Woods Hole Oceanographic Institution

WOODS HOLE OCEANOGRAPHIC INSTITUTION 1930

REFERENCE NO. 71-4

PROGRESS REPORT ON SEA GRANT GH 104 FOR OCEANOGRAPHIC ENGINEERING ACADEMIC DEVELOPMENT

July 1, 1970 through August 31, 1971

by

Dr. Albert J. Williams, III

for

Dr. Scott C. Daubin, Principal Investigator

WOODS HOLE, MASSACHUSETTS

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December 1971

TECHNICAL REPORT

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Approved for Distribution Earl E. Hays

Earl E. Hays, Chairman
Department of Ocean Engineering

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SUMMARY

Support of students, development and teaching of academic subjects, support of faculty research, and addition of another ocean engineering staff member were the goals of the Sea Grant for Oceanographic Engineering Academic Development GH-104. These goals have been met within the contract period July 1, 1970 to June 30, 1971 extended to August 31, 1971. Our department has increased its academic competence as demonstrated by our capacity to offer research problems and guidance to ocean engineering graduate students, our capacity to offer formal subjects in oceanographic engineering, and the establishment of a student population.

STUDENT PROGRESS

At the beginning of the contract period July 1, 1970, the first class of three students had completed an academic year of residence at M.I.T. They transferred to Woods Hole for summer residence at W.H.O.I. and were joined by three of the four students who had been admitted to the second class. This group of six students took the summer semester course in Oceanographic Engineering Systems - a subject encompassing lectures on instrumentation and student projects.[1]

In the fall a member of the first class left the program and the second class moved to M.I.T. for their academic year of residence there. The remaining two students at Woods Hole took the three subjects offered in ocean engineering and courses in physical oceanography, marine geology and geophysics, and marine biology offered in other departments. (A student of marine geology also took one of the ocean engineering subjects.)

In the summer of 1971, the four students in the second class who had been in residence at M.I.T. transferred to Woods Hole for the summer course in Oceanographic Engineering Systems. They were joined by two members of the third class of three students. New material was presented and different student projects pursued in the second offering of this subject.[2]

The two students of the first class worked on their respective theses. One student was a candidate for the professional degree of Ocean Engineer. He completed a satisfactory thesis and was awarded the degree at the end of the summer.[3] The other student was a candidate for the Ph.D. but failed his qualifying exams at the end of the summer. He is a competent engineer nonetheless and he has been encouraged to undertake a more restricted thesis for the professional degree.

As the fall 1971 semester starts, there are five students in residence at Woods Hole - one from the first class and four from the second class - and the three students from the third class are in residence at M.I.T. This is about two-thirds of our projected equilibrium population in the near future. However, as the academic capability of our department develops, more students can be accommodated and we would hope to have twice the present number eventually. The group of five students this fall can already be seen to form a more stimulating mass than the group of only two students a year ago. Yet so small a group as five is somewhat vulnerable and a group of eight or ten would be more stable.

ACADEMIC SUBJECTS

Oceanographic Engineering Systems, Oceanographic Engineering Systems Analysis, Buoy Engineering, and Oceanographic Deep Submergence Engineering were presented in the contract period. O.E. Systems was presented in the summers of 1970 and 1971. Reports of these projects were prepared including the student projects.[1,2] O.E. Systems Analysis was presented in two semesters and included projects in which the students analyzed various systems of importance to oceanographic engineering. Buoy Engineering was presented in the fall. The statics and dynamics of mooring systems was discussed and the students went on a cruise to deploy and recover current meter moorings north of the Gulf Stream at our Site "D". A very complete set of handwritten notes was prepared for this subject. Oceanographic Deep Submergence Engineering was presented in the spring. Pressure hulls, instrumentation, and support systems were considered and topics of student interest were considered by the class. A more detailed description of the subject is presented as an appendix.[4]

The latter two subjects are to be prepared in book form this year. Currently Deep Submergence is being taught and the notes are being revised for publication form. Buoy Engineering will be taught in the spring and the notes from that course should appear in book form next summer.

O.E. Systems Analysis is not being offered this year as we have no suitable instructor. It is hoped this void can be filled by distributing the subject matter between several other subjects. Probabilistic Systems Analysis and Engineering Systems at M.I.T. cover part of the subject and the remainder can be included in O.E. Systems and a new subject on Instrumentation at W.H.O.I.

FACULTY RESEARCH PROJECTS

It had been proposed that a program of long term instrument evaluation at sea be developed as a project. An addition to the staff was to have been made to carry out this project. However, our choice for new staff member was a metallurgical engineer and his interests were directed toward evaluation of marine materials at sea and studies of fouling by electron microscopy. His appointment was effective this spring. Studies at deep ocean observatories of corrosion began then under his direction and that of another of our faculty. This work is described further in appendices.[5,6]

A second project to study the problem of detection of salt fingers in the ocean was proposed and this study was pursued during the summer of 1970 both as faculty research and as a student project. The study continued through December 1970 when further support was received from the Office of Naval Research. The discoveries during the period when the research was supported by Sea Grant are reported in the Summer Project report[1] and an appendix.[7] This support through Sea Grant proved very effective in establishing a new area of faculty research. Under ONR support this work is continuing for a third year and covers a graduate student as well.

NEW STAFF

It was proposed to add an academically qualified member to the ocean engineering department staff and this was done in June 1971. Stephen C. Dexter received his Ph.D. this spring from the University of Delaware in Applied Science Metallurgy. He is interested in our education program and will be preparing a syllabus for a subject in Marine Materials. His own research involves the scanning electron microscope in studies of fouling on metals. He is also involved with another faculty member in deep ocean exposures of marine materials.

