American Mineralogist, Volume 73, pages 1221–1234, 1988

Mammon and prestige in earth science departments[1]

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Abstract

What is perceived as a crisis in federal funding of basic research in solid earth geosciences is traced in part to the logistic approach of the scientific enterprise to a saturation limit (cf. Price, 1963), but more immediately to the soaring expenditures of the U.S. defense establishment on research and development (R&D), the concomitant decrease or bare maintenance of nondefense-related R&D funding, and the malaise of the energy and mining industries and NASA.

The Earth Sciences Division of the National Science Foundation (NSF-EAR) funds more than half of the federally supported research undertaken by academic geoscientists. The distribution of these funds ("mammon") among the ten designated projects within the division (little science, big science), among the line items (salaries, overhead, equipment, subcontracts, etc.), and among the institutions and individuals that compete for research dollars is analyzed in detail, the last with reference to the ranking of research-doctorate programs of geoscience in 82 universities for "prestige" by the Conference Board of Associated Research Councils in 1982. The "Scholarly Quality" (SQ) of these institutions is compared with their self-acclaimed productivity (numbers of publications) and grants received from NSF-EAR (numbers of dollars): both show parallel exponential decreases with perceived SQ. In the period 1978–1986, the top 9 institutions received 32% of the ~$240 million dollars awarded, the next 9, 15%, and the subsequent groups of 9, 11%, 8%, 7%, 5%, 2%, 2%, and 1%. As recently as 1986, these institutions accounted for more than 87% of the EAR research budget. A closer look finds that at least since 1984, about one-third of all this mammon goes to those individuals who receive two, three, four or more grants, and, in addition, "big science" consortia (COCORP, DOSECC, etc.) have absorbed nearly all the increase in EAR funding in recent years. Meanwhile the success rate for new proposals from individuals has declined below 25% in several programs. Creative initiative and productivity are being eroded as hope for funding at any level fades for a very large proportion of the earth science research community, which is rife with self-protective strategies, cynicism, desperation, and despondency. The recent cessation of drilling to the San Andreas fault suggests that the system has foundered at both ends of the big-science–little-science scale. A formula for hope is offered for those at the low end of the scale; the political process will have to deal with national priorities if the long-term problems are to be solved.

Introduction

In October 1987 I presented an address to the Mineralogical Society of America (MSA) entitled "Mammon and Prestige in Mineralogy and Petrology." I found it expedient to prepare the written version in two parts. The first was an assessment of prestige and prices of professional publications in the fields of mineralogy, petrology, and geochemistry (Ribbe, 1988). This, the second part, deals primarily with funding of basic research in academic departments of earth science.

The federal funding picture for the geological sciences is complex (8 agencies, 12 programs), and in order to reduce it to manageable proportions, I have investigated only the grants awarded in the period 1978–1986 by the National Science Foundation Earth Sciences Division (NSF-EAR), which accounts for more than half of the research funds. These were considered as a whole in relation to the "prestige" of university departments that were ranked in a reputational survey by the National Research Council (NRC) and other members of the Conference Board of Associated Research Councils in their assessment of scholarly quality in U.S. research doctorate programs in the geosciences (NRC, 1982). [These 91 programs in 82 universities, plus the (unrated) oceanographic institutes, the Carnegie Institution of Washington, and the National Academy of Science and National Research Council, account for 92% or more of NSF-EAR grants in any given year.] Research funding was also examined at

[1] Adapted from the Presidential Address at the annual meeting of the Mineralogical Society of America, October 27, 1987, in Phoenix, Arizona.

0003–004X/88/1112–1221$02.00

the level of two NSF-EAR programs of particular interest to members of MSA, namely, Experimental and Theoretical Geochemistry and Petrogenesis and Mineral Deposits.

In order to maintain proper perspective in the ensuing discussion of "prestige" as it relates to the distribution of "mammon" among earth science departments and individuals therein, some definitions are in order. In the *Oxford Dictionary of the English Language,* the first meaning of "prestige" is "an illusion; a conjuring trick; a deception, an imposture." It is etymologically related to "prestidigitation." The second and more modern meaning of the word is the one most of us prefer: "blinding or dazzling influence; 'magic', glamour; influence or reputation derived from previous character, achievements, or associations, or esp. from past success." "Mammon" is a first-century Aramaic word for money that was transliterated into the Greek (μαμωνα) and subsequently into English in early translations of Jesus' Sermon on the Mount (Tyndale, 1526; Matthew 6:24):

> + No man can serve two masters. For other he shall hate the one, and love the other: or els he shall lene the one, and despise the other. Ye can nott serve God and mammon.

It is no secret that a self-serving funding war is being waged with ever-increasing intensity. Figure 1 is a timeless caricature of the conflict in which corporate names could well be substituted by individual monikers. Metaphrasing Hobbes (1651): "In all times *scientists,* because of their *imagined* independency, are in continual jealousies, and in the state and posture of gladiators; having their weapons pointing, and their eyes fixed on one another . . . in a posture of war" [words in italics are mine]. Distressed by NSF funding policies and peer review tactics, Hollister (1988) has put it in modern parlance, speaking of burnout, "the massacre of projects," "alienation . . . growing to a state of civil war," and "starvation of individual investigators."

Mixing metaphors, we may well ask: What has happened to the wellspring of mammon that once bubbled with artesian delights? Is the fountain running dry? Has demand exceeded supply—more consumers, less precipitation, lower water table—those sorts of things? Or have the bureaucrats and/or the prestigious, powerful few diverted the flow into their own reservoirs, leaving the besieged, despondent masses to shrivel and mummify in the searing desert heat?

There is no simple answer, but there are some clues.

Logistic growth of the scientific enterprise

> Using any reasonable definition of a scientist, we can say that 80 to 90 percent of all the scientists that have ever lived are alive now. Alternatively, any young scientist, starting now and looking back at the end of his career upon a normal life span, will find that 80 to 90 percent of all scientific work achieved by the end of the period will have taken place before his very eyes. . . . In that respect, surprised though we may be to find it so, the scientific world is no different now from what it has always been since the seventeenth century. [Derek J. de Solla Price in his Pegram Lectures, "Little Science, Big Science" (p. 1, 2, 14, 15, in Price, 1963; reprinted with addenda 1986).]

Price concluded that there has been a doubling of the population of scientists every 15 years for at least two and a half centuries and that at this rate, every doubling of the world's population would produce about three doublings of the number of scientists.

In the United States, about 3.6% of the population are now classified as "scientists and engineers," up from 2.4% in 1976 (S&EI, 1987, p. 6). The exact number and precise definitions of "scientist" and "engineer" are not important: the question is, will society support two, three, or four times the current proportion of technocrats? It should be obvious that the historical pattern of pure exponential growth, shown alongside Price's logistic curve in Figure 2, has already ceased. So at least in the U.S. we are near or even past the logistic inflection. A saturation limit relative to the total population of the country will be reached eventually, though certainly not in any ideally predictable manner. How long will it take? What are, what will be the repercussions?

It is my personal opinion that this matter is a significant but by no means the only factor in what we perceive to be a crisis in federal funding of basic research and the decline of scientific prodigality of the United States relative to other nations.[2]

Mammon: The big picture

Defense R&D

Figure 3 shows federal spending for R&D as apportioned between "defense" and nondefense ("other") for the period 1960–1987. The research of most earth scientists and probably all mineralogists, petrologists, and geochemists is funded in the latter category that has languished rather forebodingly since 1980. The impact of the Reagan era, as reflected in federal budgeting priori-

[2] According to Price (1963), logistic growth often reacts to saturation conditions with "violent" fluctuations; he called them convergent and divergent oscillations (see his Fig. 7, p. 24). One such oscillation, though hardly "violent," has been experienced since 1965 in the number of scientists and engineers specifically engaged in research and development (R&D) in the U.S.: from 64 per 10000 in the labor force in 1965, the number rose to 68 in 1968, fell to 56 in 1974–1976, and rose to 66 in 1983. U.S. expenditures for R&D as a percent of gross national product show a parallel fluctuation, actually ending up 0.2% lower (8% of the total dollar amount) in 1983 than in 1965 [data from "Science Indicators" (NSB, 1985), p. 186–187]. In the latter category Japan and West Germany have grown steadily (by 65–70%!) during this period to equal the U.S. percentage expenditures on R&D, but without any significant "defense" components—a budget category that consumes fully two-thirds of our federal R&D funds (see Fig. 2). For example, in 1983 Japan and West Germany each spent 2.5% of their GNP on nondefense R&D, but the U.S. was only at the 1.85% level (NSB, 1985, p. 6).

