Mohole:

The Project That Went Awry

In the partnership between science and government, Project Mohole—a design to drill the earth to unprecedented depths—stands out as an administrative fiasco that deserves earnest scrutiny. For Mohole, while it has its own peculiar characteristics, is a classic case of how not to run a big research program, and those who feel that it is inconceivable that it could happen again might be reminded that it is inconceivable that it could happen at all. Nevertheless, it did, with the result that nearly 6 years after the project was formally initiated, there is no Mohole, and there is not going to be one for a long time. There is, however, a lengthy and unattractive trail of bickering, bitterness, and shortsightedness, involving some of the leading figures of American science and science administration. And there is a record that includes:

1) A burgeoning of costs, from early informal estimates of $5 million to later official estimates of $40 million, and current official estimates of $67.7 million;

2) A running, and still unresolved, dispute over the objectives of the project—specifically, whether Mohole should be narrowly defined as a deep-drilling effort or whether it should be considered part of a comprehensive, multilevel drilling program.

3) An estrangement between the National Academy of Sciences' committee which originated Project Mohole and the National Science Foundation, which is paying for it;

4) The resignation of the committee chairman after the president of the Academy chastised him for publicly discussing the project without first clearing his views with the Academy;

5) The complete dissociation from Mohole of the oceanographic engineer who, to unanimous acclaim, carried out a preliminary phase that set a record for drilling at sea;

6) Congressional charges of political influence and irregularities in the award of the lucrative Mohole engineering contract, with the U.S. Senate voting at one point to withhold further funds;

7) A decision of the Bureau of the Budget virtually freezing Mohole funds until the administrative and financial picture has been clarified.

To trace the events that produced this record it is necessary to go back to the summer day in 1952 that saw the birth of a brilliant, amorphous, and often frivolous group that called itself the American Miscellaneous Society—AMSOC, for short. On that day, at the Office of Naval Research, in Washington, two geophysicists, Gordon Lill and Carl O. Alexis, were sorting research proposals when they concluded that the existing research categories were inadequate for the diversity of the proposals. Everything, it seems, was falling into miscellaneous piles. So, then and there, they decided to establish a miscellaneous society to accommodate diversity; AMSOC was thus born, and in short order many of the outstanding figures of American science spoke proudly of their AMSOC affiliation, though it is clear that if AMSOC were any less of a society it would have been nonexistent. As an organization, its chief function seemed to be to revel in whimsy and in contrasting its free-wheeling and witty ways with the ponderous motions of the standing professional societies. AMSOC delighted in its lack of membership rolls, bylaws, officers, publications, and formal meetings. Its only divisions, it noted, were in Etceterology, Phenomenology, Calamitology, Generalogy, and Triviology. It also maintained, it was pleased to point out, relations with the Committee for Cooperation with Visitors from Outer Space, as well as with the Society for Informing Animals of Their Taxonomic Positions. On the serious side, however, AMSOC prided itself on the quality of its "members," its ability to chew over professional matters without fuss or formality, and its abhorrence of stuffiness.

For the first 5 years of its existence it performed no visible function outside of delighting its members, and seemed happily inclined toward promoting the impression that it was a bit on the screwy side (at one meeting, it toyed with a proposal to alleviate Southern California's water problems by towing antarctic icebergs to Los Angeles). Then, in the spring of 1957, some men sitting around a table came to a conclusion that was to have enormous implications for the earth sciences and, ultimately, to bring AMSOC to world attention.

The scene was the National Science Foundation headquarters, where the earth sciences review panel was feeling a bit discouraged after having reviewed some 65 research proposals. The proposals were sound and worth while; nevertheless, the panel felt that something was missing. The missing ingredient and the atmosphere of the meeting were later described by Willard N. Bascom, the oceanographer who was soon to be brought in as director of Project Mohole, in his book *A Hole in the Bottom of the Sea:*

> None of these [research proposals] attempted to courageously break through to new ground on any of the most important problems of the earth sciences. While the proposals were by no means trivia, it did not appear likely that any major advance would be produced even if each were carried out to the complete satisfaction of its proponent. Two of the panel members . . . were especially bothered by this. They were geologist Harry Hess [professor of geology at Princeton University] and geophysicist Walter Munk [professor of oceanography at the University of California] and they asked themselves, "How could the earth sciences take a great step forward?" Munk suggested that they consider what project, regardless of cost, would do the most to open up new avenues of thought and research. He thought that the taking of a sample of the earth's mantle would be the most significant.

