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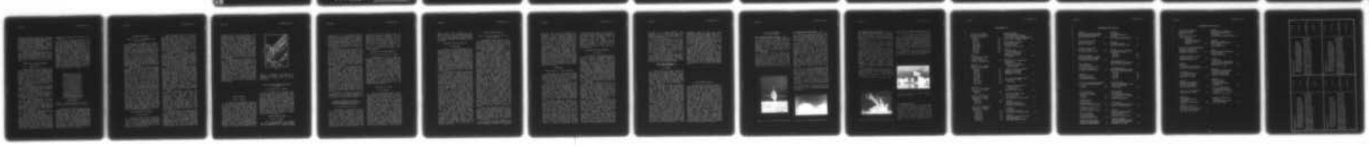

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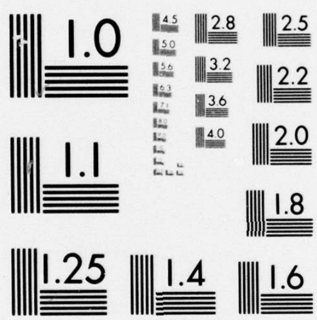

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CURRENT MAJOR PROJECTS OF THE MARINE PHYSICAL LABORATORY

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This report describes the early 1976 status of major research programs at the Marine Physical Laboratory of the Scripps Institution of Oceanography, University of California, San Diego. The work is conducted in the four general topics of Ocean Acoustics, Sea Floor Studies and Technology, Signal Processing, and Environmental Studies. Special facilities used in the MPL research programs are described briefly.

UNIVERSITY OF CALIFORNIA, SAN DIEGO
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CURRENT MAJOR PROJECTS OF THE MARINE PHYSICAL LABORATORY

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ABSTRACT

This report describes the early 1976 status of major research programs at the Marine Physical Laboratory of Scripps Institution of Oceanography, University of California, San Diego. The work is conducted in the four general topics of Ocean Acoustics, Sea Floor Studies and Technology, Signal Processing, and Environmental Studies. Special facilities used in the MPL research programs are described briefly.

INTRODUCTION

The Marine Physical Laboratory is one of the research laboratories of the Scripps Institution of Oceanography, an institution of the larger University of California, San Diego campus. Headquarters for the laboratory are located within the Naval Undersea Center compound on Point Loma. Some of the staff carry out their research program on the La Jolla campus of the University.

The work of the Marine Physical Laboratory, since its origin in 1946, has been continuously directed toward furthering understanding of the generation, propagation and detection of energy in the ocean and surrounding media. In overview of the laboratory program several topics would emerge as characterizing the work: The Ocean Acoustic Environment, Sea Floor Properties, Signal Processing, Ocean Technology, and Advisory and Exploratory functions of the staff. Acoustic studies in the program range from the conduct of ocean experiments using complicated electronics data processing systems to small boat recording of sounds emitted by whales in the ocean. Studies of sea floor properties span from the measurement of residual magnetism of cores taken from the sea floor to the investigation of fine scale topography using advanced sonar equipment. Signal processing theoretical studies are augmented by hardware development and practical ocean experiments. Ocean Technology efforts at the laboratory have developed a variety of research platforms, tools and techniques for use in the program. Over and above the research program, members of the laboratory participate in many ways in the planning of Navy and University long range programs.

Primary support for the laboratory comes from the U. S. Navy. The basic support from 1946 to 1958 was provided through the Bureau of Ships (now Naval Ship Systems Command). Since 1958 basic support funds have been received through the Office of Naval Research; this basic support has been augmented by other branches of the Navy for special projects. The National Science Foundation also contributes support for specific problems.

The first director of the Marine Physical Laboratory was Dr. Carl Eckart, a leading scientist from the World War II University of California Division of War Research at Point Loma. Dr. Eckart served as director from 1946 to 1952. He was succeeded in 1952 by Sir Charles S. Wright, followed in 1955 by Dr. A. B. Focke and in 1958 by the present director, Dr. F. N. Spiess.

The present staff of the laboratory numbers 105 of which 19 are senior academic staff members, 16 graduate students, 17 engineering, 25 technical, 14 administrative and clerical and 14 support people.

VOLUME REVERBERATION

Brett Castile

A submersible sonar system has been built which at present operates at 155, 227, 557, and 819 kHz. The beam patterns are narrow, ranging from 1.6° in equivalent cone at 819 kHz to 6.6° at 227 kHz. Combined with the ability to operate at depth, suspended from R/P ORB, this sonar system permits resolution of instantaneous scattering volumes as small as 1/50 m^3 at short ranges.

Some good quality data have been obtained which are now being studied. It is apparent that one may see quite different sets of scatterers within the water at different frequencies since the structure of the scattering layers is strongly frequency dependent. In May, a scattering layer was observed north of Catalina Island which coincided with the thermocline, the salinity minimum, and the knee of the O_2 profile below which O_2 content fell off very rapidly. Although observed at the higher frequency, it was not seen at either 227 or 155 kHz, and probably was composed of detritus, phytoplankton, or both.

Characteristics of distributions of backscattering strength in horizontal directions are still somewhat obscure, but it is evident that backscattering strength is much more variable at shallow depths than at deep ones. In the upper 10 m it has been observed to change 35 dB over a period of 50 minutes. At around 300 m depth, fluctuations of 2 or 3 dB over periods of around 20 minutes have been observed to occur around a mean which remains constant over hours. During this time, water transport covered 100 to 150 m horizontally. This could either represent patchiness on this scale, or be the result of thin horizontal layers riding up and down past the transducers on internal waves. There is also a suggestion from some data taken at 400 m depth that there may be some horizontal structure on a scale of 1 to 5 m.