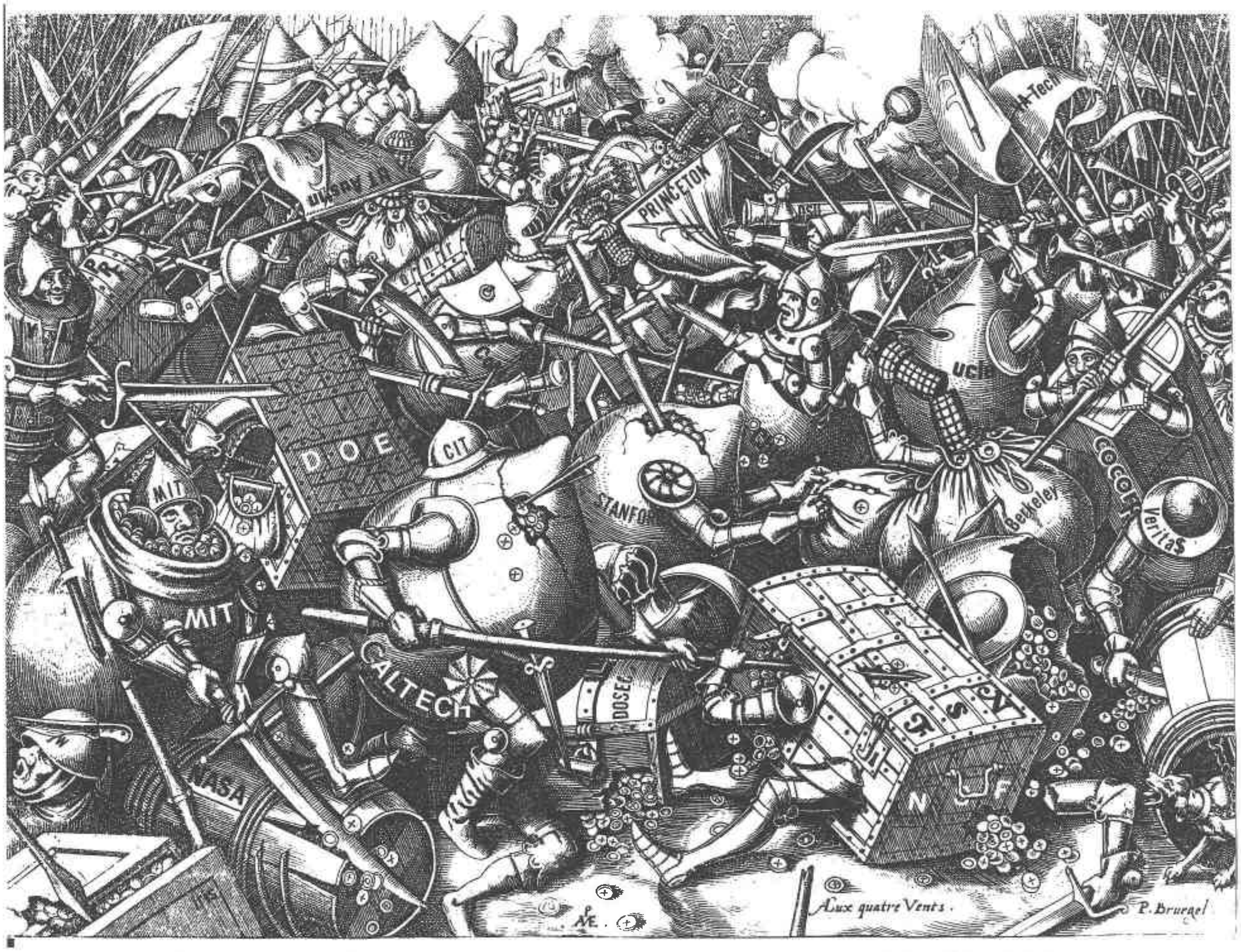


Fig. 1. The battle for mammon. Modified from a woodcut by Pieter Bruegel, the Elder (1563).

ties, tax cuts and resultant deficit financing, has been harsh on those engaged in *basic* scientific research.

Nondefense R&D

In the "other" category of federal R&D expenditures (see Fig. 4), it is immediately obvious and not surprising that "health" is of primary concern; in the past decade it has enjoyed a two-thirds increase in its budget (in inflation-adjusted dollars). Although "space" and "energy" provide a portion of R&D funding for earth science, most researchers in mineralogically related professions receive

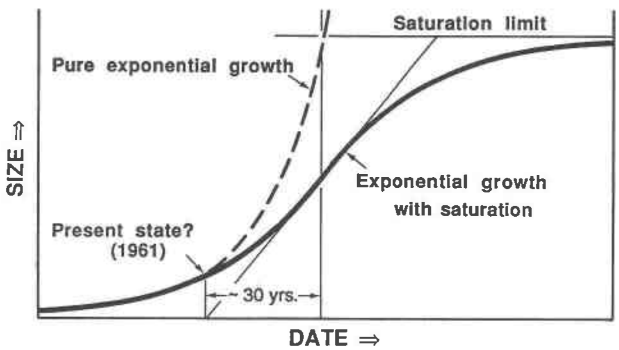


Fig. 2. The general form of the logistic curve. Modified from Price (1963; originally published in *Science Since Babylon,* Yale University Press, 1961).

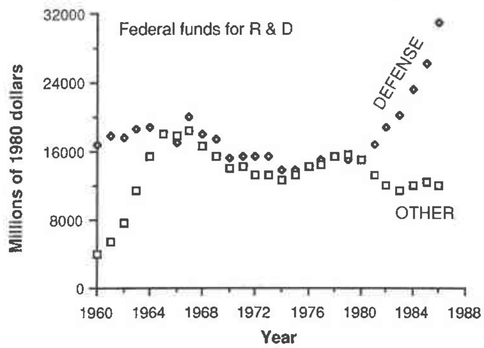


Fig. 3. The U.S. federal budget authority for research and development apportioned between defense and all other categories in 1980 dollars, $\times 10^6$. Data for 1985 and 1986 are estimated. From Office of Management and Budget, "Special Analysis K," Budget of the U.S. Government, 1986; see Appendix Table 2–11 in NSB (1985).

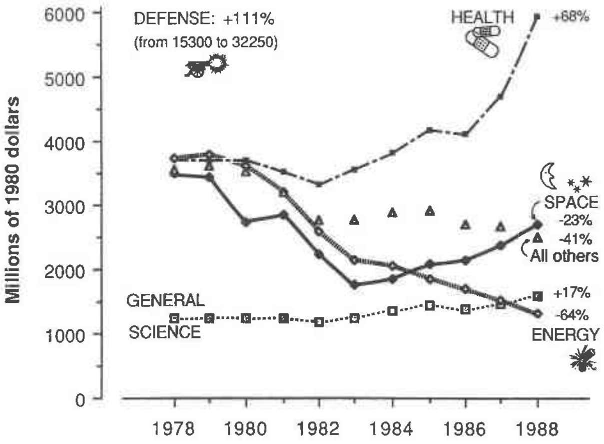


Fig. 4. Plot of federal nondefense R&D funding by category, in 1980 dollars, $\times 10^6$. The percent increase or decrease in budgets are calculated for the years 1978–1988; 1987–1988 data were estimated by NSF. Data from NSF (1987).

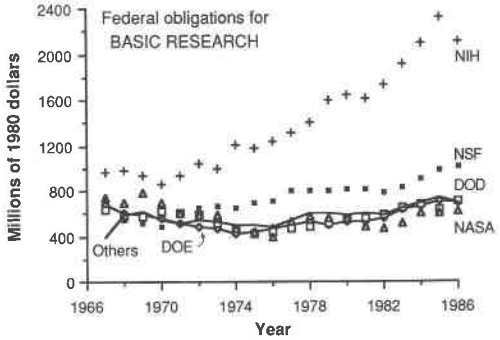


Fig. 5. Federal obligations for "basic research" by agency, in 1980 dollars, $\times 10^6$. + = National Institutes of Health (NIH); ■ = NSF; □ = Department of Defense (DOD); △ = National Aeronautics and Space Administration (NASA); ◇ (joined by line) = Department of Energy (DOE); no symbol (line only) = all other federal agencies. Data from NSF (1987).

support from what is represented in Figure 4 as "general science." This is the one federal budget function that has been funded consistently but parsimoniously for the past ten years.

Basic research

In the federal funding scheme, "basic research" is a subset of R&D, and in 1986, expenditures of $8.2 billion amounted to 15.4% of the total R&D budget authority (NSF, 1987). Figure 5 indicates the inflation-adjusted distribution of basic research funds among federal agencies. The National Institutes of Health (NIH) thrives and will do so all the more as AIDS and other major health problems continue unabated. NSF shows only modest growth with time, and in my study of research funding of the earth sciences, and of mineralogy, petrology, and geochemistry in particular, this trend is of great concern.

National Science Foundation

In his 1986 presidential address to the Geological Society of America, W. G. Ernst (1987) issued a clarion call for increased cooperation among subdisciplines in earth sciences, convincingly arguing that this would enhance our political appeal and thus the potential for additional R&D funding. He justified substantial increases relative to other scientific disciplines in both economic and societal terms (cf. Anderson, 1986). Ernst's concern, and mine as well, arises in part from data in Figure 6 that show that Earth Science funding within NSF seems firmly anchored to the bottom. This disturbing fiscal neglect of the discipline that encompasses much of "the environment" as well as the now moribund but in the long term critically indispensable minerals and fossil fuels industries (especially in view of the present global instability) is most unfortunate. If the commitment of so great a proportion of the nation's financial resources to the "defense" of the entire free world is allowed to continue, basic research will not be the only casualty.

