

## **Deep Seismic Imaging Study of the Taiwan Arc-Continent Collision**

### **Cooperative Research-US & Taiwan**

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Greg F. Moore, University of Hawaii  
Kirk McIntosh and Yosio Nakamura, University of Texas Institute for Geophysics  
Char-Shine Liu, National Taiwan University  
Allen Chen and Tan-Kin Wang, National Taiwan Ocean University  
How-Wei Chen, National Chung-Cheng University  
Tung-Yi Lee, National Taiwan Normal University

This project represents a collaborative seismic imaging program between geoscientists of the United States and the Republic of China (ROC) to study orogenic processes associated with the Taiwan arc-continent collision. Uplift rates measured along the collision suture in southeastern Taiwan are among the fastest in the world. Little is known about the crustal structure beneath this region or the mechanisms responsible for uplift at the critical transition from subduction to collision located in the offshore south and east of Taiwan. The US-ROC program will significantly increase understanding of crustal deformation in critical regions of a modern orogenic belt, which has served as an important model for the mechanics of fold-and-thrust belts worldwide. This investigation will provide the necessary regional information for ODP drilling proposed to study the closure of a forearc basin during arc accretion to a continent.

The seismic acquisition program will be cost-shared by U.S. and R.O.C. funding agencies. Our ROC colleagues have received an award to study collision processes along eastern Taiwan, including support for deep seismic profiling (MCS), ship time aboard the *R/V Ocean Researcher I* of the National Taiwan University to deploy and retrieve ocean bottom seismographs (OBS) from UTIG and the National Taiwan Ocean University, and land-based seismographs to record large airgun shots.

The U.S. component of this program will acquire approximately 1300 km of deep-penetration MCS data and the ROC-funded program will collect another 1600 km; both acquisition programs will be performed on a single cruise using the *R/V Ewing*. The MCS data acquisition will be overseen by D.L. Reed (SJSU) and Char-Shine Liu (NTU). The MCS data processing and modeling effort will be supervised by G.F. Moore (UH).

In addition to the proposed MCS program, each of two crossings of the collision zone will be instrumented with OBSs deployed by K. McIntosh, Y. Nakamura (UTIG) and A. Chen and T-K Wang (NTOU), as well as a line along the Chinese continental margin west of the accretionary prism, two east-west lines and one north-south lines east of Taiwan. There are 64 planned OBS deployment during the project. Onland seismometers will be deployed by ROC scientists along several lines to record far-offset arrivals for wide-angle reflection and refraction studies. Underway gravity along all lines will be integrated into the results.

The MCS program will focus on imaging the structure of the collision complex. MCS data will be recorded for 16-20 seconds using a 240-channel streamer, thereby producing 80-fold CDP every 12.5 m. The tuned source array will consist of 20 airguns with a capacity of 8385 in<sup>3</sup>; broad bandwidth of the array should provide excellent imaging of the upper crust as well as the lower crust. Each MCS transect is more than 200 km long and crosses a distinctly different region of the collision and subduction system.

Among UTIG staff and students participating in the OBS data acquisition and processing are Kirk McIntosh, Yosio Nakamura, Glen Caglarcan, Stephane Operto and Julia Liu. Ex-Students participating are Allen Chen of National Taiwan Ocean University and Tung-Yi Lee, National Taiwan Normal University.

**\*The OBS crew left port August 23, 1995 and is underway to the first deployment sites. The *R/V Ocean Researcher* does not have the capability to send electronic mail. We may receive updates from the *Ewing*. The two ships will be communicating by short wave radio.**

## Ship Report

Date: Fri, 25 Aug 95 14:37:47 GMT

From: ewing02@ewing.ldgo.columbia.edu (R/V Ewing Science Party E-Mail Box # 02)

Subject: message from Ewing

Cc: fly@classic.oc.ntu.edu.tw

Status: R

Dear Colleagues:

Due to the strong Kuroshio current which slows the ship down substantially, we are now 9 hours behind the shooting schedule. However, we will make that up by cutting out one or two of the MCS lines. So we still plan to shoot the Line 9 on time. Actually the airguns began to fire around 8:00 PM last night (August 24th) and have been continuous firing since. So your PANDA array may have received something if we are lucky.

Subject: message from Ewing  
by way of Tung Yi Lee

Cc: chiao@ccms.ntu.edu.tw  
Status: R

Dear Colleagues:

With a little bit delay due to getting the permits for the members of ROC scientific party to join the cruise, Ewing left Chilung at 3:30 PM yesterday (August 23rd). Due to the threat of typhoon, we modified our shooting schedule and headed to a southern location.

After discussing with the OBS group, we decided not to deploy OBSs #1 to #4, and will start collecting MCS and OBS data in the early evening of August 24th. This will put us back on the original shooting schedule, so there is no change on the sea-land shooting schedule.

The typhoon is no longer a threat to us, the sea condition is very good right now except that it is raining and a little difficult to work on the back deck. We are deploying MCS streamer on board Ewing and R/V Ocean Researcher I is deploying OBSs along Line 1 starting from OBS #5.

Everything is working fine. I will keep you posted.

Regards,  
Char-Shine

Date: Tue, 29 Aug 95 21:22:23 CST  
From: yosio@sun1.iag.ntou.edu.tw (dr. yosio)  
To: patty@utig.ig.utexas.edu

Hi, Patty,

You may be hearing from others also, but an approaching typhoon is giving us an unexpected break in our very busy schedule to send you this message. [We haven't be able to establish an Internet connection from R/V Ocean-researcher I, and thus we cannot send/receive e-mails while we are at sea.]

We sailed from keelung on August 24, a day later than we originally planned because of an approaching typhoon. We were forced to shorten our OBS coverage on the first line across Okinawa trough, Nan-ao basin, Ryukyu trench and the Philippine Sea, but we managed to drop 8 OBS's along the line and recovered them all with full data recorded on each.

Although the sea was rather rough for the first day out of Keelung, all five of us from UTIG, Kirk, Glen, Stephane, Julia and I, have been doing fine. Jack Pittar, the technician from AGSO, has been a great help for Glen and learning the OBS operation quickly, which is very assuring because we must depend on him for the second leg of our current cruise and then for the upcoming OBS cruise on the Northwest Shelf of Australia later this year.

Our next OBS line, the first onshore-offshore line east of Taiwan, was again delayed due to another typhoon, and we came back to Keelung to escape from rough weather, and we are standing by to find out which way the typhoon will move. Glen has already prepared 12 OBS's for the next two consecutive lines, and we are ready to go out to drop them as soon as the typhoon moves out of the area.

If we don't have any more typhoon coming our way, which may be a wishful thinking, we will stay at sea for the next two weeks until our port call at Kaohsiung, originally scheduled for August 9 but probably will be a few days later.

Regards,

Yosio  
on board R/V Ocean Researcher I - docked at Fisheries  
Research Institute in Keelung.

August 29, 1995

Date: Tue, 29 Aug 1995 08:53:57 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.ldgo.columbia.edu>  
Subject: Weekly Report From Ewing  
To: rawson@ewing.ldgo.columbia.edu  
Cc: patty@utig.ig.utexas.edu, ewing01@ewing.ldgo.columbia.edu,  
Eli Silver <esilver@earthsci.ucsc.edu>  
Mime-Version: 1.0

Hi Michael,

All systems operating well, but typhoon Kent is forcing modification of program until R/V Ocean Researcher I can resume deployment of OBS.

I have enclosed a weekly report, please forward to all interested parties at LDEO.