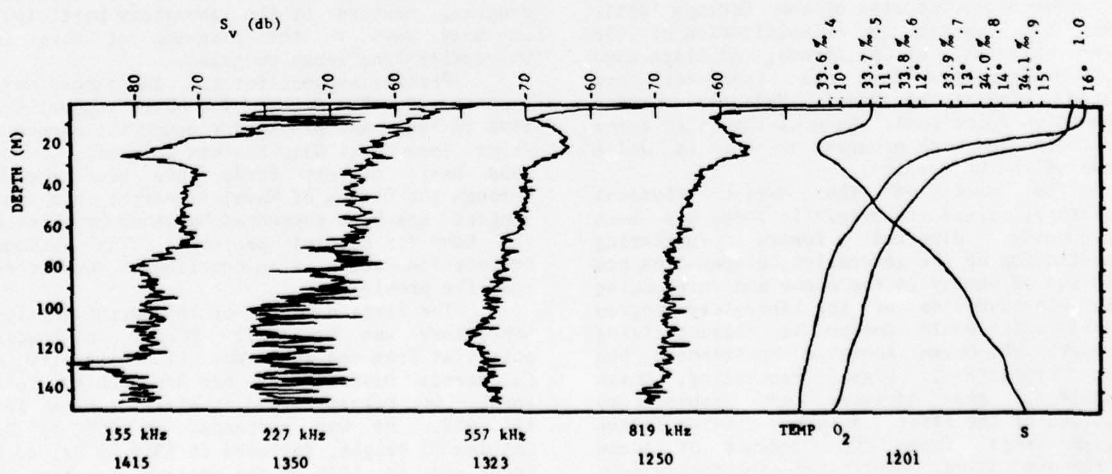

Figure 1. Comparison of scattering volume - depth profiles at four frequencies with environmental parameters.

OBSERVATION OF ACOUSTIC LAYERING AND INTERNAL WAVES WITH A NARROW BEAM 87.5 kHz ECHO SOUNDER

F. H. Fisher and E. D. Squier

Measurements with the 87.5 kHz narrow beam (1°) echo sounder (SIO Reference 76-8, 1 June 1976) mounted at a depth of 85 m at the bottom of FLIP and pointed down have revealed multiple thin layers. Recent measurements using short pulses ($\sim$0.1 msec) at 1 pps demonstrate the layers are less than $\sim$10 cm thick as seen in Fig. 2. The record was obtained by direct magnetic tape recording of the received echos shown in Fig. 3 on a standard GDR recorder and then using a computer to expand the plot. Observation of 10 m peak-to-peak internal waves at periods of 20 minutes is quite common with this echo sounder. The large cloud in Fig. 3 is probably due to biological scatterers.

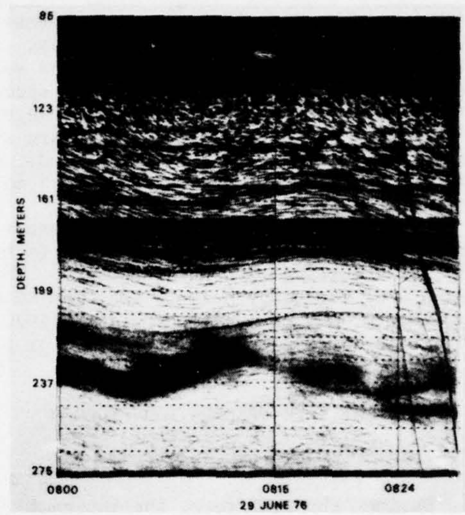

Figure 3. GDR record using 0.1 ms pulses at 87.5 kHz.

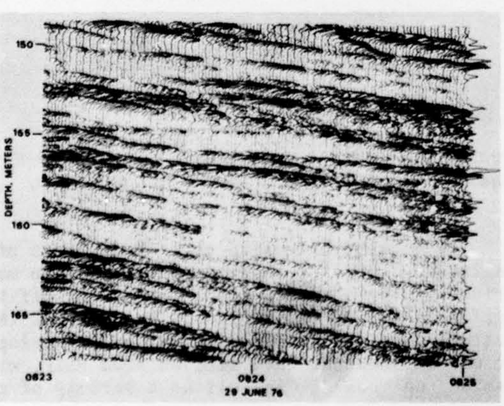

Figure 2. Computer expanded plot for a portion of the GDR record in Fig. 3.

SCATTERING STUDIES

G. Thomas Kaye

The MPL Scattering Array (SCAR) was lost at sea in March, 1976, during diving operations. The array was to be used to investigate the back- scattering of sound from temperature layering in the water column. Data previously obtained with the array have shown a positive correlation between acoustic scattering layers and the fine structure temperature features from an XBT trace.

The signal processing consists of a time-delay, phase-shifting of clipped signals in a hardware beamformer, similar to Anderson's DIMUS system. It is possible to discriminate between coherent point scatterers like fish and the specular reflections from temperature layers because of the different wavefront curvatures from these two target types within the array nearfield. A dual plot of the time-depth distributions of these scatterer types will be shown. It is suggested that the layered scatterers may consist of temperature layering and densely-packed biota which might be resident upon the temperature layers. The high gradient temperature microstructure can be expected to have reflection coefficients of -85 to -95 dB.

The figure shows the marked directional effect of the back-scattering from layered scatterers. Each point on the figure represents an average of 50 beam sums, ten consecutive pings by five adjacent range bins. The point scatterers suffer greatly by averaging; however, the layered scatterers average coherently. At a steering angle of 0° with respect to the vertical array axis, there appears to be a specular reflection from these temperature layering effects. At 1° the layered scatterers are still apparent, but much diminished in magnitude. At a steering angle of 2°, we are nearly down to the noise level for all depths.

Because of these interesting results, a second array, with an aperture of 6 m, is being built for mounting upon FLIP's stern. To be operated at a frequency near 30 kHz, the SCAR II array should be completed in late 1976 for initial at-sea testing at that time or early 1977.