Most scientists are well aware that funding of basic research is by no means free from partisan or provincial political interference, and I suspect that most of us would welcome it on our own behalf. But when the opposite is true, we react with indignation. In 1986 the Ocean Sciences (OS) division of NSF was protected by an act of Congress from Gramm-Rudman-Hollings budget cuts, but their would-be share of the cut (very large in dollar terms) had to be absorbed elsewhere in NSF (notice the recent precipitous increase in the OS funding curve in Fig. 6). It was taken out of the allotments of Atmospheric Sciences, Polar Programs, and Earth Sciences. Within the Earth Sciences division, this substantial cut came almost entirely out of the standard research programs—the budget of Continental Lithosphere was unaffected. At the time of writing (early 1988), similar legislation had been passed by the House, but not the Senate, so the outcome for the current year is uncertain. What seems inevitable, however, is further belt-tightening in basic research funding, whether by inflation, by decree of the Gramm-Rudman-Hollings Act or by other deficity-cutting legislation.

Given Price's logistic curve (Fig. 2), the climate of federal funding for earth science research, and the pervasive malaise of geologically related industries (and NASA) that once had extensively supported academic investigators, it is inevitable that competition for grants would increase. The National Science Foundation has felt this most keenly (see Ernst, 1987), and a recent letter by Hollister (1988; see above) expresses the frustrations of many hundreds of earth scientists, of whom not a few have abandoned hope of ever receiving another grant.

Although the current and inflation-adjusted dollar amounts available to NSF have increased (Fig. 6), the trends of the numbers of proposals received and awards made (Fig. 7) are diverging ever more sharply with time. The "percent success" of proposals for *new* awards (Fig. 8) in the eight *S*tandard *R*esearch *P*roject*S* (SRPS) of

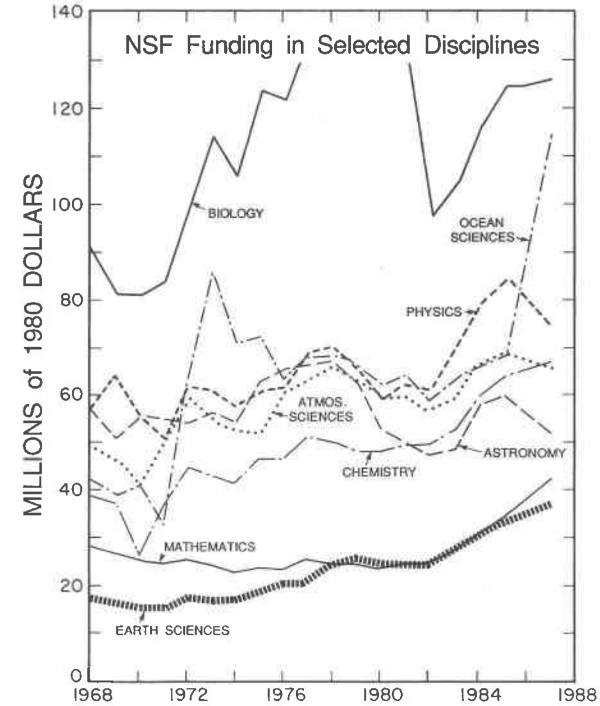


Fig. 6. Funding for selected divisions of NSF in 1980 dollars, $\times 10^6$, for 1968–1987. Modified from Ernst (1987, Fig. 1) with additional data from NSF.

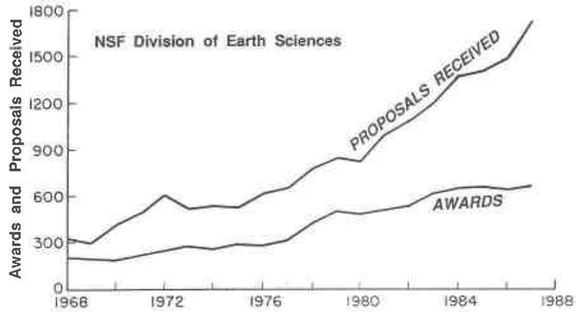


Fig. 7. The numbers of proposals received and awards made for the years 1968–1987. Data from J. F. Hayes, director of NSF-EAR (pers. comm., 1987).

EAR mimics the decline of those in the division as a whole. Success rates for three separate programs of particular interest to MSA members are shown in contrast to those for the Continental Lithosphere program (off scale in Fig. 8; also of interest to MSA). Numbers below 25% are more than discouraging, they are devastating! And it would appear that several programs have reached such depths in 1988. The good news—for those of a cynical turn of mind—is that as more scientists realistically face the futility of obtaining a grant and abandon hope, the success rates will rise.

* * *

Before discussing actual amounts and distribution of NSF-EAR funding, both among their project designations and to individual researchers in academic institutions, I will comment on the "prestige" of the latter in order to establish a basis (however subjective) for studying the distribution of "mammon" among the universities. A by-product of this investigation is an overview of the sources of Ph.D. degrees and the employment of mineralogy and petrology faculty among the ranked universities and colleges in the United States.

Prestige

Universities, colleges, and earth science departments

Hagstrom (1971) studied the prestige of 125 departments of mathematics, physics, chemistry, and biology based on an assessment of quality in graduate education sponsored by the American Council on Education (Cartter, 1966). He found large and significant correlations of prestige with department size, numbers of research articles and citations thereto, research "opportunities" (funding, facilities, etc.), faculty background, number of postdoctoral fellows, undergraduate selectivity, and faculty awards and offices. Of course, none of these factors is unexpected, and as will be observed in this smaller, discipline-restricted study, nothing much has changed with time.

In 1970 the Carnegie Foundation (CF) initiated a classification system for universities and colleges that was last updated in 1976. Then there were 3072 institutions of higher education. In CF's 1987 report there were 3389. CF grouped these universities and colleges into categories "based on the level of degrees they award, the fields in which the degrees are conferred, and, in some categories, enrollment, federal research support, and selectivity of admissions criteria" (CF, 1987, p. 23). Table 1 contains the numbers of institutions in each classification, the num-

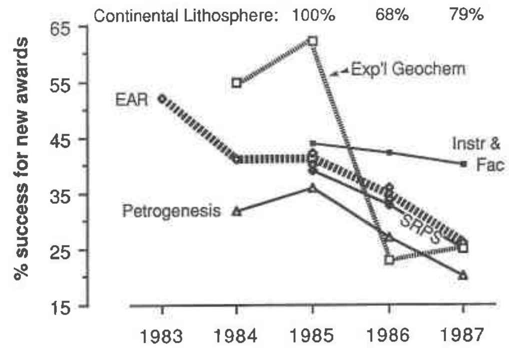


Fig. 8. The success rates in recent years for new award proposals submitted to NSF-EAR as a whole (heavy segmented line), the eight *S*tandard *R*esearch *P*rogram*S* = SRPS (◆), Instruments and Facilities (■), Experimental and Theoretical Geochemistry (□), and Petrogenesis and Mineral Deposits (△). Continental Lithosphere rates (top) are off-scale. Data compiled by Alan Gaines of NSF-EAR (pers. comm., 1987) and, according to him, subject to some reinterpretation depending on exact definitions of "proposal" and "success."

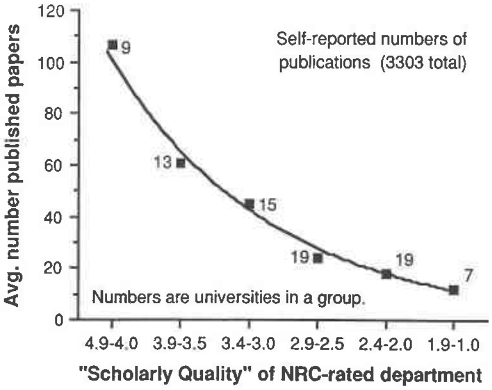
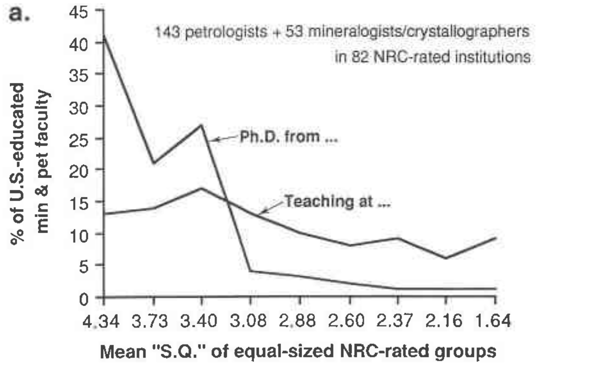


Fig. 9. The average numbers of publications per institution (self-reported to NRC, 1982, for the years 1978–1979) as a function of "Scholarly Quality" of the institution, by groups. Numbers next to data points are numbers of institutions in each SQ group.



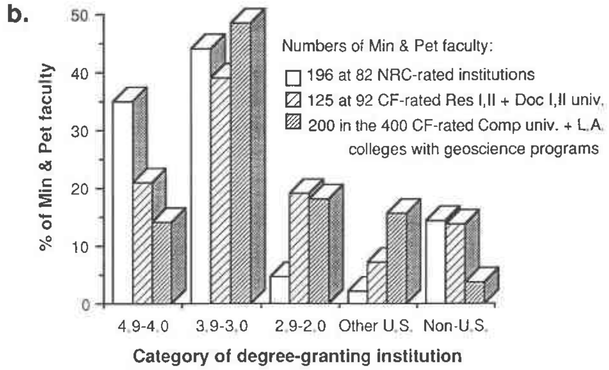


Fig. 10. **(a)** Percentages of the 196 U.S.-educated faculty listing petrology or mineralogy/crystallography as their speciality in the *Directory of Geoscience Departments* (AGI, 1986) versus the mean SQ of the institutions (by group) from which they received their Ph.D. degrees and at which they are teaching. **(b)** Percentages of mineralogy/crystallography and petrology faculty spread amongst five categories of degree-granting institutions, the first three of which are SQ groupings (NRC, 1982). "Other U.S." = all unrated U.S. institutions or those with SQ < 2.0. The three groupings are detailed in the figure.

bers of those that have geoscience programs (AGI, 1986), and for comparison the numbers of those institutions in each group that had been rated in the reputational survey discussed below.