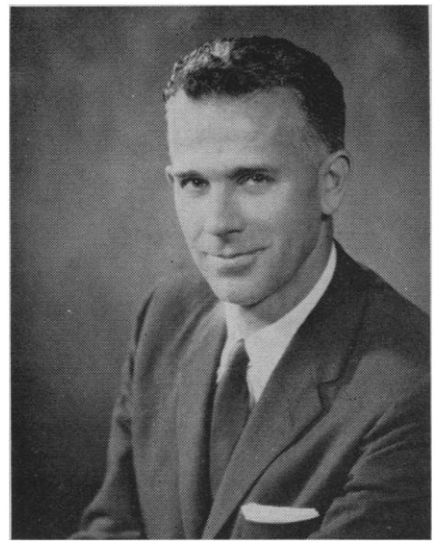
The idea was indeed a quest for "new ground," for the mantle, which comprises about 85 percent of the earth's interior, lies under 32 to 40 kilometers of crustal covering on the continents, and was far beyond the reach of any available or even dreamed-of drilling equipment. At sea, however, it might be a different story, though at this early stage the thinking had not yet passed to the question of earth versus ocean drilling. At ocean depths of 3000 to 6000 meters there was evidence that the mantle could be reached somewhere around 4500 meters below the ocean floor. It lay there, according to seismic

evidence, below the "Mohorovičić discontinuity," named for the Yugoslav geologist Andrija Mohorovičić whose seismic soundings revealed a gap between the crust and the mantle. Clearly the goal of reaching the Moho was about as elusive and as challenging as that of landing a man on the moon, since the deepest land drilling at that date was only 7600 meters, while drilling at sea had been done only in relatively shallow waters. Nevertheless, with the details still to be resolved, the climate was perfect for such a proposal, for the earth scientists had been standing by enviously for several years observing the new-found affluence of the health-related, space, and nuclear sciences, not at all sure how their own disciplines could get in on the expansion of federal support. And there was a series of tantalizing scientific questions that could be answered only by bringing up pieces of the mantle, questions involving the history and composition of the globe's interior. Bascom reports that Munk's proposal evoked the observation, "This [the mantle project] would be the perfect antianalogue of a space probe. Think of the attention it would attract to the earth sciences."

Refer It to AMSOC

Then Hess suggested that the proposal be referred to the American Miscellaneous Society.

The following month, at a "wine breakfast" at Munk's home in La Jolla, California, AMSOC accepted the challenge, and the attempt to drill to the Moho—later christened Project Mohole by Bascom—began to move along. Lill, the cofounder of AMSOC, became chairman, and a who's who of American geophysics was invited to join AMSOC's first formal subdivision, a deep-drilling committee especially established to promote the nation's venture into inner space. The committee members were Roger Revelle, director of the Scripps Institution of Oceanography; Joshua Tracey and Harry Ladd, of the U.S. Geological Survey; Munk; and Hess, who was head of the National Academy of Sciences–National Research Council earth sciences division. Other members were added later; among them was Maurice Ewing, director of Columbia University's Lamont Geological Observatory. Ewing, it seems, was sitting in the lobby of Washington's Cosmos Club when the newly formed deep-drilling committee passed by en route to its first meeting. He was invited to come along, and thus became a member. (Some persons associated with AMSOC's early days recall that when Ewing protested that he was interested in sedimentary studies—not in boring to the mantle—he was scoffed at and told, "Maurice, you're thinking too small." Two years later, Ewing resigned in disgust, but subsequently was persuaded to return.)



Willard N. Bascom, director of Mohole's opening phase.