INTERNAL WAVE OBSERVATION PROGRAM

Robert Pinkel

During the past year, the internal wave group at MPL has been developing a Doppler backscatter sonar system for the measurement of water movement in the upper ocean. Acoustic energy is transmitted in a narrow beam and is scattered by the marine plankton. The Doppler frequency shift of the returning signal is measured. From this, the component of water motion along the beam can be calculated at many ranges. Initially the system will be mounted on FLIP, transmitting horizontally, for use in internal wave studies.

This approach to measuring ocean currents provides several advantages over the traditional approach of hanging individual mechanical current meters from mooring lines.

1) Velocity estimates are obtained continuously with range. The problem of spatial aliasing of current observation, inherent in measurements by arrays of discrete sensors, is not present in this system.

2) Velocity measurements at fixed horizontal spatial separations are attainable, without deployment of many moorings.

3) The water flow is not disturbed by the instrument body right at the spot where the measurement is to be made. Eddies shed from traditional current meters have been known to affect their performance.

4) Very small currents can be measured. There is no mechanical threshold, as with conventional rotor-vane current meter.

Among the disadvantages of using a sonar to measure ocean currents is that information is obtained only about that component of velocity which lies along the beam. Also, there is some maximum range beyond which the backscattering signals will be too weak to detect. Finally, the sonar must be held very steady to prevent the outer reaches of the beam from gyrating in space. This restriction, plus the requirement of high power consumption will initially limit the use of this device to FLIP, and other stable platforms.

One of the problems with developing an entirely new type of remote sensor, is that there is no similar instrument whose performance is known, with which to compare results. For this reason development of the Doppler sonar has been conducted primarily in the test facility at Lake San Vicente. The sonar transducer is suspended from a barge in the lake. The relative motion between the barge and the water can be deterministically influenced by moving the barge. In Fig.4, the results of a representative test are presented. Backscattering intensity at 35 m range is plotted vs Doppler frequency for 64 discrete arrival times, representing 5 minutes of total data. Note that the system can determine water velocity at distant ranges to 1 cm/sec every second. This contrasts with most mechanical current meters, which require several minutes of averaging to produce a velocity estimate good to ~ 2 cm/sec.

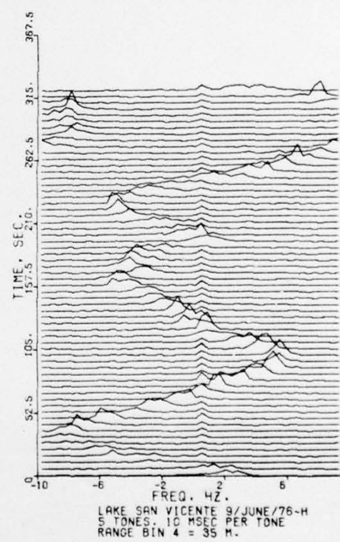

Figure 4. Lake San Vicente 9 June 1976-H, 5 tones 10 msec per tone, range bin 4 = 35 m.

The first extensive open ocean tests of a preliminary Doppler sonar system will be made during a three week FLIP operation off the California Coast in early 1977. The MPL temperature profiling array, previously developed for use in internal wave studies from FLIP, will also be on board, as well as a variety of environmental sensors. Following this cruise, and some final testing at San Vicente, construction will begin on a special purpose Doppler sonar array, which will provide an extended view of the upper ocean velocity field to ranges in excess of 1 km. This new array should be ready for scientific work at sea in 1978.

LOW FREQUENCY ACOUSTICS

George G. Shor, Jr., William Whitney and Gerald B. Morris

Under the core contract in previous years, we commenced design and construction of a linear array and recording and analysis equipment to study the transmission of infrasonic energy through the seafloor. In the past year, support for the data acquisition and analysis work was transferred to the Infrasonics project under Code 480, and emphasis was placed on studies of the noise characteristics of low frequency linear arrays. Because of conflicts in ship scheduling, the testing of a vertical array from FLIP had to take place at the same time as installation of the horizontal array and recording equipment on THOMAS WASHINGTON (in Guam); the vertical array studies were, therefore, carried out by Morris and are reported by him.

The horizontal array (a 5000 m array with 500 m spacing of elements) was used from THOMAS WASHINGTON on Legs 5 and 8 of INDOPAC Expedition. The system showed excellent towing characteristics; with 4500 m of the array out, it could be towed at a speed of 5 knots with a drag of at most 771 kg, and achieved maximum quieting within 5 minutes of the time that the ship stopped engines. Since we did not back down, some of this time the ship was still moving; the actual array quieting time was, therefore, a matter of a few minutes only. The hydrophones did not, however, achieve the self-noise levels of individual streamed hydrophones arranged in the manner normally used for seismic refraction work, by about 12 dB. Field tests using a spar buoy at the surface instead of the more towable "raft" shaped buoy used in the array design demonstrated that the quieting could be improved if the surface unit were changed and the natural frequency of the float/weight combination thereby reduced below the range of signals of interest. Another opportunity for testing of the horizontal array will occur next spring, when the THOMAS WASHINGTON and an Indonesian ship will carry out long-range seismic refraction work under IDOE sponsorship; since the equipment is mostly still aboard the WASHINGTON, we hope to do additional tests with modified mechanical units.

LONG RANGE ACOUSTIC PROPAGATION

Gerald B. Morris

The Long Range Acoustic Propagation Project (LRAPP) work at MPL during the past year has been devoted to analysis of low- frequency (10 Hz to 1 kHz) sound propagation and ambient noise data collected during previous at-sea studies. Efforts during the year have been directed at five specific tasks.

Radiated acoustic signals from a 225,000 ton tanker operating off the southern California coast were processed. The results show that these very large tankers are strong sources of acoustic noise in the ocean. The noise level in the 50 Hz to 100 Hz band for this particular vessel was about 20 dB greater than that of a 150 m length, 10,000 ton, 15 knot merchant ship. In addition, the received acoustic signals from this supertanker increased in level by as much as 10 dB during its passage over the region of the continental slope.