In 1980–1981, 177 earth science faculty members were selected to participate in the evaluation of 91 programs of geoscience in 82 universities (NRC, 1982). They ranked "Scholarly Quality" of these programs on a scale of 5 to 0 (App. Table 1 and App. Fig. 1). I have taken the liberty of averaging the ratings of multiple programs within a university for this study in order to produce a data set compatible with NSF-EAR reports of awards to individual investigators (often listed only by university addresses). For the most part, our discussion of institutional "prestige" is based on the following groupings of scholarly quality (SQ) [numbers of universities in a group are given in brackets]:

$4.9 \le SQ \le 4.0$ [9];
$4.0 < SQ \le 3.5$ [13];
$3.5 < SQ \le 3.0$ [15];
$3.0 < SQ \le 2.5$ [19];
$2.5 < SQ \le 2.0$ [19];
$2.0 < SQ \le 1.0$ [7].

An indication of the validity of these ratings is shown in Figure 9 in which I have averaged the self-reported numbers of publications per institution for 1978–1979 and plotted them against SQ. The result is predictably exponential, but bear in mind that the more highly rated institutions tend to have larger faculties (App. Fig. 1, inset) and more Ph.D. and postdoctoral students, not to mention more money for research, the distribution of which closely follows the curve in Figure 9 (cf. Fig. 12b in this report and see Hagstrom, 1971). On this coarse a scale, the SQ ranking is an excellent measure of prestige.

Mineralogy and petrology faculty

Our discussion of faculty prestige is based on programs of SQ assessments of *entire* earth science departments. But as a matter of provincial curiosity, MSA members should note that the numbers of faculty who considered themselves "petrologists" or "mineralogists" and/or "crystallographers" (AGI, 1986) was 196 in the 82 NRC-rated institutions, only 125 in the 92 universities rated as "Research" or "Doctoral-granting" but not on the NRC list, and 200 among the 400 geoscience programs in smaller "Comprehensive Universities" and "Liberal Arts Colleges" (cf. Fig. 10b).

Ranking the perceived prestige of individual faculty members is an even more rancorous matter than ranking university geoscience programs. I will not attempt that; readers no doubt have their own firmly set opinions. But it is informative to examine the sources of Ph.D. degrees of faculty in terms of the SQ of the institutions that granted them. Figure 10a shows that nearly 90% of U.S.-educated faculty obtained Ph.D.'s from the top one-third of

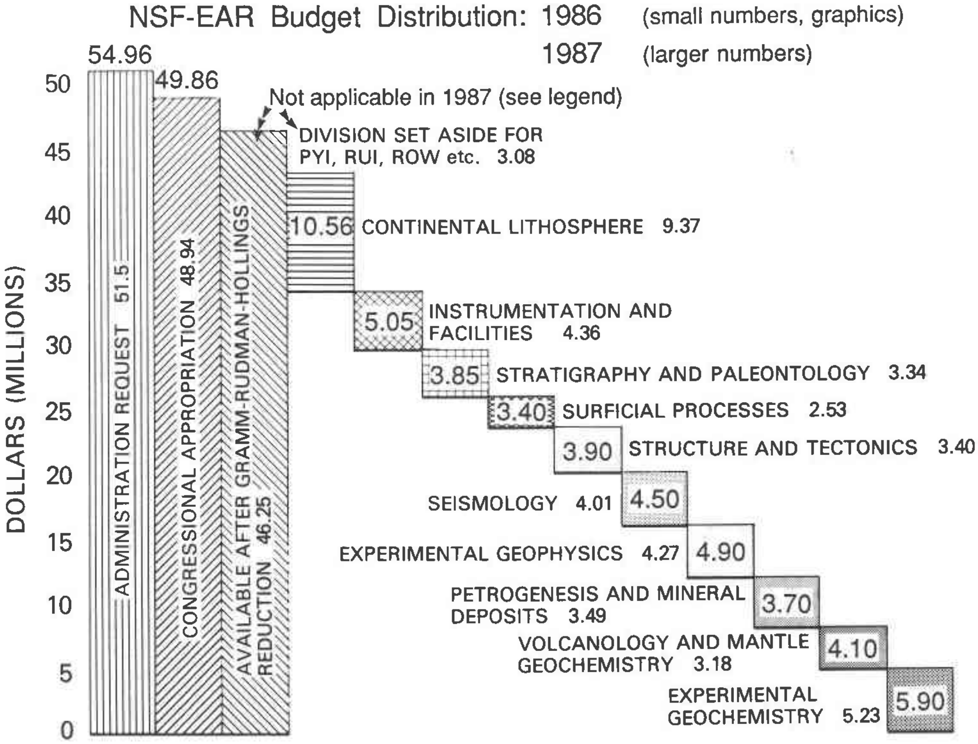


Fig. 11. NSF budget distributions among the ten EAR programs for fiscal years 1986 (bar graphics) and 1987 (larger numbers). Amounts are in current dollars, $\times 10^6$. There was no specific Gramm-Rudman-Hollings reduction for 1987 and no "division-set-aside" for special projects such as Presidential Young Investigator (PYI), Research in Undergraduate Institutions (RUI), and Research Opportunities for Women (ROW). The "set-asides" for 1987 were taken as "taxes" from the full amounts recorded for that year. Data courtesy of J. F. Hays and I. D. MacGregor (pers. comms., 1987, 1988).

the institutions in the NRC survey. And not surprisingly there are considerably larger numbers of mineralogists and petrologists at the "better" and generally bigger universities. That information is expressed in a different form in Figure 10b, onto which are added data for two groupings of CF-classified institutions that were not rated for "Scholarly Quality." If NRC- and CF-rankings mean anything at all, Figure 10b simply tells us what we knew all along—that higher-ranked institutions really are better. [Note that faculty with "Non-U.S." degrees are concentrated in the "Research" and "Doctoral-granting" universities.]

MAMMON: THE SMALLER PICTURE

NSF Earth Science budgets

Allocations to programs. Given the distressingly low percentage of federal R&D funds that go to nondefense, basic-research programs in the general sciences (Figs. 3–5), and given the small part of that allotment that trickles down to the Earth Science Division of NSF (Fig. 6), there is not an excess of mammon to apportion among the ten EAR programs. Figure 11 shows the budget distribution for 1986 and 1987, courtesy of Ian MacGregor (pers. comm.). At 21% of the $49.86 million allocated in 1987, Continental Lithosphere, which has received most of the increase in funding of EAR in recent years (Ernst, 1987, Fig. 3), is by far the largest. Many geoscientists decry the trend promoted by Eric "*We Need Centers*" Bloch, director of NSF (see Walsh, 1987). Others praise it because they happen to benefit from what have become known as "bloch-grants" to consortia such as DOSECC, COCORP,

TABLE 1. Carnegie Foundation's 1987 classification of universities and colleges

Carnegie Foundation category (CF, 1987)	Total in CF category	No. with geoscience programs	No. of CF institutions NRC-rated
Research university I	70	64	48
Research university II	33	31	18
Doctoral-granting univ. I	51	38	8
Doctoral-granting univ. II	59	40	7
Comprehensive univ. I	427	} 400	1
Comprehensive univ. II	174		
Liberal arts college I	125		
Liberal arts college II	439		
Totals	1378	573	82

Note: This classification is exclusive of two-year colleges, professional schools, and other specialized institutions. The number of institutions with earth science programs was determined from the *Directory of Geoscience Departments* (AGI, 1986) and those rated in the reputational survey from NRC (1982).

TABLE 2. NSF-EAR line item budget in percent of total dollars, 1984–1987

	1984–1987	Numbers of persons	Avg. months supported
Senior personnel	12.0	668	2.2
Other personnel			
Post-docs	2.6	78	7.5
Other professionals	2.3	155	4.1
Graduate students	13.2 → 11.6	548	
Undergraduates	0.9	171	
Clerical	1.5	273	
Other	0.7	84	
Total salaries and wages	32.0		
Fringe benefits	5.5		
Permanent equipment	13.5 → 11.6		
Travel, domestic	4.3		
Travel, foreign	2.0 → 1.6		
Participant support	0.4		
Other direct costs			
Materials & supplies	4.0		
Publication	1.5 → 1.0		
Consultant services	0.4		
Computer services	1.9 → 1.2		
Subcontracts	2.7 → 12.9		
Other	6.1		
Indirect costs	23.0		

Note: Percentages for the entire period are given except for those items for which significant trends were noted; in those cases beginning and ending values are listed. Numbers of persons and the average number of months they were supported are shown for 1987 only. Data from annual summary sheets provided by J. F. Hays and I. D. MacGregor of NSF-EAR.

and IRIS, and the much-touted science and technology centers. I leave judgments to historians of science who may someday be repeating the theme of "MOHOLE—Geopolitical Fiasco" (Greenberg, 1972). A budget overrun that led to the cessation of drilling to the San Andreas fault is a recent example of the problems that plague big science.

