MARINE GEOPHYSICS: A NAVY SYMPOSIUM

in honor of
the 80th birthdays of
Russell W. Raitt and Victor Vacquier

and the 40th anniversary of
the Marine Physical Laboratory
of Scripps Institution of Oceanography
of the University of California San Diego

held on 16 October 1986
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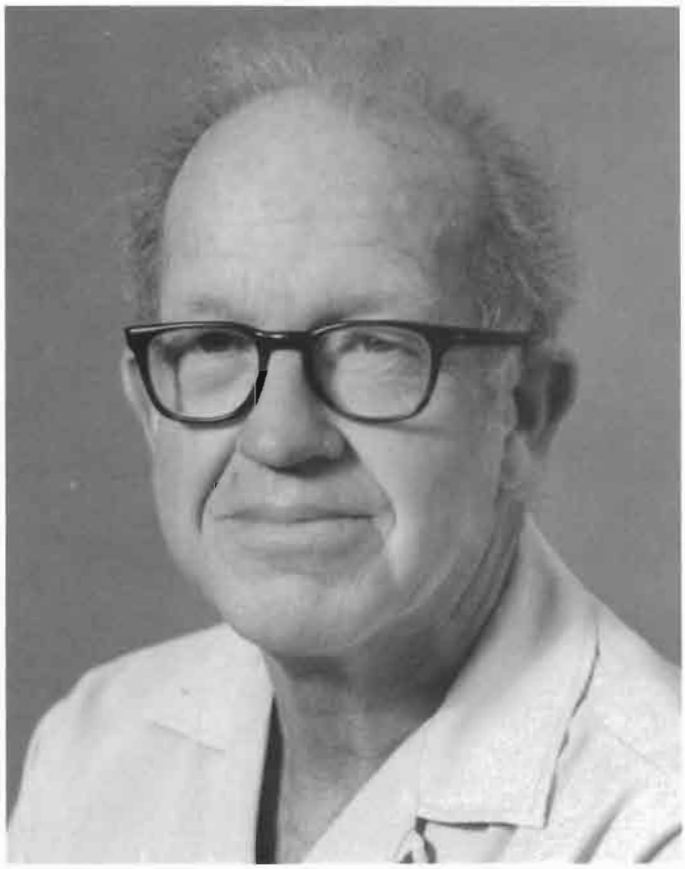

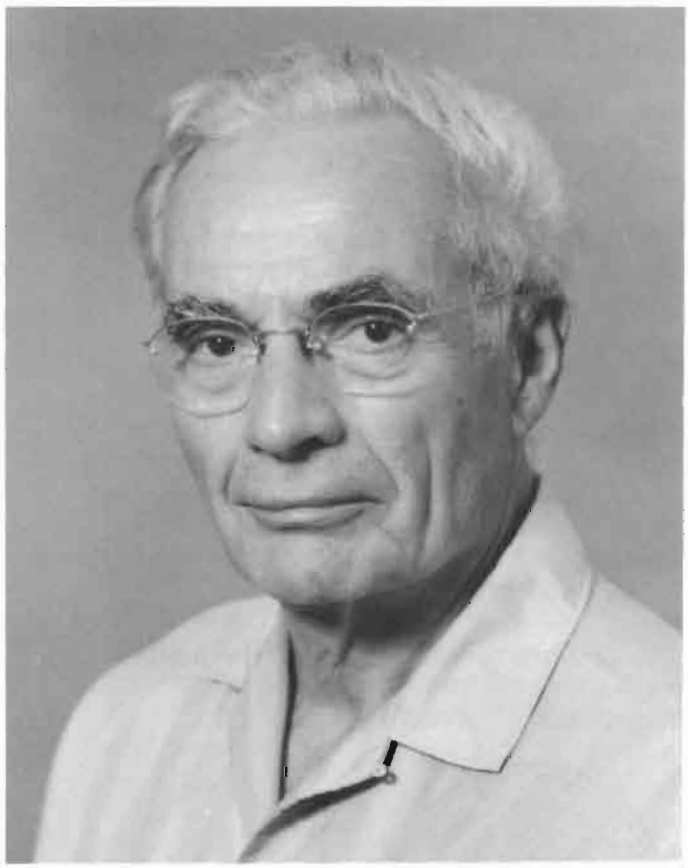

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FORTY YEARS OF OCEANIC RESEARCH, AND AN APPRECIATION OF RUSSELL W. RAITT AND VICTOR VACQUIER

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Introduction

It is a great privilege to stand here in front of so many distinguished oceanographers to present an appreciation of MPL on its 40th birthday by honoring the work of two scientists for whom I have long had a high regard: Russell Raitt and Victor Vacquier.

It is especially gratifying to honor MPL on this occasion because I spent seven very rewarding years at the laboratory and have a deep appreciation and respect for the distinguished scientists who have directed it: Carl Eckart, Sir Charles Wright, Al Focke, Fred Spiess, and Ken Watson.

Today we recognize the research achievements of Russ and Vic.

Being a geologist by inclination but having had a classical physics education in Europe, I have always had a high regard for scientists who have made important observations that have stood the test of time. Russ and Vic are such scientists. What has struck me so much in reviewing their accomplishments is the fundamental understanding they have brought to our knowledge of the ocean floor by their careful observations and measurements, which form the central basis for the theory of sea-floor spreading.

They have both led remarkably interesting and productive careers. These involved an exciting and varied childhood, industrial and war research after graduate school and finally a long period of productive research at MPL and Scripps.

Both are seagoing observational scientists. Between them they have supervised about 20 Ph.D. students and directed the research of an equal number of post-docs. Most of these students and post-docs are still seagoing scientists. In fact, three of them — Larry Lawver, Roger Anderson, and John Hildebrand — could not be here today because they are at sea. In addition, many of these students and post-docs are now the current leaders in marine geology and geophysics, not only in the United States but also in Britain, France, and Australia.

