ORAL HISTORY COLLECTION
TEXAS A&M UNIVERSITY

OCEANOGRAPHY PROJECT

George G. Shor

Project Coordinator: Robert A. Calvert
July 1976

GEORGE SHOR

From an interest in mathematics, George Shor went into the field of mechanical engineering. He served in the Naval Reserve in college as an apprentice seaman and decided then to enter the field of mechanical engineering. In 1944, he graduated with a Bachelor of Science Degree in this field from the California Institute of Technology, even though by this time he had developed an interest in geology.

During World War II, Shor was called into active duty by the Navy. He was placed aboard a ship as a radar and communications officer, where he worked on underwater sound and anti-submarine warfare. When the war ended, he was employed by the oil industry in West Texas, New Mexico, and Louisiana, as a seismic party chief.

However, he returned to the academic realm to receive a Master's in geophysics in 1946. This degree was then followed by a Ph.D. in seismology from the same university in 1954.

Scripps Institution of Oceanography was Shor's next place of employment. When he arrived, Scripps was one of the largest oceanographic institutions at the time, oceanography being on the frontiers of seismology. During his 23 years there, reflection and refraction seismology and marine geology have been his specialty areas.

Lucille Gates, 1976

TEXAS A&M UNIVERSITY
ORAL HISTORY COLLECTION
HISTORY OF OCEANOGRAPHY

INTERVIEWEE: George G. Shor

INTERVIEWER: Robert A. Calvert

DATE: July 3, 1976

TIME: 9:00 AM

PLACE: Scripps Institution of Oceanography

RC: How did you become interested in the discipline of oceanography?

GS: Well, I was pretty good in math; and if a student was interested in mathematics in those days, it was suggested that he go into engineering. That seemed rather interesting. I went to Cal Tech, in engineering, and decided on mechanical engineering. This was during the war, and Naval Reserve had something to do with all this. Once one was in an option in the Naval Reserve, one couldn't shift; so I went through and graduated in mechanical engineering, even though partway through college I got rather interested in geology. So, I ended up in the U.S. Navy in World War II, doing electronics, naturally, since I had no background in it...this was normal. They sent me to radar school, sent me out on board ship as a radar and communications officer. I was still rather interested in geology; and, after the war, I went back to Cal Tech to learn a little bit more and ended up with a Master's degree in geophysics and then went off and worked in the oil industry, running a seismograph crew. I ran a reflection crew in New Mexico, West Texas, and Louisiana; I did that for three years. I went back to college to learn a bit more geophysics, got a Ph.D. At the end of that period, I found the opportunity to do something that was rather more exciting than looking for oil in West Texas, which was coming down here to Scripps, where people were just starting to do refraction work at sea, learning a bit more about the structure under the oceans. I think I was typical of people at that time. We were not oceanographers; we were people in various disciplines of science who like the ocean.

RC: Was it the Navy that gave you your first experience with the ocean, that attracted you toward it?

GS: Right, that's right. I was out on board ship for about two years--World War II. I very much enjoyed being on ships; I just plain like ships and the ocean, being at sea. And I think that was what lured me into doing marine geophysics instead of land geophysics.

RC: How did you come into contact with Scripps?

GS: I came down here to a meeting that was held at Scripps in 1952 and talked to some of the people here and found out what they were

doing. The next thing I knew, I had a job offer. In other words, I was at Cal Tech, and I came to a meeting that happened to be held here. At that time, I thought it was a biological institution. It was only when I got down here that I discovered that it wasn't.

RC: Your first contact, in terms of the academic world after the Ph.D., was Scripps. Is that correct?

GS: Yes, that's right. Matter of fact, I had another contact with Scripps before I actually came to the meeting here. When I was at Cal Tech, Cal Tech had seismographs scattered all over southern California. One of them was in the basement of the library building at Scripps, and I came to repair it one time. But I never found out what else there was here, except the seismograph in the basement. I came here right after a Ph.D., having had two interruptions in my career--one for the Navy and one to run a seismograph crew, which I had thought was going to be a career, but it wound up as a three-year period.

RC: With whom did you first have contact here at Scripps?

GS: Oh, Russ Raitt. I came to work as his assistant and stayed on.

RC: In moving to Scripps, was there anybody else who influenced you down here in your move towards oceanography?

GS: Oh, sure, Roger Revelle. Roger Revelle had a great deal of effect on me and on a lot of other people. His enthusiasm at that time was so great that, after you talked to him for a little while, you couldn't imagine yourself doing anything but going to sea. Roger was all enthusiasm for exploration, long sea trips, all the things that one might find at sea; and he could talk anybody into coming to work and going to sea, if he wanted to.

RC: Do you think it's necessary for an oceanographer to go to sea, to do what Spilhaus calls "get his feet wet," to be a good oceanographer?

GS: I don't know--depends on what you mean "to be an oceanographer" really, I guess. There are a lot of people in theoretical fluid dynamics who don't go to sea. And one could call them physical oceanographers. And, indeed, other people build upon their work. There are people in geophysics who don't go to sea. I would guess that well more than half of the academic staff here at Scripps doesn't ever go to sea. We have theoretical geophysicists, we have laboratory marine biologists, we have chemists who work strictly with what the other people gather. All the way down the line, we have a non-seagoing group. I don't think it's a good idea for them never to go, but the degree to which people go to sea is tremendously variable. I guess anybody who works with data that are gathered at sea ought to go out a few times just to get an idea of how good and how bad those data are. It is terrible for people to write grandiose papers based on bum data that they didn't know was bum.

RC: How many vessels were here when you arrived at Scripps?

GS: That's a good question. I may have a list in here. When I came, there were five.

RC: Was it the largest oceanographic institution at that time?

GS: Yes, definitely. From five, then we got up to ten at one point, while I was still here, and then dropped back down again to the current five. As a matter of fact, they used to joke that we had the thirteenth largest navy in the world. I think we came just after Chile. It very definitely was the largest oceanographic institution of the time. In fact, it was one of the very few in '53.

RC: What do you see as the single greatest spur that moved us into oceanography, as an academic discipline? By "us," I mean America, the United States.

GS: Oh, I think it was, in part, the loss of the land frontiers. People in the U.S. have had the urge to explore; and I really think it was the fact that there wasn't much of anything left to explore on land, plus the fact that we had acquired methods of exploring the ocean. It was no longer just something you went over the surface and never saw what was down within. The recording echo sounder was a tremendous leap forward. That was a device that let you see the bottom of the ocean. The things that you saw coming up on that, in those days, were amazing--mountains, tremendous mountain ranges, the Rocky Mountains suddenly appearing. You got a feeling that you were looking at something that nobody had ever seen before. This is the same as land explorations. So we had a few new tools and a frontier we could look at. And the old frontiers were really pretty well done.

RC: What is seismic exploration? You were talking about seeing things for the first time.

GS: Seismic exploration, as distinguished from earthquake seismology, is reflection and refraction seismic methods. It is methods of determining earth structure by use of elastic waves, technically speaking; sound waves is a simple way of putting it. Of course, reflection systems, which are very widely used, give you a fair indication of the shape of reflecting interfaces. Refraction systems give you a deeper penetration, a poorer picture of the geometry, but better determination of velocities and, therefore, of the composition of rocks. Of course, echo sounders are a very simplified version of a seismic reflection system. They're a single source, single receiver, and they work just fine for depth of water; then, modified into a sort of seismic profiler, they give you both water and sediment--things just below it.

RC: Could we have used those sorts of implements, developed those kinds of tools, without World War II?