It is expected that this new research interest will lend expertise to our department and provide topics for thesis research. It is also expected that Dexter will share the advising, admitting, teaching, and administration of education.

REFERENCES

1. S.C. Daubin et al "Report of the Oceanographic Engineering Summer Project" WHOI Report 71-5, Unpublished Manuscript.

2. A.J. Williams et al "Report of the Oceanographic Engineering Summer Project 1971" WHOI Report in preparation.

3. Daniel P. Charnews "Drag Coefficients of Vibrating Synthetic Rope" MIT/WHOI Thesis.

4. Appendix A, "Syllabus of Oceanographic Deep Submergence Engineering"

5. Appendix B, "Interim Report on Marine Materials Project"

6. Appendix C, "In Situ Monitoring of Structural Performance"

7. Appendix D, "Salt Fingers Progress Report"

APPENDIX A

Syllabus of Course 13.995
Oceanographic Deep Submergence Engineering

Feb. - May 1971 Instructor - J.W. Mavor, Jr.

Tuesdays - Seminars on scheduled subjects as follows:

1. Use of submersibles in oceanography
2. Hydromechanics of the submersible, other submerged platforms and instruments
3. Structure I Pressure vessels as oceanographic containers
4. Structure II Miscellany
5. Selection of materials for deep oceanographic use
6. Machinery systems and power sources
7. Concepts of deep oceanographic systems
8. Surface support for the deep submersible and logistics of instrument deployment from surface or submerged
9. Long, deep line problem, trawling, anchoring, tethering
10. Tethered platforms
11. Life support systems, man-in-the-sea
12. Navigation in the deep sea
13. Safety of manned submersibles and other oceanographic systems
14. Deep submergence systems for sampling and measurement.

Thursdays -
1) Discussion of student projects
2) Presentation of student project reports
3) Discussion of relevant student GRA project problems
4) Discussion of case studies

Assignments* Term project paper
Reading, problems and reports on subjects of Tuesday seminars

Subjects of term project papers were as follows:

"Deep Sea Rock Drill and Heat Flow Measuring Instrument"
"System Analysis of Deep Submersibles"
"Titanium for Deep Submergence Application"

The contents of the course as given in spring and fall 1971 semesters will be compiled in a text to be submitted in May 1972 and published by the M.I.T. press under its Sea Grant Program.

APPENDIX B

Interim Report on Marine Materials Project

(Activities prior to September 1, 1971)
Dr. Stephen C. Dexter

A. Data Collection for Marine Materials Handbook

Numerous references were collected and partially read in preparation for assembling a handbook of the most useful marine materials. The purpose of the handbook will be to provide ocean engineers with a source for direct comparison of the physical and mechanical properties, availability, cost, fabricability and corrosive behavior of established and experimental metallic and non-metallic materials.

B. Use of Scanning Electron Microscope

The capability of using the Institution's scanning electron microscope for metallurgical and corrosion research was developed. Two preliminary experiments were run:

1) A polished surface of 6061-T6 aluminum was exposed to well aerated seawater for 55 hours in the laboratory and the surface subsequently examined in the SEM. Numerous corrosion pits such as the one in Figure 1 were observed. It is intended in the future to see if there is a correlation between such anodic areas and bacterial attachment sites on a variety of metallic materials.

2) The unexposed surfaces of stainless steel wafers made by sintering from the powder metal (both 316 and Allegheny's-Ludlam's experimental alloy 6X) were observed. Sintering is an attractive method for manufacturing ocean engineering hardware but crevice corrosion may be a problem. Note as shown in Figure 2(a) that even at 86% of the density of the cast material the structure is laced with pores and crevices. It is also felt that this type of structure may be susceptible to corrosion by anaerobic bacteria. The anaerobic conditions (i.e. oxygen free)