*Speaker, so represents the first-person pronouns.

About Russ Raitt

Russell Watson Raitt was born in Philadelphia, Pennsylvania on September 30, 1907. His father was a minister in the United Presbyterian Church with responsibility for founding new churches. In 1921 Russ's parents moved to California, and Russ entered high school in Hollywood. He found it much more sophisticated than schools he had known before. In fact, his parents decided it was a den of iniquity and soon moved to South Pasadena, where Russ finished high school.*

In 1925 he entered the California Institute of Technology, partly because it was gaining a reputation as an excellent school under the new leadership of Robert A. Millikan, but mostly because it was nearby. There he was exposed to many outstanding teachers, such as Ira Bowen for sophomore physics, and Linus Pauling, who supervised a research project of Russ's in his junior year. He graduated in 1929 with a B.S. in physics, travelled in Europe, and then worked for Hercules Powder Company for two years.

Russ returned to Caltech for graduate work in 1931. His doctoral work, under Millikan, was to measure the radioactive content of a large number of dirt samples collected by Millikan and associates around the world in their study of cosmic rays. His dissertation was titled: "Direct measurement of Alpha particle activities of rocks and determination of thorium." Russ received his Ph.D. in 1935, and that same year he married Helen Hill, whom he had known in the South Pasadena high school. He acquired an instant family, Helen's three children by her first marriage. Russ and Helen's daughter Martha was born in 1939.**

Helen, her three children, and Russell Raitt, a few days after their marriage in 1935.

Also in 1935 Russ joined two Caltech geophysics graduates, Josh Soske and Raymond Peterson, in Geophysical Engineering Corporation, a company established to look for oil fields. Their first project was reflection prospecting in the Los Angeles basin. To interpret their reflection records, Russ had to obtain

*Some of this material is from a taped conversation among Raitt, G. Shor and E. Shor on 30 October 1984, which is the source of quoted comments by Raitt.

**She is the wife of Christopher G. A. Harrison.

velocity as a function of depth, and so he discovered that Beno Gutenberg had shot a long refraction profile across the Los Angeles basin about 1933, to measure the depth of alluvial fill. It provided him with what he called "a beautiful profile of the travel time versus distance which fit quite well to a linear velocity/depth function." The three-man field party also surveyed the Pasadena water basin for depth to the granite basement, and did refraction prospecting in the San Joaquin Valley. By 1941 the company was definitely declining. It had been "kind of fun," Russ said, "and I think we pioneered in some ways."

Having learned of a new laboratory being formed in San Diego, Russ visited it to talk to its director, Vern O. Knudsen from the physics department of UCLA. The new laboratory was the University of California Division of War Research, which Russ joined in the summer of 1941. Helen was quite delighted, as she had always enjoyed being at the beach.

Russ's work at UCDWR was in acoustics, using explosives and echo-ranging transducers to measure sound propagation and scattering in the water and reflections from the sea floor. The available ships were the *E. W. Scripps*, on loan from Scripps Institution of Oceanography, and the *Jasper*, a preempted yacht later owned by SIO as the *Stranger*. Carl Eckart was head of one of the two divisions of UCDWR, which included the echo-ranging section to which Russ belonged. Russ found him to be a "marvelous scientist...he had such a wonderful conception of what was important in every thing he did."

During 1942, Russ and colleagues observed the phantom bottom, which registered as if the sea floor was very shallow when it was known to be deep (Eyring, Christensen, and Raitt, 1948; Raitt, 1948). They concluded that this was not an instrument problem, and called it the Deep Scattering Layer because it scattered the sound waves. Biologist Martin W. Johnson suggested that the layer was composed of living organisms, and on a sea trip in June 1945 he followed its daily cycle through 24 hours.

UCDWR began to be dismantled during 1945, and the Navy Electronics Laboratory was established from it. However, Carl Eckart wanted a university affiliation; he almost gave up because of interminable delays. Russ hung on, having chosen not to transfer to NEL. And on July 1, 1946 the Marine Physical Laboratory of the University of California began operations. Its scientific staff members were: Carl Eckart, Director and Professor of Geophysics; Russell W. Raitt, Senior Research Associate; Robert W. Young, Research Associate; William C. Kellogg, Research Fellow (i.e., graduate student); Finn W. Outler, Marine Supervisor.

MPL was joined to SIO instead of the University of California at Berkeley in 1948, when Carl Eckart became director of both MPL and SIO. Russ became associate professor at SIO in 1949 and professor in 1956. He had begun teaching at SIO in 1947 a course in principles of underwater sound.

Russ's first research at MPL was a carryover from UCDWR: analyzing oscillograms of bottom echoes derived from vertical beams of 24-kc sound. He devised improved equipment and gathered more reflection records at sea off San Diego. Using the bottom surveys done by the geological group under Francis P. Shepard for UCDWR, he selected sites of specific sediments from rock to mud, and analyzed the records for the dependence of echo amplitude and form on bottom type, depth and topography. By 1948 he could say: "Observations of the reflection of ultrasonic sound from the sea bottom have been explained reasonably well by the hypothesis that the sound is diffusely scattered from the ocean bottom, or from a layer extending a few feet into the bottom" (MPL Quarterly Report, 1 Jan. - 31 Mar., 1948).