Regards,

Don Reed  
Char-Shine Liu

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Cruise Report for EW9509  
Week 1  
23 August to 29 August 1995  
Chi-lung to Kaohsiung

The week began with the R/V Maurice Ewing arriving in Chi-Lung on Sunday 20 August, 1 day ahead of schedule. Several members of the oncoming scientific party joined the ship late in the afternoon on Monday 21 August in order to hold a pre-cruise scientific meeting with members of the OBS program to be conducted with the R/V Ocean Researcher I of the National Taiwan University. Char-Shine Liu, chief scientist in charge of the R.O.C. component of the MCS program made great efforts throughout the day to finalize clearance issues with R.O.C. officials, principally involving clearance for the R/V Ewing to conduct research in R.O.C waters, as well as allowing R.O.C. citizens to join the research expedition. Later that afternoon, workstations and personal computers were loaded aboard the ship for seismic data processing and analysis during the voyage.

On the morning of 22 August, Michael Rawson informed the scientific party that in order to receive clearance for work in the EEZ of the Philippines, it would be necessary to accomodate two visiting scientists from that country. A plan was proposed by which the Philippine observers would first fly to Taipei and meet with Dr. Allen Chen who will be joining the M/V Ocean Researcher I during a port call currently scheduled for Kaohsiung on 10-11 September. The observers will accompany Dr. Chen on the R.O.C. ship and be transferred to the R/V Ewing at a scheduled meeting time on 14 September, 1 day prior to entering the Philippine EEZ. The observers will be transferred back to the R.O.C. vessel on 17 September for return to Kaohsiung following completion of work in the Philippine EEZ.

Throughout the day of 22 August, Char-Shine Liu continued shuttle diplomacy with R.O.C. authorities on clearance matters. Prior to lunch, guests and family from R.O.C. scientific institutions are provided with tours of the ship. Members of an R.O.C. television crew join the R/V Ewing in order to

produce documentary of experiment during the first two weeks of the voyage after which they will be transferred to the M/V Ocean Researcher I to film the OBS program. A catered lunch reception was held for all members of the ship, as well as visiting members of R.O.C. scientific institutions and the press at National Taiwan Ocean University in Chi-lung. The Institute of Oceanography at National Taiwan University and the National Taiwan Ocean University served as hosts for the reception, which was followed by tours of the R/V Ocean Researcher I in the afternoon.

In the meantime, news arrives on 22 August that tropical storm Janis may move into region scheduled for MCS streamer deployment. Also, several pressure relief valves for compressors have not arrived aboard ship as scheduled with other packages and a tracking search is begun with the shipping company. On Wednesday 23 August, the scheduled morning of departure, Michael Rawson informs chief scientists that clearance to work in EEZ of Japan does not appear to be issue, as long as fishing rights are not violated and daily report of location provided to nearest Japanese radio station.

However, tropical storm Janis remains a threat to both the streamer deployment plans of R/V Maurice Ewing and the OBS deployment program from R/V Ocean Researcher I. However, R.O.C. clearance issues appeared to be headed towards a solution, it is only a matter of time before the proper stamps of approval are in place. By late morning, the pressure relief valves are located with UPS and transferred to the ship. Master O'Loughlin requests a new area for streamer deployment in order to avoid path of approaching tropical storm Janis. New deployment site is selected to the south of original site. In mid- afternoon, clearance from the R.O.C. is approved and the R/V Maurice Ewing departs Chi-Lung harbor at approximately 1530 on 23 August.

Scientific Lab watches begin at 1930, following scientific meeting in ship's lounge. A Hydrosweep and 3.5 khz echo-profiler survey is conducted adjacent to Line 1 of MCS/OBS program during transit to streamer deployment location. Deployment of MCS streamer begins on Thursday 24 August shortly after breakfast under rainy skies, but reasonably light winds and calm seas. Hydrosweep acquisition continues throughout streamer deployment. M/V Ocean Researcher I departs Chi-lung to begin OBS deployment area at stations 5 through 13 along line 1; stations 1 through 4, 7, and 14 are cancelled in order to make up for time lost to delayed departure and change in streamer deployment plans caused by tropical storm Janis. Several sections of streamer are swapped out during deployment and a large amount of oil is added to streamer; leaks in streamer also are patched. All in all, streamer is deployed efficiently and with care by members of LDEO and ship, an excellent job by all under rainy conditions. Streamer is deployed by 1900 and airgun deployment begins with first shot of LDEO 20-gun array fired at 1945. Ship begins transit to beginning of line 1.

Seismic data acquisition along Line 1 begins in the early morning hours of 25 August. As ship proceeds southwards along course of 180, the power of Kuroshio current slows progress of ship; a maximum speed of 5.0-5.5 kts results in 1.8-2.0 knot speed over ground. However, all data acquisition systems are performing well. MCS data acquisition falls behind schedule through the day and evening due to strength of the Kuroshio. OBS recording windows are increased an additional three hours to accomodate delayed schedule. Layout of MCS program is shortened along lines 2 and 3 in order to make up time and meet OBS deployment schedule

for line 9 northeast of Taiwan. Several interesting features are noted along early seismic lines including seismic reflectors in lower crust of the Philippine Sea plate to the west of Gagua ridge. Hydrosweep provides excellent imaging of deep-sea channel which extends from southeast Taiwan, across the Luzon volcanic arc, and into the backarc region of the Philippine sea plate before bending northward towards the Ryukyu trench.

Greg Moore makes excellent progress in display of near trace sections with onboard processing system and migrated brute sections of near 30 channels. Also Bill Robinson activates Peter Buhl's real-time seismic display program, splitter.

Early in morning on 27 August, Line 1 is completed, all 337 km and 9758 Shot Records. Major observations include accretion of thick trench turbidite wedge overlaying thick pelagic sequence along Ryukyu trench; backthrusting at rear of accretionary prism, faulting on south side of Okinawa trough, and previously noted deep reflector (4.5-5.0 km deep) in lower crust in Philippine Sea basin near Gagua Ridge. MCS data is acquired along Lines 2 and 3 while OBS instrumnets are retrieved by M/V Ocean Researcher I along Line 1. Unfortunately, another tropical storm, Kent, is brewing east of the Philippines with projected path located just below southern tip of Taiwan. Consequently, the Master of R/V Ocean Researcher I will make decision on morning of 28 August about modifications to OBS deployment program over next few days.

Throughout the day of 27 August and into morning of the 28th, we collect 50 km of MCS data along line 2 followed by 93 km of MCS data along line 3, the latter being a west to east crossing of the Gagua ridge, a steep-sided linear volcanic ridge with a relief of more 2500 m above the basin floor. The crossing of the ridge lies near its intersection with the Ryukyu trench, which is located only 40 km to the north. The basin floor to the west of the ridge exhibits a major graben containing more than 2 seconds of sediment. The basement low also appears to control the location of a major deep-sea channel which extends from the collision suture along southeast Taiwan to the Ryukyu trench to the north; it is a very interesting sediment transport system in a collisional setting and clearly merits additional studies in the future.

The morning of 28 August dawns with a rolling sea, presumably related to tropical storm Kent, which lies to the south of us near Luzon. We begin line 5 which extends west-northwest, crossing the Gagua ridge near the outer trench slope along the Ryukyu arc; Line 5 north westward to the coastline along eastern Taiwan, near the western termination of the trench. Complex patterns of deformation mark region as well as highly sediment accumulations. Line 5 is completed successfully, adding another 268 line kilometers of MCS/Hydrosweep data. Tropical storm Kent is upgraded to Typhoon status and is heading for survey area, although exact path is not clear. Seas remain calms and winds are light, but swell begins to slowly increase. R/V Ocean Researcher I heads for safe post in Chi-lung after successfully recovering all eight OBS instruments along Line 1. MCS operations continue into 29 August with crossing of upper Ryukyu trench slope with additional 170 km of MCS/Hydrosweep data collected along Line 7. We are now running a due north line across the Okinawa trough as we await return of R/V Ocean Researcher I following passage of typhoon. Seas in this region are relatively calm, although moderate swell is developing. The Bridge and scientific party are keeping a close eye on typhoon Kent in

order to determine appropriate form of action once storms' path near Taiwan is known.