GS: We could have. In fact, the real essentials of the seismic reflection system and the echo sounder were around for World War I,

but people just didn't pick them up and use them. Fessenden worked back in the period, I guess, before World War I, and developed a fairly good sound source that could have been used for an echo sounder. There were people working on detection systems. In fact, it was some of the people who were involved in World War I--submarine detection work--who later started seismic reflection work in the oil industry. Karcher and a few others, in the early 1920's, decided to apply what they had learned in World War I. But the push to do it at sea wasn't really there. Land work did develop. World War II...yes, a lot of people got involved, a lot of equipment got developed. And it was at least as much the people who had been deeply involved in the ASW work in World War II as the equipment they developed.

RC: Well, then, after you left the military service, did you move immediately into work towards a Ph.D.? Was that your intention?

GS: No. At that particular time, when I got out of the Navy in '46, I wanted to go to work looking for oil in Arabia. I had just gotten out of the naval hospital, and Arabian-American Oil wouldn't take me, so I went back to school for a year to learn some more geology and geophysics. At the end of that time, I discovered that West Texas was just as good foreign duty as Arabia! I was aiming toward the oil industry; it was only in '51, when I went back to college to finish up for a Ph.D., that I began to hear about some of the work that had been started at sea. And this was work by Russ Raitt, Morris Ewing, and Brackett Hersey: the beginnings of marine geophysics, which was being done by the people who had been involved in the World War II sonar work. They were all people who had been either at the University of California Division of War Research or the Columbia University Division of War Research or Woods Hole. These were the three places where things were going on. And, after the war, the equipment, the people, and the ideas were there and just ready to go.

RC: Do you feel as if the fact that you come from a family that was scientifically oriented helped to direct you toward science as a profession?

GS: Yes, quite probably. I guess so, although I don't know. I could have wound up in the newspaper business just as well. We had enough of them in the family, too. Yes, people who come from a family that has had scientists in it have a respect for science and know enough about it to consider it as one of the things one might do for a living.

RC: Then would you agree that oceanography is on the frontiers of seismology when you entered it? Is that fair to say?

GS: At the time I entered, it was the most interesting part of seismology, yes. Earthquake seismology was, at that time, in a rather stable situation. There were not great leaps forward being made. It was just plain hard work and study, one more phase in the earthquake waves. The great push in earthquake seismology occurred a bit later

in the early 1960's. And that, of course, was given its impetus by the bomb test problem--how to detect a bomb test and tell it from an earthquake. The funny thing is that these two pushes have come back and merged in the whole plate tectonics problem, where the earthquake seismologists are now working at sea, or at least getting data that is usable in combination with the seagoing exploration seismic data. So Jim Brune, who is here at Scripps, for instance, is an earthquake seismologist and never has switched out of that field. He goes out and drops ocean bottom seismographs to record micro-earthquakes at sea so that the seismicity becomes one more tool for the study of the structure of the plates in the plate tectonics system.

RC: Why did you choose Cal Tech for all three degrees?

GS: Oh, the reason, originally, was very simple. I knew it was one of the best scientific schools, engineering schools, in the country. It cost no more to go to Cal Tech than to go to MIT, and the sun shone out here. The reason for going back there for a Master's was also rather prosaic. In 1946, it was pretty hard to get into a college; everybody was trying to do it. I could get back into Cal Tech, since I'd been there. And, as for 1948, when I went back for the third time...well, by that time, I was getting pretty specialized into seismic work; and it was one of the better places, although I probably would have gone to Columbia, if I'd known that Morris Ewing was there. I just hadn't gotten the word.

RC: That was the point of the question--was there something at Cal Tech that turned you towards seismology?

GS: There were three people in the country at that time who were really doing good things in seismology of any sort; and they were Beno Gutenberg at Cal Tech, Morris Ewing, who was at that time at Lamont but had just moved there, and Father Macelwane at St. Louis. And those were the three people. There was nowhere else one would go. I was more interested in the sorts of things Gutenberg and Richter did at Cal Tech than what Macelwane and his group did at St. Louis, and I didn't know where Ewing was. He wrote papers at the time that said that he was on leave from Lehigh, visiting at Woods Hole, connected with somewhere else. I didn't realize that he had just started the Lamont Observatory at Columbia. So, it was a couple of years before Ewing's reputation began to settle down, being at Columbia. It was a period of flux.

RC: Is seismology necessarily associated with oceanography?

GS: No, not a bit. Of course, a great deal of exploration seismology is purely land work. Earthquake seismology has only recently had any connection with oceanography. And this is sort of typical. There's an awful lot of people in oceanographic institutions who basically are in a specific discipline that could be at sea or not at sea. And quite often we say that oceanography isn't really a science; it's just a place where you do science.

RC: I've been struck in the course of interviews at how many people began in meteorology or geology and drifted from there into oceanography, if I may use that metaphor. Does that seem to be the experience here at Scripps?

GS: That's right. A great many of the physical oceanographers who were here in the 1950's--almost all of them, in fact--were former meteorologists. They were people who had gotten their meteorological training during World War II. And, you know, there isn't a tremendous difference between meteorology and physical oceanography; it's just a matter of scale and speed of the processes. There are the same equations, just different time scales. The motions of the atmosphere and the motions of the ocean are similar. And so we found a lot of meteorologists who had been trained during World War II, who came across into oceanography because they had the background and it was an interesting subject. Of course, also, quite a number of meteorologists were trained to do wave and surf forecasting. And the place that they got trained was here at Scripps. I hope you'll ask Walter Munk about that. And meteorology was their background, but oceanography was the thing that they had been taught here.

RC: I'm also struck in the course of interviewing by how many people moved into oceanography through anti-submarine warfare, but you've not said anything about it in the interview.

GS: I, myself, was not involved in ASW in World War II. The only ship I was on was an AKA, which is just a target. It's an immediate target for the submarine, but it can't do anything to the submarine. After the war, however, in Naval Reserve, I was affiliated with an anti-submarine warfare program in Naval Reserve work, because it had a pretty strong relationship to oceanography. But the organization that was here at Scripps that turned into the Marine Physical Lab, the University of California Division of War Research, was an ASW lab in World War II. It has continued to be an underwater sound laboratory over the years. Geophysics and underwater sound are inextricably intermingled. The same data can serve two purposes; and, actually, the beginnings of the geophysical work, or at least of the seismic-refraction work here, were studies of the propagation of low-frequency sound for ASW purposes and shifted across into studies of the bottom of the ocean, using those same methods for scientific purposes. So, yes, there is a very strong intertie between underwater sound, anti-submarine warfare, and geophysics.

RC: When the Office of Naval Research was first organized 30 years ago, it seemed to fund certain institutions to help create military research, and, also--if I may call it such--pure research, rather than mission-oriented research, in oceanography. Was that, do you think, a spin-off of anti-submarine warfare?

GS: No, it was a spin-off of NDRC. And, of course, Russ Raitt could tell you a lot more about NDRC, OSRD, and World War II activities than I could because he was involved in them; and I merely read about them afterward. But, of course, Roger Revelle could tell you a great

deal about them, since he was on both sides of the fence. He was in ONR, and he was here. But when ONR started, it was, essentially, taking over the remains of the tasks that the Office of Scientific Research and Development had done during World War II. Well, it was... not quite just an extension, but it picked up things that had been supported under the NDRC program. And ASW, in particular underwater sound, was a vital part of that World War II work. Somehwere in here I have the old reports, the so-called redbooks. Underwater sound books were declassified postwar reports of what had come out of the work here and at Columbia. Anyhow, there was really a tremendous amount of work accomplished in just a very short time during World War II, and it built on a lot of prewar work. And, of course, ONR was set up because people realized that the U.S. had sort of mined out basic research. Other people will tell you a great deal more about ONR.

RC: What I really want is an impression. Is your impression that the ONR is becoming more mission-oriented and less hard science-oriented in the present?