Early in 1948, Russ began reflection studies using explosives at sea, first on a 12-day trip to Erben Bank (800 miles west of San Diego), on which he recorded 132 shots from 1/2 pound to 5 pounds of TNT. By the middle of that year he was doing refraction studies with SOFAR detonators and 50-pound charges of TNT. He quickly learned that hydrophone motion was lessened by floating the hydrophone at nearly neutral buoyancy at depths of 100 to 200 feet. The TNT charges were fired from a motor whaleboat — when practical. "Only a small percentage of the time did weather conditions permit operating in the deep ocean beyond the continental slope" (MPL Quarterly Report, 1 Apr. - 30 June 1949). For that reason a number of shallow-water profiles were recorded in the lee of islands such as Guadalupe, Cedros, and the San Benitos.

SIO acquired *Paolina-T*, a former purse seiner, in 1948, and Russ began two-ship refraction profiling in the spring of 1949 with that ship as the shooter and the *EPCE(R):855* of NEL as the receiver. He shifted to slow-burning time fuse instead of electric detonators so that the shooting ship could travel at full speed. "It was found quite practicable to record 50 miles of profile, with shots about one mile apart, in an eight hour working day" (MPL Quarterly Report, 1 July - 30 Sept. 1949).

In the experimenting of that era, Russ's group tried various ways of measuring reflections from the sea floor. They used hydrophones built by others, and they tried making their own. They used the "snake" — a long plastic hose full of hydrophones devised by L. C. Paslay of Dallas, Texas. Russ thinks it may have been the first towed seismic array.

In August 1949 Russ participated in the project of Merle A. Tuve to determine the structure of the earth's crust down to tens of kilometers. Tuve's work was sponsored jointly by the Carnegie Institution of

Washington and the three-year-old Office of Naval Research. From the *Paolina-T* were fired six charges of 1200 pounds, six of 2400 pounds, and one of 600 pounds. MPL recorded these at 13 ocean stations while Tuve and associates recorded them at many land stations. As part of the same project Russ set up an ocean station to record a quarry blast on August 6, 1949 at Corona (California) that used 156,000 pounds of explosives.

In 1950 he participated in SIO's first postwar cruise, Midpac — the Mid-Pacific Expedition. He recorded some 1,200 miles of refraction profiles, including a reversed profile inside Kwajalein Lagoon and many reversed profiles inside Bikini Lagoon and on the flanks of the atoll (Raitt, 1954). From the blue-water profiles he was surprised to find the average sediment thickness of the Pacific Ocean basin very thin. More detailed analyses revealed a low-velocity layer apparently related to volcanic rocks, later called Layer 2.

On Capricorn Expedition in 1952 Russ recorded 2,542 nautical miles of profiles and experimented with larger charges up to 480 pounds of TNT (MPL Quarterly Report; 1 January - 31 March, 1953). All but four stations reached the Mohorovičić discontinuity. The estimate of sediment thickness was of the order of only 100 to 200 meters in many cases. In the Tonga Trench the sedimentary fill was no more than a few hundred meters, and there the Mohorovičić discontinuity was 10 to 15 kilometers deep; elsewhere it was 5 to 10 kilometers deep. The low-velocity layer was again identified on many of the records (MPL Quarterly Reports; Raitt, 1956; Raitt, 1957).

Helen joined Russ at Tonga for the last part of Capricorn Expedition, although she had not set out to do so. She recounted that trip in a popular account *Exploring the Deep Pacific* (1956, W. W. Norton) which was translated into several languages and sold worldwide.

Russ and Helen on Fiji during Capricorn Expedition, 1952. Photo by Richard Von Herzen.

Russ continued reflection and refraction studies in the borderland (Shor and Raitt, 1958a, 1958b; Shor, Raitt and McGowan, 1976) and, whenever possible, farther afield in the Pacific Ocean (Raitt and Fisher, 1962; Shor, Menard and Raitt, 1971) and eventually into the Indian Ocean (Francis and Raitt, 1967). He — and George Shor, who joined MPL to work with Russ in 1953 — tried new kinds of hydrophones, including ones on the bottom, towed streamers, and new techniques. But basically they stayed with the methods that Russ had devised in his early years, because they worked.

Over the years, others adopted the techniques. Although the instrumentation and procedures were described in two papers (Raitt, 1952; Shor, 1963), the spread of the methods was mostly through personal contact: by visitors to Scripps, and by people whom Russ talked to abroad and on their own ships. The

Top: Dale C. Krause (left) checking the echo sounder while Russ looks at a monitor seismic record; Mukluk Expedition, 1957. Photo by Alan Jones.

Center: Russ (in stern) transferring to *Hugh M. Smith* from *Baird*; Fanfare Expedition, 1959. Photo by Alan Jones.

Bottom: Launching a Jalbert kite-balloon to measure anisotropy, on Scan Expedition, 1969; (from left) Russ Raitt, Gerald Morris, George Shor, Helen Kirk, and Fred Stone. Photo by Alan Jones.

methods were adopted first by British and Soviet groups, then by the Japanese, and finally by geophysicists at Lamont and Woods Hole in preference to methods they themselves had developed.

A summary of the most important discoveries from these wide-ranging surveys was reported by Russ in *The Sea,* Volume 3 (Raitt, 1963): the small thickness of sediment in the ocean basins, and the widespread existence of Layer 2, the material just beneath the unconsolidated sediments, now known to be pillow basalts. Those who did refraction work in the Atlantic Ocean did not detect it, and so calculated excessive thicknesses of the sedimentary layer. Russ detected it early, and worked to determine its nature. In part he was lucky: Layer 2 was easier to detect in the Pacific, because the sediments are thinner on average there than in the Atlantic. In part, it was an unexpected benefit of a quirk in field procedure. Russ called for the small shots at close range at the shortest time intervals possible; he monitored the quietest hydrophone on a pen-and-ink recorder, and thereby obtained detailed data over the limited range in which Layer 2 appeared as a first arrival. Those researchers who waited to develop each photographic oscillogram before calling for the next shot (the standard procedure in industry) had longer intervals between shots and missed Layer 2.