My agenda is not to attack or defend big science—there are many in the fray on both sides (cf. Koshland, 1986). Instead, I will approach the problems of research funding from a different though not entirely unrelated direction.

NSF-EAR line item budget. Before undertaking an analysis of distribution of EAR funds among institutions and individuals, I direct your attention to Table 2, in which the EAR line item budget is presented as percentages of total dollars expended for the years 1984–1987. For all but a few entries, relative amounts have remained rather stable, showing no significant trends with time—average values are listed for them. But for those whose variations have been significant, both the 1984 and 1987 percentages are given. There has been a consistent decrease in the amounts allocated to supporting graduate students (by 12%), to purchasing permanent equipment (14%), and to paying for foreign travel (20%), for publication costs (33%), and for computer services (37%).

These are more than offset by the tremendous growth in the Continental Lithosphere consortia, which account for the 375% increase in the "Subcontracts" category. "Indirect costs," the overhead vampires of everyone's grant (or ex-grant), have remained surprisingly stable in recent years, as have fringe benefits.[3] I hasten to remind the reader, especially if his or her experience with grants is but a memory, that items in Table 2 represent summaries of line item budgets *as submitted* to EAR by principal investigators (PIs), not the *actual* expenditures of NSF funds.

Questions

Because as fallen men and women we operate from self-interest, the bottom line for all of us is, "Where's the cash?" "Why don't I have any?" or "Why don't I have more of it?"

This investigation began with the express purpose of answering the first two of those questions. But the list grew as colleagues and friends—some discouraged, some despondent, some paranoid, some cynical, some bitter, but only one well-funded—contributed suggestions:

"Track down the insiders in the 'peer' review process and especially those on the panels." [See Klahr (1985) on the subject; cf. Hagstrom's (1971) geographic study.]

"Expose the cronyism that has developed between program directors and PIs, especially those with 3- and 5-year grants." Stories abound, some of which are true! And long-term grants *do* obviate competition from new proposals because very large percentages of funds are held in escrow for years.

"Peer review is distorted by pettiness and self-protective motives, the more so as money gets tighter. Only 'safe science' can get funded. Will there ever be true objectivity again?" Consider this illustration from an NSF-EAR (Paleontology) Proposal Evaluation Form: "In summary, let us not encourage another young scientist to megathink at a time when we have much too many [*sic*] megathinkers who give us very little that is believable." [Read the letters to the editor of *Science* (vol. 212 for 6/19/1981); see Gillespie et al. (1985) on cynicism about the review process; cf. Garfield (1986a, 1986b, 1987a, 1987b), Hollister (1988), and others. Cole et al. (1981) conducted an insightful study of chance and consensus in peer review.]

[3] I was informed by a source in NSF that attempts to even slightly reduce the rates of overhead charged to NSF grants met a brick wall in the National Science Board (NSB). NSF is accountable to the NSB, which is replete with chief executives of large, prestigious universities that in turn have the highest overhead rates and the largest numbers of grants. Can it be that James Buchanan, the 1986 Nobel Laureate in Economic Science, was speaking for science as well as economics and government when he stated that persons in power are always motivated more by self-interest than by an altruistic commitment to higher callings? In an interview with *Science,* he told R. Lewin (1986), "This should be no surprise, because governments are made up of individuals, and individuals operate from self-interest when they are engaged in a system of exchange, whether this is in the market economy or in politics." Or in science; see Koshland (1986)!

I cannot address such motivational questions, at least not in an objective manner. So I present in conclusion the results of my analyses of the distribution of NSF-EAR funds in relation to perceived institutional prestige, with comments and recommendations for changes that might revive hope and productivity in an increasingly threatened community of capable and dedicated researchers.

The recipients

To compile the yearly grant totals to the 82 NRC-rated institutions was a formidable undertaking, because NSF-EAR records were given to me in a variety of forms. Some records were sorted by state, some by program (whose designations may have changed with time). Some early listings contained large Ocean Science components. Some enumerated *all* principal investigators, others only the first. Grants that were "split-funded" between NSF divisions or among EAR programs were often difficult to track. Presidential Young Investigators technically receive many "grants" (one each time they raise matching funds from an outside source)—their funding needed special consideration. And so forth.

Thus it is with a number of implied caveats to cover possible errors of interpretation and compilation that I present the data (see App. Table 1 and App. Fig. 1). Figure 12a contains the yearly grant totals as a function of "Scholarly Quality" of the 82 individual institutions rated by the reputational survey (NRC, 1982), and Figure 12b displays the total funding amounts for the entire nine years, with the top twelve institutions identified (COCORP = Cornell). As one might have guessed, the trend is exponential (cf. Fig. 9). There is a continuum, but the richest are very much richer than the poor. It has always been so. The top two institutions received 11.8% of all EAR money awarded to the NRC-rated group (87.5% of total in 1986); the next nine institutions were given 22.9% (excluding COCORP and Cornell, which got 10.6%). In terms of natural history, this may be considered the result of Darwinian evolution in its broadest application. But in the sociology of science, it is known as the Matthew Effect, a name made popular by Robert Merton (1968) who took it from the occurrence of Jesus' Parable of the Talents in the Gospel According to Matthew, chapter 25, verses 14–30. Merton quoted a modern version of just verse 29:

> For whosumever hath to him shall hit be geven: and he shall have aboundance. But whosoever hath not: from him shalbe takyn awaye even that same that he hath.

(reproduced from Tyndale's 1526 translation). For many [Hollister, 1988?], verse 30 has even greater significance: "And cast the worthless servant into the outer darkness; there men will weep and gnash their teeth."

Perhaps for all this effort we have learned little that our realistically cynical minds would not have told us. However, the fallout is most informative.

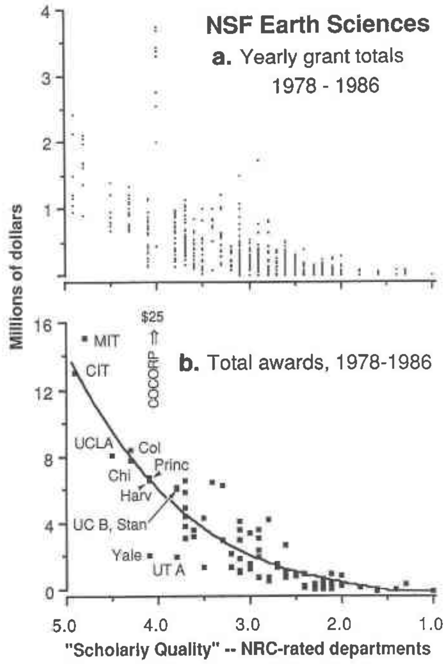


Fig. 12. (a) Yearly grant totals in current dollars ($\times 10^6$) for 1978–1986 plotted versus SQ of recipient institution. (b) Grand totals of amounts awarded to the various institutions over the same period of time. Abbreviations of university names should be self-explanatory; Cornell University received $25 million, most of it going to the COCORP consortium (not all of it expended at that university). See App. Table 1a for data.

Multiple grants

In a 1987 poll of its members in which more than 730 of the ~2500 members responded, MSA found that among 348 academic professionals in the United States, 15% had received no federal funding for research in the previous year, and an additional 29% had none in the previous five years. Of the remaining 195 respondents whose research was currently supported, 41% had one federal grant, 36% had two, 14% three, and 9% four or more. This high a proportion of multiple grants came as a surprise to me, although I was certainly aware of the phenomenon.

Consequently, I searched the records of NSF-EAR grants made in three recent years: 1986 and 1984, for which only one PIs name was listed per grant, and 1982, for which all co-PIs were listed. In the last instance, if, for example, a PI was listed as the only investigator on one grant and as co-PI on three others, he was given credit for 2½ grants. The numbers of dollars per PI are plotted in Figure 13 as a function of the number of new or continuing awards per PI in a given year. [A five-year $500 000 grant to one PI is recorded as five one-year $100 000 grants (or some such distribution) over the duration of it.] Grants to organizations (e.g., the National

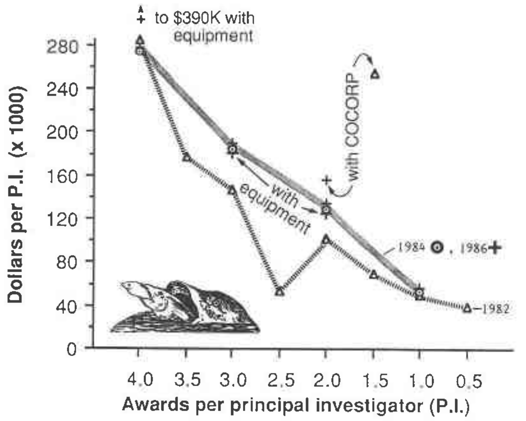


Fig. 13. Average amounts (current dollars × 10^3) received per principal investigator as a function of the number of awards granted to individuals by NSF-EAR for the years 1982, 1984, and 1986. See text for discussion.

