CRUISE SUMMARY

Moana Wave Operations on DUMAND Site

29 September - 5 October 1992

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1. Recovery of Current Meter String and Preliminary Analysis

The recovery of Dr. Flament's current meter string proceeded smoothly on 29-30 September. Initial acoustic telemetry with the dual acoustic releases at the mooring base indicated that only one of the acoustic releases was replying. The mooring was commanded to release in the early morning of 30 September and the morring was located on the surface using the strobe lights shorly after it surfaced. The distribution of mooring floatation was such that it should have all surfaced; however, only the top floats were seen at the surface.

Upon recovery it was found that 5 of the 17 floatation spheres had imploded. Most of the spheres were Benthos 17" float spheres made of pairs of mated hemispheres, with the remainder being ORE sealed spheres or other types. Most of the spheres were new or had received only one or two uses. Dr. Flament had checked each sphere carefully before deployment. The imploded spheres occurred in two clusters: the upper in a cluster of three where all of the spheres in the cluster had imploded, probably due to sympathetic implosion, since the spheres were all mounted of order 1 m apart. The lower cluster had two of three spheres imploded, although the spacing was the same. The damage to the hardhats varied considerably, with a general appearance as if a shotgun blast had been fired through the hat. This suggests that the implosions were quite asymmetric, but the appearance could be due to the way the hardhat was deformed upon initial infall before the explosive shock wave blew it out. All harhats retained their coupling to the chain mooring to which they were attached.

The top two current meters in the 350 m mooring were still functioning as they came on board. The bottom meter was missing its rotation vane. Since this meter was adjacent to the bottom cluster of floats which imploded it is probable that the implosion caused the loss of the vane. No other obvious damage was apparent on this meter.

All of the equipment on this mooring returned to the surface quite clean in appearance, with no indication of any marine growth after approximately six months of bottom time.

2. Acoustic Transponder deployment and survey

Deployment of 5 acoustic transponder moorings occupied the next 24 hours. The moorings consisted of a clump anchor made of heavy-link chain with approximately 100 kg weight in water, followed by a 1.5 m dacron pennant which was then joined to a 50 m length of 2.5 cm diameter polypropylene line. This line terminated to a dacron line bridle about 0.3 m in length which was joined to the transponder hardhat at its horizontal equator with four stopper knots. Above the transponder a 4 m bridle was left to allow anchor first deployment. One of the moorings contined two transponders, one at 50 m height above the anchor and the top one at an additional 39 m above.

The anchor-first deployment allowed us to check that the transponder was still functioning at the surface before it was let go. The transponders were deployed in the positions indicated by figure 1, with the double mooring at the northernmost positions. All transponders were found to be still responding after they reached the bottom.

Real-time position fitting software for the transponders was not available on this cruise, but single ranges taken with the UW deck box appeared to be repeatable at the few meter level. Data was collected independently using Digital Audio Tape recorders, and using the Sun workstations aboard the Moana Wave. An Oceano instrument command unit was used to initiate calibration data by a relay transponder method:

SHIP ---> RELAY XPONDER j -----> XPONDERS k,l,m... ----> SHIP
FR2(j) 9 KHz FT2(k,l,m...).

This sequence produces a path which involves the ship-to-relay transit, the transit over the bottom between the relay and the other transponders, and the final transit from all transponders back to the ship. To remove the slant range transit times, a second sequence closely followed the first:

SHIP -----> TRANSPONDERS k,l,m... ---------> SHIP

9 KHz FT2 (k,l,m...) .

By this method the slant range times, which have the greatest uncertainty for conversion to true ranges, can be subtracted from the realy. range times, leaving only the times for the bottom range. Since the bottom transits have only a small vertical component the time can be converted to a range with only a knowledge of the depth, since the sound velocity is pressure dominated at the bottom, and is a nearly linear function of depth.

A set of relay data for each transponder was taken during the cruise and recorded on DAT. Each data set contains 80-100 pairs of the sequences noted above, repeated at either 1 min or 1/2 min intervals. A WWVB time code is recorded on the second channel of the DAT for synchronization of the GPS position, speed, and heading of the ship during these ranging sequences. The GPS data is logged in a separate file available in ASCII form.

The UW deck box was also successfully used after much initial debugging. It could not perform the sequences noted above exactly since it could not correlate more than one transponder response at a time. However, by repeating a single transponder sequence as quickly as possible, it was able to complete a single relay sequence (without the direct sequence) in about a minute. The data was logged to the Sun workstation. The combinatoion of the two datasets should be adequate to calibrate the transponder array to a few meters accuracy.