Other significant observations by Russ through the years were the remarkable uniformity of velocity of the oceanic crust, the small variations in depth to the mantle, and the accidental discovery of the low mantle velocity beneath the East Pacific Rise. Russ's early work in the borderland and around Guadalupe Island provided the background for the site selection of the test holes and the location of the Experimental Mohole drilled by *CUSS I* in 1961. From that came finally a sample of Layer 2: stark blue basalt. Russ and Shor both served on the panel that chose a site near Hawaii for the not-yet-drilled Mohole.

Both of them were also drawn into the puzzling question raised by Harry Hess in 1964: why, in refraction data taken by Raitt and Shor near California and Hawaii, did the velocity of seismic waves within the mantle appear to be faster in an east-west direction than in a north-south one? The term is anisotropy, and measurement of this small difference with any reasonable precision requires an elaborate pattern of shooting and receiving, such that observations are distributed over at least one-half the arc of a circle 30 miles in radius. The definitive experiment that finally proved the existence of anisotropy of seismic velocity in the mantle involved five ships from four institutions on Show Expedition in 1966. Russ was still pursuing the phenomenon on Scan Expedition in 1969 when he broke his leg while boarding a longboat after a visit on the enigmatic island of Pitcairn. His doctoral student Gerald B. Morris completed the scientific program of that expedition after Russ was airlifted to Tahiti (Raitt, Shor, Francis and Morris, 1969).

Besides enjoying going to sea, Russ has always loved to travel, and he has combined these pleasures at every opportunity, which have included many tropical isles.

In Conclusion

What has always impressed me about Russ and Vic is that, in addition to their scientific competence, they have always been so energetic and enthusiastic about the work they were doing. Their interest in going to sea, their ability to do high-quality work and to make it fun both for themselves and for others was the keystone of the success of the marine geology and geophysics program at Scripps. They, with Bob Fisher, Bill Menard, George Shor, Harmon Craig, Ed Goldberg, Fred Spiess and others, made Scripps famous as a research institution in that marine program. The quality of work that these scientists were doing at sea, their openness and the freedom with which the post-docs and students were treated are among the factors that made Scripps such an exciting place for research on the ocean floor. They are also the major reason that their students were so successful later in capitalizing on the advances to be made by interpreting marine data within the concepts of sea-floor spreading and plate tectonics.

Looking into Vic's and Russ's lives has also taught me that research can be fun and vigorous after the age of forty, and that it is possible to have an active and productive research career into one's sixties — especially if one remains an active sea-going oceanographer.

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Patent

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AFTER-DINNER REMARKS*

Presiding: George G. Shor, Jr.

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Shor: It is not entirely clear to me why I am presiding at this evening session. I suspect that it is because I have somehow acquired the undeserved reputation of being part of the "corporate memory" of Scripps. I therefore have to precede all of the remarks and stories that may follow with a disclaimer: my memory is just as bad as anyone else's. Many of the things that I remember very clearly probably never happened, and some of them undoubtedly happened at some other time to other people. I also want to assure both Russ and Vic that this is not "This is your life," and we will not present any forgotten acquaintances from Tahiti or Ceylon, or engage in overblown praise more than is deserved.

The following things may occur in this session: First, I will read a few messages from people who couldn't be here. Second, Roger Revelle will keep his promise to talk on a subject of his own choosing. We did not ask him to be brief. I, at least, can listen to Roger for any length of time he chooses. After that, the meeting will be open for anyone who wishes to speak about aspects of the scientific work of Russ and Vic that were omitted in today's sessions, or tell relevant sea stories. Equal time will then be given to Vic and Russ for rebuttal.

To begin, in addition to brief notes from Roger Anderson, Bill Normark, Tony Rees, Bill Nierenberg, and others who cannot be here, there are longer letters from John Knauss and Fred Spiess, which represent significant contributions to today's symposium. First, the letter from Fred Spiess, who is on a plane back from Washington at the moment:

> *It is not surprising that for any MPL senior staff meeting at least two members should be away from San Diego, either at sea or contributing to some advisory committee or scientific meeting. In this case Fred Fisher and I are the ones who can be here only in spirit to help celebrate the achievements of Russ Raitt and Vic Vacquier.*
>
> *With Carl Eckart, Russ Raitt symbolizes for me our laboratory's beginnings — that era beyond my personal experience in which UCDWR, the wartime Research Division of the University of California, was transformed into MPL, a peacetime source of national strength, innovation and knowledge about the ocean. I came from my own undersea origins to find the excitement and satisfaction of struggling to extract data from the ocean, following Russ Raitt's example. In the early stages of MPL's existence Russ personified the persistent seagoing scientific effort which must remain the essential element of oceanography in the future. No amount of manipulating satellite pictures or stirring numbers in a supercomputer will solve our problems unless some of us go out and explore the real ocean and the sea floor beneath it as Russ and Vic have done.*
>
> *Vic flew into our midst on the wings of inventiveness which brought him into contact first with the airborne Navy and through that path to MPL. Once he was here he became a model for experimental marine geophysicists — visualizing problems and the means for their solution and then making the new devices work for him in the oceanic environment.*
>
> *Although Russ and Vic were rarely collaborators in research, they did combine to generate a major contribution to the life of MPL in the 60s. They forged the links to the U. K. academic community that brought us a steady flow of young post-docs. John Sclater, Chris Harrison, Mike Fuller, John Mudie, Tim Francis and Tony Rees all kept us on our toes and made this an exciting place for both staff and students. Those of us who were spending our time either at sea or in workshops and committee meetings in the U. S. were most grateful for the breadth and stimulus that these contacts added to our lives.*

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* Dinner held at the Kona Kai Beach and Tennis Resort, San Diego, CA

This concept of interaction among all members of the staff, and our dedication to testing ourselves and our ideas against the real ocean have been essential elements of MPL in the past 40 years. I trust they will continue in spite of changing patterns of funding and administration. The styles of research support may change, but the ocean is still out there challenging us to discover its secrets and rewarding us with calm sunny days after we brave the storm.