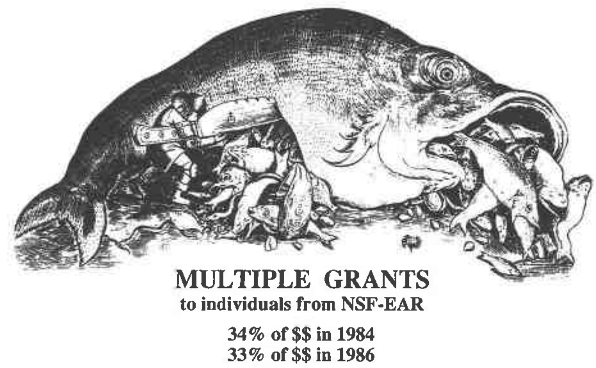


Fig. 14. Comment on multiple grants. Taken from the woodcut entitled "The Large Fishes Devouring the Small Fishes" by Pieter Bruegel, the Elder (1556–1557). Note that total EAR dollars ($$) exclude grants to COCORP or DOSECC.

Academy), to Presidential Young Investigators, and to people in several miscellaneous, low-dollar categories were eliminated from the study, as was one datum—the individual who received five grants in one year. One set of data for all years takes no regard of the program in which the awards were made. A second set for 1984 and 1986 differentiates the effect of instrument and facility ("equipment") grants on the average amounts awarded to an individual (yes, I realize these grants are often written by an individual for use by several, even many investigators). Note that only the 1986 value is significantly inflated—and in that case the support of (*not* the purchase of) an ion microprobe facility was involved and the proposal was written by a person who had three other large and current EAR awards. The effect of grants acknowledging COCORP are also recorded—very large on the average value for the 11 recipients of 1½ grants in 1982, relatively small on the 90 dual-grant recipients for 1986.

The coincidences of the curves in Figure 13 are remarkable: for the single-grant recipients, the average award was $50,000 for each of the three years sampled. Likewise, if the "ion probe" datum is excluded, the average total of the awards to four-grant recipients was near $280,000 (or $70,000 per grant—Darwin and the Matthew Effect are at work again!). The profile for 1982 (dashed line) was significantly lower than that for 1984 and 1986, but of greater interest is the fact that about one-third of the EAR dollars in the latter two annual budgets went to holders of multiple grants, exclusive of those clearly identified with COCORP and DOSECC (see. Fig. 14).

Parenthetical to this discussion of multiple grants, the fact that there are extremely large single grants given to single investigators must not be overlooked. In processing EAR data for 1985 and 1986 in two programs of special interest to MSA members (Fig. 15), I found that one department received more than 9% and one *individual* nearly 3% of the $19.65 million awarded by the Petrogenesis and Mineral Deposits and the Experimental and Theoretical Geochemistry programs. Admittedly, only 56 of the 82 NRC-rated departments received grants during that period, but the amount awarded to the one person exceeded the amounts given to 47 of those departments—and more than the entire Geophysical Laboratory! What is the impact of this information? Are the superstars of earth science research truly worthy of such adulation and reward? Or not? And what of the shriveled, mummifying masses?

To process the multiple-grant data in terms of people rather than money, I have contrived an unconventional diagram (Fig. 16) in which numbers of earth scientists are plotted on a multilog scale versus grants per PI. Whereas the total numbers for 1984 and 1986 are only 5 four-grant, 30 three-grant, and 160 two-grant recipients, the proportional amount awarded to them is great (Fig. 14). If a straight line is drawn through these data and those for the numbers of one-grant recipients, and the line extrapolated to zero on the abscissa, it has an ordinate value of ~2000 (star on Fig. 16). That number is not unrealistic, because 1070 proposals were declined in 1987 (although some may have come from already-funded individuals), and it is not hard to imagine that there are a like number or perhaps only two-thirds as many earth scientists who are or have been recently involved in serious research and have given up hope of being funded by NSF.

To my mind, as to many others', this represents an enormous waste of creative ability. In 1986, by my calculation, $15.8 million was granted by NSF-EAR to multiple-grant holders (MGHs) exclusive of DOSECC and COCORP members. If each MGH were given only his or her biggest award, including those from Instrumentation and Facilities (I&F), there would be $6.1 million available for use elsewhere. If I&F grants were to be removed from the calculation, current MGHs would get $10.9 million, and $4.9 million (about 10% of EAR monies) would be "available." Available for what?

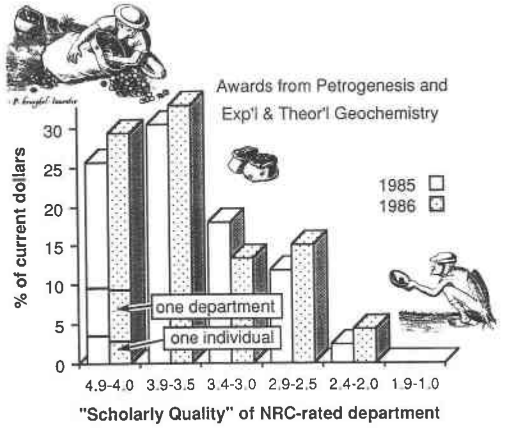


Fig. 15. Percentages of total amounts awarded to institutions by SQ grouping from the Petrogenesis and Mineral Deposits and the Experimental and Theoretical Geochemistry programs for 1985 and 1986. Total for both programs for two years = $19.65 million. See text for discussion of the amounts received by one department and a single individual within that department.

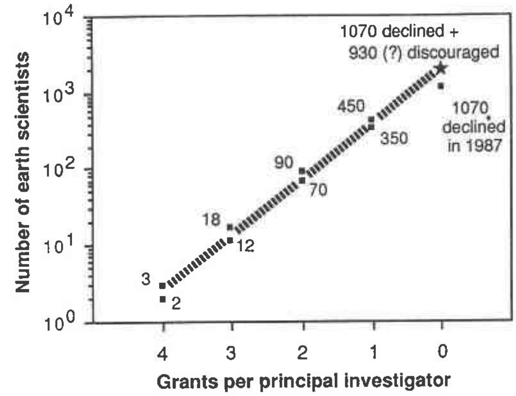


Fig. 16. Number of earth scientists (multilog scale) receiving awards from NSF-EAR in the 4-, 3-, 2-, and 1-grant categories. Numbers above the line are for 1986, those below the line for 1984. See text for discussion of the extrapolation to zero grants (star).

Hope

In the current climate of federal research funding (Fig. 1), objectivity in peer review—if it ever was a reality—has succumbed to cynical self-protection. Who, having had his or her proposals declined (=rejected) three, four, or five times, will give high praise to a peer's proposal that competes for mammon on the same battlefield? Furthermore, the accepted, though flawed, NSF review process is easily subverted by the "general officers" of consortia and large facilities, who can award large dollar amounts to whomever they will for work they deem to be in concert with their objectives. And thus individual initiative is discouraged, even crushed. Though a necessary and exciting component of the scientific enterprise, "big" science has its dangers and most assuredly its gross inefficiencies.

Emerging from the pile of real data and the mountainous heap of opinion and advice, ranging from rational (though often bitter and despondent) to impractical to hopelessly idealistic, I am constrained to conclude that some reallocation of NSF funds is essential to the health of the earth science research endeavor. But how? And how much?

The suggestion that the $50 million EAR allocation be divided evenly amongst the 2000± investigators (that's $25,000 a year per person!) is interesting but certainly unrealistic. A Robin Hood would consider multiple-grant holders or postdocs and "other professionals" (see Table 2) fair game and find $5–6 million in either category for distribution to the poor. Summer salaries could be restricted to one month, or capped (Petroleum Research Fund enforces a current cap of $4000 per PI), or eliminated. After all, it *is* research we're interested in, isn't it? Projected "savings" from salary plus fringe benefits plus overhead would be enormous. Alternatively, traditional grantsmanship could continue but with each program director setting aside 10% of his or her budget to award in small bits to those whose proposals were of sufficient merit to receive *some* support and encouragement. [One director is said to be doing just that.]

At $10,000 per year, about 500 additional investigators could then be taken off the casualty list and rehabilitated to at least some level of productivity. The idea would be to fund only those without other federal research money. The amount awarded might be given with no strings, or with stipulations (no faculty salaries, no overhead—take it or leave it, adminstrators!), and certainly with time limitations.

This approach has the advantage of relieving panels and/or program directors from the often agonizing "Yes" or "No," "Life" or "Death" decisions and putting them in the category of "More" or "Less." Researchers, especially the newcomers and those fighting for survival (tenure, promotion, etc.), would be given a chance to do at least some creative work.

It should not be forgotten that there is an implicit and large subsidy attached to the research activity of every faculty member. Each is supported to some degree by his or her institution, which pays salary and fringe benefits and overhead, whether or not there is external funding of research. Instrumentation exists but often languishes where absolutely no external money is available to activate it in pursuit of scientific objectives. A $10,000 grant from NSF may be used to fund, however parsimoniously, 30 to 50% of a desperate scientist's professional effort for a considerable period of time.

Bureaucratic war may need to be waged to restore some balance in the funding of earth science research. But without changes of some sort, hope will continue to fade, and with it a large proportion of the creative initiative embodied in the growing population of unfunded geoscience faculty.

Give me your tired, your poor
Your little scientist yearning for a grant,
The wretched refuse of the Budget Battle,
Send them, competitition-tossed, to me:
I lift the lamp beside the Treasury door.