GS: No, no, but I'll tell you, the change I've seen in ONR is a different kind of a change. I can't quite quote what the first couple of contracts from ONR said Scripps was to do, but I can paraphrase. The contract to the Scripps Institution for "general oceanography research" essentially said: go out and study the ocean, make observations, make maps, give us some reports, study the physics, the chemistry, the biology, the geology, the everything of the ocean--go out and do it. A lump sum of money.... There was so much for salaries, so much for supplies; and please tell us what government-furnished equipment you would like. It was a pretty open-ended one. There was another parallel contract with the Marine Physical Laboratory, which, I remember, I once heard the phrasing that goes approximately, "The mission was to study the generation, propagation, and detection of energy in the ocean and surrounding media." Of course, there's nothing else. That's all there is in the world, the ocean and surrounding media! So these were very broadly written contracts--go out and do things. And then, next year it was, "What did you do last year? Fine. Keep on." We were not tied down very much at all on what we were to do under these contracts. It was left very much to the discretion of the Director of the Scripps Insitution, Roger Revelle, and the discretion of the director of Marine Physical Laboratory, as to what the details were to be. And, as long as the work is good, the next year they give you another chunk of money, and you go and do some more and see if that's good. Right now, we are in a sort of a soap prize contest: in 10,000 words or more, please tell me why you should be given a grant of $73,000. People write these very detailed grant proposals, saying exactly what it is that they are going to do--literature search, background material, operations plans, data-handling plan, on and on and on. It's not unusual to see a 100-page proposal. There are an awful lot of proposals that come out that are an inch thick; and, even for a $50,000 project, I've seen many a proposal that's 100 pages. Okay, people really outline in great detail exactly what they are going to do. Moreover, it's the individual scientist to the funding agency.

Now, NSF has almost always operated that way, but ONR is operating that way now. Even if the Scripps proposal to ONR goes in one package, it consists of 20 individual proposals written by Mr. "X" and MR. "Y"; and so it's a very, very different sort of an operation. It was an institutional operation in the '50's. It is an individual operation now, with a lot more decisions--management from Washington instead of management by the institution. So the director of the Scripps Institution, the director of Woods Hole Oceanographic, and the director of any of the oceanographic institutions has very, very little leverage on what his institution is going to do. He is bypassed by the system. In a sense, it may be good and it may be bad, but it is sure different. And this is what, I think, people notice the most from ONR: much more direct decisions, what is to be done next year with each piece of money by each person under an ONR contract.

RC: That leads me to the next question. I wanted you to describe, in general terms, the research atmosphere at Scripps, as it has progressed the last three decades.

GS: Well, there always has been a good deal of individual freedom. I will give you an old joke. Years ago, I tried to describe the difference between Lamont and Scripps. Of course, I've only worked here at Scripps, not Lamont, but I know reasonably well how they operate. That is, Lamont is the world's greatest widget factory. It makes absolutely magnificent widgets designed by Morris Ewing, and it makes them exceedingly well. And everygody there works for Morris Ewing, making widgets, whereas the Scripps Institution is a summer hotel in which the director did his very best to provide good conditions, pleasant surroundings for people to do their own thing. And he had no more control over what they did than the manager of the summer hotel had over his guests. There are, of course, extreme statements--Woods Hole being somewhere between these two. But, a good deal, to a great extent, it is true. At Lamont...Lamont was a shadow of one man, a directed laboratory with a bunch of very loyal people working for the boss and doing his thing, and doing it very, very well. At Scripps, under Revelle, there was some leadership involved; it was purely force of personality. So, there was some organized research. But if somebody didn't want to work on Revelle's project, he didn't have to; he could 'gin up his own. Over the years, due to the way the government funding agencies have worked and the size of the institutions, the whole place has become more and more of an individual effort operation, where everybody does his own thing. It's not totally that way. Within the institution, we have organized research groups, of course--in the Marine Physical Laboratory, the Institute of Geophysics, the Physiological Research Lab, and the Marine Life Research Program. Those four groups are organized to the extent that the head of each of those groups sets up a program, gets funding, hires people to do it; and the people have some obligation to work on the laboratory program. Not totally.... I mean, that I've been in the Marine Physical Laboratory the whole time, and some of the time I am working on the programs that Fred Spiess, who is director of MPL, writes up and gets funded; and some of the time

I'm working on programs that I 'gin up myself. There is some obligation there, whereas in the rest of Scripps, there is no obligation at all. A person works on his own project. If everybody is doing his own thing, and if very few people here are really oceanographers, they're all physicists and geologists and so on, what the hell is an oceanographic institution? How does it differ from just being a college campus that is just near the ocean?

RC: You now, as a matter of fact, described the next question. If, in effect, then, each person does his own individual research at Scripps, what gives an institution like Scripps some kind of a general character in terms of contribution, let's say, to knowledge?

GS: People from University Statewide Administration have asked that question. There were one man from Statewide and three from the State Department of Finance down here earlier this week, trying to find out what makes Scripps tick. And I think that they were discovering this question and wondering about its answer. And the answer is very simple: if you have people in different disciplines working in the oceans but not speaking to each other, you don't have an oceanographic institution. You merely have a campus by the sea. If these people are thrown together enough so that they talk to each other, both in planning what they are going to do, socially, and in reporting back what they found to the point where the results by the biologists interest the underwater sound man, or whether the results by the geologists interest the physical oceanographer, then you begin to have an institution; because, if you get information cross-feeding from one discipline to another, then you have accomplished the real purpose of having this interdisciplinary sort of an institution. And, if you compartment people and keep them from talking to each other, then they might as well be in separate institutions. Some of the time it's just a matter of sharing equipment and going out on the same sea trip; it just becomes a logistic advantage to an institution. A lot of times it's ideas feeding back and forth. And, a prize example is heat flow. It's a geophysical discipline measuring the geothermal flux through the ocean floor, but a geothermal flux has some influence on the temperatures on the bottom water. Moreover, the instrumentation that you use for measuring the temperature gradients of the bottom are rather applicable to measuring temperature gradients and absolute temperatures in the water, which is what physical oceanographers do. So, physical oceanographers and geophysicists working on heat flow have a great deal in common. Marine chemists can start out doing strictly solution chemistry in the ocean, just for the sake of the chemistry; and they could do it in the laboratory. But pretty soon they discover that the chemistry becomes a very good tracer for physical oceanography, or at least a tracer for measuring currents. And so I would say that one of the most active physical oceanographers at Scripps right now is Harmon Craig, who is either a chemist or geologist, depending on which year you ask him what he is. I mean, I remember that I used to accuse him of being a chemist; and he would indignantly deny it and say that he was a geologist; and other times he would argue the other way, too. But right now he is really doing physical

oceanography by using rare gasses as the tracers. It turns out that at Woods Hole the people in the chemistry there are doing physical oceanography. Really, they are tracing currents by means of the chemistry. My son, who is a graduate student at Woods Hole in geology, was out here a couple of months ago digging data out of the GEOSECS file for the chemist at Woods Hole to try to work out what the flow of bottom waters were through a fracture zone in the North Atlantic. So there is a geology student working for the chemist, digging out chemical data to sort out a physical oceanographic problem. That's why oceanographic institutions exist and why they will die, if they grow so big you finally get the people in the different scientific disciplines separated from each other.

RC: It's the interchange of ideas in the academic disciplines that creates an oceanographic institution. Is that also true of oceanography in general?

GS: Yes.

RC: Is the department of oceanography, in effect, a group of scientists brought together who exchange ideas on central problems?

GS: With a wide variety of scientific backgrounds. In any such department, you may have just a few people who cross the lines and other people who are, essentially, resources for them--a mathematician, a geologist, a chemist, a biologist, who themselves are very tightly focused in their own field. And I guess the system can still work, if there's a few people who cross the lines back and forth. It works better, of course, if there's a lot of people who cross the lines.

