cooling system to Port Compressor because of starboard crankcase oil blowby.

Line #5 15/16 May

Air Gun operating time:		22 hours 53 minutes
Shots	:	1076
Comments	:	Lots of problems this line with air gun. 1st Trigger cable failed to gun 2nd Gun failed and had to swap in second gun.
Compressor comments	:	Port compressor failed, 3rd and 4th stages air pressure fell to 0 psig. Lost time while moving cooling system back to Starboard compressor and Diesel. At end of line starboard compressor 3rd stage reading 320 psig. Still putting out 2000 psig to gun.

Between Lines 5 and 6 pulled 4th stage booster cylinders from both compressors. Port 4th stage piston and cylinder wall in

excellent shape. Starboard 4th stage booster piston had almost no rings left, however cylinder wall was in excellent condition, with no damage. Decided to use port 4th stage piston in starboard 4th stage. Installed new inlet and exhaust valves from spares in starboard 4th stage. Suspect that starboard 4th stage sucked in a piece of the inlet booster valve gasket causing the damage to the rings.
Ran starboard compressor to check work, all stage pressures normal. Closed up port 4th stage booster cylinder with piston. Piston and used inlet and exhaust valves in box with spare filters.

Line #6 18/19 May (Last Line)

Air Gun operating time:		35 hours 14 minutes
Shots	:	1657
Comments	:	Finished scheduled track 5 hours early, ran additional lines until gun began leaking about 30 minutes before end time and compressor could not hold 2000 psig. Lost 30 minutes worth of shots.
Compressor comments	:	Compressor 3rd stage pressure dropped to 400 psig (660 normal) approximately 2 hours before end of shooting, but continued to supply gun with 2000 psig air until unable to supply 2000 psig because of leaking gun.

Air Gun s/n 22	shot total	=	5020 (with one rebuild)
s/n 29	" "	=	3652 (no rebuild)
Total shots both guns		=	8670 +1%
Port Compressor Operation (s/n 080292)		=	approximately 20 hours
Starboard Compressor Ops (s/n 080892)		=	approximately 220 hours