["(with apologies to Emma Lazarus)"
D. E. Koshland, Jr. (1986)]

Acknowledgments

I am much in debt to James Fred Hays and Ian MacGregor, sequential directors of NSF Earth Science Division, and to Alan Gaines, Daniel Weill, John Snyder, Jane Ernst, and others at NSF-EAR who labored to provide data (but *not* interpretations) for this study. I am grateful to Mark Wyer, Linda Zackrison, and Marianne Stern for help in sifting through mountains of data. For encouragement (greatly needed) and advice (often unheeded), I thank my successor as President of MSA, David Stewart, who by now will be needing both.

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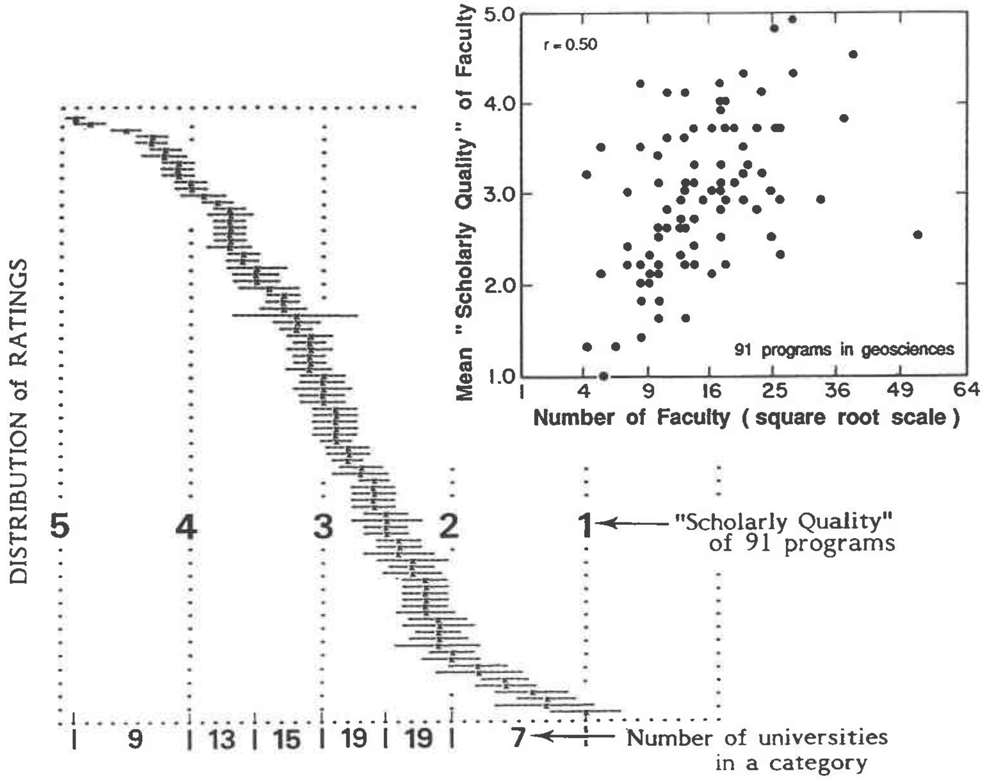
Manuscript received August 5, 1988
Manuscript accepted August 10, 1988

App. Table 1a. Amounts awarded in 1978-1986 by NSF-EAR to institutions in order of decreasing SQ ("Scholarly Quality"); scale: 5-0. EP = "Effectiveness of Program in educating research scholars/scientists"; scale: 3-0. (NRC, 1982).

INSTITUTION	SQ	EP	1978	1979	1980	1981	1982	1983	1984	1985	1986	Totals
(decreasing order of SQ)	*NRC, 1982*					Current dollars, x 1000						*1978-86*
California Institute of Technology	4.9	2.8	1164.1	1068.8	1155.0	1213.0	957.0	1504.0	1492.8	2426.0	2150.0	13130.7
Massachusetts Institute of Technology	4.8	2.7	1361.1	893.1	1625.0	1696.8	1710.4	1689.5	2054.4	2106.0	2001.0	15137.3
Univ of California, Los Angeles	4.5	2.4	739.1	878.2	798.9	809.4	667.0	1202.8	792.7	1407.0	959.0	8254.1
Univ of Chicago	4.3	2.3	708.8	702.2	931.9	678.0	766.3	1117.0	1095.2	1018.0	894.0	7911.4
Columbia Univ	4.3	2.4	756.5	969.9	707.9	1152.7	685.7	736.0	1219.0	955.0	1352.0	8534.7
Yale Univ	4.1	2.3	123.4	206.4	124.5	121.5	157.9	272.9	441.4	414.0	348.0	2210.0
Harvard Univ	4.1	2.4	373.2	443.2	710.3	615.3	963.0	840.8	724.8	1140.0	878.0	6688.6
Princeton (Mean)	4.1	2.3	722.6	468.4	794.0	751.0	640.4	1168.0	890.2	741.0	693.0	6868.6
Cornell Univ	4.0	2.3	441.5	2765.7	2553.9	3301.6	3682.2	3370.1	2020.5	3442.0	3739.0	25316.5
Univ of California, Berkeley (Mean)	3.8	2.2	364.8	641.2	491.1	382.4	898.9	717.0	919.3	961.0	803.0	6178.7
Stanford Univ (Mean)	3.8	2.3	379.4	413.7	677.0	573.1	759.5	657.6	881.3	993.0	935.0	6269.6
Univ of Texas, Austin	3.8	2.2	319.4	215.0	132.5	214.8	249.2	207.5	138.2	227.0	368.0	2071.6
Univ of Arizona	3.7	2.2	459.8	439.9	456.9	496.1	372.3	459.5	530.1	794.0	520.0	4528.6
Univ of California, Santa Barbara	3.7	2.2	608.1	383.4	453.3	370.8	583.1	917.3	539.0	693.0	449.0	4997.0
State Univ of New York, Stony Brook	3.7	2.1	347.1	674.5	842.7	610.3	493.3	791.3	853.4	1069.0	973.0	6654.6
Brown Univ	3.7	2.1	531.2	380.1	634.5	600.5	602.6	514.5	1042.2	1141.0	521.0	5967.6
Virginia Polytech. Inst. & State Univ	3.7	2.1	237.4	145.1	444.3	305.1	436.5	302.2	491.5	362.0	490.0	3214.1
Univ of Wisconsin	3.7	2.3	287.5	549.0	666.5	303.3	329.0	422.3	427.6	361.0	608.0	3954.2
Northwestern	3.6	2.1	293.4	278.6	181.5	377.5	158.8	414.3	681.5	351.0	541.0	3277.6
Johns Hopkins	3.6	2.1	124.8	224.5	116.3	330.3	416.3	500.8	465.1	645.0	857.0	3680.1
Univ of Michigan	3.5	2.1	125.5	409.8	234.8	397.8	302.2	573.2	536.3	1001.0	829.0	4409.6
State Univ of New York, Albany	3.5	1.8	218.8	131.3	95.1	34.8	123.8	139.4	75.6	141.0	482.0	1441.8
Penn State Univ (Mean)	3.4	2.0	838.1	716.8	853.1	760.5	1021.4	1003.1	714.7	88.0	522.0	6517.7
Univ of Minnesota	3.3	2.0	355.9	396.2	291.3	168.0	600.6	464.2	361.0	196.0	279.0	3112.2
Univ of Washington	3.3	2.0	297.3	647.6	291.7	652.2	613.4	563.3	1040.6	1218.0	1014.0	6338.1
Univ of Illinois, Urbana	3.2	1.9	81.0	369.9	74.4	152.1	127.7	381.5	335.7	243.0	453.0	2218.3
Indiana Univ	3.2	2.0	77.7	200.3	157.5	165.5	78.0	125.4	391.3	134.0	144.0	1473.7
Arizona State Univ	3.1	1.9	246.5	353.3	243.6	344.0	352.0	605.9	704.3	400.0	450.0	3699.6
Univ of California, Santa Cruz	3.1	1.9	232.0	181.7	218.0	205.2	359.3	286.2	507.4	702.0	346.0	3037.8
Univ of Southern California	3.1	1.9	269.6	82.8	291.2	126.4	225.3	477.4	879.1	1091.0	786.0	4228.8
Univ of Colorado	3.1	2.0	189.6	218.4	154.4	296.6	212.7	0.0	606.6	1494.0	1012.0	4184.3
Univ of Miami	3.1	1.9	173.5	178.8	85.0	102.5	61.2	69.7	118.9	174.0	227.0	1190.6
Ohio State Univ (Mean)	3.1	1.8	57.5	23.9	127.2	177.1	94.1	32.3	97.9	486.0	66.0	1162.0
Texas A & M Univ (Mean)	3.1	1.8	301.8	0.0	133.4	188.1	241.7	71.8	297.6	319.0	378.0	1931.4
Univ of Massachussetts	3.0	1.8	69.3	273.4	258.8	166.2	73.6	300.7	157.3	231.0	136.0	1666.3
Univ of Oregon	3.0	1.9	271.2	302.8	369.4	414.3	414.3	534.0	400.5	505.0	287.0	3498.5
Univ of Utah	3.0	1.9	230.6	15.0	75.0	212.4	133.2	164.8	110.0	209.0	191.0	1341.0
Univ of California, Davis	2.9	1.8	206.8	189.6	95.8	214.3	217.0	286.9	203.0	458.0	637.0	2508.4
Univ of Hawaii	2.9	1.6	356.6	423.9	368.3	255.2	371.1	335.9	314.9	328.0	389.0	3142.9
Univ of Kansas	2.9	1.8	124.0	82.7	103.7	162.9	194.7	475.6	355.6	198.0	378.0	2075.2
Univ of North Carolina	2.9	1.9	91.5	70.4	128.0	225.3	156.7	64.6	0.0	0.0	94.0	830.5
Univ of South Carolina	2.9	1.7	90.5	125.2	57.1	154.2	222.1	276.3	234.9	1725.0	784.0	3669.3
Purdue Univ	2.8	1.7	201.6	45.0	55.1	94.2	14.5	88.7	35.5	110.0	141.0	785.6
Univ of Cincinnati	2.8	1.7	25.0	0.0	64.5	119.2	41.8	0.0	89.0	118.0	141.0	598.5
Univ of Wyoming	2.8	1.8	224.8	355.1	230.4	328.4	445.4	655.7	441.7	819.0	811.0	4311.5
Washington Univ	2.7	1.8	0.0	393.0	131.6	0.0	253.4	218.8	172.4	338.0	175.0	1682.2
Univ of New Mexico	2.7	1.7	30.1	123.4	10.0	74.9	273.5	0.0	191.9	354.0	370.0	1427.8
State Univ of New York, Binghamton	2.6	1.6	57.3	56.1	71.9	126.6	0.0	106.6	82.9	226.0	113.0	840.4
Univ of Oklahoma	2.6	1.5	71.5	36.6	82.6	51.7	38.8	43.8	159.5	62.0	490.0	1036.5
Oregon State Univ	2.6	1.6	310.2	297.5	138.9	363.1	328.1	207.6	393.6	350.0	369.0	2758.0
Rice Univ	2.6	1.6	50.0	40.5	93.4	61.5	177.6	109.6	205.0	101.0	448.0	1286.6
Univ of Texas, Dallas	2.6	1.7	194.9	492.6	146.7	282.5	288.1	205.0	268.3	326.0	522.0	2726.1
Univ of Alaska, Geophys Inst	2.5	1.4	317.6	68.7	145.7	38.1	49.5	240.9	90.3	0.0	20.0	970.8
Louisiana State Univ	2.5	1.7	36.3	83.5	95.4	96.4	152.9	138.3	109.8	97.0	149.0	958.6
New Mexico Institute of Mining	2.5	1.6	59.9	79.0	120.4	0.0	31.4	5.0	200.4	281.0	287.0	1064.1
Southern Methodist Univ	2.5	1.6	45.2	119.2	11.0	56.0	68.8	255.3	90.0	177.0	148.0	970.5
Univ of Iowa	2.4	1.7	0.0	4.0	0.0	10.0	70.0	0.0	0.0	57.0	60.0	201.0
Michigan State Univ	2.4	1.5	34.2	38.5	0.0	88.8	0.0	41.1	0.0	67.0	37.0	306.6
Rensselaer Polytechnic Institute	2.4	1.4	0.0	68.9	0.0	87.9	45.1	148.3	137.7	387.0	182.0	1056.9
Syracuse Univ	2.3	1.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	31.0	165.0	196.0
Univ of Pittsburgh	2.3	1.4	50.9	107.0	1.1	78.0	74.6	0.0	12.6	0.0	124.0	448.2
Univ of Virginia	2.3	1.4	0.0	0.0	54.6	0.0	0.0	0.0	0.0	61.0	18.0	133.6
Florida State Univ	2.2	1.4	55.4	50.0	71.0	182.6	87.3	0.0	114.8	93.0	97.0	751.1
Iowa State Univ	2.2	1.2	0.0	230.0	54.5	23.2	123.7	57.1	67.8	50.0	53.0	659.3
Univ of Missouri, Columbia	2.2	1.4	2.3	48.6	0.0	234.0	39.3	80.1	0.0	59.0	227.0	690.3
Univ of Montana	2.2	1.5	26.0	0.0	22.5	75.0	0.0	61.9	81.5	74.0	93.0	433.9
Case Western Reserve Univ	2.2	1.3	40.0	77.3	99.0	145.8	50.8	52.9	56.5	116.0	55.0	693.3
Univ of Houston	2.2	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	64.0	59.0	123.0
Univ of Kentucky	2.1	1.0	0.0	0.0	0.0	0.0	0.0	0.0	37.3	31.0	38.0	106.3
St Louis Univ	2.1	1.5	20.6	0.0	22.5	75.0	0.0	61.9	39.9	29.0	68.0	316.9
Lehigh Univ	2.1	1.2	36.5	87.9	65.0	57.1	50.5	104.9	105.7	253.0	245.0	1005.6
Washington State Univ	2.1	1.3	0.0	0.0	0.0	0.0	41.9	84.9	110.5	0.0	143.0	380.3
West Virginia Univ	2.1	1.3	0.0	53.2	0.0	0.0	25.5	0.0	0.0	0.0	14.0	92.7
Univ of California, Riverside	2.0	1.4	60.2	21.7	48.6	75.2	65.8	64.1	283.5	148.0	140.0	907.1
Univ of Tennessee	2.0	1.3	23.5	75.0	42.5	37.7	0.0	0.0	61.7	20.0	25.0	285.4
Univ of Delaware	1.8	1.3	0.0	50.2	0.0	0.0	0.0	0.0	54.4	77.0	55.0	236.6
George Washington Univ	1.6	1.0	0.0	13.1	0.0	24.3	41.9	0.0	27.9	20.0	0.0	127.2
Univ of Idaho	1.6	1.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Univ of Missouri, Rolla (Mean)	1.6	0.9	43.8	40.9	0.0	0.0	10.0	55.0	0.0	0.0	0.0	149.7
Univ of North Dakota	1.4	0.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	92.0	0.0	92.0
Boston Univ	1.3	0.9	41.7	22.8	67.3	31.1	20.0	91.0	41.5	71.0	10.0	396.4
Univ of Tulsa	1.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