RC: It has been suggested that the focal point of oceanography--that is, what gives the oceanographic institute character--is, as a matter of fact, sea voyages. Oceanographic institutes, as a matter of fact, have to be on the ocean, have to have identification with ships psychologically. Would you agree with that?

GS: Oh, I like it that way, but I'm not sure it's essential. It does tend to pull the interdisciplinary group together in that the ships become one of the focal points, one of the things they have in common. And going out to sea together, again, is a very good way of getting to talk to people, although you may end up filling the ship entirely with your own group and squeezing out the people in the other disciplines, which means that then you haven't accomplished that at all. I don't know.... There have been oceanographic institutions--ones that have done, really, rather well--that haven't had this tie. Cambridge University, of course...the Division of Geodesy and Geophysics, Cambridge University, violates all these little rules of thumb I've come up with. It's a strictly earth science; it's not physical, or chemical, or biological oceanography. They're a long way from the ocean; they don't have their own ship, and they've done amazing things. The Princeton geology group has done a great deal with other people's data from the oceans. They've had time to sit back and look at the data the rest of us have gathered, so that a

great deal had come out of Princeton, particularly when Harry Hess was there, before, and since. I think, in general, though, yes, an oceanographic institution needs a ship, needs the sea voyages, something that becomes a focus for the place and doesn't let people drift back into their classical departments.

RC: How do you arrange who receives the right of the use of the vessel, for how long, and what mission, at a place like Scripps?

GS: It's hardly necessary to ration. It's more necessary to encourage people to use them. And it's funny. Some people in the federal government have asked us at times,you know, how we decide who gets the ship time. Right now, of course, it's the farsighted people who write their proposals and get the money to pay their costs of going to sea that really wind up getting the ship time; but back in the earlier and happier day, when the ship funding was very much of a block-funding operation, so you didn't have to go out and really raise all that much money, we rarely had a head-on collision between staff members wanting the same ship at the same time. It's rather funny. I did the ship scheduling for a few years; other people have done it. We have normally had one person in the institution whose title was "ship scheduler". And, in the distant past, it was one of the scientific staff. It shifted over a bit to one of our few people who crossed the line between ship operations and science--Jim Faughn, who is both a captain and a good physical oceanographer and a few other things. And now, it's done by one of the captains who is ashore for a stretch and schedules ships. But people put in their requests. Now, if the requests conflict, then it's his job to try to come up with some comprimise that will let everybody get their work done. If he can't work up a compromise, he gets the people together and lets them argue it out a bit. And once in a long, long time, there has to be a decision made by the director, who does it; but such decisions have been very, very few. Generally speaking, we've tried to match up ship availability to the need, rather than whittle the need down to match the availability. And this is why the number of ships we've had has varied over the years--went up as high as ten, and is now, really, five. We've tried to keep the ships busy but not to have a shortage or oversupply of ship time. Now, of course, admittedly, there is much more demand for ship time in the summertime than in the dead of winter, but not all that much difference; you can always get some.

RC: Those of us who work on land always feel as if oceanographers always have to go to the Mediterranean in the summertime, best we can figure out.

GS: Well, somebody said there is no point--I guess it's Bill Menard who made the point--if there's a choice between doing geology on a beautiful tropical island and an unpleasant island, why not do it on the beautiful one? But there's another part of it: if you're going to do geology or geophysics in the Bering Sea, only a fool does it there in the wintertime; the geology is still the same in the summer. On the other hand, the physical oceanographer sometimes

has to show his machismo and head up to the Bering Sea in the winter-time, whether or not, because you can't get winter data in the summer in that field. No, I used to go up to the Bering Sea and the Gulf of Alaska almost every summer. Winter cruises...one would naturally head south. I darn well wouldn't go up there in the winter-time.

RC: How many cruises have you actively participated in since you've been here at Scripps? Would you give a rough estimate?

GS: Well, I've been here 23 years, so, I'd say, roughly, 23 cruises. If one counts as a cruise something where I'm out a month or more, that's about it. I average about 2 months a year. I missed 1955, and I missed 1975, and I think there was one other year that I didn't go out to sea. I'll be going out all summer this summer and probably for a couple of months in March and April next year.

RC: Has the equipment made astonishing developments over the last 23 years, or has it remained essentially the same?

GS: Gotten more reliable; that's one thing for sure. I distinctly remember times in years gone by when, due to failure of one piece of equipment, we were able to do practically nothing aboard ship. In 1957, we took two ships and went down to the East Pacific Rise on the IGY. It was a major cruise. We had people from all sorts of disciplines--geology, geophysics, chemistry, one biologist along--a well-mixed group. The Horizon tried to go up a channel to Rapa Island, without having a proper chart, ran up on a coral head, and damaged her echo sounder. They didn't know they'd damaged it until after they got back out to sea again, and it gradually got worse and worse and quit on them. And, for a matter of about three days, while they were trying to pull the echo sounder transducer in and fix it, if possible, and put a new one on to put it out, they couldn't do anything except take plankton tows. They could not do refraction work; they could not do echo sounding; and that's what they were out there for. Without the echo sounder, they were dead. In that case, of course, they just had one echo sounder. It was not a matter of long-term availability, but this was an example. You see, if the echo sounder quit, there was nothing much you could do. And echo sounders weren't reliable, so we have frequently had echo sounders that just quit because of some electronic problem where nobody aboard ship could solve the problem. And so you were dead unless you just wanted to take plankton tows, which was just about the only thing you could do that didn't involve it. I'd say our equipment is a great deal more reliable, and, of course, much of the electronics, at least, is more compact; so you can wind up with several spare sets of things. The seismic reflection systems are much, much better. Physical oceanography, I suspect, has changed more than most things because it became very heavily electronic, whereas it used to be pretty basic--reversing thermometers and Nansen bottles. Now it's STD's and CTD's and a great deal more, and every-thing is directly coupled into the computer. It became a little harder for people to cross fields. You can't look at the other guy's

data raw anymore; you've got to have him explaining it to you.

RC: That is one of the things I was aiming at. There seems to be, using geophysics as an example...there seemed to be a way in the '40's and '50's where one could traverse--may I use this word--through oceanography picking up one discipline after another as they went through. That seems now to be impossible. Would you agree with that?

GS: Well, I don't know. I think some people maybe can. We are getting a bit more separated, and people do not become quite as much a jack-of-all-trades. Some of the younger guys really do cover quite a broad spectrum of fields still. The older one gets, the harder it is to learn new things, and this may be just part of the problem. But the real problem, I think, is that no longer can anyone just step in and look at the data somebody else is gathering and know what it really means, which is not surprising. After all, we've learned an awful lot about the ocean, so we're looking at things that are not quite as obvious anymore.

RC: Okay, that's another question. How has geophysics progressed through the decades in relationship to oceanography? Have your problems become more specialized, and, if so, exactly how?

GS: It depends on the part of geophysics. The seismic refraction work, basically, has not changed tremendously. We're still doing things in very similar ways to what we were doing 20 years ago and looking a bit more closely, perhaps, but not a tremendous change in methods. Reflection work, well, that's been, primarily, an improvement in equipment--the better we can see things we couldn't see before. It used to be a real tour de force just to get a reflection record; now, you can do reflection profiling almost automatically. There's no scientific skill in getting a reflection record; it's a matter of interpretation. So this becomes more something for the geologist than the geophysicist. The magnetics, of course, have been the real surprise. Twenty years ago, towing a magnetometer around was something one did and wondered what the results meant. And then, of course, the whole interpretation of seafloor magnetics, in terms of seafloor spreading, made magnetometers the most important instrument anybody could use. It's a simple instrument, and it's a somewhat subjective interpretation. An awful lot of people spend an awful lot of effort to get magnetic data and to interpret them in terms of seafloor spreading. Gravimeters are another matter. The gravimeters have gotten better and better and better, and the gravity data have really been a disappointment, in general. There haven't been tremendous discoveries in marine gravity. Of course, operating a gravimeter on board a moving ship is a tour de force in itself, anyhow; but it's done; it's been improved steadily. But still, gravity data.... You spend more effort for less knowledge of the earth, I guess, than any other form of geophysics. Heat flow was a funny one, too. It has become more and more important, yet it's still a very simple measurement.