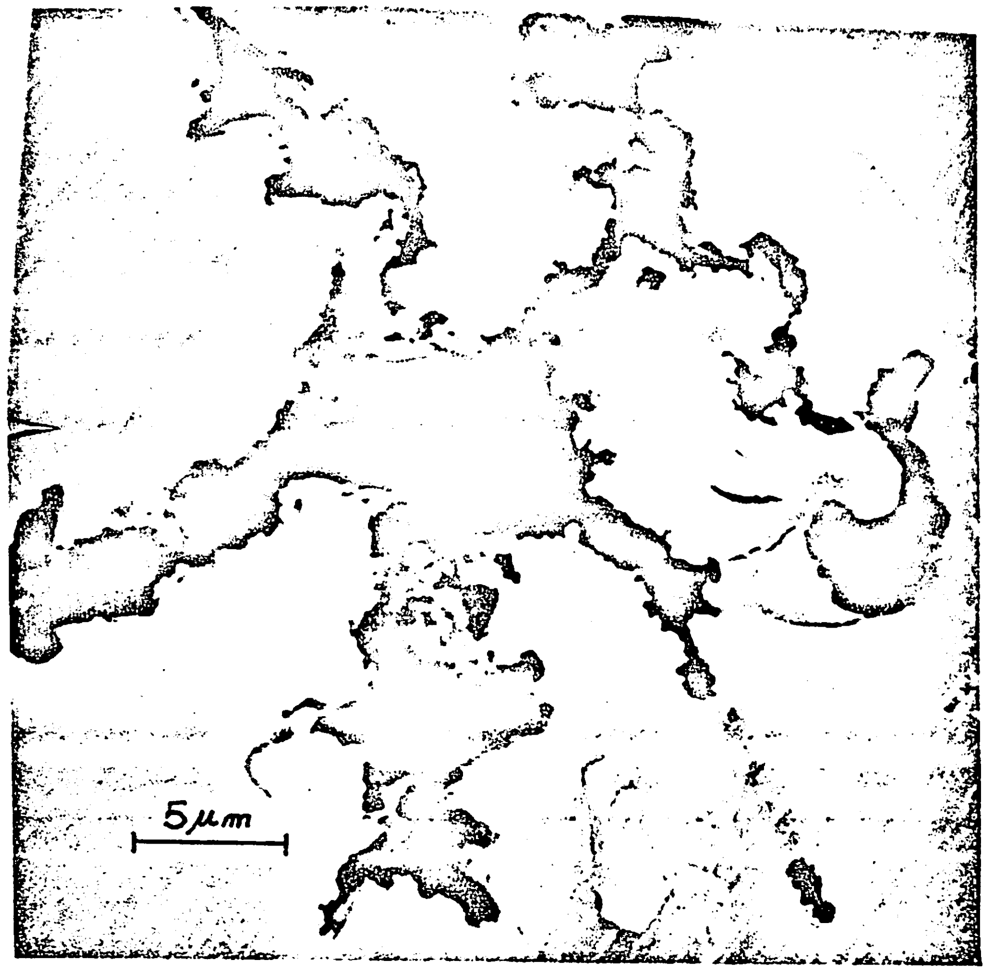
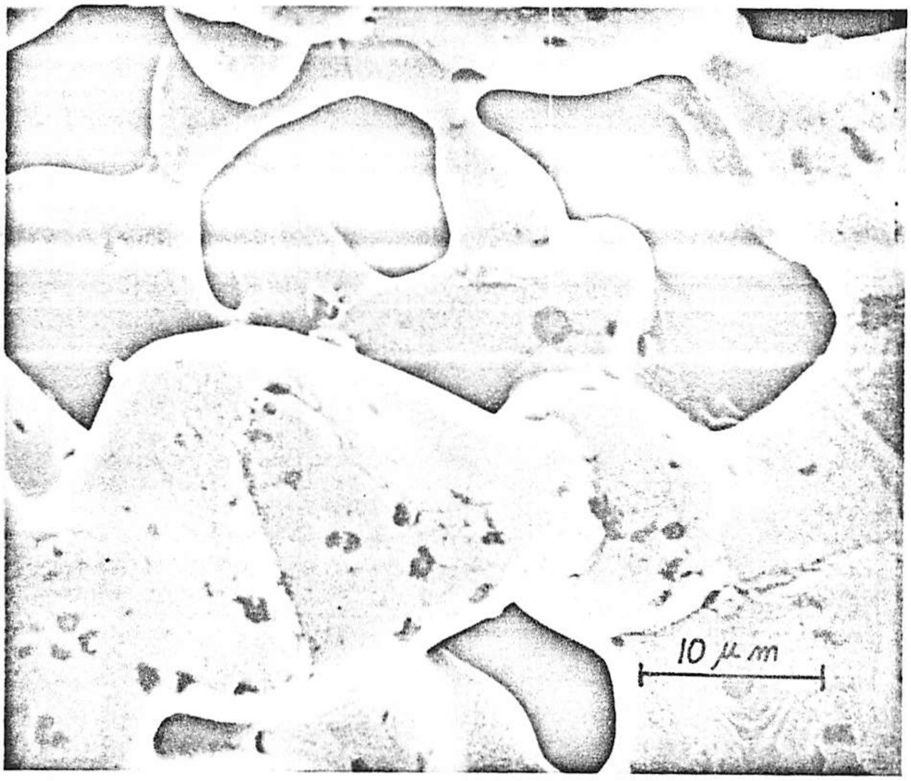


Figure 1. Small branching corrosion pit at an anodic area on surface of 6061-T6 aluminum. Mechanisms of nucleating such pits in the presence of micro-organisms will be investigated.

A



B

Figure 2. a) Pore structure on the surface of a sintered stainless steel wafer b) Large pores such as this are ideal for studying the influence of bacteria on localized corrosion.

necessary for the growth of these microbes may become established rather easily in the internal pores of the structure. It is intended to grow bacteria of the strain Dv. desulfuricans in surface pores such as shown in Figure 2(b) and observe the relations between corrosion and the bacterial attachment sites. A number of materials other than stainless steels may also be used.

C. Materials Exposures

1) Samples of sintered 316 stainless steel and Allegheny's-Ludlam's experimental alloy 6X were placed at 4 different depths on a two-month surface mooring at 70.00°W, 34.00°N. These are to be recovered in early November, 1971 and examined for crevice corrosion and the presence of anaerobic bacteria as described in Section B(2) above.

2) Galvanic corrosion couples of several marine materials including 6061-T6 Al, 316 SS, low carbon steel, zinc, sintered 316 SS and 6X, and 7079 Al were placed on the bottom at the DOOR site by the deep submersible ALVIN. The general configuration of the samples was that suggested by ASTM and is shown in Figure 3. It is intended to see if present corrosion data will allow the galvanic effects to be predicted analytically. Recovery is slated for early June, 1972.