All systems are working very well, except for relatively minor problems, MCS tape labels occasionally stick to feed roller and real-time MCS display generates large disk files (seg.y.gmt) which fill file systems on splitter. In summary, both ship and crew of R/V Maurice Ewing perform very well throughout first six days at sea during acquisition of nearly 1100 km of MCS/Hydrosweep data with all major scientific objectives reached. OBS deployment is successful due to efforts of group aboard R/V Ocean Researcher I. By the late afternoon of 29th, typhoon Kent appears to be headed slowly west-northwest and is forecasted to track south of Taiwan. MCS operations aboard R/V Maurice Ewing will move to north of survey area due to forecast of high seas east of Taiwan and will acquire MCS data across Okinawa Trough until seas decrease following passage of typhoon. OBS operations will await R/V Ocean Researcher I departure from Chi-lung, probably on morning of 31 August.

Don Reed  
Char-Shine Liu



Date: Fri, 1 Sep 95 08:33:58 GMT

From: ewing02@ewing.ldgo.columbia.edu (R/V Ewing Science Party E-Mail Box # 02)

To: b0208@ntou66.ntou.edu.tw, chenth@vax.oce.ntou.edu.tw,  
chiu@ceri.memphis.edu, fly@classic.oc.ntu.edu.tw,  
gensin@taiwan.cwb.gov.tw, patty@utig.ig.utexas.edu,  
seirock@eq.ccu.edu.tw, seiswei@eq.ccu.edu.tw, t44001@cc.ntnu.edu.tw,  
wang@sss.gep.ncu.edu.tw, wangcs@vax.oce.ntou.edu.tw,  
wbin@taiwan.cwb.gov.tw, wu@sunquakes.geol.binghamton.edu,  
yehyh@earth.sinica.edu.tw

Subject: New survey schedule

Dear Colleagues:

Following is a revised waypoint log which should replace the one I sent to you yesterday. This one is more complete and have corrected some typo errors in the previous one (corrected waypoints are showing with @ symbols).

#### WAYPOINT LOG:

Following is a list of the EW9509 survey waypoints and shooting log. The time for the beginnin and ending of each line is good to min. Please see actual shot time table for the exact time.

We have put new waypoints between the end of the first sea-land profile and the starting point of the third sea-land profile (the one across the Henchung Peninsula). After that, we should get back to our original planned survey track. Yosio and Kirk may help us to calculate the time needed for this revised survey track. If we are no more than three days behind our planned schedule by the time we get to waypoint 26, we are in good shape.

Best of luck.

Char-Shine, Don, Neil and Greg

#### EW9509 WAYPOINTS

WAYPOINT	LAT	LONG	
A	25 06'	122 33'	
B	24 57'	122 34'	
C	24 30'	122 31.5'*	* MODIFIED
D	23 55'	122 34.5'*	
E	23 55'	122 25.5'	
F	24 30'	122 28.0'	DEPLOY STREAMER
G	24 56'	122 28.0	

Begin Seismic Survey

\* Please note that local time = GMT + 8 hours.

\* The planned ship track is ship tract version 0802 (in ftp file).

WP #	Lat.	Long.	Type of work & estimated operation time
0.	24 49' N	122 41' E	Begin Line 0 at 13:50 (GMT), 08/24
0a.	24 58' N	122 33.5' E	
0b.	25 8.5' N	122 33.5' E	End Line 0 at 16:36 (GMT), 08/24
1. @	25 10' N	122 30' E	Begin Line 1 at 17:40 (GMT), 08/24
2.	22 07' N	122 30' E	End of Line 1 at 23:19 (GMT), 08/26 Begin of Line 2 at 01:35 (GMT), 08/27
3.	22 44' N	122 20' E	End of Line 2 at 05:53 (GMT), 08/27
4.	22 44' N	123 15' E	End of Line 3 at 16:11 (GMT), 08/27
5.	22 42' N	123 15' E	Begin of Line 5 at 16:40 (GMT), 08/27
6.	23 30' N	121 37' E	End of Line 5 at 14:18 (GMT), 08/28
7.	23 23' N	121 37' E	End of Line 6 at 17:30 (GMT), 08/28
8.	24 24.5' N	122 45' E	End of Line 7 at 05:04 (GMT), 08/29
9.	25 41.5' N	122 45' E	End of Line 8 at 17:42 (GMT), 08/29
10.	25 40' N	122 15' E	End of Line 9 at 23:05 (GMT), 08/29
11.	25 10' N	122 15' E	End of Line 10 at 07:05 (GMT), 08/30
11a.	25 27' N	121 46' E	End of Line 11 at 13:40 (GMT), 08/30
11b.	25 23' N	121 44' E	End of line 11a at 15:20 (GMT), 08/30
11c.	25 04' N	122 16' E	End of line 11b at 23:16 (GMT), 08/30
12.	24 55' N	122 15' E	Begin of line 12 at 05:00 (GMT), 08/31
13.	24 55' N	123 25' E	End of line 12: MCS (12 hrs.)
13a.	23 52' N	123 25' E	Continuation of MCS Line 13
14*.	23 42' N	123 30' E	End of Line 13: MCS (15 hrs) Begin of Line 14 at 08:00 (GMT) 09/01: MCS, OBS, 20 second shot interval (29 hrs.)
			* Waypoint #12 of planned ship track
15*.	24 05' N	121 41' E	End of Line 14 at 13:00 (GMT) 09/02
			* Waypoint #11 of planned ship track

- 16\*. 24 09.38' N 121 42' E Begin of Line 16 at 14:00 (GMT) 09/02:  
MCS, OBS, LAND RECORDING, 40 second  
shot interval (15 hrs.)  
\* Waypoint #10 of planned ship track
- 16a\*. 23 59.7' N 123 00' E  
\* Waypoint #9 of planned ship track. This location is the end of  
the first sea-land profile of planned ship track Line 9.  
The present plan is to continue shooting to Waypoint #17a.
17. 23 56.7' N 123 25' E End of Line 16 at 10:00 (GMT) 09/03
18. 21 51' N 123 25' E End of Line 17: MCS (25 hrs)
19. 21 51' N 121 05' E End of Line 18: MCS (29 hrs)
20. 22 40' N 121 05' E End of Line 19: MCS
21. 22 40' N 121 20' E End of Line 20: MCS/Transit
- 22\*. 23 2.72' N 121 20' E End of Line 21: MCS/Transit  
Begin of Line 22 at 04:00 (GMT) 09/06:  
MCS, OBS, LAND RECORDING, 40 second  
shot interval (20 hrs.)  
\* Waypoint #17 of planned ship track
23. 22 20' N 122 45.5' E End of Line 22 at 00:00 (GMT) 09/07
24. @ 22 20' N 120 55' E End of Line 23: MCS
25. @ 22 32' N 121 00' E End of Line 24: Transit
26. @ 22 32' N 121 47' E End of Line 25: MCS
27. 22 12' N 122 00' E End of Line 26: Transit  
Begin of Line 27: MCS, OBS, Land Recording
28. @ 22 12' N 120 55' E End of Line 27: MCS, OBS, Land recording
29. 21 51' N 121 10' E End of Line 28: MCS/Transit
30. @ 21 51' N 120 25' E End of Line 29: MCS

Then we are back to the original planned survey tracks (the waypoint numbers will need to be changed after this modification).