RC: A seismologist today is involved in investigation and prediction. Is seismology a tool more than a science today?

GS: It's both. Reflection and refraction seismology are tools for geologists. The geophysicist is acquiring data that the geologist wants to interpret. Earthquake seismology is science to itself. It's, in part, a tool for predicting earthquakes; but, primarily, it is a study of the stress state within the earth, the motion of plates. I guess I would have to back off and say earthquake seismology is becoming a tool of tectonics--of tectonophysics. But, in good part, people are still studying the earthquake mechanisms themselves and the propagation mechanism; so, in that respect, you'd say that seismology is science that is being studied for its own sake rather than as a tool for something else. But exploration seismology is a tool for studying geology. So I find it very difficult to work up a research program using seismic refraction or reflection without getting a geologist to work with.

RC: Why did you first begin teaching seven years ago?

GS: Figured that somebody maybe would like to learn some of these techniques, too. I guess that's really about it. Nobody else was teaching the seagoing techniques. And what I've taught had always been very much a how-to-do-it course, not a theoretical course. And even when I first came here, I found I was teaching people out at sea, sort of an on-the-job-training kind of an operation. It works a bit better when you give them a classroom course first, and then take them out. Of course, I'm going out to sea with a whole bunch of students this time. We will have seven students out this month, so it's practically a class at sea, anyhow. I guess, if you work for a university, there's some vague obligation to teach.

RC: Then would you agree with Revelle's philosophy that education and research should be inextricably intertwined? Is that what would direct you towards teaching?

GS: No. I'd say that having students around makes life a lot more interesting. They're fun; they really are. They come up with some awfully stupid ideas, and they come up with some awfully bright ideas. The nice thing about graduate students is that they don't know what can't be done, and, therefore, they are quite inclined to suggest doing things that you have never thought of before. A lot of the time these things they suggest doing are impossible, but sometimes they aren't. And I say that's the fun of an educational program, whereas people in a research lab with no students around at all get very inbred. They talk to people of their own age and their own group, and new ideas are not necessarily going to pop up that way. So that's why I think an educational program is fun.

RC: Did the University of California at San Diego, its locations here in the '50's, have any influence on Scripps in terms of this teaching-research relationship?

GS: Not as strong an effect as you would think. Scripps had students here a long time ago. We bootlegged students way back. In fact, Helen Raitt's book, I guess, lists the various graduates of Scripps. We finally had to form a Scripps Alumni Association a few years ago. And I'm not a member of it; I merely founded it. But it had a very interesting set of ground rules, which was that you would not necessarily have to receive a degree from the University of California to be a Scripps alumnus. They merely had to have done a major portion of their graduate work here. The president of the Alumni Association this year is Fred Fisher. He didn't get a degree from the University of California; he got it from the University of Washington for research done here. There are a few others like that; Ken Emery is another one. He got his degree from the University of Illinois for work done here. There were students at Scripps almost from the beginning, and...a small number, but enough to really liven the place up. And then, when UCSD started to grow, of course, the number of students expanded a bit. They mostly expand up the hill, and it was quite a while before the number of graduate students at Scripps showed much change. One thing that the existence of UCSD did was it almost destroyed Scripps because there's a certain love of logic on the part of university administrators. The basic idea that all biologists should be in a biology department and all geologists should be in an earth science department and all physicists should be in a physics department--it's hard to argue against that. You know that there's something wrong about that because you wouldn't have these interdisciplinary things, but nobody here really could argue very hard against the logical thought that some people have that the geologists at Scripps should be in the new earth science department. And many of the geologists went into it. Fortunately, Bonner, who started the biology department, didn't want the marine biologists who dealt with floppy starfish instead of with DNA and RNA so we weren't quite that badly raided in biology. And I'm not sure whether Bruckner, starting physics, really quite knew what he would do with a physical oceanographer. But there was, really, a push that everybody should move into the department of his appropriate discipline on this campus; and Scripps would remain as an organization to operate ships and a scuba program--a service facility. Fortunately, there were a lot of us who fought against that. And the idea slowed down and then reversed. And the old earth science department merged back into Scripps Institution, so that now all the geology that is taught on this campus is actually taught by Scripps. We almost were taken apart, and then we were put back together again. I think it was a very good move to keep Scripps as an interdisciplinary unit. Some people have cross ties, joint appointments, into one of the traditional departments; but Scripps biologists are basically in Scripps, not in the biology department.

RC: The whole trend, however, in the '50's, seems to be the reverse of that. That is, it seems almost as if ONR and NSF are deliberately encouraging departments of oceanography, which are interdisciplinary, to develop.

GS: Yes, they were.

RC: And so the Scripps' experience was the opposite?

GS: Yes, our experience was what happens when you try to set up a normal campus around an oceanographic institution. And it was the impact of USCD that started to pull us apart. It does seem logical, of course, if one wished to start up a new campus, why not build on the group that's there. So here you have a group of geologists; let's start a geology department. But anyhow, it didn't happen in the long run; and I'm glad it didn't because, you know, that has always been one of the real problems that the University of Washington has. University of Washington doesn't have a single institution of oceanography; there is an oceanography department, yes. It also has a geology department, a physics department, and so on. And the people doing work in the ocean up there are scattered in I don't know how many departments and schools and colleges of the University. And they don't have the interdisciplinary ties they would like, and they've struggled with this problem. They're trapped by the framework of a big state university campus, and it has always been a problem for them.

RC: In terms of funding research in the '50's, it's been suggested that the IGY, in 1957, is the take off pad one should look for towards oceanography. Would you agree with that?

GS: I'm not sure. It was very, very important, yes. You're talking about expansion of funding, expansion of work?

RC: Expansion of funding and focusing of research activities on the sea.

GS: I don't know. I saw things happening a bit before that. I had a very busy couple of years in '56-'57. ONR had a fair chunk of money, money that they essentially told us to go out and do good things in the Gulf of Alaska. I remember I put together an interdisciplinary trip in the summer of '56 to the Gulf of Alaska, and it covered all sorts of things. There was another one in the summer of '57, and then the IGY took off in the winter of '57, going south. And at the same time, we had the island programs. So, I think that IGY was only part of it. It was a major part, but it was only part of this take off. The fact was: ONR did seem to have a good deal of money for oceanography, and they were willing to let us choose our own topics pretty much. I guess maybe the fact that both of these things happened may have had a real impact. In other words, two groups putting money into oceanography at once was what made things seem as if they were taking off on an exponential curve.

RC: Do you think the ONR funds have shrunk recently in terms of the money that they're putting in oceanography?

GS: Well, there were several years in a row when they were level-funded. This year, I understand, they're up a bit again; but they... well, there was a period, you know, when ONR was supporting a wide

variety of things, not just oceanography. And they, when they first had to cut back, somehow protected oceanography and cut off things like psychology and sociology and high energy physics. As NSF grew, ONR sort of retreated back to saying that the ocean is our real field; and, if given the choice, we'll support things related to the ocean and meet the cuts elsewhere. But then, of course, they got cut back so badly that during some of the last few years, they were really level-funded. And level-funding gets worse when you have just encouraged a group of new departments to grow. We were slicing a constant size pie in an inflating world among a larger number of institutions; and whereas once it had been Scripps, Lamont, Woods Hole, Miami, and University of Washington, there was Oregon State, and Rhode Island, and Texas A&M beginning to boom again, University of Texas, and on and on and on. The number of good institutions was growing, the amount of money was constant, so any given institution found less. It was several years ago that people at ONR finally informed us that they felt they no longer could take responsibility for continuing an institutional program; they would just have to look at individual projects. It used to be that you could count on the fact that your ONR money for next year might go up a little and it might go down a little, but it wasn't just going to be cut off. They would give warning; they would support the institutional program over hard times. They can't do it anymore. Their amount of money is small in proportion; it has grown a little bit this last year, but it's down a long way. So, yes, ONR is no longer the major mover in oceanography.