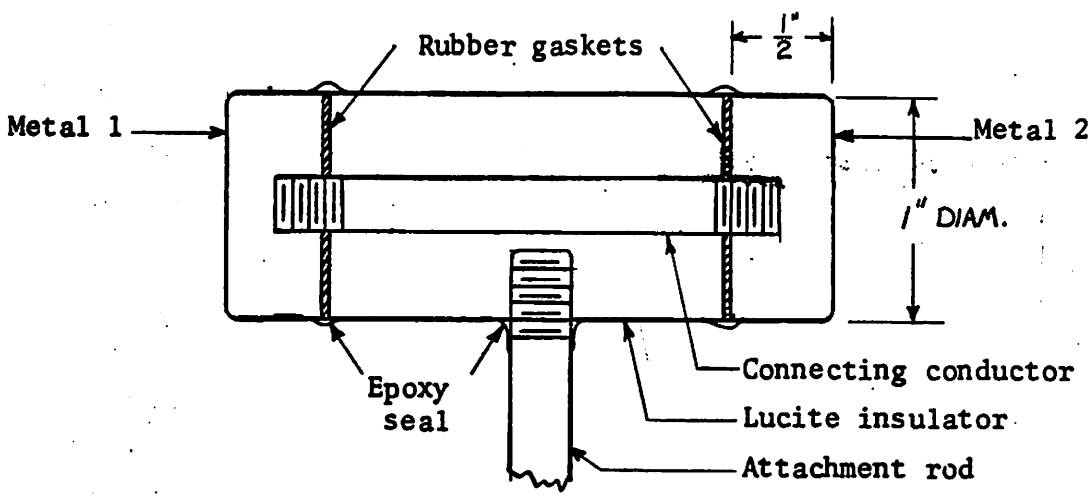


Figure 3. Geometry of galvanic corrosion couples

APPENDIX C

"*In Situ* Monitoring of Structural Performance"

The W.H.O.I. Deep Bottom Research Station

Technical Note by James W. Mavor, Jr.

The Woods Hole Oceanographic Institution established, in June, 1971, a permanent deep bottom research station at 70° 40' W, 39° 36' N for monitoring bottom environmental processes. This is a location on the continental rise some 125 miles due south of Woods Hole, Mass. in a region of rolling hills up to 50 meters in height. The bottom sediment is characterized by brownish ooze overlaying greenish compact clay. There is some sand and there are occasional pebbles and rock outcrops. The main depth of water is 1785 meters. Four sonar reflecting towers about five feet high spaced evenly along a straight line one kilometer long mark the site. (Fig. 1). It is planned to monitor closely the natural environment, sediment and water column, using the manned submersible, ALVIN, for placing, operating and retrieving instruments at intervals of time over a period of years. Engineering material exposure tests have started at the site and the structural performance of instruments placed for measurement will be monitored. It is planned to visit the site twice yearly with ALVIN, spring and fall.

The location was selected on the basis of four criteria:

1. Distant from underwater canyons and other topographical features which might by their presence affect the environment.
2. In a well studied area. It is near W.H.O.I. site "D".
3. In deep water but within ALVIN's operating depth range.
4. As near Woods Hole as possible.

In 1971, three dives were made with ALVIN to the station. Sediment core samples were taken and detailed soundings were made so that a detailed topographic map could be constructed. Wood samples were exposed within and above the sediment. Instruments were deployed for injecting nutrients into the sediment and into the nearby water column. A sample of Eel Pond, Woods Hole mud was placed and exposed on the bottom. Galvanic couples of commonly used structural materials were placed for long term exposure.

Data from previous surveys of the general area of the site have been compiled to which will be added current and specific data as it is taken by scientists of several diciplines who are studying the site.

Some recent data from locations nearby is presented (Fig. 1) which are expected to be generally applicable to the station site. Fig. 2 presents the variation in dissolved oxygen at two locations within 21 miles of the deep station as indicated in Fig. 1 (1). Fig. 2 also presents oxygen data as reported off Port Hueneme, California for comparison (2). Salinity and temperature are presented in Fig. 3 (1), also with comparison with west coast sites. The striking differences between east and west coast sites have significant effects. Benthic fauna and sediment analyses performed in 1965 within a few miles of the bottom station are available (3).

(1) R/V KNORR, Report of Cruise No. 13, Oct. 14, 1970. W.H.O.I.

(2) F. M. Rinehart, "Corrosion of Material in Hydrospace - Part I," USNCEL Tech. Note N-900, July 1967.

(3) H. L. Sanders, P.R. Hessler, G.R. Hampson, "An introduction to the study of deep-sea benthic faunal assemblages along the Gay Head-Bermuda transect." Deep-Sea Research 1965 Vol. 12.