I hope you all are enjoying this celebration and are imagining new victories in a future built on remembrance of past achievements.

Our thanks for some of those achievements go to Russ and Vic with best wishes for their futures.

*Fred Noel Spiess**

Director
Institute of Marine Resources
University of California
La Jolla, California 92093

Shor: John Knauss writes as follows:

Of all the Scripps parties to which I have received invitations in the last few years, the one I would most like to attend is the one you are arranging for Russ Raitt and Vic Vacquier on the occasion of their 80th birthdays. Unfortunately I will be in Victoria, Canada on that date at a meeting I cannot escape.

I remember Russ and Vic as friends, teachers and shipmates. It was from Russ Raitt I learned one of my most valuable lessons as a seagoing scientist. Most of us are a bit less efficient working at sea than on land, and the rougher the seas the lower the efficiency. When your efficiency slips to ten percent, you are seasick, whether or not you are still capable of ingesting and holding food. It was Russ who taught me to commit to a notebook your entire game plan before going to sea, and each night take out that notebook to be certain you are doing everything you had planned. When the seas are rough, it is tempting to cut corners and convince yourself that one more observation does not make that much difference; but when you are back in the lab on land, you know you should have hung in there. It is my recollection that Russ's tolerance of heavy seas was somewhat below average, but apparently he always dug out that notebook and he hung in there. The results of that self-discipline are evident in his published works.

My fondest memory of Vic Vacquier is of a different kind. On a cruise together in 1958, he had the good luck and the good sense to bring the first Polaroid camera ever seen at the far end of Tahiti. His instant photographs brought an entire reef fishery to a grinding halt as natives clamored for his photographs. It was just one more example of the Vacquier joie de vivre that he brings to all of his work and to his life. Please give them my best regards. I am sorry I will miss the party.

John A. Knauss

Dean
Graduate School of Oceanography
University of Rhode Island
Narragansett, RI 02882

*Director of the Marine Physical Laboratory from 1958 to 1980.

Shor: What I can say for myself is:

Russ and Vic share with many of us here a belief in the truth of a long-ago statement by Roger Revelle: Oceanography is fun. (It was frequently quoted bitterly when everything was going wrong and the weather was lousy.) Going to sea is fun if you are there to do something, not just be a spectator. (I occasionally tell people that the reason I came to Scripps was simply that I was offered the opportunity to do two things I enjoy most: go to sea and set off explosions, and that surprisingly they were willing to pay me to do it.) Russ and Vic made it more fun for everyone else by the contagion of their enthusiasm, by their unselfishness, and by not worrying terribly much who got the credit.

I worked closely with Russ for 25 years. Russ has always had a high regard for the sanctity of original data, unsullied by subjective manipulations, and an extreme passion for accuracy. This created a minor conflict between us, since I was always sloppy about calibrations, and addicted to a degree of subjectivity best defined as drawing a straight line through one point and a guess. (Russ has always been kind; he never said that.) On the other hand, I always had to guard against the possibility that Russ might some time concentrate on an idea and absent-mindedly forget that he had a half-pound charge and a lighted fuse in his hand. I also frequently had to harass him to get his part of a paper written without making one more analysis just to check the data. It was a comfortable and productive collaboration. I shall always be grateful to him for his extreme tolerance over that quarter-century of Moho hunting.

And now, I would like to have Roger talk.

Roger Revelle*

University of California, San Diego
La Jolla, California 92093

I have always thought that physicists were sticklers for accuracy, and that oceanographers don't know much about accuracy or precision or doing things right. I admire physicists from afar. But I've made a careful investigation of the situation tonight, and it turns out that neither Russ nor Vic are anywhere near 80 years old. They may become 80 some time in 1987 — Vic in October, I think Russ in September. They claim, I guess, they're somehow thinking of themselves as Chinese, that they are in their 80th year. You know the Chinese say that they are one year old the day they are born, sort of like a racehorse. And if that's the case we may be able to concede that there's something to this 80-year-old business. I think it is just a dramatic desire to double the age of the Marine Physical Laboratory, which really did become 40 years old some time this summer.

I thought I might say a word about the Marine Physical Laboratory, how it started. We've talked about Russ and Vic all day, but people have not said much about the laboratory. Maybe some of you do not really know much about how it began.

During World War II here in San Diego there was something called the University of California Division of War Research. Many scientists became part of the laboratory, including a few oceanographers. But when the laboratory first started, it was inhabited largely by physicists from Berkeley: the great Ernest Lawrence, the inventor of the cyclotron; Ed McMillan, the discoverer of plutonium; and several other physicists. Lawrence said, "These oceanographers don't really know what they are doing — the idea that you look for submarines with underwater sound is ridiculous. The way to look for them is with light and electromagnetic radiation." The physicists built the biggest searchlight that had ever been built, millions and millions of candlepower, and they built a big black sock — several hundred feet long and about 30 feet in diameter. The idea was that you could turn the searchlight on and see this sock, see it from thousands of feet, thousands of yards, maybe miles. Well, they turned it on, a glaring light; they could barely see the black sock about a hundred feet away. So the physicists decided that maybe finding submarines was not

*Director of Scripps Institution of Oceanography from 1950 to 1964.

really very good physics, and they all went away. Of course, where they went away to was Los Alamos — and the development of the atomic bomb. I think from the standpoint of humanity all of us might have been better off if they had stayed in San Diego.