RC: How would you account for that?

GS: One was the Mansfield Amendment. But, before that, it was just a growth of NSF and the feeling within the Navy somewhere that the basic research was going to get taken care of somehow by NSF. ONR's money was not a big enough portion. I don't know. It's really very hard to find out why people have done what they've done, why the money for the oceanography in the Navy has been held down. I don't know. Nierenberg can probably tell you a great deal more than I can about whether it was Congress or the Defense Department where these decisions have been made.

RC: Okay, let me sketch something for you. It's been suggested that in 1957, both the combination of cooperation and competition with the Soviet Union encouraged the growth in oceanography; that this growth sort of peaked in 1960's with, if you should like, the Kennedys' idea of the new frontier, the space program, and new limited frontiers; and that now there seems to be a drop, or oceanography is no longer the glamorous field it once was. Now would you agree with that as an historical sketch of the accumulation of funds?

GS: Yes, I think that probably is a reasonable interpretation. It started out as the adventure of the new frontier and then quite a bit of it came with "feeding the starving millions with the resources of the ocean". That phrase just keeps being kidded back

and forth. It's sort of sad that some people take it seriously, and most people in oceanographic institutions don't. We know darn well we're not going to feed the starving millions out of the resources of the oceans. It sometimes gets a little sad when you see an application from a prospective graduate student. On the back of the form that lists all their vitae--where they went to school and so on--they're supposed to put a half-page statement about why they would like to come as a graduate student; and whenever you see one of those that says, "I want to learn about oceanography so I can help to feed the starving millions." you think, "Oh, my Lord, another naive one." Well, anyhow, I think people have finally become a little cynical. We're not going to feed the starving millions out of the ocean. The fisheries of the world are pretty well peaking out. I'm sure there's a few more fisheries that may be yet to come; maybe people will learn how to eat brittle stars and jelly fish and a few things like that, although I doubt it. The answer to that is the supply off Peru has sort of peaked. You know, you can't be really as fascinated with the whole thing when you discover that the fish are really being turned into chicken feed, that your 29¢ or 30¢ a pound chickens on special are only there because of Peruvian anchovettas, and that really those fisheries are competing with soybean growing, too. I mean, soybean is just as good as an anchovetta for chicken feed; and the glamour sort of fades away when you look at that. I know this is one of the things that took some of the glamour out of Sea Grant. Sea Grant was going to be this great burst forward of using the resources of the ocean. And I ran the Sea Grant program here for five years, and we finally got down to more and more pragmatic sorts of things.

RC: Now I want to digress slightly and ask a question I was going to ask later on. Is Sea Grant succeeding in Scripps?

GS: Sea Grant is succeeding in the University of California. The headquarters of the University of California Sea Grant Program is at Scripps. There is not a large group of Scripps' people involved in it. That was in some part deliberate, on my part, as a matter of fact. I pushed it that way because I thought that was the way it ought to go, because I was a bit cynical about feeding the starving millions. Well, let's see, this year.... I haven't been running Sea Grant for several years; let's take a quick look through at who, where, is doing the Sea Grant work from the University of California. Well, who are the Scripps people? Of course, Jim Sullivan runs it, and he's an economist; originally, he was up on the Santa Barbara campus, but I brought him down here. The near-shore physical oceanographers, Inman and Winant, are doing work on this; and Cox, the deep-sea physical oceanographer, is somewhat involved. There's one group right here. The other group is some of the biologists who work close in-shore and a few of the marine chemists who are looking at marine products. And, that is about it. The real push in Sea Grant has been in more of the classical departments and in the agricultural school. One thing I set work to do from the very beginning was to bring the Davis campus to the Sea Grant Program because they're the only.... Well, the people in the ag school are

the only people in a normal university who are really used to doing very applied research, and I mean short-term applied--buy somebody today, do something that will produce a result next year or two years hence. And for Sea Grant, when it was first started, it was very much oriented to short-term goals. We couldn't do that here. A few of our people knew how; most did not. And most of the rest of the university people did not know how to do that kind of research. At the ag school they do. And so, we pushed the development of an aquaculture program up at Davis and another aquaculture program up at San Diego State. It was interesting because, you know, the state colleges are not really supposed to be involved in much research at all. But again, those guys were sufficiently anxious to do some research, so they take the applied stuff on one way or another, and they did very well at it. Okay, the people at Scripps were more oriented to basic research at this point. We started back in the '40's and the '50's, doing rather applied things--going out and looking at bomb tests, and doing echo sounding, and things that were related to ASW and so on. People at Scripps have gotten more and more basic research-oriented, pure in their approach. I knew I couldn't push a prosaic, applied program like Sea Grant through this place; I'd build it up elsewhere. It's coming back in here now. You're seeing more oceanographers in the Sea Grant Program now than before. I've gotten off the question you asked. The question was what?

RC: Did it succeed here, would you say?

GS: Yes, it has succeeded. I think that we could probably say that the California Sea Grant Program is the pride and joy of Bob Abel's office in Washington. You know, we fought him awful hard to make it that way, too. We refused to do things that he said we ought to do, that we thought we knew a little better than he did about what we should be doing. He used to remark that we were the most far-out program that Sea Grant had in terms of how much basic research and how much applied research and advisory service we had. Texas A&M was very heavily on the applied side at the start, and Oregon State put all their bets on the advisory services. We started out with a fairly basic program, and I started pulling in these aquaculture programs. And, things were getting a little more applied and a little more applied; but, still, we stayed way over on the basic side. And they seemed to be much happier. Of course, the real problem with Sea Grant is a lot of the things will just make a little bit of improvement in the world; and there are a few things that will come out of Sea Grant that will be major, will have major effects. And it's very hard to tell which are going to be the ones with the big impact in the beginning. You can spot the ones that will have the little impact. You know, the better belt buckle for the diver's belt and the better catch for the diver's backpack--those were real Sea Grant projects, by the way--and the machine for cleaning squid, and so on, you know, small steps forward. Those are easy to spot. The engineer comes in and says, "Look, the squid fishermen need a machine for cleaning squid, and I could design a machine." and you give him $10,000 and he spends his year designing and testing out a machine

to clean squid. And MIT did it. I hope it's being used by somebody. On the other hand, the one project we've had that really succeeded was Dick Seymour and John Isaacs on the artificial breakwater, the dynamic breakwater. Now there's a winner, a real winner! And that was a gamble of the worst order, one of John Isaacs' many wild ideas. Dick Seymour, a graduate student with a good engineering background, picked it up and ran it through computer simulation and then ran the next state, hydraulic tank model tests, and scaling it up. And now we have a system that's going all the way: the first prototype was tested down in San Diego Harbor and is now in use to protect a pier down there. The next bigger one is going to protect the entrance to Mission Bay. They're going to get bigger; there are going to be dynamic breakwater harbors all over the world sooner or later. It's a beautiful way to build a harbor, and it's a way to build a harbor without wrecking the beaches in the process. Anyhow, this was a gamble. I think it's the most successful thing Sea Grant has, and it came out of a wild idea by John Isaacs. We've had a lot of Sea Grant projects that have been real failures, just nothing.