In conjunction with the general study of the propagation of low frequency acoustic signals in the ocean, some 1955 explosive measurements made off Bermuda were reprocessed to yield propagation loss at frequencies ranging from 50 Hz to 3200 Hz. In addition to putting the data into a form more amenable to current usage, sound attenuation coefficients were also derived that are in good agreement with values obtained in the Atlantic by others.

The third task was directed at completing the analysis of the signal propagation measurements for the 18 m (60 foot) SUS charges detonated in the central northeastern Pacific Ocean during September 1973. The signals from approximately 700 SUS, at ranges varying from 43.5 km to 994 km, were received at four hydrophones suspended beneath the Research Platform FLIP at depths of 775 m, 2492 m, 4250 m and 5180 m. Analyses were made at selected frequencies in the band from 10 Hz to 400 Hz. Signal propagation characteristics and signal-to-noise ratios were examined as a function of source-to-receiver range, receiver depth, and frequency. Bathymetric or changing water mass effects on the sound propagation were also observed.

Using differences in these SUS propagation losses at various frequencies in the 10 Hz to 400 Hz band, sound attenuation coefficients were calculated. Only the coefficients in the 50 Hz to 400 Hz region were statistically significant. At these frequencies, the coefficients are only about half the value of those measured in the North Atlantic and Mediterranean regions. These results offer support to the observation that the boric acid relaxation effects on the attenuation of low frequency sound in the North Pacific Ocean is about half that in these other oceanic areas.

The final task was the combined analysis of omnidirectional ambient noise levels measured at two deep-water locations in the Northeastern Pacific Ocean. At both sites, the Research Platform FLIP had acted as the hydrophone suspension and data recording platform. Hydrophones were positioned throughout the water column from within about 200 m of the surface to within about 150 m from the sea bottom. Analyses of the data over the frequency band extending from 15 Hz to 800 Hz show that at low frequencies the noise levels decrease with increasing depth. The decrease with depth is greater below the critical depth than it is in the sound channel. These low frequency noise levels, and their depth dependence, are independent of the wind speed. At higher frequencies, the noise and its depth dependence is controlled by the wind-generated noise. At low wind speeds there is a decrease in levels below the critical depth, but above this depth both increases and decreases in levels were noted. At these high frequencies, during high wind speeds, the noise levels not only rise but the noise fills the water column to the extent that there is little decrease in level with increasing depth, even for the region below the critical depth.

Low-frequency acoustics measurements were made with the 20 element, 532 m vertical array used by Fisher in the study of multipaths and caustics. Efforts were concentrated in the 0 to 50 Hz band with particular interest in the infrasonics region of 20 Hz or less. Analysis of single sensor outputs show considerable noise below about 10 Hz which is believed to be flow-induced noise resulting from strong variable currents at the site. During the major data collection period a large bulk carrier (approximate overall length 305 m) passed within 2 km of FLIP. The vertical arrival patterns of noise from this ship and also those patterns when no local ships are present have been processed.

SIGNAL PROCESSING

Victor C. Anderson

A study has been completed on the use of various algorithms for computing array patterns. The impact of a symmetrical array geometry, the use of a quantized stored cosine function, the exploitation of Digital Fourier Transform algorithms and the application of trigonometric interpolation in the computation of array patterns have been considered. The results show that careful selection of parameters permits sampling the array pattern only 6% above the theoretical Nyquist limit. A saving of 8000:1 in computation time over direct "brute force" array pattern computation is illustrated for a hypothetical array in the accompanying Fig. 5. The two sequences of points identified by Roman numerals and arabic numerals represent times associated with successive interpolation steps.

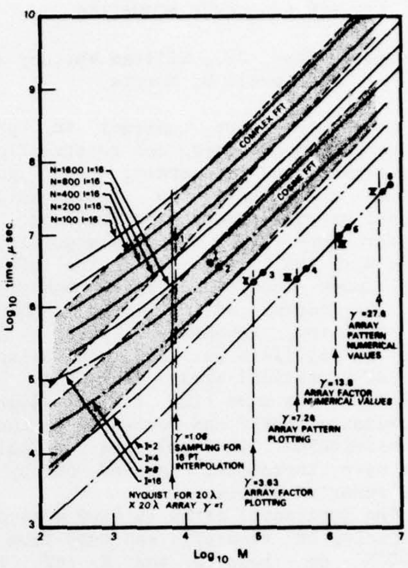

Figure 5. An example of the reduction in computing time achieved through the use of interpolation algorithms in array pattern computation.

VERTICAL ARRAY MEASUREMENTS/MULTIPATHS AND CAUSTICS

F. H. Fisher and F. M. Phelan

A 20-element 500 m vertical array, suspended from FLIP at the sound channel axis, is used to measure the vertical angles of arrival of 445 kHz sound transmitted from a source towed at about 100 m depth. The object is to eliminate interference effects due to multipaths and determine the effects of variability in the medium on individual arrivals at ranges out to a few hundred miles. With a pseudo- random spacing of the elements in the array we can form 240 beams within various angular apertures, ±15° usually, to resolve the various arrivals. Analysis of the June 1976 cruise is now in process which includes comparison of results with those from ray path modelling as well as from the parabolic equation.

ADVANCED DETECTION ARRAY

Victor C. Anderson

Under ARPA sponsorship the Advanced Detection Array (ADA) project at MPL has undertaken the construction of a remotely operated large-aperture (7 m x 20 m) receiving array composed of 720 directional hydrophone elements and capable of being submerged to a depth of 1200 m. It will serve both as an instrument for the experimental measurement of the statistics of the acoustic background and signal fields for high resolution sonar systems, and as an experimental passive sonar for the evaluation of the detection performance of a high gain receiving array.