Before the end of the war, in 1945, the University of California Division of War Research and the other components of the wartime effort rather rapidly faded away. I was at that time with the Bureau of Ships in Washington in the Navy Department, and we were very much impressed by what good work the laboratory had done in underwater sound, which *is* really the way to look for submarines. And how much there was still to do, how much science there was still to do.

The moving spirit of this enterprise in Washington was an astronomer named Lyman Spitzer. He is one of the great astronomers of our generation, and I believe one of the great intelligences of our generation. He has an IQ of about 180. My IQ is about 140, so that I was always trailing along behind him at a respectable distance. Lyman and I together wrote a letter — as you may know, in the Navy you never write a letter you sign and you never sign a letter you write. We wrote a letter for the Chief of the Bureau of Ships [Vice Admiral Edward L. Cochrane] to sign. It was a revolutionary letter to President Robert Gordon Sproul of the University of California. It said to President Sproul that the Bureau of Ships of the Navy Department wanted the University of California to establish a laboratory under the direction of a particular man, named Carl Eckart, and if the University established this laboratory, the Bureau of Ships would give it tenure — which meant that we would support it indefinitely, without limit of time, as long as the Navy existed as a Navy and was concerned with submarines.

This was an unprecedented thing for anybody in the government to do. We operated on one-year or at the most two-year contracts, and the idea of support for an unlimited time was quite shocking to Admiral Cochrane. So he sat on this letter for seven or eight months.

We went to see him from time to time about the letter, and he said, "Well, I'm thinking about it." And finally in January of 1946, he actually signed the letter. (I recently got a copy of it from the Archives at the Scripps Institution of Oceanography.) Then it turned out that we had an equally difficult time persuading the University of California. President Sproul and [business manager] Bob Underhill and the other officers of the University were not at all certain that they wanted to cooperate with the Navy or that they wanted to do anything in underwater sound or that they wanted to do research that would be paid for by the federal government. It's hard to believe now, but that's the way it was in 1946.

It was not until the summer of 1946, six months after Admiral Cochrane signed this letter and sent it to Berkeley that President Sproul and the regents agreed that maybe they could do this. And all this time Carl Eckart was wanting to go back to the University of Chicago. I would have to come out and hold his hand every two weeks or so and tell him, "It's going to happen pretty soon now, Carl." And it finally did happen of course, and the regents and the President of the University did agree to accept this contract with the Navy. Carl Eckart did become the director of the laboratory and professor of marine physics in the University of California.

The very first thing he did was to ask Russ Raitt to join him. Russ was the first appointee of the Marine Physical Laboratory, after Carl of course. He was appointed associate professor; in other words he got tenure too. This was a wonderful thing, a great coup on Lyman's part and my part and Carl Eckart's part and everybody connected with the University and the Navy who got Russ Raitt into this business.

Russ and Vic between them were two of the heroes of what I think of as the new age of exploration. Between about 1948 and 1975 a part of the world that was never really understood or known before was discovered and explored and partly at least understood: that's the bottom of the ocean, the bottom of the deep sea which covers about two-thirds of the entire earth. This age of discovery, it seems to me, ranks in the same league as the great ages of discovery in the 17th and the 18th centuries. I'll admit that my hero is Captain Cook, and none of us were quite as good as Captain Cook, but among all of us we really changed man's understanding of the world. Two of the people who did this were Russ Raitt and Victor Vacquier, in a series of great expeditions. There are other people in this room who were involved: Bob Fisher was one; Dick Von Herzen; Art Raff; Art Maxwell; several others are dead: Bill Menard; Teddy Bullard; Maurice Ewing; — many people were involved, maybe 50 people altogether were participants in this new age of exploration, as leaders of the enterprise. Of course, there were lots of people who helped out enormously, without whom the work could not have been done.

So this, it seems to me, is the real justification for celebrating Vic and Russ tonight. They were heroes of the new age of exploration.

Finally, what we are having is a family party. In the first place there are many members of the family here; I've just been counting up Russ's progeny around him: Martha and Chris [Harrison] and their two children; Craig and Kayo and Monique [Biddle]; Alison and Dick and Vickie [Gist]. We miss Helen, of course, that wonderful shipmate and loving woman, that warm-hearted woman who while she was alive was in many ways the heart of the Scripps family. In Vic's case, young Vic and his wife, and Vic's wife

[Mikoho] herself; all of them are here. In addition we're all part of the extended family of Russ and Vic — and of the others who have worked together so effectively and so loyally and so generously in this enterprise that I was talking about.

I'd like to propose a toast: to Vic and Russ and to all of the extended families of the Raitts and the Vacquiers.

Shor: There are some people here who go back to the era Roger was speaking about, and even a little farther back. I would like to ask Ray Peterson to stand up; he represents an era of Russ's life back before any of us can remember, back in the 1930s.

Raymond A. Peterson*

I should say, unaccustomed as I am to public speaking, I can gather a few thoughts here, perhaps together — if you'll pardon it being just a little personal, because my memory is around personal experiences. One of my early great friendships and delights was with Russ Raitt. I think Russ graduated around 1927 or 1928 at Caltech, and he went to work for Hercules Powder Company. His job was designing the little sticky black pitch that you put in the top of blasting caps, which was really the beginning of Russ's career.