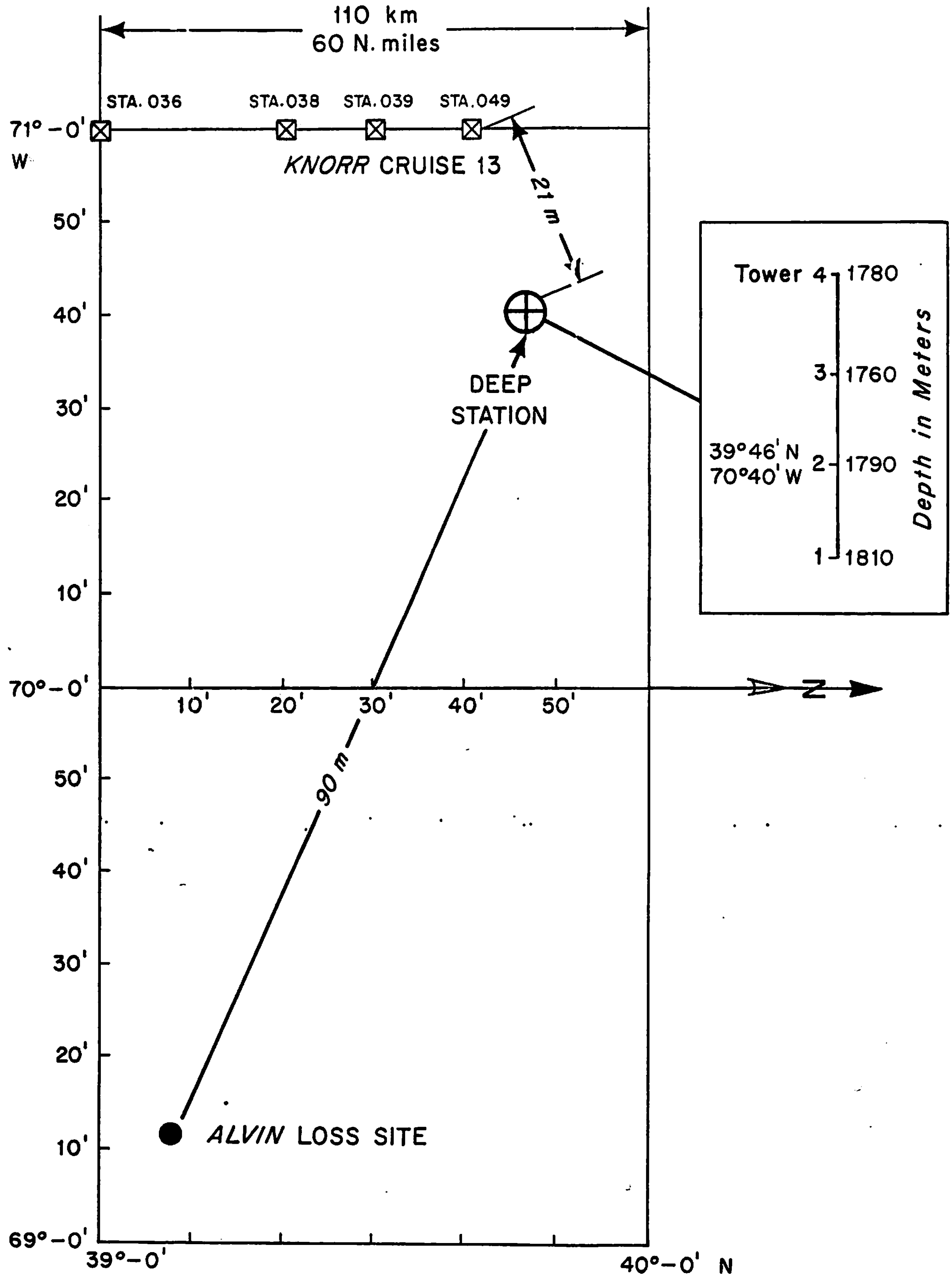


Figure 1. Deep Research Station, Alvin Loss Site, Knorr Cruise 13 Stations

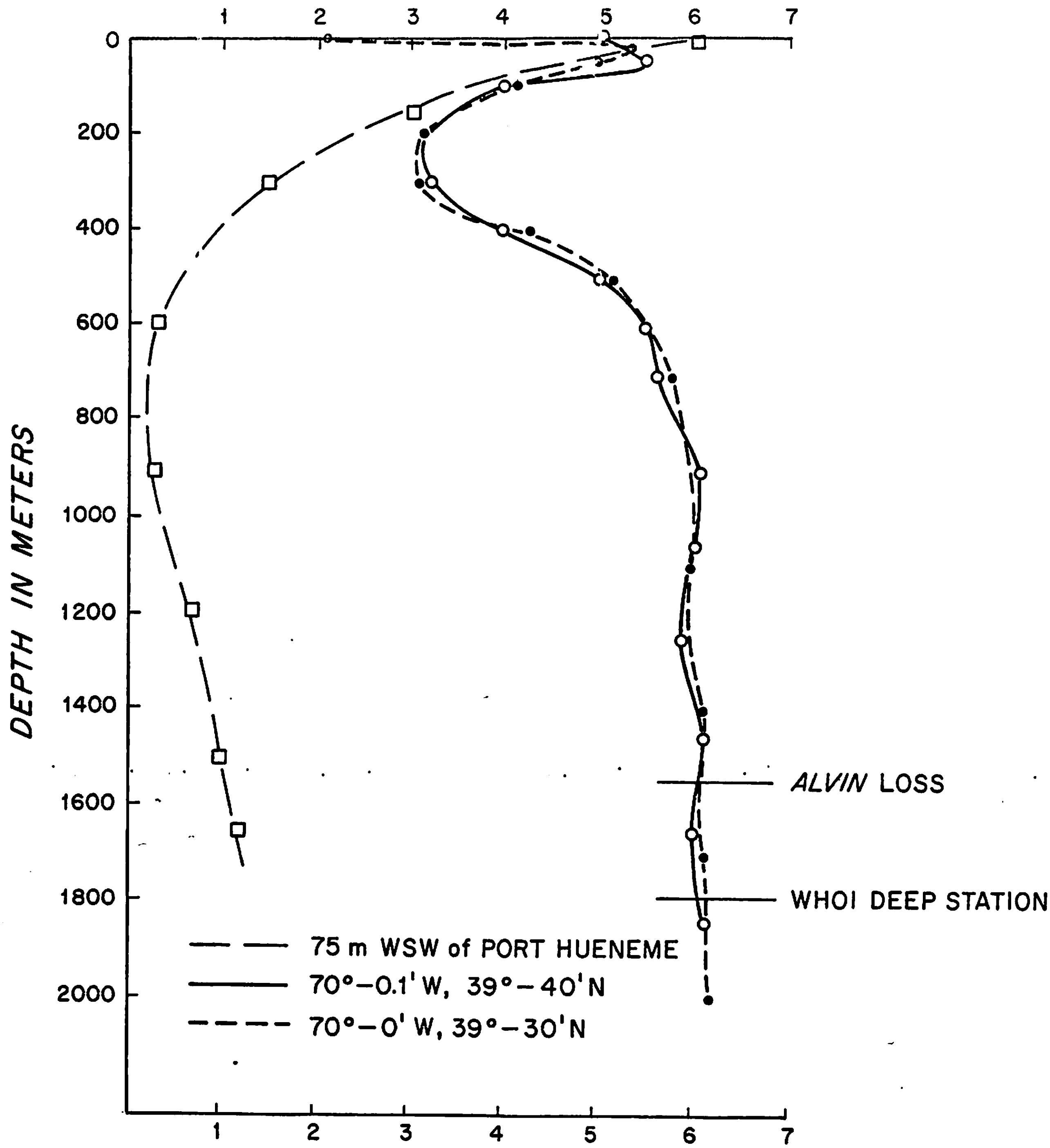


Figure 2. Dissolved Oxygen - mℓ/ℓ, Comparison of East and West Coast, North America