All transponders were still functioning at the end of the survey operations on 4 October. Transponder 122, which was the lower of the two in the vertical pair at the north point of the DUMAND "pentagon", produced a weak output which was difficult to hear in the returns, but which may still be usable with correlation techniques.

3. Mechanical Implosion Tests with Mock String Risers

3.1 OM riser section

For this test, a section of a DUMAND string was constructed that was mechanically equivalent to the present planned string design, although one of the modules was not completed in time for use on the cruise. 12 mm diameter kevlar risers were mated using polyethylene spiral wrap to a set of dummy electrical and fiber optical cables, including a section of the umbilical cable. Titanium frames were used with two dummy optical modules encased in acrylic hardhats provided by Tohoku University via Prof. Tanaka. The lower optical module contained a pre-weakened sphere for implosion, and the middle position (5 m above) contained an OM from the SPS. A number of commercial packing-crate accelerometers (single trigger) were placed in the sphere for accelerations ranging from 5 g up to 300 g. A set of crystal oscillators were also placed on the PC board. The upper position of the mock string contained only another

Ti frame. The kevlar was eye-spliced to thimbles at the Ti frames. The thimbles were both glass-reinforced Delrin (Acetyl) and ultra-high molecular weight polyethylene. The eyes were shackled to each of the Ti frames, and the string was pre-tensioned to adjust the final lengths to even the tension. The string ballast was a 1 ton lead dredge weight.

3.1.1. Deployment

The deployment used a hand-over-hand method employing a crane that was capable of approximately 7 m of lift span off the deck, and a fixed pennant hanging down from the ship's aft A-frame to 1 m above deck level. The weather was very calm with a 0.5-1 m swell from the NNW and very little wind. The ship was all stop and lay in the trough of the swell. There was some rolling, but it did not seriously interfere with the operation. In a larger swell, keeping weigh on into the swell would probably be preferable, but at the expense of the drag on the section of the string below water tending to pull the string away from the ship when attachment operations are necessary. In this case a robust system of pulling the string in close when necessary would be required.

The deployment proceeded by first picking up the weight with the crane hook, and hanging the weight from a lift point on its bridle. The crane pennant was then slacked off and the crane hook was placed in a lifting tool attached to the nect lift point up the string. The cran then hoisted this section of string up high until it again picked up the ballast to the point that the fixed pennant could be removed. The crane then payed out its pennant until this new section of string had been lowered into the water to the point that the fixed pennant could take the load. Once the load transfer was made the operation was repeated until the final load transfer could be made to the ship's main winch wire. At this point the lowering could proceed.

Only minor problems were encountered during this operation. Initially there was some problem of the load transfer hooks binding; this was solved by use of slings which reduced the "crowding" of hooks near the load transfer point. Also the fixed pennant turned out to be a very stretchy nylon line which meant that approximately 1 m of the crane's lift span was lost to accommodate this stretch at the load transfer. The lifting tool was also somewhat cumbersome and its design could be improved by using lighter materials. The design of the lifting tool attachment points, which were at the edges of the kevlar eye-splice thimbles at the corners of each Ti frame, was found to be actually very good in practice, and can be used without modification with an improved lifting tool. Mid-span lifting points should follow this design if possible.

It was found that niether of the mid-line loop knots that were used, a mid-line bowline, and a mid-line linesman's loop (or butterfly knot), could be undone by hand after they were put under load. This appears to be an effect of the kevlar: it is known that kevlar increases its friction dramatically when wet; thus the knots that are cinched up and then wetted become much tighter than in other types of line. Both of the mid-line loops used are commonly used in other line for situations where a mid-line loop must be quickly untied after taking load.

The recovery operation was a reverse of the deployment operation and no additional problems were encountered. It was noted that the HDPE thimbles had elongated somewhat under the tension of the dredge weight; the Delrin thimbles were unaffected.

3.1.2 Implosion Damage

Upon recovery of the string section after the implosion, which took place at about 4100 m depth, It was seen immediately that the photomultiplier in the optical module 5 m above the imploded sphere had itself imploded within the sphere. Upon disassembly it was found that only two of the accelerometers had tripped: one of the 50 g and one of the 100 g units. Eleven other units, with threshholds of 5, 10, 20, 50, 100, 200, 300 g were all untripped. The units had been mounted with random orientation around the OM electronics board, and they are most sensitive along two distict axes, so it is possible that the units that tripped were those most aligned to the acceleration. Also, the acceleration bandwidth of these units generally rolls off well below 1 KHz, so their response to the 0.1 ms shock wave of the implosion may have been attenuated. Another possibility is that the implosion of the PMT could have tripped the accelerometers. However, based on the estimates of the acceleration from our previous implosion experiments, it is possible that accelerations in excess of 100 g were responsible for the PMT collapse. *

The instrument sphere that contained the PMT showed some spallation damage along a section of approximately 20 cm length. Since spheres occasionally show some spallation after exposure to depth it is not certain that this was due to the effects of the implosion. However, since this sphere had already received some pressure cycling from the SPS experiment it is less likely that new spallation would occur simply from depth exposure.