At the end of Line 16, MCS lines will be designed to provide about 66 hours for the redeployment of land seismometers and OBSs along the southern cross-island profile (Line 22).

Time to start shooting the second sea-land profile is around 4:00 (GMT) or 12:00 local time of 09/06. Note that we will shoot both sea-land lines starting from the west (near Hualien for line 16, near Taitung for Line 22) and shoot steaming to the east, so that land instruments should start

to record at the begining of both these lines. Firing rate for these lines  
will be 40 seconds.

Date: Sat, 2 Sep 95 08:07:09 GMT

From: ewing02@ewing.ldgo.columbia.edu (R/V Ewing Science Party E-Mail Box #

Subject: message from Ewing

Hello, our dear Colleagues:

After typhoon Kent passed, we continue our survey in the Okinawa Trough, Ryukyu arc and forearc basin area. The weather is beautiful, the sea is calm. We have collected many high quality and interesting seismic data.

Well, yesterday was a busy day. We were sailing between two Japanese islands along 123 25' E on our way to the starting waypoint of the next MCS/OBS profile along the center of the forearc basin. The captain thought we had obtained permission to work in the Japanese water, so we let our survey line come less than 12 nm from a small Japanese island. Then suddenly a Japanese airplane came circling over the ship. Soon, a helicopter came and talked to the Ewing via radio. We told them why we were there and what we were doing. Later, as the helicopter and airplane left, a patrol boat came and followed us.

By two o'clock in the afternoon, the Ocean Researcher I came to meet the Ewing and prepared to pick up the two Public Television Station reporters. There was a Japanese patrol boat following the Ocean Researcher I as well. Ewing lowered small boat and sent the two media people to the Ocean Researcher I while the two Japanese patrol boats were watching from a distance away. Dr. Yosio Nakamura on board the Ocean Researcher I talked to one of the Japanese patrol boat to explain what we were doing, it seemed that everything was OK. Then late in the afternoon when Ocean Researcher I headed west to prepare the deployment of OBSs (the patrol boat that followed the Ocean Researcher I had left), the patrol boat following Ewing radioed and requested to board Ewing for an inspection. Since the Ewing was out of Japanese territorial water long time ago, the radio communication from Japanese boat was not very clear and difficult to understand, tension was high for a short period of time on board Ewing. The Ocean Researcher I turned back and Yosio tried to talk to the Japanese patrol boat but without success. This situation lasted for over one hour while Ewing was still conducting the seismic survey. Finally by early evening, the Japanese patrol boat talked to the captain of the Ewing, asked some questions, emphasized the 12 nm territorial water zone, and requested the Ewing to report her position everyday while in the waters near Japanese islands, etc. They did not request boarding the Ewing anymore. The Ocean Researcher I then headed back to the OBS deployment location, and the Japanese patrol boat went away after another couple hours of escorting.

Things had not finished yet. Late at night, we received fax from Lamont that forwarded a request from the U.S. State Department for an explanation of the incident. So we had to submit an explanation. By that time, it was one o'clock this morning. What a day!

Today (September 2) is a quite day. We are conducting the MCS and OBS profiling along the Nanao Basin. Very dramatic variations are observed for the forearc basin basement. Tonight we are going to conduct the first sea-land profile that across the central Taiwan. Hope everthing goes well.

Cheers,  
Char-Shine

## **R/V EWING SHIP REPORT**

Date: Wed, 6 Sep 1995 10:40:06 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.lldgo.columbia.edu>  
Subject: Weekly Report Forthcoming

I am finishing up the weekly report from Ewing, but will not complete it for another hour or so and will miss the evening (morning EST) e-mail deadline on the ship. I will send it with the ship's morning (afternoon EST) transmission.

Have you heard anything from the Philippine observers? The R/V Ocean Researcher I will be delayed by a few days from reaching Kaohsiung with port call scheduled for 13 September, I believe, we will send dates tomorrow.

Don Reed  
Char-Shine Liu

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**\*FYI**

*The way the mail works to/from the Ewing is that twice a day at 0730AM and 0430PM (East Coast time) the ship calls Lamont and transfers a batched compressed file of e-mail via uucp and a command to uncompress and unbatch the file and mail the individual messages out. Then the ship receives a batch file from shore and does the same thing there.*

Date: Thu, 7 Sep 1995 00:35:55 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.ldgo.columbia.edu>  
Subject: Weekly Report  
To: Michael Rawson <rawson@ldgo.columbia.edu>, sci@ewing.ldgo.columbia.edu,  
ewing02@ewing.ldgo.columbia.edu, patty@utig.ig.utexas.edu  
Mime-Version: 1.0

Hi Michael: Here it the weekly repot, sorry about its length, but it has been an exciting week.

Don and Char-Shine

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Cruise Report for EW9509  
Week 2  
30 August to 6 September 1995  
Chi-lung to Kaohsiung

The second week of the TAICRUST (EW9509) expedition began with a watchful eye on tropical storm Kent as it was upgraded to a typhoon, and ultimately to a supertyphoon. Throughout the early part of the week Kent's path was unpredictable, but it appeared that the storm would either cross over from the Philippine sea to the South China Sea south of Taiwan or take a more northerly route from the Philippine Sea to the east China Sea; it was a coin toss. However, the seas in our area remained relatively calm at least for the time being, so our work continued and we hoped for the best. In the meantime the captain of the R/V Ocean Researcher I, the OBS deployment ship, decided to return to the safety of the port of Chi-Lung because of the threat posed by Kent. MCS and Hydrosweep acquisition aboard the R/V Maurice Ewing continued at a good pace with all systems operating well.

We completed Lines 7 and 8 across the Philippine Sea, the Ryukyu trench-forearc system, and proceeded into the Okinawa trough. The seas, however, began to turn against us and the wind grew in strength as Kent approached Taiwan.

Compounding our troubles was the fact that the CSRU began to encounter intermittent errors of unknown origin requiring watchstanders to reboot the system on numerous occasions, thereby losing from 3-10 shots in the process each time. Joe and Chris worked around the clock attempting to find the source of the CSRU problem, but its intermittent nature made diagnosis difficult and frustrating; most every circuit board in the system was swapped with a replacement board, but the problem lingered on, albeit less frequently with the new boards.

We next acquired Line 9 extending due west along the northern flank of the Okinawa trough. The seas and wind continued to build through the evening of the 29th and into the following morning. From the northern margin of the Okinawa trough, we headed southward, into the building sea, just offshore of NE Taiwan where it is believed that the Okinawa trough spreading axis extends on land at the Ilan plain. Later that afternoon, Captain O'Loughlin advised that we seek shelter from the fierce winds and rapidly growing swell in a region north of Taiwan. R.O.C. chief scientist Char-Shine Liu designed two transects of the offshore extension of the northern portion of the Taiwan mountain belt, an offshore region which is normally inaccessible to MCS work due to a high level of fishing activity. However, it seems that the long-liners were fleeing from the path of Kent

as well (every dark cloud has a silver lining; no long-lines in this case). Two lines of MCS and Hydrosweep data were acquired north of Taiwan using the island as a shield from supertyphoon Kent which was crossing over to the South China Sea at the time. The rough seas degraded the quality of the MCS data nonetheless, as we awaited an opportunity for considerably calmer seas.