But after a while I think he got a little tired of that sticky gooey stuff, so he went back to Caltech for several years. This was a little after the Depression. In 1935, 36 and 37 we worked together with a little company — Josh Soske was president — called Geophysical Engineering Corporation. I was out in the field, crossing canals, hiring and firing people, and Russ was in doing really heavy scientific work. Those of you familiar with reflection seismograph work remember that velocity generally increases with depth in the ground and if you have a very simple case, where the velocity increases in a linear fashion, then the wave fronts are circles which are descending with time, and ray paths are circles, everything is circular. Russ really went to work on that and taught me what I knew about the subject. Later on, some time, I was working with United Geophysical; we were working for Shell, and they were working with linear increases of velocity with depth. So all this knowledge I gained from Russ really paid off for me. I really should credit Russ; the boss gave me a Lincoln Zephyr to drive around in, and several other things.

In 1937 the company ended; I don't know how Russ stayed on a little longer; we had pretty good sign on the books, but there was no cash in the till to pay us, so we had back salary chits. So I couldn't carry on; I went to Caltech for a quarter there, and then I got out and went with another company, United Geophysical. Then, in 1941 Louis Slichter of UCLA implored me to come down to San Diego; I did a little magnetometer work here he had to get done. So I went to my boss and said Louis Slichter wants me to to come down to the NDRC lab at Point Loma, and he said "Well, you can't do it unless you get a replacement," and at that time I got Hewitt Dix. Well, I came down here and was three or four months down in La Jolla. One thing I particularly remember is Pauline, my wife, went out and bought a house for $4500, right on Curtis Street [on Point Loma], and we put a thousand dollars into fixing it.

Then, come January of 1942, there was great interest in magnetic airborne detection of submarines, so I was told to go back on Monday morning to the office of T. D. Shay in New York City. So I did; I didn't know just what was coming up, but there was a line of about 75 people, and they went all around and gave everybody jobs. Well, I was about [number] 73, and they finally came to me and said, "Can you service amplifiers?" I said, "In a very crude way." They said, "Can you solder?" I said, "I can hold a soldering iron." Then they said, "What in the hell have you been doing?" I said, "Well, supervising geophysical crews." They said, "Supervisor? You go up to Quonset Point, Rhode Island and supervise the lab." I went up there right away, and found a lot of people milling around, including Vic Vacquier and another one who later won the Nobel prize, and several other distinguished people. Nobody had told anybody I was coming, so I got up on a chair and whistled, and said, "Fellows, I'm your new supervisor."

*1946 Midlothian Drive, Altadena, CA 91001

I had a very nice nine months with Vic Vacquier. At the end of the year I went back into geophysical work. Later on, we built a magnetometer, and we discovered a very valuable copper mine with it, and a lot of credit goes to Vic for instructing us on how to make magnetic measurements. I'm greatly deeply grateful to Russ and Vic — and they're great fellows.

Shor: We also have with us one of the original staff members of the Marine Physical Laboratory; there were five in the original list: Russ, Carl Eckart, Finn Outler, Robert Young, and a young graduate student named Bill Kellogg. Bill, will you come up and say a bit about the beginnings?

William C. Kellogg*

It's a real pleasure for me to be here. It was about 40 years ago, I — just out of the U. S. Air Force, graduate of the Colorado School of Mines, attendee at NYU in meteorology, at Harvard in electronics, at MIT in radar — came on a family that used to live where I still live: Altadena. This was the Raitt family in La Jolla. For reasons best known to Russell Raitt, he selected me to be his assistant. We journeyed from time to time out San Diego Bay and around Point Loma in a boat known as the motor vessel *Jasper*. Whether the motor vessel *Jasper* still remains afloat I don't know.** It was on missions of sonar reflections from the bottom. Russ was conducting this as part of his assignment at the Marine Physical Lab. Little did I realize what a privileged position I had in those days, but my interests were perhaps more in the worlds of action than in academics. I didn't last very long with Russ. I am indeed grateful for having had that experience. The action led me later to a career in airborne geophysics, and of course the tool of the trade was the Gulf magnetometer invented by Victor Vacquier. Both of these gentlemen have affected my life, and I am indeed proud and pleased to be here to say these few words tonight, and to wish them both congratulations.

Shor: I forgot a letter that Gerry Morris brought out, which I shall read:

> *On behalf of the management and staff of the Naval Ocean Research and Development Activity (NORDA), it is my genuine pleasure to extend congratulations to you and the members of the Marine Physical Laboratory on the 40th anniversary of MPL's establishment. The people of NORDA are proud to salute Dr. Russell Raitt and Dr. Victor Vacquier, in whose honor this special symposium is held and wish MPL a very happy birthday.*
>
> *Sincerely,*
>
> *A. C. Esau*
> *USN, Commanding Officer*

*425 E. Las Flores Drive, Altadena, CA 91001

**Several in the audience called out yes; after World War II the ship resumed its former name *Stranger*.

[Shor called for others from the audience, and Raitt volunteered.]

Russell W. Raitt*

I just have a footnote to add to what Roger already said about the beginning of the Marine Physical Laboratory. I think some of us were only slightly aware of all of the activities going on with Roger and Lyman Spitzer. But I think we were aware of the fundamental idea. During the wartime laboratory we discovered that the study of the oceans was a really undeveloped scientific field. However, there was this series of reluctances: the reluctance of the Admiral to sign the letter, and the reluctance of President Sproul to go ahead with this scheme worked out by Roger and Lyman Spitzer.

There was a third reluctance. The Academic Senate of UCLA was unwilling to go ahead with the idea of granting tenure, and it took two years for me and I believe also Robert Young to achieve appointment as associate professor. I don't know whether you knew that, Roger.