If Ewing was thinking small, he definitely was out of harmony with his colleagues, for AMSOC soon was swept up with the excitement of the Mohole venture, and when the National Science Foundation declared that it could not dispense funds to so ephemeral a group, the once-freewheeling scoffers at institutionalism cheerfully took refuge inside the National Academy of Sciences. It was unprecedented for the Academy to take in an existing committee, but since many of those associated with AMSOC were members, and one—Hess—was an officer of the Academy, goodwill and personal confidence overrode tradition. Thereafter, the quest for the mantle became a project of the AMSOC committee of the Division of Earth Sciences of the National Academy of Sciences. And it was this Academy setting that, quite by accident, brought into the picture Willard N. Bascom, an inventive, restless, cocky oceanographer and mining engineer with long experience and unconventional ideas about deep-water engineering.

Up to this point Bascom had had nothing to do with AMSOC or the deep-drilling venture. Formerly of Scripps, he came to the Academy staff in 1954 to handle a variety of tasks, ranging from studies of civil defense and amphibious warfare to service as science adviser to the Columbia Broadcasting Company. Situated next door to Hess in the Academy building, Bascom became interested in the project and not long afterward was asked by Hess to become AMSOC's executive secretary and to organize and conduct studies on how to carry out the project. Bascom, who doesn't have to be told to run with the ball, interpreted his mandate generously, and, pushed on by his energy and enthusiasm, Mohole proceeded in rapid fashion.

Meanwhile, the fall of 1957 brought Mohole an extraordinary bit of luck when the annual meeting of the International Union of Geodesy and Geophysics adopted a resolution, sponsored by Hess and Revelle, urging nations with experience in deep drilling to study the feasibility of drilling to the mantle. In the course of discussing the resolution, a Soviet scientist arose to announce, "We already have the equipment to drill such a hole; we are now looking for the place." The Soviet boast was money in the bank for AMSOC, and the members knew it, although 6 years later it appears that, if the Soviets do have the equipment, they are still "looking for the place."

Grant Application

Now properly housed in the National Academy of Sciences, AMSOC sent over a grant application to NSF, seeking funds for what it referred to as "a courageous attempt to broaden the base on which the most fundamental of earth problems rests." The details of this application are worth noting, for when the fighting broke out several years later, a good deal of it centered around the issue of just what it was that AMSOC had proposed to NSF—was it a narrowly defined effort to drill through to the mantle, or was it a broad-based ocean-drilling program, with the mantle the most ambitious, but by no means the only, objective? In the beginning, when goodwill and enthusiasm were abundant, the documents were fuzzy on this score, and the fuzziness continued for some time, giving rise today to fervent textual analysis in behalf of sharply conflicting positions.

The grant application opened with a request for funds "for support of the study of the feasibility of drilling a hole

to the Moho discontinuity." It then went on to itemize the scientific benefits that might result "if an authentic sample of the material *below* the discontinuity were obtained. . . ." But next it proceeded, without great precision or explicit reference to a broad—or, as it later came to be called, an "intermediate"—program, to refer to the value of conducting studies of the "layer immediately *above* the Mohole discontinuity"; and it added that "the sedimentary column from the sea floor to the material mentioned above could be sampled."

Was this a proposal simply to drill to the Mohole, or was it a proposal to conduct a broad and multilevel drilling program? On this very issue a bitter row eventually was to break out (a row, incidentally, which in many respects parallels the controversy over the manned lunar landing; there the camps are roughly divided between those who say getting a man to the moon should take precedence over all else, and those who say the manned landing should be part—but by no means the all-consuming part—of a broadly based space exploration program).

Mohole Underway

In any case, NSF granted AMSOC $15,000 as a starter, and Project Mohole was officially under way, on the following organizational basis: AMSOC was responsible for supplying the scientific guidance, but since AMSOC was a part-time organization and its executive secretary, Bascom, was full-time, the energetic Bascom pretty much ran the show; at the same time, the Academy provided an institutional base and NSF paid the bills.