On Wednesday 31 August the sea continued to be rough, although probably somewhat less so than the previous evening. A sustained wind of more than 40 knots had weakened to 20-25 knots by 0900, more importantly the 50 knot gusts had disappeared. Consequently, it was decided to undertake some streamer work prior to returning to the survey area south of the Ryukyu arc. Several bad sections were swapped out and at least three leaks were repaired, in addition to attempting to trace the data acquisition problem to the streamer. Joe and Chris have worked long and hard on this problem both in the lab and on the deck. Members of the crew, led by the Captain, and Hydrosweep and airgun personnel all pitched in...great work by all. One section of the streamer was removed reducing the system to 156 channels. The MCS system was back on line by noon thus providing for the acquisition of high quality MCS data along a west-to-east transect along the axis of the Okinawa trough.

A crossing of the Ryukyu forearc was designed to avoid the strong effects of the Kuroshio current and to minimize the lingering ocean swell generated by supertyphoon Kent. The seas began to improve rapidly, consequently we headed southward for a waypoint in Ryukyu forearc to collect MCS/OBS line 14. On the way to this waypoint, we designed a forearc transect between two Japanese islands, thus allowing the ship to remain outside the 12 n.m. territorial limit surrounding each island. Unfortunately, a tiny island was not detected on the charts in the science lab when the track was first designed. However, in the early morning hours of Friday 1 September, the tiny island was first noticed on a second chart by Neil Lundberg; U.S. chief scientist Don Reed subsequently altered the ship's track to avoid the 12 n.m. limit of Japanese waters. Reed and Liu consulted with Captain O'Loughlin later that morning about the definition of our Japan clearance in order to determine if clearance included research in territorial waters. Based on an examination of a fax describing our clearance from Japan, which arrived the day before our departure from Chi-Lung, in combination with our combined experience with clearance issues in other foreign waters, it was agreed that clearance normally covers research work in territorial waters as well as the EEZ. Consequently, the ship's track was altered once again to return to our original MCS line which extended 1-2 n.m. inside Japanese territorial waters.

Within two hours, the ship was intercepted by a Japanese "Coast Guard" plane and a helicopter was dispatched from one of the nearby islands to investigate our activities. Conversations were held between Captain O'Loughlin and the helicopter pilot resulting in what appeared to be a resolution of the matter after we identified ourselves and clarified our research mission. We maintained a constant southerly course which had begun many hours before and a MCS acquisition speed of 4.0 knots. A Japanese vessel tracked our progress through the Japanese EEZ for the rest of the day and into the evening. Yosio Nakamura of the OBS group from UTIG on the R/V Ocean Researcher I negotiated in Japanese with the commander of the vessel, in order to avoid delays in our progress along Line 14. Yosio's assistance was critical to the successful acquisition of this MCS line.



On the evening of 1 September (local time), LDEO faxed word from the U.S. State Department that a formal complaint was issued by the Japanese government for a violation of territorial waters; the Master and chief scientists issued a reply stating the conditions which lead to the unfortunate situation. In retrospect, we should have notified the appropriate Japanese authorities by radio on the previous day even though our plans were not clearly defined at the time due to the changing weather conditions and the fact that we had yet to enter the Japanese EEZ. It also would have been helpful if the clearance papers from Japan would have distinguished between access to the EEZ versus territorial waters, although our original plans made no mention of work in territorial waters, but then again we did not anticipate the impact on our survey plan caused by supertyphoon Kent.

Late in the afternoon of 1 September, two members of the R.O.C. media, on board the R/V Maurice Ewing to film a TV documentary on TAICRUST, were transferred to the R/V Ocean Researcher I to film OBS activities. Excellent work by the crew of the Ewing during this potentially difficult operation.

Throughout the afternoon and into the next day, we acquired excellent MCS/OBS data along the strike of the Ryukyu forearc basin, which revealed dramatic variations in structural style and seismic stratigraphic relations where the Gagua ridge underthrusts the forearc as well as complex deformation near the termination of the forearc to the west at the boundary with the Eurasian plate. This line will contribute greatly to our understanding of the region.

Back in the lab, Chris suggested that the rigging of the tow leader for the streamer may be the source of our data acquisition errors, since the problems disappeared when the calm seas returned. This potential culprit will be examined next time work on the streamer is necessary.

MCS, OBS, and presumably land-based recordings proceeded smoothly on Line 15 to the north of Line 14. Land-based seismographs were deployed by R.O.C. and U.S. scientists across the island to record shots at 40-second intervals from the Ewing. Following the successful completion of Line 16, we began a due south line (Line 18) across the Ryukyu accretionary prism and trench and extending into the Philippine sea; this line also provides a southern continuation of our transect of the arc along Line 13. OBS along Lines 14 and 15 were retrieved, although we have not received word of their recording status.

On the morning of 4 September, we headed west along Line 19 marking the beginning of the NSF-funded portion of our program. We collected MCS and Hydrosweep data across the Philippine Sea while we headed towards the Luzon arc along southeast Taiwan. Our second sonobuoy profile was completed. The weather has been spectacular for several days running, helping to erase memories of Kent. By 5 September we crossed the Luzon island arc, which shows no evidence of backarc thrusting in contrast to past tectonic models in the region. Next we crossed the Taitung trough, a region which accomodates more than 50% of the convergence rate between the Philippine Sea and Eurasian plates according to recent GPS studies.

At 1030 in the morning, the ship was buzzed by a large helicopter of the

R.O.C. military. We continued our progress over the Huatung ridge and into the southern Longitudinal trough, a region of compressive deformation. We are intercepted by a fast-charging (28 knots) frigate of the R.O.C. Navy and are ordered out of the region immediately as a "live fire" military exercise is currently in progress. We subsequently received a telex which offered information on the dates, times, and offshore locations of naval exercises planned for this month around Taiwan. Luckily the exercise in our area of interest was scheduled to end that afternoon so we returned to the region later that evening to complete Line 19; the other military exercises will not impact our plans. After abandoning a very interesting Line 19, a long-line became entangled in the airgun array, much to the dismay of an irate Chinese fisherman who came suspiciously close to the tail buoy upon leaving the scene, however, no damage was done to the streamer. Char-Shine Liu had previously broadcast our plans for surveying the offshore in this region over the local fishery radio, but it seems that fisherman do not monitor these broadcasts nor calls from the bridge of the Ewing.

We proceeded northwards to collect an MCS crossing of the southern Longitudinal trough and Taitung trough; the onland extension of these features are considered by many to form the suture zone between deformed rocks of the Chinese continental margin (Eurasian plate) and the accreting volcanic arc located on the Philippine Sea plate. We have run several short MCS lines across this region, which have been added in our original plan because of the recent results of GPS studies in the region, especially in regards to the large amount of Eurasian-Philippine sea plate convergence which occurs in this region. However, this region is also located along a busy shipping lane within a narrow seaway between the island of Taiwan and a nearby volcanic island. The high volume of ship traffic forces us to leave the region in order to avoid jeopardizing the streamer.

During the late morning, Joe and Chris lead a group in replacing a section of the streamer, returning it to 160 channels. By mid-afternoon on 6 September we begin a combined MCS/OBS/Land station line extending across the entire width of the island and collision zone.

In summary, we have made great progress in reaching our objectives over the past week, which allowed submission via e-mail of an abstract describing our work to the Fall AGU meeting. The OBS deployment and retrieval has gone well along the first three lines scheduled for deployment with the completion of a fourth line expected on the morning of 7 September. Greg Moore is processing data at sea, allowing trace editing, mutes, and parameter testing to be undertaken shortly after MCS line is acquired; it is great to see near-trace sections, decon and filter tests, selected velocity analyses and F-K filtering, as well as portions of preliminary stacked and F-K migrated sections at sea. Seismic sections are produced on the NovaJet plotter in the Science lab.