No mechanical damage to any of the riser kevlar or the electrical and fiber optic bundles could be seen. As in our previous experiment, none of the acrylic hardhat survived at the implosion module, but there was no damage to the acrylic 5 m above. The Ti frame containing the implosion module had one broken crossmember. The break was clearly a tension break, and began in one corner at a weld, but also tore through an unwelded section of the Ti. The crossmembers, which were not T-stock as in the side members, also were significantly bent by the compressional part of the implosion. Since it is quite difficult to produce permanent bends in the 6AL4V Ti alloy even in the machine shop, this is some indication of the forces involved in the compression stage of the implosion.

3.2. Float riser section

Based on previous tests which indicated that syntactic foam floats are sensitive to damage from implosion shock waves, we tested a simulated section of a riser with glass floats to see if a simple riser section, without Ti frames, could survive implosion

* see note below

of the floats. We also wished to make an estimate of the distance required between the floats to avoid sympathetic implosion. Thus the mock float string section consisted of a pair of kevlar risers with the HDPE hardhats of the floats attached to tied loops in the risers with lashing line. The lashing line used was line of opporunity, and was simple cotton clothesline with a diameter of about 6 mm. The implosion float was at the top of the float cluster, with one float 2 m below it and one float 5 m below. Based on the implosions seen in the current meter mooring, we judged that the 1 m spacing used was too small. The 2 m and 5 m spacings used were intended to test the 2 m spacing directly, and the 3 m spacing if the 2 m spacing was inadequate.

The string was deployed in a manner similar to that of the mock instrument string, and recovered in the same manner. The implosion occurred at about 4 km depth. The implsoion hardhat remained attached to the dual kevlar riser by the cotton lashing lines, although some portion of these were severed, possibly due to chafing on the ascent, rather than the implosion. The hardhat itself was extensively torn, with far more damage than was seen in the current meter mooring implosions. This could be due either to the higher strength of the ribbed hardhats used in the current meter floats, of may indicate that the current meter implosions took place at a more shallow depth where the shock wave energy was lower.

The kevlar riser, and a PVC spreader within 0.5 m of the sphere center, showed no damage. Even the cotton lashing line holding the hardhat to the riser showed minimal damage except where it had been dragged into the torn hardhat during the implosion. No sympathetic implosion occurred.

4. Camera Survey

Two towed-camera surveys were made across the DUMAND site. The first of these began up the Island slope somewhat, heading west down the slope initially, then turning on a heading of approximately NW through the center of the site. The camera sled was navigated using only a pinger-altimeter and a precision depth recorder (PDR), and the camera was set to shoot at approximately 15 s interval. The second survey began to the southwest of the site and continued on a NE heading, passing very near to site center. This leg was also navigated in real time with a pinger altimetyer and PDR, but a transponder was also used in relay mode to record relay transponder responses on the DAT. The data will be used to calibrate the navigation track of the camera sled once the transponder field itself has been calibrated.

The first camera survey yielded only about 20 min worth of pictures at the beginning of the run. The cause of the failure was not completely understood, but was thought to be due to an intermittent strobe. The pictures from this segment showed sandy sections with some rocks of order 1 m across.

The second survey was much more successful and it was fortunate that the transponder navigation data was taken for this station. The pictures show a bottom with what is apparently a top layer of light sil or very fine sand, mottled often with tracks due to fish or bottom crawlers. These tracks are typically quite distinct. In some cases, clouds of material due to the camera sled impacting the bottom can be seen in the frame, along with clear water, and the sediment is quite opaque. No obvious rocks are seen in any of these frames. The tentative conclusion is that the bottom appears to be quite suitable for the array bases and junction box frame.

5. CTD casts.

A prelimiary lowering of the UW CTD (conductivity, temperature, depth) meter was made in conjunction with a drop of an expendable temperature probe (XBT) for cross calibration to about 450 m depth. However, upon recovery, the CTD pressure data (from which depth is obtained) was found to be incorrect, probably due to a malfunctioning pressure sensor. This could not be repaired on board, so depth was estimated using the lowering speed profile, and rough correlation found with the expendable probe data.

A second CTD cast to 4500 m was unsuccessful; the data logging system on the CTD apparently malfunctioned and no data was recorded. The cause ofthis malfunction could not be determined.

A third cast to 4500 m was successful, with depth obtained by the amount of wire lowered out. The data appeared reasonable. However, in the absence of certain calibration of the CTD data, it should be used with caution.