In the coming year the construction and outfitting of the array platform will be completed and the necessary modifications to ORB (Ocean Research Buoy) will be carried out. ORB is the tending platform for the ADA vehicle. The two are coupled with a triaxial electrical strain cable which transmits 100 kw of three-phase 60 Hz power to the unmanned array, and also serves as a wide-band two-way telemetry channel for the transfer of control signals and experimental data to and from the manned data control center on ORB.

The project has involved many unconventional applications in the technological area. Among these are a thin-skinned light weight barge structure, a cable reinforced inflatable dome, light weight plastic four-element hydrophones with ambient pressure electronics, and a taut moor suspension system for submerging the ADA array with a net positive buoyancy. Initial tests will be concerned with a measurement of the platform dynamics under tow and deployment. Next will follow the measurement of the acoustic characteristics of the array and processor system. Then the program will proceed to the measurement of the background and signal field statistics with particular emphasis on the envelope or fluctuation spectrum of the output of the high resolution beams formed by the array processor.

During this coming year the project will progress from its intial ARPA funding base to a joint project in which funding is provided both by ARPA and the Navy under ONR and NAVSEA.

PRESSURE DEPENDENCE OF ELECTRICAL CONDUCTIVITY OF ELECTROLYTES IN SEA WATER AND SOUND ABSORPTION IN THE OCEAN

F. H. Fisher and A. P. Fox

Measurements of the electrical conductance of solutions of electrolytes in sea water are used to determine the equilibrium constants. From the pressure dependence of these equilibrium constants in simple salt solutions it is possible to determine a volume change upon dissociation. Sound absorption in sea water below 100 kHz is due to the presence of $MgSO_4$ in sea water. The extent to which other ions complex either with the magnesium ion or the sulfate ion reduces sound absorption. The pressure dependence of the equilibrium constants of various ion pairs containing either the sulfate or magnesium ion can then be used to predict the pressure dependence of sound absorption in sea water. For K_2SO_4 our initial results find the equilibrium constant to be 0.091 and $\Delta V°$ to be -7.9 $^{cc}/mole$ at 1 ATM, and 0.122 and -6.0 $^{cc}/$ mole at 1000 ATM. For $MgCl_2$ we find K = 0.17 and $\Delta V \cong -5$ $^{cc}/mole$ at 1 ATM, K = 0.21 and $\Delta V \cong -3.5$ $^{cc}/mole$ at 1000 ATM. Further analysis is in progress which will change these results slightly.

PRESSURE EFFECT ON SOUND ABSORPTION

F. H. Fisher, G. F. Denny, and E. D. Squier

Measurements are now in progress to determine the effect of pressure on sound absorption in sea water at frequencies of 20 kHz and above. A 100 liter titanium sphere, part of the ballast system of the submersible ALVIN, is being used as a resonator in a manner similar to the glass sphere used for the low frequency boric acid work by CDR V. P. Simmons (Ph.D. Thesis 1975). The decay of the sound field for a given resonance mode is measured as a function of pressure with sea water in the sphere and then with another solution exhibiting no sound absorption but having the same sound velocity. The difference between the two values is then the absorption due to sea water. These measurements will hopefully resolve the differences in pressure effects that the Schulkin and Marsh equation predicts and that Bezdek measured in the ocean.

HEAT FLOW IN OIL FIELDS

Victor Vacquier

We have made many measurements of terrestrial heat flow in the oceans, now we are developing a method for determining heat flow on land from data that has been filed away by oil companies. In the logging of oil wells done shortly after drilling, temperature is measured near the bottom. Because wells are finished at different depths, a plot of bottom hole temperatures against depth gives the temperature gradient, and oil companies have been doing this lately because the maturation of petroleum depends on paleo-temperatures. To get the heat flow we need to multiply the temperature gradient by the mean thermal conductivity which we shall determine by combining laboratory measurements on oil well core samples with electric logs. We have been developing a rapid method of measuring the thermal conductivity of rock specimens by placing a flat surface of the specimen against a heated needle and measuring the rise of temperature of the needle against time. This is essentially the method we are using on cores of ocean mud. The scheme as a whole has been tried in Brazil and we are getting ready to go to Indonesia where the fields of central Sumatra are located landward of a major subduction zone, and where we have many heat flow measurements seaward of the deep sea trench.

GEOLOGICAL STUDIES WITH DEEP TOW

Peter Lonsdale

In the fall of 1975 the deep-tow instrumentation system was used in the North Atlantic from the Woods Hole Oceanographic Institution's R/V KNORR. Detailed studies of tectonic processes at oceanic spreading centres were made at the intersection of the Mid-Atlantic Ridge and the Charlie-Gibbs Transform Fault, and at the Reykjanes Ridge (in cooperation with Dr. T. Atwater of M.I.T.). During the second part of this two-month cruise, effort was concentrated on the geological effects of the fast overflow of cold bottom water from the Norwegian Sea, which controls sedimentation throughout the northeast Atlantic. Results of the surveys are being worked up in cooperation with Dr. C. Hollister of Woods Hole.

In the summer of 1976 the deep-tow system was used on three legs of Expedition PLEIADES in the eastern Pacific. Several sites in the California Borderland were examined for the U.S. Geological Survey, in connection with their task of exploring the resources and environmental problems of the outer continental shelf. NSF-funded geological and geochemical surveys of the actively spreading crests of the East Pacific Rise and the Galapagos Rift were directed primarily toward mapping and sampling emanations of hydrothermal fluids from the warm, newly formed crust. This was successfully accomplished with CTD and water-sampling device, designed by Dr. R. Weiss of Scripps, that was attached to the deep-tow vehicle. Springs of warm, chemically altered water were found to issue from cracks in a zone a few tens of meters wide along the axis of spreading. A secondary purpose of this leg was to map the geologic structures of a medium-fast-spreading rise (the Galapagos Rift), of a very-fast-spreading rise (the East Pacific Rise), and of the region where they meet, at the Galapagos Triple Junction. Only a brief lowering was made at this last site, to complement observations from a surface-ship survey that we made there in 1974.