The weather has been excellent after the passage of supertyphoon Kent. We have bounced back from several major setbacks, both natural and man-made, and have acquired more data than anticipated by this point in the cruise due largely to the hard work of the ship's crew from the bridge to the galley to the engine room. Special recognition goes to Joe and Chris for their valuable efforts, to the airgun crew, and to the bridge, which has had the difficult chore of guiding the ship (and streamer) though less

than hospitable fishing boats, commercial shipping vessels, naval operations, and storm conditions.

Before leaving one small item should be mentioned, there is a distinct sewer odor on A deck, which makes work in the science offices unpleasant.

Date: Thu, 14 Sep 1995 08:40:20 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.ldgo.columbia.edu>  
Subject: Week 3 Report  
To: rawson@ldgo.columbia.edu, patty@utig.ig.utexas.edu  
Mime-Version: 1.0

Hi Michael,

Here is the report for week 3 aboard the ship. We are currently doing a little on the streamer as we head south in the Taiwan strait. There is a tropical depression forming to the south of us, near the Philippines, and a monster of storm in the western Pacific (typhoon Oscar). It appears that Oscar is moving towards Japan and may not impact our work, however, the small storm near the Luzon is difficult to predict at the moment.

Don and Char-Shine

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Cruise Report for EW9509  
Week 3  
7 September through 13 September 1995  
Chi-lung to Kaohsiung

The third week of the TAICRUST (EW9509) expedition proved less eventful than the first two, i.e. no typhoons or international incidents, but no less scientifically successful.

The weather and seas have remained calm and all data acquisition systems are working well. The MCS data acquisition system has experienced few of the errors which hampered operations earlier in the cruise. In general the streamer has been behaving well although variable currents in the region sometimes result in depressing the head of the streamer (first 4 birds) to a depth of 12-17 m during 10-15 km-long segments of several lines; maintaining a speed of 5.0-5.3 knots through the water seems to lessen the problem. Strong currents caused by the Kuroshio and other seasonal currents also cause significant streamer feathering, especially on east-west lines. Greg Moore continues to copy all MCS data to DLT tape and produce processed versions of near trace sections shortly after completion of MCS lines, adding to the quality of shipboard interpretations and our confidence in the quality of MCS data acquisition.

Hydrosweep is operating well as are the underway geophysics systems. One noteworthy problem occurred on the afternoon of 11 September when all GPS systems mysteriously gave erroneous readings and the GPS clock showed an incorrect time; there was no apparent source for the error aboard the ship and we were a great distance from land. Joe suggested that possibly we were being showered with microwave energy. Approximately 1.5 hours later, the Magnavox systems first returned to operation, but the Trimble required a recycling of power.

During the week, we accomplished several major scientific objectives and collected more data than anticipated during the period. We have successfully completed all MCS/OBS acquisition across collision region around the southern tip of Taiwan. Southeast of Taiwan we have acquired seven MCS lines, one deployed with OBS, across the region where the forearc basin is in the process of closing due to the accommodation of as much as 50% (40-50 mm/yr) of the motion between the Eurasian and Philippine

Sea plates. Crust shortening in the region occurs principally along a west-dipping thrust located at the base of the western margin of the Taitung trough (collapsed forearc basin). Along this feature, the volcanic arc underthrusts the Huatung ridge, which is composed of thrust-deformed sediments which formerly occupied the forearc basin. The growth of the ridge adds significantly to the width of the accretionary prism. The detailed structural and sedimentologic variation is remarkable in the region, due to the impingement of the irregular surface of the island arc against the rear of the prism, thereby dividing the forearc basin into several small, satellite basins located along the zone of convergence at the back of prism. All seven crossings of the Taitung trough, however, show a west-dipping thrust which separates thrust deformed strata of the Huatung ridge from the underthrusting slope of the volcanic arc. Even without the GPS data, one certainly gets the impression that a large amount of convergence occurs along this feature, based on the cross-sectional area of the Huatung ridge (deformed forearc basin sediments) and the decrease in distance between the volcanic islands and the crest of the accretionary prism, the latter feature maintains a constant orientation and position from the region of subduction in the south to that of collision in the north, thereby providing a useful datum for measuring changes in width of the prism produced by the collision.

We have imaged deformation along the boundary between the Huatung ridge (i.e. forearc basin strata incorporated into the rear of the accretionary prism) and the prism itself, although an interpretation of the structural style in this region must await the generation of migrated sections. Clearly, however, the volcanic arc is not deformed by thrusting either on its east (backarc basin) side or west side (forearc basin side) as hypothesized in previous models or as in the latter case has been documented onland along the Longitudinal Valley on Taiwan.

One MCS/OBS line with land stations has been completed across the southern tip of Taiwan as well as a second MCS line crossing the entire forearc region from the island arc to the northern extension of the Manila trench. All OBS instruments have been recovered up to this point by the scientific group aboard the R/V Ocean Researcher I, which is currently making a port call in Kaohsiung to take on additional provisions and to exchange members of the scientific party. The second MCS line across the entire forearc just south of the island shows the volcanic arc underthrusting deformed forearc basin strata along the rear of the accretionary wedge, a possible offshore extension of the Hengchun fault, an east-dipping thrust mapped onland at the southern tip of Taiwan, and thrust deformation of very thick deposits of the Chinese continental margin and overlying orogenic deposits derived from Taiwan. We have identified several mud diapirs in MCS data and at least 1 mud volcano (beautiful circular image on Hydrosweep record) near the southwest coast of Taiwan. A short MCS line across the outer Chinese passive continental margin reveals a total sediment thickness in excess of 6 sec overlying fault blocks in the underlying basement.

Operations aboard the R/V Maurice Ewing are proceeding well with the good weather allowing for the completion of a significant amount of deck maintenance. The sewage odor is no longer a problem in the science office on A Deck, but the shipboard air conditioning system(s) are deteriorating and being kept alive by the ingenuity and hard work of the Engineering department. Meals aboard ship have been very good with the gang of three in the galley making a special effort to accommodate

the tastes of members of the Chinese scientific party. The galley graciously allowed the Chinese participants to bake mooncakes for the Moon (Autumn) Festival, which is one of the most celebrated holidays in Taiwan. This courtesy is much appreciated by the scientific party.

The bridge has expertly guided the ship, plus streamer, through a high volume of small fishing boat and large commercial ship traffic along southwest Taiwan made especially difficult by periods of poor visibility. A chase boat, hired by Char-Shine Liu, is assisting the bridge's effort in plying major fishing grounds off western Taiwan. The chase boat has greatly assisted our operations by: (1) warning fishing boats of the approaching path and operations of the R/V Maurice Ewing, (2) removing long-lines caught on the streamer, and (3) advising the bridge on the nature of fishing operations in progress along the course of the ship.

We will have begun our operations in the Taiwan Strait funded by the Chinese Petroleum Company and National Science Council of the R.O.C., which will be completed by 0100 on 17 September (local time) after which we will return to region south of Taiwan. We are looking forward to completion of the current phase of work since ship traffic is quite high in the Taiwan strait, often ignoring pleas for distance from the bridge and the very shallow water, combined with hard seafloor, causes more than a little loss of sleep for all onboard due to the reverberations of the 8425 cu. in. airgun array.