This arrangement was a departure from preferred practice for the Academy and NSF, since the Academy, with a few exceptions, is an advisory, rather than an operational organization; and NSF, again with a few exceptions, supports research through standing research institutions. (Not long afterward the Academy was to find itself uncomfortable with its Mohole relationships and was to take steps to disentangle itself, though still remaining associated with the venture.)

At this point in Project Mohole, who was in charge? In the era of goodwill that then prevailed, no one seemed to be particularly concerned. Everyone was pulling together. As for the costs, these would be high, it was acknowledged, in relation to the funds normally available for the earth sciences, but compared to the vast expenditures then pouring into the new-born space age, they were trifling. Collaborating on an article in *Science* in 1959, AMSOC chairman Lill confidently stated:

> The Mohorovičić Discontinuity project probably can be accomplished for $5 million. Earlier and larger estimates were out of bounds. Five million dollars is a lot of money, but compared with the many millions of dollars that are being spent on moon rocketry and the billions being spent on atom bombs, this is not an overly ambitious scientific endeavor.
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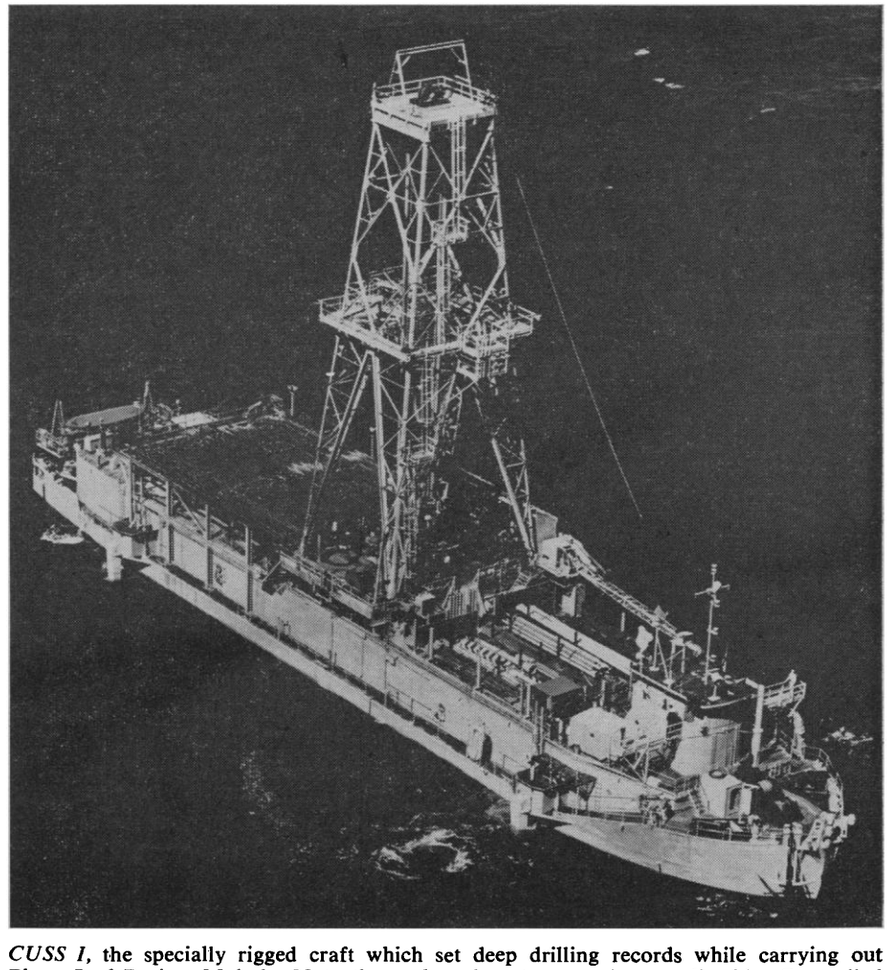
> The American Miscellaneous Society, with its flair for seeing the lighter side of heavier problems, likes to quote the following proverbs when discussing the "Moho": (i) "When going ahead in space, it is also important to go back in time"; (ii) "The ocean's bottom is at least as important to us as the moon's behind!"