Comparison of the XBT data with standard temperature data for the area showed a very close correlation, and it is apparently adequate to use standard sound velocity curves for the area to do the transponder calibration, at least to the level of a few meters accuracy.

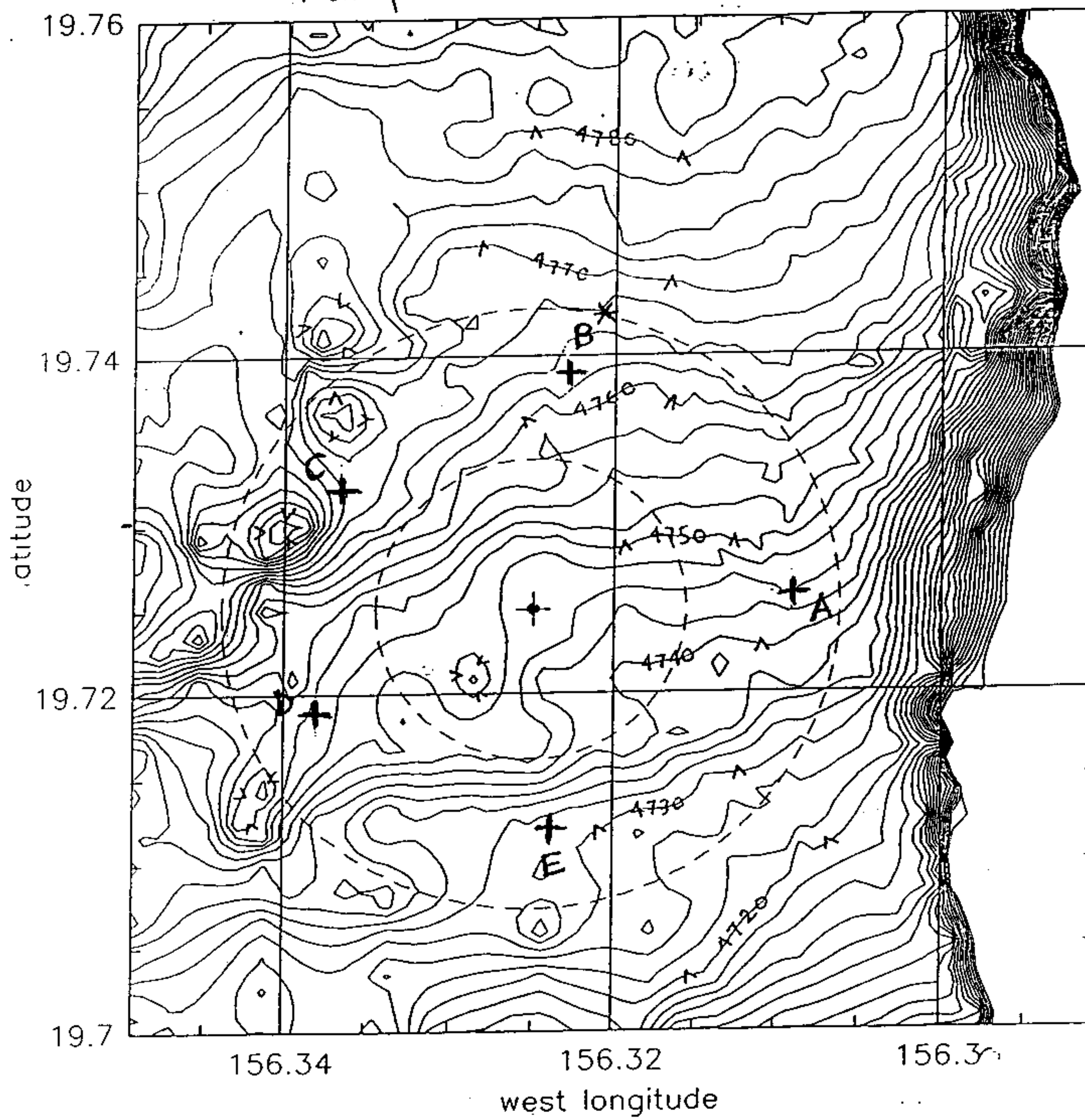
* note:

We have discovered, since this report was written, that the accelerometers were incorrectly prepared for operation because a safety catch was left in place. This reduced the sensitivity of the meters greatly. Thus the fact that some of them were tripped in spite of this indicates that accelerations in excess of 100 g are probably even more likely to have been present.

—PG

DUMAND site, 2.5 m contours

Transponder sites marked A — E



circle radii 1 km, 2 km

USNOS survey + Moana Wave survey '91 (splined)

* Transponder mooring B contains two units