After the Taiwan Strait and with the blessings of a tropical storm approaching the region, we will collect an MCS/OBS transect across Chinese passive continental margin, an MCS/OBS line across the forearc system at the transition from subduction in the south to arc-continent collision to the north, and a MCS transect of the Luzon arc subduction system. Weather permitting, we will collect additional MCS data over proposed ODP sites in the North Luzon trough (forearc basin) and across the accretionary prism during the final three days of our operations, prior to retrieving the streamer and entering the port of Kaohsiung on morning of 24 September.

In summary, we have made great progress in reaching the fundamental scientific objectives of the TAICRUST expedition. All members of the ship's crew and shore-based personnel in Marine Operations have contributed to our success thus far and we thank them. We look forward to the final 10 days of our operation.

Date: Fri, 15 Sep 1995 00:32:59 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.ldgo.columbia.edu>  
Subject: Re: Week 3 Report  
To: "Patricia E. Ganey-Curry" <patty@utig.ig.utexas.edu>  
Cc: ewing01@ewing.ldgo.columbia.edu  
Mime-Version: 1.0

Hi Patty,

Not much of the R/V Ocean Researcher I other than all OBS instruments have been successfully retrieved thus far. I haven't heard about the status of recording itself. The ship is in the port of Kaohsiung exchanging members of the scientific party and taking on food provisions. We expect them to return to sea on the 18th to begin deploying the final OBS line, which is actually two intersecting lines. Our weather has degraded over the past 24 hours, which may prevent Ocean Researcher from leaving port. In addition, a ship ran over the MCS streamer at 1830 last evening, severing the last seven sections in rough weather and in the dark. We returned to the scene but could not locate the lost sections. Today the Ewing will steam to the region southwest of Taiwan replace the lost sections and hope that our weather and the seas improve.

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Don Reed  
Dept. of Geology  
San Jose State University  
San Jose, CA 95192-0102  
dreed@geosun1.sjsu.edu or ewing01@ewing.ldgo.columbia.edu

!!!!!!!!!!!!!! Currently at sea off Taiwan aboard the !!!!!!!!!!!!!!!  
Research Vessel Maurice Ewing  
until 25 September  
R/V Ewing receives E-mail

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## FINAL EWING REPORT

Date: Thu, 21 Sep 95 07:48:15 GMT  
From: ewing02@ewing.ldgo.columbia.eduw  
Subject: Ewing cruise

Dear Colleagues and friends:

Well, this cruise started with a storm moving toward Japan which prevented us to collect MCS data as well as to deploy OBSs across the Okinawa Trough, and will end with typhoon Ryan that forces us out of the survey area off southern Taiwan.

We have now stopped all the seismic survey and are heading south toward the area east of Luzon to avoid rough seas south of Taiwan. By the time Ryan passes Taiwan, we probably will have to finish the cruise and head back to Kaohsiung. So I will just summarize the cruise in this short note.

The first week of the survey was carried out under the threat of typhoon Kent. Luckily we were able to collect some MCS profiles in the seas off eastern and off northern Taiwan before and during typhoon Kent passed through southern Taiwan.

In the following 10 to 12 days, we were having beautiful weather, and have completed all the work designed for the area off eastern Taiwan and on either side of the Hengchun Peninsula. Up to this time, we have collected MCS profiles across the Okinawa Trough and the Ryukyu subduction zone, the Ryukyu forearc basins (I use plural because we found that the Nnao Basin is not a single basin). We mapped thick deformed sedimentary layers in the eastern foot of the Luzon arc and meandering deep sea channel which connects the Taitung Trough to the Ryukyu trench. We have several profiles across the Gagua Ridge which suggests a more complex nature of that Ridge. During this period of time, we have also completed the shooting of 3 onland-offshore MCS-OBS profiles and 2 MCS-OBS profiles. Several E-W trending MCS profiles cross the incipient collision zone off southeastern Taiwan are collected. In the area off southwestern Taiwan, we have collected good quality MCS profiles across the passive Chinese continental margin and the frontal portion of the accretionary wedge. The Ocean Researcher I went back to Kaohsiung with plenty of OBS data on hand and without losing a single OBS. I was extremely pleased by then.

Our luck seemed ran out once we got into Taiwan Strait. The rough seas and shallow water degraded the data quality while made the chase boats ineffective in protecting the streamer. We were forced to discontinue the seismic data acquisition on a N-S trending profile very much interested by the Chinese Petroleum Co. Then we lost seven sections of the streamer by a cut-and-run ship. The last onland-offshore shooting for the purpose of getting a reversed profile across the southern portion of the Taiwan mountain belt was thus cancelled. The streamer repair job took us almost two days time. When we back on the MCS shooting, the rough sea bugged us continuously by raising the streamer almost to the surface thus severely degraded the data quality. The announcement by the ROC navy about a military exercise zone right in the middle of the Tainan basin caused great difficult in collecting a long profile along the axis of the Tainan Basin which is highly desired by the Chinese Petroleum Co. Even though, we still managed to collected couple short MCS profiles in



the Tainan Basin area and a long profile across the passive Chinese continental margin.

In the mean time, three tropical depressions became typhoon on after another. The first typhoon Oscar moved northward toward Japan that relaxed us a little bit. Typhoon Polly was stationary to the east of Luzon and then was pulled by Oscar and moved northeastward. However, typhoon Ryan that was the furtherest from us is now coming directly toward us. The OBS operation for the 2nd leg of the Ocean Researcher I could not be executed, and the MCS survey across the Luzon subduction complex was serverly curtailed by the bad weather and the equipment failures which were mostly cause be the rough seas. In the end, we spent more time repairing the streamer than collecting seismic data. Finally, the forecast of typhoon Ryan made the call to shut down our MCS survey.

Overall, when I look at the ship-track distribution on the map and the data we got, we have gone beyond the dream proposed during the TAICRUST Symposium back in 1991. Preliminary results came from this survey already helped us clarifying some thinkings from previous observation, and we have had many exciting discussions which generated new ideas about the Taiwan arc-continent collision. The marine seismic profiles and the OBS and onland seismometers will no doubt provide us fruitful information to test some of the new ideas. We have also defined several problems which could well be addressed by a Ocean Drilling cruise, and we are preparing a draft for an ODP proposal.

See you soon when we get back to Kaohsiung safely.

Cheers,

Char-Shine Liu

On board of the rocking and rolling R/V Maurice Ewing.

Date: Fri, 22 Sep 1995 07:54:47 +0000 (GMT)  
From: R/V Ewing Science Party E-Mail Box # 01 <ewing01@ewing.ldgo.columbia.edu>  
Subject: Weekly Report  
To: rawson@ldgo.columbia.edu, Patty Ganey-Curry <patty@utig.ig.utexas.edu>,  
Chi Wang <chiyuen@decollem.berkeley.edu>,  
Eli Silver <esilver@earthsci.ucsc.edu>  
Mime-Version: 1.0

Cruise Report for EW9509  
Week 4  
14 September through 21 September 1995  
Chi-lung to Kaohsiung

The fourth week of the TAICRUST (EW9509) expedition proved to be one that would severely test the will power, stamina, and patience of all members of the R/V Maurice Ewing. After two weeks of perfect weather and excellent data acquisition, the seas took a turn for the worse, which was shortly followed thereafter by a decline in the quality and amount of MCS/OBS data acquisition. Survey lines were constantly under revision as no less than 5 lines had to be abandoned due to rough sea conditions; two OBS lines were cancelled. The MCS streamer suffered as well with damage from ships and fishing long-lines.

Last week and early this week, the R/V Maurice Ewing proceeded north along the southwest margin of the Hengchun Peninsula where a high concentration of fishing long-lines were crossed by the vessel. A chase boat, hired by Char-Shine Liu, provided information on long-line locations as best it could.