At about the same time, to help clarify the project for an increasingly interested public, Bascom spelled out its past, and speculated on its future, in an article in *Scientific American*. The article, though not an official statement of the AMSOC committee, unquestionably had its endorsement and stands as the most definitive statement of what AMSOC—the originator of Project Mohole—thought it had in mind when it sought support from NSF. Later statements unfortunately clouded and confused the AMSOC position, but at that early stage Bascom, presumably speaking for AMSOC, stated:

> "The principal objectives of drilling to the mantle are . . . to obtain samples of the various rocks of the mantle and the deep crust. . . . Although reaching the mantle is the ultimate objective of the Mohole project, an intermediate step is likely to yield equally valuable and interesting information. . . . No one site or hole will satisfy the requirements of the Mohole project. . . .

Bascom then went on to state that "we will have to feel our way along." The first step, he said, would involve



CUSS I, the specially rigged craft which set deep drilling records while carrying out Phase I of Project Mohole. Note the outboard motors on the vessel's side. Controlled from a central point, they kept the *CUSS* virtually motionless over the drill pipe while drilling on the high seas.

drilling in about 3000 meters of water. With this experience, modifications could be made that would permit drilling around depths of 4800 meters. After that "it will be possible to make a sound reappraisal of the kind of equipment needed to go on to the Moho."

And not long afterward, the annual Pick and Hammer Show of the Washington Geological Society presented a review entitled, "Mo-Ho-Ho and a Barrel of Funds."

Now, with surprising speed and a quick success that obscured some of the enormous problems involved in going down all the way to the mantle, AMSOC's professional staff carried out Mohole's phase I, a series of record-setting test drillings in the vicinity of La Jolla, California, and Guadalupe Island, 400 kilometers south of San Diego. Their vessel was *CUSS I*, a modern drilling ship that took its name from its original sponsors, an exploration combine comprising the Continental, Union, Shell, and Superior oil companies. Operated under contract by its owners, the Global Marine Exploration Company, but modified, equipped, and run under Bascom's direction—at a cost to NSF of $1.5 million—it set out from San Diego early in 1961 to test the feasibility of drilling in very deep water, 10 times deeper than any in which oil-drilling attempts had been successful. Of critical importance was Bascom's unique dynamic positioning system, consisting of four 200-horsepower outboard motors, located around the hull and operated by a central joystick which activated them to compensate for shifts caused by wind and current. The purpose of this system, which had aroused considerable skepticism, was virtually to hold motionless the *CUSS I* in winds up to 37 kilometers per hour (20 knots) and surface currents up to 0.55 kilometer per hour (0.3 knot), so that no undue stresses would be introduced into the more than 3 kilometers of drill pipe dangling from its underside. (It worked so well that the 81-meter vessel was generally maintained within a ship's length above the point where the pipe entered the bottom.)

Setting Records

The results were spectacular, and are yet to be matched. Operating in 3300 meters of water, *CUSS I* drilled as far as 180 meters into the bottom. And the AMSOC group pulled off the job within a matter of weeks and within its stated budget. (Once again, all this took place in a period of extreme goodwill when no one was paying very much attention to organizational details. Bascom, though working for the Academy as a member of the AMSOC staff, was designated a technical representative by NSF. As Bascom later explained this setup to a congressional committee: "This method was an administrative makeshift, but it worked, primarily because all of us were anxious to make the tests a success.")

Successful as phase I was, it literally only scratched the surface, for to get to the Mohole it would be necessary to drill in some 4500 meters of water and down through some 4500 to 6000 meters of rock. No rig capable of this was in existence, and now thoughts turned to Mohole's phase II. And it was at this point that the trouble began.

It was the spring of 1961, 9 years after AMSOC's birth, 4 years after Munk had first proposed the mantle project, and a period of stocktaking was at hand. AMSOC's staff triumphantly wrote up its *CUSS I* experiences, "Experimental Drilling in Deep Water," which was issued as an Academy document. (Included was a congratulatory letter from John F. Kennedy, addressed to Academy president Detlev W. Bronk and NSF director Alan T. Waterman. Kennedy extended his congratulations to all associated with Project Mohole "and especially to all those on board the CUSS I and attendant vessels who have combined their talents and energies to achieve this major success.")