RC: Okay, that leads me to the next question, which is, what criteria should be used upon designating the type of research to be funded under Sea Grant?

GS: That's a good question because, of course, the whole goal of Sea Grant is to take oceanographic knowledge and make it useful to man. And so, I guess the criterion's got to be there...must be some potential real use; but I think there should be a certain percentage of far-out ones because those are the ones that, if they succeed, succeed the big gamble. You know, it's like putting your money on the double zero. If you're playing the roulette wheel, you should occasionally put a chip on the double zero and not always play black versus red. There's just no point in going to Las Vegas and dropping chips on the black, or the odd-even. You can match pennies and do that. I think that's the difference. You see, every research program should have a few gambles in it, or there's no fun in life. Going back to the earlier comparison, it's making widgets, if you're just trying to make something a little bit better.

RC: As a scientist who is working with a type of discipline closely connected to military development, do you feel as if the military's played a viable role in aiding knowledge in oceanography? Or has your connection with the military been too close?

GS: The connection hasn't been all that close. You know, the people in ONR, both the civilian and the military officers back in the Office of Naval Research in Washington, have really served as a buffer between the research scientist and the Navy. (I don't know whether the word is buffer.) They are an interface. I think they tried a little too hard to keep the Line Navy from affecting us very much. I think that we'd be better off if we did talk to the people in the fleet more, but we don't. The basic approach is for us to send in unsolicited proposals to ONR; for the fleet, in some manner, to tell

ONR what their needs are; for the ONR people to try and match them up and to try to influence us a little bit as to what the direction of the research is, slightly; and to try to meet the fleet's needs. I don't think the people in ONR necessarily talk to the fleet sufficiently. We sure don't. Now there was a period when I was, you know, a Reserve officer--just post-World War II--where I found out for myself what the Navy's problems might be, because I was Reserve officer and getting the normal Reserve training. So, I was somewhat more oriented than most; but, really, there are very few people in oceanography who have had a close tie to the Navy, and I think that's the Navy's mistake. A lot of their problems could have been solved, I think, by some of the oceanographers; and the oceanographers didn't know that the problems were there.

RC: Would you suggest that oceanography should become more mission-oriented in terms of its direction of research vis-a-vis the ONR?

GS: I don't know about that. I think that people in oceanography who are supported by ONR money should be encouraged to somehow find out more about what the Navy's needs are. Now, this may mission-orient them in the process or it may not; but, sometimes it's possible to be of help without really changing your program very much, if you just know what the guy needs. And, as I say, in the '50's, it was not too difficult because an awful lot of people in oceanography were ex-Naval Reserve officers, and so they knew what the needs were. But nowadays, the separation is tremendous. A new Ph.D., post-doc at Scripps Institution, knows little or nothing about the Line Navy, and vice versa.

RC: Now, I'd like to use the same question in terms of private enterprise. Also, oceanography has been accused of being too closely allied with private enterprise, particularly in such things as gulf coast development, offshore drilling along the California coast, and specialized work they do in mariculture. Do you feel as if, perhaps, your discipline is too closely attached to private enterprise?

GS: No. I would like to see it a great deal more closely attached. Of course, I spent some of my time trying to raise money from oil companies. I will have to say that we're not very closely tied there. I wish that we were tied a lot more closely with a lot more dollars. But some of the oil companies give support to oceanography, and I think that the feedback helps them some--not a great deal. The methods we've used have been something that they've copied in many places. The data that we've gathered is of some use to them in interpreting offshore geological structure. The data have been open to the whole world, so USGS has had just as much access to it as the oil companies--no more, no less--which I think is as it should be. The aquaculture ties into private enterprise have been sort of curious and have mostly resulted in the people in private enterprise losing their shirts. So, I think that any guy that goes into aquaculture deserves all the help he can get because he's probably going to go broke. And I would hate to see aquaculture done just by government labs; those would be sure to fail. You know, aquaculture's

going to be primarily a matter of learning how to cut corners and do things efficiently on a shoestring. And I don't think any government lab, in the long run, can succeed in that. It's got to be some guy who's desperate; he's not going to have enough money to pay his own salary if he doesn't figure out how to save a nickel somewhere in the aquacultural program.

RC: Along this same line, there has been a sizable amount of discussion about the role oceanographers ought to play in the ecology movement, with the assumption that, perhaps, oceanographers ought to be in the vanguard of ecology. What's your opinion towards that?

GS: I'm always baffled by the ecology movement. I know a number of ecologists who are not, of course, in the ecology movement; they merely study the interrelationships of marine animals to their environment. Let's say, "the people who are trying to save the environment." Yes, oceanographers should have some conscience about what one should and shouldn't do in the ocean because the ocean is the ultimate sink for everything, and you can't just pour something in the ocean and figure it'll go downstream to somewhere else. I mean, the Hudson River is not a problem; you can clean up the Hudson very simply by moving the sewer outfall farther and farther downstream and putting it in the Atlantic Ocean. Then the Hudson's clean--you've got shad in it, all beautiful. Of course, the question is: does that sewage wreck the ocean? If you think about that, I suspect that, in the long run, the sewage doesn't bother the ocean a bit, in terms of what everybody normally calls sewage. But some of the chemicals that go into the ocean could, indeed, be a problem. So, yes, oceanographers should be concerned. But I think that when one starts listening to Jacques Cousteau or Jacques Piccard, well, I have.... I remember one time when I was ready to kill Jacques Piccard, or, at the very least,put him inside a large sack and tie him up and drop him in the ocean to go down and look at things himself. These statements, like "The Mediterranean is dead; the ocean is dead." are so greatly overblown that I cannot imagine anybody that calls himself a scientist making such statements. They are about as bad as saying that there's nothing that we can do that can harm the ocean. I mean, it's an equally baseless statement, and I just don't understand how people can go that far out on a limb. Now, maybe what Cousteau is doing is playing an advertising game. But, if so, he really ought to be hauled in for false advertising. And the ecology movement is a mixture of very concerned, well-meaning, ignorant people and of good scientists who have some concern and of people who are out trying to get a bit more publicity. They're all mixed into this. And I think it's a good thing that people have finally become concerned about the world around them, but I wish they didn't always have to get so damned emotional in the process.

RC: It's been suggested by one of your colleagues that the ocean is simply an extension of the land. For example, the ocean's ultimate benefit ought to be the service of mankind. Would you agree with that?

GS: That would be rather a religious question. I mean, whether the purpose of the world is to be of service to mankind--that's a basic question, basic precept of the Christian religion, I think. I feel rather unreligious in that respect. Maybe it isn't religion--I think it is, though. It's a basic precept of the Christian religion that the world exists to serve man. I'm not so sure of that. I think that maybe we exist to serve the decay bacteria. I don't know; how are you going to know? I know that man is going to use up the land; he's going to use up the ocean. Whether he ought to or not is something that nobody's really going to decide.

RC: The last series of questions I'd like to ask are really sort of "what if" questions. What change, if any, would you like to see in instruction in oceanography?

GS: I don't know. Around here I can't say about change because it's so amorphous anyhow. The Scripps Institution's educational program.... There is no curriculum really. I find that out every year when I start advising new graduate students on what courses they should take, and it's always a free-form discussion about what they had before and what they are interested in and let's see what is being taught this term. And it turns out that the course I thought was being taught this term has been postponed until spring term, or vice versa, or was taught last spring but not next spring. So, the form of education in oceanography here is pretty loose; but, basically, the Scripps' approach towards education is: we do not encourage people to take undergraduate training in oceanography before they come here; we definitely do not. We have accepted a few who have had undergraduate oceanography degrees, very few. Generally speaking, we admit people with degrees in geology, geophysics, physics, chemistry, a few mathematicians even, biology, electrical engineering...I guess that's about the limit. And they all wind up in their first year taking some basic oceanography courses. I think they should all take a lot of basic oceanography courses their first year here. The attitudes here vary on that. Some students wind up taking marine biology, marine chemistry, marine geology, and physical oceanography--all of them. Some students can go through this place without even one oceanography course ever in their whole career. That's bad. I think all of them should learn more of the other guy's fields. The basic course is equivalent to about a junior year undergraduate course. From there on, they always wind up specializing anyhow. I think that's a good way. The only change I would make is everybody gets more of the interdisciplinary approach in their first year of graduate work, and then they go on and specialize in their own corner.