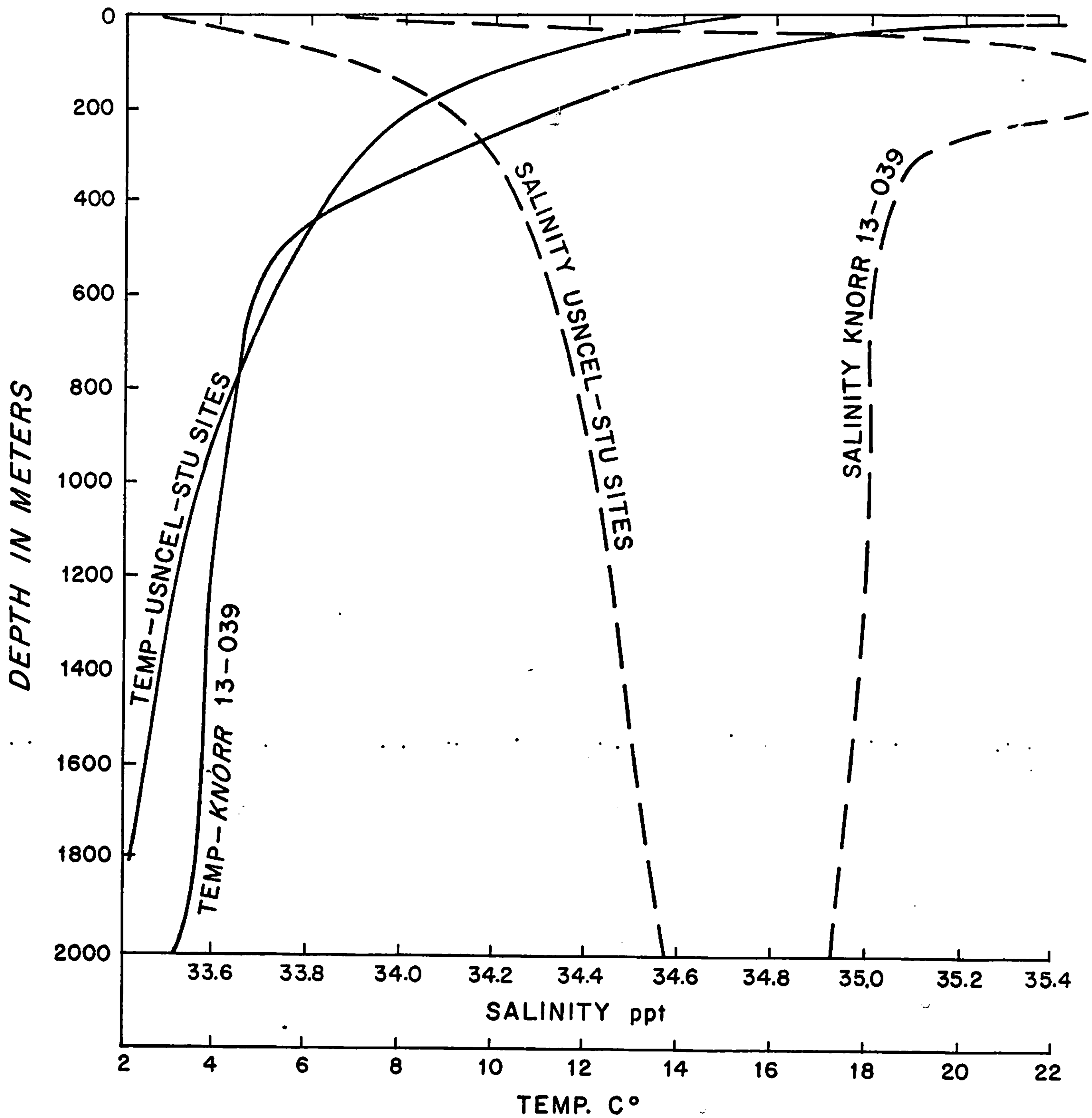


Figure 3. Salinity Temp. Profiles, Knorr Cruise #13, Sta 039, Compared with USNCEL Stu Sites

APPENDIX D

December 23, 1970

"Salt Fingers Progress Report"
Dr. Albert J. Williams, III

In February 1970, it was proposed to build an optical instrument to detect salt fingers in situ and deploy it near Bermuda in July. As work was not started until July, this plan was abandoned in favor of a more careful investigation of optical detection techniques. This work involved students in the MIT/WHOI joint program in ocean engineering.