Reorganization

Thus, on the surface, everything was rosy, but, meanwhile, the organizational relationships underlying the project were beginning to wear badly. Within the AMSOC Committee, the Academy, and NSF there was a feeling that the next phase of Mohole would be so vast, complex, and costly that a new organizational basis would be required. Meeting in late May and mid-June, the AMSOC Committee concluded that it wanted to disengage itself from the actual operations of Project Mohole. Reporting to the Academy on its decision, it stated:

> . . . the administrative demands of continuing work at sea, and the deliberate pace of Committee activities do not mix well. . . . We decided that the Amsoc Committee should in the future concern itself with matters of scientific policy, engineering review, and budget. . . . We consider that we are responsible to both the National Academy of Sciences–National Research Council and the National Science Foundation. The dual responsibility arises because of our origin and existence in NAS–NRC, and because of our financial support from NSF. In this relationship, we may properly act as the representatives of NAS–NRC in its role of adviser to the National Science Foundation for drilling to the mantle.

The AMSOC Committee then went on to recommend "that the operational and engineering future of Project Mohole be entrusted to a prime contractor," but it urged that Bascom's staff be kept intact and "as part of the terms of the prime contract . . . the contractor must agree to make our staff the nucleus of his endeavor by absorbing them into his organization." Adding a prophesy that was to turn out to be a stunning understatement, the AMSOC Committee noted that "these terms may have inherent difficulties but we may not overlook our responsibility to the staff. . . ."

At about the same time, voices were being raised within the Academy to the effect that the heavy involvement with an operational program such as Mohole was inappropriate for the Academy; that the Academy, in accepting the Mohole project, was veering from its traditional role of aloof and politically uninvolved adviser to government and moving in the direction of the Soviet Academy, which is a heavily operational organization. At the June meeting of the Academy's governing board, these views came to predominate. Several days later, Bronk wrote to Waterman, reporting that the governing board had formally endorsed Project Mohole "as a scientific undertaking of great significance. At the same time," he continued, "the Board urged that the actual operating responsibility for carrying the project to completion be lodged with an organization other than the Academy–Research Council, preferably an organization having experience in the operation of large engineering undertakings. . . ."

Staff's Future

Then addressing himself to the question of what was to happen to Bascom's roundly praised and accomplished group, Bronk wrote that in the new fiscal year, which was to start in a week, the Academy would provide support for the AMSOC staff for 90 days "pending completion of the recommended transfer of the staff to whatever

prime contractor is selected for operation of the project." Bronk next went on to write:

In connection with the proposed transfer of the staff, I am glad to record my own admiration, and that of our division of earth sciences and our governing board, for the exceptional performance of Mr. Willard N. Bascom and the staff members he has assembled in the planning and execution of the experimental drilling phase of the project. . . . In our estimation, this group has been chiefly responsible for the successful carrying out of an undertaking that represents not only a scientific advance of unusual significance, but also a distinguished engineering achievement and a major extrapolation of previous practice and experience.

And thus, with the decision to hire a prime contractor, began the detachment of Bascom and his group from Project Mohole. It began slowly at first, but in less than 2 years the much-acclaimed staff of oceanographers and engineers was completely cut off from the project whose first stage they had carried out so brilliantly.

Within a few weeks NSF announced that it would hold a briefing session for prospective contractors for phase II of Project Mohole. At this point, then, Bascom's group was moving toward a limbo; the Academy was getting ready to disengage itself from the direct operations of the project; AMSOC was seeking for itself an advisory role close enough to be influential but not so close that it would be in day-to-day touch with the project, and NSF was looking for a contractor to carry out the venture. Who was in charge? What was the objective of phase II? It is difficult to say.—D. S. GREENBERG

(*This is the first in a series on Project Mohole.*)

Announcements

"Chronicle," a public affairs program of CBS News, will present a report on social, ethical, and political implications of some of the **major scientific discoveries** since 1948. The program, entitled "Tomorrow was Yesterday," is scheduled Wednesday, 15 January, 7:30 P.M. EST. The participants and their topics include:

Gary Westerhout, director of astronomy, University of Maryland; use of radio astronomy to map the galaxy.