Maybe I should say one more thing, a comment on the proceedings up to now: this occasion is a time when it is appropriate to exaggerate. It's impossible for me to exaggerate the feelings that I have, the feelings of gratitude for the opportunity to have participated in this forty years, which I think have been the most exciting, the most productive, and the most rewarding and the most fun period in the history of geophysics and geology. I feel extremely fortunate and extremely grateful to the people — Roger, Lyman Spitzer, many other people — who made this possible for me. Especially I think I am grateful to a number of people, some of whom are here tonight, some of them you've already heard from in the symposium this afternoon, who shared with me the often miserable work at sea and the joys of coming into port and beautiful places like Tonga, Samoa, Tahiti, Singapore. I'm very grateful to people like George Shor, Betty, Marilee Henry, Helen Kirk, Alan Jones, Arthur Raff, who was in the work from the very beginning — I can't possibly think of all the people with whom I've shared this marvelous experience. Thank you very much.

*Scripps Institution of Oceanography, San Diego, CA 92093

WELCOME

Robert L. Fisher

Scripps Institution of Oceanography
La Jolla, CA 92093

Today we are celebrating the 80th year, not 80th birthday, of each of two distinguished colleagues, who — more importantly for today — are warm and modest and delightful humans, and good friends to nearly everyone in this room: Russ Raitt and Vic Vacquier.

In my view a third friend is much in evidence: Bill Menard's latest book, *The Ocean of Truth*, became available in published and easily used form last week. It sets forth what many of us at Scripps Institution of Oceanography would call the true story of plate tectonics, and exposes its real roots. Both of these men figure prominently in Bill's story. It can be argued, Russ, that you are the hero of Bill's tale, and, as one who saw you firsthand for some months on long expeditions in the 1950s and early 60s, I can buy that view.

Victor Vacquier with Jean Francheteau from Paris.

This is indeed an impressive gathering of friends who are also professional colleagues, but there too are several family members who have come to share in celebration today. These include: Mihoko Vacquier, and Victor D. Vacquier (recording on video); and on Russ's side of the aisle: Martha and Chris

Harrison and their children, Alison and Dick Gist and Vickie, Craig Biddle and Sharon from Sacramento, and La Jolla's own Charles and Monique Biddle.

Russ Raitt's shipboard investigations, in post-Midpac years in large part accompanied by Alan Jones and the late Max Silverman, covered a very large part of the Pacific and most of the temperate Indian Ocean. As a participant in most of these up to Lusiad Expedition, I gained a tremendous respect for Russ's dedication, his tenacity and stamina, and his improvisational abilities. His work with that of George Shor and Tim Francis in the Indian Ocean has never been bettered in categorizing a major suite of tectonic features throughout an ocean. Others in this room more recently have mined these data; no one has shot better. For me, at least, the most fascinating results were those from the trenches, where all of us worked to the limits of our equipment and our luck to establish what every schoolboy now knows as obvious, and can clearly pronounce: "subduction."

Russ Raitt and Gerald B. Morris before opening of Symposium session.

Most of us at Scripps first knew of Vic Vacquier from his contributions at Gulf Research and Development Company, where he had invented the flux-gate magnetometer. After its wartime use in submarine detection, the technique was applied to airborne mapping. Vic co-authored GSA Memoir 47 (Vacquier, Steenland, Henderson, and Zietz, 1951): "Interpretation of aeromagnetic maps," the handbook and how-to-do-it publication on the subject. The instrument was modified for work at sea; it first surfaced at SIO when Edward Titus Miller of Lamont Geological Observatory installed an instrument on *Spencer F. Baird* for the Capricorn Expedition in the summer of 1952. This early experience led to *Pioneer* surveys by Ron Mason and Art Raff in the mid-1950s that discovered and established the magnetic anomaly lineation patterns off the western United States. These SIO data prompted the early, unfortunately-not-published explanation by Canadian Lawrence Morley — a sobering story most recently detailed in *Eos* (Morley, 1986).

At SIO from 1958 on, Vacquier helped develop a simplified version of the proton precession magnetometer for measuring total magnetic field. In the field he worked with Art Raff and Bob Warren to extend well westward the pattern of magnetic lineations off the west coast. In August 1963 Vic received AMSOC's "Albatross" for "displacing the seafloor by 700 kilometers"; later accounts for geophysicists list this figure as 1400 kilometers. Incidentally, this award ceremony represented a mere one-hour commute, from San Francisco. It became Vic's albatross in the poetic sense, too; he was enjoined to deliver it to Henry Stommel, at Tokyo, in 1966.

Since the early 1960s Vacquier has made and supervised hundreds of measurements of terrestrial heat flow in various oceans, in lakes such as Titicaca and Malawi, and in oil fields in Sumatra and Brazil. In this work he taught, and learned from, such people as Dick Von Herzen, John Sclater, Chuck Corry, and Pat Taylor.

A partial list of Vic Vacquier's honors includes the Wetherill Medal of the Franklin Institute (1960), AMSOC's Albatross (1963), AGU's John Adam Fleming Medal (1973) and SEG's Fessenden Medal (1975). At least two of these stemmed from his invention of the magnetic airborne detector and its impact on exploration, a third for contributions in several fields of observational geophysics, the fourth for — as Archimedes dreamed of doing — "moving the earth."

Others today will outline Vic's tremendous achievements, and show slides and tell sea stories about his many SIO activities. My warmest memories are of the early sixties: of Vacquier the tireless tourist going halfway along Java by jitney in the dead of night for a brief look at Bourabadour, or disappearing for several days in the Mauritian French culture on the beach at Le Morne Brabant, or standing beside me on *Argo* one night near Sunda Strait when we took her across the submerged crater lip of Krakatoa and watched volcanic ejecta the size of Volkswagens being hurled up from Anak Krakatoa not far from *Argo's* bow.

Shipboard times around the globe with such men as Russ and Vic are unforgettable. But now let's recognize their ongoing influences, as marked by these reports of geophysical colleagues who are also their warm admirers.

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