The instrument I had planned to build in February would have passed a beam of laser light through a long folded path in the water to fall on a photographic plate. If there had been a vertical gradient in index of refraction, the point where the laser beam exposed the plate would have moved vertically. If there had been lateral inhomogenieties in index, the plate would have been exposed in a lateral pattern. The minimum condition for detection in this system is that the beam be deflected a distance of the order of its diameter. If the path is lengthened, the beam diameter at the plate increases linearly with the distance, after a certain point, while the deflection due to an index gradient varies with the square of the distance, and the spreading due to local random inhomogenieties varies with distance to the 3/2 power. So a greater path length increases the sensitivity of the instrument, but not quickly. A practical limit is set by the scale of the instrument and the number of reflections which can be tolerated. Because the instrument proposed would have been relatively simple, it was intended that it be built and deployed rather than analyzed and tested. However, in the meantime a test of this sort was made by a British group as was reported to me by Stewart Turner. They saw nothing above their threshold.

Two other detection schemes were under my consideration and with the inadvisability of putting the proposed instrument in the water, I prepared to test these schemes in the laboratory. I felt this re-direction of my effort was not incompatible with the intention of the proposal to investigate the measurement problem of salt fingers. The first scheme was to photograph vertical and horizontal grids of various ruled spacings through a field of sugar-salt fingers. The ability to resolve the lines would be a measure of scattering in the horizontal and vertical planes. Such an instrument would also be simple, consisting of an underwater camera, light source, and ruled target screen. The path could be folded as well. The second scheme was to pass collimated light through one ronchi ruling and eclipse the light passing the first ruling with a second ruling. Between the rulings, the light would pass through the field of sugar-salt fingers where scattering would cause light to leak past the eclipsing ruling. The light passed by the system would be detected photoelectrically.

The first scheme, the effect fingers would have on the visibility of grids, was studied with several grids. Horizontal lines were resolvable with spacings less than 1 mm through 20 cm of quite strong fingers. Vertical lines could no longer be resolved with spacings less than 3 mm. The difference was pronounced. However, the image of a diagonal edge was as sensitive to fingers and less dependent on finger size than grids. A pattern of diagonal stripes was employed as the background in most photographic experiments that followed. Such a pattern viewed through sugar-salt fingers can be seen in Figure 1.

Two graduate students in the Joint Ocean Engineering Program elected to study salt-finger detection as a portion of their requirement in Oceanographic Systems I & II. They explored the second scheme, the passing of light through eclipsed ronchi rulings.[1] A matched set of rulings was made with 10 lines per inch. Expanded and collimated laser light was allowed to pass through the first ruling, a tank of salt fingers, and the second ruling.

It was quickly found that the absolute light passing the second ruling was not a dependable signal. However, if the tank containing the fingers was moved across the beam, a fluctuating light intensity passed the second ruling. The fluctuations in intensity were related to position of the tank and found to correlate with the spacing of the fingers. Freshly made fingers were strong and small. As the solutions mixed, the fingers became weaker and larger. The amplitude of the fluctuations seemed to increase until the finger spacing was about the same as the spacing of the edges of the rulings--1/20 inch.

This result was somewhat surprising as it implied the deflection of light varied regularly in the fingering field though the tank was 4 inches thick. One might have expected a more random variation in deflection. The regularity could result from an induced alignment of the fingers near the wall which would deflect the light in the observed way while remote regions would contribute a random background. However, when the region near a wall was observed from below, the alignment was seen to be only somewhat influenced by the wall. Many orientations occurred. Another possibility was that only regions with some specific alignment contributed sizable deflections. An analogy could be drawn to X-ray powder pattern diffraction in which only certain grains of powder with the right orientation contribute to the diffraction pattern.

Interpreting the results of the ronchi ruling experiment is complicated by the multiplicity of edges. It is simpler to consider one edge at a time. An edge at the first ruling casts a shadow which to first approximation can be considered a vertical plane dividing a region of no light from a region of finite and uniform light. (Actually, a fresnel diffraction pattern is produced.)