The week began with three days of MCS contract work for the Chinese Petroleum Company (CPC) in the Taiwan Strait, which was scheduled to coincide with a port call in Kaohsiung by the OBS ship, R/V Ocean Researcher I, in order to take on additional provisions and exchange members of the scientific party. The MCS work in Taiwan Strait was plagued by a number of problems, including the high volume of commercial and naval ship traffic along the industrialized west coast of Taiwan, rough seas and high winds, in addition to shallow water with a hard seafloor, causing more than a little loss of sleep for all onboard due to the reverberations from the airgun array. The bridge maintained excellent control of operations and avoided ship traffic.

The sea condition degraded rapidly near the end of the first day of surveying in the Taiwan Strait, forcing an abandonment of MCS line 39 and a return to hopefully calmer waters in the south. It appeared that the northeast monsoon had arrived early this year as the seas all around Taiwan were very rough without an obvious low pressure system in the region. The rough seas also caused a decrease in the quality of the seismic data; part of the problem was traced to the streamer. The seas began to moderate on the following day, which provided an opportunity to undertake work on the streamer in the late afternoon.

The effort on the streamer proceeded well until shortly after dinner when two ships crossed in front of the tail buoy. The first vessel, a fast-moving R.O.C. naval vessel, did not pose a problem as the streamer responded to an emergency dive procedure and rose back to 10 meters after it was completed. However, 30 minutes later a freighter went over the end of the streamer,

ignoring calls and warning flares from the bridge. Shortly thereafter the birds at the end of the streamer failed to respond, so the streamer was retrieved in order to investigate the source of the problem. Many longlines with hooks and floats were wrapped around the first 4 to 5 birds of the streamer. By midnight of that evening our fears were confirmed as the severed end of the streamer was brought aboard the ship, short seven sections, two birds, and the tailbuoy. We returned to the area of the incident and began a nighttime search for the severed end.....without success. A reward notice for the lost sections was transmitted to the commercial fishing community in the area. Morale aboard ship was low.

We continued southward in order to undertake repair work on the streamer as best we could. Calm seas returned for a period of time-consuming streamer work. Everyone contributed to the effort from the ship's crew to the scientific personnel with especially long hours logged by Joe and Chris. The streamer was reduced to 144 channels and short 2 birds. To make matters worse, two of the import bird models were not responding. We began the survey for the CPC once again, although it was shortly evident that the streamer was not adequately balanced. Another streamer party was held to redistribute the birds and add lead weights to the head of the streamer. This portion of the survey also needed to work around specific hours and regions in the area that were restricted for military exercises during the month of September. The streamer could not be controlled, especially in a following sea. During this period, the R/V Ocean Researcher I returned to action, but OBS instruments could not be deployed due to the rough sea condition.

The CPC work was terminated after 3.5 days, even though the number of line kilometers of MCS data were below that stipulated in the contract. We returned to the NSF-sponsored portion of the expedition with a somewhat compromised streamer. The first line to be acquired was a long crossing of the passive margin to the west of the collision zone. This line was designed to assess the structure of continental margin prior to its entrance into the collision zone. OBS deployments had been planned along this line, but had to be abandoned as rough seas caused by the northeast monsoon continued into the third day. In addition a low pressure trough had formed to the south near Luzon island containing Typhoon Oscar, tropical storm Polly and a tropical depression to the west of Luzon. Oscar moved to the northeast and did not pose an immediate problem, although the other two storms were stationary with one on each side of Luzon. These storms posed a significant threat and the seas were already rough, so the R/V Ocean Researcher I returned to anchorage near Kaohsiung. The streamer behaved quite well during this line as we headed into the prevailing current and lowered the streamer operating level to 12 m, below wave base. After 24 hours, this line had to be abandoned as well, since the sea condition continued to worsen and it was not clear that we could reach of our objective in the south, a crossing of the Luzon subduction system. In general, however, this proved to be an excellent line. We imaged many new features on the margin, which sparked a stimulating round of scientific discussion about a chain of buried seamounts along the margin and their role in deforming the prism.

Next, we decided to undertake a crossing of the accretionary prism while the weather still permitted MCS acquisition. This line was designed to connect with a line across the forearc basin collected during the previous week. The line was completed successfully with excellent data being acquired. A short line was shot shortly thereafter across one of the

proposed ODP sites.

The seas began to calm down once again, so it was decided to install three sections to the streamer in order to increase fold during two critical crossings of the forearc basin and the rear of the accretionary prism. These sections had been punctured by longlines during the CPC survey, but were repaired and drained of seawater during work on the previous day. The seas were very calm and it was estimated that the work would take 3-4 hours.

Meanwhile, the tropical storm to the east of Luzon was upgraded to Typhoon Polly and began to move slowly to the northeast away from the study area. The system to the west of Luzon was upgraded to tropical storm Ryan and remained stationary between southern Luzon and Vietnam.

Things did not go well with the streamer, despite a great effort by Chris, Joe, and Captain O'Loughlin. The streamer developed an electrical short during retrieval and many leaks, which required a significant amount of time to correct. Every time one bad section was removed, the next in line would also be bad. Shortly thereafter the "bad" sections would test good on deck and on the reel; section after section was swapped out.

On at least two occasions the problem appeared to be fixed. On one occasion, all of the equipment was redeployed and we were waiting to fire the airgun array and then the error showed once again. All of this was very demoralizing, especially since the operation was consuming valuable time when the seas were calm during a week when the seas were rarely calm. More disconcerting was the fact that Tropical storm Ryan had developed into a typhoon which was forecasted to reach our work area in 24 hours or less. It was decided that the sections we were attempting to install, were the source of the problem, possibly due to water damage associated the longlines of the previous week. These sections were removed and the streamer was rebuilt approximately 22 hours from the beginning of the effort. We next began a crossing of the north Luzon trough in a critical region where the backthrust is well-developed. After only a few hours of shooting and two hours from our primary objective, the streamer died once again....same problem as before. Captain O'Loughlin also advised that we should consider leaving the area as Typhoon Ryan was approaching.

The decision was clear, retrieve the streamer and make our way for shelter from the typhoon to the northeast of Luzon where we would conduct a hydrosweep survey of the Gagua ridge and the east Luzon trough. At this point, we advised the R/V Ocean Researcher I to abandon any hope of OBS operations and head for its home port of Chi-lung as typhoon conditions were forecast for the remainder of our work. Hopefully we may have a few hours to return to our MCS survey after Typhoon Ryan passed and before our short transit to Kaohsiung.

Through the evening of 20 September and following day we conducted a survey east of the northernmost islands of the Philippines. The seas were only moderate in height through the evening of 21 September. However, by the early morning of 22 September, the seas and winds both increased so the Captain requested that we move further south as far from Ryan as possible, which we heartily agreed.

Currently we are steaming slowly northward after the typhoon has passed in

order to allow the sea conditions to decrease. We will attempt to return to the survey area late on the evening of 22 September to see if it is possible to acquire a small amount of MCS work prior to our transit to Kaohsiung.

In summary, the past week of work on the R/V Maurice Ewing has been plagued by rough weather and equipment problems. We have lost between 4 and 5 days of MCS survey time and two OBS lines. Even while working, we have been forced to modify line locations and lengths because of weather conditions. Everyone has given their top effort in attempting to circumvent these problems and we thank the crew and scientific personnel on the ship. We have collected excellent data during the relatively brief periods of calm seas. People are tired and the sea is rough, but everyone would like to make one last ditch effort to collect a small amount of MCS data in a critical area of our scientific program. Typhoon Ryan, however, has produced high seas in its wake, so the prospects do not appear to be good.