The final leg of Expedition PLEIADES included deep-tow surveys of two sites in the equatorial Pacific, as part of our contribution to IDOE/NSF's Manganese Nodule Project. Attempts were made to assess the local distribution of manganese nodules with a combination of photographic and side-scan sonar mapping. In addition, the standard suite of deep-tow sensors was used to interpret the geology of the sites.

SEISMIC REFRACTION STUDIES

George G. Shor, Jr., Russell W. Raitt, and Richard Phillips

This general heading represents work on 5 different grants, in order of age: Anisotropy and Crustal Structure of the Pacific (expired this year); Philippine Sea Survey (expired this year); IPOD Site Surveys of the Marianas Arc; Sino-American Philippine Sea Seismic Surveys; and Southeast Asia Tectonics (Banda Sea).

Work under the older grants has resulted in several completed publications, and additional ones in progress. Rosendahl completed a doctoral thesis and has submitted several papers for publication on work along the East Pacific Rise. He showed that the seismic and petrographic data were compatible if a magma chamber exists at shallow depth beneath the central horst of the East Pacific Rise, and the basement, oceanic crust, and upper mantle all form by separation from a single shallow melt. The separation is virtually complete at the edge of the central horst, and later changes in velocity and delay times can be explained by cooling of the already solidified rocks. Bibee and Shor carried out a study of past refraction data which shows that there is extremely good correlation of mantle compressional-wave velocity with the angle between the station direction and the local magnetic lineations; within one degree the high-velocity direction is perpendicular to the magnetic lineations. The correlation with age is strong, but non-linear. Most of the change in velocity occurs within the first 25 million years of lithospheric aging, which is compatible with the cooling curves by Sclater et al. A possible correlation of crustal velocity with azimuth, suggested by Christensen, is not supported by the data. This work has been accepted for publication. Shor and Fornari (who is now at LDGO) completed analysis of anisotropy and structure in the Kamchatka Basin, and had the results accepted for publication. They found that the anisotropy in the basin is in agreement with the weak magnetic signature, but does not conform with the direction that should be observed if the area conforms to the hypothesis of crustal extension in marginal basins as proposed by Karig.

Other work in progress includes results of the Cocos Plate studies of previous years (in which we have completed our part of the work, and have returned the draft paper to George Sutton at the University of Hawaii, who will submit it), and ongoing studies of shear wave transmission in the crust and mantle, of which Jacobson has found large numbers of instances in our older records.

On Leg 5 of INDOPAC Expedition, we carried out seismic refraction studies and other underway geophysical measurements in cooperation with the R/V CHIU LIEN of the National Taiwan University, from the Marianas Trough west and northwest to Taiwan. Despite a typhoon which disrupted operations in the first week of the work, we obtained a large number of refraction lines in several basins of the Philippine Sea. The structure is all closer to oceanic than to continental, but detailed differences (which were the purpose of the program) await full correction of the records. On Leg 8 of INDOPAC, under IDOE sponsorship, we worked with the R/V ATLANTIS II of Woods Hole Oceanographic Institution on a geophysical investigation of the Banda Sea and adjacent continental shelf. During this program, we made some extremely long seismic refraction runs in shallow water; on one 200 km run north of Australia we determined Moho depth at approximately 30 km beneath normal continental crust. Other runs in the Timor Trough and Tanimbar Trough gave similar structure; work in the Weber Deep, on the other hand, showed structure similar to normal oceanic inside the island arc.

INFRASONICS

George G. Shor, Jr., and William Whitney

Work under this task has been directed towards determination of the amount of energy transmitted through the seafloor in long range explosive runs. Field work has been combined with the seismic refraction studies for studies of seafloor structure supported by NSF.

Data from previous short runs near Southern California have been worked up, and show some cases in which the sub-bottom transmission has been of the same magnitude as the water-path transmission at frequencies near 6 Hz. Examination of the relative energy levels from shot to shot on these runs showed large fluctuations in both sub-bottom and water-transmitted energy, however. The only reasonable explanation for this fluctuation is incomplete detonation of the Tovex watergel explosives used. This makes computation of absolute energy dubious.

On INDOPAC Expedition, working in the Philippine Sea, the Banda Sea, and the continental shelf north of Australia, we obtained transmission records in a variety of environments using more reliable explosives. On INDOPAC Leg 5, in the Philippine Sea, we carried out three attempts to record digital records from the horizontal linear array; of these, one run gave multi-channel records over a significant range of distances; sound sources were 54.3 kg charges of tetratol which gave no problems of partial detonation (at least at first inspection). Additional digital recordings were made on about 10 runs of varying length (up to 200 km) in water depths varying from 50 to 7000 m in the Banda Sea and the Australian continental shelf. One of these runs was received on the linear array; the remainder were recorded from one to three hydrophones on individual quieted suspensions. On the shallow-water runs the energy in the bottom-transmitted sound obviously greatly exceeded the energy in the water-transmitted paths; at distances in excess of 100 km, **little** if any increase in sound energy levels was observed at the arrival times for water-transmitted paths.

PRECISION TRANSPONDER DEVELOPMENT

F. N. Spiess

In a number of sound propagation studies it would be useful to be able to document the motion of hydrophone assemblages suspended in midwater. This is particularly true, for example, in the study of fluctuations using hydrophones suspended from FLIP, in monitoring the geometry of midwater arrays in order to provide inputs to programmable beamformers such as those built by Anderson, and in tracking small motions of submerged floats such as those proposed by Munk for experiments to deduce ocean current information from sound propagation data.

With those applications in mind we have begun development of a precision transponder system with a design goal of monitoring displacements of midwater equipment in a local area (few kms) to a precision of 10 cm over periods of a month, with observations at about one minute intervals.