App. Table 1b. Totals and percentages of amounts of NSF-EAR awards from App. Table 1a.

		1978	1979	1980	1981	1982	1983	1984	1985	1986	Σ'78-'86
Totals by year, x $1000		17308	21314	21151	23397	24636	28216	29907	37746	36055	239730
	SQ range										
	4.9-4.0	6390	8396	9401	10339	10230	11901	10731	13649	13014	94052
	3.9-3.5	4297	4886	5427	4997	5726	6617	7581	8739	8376	56645
Totals by SQ	*3.4-3.0*	3692	3961	3624	4131	4609	5080	6723	7490	6291	45600
group, x $1000	*2.9-2.5*	2494	3082	2151	2705	3325	3715	3639	6068	6466	33644
	2.4-2.0	350	862	481	1170	675	757	1110	1540	1843	8788
	1.9-1.0	86	127	67	55	72	146	124	260	65	1002
	4.9-4.0	31	34	36	37	35	34	31	29	28	32
	3.9-3.5	21	20	21	18	19	19	22	19	18	19
% of NSF-	*3.4-3.0*	18	16	14	15	16	15	20	16	14	16
EAR funds	*2.9-2.5*	12	12	8	10	11	11	11	13	14	12
	2.4-2.0	2	3	2	4	2	2	3	3	4	3
	1.9-1.0	0	1	0	0	0	0	0	1	0	0
	SQ range										
	4.9-4.0	6390	8396	9401	10339	10230	11901	10731	13649	13014	94052
	3.8-3.7	3535	3842	4799	3856	4724	4989	5823	6601	5667	43836
	3.6-3.2	2413	3375	2296	3039	3442	4165	4602	4017	5121	32469
Totals, x $1000	*3.1-3.0*	1811	1615	1881	2020	2034	2378	3770	5402	3688	24599
for SQ groups of	*3.0-2.8*	1551	1307	1178	1766	1797	2349	1785	3965	3566	19263
approx. 9 univ's each	*2.7-2.5*	1068	1592	916	1095	1562	1271	1674	1854	2656	13687
	2.5-2.2	246	467	258	503	377	450	556	1154	1118	5128
	2.2-2.1	125	444	264	610	306	504	499	676	981	4409
	2.1-1.0	169	277	158	168	163	210	469	428	244	2287
	4.9-4.0	31	34	36	37	35	34	31	29	28	32
	3.8-3.7	17	15	18	14	16	14	17	14	12	15
	3.6-3.2	12	14	9	11	12	12	13	9	11	11
% NSF-EAR funds	*3.1-3.0*	9	6	7	7	7	7	11	12	8	8
for SQ groups of	*3.0-2.8*	8	5	5	6	6	7	5	8	8	7
approx. 9 univ's each	*2.7-2.5*	5	6	4	4	5	4	5	4	6	5
	2.5-2.2	1	2	1	2	1	1	2	2	2	2
	2.2-2.1	1	2	1	2	1	1	1	1	2	2
	2.1-1.0	1	1	1	1	1	1	1	1	1	1



App. Fig. 1. Distribution of "Scholarly Quality" ratings of 91 programs in 82 universities. From NRC (1982, Fig. 5.3). Broken lines (----) indicate a confidence level of ±1.5 standard errors; x = mean rating.
INSET: Mean "Scholarly Quality" of faculty vs. number of faculty (square root scale). After NRC (1982, Fig. 5.1).