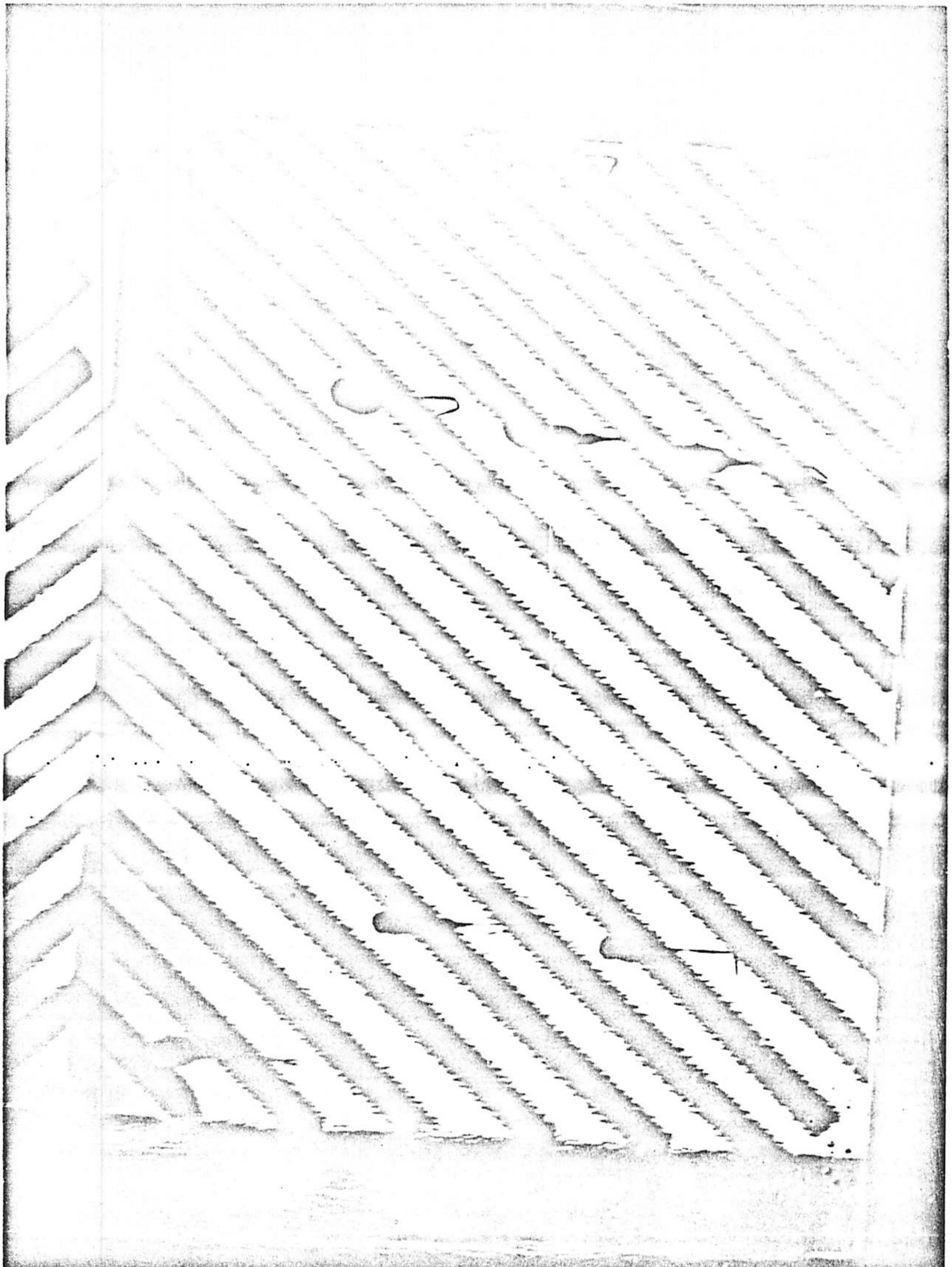


Figure 1. Sugar-salt fingers and neutrally buoyant floats photographed against diagonal stripes.

The edge at the second ruling lies in the shadow plane so that it just eclipses the light passing the first edge. (Actually some light diffracted by the first edge passes the second edge.) In this case, light deflected across the shadow plane by optical inhomogenieties in the intervening space can pass the second edge. If a row of high index fingers is aligned parallel to the shadow plane and displaced about half a finger space on the dark side, light will be refracted across the plane. If the displacement were half a space on the light side, the refraction of light near the shadow plane into the light region would not be noticed were the eclipsing exact. In practice, the eclipsing is inexact due to fresnel diffraction and imperfect alignment and some light passes the second edge in the absence of inhomogenieties. The effect of light near the shadow plane being refracted deeper into the illuminated region is to decrease the leakage of light past the second edge. If the rows of high and low index fingers were moved across the shadow plane, the light passing the second edge fluctuates achieving its mean intensity when a row of fingers is coplaner with the shadow.

A second pair of edges displaced from the first by the spacing of one row of fingers would give a signal in phase with that from the first. However, if the spacing of the shadow planes were not equal to the row spacing of the fingers, the signals due to movement would not be in phase, and when the shadow plane spacing is two row spacings, the signals cancel. When N pairs of edges are used, the matching of spacings becomes more critical with the condition for zero signal being that the N shadow spacings equal N + 2 row spacings.

In the ronchi ruling experiment this appeared to be the case. About eight edges were illuminated which would lead one to expect zero signal when the spacing of rows was 20% less than the edge spacing. In fact, the amplitude of fluctuations increased as the fingers in the experimental set up matured and their spacing increased. Since it appeared that the finger spacing was close to the edge spacing, it is reasonable to suppose that early in the experiment it was less than the edge spacing but later the match improved.

Domains of suitably aligned rows have another effect on the signal. If one first considered a single shadow edge, the signal due to one moving domain would fluctuate as many times as there were rows in that domain. If suitably aligned domains were rare, the signal one might expect as a tank containing fingers was moved across the shadow edge, would be uniform sections alternating with fluctuating sections in which each fluctuating section had a number of cycles typical of the conditions in the tank at that time. If a typical domain were M rows in extent, a misalignment of 1/M radians between the plane of the rows and the plane of the shadow would destroy the contribution of that domain. Thus in a field of randomly oriented domains of fingers, $4 \times \frac{1}{M} \times \frac{1}{2\pi}$ or $2/M\pi$ is the fraction of domains which might contribute to the signal. In the ronchi ruling experiment, the path was about 80 rows long. If M were 5, one would expect 1/8 of the domains to contribute and there would be about 16 domains in the optical path so sometimes there would be no domain, sometimes a single domain, and most often, several domains with suitable alignment. If two domains contribute, their combined effect can vary from nearly twice that of one domain to nearly zero. The phase of the fluctuations also would shift as a new domain added its contribution to a domain already causing a fluctuating signal. But the period of the fluctuations would not change. This describes the signal observed in the ronchi ruling experiment; fluctuations of similar amplitude occurred in trains of 3 to 7. When repeated several minutes later, some series were unchanged while others showed modification. In 30 minutes, all series were changed considerably.

In conclusion, it appears that the model for scattering of light by salt fingers must recognize the local order of the alignment. Any detection scheme based on optical methods must be designed to take advantage of the domains of cells having the right alignment with respect to the beam direction. A random walk model for a ray path in a field of salt fingers is not the best model. Rather a kind of X-ray powder pattern analogy of select domains with optimum alignment for scattering is the appropriate model.

1. S.C. Daubin et al "Report of the Oceanographic Engineering Summer Project." WHOI Report 71-5, Unpublished manuscript.

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