RC: What would you consider the future of oceanography, the new frontiers, let's say, of research that would develop?

GS: I don't know. We're ending the stage of general exploration. It's very hard to find a piece of the ocean that hasn't been looked at pretty thoroughly before. We're finding some, I mean, both in geology, geophysics, physical oceanography. We are now looking at

the little corners that we didn't look at earlier, going down to the Banda Sea, going over to the Philippine Sea. With the fairly intensive level of work people are doing and with the number of oceanographic ships and oceanographers around, I have a feeling that we're going to run out of places of that sort to look at within a very few years. And I think that's going to take an awful lot of the fun out of it for people like me who aren't really all that specialized, who are really explorationists. And it's going to make the field more and more for the person who's looking at fine-scale things or conducting experiments in the ocean. Now, we have a number of those people here already, people whose seagoing work involves a long period of theoretical work and lab experiments and then maybe going out to sea for a day or a week or a month and maybe with one ship, or two, or three doing an experiment. And then coming back and spending a lot of time looking at the results. People doing microstructure work, for example. They're not mapping; they're studying processes. They're studying what the microstructure of the ocean is and how it gets that way, and it does not involve going out on long cruises over large areas. So, for geophysics, geology, physical oceanography, the exploration stage may well be ending. For the biological oceanographers, it probably isn't quite. There is little that, I think, they understand. I think they all admit that. They're just beginning to understand the structure of the relationships of the living things in the ocean. They can probably spend another decade exploring; geologists and geophysical oceanographers can't. And without that exploration approach, it's not going to be nearly as interesting. It's going to be dull. Well, to some people it would be. After all, people are still mapping geological quadrangles on land, too. I'm not sure I like quadrangle mapping. So, it's going to be duller for people who aren't really highly skilled specialists in science.

RC: Do you think the period of the boom in creating oceanographic departments is over?

GS: Yes, definitely. I think we've got entirely enough departments of oceanography in the country. I think the National Science Foundation also feels this way. I notice they don't make any more building grants or equipment grants. I think they're a little over-concerned that they've gone too far, and they have. Not every state has to have a major oceanographic institution, just as not every state needs a cyclotron. And yet, there was a real push to have it in every state. In fact, Sea Grant got badly hurt by that kind of a push that there had to be a Sea Grant institution in every state. Thank goodness, they've at least merged Alabama and Mississippi into one, and they don't have any for Tennessee.

RC: Would you hazard, or would you guess or estimate, the sort of training one receives in departments of oceanography, as ill-defined as oceanography is? Is the training good or bad, as a general rule?

GS: Well, it's one of the few places in the country where naturalists

are created anymore. There aren't very many other places where one can get some interdisciplinary scientific education. And I think that.... I don't know what is defined as a "good" education, but I think a "good" education is one where students get turned on. And the way they get turned on is by meeting a professor or post-doc or somebody who is doing interesting things, not necessarily by taking a formal course. And one of the nice things about the oceanographic institutions is that the faculty-student ratio is a pretty good one. You know, when you have a class with six people in it, you do get to know all their names. Oceanography is not normally taught in classes of 300. Yes, I think that the graduate students in the oceanographic institutions get a very, very good education, about as good as anyone can get anywhere. They learn a lot of interesting things, are in direct contact with people who are doing them, and they usually get vitally interested in the subject. They don't just go through doing routine things. In that respect, it's pretty good.

RC: Will the job market in oceanography expand to absorb these new graduates of these departments of oceanography?

GS: No. I don't think it will. I think we're saturating the system in many respects. Not all of them go into oceanography when they get through. I notice that, of the geologists who go through marine geology, many of them are going back into classical geology departments or in new oil company geology departments. It's just that they happen to have a rather different background from the man who went through the classical undergraduate course. I suspect that a good many of the marine biologists are going to end up not doing marine biology, just doing biology. Maybe not. I think the system is going to get saturated.

RC: Do you suppose, just as the fields of meteorology and military science spun off oceanography departments, that oceanography departments might spin off, also, departments of ecology and natural science?

GS: Well, I think we're going to see a shift of biology departments over into ecology. Whether they become separate departments or not, I don't know. I realize at some places they have a department of chemistry and a department of chemical engineering, but whether they'd have a department of biology and a department of ecology depends, really, on whether people are speaking to each other. You know, UC Berkeley has two geology departments and always has had. And Princeton, for a long time, had two geology departments. They had different names, of course; they didn't call them both geology, but that's what they were. Let's see, at Berkeley they had a department of mineral technology in the engineering school, and they had a department of geology in the liberal arts school. They were both geology departments. Princeton had the same sort of a thing. So, if accident or history or tradition or people not speaking to each other causes it, you could very easily have a department of ecology, especially if you have a campus where the biology department was primarily devoted to genetics. Then you might well have an ecology department spring up along side. But I'm not sure

whether this would grow out of oceanography or just out of a faculty club in-fight.

RC: What do you anticipate for your future in oceanography? Do you intend to expand?

GS: Me, personally?

RC: You, personally.

GS: Well, what I have done recently...you know, I drifted out of marine geophysics into administration, running a Sea Grant program. And then I deliberately and intentionally shut that off and tried to go back into geophysics to see if I still knew how to do some research. And so, this year and next year I am submerged up to my ears in going to sea and gathering geophysical data. And the real test is whether I can write reasonably acceptable papers out of it. That's the final test of whether you're doing that. If I can't, I may go back and be an administrator, which is the last resort of the incompetents. Isn't that a miserable situation? In industry, the most competent people are supposed to become the administrators. In universities, typically, the guy who hasn't kept up with his field becomes the administrator.

RC: Or once he becomes an administrator, he can no longer keep up with it.

GS: Well, I mean.... You see, the guy who's really intent on keeping up with his field neglects his administration.

RC: What do you see to be the future of Scripps?

GS: Well, the thing I worry about in the future of Scripps is it getting too big and separating out into groups that don't communicate. And this is a very hard thing to avoid. I hope that doesn't happen; I hope it doesn't happen to Scripps, and I hope it doesn't happen to Woods Hole. I see it happening to both. And Lamont, too. I mean, the three biggest oceanographic institutions are, all of them, growing too big. And I think Scripps is definitely too big, and how do you keep it from growing? I will say that ONR and NSF help us fight that problem by keeping our funding cut down. The number of people working at Scripps has stayed stable for the last three years, and I think it ought to really decrease a bit, if this place is going to continue acting like an institution rather than like a set of separate departments. The future of it, on the short term.... I think the biggest growth is going to be in physical oceanography, amazingly. I have a suspicion that, in the longer term, there's going to be more growth in biological oceanography. I think that geology and geophysics have peaked out for the time being. They've gone through the tremendous growth rate; the whole plate tectonics business has resulted in a lot of fame and glory and interest, in general, in marine geology and geophysics. People are rushing into it at the time that it is, of course, overexpanded. I think this is standard. Everything pulsates. People rush into things as the

stock market always has, peaks out and drops down. People rush into fields of science as they're peaking out. My feeling is that marine geology and geophysics are going to be rather level operations for a bit, or even down, until somebody comes up with something quite unexpected that results in renewed interest. And, right now we're sweeping out the corners and tying everything up in neat packages.