Charles H. Townes, provost, Massachusetts Institute of Technology; lasermaser light.

Bruce Heezen, senior research scientist, Lamont Observatory and assistant geology professor, Columbia University; discovery of a 40,000 mile submarine mountain ridge which leads to a general theory on the origin of continents.

Chen Ning Yang, Institute for Advanced Study, Princeton University; the "fourth force," or weak interactions.

Severo Ochoa, chairman, biochemistry department, New York University College of Medicine; cracking of the genetic code.

Gerard Piel, president and publisher, *Scientific American*; the impact of basic scientific breakthroughs on human values.

The **editorial offices** of *Experimental Neurology*, an Academic Press publication, were moved this month from the National Institutes of Health, Bethesda, Md., to New York. The change was necessitated by the transfer of the journal's editor, William F. Windle, formerly chief of the Laboratory of Perinatal Physiology, NIH, to the New York University Medical Center, where he has been appointed research professor in the Institute of Physical Medicine. Communications to the magazine should be addressed to Dr. Windle at the Medical Center, 400 E. 34 St., New York 10016.

The University of Denver has instituted a graduate program in **physical ceramics**, leading to both the master's and doctoral degrees in metallurgy. It will center around the concept of properties (thermal, mechanical, electrical, optical, and magnetic), and the response of ceramic materials to their physical environment. The program will be headed by Jerry Plunkett, associate professor of metallurgy and research ceramist at the university's Denver Research Institute.

Courses

A program in **comparative physiology** will be conducted 15 June to 31 August at the Marine Biological Laboratory, Woods Hole, Mass. Six to nine pre- and post-doctoral fellows will participate in the program, which will include comparative cardiovascular physiology, endocrinology, muscle physiology, metabolism, enzymology, and animal behavior and orientation. Financial aid is available. Deadline for applications: *1 February*. (L. H. Kleinholz, Biological Laboratories, Reed College, Portland, Ore.)

A summer institute in **behavioral genetics** will be presented 22 June to 31 July at the University of California, Berkeley. Applicants must be U.S. citizens, and have had at least 1 year of graduate study in an area relevant to behavioral genetics. The course is supported by an NIH training branch grant. Enrollment deadline: *1 February*. (G. E. McClearn, Department of Psychology, University of California, Berkeley 4)

Meeting Notes

The annual meeting of the **Health Physics** Society is scheduled 15–18 June in Cincinnati, Ohio. Sessions will include papers on developments, current state of progress, and the future of various areas of health physics. Fifteen copies of a 200- to 400-word abstract are required. Deadline: *1 February*. (C. P. Straub, Taft Sanitary Engineering Center, 4676 Columbia Pkwy., Cincinnati, Ohio, 45226)

Four travel grants are available for participation in the third European conference on **microcirculation** in Jerusalem, Israel, 15 to 20 March. The awards, $900, are provided through an NIH grant. Applicants must submit two copies of a 500-word abstract of the paper they wish to present at the conference, along wtih a brief curriculum vitae. Maximum age for applicants is 35 years. Deadline for receipt of applications: *30 January*. (H. J. Berman, Department of Biology, Boston University, Boston, Mass. 02215)

The 41st meeting of the American **Orthopsychiatric** Association will be held 18–21 March in Chicago. The major topics will include: social change and the underprivileged; race relations; college dropouts; research and programs for the mentally retarded; education for the poor and the urban child; therapy and mental health programs in India, Israel, the Soviet Union, and Communist China; violence in children; and the report of work of the President's committee on juvenile delinquency and youth crime. Further information on the meeting is available from Marion Langer at the Association, 1790 Broadway, New York 19.