The system initially will be for use of FLIP-based systems although it should be adaptable to use on unmanned buoys and the like with modifications primarily relating to packaging of the signal generation and recording portions. The principal elements are a signal generation and transmission portion, the sea floor transponder, a preliminary recognition and telemetry unit for installation in the hydrophone array suspension assembly, and a signal recognition and display unit.

The design concept involves the generation of a 2 kHz bandwidth, 1/20 sec long pulse at 14 kHz. The transmission will be coded by phase reversal modulation to allow matching at the receive end to within one cycle at 14 kHz. This signal will be transmitted, followed immediately by one of three simple 2 msec pulses - at 10, 10.5, or 11 kHz - to designate the particular transponder being interrogated.

The transponders will receive continuously, with two outputs being provided following the first stage of amplification. One output will go to one of our conventional transponder recognition circuits, tuned to 10, 10.5, or 11 kHz. The other covering the 13-15 kHz band, will go to a precision clock delay line which will hold somewhat over the length of the coded 14 kHz pulse sequence. Upon recognition of an interrogation pulse an answering 2 kHz reply will be transmitted, followed immediately by a transmission of the contents of the delay line.

The unit on the hydrophone array would be similar to a transponder, with a 12 kHz recognition circuit. Upon receipt of the 12 kHz pulse it would immediately activate a telemetry channel on the array wire and send the received coded pulse, followed by a signal from a precision pressure gauge. At FLIP the received pulse train would be matched with the signal generator to determine travel time and the pressure signal would be recorded.

With this system it is possible for ships having conventional transponder capability to use the system and survey in the transponders, with the high precision appearing as an added capability for more accurate positioning within the local area of the hydrophone array.

QUANTITATIVE MEASUREMENTS OF SEA FLOOR REFLECTIVITY

F. N. Spiess

The deep tow 4 kHz sounder system has been in use, in conjunction with a PDP-11 as data processor, to gather and display oceanic subbottom structure (uppermost 100 m) at several sites during the current year. Data analysis and reporting has proceeded as well, with final draft of Tyce's Ph.D. thesis on this topic under review. Summarization and documentation of computer programs for general use should be complete in early 1977.

Two major types of numbers have emerged from this investigation - bottom reflectivity and sound attenuation. In the latter category values of 0.25 dB/m at 4 kHz appear to be common. In the Southern California Borderland there is a wide range of sediment types with values of effective attenuation (some the result of work as recent as March 1976) ranging from 0.21 to 0.63 dB/m. Highly calcareous (85% carbonate) sediments of the Carnegie Ridge give quite low values (0.1 to 0.2 dB/m). Other carbonate area values will be derived from data collected in September 1976, at 4°N, 136°W.

The bottom loss on reflectivity values now available from areas in both the Atlantic and Pacific are treated in detail in a paper in preparation by Tyce. A major characteristic is the variability of these values. Much of this can be related to local geological circumstances giving rise to variable depth of burial of reflectors, discontinuities due to faulting and focussing due to folding and erosion. The extent to which these processes appear to have been active in the past is greater than had been anticipated. In addition the amount of finely layered structure in the top 50-100 m is also surprising. Much of this has become particularly obvious through application of data processing and display schemes developed by Tyce, and only fully operational at sea during our most recent expedition. These data will be of primary importance in the correlation with physical properties to be determined by Hamilton and Mayer from cores taken in the same area during our August/September expedition.

A major conclusion is that some of the 4 kHz reflectivity numbers seem large compared with what one might reasonably expect from physical properties of the material. The suggestion is that the fine layering may frequently give rise to constructive interference, selecting out to some extent the layer spacings directly related to the wavelength of sound being used. With this conclusion in hand it appears that subsequent investigations should include use of at least one additional frequency (e.g. 6 kHz) and use of variable pulse lengths to establish the extent to which this phenomenon occurs.

STAFF ADVISORY ACTIVITIES

Activity under this heading includes involvement with various Navy and related advisory groups, and the conduct of low level research or study activity. The former category provides one of the principal links through which we transmit ideas and research results into other parts of the Navy (particularly the large Navy laboratories and system commands) and also exposes our senior staff members to a broader range of problems than would otherwise be the case. The other category provides for starting efforts on new topics and occasionally for bringing forth some new conclusion from work which has been considered as completed in the past. Staff advisory activities include the Navy Undersea Warfare Research and Development Planning Council and its subcommittees, Underwater Sound Advisory Group, Laboratory Advisory Board for Research of the Naval Research Advisory Committee, Mobile Sonar Technology Working Group, Oceanographer's Advisory Council, NavOceano Consultants Panel and DNL Advanced Technology. In addition, there is participation in various ad hoc studies, working groups and symposia which are convened by Navy activities during any given year.

FACILITIES SUPPORTING MPL RESEARCH PROGRAMS

FLIP - Floating Instrument Platform *Fig. 6*

FLIP, which has an overall length of 108 m, is towed in the horizontal position to the area where scientific operations are to be carried out. Upon arrival on station the tow line is cast off and ballast tanks distributed throughout the after 78 m of the vessel are flooded. In about 20 minutes the vessel is completely vertical with approximately 17 m of prow pointed skyward and the remaining 91 m of vessel underwater.

The diameter of the hull, which is 6 m from the 91 to 46 m depth, tapers down to 3 m at the 18 m depth. This change in diameter gives FLIP a natural period of 27 seconds for vertical motion compared to an 18 second period for a cylinder of the same depth. The longer period reduces FLIP's response to wave motion since wave energy in the ocean usually occurs at periods below 18 seconds; for a 3 m wave, FLIP's vertical motion is less than 0.9 m.

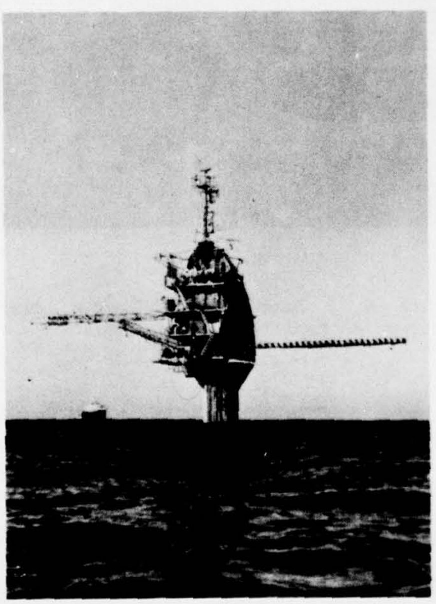

Figure 6. FLIP - Floating Instrument Platform.

ORB - Oceanographic Research Buoy *Fig. 7*

ORB, a 21 x 14 m rectangular shaped vessel displacing approximately 300 tons was developed by the Marine Physical Laboratory to serve projects the laboratory which require the launch, retrieval, implantation or handling of large equipments of systems in the open ocean.

In contrast to FLIP, ORB is designed to follow the sea surface as closely as possible, in order to simplify the task of placing and retrieving large objects in the ocean. The vessel has a center well of 5 x 6 m area which can be opened to permit the lowering of equipment through it. The well doors when closed provide a dry work space and will safely support a weight of 11 tons. Loads up to 11 tons can be lowered to a maximum depth of 2890 m. They are safely handled with a system that includes a number of automatic control features. The supporting cable also serves simultaneously to transmit as much as 30 kw of power and all necessary control signals to the remote equipment, and to return from it a variety of data, including television video signals.

ORB is 8 m high from keel to upper deck. It has no means of self-propulsion and must be towed to and from operating areas. The vessel is equipped with diesel generating sets which provide up to 240 kw of electrical power. ORB's equipment also includes a normal amount of navigation aids, communication and safety equipment. It can carry sufficient fuel and water for a stay of up to 45 days while moored on station. Personnel rotation and provisioning at sea where necessary have been accomplished by small boat.

In addition to laboratory work spaces and machinery space, ORB is equipped with complete living facilities for 14 people including four crew members.

Figure 7. ORB - Oceanographic Research Buoy.

RUM - Remote Underwater Manipulator *Fig. 8*

RUM is a remotely controlled, tracked sea floor work vehicle which has been developed under the sponsorship of the Office of Naval Research at the Marine Physical Laboratory for use as a research tool in sea floor technology experiments.

During operations, RUM is launched through the well on ORB, lowered to the sea floor and the cable tensioning system is set for a tension of from 1814 to 5443 kg depending on conditions and depth of water.

The vehicle is propelled by two independently controlled reversible 7-1/2 hp direct current motors, one driving each track. Other equipment includes three television cameras, ten 500 W quartz iodide lights, two 600 W mercury vapor lights, color movie and still cameras, an obstacle avoidance scanning sonar with a 23 m range, a high resolution search sonar with a 182 m range, up- and down-looking depth sounders, a magnetic compass, listening hydrophones, acoustic transponder navigation system and a manipulator capable of exerting 23 kg of force in any direction at full arms length.

Design depth for the vehicle is 2438 m. Extensive operations have been carried out in a variety of locations of diverse bottom characteristics within a 121 km radius from San Diego. Depth of operations has ranged from 31 to 1859 m.

RUM is currently in an inactive status.

Figure 8. RUM - Remote Underwater Manipulator.

Lake San Vicente Transducer Calibration Facility *Fig. 9*

The Marine Physical Laboratory maintains a 7 x 15 m covered test and calibration barge at San Vicente Lake, one of the reservoirs of the San Diego water system, located approximately 48 km northeast of the laboratory. This research platform is equipped with electrical power and electronic instrumentation for calibration of acoustic transducers and hydrophones and for conducting a variety of other tests and calibrations in the quiet calm of a large fresh water lake.

Availability of these facilities to support appropriate projects can be ascertained by contacting C. B. Bishop, Assistant Director, MPL/SIO, at (714) 452-2303 or AV 933-7176.

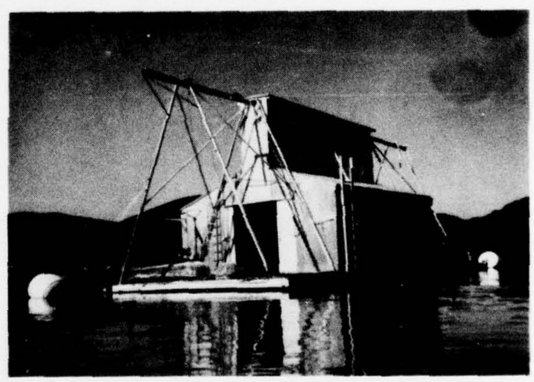

Figure 9. Lake San Vicente Transducer Calibration Facility.

MPL Calibration Center

Calibration and testing of oceanographic instrumentation, primarily CTDSV and STDSV packages is continuing, principally for the Naval Oceanographic Office. Pressure cycle testing as well as conventional pressure, temperature, salinity and sound velocity calibration services are available to others on a limited basis. Inquiries regarding services should be made to Mr. W. Semonchuk at (714) 565-0313 or 9284 Balboa Avenue, San Diego, CA 92123.

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Marine Physical Laboratory
MPL-U-74/76

CURRENT MAJOR PROJECTS OF THE MARINE PHYSICAL LABORATORY by the MPL Staff, University of California, San Diego, Marine Physical Laboratory of the Scripps Institution of Oceanography, San Diego, California 92132. SIO Reference 76-22, 31 December 1976.

This report describes the early 1976 status of major research programs at the Marine Physical Laboratory of Scripps Institution of Oceanography, University of California, San Diego. The work is conducted in the four general topics of Ocean Acoustics, Sea Floor Studies and Technology, Signal Processing, and Environmental Studies. Special facilities used in the MPL research programs are described briefly.

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